HANDBOOK
for
SHIPWRIGHTS

This book is produced in full compliance with the government's regulations for conserving paper and other essential materials.

HANDBOOK
for
SHIPWRIGHTS

BY

H. F. GARYANTES
Foreman Shipwright, Newport News Shipbuilding and Dry Dock Company; Member Society of Naval Architects and Marine Engineers

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1944

HANDBOOK FOR SHIPWRIGHTS

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

To my wife

MARGARET LAURA GARYANTES

PREFACE

The rapid expansion of shipbuilding with the accompanying demand for skilled shipwrights has prompted the preparation of this handbook. It deals with the fundamentals of work as practiced by shipwrights today. It can be used conveniently in solving everyday problems encountered in the construction of a ship but is not intended for use as a classroom text.

The subjects discussed may not cover all the work performed by shipwrights in various shipyards, though work on hull construction is fully treated.

Shipbuilding had its origins before the days of recorded history, beginning with the hollowed-out logs of our early ancestors. Through the generations ships developed in size, complexity, and maneuverability in response to the needs of fighting men, explorers, and merchants. A peak in the construction of wooden ships was attained with the building of such clipper ships as the *Flying Cloud.*

With the advent of steel ships, the shipwright, who was the first ship craftsman, was to a large degree replaced by the ship fitter. Today, owing to the revolutionary changes in ship design brought about by the development of welding, the shipwright is on his way back. His work, which formerly consisted in working with wooden timbers, now consists almost entirely in the working of steel, both with and without the collaboration of the ship fitter.

With the extensive welding now done in ship construction, the work and responsibility of the shipwright have increased. Large subassemblies by means of which ships can be constructed more rapidly require that the shipwright assist in holding them in proper alignment so that each successive unit will make up to another. When subassemblies are erected into the ship, the shipwright must brace and support the structure so that it can be released by the cranes. He must then align, set, and brace the subassemblies so that other fabricated material will fit as the ship progresses in construction. Where combination riveted and welded construction is specified, or where the entire construction is welded, compensation must be made for shrinkage. Stiffening is called for to resist excessive buckling both before and after the ship fitter makes up final connections and during the process of welding.

In general, the work of the shipwright is to see that all fabricated material is set in the ship to conform to designed lines from the mold loft floor. If this is done, it will materially reduce difficulties in the outfitting of the ship with machinery, equipment, and furniture.

In holding the ship in alignment, the primary factors are the proper lining up of the various parts for structural strength and the reduction of difficulties that arise when the ship does not conform to the designed lines. It is therefore necessary that the shipwright have a fair knowledge of the lines of a ship, a knowledge of the results of welding reaction, and a knowledge of working steel. He is required to supply suitable scaffolding and staging for the construction of the ship. Finally, when the ship is ready, it is his work safely to launch the ship into her element.

H. F. GARYANTES.

NEWPORT NEWS, VA.,
September, 1944.

ACKNOWLEDGMENTS

Grateful acknowledgment is due G. Guy Via, Supervisor of Training of the Newport News Shipbuilding and Dry Dock Company, whose advice and aid have been largely instrumental in the development of this handbook.

Acknowledgment is also made to the following men and organizations for the aid and time they contributed. Without their assistance and comments this work would not have been written.

F. E. Brooker, Senior Specialist in Visual Aids, U.S. Office of Education, through whose efforts the working photographs from "Shipbuilding Skills," prepared by the Jam Handy Organization and Caravel Films and printed by Castle Films, were made available.

Jam Handy Organization.

Caravel Films.

Castle Films.

Newport News Shipbuilding and Dry Dock Company:

W. B. Ashe, Foreman Loftsman.

Elijah Baker, III, Hull Technical Department.

S. B. Besse, Hull Superintendent's Staff.

J. R. Canada, Shipwright Civil Engineer and Draftsman.

J. J. Carvil, Apprentice Drafting Instructor.

W. R. Furman, Shipwright Civil Engineer and Draftsman.

R. E. Holzbach, Hull Superintendent's Staff.

G. O. McClary, Shipwright Office Staff.

Others of this organization, too numerous to be named, have made generous contribution to this work.

H F. GARYANTES.

CONTENTS

HANDBOOK FOR SHIPWRIGHTS

CHAPTER I

MATHEMATICS FOR SHIPWRIGHTS

All construction involves the use of mathematics. The purpose of this chapter is to give the shipwright in simple and condensed form the mathematics most needed by him in his work.

On the ship the chief phase of mathematics confronting the shipwright is centered in the solution of *right triangles.* This is due to the ship's being set on a declivity, or inclined on its foundation for the purpose of launching when completed.

In submerged shipways, however, ships are usually built with a level base line, and these problems are thereby eliminated. Nevertheless, there still remain many similar problems, such as cutting shores and squaring lines, in which the solution of the right triangle must be employed.

Before going into detail with regard to deriving and solving right triangles, it should be stated that a fair knowledge of the fundamentals of mathematics—addition, subtraction, multiplication, and division of whole numbers—is assumed. However, a brief review of fractions is included since they are somewhat complicated and are used consistently by the shipwright when the ship is being built on a declivity and in taking measurements.

FRACTIONS

A *fraction* denotes the number of equal parts of anything. The *denominator* of the fraction shows into how many equal parts the whole has been divided. The *numerator* shows how many parts form the fraction. For example, take the fraction $^{13}/_{16}$. The denominator in this case is 16, the number of parts into which the unit is divided. The numerator, 13, is the number of those parts to be used.

When the denominators of two fractions are the same, the fractions are said to be *similar;* for example, $^5/_{16}$ and $^7/_{16}$ are *similar fractions.* Fractions such as $^3/_8$ and $^3/_6$ are not similar.

Before adding or subtracting fractions, they must be made similar. To do this, make all denominators the same as the largest denominator or as some multiple of the group of denominators. This process is known as the *reduction of fractions.* In the reduction of fractions their form is changed without changing their value.

REDUCTION OF FRACTIONS TO HIGHER OR LOWER TERMS OF A REQUIRED DENOMINATION

Example. Reduce $5/8$ to 16ths.

The required denominator, 16, is two times the given denominator, 8; hence, not to change the value of the fraction, the required numerator must also be two times the given numerator, 5; and 5 multiplied by 2 is 10; therefore, $5/8$ reduced to 16ths equals $10/16$.

REDUCTION OF FRACTIONS TO LOWEST TERMS

Rule: Divide both terms by any common factor. Divide both terms of the resulting fraction by any common factor. Continue the operation until a fraction is obtained whose terms cannot be reduced further. Or divide both terms of the fraction by their greatest common divisor.

Example. Reduce $72/108$ to its lowest terms.

$$\frac{72 \div 9}{108 \div 9} = \frac{8}{12} \qquad \frac{8 \div 4}{12 \div 4} = \frac{2}{3}$$

Divide both terms of $72/108$ by any common factor, say 9, obtaining $8/12$ as an equal fraction in lower terms. Divide both terms of the obtained fraction by 4, a common factor, obtaining $2/3$. Since the term $2/3$ has no common divisor, this must be the required fraction in lowest terms.

ADDITION OF FRACTIONS

Example. Add $3/4$, $3/16$, and $5/8$.

First, make all fractions similar by changing them to 16ths. Thus, $3/4$ is $12/16$, and $5/8$ is $10/16$. Now, the three fractions are ready to be added, in the form shown below:

$$12/16 + 3/16 + 10/16$$

The fraction resulting from the addition is similar to the fractions that were added; that is, the denominator does not change. The numerators are treated just as if they were whole numbers and are added, the sum being placed over the denominator.

Using the example above, we get

$$12/16 + 3/16 + 10/16 = 25/16, \text{ or } 1\,9/16$$

SUBTRACTION OF FRACTIONS

In subtracting fractions, first make the fractions similar. Then the smaller numerator is subtracted from the larger, and the answer is placed over the least common denominator.

Example 1. Subtract $9/16$ from $3/4$.

$$3/4 - 9/16$$

Made similar, $3/4$ is $12/16$. Therefore, $12/16 - 9/16 = 3/16$.

Suppose it is desired to subtract *mixed numbers*, a mixed number being made up of a combination of a whole number and a fraction. For example, let us take the mixed number $11\,5/8$. In this case, 11 is the whole number, and $5/8$ is the fractional part of another unit of the whole number.

Example 2. Subtract $11\,5/8$ from 15.

Both the numbers in this example contain a *whole number*. However, only the number to be subtracted contains a fraction. In any event, the two forms of numbers must be subtracted separately; that is, the fraction must be subtracted from another similar fraction, and one whole number subtracted from the other. In order to obtain a fraction for the whole number 15, which has no fraction, one unit must be borrowed from the whole number, 15, thereby leaving a remainder of 14. The borrowed unit is written in a fractional form with the denominator the same as that in the fraction to be subtracted from it. Thus, in the example $15 - 11\,5/8$, borrow 1 from 15, and express it as the mixed number, $14\,8/8$.

$$14\,8/8 - 11\,5/8$$

$$8/8 - 5/8 = 3/8$$

In like manner,

$$14 - 11 = 3$$

Therefore,

$$14\,8/8 - 11\,5/8 = 3\,3/8$$

In like manner, in the addition of mixed numbers the whole number and the fraction must be handled separately. The fractions, as above, must be made similar before they can be added.

MULTIPLICATION OF FRACTIONS

In multiplying, fractions need not be made similar. The numerator of one is multiplied by the numerator of the other to obtain the numerator of the product. In like manner, the denominators are multiplied together, to get the denominator of the product.

Example 1. Multiply $1/4$ by $3/8$.

To get the numerator of the product: 1 multiplied by 3 equals 3. To get the denominator of the product: 4 multiplied by 8 equals 32.

Therefore,

$$\frac{1}{4} \times \frac{3}{8} = \frac{3}{32}$$

which is the product.

When a fraction is to be multiplied by a whole number, the whole number can be written as a fraction and the product obtained as above.

Example 2. Multiply $\frac{3}{8}$ by 10.

$$\frac{3}{8} \times \frac{10}{1} = \frac{30}{8}, \text{ or } 3\frac{3}{4}$$

DIVISION OF FRACTIONS

With the exception of one operation, the same procedure is followed in dividing as in multiplying. To divide fractions, first invert the divisor and then multiply.

Example. Divide $\frac{13}{16}$ by $\frac{1}{4}$.

$$\frac{13}{16} \div \frac{1}{4} = \frac{13}{16} \times \frac{4}{1}$$

Therefore,

$$\frac{13}{16} \times \frac{4}{1} = \frac{52}{16}, \text{ or } 3\frac{1}{4}$$

DECIMAL FRACTIONS

The division of anything into *tenths, hundredths, thousandths,* etc., is known as *decimal division.* The decimal fraction may be obtained by dividing the denominator of any fraction into the numerator, thereby eliminating the denominator entirely. One might think of a decimal fraction as a fraction in its simplest form. Take the fraction $\frac{4}{10}$. By dividing the denominator, 10, into the numerator, 4, one gets .4, which is the *decimal equivalent* of the common fraction 4 over 10.

In like manner, $\frac{63}{100}$ may be represented decimally by .63, and $\frac{415}{1000}$ may be represented decimally by .415.

In the case of a fraction whose denominator is not in units of ten, for example, $\frac{3}{16}$, the same procedure is followed.

Rule: Annex ciphers to the numerator, divide by the denominator, and point off from the right of the quotient as many decimal places as there have been ciphers added. Thus,

$$\frac{3}{16} = .1875$$

```
       .1875
16)3.0000
   16
   140
   128
    120
    112
      80
      80
```

Then, .1875 is the decimal fraction of 3/16. This decimal fraction is read "one thousand eight hundred seventy-five ten-thousandths." Just as this fraction is read, the shipwright may take the table shown below and read any number with which he is likely to come in contact.

Millions	Hundred thousands	Ten thousands	Thousands	Hundreds	Tens	Units		Tenths	Hundredths	Thousandths	Ten-thousandths	Hundred thousandths	Millionths
5	7	8	3	2	1	9	.	6	4	2	5	0	6

In order to change a *decimal fraction* to a *common fraction*, multiply it by the number that is wanted as the denominator of the common fraction.

Example. Change .321 ft. to inches.

Since there are 12 in. in a foot, 12 is to be the denominator. So

$$12 \times .321 = \frac{3.852}{12} \text{ ft., or } 3.852 \text{ in.}$$

The numerator represents the number of inches there are in .321 ft.

Let us change the decimal fraction of the inch which remains, .852, to 16ths of an inch. In this case, 16 will be the denominator. So

$$.852 \times 16 = \frac{13.632}{16} \text{ in., or } 13.632 \text{ sixteenths}$$

Since .632 is a little greater than one-half, the fraction 13.632/16 can be rounded off to 14/16 in ordinary shipwright work. Thus .321 ft. has been changed to $3\frac{14}{16}$ in., or, better, $3\frac{7}{8}$ in. In like manner, any decimal fraction can be changed into a common fraction, and vice versa.

PRACTICAL MEASUREMENTS

Because the work of the shipwright constantly involves measurements, this subject should also be given some thought. Since the measurements made by the shipwright consist mainly of distances or the lengths of lines, their measurement will be emphasized more than that of surfaces and volumes, and will be explained in greater detail.

A *surface* is the outside of a solid or body. Therefore, only two of the three dimensions of the body are used; the thickness of a surface is not considered, as a surface has no thickness.

The surfaces with which the shipwright will deal primarily are *square, rectangular,* and *triangular* surfaces.

A *square* is a rectangular surface having all its sides the same length.

A *rectangular surface* is a plane surface of four sides, with opposite sides equal to each other and adjacent sides at right angles to each other.

A *triangular surface* is a plane bounded by three straight lines. The three boundary lines are the sides. There are several types of triangles; however, since the major portion of shipwright mathematics centers in just one of these, the discussion will be confined to the *right triangle.*

The *area* of a surface is considered as the number of square units that it contains.

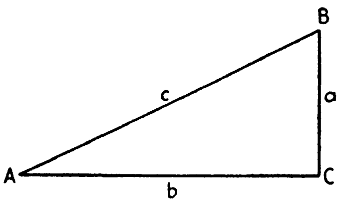


Fig. 1.—Right triangle.

In order to obtain the *surface area* of a *square,* we simply square the sides. For example, in order to find the number of square feet in a 5-ft. square, multiply 5 by 5, which equals 25 sq. ft.

To obtain the area of a *rectangular surface,* multiply the length of one side by the length of the adjoining side. For example, find the area of a rectangular surface 6 ft. wide and 12 ft. long; 6 multiplied by 12 equals 72 sq. ft.

To find the area of a *right triangular surface,* we simply multiply the length of one of the sides by the length of the adjoining side and divide by 2.

From Fig. 1:

$$\frac{a \times b}{2} = \text{area}$$

For example, the area of a triangle 3 ft. long on one of its sides and 6 ft. long on the other would be 9 sq. ft.

A **general rule** to follow in the measuring of surfaces is *length times breadth equals area.* The area divided by breadth equals length. The area divided by length equals breadth.

In the measurement of lines, the right triangle is used most by the shipwright. For example, take the right triangle shown in Fig. 1. a and b are the sides of the right triangle, and when joined together, they form a right angle. Side c is the *hypotenuse* of the triangle. It is the longest side and is always opposite the right angle C. There is a definite relationship existing between the sides that makes it possible to find the length of any side, provided that the other two are known. This relationship may be expressed in the formula as

$$a^2 + b^2 = c^2$$

Other relations between these sides may be derived from the above formula:

$$c = \sqrt{a^2 + b^2}$$
$$a = \sqrt{c^2 - b^2}$$
$$b = \sqrt{c^2 - a^2}$$

In Fig. 2, we notice that the sum of the squares joining sides a and b is equal to the squares joining side c. We now know the relationship of one side of the right triangle to another.

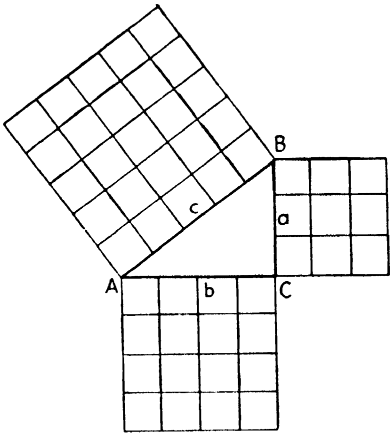


FIG. 2.—Squaring the sides of a right triangle, $a^2 + b^2 = c^2$.

SQUARE ROOT

Now, let us review the method of taking the *square root of a number.* To begin with, in order to square a number, we merely multiply the number to be squared by itself. Now the square root of a number is exactly the reverse procedure, but somewhat more complicated to figure.

Let it be required to take the *square root* of the number 573. First we separate the figure, beginning at the decimal, into periods of two figures each, as shown here. The number of periods obtained in such a separation is exactly the same as the number of units there will be in the root. In 573., for example, 73 makes up the first period, and 5 is the second period, and so there are to be two units in the root. 2, the first number in the root, is the greatest square that can be obtained from the left-hand period, which is 5. We square the first number in the root, which is 2, and we get 4, which is placed under the second period, 5. Subtracting, we get 1.

```
        23.93 +
     | 5 73.00 00
     | 4
  43 | 1 73
     | 1 29
 469 |   44 00
     |   42 21
4783 |    1 79 00
     |    1 43 49
     |      25 51
```

Now, the next period, 73, is brought down, and we have 173 for a dividend. To get a divisor, we multiply that part of the root already obtained by 2; here $2 \times 2 = 4$. We place 4 to the left of the new dividend. Now, a unit must be added to the right, which makes a complete divisor of 40. The number of times 40 plus the root to be obtained in this case will divide into 173, the dividend, is the second figure of the root. It is 3. Subtracting 129 from 173, we get 44. Bringing down another period, we have 4400 as a dividend. Now we multiply the root 23 by 2, obtaining 46 for a partial divisor. Adding one unit, we get 460. 460 will divide into 4400 nine times; so we get 469 as the divisor and 9 as the third figure of the root. Subtracting 4221 from 4400, we get 179. Bringing down another period, we get 17,900 as a dividend. Now, multiplying the unit 239 by 2, we get 478 for a partial divisor; and, adding one unit, we have 4780. 4780 will divide into 17,900 about three times; so we have 4,783 as a complete divisor, and 3 as the fourth number of the root.

Therefore, from the example shown, 23.93 is the approximate square root of 573. The answer can always be checked by squaring the root; for example, when 23.93 is multiplied by 23.93, it equals approximately 573.

While the foregoing solution seems somewhat long, a little practice will prove that it is not quite so laborious as it appears.

Table I can be used conveniently in calculating the length of the hypotenuse of a right triangle by simply squaring the lengths of the two sides of the angle, adding the results together, and then looking up the square root of that sum.

In shipwright work it often becomes necessary to *run a line square with another line*, and it has been found practical to use the right triangle in doing this. Any right triangle will work in this case. The right triangle having its two sides 3 and 4 ft. long and its hypotenuse 5 ft. long is most often used, since all sides work out in even feet and there is less chance of error. It is advisable to use as large a triangle as space permits in obtaining this square line because the larger the triangle the more accurate the right angle or square line. If the triangle is made larger, a multiple of these sides is used. For example, multiply all sides by 2, and the measurements will be 6, 8, and 10 ft.; or multiply by 3, and they will be 9, 12, and 15 ft.

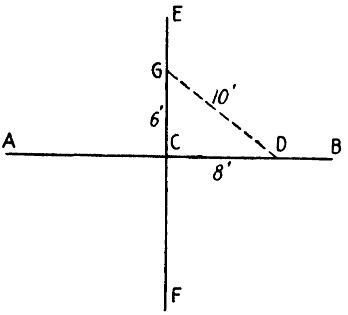


FIG. 3.—Squaring a line.

Example. Let it be required to construct a line square to the line *AB* at point *C*, as shown in Fig. 3. A rough analysis of the available space is made, and it is decided to use 6, 8, and 10 ft., provided that the long leg, which is to be 8 ft., is used on the line *AB*. Measure 8 ft. from the point *C* in either direction, or toward *A* or *B*, and find point *D*. Construction line *EF*, by eye, will be approximately square with the line *AB*. Measure 6 ft. from *C* along the line *EF* for the point *G*. The distance from *D* to *G* must be 10 ft. in order for the line to be square or at right angles to the line *AB*. If not, the point *G* must be moved and kept 6 ft. from point *C* until the distance *DG* is 10 ft.

This method of squaring a line can be used only where the surface is flat.

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.

0 ft.				1 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	0	0	0	0	1.000	1.00	1.00
1	.083	.007	0.288	1	1.083	1.174	1.040
2	.167	.028	0.409	2	1.167	1.361	1.079
3	.250	.063	0.500	3	1.250	1.563	1.114
4	.333	.111	0.577	4	1.333	1.778	1.155
5	.417	.174	0.646	5	1.417	2.007	1.190
6	.500	.250	0.707	6	1.500	2.250	1.225
7	.583	.340	0.764	7	1.583	2.507	1.258
8	.667	.444	0.816	8	1.667	2.778	1.291
9	.750	.563	0.866	9	1.750	3.062	1.323
10	.833	.694	0.913	10	1.833	3.361	1.354
11	.917	.840	0.957	11	1.917	3.674	1.385
2 ft.				3 ft.			
0	2.000	4.000	1.414	0	3.000	9.000	1.732
1	2.083	4.340	1.444	1	3.083	9.507	1.756
2	2.167	4.694	1.472	2	3.167	10.028	1.779
3	2.250	5.062	1.500	3	3.250	10.563	1.803
4	2.333	5.444	1.527	4	3.333	11.111	1.826
5	2.417	5.840	1.554	5	3.417	11.674	1.849
6	2.500	6.250	1.581	6	3.500	12.250	1.871
7	2.583	6.674	1.607	7	3.583	12.840	1.893
8	2.667	7.111	1.633	8	3.667	13.444	1.915
9	2.750	7.563	1.658	9	3.750	14.063	1.937
10	2.833	8.028	1.683	10	3.833	14.694	1.958
11	2.917	8.507	1.708	11	3.917	15.340	1.979
4 ft.				5 ft.			
0	4.000	16.000	2.000	0	5.000	25.000	2.236
1	4.083	16.674	2.021	1	5.083	25.840	2.255
2	4.167	17.361	2.041	2	5.167	26.694	2.273
3	4.250	18.063	2.062	3	5.250	27.623	2.291
4	4.333	18.778	2.082	4	5.333	28.444	2.309
5	4.417	19.507	2.103	5	5.417	29.340	2.327
6	4.500	20.250	2.122	6	5.500	30.250	2.345
7	4.583	21.007	2.141	7	5.583	31.174	2.363
8	4.667	21.778	2.161	8	5.667	32.111	2.381
9	4.750	22.563	2.180	9	5.750	33.063	2.398
10	4.833	23.361	2.199	10	5.833	34.028	2.415
11	4.917	24.174	2.218	11	5.917	35.007	2.433

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

6 ft.				7 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	6.000	36.000	2.449	0	7.000	49.000	2.646
1	6.083	37.007	2.466	1	7.083	50.174	2.661
2	6.167	38.028	2.483	2	7.167	51.361	2.677
3	6.250	39.063	2.500	3	7.250	52.563	2.693
4	6.333	40.111	2.516	4	7.333	53.778	2.708
5	6.417	41.174	2.533	5	7.417	55.007	2.723
6	6.500	42.250	2.549	6	7.500	56.250	2.739
7	6.583	43.340	2.566	7	7.583	57.507	2.754
8	6.667	44.444	2.582	8	7.667	58.778	2.769
9	6.750	45.563	2.598	9	7.750	60.063	2.784
10	6.833	46.694	2.614	10	7.833	61.361	2.799
11	6.917	47.840	2.630	11	7.917	62.674	2.814
8 ft.				9 ft.			
0	8.000	64.000	2.828	0	9.000	81.000	3.000
1	8.083	65.340	2.843	1	9.083	82.507	3.014
2	8.167	66.694	2.858	2	9.167	84.028	3.028
3	8.250	68.063	2.872	3	9.250	85.563	3.042
4	8.333	69.444	2.887	4	9.333	87.111	3.055
5	8.417	70.840	2.901	5	9.417	88.674	3.069
6	8.500	72.250	2.915	6	9.500	90.250	3.082
7	8.583	73.674	2.930	7	9.583	91.840	3.096
8	8.667	75.111	2.944	8	9.667	93.444	3.109
9	8.750	76.563	2.958	9	9.750	95.063	3.123
10	8.833	78.028	2.972	10	9.833	96.694	3.136
11	8.917	79.507	2.986	11	9.917	98.340	3.149
10 ft.				11 ft.			
0	10.000	100.000	3.162	0	11.000	121.000	3.317
1	10.083	101.674	3.175	1	11.083	122.840	3.329
2	10.167	103.361	3.188	2	11.167	124.694	3.342
3	10.250	105.063	3.202	3	11.250	126.563	3.354
4	10.333	106.778	3.214	4	11.333	128.444	3.366
5	10.417	108.507	3.228	5	11.417	130.340	3.379
6	10.500	110.250	3.240	6	11.500	132.250	3.391
7	10.583	112.007	3.253	7	11.583	134.174	3.403
8	10.667	113.778	3.266	8	11.667	136.111	3.416
9	10.750	115.563	3.279	9	11.750	138.063	3.428
10	10.833	117.361	3.291	10	11.833	140.028	3.440
11	10.917	119.174	3.304	11	11.917	142.007	3.452

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

12 ft.				13 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	12.000	144.000	3.464	0	13.000	169.000	3.606
1	12.083	146.007	3.476	1	13.083	171.174	3.617
2	12.167	148.028	3.488	2	13.167	173.361	3.628
3	12.250	150.063	3.500	3	13.250	175.563	3.640
4	12.333	152.111	3.512	4	13.333	177.778	3.651
5	12.417	154.174	3.523	5	13.417	180.007	3.663
6	12.500	156.250	3.535	6	13.500	182.250	3.674
7	12.583	158.340	3.547	7	13.583	184.507	3.686
8	12.667	160.444	3.559	8	13.667	186.778	3.697
9	12.750	162.563	3.571	9	13.750	189.063	3.708
10	12.833	164.694	3.582	10	13.833	191.361	3.719
11	12.917	166.840	3.594	11	13.917	193.674	3.731
14 ft.				15 ft.			
0	14.000	196.000	3.742	0	15.000	225.000	3.873
1	14.083	198.340	3.753	1	15.083	227.507	3.884
2	14.167	200.694	3.764	2	15.167	230.028	3.895
3	14.250	203.063	3.775	3	15.250	232.563	3.905
4	14.333	205.444	3.786	4	15.333	235.111	3.915
5	14.417	207.840	3.797	5	15.417	237.674	3.926
6	14.500	210.250	3.808	6	15.500	240.250	3.937
7	14.583	212.674	3.819	7	15.583	242.840	3.948
8	14.667	215.111	3.830	8	15.667	245.444	3.958
9	14.750	217.563	3.841	9	15.750	248.063	3.969
10	14.833	220.028	3.851	10	15.833	250.694	3.979
11	14.917	222.507	3.862	11	15.917	253.340	3.989
16 ft.				17 ft.			
0	16.000	256.000	4.000	0	17.000	289.000	4.123
1	16.083	258.674	4.010	1	17.083	291.840	4.133
2	16.167	261.361	4.021	2	17.167	294.694	4.143
3	16.250	264.063	4.031	3	17.250	297.563	4.153
4	16.333	266.778	4.041	4	17.333	300.444	4.163
5	16.417	269.507	4.052	5	17.417	303.340	4.173
6	16.500	272.250	4.061	6	17.500	306.250	4.183
7	16.583	275.007	4.072	7	17.583	309.174	4.193
8	16.667	277.778	4.082	8	17.667	312.111	4.203
9	16.750	280.563	4.092	9	17.750	315.063	4.213
10	16.833	283.361	4.103	10	17.833	318.028	4.223
11	16.917	286.174	4.113	11	17.917	321.007	4.233

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

18 ft.				19 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	18.000	324.000	4.243	0	19.000	361.000	4.359
1	18.083	327.007	4.252	1	19.083	364.174	4.369
2	18.167	330.028	4.262	2	19.167	367.361	4.378
3	18.250	333.063	4.272	3	19.250	370.563	4.388
4	18.333	336.111	4.282	4	19.333	373.778	4.397
5	18.417	339.174	4.291	5	19.417	377.007	4.406
6	18.500	342.250	4.301	6	19.500	380.250	4.416
7	18.583	345.340	4.311	7	19.583	383.507	4.425
8	18.667	348.444	4.321	8	19.667	386.778	4.435
9	18.750	351.563	4.330	9	19.750	390.063	4.444
10	18.833	354.694	4.340	10	19.833	393.361	4.453
11	18.917	357.840	4.349	11	19.917	396.674	4.463
20 ft.				**21 ft.**			
0	20.000	400.000	4.472	0	21.000	441.000	4.583
1	20.083	403.340	4.481	1	21.083	444.507	4.592
2	20.167	406.694	4.491	2	21.167	448.028	4.601
3	20.250	410.063	4.500	3	21.250	451.563	4.610
4	20.333	413.444	4.509	4	21.333	455.111	4.619
5	20.417	416.840	4.518	5	21.417	458.674	4.628
6	20.500	420.250	4.528	6	21.500	462.250	4.637
7	20.583	423.674	4.537	7	21.583	465.840	4.646
8	20.667	427.111	4.546	8	21.667	469.444	4.655
9	20.750	430.563	4.555	9	21.750	473.063	4.664
10	20.833	434.028	4.564	10	21.833	476.694	4.673
11	20.917	437.507	4.574	11	21.917	480.340	4.681
22 ft.				**23 ft.**			
0	22.000	484.000	4.690	0	23.000	529.000	4.796
1	22.083	487.674	4.700	1	23.083	532.840	4.804
2	22.167	491.361	4.708	2	23.167	536.694	4.813
3	22.250	495.063	4.717	3	23.250	540.563	4.822
4	22.333	498.778	4.726	4	23.333	544.444	4.830
5	22.417	502.507	4.735	5	23.417	548.340	4.839
6	22.500	506.250	4.743	6	23.500	552.250	4.848
7	22.583	510.007	4.752	7	23.583	556.174	4.856
8	22.667	513.778	4.761	8	23.667	560.111	4.865
9	22.750	517.563	4.770	9	23.750	564.063	4.873
10	22.833	521.361	4.778	10	23.833	568.028	4.882
11	22.917	525.174	4.787	11	23.917	572.007	4.891

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

24 ft.				25 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	24.000	576.000	4.899	0	25.000	625.000	5.000
1	24.083	580.007	4.907	1	25.083	629.174	5.008
2	24.167	584.028	4.916	2	25.167	633.361	5.017
3	24.250	588.063	4.924	3	25.250	637.563	5.025
4	24.333	592.111	4.933	4	25.333	641.778	5.033
5	24.417	596.174	4.941	5	25.417	646.007	5.042
6	24.500	600.250	4.950	6	25.500	650.250	5.050
7	24.583	604.340	4.958	7	25.583	654.507	5.058
8	24.667	608.444	4.967	8	25.667	658.778	5.066
9	24.750	612.563	4.975	9	25.750	663.063	5.074
10	24.833	616.694	4.983	10	25.833	667.361	5.082
11	24.917	620.840	4.992	11	25.917	671.674	5.091
26 ft.				27 ft.			
0	26.000	676.000	5.099	0	27.000	729.000	5.196
1	26.083	680.340	5.107	1	27.083	733.507	5.204
2	26.167	684.694	5.115	2	27.167	738.028	5.212
3	26.250	689.063	5.123	3	27.250	742.563	5.220
4	26.333	693.444	5.131	4	27.333	747.111	5.228
5	26.417	697.840	5.140	5	27.417	751.674	5.236
6	26.500	702.250	5.148	6	27.500	756.250	5.244
7	26.583	706.674	5.156	7	27.583	760.840	5.252
8	26.667	711.111	5.164	8	27.667	765.444	5.260
9	26.750	715.563	5.172	9	27.750	770.063	5.268
10	26.833	720.028	5.180	10	27.833	774.694	5.276
11	26.917	724.507	5.188	11	27.917	779.340	5.284
28 ft.				29 ft.			
0	28.000	784.000	5.292	0	29.000	841.000	5.385
1	28.083	788.674	5.299	1	29.083	845.840	5.393
2	28.167	793.361	5.307	2	29.167	850.694	5.401
3	28.250	798.063	5.315	3	29.250	855.563	5.408
4	28.333	802.778	5.323	4	29.333	860.444	5.416
5	28.417	807.507	5.331	5	29.417	865.340	5.424
6	28.500	812.250	5.339	6	29.500	870.250	5.431
7	28.583	817.007	5.346	7	29.583	875.174	5.438
8	28.667	821.778	5.354	8	29.667	880.111	5.446
9	28.750	826.563	5.362	9	29.750	885.063	5.454
10	28.833	831.361	5.369	10	29.833	890.028	5.462
11	28.917	836.174	5.377	11	29.917	895.007	5.469

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

30 ft.				31 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	30.000	900.000	5.477	0	31.000	961.000	5.568
1	30.083	905.007	5.485	1	31.083	966.174	5.575
2	30.167	910.028	5.492	2	31.167	971.361	5.583
3	30.250	915.063	5.500	3	31.250	976.563	5.590
4	30.333	920.111	5.508	4	31.333	981.778	5.598
5	30.417	925.174	5.515	5	31.417	987.007	5.605
6	30.500	930.250	5.523	6	31.500	992.250	5.612
7	30.583	935.340	5.530	7	31.583	997.507	5.620
8	30.667	940.444	5.538	8	31.667	1002.778	5.627
9	30.750	945.563	5.545	9	31.750	1008.063	5.635
10	30.833	950.694	5.553	10	31.833	1013.361	5.642
11	30.917	955.840	5.560	11	31.917	1018.674	5.649
32 ft.				33 ft.			
0	32.000	1024.000	5.657	0	33.000	1089.000	5.745
1	32.083	1029.340	5.664	1	33.083	1094.507	5.752
2	32.167	1034.694	5.671	2	33.167	1100.028	5.759
3	32.250	1040.063	5.679	3	33.250	1105.563	5.766
4	32.333	1045.444	5.686	4	33.333	1111.111	5.772
5	32.417	1050.840	5.694	5	33.417	1116.674	5.781
6	32.500	1056.250	5.701	6	33.500	1122.250	5.788
7	32.583	1061.674	5.708	7	33.583	1127.840	5.795
8	32.667	1067.111	5.715	8	33.667	1133.444	5.802
9	32.750	1072.563	5.723	9	33.750	1139.063	5.809
10	32.833	1078.028	5.730	10	33.833	1144.694	5.817
11	32.917	1083.507	5.737	11	33.917	1150.340	5.824
34 ft.				35 ft.			
0	34.000	1156.000	5.831	0	35.000	1225.000	5.916
1	34.083	1161.674	5.838	1	35.083	1230.840	5.923
2	34.167	1167.361	5.645	2	35.167	1236.694	5.930
3	34.250	1173.063	5.852	3	35.250	1242.563	5.937
4	34.333	1178.778	5.859	4	35.333	1248.444	5.944
5	34.417	1184.507	5.867	5	35.417	1254.340	5.951
6	34.500	1190.250	5.874	6	35.500	1260.250	5.958
7	34.583	1196.007	5.881	7	35.583	1266.174	5.965
8	34.667	1201.778	5.888	8	35.667	1272.111	5.972
9	34.750	1207.563	5.895	9	35.750	1278.063	5.979
10	34.833	1213.361	5.902	10	35.833	1284.028	5.986
11	34.917	1219.174	5.909	11	35.917	1290.007	5.993

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

36 ft.				37 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	36.000	1296.000	6.000	0	37.000	1369.000	6.083
1	36.083	1302.007	6.007	1	37.083	1375.174	6.089
2	36.167	1308.028	6.014	2	37.167	1381.361	6.096
3	36.250	1314.063	6.021	3	37.250	1387.563	6.103
4	36.333	1320.111	6.028	4	37.333	1393.778	6.110
5	36.417	1326.174	6.035	5	37.417	1400.007	6.117
6	36.500	1332.250	6.041	6	37.500	1406.250	6.124
7	36.583	1338.340	6.048	7	37.583	1412.507	6.130
8	36.667	1344.444	6.055	8	37.667	1418.778	6.137
9	36.750	1350.563	6.062	9	37.750	1425.063	6.145
10	36.833	1356.694	6.069	10	37.833	1431.361	6.151
11	36.917	1362.840	6.076	11	37.917	1437.674	6.158
38 ft.				39 ft.			
0	38.000	1444.000	6.164	0	39.000	1521.000	6.245
1	38.083	1450.340	6.171	1	39.083	1527.507	6.252
2	38.167	1456.694	6.178	2	39.167	1534.028	6.258
3	38.250	1463.063	6.185	3	39.250	1540.563	6.265
4	38.333	1469.444	6.191	4	39.333	1547.111	6.272
5	38.417	1475.840	6.198	5	39.417	1553.674	6.278
6	38.500	1482.250	6.205	6	39.500	1560.250	6.285
7	38.583	1488.674	6.211	7	39.583	1566.840	6.291
8	38.667	1495.111	6.218	8	39.667	1573.444	6.297
9	38.750	1501.563	6.225	9	39.750	1580.063	6.305
10	38.833	1508.028	6.232	10	39.833	1586.694	6.311
11	38.917	1514.507	6.239	11	39.917	1593.340	6.318
40 ft.				41 ft.			
0	40.000	1600.000	6.325	0	41.000	1681.000	6.403
1	40.083	1606.674	6.331	1	41.083	1687.840	6.409
2	40.167	1613.361	6.338	2	41.167	1694.694	6.416
3	40.250	1620.063	6.344	3	41.250	1701.563	6.422
4	40.333	1626.778	6.351	4	41.333	1708.444	6.429
5	40.417	1633.507	6.358	5	41.417	1715.340	6.435
6	40.500	1640.250	6.364	6	41.500	1722.250	6.442
7	40.583	1647.007	6.370	7	41.583	1729.174	6.448
8	40.667	1653.778	6.377	8	41.667	1736.111	6.455
9	40.750	1660.563	6.383	9	41.750	1743.063	6.461
10	40.833	1667.361	6.390	10	41.833	1750.028	6.468
11	40.917	1674.174	6.397	11	41.917	1757.007	6.474

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

42 ft.				43 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	42.000	1764.000	6.481	0	43.000	1849.000	6.557
1	42.083	1771.001	6.487	1	43.083	1856.174	6.564
2	42.167	1778.028	6.493	2	43.167	1863.361	6.570
3	42.250	1785.063	6.500	3	43.250	1870.563	6.576
4	42.333	1792.111	6.506	4	43.333	1877.778	6.583
5	42.417	1799.174	6.513	5	43.417	1885.007	6.590
6	42.500	1806.250	6.519	6	43.500	1892.250	6.596
7	42.583	1813.340	6.525	7	43.583	1899.507	6.602
8	42.667	1820.444	6.532	8	43.667	1906.778	6.608
9	42.750	1827.563	6.538	9	43.750	1914.063	6.614
10	42.833	1834.694	6.544	10	43.833	1921.361	6.621
11	42.917	1841.840	6.551	11	43.917	1928.674	6.627
44 ft.				45 ft.			
0	44.000	1936.000	6.633	0	45.000	2025.000	6.708
1	44.083	1943.340	6.640	1	45.083	2032.507	6.714
2	44.167	1950.694	6.646	2	45.167	2040.028	6.720
3	44.250	1958.063	6.652	3	45.250	2047.563	6.727
4	44.333	1965.444	6.659	4	45.333	2055.111	6.733
5	44.417	1972.840	6.665	5	45.417	2062.674	6.739
6	44.500	1980.250	6.671	6	45.500	2070.250	6.745
7	44.583	1987.674	6.677	7	45.583	2077.840	6.751
8	44.667	1995.111	6.683	8	45.667	2085.444	6.758
9	44.750	2002.563	6.689	9	45.750	2093.063	6.764
10	44.833	2010.028	6.696	10	45.833	2100.694	6.770
11	44.917	2017.507	6.702	11	45.917	2108.340	6.776
46 ft.				47 ft.			
0	46.000	2116.000	6.782	0	47.000	2209.000	6.856
1	46.083	2123.674	6.789	1	47.083	2216.840	6.862
2	46.167	2131.361	6.795	2	47.167	2224.694	6.868
3	46.250	2139.063	6.801	3	47.250	2232.563	6.874
4	46.333	2146.778	6.807	4	47.333	2240.444	6.880
5	46.417	2154.507	6.813	5	47.417	2248.340	6.886
6	46.500	2162.250	6.819	6	47.500	2256.250	6.892
7	46.583	2170.007	6.825	7	47.583	2264.174	6.898
8	46.667	2177.778	6.831	8	47.667	2272.111	6.904
9	46.750	2185.563	6.837	9	47.750	2280.063	6.910
10	46.833	2193.361	6.843	10	47.833	2288.028	6.916
11	46.917	2201.174	6.849	11	47.917	2296.007	6.922

TABLE I.—DECIMALS, SQUARES, AND SQUARE ROOTS IN FEET AT 1-IN. INTERVALS TO 50 FT.—(*Continued*)

48 ft.				49 ft.			
Inches	Decimal form	Square	Square root	Inches	Decimal form	Square	Square root
0	48.000	2304.000	6.928	0	49.000	2401.000	7.000
1	48.083	2312.007	6.934	1	49.083	2409.174	7.006
2	48.167	2320.028	6.940	2	49.167	2417.361	7.012
3	48.250	2328.063	6.946	3	49.250	2425.563	7.018
4	48.333	2336.111	6.952	4	49.333	2433.778	7.024
5	48.417	2344.174	6.958	5	49.417	2442.007	7.029
6	48.500	2352.250	6.964	6	49.500	2450.250	7.035
7	48.583	2360.340	6.970	7	49.583	2458.507	7.042
8	48.667	2368.444	6.976	8	49.667	2466.778	7.048
9	48.750	2376.563	6.982	9	49.750	2475.063	7.053
10	48.833	2384.694	6.988	10	49.833	2483.361	7.059
11	48.917	2392.840	6.994	11	49.917	2491.674	7.065

CIRCULAR OR ANGULAR MEASURE

This measurement is used to measure *arcs of circles and angles in determining direction.*

That part of the circumference which is included by the lines forming the angles is the measure of the angle.

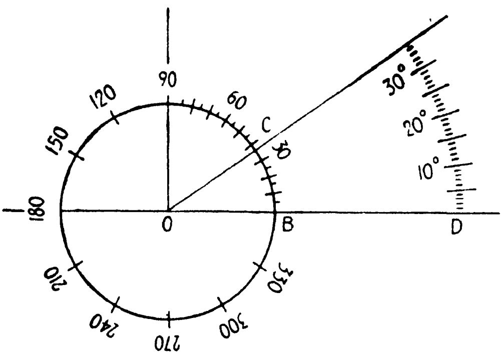


FIG. 4.—Using the protractor.

At times, in shipwright work, owing to limited space, it is found impractical to lay off lines or to form a triangle so that the direction of the lines desired can be determined. In such cases, a protractor, or semicircular instrument employed for laying off or measuring degrees, is used. To begin with, we must have a point such as *O* in Fig. 4. This is the *vertex* of the angle to be constructed. Line *OBD* is one side of the angle. Place the protractor along the line *OBD* with the center at *O* and with the line on the 0-deg. mark on the protractor.

To Lay Off an Angle of 35 Deg.

Now, let it be required to lay off an angle of 35 deg. Proceed around the protractor in a counterclockwise direction until the 35 deg. mark on the protractor is reached, and mark a point *C* here. From point *O* to the point *C*, which is established, draw a line. This angle *COD* is the desired angle of 35 deg.

In like manner, the direction of any line may be determined from a point and another line, the accuracy of which depends on the size of the protractor and the manner in which it is used.

To Construct a Protractor of Any Desired Size

All that is necessary to lay out the lines for building a protractor is to erect a perpendicular line to a base line. At the intersection of the perpendicular and the base line, draw an arc of approximately the desired size of the protractor. Along this line or the circumference of the quarter circle, with a pair of dividers mark off two equal parts. This will indicate two angles, 45 and 90 deg. After this has been accomplished, divide each one of the angles into three more equal parts, and this will give angles of 15-deg. increments. The 15-deg. increments can then be divided into 15 equally divided parts, creating 1 deg. for each part.

The above method will be found to be much simpler than trying to divide the quarter circle into 90 divisions.

Lines can now be drawn from the center of the quarter circle to each of the degree points similar to those on any protractor.

CIRCULAR AND CYLINDRICAL MEASUREMENTS

The Circle. A circle is a line all points of which are equidistant from a point within called the *center*.

Properties of the Circle.

r = radius = distance from center to any point on the circumference

d = diameter = length of any line connecting one point on the circumference with another on the circumference that passes through the center = $2r$

c = circumference = distance measured around the circle. It is a constant times d. This constant is called π and has been found to be 3.14159. $c = \pi d = 2\pi r$

A = enclosed area $= \pi r^2 = \dfrac{\pi d^2}{4}$

The Cylinder. A cylinder is the surface traced by one side of a rectangle when rotated, the parallel side being used as an axis.

Properties of the Cylinder.

A = area of the base $= \pi r^2 = \dfrac{\pi d^2}{4}$ (same as circle)

h = height of the cylinder

A' = area of the cylindrical surface $= ch = 2\pi rh = \pi dh$

V = volume of the cylinder $= Ah = \pi r^2 h = \dfrac{\pi d^2 h}{4}$

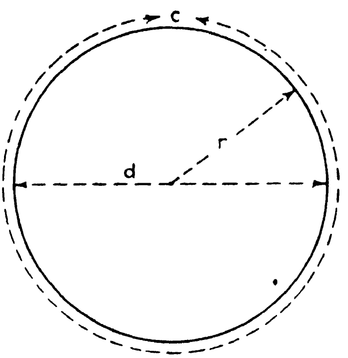


FIG. 5.—The circle.

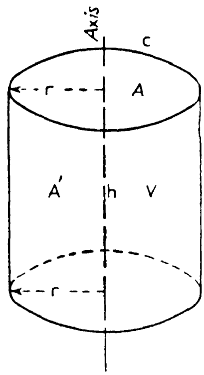


FIG. 6.—The cylinder.

GEOMETRY

Considering the numerous types of lines and their location and purpose, it is important for the shipwright to familiarize himself with the geometric methods that may be used to determine the location of points to which lines may be erected. Two points, or a point and a direction, will determine the location of an alternate line. For example, a line is to be erected from a point, perpendicular to another line; thus the line to be erected has been located, and since we have a point and a direction such a line can fall into but one position.

Examples of the location of points and lines and their solution are given below.

To Bisect a Straight Line

It is required to *bisect*, or to divide into two equal parts, the straight line AB. With A as the center, take a compass and, with its radius set more than one-half the length of the line AB, scribe an arc on both sides of the line AB. Now, with B as a center and using the same radius, scribe an arc on both sides of the line AB, intersecting the two arcs previously drawn.

At the points where these arcs intersect, we have *C* and *D*. With a straightedge, draw the line *CD*. The line *CD* now intersects the line *AB* at the point *E*. The distances *AE* and *BE* are equal; therefore, the line is bisected (Fig. 7).

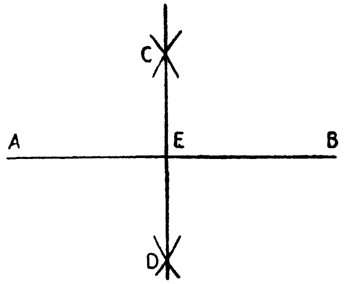


Fig. 7.—Bisecting a line.

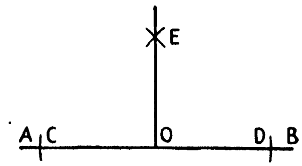


Fig. 8.—Erecting a perpendicular at point *O*.

To Erect a Perpendicular Square, or at Right Angles, to a Straight Line from a Point in That Line

Let *O* be the point at which the perpendicular is to be erected. Now, with point *O* as a center, take the compass and describe an arc cutting the original line *AB* at points *C* and *D*. With *C* and *D* as centers and a radius greater than *OC* or *OD*, which are equal, describe arcs that intersect, making point *E*. A line drawn from point *E* to point *O* is perpendicular to the line *AB* (Fig. 8).

To Erect a Perpendicular to a Straight Line from a Point Not in That Line

Let *AB* be the line and *P* the point. With a compass set to a radius greater than the shortest distance between the line *AB* and *P*, and using *P* as a center, describe an arc intersecting *AB* at points *C* and *D*. Now with *C* and *D* as centers with any convenient radius, describe short arcs intersecting at *E*. A line from *P* to *E* will be perpendicular to *AB* at *F* (Fig. 9).

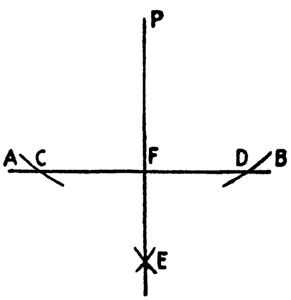


Fig. 9.—Erecting a perpendicular from point *P* to line *AB*.

To Bisect a Given Angle

To *bisect* a given angle, let *DAC* be the angle to be bisected. With the vertex *A* as a center and any convenient radius, describe an arc intersecting *AD* at *E* and *AC* at *F*. With *E* and *F* as centers and a radius greater than half the arc *EF*, describe two arcs intersecting at *B*. A line drawn through *AB* will bisect the angle; that is, *BAC* equals *BAD* (Fig. 10).

To Construct an Equilateral Triangle

Let us construct an *equilateral triangle*, the length of the sides being given. From Fig. 11, lay off side AB to the designed length given.

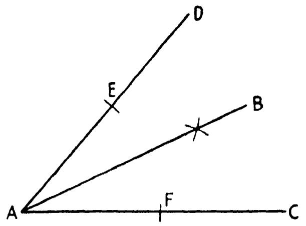


Fig. 10.—Bisecting an angle.

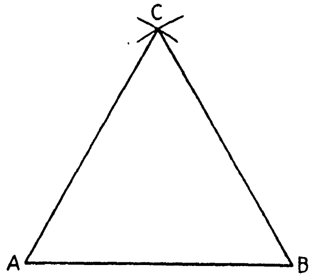


Fig. 11.—Constructing an equilateral triangle.

Then, with A and B as centers and a radius equal to the length AB, describe arcs that intersect at point C. Draw lines AC and BC. Triangle ABC is an equilateral triangle.

To Construct a Triangle with Length of Sides Given

Let it be required to construct a *triangle* whose sides are equal to three given lengths a, b, and c, as shown in Fig. 12. Lay off side c to its designed length. With A as a center, draw an arc of a circle with a radius

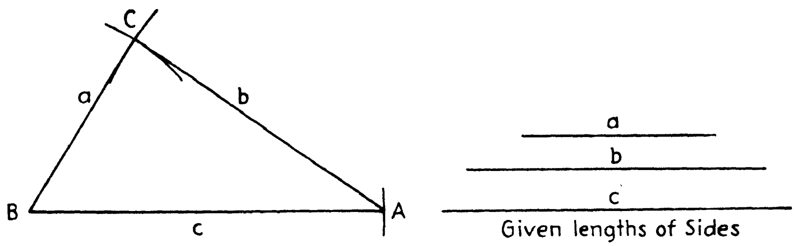


Fig. 12.—Constructing a triangle with sides given.

equal to one of the given lengths. Now, with B as a center and a radius equal to the other given side, draw an arc intersecting the arc previously drawn. Call this point of intersection C. Connect points A and B with C, and we have a triangle with three sides equal, respectively, to the three lengths desired, a, b, and c.

To Construct a Parallelogram, Two Sides and an Angle Being Given

From Fig. 13 lay out angle θ. Lay off the sides of the angle so that AD and AB equal the values given. At point B, swing a radius equal to AD. At point D, swing a radius equal to AB. At the intersection of the two arcs, locate point *C*. Now, draw lines *BC* and *DC*, and a *parallelogram* has been constructed.

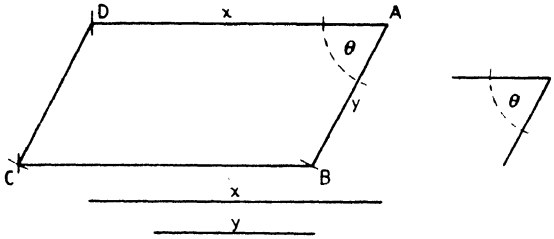


FIG. 13.—Constructing a parallelogram with two sides and an angle given.

To Inscribe a Square within a Circle

From Fig. 14 scribe a circle with the desired radius. Draw two perpendicular diameters *CEA* and *DEB*. Connect the points *A*, *B*, *C*, and *D* with chords *x*.

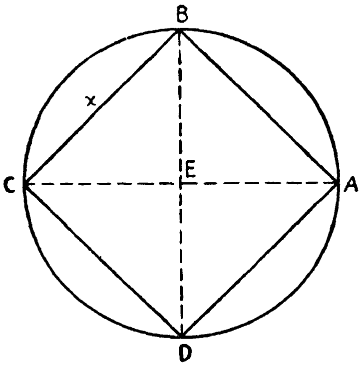


FIG. 14.—Inscribed square within a circle.

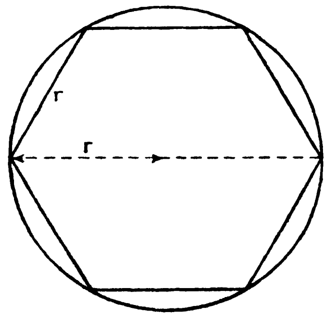


FIG. 15.—Inscribed hexagon within a circle.

To Inscribe a Hexagon within a Circle

Beginning at any point desired, step around the circumference with a chord equal to the radius, and connect these points with chords *r* as shown in Fig. 15.

To Inscribe an Octagon within a Circle

As shown in Fig. 16, draw two perpendicular diameters *CEA* and *DEB*. Bisect each of the quadrant arcs. Connect the points *A*, *F*, *B*, *G*, *C*, *H*, *D*, and *J* with chords *x*.

To Construct an Ellipse, the Diameters Being Given

As shown in Fig. 17, draw two circles with the given diameters about a common center *E*. Construct two perpendicular diameters *CEA* and *DEB*. Divide the quadrant *AEB* into as many divisions as are easily worked. Take these divisions one at a time, for example, line *EO*. At the point where *EO* intersects the smaller circle, draw a line *x*, parallel to the axis *EA*; at the point where *EO* intersects the large circle, draw a line *y* parallel to the axis *EB*. The intersection of *x* and *y* is a point on the ellipse. Repeat this operation for all the lines in quadrant *AEB*.

For quadrants *CEB*, *CED*, and *AED*, this can be repeated, or the points can be plotted from ordinates taken off the points in quadrant *AEB*, using dimensions from axes *EA* and *EB*.

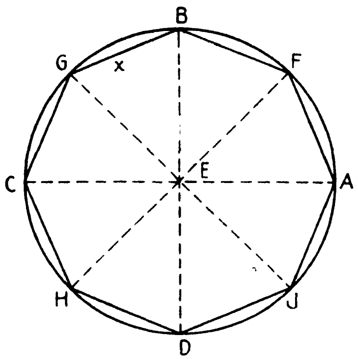


FIG. 16.—Inscribed octagon within a circle.

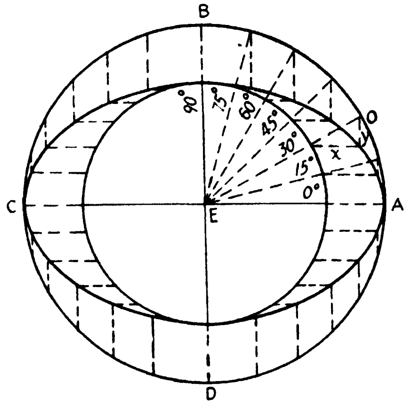


FIG. 17.—Constructing an ellipse with the diameters given.

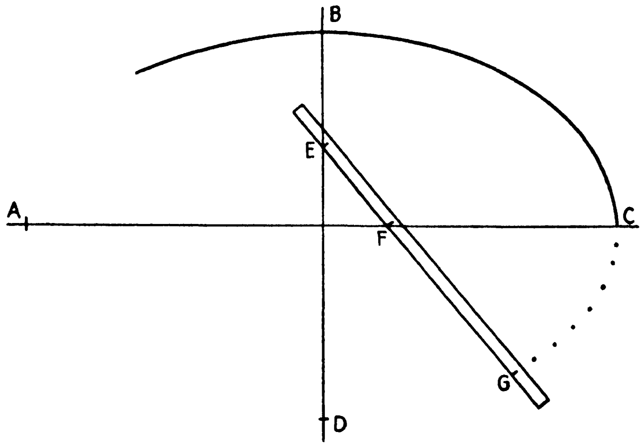


FIG. 17*a*.—Constructing an ellipse with a straightedge.

Another method of laying out an ellipse is shown in Fig. 17*a*. The major axis of the ellipse is *AC*; the minor axis is *BD*. When the lengths *AC* and *BD* are known, a wooden batten is marked off with points *EF* and *G*, such that the distance *EG* equals one-half the major axis and *FG* equals one-half the minor axis. This batten is then moved around to various positions, point *F* always being kept on the major axis and point *E* on the minor axis. The point *G* will then trace out the curve of the ellipse.

CHAPTER II

BLUEPRINT READING

The ability to interpret a *plan*, or *blueprint* as it is popularly known, is of great importance in any industrial field and is therefore a prerequisite in the training of craftsmen working in such fields.

There is no place in ship construction for guesswork. Every part of the ship must meet the specifications and particular requirements of the owners and the purpose for which the ship is being built. For the craftsmen in different trades to carry on their work successfully, they must have a clear picture of exactly what is wanted on each job.

This is where the draftsman plays his part in construction. His job is to develop from specifications the detailed picture of what is required for each part of the ship. He then makes drawings from which blueprint copies are made for use on the job. In drawing a plan, the draftsman must give a pictorial representation of how the finished product will look. This is done by drawing corresponding views to enable the craftsmen to build what the draftsman visualizes in his mind. To do this, the draftsman uses a graphical language which is universal among craftsmen and engineers and which can readily be understood by anyone having a trained imagination with respect to this language.

The chief requirement of a blueprint is to give necessary information as briefly as possible; thus, abbreviations and symbols are used wherever possible. In a drawing the draftsman shows only the standard lines and symbols that are necessary and can be understood by the man who is going to perform the work; therefore, each line has a meaning bearing on the finished product. If out-of-the-ordinary views or symbols are necessary, he will clearly state somewhere on the plan an explanation of these, so that there will be no chance of misinterpretation.

No great amount of skill is necessary to read a plan. Anyone desiring to acquire a knowledge of this graphical language may do so with little difficulty. To read or interpret a blueprint, one must have a knowledge of the various lines and their meanings and of the abbreviations and symbols used.

For the craftsman to carry out successfully the instructions on a drawing, he must be able to interpret them accurately. The following points should also be kept in mind:

1. Be sure to have the correct and latest drawings for the particular ship on which the work is being done, and also the correct location.

2. Read all the notes that have any bearing on the collaboration of the job.

3. Study all plans carefully and thoroughly before starting work. Try to bear in mind how the finished job will look, and note particularly any details.

4. Pay particular attention to references made on a plan to details shown on another plan, thus avoiding mistakes.

5. Do not attempt to scale dimensions from a blueprint.

6. Recheck all figures when adding or subtracting dimensions taken from a plan.

7. Check drawing with work as often as necessary, and do not rely on memory, particularly in the case of dimensions.

THE ALPHABET OF LINES

All lines used by draftsmen follow certain conventions so that one type of line may be distinguished from another. Figure 18 shows the various types of line generally used in shipbuilding.

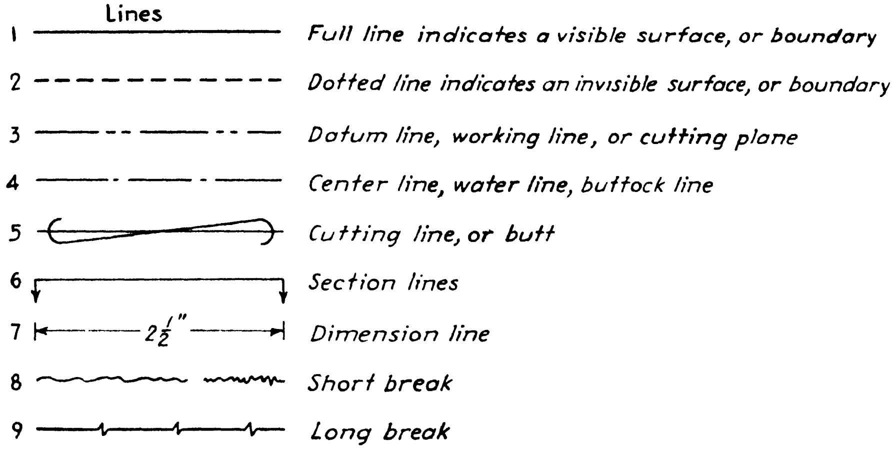


Fig. 18.—Types of lines used in drawing plans.

METHODS OF REPRESENTATION

Objects can be represented on working drawings by (1) orthographic projection, (2) isometric drawing, or (3) oblique drawing.

1. Orthographic Projection. Any object as it appears to the eye may be shown in a drawing as it would appear in a photograph or picture. This is known as a *perspective drawing.* The perspective drawing shown in Fig. 19 is not suitable as a working drawing inasmuch as the lines and measurements cannot be accurately scaled.

A working drawing gives all the information necessary to build the object represented. Although pictorial drawings are used in some cases, the basis of all working drawings is *orthographic projection.*

In orthographic projection the picture planes are called the *planes of projection*, and the perpendiculars are called *projectors*. This means that the drawing is made up of a set of separate views, looking at the object from different positions, and arranged in such a way that each

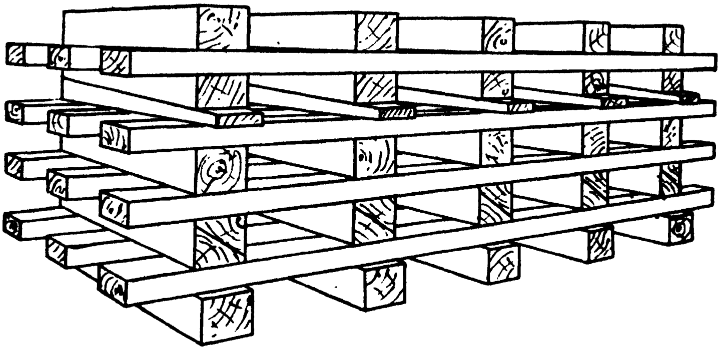


FIG. 19.—A perspective drawing.

view shows two of the three dimensions. The three views of a block drawn in orthographic projection are shown in Fig. 20. The elevation, or front view, shows the length and height. The projection to the right

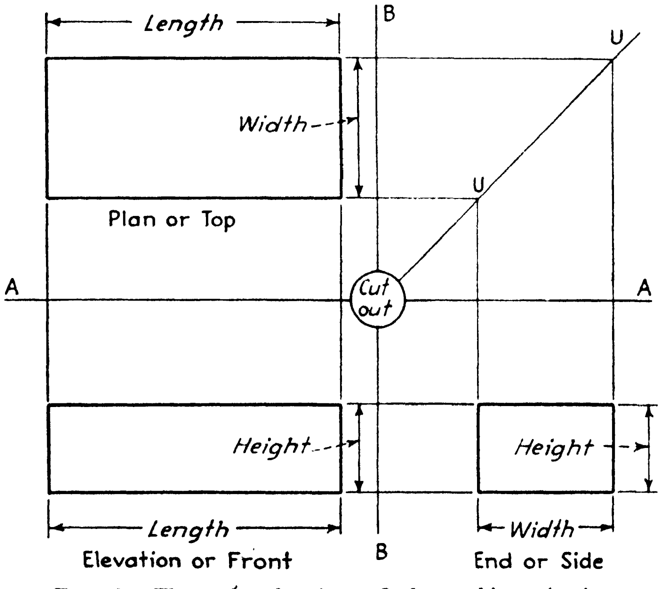


FIG. 20.—Three view drawing. Orthographic projection.

of the front shows the width and height. The projection carried to the top of the plan, or the top view, shows the length and width. By folding along section lines *AA*, *BB*, and *UU* the three views of this particular block can be readily seen.

2. Isometric Drawings. These are made to clarify orthographic projection and structural detail and may be used to advantage in some diagrams. In an isometric drawing, measurements can be made only on isometric lines. Lines not parallel to one of the isometric axes are called *nonisometric lines.*

The principle used in representing objects in isometric drawing is shown in Fig. 21. Lines *AB*, *AC*, and *AD* make equal angles with each other and are called *isometric axes.* Since parallel lines have their projections parallel, the other edges of the object will be respectively parallel to these axes. Any line parallel to an isometric axis is called an *isometric line.*

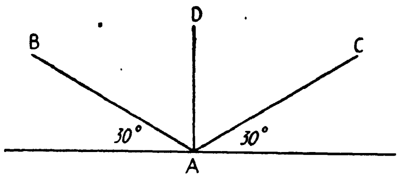


FIG. 21.—Isometric axes.

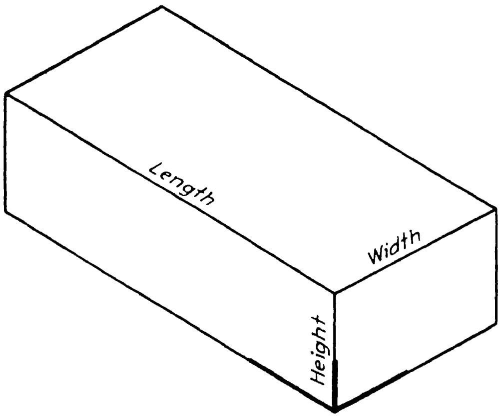


FIG. 22.—Isometric drawing.

Isometric drawings lend themselves readily to freehand drawings which the craftsman may find necessary in explaining some part of his work. The block shown in Fig. 20 is illustrated in Fig. 22 but it is drawn in an isometric view.

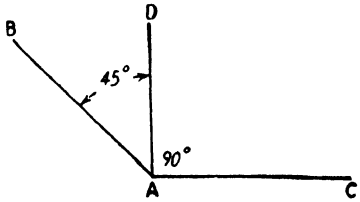


FIG. 23.—Oblique axes.

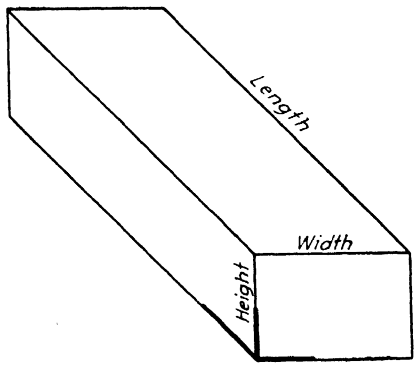


FIG. 24.—Oblique drawing.

3. Oblique Drawing. This is similar to the isometric drawing in having three axes representing perpendicular lines upon which measurements can be made. Two of the axes will always be at right angles to each other, being parallel to the picture plane. The third axis may be at any angle desired and this method is therefore more flexible than the isometric drawing.

The oblique drawing may lend itself better than the isometric to showing some objects, especially when the surfaces run in the same picture plane. A plan that may be used in making an oblique drawing is shown in Fig. 23. The blocks shown in Figs. 20 and 22 are also shown in Fig. 24, but done in oblique drawing.

USE OF SCALE

In drawing large objects, it is, of course, impossible to draw them full size. It is necessary, therefore, to reduce the size in proportion, and for this purpose the scale rule is used.

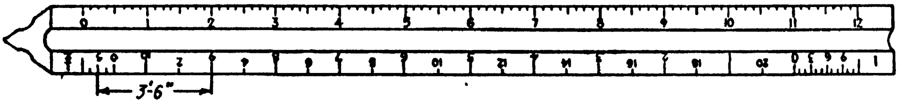


Fig. 25.—Scale.

With the scale rule, objects may be represented from full size to $\frac{1}{128}$ size, or $\frac{3}{32}$ in. per ft. Smaller scales are not suitable for details. When layouts are drawn in small scale, the details are generally drawn in a much larger scale to show them more clearly. In such cases, drawings may state a number of different scales used in developing them.

Dimensions are always given on drawings. Therefore, it is not necessary for the craftsman to scale them, except for rough purposes.

In using the scale, if the drawing states that $\frac{1}{2}'' = 1'0''$, then the object is drawn $\frac{1}{24}$ of its actual size. Therefore, if $\frac{1}{2}$ in. equals 1 ft., $\frac{1}{12}$ of $\frac{1}{2}$ in. actually equals 1 in. It will be observed on the scale rule that one division at the end of the rule for each scale is divided into 12 parts, which represent inches of that scale. The fractions of an inch are divided along this scale by eye. The scale shown in Fig. 25 shows $\frac{1}{2}'' = 1'0''$. Arrows show 3'6" laid off along the scale.

Dimensions are shown in the following manner:

$$2'10\frac{1}{2}'' = 2 \text{ ft. } 10\frac{1}{2} \text{ in.}$$

PROJECTION

Drawings are usually made similar to that shown in Fig. 26. Such drawings are known as *three-view drawings* or *third-angle projection*.

The top view shows the *length* and *width*.

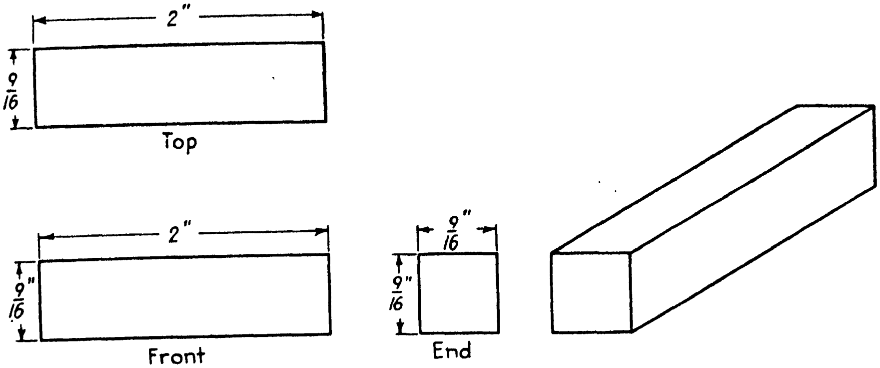


FIG. 26.—Three-view drawing or third-angle projection.

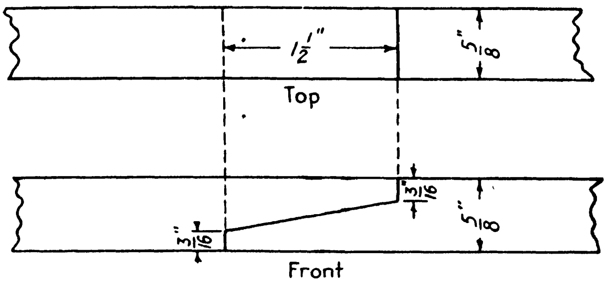


FIG. 27.—Scarf joint.

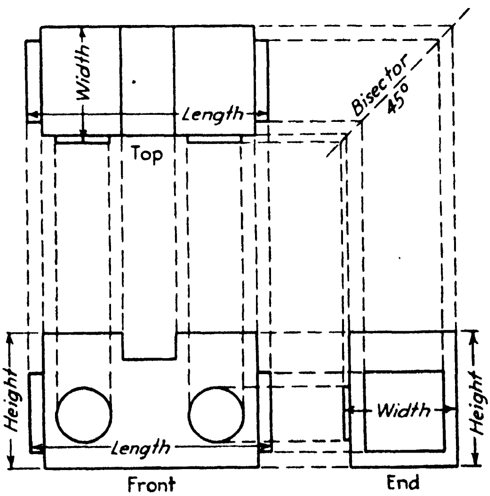


FIG. 28.—Orthographic projection showing lines of projection.

The front view shows the *length*, *thickness*, or *height*.

The end view shows the *width*, *thickness*, or *height*.

The drawing in Fig. 27 is that of a *scarf joint*. Only two views are required in this particular case since all the necessary information is shown in these two views. This is known as a *two-view drawing*.

The object shown in Fig. 28 is no more complicated to interpret than the block shown in Fig. 26. All dotted lines are known as *lines of projection* and have nothing whatever to do with the construction of the object. They are used only to point out more clearly the projection from one view to the other. The object itself is clearly outlined by solid lines. The three views of this particular object are required in order to give all the necessary information for its construction.

INVISIBLE LINES

All the boundaries or edges of the objects discussed in the foregoing paragraphs could be seen in the two or three views shown. For this purpose a solid line was used.

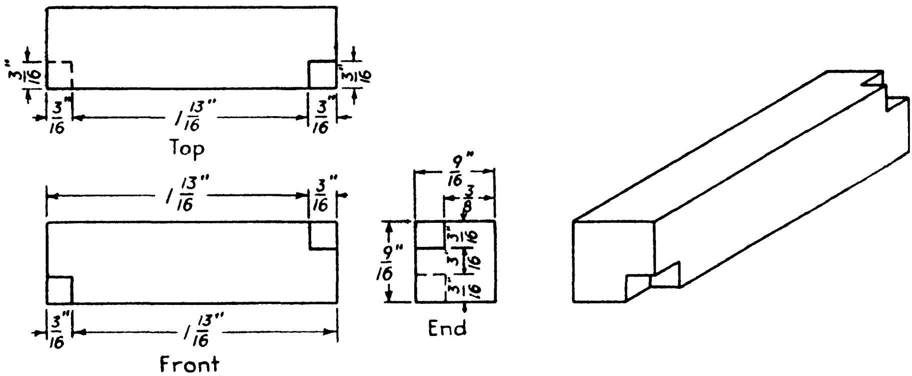


FIG. 29.—Object with invisible surfaces.

Many objects shown on drawings are of such construction that hidden, or invisible, edges must be represented in order to give the necessary information for their construction.

The invisible line is called a *dotted line* but is, in reality, a dashed line, thus- -.

The notched recesses at the top and bottom of the block shown in Fig. 29 are examples of invisible surfaces.

It will be observed that the recesses affect all the surfaces except the back. To eliminate the necessity of showing each surface affected, the invisible line is used, and thus all the necessary information is given in three views. The front and plan views actually give all the necessary information. However, to leave no doubt in the mind of the craftsman, the side view or end view is shown. It indicates that the recess at the bottom is nearest him, while the recess at the top is in the surface opposite.

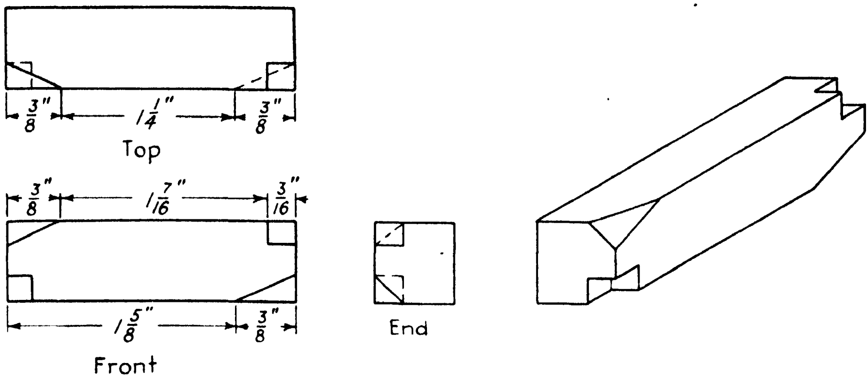


FIG. 30.—Object with additional invisible surfaces.

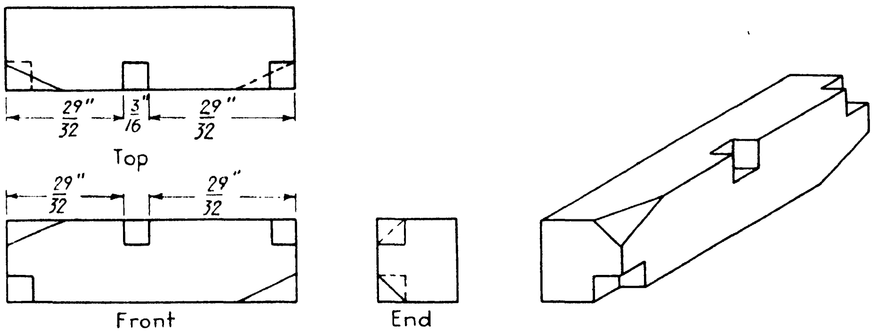


FIG. 31.—Object having recessed surfaces.

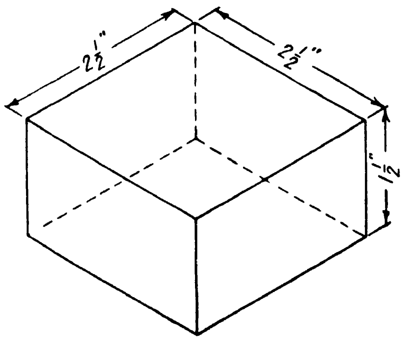


FIG. 32.

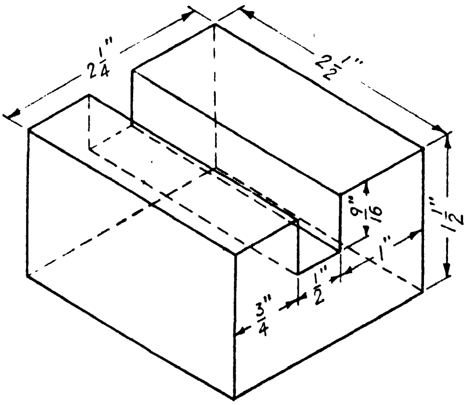


FIG. 33.

The object given in Fig. 30 is carried one step further with respect to invisible surfaces in that it shows the object given in Fig. 29, but with the opposite top and bottom corners beveled.

The same block is again used in Fig. 31, with an additional recess shown at the top of the vertical center on the front, and one side only.

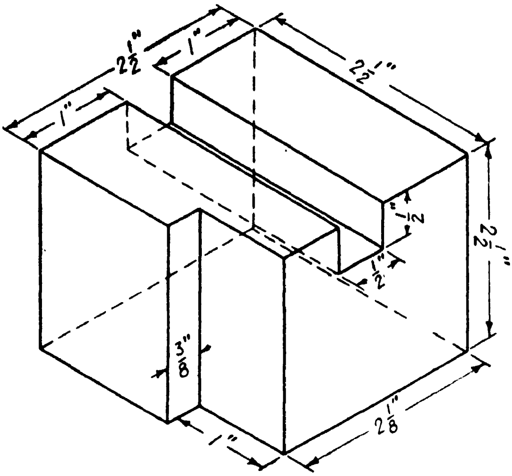


Fig. 34.

To aid in forming a mental picture of the various views of an object containing invisible surfaces and edges, the following are suggested for practice:

1. Draw three views of the block drawn in isometric and shown in Fig. 32.

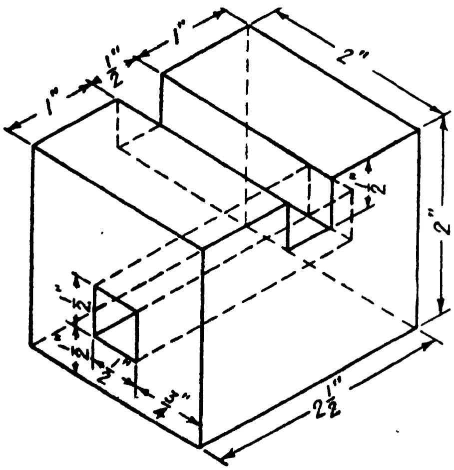


Fig. 35.

2. Draw three views of the isometric shown in Fig. 33.
3. Draw three views of the object shown in Fig. 34.
4. Draw three views of the object shown in Fig. 35.

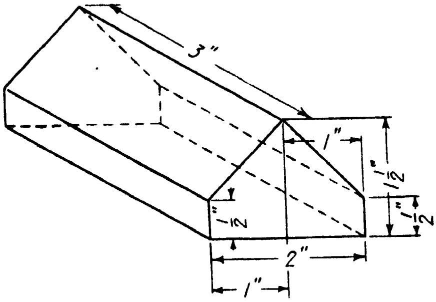


FIG. 36.

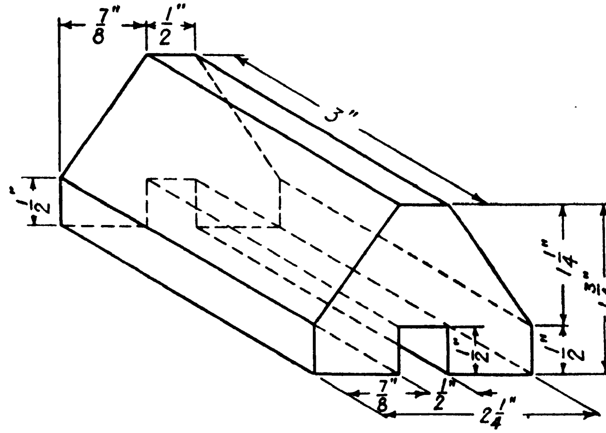


FIG. 37.

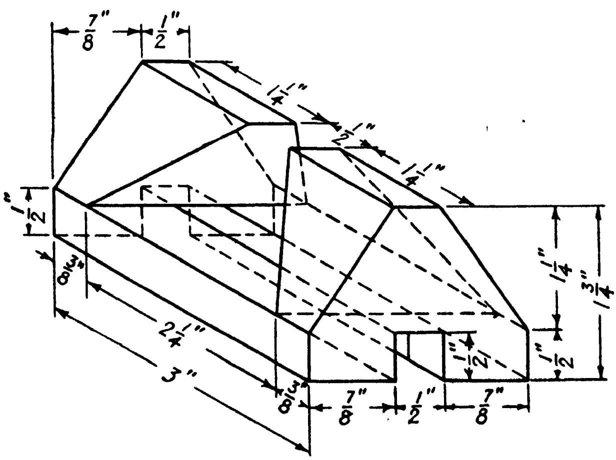


FIG. 38.

Figures 36, 37, and 38, which have *inclined*, or *angular*, surfaces and are drawn in oblique drawing, can also be used for practice. Draw three views of the objects shown in them.

DRAWINGS SHOWING SECTIONS

To give the craftsman all the necessary information for performing his work, another view is sometimes required that is not apparent in the three-view drawing. This is done by showing a cut, or section, through the object whereby the inner parts of it can be seen. Sections can be shown in horizontal, vertical, or diagonal cuts as may be required to give the views most desired. On structural plans many references to other plans can be eliminated by the use of sections.

Let us imagine that we can see through a block to a given cutting plane. A draw-

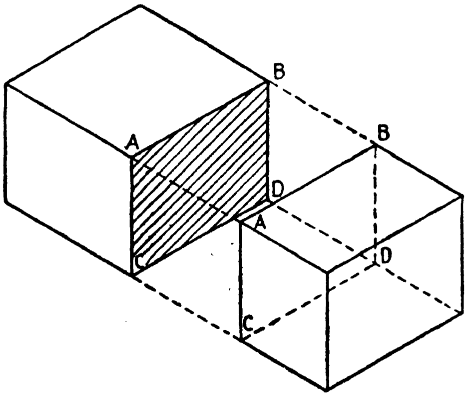


FIG. 39.—Section drawing.

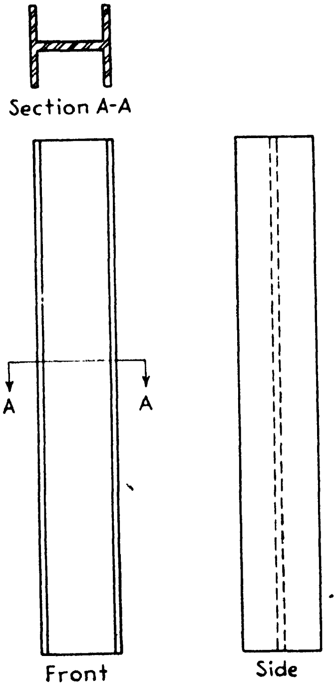


FIG. 40.—Cross section of a stanchion.

ing of this view of the cut surface would be indicated by section letters *AA*, *BB*, etc. In Fig. 39 it can be seen that the block shown has been cut and separated at points *A*, *B*, *C*, and *D*, disclosing the appearance of the block at the cutting plane as shown by the hatched sections *A*, *B*, *C*, and *D*.

Figure 40 shows an elevation of the front and side views of a stanchion. To give a clearer idea of this object a section is also given through section line *AA*, which shows the designed cross sections of this rolled shape.

Now, suppose a cross section is desired through section line *AA* in Fig. 41. The drawing is of a vertical plate with an angle stiffener fastened to it on the side nearest the eye. This cross section projected directly

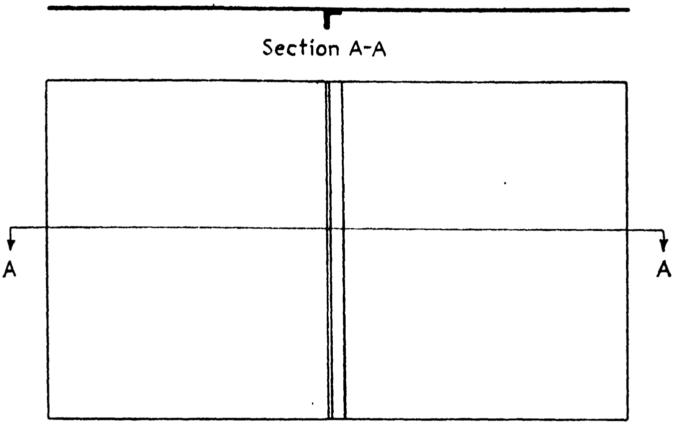


FIG. 41.—Section drawing.

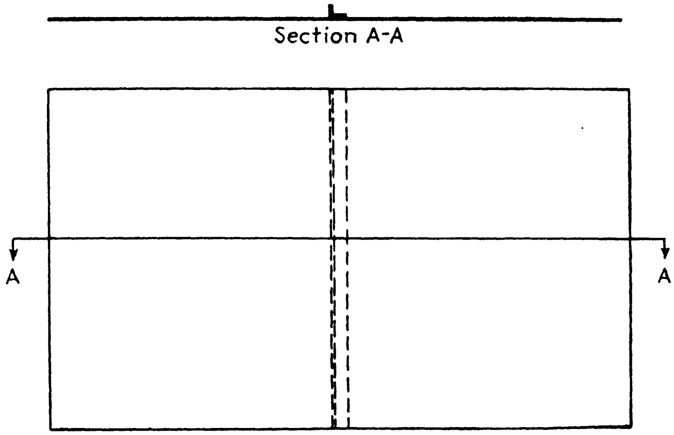


FIG. 42.

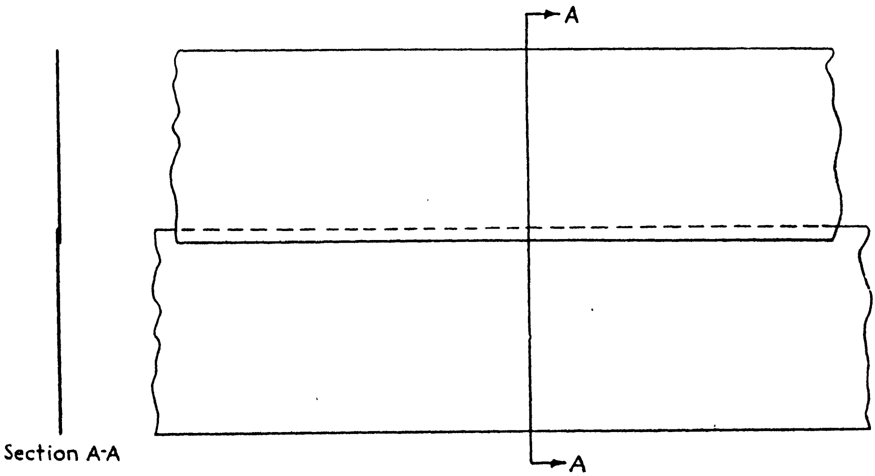


FIG. 43.

above would clearly show the arrangement and construction of this plate and stiffener, leaving no doubt in the mind of the craftsman.

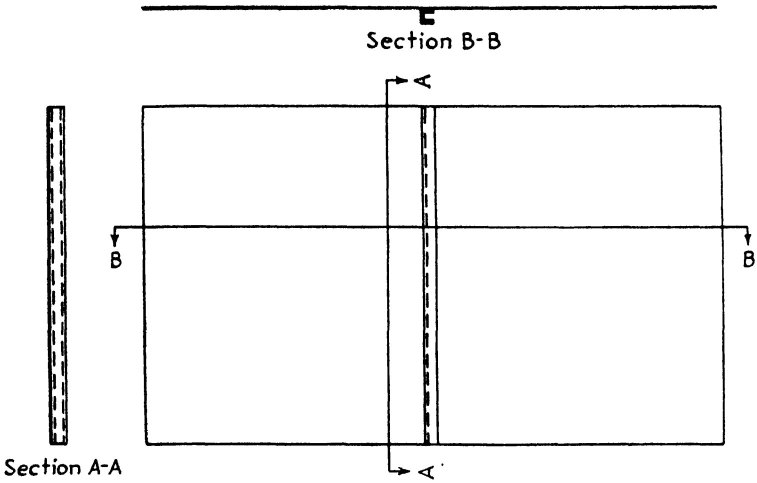


FIG. 44.

Figures 42 to 44 also show section views at the section lines as indicated.

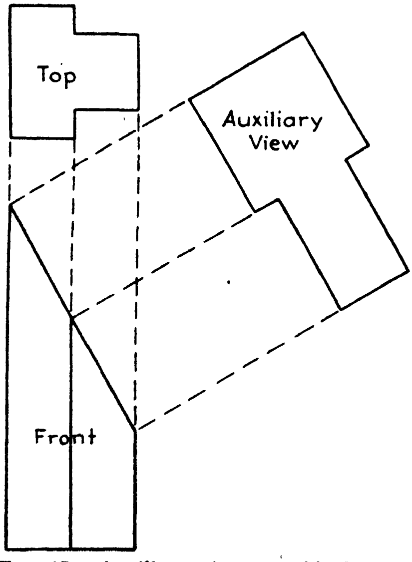


FIG. 45.—Auxiliary view of a block with an inclined top surface.

AUXILIARY PROJECTION

In drawing some types of object it is sometimes necessary to show more than the three views and section already mentioned.

An auxiliary view may be described as a *projection* of an object on a plane that is perpendicular to one of the principal planes but inclined to the other two. Therefore, an auxiliary view would show as an edge view on the plane to which it is perpendicular. This kind of view is used to obtain the true shape of an inclined surface.

An example of such a surface, which is common in ship construction, is the enclosure bulkhead around the uptakes.

An auxiliary view is shown in Fig. 45.

MATERIALS USED IN HULL CONSTRUCTION

In the interpretation of blueprints it is, of course, necessary that the craftsman know something of the particular type of material used in connection with hull construction.

The principal material used for the construction of the hulls of ships is steel. It may be found in various forms, such as forgings, castings, plates, and shapes. In vessels of the combat type, special-treatment high-tensile and other face-hardened steel for armor are used.

Forgings. Forgings are used where strength is required. Owing to the irregular shapes necessary for special large parts used in the hull, the forging is more or less complicated and expensive. Since steel castings that possess sufficient strength for most purposes can be obtained, there are few large forgings made for the hull of a ship. Forgings are found principally in the machinery, as in crankshafts, propeller shafts, and rudderstocks. In some cases the stem- and sternposts may be forgings. Certain other hull fittings or working parts will be forgings.

Castings. Many steel castings are used on a ship. The stern frame, stem, stern tubes, rudder frame, propeller struts, hawsepipes, and various small hull fittings are all castings. Different grades of steel are used, depending on the class of casting required.

With the advent of extensive welding a great many castings have been replaced with built-up structural plates, called *weldments*. A large casting can also be cast in several pieces, which are then welded together; thus the possibility of sand holes and other flaws that often occur when such a casting is being made can to a large extent be eliminated.

Plates. Plates are rolled sheets of steel of varying thickness. They range in thickness from $\frac{1}{16}$ to $1\frac{1}{2}$ in. Plates less than $\frac{1}{16}$ in. are generally spoken of as *sheets*, and their sizes are given in *gauges*.

The weight of a cubic foot of steel is approximately 490 lb. Therefore, a plate 1 in. thick will weigh one-twelfth of 490 lb., or about 40.8 lb. per sq. ft. Plates are specified by the weight per square foot. Therefore, a plate weighing 15 lb. is slightly less than $\frac{3}{8}$ in. in thickness. The practical method of determining the weights of plates is to allow $\frac{1}{8}$ in. thickness for every 5.1 lb. per sq. ft. of weight.

Plates are used for the shell, inner bottom, decks, trunks, floors, brackets, built-up girders, and other structural members.

Shapes. There are a large number of types and sizes of shapes used in hull construction, some of which are shown in Fig. 46.

Angles. Angles may have equal or unequal legs. They are used for frames, beams, stringers, and stiffeners and for joining other members that meet at, or almost at, right angles.

When an angle made by the two legs, or flanges, is not 90 deg., it is said to be a *bevel.* If it is more than 90 deg., it is called an *open bevel.* If less than 90 deg., it is called a *closed bevel.* An angle with legs of equal widths is called an *equal-legged angle.* An angle with flanges of different width is known as an *unequal-legged angle.*

The size and the thickness of angles are always shown on drawings. In dimensioning an angle it is conventional to give first the width of the leg which is shown.

Bulb Angles. Bulb angles are used for framing, transverse or longitudinal stringers, bulkheads, stiffeners, deck beams, etc. The bulb angle is a development of the plain angle, having a bulb, or swell, along the edge of one flange. The size is denoted by dimensions of cross section and weight per running foot.

T Bars. A T bar is a rolled shape generally having a cross-section shape like the letter T. It is used for bulkhead stiffeners, brackets, floor

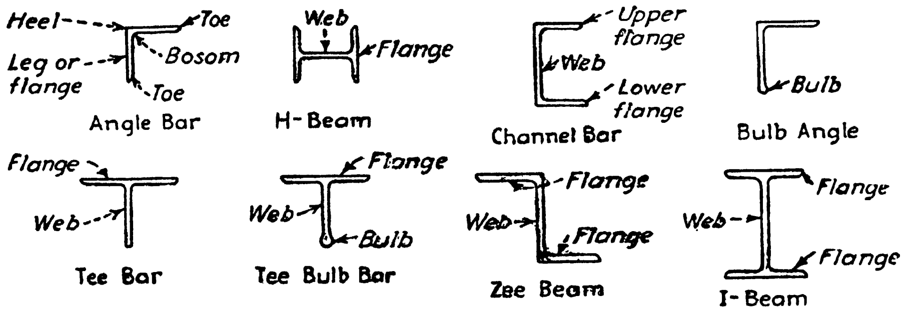


FIG. 46.—Structural shapes commonly used in hull construction.

clips, deck beams, pillars, bilge keel, and other connections. Size, thickness, and weight per foot are shown on drawings.

Channels. Channels may be used for framing, transverse or longitudinal stringers, bulkhead stiffeners, and deck beams and girders. There are two types of rolled channels, the structural channel, which is used most generally now, and a shipbuilding channel, in which the flanges decrease in thickness from the heel to the toe of the flange. The size is denoted by dimensions of cross section and the weight per running foot.

I Beams. I beams are used for transverse or longitudinal girders, bulkhead stiffeners, and deck beams. The size is denoted by dimensions of cross section and the weight per running foot.

H Beams. H beams are generally used as stanchions for supporting girders. They may also be used as beams or girders. The sizes are denoted by dimensions of cross section and the weight per running foot.

ABBREVIATIONS FOUND ON STRUCTURAL SHIPBUILDING DRAWINGS

Various symbols and abbreviations will be found on all drawings. Those generally found on structural shipbuilding drawings are listed.

△(8) or ALT#8	Alteration and number of alteration
ABV	Above
A.E.	Afterend
AMM	Ammunition
A.P.	Afterpeak or after perpendicular
AUX	Auxiliary
B.A.	Bulb angle
BDRY	Boundary
BET	Between
BEV	Bevel
BFL. PL.	Baffle plate
B.H.	Breasthook
BHD	Bulkhead
BKT	Bracket
B.L. or ℄	Base line
BOTT	Bottom
BR	Bridge
B.S.	Butt strap
℄	Center line
CLK	Calking
COFF	Cofferdam
COMPT	Compartment
COND	Condenser
CONN	Connection
C.R.C.	Closed roller chock
CSK	Countersink holes
C.T.C.	Closed towing chock
C to C	Center to center
CTRS	Centers
C.V.K.	Center vertical keel
D or DIA	Diameter
D.E.S.	Double extra strong
DIM	Dimension
DK	Deck
DR or DRWG	Drawing
ELEV	Elevation
E.R.	Engine room
E.S.	Extra strong
F.B.	Flat bar
F.DK.	Forecastle deck
FDN	Foundation
F.E. or FWD	Forward end
F.K.	Flat keel
FLG	Flange
F.O.	Fuel oil
F.P.	Forward perpendicular
FR	Frame
F.W.	Fresh water
GALV	Galvanize
GEN	Generator
GR	Group
H.I.	Height of instrument
HLS	Holes
H.P.	High pressure
H.R.	Half round
H.T.S.	High tensile steel
①	Item 1
IB	Inboard
I.C.	Interior communication
I.D.	Inside diameter
KP	King post
∟	Angle, longitudinal, length
L.B.P.	Length between perpendiculars
LKG	Looking
L.O.A.	Length over all
LONG	Longitudinal
L.P.	Low pressure
L.S.S.	Lower side stringer
LUB	Lubrication
LUB. OIL	Lubrication oil
L.W.L.	Load water line
MACHY	Machinery
MAX	Maximum
MIN	Minimum
MISC	Miscellaneous
MLD or M.L.	Molded line
M.L.W.	Mean low water
M.S.	Mild steel
#(6)	Number (6)
NAV	Navigation
N.W.T.	Nonwatertight
OB	Outboard
O.C.	Open chock
O.D.	Outside diameter
O.T.	Oiltight
O.T.F. or OT. FL.	Oiltight floor
O.T.H.	Oiltight hatch
(6)#	(6) pounds
P. DK.	Poop deck
PL	Plan
PLT	Plate
PLT'G	Plating
Q.R.	Quarter round
R or RAD	Radius
R.C.	Roller chock
REQ	Required

REV	Reverse	T.T.	Tank top
RIV	Rivet	U.DK.	Upper deck
r.p.m.	Revolutions per minute	U.S.S.	Upper side stringer
		VENT	Ventilator
S.A.	Subassembly	V.K.	Vertical keel
S.DK.	Shelter deck	V.L.	Vertical ladder
S.P.	Shell plate	V.S.W.T.DOOR	Vertical sliding watertight door
SPCG	Spacing		
S.R.	Stateroom	W.J.	Welded joint
ST'B'D or STAR	Starboard	W.L.	Water line
		W.T.	Watertight
STIFF	Stiffener	W.T.F. or W.T.FL.	Watertight floor
STR	Stringer		
S.T.S.	Special-treatment steel	⊠	Midship
TEMP	Template		
T.F.W.	Taken from work	(8)″	(8) inches
THD	Thread	(8)′ (8)″	(8) feet and (8) inches
TRANS	Transverse	°	Degrees

WELDING SYMBOLS FOUND ON STRUCTURAL DRAWINGS

Since welding plays such an important part in ship construction and references and sizes of welds are constantly shown on drawings, it is necessary for the craftsman to understand and interpret welding symbols. The symbols shown in Fig. 47 are generally used in connection with hull construction.

WORKING DRAWINGS

We have discussed visible and invisible lines, three-view, auxiliary-view, and section drawing, materials used in hull construction, abbreviations found on drawings, and welding symbols. We are now ready to analyze typical working drawings.

As previously stated, in working from structural plans it is impossible for the draftsman to show the three views of each connecting structure on the same drawing; it is necessary to refer to other plans to obtain all the necessary information. Where special references are necessary, the draftsman usually gives a tabulation of reference plans used in developing the drawing.

For example, in a transverse-bulkhead drawing, it may be necessary to refer to the shell plan, the inner-bottom plan, the deck plan, or other plans in order to determine the type of connection and to obtain other necessary information for the construction of the bulkhead.

Drawing of a Miscellaneous Bulkhead. Figure 48 shows a nontight transverse bulkhead at frame 11. This bulkhead is made up of four plates at the bottom, numbered 86, 87, 88, and 90, and of two plates at the top, numbered 85 and 89.

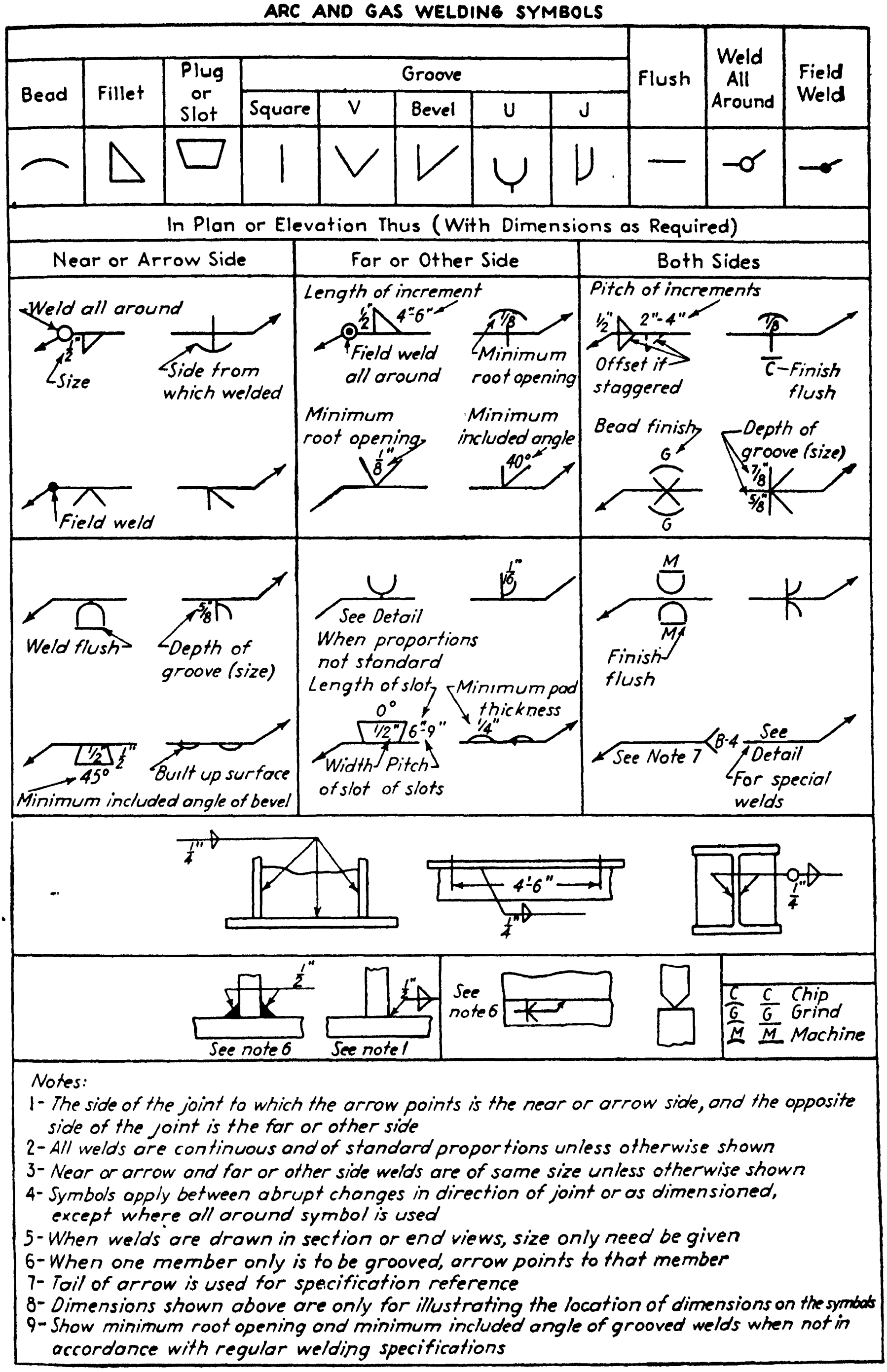
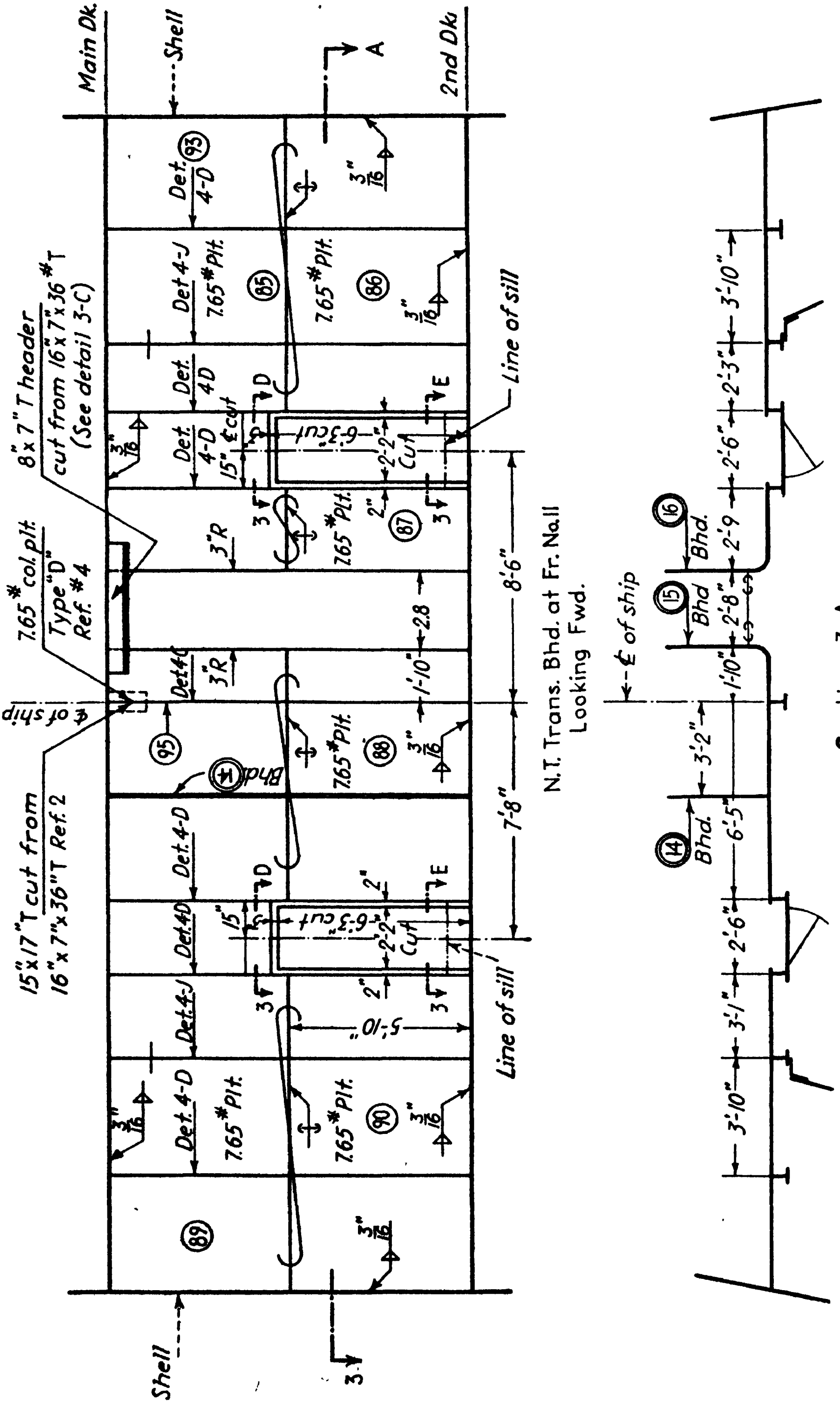


FIG. 47.—Arc- and gas-welding symbols.



N.T. Trans. Bhd. at Fr. No. 11 Looking Fwd.

Section 3-A

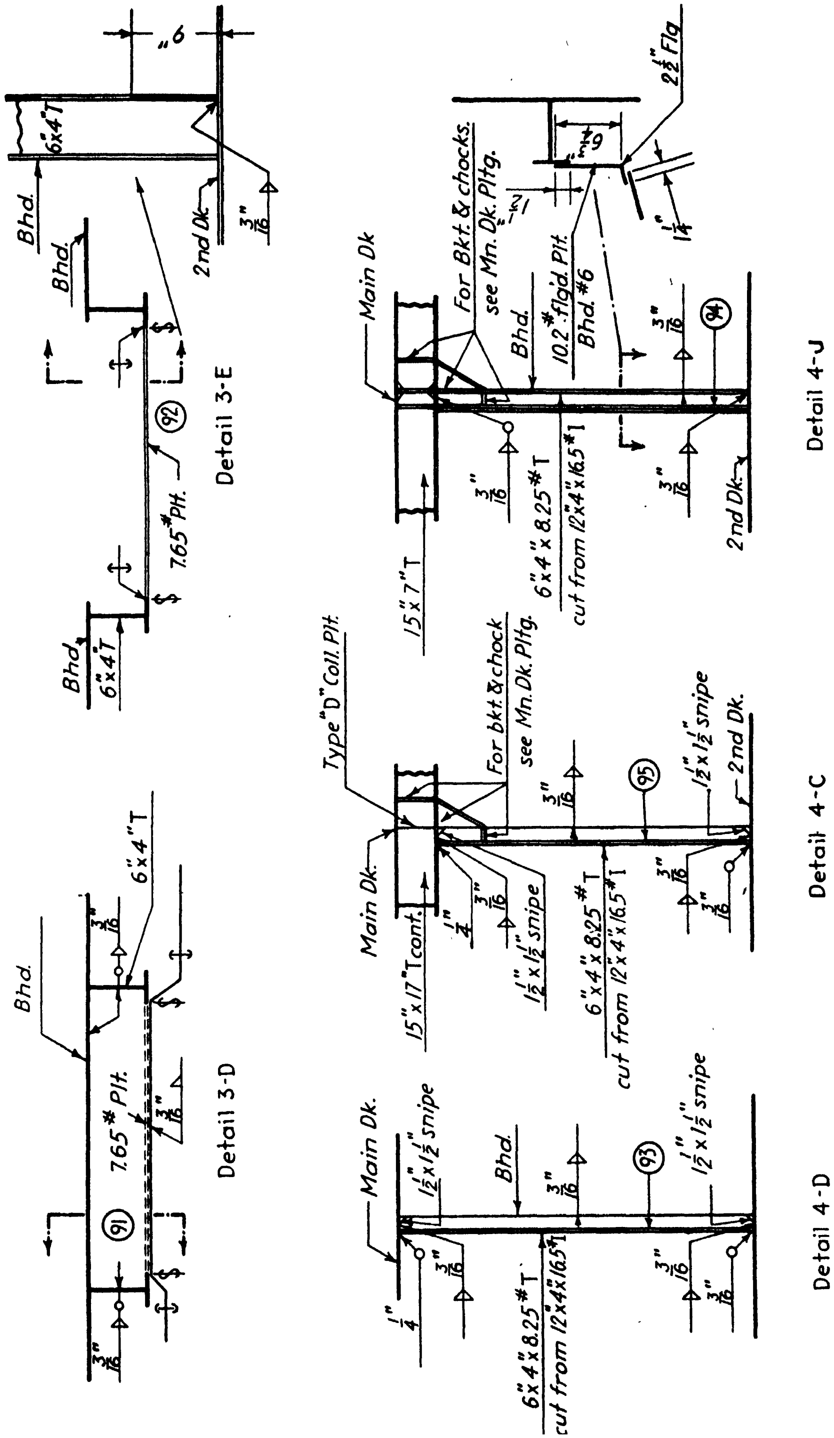
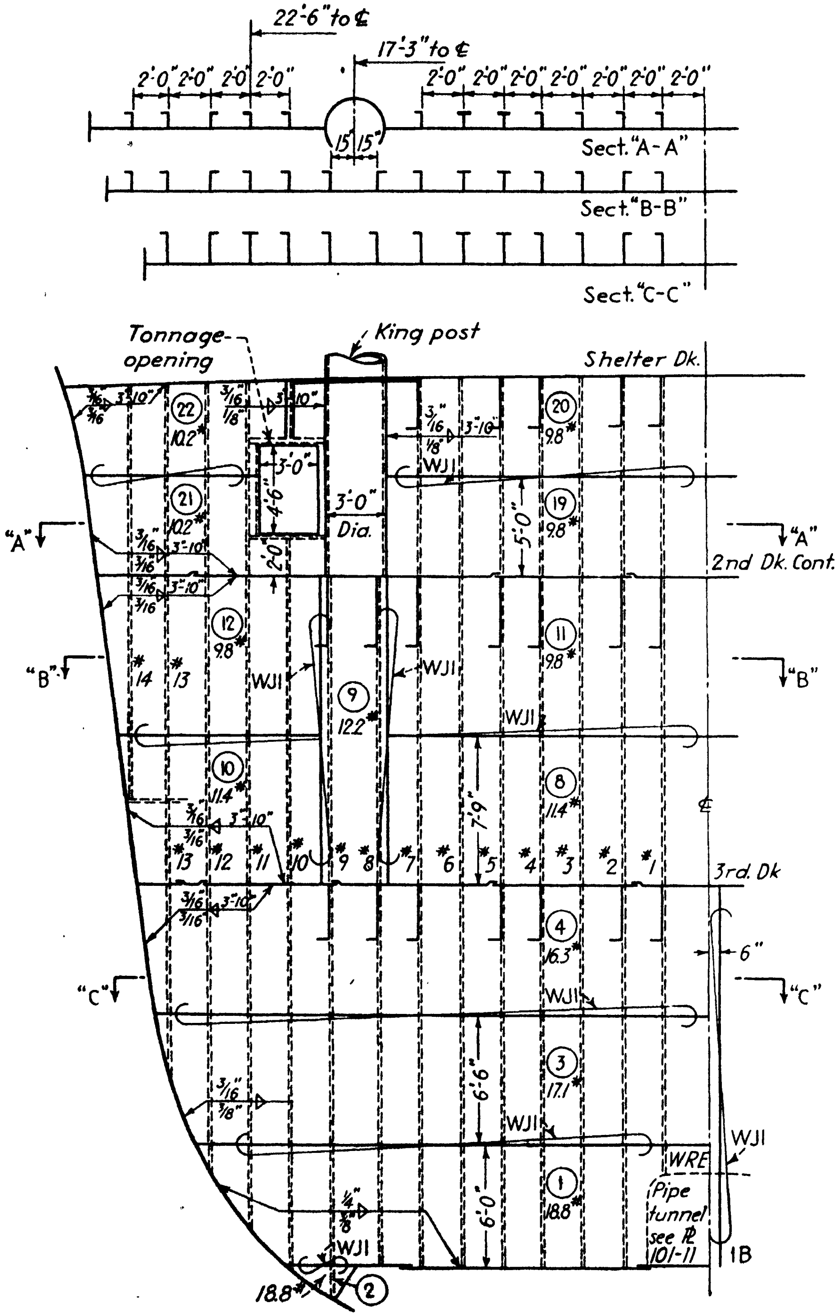
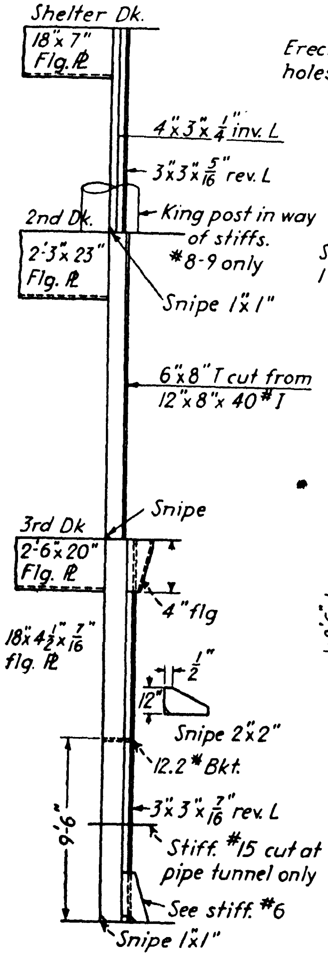


FIG. 48.—Miscellaneous bulkhead.

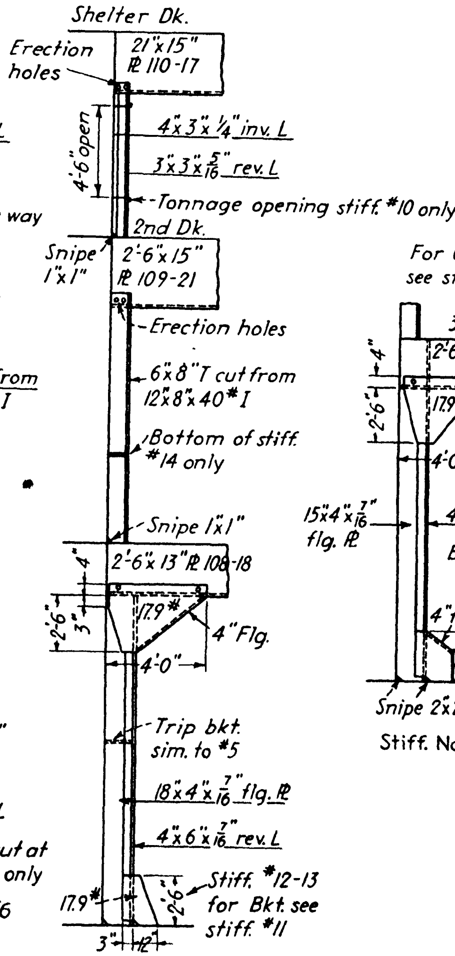


22'-6" to ℄
17'-3" to ℄
2'-0" 2'-0" 2'-0 2'-0"
2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0" 2'-0"
15 15
Sect. "A-A"
Sect. "B-B"
Sect. "C-C"
Tonnage-opening
King post
Shelter Dk.
2nd Dk. Cont.
3rd. Dk
3'-0"
4'-6"
2'-0
3'-0" Dia.
5'-0"
7'-9"
6'-6"
6'-0"
6"
WJ1
WRE
Pipe tunnel see ℞ 101-11
1B
"A"
"B"
"C"
22 10.2#
21 10.2#
20 9.8#
19 9.8#
12 9.8#
11 9.8#
9 12.2#
10 11.4#
8 11.4#
4 16.3#
3 17.1#
1 18.8#
2 18.8#

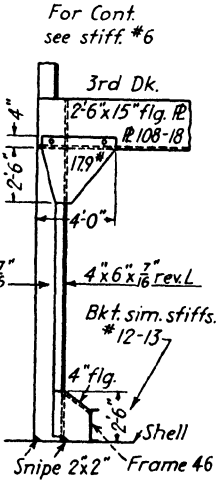
FIG. 49.—Trans-



Stiff. No.5
Stiff. No. 1-2-4-7-8-9
Sim. Except as Noted

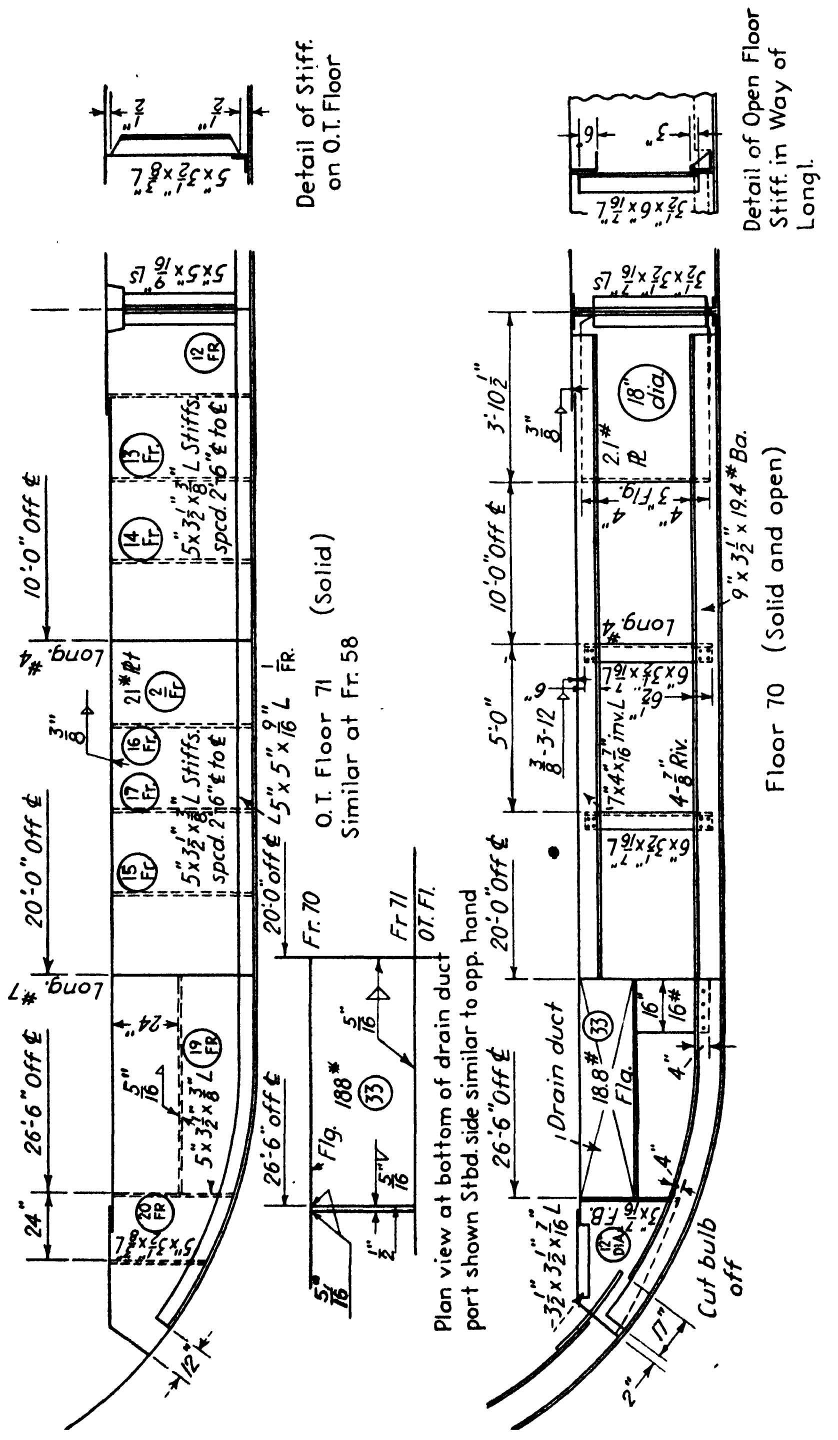


Stiff. No. 6
Stiff. No. 3-10-12-13-14
Sim. Except as Noted



Stiff. No. 11

verse bulkhead.


Detail of Stiff. on O.T. Floor
O.T. Floor 71 (Solid)
Similar at Fr. 58
Plan view at bottom of drain duct port shown Stbd. side similar to opp. hand
Detail of Open Floor Stiff. in Way of Longl.
Floor 70 (Solid and open)
Drain duct
Cut bulb off

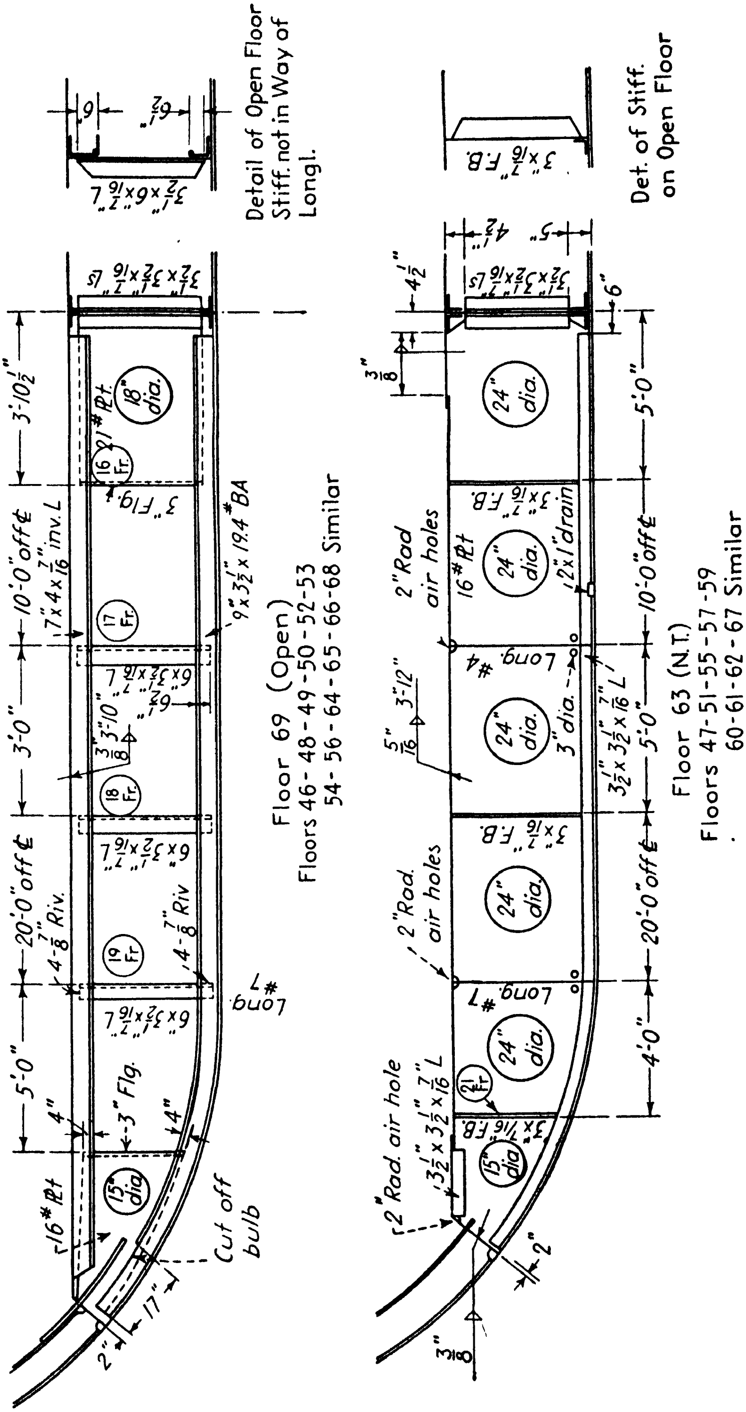


FIG. 50.—Innerbottom floors.

In section 3A, which is a horizontal cut or cross section of the bulkhead, it will be observed that the stiffeners marked Detail 4C, 4D, and 4J are all on the side nearest the eye. The notes at the bottom of the bulkhead state that it is drawn looking forward. Consequently, this places the stiffeners on the after side of the bulkhead. A detail of each one of these stiffeners is also shown; it will be observed that stiffeners 4C and 4J are cut below a 15 by 7-in. T longitudinal under the main deck. The stiffener shown in detail 4D, however, extends from the top side of the second deck to the underside of the main deck, and all the necessary information as to the size and weight is shown in the detail.

To continue analyzing the job shown on this drawing, a bulkhead numbered 14, which is located 3 ft. 2 in. off center line, is shown with an invisible line; this is consequently on the far, or forward, side of the bulkhead. In order to obtain further information about this particular bulkhead and type of connection, it is necessary to refer to another drawing showing this bulkhead.

On the starboard side of the center line, 1 ft. 10 in. off center line and 2 ft. 8 in. from this point, bulkheads numbered 15 and 16 can be seen in section 3A. Therefore, it is apparent that a passageway exists at this point. It will also be observed that the bulkhead turns into the passageway with a radius plate. Further details of these two particular bulkheads must also be obtained from another drawing.

At the boundaries of this bulkhead, namely, at the second deck, main deck, and shell, port and starboard, no dimensions are given. These dimensions are obtained from the mold-loft body plan or offsets. Welding symbols are clearly shown at all connections, stating their size and type of weld.

It will also be observed that two sections are shown in the way of doors at 3D and 3E.

Drawing of a Transverse Bulkhead. The drawing shown in Fig. 49 is that of a transverse bulkhead extending from the inner bottom to the shelter deck.

The plating of this bulkhead varies from 18.8 lb. at the bottom to 9.8 lb. at the top. The different weights are divided by the cut lines. The stiffeners are numbered from 1 to 14, and a detail of each is shown. As previously stated, all the necessary information cannot be shown on this plan, as, for example, the deck girder shown at stiffeners 6 and 11.

This drawing shows that the starboard side of the bulkhead has been drawn looking aft and that the port side is similar, but to the opposite hand. Therefore, all the dotted or dashed lines shown on the drawing are connections on the after side of the bulkhead, while all solid, or visible, lines are connections on the forward side of the bulkhead. Sec-

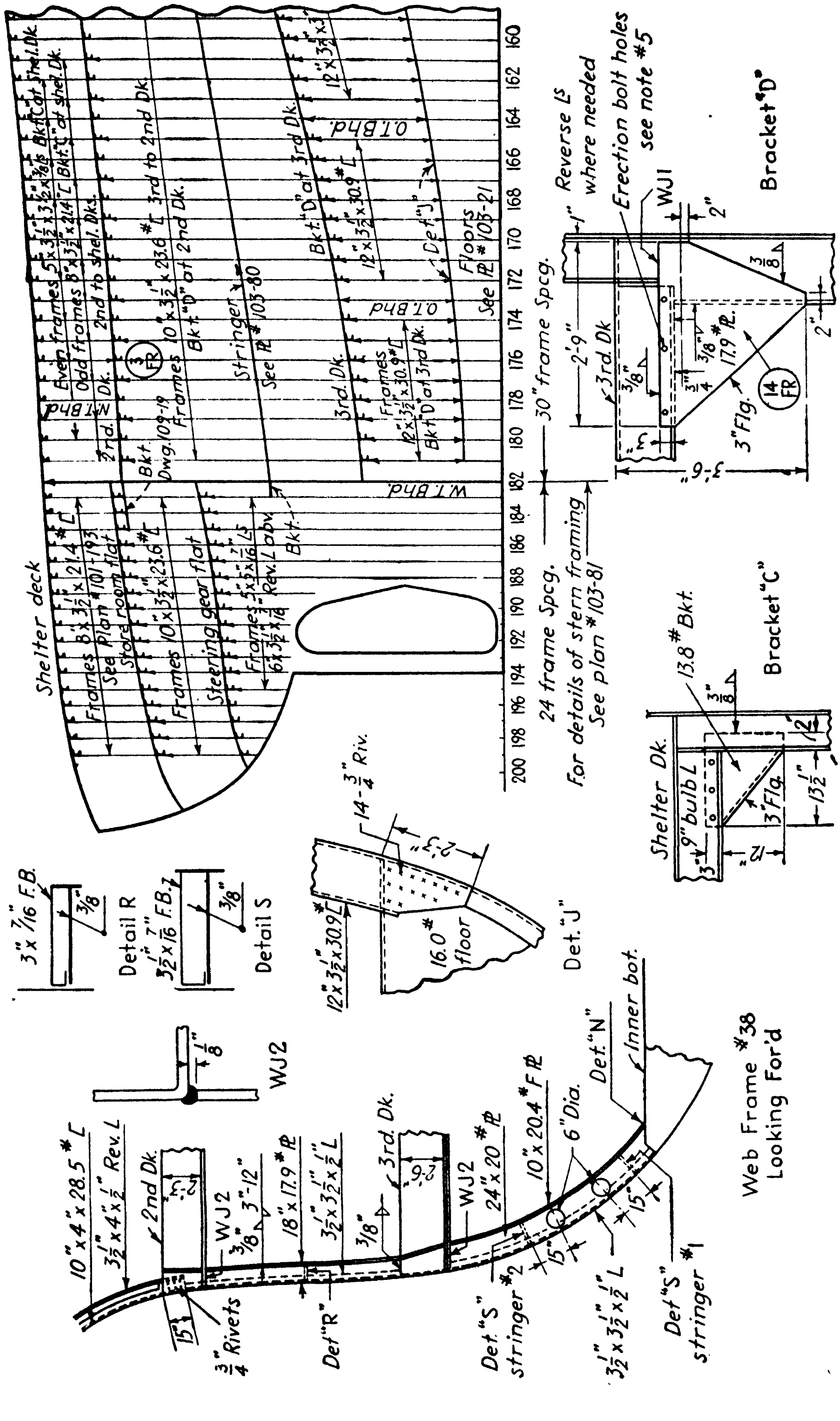


FIG. 51.—A portion of a framing diagram and detail drawing.

tions *AA*, *BB*, and *CC* shown above clearly give the locations and arrangement of all stiffeners.

Drawing of Inner-bottom Floors. The drawing shown in Fig. 50 is of inner-bottom floors and covers all those floors between frames 46 and 71. The boundaries of the floors must be obtained from templates

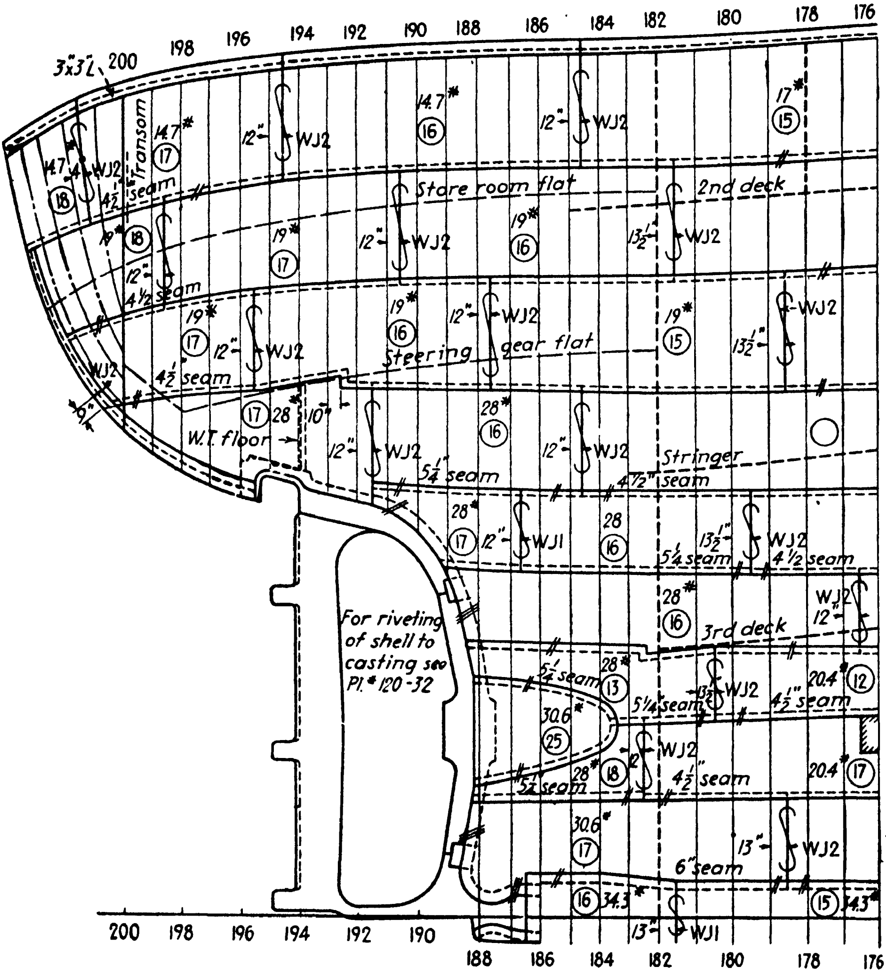


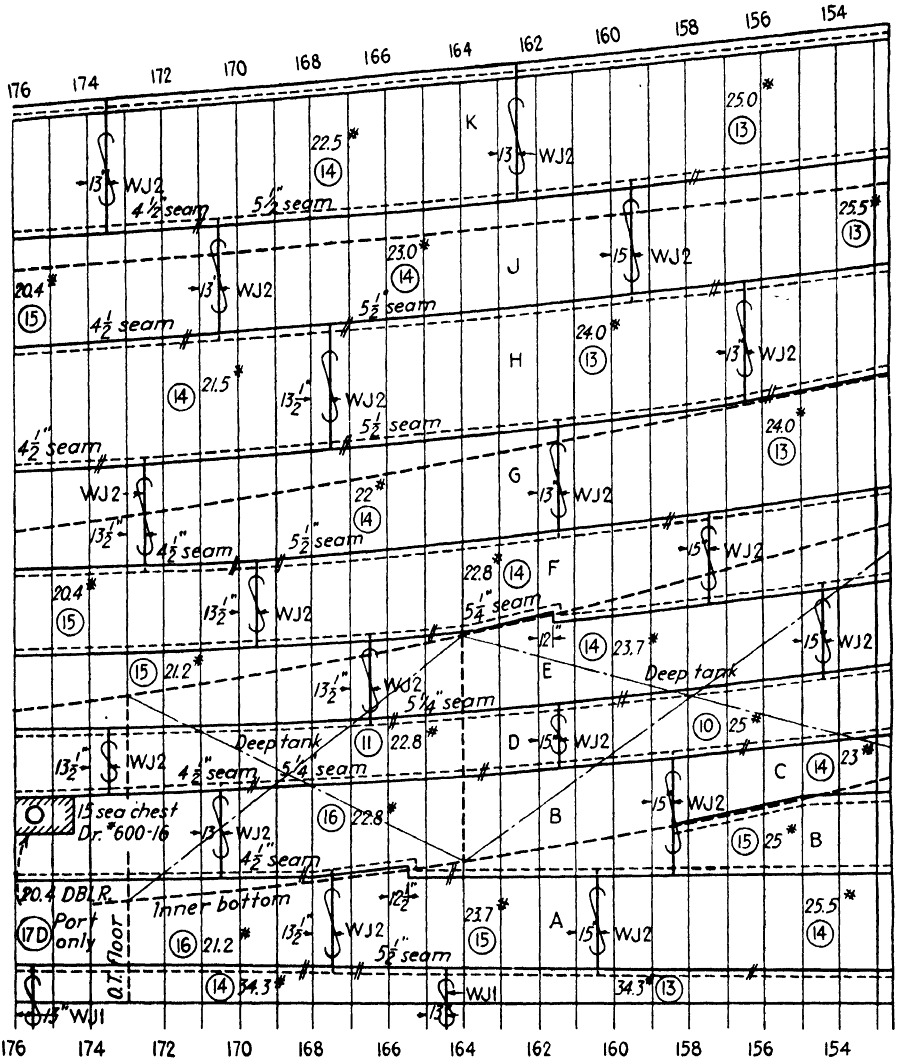
FIG. 52.—A portion

developed in the mold loft; all other information and the general construction of the floors are given on this drawing.

Riveting details or specifications are shown, not on this drawing, but on another plan of riveting details and spacing.

Four types of floors are given on this drawing. Floor 71 is an oiltight floor; floor 63 is a nontight all-solid floor; floor 69 is an open floor; and floor 70 is a combination oiltight and open floor.

The spacing of the stiffeners and other connections to these floors is generally marked on the plating and bars at the time when the material



of a shell expansion.

is laid off for fabrication from molds developed in the mold loft. However, all the necessary dimensions for building the floors are obtained from this drawing.

Drawing of a Framing Diagram and Detail. Figure 51 shows the framing and details of side framing of a vessel above the inner-bottom plating. The arrows at each frame indicate the points to which the frames extend. Some of the framing extends through the decks, while other framing stops immediately below the deck beams, as shown in the detail. The reason for this is that the frames differ in size, decreasing in weight and size toward the upper portion of the ship. This is, of course, the result of design; where necessary, framing is made heavier.

The details shown on this plan are clear and concise. For example, the detail of bracket *D* shows a bracket the bottom of which extends 3 ft. 6 in. below the third deck. The width of the bracket is 2 ft. 9 in., the bracket being cut 1 in. from the outside of the frame. The leg of the bracket, which connects to the side frame, is secured by a 3/8-in. weld, both to the web of the frame and at the flange. The top of the bracket shows three holes. These are used for erection purposes only. It will be noted by the symbols at the top of the bracket that it is also made with a fillet weld in the same manner as the connection to the side frame.

The framing is shaped from templates developed in the mold loft; however, all other details for the performance of the job are shown on this plan. It must be remembered that, inasmuch as the beams and framing affect the shell plating and various decks, it will be necessary to refer to the plans affected. All other necessary information is clearly shown and can readily be analyzed.

Drawing of the Shell Expansion of a Vessel. The drawing shown in Fig. 52 is that of the shell plating, or shell expansion as it is generally known. This drawing gives all the shell plating on the ship, including the flat-keel plating, in the area shown.

In developing this drawing to show all the plating, including the bottom and sides, it is necessary for the draftsman to show it in an expanded view. That is, the girth of the plating is taken from the center line of the outside of the model for this ship and is laid out at convenient stations. This is somewhat misleading to those not familiar with reading this type of drawing.

The numbers of each plate are encircled. The weight of the plate is usually immediately below or above the plate number. The boldface capital letters on the plan denote strake letters. Shell plating is recognized by strake letters and the number of the plate. Beginning at the center flat keel, the strake of plating adjacent to this is known as the *garboard*, or *A Strake*, and each successive strake is lettered alphabetically toward the upper part of the ship.

The seams and butts of the shell plating can readily be distinguished from other markings. It will be noted, however, that, in way of the engine room, sea chests, and openings, doublers have been added. Those doublers shown in full lines are designed for the outside of the shell

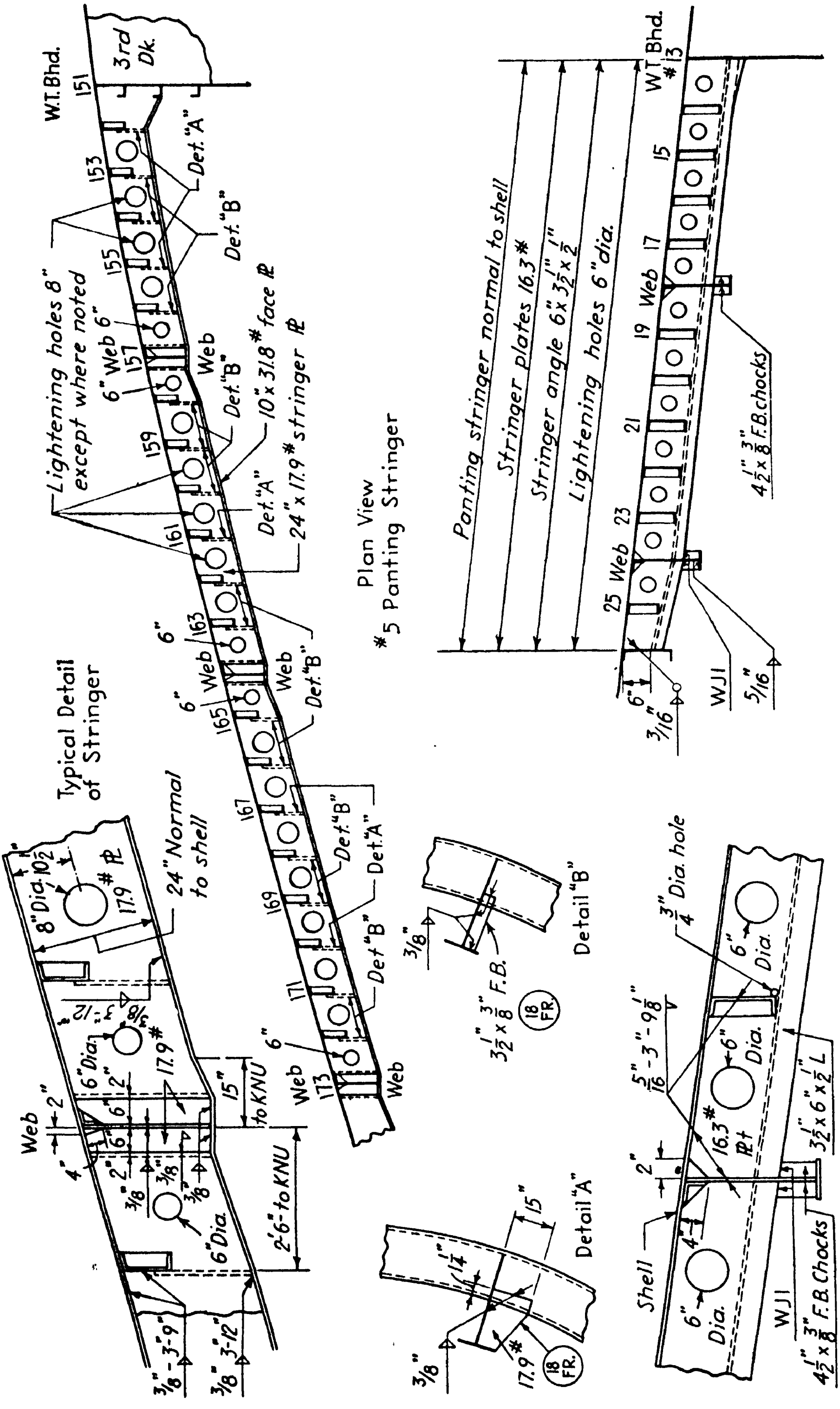
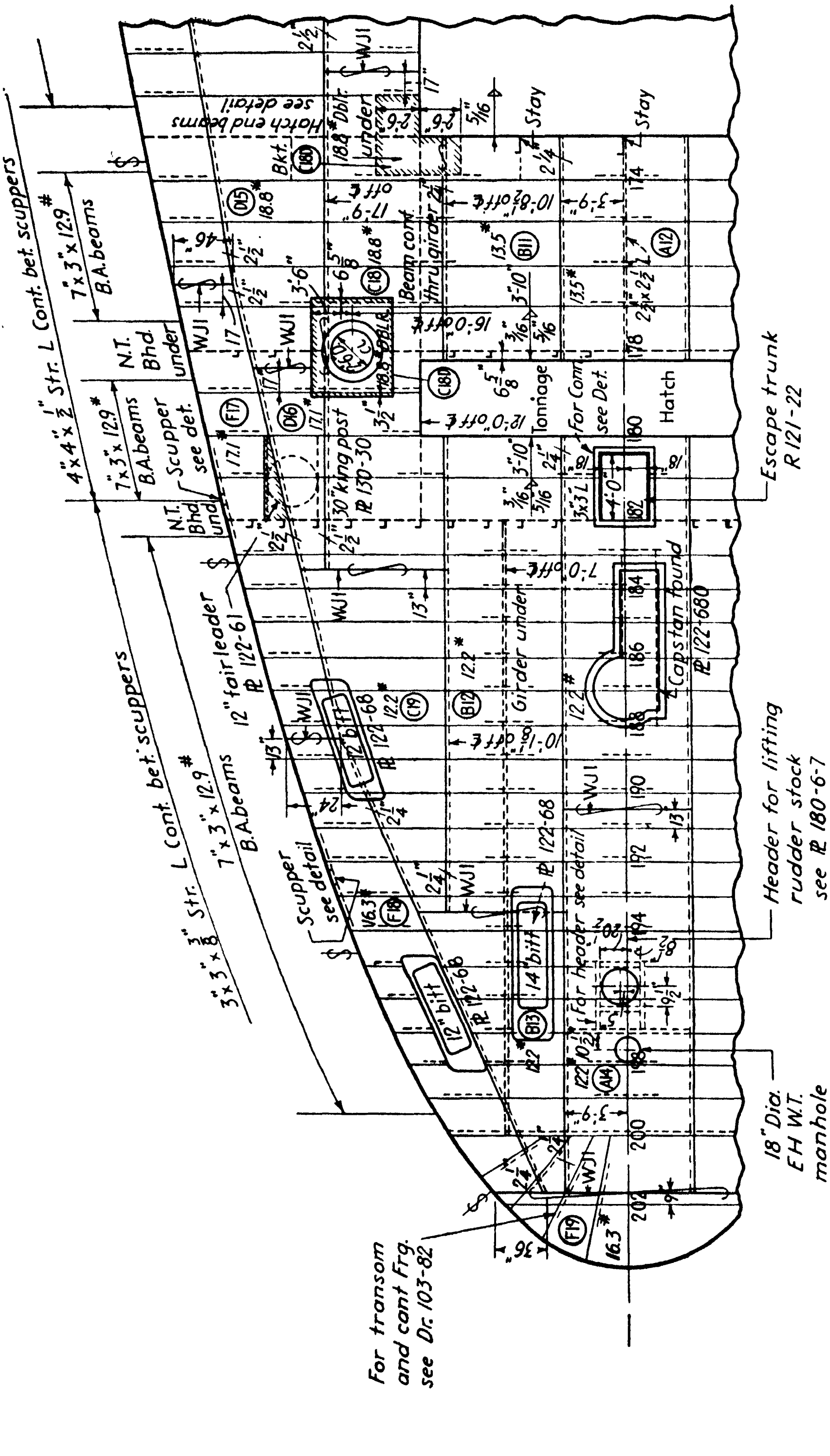


Fig. 53.—Stringers.



4" x 4" x 1/2" Str. L Cont. bet. scuppers
7" x 3" x 12.9# B.A. beams
N.T. Bhd. under
Scupper see det.
3" x 3" x 3/8" Str. L Cont. bet. scuppers
7" x 3" x 12.9# B.A. beams
Hatch end beams see detail
Stay
Beam cont. thru girder
Tonnage
For Com. see Det.
Hatch
Escape trunk R 121-22
30" king post ℞ 130-30
12" fair leader ℞ 122-61
Capstan found ℞ 122-680
Girder under
12" bitt ℞ 122-68
14" bitt
Scupper see detail
For header see detail
Header for lifting rudder stock see ℞ 180-6-7
18" Dia. E H W.T. manhole
For transom and cant Frg. see Dr. 103-82

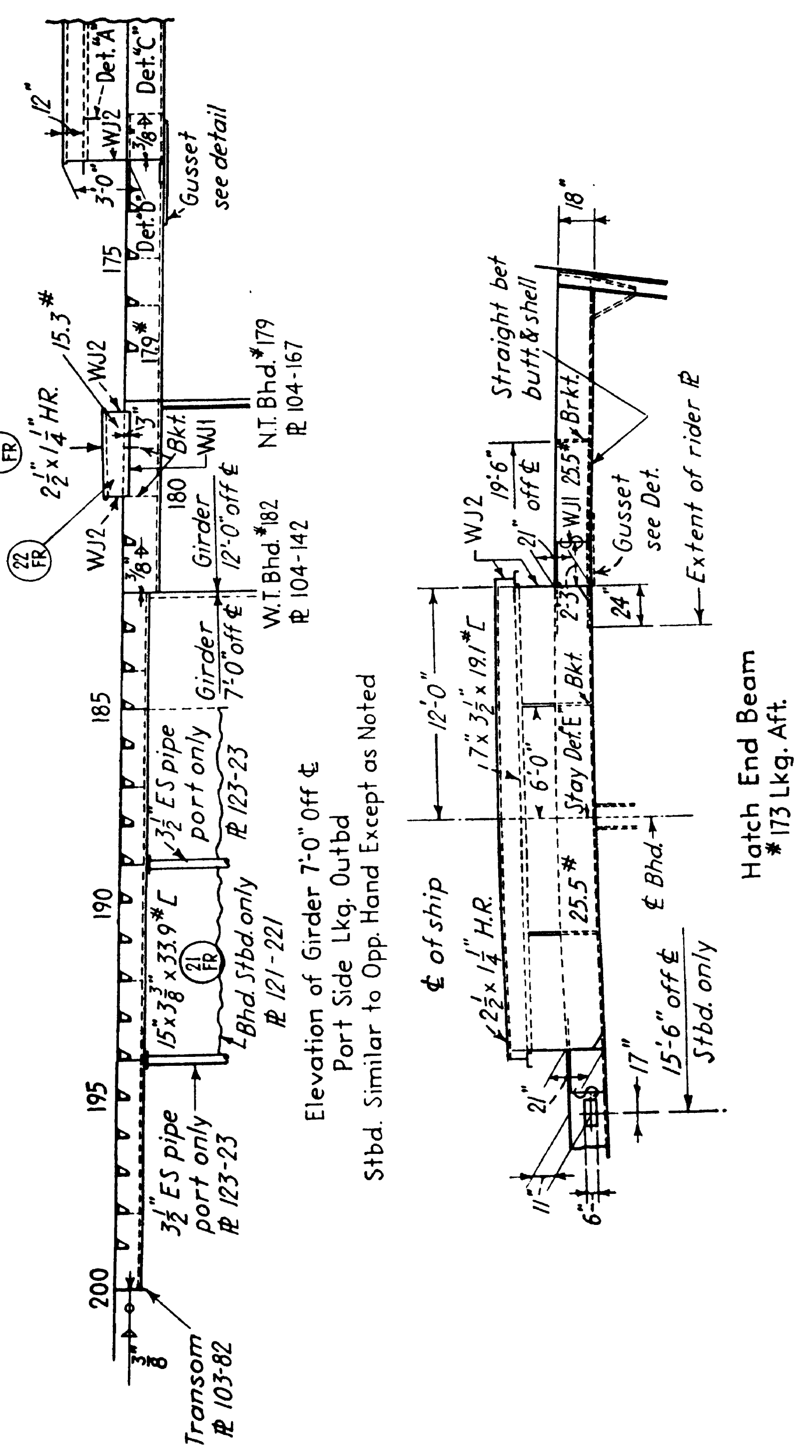


FIG. 54.—A portion of deck plating.

plating. Doublers denoted by a dotted line are to be installed inside the ship.

In some shipyards on particularly large ships some of the strakes of shell plating are not developed and fabricated from the mold-loft templates. Certain convenient strakes are *lifted* from the ship, after the balance of the shell plating has been regulated and set. This affords an opportunity for adjustment without the loss of shell plating, especially on the riveted type of shell construction.

On medium-sized ships all the shell plating is usually developed and fabricated from mold-loft templates, with the exception of such plates at the forward and after ends as may be *lifted* from the ship to simplify difficult fitting, particularly around some of the streamlined sternposts.

Drawing Showing Panting Stringers. Figure 53 shows the panting stringers at the forward and after ends of a cargo vessel. The material for these stringers is fabricated from templates developed in the mold loft. This drawing shows the construction and gives the necessary information for subassembling and installing stringers in the ship. It will be observed that the stringers are intercostal between the web frames and that they are supported at the framing by 17.9-lb. plate brackets, as seen in detail A. The location of these brackets can be seen in a plan view of the stringers, where reference is made to detail A or detail B. Detail B shows a 3½- by ⅜-in. flat bar connection to the frame; this is shown on the plan beside detail A.

The connections of the stringers to the web frames is typical, as shown in the left-hand upper corner of the drawing; by *typical* is meant that the same type of connection occurs at each frame, though some of the dimensions may vary, depending on the depth or width of the web frame.

Riveting and welding details are shown for all connections, including the type and size of weld to the shell plating.

Drawing Showing Shelter-deck Plating, Beams, and Girders. The drawing shown in Fig. 54 is that of the shelter-deck plating, beams, and girders for a cargo vessel. Butts and laps of the deck plating can readily be distinguished, together with various hatch openings in the deck and the outline of deckhouses and bulkheads located on this deck.

The general notes on this drawing state that it is a cambered deck. From the appearance of the drawing of the girder shown at the top of the drawing, this deck also has a sheer, or fore-and-aft, shape. Doublers will be noted at the corners of the hatch openings and in way of ventilators and king posts, as well as bitts. The lower part of the drawing gives various details covering transverse beams and transverse girders in way of hatches.

Deck plating is distinguished by strakes lettered alphabetically as for the bottom shell plating. The center-line strake is known as *A strake.* Successive strakes toward the side of the ship are lettered alphabetically and are known as *B strake, port* or *starboard,* etc.

A careful study of the plans shown is suggested for acquiring efficiency in the reading of blueprints, since a detailed explanation of each plan would be too lengthy and involved. If the reader understands the fundamentals of blueprint reading, it is not difficult for him to analyze any plan with some study.

It should be pointed out that the greatest difficulty experienced by the novice in reading a plan is in looking at it as a whole before attempting to break it down, piece by piece. The job should be analyzed by fixing in mind the erection sequence, noting the connections, and gradually building up the entire job. If this is done, no great difficulty will be experienced.

CHAPTER III

SHIP'S LINES, BODY PLAN, OFFSETS, AND DEVELOPMENT

It is the responsibility of the shipwright to align and set the structure of the ship so that the fabricated material laid off from templates developed and made in the mold loft from the body plan of the ship will fit properly as the ship progresses in construction. It is therefore important for him to understand the basic working lines, lines plan, and offsets, and their value and use. This chapter will be devoted to a discussion of these fundamental lines.

To know the lines of a ship, it is essential that the craftsman be familiar with the terminology peculiar to this part of the work. The terms and definitions pertaining to the lines of a ship are as follows:

DEFINITIONS PERTAINING TO SHIP'S LINES

Afterbody. That portion of a ship's body aft of the midship section.

After perpendicular. A line perpendicular to the base line, intersecting the after edge of the sternpost at the designed water line. In a single-screw vessel, it is usually the after side of the sternpost.

Amidships. In the vicinity of the middle portion of a vessel, as distinguished from her ends. The term is used to convey the idea of general locality, not that of definite extent.

Aperture. The space provided between the rudder and sternpost for the propeller.

Athwartship. In a transverse direction; from side to side at right angles to the fore-and-aft center line of a vessel.

Batten. A thin flexible strip of wood, usually tapered, used in laying down lines. A strip of wood or steel used in securing tarpaulins in place, as to batten down a hatch.

Battens, sheering. Long narrow strips of wood, clamped lengthwise to the frames of a ship to locate the edges of the shell-plating strakes in relation to the sheer of the ship's deck.

Beam. The extreme width of a ship. A transverse horizontal member supporting a deck or flat.

Beam, molded. The width over the widest portion of the ship measured to the outside of the frame angle or channel, but inside the plating. Also called *molded breadth.*

Bevel board. A wooden board upon which the bevels are drawn applying to some part of the ship's structure such as the frames and given to the workmen in the yard for easy reference where a paper plan or sketch would not stand rough usage.

Bilge. The rounded portion of a vessel's shell, connecting the bottom with the sides.

Body plan. A plan showing the intersection with the vessel's molded form of a series of transverse vertical planes located at frame stations or displacement ordinates. These intersections are called *frame lines* and are curved; the water lines and buttocks show as straight lines in this view.

Breadth, register. The width of the broadest part of the *outside of the vessel.*

Buttock. The rounded portion of the lower stern.

Buttock line. A longitudinal vertical working plane.

Camber. The rise or crown of a deck athwartship, for the purpose of draining rain or sea water to the sides of the ship where it can be led overboard through scuppers.

Cant. To turn, or tilt, anything so that it does not stand perpendicularly, or square, to a given object.

Chamfer. To bevel the edge of a plate.

Counter. That part of a ship's afterbody extending aft from the after perpendicular (usually above the water line).

Dead flat. The midship portion of a vessel, which maintains throughout its length a constant shape of cross section.

Dead rise. The angle that the straight portion of the bottom floor of the midship section makes with the base line. It is expressed by the number of inches rise above the base line in the half beam of the vessel.

Deck heights. The vertical distance between the molded lines of two decks, one above or below the other.

Deck line. A line drawn through the intersection of the molded line of the deck beams and the molded line of the frames.

Dished. A term applied to the end of a cylinder, or drum, where it is concave. A shell plate or any plate is said to be dished where it has fore-and-aft and athwartship shape.

Fair, or fair up. To draw the lines of a vessel in such a manner that the defined surface will show no irregularities throughout its extent.

Fair curves. Curves that do not in any portion of their entire length show changes of direction to mark them as out of harmony as a whole or with other portions of the curves.

Fair line. A term applied to a curved line when it is smooth and without humps or abrupt breaks in direction.

Fantail. The stern overhang in vessels that have round or elliptical afterends to uppermost decks and that extend well abaft the after perpendicular.

Flam. A term often used to express the same meaning as flare but more properly used to denote the maximum curl, or roll, given to the flare at the upper part just below the weather deck.

Flare. The spreading out from the central vertical plane of the forebody of a ship with increasing rapidity as the section rises from the water line to the rail.

Flat. A term applied to a partial deck built without any camber.

Fore. A term used in indicating that part of the ship at or adjacent to the bow. Applied to that portion of the ship lying between the midship section and the stem, as *forebody*, and also to portions or parts of the ship lying between the midship section and stem, as *forehold* and *foremast*.

Forebody. That portion of the ship's body forward of the midship section.

Full ended. When the extremities of the water lines in the vicinity of the load line are strongly convex to the surrounding water and the ends of the sectional area curve are full, indicating that the displacement is carried well forward and aft toward the ends of the vessel.

Girth. The distance measured on any frame line from the intersection of the upper deck with the side around the body of the vessel to the corresponding point on the opposite side.

Grade line. An established reference line from which measurements are taken to any point.

Half-breadth plan. A drawing or view showing the intersections with the vessel's molded form of a series of fore-and-aft horizontal planes. These intersections are called *water lines* and are curved in this view, while the frame lines and buttocks are straight lines.

Hollow ended. When the extremities of the water lines in the neighborhood of the designed load line are concave to the surrounding water, and when the sectional area curve at the ends is fine, indicating relatively small displacements in these locations.

Inboard. Toward the center: within the vessel's shell and below the weather decks.

Kink. An abrupt bend or short curve; loop in a rope or cable, frequently caused by excessive lay, or twist.

Length. By American Bureau of Shipping Rules, the distance in feet on the estimated summer load line, from the foreside of the stem to the after side of the rudderpost. Where there is no rudderpost, the length is to be measured to the center of the rudderstock.

Length over all. The total length over all is the length measured from the foremost to the aftermost points of a vessel's hull.

Lift. The act of constructing a template of any part of a ship, thus transferring the required size, form, and other necessary details to the material to be worked into the fabricated object.

Linesman. A mold loftsman who is expert in laying down ship's lines and developing work from these.

Longitudinal. A general term meaning *fore and aft,* as longitudinal bulkhead or longitudinal strength. A fore-and-aft girder in the bottom of the ship or a side keelson.

Main body. The hull exclusive of all deck erections, spars, stacks, etc. The naked hull.

Mathematical lines. Lines of a ship whose offsets have been developed by mathematical means, that is, by the use of formulas, coefficients, etc., rather than by the eye at the dictation only of judgment and experience.

Mold. To draw out to full size the lines of a vessel or part of its structure; a pattern or form built up to show the contour or shape of anything.

Mold beam. A pattern showing the curvature (commonly called *camber*) of the beams for a deck.

Mold loft. A space used for laying down the lines of a vessel to actual size and making templates from them for the structural work entering into a hull.

Mold skeleton. A template, or pattern, made up of open framework instead of solid, to show the outline of some part.

Molded breadth. The ship's maximum breadth measured to the outside, or heel, of the frame bar and occurring generally, though not always, at the midship section.

Molded depth. The vertical distance from the base line to the molded line of the main deck at the side, measured at the midship section.

Molded line. Any line in the body plan (except base, water, or buttock lines) from which templates are developed.

Offsets. A table of dimensions usually given in athwartship, longitudinal, and height directions involving the shaping, or mold, of the ship's structure.

Ordinate. One of the equally spaced vertical divisions between the forward and after perpendicular, used for calculating volume, displacement, or form.

Outboard. Away from the center toward the outside. Outside the hull.

Profile plan. A drawing or view showing the intersection with the vessel's molded form of a series of fore-and-aft vertical planes. These intersections are called *buttock lines* and are curved in this view, while the water lines and frame stations are straight lines.

Quicken. To lessen the radius of a curve or make it sharper. To snub. For example, to quicken a water line is to make its curvature more pronounced.

Scantlings. A term applied to the dimensions of the frames, girders, plating, etc., that go into a ship's structure. The various classification societies publish rules from which these dimensions may be obtained. As these rules are the results of continued observation of ship's structures, they give the most reliable information from a practical standpoint that can be obtained. The forces acting on a ship at sea cannot be accurately determined. Hence, calculations made to determine the size of a member of a ship's structure should be compared with similar calculations or existing practice when possible.

Scarf. A connection made between two pieces by tapering their ends so that they will mortise together in a joint of the same breadth and depth as the pieces connected. It is used on keels, stem and stern frames, etc. Also, the tapering of the corner of a plate where a joint occurs.

Scrive board. A portable platform made of soft, clear-planed lumber on which a full-sized body plan of a ship is drawn, the lines being cut into the surface of the wood in small U-shaped grooves by means of a scriving knife to prevent them from being obliterated. The scrive board is set up in some convenient spot and used as a ready reference for the shapes of frames, floors, etc., or to take dimensions from. The scrive board is rarely used in this country.

Set iron. A flat bar of soft iron used in transferring the shape of the frame from the scrive board to the bending slab. (This is done only where no frame mold is made.)

Shapes. Bars of rolled steel having certain forms of cross section throughout their entire length. The forms of cross section given are such as to lend to strength and rigidity in fabrication.

Sheer. The longitudinal curve of a vessel's rails, deck, etc., the usual reference being to the ship's side. However, in the case of a deck having a camber, its center line may also have a sheer.

The amount by which the height of the weather deck at the after or forward perpendicular exceeds that at the mid perpendicular. Mean sheer is the average of the sheers forward and aft as just defined.

Sheer line. The longitudinal curve of the rails or decks, which shows the variation in height above water, or freeboard, throughout the vessel's entire length.

Sheer plan. See Profile plan.

Skin. Usually applied to the outside planking or plating forming the watertight envelope over the framework. Also applied to the inner-bottom plating, when it is called the *inner* skin.

Stem, or stempost. The bow frame, forming the apex of the triangular intersection of the forward sides of a ship. It is rigidly connected at the lower end to the keel. In wooden ships the main piece of the bow frame is called the *stem.*

Stern. The afterend of a vessel; the farthest distant part from the bow.

Stern frame. A heavy casting or forging used for the purpose of supporting the rudder and the propeller shaft in single-screw vessels. It also serves as a frame for rigidly connecting the converging sides of the ship at the stern.

Sternpost. The main vertical post in a stern frame upon which the rudder is hung.

Sweet line. A term applied to a curved line when it is smooth and without humps or abrupt breaks. A fair line.

Taut. The condition of a rope, wire, or chain when under sufficient tension to cause it to assume a straight line or to prevent sagging to any appreciable amount.

Template. A mold or pattern made to the exact size of a piece of work that is to be laid out, or formed, and on which such information as the position of rivet holes and size of laps is indicated. The most common types of template used in ship work are made out of paper or thin boards.

Tumble home. The decreasing of a vessel's beam above the water line as it approaches the rail. The opposite of flare.

Water line. The line to which a vessel submerges when she is afloat, that is, without cargo or ballast in the case of merchant vessels and without complement stores, fuel, ammunition, feed, water, etc., in the case of combat vessels. Also horizontal working planes, parallel to the base line.

THE BODY PLAN

In developing the body plan, certain basic lines must first be established.

Base Line. The first line to be established is the *base line.* It is from the base line that all heights, or vertical dimensions, are taken. The two illustrations in Fig. 55 show the location of the base line with reference to the keel of the vessel on two types of construction, (1) where shell plating is butt-welded, in which case the base line falls on the top or inside surface of the keel plate itself, and (2) where the shell plating is lapped, in which case the base line falls at the inside edge of the garboard plate, that is, the thickness of the garboard plate above the keel.

Center Line. The second basic line is the *center line.* All widths, or transverse measurements, are taken from this center line.

The base line and center line must always be considered as planes. The base line is an established plane at the base of the ship running fore and aft and athwartship. The center line runs the length of the ship, midway between the two sides, bisecting it. Figure 56 shows the base- and centerline planes of a vessel.

Molded Line. The next fundamental which must be understood is that of the *molded line.* The molded line is defined as any line in the body plan, except water lines and buttock lines, from which the templates are developed.

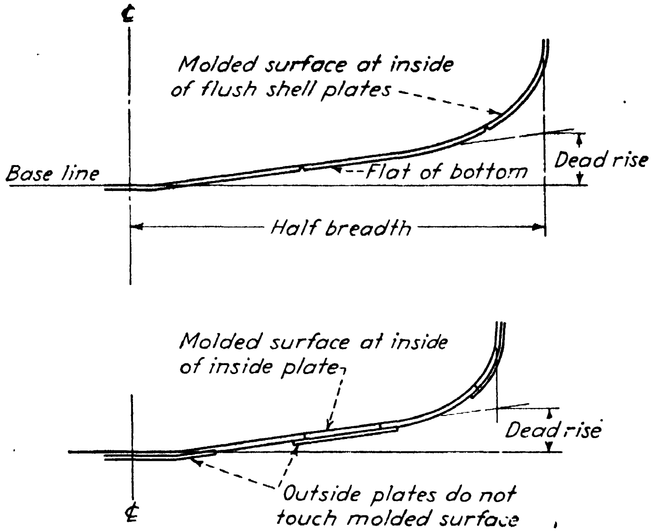


FIG. 55.—Location of the base line.

The molded surface is the inside surface of the plating of the ship and has no thickness. Actually, the thickness of the plating will extend outside the molded surface; and where shell plating is lapped, outside

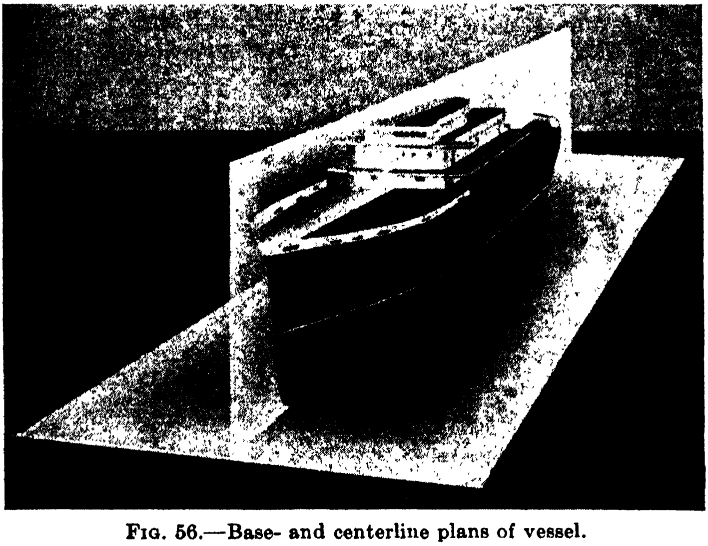


FIG. 56.—Base- and centerline plans of vessel.

strakes do not touch the molded surface at all. Where a strake of plating is clinkered, that is, where it laps underneath one strake and on top of another, only that portion of the plate which laps under will touch the molded line.

The same is true for deck plating in respect to the molded line of the deck; that is, the inside plates will contact the molded line at the underside, while the lap strakes fall the thickness of the skin plate above the molded line.

In certain types of construction, particularly on ships of the combat type, the molded line is used only as a reference line, especially where the thickness of plating varies and where either the top or undersurface is specified to be flush in certain areas. Where the top of the deck is specified to be flush, the molded line usually falls at the underside of the

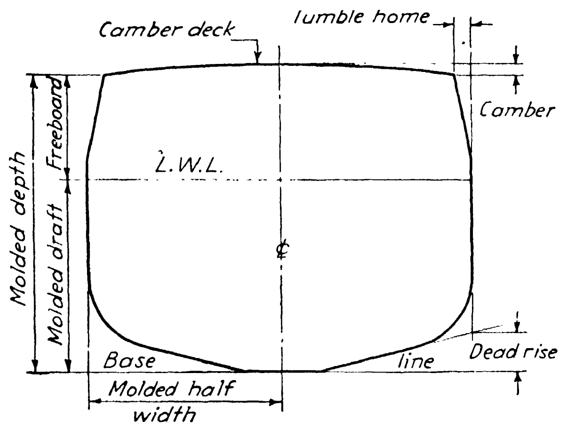


FIG. 57.—Molded lines of a midship section.

lightest plate on that deck, and the variation in the thickness of the heavier plating falls below the molded line. This may be reversed in cases where the underside of the deck is specified to be flush. Figures 57 and 58 show the molded dimensions of a midship section, together with some examples of the molded line with reference to the ship's structure.

Water Lines. For convenience in locating and checking heights above the base line, a series of horizontal lines called *water lines* is used. They are similar to the subdivisions on a ruler and are generally, but not always, marked off every 4 ft. Figure 59 shows the water-line planes of a vessel.

Since water lines are measured upward from the base line, they are marked in terms of distance, as 4, 8, 12 ft. Figure 60 shows the water-line numbering on the midship section of a vessel.

Buttock Lines. For convenience in checking athwartship, or transverse, measurements, a series of vertical lines is used. These are called *buttock lines*. All water lines and buttock lines are actually planes, subdividing the entire ship into long strips, or sections.

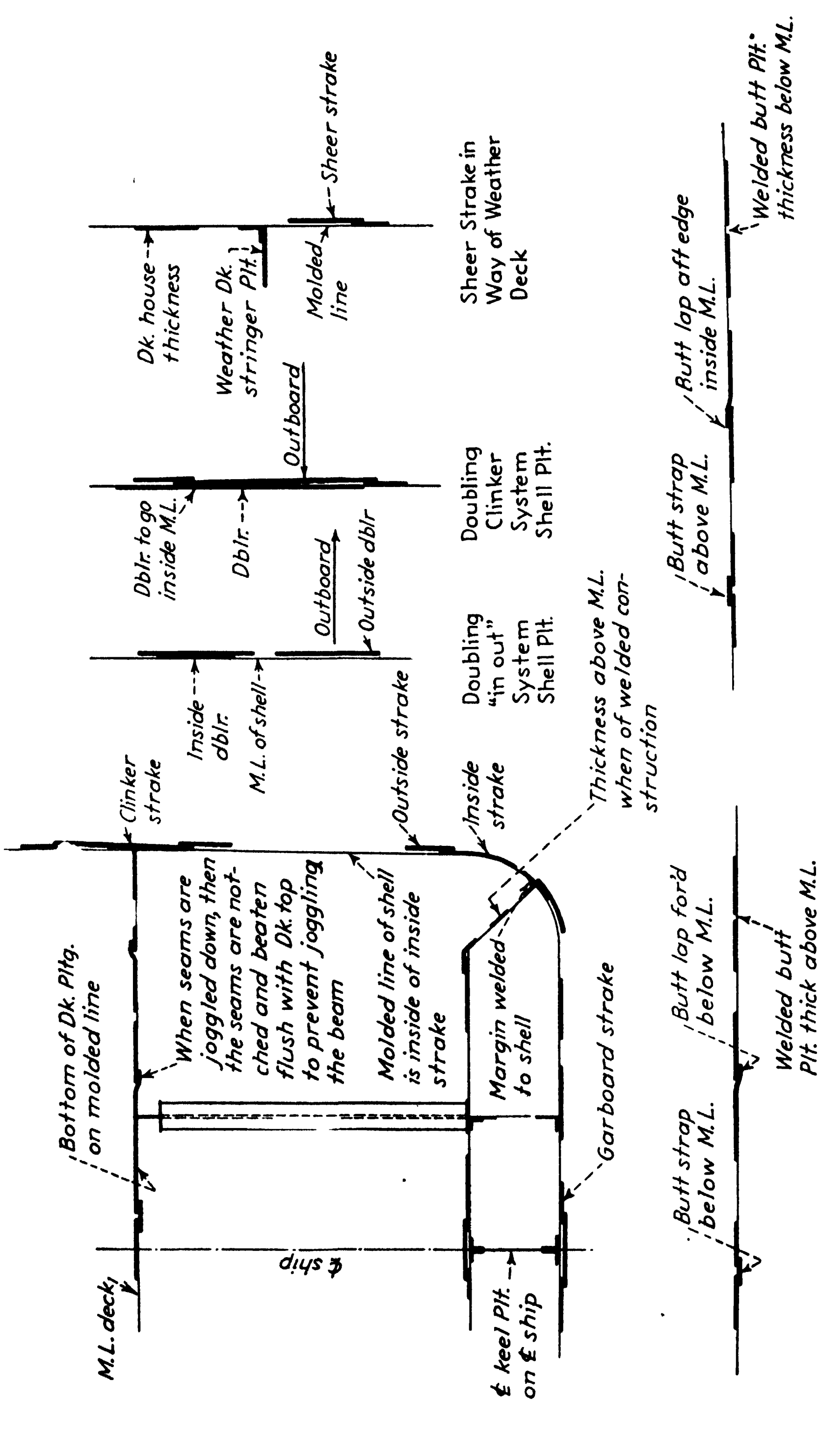


Fig. 58.—Example of the molded line with respect to ship's structure.

The buttock lines are also marked in terms of distance, in this case, the number of feet from the center line.

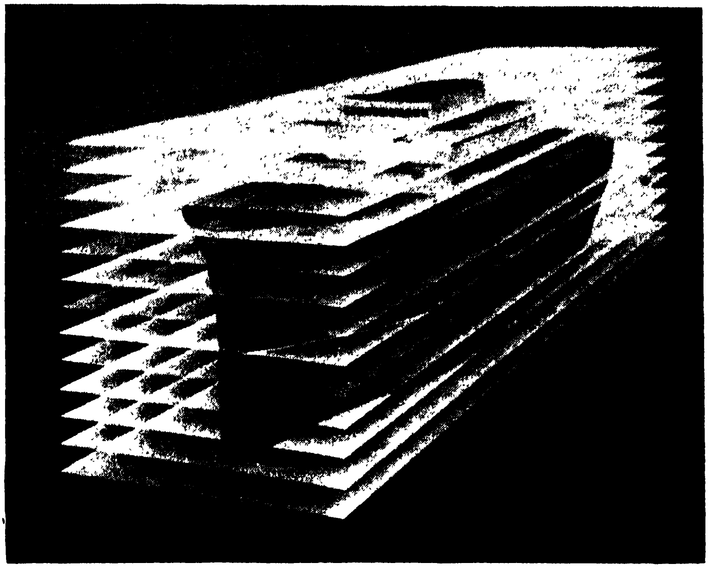


FIG. 59.—The water-line planes of a vessel.

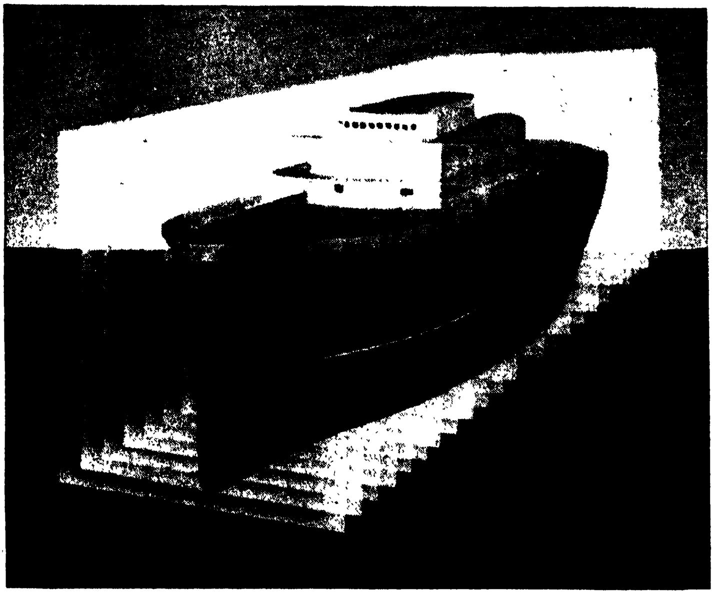


FIG. 60.—Frame-line planes of a vessel.

Frame Lines or Frame Stations. In order to shape the ship, one other set of lines is required. These are called *frame lines* or *frame* *stations.* Frame lines are vertical planes subdividing the ship crosswise at fixed points. Figure 60 shows the frame-line planes of a vessel.

The frame lines are generally numbered progressively from the forward end to the afterend of the ship; however, some naval architects

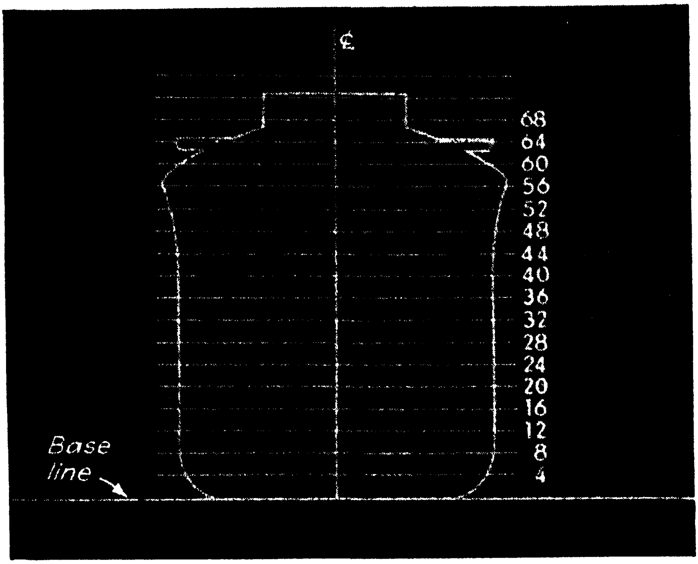


FIG. 61.—Water-line numbering in feet above the base line.

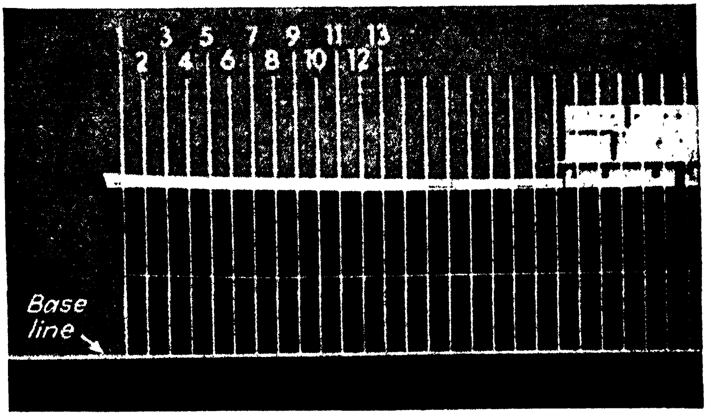


FIG. 62.—Frame stations and numbering.

hold to the older method of numbering frames from the afterend forward. This is particularly true in the building of oil tankers.

Frame stations shown and numbered in accordance with the way in which the ship will be constructed are shown in Fig. 62.

These lines enable us to regard the entire ship as composed of many small sections of various shapes and sizes. A knowledge of these lines and their relation to one another is essential to all shipbuilding work. It is important to remember that the basic lines retain the same relative position regardless of the angle on which the ship is built.

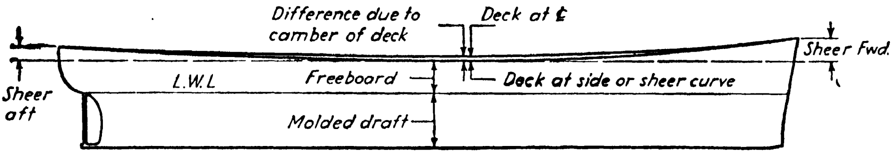


FIG. 63.—Profile or sheer plan.

Profile. One other view is necessary in developing the lines for a vessel, that is, the *profile* or sheer plan, showing outlines of the bow and stern together with *sheer curve* of deck. This is shown in Fig. 63.

OFFSETS

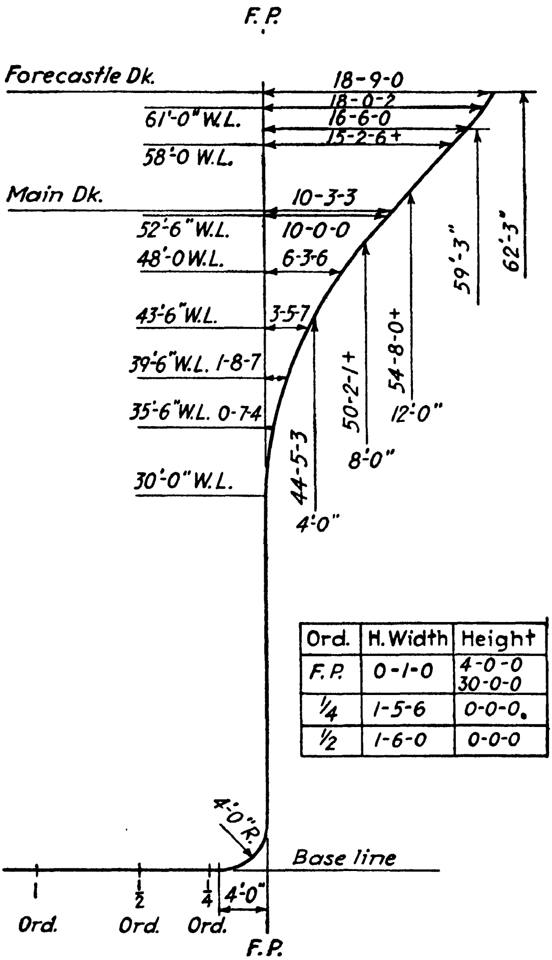
In developing the body plan on the mold-loft floor, offsets from drawings determine the inner sections of the various frames at the water lines and buttocks. *Offsets* are measurements of distances from the base line or from the center line to any point in the molded surface. Half widths are measured transversely from the center line. Heights are measured vertically from the base line.

Book of Offsets. A book of offsets for a ship usually gives dimensions and outlines for the following:

1. Stem profile.
2. Stern profile.
3. Half widths of torpedo bulkheads (combat ships).
4. Sections of inner bottom.
5. Camber diagram.
6. Half widths of water lines at ordinates.
7. Heights of buttocks at ordinates.
8. Half widths of water lines at frames.
9. Heights of buttocks at frames.
10. Heights and half widths of decks.
11. Half widths of sight edges of shell plating.
12. Heights of sight edges of shell plating.
13. Girths of sight edges of shell plating.
14. Heights of torpedo bulkheads (combat ships).
15. Heights and half widths of side armor (combat ships).
16. Heights and half widths of longitudinals.
17. Heights and half widths of inner bottom.
18. Heights and half widths of stringers.
19. Heights and half widths of shaft centers.
20. Heights and half widths of bilge keel.

21. Heights and half widths of shaft alley.
22. Knuckles on decks.

Offsets for Stem Profile. Figure 64 gives the outline and offsets for the stem of a vessel. The offsets shown in the tabulation give the half widths and heights at the forward perpendicular, and ordinates $\frac{1}{4}$ and



Ord.	H. Width	Height
F.P.	0-1-0	4-0-0 30-0-0
¼	1-5-6	0-0-0
½	1-6-0	0-0-0

FIG. 64.—Offsets for stem profile.

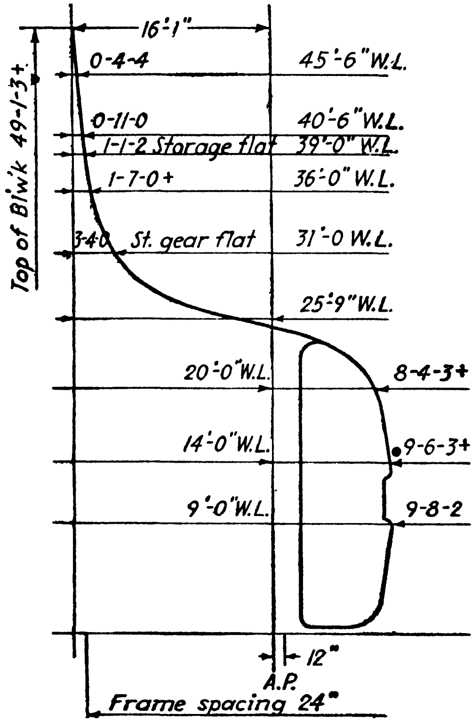
$\frac{1}{2}$. All dimensions in offsets are read in feet, inches, and eighths of an inch; for example, the half width shown at ordinates $\frac{1}{4}$ reads 1-5-6. This means 1 ft. $5\frac{3}{4}$ in.

The half widths shown in this tabulation give the half width of the stem from the 4-ft. to the 30-ft. water line. The half widths at ordinates $\frac{1}{4}$ and $\frac{1}{2}$ are the half widths of the stem at the base line, or at height

0-0-0. The dimensions shown in profile can readily be understood, all being given from the forward perpendicular at the water lines shown.

The vertical dimensions forward of the forward perpendicular are shown to be 4, 8, and 12 ft. forward of the forward perpendicular. Two other vertical dimensions shown forward of this intersect at point 16-6-0 and 18-9-0 forward of the forward perpendicular.

Offsets for Stern Profile. Figure 65, together with the tabulation at the side, shows the necessary offsets for lining in the profile of this stern. Heights are given at each frame station, as well as the half widths



Fr.	Height	H Width
178	21-10-5	0-4-3
179	23-3-6	0-8-0+
180	24-1-6	0-8-0+
181	24-8-5	0-8-0
182	25-2-2	0-7-1+
183	25-7-6	0-4-7
184	26-1-4	0-3-2+
185	26-8-2	0-2-3
186	27-6-3+	0-1-5
187	28-11-0+	
188	31-5-2+	
189	39-1-0	

Fig. 65.—Offsets for stern profile.

at these points. Additional horizontal dimensions given at the water lines shown give the remaining offsets for lining in the shape of the stern.

The contour of the stern is for fairing and outlining purposes only. Other details in connection with the stern post are shown on the stern casting plan.

Longitudinal Bulkheads. In some types of ship, longitudinal bulkheads are designed to subdivide a ship into compartments for protection. Figure 66 shows the arrangement of these bulkheads, which happen to be parallel to the center line of the ship; therefore, only one dimension is necessary.

Inner-bottom Sections. Figure 67 shows an outline of *inner-bottom* sections and their arrangement in order to give the craftsman some idea of their design. No offsets are shown in this section.

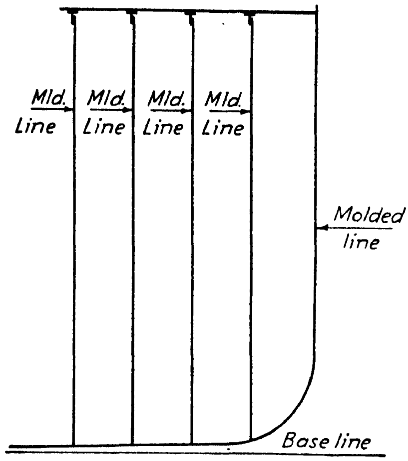


Fig. 66.—Torpedo-bulkhead offsets.

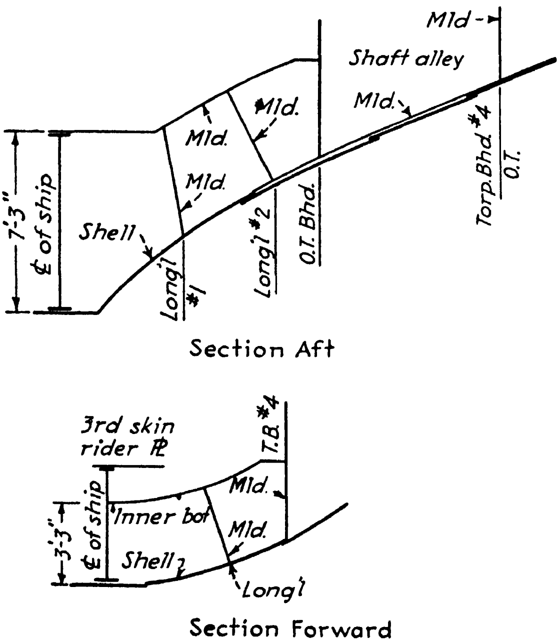


Fig. 67.—Innerbottom sections.

Offsets for Camber Curve. Figure 68 shows the *offsets for the camber curve of a deck.* The upper figures are the distances in feet from the center line. The lower figures are the offsets in inches at these points below a line parallel to the transverse base line.

Offsets for Half Widths of Water Lines at Frames. Figure 69 gives the *offsets of half widths* of the 4-ft., 30-ft. 9-in., and 44-ft. water lines at

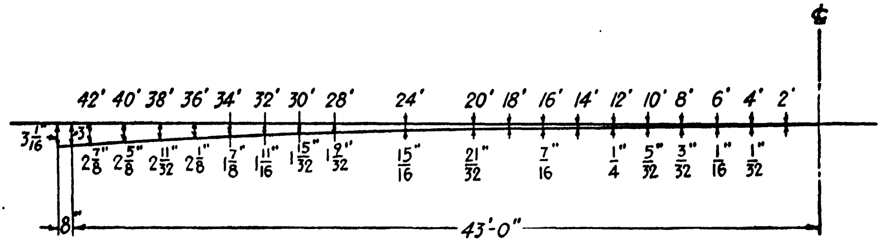


Fig. 68.—Offsets for camber curve.

frames 14 to 34. The arrow dimensions at each even frame station clearly show the method of laying out these water lines.

Offsets of Heights at Ordinates. Figure 70, together with the tabulation above, gives heights at the various buttocks shown.

Half Breadths of Water Lines

Fr.	4'-0" W.L.	30'-9" W.L.	44'-0" W.L
14	6-5-1	7-7-4	13-9-5
16	6-8-4	8-9-3	15-1-3
18	7-0-0	9-11-3	16-4-4
20	7-3-6	11-1-2	17-6-5
22	7-7-2	12-3-1	18-8-1
24	7-11-2	13-4-7	
26	8-3-4	14-6-4	
28	8-8-1	15-8-2	
30	9-1-4	16-10-0	
32	9-7-2	17-11-6	
34	10-1-7	19-1-1	

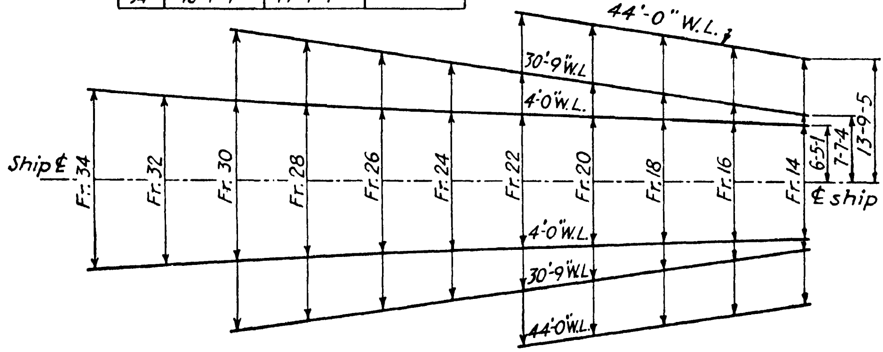
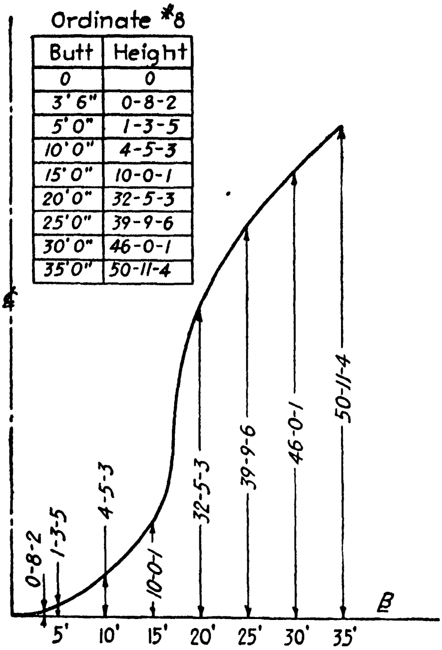


Fig. 69.—Offsets for half widths of water lines at frames.

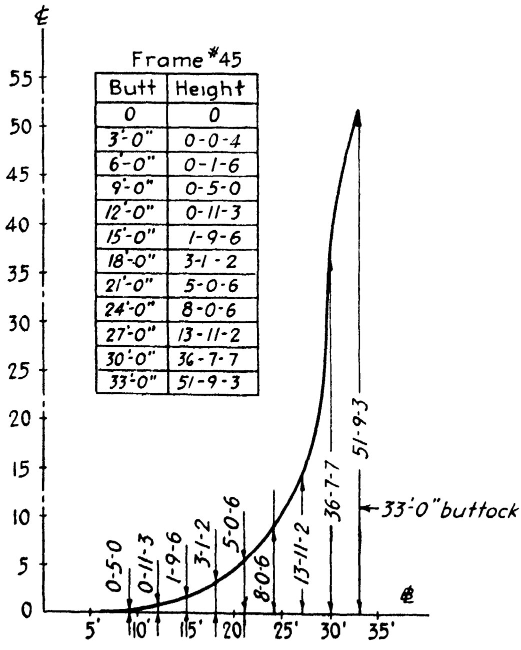
Heights at ordinates are used only in fairing the line plan in full size on the mold-loft floor. It will be observed that the dimensions shown on deck lines correspond to the dimensions shown in the tabulation.



Ordinate #8

Butt	Height
0	0
3' 6"	0-8-2
5' 0"	1-3-5
10' 0"	4-5-3
15' 0"	10-0-1
20' 0"	32-5-3
25' 0"	39-9-6
30' 0"	46-0-1
35' 0"	50-11-4

FIG. 70.—Offsets for heights at ordinates.

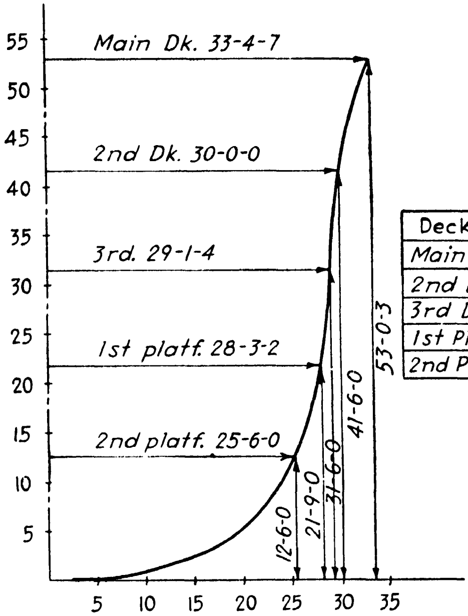


Frame #45

Butt	Height
0	0
3'-0"	0-0-4
6'-0"	0-1-6
9'-0"	0-5-0
12'-0"	0-11-3
15'-0"	1-9-6
18'-0"	3-1-2
21'-0"	5-0-6
24'-0"	8-0-6
27'-0"	13-11-2
30'-0"	36-7-7
33'-0"	51-9-3

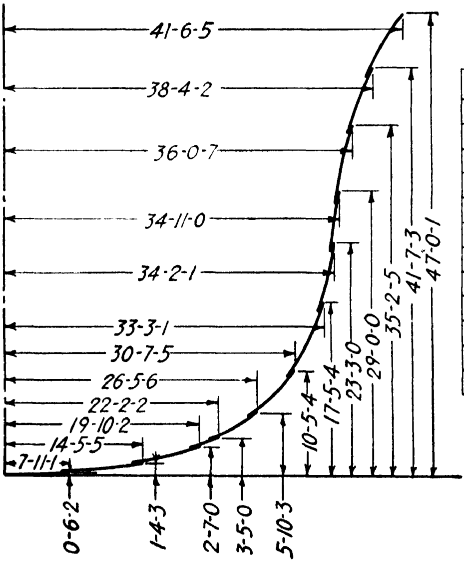
FIG. 71.—Offsets for heights of frames.

Offsets for Heights of Frames. Figure 71 gives the *offsets and heights* of frame 45. A tabulation at the top gives the heights at each buttock



Deck	H. Width	Height
Main Dk.	33-4-7	53-0-3
2nd Dk.	30-0-0	41-6-0
3rd Dk.	29-1-4	31-6-0
1st Plat.	28-3-2	21-9-0
2nd Plat.	25-6-0	12-6-0

FIG. 72.—Offsets for decks.

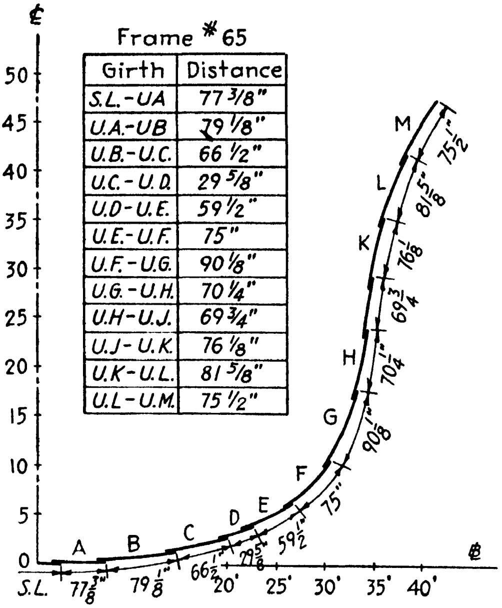


Frame # 65

Sight Edge	Height	H.Width
UA	0-6-2	7-11-1
UB	1-4-3	14-5-5
UC	2-7-0	19-10-2
UD	3-5-0	22-2-2
UE	5-10-3	26-5-6
UF	10-5-4	30-7-5
UG	17-5-4	33-3-1
UH	23-3-0	34-2-1
UJ	29-0-0	34-11-0
UK	35-2-5	36-0-7
UL	41-7-3	38-4-2
UM	47-0-1	41-6-5

FIG. 73.—Offsets for sight edges.

shown. Their application can readily be seen by the dimension lines shown at the various buttocks.



Girth	Distance
S.L.-UA	77 3/8"
U.A.-UB	79 1/8"
U.B.-U.C.	66 1/2"
U.C.-U.D.	29 5/8"
U.D-U.E.	59 1/2"
U.E.-U.F.	75"
U.F.-U.G.	90 1/8"
U.G.-U.H.	70 1/4"
U.H-U.J.	69 3/4"
U.J-U.K.	76 1/8"
U.K-U.L.	81 5/8"
U.L-U.M.	75 1/2"

FIG. 74.—Girths of shell plating.

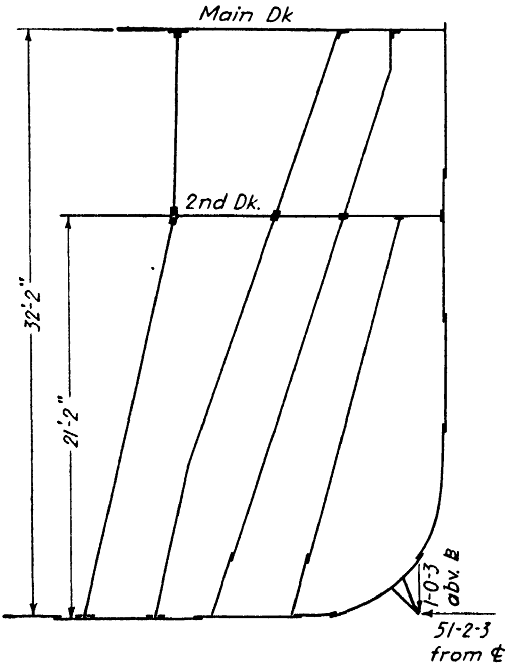


FIG. 75.—Longitudinal bulkhead arrangement.

Offsets for Decks. Figure 72 gives the offsets of the half width and heights of the various *decks* at frame 36. Their application can readily be seen from the dimensions shown in the drawing.

Offsets for Sight Edges. Figure 73 shows the application of the offsets for the various *sight edges* of shell plating at frame 65. Their application can readily be seen from this drawing.

Girths of Plating. Figure 74 gives the *girths* of each sight edge of shell plating. These dimensions are used as a check against the offsets for sight edges. They can also be used for the purpose of ordering shell plating.

Sketch of a Longitudinal-bulkhead Arrangement. Figure 75 shows an arrangement of longitudinal bulkheads used for protective purposes. The figure serves primarily as a guide in laying out the lines for these bulkheads.

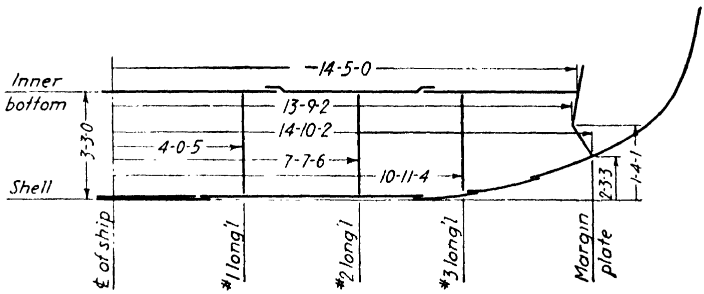


FIG. 76.—Half widths and heights of innerbottoms and longitudinals.

Half Widths and Heights of Inner Bottom and Longitudinals. Figure 76 is an outline showing the height and half width of the inner bottom and longitudinals together with the margin plate through the midship part of the ship. All these dimensions are clearly shown and can readily be analyzed.

LAYING DOWN THE BODY PLAN

In the foregoing paragraphs an explanation of the offsets was made, their application being limited to one frame for the sake of simplicity.

To give the reader some idea of the procedure followed in laying down the body plan, a general outline of the process is given below:

After the *base line*, the *center line*, the *water lines*, and the *buttock lines* have been laid down full size on the mold-loft floor, the loftsman is ready to fair in the body plan from the lines plan furnished by the drawing room. This plan is usually drawn to a scale of ¼ in. to the foot. On it are indicated the *water lines*, *buttocks*, and *deck lines;* both elevation and plan views; contours of the bow and stern; and the body plan, which shows sections, or ordinates, taken throughout the length of the vessel.

The ordinates are usually located in 20 equal spaces between the forward perpendicular and the after perpendicular. On this lines plan the offsets, that is, the distance of the crossing points from the center line, are given in a table.

In developing the body plan on the mold-loft floor, the ordinates are first laid in perpendicular to the base, after which the dimensions are faired both in elevation and plan and the contour of the bow and stern is also traced in. These lines are usually fixed except at the ends, which become subject to change in the process of fairing the buttocks. This is all that is done on the longitudinal lines at this time.

The body plan is next laid in, and all the offsets for the ordinates as checked from the lines plan are located in their respective positions. The heights and half widths of the decks are taken from the lines that have already been faired in on the floor.

Wooden battens are then laid through the spots marked on the floor for all ordinates, and fair lines are produced by averaging through these spots.

When this is done, offsets are taken from these lines and located in their proper positions on both water lines and buttock lines in the longitudinal layout. Long wooden battens are then laid through these spots and fair lines produced, beginning with the water lines. It must not be expected that fair lines are produced from these offsets the first time that they are put down, for this is rarely the case.

After all the water lines are faired, crossing spots are put in. These crossing spots are the points where the water lines cross the buttock in their corresponding positions. After the spots are put in, battens are laid through them and the lines faired. In nearly all cases in fairing lines through the crossing spots some of the section spots will be missed, which makes it necessary to go back and place the section line in the body plan to agree with whatever changes have been made in the longitudinal layout. The lines for the vessel are not fair until the water lines, buttocks, and sections cross in their corresponding positions, and the water lines end according to the contour of the bow and stern. The buttocks must also agree with the deck lines.

The drawing furnished to the mold loft by the drawing room showing the faired lines of the decks on ordinates of sections is given in Fig. 77.

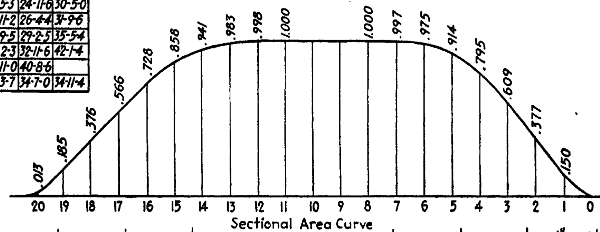
After the water lines, buttocks, sections, and deck lines are faired in and in agreement as far as the body plan and elevations are concerned, the regular frame lines are established. These frame lines are, of course, spaced much closer than the ordinates. Offsets are then taken at each water line, buttock line, and deck line at each frame, and a complete table of offsets for the vessel is made up.

General Particulars

L.O.A.	411'-0"	Wetted surface		B/D	2.25
L.B.P.	390'-0"	Bare hull	31,650	V/√L	0.6625
Effective length for Displ't & Coef'ts.	385'-0"	Rudder	400	Waterplane Coef'ts.	0.8042
Breadth, Molded	55'-0"	Bilge keel	600	Long. C.B.	191.47' Aft F.P.
Depth, molded to upper Dk. at side	30'-6"	Total	32,650 Sq. Ft.	Length of entrance	154' 40%
Designed draft, molded	24'-4¾"	Block Coef'ts.	0.7189	Length of parallel body	59.54' 15.45%
Designed speed	13 knots	Max. section Coef'ts.	0.9261	Length of run	171.46' 44.55%
Displacement, molded	10,583 tons	Prism Coef'ts.	0.7240	Tons per inch	40.5 tons

Mold Loft Table of Offsets for Fairing

	F.P.	½	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19½	20	A.P.	A
Half Breadths																									
3'-0" W.L.			3-0-0	8-4-6	14-4-0	19-9-4	23-11-0	26-0-2	27-0-0	27-4-0			27-4-0	27-0-7	26-1-1	23-4-1	18-1-6	11-8-0	6-9-1	3-8-6	1-11-0	1-0-1			
6'-0" W.L.		1-6-2	4-1-7	9-11-0	16-3-0	21-7-3	25-0-0	26-9-0	27-5-0	27-6-0				27-6-0	27-0-4	25-6-7	22-3-1	16-8-3	10-3-3	5-4-5	2-5-2	1-1-2			
12'-0" W.L.		1-11-2	4-6-0	10-10-1	17-4-6	22-5-0	25-6-0	26-11-2	27-6-0	27-6-0				27-6-0	27-4-3	26-9-6	25-2-7	21-11-1	16-3-2	9-3-7	3-4-6	1-3-7			
18'-0" W.L.		2-0-0	4-8-5	11-3-0	17-9-0	22-7-6	25-6-6	27-0-0	27-6-0	27-6-0				27-6-0	27-5-6	27-2-1	26-2-5	24-2-3	20-8-1	14-11-6	6-8-1	2-8-4			
24'-4¾" W.L.		2-2-4	4-11-6	11-6-5	18-0-7	22-10-1	25-8-6	27-1-0	27-5-6	27-5-6					27-5-6	27-2-1	26-6-2	25-3-6	23-1-3	19-8-1	14-1-7	10-0-0	4-8-0	1-2-2	
30'-0" W.L.	0-3-6	2-10-7	5-11-0	12-6-7	18-9-6	23-3-4	25-10-5	26-11-7	27-2-1	27-2-1					27-2-1	27-0-0	26-6-5	25-7-4	24-1-6	22-0-1	18-5-3	15-9-0	11-9-1	8-11-1	1-4-0
36'-0" W.L.	1-0-2	4-8-0	8-3-7	15-1-6	20-8-2	24-5-0	26-3-4	26-10-2	26-11-0	26-11-0					26-11-0	26-9-0	26-5-1	25-9-6	24-8-4	23-2-2	20-8-0	18-9-2	16-0-4	14-1-0	8-5-7
Focsle Dk.	4-0-5	9-9-0	14-0-7														Poop	deck	24-11-4	23-6-7	21-6-0	20-0-4	17-10-6	16-4-4	12-1-2
Heights																									
2'-0" Buttock	40-6-0	17-7-4	2-0-0	0-0-4												0-0-4	0-0-6	0-1-6	0-4-1	0-11-3	3-4-3	16-4-2	22-5-3	24-11-6	30-5-0
4'-0" Buttock	46-0-0	34-2-2	5-0-0	0-4-4	0-0-7										0-0-7	0-1-2	0-2-5	0-5-6	1-2-3	3-5-6	13-11-0	19-10-4	23-11-2	26-4-4	31-9-6
8'-0" Buttock		42-6-0	35-4-3	2-6-2	0-3-6	0-1-6									0-1-6	0-3-1	0-6-4	1-6-4	3-11-7	10-3-4	19-2-2	22-10-4	26-9-5	29-2-5	35-5-4
12'-0" Buttock			41-8-2	27-3-0	1-3-3	0-2-6	0-2-4								0-2-4	0-5-7	1-2-2	3-2-0	7-8-0	14-11-7	22-4-3	26-0-6	30-2-3	32-11-6	42-1-4
16'-0" Buttock				37-4-2	5-4-0	0-9-7	0-3-3							0-3-3	0-3-4	0-9-2	2-2-4	5-5-6	11-8-2	19-1-2	26-5-2	30-4-0	35-11-0	40-8-6	
Upper Dk. at side	38-8-0	37-9-6	37-0-2	35-9-0	34-7-1	33-6-2	32-7-6	31-10-7	31-3-7	30-10-6	30-7-2	30-6-1	30-6-7	30-7-3	30-10-0	31-1-1	31-5-5	31-10-5	32-5-1	33-0-0	33-7-4	33-11-6	34-3-7	34-7-0	34-11-4



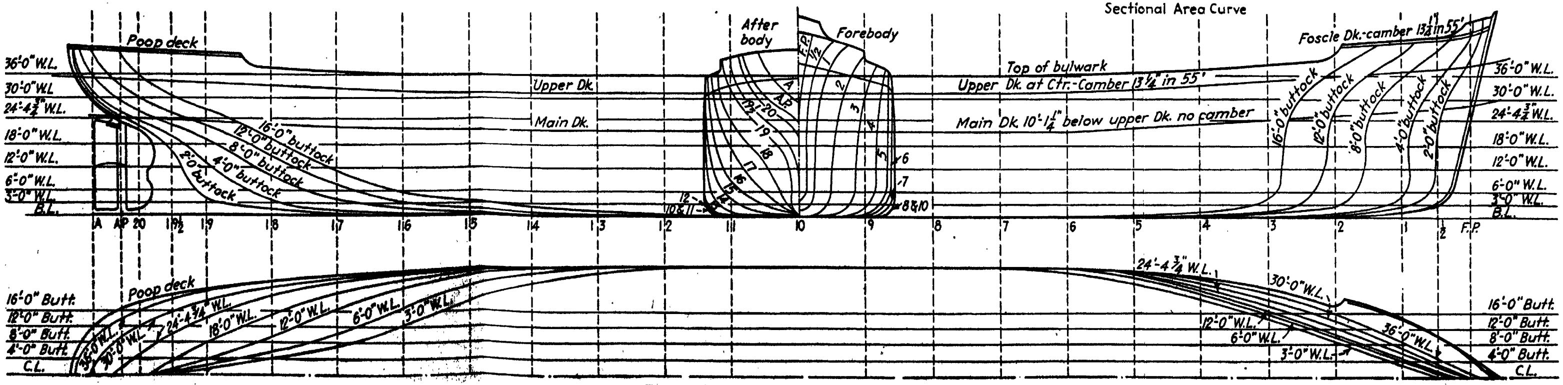


Fig. 77.—Faired lines on ordinates of sections.

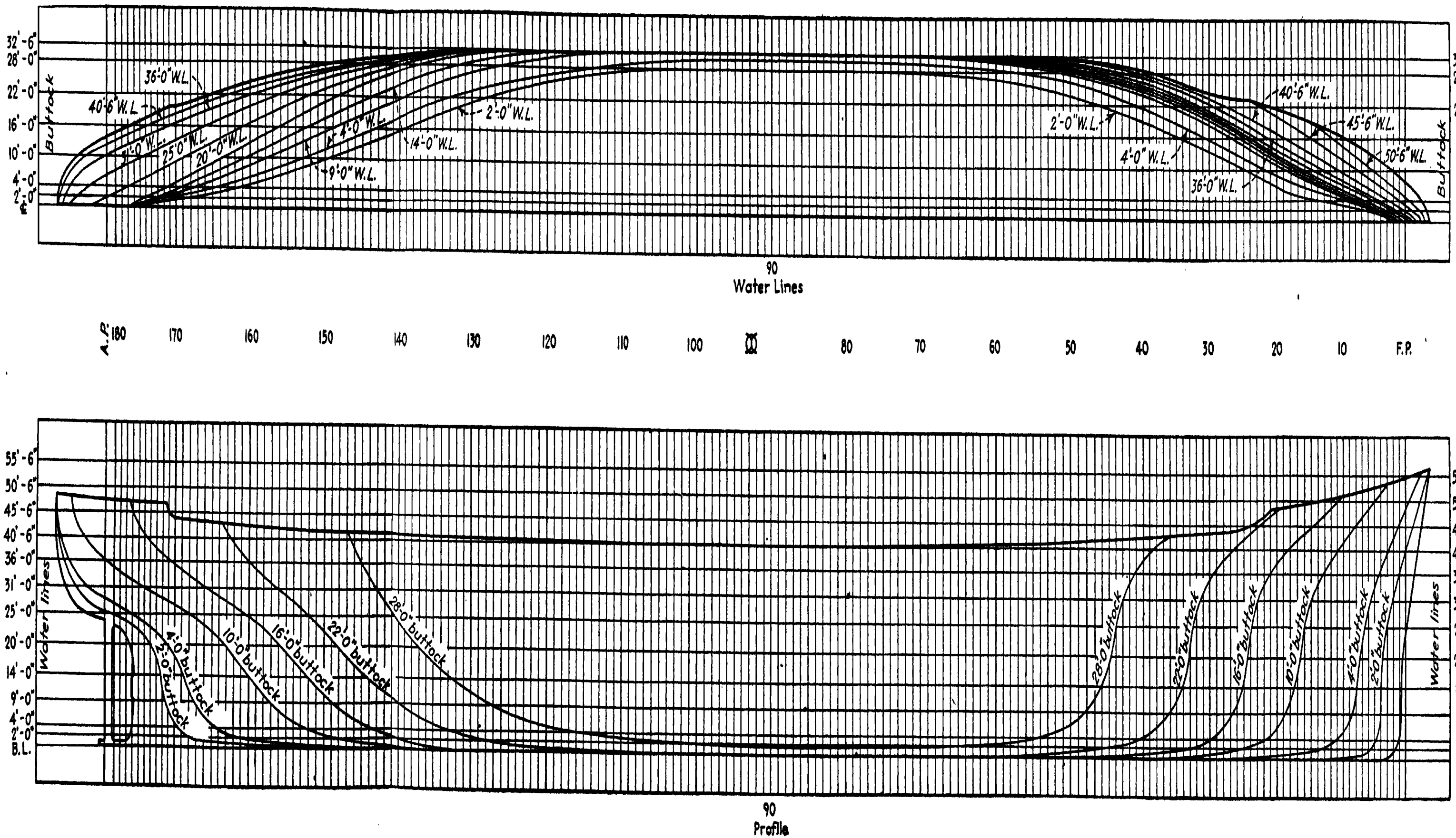


FIG. 78.—Faired water lines and buttocks at frame stations.

The offsets are next placed in the body plan, and battens are laid through these spots, and the fair lines penciled in on the floor. (All lines that have been put in prior to this have been temporary only; chalk has been used to trace them.) Figure 78 shows the faired water lines and buttocks at frame stations. Figure 79 shows the body plan of the framing only at every tenth frame.

After the drawing room receives the offsets from the mold loft, work is immediately started on the sheet line and stringer plan, which outlines the strake edges of the stringers. As soon as this is received by the mold

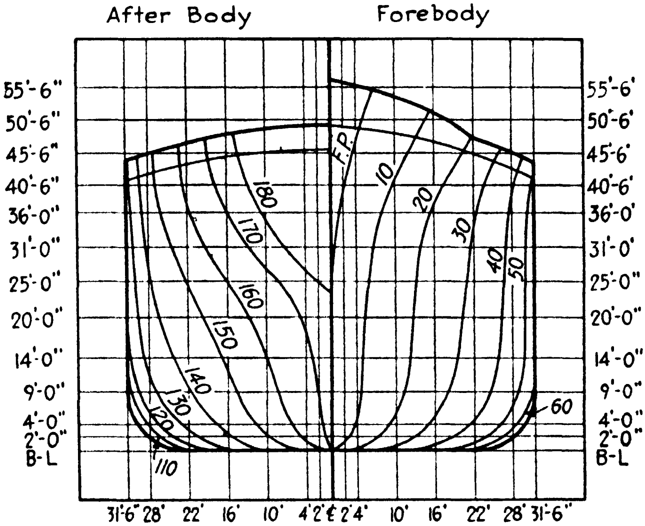


FIG. 79.—Body plan showing every tenth frame.

loft, the strake edges and stringers are immediately incorporated into the full-scale lines and the offsets again returned to the drawing room.

The offsets for the sheet lines are given for the sight edges of the plan so that the drawing room may order the shell plating at the ends of the vessel. The sight edges of the plating, however, are not put in on the floor, but the inside edges are the lines laid in on the body plan. This is because the latter determine the point of joggling the frames.

Lines for margins, bossing, bow and stern contours, cant frames, etc., are next put in.

The bow and stern contours and the cant frames are usually laid down apart from the body plan.

The next step is developing the battens for half widths and heights of decks, the half-width batten being expanded to take care of the camber if the deck has one.

DEVELOPMENT OF CAMBER CURVE

In developing the *camber curve*, various methods are used, the two most common among shipbuilders being shown in Figs. 80 and 81.

In Fig. 80, line *AB* represents the beam length of the ship. With the beam length as a radius and *A* and *B* as centers, arcs *AE* and *BF* are

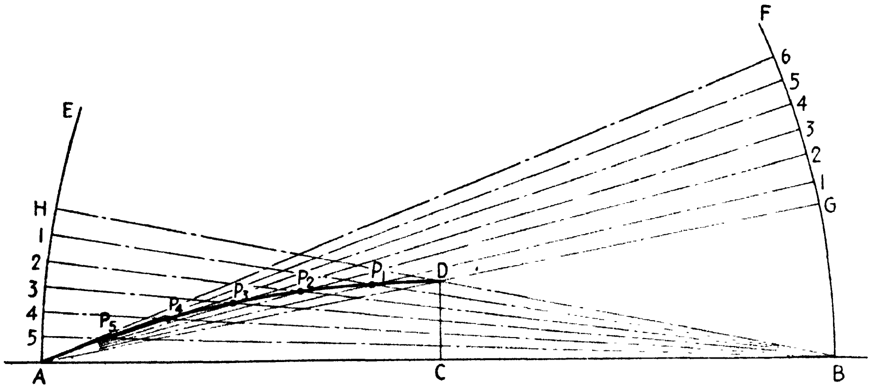


Fig. 80.—Development of true-arc camber curves.

drawn. The camber height at the center, which must be known in order to develop a curve, is represented by the line *CD*. Now, with *A* and *D* as points, a straight line is drawn intersecting arc *BF* at *G*. In like manner, with *B* and *D* as points, a straight line is drawn intersecting arc *AE* at *H*.

Beginning at *H*, divide arc *AH* into any number of equal parts; from point *B*, draw lines intersecting these points. In the same manner,

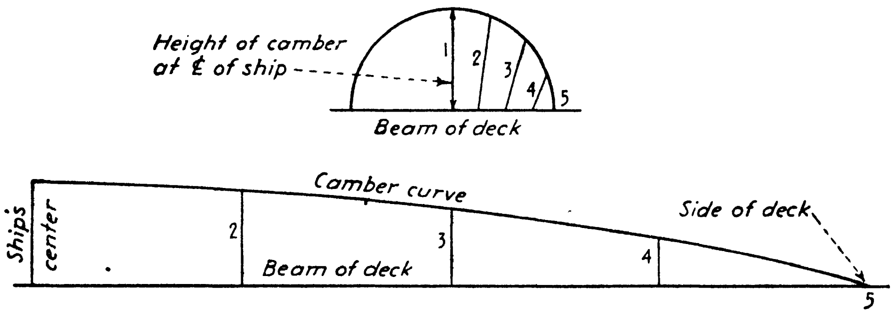


Fig. 81.—Development of camber curves.

begin at *G*, divide arc *GF* into the same number of equal parts, and draw lines from *A* intersecting these points. Where corresponding numbered lines intersect the points, they represent points on the camber curve. A curved line drawn from *A* to *D* through these points is the curve of the camber.

In Fig. 81 a camber curve is determined by a different method. In this figure, a half circle is drawn the radius of which represents the height of the camber at the center line of the ship. The quarter circle is then divided into any number of convenient equal parts, and the radius is divided in like manner, beginning at the center. Corresponding points on the quarter circle and radius are connected with a straight line.

The beam of the deck from the center line of the ship to the side is laid off and divided into the same number of equal parts as the quarter circle, and perpendiculars are erected at these points. The heights of corresponding points taken from the half circle above are laid off on the perpendiculars, and a batten laid through these points will give the desired camber curve.

DEVELOPMENT OF SHEER STRETCH BATTEN

In establishing the position of the frames on the deck plating of a ship that has considerable sheer, it is necessary to obtain a batten from

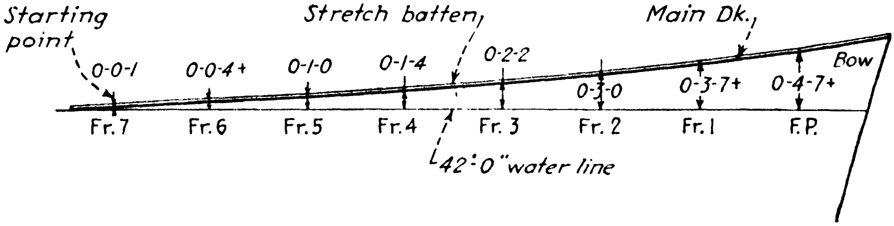


Fig. 82.—Development of sheer stretch batten.

the mold loft giving the stretch between the frames due to the increased length of the deck when laid on the designed sheer line.

From the offset book it is possible to obtain the amount of sheer above some water line at each frame station. From this water line, perpendiculars are erected at each frame, and the height of the sheer above any convenient water line is established on these perpendiculars. The batten is then laid through these established points and the frames are marked on the batten, which will give the true distance between each frame on the sheer line.

In establishing the frame stations on the ship, the same starting point must be held, and the frame stations marked on the batten can then be transferred to the deck, which will correspond to design (see Fig. 82).

The same result can be obtained if a tape line is held parallel to the base line and the distances between frames are stepped down by declivity to the deck from the tape. This, however, is an uncertain and a much more lengthy procedure, particularly where it is necessary to use the declivity board.

DEVELOPMENT OF CAMBER STRETCH BATTEN

The *camber stretch batten* is developed in the same manner as the sheer stretch batten; however, it is in an athwartship position.

After the camber curve has been established, convenient distances, particularly on buttocks every 2 ft. from the center line, are laid off, and perpendiculars are erected at these points. A batten is then laid along

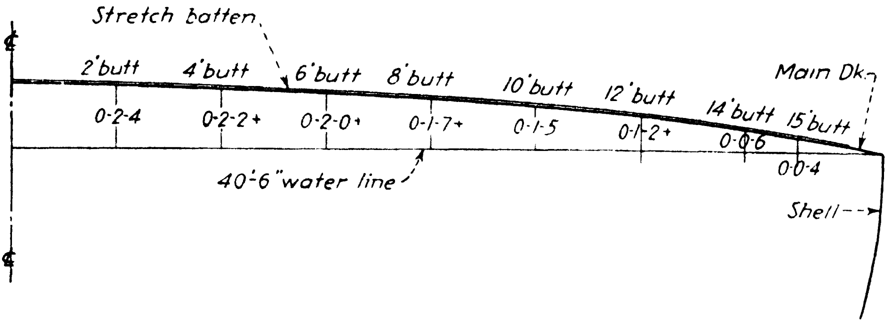


FIG. 83.—Development of camber stretch batten.

the camber curve, and the points of intersection at the buttocks are marked on the batten, together with the center line of the ship.

The camber stretch batten can then be used for laying out the deck on a flat surface, which, after being laid in the ship on the cambered beams, will result in proper distances for deckhouses and half widths according to design (see Fig. 83).

A camber stretch batten is used by shipwrights in establishing positions of foundations, deckhouses, etc., from the center line of the ship along the camber curve. It eliminates the necessity for plumbing down from a tape line held parallel to the base line.

CHAPTER IV

CARE AND USE OF TOOLS

The shipwright is generally expected to supply the ordinary tools that he uses, with the exception of large heavy tools, which are supplied by the shipyards.

For general purposes, the tool kit of a shipwright should consist of the following:

1. Handsaws.
   a. Rip, straight back No. 5, 26-in. blade.
   b. Crosscut, straight back No. 8, 26-in. blade.
   c. Hack saw and frame.
2. Hammers.
   a. Claw hammer, $1\frac{3}{4}$ lb.
   b. Ball-peen hammer, $1\frac{1}{2}$ lb.
   c. Pin maul, $2\frac{1}{2}$ in. face, 5 or 6 lb.
   d. Mallet.
3. Chisels.
   a. $\frac{1}{2}$-in.-socket firmer chisel.
   1-in.-socket firmer chisel.
   $1\frac{1}{2}$-in.-socket firmer chisel.
   2-in.-socket firmer chisel.
   b. 1-in. gouge.
   $1\frac{1}{2}$-in. gouge.
   c. 3-in. slick, or slice.
   d. $\frac{7}{8}$-in. cold chisel.
4. Files.
   a. 8-in. slim tapered, three-cornered.
   12-in. tapered, three-cornered.
   b. 16-in. wood rasp.
5. Squares.
   a. Framing square, 2-ft. blade, 16-in. tongue.
   b. Try and miter square, $7\frac{1}{2}$ in.
   c. Combination square, 12-in. blade.
   d. Bevel square, 10-in. blade.
6. Ship ax, 7-in. cut.
7. Foot adz, 5-in. lipped.
8. Draw knife, 14-in. blade.
9. Bits.
   a. One each of size 8 to 16 auger bits; double thread; double spur.
   b. Auger bit, $\frac{9}{16}$ in.
   Auger bit, $\frac{11}{16}$ in.
   Auger bit, $\frac{13}{16}$ in.
   Auger bit, $\frac{15}{16}$ in.

c. Screw-driver bit, round shank, 5/16 in.
Screw-driver bit, round shank, 1/2 in.
Screw-driver bit, round shank, 3/4 in.

10. Planes.
    a. Iron block plane, 6 in., 1 3/8 in. cutter.
    b. Smooth iron plane, 9 in. long, 2-in. cutter.
    c. Iron jack plane, 15 in. long, 2-in. cutter.
11. Pair dividers, 10 in.
12. Oilstone, carborundum, 8 by 2 by 1 in.
13. Hatchet.
14. Spirit level, 24 in., metal frame
15. Brace, 14-in. sweep.
16. Hand screw driver, 12 in.
17. Steel tape, 50 ft.
18. Plumb bob about 19 oz., steel point.
19. Trammel points.
20. Ripping bar.
21. Straightedge.
22. Chalk lines and chalk.

The shipwright's tools should be kept in good working order at all times. All edged tools should be sharpened to the proper bevel. The cutting edges should be cleaned, and the tools placed in a toolbox in such a manner that the edges will not become nicked or dull.

In using edged tools on the job, they should not be laid where they will fall or where someone is likely to be injured by tripping on them.

All tools should be cleaned and given a light coat of oil at least once each week—oftener if used in wet weather or damp locations.

CARE AND USE OF SAWS

Handsaws[1]

A saw, when shipped from the manufacturer, is in first-class working condition. However, after being used for some time, the points of the teeth become dull and out of set.

To be sharpened, a saw should be placed in a saw frame, or it can be clamped between two wooden strips in a vise. A frame clamp is preferable.

The first operation is to bring all the teeth in line. This is termed *jointing a saw*.

To Joint a Saw. Place the saw in a clamp with the handle to the right. Lay a mill file lengthwise on the teeth, and pass it lightly back and forth the length of the blade on the tops of the teeth until the file touches the top of every tooth (see Fig. 84). If the teeth of the saw are very irregular, it is best not to make all the teeth the same height the first

[1] Based on material from "Disston Saw, Tool, and File Manual," Henry Disston and Sons, Inc., Philadelphia, April, 1942.

time they are jointed. In this case, *joint only the highest teeth first,* and then shape them.

Shaping the Teeth. This is to be done only when the saw has been jointed. After jointing, the teeth must be filed to the correct shape. The gullets must be of equal depth. The fronts and backs of the teeth must be the proper shape and angle.

To shape the teeth, place the file well down in the gullet and file straight across the saw at right angles to the blade. If the teeth you are

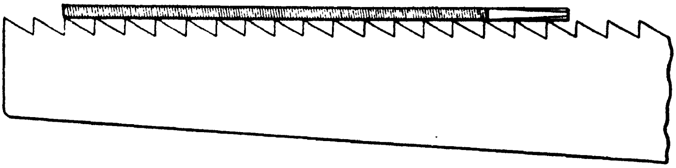


FIG. 84.—Jointing a saw.

filing are of unequal sizes, use the file against the teeth having the largest tops until you reach the center of the flat top made by jointing. Then move the file to the next gullet and file until the rest of the top disappears and the tooth has been brought up to a point. Make no effort to bevel the teeth at this time.

The teeth now shaped and of an even height are ready to be set.

Setting the Teeth. In order that the saw will not bind when it is pushed through the wood, it is necessary that the teeth be bent slightly to afford a clearance for the blade. Therefore, each alternate tooth is bent over to one side approximately one-half the thick-

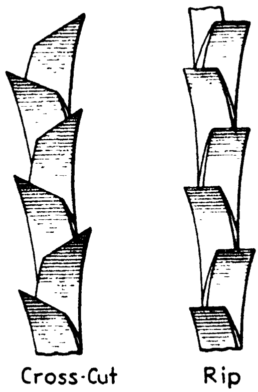


FIG. 85.—Setting the teeth of a saw.

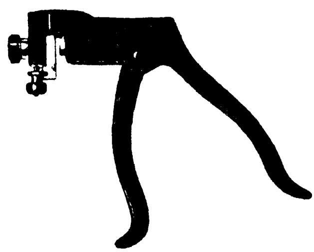


FIG. 86.—Pistol-grip saw set.

ness of the blade. The other alternate teeth are bent toward the opposite side the same amount (see Fig. 85).

Setting the teeth of a saw can best be done with a saw set. This is a tool having either a pistol- or a plier-grip handle. A pistol-grip set is shown in Fig. 86, and a plier-grip set is shown in Fig. 87.

A plunger is fastened to one of the handles, and pressure on the handles forces the plunger against the teeth of the saw. The plunger bears against an anvil, which is beveled and which can be regulated to give the teeth a fine, medium, or coarse set by simply adjusting the anvil to the desired set.

The saw set is then placed on the saw, as shown in Fig. 88, and in line with the tooth, bent away from the position of the operator. Pressure on the grips of the set will press the plunger against the tooth and bend it to the bevel of the anvil.

Whether the saw is fine or coarse, the depth of the set should be no deeper than one-half the length of the tooth. This is important. If deeper than this, it is likely to spring, crimp, or crack the blade, if it does not break out the teeth.

A taper-ground saw requires very little set for the blade. Being of uniform thickness along the entire tooth edge, it tapers thinner to the back and also tapers from the butt to the point along the back, which provides the measure of clearance necessary for easy running.

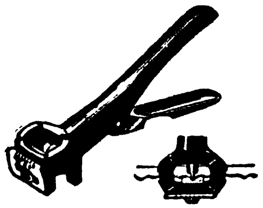


FIG. 87.—Plier-grip saw set.

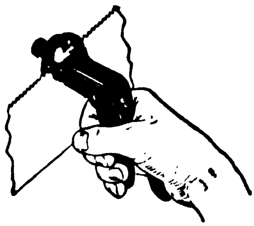


FIG. 88.—Saw set placed on the saw.

Soft wet woods require a saw with more set and coarser teeth than dry hardwoods. For fine work on either hard or soft dry woods, it is best to have a saw with fine teeth and only a slight set.

In setting teeth, particular care must be taken to see that the set is regular. It must be the same width from end to end of the blade and the same width on both sides of the blade; otherwise, the saw will not cut true and will run out of line, and the cut will be crooked.

Filing a Saw. *After the saw has been set,* the operation of filing can begin.

There are a variety of shapes in teeth and variation in angles, bevels, etc., adapted for special work such as cutting dry seasoned lumber, wet or green lumber, hardwood, or softwood. The saw user should follow these instructions (for saws in ordinary use) for the teeth, whether large or small. All but the most experienced should follow these recommendations for best results.

Place the saw in the filing clamp with the handle to the right. The bottom of the gullets of the teeth should be about $\frac{1}{8}$ in. above the jaws of the clamp.

Filing Hand Crosscut Saws. The crosscut saw, being designed to cut across the grain, cuts with an action similar to a number of small knife blades. The front faces of the teeth of a crosscut saw have an angle of 15 deg.; the back of the teeth have an angle of 45 deg. The teeth are usually filed with a bevel of about 24 deg.

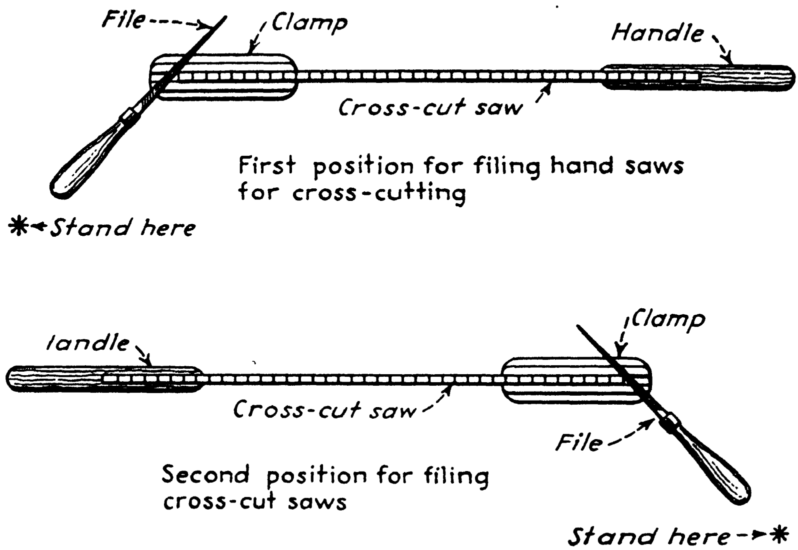


FIG. 89.—Standing position for filing saws.

Stand at first position as shown in Fig. 89. Start at the point. Pick out the first tooth that is set toward you. Place the file in the gullet to the left of this tooth. Hold the file directly across the blade. Then swing the file handle toward the left to the desired angle. The correct angle is shown in Fig. 89*a*.

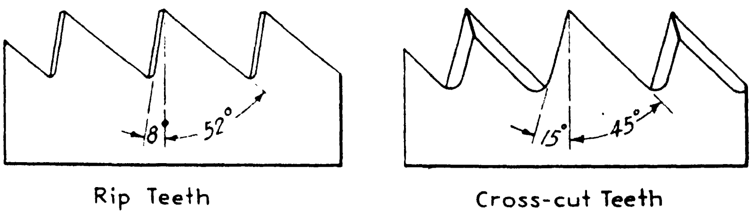


FIG. 89*a*.—Angle for filing the teeth of handsaws.

Hold the file level and at this angle. Do not allow the file to tip upward or downward. Be sure the file seats down well into the gullet, and let it find its own bearing against the teeth it touches. It will help the beginner if he will first observe the shape and bevel of some of the unused teeth that can always be found near the handle end of the saw.

These teeth are shaped as they left the factory and will act as a guide (see Fig. 90).

The file should cut on the push stroke. It files the tooth to the left and the tooth to the right at the same time. File the teeth until you cut away one-half the flat tops made on the teeth when jointing. Skip the next gullet to the right, and place the file in the second gullet toward the handle. Repeat the filing operation on the two teeth the file now touches, being careful to file at the same angle as before. Continue in this way, placing the file in every second gullet until you reach the handle end of the saw.

Now, study the second position illustrated in Fig. 89.

Turn the saw around in the clamp handle to the left, and take the second position. Place the file in the gullet to the right of the first tooth

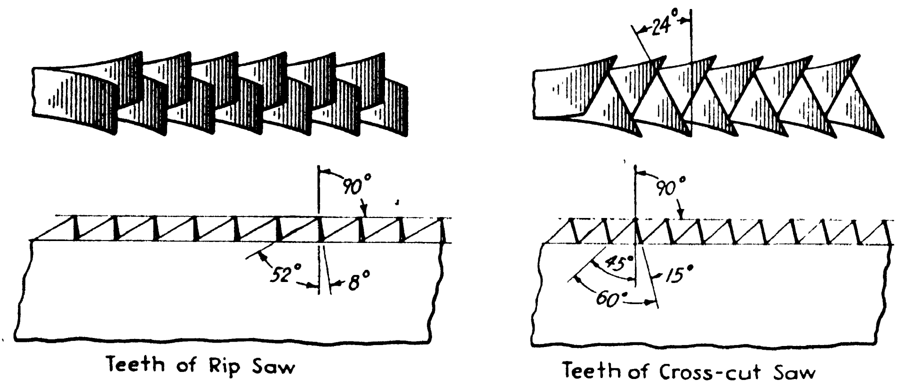


FIG. 90.—Factory-filed teeth of ripsaws and crosscut saws.

set toward you. This is the first of the gullets you skipped when filing the other side of the saw. Turn the file handle to the desired angle toward the right. Now, file until you cut away the other half of the flat top made on the teeth when jointing and sharpening the teeth to a point. Continue this, placing the file in every second gullet until you reach the handle end of the saw.

In filing teeth, use care to see that in the final sharpening all the teeth are of the same size and height; otherwise, the saw will not cut satisfactorily.

Filing Saws for Ripping. With one exception this method is exactly the same as that given for crosscut saws. This exception is that ripsaws are filed with the file held straight across the saw, or at right angles to the blade. The file should be placed in the gullet so as to keep the angle on the front of each tooth 8 deg., and 52 deg. at the back, as shown in Fig. 90.

Files to Use for Properly Filing Handsaws. The following table indicates the length of file to be used.

	File Length, in.
5- and 6-point crosscut	7
5-, 5½-, and 6-point rip	7
7-, 8-, and 9-point crosscut	6
7-point rip	6
9- and 10-point crosscut	5½
10-, 11-, and 12-point crosscut	4½

To determine the point of a saw, count the number of tooth points to the inch, measuring 1 in. from the point of any tooth. Note that, in ripsaws of six points and coarser, the teeth at the point of the blade are finer than at the base of the blade; therefore, in measuring the ripsaw teeth, take the region at the butt of the blade.

Bevel of Teeth. The proper amount of bevel to give the teeth is very important, for if there is too much bevel, the point will score so deeply that the fibers severed from the main body will not crumble out as cut. The first figure in Fig. 91 shows a tooth of a crosscut saw with the amount

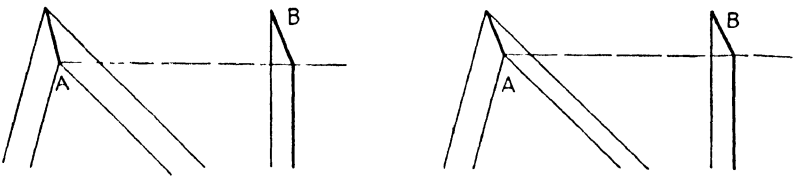


Fig. 91.—Bevel of teeth of crosscut saw for soft and medium hardwoods.

of bevel front and back. This saw with the long front, *B*, is best suited for work in softwoods in which speed rather than accuracy and delicacy are required.

The second figure in Fig. 91 shows a tooth of a saw for medium hardwoods. This tooth has less bevel on the back, which gives a shorter bevel to the point as at *B*.

It will be seen from these illustrations that the bevel on the front of the teeth is about the same, but the bevel of the point looking the length of the saw is quite different, depending upon the difference in the angles of the backs of the teeth. Here again experience will indicate what is best.

Side Dressing the Saw. After a saw has been filed, it should be laid on a board and the flat side of a file run gently along the sides of the teeth. The same operation should be followed on both sides.

When the saw has been properly set and sharpened, a straight groove should exist between the lines of the teeth down the center (see Fig. 92).

Unless a saw is used roughly, it is not necessary to set the teeth each time it is sharpened. It may be filed two or three times without resetting.

Using the Saw. The teeth of a saw act as small chisels cutting out particles of the wood as the saw is pushed through it. In using a crosscut saw, it is best to maintain an angle of 45 deg. between the saw and the face of the work. Extending the forefinger along the side of the handle aids in guiding the blade. Take long easy strokes, and make each stroke do its work.

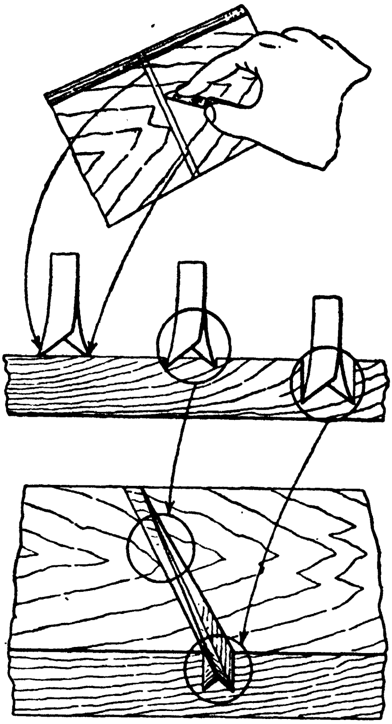


Fig. 92.—Straight line between the teeth after filing; cutting action of handsaws.

To start the cut, rest the blade on the waste side of the line, supporting the side of the blade with the thumb, and draw the saw toward you a few times until a slight groove is formed; then cut straight with a full stroke (see Fig. 93).

In using the ripsaw, the position for ripping should be such as to permit long easy strokes. The user who does most of the cutting with a few inches of the blade in the middle of the saw has difficulty in keeping the line of the cut straight. He also dulls the saw more rapidly because a few teeth are called upon to do all the cutting. In ripping, the cut should be started with the finer teeth at the point of the blade. Ripping usually is done with the work supported on sawhorses.

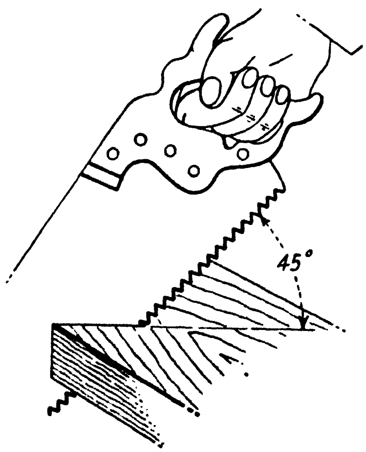


Fig. 93.—Using the crosscut saw.

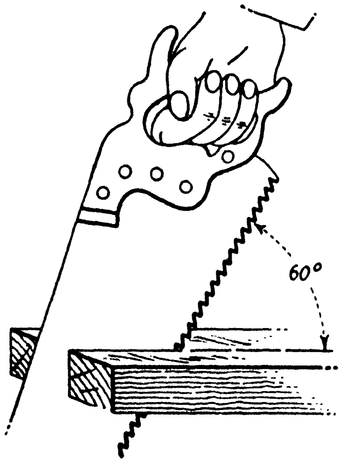


Fig. 94.—Using the ripsaw.

An angle of 60 deg. between the edge of the saw and the face of the work, as shown in Fig. 94, gives best results in using a ripsaw.

SHARPENING TWO-MAN CROSSCUT SAWS[1]

Like handsaws, there are numerous types of heavy crosscut saws. These are divided into three groups:

1. The lance-tooth type.
2. The peg-tooth type.
3. The champion-tooth type.

These are shown in Fig. 95.

The lance-tooth and champion-tooth saws are commonly known as *drag-tooth saws*. Their action in cutting is shown in Fig. 96.

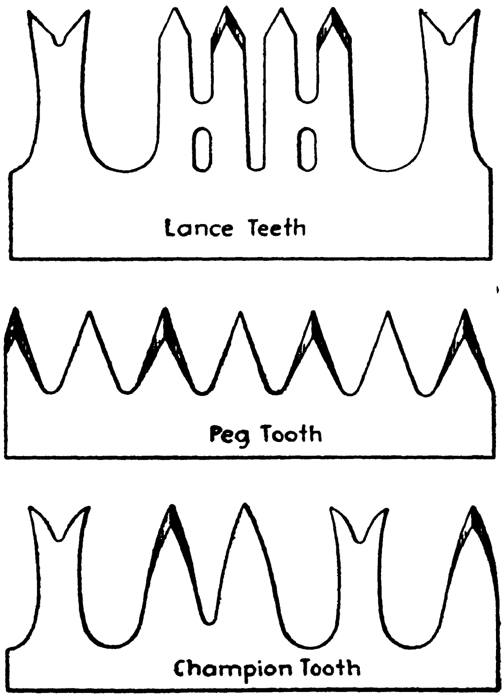


FIG. 95.—Type of teeth on two-man crosscut saw.

The teeth of the peg-tooth saw work like those of the crosscut handsaw. They act like small knives, cutting the particles of wood as the saw is pulled in either direction, whereas the handsaw teeth cut in only one direction.

[1] Based on "How to File a Cross-cut Saw," Simonds Saw and Steel Co., Fitchburg, Mass., 1941.

Jointing. In jointing the saw the flat file is used as for handsaws. However, a better method is to place a 7- or 8-in. special crosscut file in a filing rack similar to that shown in Fig. 97.

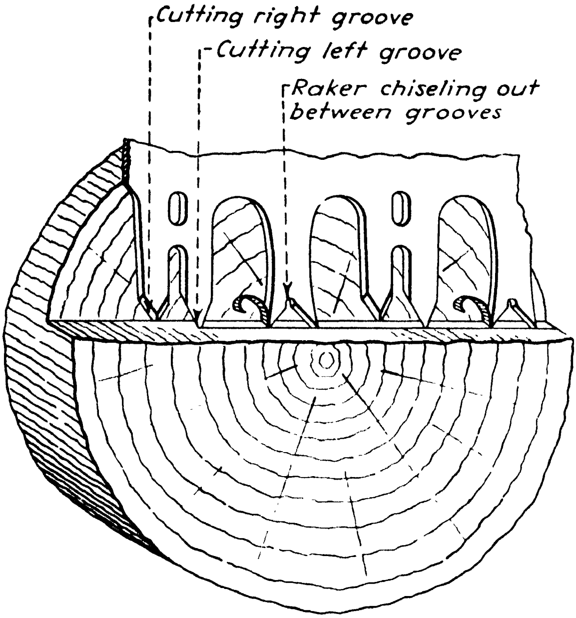


FIG. 96.—Action of lance- and champion-tooth saws in cutting.

If the file is properly placed as directed in Fig. 97 it will have an even curve and will set square with the body of the saw and when run over the tops of the cutting teeth will joint them evenly, that is, make them all the same length by taking off the high spots. A worn file is com-

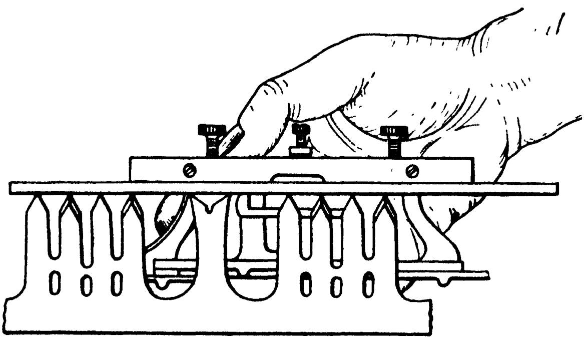


FIG. 97.—Jointing the teeth of a crosscut saw.

monly used for this purpose. In filing the raker teeth of a drag-tooth saw the object is to cut the raker to the exact height at which it will scoop out the chips left by the teeth and yet not drag as it goes through the cut. To do this properly, all the rakers must be the same height. The two points of each raker must be the same, and they must be filed square across. In no case should the raker points be longer than the points of the cutting teeth.

A saw gauge is indispensable for this work. An efficient gauge is manufactured by the Simonds Saw and Steel Co. (see Fig. 98). The raker teeth may be made shorter or longer by moving the slide on the

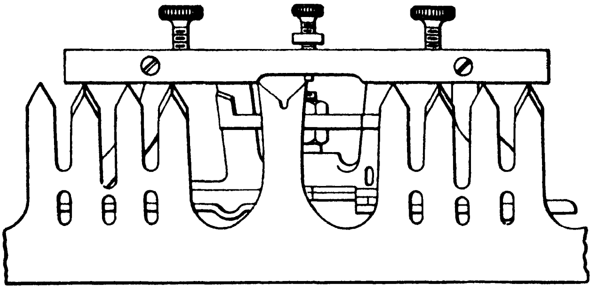


FIG. 98.—Saw-tooth gauge.

top left or right. The slide moves across the graduated scale by means of which it is possible to get accurate results. When the notch on the filing rack is set opposite the first graduation mark on the scale, the raker, when filed, will be 0.004 in., or about the thickness of an ordinary sheet of paper, below the points of the cutting teeth.

An inexperienced filer will do well to get the guidance of an experienced man in setting his gauge the first time. If no advice is available, the gauge may be set at No. 8 for softwood and at No. 5 or 6 for hardwood.

Lowering the raker by a full 1/64 in. for softwood and a scant 1/64 in. for hardwood will give satisfactory results.

After the raker teeth have been filed to the gauge, they should be sharpened, particular care being taken not to file too much and to file the face square across. It is quite important that the face or edge of the face of the rakers is filed true and level and that it is not reduced in height. It should be filed only to a sharp edge. After being filed, the V in the rakers should have an approximate angle of 45 deg. from the center of the raker to both cutting edges.

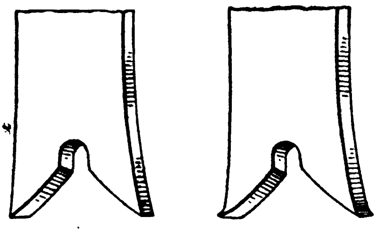


FIG. 99.—Swaged and unswaged rakers.

Swaging Rakers. The rakers are now ready to be swaged (if swaged rakers are to be used). Figure 99 shows swaged and unswaged rakers.

Take a small hammer and strike lightly each edge of the raker. The hammer should cover only about 1/8 in. from the cutting edge of the raker back. The slight strokes will bend the edges downward a trifle. By resting the finger on the raker you can feel the "hook" being made when the raker is tapped with the hammer. This hook puts the raker in proper shape to clean out the kerf. After swaging, the rakers should be filed lightly in order to make the face square.

Setting Cutting Teeth. In setting the cutting teeth it is necessary to give all of them exactly the same set so that each tooth will fall in the same line. For example, should several teeth have too much set and several too little, this means that unnecessary wood is being cut and useless energy is being expended in pulling the saw through the cut. Common practice shows that, for hardwood, teeth should be set 0.008 in. and for softwood about 0.016 in. A setting block should be used for this purpose, as shown in Fig. 100.

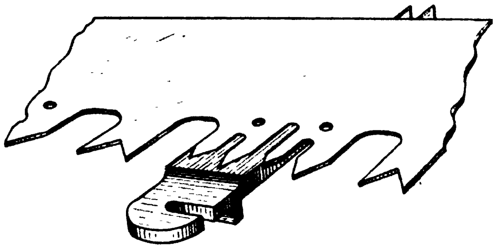


FIG. 100.—Setting block for crosscut saws.

Set the saw on the setting block with the teeth to be set immediately over the bevel. Then take a hammer and strike the tooth lightly until it conforms to bevel. Proceed in like manner to set every other tooth. Then reverse the saw, and set the balance of the teeth. Each tooth must extend the same distance over bevel. The same procedure is followed with respect to the peg-tooth crosscut saw.

Filing Bevel on the Cutting Teeth. Before filing, tilt the clamp to a 30-deg. angle, and start on the first tooth of the saw. See Fig. 101, which shows a four-cutter and raker-tooth blade. If a two-cutter raker-tooth saw is being sharpened, the method will be practically the same.

Observe in Fig. 101 how the filer grasps the file. Also notice the angle at which the file is held. Then proceed to file as follows: Start with the right-hand bevel of the first tooth on the left-hand end of the blade facing you. Then file every right-hand bevel in order on the side of the blade facing you. It is of little importance which bevel is started first. This brings you to the left-hand end of the blade. Start there, and file the other bevels facing you.

Now reverse the blade, and file the bevels facing you in similar manner. Of course, should the kind of wood to be sawed require a bevel different from the one shown, hold the file at an angle that will give the

FIG. 101.—Filing crosscut saws.

FIG. 101a.—Filing crosscut saws. Correct position for holding file.

bevel desired. The bevel should be greater for softwood than for hardwood.

In filing a peg-tooth crosscut saw the teeth should be brought to a point at an angle of 67 deg. to the border of the saw. The bevel of the tooth should be about 23 deg. at the apex of the tooth and should fade out in the gullet of the tooth, as shown in Fig. 95. In setting the teeth of a peg-tooth saw the amount of set must be determined by the thickness of the back of the saw and the kind of timber to be cut. A set less than $\frac{1}{64}$ in. wider than the saw on each side is sufficient clearance under ordinary circumstances. In hardwood less set may be carried than in green softwood. In any case, the set absolutely must be enough to prevent the saw from jumping or scratching.

CARE AND USE OF HAMMERS AND MAULS

A good grade of steel is important for this type of tool, for inferior grades will chip on the face and render the tool useless for service.

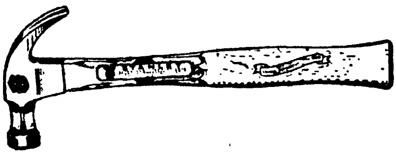


Fig. 102.—Semiripping claw hammer.

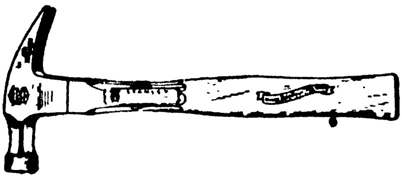


Fig. 103.—Ripping claw hammer.

In using hammers and mauls the handle of the tool should always be held parallel with the plane of the work. The handles of claw and ball-peen hammers vary in length to suit the individual, but the hand should always grasp the handle close to the outer end.

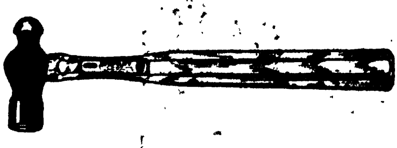


Fig. 104.—Ball-peen hammer.

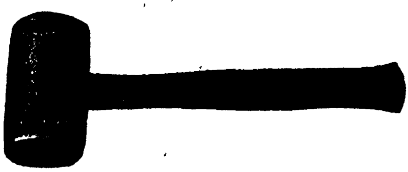


Fig. 106.—Mallet.

Fig. 105.—Ship maul.

The claw hammer shown in Fig. 102 is known as a *curved-claw semi-ripping hammer;* that shown in Fig. 103 is a *ripping* claw hammer generally used on concrete form work and framing.

The *ball-peen hammer*, shown in Fig. 104, should always be employed for center punching or in using a steel cutting chisel. The claws on the claw hammer are likely to snap off when used for this purpose.

In using the *pin*, or *ship*, *maul*, shown in Fig. 105, spikes are usually given a slight angle so that the face of the maul will strike squarely on the heads in driving in a standing position. In order to secure maximum striking power in driving, the maul handle should be held close to the extreme end.

The *mallet* shown in Fig. 106 is used in working with a wood chisel, because it does not batter up the handles.

CARE AND USE OF CHISELS

The chisels used by shipwrights are usually the *firmer type*, since these are substantial tools and are adaptable for general work (see Fig. 107). On some classes of work it is necessary to use a wide-bladed chisel termed a *slick* or *slice*. This tool is generally used with the hands and only on heavy work.

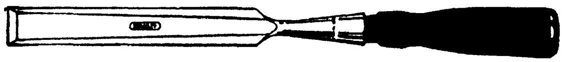


Fig. 107.—Firmer type chisel.

Sharpening Chisels. A chisel should be sharpened from one side only, and the bevel of the blade should be twice its thickness in length. The method of sharpening chisels and plane irons is shown in Fig. 108.

Using the Chisel. Chisels should not be used for prying open boxes or crates, owing to the danger of breaking them because of the high carbon content of the steel. In using the chisel for paring, it should always be held parallel to the work with the bevel side up.

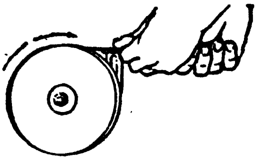
In using the chisel for mortising, the blade should be held vertically at all times except in roughing out parallel to the grain of the wood, when the bevel side should be down. This will prevent making a cut that is too deep.

Gouges. The *gouge* is a chisel with a hollow-shaped blade for scooping out or cutting around holes; some have an inside bevel, while others are beveled on the outside. Rules for sharpening this type of chisel are the same as for firmer chisels, the bevel being two times the thickness in length.

Cold Chisel. The cold chisel shown in Fig. 109 is used in chipping off tack welds or rough spots on castings and cutting cross marks for center lines and buttocks on steel plating.

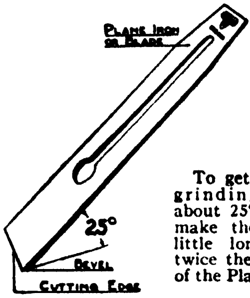
In cutting with a cold chisel, the cut should not be too heavy or the chip will not curl ahead of the cutting edge. A light cut will require much less energy, and the chipping can be done more quickly.

Grinding

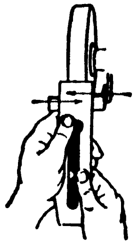


The grindstone should turn toward the Plane Iron. Use the guide to assure a flat even bevel.

Keep the Plane Iron cool to prevent burning by frequently dipping it in water. Stones running in water or oil are preferable.



To get the right grinding angle—about 25° to 30°—make the bevel a little longer than twice the thickness of the Plane Iron.



Move the Plane Iron from side to side to grind full width of bevel and to keep wheel true.

The edge should be straight and almost at right angles to the sides of the Plane Iron.

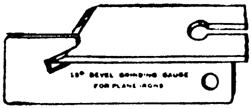
When to Grind a Plane Iron or Chisel

When the cutting edge is nicked.

When the bevel has been worn down by much whetting.

When the bevel has been rounded by careless whetting.

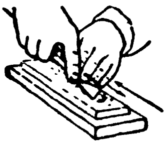
New! Bevel Grinding Gauge No. 149



By inserting a plane iron in this gauge you can quickly tell if it has been ground to the correct bevel. Stainless steel. 2 7/8 inches long.

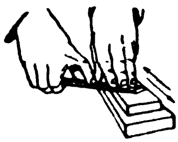
Whetting

Whet the Plane Iron on the oil stone to produce a real sharp cutting edge. Use enough oil to keep the surface of the stone moist. Try to wear the stone evenly.

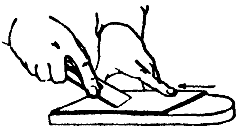


Place the bevel of the Plane Iron on the stone with the back edge slightly raised.

To Keep the Bevel Straight be sure the hands move parallel to the stone so that the angle between the Plane Iron and the stone will stay the same throughout the stroke.



Remove the wire edge by taking a few strokes with the flat side of the Plane Iron held **Flat** on the stone. Avoid even the slightest bevel on this side.



Finish with a few strokes on a leather strop to produce a keener edge.

Do not put a bevel on the flat side as it prevents the Cap Iron from fitting tightly.

Plane marks will show less on a finished surface if the corners of the Plane Iron are rounded slightly.

FIG. 108.—Sharpening a chisel.

FIG. 109.—Cold chisel.

FILES

The files used by the shipwright are usually *slim-tapered*, *flat-bastard*, and *half-round rasps*. In using a file, it should never be permitted to drag when pulled back. Both hands should be used, one for applying the desired pressure and the other for pushing the file. The flat file and rasp are used for smoothing down and finishing off rough edges on wood, not for use on anything harder than brass or copper.

SQUARES

Framing Square.[1] The steel square is made in the form of a right angle; that is, its two arms (body and tongue) make an angle of 90 deg., which is a right angle.

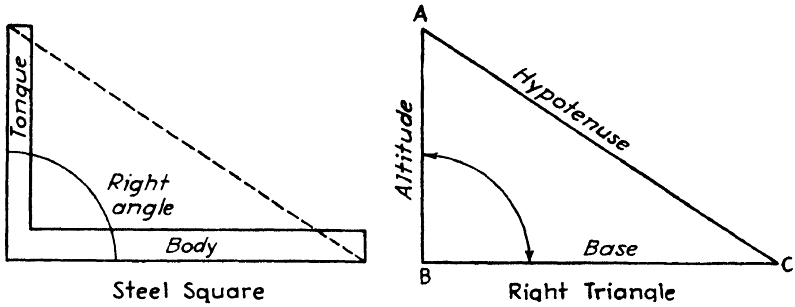


FIG. 110.—Right triangle using framing square.

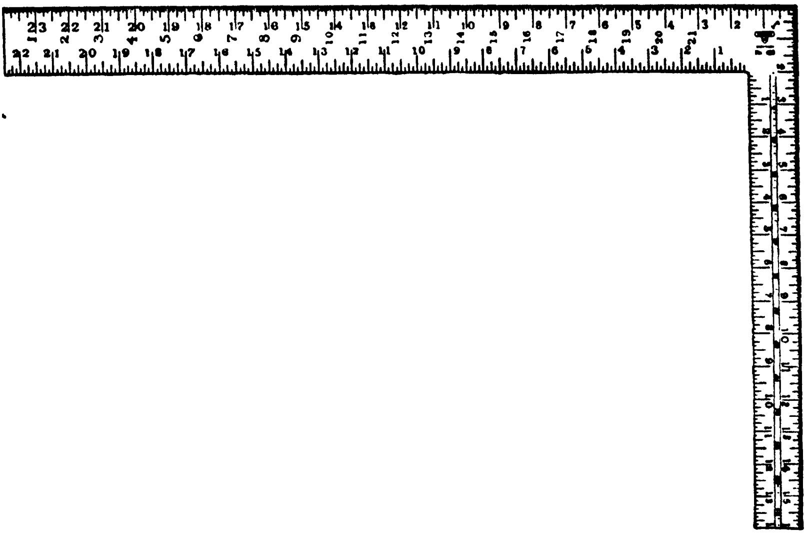


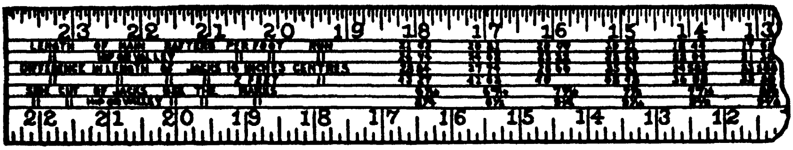
FIG. 111.—A steel square.

In Fig. 110, it will be noted that if we connect points A and C by drawing a straight line, we have a triangle ABC, and since the angle B on the square is a right angle the triangle will be a right triangle. Therefore, the steel square is based on the principles of a right triangle.

[1] Based on material from L. Perth, "The Steel Square," 1937, by permission of the Stanley Rule and Level Plant, New Britain, Conn.

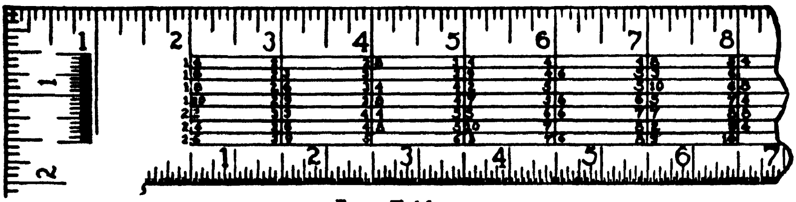
The steel square consists of two parts: the body, or blade, and the tongue (see Fig. 111). The *body* is the longer and wider part and is 24 in. long and 2 in. wide. The *tongue* is the shorter and narrower part and usually is 16 in. long and 1½ in. wide.

Steel Square Tables



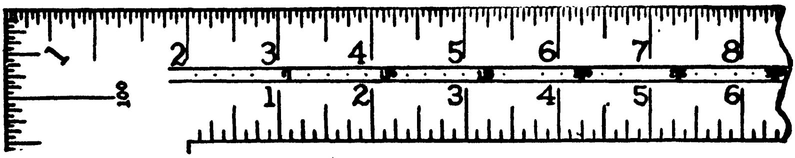
Rafter or Framing Table

This table appears on the body of the Square. It is used to determine the length of the common, valley, hip and jack rafters and the angles at which they must be cut to fit at the ridge and plate. Complete directions for reading and using are packed with each Square.



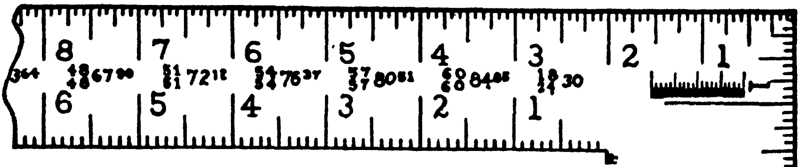
Essex Table

This table appears on the body of the Square. It shows the board measure, in feet and 12ths of feet, of boards 1 inch thick of usual length and widths. Complete directions for reading and using are packed with each Square.



Octagon Scale

This Scale appears on the tongue of the Square. It is used to layout a figure with eight equal sides on a square piece of timber. Complete directions for reading and using are packed with each square.



Brace Table

This table appears on the tongue of the Square. It shows the length of the Common braces. Complete directions for reading and using are packed with each Square.

Hundredths Scale

This scale appears on the tongue of the square. With a pair of dividers, decimals of an inch can be quickly obtained.

Fig. 112.—Essex board measure.

The *heel* is the point at which the body and tongue meet on the outside edge of the square. The intersection of the inner edges of the body and the tongue is sometimes also called the *heel*.

The face of the square is the side visible when the body is held in the left hand and the tongue in the right hand. The back is the side opposite to the face.

The steel square is an indispensable tool in shipbuilding as it has a wide range of uses. While it is not necessary for the shipwright to know many of the tables used by house carpenters, he should familiarize himself with the tables on the square,[1] as they can be applied to many problems in everyday work, such as building sheds or stairways on the ship and to board the ship.

Rafter Tables. These tables will be found on the face of the body. They will help to determine rapidly the lengths of the rafters as well as their cuts.

The rafter tables consist of six lines of figures, and their use is indicated on the left end of the body.

FIG. 113.—Try and miter square.

The first line of figures gives the lengths of common rafters per foot run. The second line gives the length of hip and valley rafters per foot run. The third line gives the length of the first jack rafter and the differences in the length of the others, centered at 16 in. The fourth line gives the length of the first jack rafter and the differences in length of the others, spaced at 24-in. centers. The fifth line gives the side cuts of jacks. The sixth line gives the side cuts of hip and valley rafters.

Octagon Scale. The *octagon,* or *sight square, scale* is found along the center of the face of the tongue. By the use of this scale square, a timber may be shaped into one having eight sides (an octagon).

Brace Measure. This table is found along the center of the back of the tongue and gives the exact lengths of common braces.

Essex Board Measure. This table is on the back of the body and gives the contents of any size timber (see Fig. 112).

Numerous applications of the steel square to work performed by the shipwright will be referred to in succeeding chapters, particularly in cutting shores and braces, building stairways and ramps, and problems in laying out work.

Try and Miter Squares. Try and miter squares may be used on light work as a square and by applying the beveled corner may also be used for a 45-deg. miter cut. The try square derives its name from trying lumber or objects for square (Fig. 113).

[1] Space does not permit the explanation of all the tables. The reader desiring further information may obtain a pamphlet on the steel square by writing to the Stanley Rule and Level Plant, New Britain, Conn.

Combination Square. The combination square shown in Fig. 114 may be used for eight distinct operations. These are all shown in the figure. The best type is that with the groove blade, as the blade can be removed readily and used as a straightedge. The various other operations in which the combination square can be used are quite apparent.

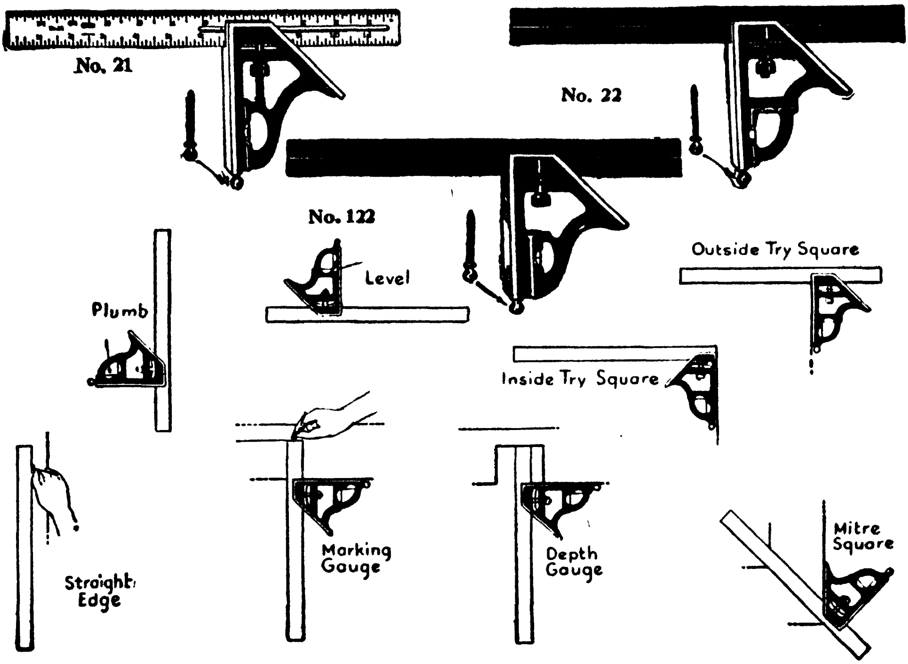


FIG. 114.—Combination square.

The Bevel Square. The bevel square shown in Fig. 115 is used in obtaining bevels of cuts and various other kinds of cuts that are not square.

By the use of the set wing nut, the blade can be held in any desired position. After the square has been set and the wing nut tightened, a bevel can be transferred and applied wherever desired.

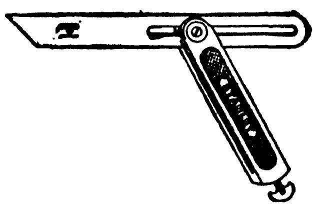


FIG. 115.—Bevel square.

THE AX AND ADZ

Ship, or Broad, Ax. The *ship ax*, or *broad ax* as it is commonly known, is used by the shipwright in hewing rough timbers to a line. Much practice is required before it can be manipulated with any degree of skill.

In using the ax for rough cutting, it may be slung overhand as shown in Fig. 116. When used in dressing to a line, it should be held in the manner shown in Fig. 117.

The ax is sharpened with a bevel on both sides of the blade. The bevel should be twice the thickness of the blade in length. The blade

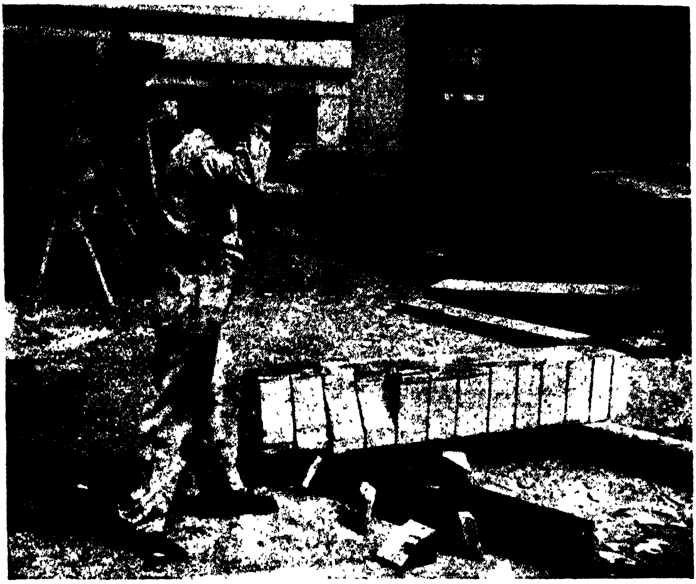


Fig. 116.—Swinging the broad ax overhand when chopping.

Fig. 117.—Using the broad ax when dressing to a line.

should be ground on a water-cooled sandstone and then whetted on a very fine oilstone.

Fig. 118.—Showing block with edges chamfered to a cutting line ready for adzing.

Fig. 119.—The proper standing position for, and grip on the handle of, a foot adz.

Foot Adz. The foot adz generally used by the shipwright is the 5-in. lipped type. Like the broad ax, much practice is necessary before the craftsman can use it with the skill necessary to do a good job.

The foot adz is generally used after timbers have been roughed out with a broad ax; then the finished cut is made with the adz. The cut made with a foot adz should always be across the grain of the wood. The best results will be obtained by trimming the edges of the block to the finished line, as shown in Fig. 118, and then cutting across to the finished edge with the adz.

The lipped adz has an advantage in working blocks having a concave shape to fit the hull of the ship. The lip prevents a tendency on the part of the adz to dig in when cutting across grain; however, some craftsmen will use nothing but a straight adz. The proper standing position and grip on the handle are shown in Fig. 119.

RULES

The shipwright's tool kit should contain three types of measuring tools, namely, a steel tape, either 50 or 100 ft., of good quality and make; a zigzag or 6-ft. folding rule; and a 2-ft. fourfold rule.

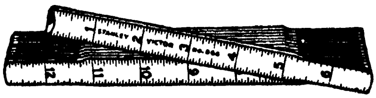


FIG. 120.—Zigzag rule. (*Courtesy of Stanley Tools.*)

Two types of zigzag rule may be used, one with vertical figures, shown in Fig. 120, and the other with figures marked horizontally. Either of the two rules shown in Figs. 121 and 122 is generally carried in conjunction with a zigzag rule as this type of rule can be handled more easily in measuring distances under 2 ft.

The rule shown in Fig. 121 is a brass-bound fourfold rule graduated in eighths, tenths, twelfths, sixteenths, and drafting scales.

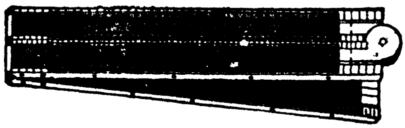


FIG. 121.—Brass-bound fourfold rule. (*Courtesy of Stanley Tools.*)

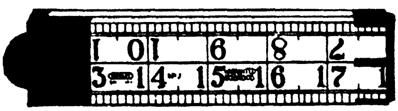


FIG. 122.—Blind man's rule. (*Courtesy of Stanley Tools.*)

The rule shown in Fig. 122 is known as a *blind man's* fourfold rule, having extra-heavy figures for easy reading. It is graduated into eighths and sixteenths.

Standard Measures. If his work is to agree with the dimensions shown on the drawings, the craftsman must use the same type of measuring rule as the draftsman. That is, the rule must be standard, and 1 in.

or 1 ft. on one rule must be the same length as 1 in. or 1 ft. on another rule.

Measurements. Measurements are given in feet and inches or in feet, inches, and parts of an inch. The general practice is to give the width dimension first, the length second, and the thickness last. That is, a plate 60 in. wide, 300 in. long, and 1 in. thick would be shown on the plan as 60″ × 300″ × 3/4″, or 5′0″ × 25′0″ × 3/4″. The × used means *by*.

Reading the Graduations on a Rule. There are 12 in. in 1 ft.; therefore, 1 ft. would be divided into 12 equal spaces. These spaces are called *graduations* or *parts* of 1 ft.

The divisions of 1 in. are then further graduated into parts of an inch to enable the craftsman to make exact measurements. From Fig. 123

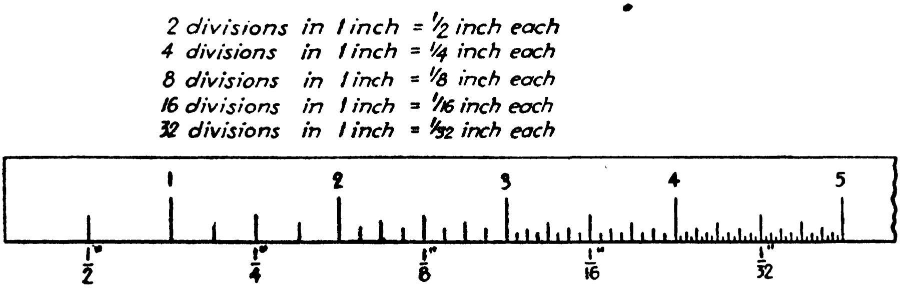


Fig. 123.—Reading the graduations on a rule.

it will be seen that the first inch shown is divided into two parts, the second into four parts, etc. Graduations are read in accordance with the following tabulation:

Divisions in In.		Inches Each
2	=	1/2
4	=	1/4
8	=	1/8
16	=	1/16
32	=	1/32

Extreme care must be exercised to read dimensions correctly. This ability is fully developed only by practice. Mistakes are easily made, particularly in reading 16ths or 32ds of an inch.

Zigzag Rule. In using the zigzag rule for taking dimensions, inaccuracy of the rule will develop as the joints become worn and loose. On work requiring extreme accuracy it is well to use the steel tape or to check the rule with a tape from time to time rather than to take the risk of possible errors.

Steel Tape. There are two types of steel tape, manufactured in varying lengths. On one type, dimensions begin at the end of the ring.

These rings often become distorted through use and create an inaccuracy from the end of the ring to the 1-ft. mark. On this type it is always well to start at the 1-ft. mark, and in reading the tape to add a foot to the dimension desired.

The other type contains an extra 3 or 4 in. of tape between the ring and the zero dimension on the tape. This type eliminates any necessity for making allowances for errors.

The steel tape, when in use, should always be kept straight and not allowed to kink.

Variations in Tape Measurements. Steel tapes are usually of standard length at 60°F. with a 10-lb. pull for tapes 100 ft. or less. The length of a tape will change 0.00000654 of its length per degree change in temperature. That is, a 100-ft. tape standard at 68°F. will be short 0.044 ft. at 0° and long 0.021 ft. at 100°F. The temperature correction is positive or negative as the temperature is higher or lower than standard.

MISCELLANEOUS EQUIPMENT

Draw Knife. The draw knife shown in Fig. 124 is used in rounding off handrails, light masts, and other timbers having rounded edges. It is used generally in roughing out, before finishing with a plane or spoke shave.

Auger Bits. Auger bits generally used by the shipwright are the double-thread double-spur type. Ordinarily they are employed with a brace and are not suitable for use with pneumatic machines.

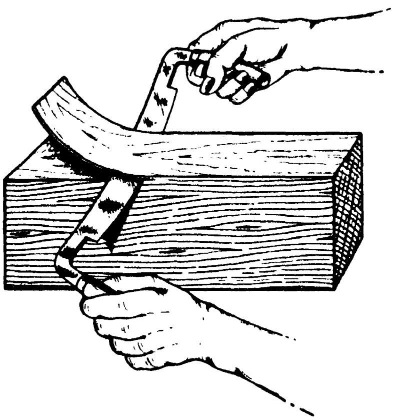


FIG. 124.—Draw knife.

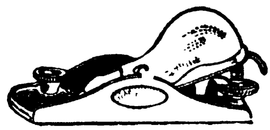


FIG. 125.—Block plane. (*Courtesy of Stanley Tools.*)

In sharpening auger bits the spurs should be at least one-sixteenth longer than the cutter. If the spurs are left too long, the cutter will ride on the wood rather than cut it out. If the spurs are too short, a ragged hole will result.

Screw-driver Bits. Screw-driver bits of various sizes are used in connection with the brace, particularly where long screws have to be driven. They should not be sharpened too thin, or they will tend to slip out of the slot in the screw.

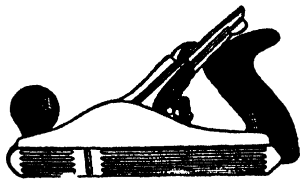


Fig. 126.—Smoothing plane. (*Courtesy of Stanley Tools.*)

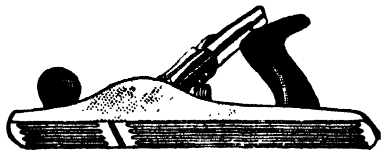
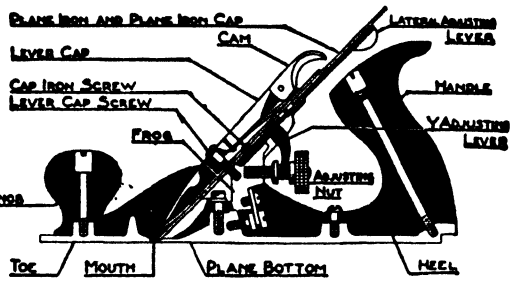
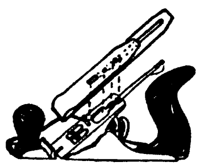


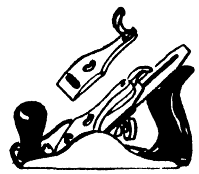
Fig. 127.—A jack plane. (*Courtesy of Stanley Tools.*)



To Put the Plane Together



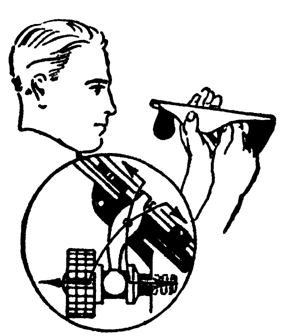
Lay the Plane Iron, bevel side down, on the Frog. Be sure the Roller on the Lateral Adjusting Lever, the end of the Y Adjusting Lever, and the Head of the Plane Iron Cap Screw are correctly seated.



Slip the Lever Cap under the Lever Cap Screw and press down the Cam. If the Cam will not snap in place easily, slightly loosen the Lever Cap Screw. If the Plane Iron is not firmly held when the Cam is in place, slightly tighten the Lever Cap Screw.

To Adjust for Thickness of Shaving

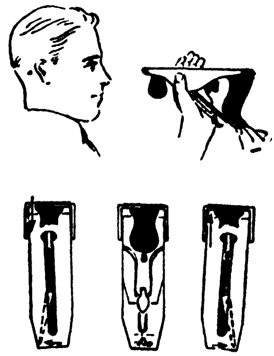
Sight along the bottom of the Plane and turn the Adjusting Nut until the cutting edge projects about the thickness of a hair.



The Plane Iron is pushed out when the Adjusting Nut moves out toward the Handle and drawn in when the Adjusting Nut moves in toward the Frog.

To Adjust for Evenness of Shaving

Sight along the bottom of the Plane and move the Lateral Adjusting Lever toward the Right or the Left.

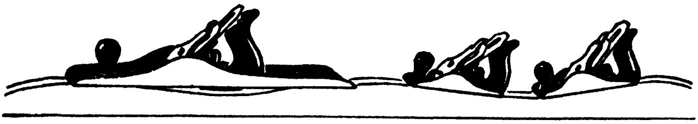


Knob, Lever Cap and Plane Iron Cap removed to show the action of the Lateral Adjusting Lever.

Fig. 128.—Adjusting plane irons. (*Courtesy of Stanley Tools.*)

If dressing is necessary, the bit should be ground to the desired thickness parallel to its center.

Planes. The iron block plane shown in Fig. 125 is used on small work such as dressing templates or boss molds.



It is easier to plane a long edge straight with a long plane than with a short one. A long plane bridges the low parts and does not cut them until the high spots are removed.

The types of Bench Planes are:

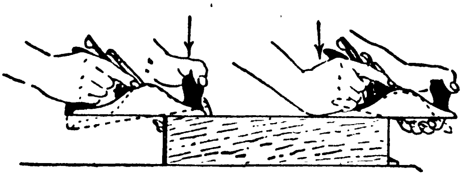
Smooth Plane (5½ inches to 10 inches long) gives a very smooth surface.

Junior Jack Plane (11½ inches long) an intermediate size for manual training work.

Jack Plane (14 inches and 15 inches long) is used to true up the edges of a board as it comes from the saw, and for rapidly preparing the surface for the Smooth Plane.

Forè Plane (18 inches long) is simply a short Jointer Plane.

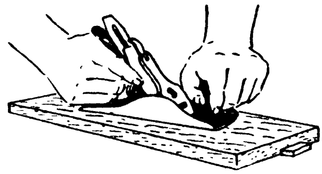
Jointer Plane (22 inches to 26 inches long) is for long work and for obtaining a true surface when joining two boards.

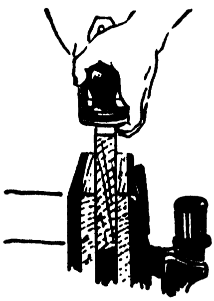


To Cut a Smooth Straight Edge the Plane is pushed with the grain.

To Keep the Plane Straight press down on the knob at the beginning of the stroke and on the handle at the end of the stroke. Avoid dropping the Plane as shown by the dotted lines.

To Obtain a Smooth Surface plane with the grain. If the grain is cross or curly, set the Plane Iron Cap as near the cutting edge as possible and adjust the Plane Iron to take a very thin, even shaving.

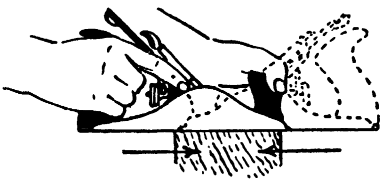




To Start Planing take an easy but firm position directly back of the work.

Hold the Plane square with the work face of the work.

At the end of the stroke the weight of the body should be carried easily on the left foot.



Plane End Grain half way from each edge. If the Plane is pushed all the way the corners will break.

Fig. 129—Method of using smoothing or jack plane. (*Courtesy of Stanley Tools.*)

Smoothing Plane. The smoothing plane (Fig. 126) as its name implies is used in planing down flat surfaces. It can also be employed for planing boss molds and various other classes of small work.

The Jack Plane. The jack plane shown in Fig. 127 is used in jointing work and planing to a straight line.

Sharpening and Adjusting Plane Irons. The method used in sharpening plane irons is shown in Fig. 108 and is similar to that used in sharpening chisels.

The method of adjusting plane irons is shown in Fig. 128. The proper method for using a smoothing or jack plane is shown in Fig. 129.

Level. It is important that a good-quality spirit level be selected. That shown in Fig. 130 is a 24-in. aluminum adjustable level. The glasses are set in adjustable aluminum cases.

Fig. 130.—Spirit level. (*Courtesy of Stanley Tools.*)

When the bubble is exactly between the two hairlines on the glass, the surface upon which the instrument rests is level. Some levels have three "glasses," which may be used to plumb a perpendicular.

Brace. The brace shown in Fig. 131 is a Stanley boss ratchet brace. It is built for strength and will withstand hard usage.

Trammel Points. Trammel points (Fig. 132) are used in scribing radii. There are several sizes and styles of trammels, which make it possible to get into many difficult places that would ordinarily be hard to reach.

The beam can be of either wood or metal to suit the size of the slots and of almost any length, provided that it does not sag. It is well to

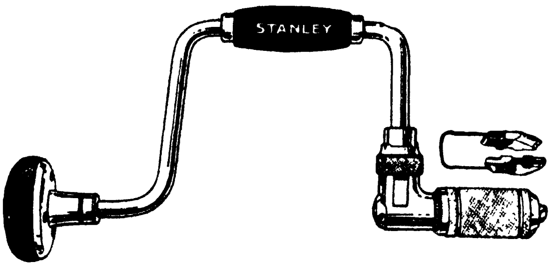


Fig. 131.—Brace. (*Courtesy of Stanley Tools.*)

have two or three lengths of beams so that they can be adapted to various sizes of radii.

Plumb Bob. Where it is necessary to plumb a spot up vertically for a considerable distance, a spirit level is out of the question.

The plumb bob can be used for this purpose. The bob is suspended from a long chalk line, which is maneuvered into position until the point of the plumb bob will hang directly over the point to be plumbed up. Any point connecting with this line can then be considered plumb with the point of the plumb bob.

Ripping Bar. A ripping bar of good-quality steel, as shown in Fig. 133, should be included in every shipwright's tool kit.

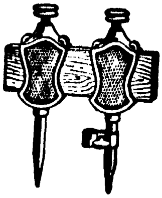


FIG. 132.—Trammel points. (*Courtesy of Stanley Tools.*)

FIG. 133.—Ripping bar. (*Courtesy of Stanley Tools.*)

TOOLS GENERALLY FURNISHED BY THE SHIPYARDS

Other tools used by the shipwright and generally furnished by the shipyards are as follows:

Ratchet chain hoist.
Hydraulic oil jacks.
Steamboat jacks.
Mold clamps.
Thumb clamps.
Steel wedges.
Turnbuckles.
Fairing battens.
Crosscut saws.
Pneumatic portable circular saws.
Pneumatic wood-boring machines.
Chain-link power saws.
Circular crosscut saws.
Tension wire reels.

The same care should be given to these tools as to personal tools. Jacking and pulling tools should not be strained above their rated capacities; if in doubt, double up on the number used. Tools used in and around water should be wiped dry and oiled after being used.

The proper use of these tools will be explained in connection with various operations for which the tools themselves are used.

Tools that are kept in good order will help the craftsman to perform good work.

CHAPTER V

TIMBER

General. To the novice, the term *timber* has no precise and accurate connotation. To the craftsman working with timber, however, the term implies a kind and grade for every job. For general construction work, local timber is used wherever possible. All timber is subjected to certain processes before being delivered to the job ready for use.

To judge definitely the type of cut that should be used in different kinds of construction, a general knowledge of the structure and characteristics of the various woods is needed. In ship construction the kinds of timber generally employed are as follows:

1. Ash.
2. Balsa.
3. Cypress.
4. Fir, Douglas.
5. Oak.
6. Pine, loblolly.
7. Pine, longleaf yellow.
8. Pine, shortleaf yellow (North Carolina pine).
9. Pine, white.
10. Spruce.
11. Teak.

Many other kinds of timber may also be used in the construction of a ship.

Timber may be classified as to growth, density, grain, and leaves. With respect to growth, timber can be divided into two groups, trees growing by additions to the outside, and those growing by additions to the inside.

The trees growing by additions to the outside supply the timber for general construction. A transverse section of a tree in this class is shown in Fig. 134. This section shows a tree in its tenth year, pointing out the concentric rings comprising the *pith*, *wood*, *cambium*, and *bark*. This tree was formed by the addition of one layer of wood to the outside of the tree each year. Owing to these yearly additions, the rings are called *annual rings*.

The wood nearest the center, or heart, of the tree is called *heartwood*, while that found outside is called *sapwood*. The heartwood is darker in color and harder because it is older and has been compressed by the tree growing around it each year.

Ten to thirty-five years' growth is required for the transformation of sapwood into heartwood. The hardwood tree which goes through this process rapidly is usually stronger and firmer than that which has a slow growth. Among the softer woods, however, the opposite is true.

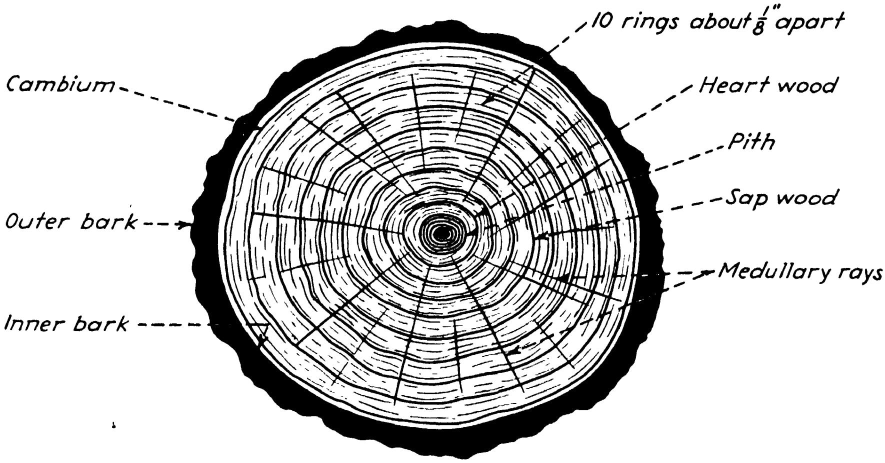


FIG. 134. -Transverse section of a tree.

On most of the trees growing in the temperate zone, there are two rings, one for summerwood and one for springwood. The soft layer is formed early in the season when rapid growth is taking place.

The width of the annual rings varies according to the type of tree and weather conditions from $\frac{1}{50}$ to $\frac{1}{100}$ in.

The *medullary rays* radiate from the center of the tree to the bark and tend to bind the annual rings together as well as to supply nourishment from one part of the tree to the other.

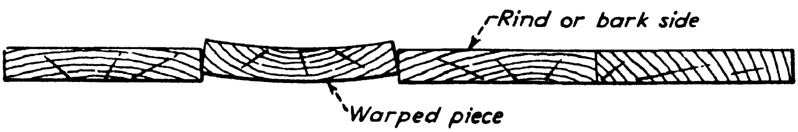


FIG. 135.—Laying timber for decking.

The Grain of Timber. The grain of timber is the marking caused by cutting through annual rings. When the growth of a tree is rapid, the rings are larger and the tree is said to be *coarse-grained.* This is particularly true of loblolly pine.

In laying timber for decking, the rind side of the timber should always be laid to the weather because of the fact that the annual rings will resist a tendency for the timber to roll up, as shown in Fig. 135. To secure the greatest strength of timber used for beams, the timber should always be set so that the grain will be in a vertical direction, the natural stiffness of the timber fibers being thus utilized.

Straight-grained woods are taken from straight trees in which the fibers are nearly parallel to the width and edges of the board. Crooked-grained timbers come from crooked trees (see Fig. 136).

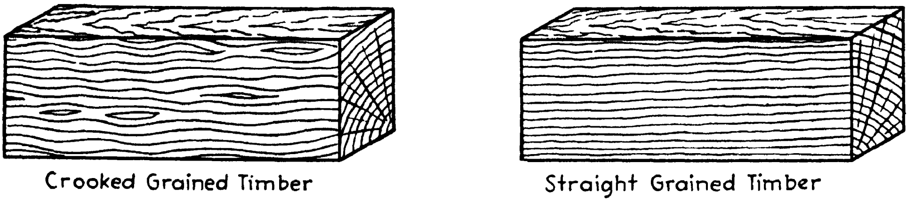


FIG. 136.—Crooked- and straight-grained timbers.

Sawing Timber. The sawing or cutting of logs into sizes of timber has an important bearing on its quality and behavior. Of the several methods of sawing, the following are most generally used: (1) plain sawing and (2) quarter sawing.

Plain sawing consists in cutting completely through a log after it has been squared up. In respect to labor and waste this is the cheapest way to cut logs. Most logs are not circular in cross section; therefore, by using this method of cutting, many boards are obtained with much cross grain (see Fig. 137).

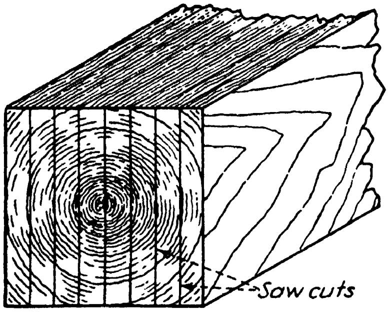


FIG. 137.—Plain sawing of timber.

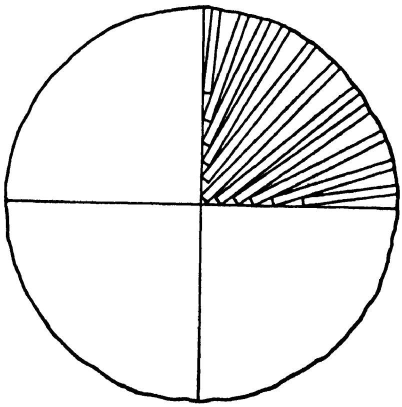


FIG. 138.—Quarter, or radial, sawing of timber.

Quarter, or *rift, sawing* is wasteful in respect both to labor and to material and is therefore more expensive. Four methods of quarter sawing are possible. The radial method shown in quadrant is the best but is the most wasteful (see Fig. 138). The cuts along the radii are nearly parallel to the medullary rays. This method will yield planks that will have the least tendency to warp.

Warping. Timber shrinks in a direction parallel to the annual rings. Therefore, in planks that are plain-sawed the annual rings run through at an angle, and the shrinkage will not be normal to the surface. In radially cut planks most of the shrinkage is normal, or at right angles to the surface; for that reason they tend to warp only in size, not in shape.

DEFECTS IN TIMBER

Defects in timber can be divided into two classes, those occurring before the tree is cut and those occurring afterward.

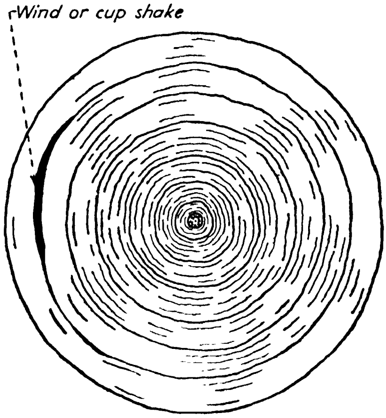


FIG. 139.—Wind, or cup, shake.

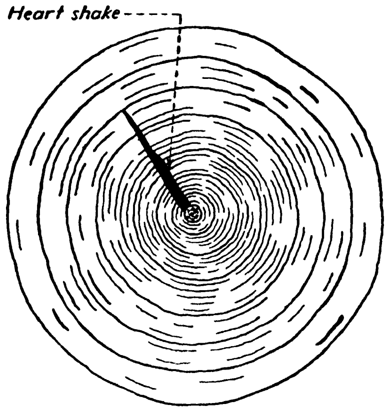


FIG. 140.—Heart shake.

Defects in Timber before It Is Cut. Four of the most common defects in timber before the tree is cut are as follows:

1. *Wind, or Cup, Shake.* These are cracks following the porous part of the wood. They may be caused by too rapid expansion of the sapwood or twisting because of high winds. The annual rings separate and cause the crack (see Fig. 139).

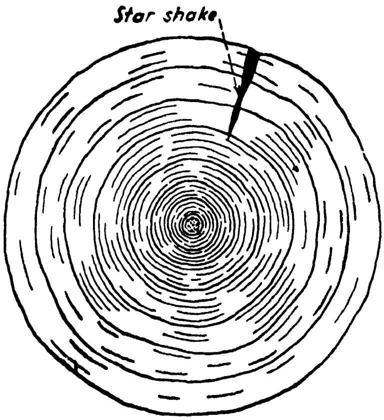


FIG. 141.—Star shake.

2. *Heart Shake.* This is a crack beginning in the heartwood and following the medullary rays. It is usually widest at the pith, tapering off to nothing before it reaches the bark (see Fig. 140).

3. *Star Shake.* This is a crack that is wider at the bark and tapers off to nothing as it approaches the center of the tree (see Fig. 141).

4. *Knots.* These are caused by the breaking off of branches, the tree growing over the injury.

The foregoing defects are all common and are sometimes so numerous that they render the log useless (see Fig. 142). Lumber is classified on the basis of these defects.

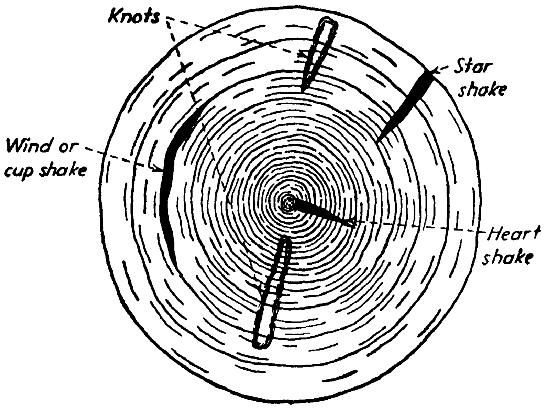


FIG. 142.—Knots in timber.

Defects in Timber after It Is Cut. The greatest defect occurring after timber is cut is rot and physical failure. *Dry rot,* contrary to its name, occurs in the presence of moisture and when there is no circulation of air.

Physical failure, namely, warping, checking, and splitting, can be traced back to the methods of cutting and drying, or seasoning, the lumber.

Seasoning of Timber. Seasoning of timber consists in removing some of the water content from the wood. The more thoroughly this is done, the more resistance the timber will have to shrinkage or decay. There are innumerable variations of artificial seasoning processes, but they are all toward the same end, to give the wood such properties that it will shrink and warp the least and be impervious to rot.

Natural seasoning, or air-drying, is merely letting the lumber stand in the open exposed to the free circulation of air.

Artificial drying is done in a kiln. This is a building, usually fireproof, in which heated air is circulated for a certain period of time, depending on the kind of wood and the amount of drying desired. Temperatures may vary from 100 to 200°F.

Lumber that is thoroughly air-dried contains about 12 per cent of moisture and, if kiln-dried, 6 per cent. However, kiln-dried lumber will, if exposed to the atmosphere, absorb about 6 per cent of moisture from the air. For this reason it is best to leave such lumber exposed to the air for at least 48 hr. before it is used, to eliminate trouble caused by swelling when it absorbs atmospheric moisture.

Preserving Methods. In preserving timber, the first essential is good seasoning; however, preservation may be carried further by subjecting the timber to another process. Preservation processes may be divided into two general classes, (1) those applied externally and (2) those applied internally.

External preservation includes all the penetration processes that employ any preservative of a penetrating nature, such as creosote and chloride of zinc. These may be applied by brush or spray or by immersion in an open tank. If the preservative is used while hot, it will penetrate to a greater extent and dry out more of the moisture.

Internal preservation includes all the processes that cause the wood to be impregnated by chemical compounds at a pressure sufficient to cause it to permeate wood thoroughly.

KINDS AND PROPERTIES OF WOOD

Ash. There are many varieties of ash grown in the United States. Ash is pliable when green but very stiff and strong when dry. It weighs about 40 lb. per cu. ft. when dry.

Although ash lumber looks like oak, it can readily be kiln-dried before it is air-dried, which is not true of oak. If not first kiln-dried, ash is practically ruined by pinworms.

It is used especially for tool handles, oars, and ladders and for light but durable framing.

Balsa. Balsa is an extremely light wood generally used for the packing of bilge keels, rudders, etc. It is an imported wood and is the lightest known, weighing when dry 8½ lb. per cu. ft.

Cypress. Cypress is one of the heaviest of the softwoods, weighing when dry 32 lb. per cu. ft. It is much heavier when green, weighing about 50 lb. per cu. ft. It shrinks in drying only about 10 per cent. For this reason it swells very little when wet and thus is suitable for small boats. Large quantities are also used for piles, wharf timbers, and other poles. The logs may be easily identified by the fact that the season grains are spiral instead of parallel to the pole.

Nearly all cypress grows only in the Southern States in low marshy sections. There are a number of varieties that grow on the Pacific Coast, but only in small quantities. Cypress is very slow-growing and attains immense proportions; some of the largest trees are more than a thousand years old.

Douglas Fir. Douglas fir grows in the northwestern section of the United States, but comparatively little is cut outside Washington and

Oregon. The wood is like pine but not nearly so heavy; it is tough and strong and may be cut in any dimension desired.

Douglas fir weighs 38 lb. per cu. ft. when green and 34 lb. when dry.

It is the strongest of the softwoods except longleaf pine, and the greater proportion of the lumber is heartwood. The lumber is yellow to reddish in color. It has innumerable purposes; in ship construction it is used generally for shoring, blocking, cribbing, decking, and framing.

Oak. Oak is next to pine in its varied uses. In general, oaks are divided into two classes, white oaks and red oaks.

The sapwood of both groups is alike both in color and in formation. The heartwood of practically all white oaks is fine-grained and hard. In the red oak group the heartwood is much coarser.

With the exception of live oak, which is considerably heavier, all oaks weigh about the same, about 45 lb. per cu. ft. when dry.

Oak is used extensively for blocking, wedges, foundations, flooring, and trimming.

Loblolly Pine. This is frequently known as *field pine*. The wood varies according to the composition of the soil and is sometimes hard and tough and sometimes soft and brittle. The sapwood is thick and it has practically no heartwood at all, being a very rapid-growing tree.

Loblolly pine has a number of uses. It is generally employed for rough construction and heavy timbers.

Longleaf Pine. This is also known as *Georgia,* or *southern, pine.* The growth rings are mostly narrow and uniform in width. The wood is extremely heavy and hard and is a reddish yellow in color. The bark is brownish red and is thinner and lighter in color than that of the loblolly pine.

Longleaf pine is considered the best of the pines for strength and durability in all types of construction work.

Shortleaf Yellow Pine. In this tree the growth rings are mostly all of medium width. The wood is of medium hardness and weight and light-brown to reddish in color. The sapwood is usually rather thick.

Shortleaf is used for all types of construction, particularly along the Atlantic Coast, where it is very plentiful. It lends itself to both small- and large-sized construction timber.

White Pine. White pine grows best in the northern part of the United States and extends as far south as North Carolina, particularly in the mountain section. The bark is thick and dark brownish gray in color. It is known for the high percentage of high-grade lumber it will yield. While a softwood, it has innumerable uses, though it is generally employed for sashes and window frames.

Spruce. There are five types of spruce grown commercially in the United States.

1. Red spruce, which grows in the Atlantic states as far south as North Carolina.
2. Black spruce, which grows in the Northeastern states.
3. White spruce, which grows in the Lake region.
4. Sitka spruce, which grows in the Rocky Mountains from Arizona to Canada.
5. Blue spruce, which grows west of the Mississippi River. The bark is thick and broken on the surface into thin gray-brown scales.

The wood of all the spruces is similar except in color. The heartwood predominates and in all species is straight-grained and compact. Different species vary considerably in weight, red spruce weighing 28 lb. per cu. ft. and Sitka only 23 lb. per cu. ft. The wood is softer than shortleaf pine, and the strength is about that of other softwoods. It is used extensively in studding and ceiling the holds of ships and as stage plank. Immense quantities are also used for wood pulp.

Teak. This tree is found in central and southern India, where, however, it is now scarce in some localities in which it was formerly plentiful. There are also extensive forests in Burma and Thailand. The wood is of a pronounced yellow color, tending to brown. Like many other kinds of timber it is called a hardwood although it is only of medium hardness. It is straight-grained and strong.

Teak does not shrink much in seasoning. It is much less resinous than some other well-known hardwoods, such as mahogany and rosewood. It is said to contain an aromatic essential oil that prevents iron in contact with it from becoming rusted and for this reason is most suitable for decking on ships. It is also used for doors and door frames, rails, and gratings.

White Cedar. This is a soft, light, fine-grained wood, and very durable when in contact with soil or water. It is used for water tanks, posts, and planking of wooden ships in small-boat building. It is neither strong nor tough.

The bark is grayish to reddish brown and thin and separates into long stringy strips. The leaves are scalelike, yellowish green and fall into short lateral branchlets.

It should be noted that different kinds of wood may be used for the same purpose. For example, white pine, Oregon pine, cypress, North Carolina pine, and longleaf yellow pine are suitable for inside finish and trim. Woods that are not so easily affected by the weather, such as white pine, cypress, cedar, Oregon pine, spruce, and longleaf yellow pine, should be used for outside work.

Where any wood is exposed to the elements, it should in all cases be given a prime coat of paint immediately following installation to prevent checking.

STRESSES AND SAFE LOADS

Many books are available that deal in great detail with the properties of the numerous kinds of wood. This chapter, however, is for the general guidance of the shipwright insofar as his familiarity with wood is concerned.

For stresses and safe loads see Tables II to IV.

TABLE II.—SAFE LOADS, POUNDS, FOR OREGON PINE* SIMPLE BEAMS SUBJECTED TO CONCENTRATED LOAD AT CENTER OF SPAN

Size, in.	Length of beam, ft.									
	4	6	8	10	12	14	16	18	20	24
2 × 4	530	350	255	200	165	135	125			
4 × 4	1,050	700	510	410	330	290	250			
4 × 6	2,400	1,575	1,170	930	770	645	545	480	420	
6 × 6	3,600	2,400	1,760	1,385	1,160	975	825	720	630	
6 × 8	6,350	4,240	3,150	2,500	2,260	1,740	1,500	1,310	1,150	915
8 × 8	8,460	5,625	4,200	3,340	2,740	2,320	1,995	1,745	1,545	1,220
8 × 12	14,325	12,690	9,450	7,500	6,150	5,325	4,525	4,050	3,600	2,850
8 × 14	16,650	16,560	12,975	10,275	8,550	7,200	6,300	5,550	4,875	3,975
8 × 16	19,050	18,975	16,950	13,500	11,175	9,525	8,250	7,350	6,450	5,250
10 × 10	14,850	10,950	8,250	6,525	5,400	4,575	3,975	3,450	3,075	2,475
10 × 12	17,850	15,750	11,850	9,375	7,800	6,675	5,700	5,025	4,500	3,600
10 × 14	20,850	20,775	16,200	12,900	10,650	9,075	7,875	6,900	6,150	4,950
12 × 12	21,450	19,050	14,250	11,250	9,375	7,950	6,900	6,075	5,400	4,350
12 × 14	25,050	24,900	19,425	15,450	12,750	10,875	9,450	8,250	2,350	5,925
12 × 16	28,650	28,500	25,275	20,250	16,725	14,250	12,375	10,950	9,750	7,875
14 × 14	29,250	29,100	22,650	18,000	14,925	12,750	11,025	9,675	8,625	7,010

* This wood is also known as Douglas fir.

Unit stress taken at 1000 lb. per sq. in. For other kinds of timber, multiply by the following conversion factors:

Ash	1.466	Cypress	1.466
Birch	1.6	Longleaf pine	1.711
Elm	1.066	Shortleaf pine	1.466
Hickory	2.0	Western pine	1.000
Maple	1.6	Spruce	1.066
Oak	1.333		

TABLE III.—SAFE LOADS, IN POUNDS, FOR OREGON PINE CANTILEVER BEAMS SUBJECTED TO CONCENTRATED LOAD AT END

Length, ft.	Size of beam, in.						
	2 × 4	2 × 6	2 × 8	2 × 12	3 × 6	3 × 12	3 × 14
½	730	1,160	2,920	6,580	2,460	9,870	13,420
1	365	820	1,460	3,290	1,230	4,935	6,710
2	180	410	730	1,645	615	2,465	3,355
3	120	270	487	1,095	410	1,645	2,235
4	90	200	365	820	308	1,230	1,680
5	73	160	290	655	246	985	1,340
6	60	135	242	545	205	820	1,120
7	52	115	208	470	176	700	960
8	45	100	182	410	154	615	840
9	40	90	162	365	136	545	745
10	36	82	146	328	122	490	670
11	33	75	132	298	112	445	610
12	30	68	120	274	102	410	560

Shearing strength of Oregon pine taken at 822 lb. per sq. in. For other kinds of timber, multiply by the following conversion factors:

Ash	1.88	Cypress	1.02
Birch	1.73	Longleaf pine	1.29
Elm	1.76	Shortleaf pine	.91
Hickory	2.27	Western pine	.783
Maple	2.17	Spruce	.785
Oak	2.18		

TABLE IV.—SAFE LOAD, IN TONS OF 2000 LB., ON OREGON PINE COLUMNS

Size, in.	Length of column, ft.						
	8	10	12	14	16	18	20
6 × 6	21.62	19.5	15.5	11.4			
8 × 8	40.4	39.2	36.8	33.4	27.6	21.8	17.7
10 × 10	65.6	64.8	63.5	61.2	57.5	52.3	45.6
12 × 12	96.5	96.0	95.0	93.6	91.0	87.8	83.0
14 × 14	133.3	132.8	132.2	131.2	129.4	126.8	123.5
16 × 16	175.8	175.4	175.0	174.2	172.7	170.8	168.0
18 × 18	224.2	223.9	223.5	223.0	222.0	220.4	218.0

Compression strength of Oregon pine parallel to the grain taken at 1466 lb. per sq. in. For other kinds of timber, multiply by the following conversion factors:

Ash	1.00	Oak	1.37
Birch	1.09	Cypress	1.00
Elm	1.09		

CHAPTER VI

ROPES AND LINES FOR HANDLING, TYING, AND BRACING

In some classes of work performed by the shipwright it is necessary to use ropes for temporary tying and bracing, particularly in connection with the erection of the ship's structure, staging, and launching. It is therefore necessary for the craftsman to have a general knowledge of ropes and the methods used in tying and securing them.

Manila hemp sisal fiber, cotton, or wire is used in the manufacture of ropes. Manila hemp and sisal fiber are stronger and more durable than cotton and are used for heavy work, while cotton is used for light work. Wire rope is used for extra-heavy work.

FIBER ROPES OR CORDAGE[1]

The term *cordage* is applied to products made by twisting together a number of vegetable fibers. Sisal and manila (structural fibers) are classed as hard fibers. Hemp (bast fiber) is classified as soft fiber. Manila (abacá) is the fiber best suited for marine purposes and general construction work.

Cordage fibers are cleaned from the surrounding pulp in the locality where they are grown. They are then washed, dried, and baled for shipment to the cordage manufacturer. At the cordage plant the fiber is taken from the bale and fed into machines, which lay the fibers in uniform, parallel ribbons without twist, called *slivers*. A certain amount of oil is applied to the fiber at this stage to lubricate the rope and reduce internal friction. From the combing machines, or drawing frames, the fiber goes to the spinning machines, where a proper amount of twist is applied. The twisting process transforms the continuous ribbon of parallel fibers into a round yarn. This yarn is now ready for the rope machines.

Ropemaking is divided into two processes, forming the strands and laying the strands into rope. In order that the ropes may hold their shape throughout their life, they are put together in a series of contra twists. In a right-laid rope, the yarns are twisted to the right, or clockwise; the strands are twisted to the left, or counterclockwise; and the rope is twisted to the right, or clockwise. Thus, it is impossible to take turn out of a rope without putting extra turn into the strands. This contra twisting holds the rope in balance.

[1] Furnished by the Plymouth Cordage Company, Plymouth, Mass., July, 1943.

Ropes are made in the so-called *plain-laid*, or *common laid*, and *cable-laid*. Plain-laid ropes are composed of three, four, or six strands twisted together. When more than three strands are used, a heart is placed in the center to hold the strands in their proper place. Cable-laid ropes are made by using three plain-laid ropes as strands. Cables are sometimes made fourstrand, but this is very uncommon.

The term *lay* is used to designate the construction of the rope and is generally distinguished as *hard*, *common*, *medium soft*, *soft*, and *extra soft*. The desired degree of firmness of lay is the result of the relationship of the twists in the rope. The twist in the strand is called the *foreturn*. The twist in the rope is called the *afterturn*. It is possible to vary the lay by varying either of these twists. For example, a rope may be hard in both foreturn and afterturn, in which case it will be extremely firm and wiry, or it can be extra soft, through being soft in both foreturn and afterturn, in which case it will be flexible but unstable and easily distorted. The common-laid, or plain-laid, rope is one in which the relation of the twists is such as to give a flexible easy-handling rope and yet one that will retain its shape under reasonable handling conditions.

A hard-laid rope is resistant to surface abrasion and is springy but is not so strong as a soft-laid rope.

A soft-laid rope will have less elongation, greater tensile strength, and less resistance to abrasive wear than hard-laid rope.

A Few Suggestions on the Care of Rope

Do not permit rope to twist continuously in one direction.

Hang up and store small ropes and slings in dry, well-ventilated places.

Kinks are caused by excess turn in a rope. To eliminate the kinks, remove the excess twist.

Do not forget the safety factor of 5 to 1 when selecting the size of rope to be used.

Dry out wet ropes before storing.

Do not let rope get near acid fumes or strong alkali.

Do not use fiber rope in locations where it will be subjected to sparks from welding.

SPLICES

In using cordage a general knowledge of the various splices and knots should be acquired.

Ropes may be joined together either by splicing or by knotting. If a rope belongs to the running class, it is necessary to use a splice, for a knot cannot pass through the swallow, or opening, in the block.

There are three kinds of splice in general use, namely, the long splice, short splice, and eye splice. In joining running lines the long splice is always employed because, when neatly done, it does not increase to any extent the diameter of the rope. The short splice is very bulgy but can be made quickly and is employed where a rope does not have to pass through a block. The eye splice is used for making a permanent loop in the end of a rope.

Eye Splice. To make an eye splice (Fig. 143), open the end of the rope and lay strands 1, 2, and 3 upon the standing part (Fig. 144). Now,

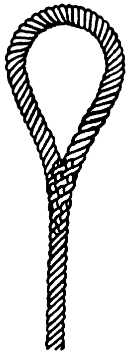


Fig. 143.—Eye splice.

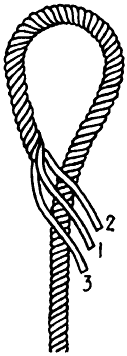


Fig. 144.—First step in making eye splice.

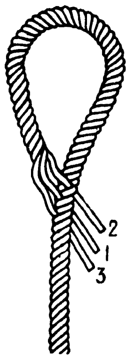


Fig. 145.—Second step in making eye splice.

push strand 2 through the rope (Fig. 145). Next, push strand 1 over the part through which strand 2 was passed. Last, push strand 3 through on the opposite side. Repeat this twice, then cut off the remaining ends, and the splice will appear as shown in Fig. 143.

Short Splice. Holding rope *B* (Fig. 146) in the left hand, pass strand 4 over strand 1, and, having thrust it through under strand 3, pull it taut. Now, take strand 5 and pass it over strand 2 and under strand 1. Pass strand 6 over the first strand next to it and under the second. Shift the rope around and treat the other end in the same way, and the result will be as shown in Fig. 147.

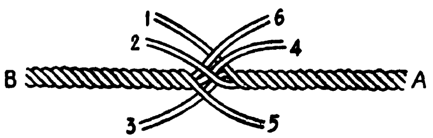


Fig. 146.—Step in tying short splice.

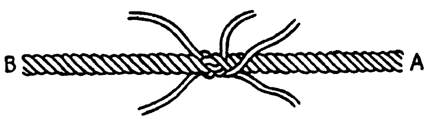


Fig. 147.—Completed short splice.

This single tucking of the ends is not sufficient for strength. So repeat the operation twice, and then cut off the ends of the strands.

Long Splice. Untwist the two ends to be joined some 2 or 3 ft. As shown in Fig. 148, place the ends together in the same manner as for the short splice. Now, take strand 1 and unlay as far as *A*. In the groove left in the rope, wind strand 2. Unlay strand 3, and in its place wind strand 4.

At this stage the rope will have the appearance shown in Fig. 149. The middle strands, 5 and 6, will now be knotted with a simple overhand knot (Fig. 150). *Care should be exercised that the knot is formed to follow the form of the rope.*

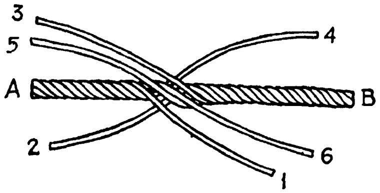


Fig. 148.—First step in tying a long splice.

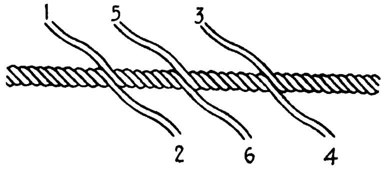


Fig. 149.—Second step in tying a long splice.

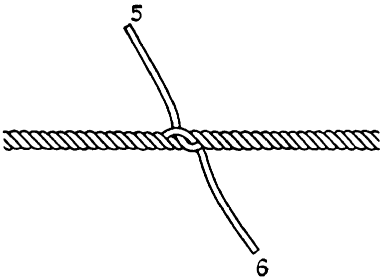


Fig. 150.—Third step in tying a long splice.

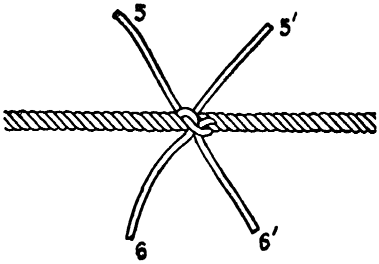


Fig. 151.—Fourth step in tying a long splice.

Next, divide these two strands equally, as shown in Fig. 151, and tuck them into the rope on the same principle as for the short and eye splices. Treat the remaining strands in the same manner. Then stretch the rope well, and cut off the ends of the strands.

KNOTS

Overhand Knot. The overhand knot (Fig. 152) is used at the end of a rope to prevent it from unreeving, or slipping through a block. It is tied by making a loop of a rope, with the short end of the rope passing

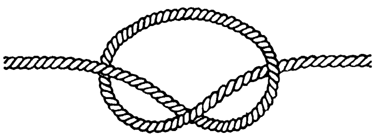


Fig. 152.—Overhand knot.

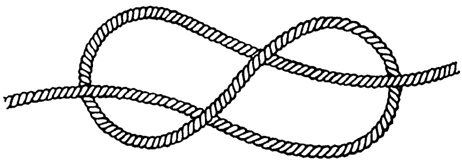


Fig. 153.—Figure-of-eight knot.

behind the long end. The knot is then pulled tight. This knot is very difficult to untie.

Figure-of-eight Knot. The figure-of-eight knot (Fig. 153) is made by passing the free end of a rope around the standing part in the second loop and the back through the first loop.

Reef, or Square Knot. The reef, or square knot (Fig. 154), is one of the most valuable of the many employed. In order to make it, simply tie an overhand knot; then pass the ends so that they take the same lay as the cross parts underneath. Should the ends be crossed wrong the knot will capsize, pull out of shape, and slip as soon as a strain is put on it.

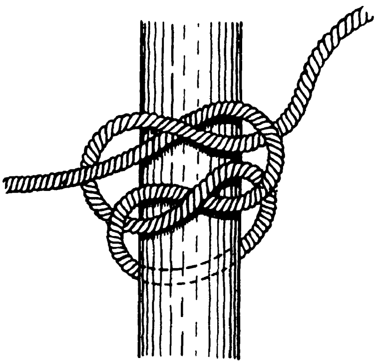


FIG. 154.—Reef or square knot.

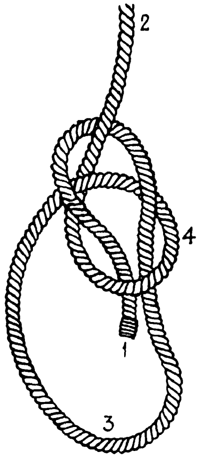


FIG. 155.—Bowline.

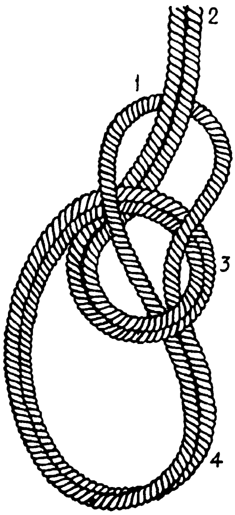


FIG. 156.—Bowline on a bight.

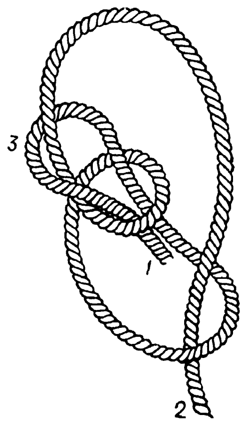


FIG. 157.—Running bowline.

Bowline. The bowline knot (Fig. 155) is employed in a variety of ways. When the rope is strained, the knot draws up tight, but it can be easily untied when the strain is removed.

To make this knot, take the end (1) of the rope in the right hand and the standing part (2) in the left hand. Lay the end over the standing part and turn the left wrist so that the standing part forms a loop (4) enclosing the end. Now, lead the end back to the standing part, and above the loop place the end down through the loop again, as shown in the figure.

Bowline on a Bight. The bowline on a bight (Fig. 156) is made in the following manner: Double the rope and take the double end (1) in the right hand and the standing part (2) on the rope in the left hand. Lay the end over the standing part and by turning the left wrist, form a loop (3) having the end inside. Now, pull up enough of the end (1) to tip under the bight (4). Bring in the end toward the right, and dipping

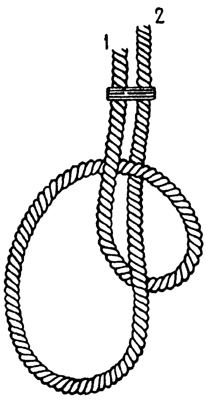


FIG. 158.—Half hitch.

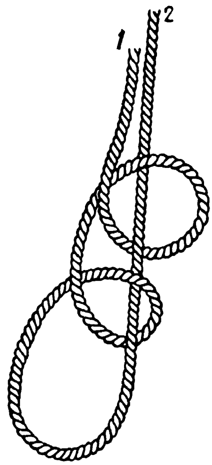


FIG. 159.—Two half hitches.

under the bight. Then pass it up to the left under the loop, and haul taut.

Running Bowline. The only difference between this knot, shown in Fig. 157, and the one shown in Fig. 155 is that the end (1) of the rope is taken around the standing part (2) and then a single bowline (3) tied on its own part. As will be understood by reference to the figure, this forms a slip knot and is not, in fact, employed for the same purposes as the bowline.

The running bowline may be used to advantage in lassoing timber in the water. It is allowed to fall over the timber and then is hauled taut.

Half Hitch. The half hitch (Fig. 158) is an exceedingly simple way of fastening a rope. It has the added advantage of being proof against jamming.

Take a turn around the object to which it is desired to fasten. Bring the end (1) on top of the standing part (2); then pass it under, and bring it through the bight. Repeat this process, and haul taut. In case the hitch is subjected to a great strain, take a round turn and seize the end of the rope to the standing part as shown.

Two Half Hitches. The two half hitches shown in Fig. 159 are made in the same manner as a single half hitch except that the end (1) is brought around on top of the standing part (2) twice instead of once.

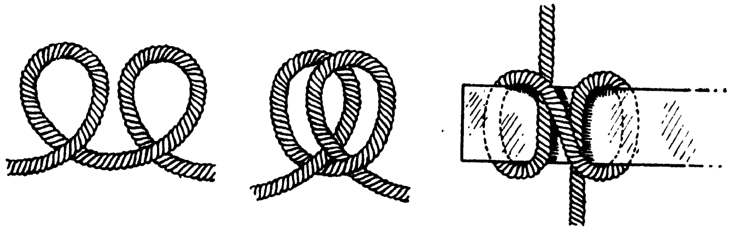


FIG. 160.—Clove hitch.

Clove Hitch. The clove hitch (Fig. 160) is another very useful hitch but is employed only when the strain upon it is temporary. When used for securing guys, sheer legs, etc., the knot should be made with a long end, which is formed into two half hitches around the standing part and then seized to it.

Timber Hitch. The timber hitch (Fig. 161) is employed in towing spars and logs, as it will not slip. Pass the end (1) of the rope around the spar, and lead it up and around the standing part (2). Then, pass two or three turns with the end around its own part, as shown in the figure.

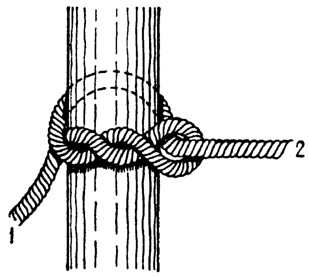


FIG. 161.—Timber hitch.

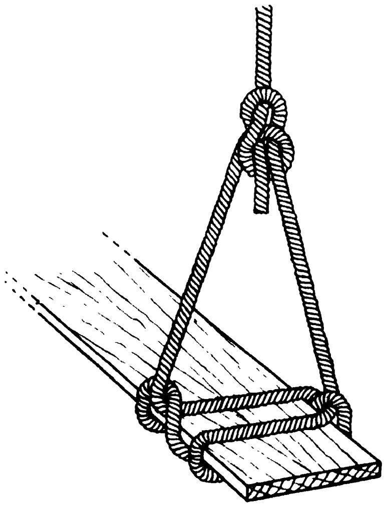


FIG. 162.—Scaffold hitch.

Scaffold Hitch. The scaffold hitch (Fig. 162) is used for swinging scaffolding so that it will not turn in the sling. It is started by making a clove hitch with the two free ends of the rope below the scaffold. Each rope is then drawn back on itself and up over the opposite sides of the board where the short end is joined to the other with a bowline knot.

Effect of Knots. A rope is weakened by knots for, in the process of forming these, the rope must be bent, which brings more of the strain on the outside fibers. The overloading breaks the outside fibers, increasing the strain below, and soon the entire rope breaks.

Based on numerous experiments the following table gives the approximate efficiency of knots, hitches, and splices.

	Efficiency, Per Cent
Straight rope	100
Eye splice, over an iron eye	90
Short splice	80
Timber hitch, anchor bent	65
Clove hitch and running bowline	60
Square knot	50
Overhand knot	45

Treatment of Rope Ends. The process of building up a rope from strands is called *laying* a rope. Twisting together the strands that have become untwisted is called *re-laying.* Rope ends may be treated to prevent untwisting by either crowning with a crown knot or whipping the ends.

Crown Wall Knot. To make a crown wall knot, over the top of the knot lay strand 1, as shown in Fig. 163. Then lay strand 2 over 1 and

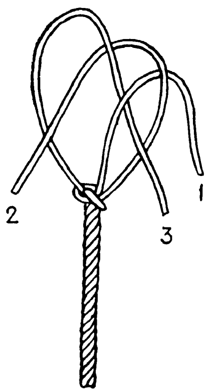


Fig. 163.—Step in tying a crown wall knot.

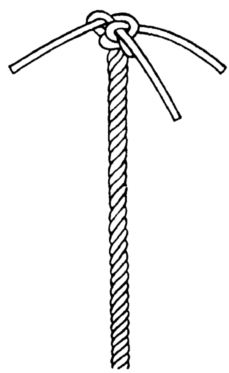


Fig. 164.—Completed crown wall knot.

strand 3 over 2, and pass strand 3 through the bight on strand 1. Now, haul taut the parts, and the knot will take the shape shown in Fig. 164.

Whipping. To whip, unfray one strand of the rope back to the point where the whip is to begin. Under this strand lay the twine, leaving the end 8 or 10 in. long. Re-lay the strand into the rope, keeping it twisted up tightly and pulled hard down into its place. In order to obtain a secure job of whipping, the twine may be tied about the strand under which it is tucked. Whip the long end of the twine around both the rope and the short end of the twine, being careful to pull it up tightly and to leave no vacant spaces between the turns. When about half the desired distance, bend back the short end of the twine so as to form a bight extending out beyond the end of the rope, and begin whipping over both ends

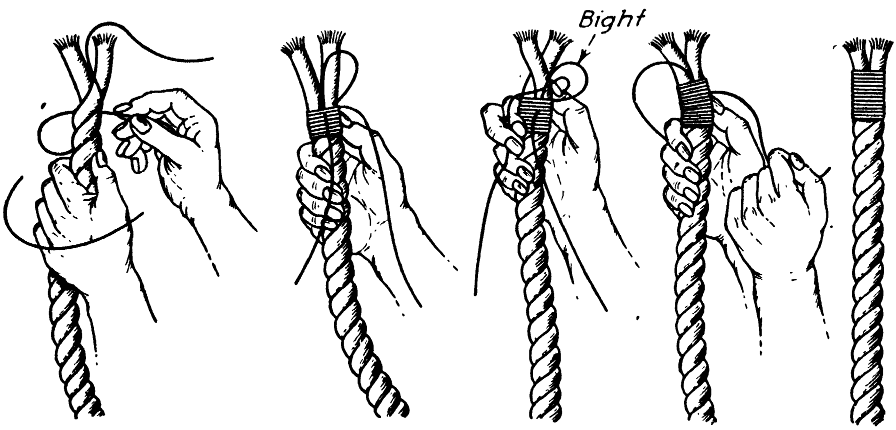


FIG. 165.—Whipping a line.

TABLE V.—SIZES, WEIGHTS, LENGTHS, AND STRENGTHS OF ALL-MANILA ROPE FOR REGULAR MEDIUM-LAY THREE-STRAND ALL-MANILA*

Sizes, in.		Weights, lb.		Lengths, ft.		Breaking strengths, lb.	Working strains, lb.
Diameter	Circumference	Full coils (gross)	Per 100 ft. (net)	Full coils	Feet in 1 lb. (net)		
3/16	1/2	33	1.33	2,400	75	500	100
1/4	3/4	50	1.67	2,950	60	725	150
5/16	1	55	2.50	2,175	40	1,225	250
3/8	1 1/8	65	3.45	1,850	29	1,500	300
7/16	1 1/4	75	4.76	1,550	21	1,800	350
1/2	1 1/2	85	6.90	1,200	14.5	2,500	500
9/16	1 3/4	120	9.75	1,200	10.25	3,250	650
5/8	2	150	12.2	1,200	8.22	4,200	850
3/4	2 1/4	190	15.4	1,200	6.48	5,200	1,050
13/16	2 1/2	230	18.7	1,200	5.36	6,400	1,300
7/8	2 3/4	270	21.9	1,200	4.56	7,700	1,550
1	3	320	26.0	1,200	3.85	9,000	1,800
1 1/16	3 1/4	375	30.5	1,200	3.28	10,200	2,100
1 1/8	3 1/2	430	34.9	1,200	2.86	11,700	2,400
1 1/4	3 3/4	500	40.6	1,200	2.46	13,200	2,700
1 5/16	4	570	46.3	1,200	2.16	15,000	3,000
1 1/2	4 1/2	715	58.1	1,200	1.72	18,300	3,700
1 5/8	5	885	71.9	1,200	1.39	22,300	4,500
1 3/4	5 1/4	1,065	86.5	1,200	1.15	26,400	5,300
2	6	1,275	103.6	1,200	0.965	31,000	6,200
2 1/16	6 1/2	1,500	121.9	1,200	0.821	35,500.	7,100
2 1/4	7	1,740	141.4	1,200	0.707	40,000	8,000
2 1/2	7 1/2	2,000	162.5	1,200	0.615	45,500	9,000
2 5/8	8	2,275	184.8	1,200	0.541	51,500	10,500

*** The working strains shown are figured at about 20 per cent of the breaking strengths for efficiency in everyday service, but somewhat higher loads are not unsafe for temporary use only. When using sisal rope, figure 80 per cent of the strength of all-manila rope.**

of the bight as shown in Fig. 165. Continue whipping as far as desired, and then pass the long end of the twine through the bight and secure.

WIRE ROPE[1]

Wire ropes are built up of strands made of wires twisted together, the number of wires commonly used being 4, 7, 12, 19, and 37. Standard

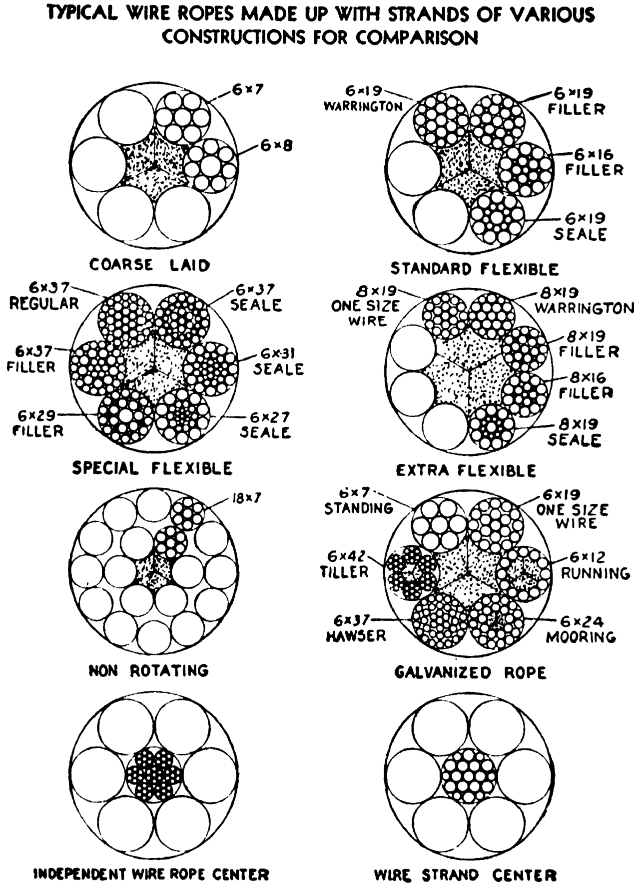


FIG. 166.—Typical wire ropes.

wire rope is made of six-wire strands and a hemp core. Wire strands are twisted around the core either to the right or to the left, the resulting rope being designated as *right-lay* or *left-lay*. The twist may be long or short, the shorter twist forming the more flexible rope.

The core of a wire rope is, as a rule, hemp saturated with a lubricant. It provides little additional strength but acts as a cushion to preserve

[1] Much of this section is based on material published by the Macwhyte Company, Kenosha, Wis., July, 1941.

the shape of the rope and helps to lubricate the wires. A wire-strand, or rope, core adds 7 to 10 per cent to the strength of the rope but will wear from the friction between it and the outer strands as rapidly as the outside of the rope.

The wire rope ordinarily used by the shipwright for guying and lashing is of the standard type and is either 6 by 19 or 6 by 37.

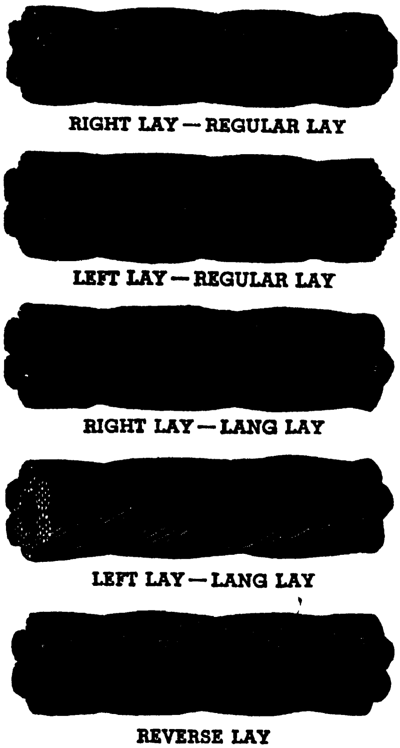


FIG. 167.—Five combinations of lays of wire rope.

Figure 166 shows typical wire ropes made up of strands and in various constructions for the purpose of comparison.

Lay. *Lay* refers to the twist, or helical form, that is characteristic of all wire rope. There are two classes to be considered, the *strand lay*, which refers to the twist of the individual wires composing a strand; and the *rope lay*, which refers to the twist of the strands around the core.

Five combinations of lays are illustrated in Fig. 167.

The type of lay ordinarily used in shipwright work is the right lay.

In the right-laid rope the strands are laid as in a right-hand screw thread, and the left-laid rope is laid in the opposite direction.

Proper Working Loads. It is advisable for the working load of a wire rope for general purposes never to exceed one-fifth of the breaking strength. This means that the factor of safety should be not less than 5.

To determine proper working load, divide the breaking strength by the correct factor of safety. For example, ⅞-in.-diameter 6 by 19 plow steel rope has a breaking strength of 28 tons. With a factor of safety of 5, the proper working load would be not over 5.6 tons.

Kinking. The kinking of wire rope can be avoided if ropes are properly handled and installed. Kinking is caused by the rope taking spiral shape as a result of an unnatural twist. One of the most common causes for this is improper unreeling and uncoiling.

A rope that has been kinked is shown in Fig. 168. Strands and wires are out of position, which puts an unequal tension on and causes excessive wear at this part of the rope.

TABLE VI.—BREAKING STRENGTH OF WIRE ROPE, 6 × 19
6 Strands, 19 Wires per Strand, One Hemp Core*

Diameter, in.	Approximate circumference, in.	Approximate weight per foot, lb.	Breaking strength, tons of 2000 lb.		
			Cast steel	Mild plow steel	Plow steel
1/4	3/4	0.10	2.1	2.3	2.5
5/16	1	0.16	3.2	3.5	3.9
3/8	1 1/8	0.23	4.5	5	5.5
7/16	1 3/8	0.31	6	6.6	7.3
1/2	1 5/8	0.40	7.7	8.5	9.4
9/16	1 3/4	0.51	9.6	10.6	11.7
5/8	2	0.63	11.8	13.1	14.4
3/4	2 3/8	0.90	16.8	18.7	20.6
7/8	2 3/4	1.23	22.8	25.4	28
1	3 1/8	1.60	29.5	33	36.5
1 1/8	3 1/2	2.03	37	41.5	46
1 1/4	3 7/8	2.50	46	51	56.5
1 3/8	4 3/8	3.03	55	61.5	68
1 1/2	4 3/4	3.60	65	72.5	80.5
1 5/8	5 1/8	4.23	76	85	94
1 3/4	5 1/2	4.90	88	98	108
1 7/8	5 7/8	5.63	100	112	123
2	6 1/4	6.40	114	127	140

* From tables by the Wickwire Spencer Steel Company, New York, N.Y.

TABLE VII.—BREAKING STRENGTH OF WIRE ROPE, 6 × 37
6 Strands, 37 Wires per Strand, One Hemp Core*

Diameter, in.	Approximate circumference, in.	Approximate weight per foot, lb.	Breaking strength, tons of 2000 lb.		
			Cast steel	Mild plow steel	Plow steel
3/8	1 1/8	0.22	4.4	4.9	5.3
7/16	1 3/8	0.30	6	6.6	7.2
1/2	1 5/8	0.39	7.7	8.4	9.2
9/16	1 3/4	0.49	9.5	10.5	11.5
5/8	2	0.61	11.6	12.8	14
3/4	2 3/8	0.87	16.4	18.1	19.8
7/8	2 3/4	1.19	22	24.2	26.5
1	3 1/8	1.55	28.6	31.5	34.4
1 1/8	3 1/2	1.96	36	39.7	43.5
1 1/4	3 7/8	2.42	44.8	48.9	53.5
1 3/8	4 3/8	2.93	53.5	59	64.6
1 1/2	4 3/4	3.49	63.5	70	76.7
1 5/8	5 1/8	4.09	74.3	82	89.8
1 3/4	5 1/2	4.75	86	95	104
1 7/8	5 7/8	5.45	98	108.5	119
2	6 1/4	6.20	111	123	135

NOTE: It is never advisable for the working load of a wire rope to exceed one-fifth the breaking load. To determine the proper working load, divide the figures given for breaking strengths by 5 to obtain a factor of safety of 5.

* From tables by the Wickwire Spencer Steel Company, New York, N.Y.

Even though the kink may be straightened so that the damage appears to be slight, the relative adjustment between the strands has been disturbed so that the rope cannot give maximum service.

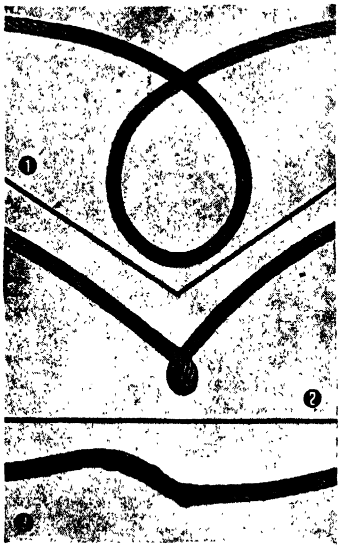


FIG. 168.—Result of kinking wire rope.

Wire-rope Lubrication. The importance of thorough wire-rope lubrication in obtaining safe and economical service cannot be overestimated. Wire rope is a complicated piece of machinery. A 6 by 19 rope is made up of 114 wires plus a core, which may be hemp or an independent wire rope center.

Wire ropes in constant daily service are less likely to corrode than inactive ropes. At the first sign of corrosion, however, apply a lubricant. It is well to lubricate rope regularly to prevent corrosion.

Corrosion strikes inactive ropes quickly unless they are adequately protected by relubrication. Therefore, wire ropes used as guys on stage standards should be examined periodically and lubricated in order to protect them against the elements and to keep them more flexible.

Wire rope may be protected by the application at intervals, depending on the lubricant used, of some sort of heavy oil or grease. The following mixture has been found to be very suitable for this purpose: 3 gal. black oil, 2 gal. fish oil, and 1 lb. plumbago. These should be mixed thoroughly before application with an angle brush and rubbed in well when applied to the rope.

Wire-rope Cutting and Seizing. When wire rope has to be cut to make attachment to fittings or for splicing, *it is important that it should be properly seized to prevent unlaying of the strands.* Annealed iron wire should be used, of the following diameters:

Rope Diameter, In.	Seizing-wire Diameter, In.
3/8 to 1/2	.047
5/8	.054
3/4	.063
7/8 and 1	.080
1 1/8 to 1 7/8	.105

Before cutting a wire rope, place seizing on each side where the rope is to be cut. Wind the seizing wire on the rope by hand, keeping the coils together and considerable tension on the wire. It is recommended that the application of not less than 8 or more than 10 laps of seizing wire for each seizing be made.

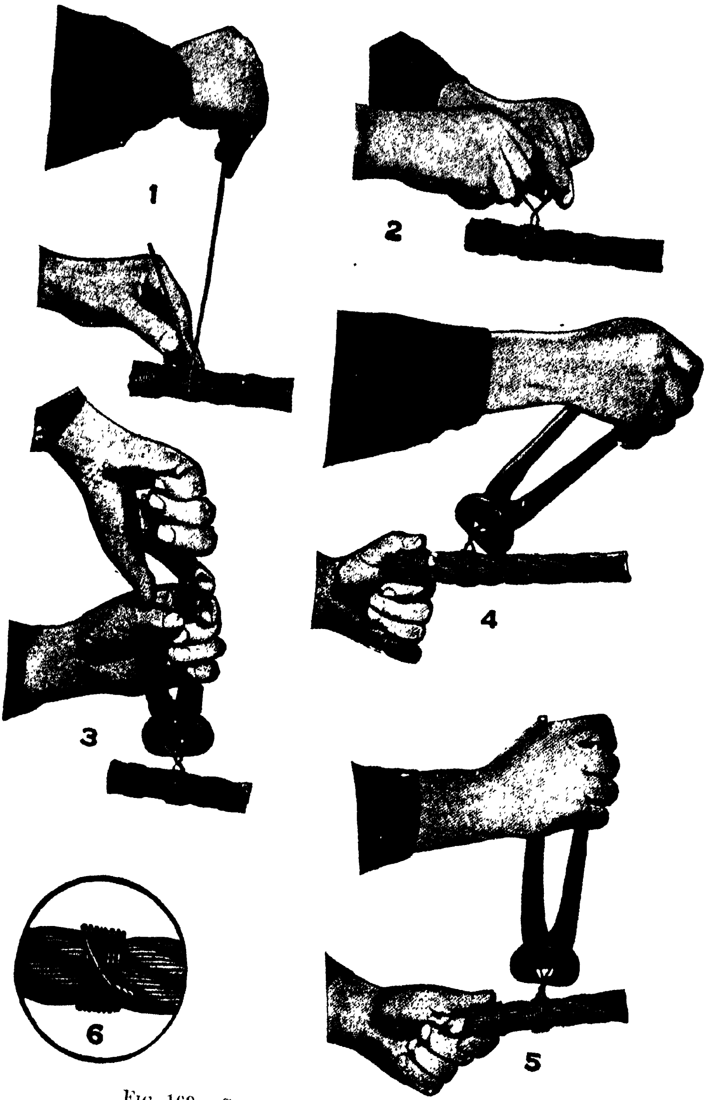


Fig. 169.—Seizing wire rope before cutting.

Twist the ends of the wire together counterclockwise by hand so that the twisted portion of wire is near the middle of the seizing. Using cutters, clip the ends of the wire just above the first twist made in operation 2, as shown in Fig. 169. Continue the twist just enough to take up the slack. Do not try to tighten the seizing by twisting. The appearance of the finished seizing should be as shown in operation 6, Fig. 169.

Figure 170 shows the wire rope that has been seized before and after cutting.

SPLICING OF WIRE ROPE, CHICAGO OR TIED SPLICE FOR EIGHT-STRAND ROPE[1]

These instructions cover the extra length of rope required and the method used in making the splices for eight-strand, right lay, preformed

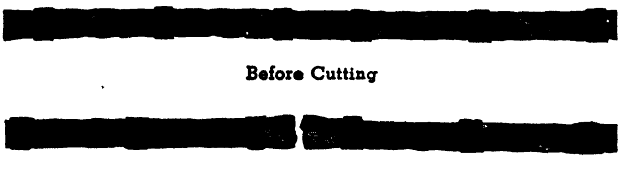


FIG. 170.—Seized wire rope before and after cutting.

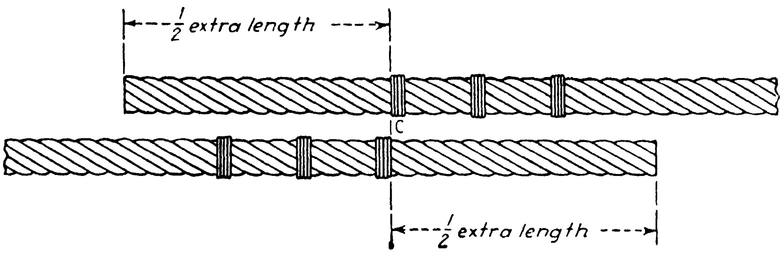


FIG. 171*a*.—End-to-end splicing of wire rope, first operation.

or ordinary ropes. The total length of splice is sixty times in feet the diameter of the rope in inches.

EXTRA LENGTH OF ROPE REQUIRED TO MAKE SPLICE

Rope diameter, in.	Extra length		Rope diameter, in.	Extra length	
	ft.	in.		ft.	in.
1/4	15	0	7/8	52	6
5/16	18	9	1	60	0
3/8	22	6	1 1/8	67	6
7/16	26	3	1 1/4	75	0
1/2	30	0	1 3/8	82	6
5/8	37	6	1 1/2	90	0
3/4	45	0			

Method Used in Making Splice. For a 1 in. diameter eight-strand right regular lay rope the following operations are necessary:

[1] From "Splicing Wire Rope," Macwhyte Company, Kenosha, Wisconsin, 1943.

First Operation. A distance of half the extra length shown above (30 in.) shall be measured back from the ends to be spliced. These ropes shall then be seized with wire at three places, starting at point *C* (see Fig. 171*a*).

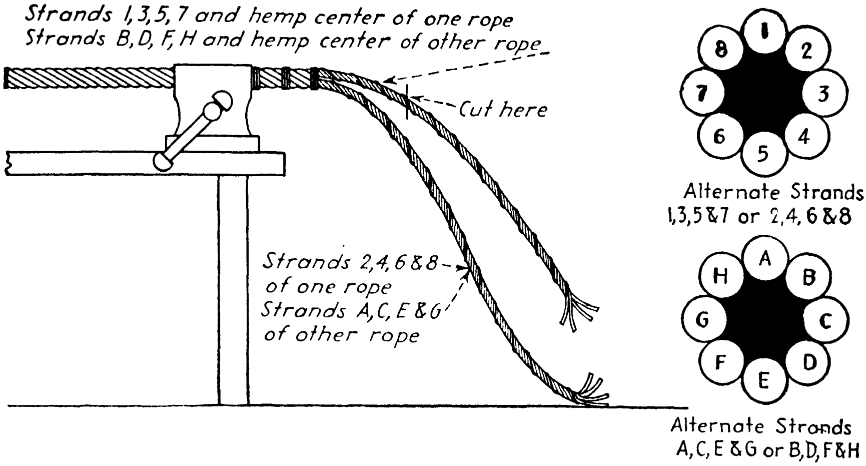


Fig. 171*b*.—End-to-end splicing of wire rope, second and third operations.

Second Operation. Unlay four alternate strands of each rope back to point *C*.

Third Operation. Cut off the four remaining strands and fiber center of each rope near to point *C* (see Fig. 171*b*).

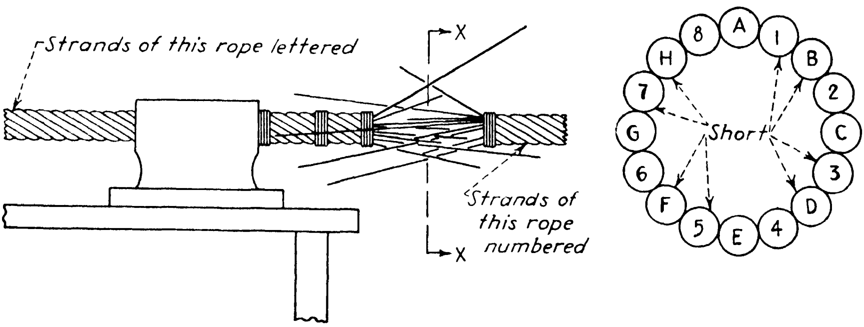


Fig. 171*c*.—End-to-end splicing of wire rope, fourth and fifth operations.

Fourth Operation. Separate the four strands of each rope: 2, 4, 6, and 8 and *A*, *C*, *E*, and *G*. There are now four long strands and four short strands at the end of each rope separated from each other.

Fifth Operation. Bring the ends of the ropes together and interlock, or marry, the strands (see Fig. 171*c*). The strands should be so arranged that the short strand shall be to the right of the long strand that is to take its place.

Assume the short strands of one rope to be numbered 1, 3, 5, and 7 and the long strands 2, 4, 6, and 8 and also that the short strands of the other rope are lettered *B*, *D*, *F*, and *H* and the long strands *A*, *C*, *E*, and *G*. Long strand *A* is to take the place of short strand 1, and, therefore, strand 1 is to the right of *A*.

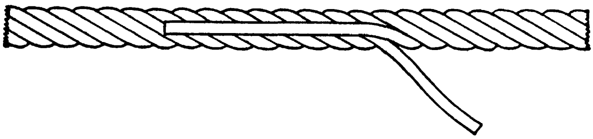


FIG. 171*d*.—End-to-end splicing of wire rope, eighth operation.

Sixth Operation. Bind long strands 2, 4, 6, and 8 to the end of the rope held in the vise, and be careful to hold the joint as tight as possible. Short strands 3, 5, and 7 should now be alternately lashed to the end of the rope held in the vise.

FIG. 171*e*.—End-to-end splicing of wire rope, eleventh operation.

If other material is lacking, the fiber center cut from the rope in the third operation may be unlaid and used as lashing.

Seventh Operation. Remove the three seizings that are farthest away from the vise or on the rope containing strand 1.

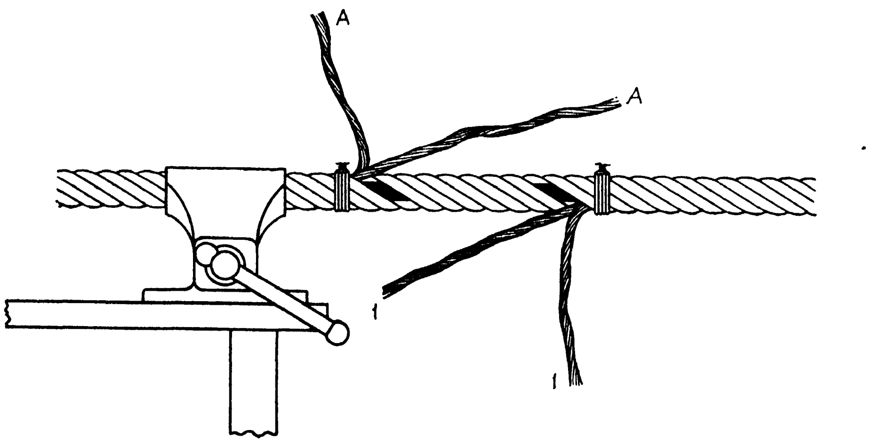


FIG. 171*f*.—End-to-end splicing of wire rope, twelfth operation.

Eighth Operation. Short strand 1 should now be unlaid one-half rope lay. A bight should be thrown into long strand *A*, which is to occupy the space left by the removal of strand 1, so as to hold the strand lay. Strand 1 should be unlaid one-half turn ahead of strand *A* until all of strand *A* has been laid into position, except the length of end allowed for making tuck. The strands 1 and *A* should then be locked in to hold them in position while laying in other strands (see Fig. 171*d*).

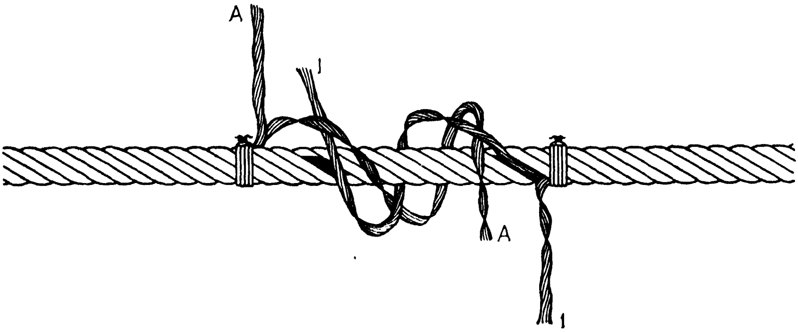


FIG. 171*g*.—End-to-end splicing of wire rope, thirteenth operation.

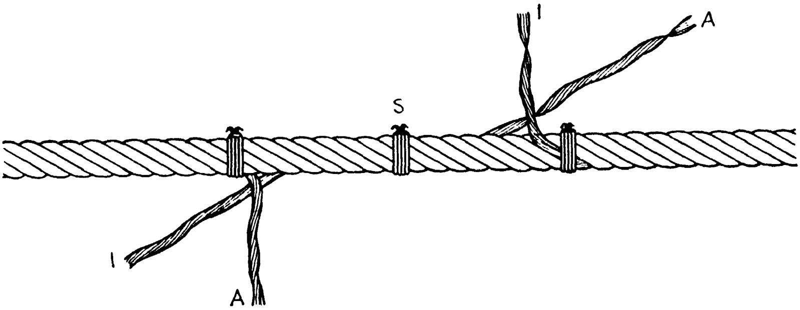


FIG. 171*h*.—End-to-end splicing of wire rope, fourteenth operation.

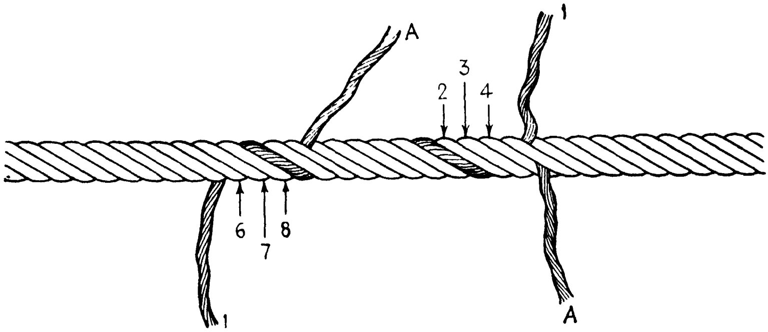


FIG. 171*i*.—End-to-end splicing of wire rope, fifteenth operation.

Ninth Operation. Strands *C*, *E*, and *G* shall then be laid into the spaces left by unlaying strands 3, 5, and 7, respectively, in the manner described above.

Tenth Operation. Remove the rope from the vise, turn it end for end, and grip the other rope.

Eleventh Operation. Unlay short strands *B*, *D*, *F*, and *H* and lay up long strands 2, 4, 6, and 8, respectively, in the manner described above.

All strands have now been rolled into place and are ready to be split, tied, and tucked.

Twelfth Operation. Place seizings equidistant on each side of the points where one set of ends extends. Space these one rope lay apart. Now unlay one-half of strands *A* and 1 (see Fig. 171*g*).

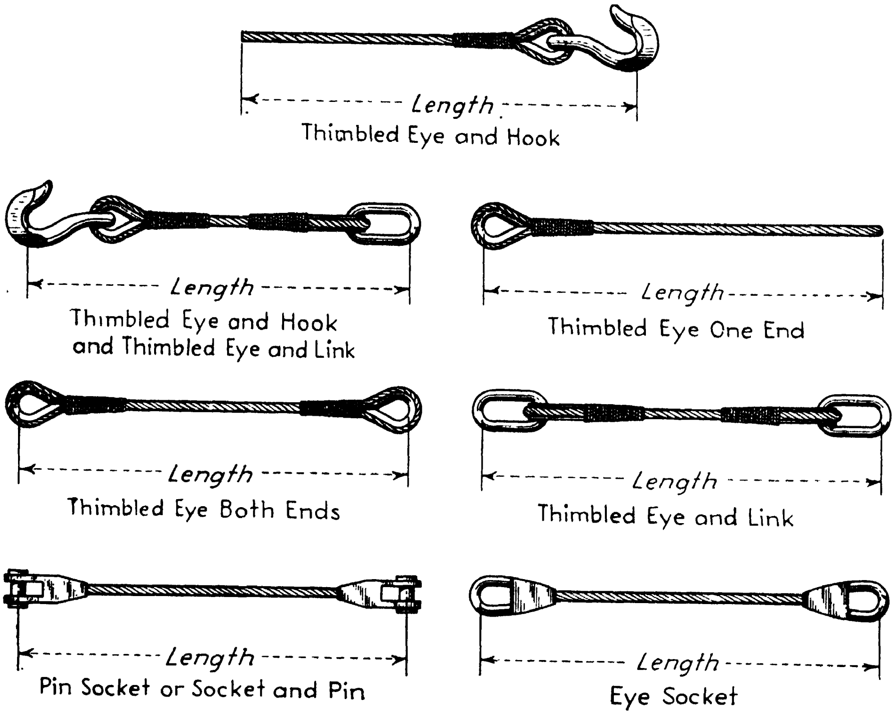


FIG. 172.—Wire-rope guys for erection.

Thirteenth Operation. Take one-half of each strand and tie it in a double knot as shown. Care should be taken to use the proper half of each strand so that the halves will lay together to form a round strand.

Fourteenth Operation. Pull this knot tightly together with some form of clamps. With large ropes it may be necessary to use block and tackle. Place a seizing directly over the knot to hold it tight (see Fig. 171*h*).

Fifteenth Operation. We now have 4 ends of half strands to be tucked in the rope. Remove the seizing. Now take a spike and stick it under strands 2, 3, and 4. Stick half strand *A* under these 3 strands and pull tight. Tuck in half strand 1 in a similar manner under strands 8, 7, and 6. Always draw these strands up tight in a direction at right angles to the strands in the rope (see Fig. 171*i*). The other two ends are tucked in in a similar manner.

Sixteenth Operation. Cut the wires off very close to the rope and force them in the count lines. Hammer down any inequalities with wooden mallets.

Seventeenth Operation. Split, tie, and tuck in the other strands in the manner described above; then the splice is complete.

End-to-end splicing is accomplished by attaching one rope to another, which makes one long rope out of two by interlocking the strands. Ropes of similar construction can generally be spliced in this way even though they are made by different manufacturers. It is apparent, however, that a right-laid rope cannot be spliced into a left-laid rope.

The *thimble splice*, which is used for standard lengths of ropes for guying, can be made by forming a loop in the end of the rope and then

FIG. 173.—Wire-rope clips.

interlocking the strands. The loop usually contains a thimble or other fitting (Fig. 172).

Wire Rope as Guys for Erection.[1] Wire rope used as guys for erection may be cut to standard lengths and fitted with sockets and hooks as shown in Fig. 172. Some of these fittings are clamped to the rope, some are fastened with molten zinc, and others are spliced in.

In installing guys, staging supports, or tricing lines of wire rope where the lengths of such ropes will vary (and particularly when the installation is only temporary), the most practical method of securing the ends of the wire rope is by wire-rope clips or clamps. With these clamps it is not necessary to cut the wire. It can be coiled up and tied at the clamp so that it can be used for a longer stretch if necessary. Figure 173 shows the use of wire-rope clips.

[1] Based largely on material published by the Wickwire Spencer Steel Company, New York.

CHAPTER VII

NAILS, SPIKES, SCREWS, AND BOLTS

NAILS AND SPIKES

There are numerous kinds of nails and spikes. Those most generally used are cut nails and spikes and common wire nails and spikes.

Nails are usually known by the *penny* (*d.*) system, which originated in England, the common theory being that 1000 tenpenny nails weighed 10 lb. *Square boat spikes* are designated by their thickness and length, for example, ½ × 6 in.

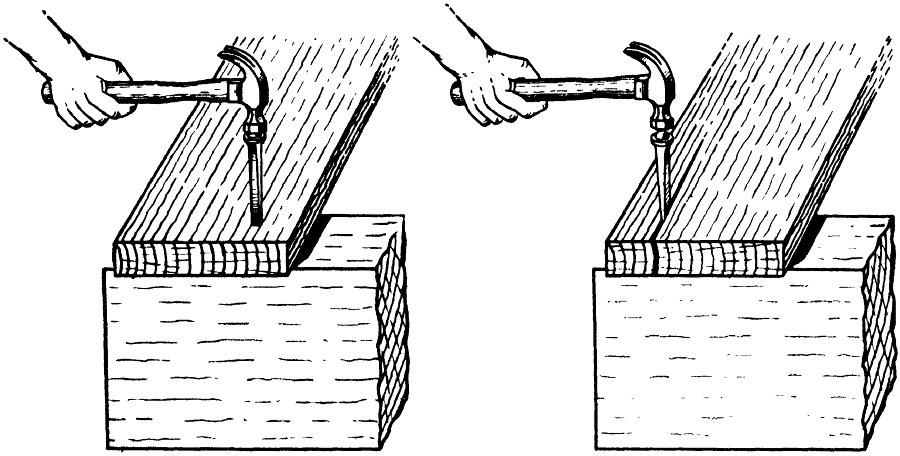


FIG. 174.—Proper method of driving cut nail or boat spike.

Nails are divided into two classes, *cut nails*, which are rectangular in shape with two sides slightly tapered and two sides parallel; and *common wire nails*, which are circular in cross section and possess only about one-half the holding power of cut nails. *Spikes* are stout pieces of material 3 to 6 in. in length and thicker than the common wire nail.

Selection of Nails. The size and kind of nail to use are important considerations in any kind of construction. Short thick nails work loose quickly. Long thin nails are apt to break at the joints of the timber. The best rule to follow is to use as long and thin a nail as will drive easily.

The following rules are used in determining the proper size of nails: (1) In timber of medium hardness, the penny of the nail should not be greater than the thickness in eighths of an inch of the board into which the nail is being driven. (2) In softwoods nails may be one- to twopenny larger than the thickness in eighths of an inch of the board. (3) In hardwoods nails should be onepenny smaller.

Driving Nails. One advantage in using common wire nails is that it is not necessary to hold them in a certain position to prevent splitting the wood when driving. However, in some instances, it is advisable to drill holes slightly smaller than the nail before driving to guard against splitting.

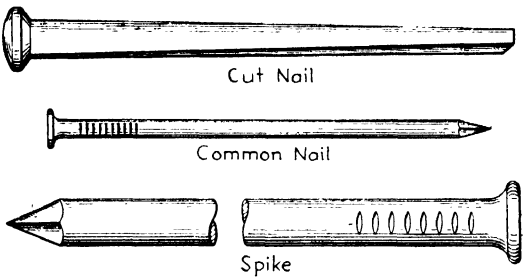


FIG. 175.—Types of nails.

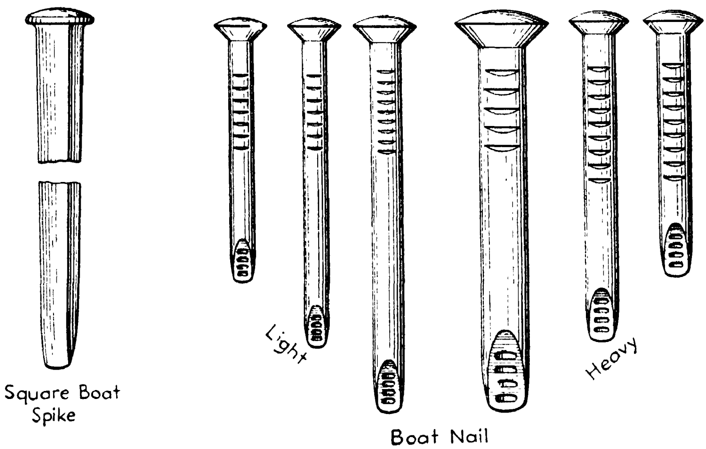


FIG. 176.—Light and heavy boat nails and square boat spikes.

This precaution is particularly important when spikes are used because it prevents crushing the wood and possible splitting. To prevent splitting, cut nails and boat spikes should be driven across the grain of the wood. If they are driven in this manner, the holding power is two times greater than if driven with the grain.

Figure 174 shows the right and wrong manner in which to drive a cut nail or a boat spike.

Figure 175 shows a cut nail, common wire nail, and ordinary spikes. In Fig. 176 are shown light and heavy boat nails and square boat spikes. Figure 177 shows *clinch pins*, used for reinforcing the ends and sides of timbers subjected to occasional heavy stresses. In Fig. 178 are shown *drifts*, used for securing heavy timbers.

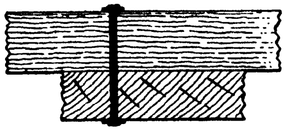


FIG. 177.—Clinch pins.

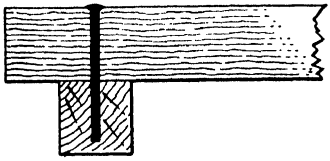


FIG. 178.—Drift bolts used for securing heavy timber.

Holding Power of Nails.[1] The resistance to withdrawal is proportional to the length of embedment (where the wood does not split). The safe resistance to withdrawal, using a safety factor of 6, of common wire nails soon after driving through the side grain of seasoned wood is given in Table VIII.

TABLE VIII.—SAFE RESISTANCE TO WITHDRAWAL OF COMMON WIRE NAILS IN SIDE GRAIN OF SEASONED WOOD
(Pounds per inch of penetration)

Species	Specific gravity	Size of nail									
		6d.	8d.	10d.	12d.	16d.	20d.	30d.	40d.	50d.	60d.
Birch, yellow and sweet	0.69	51	60	67	67	74	87	94	102	111	120
Douglas fir	0.51	24	28	32	32	35	41	44	48	52	56
Maple sugar	0.68	50	57	65	65	71	84	91	99	107	115
Oak, red and white	0.69	51	60	67	67	74	87	94	102	111	120
Pine, longleaf	0.64	34	39	45	45	47	50	55	59	64	69
Pine, northern white	0.37	13	15	17	17	19	22	24	26	28	30
Pine, ponderosa	0.42	15	17	19	19	21	25	27	30	32	35
Pine, shortleaf	0.59	28	32	36	36	38	41	44	48	52	57
Redwood	0.42	15	17	19	19	21	25	27	30	32	35
Spruce, Sitka	0.40	14	17	19	19	21	25	27	29	31	34

Nails withdrawn from green wood generally have slightly higher resistance, but these nails may lose some of their resistance when the wood seasons. Drilling lead holes slightly smaller than the diameter of the nail adds somewhat to the resistance and reduces the tendency toward splitting.

Tests at the Watertown Arsenal on different sizes of nails from eight- to sixtypenny, reduced to holding power per square inch of surface in the wood, gave the average results in pounds as follows:

Timber	Common wire nail, lb.	Cut nail, lb.
White pine	167	405
Yellow pine	318	662
White oak	940	1216

[1] "Wood Handbook," Forest Products Laboratory, U.S. Department of Agriculture, Washington, D.C.

TABLE IX.—APPROXIMATE NUMBER OF WIRE NAILS PER POUND

American Steel and Wire Co.'s steel wire gauge	3/16 in.	1/4 in.	3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.	1 1/8 in.	1 1/4 in.	1 1/2 in.	1 3/4 in.	2 in.	2 1/4 in.	2 1/2 in.	2 3/4 in.	3 in.	3 1/2 in.	4 in.	4 1/2 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.	12 in.
	Number of nails																											
3/8								29	26	23	20	17	15	15	12	11	11	8.9	7.9	7.1	6.4	5.2	4.5	4.0	3.4	3.2	2.9	2.7
5/16								43	38	34	29	25	22	20	18	16	15	13	11	10	9.0	7.6	6.5	5.7	5.0	4.5	4.1	3.8
1								47	44	40	34	29	26	23	21	20	18	16	14	12	11	9.3	8.0	7.0	6.3	5.7	5.2	4.7
2								60	54	48	41	35	31	28	25	23	21	18	16	14	13	11	9.3	8.1	7.2	6.6	6.1	5.6
3								67	60	55	47	41	36	32	29	27	25	21	18	16	15	12	11	9.4	8.3	7.6	7.1	6.6
4								81	74	66	55	48	41	37	34	31	29	25	22	20	18	15	13	11	9.8	8.9	8.1	7.5
5								90	81	74	61	52	45	41	38	35	32	28	24	22	21	18	16	14	12	12	11	9.6
6				213	174	149	128	113	101	91	76	65	58	52	47	43	39	34	29	26	24	20	18	16	15	13	11	11
7				230	205	174	148	132	120	110	92	78	70	61	55	51	47	40	35	31	28	24	19	18	16	14	13	12
8				272	238	198	174	153	139	126	106	93	82	74	66	61	56	48	42	38	34	28	24	21	19	17	15	14
9				348	286	238	213	185	170	152	128	112	99	87	79	71	67	58	50	45	41	34	29	25	23	21	19	17
10				469	373	320	277	242	216	196	165	142	124	111	100	91	84	71	62	55	49	42	36	31	27	25	23	21
11				510	417	366	323	285	254	233	200	171	149	136	122	111	103	87	77	69	61	52	44	39	35	31	29	26
12				740	603	511	442	397	351	327	268	229	204	182	161	149	137	118	103	95	87	71	63	56	50	45	40	36
13			1,356	1,017	802	688	590	508	458	412	348	297	260	232	209	190	175	153	138	123	110	93						
14		2,293	1,664	1,290	1,037	863	765	667	586	536	459	398	350	312	278	256	233	201	176	157	140	117						
15		2,899	2,213	1,619	1,316	1,132	971	869	787	694	578	501	437	390	351	317	290	246	220	196	177	145						
16		3,932	2,720	2,142	1,708	1,414	1,229	1,099	973	872	739	635	553	496	452	410	370	318	277	248	226							
17		5,316	3,890	2,700	2,306	1,904	1,581	1,409	1,253	1,139	956	831	746	666	590	532	486	418	360	322	295							
18		7,520	5,072	3,824	3,130	2,608	2,248	1,976	1,760	1,590	1,338	1,150	996	890	820	740	680	585	507	448	412							
19		9,920	6,860	5,075	4,132	3,508	2,816	2,556	2,284	2,096	1,772	1,590	1,390	1,205	1,060	970	895	800										
20	18,620	14,050	9,432	7,164	5,686	4,795	4,230	3,596	3,225	2,893	2,412	2,070	1,810	1,620	1,450	1,315	1,215	1,035										
21	23,260	17,252	12,000	8,920	7,232	6,052	5,272	4,576	4,020	3,640	3,040	2,665	2,310	2,020	1,830													
22	28,528	21,508	14,676	11,776	9,276	7,672																						
23	35,864	27,039	18,026	13,519	10,815	9,013																						
24	44,936	34,018	22,678	17,008	13,607	11,339																						
25	57,357	43,243	28,828	21,622	17,297	14,414																						

NOTE: These approximate numbers are an *average* only; the figures given may be varied either way by changes in the dimensions of the heads or points. Brads and no-head nails will run more to the pound than the table shows, and large or thick-headed nails will run less.

Tables IX to XII, from the American Steel and Wire tables, give useful information in connection with nails and spikes. Table IX gives the steel wire gauge 1 to 25 and approximate number of nails per pound

TABLE X.—COMMON WIRE NAILS

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

TABLE XI.—ORDINARY SPIKES

Size	Length, in.	Gauge No.
10d.	3	6
12d.	3¼	6
16d.	3½	5
20d.	4	4
30d.	4½	3
40d.	5	2
50d.	5½	1
60d.	6	1
7 in.	7	5/16 in.
8 in.	8	3/8 in.
9 in.	9	3/8 in.
10 in.	10	3/8 in.
12 in.	12	3/8 in.

in lengths of 3/16 to 12 in. Table X gives penny size, length, gauge number, and approximate number of common wire nails per pound. Table XI gives size, length, and gauge, or thickness, of ordinary wire spikes. Table XII gives the approximate number of square boat spikes per keg of 200 lb.

TABLE XII.—APPROXIMATE NUMBER OF SQUARE BOAT SPIKES PER KEG OF 200 LB.

Length, in.	3	4	5	6	7	8	9	10	11	12	13	14
5/8	....	....	....	330	292	260	234	210	194	178	166	152
1/2	....	648	512	434	384	338	294	262	236	212	198	186
7/16	1082	812	692	572	484	414	380	348	318	292	268	246
3/8	1476	1110	920	748	634	554	500	458	416	378	348	320
5/16	2176	1646	1386	1138	974	858	778	708	648	592		
1/4	3400	2600	2040	1748	1456	1294						

SCREWS

Wood Screws. Except in outfitting work, wood screws are not generally used by the shipwright. However, some general information will be of value.

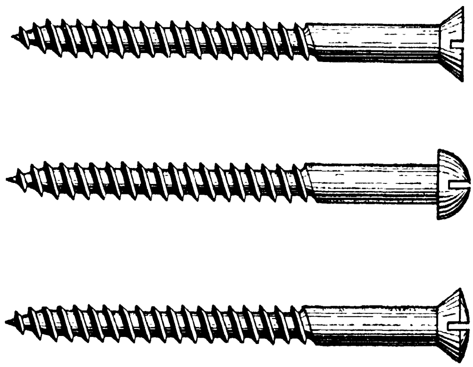


FIG. 179.—Types of wood screws.

Wood screws are nails having a right-handed thread to create a good grip and slotted heads for turning into the wood. There are many types of wood screws, those shown in Fig. 179 being the most commonly used.

The chart in Fig. 180 shows the full-sized cross section and size number of wood screws. Wood screws are ordered by size number and length, and are threaded for two-thirds the length from the point.

In putting in wood screws, it is good practice first to bore a hole slightly less than the diameter of the shank and about half its depth. This will prevent splitting the wood and will act as a guide in turning in the screws.

Lag Screws. Lag screws are heavy-duty wood screws provided with a square or hexagon head so that they may be turned in with a wrench or bolting machine. Lag screws are known by their diameter and length.

In selecting lag screws, it is good policy in wet or damp places to select a galvanized finish. In driving a lag screw, a hole equal in diameter

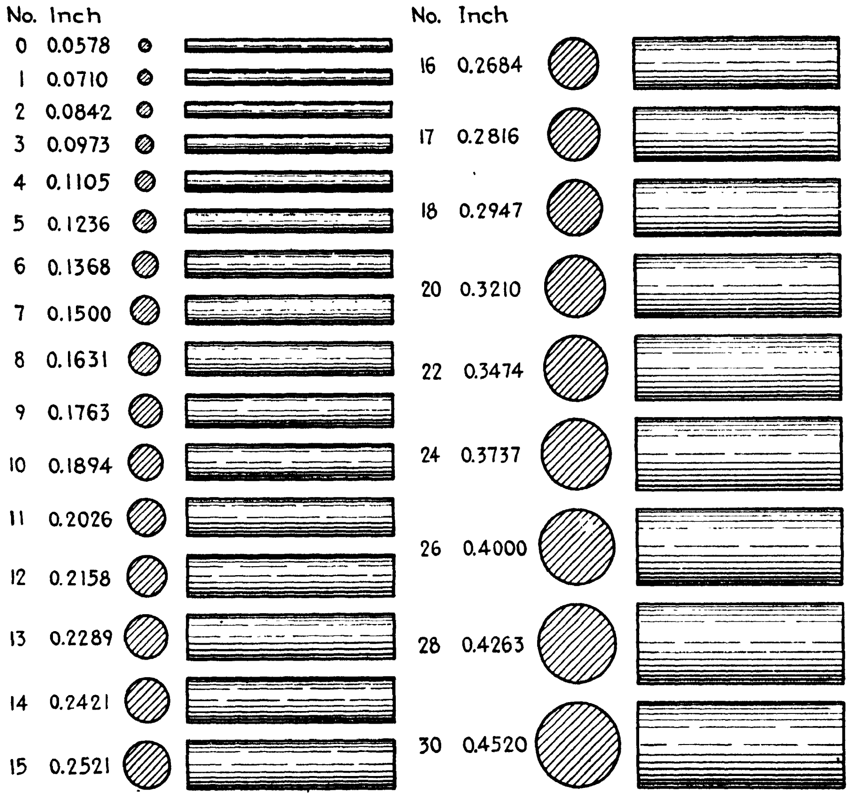


FIG. 180.—Cross section and size of wood screws.

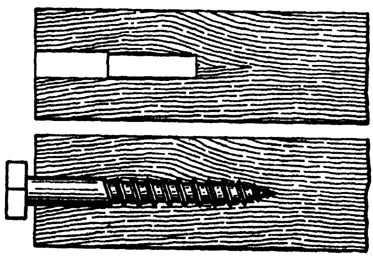


FIG. 181.—Proper method of boring and driving lag screws.

to the size of the shank must first be bored for the full depth of the length of the shank. A hole should then be bored with a bit ⅛ in. smaller in diameter than the shank for about one-half the length of the threaded portion.

The resistance to withdrawal for lag screws is as follows (these figures are in pounds per lineal inch of thread when inserted across the grain):

Kind of wood	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.
White pine	625	655	800	825	950
Douglas fir	910	930	990	1050	1170
Yellow pine	910	930	990	1050	1170
White oak	1820	1860	1980	2100	2340

Figure 181 shows the proper method for boring and driving lag screws.

BOLTS

There are numerous forms and types of bolts to suit various requirements. The types commonly used by the shipwright and shown in Fig. 182 are as follows:

1. Common, or machine, bolt.
2. Headless bolt threaded on one or both ends.
3. Countersunk bolt fitting into a countersunk hole.
4. Eyebolt provided with a ring at the head to form an eye.

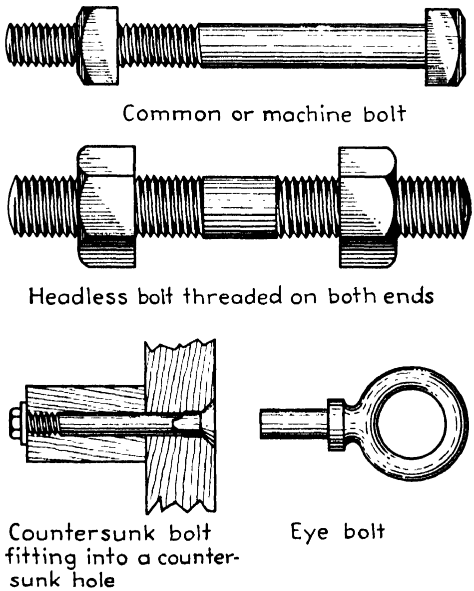


Fig. 182.—Types of bolts used by the shipwright.

Various classes of material are used in the manufacture of bolts, ranging from 45,000 to 95,000 lb. per sq. in. ultimate strength. The ordinary service bolt used on hull construction consists of material of

45,000 lb. ultimate strength. Special high-grade machine bolts are made of material up to 95,000 lb. per sq. in. ultimate strength.

A factor of safety of 5 is generally used. Therefore, the ultimate strength is divided by 5 to obtain the working load.

When there is a pull on a bolt, it is said to be *in tension* or *in tensile stress.* When the bolt is being pulled in a sidewise or vertical direction against the body of the bolt, it is said to be *in shear.* Bolts may be in single shear or in double shear, as shown in Fig. 183.

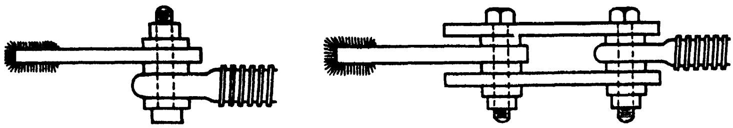


FIG. 183.—Bolts in single and double shear.

Table XIII gives the strength of U.S. Standard bolts.

TABLE XIII.—STRENGTH OF U.S. STANDARD BOLTS ¼ TO 1¼ IN. IN DIAMETER*

Bolt		Areas, sq. in.		Tensile strength, lb.			Shearing strength, lb.			
							Full bolt		Bottom of thread	
Diameter of bolt, in.	No. of threads per in.	Full bolt	Bottom of thread	At 10,000 lb. per sq. in.	At 12,500 lb. per sq. in.	At 17,500 lb. per sq. in.	At 7,500 lb. per sq. in.	At 10,000 lb. per sq. in.	At 7,500 lb. per sq. in.	At 10,000 lb. per sq. in.
¼	20	0.049	0.027	270	340	470	380	490	200	270
5/16	18	0.077	0.045	450	570	790	580	770	340	450
⅜	16	0.110	0.068	680	850	1,190	830	1,100	510	680
7/16	14	0.150	0.093	930	1,170	1,630	1,130	1,500	700	930
½	13	0.196	0.126	1,260	1,570	2,200	1,470	1,960	940	1,260
9/16	12	0.248	0.162	1,620	2,030	2,840	1,860	2,480	1,220	1,620
⅝	11	0.307	0.202	2,020	2,520	3,530	2,300	3,070	1,510	2,020
¾	10	0.442	0.302	3,020	3,770	5,290	3,310	4,420	2,270	3,020
⅞	9	0.601	0.419	4,190	5,240	7,340	4,510	6,010	3,150	4,190
1	8	0.785	0.551	5,510	6,890	9,640	5,890	7,850	4,130	5,510
1⅛	7	0.994	0.693	6,990	8,660	12,130	7,450	9,940	5,200	6,930
1¼	7	1.227	0.890	8,890	11,120	15,570	9,200	12,270	6,670	8,900

NOTE: When bolts are used in double shear, the above figures may be doubled.

* From MARKS, LIONEL S., "Mechanical Engineers' Handbook," 4th ed., Table 32, p. 909, McGraw-Hill Book Company, Inc., New York, 1941.

CHAPTER VIII

EFFECTS OF WELDING AND SHIP WELDING DATA

EFFECTS OF WELDING

The introduction of welding instead of riveting in ship construction brought to the fore an important consideration. Shrinkage resulting from welding caused buckled plating, shortened bottom frame spacing, gave a decided lift at the bow and stern, and decreased the over-all dimensions of the ship.

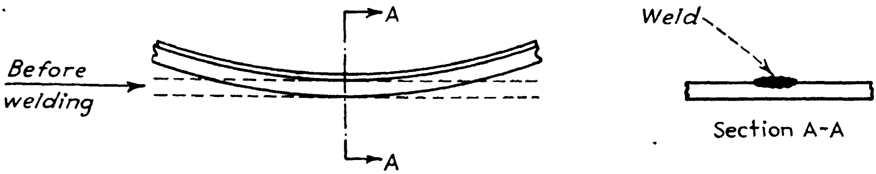


FIG. 184.—Distortions caused by welding (flat section).

The basic laws underlying all distortion resulting from welding shrinkage are as follows:

1. Metals expand when heated and contract when cooled.

2. Steel is elastic when stressed to a point slightly below its yield point. If stressed beyond its yield point, it *yields*, and a plastic flow of metal or permanent deformation results.

Typical Problems. With the above laws in mind it is easy to understand how welding causes structure to be drawn out of shape unless necessary precautions (to be discussed later) are taken. When a bead of weld metal is placed on a perfectly flat plate and allowed to cool, the contraction of the weld metal and the upset base metal tend to bend up the plate in the direction of the bead, as shown in Fig. 184. The same is true to a greater degree if heat sufficient to upset the base metal is applied along the same line as the bead of weld metal.

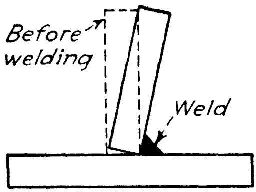


FIG. 185.—Distortion caused by welding (T section).

Upset metal is metal that has been stressed beyond its yield point. A typical example of this is furnished by the case of a red-hot spot on a bulkhead. The spot tends to expand in all directions equally but is held by the surrounding cold metal. Therefore, stresses greater than the yield point of the metal are built up, and yield, or a permanent set, occurs.

Another typical example of distortion caused by welding is given in Fig. 185, in which two pieces of plate are shown, welded together at right angles with a single bead. After this weld has cooled, it will be found that the weld has pulled the pieces toward each other in the direction of the weld.

Two plates fitted up for a butt joint with a root opening will gradually come together ahead of the weld, as the weld progresses (see Fig. 186).

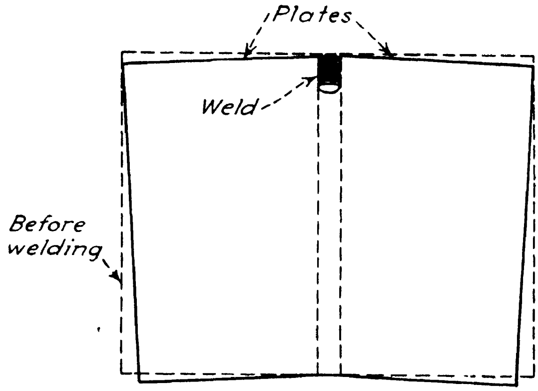


FIG. 186.—Distortion caused by welding (butt section).

As a general rule, *shrinkage will be smaller in the direction of the weld than transversely to the weld,* because, in the longitudinal direction, differently heated zones will be more in conflict and there will be more resistance to the shrinkage by the cool adjacent metal. However, high transverse rigidity may easily upset this rule.

Angular Distortion. Angular distortion is the result of an unsymmetrical shrinkage. This effect will be pronounced if the structure offers

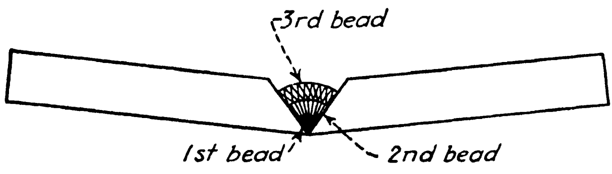


FIG. 187.—Angular distortion.

little rigidity in the direction in which the angular distortion is going to take place. This is particularly true if the shrinkage is not uniform across the thickness of the joint.

Consider, for example, a butt-weld joint made of several beads, as shown in Fig. 187. After the first bead has been laid and cooled down to room temperature, the weld will no longer be able to shrink freely in the transverse direction. Thus, the shrinkage of the second layer will be impeded by the resistance of the first layer; and since these two actions run in line, angular distortion will result. Angular distortion will increase gradually as the welding proceeds.

Preventive and Corrective Measures. From a summary study of the subject, it is apparent that the best and most effective methods of combating distortion are those which are preventive rather than corrective. Corrective measures that are effective are elaborate and expensive, but proper design and proper welding technique are entirely satisfactory in controlling most of the angular distortion caused by welding.

Space and angular-allowance deductions, wherever it is possible to use these, are convenient means of overcoming this trouble in small structures. For medium structures, tack welding and jigs will prove more suitable, provided that they are strong enough to prevent angular distortion. Strongbacks of sufficiently heavy material will assist materially in resisting this condition. In very large structures, the proper welding sequence may be the only possibility.

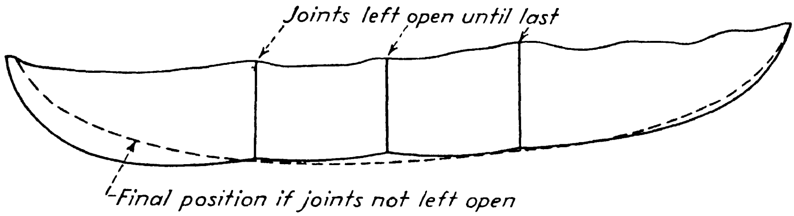


FIG. 188.—Breaking structure by leaving shrinkage joints loose.

Correct design of a welded structure plays an important role in preventing much of the trouble caused by distortion. This means the planning of the location of the welds so that partial angular distortions caused by individual welds cancel each other. The same object may be attained by the proper sequence of welding.

There are no standard rules to be recommended for this purpose, for the amount and extent of distortion cannot be computed from the factors available at present. The following may serve as a general guide:

1. Symmetrical arrangement of welds and symmetrical sequence of welding with respect to the axis of the welded member.

2. Location of welds at parts where shrinkage is less liable to cause general distortion—as a general rule, at parts easy to straighten.

Item 1 is the key to distortion control as applied to ships. It has been found that the best welding sequence is that by which the welding begins at a point near amidships and progresses simultaneously fore and aft and port and starboard. It would be desirable to have this starting point located at a spot, say about the second deck level, such that the welding could also progress up and down at the same time. This would tend to eliminate the vertical movement of the bow and stern that sometimes is sufficient to raise them from the keelblocks. However, this is not practical in view of the fact that almost all the ship's structure would have to be erected and temporarily fastened in position by erection bolts, tack welds, etc., before any appreciable amount of welding could be done.

Generally speaking, common practice is to construct ships progressively from the keel upward. Therefore, the problem of lift must be solved in ways other than by welding progressively up and down. It has been found that lift can be practically eliminated by leaving a few open joints, extending from the flat keel to the main deck, until the greatest portion of the structural welding is completed. This divides the ship into several short assemblies, or sections, each of which will have a little lift at each end but the over-all lift at completion will be slight (see Fig. 188). However, there is always the question of whether or not high stresses are set up in this area, for the two assemblies do not tend to move toward each other during the process of welding.

In any welded assembly there is a slight reduction in over-all dimensions due to the accumulated shrinkages of the welds and welded members making up the assembly. This is easily taken care of by an initial expansion of material or an addition of extra material to take care of the shrinkage so that the final dimensions will be as designed. Experience has taught that over-all shrinkage is of the order of

(1) 0.1 per cent in arc-welded plate girders.

(2) 0.05 per cent in arc-welded lattice structures.

(3) 0.03 to 0.04 per cent in welded ships in length.

In shipbuilding it is common practice to *expand* the ship initially to attempt to care for contraction and, in addition, to leave extra material at several points throughout the length and width to use in correcting the dimensions when the joints are made up.

By careful consideration of the problems presented by welding, preventive and corrective measures can be undertaken that will result in a completed structure of correct dimensions and fair in all respects. However, in no instance can the effects of welding be lightly considered.

Compensation for Welding Shrinkage. In discussing compensation for welding shrinkage, it is not the author's intention to stress the importance of the structure of the ship being absolutely perfect. However, an attempt must be made to hold the structure of the ship to designed dimensions in order that the balance of the fabricated structure will conform to them. This is particularly true of the diversified equipment and mechanism that go into combat ships. For example, an ammunition hoist must follow the designed line and cannot, therefore, weave from one side to the other or fore and aft where it makes up part of the transverse bulkhead between decks.

By keeping the structure of the ship as close to designed dimensions as practicable a large amount of bad work will be eliminated, together with the patching and margins that are inevitable when this point has not received sufficient consideration.

In making compensation for welding shrinkage, a stretch rule is not recommended, since this leads to confusion and errors if not properly applied. From experience, it has been found that the best rule to follow

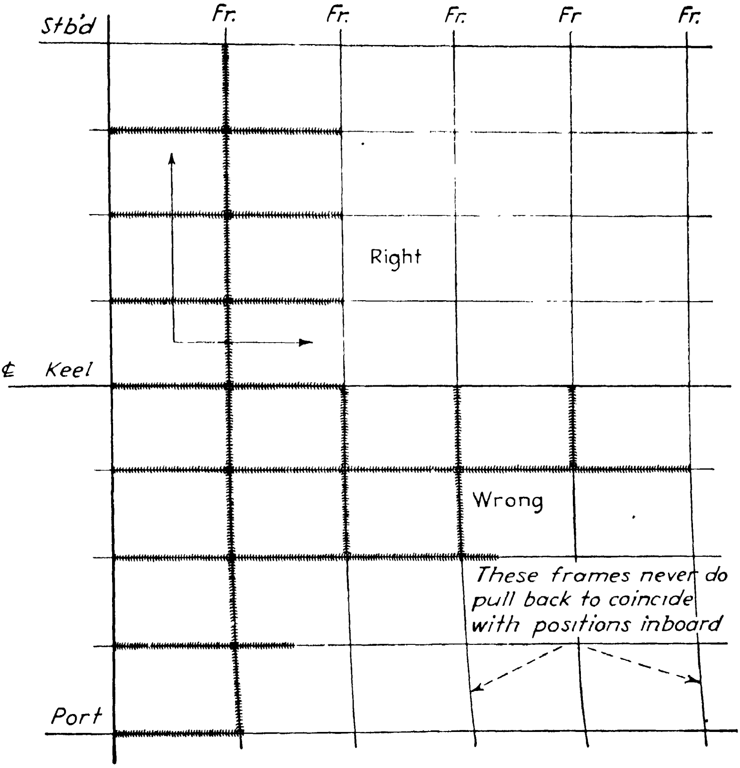


FIG. 189.—Correct and incorrect methods of welding framing.

is *to make certain allowances per foot in a fore-and-aft direction and another allowance per foot in a transverse direction.* The difference is that the reduction in dimension in a transverse direction is much less than that in a fore-and-aft direction.

For practical purposes and from past performance, it has been found that an allowance of $\frac{1}{64}$ in. per ft. is sufficient to take care of welding shrinkage where combination riveting and welding are used. However, where the construction is all-welded, the allowance should be doubled; that is, the construction should be $\frac{1}{32}$ in. per ft. greater than design.

In the beam of the ship, or in a transverse direction, to compensate for welding shrinkage, it is recommended that the allowance be no greater than $\frac{1}{64}$ in. per ft., either in all-welded or combination riveting and welding construction.

When allowances have been made for welding shrinkage, it is important that *the procedure of welding be such that the structure will shrink practically simultaneously across the entire ship,* as shown in the upper portion of Fig. 189. Otherwise, if the welding is carried too far forward

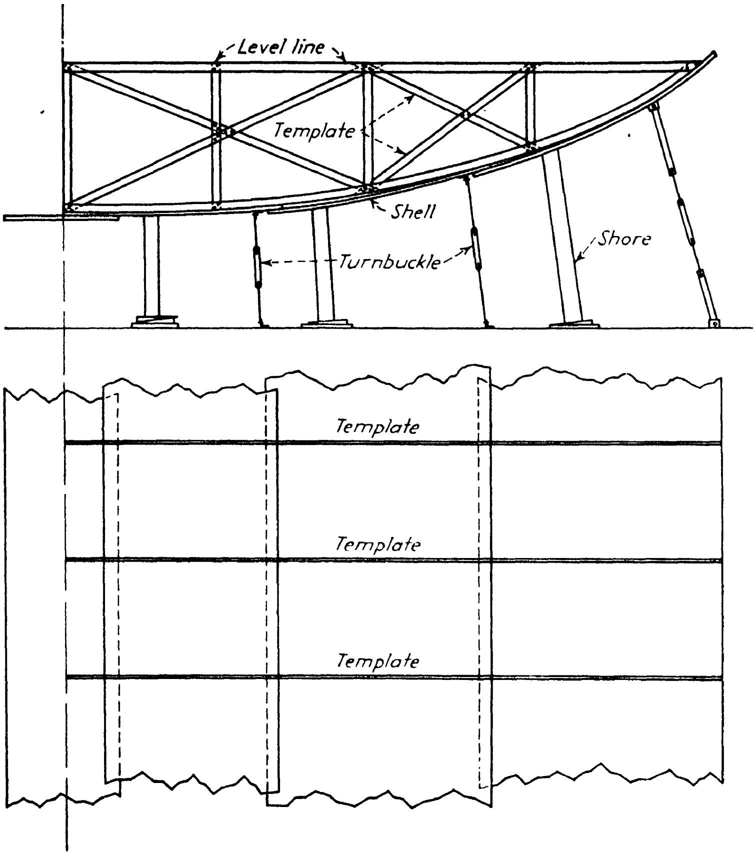


FIG. 190.—Use of template to check, and bracing to resist, welding distortion.

and aft, the shrinkage will not be uniform and the framing will take on a bowed appearance, as shown in the lower section of Fig. 189. However, it is not always possible for the structure to shrink back so uniformly as is desired; therefore, some bowing toward the ends of the ship can be expected. In welding the shell plating on the side of the ship, if practicable the upper welding should be carried in advance of the lower welding as shown in the lower portion of Fig. 189. This will to some extent reduce the tendency to lift, or rise.

Automatic Welding. With the use of automatic welding, angular distortion is materially reduced.

Particularly on bottom shell plating, it is important that the plating conform as nearly as possible to design dimension before being welded. This condition facilitates the fitting in of the inner-bottom structure after the shell plating has been welded. Therefore, templates should be applied on the shell plating and the plating shored and tied down with turnbuckles before welding, as shown in Fig. 190.

The preceding is true not only in automatic but also in hand welding. The usual procedure in welding the bottom shell plating is to weld manually the underside, beginning at the butts, and then proceed to weld the

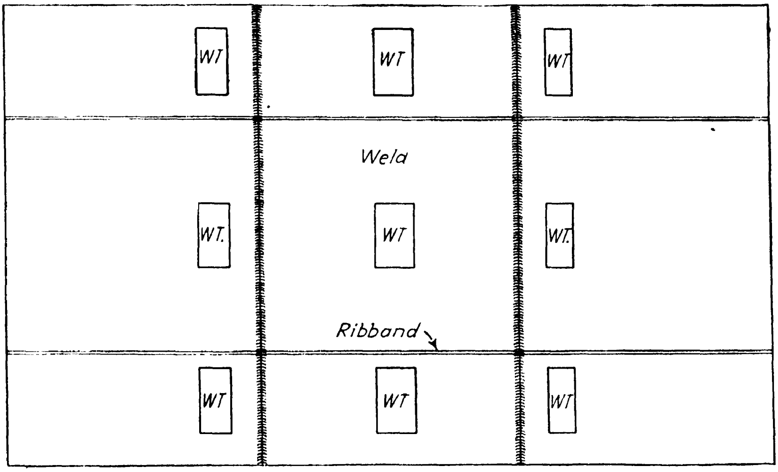


FIG. 191.—Use of ribbands and weights as a means of arresting distortion.

seams. When this operation has been completed, a check should be made to remove any distortion or unfairness that occurred during the bottom weld.

After the fairing has been done, the automatic welding can then proceed in the same manner as in hand welding.

The use of ribbands and weights (Fig. 191) is also a means of arresting distortion.

Use of Strongbacks in Welding. To reduce distortion caused by contraction on V butt welds, strongbacks are tacked across the butt at intervals of 2 ft. Strongbacks are usually scrap flat bar or plate, ½ by 4 in. to ½ by 6 in., depending on the thickness of the plates to be welded. Where automatic welding is being done, they are usually put on the underside of the deck between longitudinals. This is done so that they will not foul the machine. Strongbacks should extend across the butt so that they will bear on the beams or stiffeners, thereby producing greater resistance to distortion from the weld.

When strongbacks are applied across shell butts, they should be installed on the inside because of the scars that are left when they are removed. If not welded up and ground smooth, such scars may be the cause of a plate cracking when subjected to undue stress.

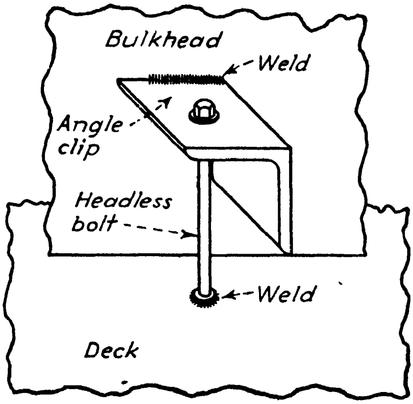


FIG. 192.—Welded angle clips used for pulling.

Other types of strongbacks used for preventing distortion due to welding will be explained more fully in Chap. XI.

WELDING DATA

In aligning the structure of a ship in the absence of rivet holes, it is necessary for the shipwright to weld temporary. clips and dogs to assist him in pulling the structure into alignment.

To perform this work with a minimum amount of welding, some idea of the strength of various tacks and welds must be acquired. It is obviously useless to apply enough welding on a clip to shear three bolts when one bolt is being used. The

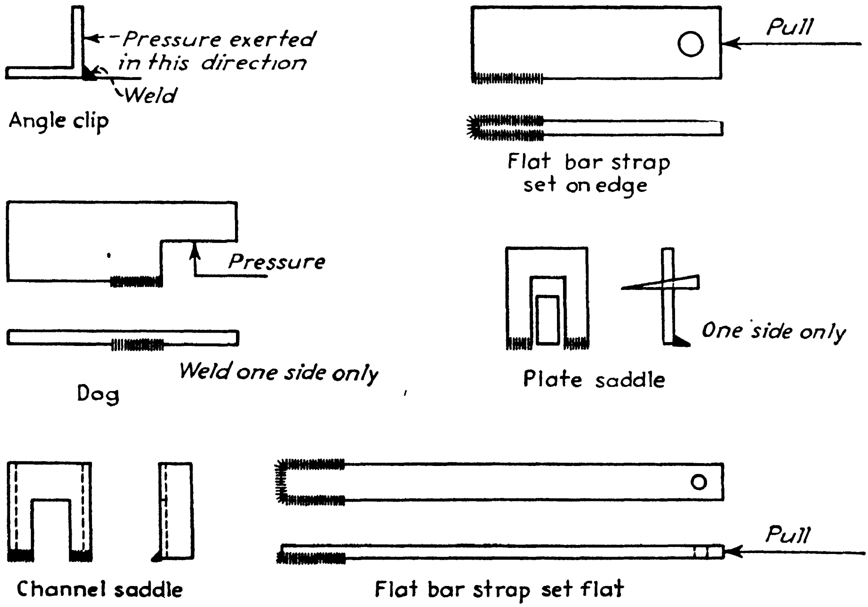


FIG. 193.—Location of welds with respect to direction of pull.

same is true of the welding of bolts for the purpose of pulling the structure into position.

Short pieces of scrap angle should always be used in pulling either up or down in a vertical direction. By attaching the clip to the structure in the manner shown in Fig. 192, the weld is made along the outside of the horizontal flange. The other flange of the clip does not require welding because the force of the bolt pushes it against the resisting structure.

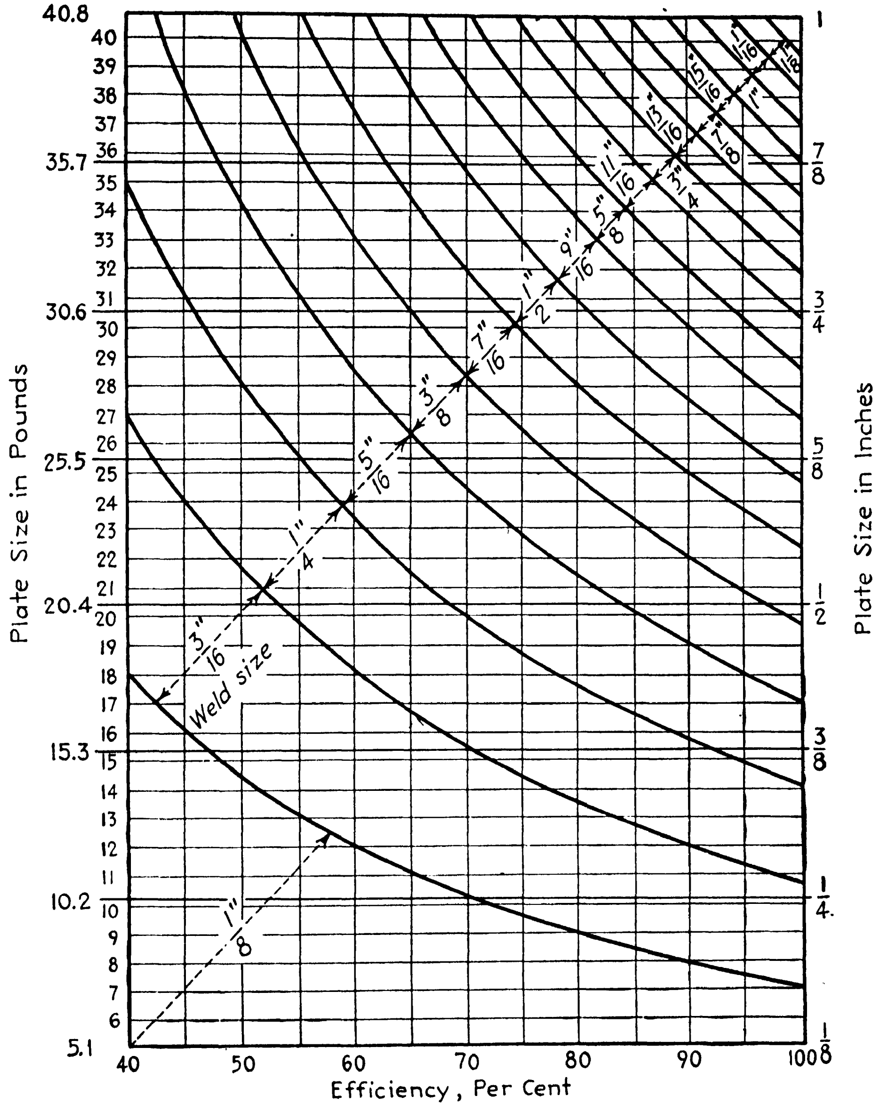


Fig. 194.—Efficiency chart for medium steel.

Amount of Welding Necessary. In determining the amount of welding necessary for holding bolts, clips, etc., a simple rule to follow with respect to mild or medium steel is the following: A ⅛-in. bead of weld 1 in. long is good for 1000 lb.

Since the direction of the pull against such a weld affects its strength, it must always be considered. Figure 193 shows the various methods of locating welds with respect to direction of load.

Wherever possible, such welds should be *placed in double shear*, commonly known as double-fillet tee joints, for added strength. For example, a flat bar clip is to be used in connection with pulling with a turnbuckle. The roughly estimated load will be approximately 6 tons, or 12,000 lb.; thus, if welding is applied to each side of the clip, or in double shear, the ⅛-in. weld 1 in. long would be good for 2000 lb. The weld could therefore be applied as a ¼-in. weld on each side of the clip 3 in. long, which would be good for a pull of 12,000 pounds. Figure 194 is an efficiency chart for medium steel and is in accordance with Navy specifications.

When a bolt and clip are used together, the amount of weld on the clip need not be greater than the weld that holds the bolt.

Welding Required to Equal Bolt Strength. Table XIV gives the size of weld equal to bolt strength, together with the amount of welding required on clips equal to the strength of bolts.

TABLE XIV.—SIZE AND AMOUNT OF WELD REQUIRED TO EQUAL STRENGTH OF BOLTS

Welding on bolts (without heads)			Welding on clips, in.				
			Size of weld				
Dia. of bolt, in.	Approx. circumference, in.	Size of weld required, in.	3/16 in.	¼ in.	5/16 in.	⅜ in.	½ in.
⅝	2	¼	2¾	2			
¾	2⅜	5/16	...	3	2½	2	
⅞	2¾	⅜	...	..	3¼	2¾	2¼
1	3⅛	½	...	..	...	3½	2¾

NOTE: For size of bolts with heads, reduce weld size 50 per cent but not less than 3/16.

Welding on Clips. To determine the amount of welding necessary on clips used for pulling with turnbuckles and straps, see Table XV, which gives the amount of welding required for various sizes of bolts used in single and double shear.

Tack Welds. In making work ready for production welding, it is necessary to tack-weld the structure into its proper position before the finished weld can be made.

According to Navy specifications, tack welds should be made with the same grade of electrode as the final weld and of an equal quality and should be deposited in such a manner as to facilitate incorporation in the weld. Cracked or broken welds and those of poor quality must be chipped out before the final weld is made.

Tack welds should be made with electrodes not larger than ⅛ in. in diameter, except that in tacking heavy sections 5/32-in.-diameter electrodes may be used. Tack welds should be as small as is consistent with the size of the electrode being used, should be not more than 1 in. long, and should be spaced only as closely as is necessary to hold the joint in proper alignment.

Welding Clips for Staging. Where it is necessary to weld temporary clips to the structure of the ship for supporting staging, only sufficient welding should be applied to take care of the load with a reasonable factor of safety.

TABLE XV.—LENGTH OF ¼-IN. WELD REQUIRED TO EQUAL SHEARING STRENGTH OF BOLTS

Bolt in single shear			Bolt in double shear	
Dia. of bolt, in.	Shear value	Length of weld, in.	Shear value	Length of weld, in.
¾	4,420	2¼	8,840	4½
⅞	6,010	3	12,020	6
1	7,850	3¾	15,700	7½

NOTE: The figures are for Class B bolt material at 45,000 lb. per sq. in. ultimate shearing strength. They may be doubled for high-grade-steel bolt material.

CHAPTER IX

SHIPWRIGHT WORK IN CONNECTION WITH SUBASSEMBLY

The term *subassembly* means the assembling of a portion of the vessel into a unit, usually to a high state of completion. Examples of subassembly are the transverse bulkhead, a section of inner bottom, a section of deck, a bow, or a stern assembly.

The building of a vessel according to the subassembly method has decided advantages provided that certain steps are taken. In other words, certain definite rules should be followed in order to make this method an advantage.

Subassemblies Should Be Planned Before Working Plans Are Drawn. This may seem like a radical statement to some, but it is nevertheless true. Working from scantling plans, the first plan to be drawn should be an erection diagram, which should break the vessel down into the component subassemblies. These assemblies should be consistent with the platen facilities and crane capacities. The actual working plans should be developed in accordance with this erection layout.

Layout of Subassemblies Should Be Planned. A layout plan should be made for the platens, giving a layout for each platen and an outline of the space allotted for each assembly. Assemblies of portions of decks, longitudinal bulkheads, sections of shell, and *boxes*, or *units*, of a vessel should always be assembled adjacent to the connecting assemblies. This is an important step, as it enables the shipwright *to prove the connection.*

In laying out the platens for large units (assemblies such as the bow or stern assemblies), space should be laid out adjacent to them to preassemble the component parts. In doing this, automatic machine welding should be used wherever possible. The layout of the platens should allow for storage spaces for incoming material and for completed assemblies, so that the platen can operate continuously.

Plating for bulkheads, decks, and flat structure need not be shop fabricated but can be ordered directly to the platens from the storage yard. These plates are laid directly on the platens to suit lines laid down by the shipwrights and ship fitters. The seams and butts are then welded with the automatic welding machines, and upon completion of this operation the stiffening is installed and welded and the assembly is turned over. The automatic welding machine is then used to back up the welding of the seams and butts. The plating is cut to outline to suit an over-all mold supplied by the mold loft, and the assembly is ready for erection in the vessel.

Subassemblies Should Be Timed. The process of timing subassemblies is called *scheduling*. One advantage of subassembling material is *that a complete unit of the vessel is ready for erection at the time when the vessel has reached a point at which erection of this portion can proceed piece by piece.* Thus, it is obvious that the job has been expedited.

Let us assume that a vessel has progressed, starting amidships, to frame 8, and that we are now ready to start erection forward of frame 8. Let us further assume that the entire bow forward of frame 8 has been subassembled on the platen and is now ready for erection. The erecting of this bow assembly enables us to continue uninterrupted construction. However if the assembly is not ready at this time, we have lost the time advantage we attempted to gain by subassembling this portion of the vessel.

Conversely, however, subassemblies must be timed, or scheduled, so that the platen is not so far in advance of erection in the ship that it becomes a problem as to where to store the assemblies.

Advantages of the Subassembly Method. The advantages of using the subassembly method are as follows:

1. It expedites construction.
2. It takes full advantage of automatic machine welding and position manual welding.
3. It simplifies erection.
4. It permits the elimination of shop fabrication of flat plates.
5. It eliminates or minimizes staging.
6. It simplifies mold making.
7. It reduces cost.

Some of these advantages will now be discussed in detail.

Subassembly Takes Full Advantage of Automatic Machine Welding and Position Manual Welding. By laying the plates flat on the platen, the automatic welding machine can be used to the best advantage. For welding that is not suitable for machine welding, downhand or position manual welding can be used.

Subassemblies are so laid out that they can be turned over within the capacities of the cranes on the platens.

Subassembly Simplifies Erection. This is especially true of complicated sections of the vessel such as the bow and stern. These sections are usually built on the platens in the inverted position with the wide portion, usually the deck, flat on the platen.

On some types of small ship, the entire stern can be subassembled on the platen, including the sternpost and rudderposts and shaft struts.

The bow of a ship may be assembled into two or three sections. It is usually built in a position best suited to the type of construction. Some bows may be built with the stem down, which necessitates a jig or form for the plating. Others may be built with the stem up by laying the collision bulkhead plate on the platen and working up from this point. This, however, can be done only if there is a clean break in the shell plating at this point, and the ship must be so designed. Other bows may be built in an inverted position, which does not interfere with the breaks in the shell plating. Any long overhanging plates may be left off and erected separately.

Subassembly Eliminates or Minimizes Side Staging. Where sections of the vessel can be built from the bilge to the weather deck, stage poles can be eliminated. Such staging as is needed at the connections of the assemblies can be supported by brackets hung from the gunwales.

Subassembly Simplifies Mold Making. If it has been determined in advance that a deck is to be subassembled in panels and the plating is not to be shop fabricated but is to be laid on the platen and welded into a panel which is later cut to outline to suit an over-all mold, *the molds are not needed for each individual plate.*

Jigs for Subassemblies. A great variety of jigs can be used in connection with subassemblies. The trend toward subassembling the structure of the ship is limited only by the capacities of the cranes. This trend means that the shipwright plays a more important part in the work on the platens than ever before.

In order that the various subassembled units will fit into the ship and make up to each other, the shipwright must continually check and observe shrinkage so that the necessary allowances will be made. He must brace, ribband, tie down, and shore assemblies that are likely to warp during the process of welding and cause difficulty in fairing and lining up when the assemblies are put into the ship.

He must be in close touch with the ship fitters and welders in order to expedite his part of the work. He must assist the ship fitter by bracing and shoring properly any of the structure that will distort during welding. He must assist the welders by observing the proper sequence of welding and the correct welding procedure, for no amount of bracing and shoring that can be installed on any assembly will help if welding is performed contrary to the proper sequence and procedure.

Foundations for Jigs. One of the most successful methods of holding a structure in position during building and welding is furnished by sturdy jigs sufficiently strong to resist to a large degree the tendency to distortion during welding. The first requirement for successfully jigging subassemblies is that *the foundation under the jig be adequate so that the jig itself will not rack or settle.* The most suitable foundation is a concrete base. This need not necessarily be a solid slab, but it must have bearing enough to support the load that will be put on the platens, depending on the size of the assemblies to be constructed (see Fig. 195).

Where it is not possible or practical to install such a foundation and where the platens are generally laid on timbers in or on top of the ground, the jigs are usually built on legs having slotted holes for adjusting. Should settlement occur, a jig can be brought back into its proper plane without attempting to relevel the platens, which will usually settle.

Jig Structure. Jigs are constructed of angle, flat bar or channel, and plating and must be made to templates supplied by the mold loft to

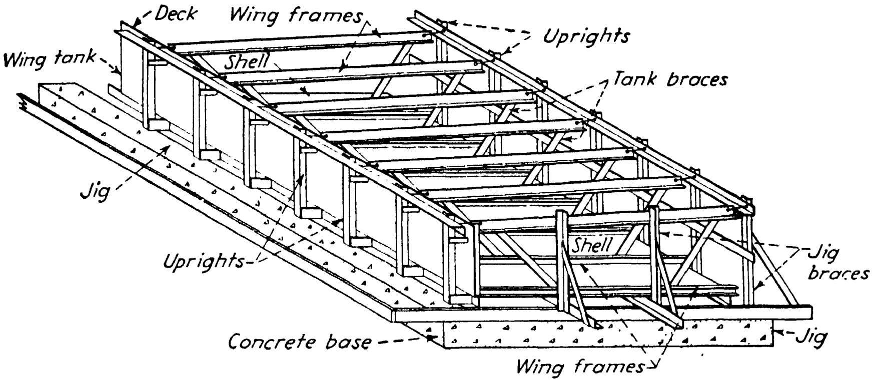


FIG. 195.—Jig for constructing a wing section of a small vessel.

conform to designed lines. They are usually built in the position best suited to construction and welding and are built to a common base that need not necessarily be parallel to water lines or buttocks. However, where possible, jigs should be so constructed that a spirit level and plumb bob can be used in lining up the steel that makes up the assembly. Otherwise, it will be necessary to secure set molds from the mold loft to apply against the base of the assembly, a procedure that is not always readily understood by inexperienced men.

Figure 195 shows a jig for constructing a wing section on a small vessel from preassembled wing frames that form the side box section.

The jig shown in Fig. 196 is for the subassembly of bottom-shell and inner-bottom section.

Height. From battens secured from the mold-loft floor, a rough idea of the length of the legs to support the jig can be obtained. Frame stations are then established on the platen, together with the center line and the locations of the longitudinals.

The flat-bar legs are then set up and plumbed with a spirit level at the intersections of the frames and the longitudinals where the fore-and-aft supports will be located. After the legs have been set up, they should be braced with scrap pieces of flat bar to hold them in a vertical position. With a leveling instrument or straightedge and spirit level, a level plane can now be established on the legs or uprights. From this level plane the desired height of the base line can be established. This is usually determined by the amount of working space desired between the platen and the underside of the subassembled sections (usually from 30 to 36 in. at the center line).

After the base line has been established from the level plane, the battens obtained from the mold-loft floor can be applied on the uprights

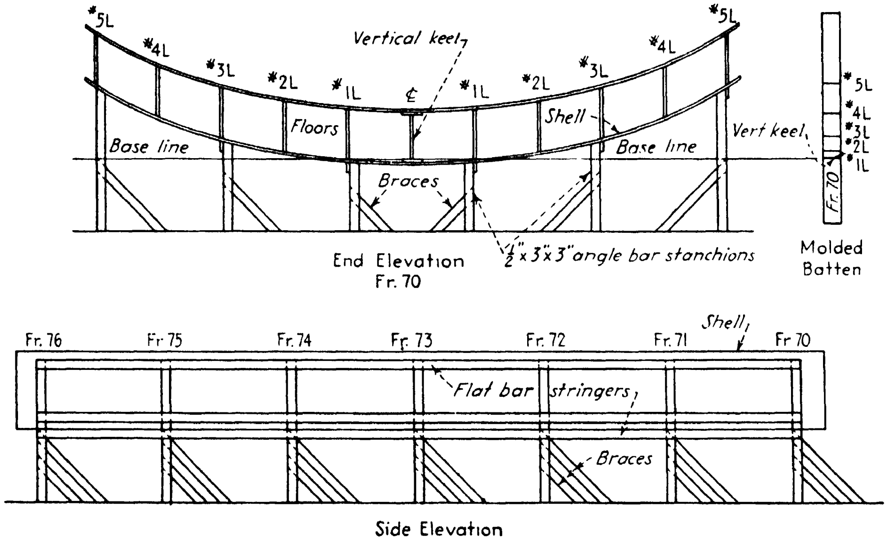


FIG. 196.—Jig for the subassembly of bottom-shell and innerbottom section.

to give the location of the fore-and-aft flat-bar stringers. If there is any great amount of fore-and-aft shape, it may be necessary to shape the fore-and-aft stringers on a coal press or furnace to templates supplied by the mold loft.

At the right side of the end elevation shown in Fig. 196, it will be observed that the batten obtained from the mold loft gives the height above the base line at longitudinals 1, 3, and 5. If the height varies at the other frames of the assembly, a batten similar to that shown in frame 70 must be obtained for each frame, although it is not always necessary to have individual battens because the heights of longitudinals of several frames can all be shown on the same batten.

After the height of the fore-and-aft stringers has been established on the uprights, the work of installing stringers can proceed. When the stringers have been installed to the height of the spots on the uprights, they should be rechecked to ensure their being correct. When this has been done, the jig can be welded and is ready for the installation of the bottom plating.

Bottom Shell Plating. In setting the bottom shell plating into the jig, frame stations marked on the plating when laid off for fabrication must be brought in line with the frame stations in the jig. At the same time the keel or center plating must also be brought into alignment with the center line of the jig. The plates can then be tack-welded to the jig, after which seams can be made ready for automatic or hand welding. After all welding has been completed on the bottom plating, the locations of the longitudinals and frames are brightened up on the inside of the plating.

The job is now ready for the shipfitter to install vertical keel floors and longitudinals. Any additional shoring and bracing needed by the shipfitter in order to hold the structure in alignment is usually installed by the shipwright.

When the vertical keel, floors, and longitudinals have been installed on the bottom plating and tack-welded and braced in position, the inner-bottom plating can be laid into position. This is done in the same manner as the bottom shell plating, and by the ship fitter.

Welding. When the assembly is completely tacked and ready for production welding, the shipwright will note from time to time as welding progresses any serious distortion that may result from welding or improper welding procedure. If the assembly tends to break loose from the jig, he can, by means of weights or turnbuckles and straps, secure it more firmly to the platen and jig to resist some of this distortion. The correct welding procedure in such a case would be to make all vertical welds first and then follow with the welds at the top of the floors and longitudinals working from the center line to each side, the upper welding being carried at least the distance between longitudinals ahead of the welding at the bottom of the floors. Somewhat the same procedure should be followed in welding in a fore-and-aft direction; that is, the top welds should be carried ahead of the bottom welds on the longitudinals and floors.

The jig shown in Fig. 197 is for the stern welding of a ship, involving the rudderpost casting and skeg. It is constructed of 12- by 3-in. channel and 4- by 4-in. angles. Unlike the jig shown in Fig. 196, for which the stringers supporting the assembly were run fore and aft, the supports for this jig are transverse.

Transverse Frames. From templates obtained from the mold loft, the transverse frames can be set at the frame locations desired and a convenient water line established on them, together with the center line of the ship. The frames can then be set at frame stations established on the foundation for the jig and in accordance with an established line from the top of the casting and rudder gudgeons. The frames are now set on the center line, plumbed, and securely braced, as shown, with 12-in. channels and flat bar.

The first operation on this assembly is to set the casting into position; after this, the bottom plating is set on the jig to suit the center and frame lines, and work above this is carried on in the same manner as for the bottom subassembly.

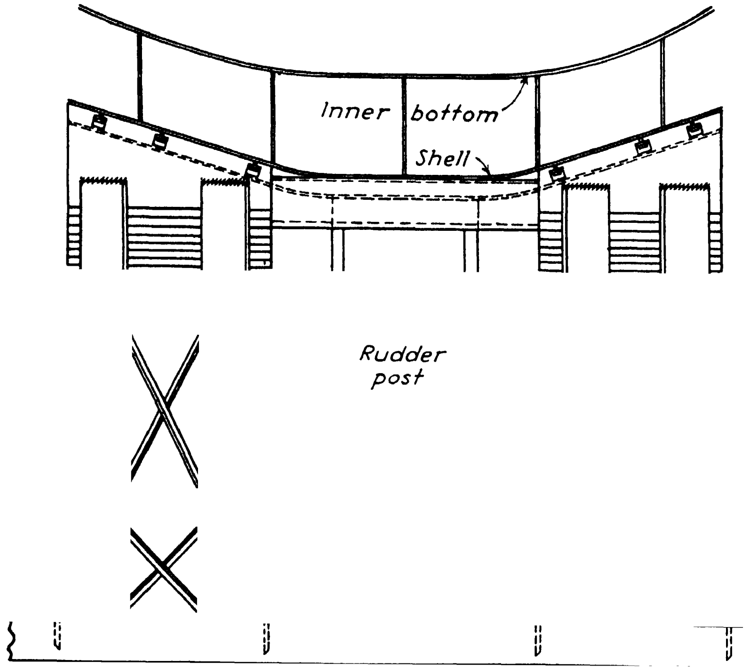


FIG. 197.—Jig for a stern weldment.

Inverted Jig. The jig shown in Fig. 198 is for an assembly toward the afterend of the ship and is built in an inverted position. It can be built from heights obtained from the body plan and applied on uprights established on frame stations at given distances from the center line. It will be observed from the plan view that the knuckles vary in distance from the center line. This makes the jig appear complicated, though actually it is not.

From the side elevation it will be observed that stringers have been run at the top for the bottom or rider plate of the inner-bottom plate and at the knuckle and top of the inner-bottom plating. The uprights supporting this jig are provided with slotted holes so that adjustment may be made from time to time should settlement or movement in the jig occur.

In the building of this subassembly, the inner-bottom plating is the first item to be laid on the jig, with the top side down. When the inner-

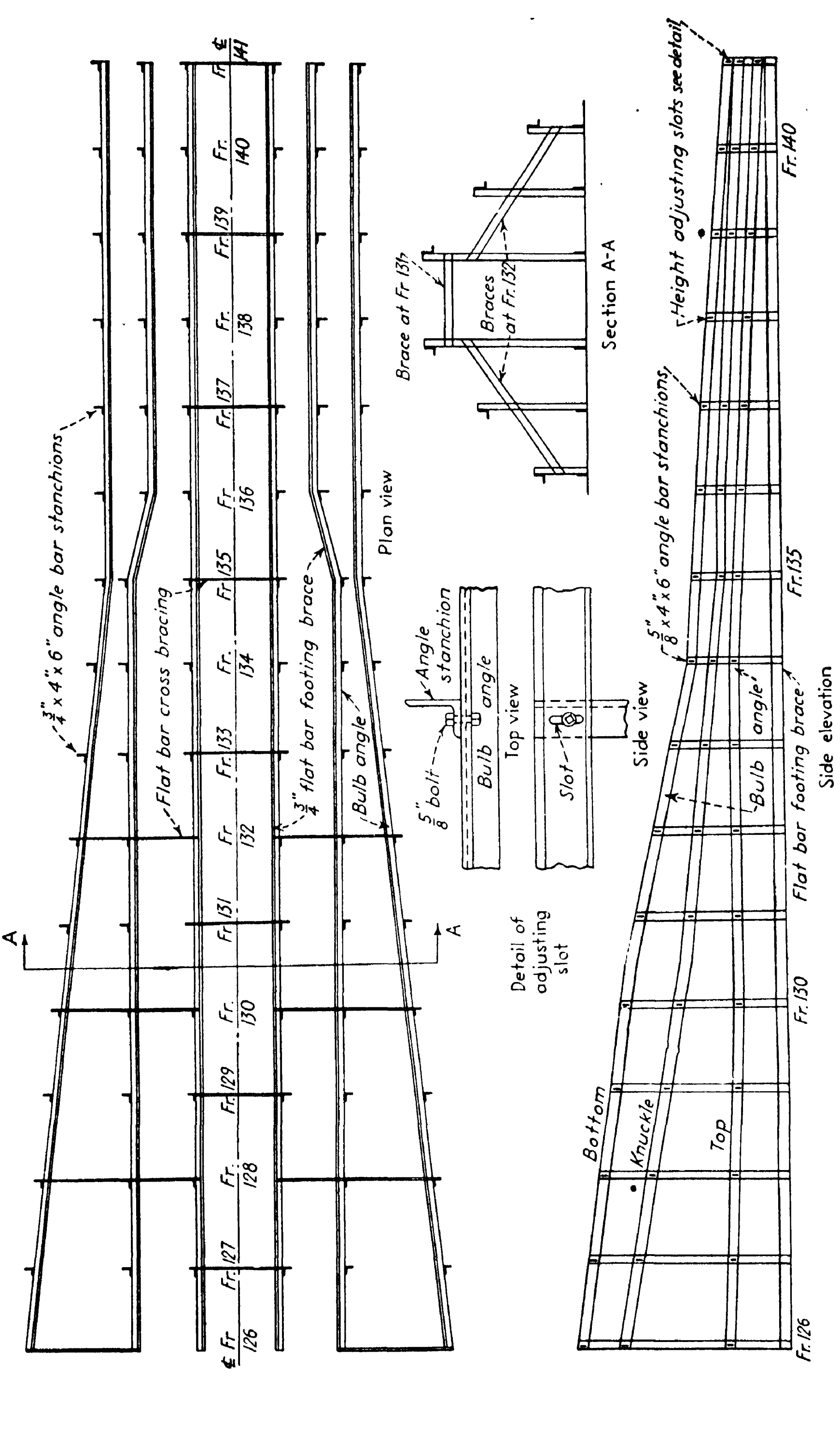


FIG. 198.—Jig for an assembly at the afterend of the ship.

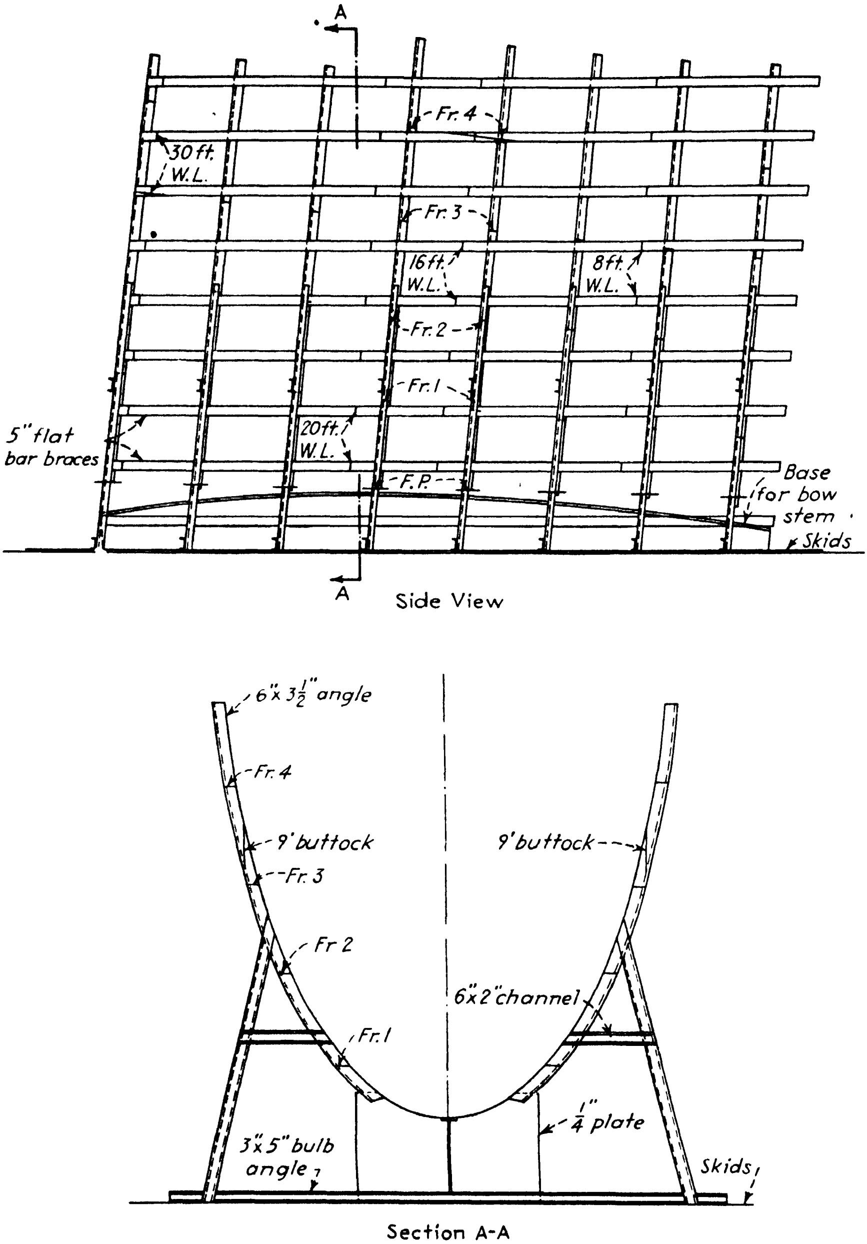


Fig. 199.—A bow jig.

bottom plating has been set and welded, the center vertical keel, floors, and longitudinals are put in position. After this, the shell plating is placed on top and set.

In setting the longitudinals and floors, extreme care must be exercised by close cooperation with the ship fitters, to ensure the correct position. If this is not done, difficulty will be experienced when this assembly is lined up with adjacent assemblies in the ship. The longitudinals, in

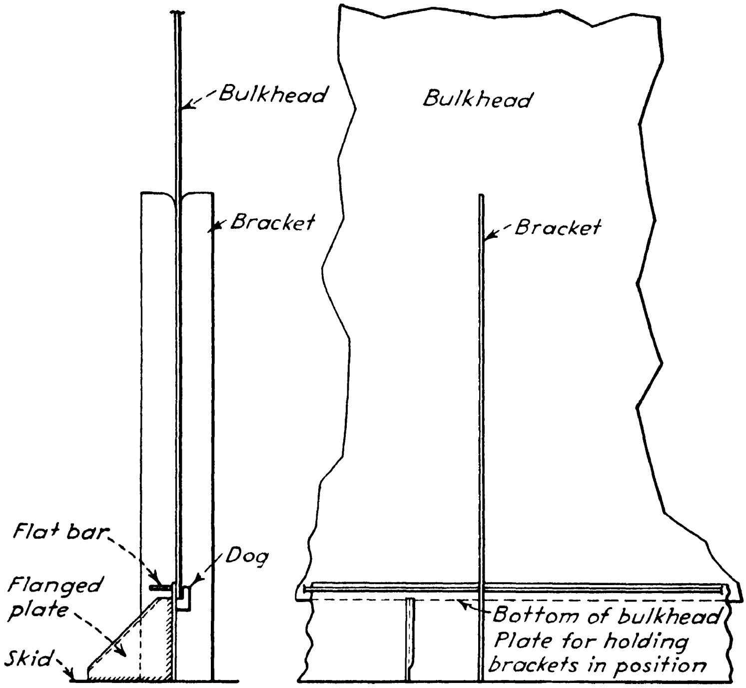


FIG. 199a.—Brackets for erection of bulkheads or superstructure assembly.

particular, should be checked both at the top and bottom by plumbing and checking to the center line against the mold-loft offsets. Care must be exercised in observing and correcting any distortion when the assembly is being welded, so that the keel will be straight when the assembly is installed in the ship.

In building jigs for subassemblies, the shipwright must be familiar with lines and offsets to be able to visualize the points at which difficulties will be encountered if the assembly is not built to designed dimensions.

Positions of Subassemblies. Subassemblies may be built in various positions. Figure 199 shows a jig for a portion of the bow of a vessel built with the stem down. In building the jig, the transverse forms are inclined so as to keep the assembly as low as possible. The transverse forms may be set at any angle desired, provided that they are all set to the same angle. The frame lines are then established at right angles to the position of the transverse forms. Since this is only a portion of the bow, care must be exercised at the connecting ends in order that the two assemblies will line up when placed together.

In general, the best conditions for subassembly are obtained by building in an inverted, or upside-down, position. However, many assemblies can be built in the position in which they set in the ship. This is particularly true of the superstructure and deckhouses, which are first sub-

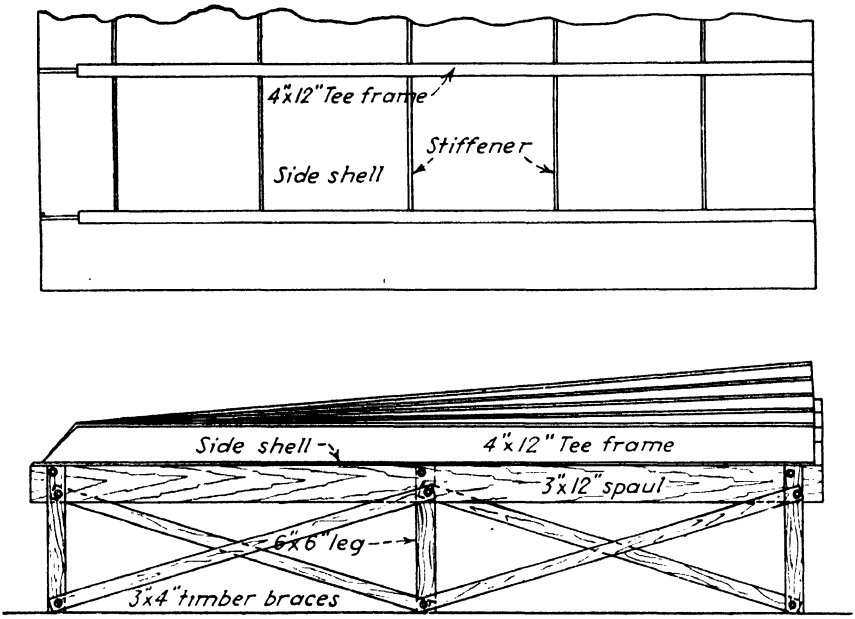


FIG. 200.—Jig for subassembling side shell.

assembled flat on the skids and then set up and welded together as a unit in the same manner as they would be built on the ship piece by piece.

Figure 199*a* shows the method of holding the sides of the deckhouse and bulkheads in position on the skids, eliminating the necessity for bracing each piece as it is set up. It will be observed that the bracket and the lower plate, which has been stiffened with a flat bar, are simply for the purpose of setting the bulkhead to its proper height. The dog on the inside is used as a means of adjustment in the event that there is settlement of the skids. When the deckhouse is completely assembled and welded, it can then be lifted vertically out of this jig and another assembly immediately started in the same jig.

Side shell is usually subassembled with the outer side lying on the platen, or jig, and the frames and stringers in turn welded to it. Figure 200 shows a very simple side-shell subassembly.

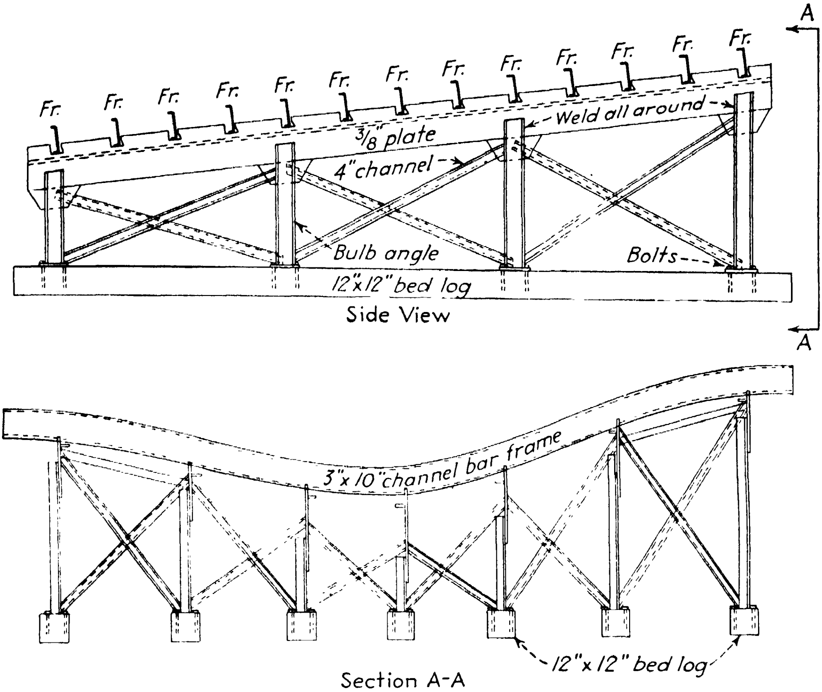


FIG. 200a.—Jig for subassembling side shell.

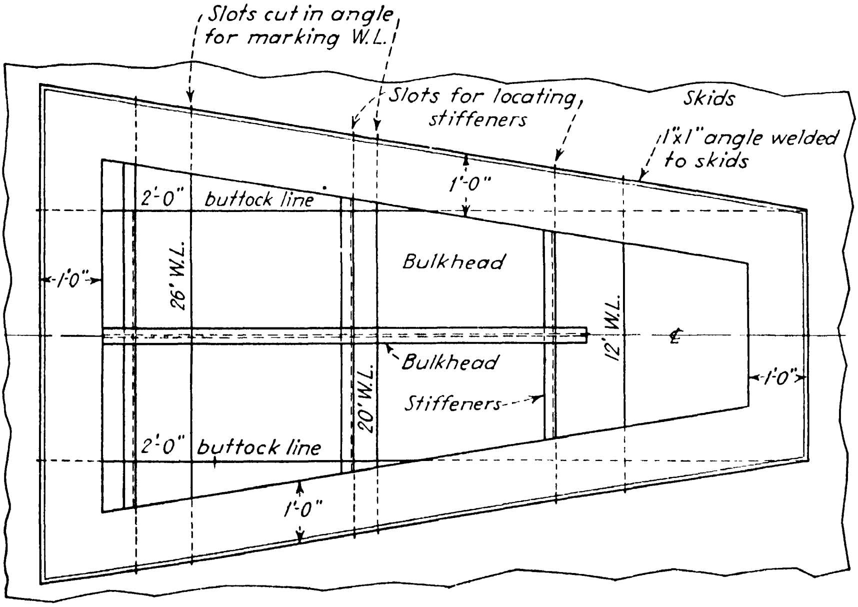


FIG. 200b.—Assembly jig for bulkheads.

The jig in Fig. 200*a* has considerable shape. It is built to any desired plane and height above the assembly skids, or platen.

Where a considerable number of similar subassemblies are required, a jig similar to that shown in Fig. 200*b* can be established on top of the welding platens.

To facilitate laying off a flat assembly, a boundary consisting of 1- by 1-in. angle is welded to the platen 12 in. from the outer edges of the bulkhead or assembly. From the mold-loft templates, the position of stiffeners and other attachments to the bulkhead is projected out and marked on the vertical flanges of the angles. A slot is then cut with a hack saw at each of these intersections. These lines can then be reproduced in exactly the same position on every assembly. The periphery of the bulkhead is cut by measuring from the established distance (12 in.) from the boundaries of the jig.

Before subassemblies are sent to the ship for erection, all working lines necessary to align them in the ship, such as center lines, water lines, or frame lines, should be checked to see that distortion from welding does not pull them out of position and thus cause them to be useless in setting. In handling subassemblies from the platens to the ship, much stiffening and ribbanding are sometimes necessary to prevent buckling. This type of stiffening will be discussed in Chap. XI.

CHAPTER X

SHORING AND BRACING

In almost every line of work performed by the shipwright some shoring and bracing are required. It is therefore necessary for the shipwright to know the best and safest methods of doing this work.

Shores may be divided into four groups, as follows:

1. Supports acting as columns.
2. Diagonal spur shores.
3. Diagonal shifting shores.
4. Diagonal lifting shores.

SUPPORTS ACTING AS COLUMNS

Bottom Shoring. In shoring the bottom of the ship, either round or square timbers may be used. The arrangement of bottom shoring is dealt

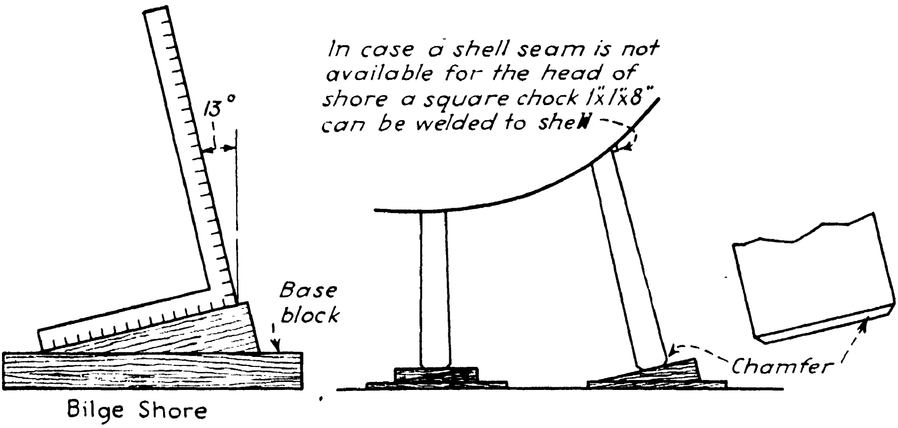


FIG. 201.—Outside bilge shores.

with in Chap. XIII. Therefore, only the method of properly cutting and setting up shores will now be discussed.

In setting shores to support the ship, they must be placed against the hull under frames, bulkheads, or longitudinal strength members. If placed where no support is given to the shell plating, they are likely to buckle the plating as the ship tends to settle.

Various lines of shores may be set at different angles. However, all shores in a row should be set at approximately the same angle to create uniformity of support as well as good appearance.

The foot of each shore should be *cut square or at right angles to its center.* The foot of all shores should be chamfered, as shown in Fig. 201, to afford better draw on the wedge and to avoid splitting of the sides of the shore.

On ships built on a declivity, the shores should be raked slightly forward at the top in order to exert a pressure forward as well as upward because of the tendency of the weight to slip aft. This is generally at the rate of ½ in. rake per foot.

Where the bottom of the ship is flat, the wedges under the shores are usually *married;* that is, one wedge is placed on top of another.

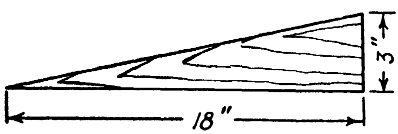


FIG. 202.—Shore wedge.

Toward the bilge of the ship only one set of wedges is generally used, as shown in Fig. 201. However, if more rake is desired on the shores, another wedge can be placed on top of the single set, thus throwing the top further inboard.

To create a smooth surface for driving up the wedges and to allow the shores to settle on flat-grained timber similar to the keel track blocking, a base block is ordinarily used under the bottom of the shores, as shown in Fig. 201. This base block may vary in thickness from 2 to 6 by 12 in. in width to 24 in. in length.

On top of the base block, oak wedges 3 in. wide, 18 in. long, and 3 in. thick are generally used. Wedges are tapered from the 3-in. width to a featheredge, as shown in Fig. 202.

Cutting Shores. In cutting shores an allowance must be made for the base block and wedges. Several methods of measuring the length of shores may be used. The measuring rig, or rod, shown in Fig. 203, can be conveniently used where the shores are short under the bottom of the ship. It will be observed that this rig is provided with wing-nut bolts. The cut of the head and foot of the shores can be accurately determined by adjusting the crossbars to suit the angle of the shore.

The length of the shore can be obtained by placing the bottom of the rig on top of the wedges or by making allowance for the thickness of the base blocks and wedges and then sliding the rod until it bears against the bottom of the ship. The wing nuts can then be tightened on the slip rod, and the rig set on the shore for marking and cutting.

Another method for obtaining the length of shores, shown in Fig. 204, is by means of a framing square set on top of a base block and wedge. With a piece of template cut to suit the shape of the ship at the location of the head of the shore, draw a line square from the wedge across the template. With a tape, measure from the top of the wedge to some convenient pitching spot on the template, and set the measurement down for transferring to the shore. The length and cut of the shore can be obtained by transferring this measurement to the shore and by holding the template the proper distance from the bottom of the shore to the pitching spot with the straight line held in the center of the shore. This will determine the rake of the cut at the top. Several shores may be cut from the same template by simply recording the measurement for each shore.

In cutting any number of shores away from the ship, the number of the line of shores and its frame location should be marked on the shore, together with the side of the ship for which it is intended. This will identify shores at all times, particularly when they have to be moved for riveting, welding, or chipping and calking.

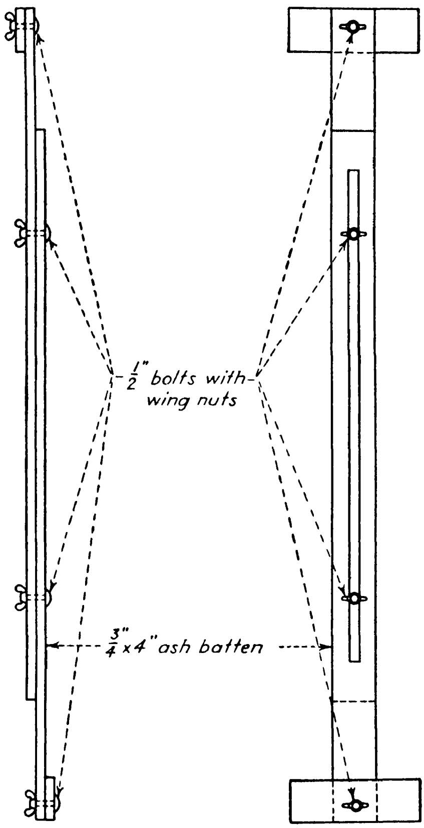


FIG. 203.—Shore measuring rig for bottom shores.

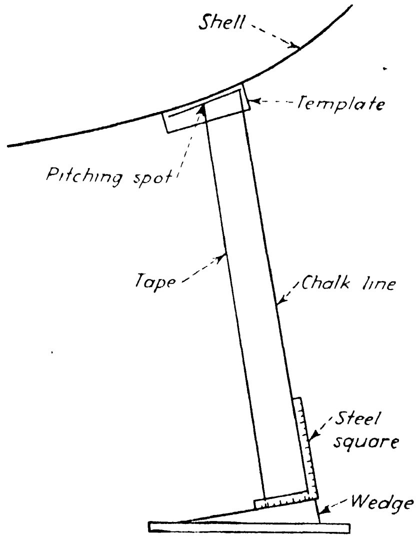


FIG. 204.—Measuring shore with tape and framing square.

Setting Up Shores. Shores may be set up with a block and tackle or with the use of overhead cranes, as shown in Fig. 205. A pinch bar is a convenient tool for prying or lifting the shores in the installation of the base blocks and wedges or in setting up the shores on top of the base blocks and wedges.

Shores are generally heavy and awkward to handle. A study of Fig. 206 will be of assistance in understanding the problem. *A*, Fig. 206, shows the shore set up on the base block and wedges. This is done by marrying two wedges close to the edge of the shore and canting the shore back until it rests on top of them. The shore can then be straightened up until it is fixed in its approximate location at the top against the shell.

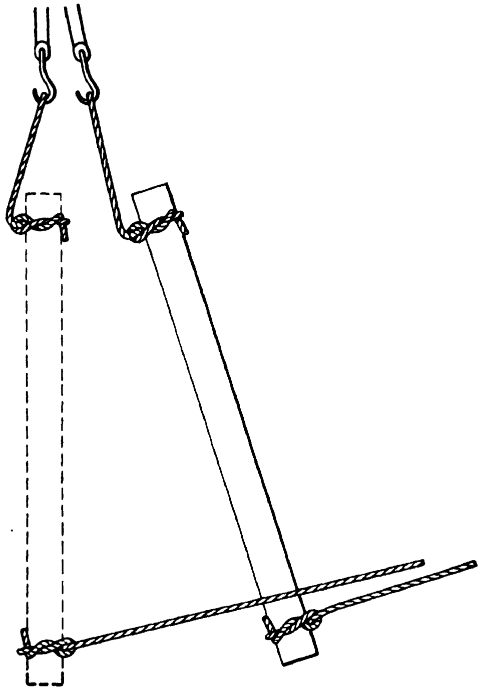


FIG. 205.—Setting up shores with the overhead crane or tackle.

The wedges should always be left slack so that no difficulty will be encountered in straightening up the shore. When the shore has been straightened up, two additional wedges can be married under it and

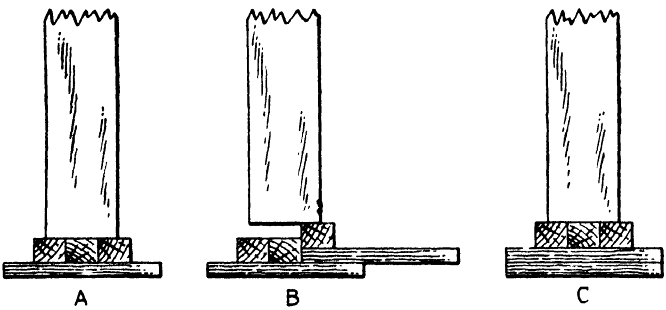


FIG. 206.—Lifting a shore with blocks and wedges.

tightened up so that the shore will bear against the shell of the ship. The other pair of wedges can then be installed and the pair that was first put in straightened and tightened up.

B, Fig. 206, shows a shore that is slightly short of its desired length; it will be necessary to add an additional base block so that it may work satisfactorily. A piece of the same thickness as the additional base block is set under the shore and the wedge on top of it. These wedges are tightened up until the shore bears against the shell. The two other pairs of wedges are then removed, and the base block and the wedges just removed are placed under the shore. The base block can then be driven against the temporary piece placed under the first pair of wedges, which will displace it. After this, all wedges can be straightened and tightened up, as shown in *C*, Fig. 206.

Placing Wedges. The proper method of placing wedges under shores is shown in Fig. 207. *Wedges should always be placed in an athwartship direction* to afford room for removal and to facilitate knocking out shores for launching.

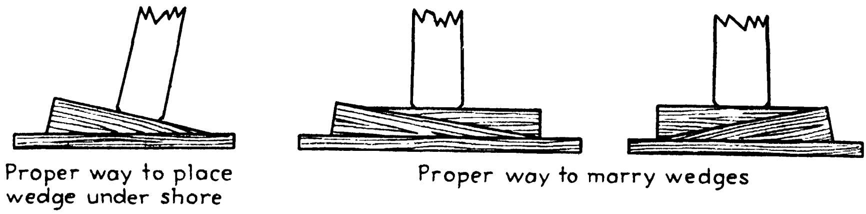


Fig. 207.—Proper method of placing shores under wedges.

A wedge, when cut, usually has one side with the grain straight, the tapered side being cross-grained, owing to the tapered cut. In using the single set of wedges, the cross grain should always be placed against the base block, not against the shore. When wedges are married under the shore, the cross grain of the wedge should always be placed against the straight grain of the wedge being used with it. Otherwise, because of the cross grain, the wedges will jam and not tighten up in the way they should.

Sizes of Shores. The sizes of shores used under the bottom will, of course, be determined by the weight to be supported.

On small light ships, shores may be as small as 6 by 6 in., if they are not too long, as shown in Fig. 208. Timbers 8 by 8 in. in cross section are also used for bottom shoring.

On ships of considerable size and weight, bottom shores should be not less than 9 in. in diameter at the small end, or top. If shores are to be of considerable length, it is best to use 12- by 12-in. timbers or round timbers 12 in. in diameter, for they are less likely to whip or bend when they are subjected to weight.

Tightening Up Shores. Mauls of not less than 12 lb. should be used for tightening up and setting shores. Lighter mauls will tend to destroy the wedge by mushrooming and splitting it.

When wedges are married under shores, one maul should be used for backing up the bottom wedge, while the upper wedge is being driven.

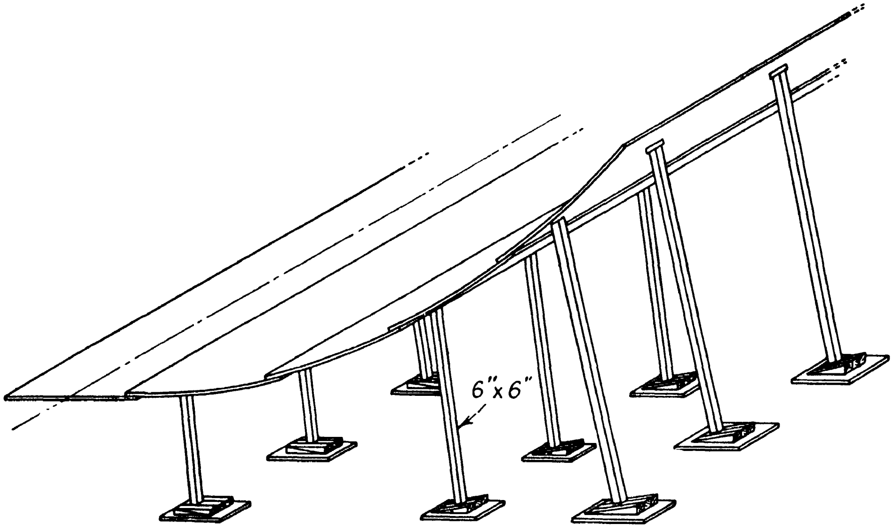


FIG. 208.—Light shoring under a small vessel.

INSIDE SHORING ACTING AS COLUMNS

Inside shoring acting as columns is installed in the same manner as outside shoring. Generally these shores are set vertically with wedges married under them. A base block is not always necessary, although where shores are used to support heavy loads, base blocks should be used, so that, in the event that the shore is difficult to remove, the base block can be split out with steel bursting wedges.

The size of these shores is, of course, governed by the load that they are expected to support, and it can be ascertained from Table IV, page 121, showing sizes of timbers to be used as columns.

DIAGONAL SHORES

Diagonal Spur Shores. Diagonal spur shores are generally used for bracing and holding the structure of the ship in alignment. These shores are ordinarily set at an angle of 45 deg., or half pitch, when a framing square is employed for cutting and obtaining their length.

Timbers for such shores may be 6 by 6 in. or 8 by 8 in. However, extremely heavy loads may require heavy timbers. Figure 209 shows spur shoring with clips welded at the top and bottom of the shores. A wedge is used between the foot of the shore and the clip at the bottom for tightening up.

Diagonal Shifting Shores. For shifting or moving the structure in a desired horizontal direction, shifting shores similar to that shown in Fig. 210 are used.

This shore is set at an angle of 37½ deg. or 5⁄12 pitch, on the framing square. Generally, 6 by 6-in. or 8- by 8-in. timbers are used.

Diagonal Lifting Shores. For lifting the structure of a ship, instead of jacks or vertical shores the diagonal lifting shore shown in Fig. 211 can be used.

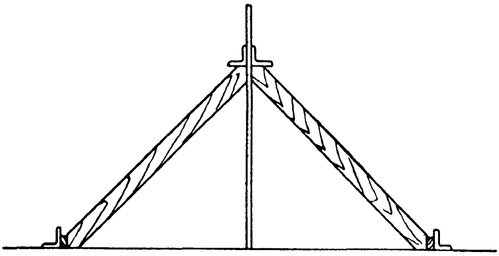


FIG. 209.—Spur shores.

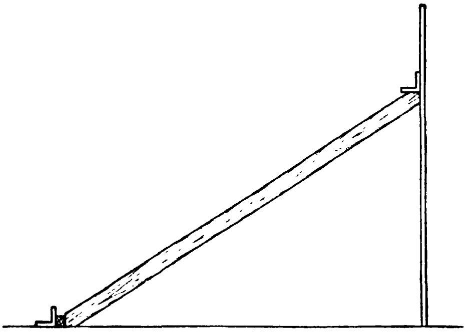


FIG. 210.—Shifting shore.

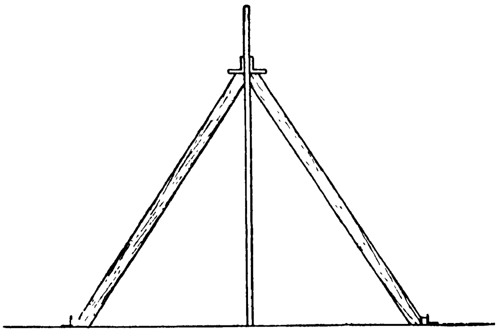


FIG. 211.—Lifting shore.

This shore is set at an angle of 56 deg., or 5⁄8 pitch, on the framing square. Timbers 6 by 6 in. or 8 by 8 in. are used.

Cutting Diagonal Shores. With a little practice, diagonal shores can be cut very readily with the use of the framing square. A tape for obtaining the length is not necessary when this is done. From Fig. 212

the length per foot run can be obtained for each type of shore, provided that the length of one leg of the angle formed by the shore is known.

From the framing square on the body of the blade, the length per foot may be found under 10 in. for a shore having a 5/12 pitch.

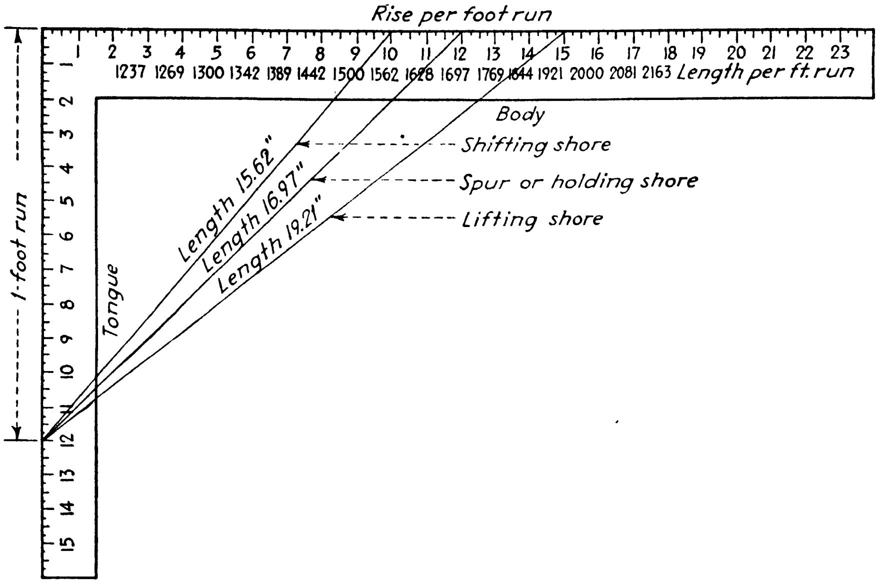


FIG. 212.—Cutting shores with framing square.

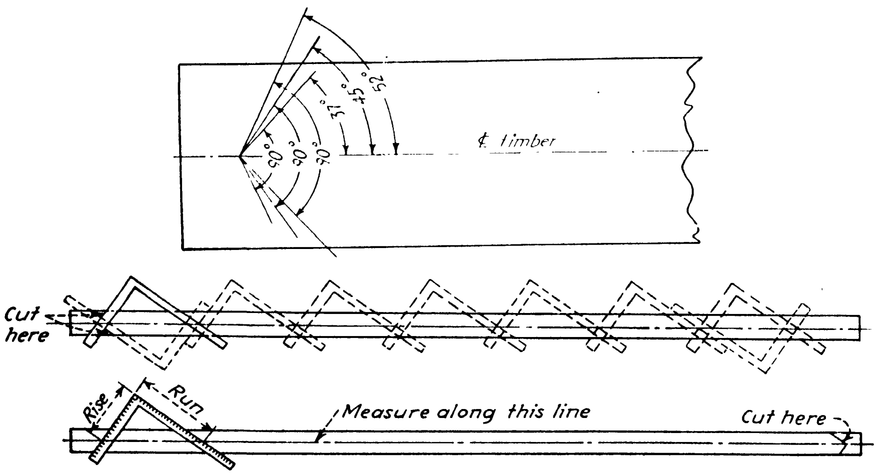


FIG. 213.—Method of laying off shores with framing square; also angle of cut at top and bottom.

For a shore having a 1/2 pitch the length per foot run may be found under 12 in.

For a shore having a 5/8 pitch the length per foot run may be found under 15 in.

Example. Shore desired is 45 deg., or $\frac{1}{2}$ pitch. Height of head is 10 in.

Look under 12 in. on the square. The first figure is 16.97, or 16.97 in. per ft. run.

16.97 in. × 10 ft. = 14.14 ft., or 14 ft. $1\frac{3}{4}$ in., the length of the shore.

The shore is measured and laid off as shown in Fig. 213.

The same method is used for measuring shores of other pitches. The angle of the cut at the top and bottom of the shores will vary, as shown in Fig. 213.

Fastening Shores. Shores on the inside of a ship should always be fastened by some means at the top so that they will not fall when jarred loose from vibration or when struck by loads on the crane. Flat-bar clips welded to the structure of the ship and bolts through the head of the shores or boat spikes driven into the head of diagonal shores are generally used for this purpose.

TENSION BRACING

Tension bracing consists of steel straps or wire rope used with turnbuckles, as shown in the case of the bucking brace in Fig. 214 and the guying brace on a ship bow section illustrated in Figs. 215 and 216.

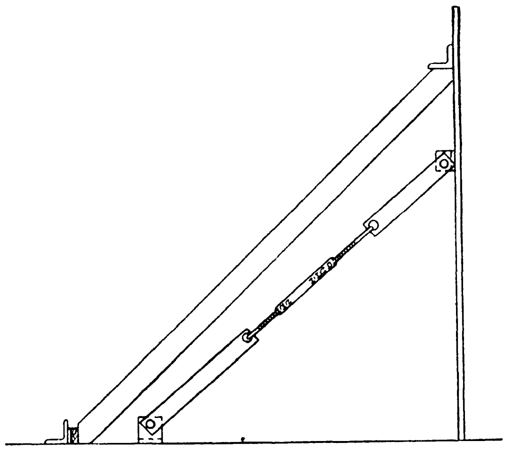


FIG. 214.—Bucking brace.

Where straps and turnbuckles are used to obtain a direct pull in both directions, the most suitable angle for installing braces is one of approximately 45 deg. This is not always possible if the structure being braced is of considerable height, owing to the lack of space and tendency for the shore to bend if too long.

Angles and flat-bar clips used for securing straps against the structure of the ship should be welded in accordance with the load to which they will be subjected (see the discussion of the amount of welding necessary for such clips in Chap. VIII).

Bucking Brace. In using a bucking brace on the structure where only one side of the bulkhead can be used for shoring, a timber shore can be employed in conjunction with a turnbuckle and flat-bar strap, as shown in Fig. 214.

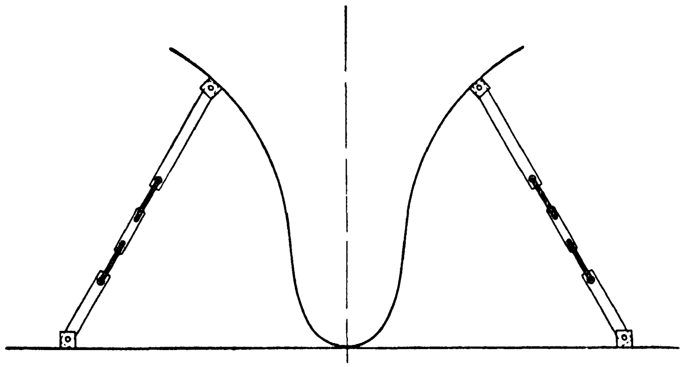


FIG. 215.—Flat-bar tension brace.

These shores are usually set at an angle of 45 deg., or ½ pitch.

For the purpose of moving heavy loads, the steamboat jack shown in Fig. 217 is more suitable than a turnbuckle.

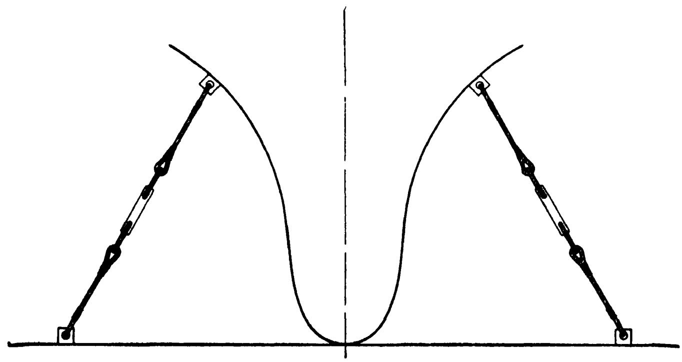


FIG. 216.—Wire-rope tension brace.

In bracing or shoring various structures on the ship, it may be necessary to "X" the shores or braces, that is, to cross in X-fashion in order to hold the structure to its desired lines. This bracing is installed in the same manner as and will act similar to outside bracing.

Size of Wires or Flat-bar Straps for Bracing. In determining the size of wires or flat-bar straps to be used for bracing in erecting bulkheads, consideration must be given to the size of bolts, flat bar, or wire rope that might be used for safely holding the bulkhead in position.

For practical purposes, bulkheads 30 ft. high and weighing 20, 30, and 40 tons, respectively, set on a declivity of ½ to ¾ in. per ft. and

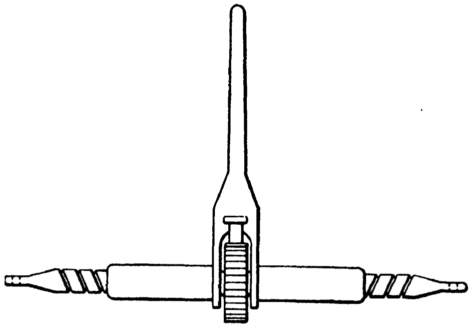


FIG. 217.—Steamboat jack.

allowing for a wind velocity of 60 m.p.h. in all cases, the following figures may be safely used:

Weight of bulkhead, tons	Dia. of bolts, in. (3 guys)	Size of cable, in. (for 3 guys)	Size of flat bar, in. (for 3 guys)
Under 20	½	¼	¼ × 3
20 to 30	⅝	⅜	5/16 × 3
30 to 40	¾	½	⅜ × 3

The foregoing figures are based on three braces on each side of a transverse bulkhead. Braces for larger or smaller bulkheads may be correspondingly increased or decreased.

Turnbuckles used in conjunction with flat-bar or wire-rope braces are 1 in. in diameter.

REVIEW

Preparations and Procedure for Shoring the Ship's Bottom

A ship when on the stocks is resting on a very narrow foundation in proportion to its size. This foundation is too narrow to support the ship in an upright position. Shores are used to keep the ship in proper alignment and in an upright position.

Shores must be placed under frames and bulkheads. If placed where there is no stiffening on the inside of the shell, they are likely to buckle the bottom shell. Several rows of shores may be required, depending upon the size and weight of the ship.

All shores should be kept in line and have about the same amount of strut. This gives a much better appearance to the job.

For practical purposes bottom shores are calculated to carry approximately 10 tons each.

CHAPTER XI

RIBBANDS, FAIRING, PULLING, AND JACKING

RIBBANDS AND FAIRING

In the construction of a ship it is necessary to use ribbands for various purposes. Ribbands may be made of wood, steel flat bar, railroad rails, or structural shapes.

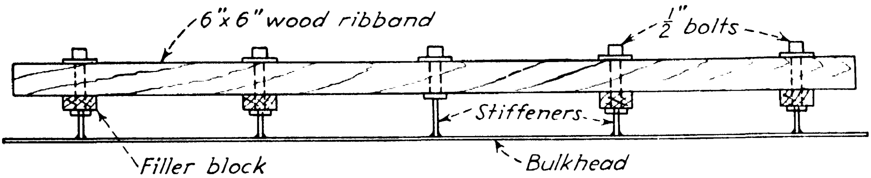


FIG. 218.—Wooden ribband showing filler blocks where depth of stiffeners varies.

Wood Ribbands. Wood ribbands, generally 6 by 6 in. in cross section, are used to a large extent in stiffening bulkheads and subassemblies so that they may be carried safely to the ship by the cranes without danger of collapsing. The size of a subassembly governs the number of ribbands necessary to stiffen it for handling. For example, on large

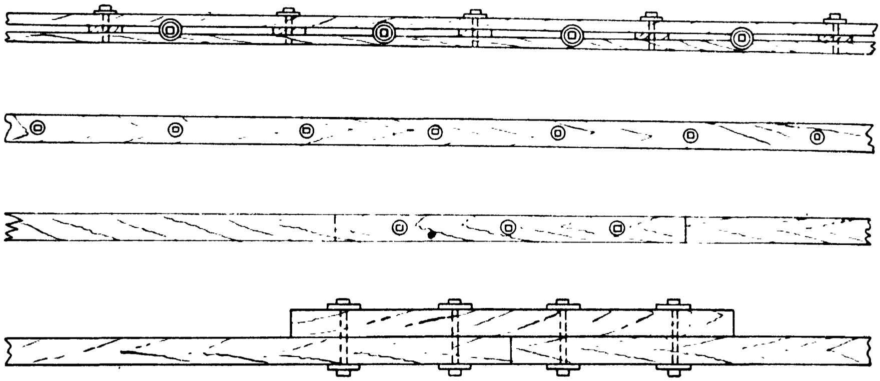


FIG. 219.—Various types of ribband used on subassemblies.

bulkheads extending from the keel to the weather deck, at least three horizontal ribbands are required to prevent buckling. Between-deck bulkheads need only one line of ribband through the vertical center. These ribbands are usually placed on the stiffener side of the bulkhead and are held in place by means of bolts welded to the stiffeners and extending through the ribband. Where stiffeners differ in depth, filler blocks, or shims, are placed between the low stiffeners and the ribband, as shown in Fig. 218.

Where it is necessary to use more than one length of timber, the timbers should overlap each other by not less than 6 ft. If timbers are butted, a butt strap should be installed across the butt. Figure 219 shows various types of wood ribbands used on subassembies.

Rail Ribbands. The arrangement for this type of ribband, commonly used for stiffening subassemblies, is about the same as for the wood

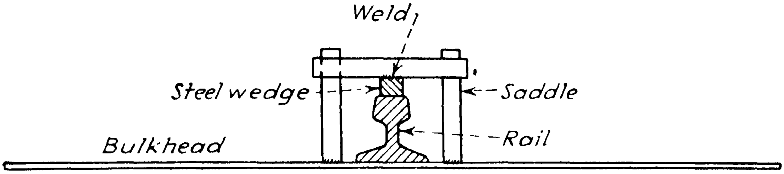


FIG. 220.—Railroad rail ribband with saddle plates.

ribband, but it is much stronger and will stand a great deal more abuse in being moved from job to job. Installation is by means of saddle plates (Fig. 220), welded to the web of the stiffeners with enough clearance at the top of the rail to enter a steel wedge. After the saddle plate is welded to the stiffener, steel wedges are inserted between the saddle and rail and driven hard up. When more than one piece of rail is necessary, the rail should be lapped by, as in the case of the wood ribband.

Structural Shapes. Obsolete types of structural shapes may be utilized as ribbands for the purpose of stiffening and straightening bulkheads. When ribbands are being installed, the bulkheads should be about in a plane, so that it will not be necessary to bend the ribband, which is also utilized to help keep the bulkhead straight in the ship until other subassemblies are attached to it.

Fairing Ribbands. A type of ribband commonly used, both on subassembly and the ship, is the *fairing ribband.* Fairing ribbands are either single or double and are usually made up of flat bar of various cross-sectional sizes.

Single Fairing Ribband. Single fairing ribband for decks, bulkheads, and shell of light plating is used in the vicinity of the welded seams for the purpose of reducing buckling during welding. It can be applied in either of two ways. If the plate is of light material and the buckles run too badly, a pinch bar and a flat bar with a hole burned in one end, as shown in Fig. 221, can be used very satisfactorily. If the material is too heavy to straighten by the first method, a saddle and wedge may be used, as shown in Fig. 222.

The flat bar should be held as nearly at right angles to the plating as possible, because, if it is allowed to buckle sideways, it loses its efficiency. To prevent this, a wedge can be driven between the sides of the

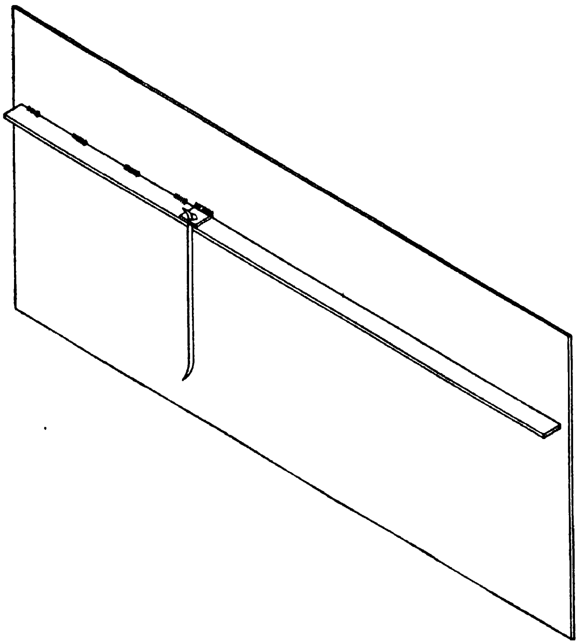


FIG. 221.—Method of installing flat-bar ribband with a pinch bar and flat bar having a hole burned in one end.

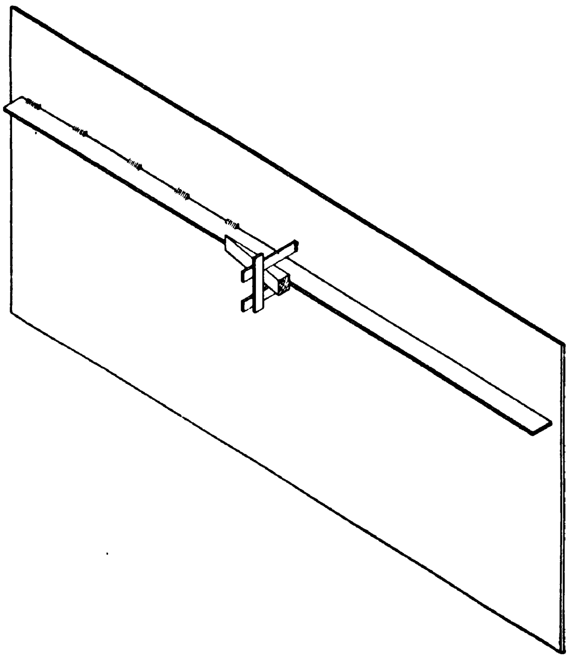


FIG. 222.—Method of installing flat-bar ribband where saddles and wedges are necessary.

saddle and the flat bar to straighten it up until the ribband is tacked on each side.

These ribbands are usually secured to bulkheads and decks in the following manner:

For light- and medium-weight plating, ½- by 4-in. flat bar with ¼- by 2-in. tacks on each side on 2-ft. centers.

For medium to heavy plating: ½- by 6-in. to ¾- by 6-in. flat bar secured with ½- by 3-in. tacks on 2-ft. centers.

When ribband is applied to floors, web framing, or bulkheads at the edges, the welds should be staggered. When it is applied close to shell or decks where it will be difficult to chip off, tacks should be used only on one side so that it can be chipped loose.

Double Fairing Ribband. Double fairing ribband is used on the shell of a ship to fair the seams and to hold them fair for welding. If seams are butt-welded, the ribband is applied as shown in Fig. 223. It will be observed that the ribband straddles the seam and is secured by means of bolts through holes burned and reamed in the butt. A flat-bar clip on top of the ribband draws it against the shell when the bolt is pulled tight. Sufficient room is provided between the two flat bars to permit welding the seam.

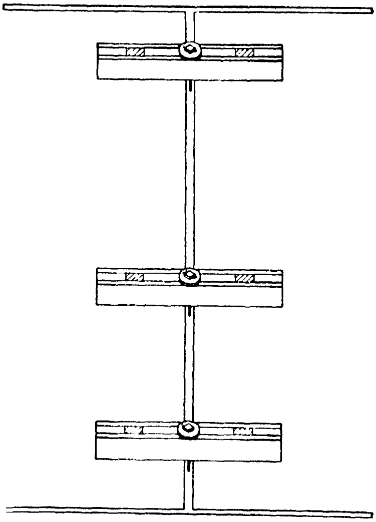


FIG. 223.—Double-fairing ribband used on shell butts.

After the seam has been welded and allowed to cool, the ribband is removed and the boltholes are then welded up.

On a welded lap seam the ribband is applied as close to the edge of the upper plate as possible. The bolt that draws the ribband tight is usually passed through holes drilled in the lap on 2-ft. centers.

The type of bolt used is a round rod threaded on both ends. One end of the rod has sufficient thread to permit of a nut on the outside of the shell as well as one on the inside. The inside nut is tightened until the seam is drawn tightly together. A flat clip is then placed over the ribband, and the bolt is tightened up to draw the ribband hard against the shell.

Any unevenness in the shell of the ship will be quite evident after this ribband is installed properly.

It is sometimes necessary to ease off bulkheads or webs where kinks occur or to wedge the shell out where it is hollow. If the shell is wedged out to any great extent from the inside frames or bulkheads, it may be necessary to fit margins.

The spacing of the bolts in the ribband must be varied as necessary to draw the shell fair. This type of ribband and its use are shown in Fig. 224.

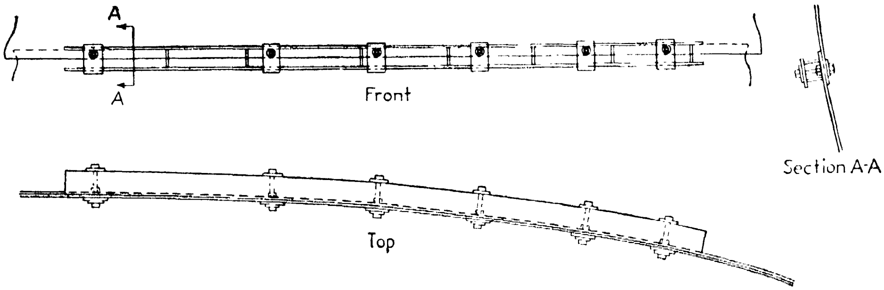


FIG. 224.—Shell-fairing ribband showing spacing of bolts.

Where it is necessary to install ribband on the shell where it takes shape, particularly at the ends, it will be necessary to shape the ribband by cold-pressing or furnacing. This may be done from a template obtained from the body plan or taken from the ship.

Fairing. To reduce the buckled effect caused by contraction of butt welds, strongbacks are used, as shown in Fig. 225. These may be scrap

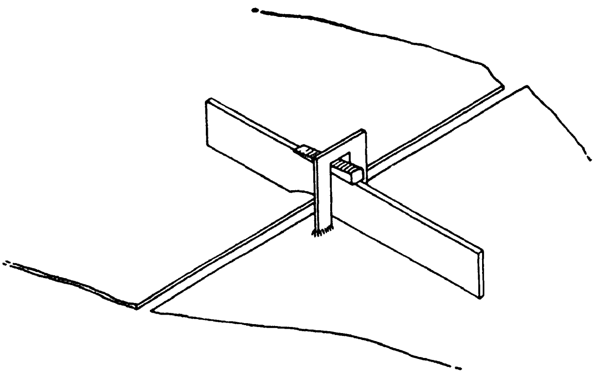


FIG. 225.—Strongbacks used for fairing butt welds.

pieces of flat bar or plate ½ by 4 in. to ½ by 6 in., depending on the thickness of the plating to be welded, and should be placed on approximately 2-ft. centers.

Strongbacks are usually installed by the ship fitter when he makes up the butts preparatory for welding. Additional stiffening is generally installed by the shipwright.

I beams are also sometimes used for the same purpose. They are held in place by means of saddle plates as shown in Fig. 226.

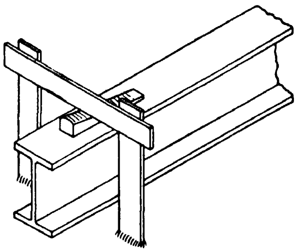


FIG. 226.—I beam strong-back using saddle plates.

PULLING AND JACKING

In pulling and jacking the various subassembled units in the construction of a ship, a large variety of rigs and methods have been devised.

Tools for Pulling. One of the most useful tools for pulling is the steamboat jack, shown in Fig. 217. It can be used in almost any position

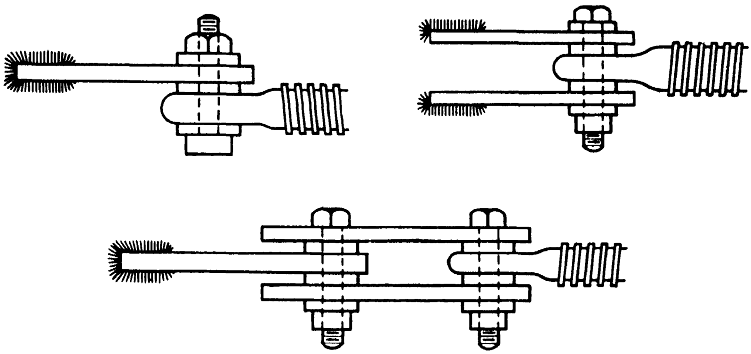


FIG. 227.—Clips used in conjunction with the steamboat jack.

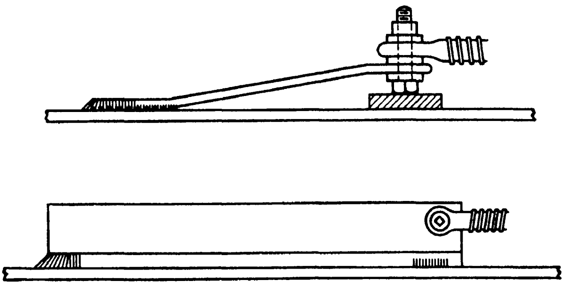


FIG. 228.—Plates used in conjunction with the steamboat jack.

and develops great pulling power. Various types of plate and angle clips can be used in conjunction with the steamboat jack, some of which are shown in Figs. 227 and 228.

Another useful tool that can be utilized for pulling is the ratchet chain hoist, some types of which are shown in Fig. 229. Care must be exercised to avoid overstraining this type of tool. The capacity of these hoists is 6 tons in the largest sizes. The capacity of the steamboat

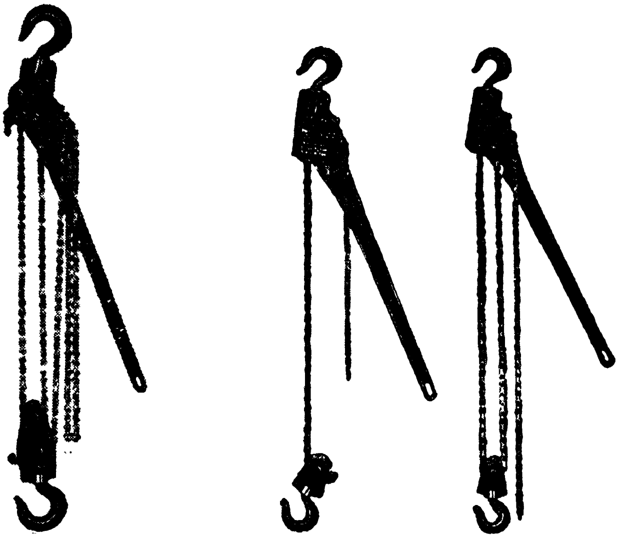


FIG. 229.—Ratchet chain hoists.

jack is 15 tons. The ratchet chain hoist, however, can be used in closely confined spaces on light work.

Jacking. Hydraulic jacks and pumps are used when it is necessary to apply great pressure or push. They can be used to push into place various subassemblies when these are being aligned into position on the

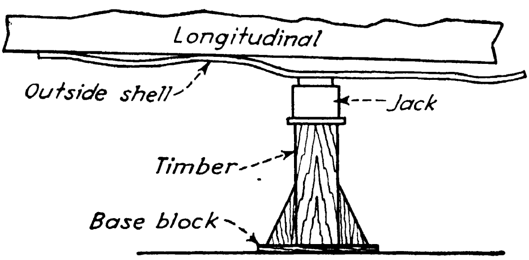


FIG. 230.—Hydraulic jack set up on timber column being used to push up bottom shell plating.

ship. Hydraulic jacks may be either water or oil operated. As shown in Fig. 230, a hydraulic jack may be used advantageously for the purpose of pushing up bottom shell plating against the inside structure of the ship, by means of a timber having attached to it a base plate to prevent tipping.

In Fig. 231 is shown the method of using the hydraulic jack in pushing a transverse bulkhead on the center line of the ship. Figure 232 shows the hydraulic jack used in a push-pull position, drawing the deck to a

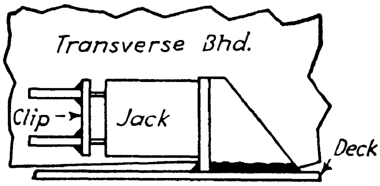


FIG. 231.—Hydraulic jack used to push transverse bulkhead on the center line of the ship.

heavy ballistic bulkhead on top of the deck. The head of the jack bears against the angle saddle, which is welded at the bottom to the deck plating. The jack is seated on a shelf welded to the bulkhead, and pressure applied on the jack tends to push the bulkhead down and, at

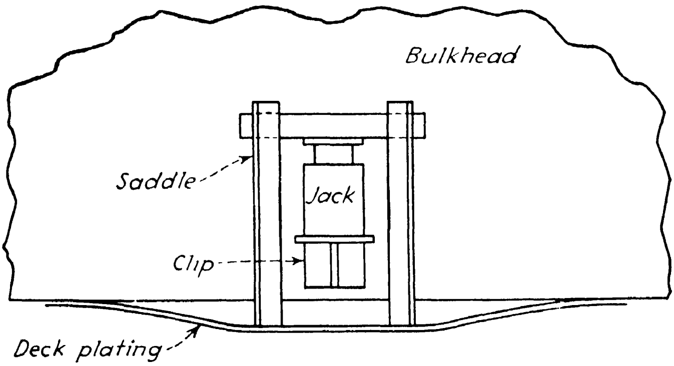


FIG. 232.—Hydraulic jack used in a push-pull position.

the same time, draw the deck up. This arrangement is used only under extremely difficult conditions.

In using a hydraulic jack, care must be taken to see that *the head and foot bear squarely against the pushing brackets.* Otherwise, it may kick out and cause injury or damage. It is always well to be on the safe side when selecting the size of brackets or the amount of welding applied.

CHAPTER XII

STAGING

Serious and fatal accidents are caused by poorly constructed and improperly used staging. The staging around the ship must be much more substantial than ordinary scaffolding because of the extreme loads to which it is sometimes subjected.

Staging is of extreme importance with respect to the safety of workmen. Those engaged in building or placing it should be made to feel that *the lives of men depend on how well it is constructed.* It should be *carefully inspected* during construction and frequently thereafter, that is, after it has been completed and put into use.

Safe means of access should be provided by means of standard stairs or permanent ladders so that workmen may reach various levels along the side of the ship. Working space should be ample to permit workmen to move freely about their work. Staging should be at least 3 ft. in width, with a minimum head clearance of 6 ft. 6 in.

At the forward and afterends where the ship overhangs the staging and where men are more likely to lose their footing, safety rails should be provided 3 ft. 6 in. above each stage. In these areas it may be necessary to make the staging 5 to 6 ft. in width to afford safe working and walking clearance.

Staging should not be used as loading or landing platforms for material unless it has first been sufficiently braced and *reinforced for such purposes.*

Daily inspection should be made to ensure against the possibility of stage planking being jarred or dislodged from the spauls or supports to the extent that they are likely to drop off while men are working on the staging. Also, it must be ascertained that none of the bracing has been broken or turned loose.

Under no consideration should stage plank be turned over if it is covered with sleet, snow, or ice, because of the possibility of its slipping off the supports. In such cases, stage plank should be left in their original position and the snow or ice cleaned or melted off. After this a light coating of sand should be sprinkled on them to prevent the possibility of workmen slipping.

On large ships in particular, staging must be provided so that workmen can work over practically every square foot of the outside shell. While not quite so extensive, considerable staging must also be provided on the inside of the ship.

On ships that can be built up of large subassemblies, the amount of staging necessary is greatly reduced. The only staging necessary will be that required at locations for making up the connections of the various assemblies.

Types of Staging. There are five types of staging generally used in ship construction.

1. Outside staging, which is supported on stage standards.
2. Inside staging, supported on trestles, brackets, or uprights.
3. Hanging staging, supported by beam clips and hangers.
4. Swinging staging, supported on wire or manila rope.
5. Bosun's-chair staging, used with block and tackle.

Outside staging, as its name implies, is staging used for work on the outside of the ship.

Inside staging is staging for work on the inside of the shell, under decks, in way of deckhouses, between decks, and on bulkheads and casings.

Hanging staging is used for work around deck hatches and hatch girders, under decks, over deep holds, in engine and boiler rooms, and on other high structures where it is advantageous to hang staging in order to afford storage or working space in the areas below.

Swinging staging is generally used in emergencies or where very little work has to be done. This may be on the outside of the shell after the outside staging has been removed for launching, at the top of king posts, masts, etc., or on the inside where it is not practical to install extensive staging, in trunks or small hatches.

Bosun's-chair staging is used only where other types of staging cannot be used, as in small ventilators, on the inside of masts and king posts, or in an emergency for work in high places.

OUTSIDE STAGING

In the construction of outside staging, wooden timbers, structural shapes, or tubular steel can be used. Outside staging consists of the following parts:

The *standard* for supporting the outrigger, or cross, members commonly known as *spauls.*

The spaul, or outrigger, which fits into the stage standard and which supports the stage planking.

The bracing and ties, which hold and brace the standard in an upright position.

The regulators, which are for the purpose of regulating the spauls to any desired height. These may vary in type. In some cases steel pins are used. In other types of standards built of structural shapes, slots are provided so that spauls can be inserted through them. On the tubular type of stage standards, clamps are used.

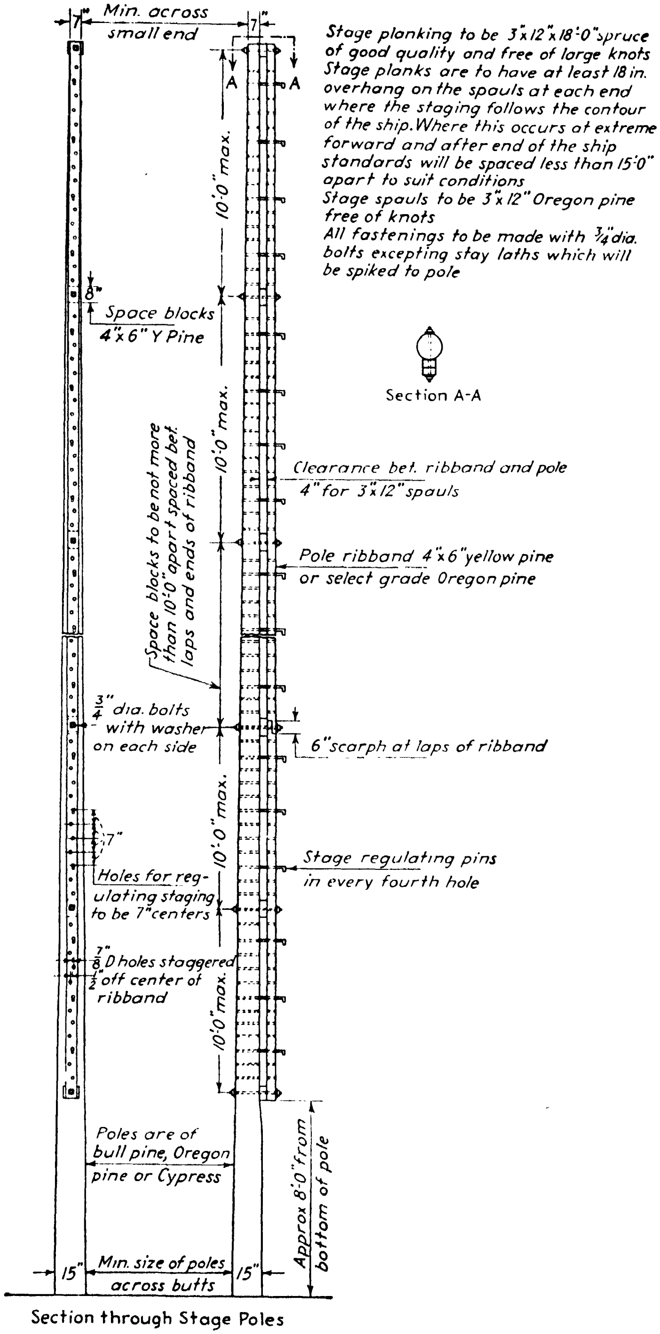


FIG. 233.—Typical timber pole staging standard.

Fastenings, which include any necessary angles, bolts, clamps, and guy wires necessary in securing and bracing the standards together.

Stage planking, which makes up the final part of the staging and forms the surface on which the men stand to work.

WOODEN-POLE STANDARDS

One of the oldest types of stage standard still being used in some yards is that made up of long straight poles to which a ribband is secured for the purpose of supporting and adjusting stage spauls (see Fig. 233). These poles are simply straight trees with the bark removed and are usually 15 in. in diameter on the butt and not less than 7 in. in diameter at the top.

The most suitable type of timber for these poles is Oregon pine, for this is usually straight and has good lasting qualities. North Carolina pine and cypress are also used for this purpose; however, straight poles of considerable length are difficult to obtain in this kind of timber.

Spacing of Poles. The practice in setting this type of stage standard around the ship is to place them not more than 15 ft. apart, center to center, for 18-ft. stage plank. The poles should be 3 ft. 6 in. from the side of the ship to allow for three-plank staging at the closest point. Toward the forward and afterends where the shape of the ship rapidly narrows, the poles should be spaced close enough so that an 18-ft. stage plank will at all times have at least 18 in. overhang on the spaul at each end, when the stage planking follows the contour of the ship.

Wherever possible, the poles should be set at least 3 ft. into the ground. Where poles rest on concrete caps, they should be secured at the bottom by ribbands or clips fastened to the shipway caps.

In addition to the bracing generally installed on stage poles, they should, wherever possible, be tied to the crane structure to ensure rigidity. Where it is not possible to tie in this manner, wire guy ropes should be used.

STAGE-POLE ASSEMBLY

Poles. When poles are assembled, whether new poles or old poles being overhauled, they must be *rigidly inspected* for weak or rotted spots as well as for the entire soundness of the pole. Any poles having weak or rotted spots should be immediately sawed through at these points so that there will be no possibility of their being set up.

Ribbands. Stage-pole ribbands should be 4- by 6-in. yellow pine or Oregon pine and should be made up into as few pieces as possible to assist in reinforcing the pole.

Spacer and Fastening Blocks. For the purpose of fastening the ribband to the poles and to keep the proper clearance between the pole and ribband for the spauls, spacer blocks are fitted. The block under each butt in the ribband should be 4 by 6 by 8 in. long. Between these points the blocks are 6 in. long.

The blocks should be slightly concave on one of the 6-in. surfaces so as to fit the pole, which is round, and they should be spaced not more than 10 ft. apart. Through the center of each block, a $\frac{3}{4}$-in.-diameter bolt will extend through the pole and the ribband, fastening together the complete assembly.

Stage Pins. The holes in the ribband and pole for stage pins are $1\frac{3}{16}$ in. in diameter and are spaced on 7-in. centers. The holes should not be spaced directly in the center of the ribband but should be slightly staggered, with the center of each hole $\frac{1}{2}$ in. from the center of the ribband. This reduces the tendency toward weakening the pole and ribband.

Stage pins should be placed in every fourth hole to allow shifting of stage spauls, as well as to facilitate the climbing of poles by stage builders.

STAGING STANDARDS

After the stage-pole assembly has been completed, the poles are then assembled into pairs and made ready to place in position. The poles are placed 6 ft. apart at the bottom and 5 ft. at the top and are held in position by *tie spauls* having a stage pin through the pole at each end.

Tie spauls for holding the poles in position are usually 3 by 12 in. Oregon pine. Stage standards up to 60 ft. in length should be fastened together by three tie spauls. Standards above 60 ft. in height require four tie spauls.

Tie spauls should extend past the sides of the poles not more than 8 in. There will thus be no possibility of their being shifted and used for stage spauls, which might result in collapse or spreading of the set.

Braces. Each standard is braced by three braces, one brace on the outside of each pole to hold it in a fore-and-aft position, and one transverse brace fastened to the after side of the inside pole. The top of the transverse brace should be slightly below the top of the fore-and-aft braces. The length of the braces will, of course, be governed by the height of the standard.

Stage Spauls. Stage spauls should be placed in the standards on approximately 3-ft. 6-in. centers to allow a shifting spaul between each level of staging. They should extend to within 6 in. of the side of the ship.

Dummy Poles. Owing to the shape of the ship at the forward and afterends, only the midship section of the ship can be staged from the spauls in the main staging standards. Where this is the case, the standards are augmented by dummy poles, which may be one or more in number, depending on the shape of the ship. Dummy poles are of the same assembly as the stage poles.

Where a single pole is used, it is braced by one fore-and-aft and one transverse brace. Where dummy poles are used in pairs, they are braced with three braces and fastened together with tie spauls similar to those for the main staging standards. However, they should be spaced to suit conditions and need not be so close together as the main standards. All dummy poles should be tied to the main standards with at least three tie spauls.

STAGE-POLE AND DUMMY BRACES

These braces should be 4 by 6 in. They should be one-half the length of the pole or poles, up to 80 ft. in height. Over this height, braces 40 ft. in length are used.

To prevent braces from splitting and breaking loose at the ends if struck by material, etc., a clinch pin is placed near the ends and riveted with a washer on each side. This pin is usually ½ or ⅝ in. in diameter and is shown in Fig. 234.

Buck Braces. For the purpose of additionally bracing the stage standards, diagonal or buck braces should be installed.

The following rule is ordinarily used to determine the number of such braces:

Sets of Standards	Sets of Braces
Up to 30	2
30 to 40	3
40 to 50	4
50 to 60	5

Each set of braces extends over five sets of standards and will be made up of 4 by 6 in. Oregon pine. Splices should be 4 ft. long and bolted together with ¾-in.-diameter bolts. The braces are then bolted through the outside of each standard in the set.

Where only two sets of braces are used, they should be installed so that the tops "buck" against each other; that is, the forward end of the forward brace should be reversed at the bottom of the forward pole of the set of five, and the afterend should be run diagonally to the top of the fifth pole of the set on the outside of the standards. The forward end of the after brace should be extended to the top of the set of five to which it is secured. This will brace the entire staging in a fore-and-aft direction from top to bottom.

Where more than two sets of braces are used, the direction of the braces should be reversed about amidships, the forward braces bracing aft and the after braces forward. The location of the braces will depend on the shape of the ship, but they should be started as far aft as possible

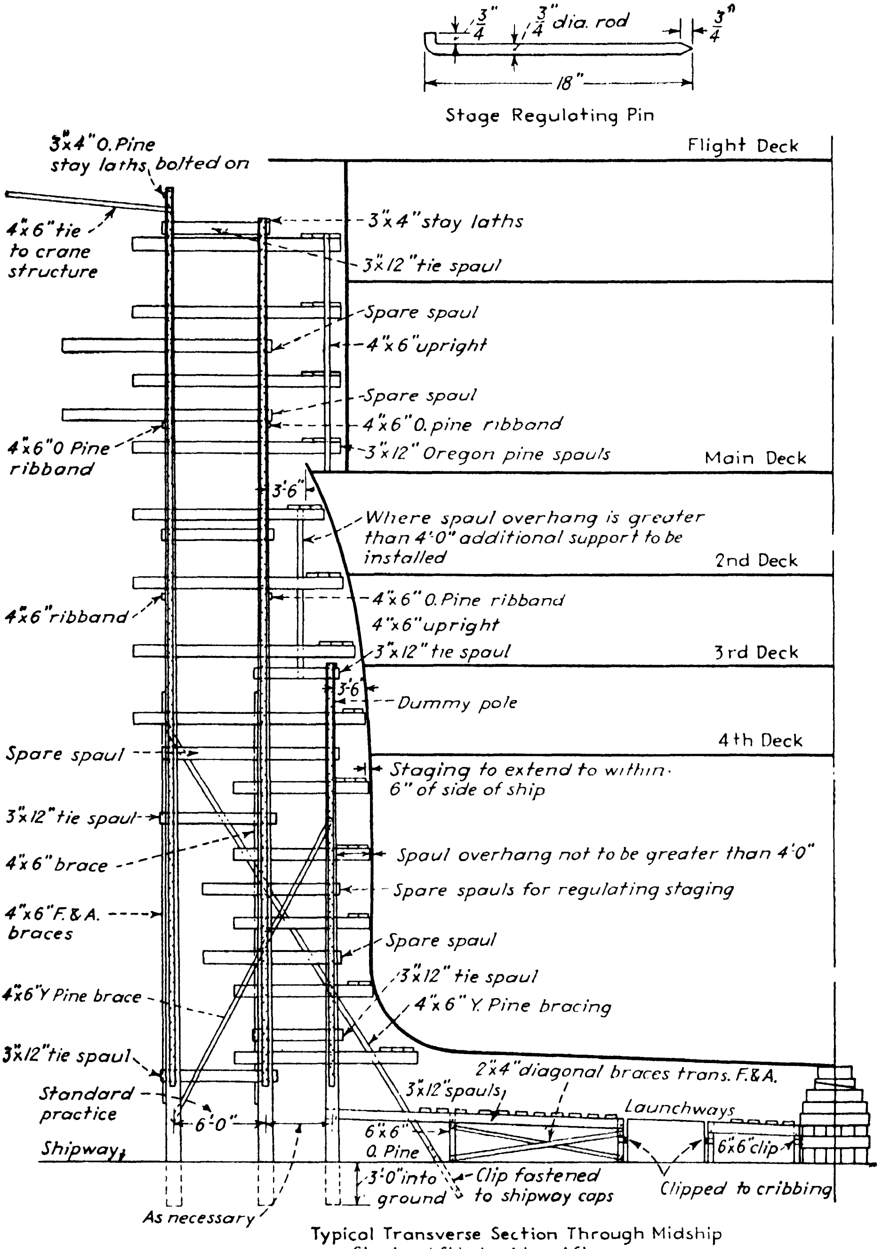
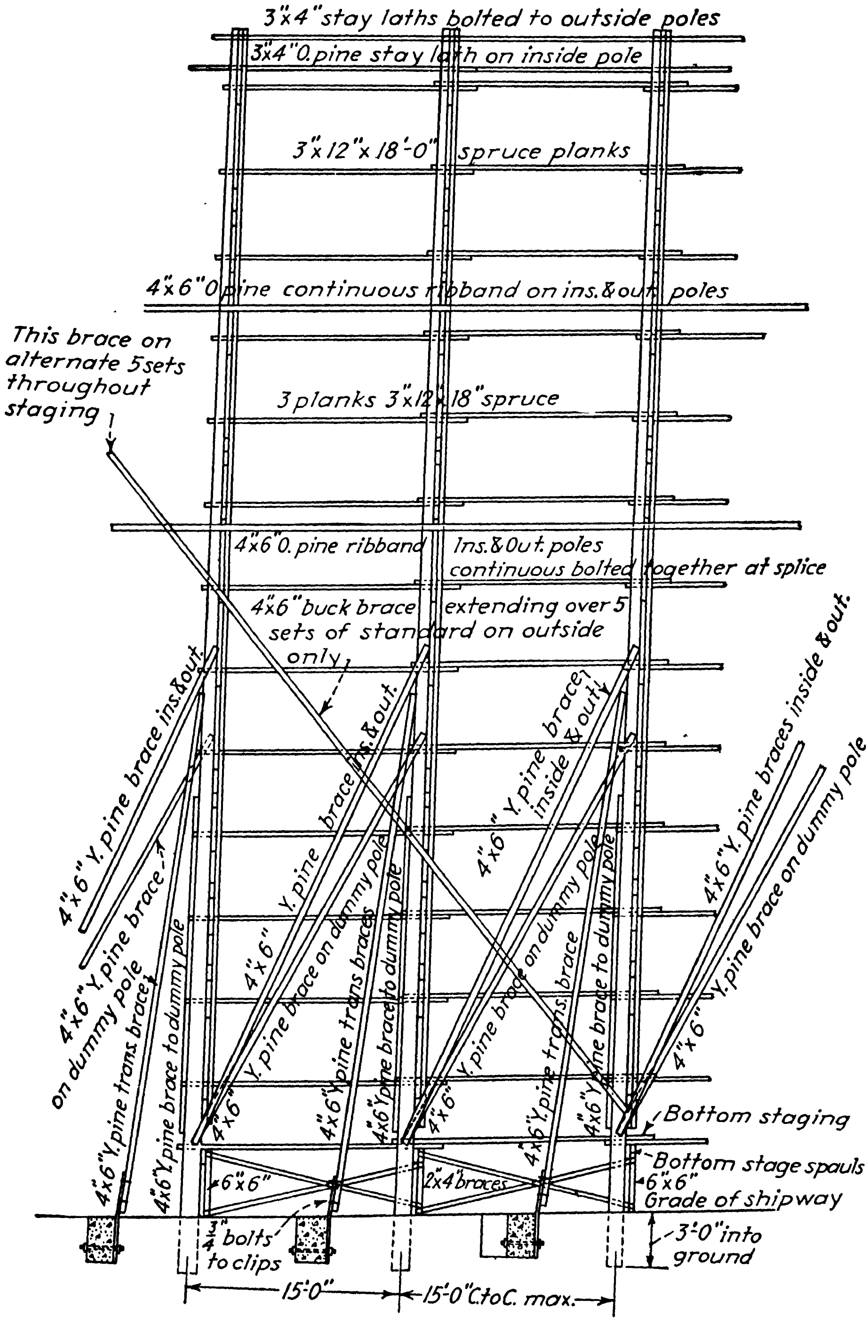


FIG. 234.—Timber stage standard and spauls in transverse section.



Elevation through Midships
Looking Inboard

FIG. 235.—Bracing timber staging standards.

without bending the braces to any great extent. The same condition applies forward.

Horizontal Braces. Horizontal braces, or ribbands, should be bolted to the inside and outside poles of the main standards at the top and midway between the top and bottom of the pole. The ribband should extend the entire length of the staging and should consist of either 4- by 5-in. or 4- by 6-in. yellow or Oregon pine timber.

Stage Spauls. Stage spauls should be 3- by 12-in. straight-grained Oregon pine. Stage spauls should overhang their support for not more than 5 ft. Where the spaul overhang is greater than 5 ft., uprights consisting of 4- by 6-in. timber should be installed for support (see Fig.

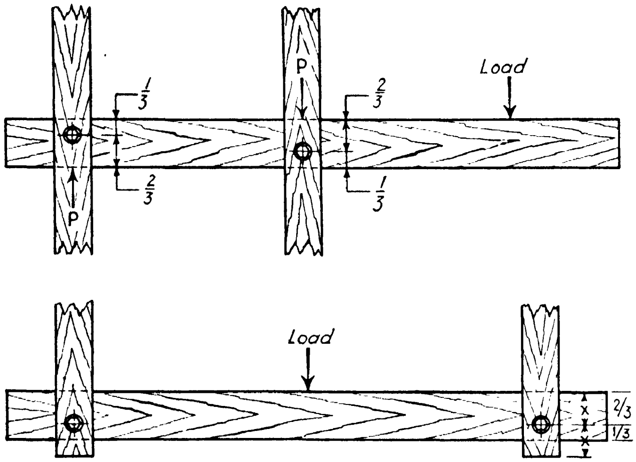


FIG. 236.—Proper method of locating bolts in spauls and hangers.

234). Where such support covers not more than two spauls, it should be bolted at least two spauls below those to be supported, provided that there is sufficient support under the latter. Where support for spaul overhang covers three or more spauls, such supports must fit close to the pole by running diagonally or being extended to the ground.

Uprights should be secured to the spauls with ¾-in.-diameter bolts. Wire nails or spikes must not be used. No spaul support should be less than 4- by 5-in. timber, regardless of length.

Stage Planking. Stage plank should be good-grade 3- by 12-in. spruce or Oregon pine, free of wing or long diagonal knots. Any stage more than 12 ft. above the ground or deck should be three planks in width. Stage boards should lie flat across the spauls with the ends extending over each spaul at least 18 in.

Where boards must be laid on more inclination than that of the ship itself, drop bolts should be inserted in the ends to prevent them from slipping off the spaul. Drop bolts are simply ¾-in. service bolts dropped

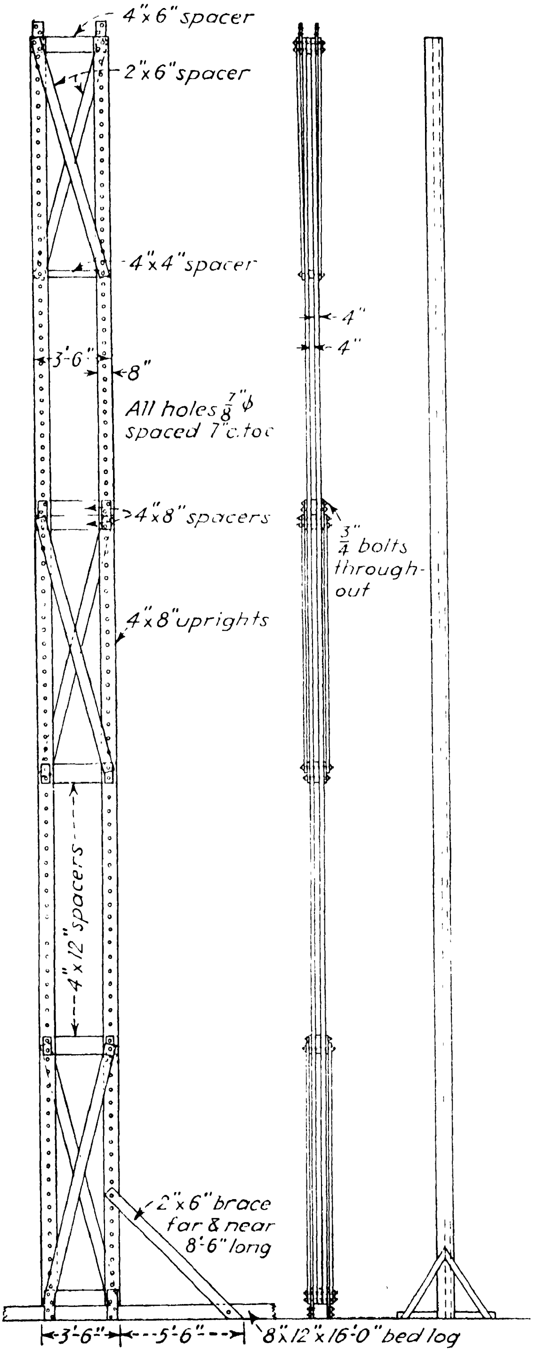


FIG. 237.—Built-up timber stage standards.

into holes bored in the ends of plank where lapped and into the plank on which they lie.

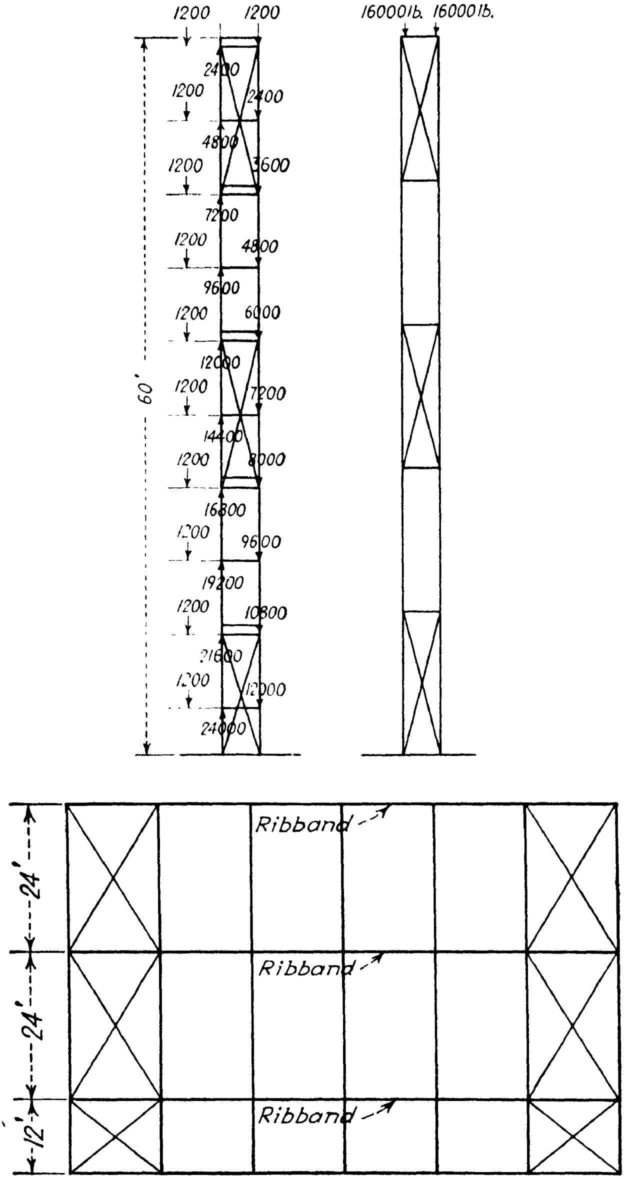


FIG. 238.—Safe loads and bracing built-up types of timber staging standards.

In lapping stage planking at the spauls, the forward end of the plank should always be on top. This will to some extent retard slippage of the stage plank and will also show from the ground the amount of lap on the

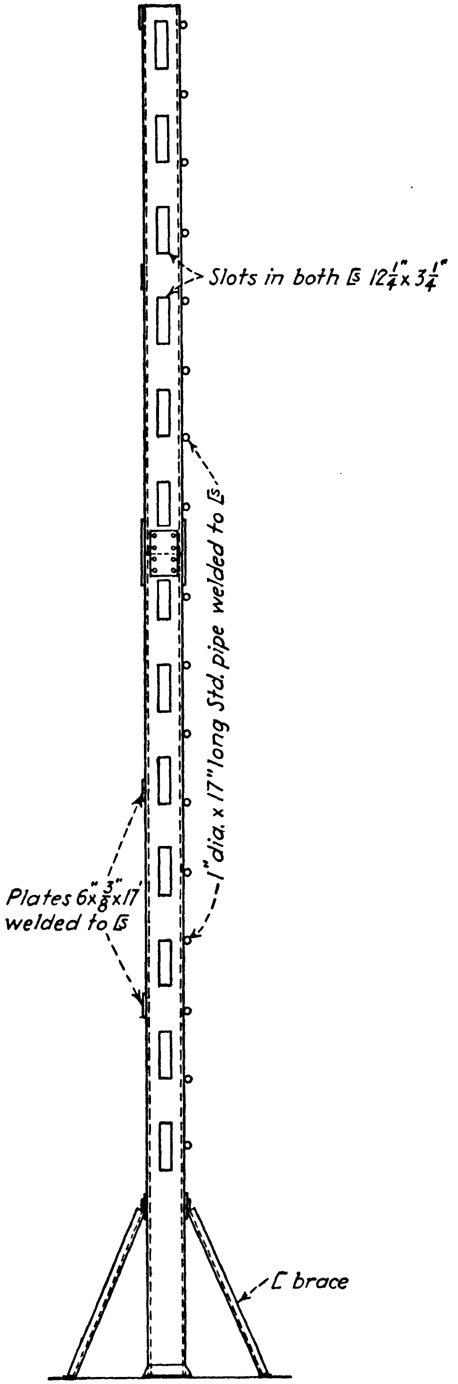
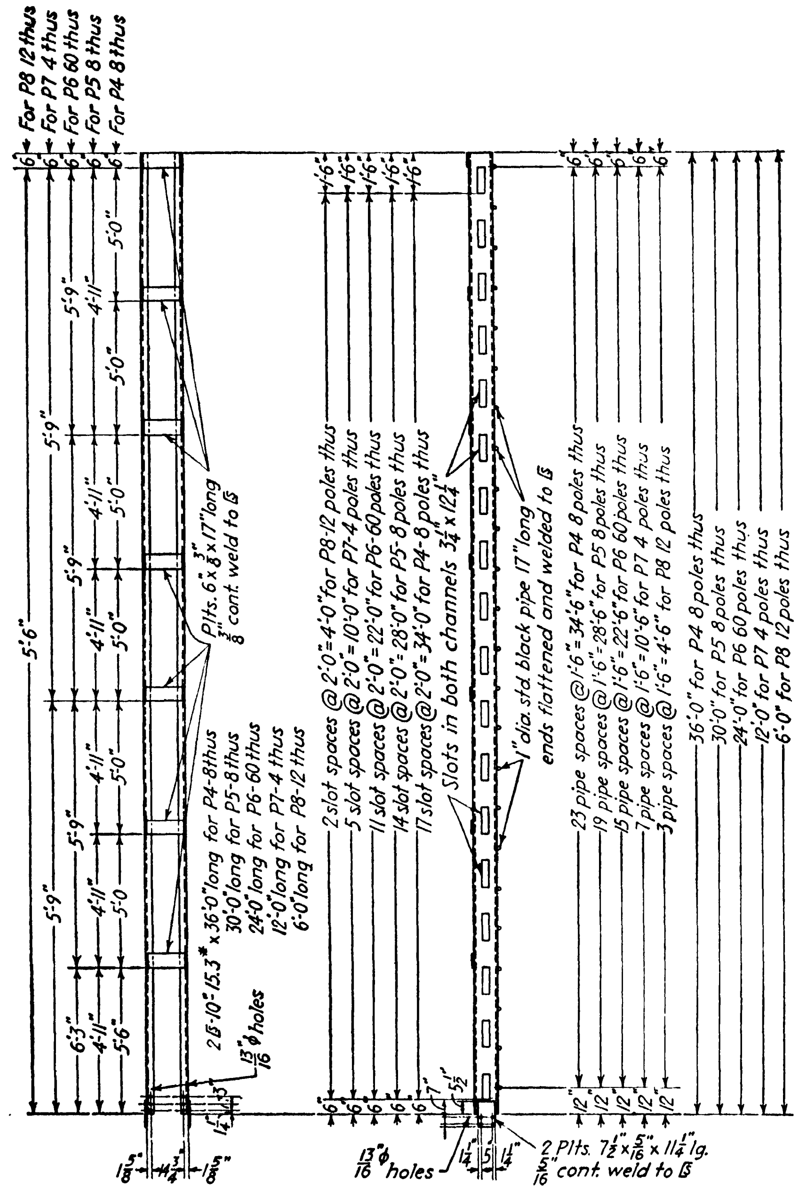


FIG. 239.—Steel stage standards.

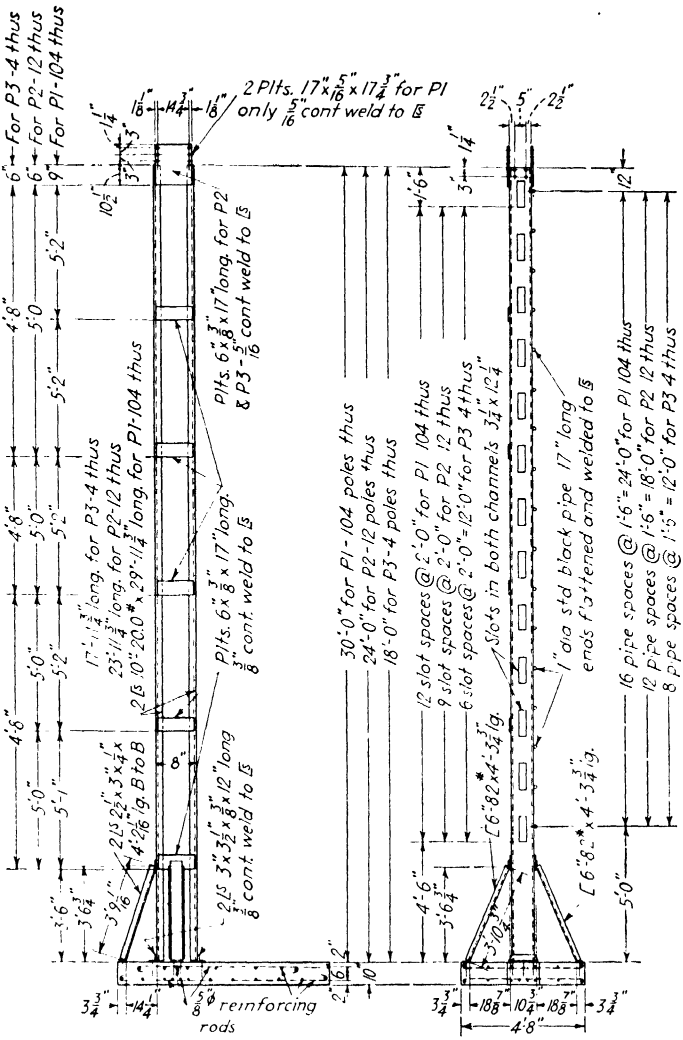


Elevation of Upper Sections of Stage Poles
Poles P4, P5, P6, P7 & P8

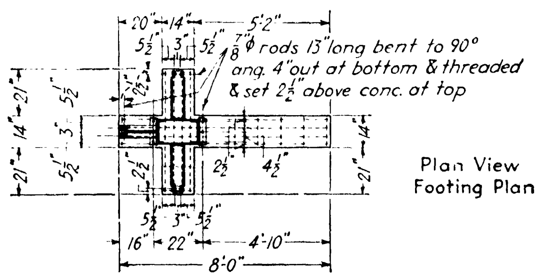
Notes: Material as ordered on this drawing is for one shipway

All material to have one shop coat of paint and one finished coat after assembling
Concrete foundation to be furnished by owners

FIG. 240.—Detail of structural-



Elevation of Lower Section of Stage Poles-Poles P1, P2 & P3



Plan View
Footing Plan

steel staging standard.

spaul when staging is being inspected. Figure 235 shows the arrangement and construction of the wooden type of poles, standards, and staging.

Bolting. In drilling for bolts to support staging, holes should be located to take the load without danger of splitting the supports. Figure 236 shows the proper method of locating bolts in spauls and hangers.

BUILT-UP TIMBER STAGING STANDARDS

Another type of wooden staging standard commonly used is shown in Fig. 237. This type of standard can be jigged with universally spaced holes so that each type of piece will fit in its location. Repairs can be made quickly and easily while the standard is in place.

This type of standard, if used to any considerable height, must be braced rigidly fore and aft to a greater extent than that used for pole staging, to prevent buckling. It is, however, more suitable to confined areas and is much easier to handle, for it may be built one section upon another and then securely braced together.

Bracing these standards is recommended as shown in Fig. 238.

With the use of space blocks and stage pin holes, bracing other than fore and aft is fundamentally the same as that used for stage poles.

This type of standard is usually bolted or secured to the building ways by means of bolts through the footing timbers at the bottom, and the standard is built as a unit rather than two separate parts as in the case of stage poles. In general, other considerations are the same as for stage poles. In Fig. 238 are illustrated safe loads and arrangement for this type of staging.

STEEL STAGING STANDARDS

The steel staging standard most commonly used is constructed of structural shapes and is shown in Fig. 239. This standard is constructed for the use of wooden stage spauls; however, rectangular steel spauls can also be used by changing the size of the opening in the standard.

The foot of the steel standard is made so that it can be secured to the shipway caps or to concrete blocks set into the ground along the side of the ship.

On one side of each standard, 1-in.-diameter rods are welded; these can be utilized as ladders for access to the staging. The standards must also be braced fore and aft and transversely to secure rigidity. The method of bracing is similar to that used for wooden standards except that the fore-and-aft braces are single rather than double. Round rod incorporated with turnbuckles is also used as bracing.

While the initial cost is much greater than for wooden standards, steel staging standards will last for years and their service over a period of years will result in a much cheaper job per ship than in the case of the wooden standard. They will not, however, stand rough treatment without damage.

A detail of this type of standard is shown in Fig. 240. Figure 241 shows this type of staging around a ship under construction.

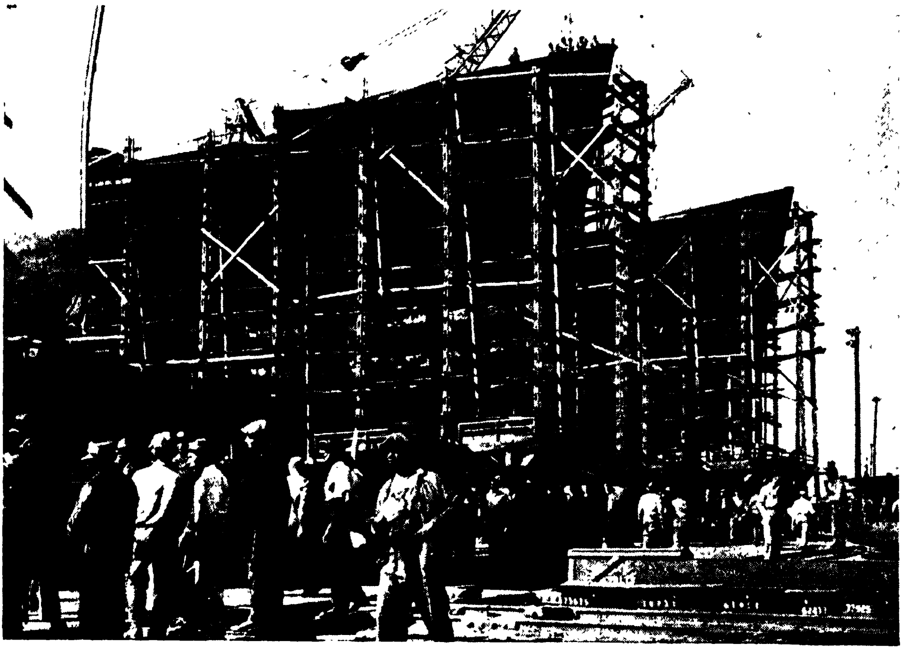


FIG. 241.—Steel staging standards around the ship under construction.

TUBULAR STAGING STANDARDS[1]

Another type of staging standard commonly used is tubular. This staging is made up of sections of tubular pipe varying from 6 to 13 ft. in length and from 1½ to 3½ in. in diameter.

It is built in the form of a cage having four legs in each section. These, in turn, are braced horizontally and diagonally with pipe braces of different sizes, clamped to the upright pipes with clamps.

Figure 242 shows this type of staging around a cargo vessel on an inclined building way.

Spauls and Regulators. By the use of two different types of clamps either a timber stage spaul or a structural channel can be used. A clamp used in connection with a 3- by 12-in. timber spaul is shown in Fig. 243. A clamp used in connection with the 5- and 6-in. steel channel spaul is shown in Fig. 244.

Dummy Standards. At the forward and after ends of the ship the same principle is used as for wooden poles or structural-shape standards.

[1] Figures by courtesy of the Dravo Corporation, Pittsburgh, Pa., 1943.

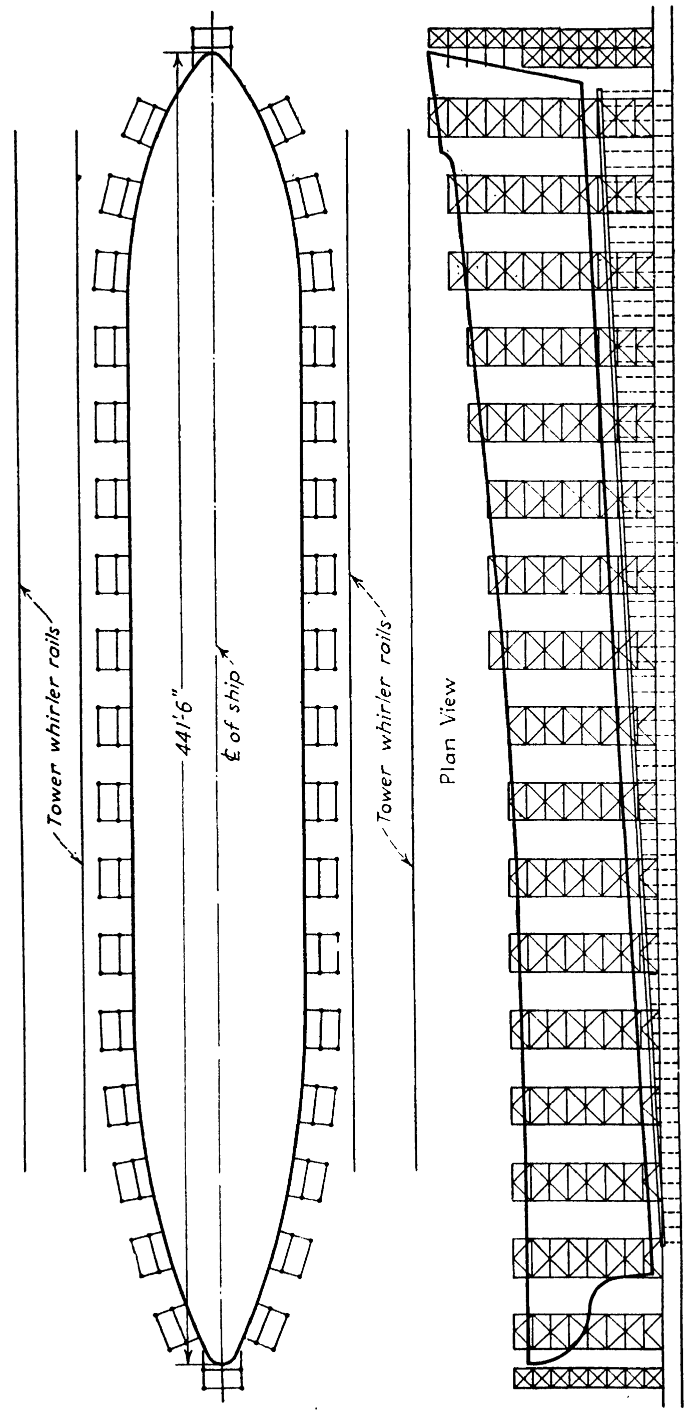


FIG. 242.—Arrangement of tubular staging around a cargo vessel. (*Courtesy of Dravo Corp.*)

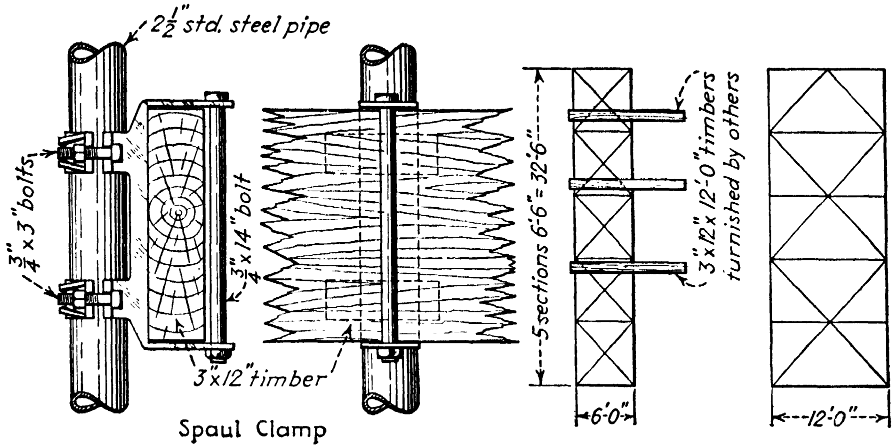


FIG. 243.—Spaul clamp for 3- by 12-in. timber spaul. (*Courtesy of Dravo Corp.*)

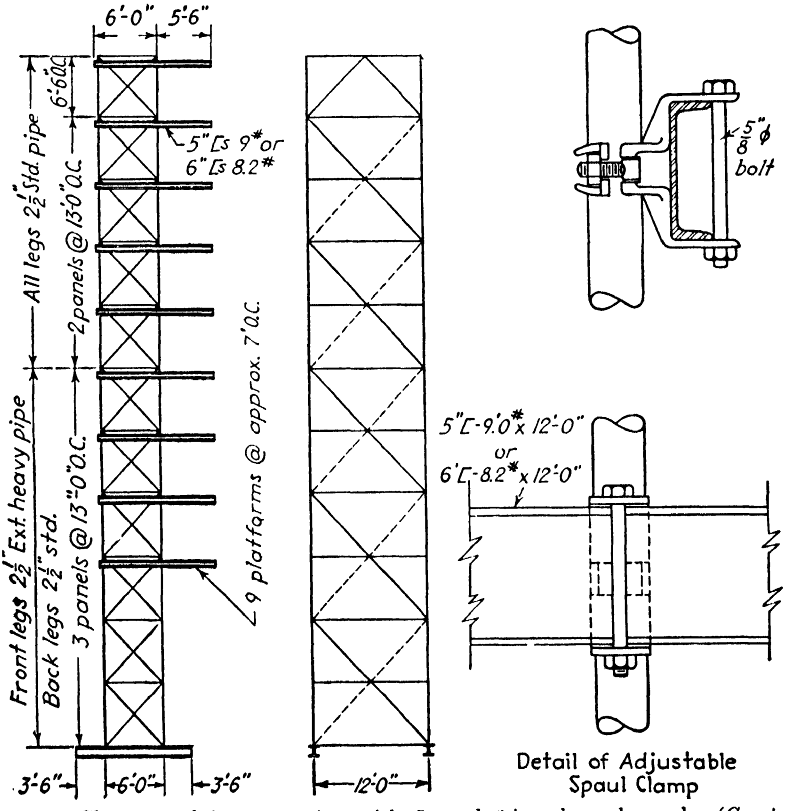


FIG. 244.—Clamp used in connection with 5- and 6-in. channel spaul. (*Courtesy of Dravo Corp.*)

This is shown in Fig. 245, which gives a transverse section of the ship at the forward end, with the addition of dummy standards made up of tubular pipe and braced to the main standard.

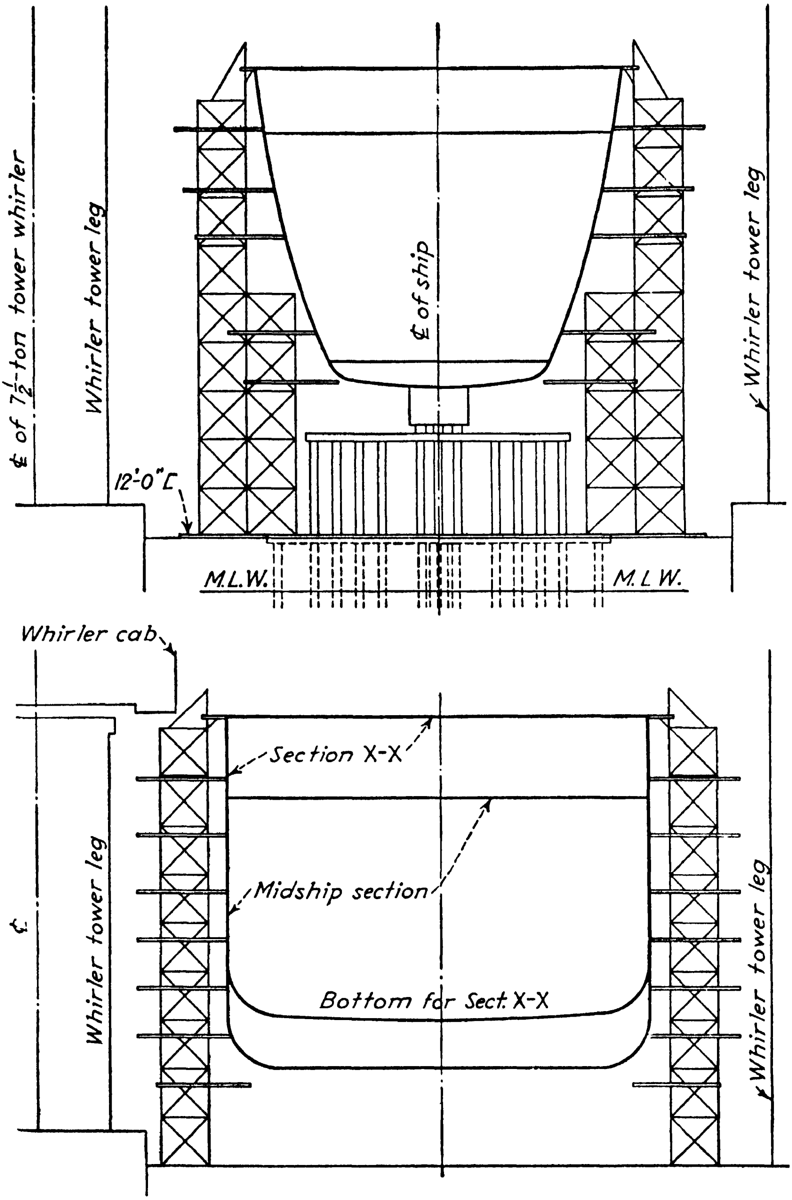


FIG. 245.—Dummy stage standards made up of tubular pipe and braced to main standard. (*Courtesy of Dravo Corp.*)

While this type of staging will withstand no rough treatment, its simplicity and ease of erection should not be overlooked. Each section of pipe for the uprights is fitted with a male and female coupling, by means of which the sections can be very easily put together or dismantled without the use of cranes. A detail of this coupling is shown in Fig. 246, together with the base plate and the clamp for securing the diagonal and horizontal bracing. A detail of the bracing of these standards is shown in Fig. 247.

Figure 248 gives the various stresses and loads which may be applied to the stage, together with other data that compare very favorably with

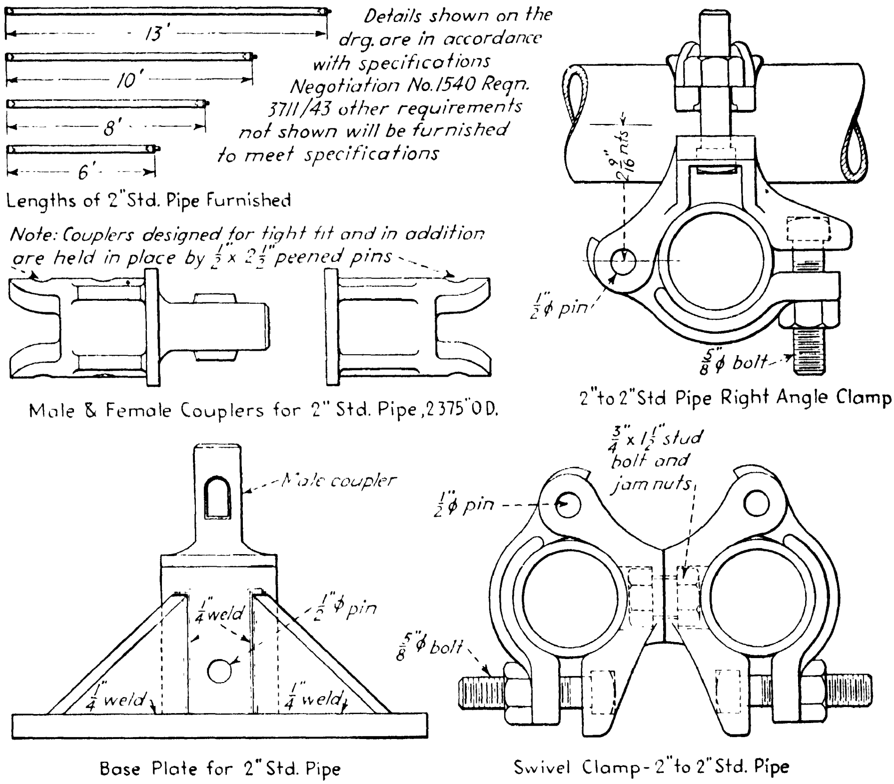


FIG. 246.—Detail of coupling on tubular staging. (*Courtesy of Dravo Corp.*)

any of the other types of staging. However, as mentioned previously, tubular staging will not withstand rough treatment or unbalanced loads thrown against it.

INSIDE STAGING

Inside staging varies according to the type of work to be done from the stage and the location in which the staging is constructed. In large spaces, uprights consisting of either 4- by 6-in. or 6- by 6-in. timber, depending on the load to be supported, can be used in pairs (see Fig. 249).

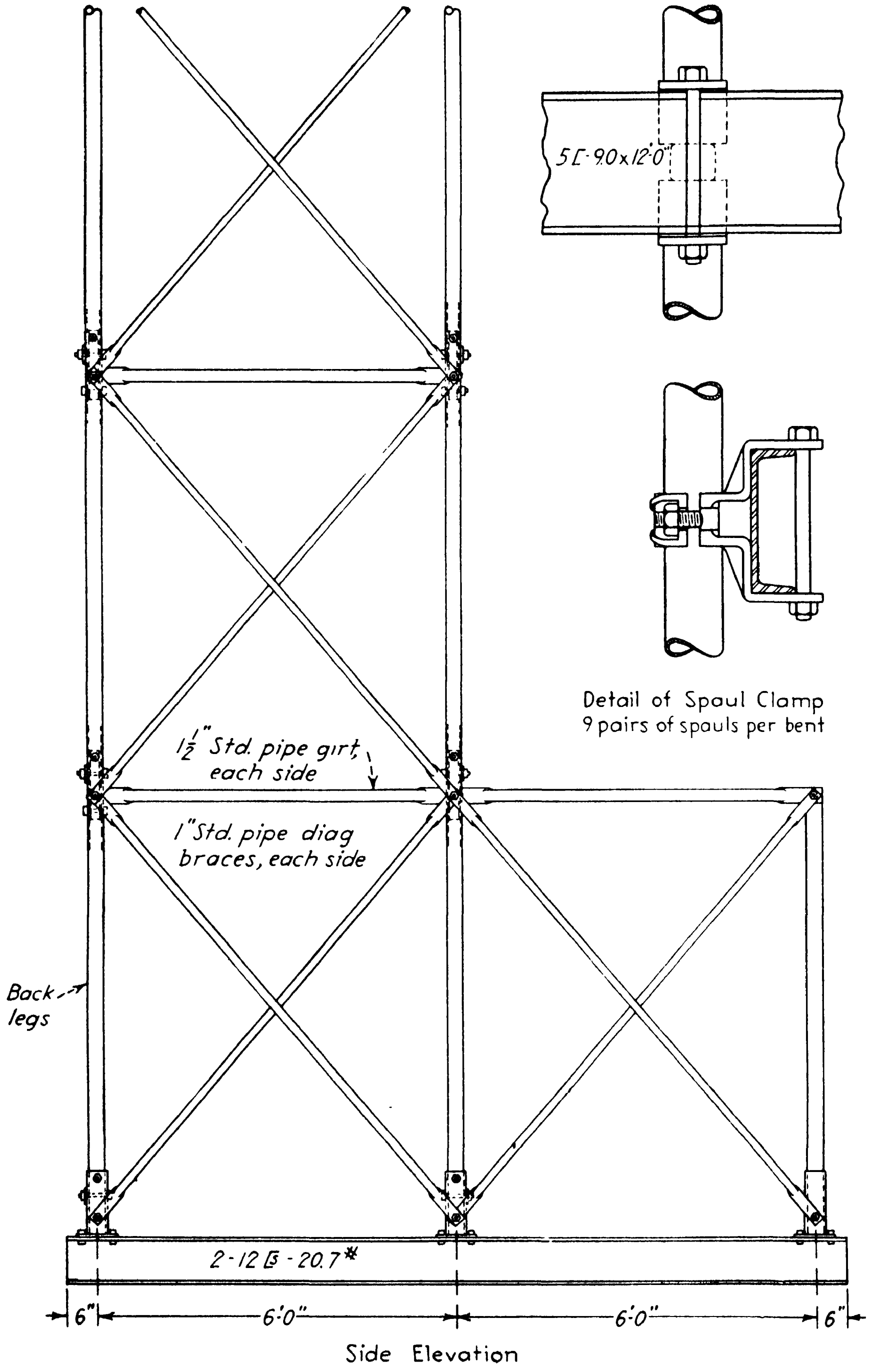
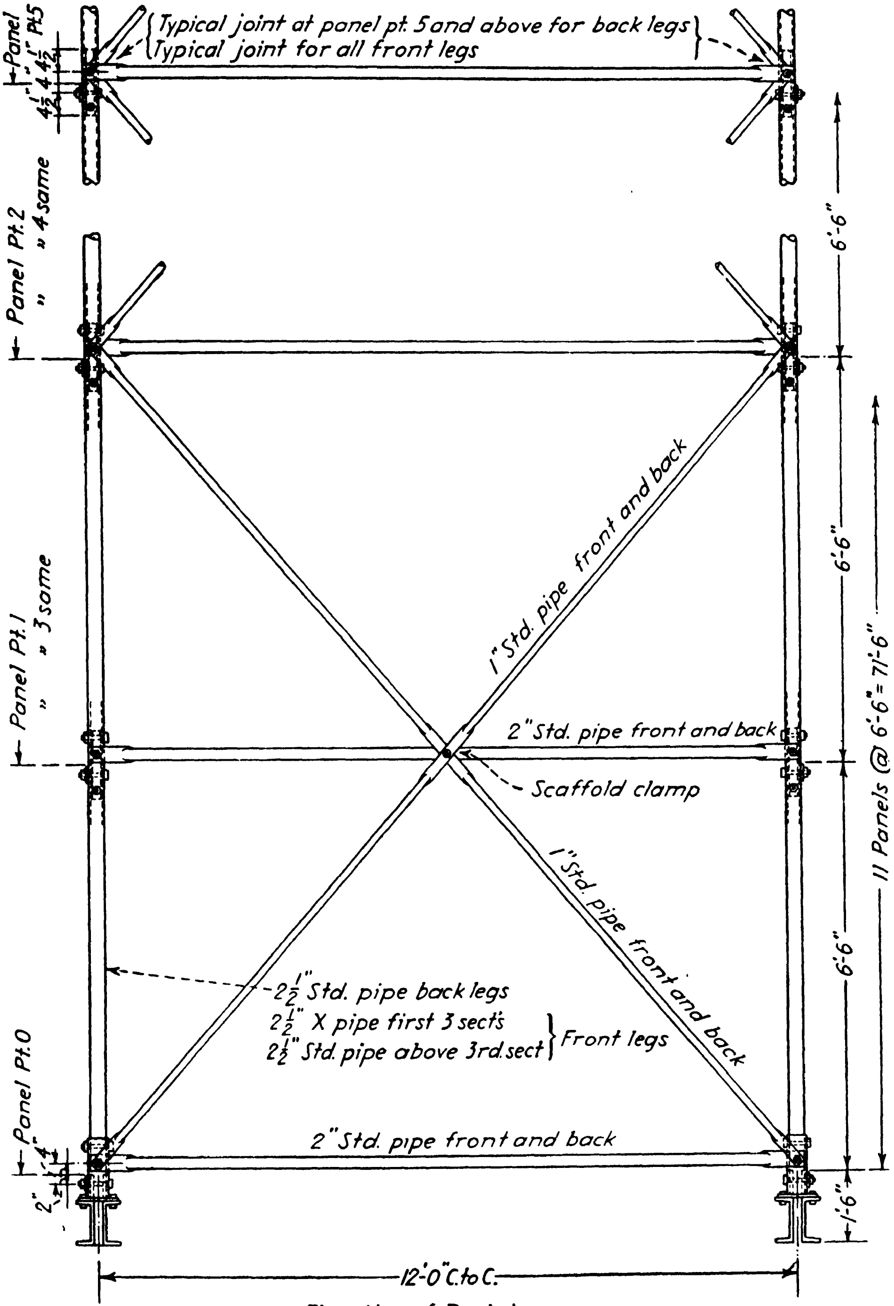


Fig. 247.—Detail of bracing tubular

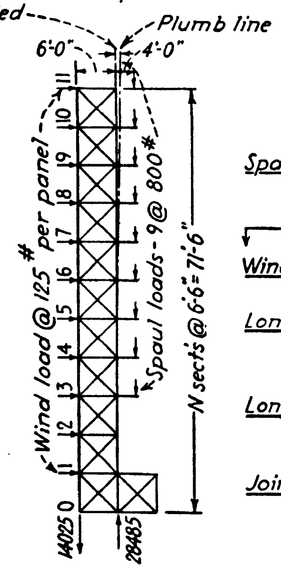


Elevation of Back Legs
Front legs Similar

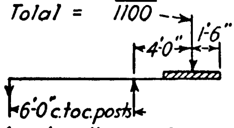
staging. (*Courtesy of Dravo Corp.*)

DESIGN TABULATION																	
MEMBER	PANEL PT.	DEAD LOAD STRESS	WIND STRESSES					SPAUL LOAD STRESS	TOTAL	DESIGN OF MEMBER					FIBRE STRESS #/SQ.IN.	
			SHEAR	DIS.	MOM Δ	MOM.	STRESS-LB		STRESS-LB	SECTION	AREA SQ.IN.	LENGTH IN.	r	l/r	ACTUAL	ALLOWABLE
FRONT LEG COMPRESSION	11															
	10	200	125	7.00	875	875	146	1833	2179	2½ STD. PIPE	1.70	78	0.948	82.2		13000
	9	400	250		1750	2625	438	3667	4505							
	8	600	375		2625	5250	876	5500	6976							
	7	800	500		3500	8750	1460	7333	9593							
	6	1000	625		4375	13125	2188	9167	12355							
	5	1200	750		5250	18375	3063	11000	15263							
	4	1400	875		6125	24500	4083	12833	18316							
	3	1620	1000		7000	31500	5025	14667	21312						12500	
	2	1840	1125		7875	39375	6563	16500	24903	2½ X PIPE	2.25	78	0.925	84.4		12900
	1	2100	1250		8750	48123	8021	16500	26621	DO	DO	DO	DO	DO		
	0	2360	1375		9625	57750	9625	16500	28485	DO	DO	DO	DO	DO	12650	
BACK LEG TENSION	10	200	125	7.00	875	875		733	533	2½ STD. PIPE	NET AREA 1.20	78	0.947	88.5		18000
	9	400	250		1750	2625	146	1467	1213							
	8	600	375		2625	5250	438	2200	2038							
	7	800	500		3500	8750	876	2933	3009							
	6	1000	625		4375	13125	1460	3667	4127							
	5	1200	750		5250	18375	2188	4400	5388							
	4	1400	875		6125	24500	3063	5133	6796							
	3	1600	1000		7000	31500	4083	5867	8350							
	2	1800	1125		7875	39375	5025	6600	9825							
	1	2000	1250		8750	48125	6563	6600	11163							
	0	2200	1375		9625	57750	8021	6600	12421						10300	18000
			MAX. DIAG. TENS. STRESS =						2100	1" ϕ STD. PIPE	.283 NET				74100	18000
			MAX. GIRT. COMP. STRESS =						1375	1½ STD. PIPE	0.80	72"	0.62	116	1720	8500

Erection note:- Provide approx. 1½" back camber so that front legs will not exceed ½" from plumb line when spauls are loaded as specified



Live load = 800# per spaul
Dead load = 300# " "
Total = 1100



Max. loading each spaul

Spauls:- $M = 1100\# \times 4' = 4400'\#$ $f = \frac{4400 \times 12}{3.5} = 15100\#/\text{sq. in.}$
Using 5 [- 9.0#

1100# — 4' ← Allow. cantilever on spaul. Allow for tubular shapes

Wind load:- Exposed area = 4.10 sq. ft; $W = 30\# \times 4.1 \times 150\% \times 2/3 = 125\#$ per panel

Long't girts:- $\frac{l}{r} = \frac{12 \times 12}{.787} = 183$; Allow $f = 6293\#/\square''$
Using 2" ϕ Std. pipe
Allow compr. $= 108\square'' \times 6293 = 6800\#$

Long't braces:- Use 1" ϕ Std. pipe; Gross area = .494 sq. in.
Net area = .283 sq. in.
Allowable tension = 16000 x .283 = 4500# per brace

Joints:- Compression - Butt joints - Milled ends
Tension:- ¾" ϕ bolts in Dbl. shear @ 8800#
¾" ϕ bolts in bearing @ 6,000#
Use - 2 thru bolts, back leg joints = 0 to 4 incl. each side of joint
Use - 1 thru bolt, each side, of all other joints

FIG. 248.—Tabulation showing stresses and loads for tubular staging. (*Courtesy of Dravo Corp.*)

In some locations, trestles of varying heights may be used. The trestle type of staging can be used only where there is no obstruction on the deck supporting the trestle.

Another form of inside staging commonly used is shown in Fig. 250. This is stage plank supported on steel brackets secured to clips welded

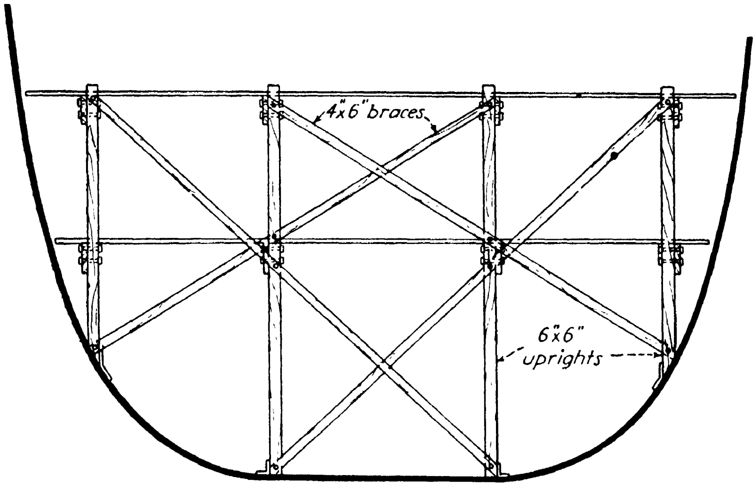


FIG. 249.—Inside staging uprights.

to the structure of the ship. It is so located that the staging is at working height above the work to be performed, and thus no adjusting is necessary.

Care must be exercised to obtain brackets of the proper size to support the load intended for the staging. Figure 251 shows the proper size and

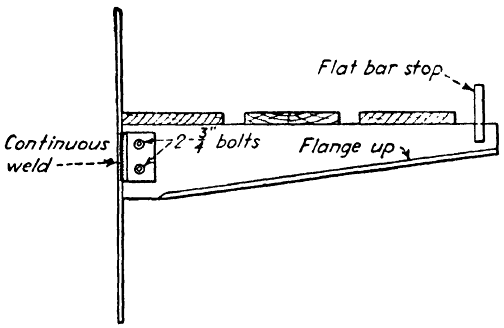
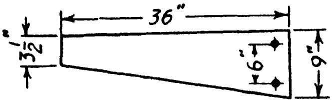
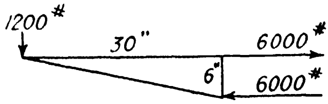


FIG. 250.—Steel bracket staging showing brackets secured to welded clips.

design of bracket to withstand a 1200-lb. load in the extreme end of the bracket, with the use of two ¾-in. bolts. Loads above this figure should be taken care of by correspondingly increasing the size of the bracket and the bolts.

Steel Brkts. for Staging





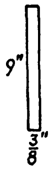
6000# shear on ¾" bolt

Area of ¾" bolt at bottom of threads .302 □"

Shear on bolt $6000/.302 = 20,000$ #/□"

Rather high

Brkt. ⅜" Plt.



$I = \frac{.375 \times 9^3}{12} = \frac{.375 \times 729}{12} = 22.8 \text{ in.}^4 \quad SM = \frac{22.8}{4.5} = 5$

Bending Mom. = 36,000 "#

Stress = $36000/5 = 7{,}200$ #/□"

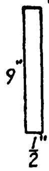
Taking a strip along the bottom as a column

$r = \frac{.375}{\sqrt{12}} = \frac{.375}{3.46} = .108" \quad l = 30" \quad l/r = \frac{30}{.108} = 278$

Failure stress for Moncrieff rounded ends 3000 #/□"

<u>⅜" Plt. is unsafe</u>

Brkt. ½" Plt.



$I = \frac{.5 \times 93}{12} = \frac{.5 \times 729}{12} = 30.3 \text{ in.}^4 \quad SM \; 30.3/4.5 = 6.73$

Bending Mom. = 36000 "/#

Stress = $36000/6.73 = 5.350$ #/□"

Taking a strip along the bottom as a column

$r = \frac{.5}{\sqrt{12}} = \frac{15}{3.46} = .144 \quad l = 30" \quad l/r = 208$

Failure stress for Moncrieff rounded ends 6,500 #/□"

<u>½" Plt. is OK</u>

Legs of angle, welded to shell for connection of brkt., should be at least ⅜" thick

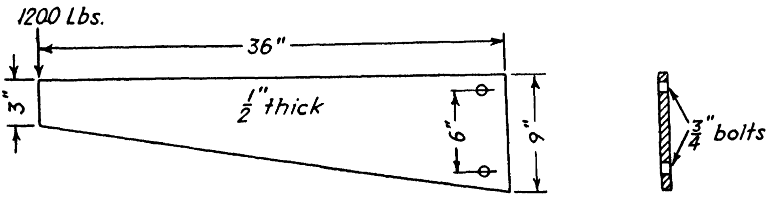


FIG. 251.—Proper size and design of bracket to withstand a 1200-lb. load.

Many other types of staging supported on clips or flat bars are resorted to on inside staging, particularly in close places, as between torpedo bulkheads. Safety is a prime consideration with respect to all

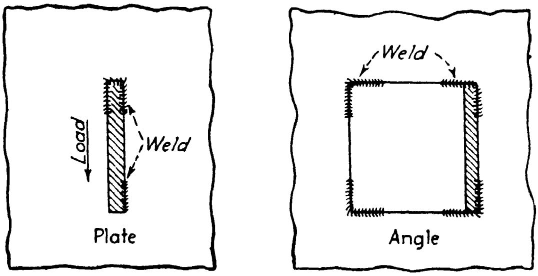


FIG. 252.—Welded clips for staging.

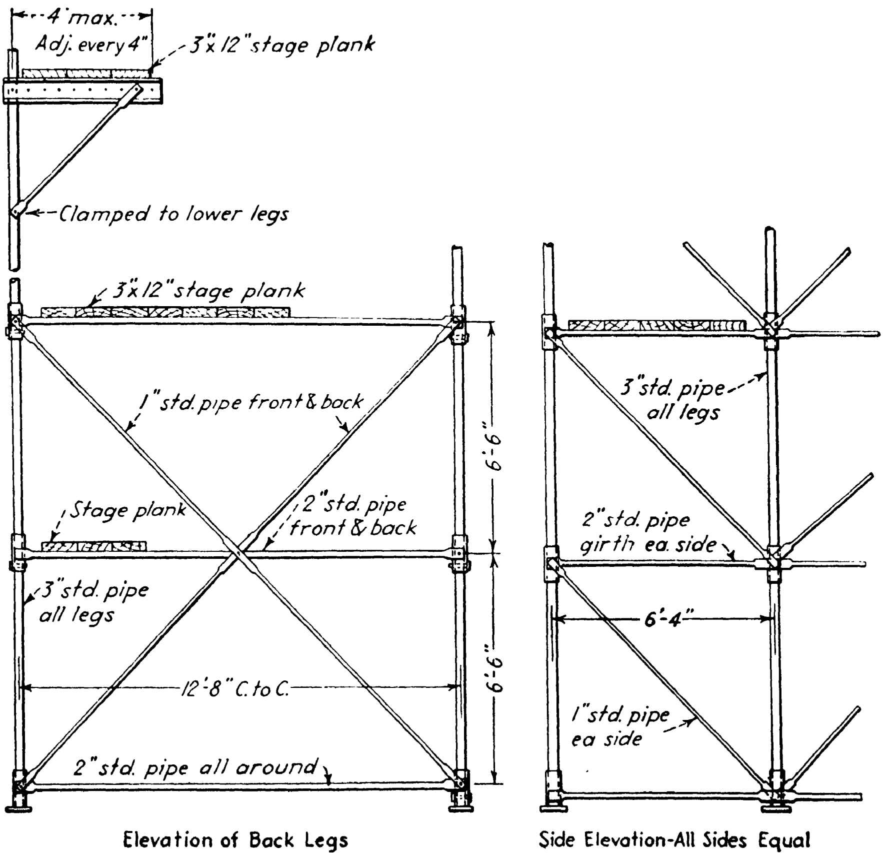


FIG. 253.—Tubular inside staging standards.

these supports. If they are welded, this should be as shown in Fig. 252. A suitable type of inside staging that can be moved conveniently in the holds of ships is shown in Fig. 253.

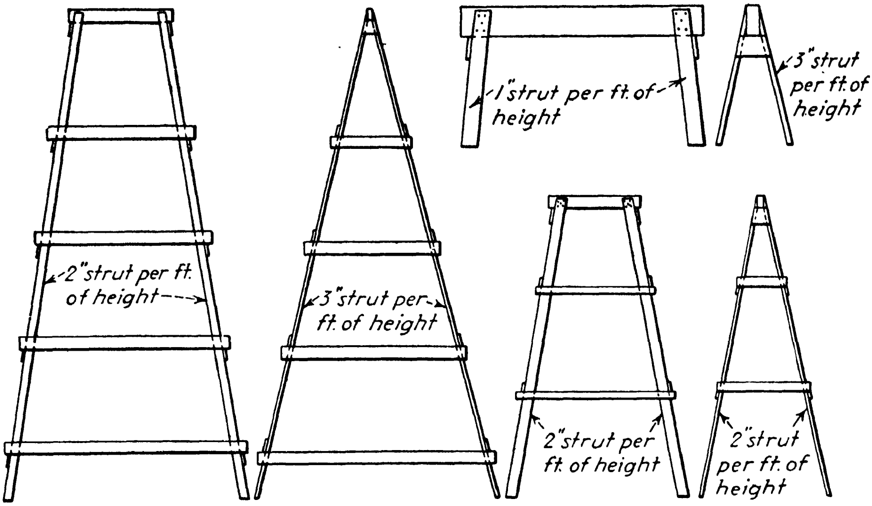


FIG. 254.—Types of trestles used in connection with staging.

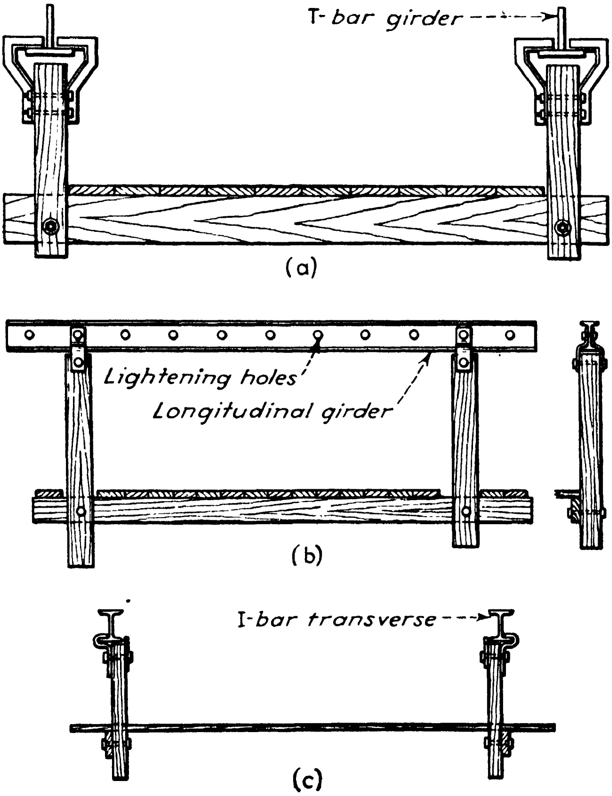


FIG. 255.—Types of hangers used in connection with hanging staging.

Between decks wooden trestle benches of different heights are used for staging, as these can be conveniently moved from one location to another with very little effort. Various types of trestles are shown in Fig. 254.

Trestles can also be constructed of 1-in.-diameter pipe and welded together. These have good lasting qualities and possess much more rigidity than wooden trestle benches.

HANGING STAGING

In locations under decks, in deep holds, in engine and boiler rooms, and around hatches and trunks, the hanging type of staging is most suitable. Various types of hangers can be used to suit the structure on which the staging is to be hung. Some of these are shown in Fig. 255.

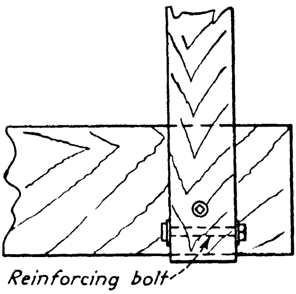


FIG. 256.—Reinforcing bolts in ends of timber used for hanging staging supports.

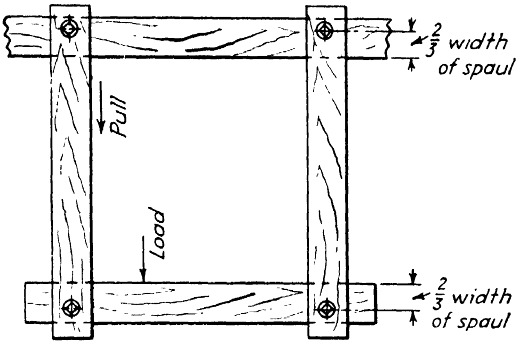


FIG. 257.—Proper location of bolts in stage spauls for hanging staging.

The *A* type can be supported on faceplates or flanges of deck beams and girders. The *B* type can be hung through lightening holes in beams and deck girders. The *C* type is a clamp used over the flange of a channel or I beam that is pulled tight with a bolt through the flat bar against the opposite side of the clamp.

In a hanging stage it is important that the holes in the timbers should not be drilled too close to the end, where they are likely to pull through and drop the staging (see Figs. 256 and 257).

SWINGING STAGING

Swinging staging is staging whose supports are suspended with manila or wire rope in places where it is impractical to build any other type of staging.

Manila-rope Staging. On staging where no great amount of weight is to be applied and where burning or welding is not being done, manila and sisal fiber rope can be used. Stage ropes for this type of staging are usually 1 in. in diameter and are cut in lengths of 30, 60, and 90 ft.

Where it is possible, staging hooks formed in the shape of an S are used to hook over part of the structure, with the rope attached to the hook with a double half hitch. The end of the rope should then be seized to the standing part with marline.

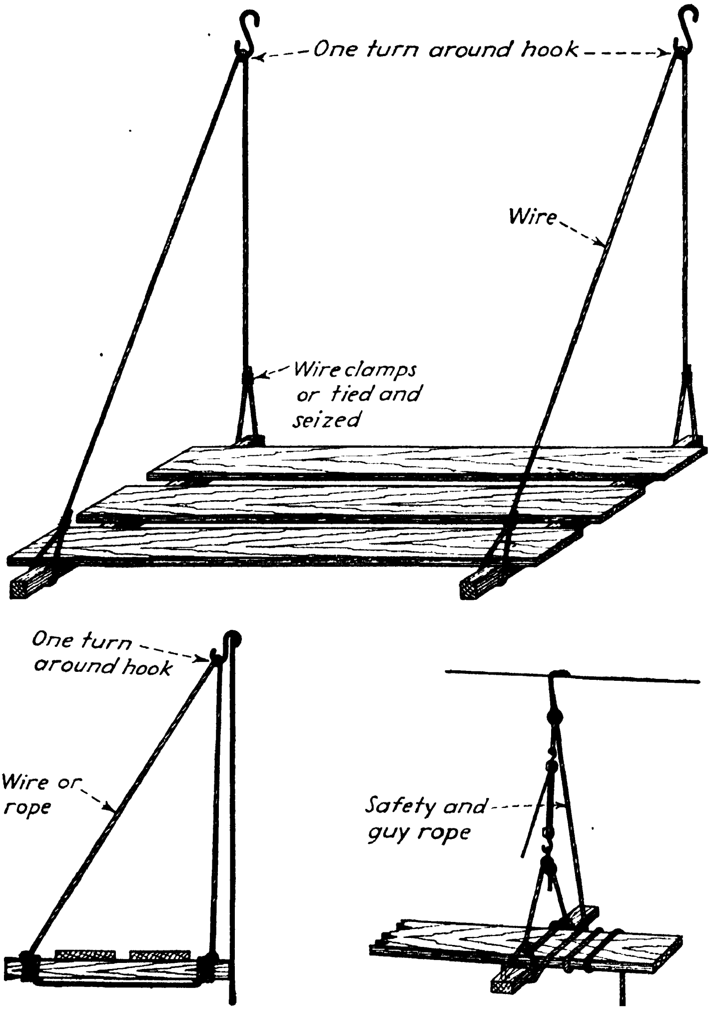


FIG. 258.—Types of swinging staging using wire and manila rope.

Wire-rope Staging. Wire-rope staging is used where staging is to be extremely heavy and where welding and burning are being done. Three or four levels of staging can be suspended on wire rope when necessary.

The most suitable type of wire rope to use for swinging staging is 6 by 37 plow-steel wire rope. This is both strong and flexible and is easy to tie around supports. As with manila rope, when wire rope is passed over sharp edges of steel, canvas shields should be used to prevent cutting.

In tying the ends of wire rope, the double half hitch is used. After this an overhand knot is tied around the standing part of the wire, and the end is then lashed to it with marline. Figure 258 shows various types of swinging staging using wire rope.

Bosun's-chair Staging. As previously stated, where other types of staging cannot be used, as in small ventilators or on the inside of masts and king posts, etc., a bosun's chair suspended on a block and tackle is used. This is shown in Fig. 259, together with the method used in securing the end of the rope, commonly known by those who use the staging as the *painter's hitch.*

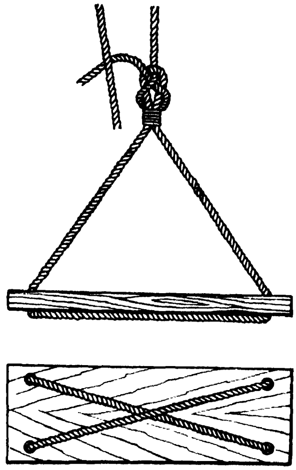


FIG. 259.—Bosun's chair staging showing painter's hitch.

SETTING STAGE POLES AROUND THE SHIP

The various types of staging having been discussed, the job of setting the staging around the ship will now be briefly explained. Assuming that the ship to be constructed has been located on the stocks or building ways with due consideration to access from crane structure or permanent ramps on the side of the shipway, work can now begin in spacing off the location of the stage standards.

A sketch is usually developed in the shipwright office, giving the extreme half breadth of the ship in a plan view. If the ship being constructed is built on an inclination for an end launching, due consideration must be given to the declivity since the deck ends cannot be carried up plumb from the stocks because of this declivity. It is apparent, therefore, that the height of the uppermost deck, or the point to which the staging will be carried, must be determined, together with the amount of declivity per foot on which the ship is to be built.

For example, let us assume that the height to which the staging will extend from the building way to the top is 52 ft. If the ship is being built on a declivity of $\frac{5}{8}$ in. per ft., then the top of the bow and stern of the ship will both be thrown aft 52 by $\frac{5}{8}$ in., or $32\frac{1}{2}$ in. The outline of the ship can then be traced in by moving the frame stations on the keel back by this amount. After this, the half width of the poles can be marked off to clear the side of the ship. If this is not done, the poles toward the afterend of the ship will be too close to the shell, and the poles at the forward end of the ship will be farther away from the ship than is desirable.

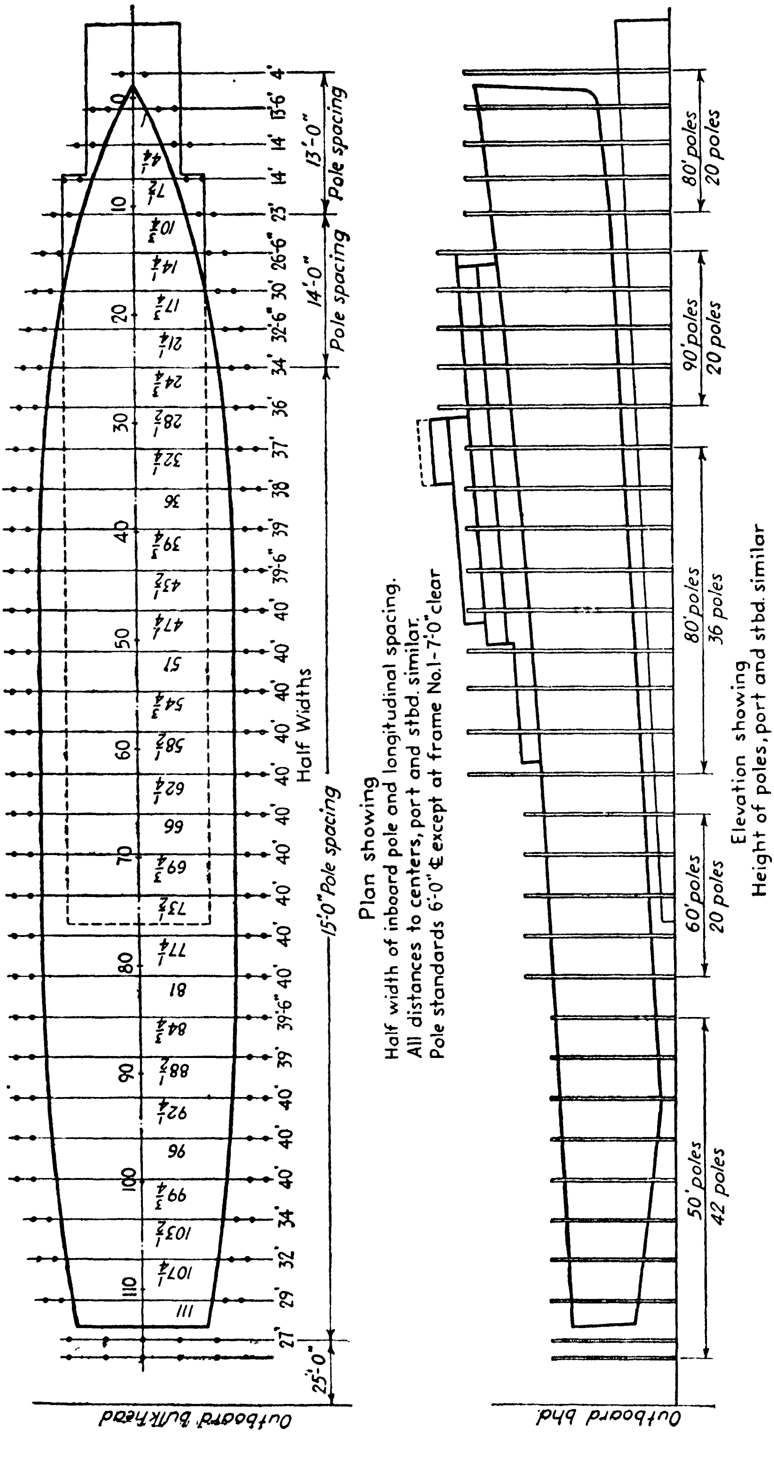


FIG. 260.—Arrangement of staging standards around a vessel.

The procedure generally followed in setting up stage poles is to begin at the stern of the ship and work toward the forward end. From Fig. 260, it can be readily observed how this is done. If the floor of the stocks is not constructed of concrete, the stage standards can be set into the ground (if the pole type of staging is to be used).

Holes are dug at points where the poles are to be set. These holes should be about 3 ft. deep.

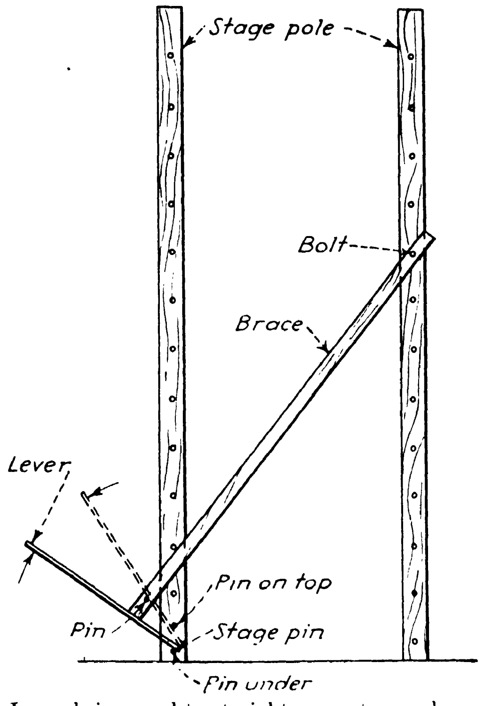


Fig. 261.—Lever being used to straighten up stage poles when setting.

The after set of poles can then be lifted into place by the crane. The braces that are fastened to it near the top are caught and extended out to some convenient spot where they can be securely bolted. This may be either a "deadman" sunk into the ground or clips secured to the shipway caps or other surrounding structure. Care should be exercised to see that braces will clear the stages to be built.

Stage poles should be set plumb in both directions in order to carry safely the load for which they are designed.

The next set of poles is then lowered into position, the braces being caught and extended to the aftermost set, which is already in position. If it is found that the poles do not settle plumb, they should be adjusted with the braces in conjunction with a lever, as shown in Fig. 261.

Only the number of poles that can safely be braced before being left to be subjected to wind should be set at one time. Horizontal and transverse bucking braces should then be installed in order to make the staging that has been set up safe in case of windstorm.

The foregoing procedure can be followed with each successive set until the bow is reached, it being of no importance whether the entire side of the ship is staged before any standards are set on the opposite side.

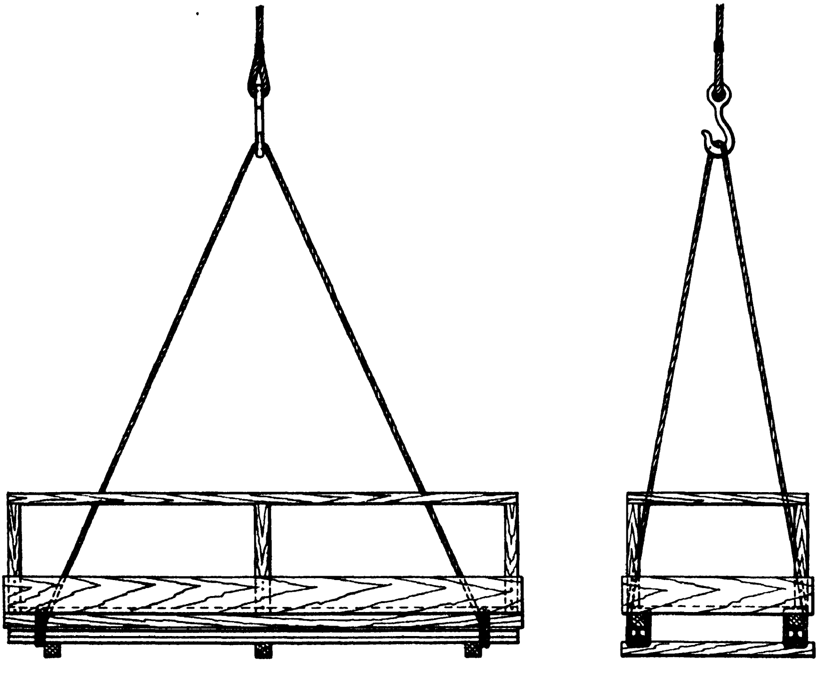


FIG. 262.—A float supported by the crane for installing horizontal and high bracing.

Where standards are extremely high, 5/8-in.-diameter wire-cable guys can be used to brace the staging temporarily. These guys may also be used as permanent braces.

The guys are fastened near the top of the standard to be braced. Each cable is stretched diagonally to the ground and pulled tight by means of a turnbuckle securely fastened at the bottom.

Where it is not possible to set the bottom of the standards into the ground, 4- by 6-in. timbers are used to fasten to the shipways caps and through the standard.

A float supported by the crane can be used conveniently in installing horizontal and high braces (see Fig. 262).

Ascertaining the Length of Poles to Be Used. In ascertaining the length of the poles to be used, the height to which the staging is to extend above the base line of the ship is added to the distance from the base line of the ship to the yard grade, together with an allowance for the amount that the pole will be set into the ground, if this is done. Each set of poles will vary in height. Standard-length standards that will best fit the height desired should be used.

Establishing Base Line and Deck Heights on Stage Poles. For the convenience of workmen working at the various deck levels, stage spauls are usually set so that a level of staging will fall 3 ft. 6 in. below the height of each deck. The required levels of staging between these points are then put in. It is therefore necessary that the stage spauls be set at these points. Since all deck heights are established from the base line of the vessel, the working point from which the spauls will be established will also be from the base line of the ship.

After the stage poles have been set and braced, the base line of the vessel should be leveled out from the keel track to the stage standards so that the various heights of staging can then be established. To do this, the inboard end of a straightedge should be held with the top even with the established base line on the keel track, care being taken that the straightedge is at right angles with the center line of the ship. When the straightedge is level, this line can then be marked on the stage pole. The marking can be done with either a race knife or paint. Three or four points along the side of the ship should be done in this manner; after this, short straightedges can be leveled out from these points and the balance of the base line sighted in from one straight edge to another.

After the base line has been established on all stage standards, a batten obtained from the mold loft, with the deck heights to each frame, can be applied vertically alongside the standards. The frame nearest to the standard is usually used and need not be exactly on the frame station. When the levels of staging have been marked on the staging standards, the spauls can be regulated so that these levels will line up and the stage planking will seat properly on the spauls.

At the forward and afterends of the ship where extra legs, uprights, or dummies are necessary, the manner of setting them is similar to that for the main stage standards.

The secret of good stage building is to foresee what may possibly happen to the stage, that is, to what strains it will be subjected and where danger spots may occur, and then build the stage to suit these conditions.

CHAPTER XIII

OUTSIDE SUPPORTS

During construction the ship's weight must be supported as uniformly as possible upon the building ways. As the center keel is considered the backbone of the ship, the major portion of the weight will naturally be supported on what is known as the *keel track*. From rough estimates it may be said that about 60 per cent of the weight of the ship is supported on the keel track, while the balance is supported on shores and cribbing on each side of the ship.

The second means of supporting the ship on the building ways is the *bilge cribbings,* which are located somewhere about the bilge of the ship. The cribbings tend to steady the ship on its main means of support, as well as being themselves a means of supporting the ship.

If the ship is an extremely heavy one and is designed with docking keels, a track similar to the center keel track is also constructed and utilized to support some of the weight. Such a keel track also tends to steady the ship, like the bilge cribbings, and thereby possibly eliminates some of these.

For ships in which the keel is knuckled and rises at the afterend (in some cases for a considerable height), the support in this area usually consists of *A frames*. These materially reduce the amount of timber that is required for blocking and cribbing.

One other means of supporting and aligning the ship is the *bottom shoring*. This is spaced and located in such a manner as to give the utmost support possible.

KEEL TRACK

In the construction of the keel track diversified methods and types of blocks are used in the various shipyards throughout the country. The spacing of the keelblocks is dependent on the foundations of the shipway and the size of the ship to be built. For example, on a shipway designed to accommodate extremely heavy ships, piling is provided at close intervals. It would therefore not be necessary to space keelblocks over each row of piles if a light ship were being constructed. That is, it might be possible to use blocks on alternate caps only.

The grade and design of a shipway and the type of ship also have some bearing on the amount of blocking necessary. If construction is on a declivity of $\frac{5}{8}$ in. per ft., a long ship would require considerably more blocking at the forward end than would be necessary on a shorter ship.

It is desirable to have approximately a uniform height of blocking throughout the ship in order that the settlement upon the keel track (which will result with flat-grained timber) will be uniform from end to end. In order to accomplish this, some shipways are constructed of concrete and stepped up from the water toward the forward end.

On shipways constructed on a straight or cambered grade to accommodate both large and small vessels, but not built up to any extent above the yard grade to permit crane lift clearance, it is sometimes necessary to use concrete cribbing blocks toward the forward end. These are used to a point at which it is more practical to resort to A frames, which give approximately the same amount of flat-grained timber as the remainder of the keel track.

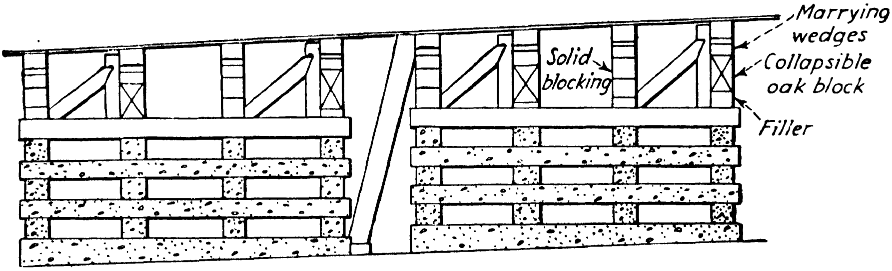


FIG. 263.—Concrete keel track cribbing.

On the old wooden type of stocks used for the construction of small and moderate-sized vessels, little consideration is given to the amount of keelblocking, for this does not increase to any great extent. However, the keel settlement is closely observed and any considerable amount of irregular settlement is taken care of by additional shoring and wedging up.

In the areas where there are greater weight concentrations, as in way of engine and boiler spaces and the after keel knuckle, it is advisable to stiffen up on the blocking and, if necessary, to crib up solidly in these areas.

For practical purposes it is roughly estimated that each keelblock 12 by 36 in. in bearing area should carry 100 tons if necessary. The construction of the flat and vertical keel must also be capable of carrying this load. Therefore, if the keel track is considered to support about 60 per cent of the weight of the ship and the weight of the ship is known, a quick estimate may be made as to just how much weight is being carried by each keelblock, provided that the keel is resting on all keelblocks uniformly.

Keelblocks must be plumb to eliminate the possibility of tripping. Where it will be necessary to split out keelblocks, the timber should be free of large knots. All timber used in the keel track must be sound, and each piece must fit solidly on top of the other.

The keel-track cribbing shown in Fig. 263 is a combination of concrete and wood blocking. The bottom blocks are built to a level plane, and above this the blocking is built up plumb.

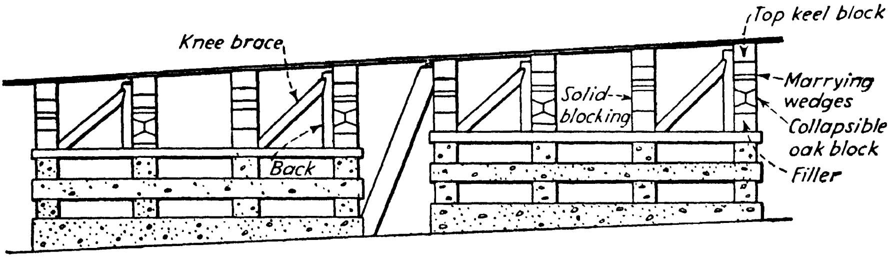


FIG. 263*a*.—Keel track showing alternate solid and collapsible blocks, including keel track backs and braces and marrying wedges.

From Fig. 263*a* it can be seen that solid and collapsible blocks are used alternately. The collapsible block (Fig. 264) affords easy removal without splitting out the keelblocks. On small or medium-sized vessels, collapsible blocks can be used throughout the keel track. The objection to the use of all collapsible blocks on heavy vessels is that greater settlement is likely to occur and the possible difficulty in their removal during launching operations, particularly in the case of the last blocks to be removed.

Keel-track blocking should be piled *not* higher than 3 ft. 6 in. *without being cribbed, to prevent it from tripping aft.*

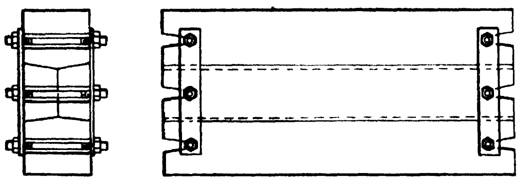


FIG. 264.—A collapsible oak keelblock.

In determining the extent of the fore-and-aft cribbing after the height and grade of the keel have been established, the following allowances must be made:

	Allowance, In.
Keelblock	7 to 11
Marrying wedges	11
Collapsible block	20

After the blocking has been cribbed up to the desired height by making the foregoing allowances, it may be necessary to use filler blocks of different sizes to make up the remainder of the distance from the fore-and-aft stringers to the grade of the keel. If filler blocks are used, they should be placed on top of the fore-and-aft stringers; after this the solid or collapsible blocking is put into position. The marrying wedges are then placed on top of a lower blocking.

Marrying Wedges. The purpose of the marrying wedge is to wedge up the blocking when it is necessary to remove the keelblocks for riveting, welding, or tank testing. When any irregular settlement takes place because of concentrated loads on the keel track, these wedges are also used to harden up in such spots to prevent further settlement. This is further discussed in Chap. XXXIII.

Marrying wedges are usually constructed of oak timber with a clinch pin riveted through each end to prevent checking and splitting. They are tapered from 8 to 3 in. The width of the marrying wedges should be the same as the remainder of the transverse blocking. On particularly heavy ships this may be 14 or 16 in. but is generally 12 in.

In placing marrying wedges in position, the thick end of alternate wedges should be placed on one side of the center line and the thick end of the alternate wedges between them should be placed on the opposite side of the center line. This causes one bevel to act against the other and reduces any tendency for the keel to slip off the center line.

Bracing and Stiffening Used on the Keel Track. Since a ship is built on an inclination for the purpose of launching when the hull is completed, much pressure is exerted aft. Although the keel track is cribbed to prevent tripping, it is necessary to brace the blocks further, to eliminate the possibility of their tripping aft.

This is done by installing braces on the after side of every alternate block. They are usually placed behind the collapsible block, because of the fact that the solid blocks are removed and replaced with sand blocks prior to launching.

Braces are made of either 6- by 8-in. or 8- by 8-in. timber. They consist of the back, which is the vertical piece, and the brace, which is placed diagonally from the top of the back to the bottom of the next set of blocking, as shown in Fig. 263*a*. In fitting the back, the bottom should rest on the fore-and-aft stringers in the cribbing at the center line and should extend to not less than 2 in. from the bottom of the keel to allow for settlement. Two shore wedges are then married over the top of the back against the keel; these can be eased off as a settlement occurs. A notch should be cut in approximately 3 in. from the top of the back to receive the head of the brace placed against it.

On particularly heavy ships 12- by 12-in. timber braces are also installed between every two cribbings, as shown in the figure.

Additional Blocking. As previously stated, where it is necessary to take care of heavy weight concentrations on the keel track, blocking should be reinforced to suit the framing structure of the ship.

Throughout the entire keel track, blocks are placed to suit the foundations of the shipway. Therefore, they cannot be placed directly under frames except at locations where frame stations occur directly over the piling or shipway foundation. In way of concentrated weights, an effort should be made to compromise between the shipway foundation and the ship in order to give support as near to the framing of the ship as possible.

Figure 265 shows a reinforced cribbing in way of the after keel knuckle of an extremely heavy ship.

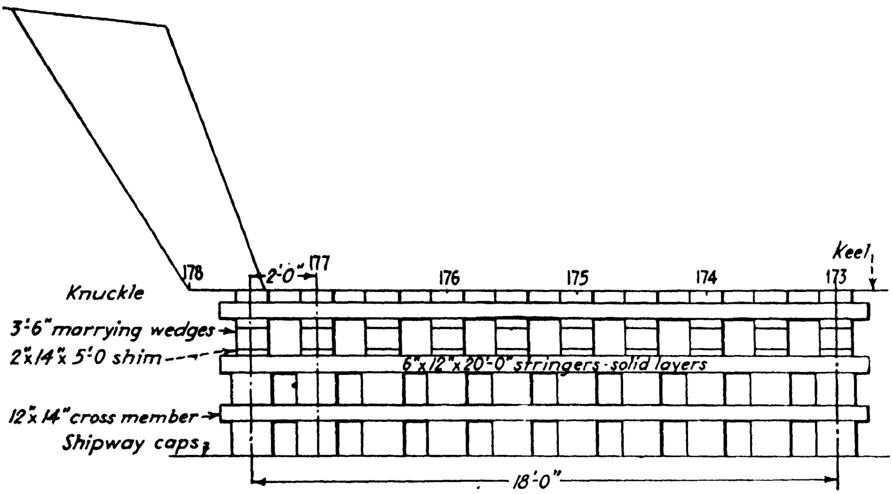


FIG. 265.—Reinforced cribbing in way of after keel knuckle of an extremely heavy ship.

A Frames. On ships in which the keel is knuckled and rises at the afterend and for which it is necessary to crib up for considerable heights at the forward end, A frames are used.

A frames are usually constructed of 12- by 12-in. timbers, having a base and top log with three columns. On light ships, timbers for A frames need not be quite so heavy, 6- by 12-in. or 8- by 12-in. timbers being used. However, the top and bottom blocks are usually 12 by 12 in.

In determining the height of the A frames, allowances are made for keelblocks, marrying wedges, and fillers, as in the case of the keel-track cribbing. Figure 266 shows a typical A frame using 12- by 12-in. timbers.

The timbers are generally fastened together with ¾-in. drift bolts and are braced in a fore-and-aft position with 4- by 6-in. horizontal and diagonal braces.

Constructing the A *Frame.* In constructing the A frame a layout may be made on some flat surface and the width of the top and bottom established from the center line. A frames are usually 6 ft. 6 in. at the bottom and 4 ft. 6 in. at the top. A template can then be made for the outside columns from the layout to be applied to the timber for cutting the proper bevel.

Both the top and bottom blocks should fit hard against all three of the columns. Therefore, care must be exercised in cutting the timbers to obtain this result. When the timbers have been cut, they can be laid on the layout and chocked in position by toenailing or with the use of 2- by 4-in. chocking blocks nailed at the boundary of the A frame. The

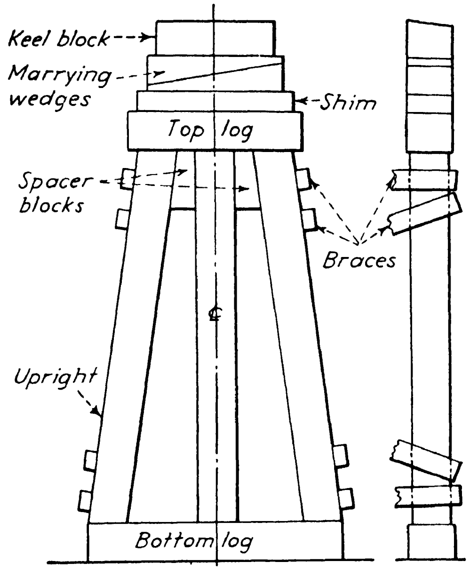


FIG. 266.—A typical A frame made up of 12- by 12-in. timbers.

top and bottom blocks can be put in place after the three columns have been set and can then be toenailed to the columns.

Holes for the driftbolts are then drilled in the top and bottom blocks and the drifts driven in. If desired, a diagonal brace can also be installed across the three columns to prevent racking.

Setting Up A *Frames.* After the necessary A frames have been built, the work of setting them up can begin. The first A frame set must be temporarily braced in a fore-and-aft direction; and 2- by 4-in. laths can be used.

After the first A frame has been set up, braced, and turned loose from the crane, successive A frames can be set up until a sufficient number have been erected to put on the final bracing. As each A frame is set up, it can be temporarily braced with a piece of 2- by 4-in. timber nailed to the first A frame set up. This first A frame should be well braced to hold it in an upright position.

All A frames should be set plumb in both directions.

After all the A frames required have been set up, the line of the keel can be established by nailing temporary uprights to the A frames to support a template obtained from the mold loft to give the line of the keel. Figure 267 shows the uprights nailed to the A frames with the template applied at the proper distance above the base line.

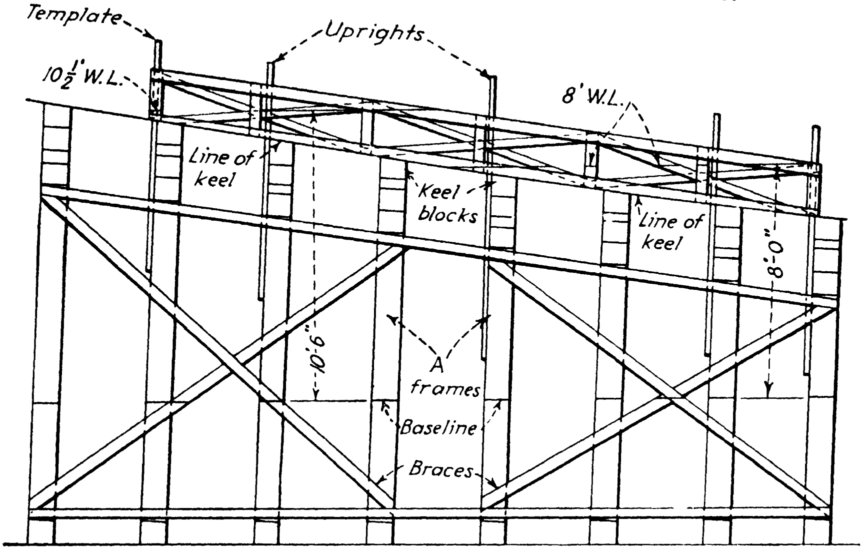


FIG. 267.—Uprights nailed on A frames with template applied to give the proper distance above the base line.

Fillers, marrying wedges, and keelblocks can then be put in place to the line of the keel. No backs or braces are installed on the blocking on top of A frames.

BILGE CRIBBINGS

Bilge cribbings are located close to the bilge of the ship. They tend to steady the ship and to act as an aid in supporting it. They are not installed under the ship until all riveting and welding in the area of the cribbing have been completed and the bottom has been painted.

The width of bilge cribbings is usually 6 ft. The length is varied to suit shipway foundations, being generally 16 to 20 ft.

The number of bilge cribbings under a ship is, of course, determined by the weight of the ship being constructed. For vessels up to 6000 tons in weight, three to four cribbings are installed on each side of the ship. For larger vessels the number is increased to a point at which it is felt that enough support has been given to steady the ship. Some shipwrights calculate a pair of cribbings for each 2000 tons of ship.

Cribbings should be so located that they will center approximately under main transverse strength bulkheads. In a transverse direction, the cribbings should be located as near to the bilge as possible, but at the same time they must be far enough inboard so that there is some flat portion of the shell bearing on the cribbing. They should also be placed under longitudinal strength bulkheads if there are any present in this area.

The cribbing shown in Fig. 268 is a collapsible cribbing to facilitate removal during launching operations.

The fore-and-aft stringers in bilge cribbings should be built to a level plane. That is, the top surface of the bottom blocking must be built up level before placing this stringer.

Blocking and cribbing are built up to within 45 in. at the closest point to the shell. From this point up, split blocks are installed as shown in

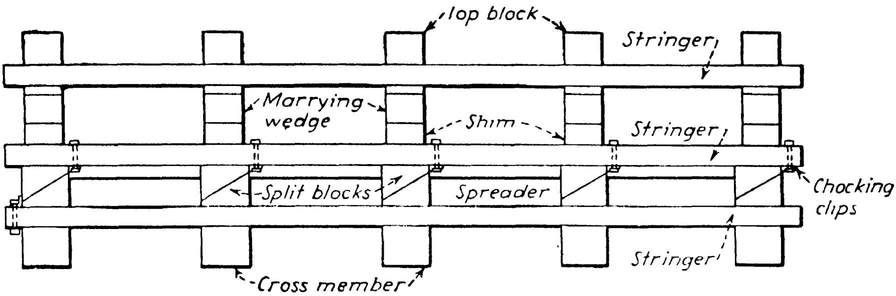


FIG. 268.—Collapsible bilge cribbing.

Fig. 268. At the after side of the after split block a clip 3 by 5 in. is placed against the block. This angle is extended across the three cribbing stringers and is bolted through each stringer with a ¾-in.-diameter bolt. This will prevent the block from slipping aft when wet or when pressure is applied on top of the cribbing. Between the remainder of the split blocks, 3- by 8-in. timber spreaders are used at the center of each stringer. These spreaders act as a backing for the remainder of the split blocks to prevent them from slipping.

It will be observed from the figure that the stringer on top of the split blocks is provided with a short clip on the forward side of the split block. This clip is a short angle extending for the width of the stringer, is located at each stringer, and is bolted with a ¾-in.-diameter bolt through the stringer.

When it is desired to remove the cribbing from under the ship for a launching by the removal of the bottom angle at the afterend of the cribbing and the spreaders between the split blocks, a blow with a ram on each of the stringers will cause these blocks to slip aft and free the cribbing from under the ship. These stringers, which are set on top of the split blocks, should not be less than 6 in. in thickness, as lighter timber will tend to split when being rammed out. In lieu of the use of clips fastened to the stringers for the purpose of collapsing the split blocks, the stringer may be notched out for a depth of 1 in. to fit over the top of the blocks, thereby serving the same purpose; however, if this is done, the bevel of the split blocks should be reduced to afford sufficient clearance for the blocks to collapse before the stringer fouls against the top of the lower split block. A light coating of graphite should be applied to the faying surfaces of the split blocks when they are installed to facilitate easy removal.

On top of the stringer containing the chocking clips, marrying wedges 6 ft. 6 in. in length are installed. This permits one end of the wedge to

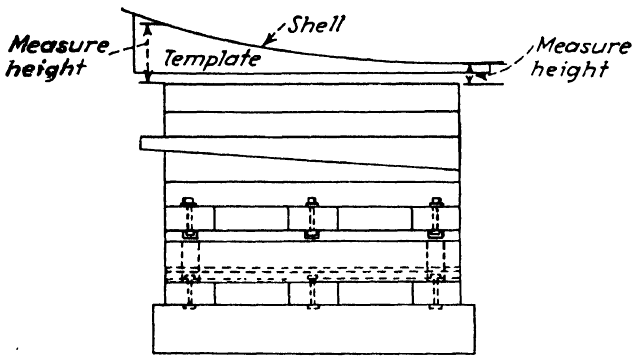


FIG. 269.—Fitting top block of cribbing from a template made on top of the cribbing and fitted against the shell.

project 6 in. beyond the side of the cribbing, so that the cribbing can be loosened if necessary by driving the wedges back in the event of a leak when tanks are being tested.

Another set of stringers is then laid on top of the marrying wedges. From this point up the necessary blocking between the stringer and the shell is fitted as shown in Fig. 268.

Fitting the Top Cribbing Block. In fitting the top block of a cribbing a template is made on top of the necessary filler, with a template fitted hard against the shell (see Fig. 269). Where there is any fore-and-aft shape, it may be necessary to fit a template at both the fore and after edges of the block. However, if the shell is flat, a template at the center of the block is all that is necessary. When the template has been finished, it can then be applied to a block and marked out for cutting.

Cutting can be done in one of two ways. If a heavy band saw is available, the block may be rough sawed to the greater size of the block. It can then be finished up with the use of a broad ax and foot adz.

Another method of cutting out the top block for cribbings is to use a crosscut or power saw, cutting notches from the top of the block to the desired lines and then splitting these out with a broad ax. The block is then worked down to the neat cut line with a foot adz.

Wedging Up Cribbing. After the top blocks have been shaped out and fitted against the shell, the cribbing is overhauled and shimmed up with thin featheredge shims where it does not fit tight. This measure should be avoided if possible and should not be applied to any great extent.

The marrying wedges, which, as stated previously, are 6 ft. 6 in. in length and which should be set back when installed for the purpose of

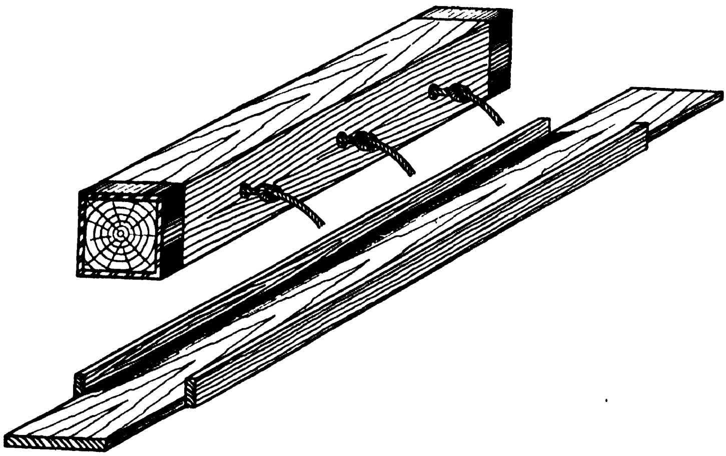


FIG. 270.—A six-man ram with slide used for wedging up bilge cribbing.

tightening up, can now be set up. A six-man ram with a slide, as shown in Fig. 270, is used for this purpose. Much effort should be put into tightening these wedges, so that the cribbing will correspond in hardness to the keel-track cribbing.

It is advisable to install cribbings as quickly as the work on the shell is completed in way of the cribbing, so that, as the weight of the ship is built up, it will exert about the same pressure on the cribbings as on the keel track.

Settlement affecting outside supports is further discussed in Chap. XXXIII, Establishing Working Lines.

ARRANGEMENT OF SHORING

The arrangement and number of shores to be placed under a vessel depend on its size and weight. As has already been stated, shores and cribbings carry about 20 per cent of the weight on each side of the keel track. In determining the number of shores to be placed under the ship,

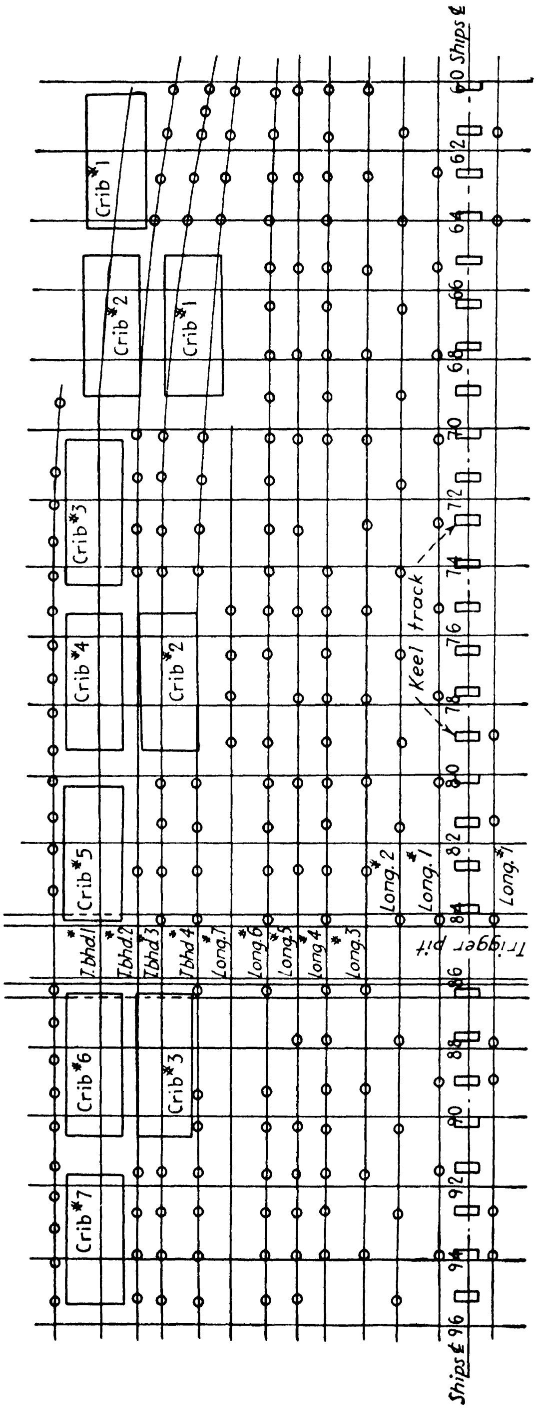


FIG. 271.—Arrangement of shoring through midships under an extremely heavy ship, together with keel track and bilge cribbing.

it is estimated that 10 per cent of the weight on each side will be supported by shores during the construction of the ship. However, on the day of launching, in some shipyards, cribbings are generally removed first, and shores will therefore carry 20 per cent of the weight on each side.

The type of construction also to some extent governs the location of the various rows of shores. For example, if the vessel is to be constructed in three sections athwartship, that is, the center portion and then the wings on each side, one row of shores should be located to support the outer end of the centerline section on each side of the ship and then additional rows installed to facilitate leveling and supporting the bottom for lining up. The same treatment should be given to the wing sections, with one row of shores on the outer end of the section or at the bilge and the additional rows necessary to line and level up the section.

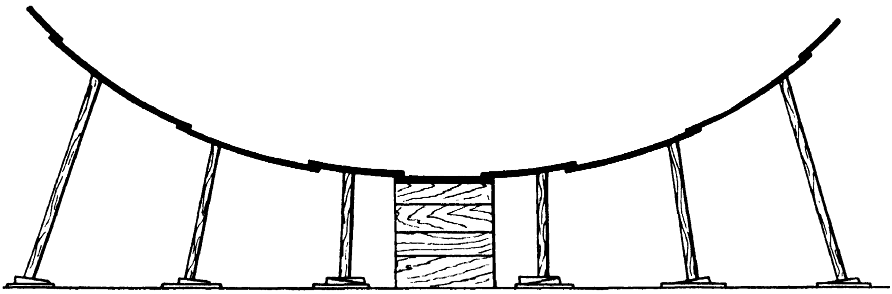


FIG. 272.—Transverse section of shoring under a moderate size vessel.

It is roughly calculated that shores carry about 10 tons each. The number of shores in each row is then determined by the number of rows required to level up and support the bottom. That is, a vessel weighing 20,000 tons is said to have 20 per cent, 4000 tons of the weight, supported on five rows of shores on each side of the ship. This would mean that 800 tons would be supported on each row. The number of shores in the row at 10 tons per shore would then equal 80.

Consideration must also be given to the fact that it is not possible to put the same number of shores in each row because of the shape of the ship at the forward and afterends. Therefore, a larger number of shores will be installed on the inner rows than on the outside row.

The foregoing is an estimate only and is to be used as a guide, since it is a well-known fact that some shores may be carrying considerably more weight than others.

It may be necessary to set up more shores than are required to carry the weight when leveling and setting the bottom of the ship and the structure on top of it. All unnecessary shores, in addition to the supporting shores to line up the structure, are generally removed during the installation of the launching cradle or a few days prior to launching.

In Fig. 271 is shown the arrangement of shoring under an extremely heavy ship, together with the keel-track and bilge cribbing. Figure 272 shows a transverse section of shoring under a moderate-sized vessel. In Fig. 273 are shown the fore-and-aft sections of the arrangement and strut of shores.

Shifting Shores. During the construction of the vessel, shores must be shifted from time to time for the purpose of completing work in the area under which the shores bear. When this is necessary, only every third shore should be removed at a time. These shores should then be

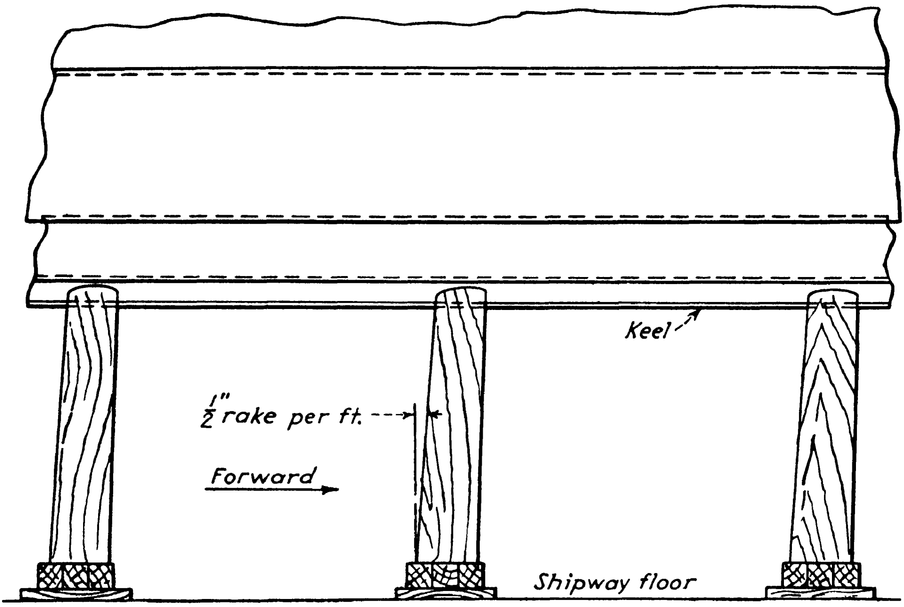


FIG. 273.—Fore and aft section of arrangement and strut of shores.

reinstalled before the next group of shores is removed. As each shore is reinstalled, all work on the shell should be checked and O.K.'d and the head of the shore marked "O.K." to inform those concerned that all work on which these shores bear has been inspected and completed.

Where extremely heavy vessels remain on the stocks for a considerable length of time, it has been found good practice to shift shores, even though they have been moved previously for inspection and completion of work under them, halfway between the time that they were checked and O.K.'d and the time of the launching. In doing this, weight on the shores is equalized and settlement on the keel track and cribbing allowed to occur, and thus the danger is removed of possibly tipping the ship if too much weight is supported on the shores alone. Another advantage in doing this is that shores will not be so difficult to remove on launching day.

CHAPTER XIV

PREPARATIONS FOR LAYING DOWN THE KEEL AND BOTTOM SHELL

In placing any vessel on the stocks several major factors must be taken into consideration.

1. Its length.
2. Width, or breadth, and height.
3. Approximate launching weight.
4. Position of trigger pit and location of existing gangways.
5. Vertical position with respect to the building ways.

Before any modern ship can be constructed, it is necessary to build a foundation that will support the ship. This consists of a keel track, or a series of wooden blocks upon which the foundation of the ship is laid.

The laying down of the keel on the stocks is usually done with the consideration of its launching uppermost in mind. At the same time, consideration must be given to locating the ship, insofar as possible, so that access may be had aboard ship from permanent gangways in the trestles or other accesses on the stocks.

HEIGHT AND GRADE OF KEELBLOCKS

Height. The height of the keelblocks must be kept as low as possible. At the same time, they must be high enough to afford sufficient thickness of packing above the setting-up wedges at the closest point to the hull after the ground and sliding ways have been installed.

Grade. The grade of keelblocks is determined jointly with the height and must meet similar conditions; that is, the vessel must be kept as low as possible. Still more important, the ship must be kept in the proper relation to the ground-way inclination so that the bottom of the keel at the stem will never drop below the level established at the top inside edges of the ground ways during the passage of the ship toward the water, particularly when pivoting occurs.

The grade of the keel is largely determined by the size of the vessel to be built. This is because a small ship, due to a probable smaller unit pressure, will not have as much tendency to slide as a larger ship on the same inclination.

The general practice in determining grades is in accordance with the following inclinations:

Vessels	Inclination, In. per Ft. Grade
Small	7/8 to 1
Moderate-sized	11/16 to 3/4
Large	1/2 to 5/8

Running Keel Grade. With the height above the top inside edges of the ground ways established and the slope of the keel grade also decided upon, the next question to be considered is the point from which the grade will be started. This will, of course, be governed by the founda-

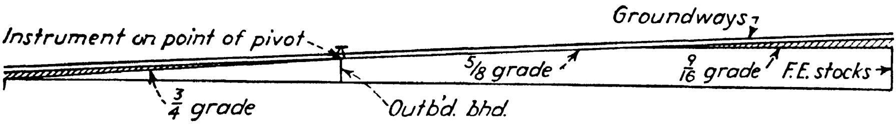


FIG. 274.—Grade of keel pivoted at outboard bulkhead.

tions that will support the ground ways for launching. If the grade of the outboard foundations differs from the grade of the stocks in order to vary keel grades to suit various sizes of ships, the grade of the keel is pivoted at the point where the shipway grade changes. This point is usually located somewhere near the low-water mark (see Figs. 274 and 280).

On shipways of the semisubmerged type where the ground ways are in the dry until the caissons are removed, the beginning of the grade should start at the caisson gate unless the grade to be established is somewhat less than that of the shipway stocks. That is, if the stocks are so constructed that cambered ways can be used, the highest point above the chord extending from the caisson to the forward end of the stocks should

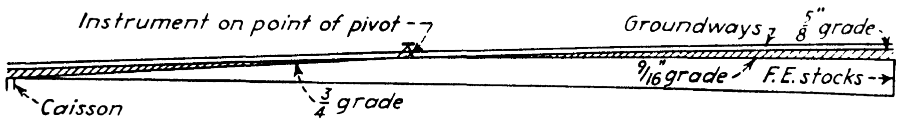


FIG. 275.—Grade of keel pivoted at highest point above cord of shipway caps.

be used in running the grade. It must, however, be remembered that in doing this the amount of water over the way ends will be materially reduced if a straight keel grade is used and therefore that other provisions may have to be made. Such a condition is shown in Fig. 275.

After the base point of the grade has been established, the procedure will then be to establish the grade. This can be done with the use of a surveyor's level or with a large straightedge and spirit level in conjunction with a declivity board.

Figure 276 shows a 5/8 in. per ft. grade run with a straightedge. With a 25-ft. straightedge, 24-ft. intervals can be used.

Setting Up Batter Boards. With a steel tape on approximately a level plane, lay off 24-ft. intervals, beginning at the lowest point of the grade at the water's edge. Next, set up legs to support batter boards at these points. These legs should be long enough to take care of the height of the keel above the launching grade after it has been established. If the grade of the keel is parallel to the grade of the ground ways, then the grade of the ground way is usually ignored until preparations for installing the ground ways are started. However, if the launching and the keel grade differ, it is necessary to establish the launching grade first in order to establish the height of the keel at the desired distances above the ground-way grade.

With thumb clamps, first set up the batter board on its leg supports at the established point above the ground-way grade. Nail the batter board to one of the supports, and then, with the spirit level, bring the batter board into a level plane. This will establish the first batter board. Now, proceed to the next batter-board support, set up the straightedge in a level fore-and-aft position, and mark the bottom of the straightedge when it is level. From this point, measure vertically 15 in., and erect a batter board similar as in the first operation. Continue this procedure until the entire length of the vessel has been covered.

After the grade has been run for the entire length of the ship, sight the batter boards with the eye to see whether or not they line up. In the event that some of the boards are out of line, set back the long straightedge over the batter board in question, and check for correction. It may be necessary to recheck all batter boards forward of this point if an error of any consequence has been made.

After all batter boards have been set in line, set up a declivity board with the designed grade on the long straightedge at various points on top of the batter boards. If the boards are on the correct grade, a spirit level set on top of the declivity board should show level (see Fig. 277).

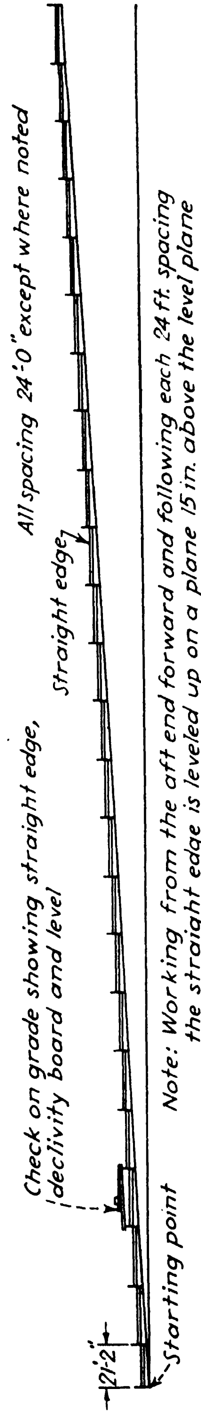


FIG. 276.—Running keel grade with a straightedge.

The experienced shipwright will not find it necessary to go through this long procedure. He can rely on the accuracy of a trained eye in sighting in the batter boards after he has once established two points of sight. This can be done by starting with the first batter board at the base of the grade and then establishing the second board with the use of the long straightedge and a declivity board on which will be set a spirit level. After the second batter board has been established accurately in this manner, the balance of the boards for the entire length of the keel can be put in by sighting across these two batter boards. They can be rechecked with an engineer's level if desired.

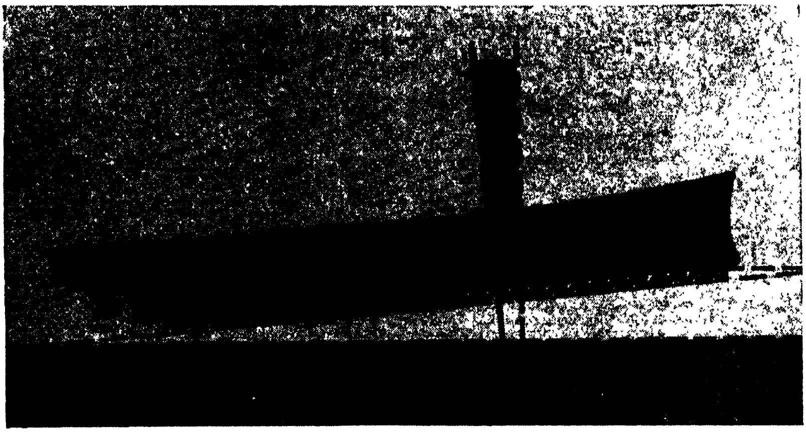


Fig. 277.—Spirit level set on top of declivity board.

Using the Engineer's Level to Run the Keel Grade. A much quicker and more accurate job of running the grade can be accomplished with the use of an engineer's level and a rod.

Method 1. By taking points approximately 200 ft. apart, the level can be set up at mid-distance between each of these points and a plus and minus reading taken on the rod. If the length of the ship is 600 ft., three setups will have to be made. The same procedure should be used for establishing the location of the batter boards at these points as was used in running the grade with the straightedge and spirit level.

By using Fig. 278, calculations are found for the setups made.

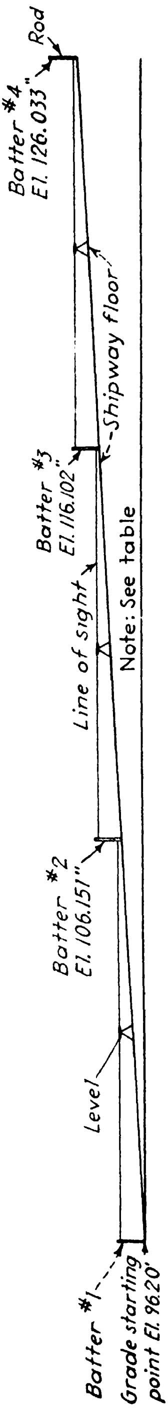
After the four base batter boards have been established, the level can be set up behind either of the straightedges and the instrument brought into adjustment with the other batter boards. Intermediate batter boards at the desired intervals can then be established to line in with the base batter boards.

Method 2. Another method of running the keel grade requires but one setup with the level in running the entire grade. This can be done as follows:

First, all uprights necessary for the entire length of the proposed keel track are set up. The exact distances between the foremost and after-most uprights must be known so that the declivity can be figured and heights set up at these points. If, for example, the distance between the uprights is 400 ft. and a grade of 5/8 in. per ft. is to be used, the elevation on the forward upright should be set 20 ft. 10 in. higher than the after elevation, which is set on the starting point of the grade. This establishes a true grade between these two points.

The engineer can now run the grade on the intermediate uprights. A rule should be clamped to the forward and after uprights at a convenient height above the spots that have been established for the grade. The instrument should then be set up about mid-distance between the uprights, with the leveling screws square with the center line. The instrument should be leveled up in both a transverse and a fore-and-aft position; then, by sighting fore and aft and using the fore-and-aft leveling screws, the instrument should be adjusted to the same height on each rule. At the same time, the instrument should be leveled over the perpendicular leveling screws. (*The latter is an important step and if it is not accomplished, an error can easily result.*)

With the instrument now on the proper declivity, the grade is established on the intermediate uprights by having someone hold a rule batter at each upright in the same manner as was done at the forward and after ends. For example, if the reading on the rule forward and aft is 17 1/8 in., then the rule must be moved up or down until the 17 1/8 in. on the rule at the intermediate upright shows under the



Note: 15 ins. the thickness of groundways is to be added to all elevations in determining final point on batter, keel grade 5/8"/ft.

Points	Elevation	+ Sight	− Sight	H.I.
Batter #1	96.20'	10.823		
Batter #2	106.151'	10.798	0.872	107.023
Batter #3	116.102'	10.848	0.847	116.949
Batter #4	126.053'		0.897	126.950

FIG. 278.—Calculations for grade run with engineer's level.

hairline of the instrument. The bottom of the rule is then marked, and this should line in with the forward and after batter boards. Both the instrument and the rule for setting the straightedge should be at the approximate center line of the proposed ship. A spirit level is then used to level the batter board in a transverse direction. Figure 279 shows a shipwright establishing intermediate batter boards with the instrument at the extreme forward end.

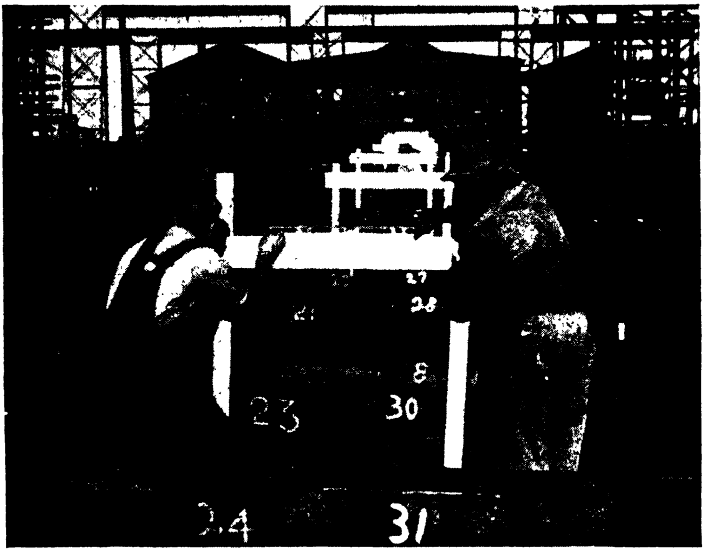


FIG. 279.—Shipwright establishing intermediate batter boards for a keel grade.

ESTABLISHING THE SHIP ON THE GRADE IN A FORE-AND-AFT POSITION

After the line of the keel has been established, the next step in locating the ship on the stocks is in accordance with the profile shown in Fig. 280. This line, or grade, is called the *declivity angle*. As shown in the figure, it is required that a point 4 ft. forward of frame 64 should be 327 ft. 2 in. from the outboard bulkhead, or the point to which the grade of the shipway pivots in this particular instance. This, then, will be the point from which the frame stations of the ship will be established.

Other dimensions shown on the figure have reference to the building ways and launching ways, which must be considered before the keel is laid, as previously stated.

Permanent Reference Points. Before the ship is actually located on the stocks, the center line and a line square to the center line must be established on them. From these lines all measurements can be made.

Permanent monuments can be set at convenient locations on the shipway, from which the center line, base line, and square lines can be taken or rechecked at any time. These monuments can be established on a commonly used grade, and elevation above *mean low water* can then be taken from them. From these elevations any desired grade can be checked very quickly. The establishment of the monuments helps the shipwright check his lines with greater accuracy.

From the permanent center line of the shipway and grade of construction a datum line can be run at equal distance from the center line for the transverse location on these monuments. Square lines are then turned at right angles off the center line of the stocks at the desired locations of the monuments.

The monuments need not be at any particular point and should be so located that no obstructions will be in the way between the monuments abreast of each other. A satisfactory arrangement is shown in Fig. 281.

Marking the Reference Points. When the points of the monuments have been established, a brass plate enclosed in a 4-in.-diameter pipe with a cap is set into concrete at approximately the proper location as shown in Fig. 282. After the concrete hardens, points and exact elevations should be punched on the brass plate and recorded so that the ship-wright can determine the base-line height from them when measuring for a water or square line.

Uses of Reference Points. After a ship has been launched, base-line heights for any grade can be established from the monuments with very little difficulty. Another purpose that the monuments serve is that they furnish a reference point, clear of the ship and the settlement which will no doubt occur, particularly on large heavy ships.

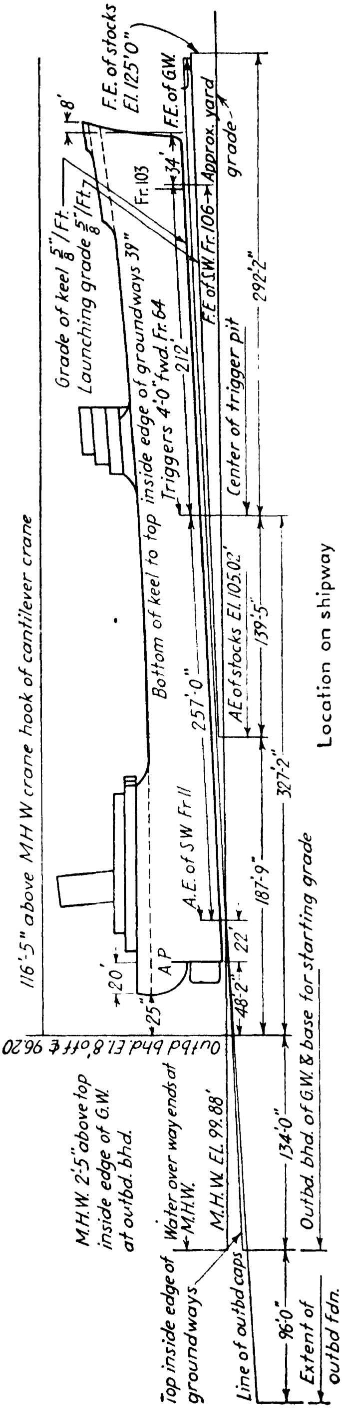


FIG. 280.—Profile of a ship's location on building ways.

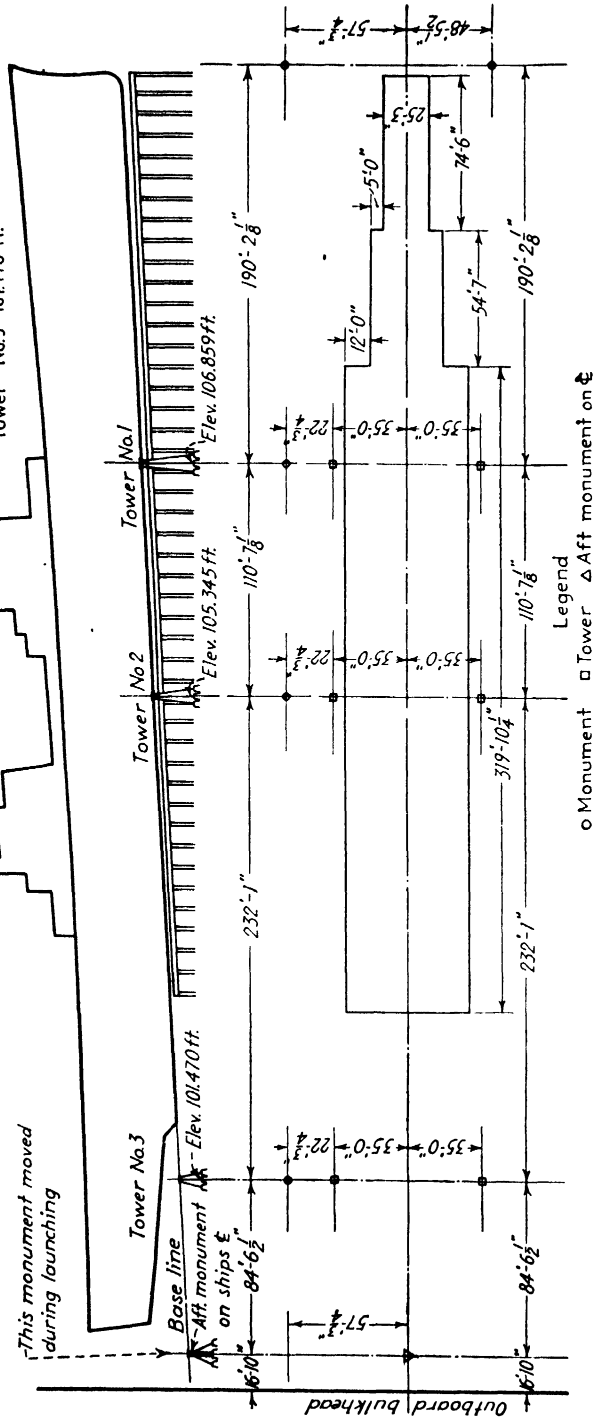


FIG. 281.—Arrangement of monuments around the shipway.

If the ship being constructed is designed to carry armor, frequent checking must be done in way of the armor installation to ascertain any great amount of movement of the structure due to welding, which will affect the armor, which usually comes from the manufacturer in a fabricated state. For this purpose, also, the monuments prove a valuable aid.

Towers as Reference Points. To establish permanent reference points for the base line of the ship, towers similar to those shown in Fig. 283 can be set in concrete. As can be seen from the sketch, the top of the plate on top of the tower is set at the base-line height. The plate is of the same thickness as the keel; therefore, the lower side will be the same elevation as the underside of the keel.

The top plate is adjustable so that by swinging a plumb bob down to the monument it can be moved in any direction until the plumb bob is centered over the point on the monument. The legs of the tower are also adjustable in order that the top plate can be raised or lowered to the desired base-line height.

The shipwright can plumb down to these towers to get his square lines, water lines, center lines, and buttock lines. However, in measuring for water lines, consideration must be given to the amount of settlement of the ship, which is deducted from the top of the tower.

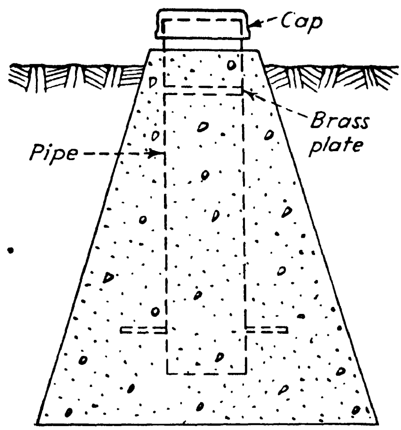


FIG. 282.—Sketch showing monument with brass plate and cap.

No matter what process is followed in the building of a ship, whether it be from midship forward and aft or from either the forward end or the afterend, any desired lines may be checked from the monuments without referring one part of the ship to the other.

WORKING THE KEEL-TRACK CRIBBING AND BLOCKING

Since the keel-track cribbing and A frames up to the point of working the keelblock have been discussed in Chap. XIII, Outside Supports, the work of lining up and setting the keelblock will now be discussed.

Chalk Lines. If the keel is designed with knuckles, either forward or aft, their location should be approximately established to determine the extent of the keelblocking on a straight grade.

From the batter boards set up to establish the height and grade of the keel, chalk lines may be extended between batter boards. When this line is pulled tight over the tops of the boards, it is at the correct angle of declivity.

Hand Cutting. If the keelblocks are to be worked by hand on the stocks, they may be laid on top of the marrying wedges with the ends at an equal distance from the center line. The chalk line extending

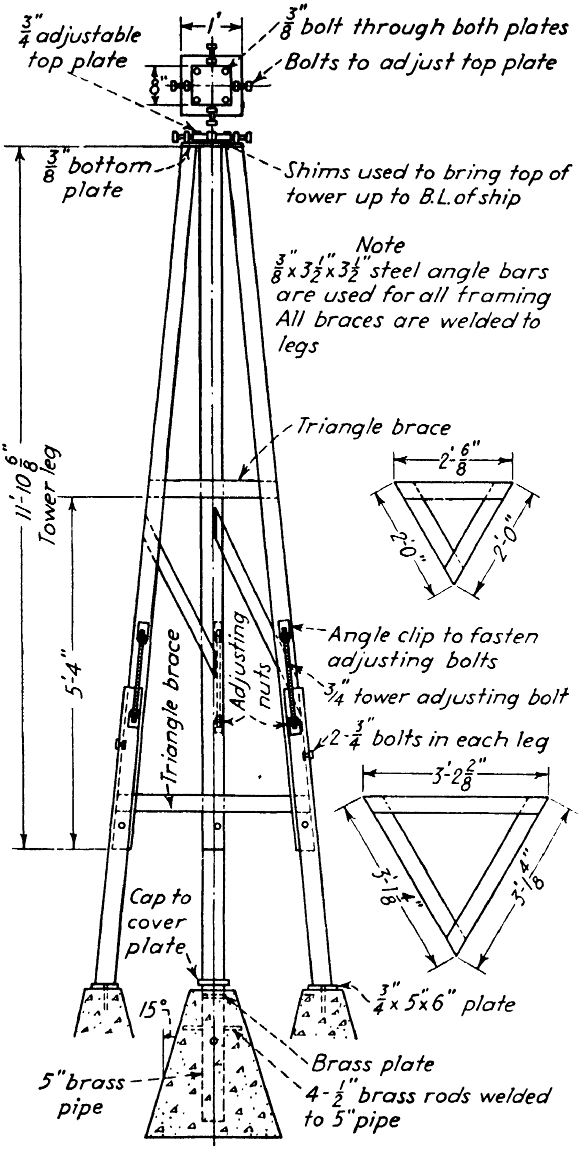


FIG. 283.—Sketch of checking towers.

between the batter boards can then be moved in to the ends of the keel blocks. The line can be chalked and snapped across the ends of the blocks so that these can be cut to exactly the correct angle and height required.

All edged tools used in working blocks must be sharp. A broad ax is first used to rough out the block; after this it is dressed to the chalk lines with a foot adz. To hold the block steady for cutting, it should be toenailed to a larger piece of timber, as shown in Fig. 284.

Milling. If keelblocks are to be worked in the mill or on a bed planer, measurements at each corner of the block will have to be furnished to the mill. The blocks are then planed down to these points.

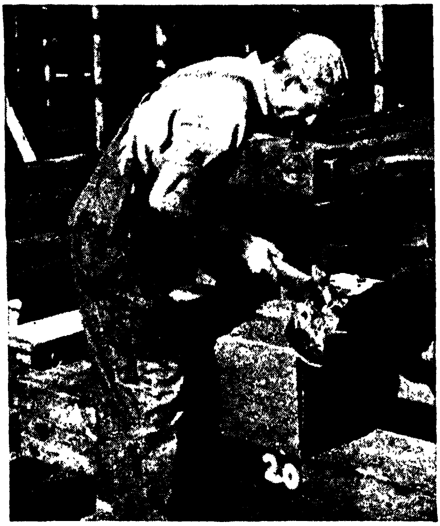


Fig. 284.—Keelblock toenailed preparatory to cutting to proper shape.

For the purpose of taking the measurements of the blocks, the measuring box shown in Fig. 285 is used. This is placed on top of the marrying wedges, and readings are taken at each corner of the box to the chalk line which is extended between the straightedges by a method similar to that for striking a line on the ends of the blocks. The outside dimensions of the box are the same as those of the keelblock to be used.

Each block is given a number, beginning forward, so that it can be placed in its proper location when brought from the mill.

Finishing. After keelblocks have been set in place, they are toenailed to the top marrying wedge. A straightedge is then placed over all

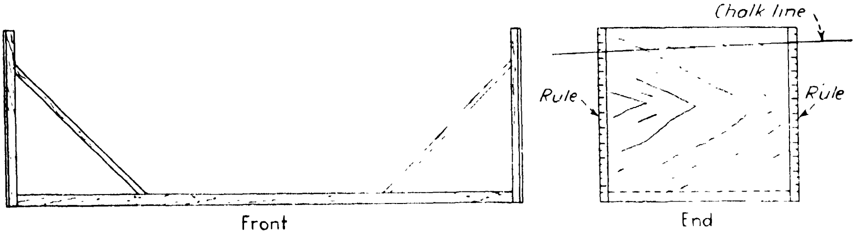


Fig. 285.—Keelblock measuring box.

blocks from one end to the other, and high spots are removed by planing with a jack plane or, if necessary, reworking with an adz.

At the forward and after ends, if the keel is designed with a rise, the amount of rise is taken from the base line at the designed frame stations, and additional batter boards are set up to the bottom of the keel. The blocks in this area are then worked in the same manner as those amidships.

After it has been ascertained that all blocks line up, the balance of the blocking and cribbing supporting the keelblocks should be toenailed with 3-in. wire nails to prevent any movement until the keel has been laid.

A shifting line is scribed, or raced, into the wood with a racing knife. This line serves as a telltale when the blocks are shifted out of position or removed to do riveting and welding on the keel. The blocks and wedges are then marked with their proper numbers. Each section is numbered to identify its position in the keel track.

ESTABLISHING THE CENTER LINE

After the keel-track cribbing and blocking are nailed so that they will not move, the center line of the ship is established on the keelblocks so

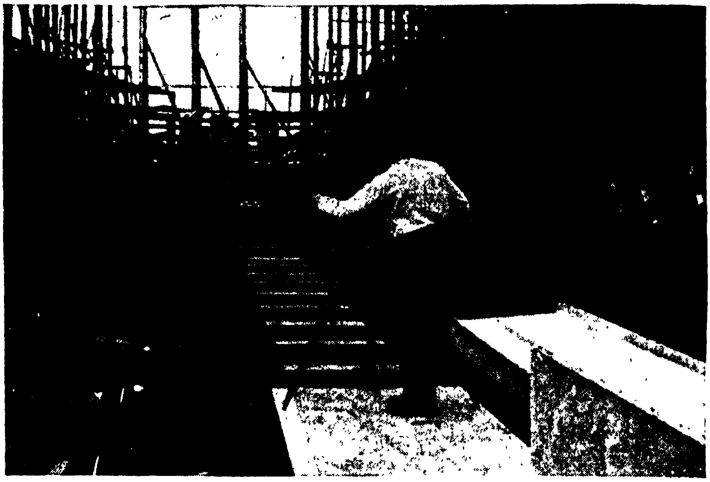


FIG. 286.—Establishing center line on keelblocks with engineer's transit.

that the keel can be set to this line. From the monuments plumbed up to the top of the keel track, spots are established and an engineer's transit is set over one of the spots. The instrument is then brought into alignment with the other spots; after this, convenient points can be established along the keel blocking, as shown in Fig. 286. The entire center line is then snapped in with a chalk line across the keel blocks, as shown in Fig. 287.

After the center line has been chalked across the keel blocks, it is sawed in at the edge of each block to avoid any error in setting to a wrong spot.

SETTLEMENT TELLTALES

As soon as the keel track has been built, telltales should be installed and a reference point center punched on the telltales. This point should be a convenient distance from the top of the block.

From this point the amount of settlement can easily be determined as the weight of the ship settles on the keelblocking. Any uneven settlement due to the flat grain of the blocking can be corrected by setting up on the marrying wedges under the keelblock.

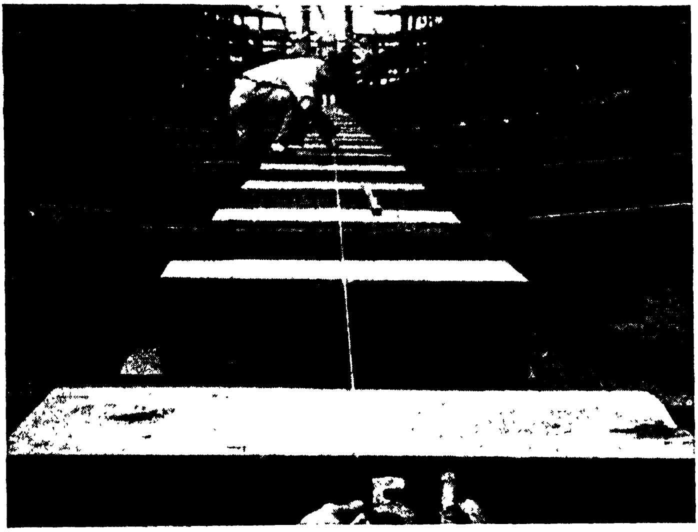


FIG. 287.—Chalking in center line on keelblocks.

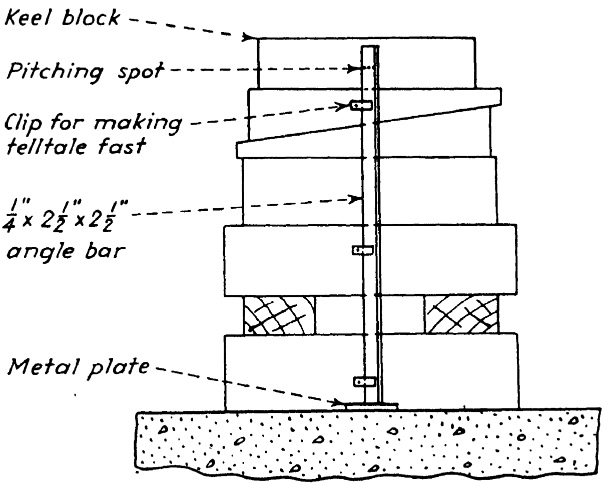


FIG. 288.—Settlement telltale with pitching spot.

Accurate measurements of settlement will not be available from the telltales because of the fact that the area in the vicinity of the keel track will sometimes settle. Therefore, checks must be made back to the monuments from time to time to detect this condition (see Fig. 288).

TRADE TERMS

Working as used here simply means cutting to fit.

Snapping the line means grasping the chalk line firmly between the thumb and forefinger of either hand, pulling it back straight until clear, and then releasing it.

SAFETY PRECAUTIONS IN WORKING KEEL-TRACK BLOCKING

Be sure that your work is in a steady position.

Keep the ax and adz blades free of chips.

Stand in a steady comfortable position when using the ax or adz, to avoid the danger of cutting yourself.

Do not lay the ax or adz where others may be hurt.

Keep your tools in good condition at all times.

CHAPTER XV

SPAULS AND CRADLE

In order that the bottom shell of the ship may be laid down in approximately its designed form, a mold, or cradle, must be built, as shown in Fig. 289. With the keel track completed and ready for the flat keel, the spauls that make up the cradle are next set in position. Since the shape of the hull is determined by the shape of the spauls, separate patterns must be used for each one. These patterns are called *template*

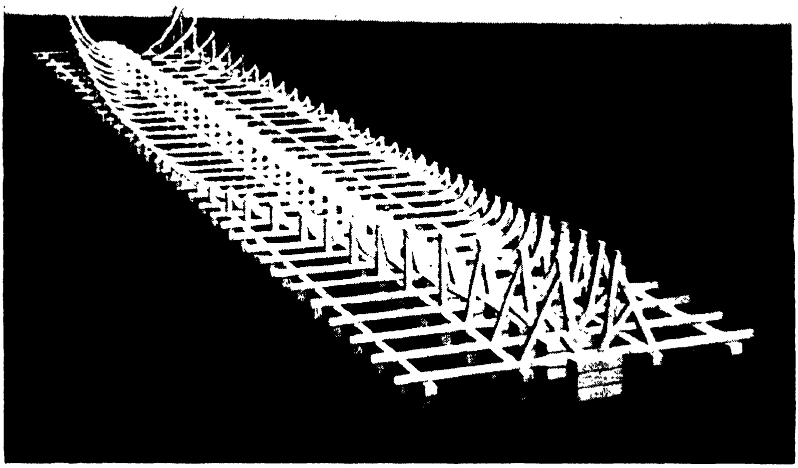


FIG. 289.—Cradle for the bottom of the vessel.

molds, and the shipwright must construct and set the spauls to conform exactly to these templates. The base line, water lines, buttock lines, and shell seams are indicated on the templates and must be carefully checked and transferred to the spauls, as shown in Fig. 290.

Shell spauls can be made of either timber or steel. If the former is used, the spauls are generally cut out of timber 3 by 12 in.

The after side of the spauls in the forward body is held on the frame line. In the afterbody, the forward side of the spaul is held on the frame line. This procedure eliminates the necessity for beveling the spaul, unless it is desired to do so. In this case bevels are obtained from the mold-loft body plan, and the spauls are cut to suit them.

If steel spauls are used, they may be constructed of heavy flat bar, angles, or channels. Heavy flat bar, preferably ⅝ by 6 in., is the most satisfactory.

From the templates the flat bar (or other structural shapes) can be shaped by cold pressing and furnacing to fit the templates. After the steel has been shaped, the templates are applied and all reference lines are accurately marked.

The lines are center-punched and marked with paint so that the spaul can be properly set in position on the shipway. The symbol for each

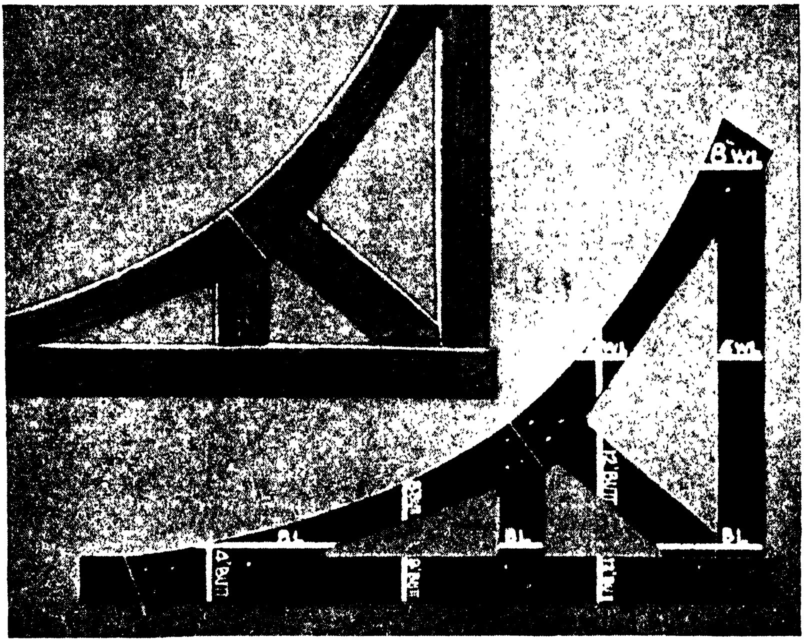


FIG. 290.—Bottom spaul and template for same.

specific line should be clearly marked with a marking brush to prevent mistakes in setting the cradle.

Since both sides of the ship are exactly the same, templates are usually made for only one side. With the half spaul completed, the template is reversed or turned over, from the center line, so that the other half of the spaul can be made. The left side, called the *port side*, is always the left side of the ship looking forward. Everything to the right side of the center line looking forward is the *starboard side*.

In building the spauls of timber, the shape is first marked on the wood and then cut out on a band saw. When the pieces of timber forming the shape of the shell and base line, together with the uprights and braces, have been put together, the spaul is clamped and drilled for bolting.

After the timbers are securely bolted, all reference lines are accurately marked. The lines are then retraced with a race knife so that they will remain permanently in the wood.

When only one ship is to be built from a set of spauls, it is more practical to construct them of wood, since much of the material can be obtained from salvage staging and bracing previously used.

Setting Timber Spauls. After all the necessary spauls have been constructed and marked with the essential working lines, the operation of setting them up can begin. If timber spauls are used and constructed as shown in Fig. 291, ribbands running parallel to the center line at a fixed distance below the base line can be set up on 6- by 6-in. timbers.

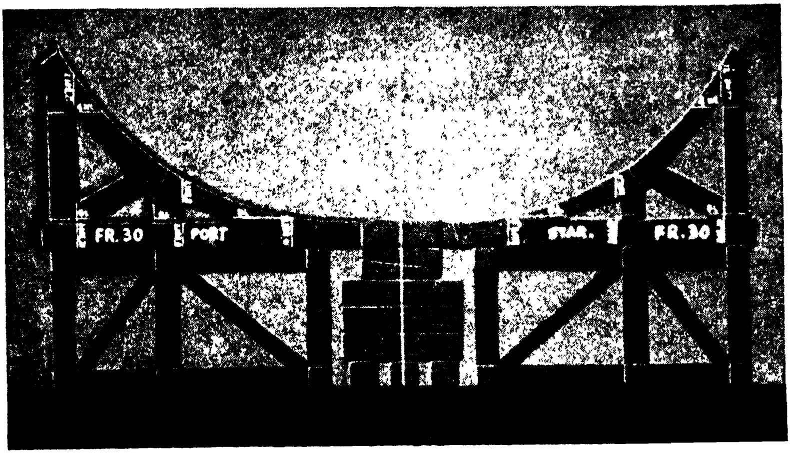


FIG. 291.—Cross section of bottom spaul and supports.

The timbers supporting the ribband are generally cut with a shoulder on which the ribband is set. The ribband used in most instances is 3 by 12 in. plank set up edgewise. The number and location of the ribbands depends on the weight to be supported. There should be one ribband at the inboard and outboard ends of the spauls and one or more, as necessary, between these on each side of the ship. Frame stations are then marked on these ribbands for the location of the spauls.

Spauls may be connected together across the center line if they do not foul the keel blocks. Where a keelblock comes in the way of a spaul, the latter is butted against the keelblock.

The spaul is lowered into position by the crane. The heel, or the side on which the template has been applied, is set on the frame station. It should then be moved until it is the proper distance from the center line of the keel track.

The spaul may be raised or lowered until its base line is in line with the base line on the keel track, as shown in Fig. 291. This is done by easing off or tightening up on the wedges under the ribband.

After the inboard end has been set, the base line marked on the spaul is checked with a level. If this is satisfactory, the spaul may be temporarily fastened in a vertical position at right angles to the base line or grade of the ship. On welded construction it has been found good practice to set the spauls about ½ in. lower than designed, owing to the fact that welding tends to raise or lift the bottom. This will to some extent compensate for the lifting.

Fig. 292.—Spauls supported on permanent shores under the ship.

For temporary bracing, 2- by 4-in. timbers can be used. Successive spauls can be erected in the same manner until a section large enough to fair up and brace has been set up (see Fig. 292). The spauls can then be tied together by means of 4- by 6-in. timber fastened to the outer uprights. It may also be advisable to run a line of braces through the center of the spauls to prevent them from tripping aft, owing to the declivity of the ship.

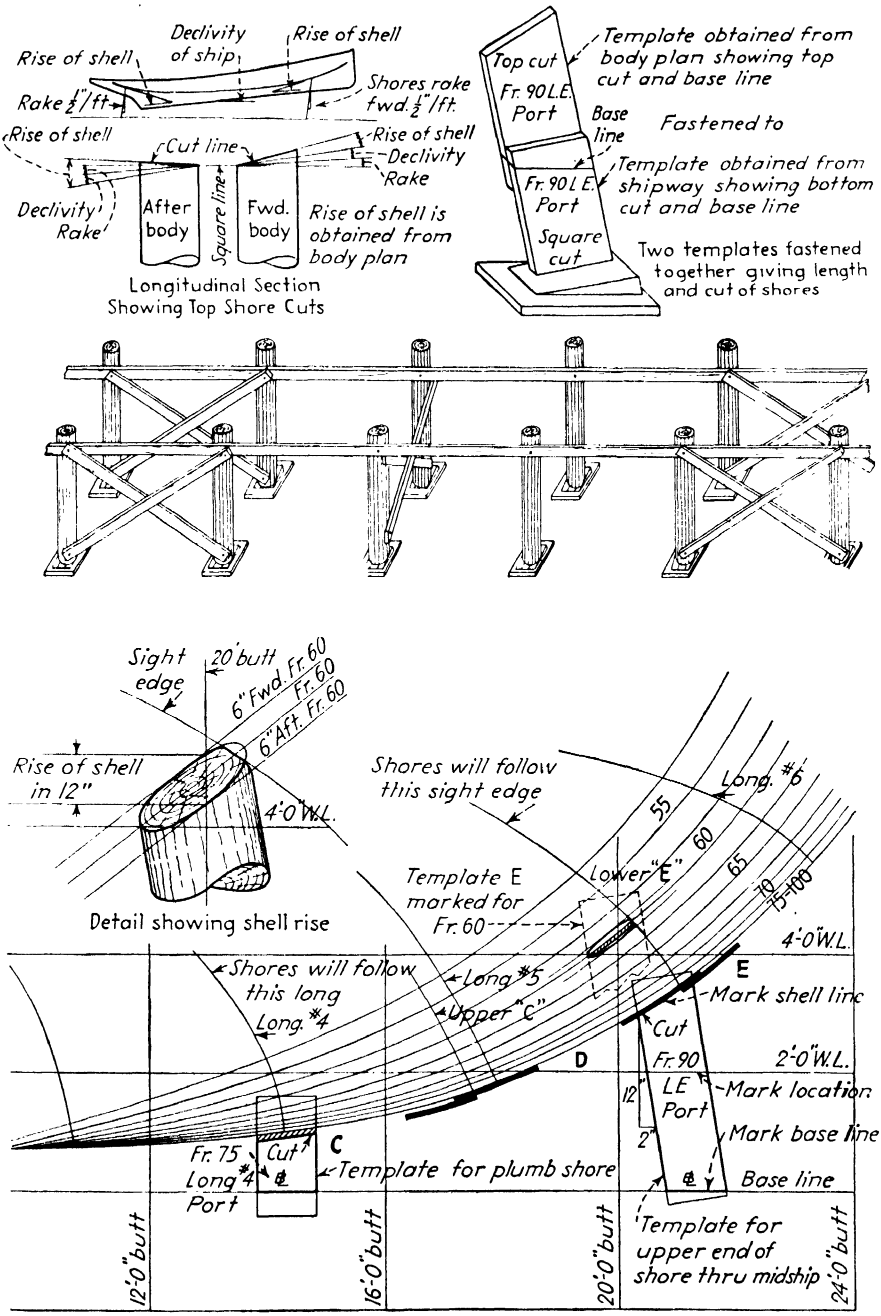


FIG. 293.—Method of obtaining the length of shores from the body plan and the manner in which the two templates are applied.

The spauls may be checked for fairness by applying a long batten across them at the plate edges. Any irregularities can be faired up by raising or lowering them at the points of unfairness (see Fig. 292).

On ships having a fairly full or flat bottom, the permanent shores may be used as uprights for supporting the spauls. When this is done, the spauls are set up in approximately their correct position and supported by 3- by 4-in. timbers and braced sufficiently to hold them upright.

The length and cuts of the shores are obtained by setting up a template on the base blocks and wedges and marking it from the spaul. The shores are then cut from these templates and set up in their proper predetermined location so that they will support the ship at the strength members of the hull. The spauls can then be secured to the shores by bolting, after being checked with the water line and checking the distance from the center line.

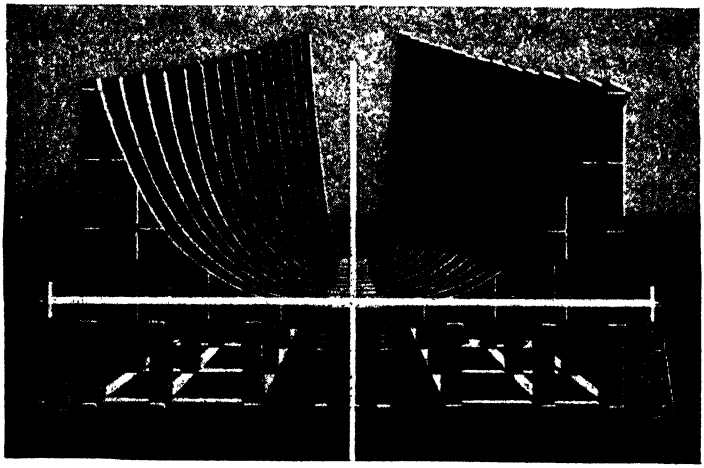


FIG. 294.—Wooden type of spauls set up to form the shape of the hull.

When the bottom shell has been laid on the spauls and sufficient inner structure erected and welded or riveted together, the spauls can be removed and the shores left in position to regulate and support the bottom of the ship during its construction.

Figure 292 shows spauls being supported by the permanent shoring under the ship.

Setting Steel Spauls. When steel spauls are used, they can be set up on temporary shores or uprights and braced in the same manner as wooden spauls, or they may be set on the permanent shores.

If flat-bar spauls are used, a shoulder may be cut in the side of the shore to give the flat bar support. The spaul is then leveled up by adjusting the wedges under the shore to suit.

The fore-and-aft location of the bottom of the shores can be marked on the shipway by plumbing down from the frame stations or points on which the shore will bear on the ship.

Cutting Shores from Body-plan Dimensions. The length and cut of shores can be obtained from the body plan of the ship. However, only

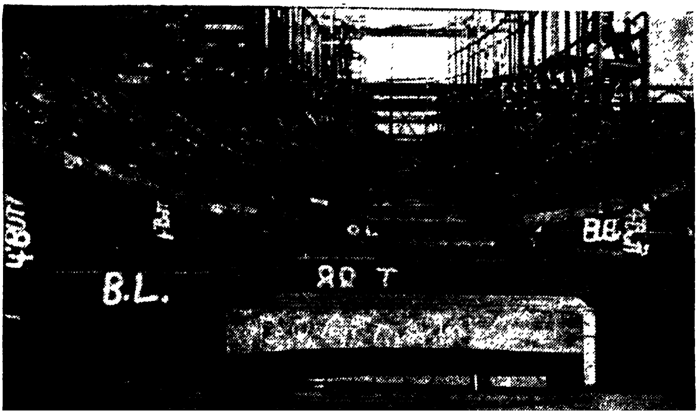


Fig. 295.—Bottom spauls and keel track ready for the keel and shell plating.

Fig. 296.—Shipwrights shown checking spauls from mold-loft templates.

that portion of the shore above the base line can be obtained from the body plan. The length of the portion of the shore that extends below the base line to the stocks, or that point on which the shores will set, or rest, must be obtained from the shipway. The two measurements are then applied jointly by matching them at the base line of the ship. The location of the shore from the center line, together with its strut or angle, must also be considered when the length below the base line is being obtained. The length and cut can then be marked on a template and applied on the shore timbers. After this they are cut and set up under the spauls.

In Fig. 293 is shown the method by which the length of shores is obtained from the body plan and the manner in which the two templates are applied, together with the method by which the spauls are set and

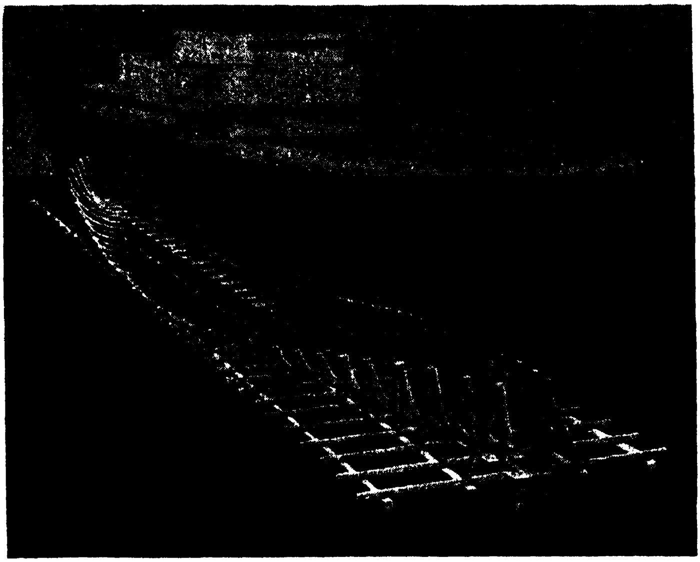


FIG. 297.—Model of a ship resting in its cradle.

braced in position. Figure 294 shows the wooden type of spaul set up to form the shape of the hull, together with the base-line and centerline monuments. Figure 295 shows the bottom spauls and keel track for a vessel, set and ready to receive the keel and bottom shell.

Figure 296 shows the use of a template to check a spaul that appears to be out of alignment. Some of the shell plating can be seen resting on the spauls. Figure 297 shows a model of a ship resting in its cradle.

TRADE TERMS

Shell. The outside plating of the hull of a ship.

Plates. Steel sheets of varying thicknesses that make up the shell.

Channel. A structural shape in the shape of a channel.

Angle. A structural shape of varying thickness made in the shape of a right angle.

Flat bar. A flat plate of varying thickness and width up to 1 by 12 in.

Outboard. Away from the center line; toward the outside of the ship.

Inboard. Toward the inside or center line of the ship.

Center line. A point midway between the two sides of the ship.

Water line. A plane parallel to the base line of the ship.

Base line. A plane at the base of the ship from which all vertical dimensions are taken.

Declivity. The inclination upon which a ship is built for the purpose of sliding it into the water after completion.

Brace. Any form of diagonal stiffening or support.

Deck batten. Long, thin, limber battens used for fairing.

SAFETY PRECAUTIONS

Be sure spauls are securely fastened before releasing them from the crane.

Put all tools in their proper place when they are not in use.

Air drills or pneumatic machines must be lubricated at least once each week.

CHAPTER XVI

LAYING THE KEEL

The keel is the backbone of the ship. Various types are used, depending on the class of ship.

The flat keel is a heavy plate of either single or double thickness, with the greatest dimension in cross section set in a horizontal position. A rubbing bar may be added for vessels plying in shallow harbors. The purpose of this is to prevent damage to the main keel of the ship. It may

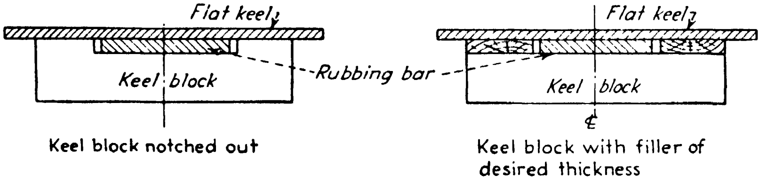


FIG. 298.—Keelblocks notched out for rubbing bar.

vary in size from 1½ by 6 in. to 2 by 9 in., depending on the size of the vessel.

The bar keel is a heavy bar, set with the greatest dimension in cross section in a vertical position.

In the preceding chapters, we have learned how the keel track is constructed. It is now ready to receive the foundation or backbone of the vessel. If a rubbing bar is specified, the keelblocks will have to be

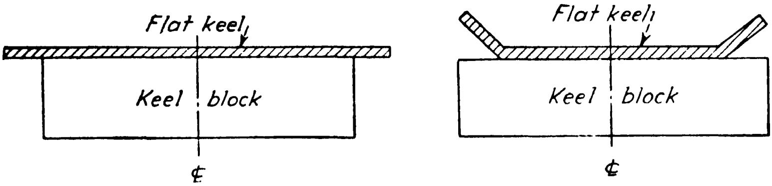


FIG. 299.—Keelblock under flat keel.

notched out or recessed to take care of it. This is necessary so that the flat keel itself may bear on the keelblocks, as shown in Fig. 298. Where no rubbing bar is used, the flat keel will bear entirely on the keelblocks, as shown in Fig. 299.

Laying the Flat Keel. In preparing the keel track for the vessel, the exact location and center line are established and the frame stations marked along it. The next operation is to lay the keel of the ship.

The starting point is decided upon jointly by the ship fitters and shipwrights. It may be agreed to start with the aftermost keel plate next to the sternpost wrapper plate and to work forward, or from amidships and work in both directions forward and aft. The latter arrangement is most commonly used because welding shrinkage is worked from the midship part of the ship toward both ends.

The first operation in preparing to lay the keel plates on the keelblocks is to strike the center line and frame lines on the outer side of the plates, as shown in Fig. 300. These lines will be used as reference lines

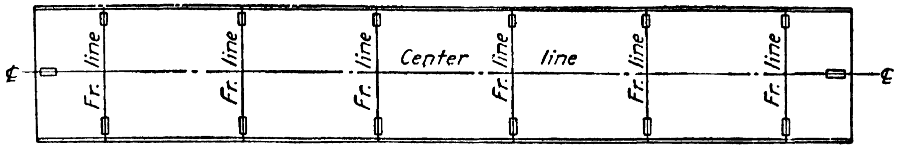


FIG. 300.—Center and frame lines marked on keel plates.

throughout the building of the ship. After this operation has been performed, the keel plates may be laid on the keelblocks in their proper positions by the cranes.

When the first keel plate is laid, it should be set exactly on the center line and frame line so that it will tie in with the reference monuments on the stocks. In Fig. 301 is shown the first keel plate landed in position.

After the first plate has been landed, the adjoining plate can then be brought in and landed on the blocks. No attempt is made at this time to set these plates in their exact position. However, the distance between frame stations at the ends should be held as near as practicable.

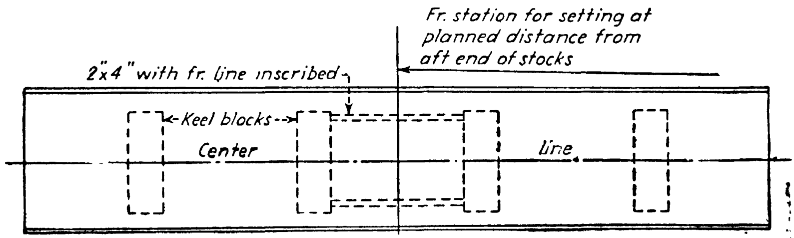


FIG. 301.—First keel plate landed on keelblocks.

This procedure is followed until all the keel plates are laid. The furnaced plates at both ends of the ship are usually left out until they have been fitted to the stem and stern castings.

Where a double keel plate is used, the lower course must first be laid and set before the inner keel can be laid on top of it. After the lower course has been set and the necessary work on the butts of these plates completed, the inner keel can be laid in the same manner as the outer keel.

In the event that frame spacing between the keel plates is greater than desired, chipping or burning may be necessary in order that the keel will not be too long.

In Fig. 302 is shown the flat-keel plating being landed on the keel blocks by the cranes.

When a rubbing bar is used, the same procedure is followed as in laying the flat keel. The bars are landed as close to the permanent frame

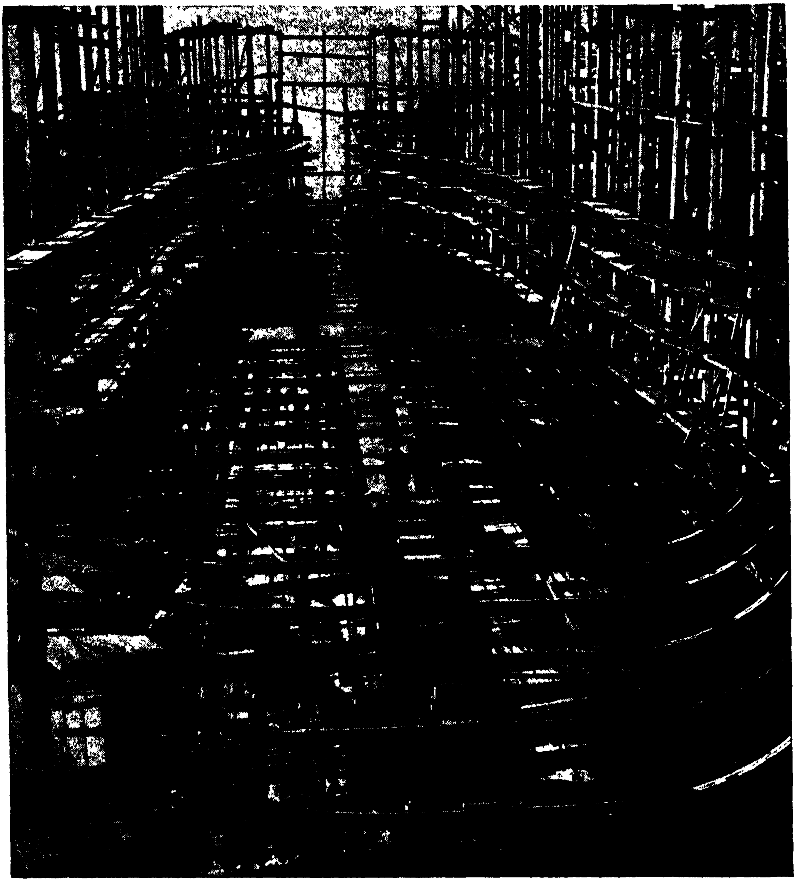


Fig. 302.—Flat keel plating being landed on keel track.

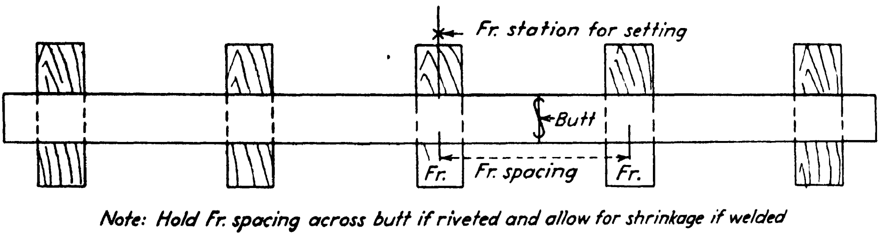


Fig. 303.—Rubbing bar laid on keelblocks.

stations as possible until the final setting takes place. Figure 303 shows a section of the rubbing bar laid on the blocks.

Laying the Bar Keel. In the laying of a bar keel the blocks will have to be slotted to take care of the bar keel and the garboard plate, as shown in Fig. 304.

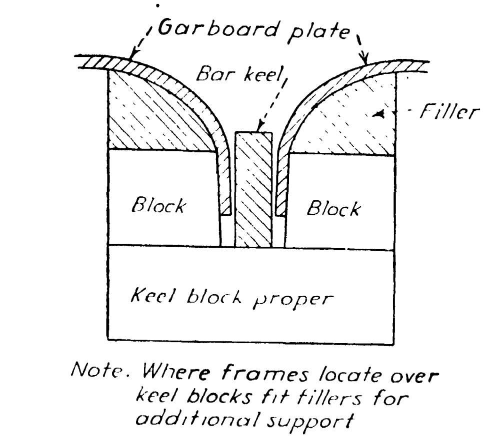


FIG. 304. Bar keel set on keelblocks.

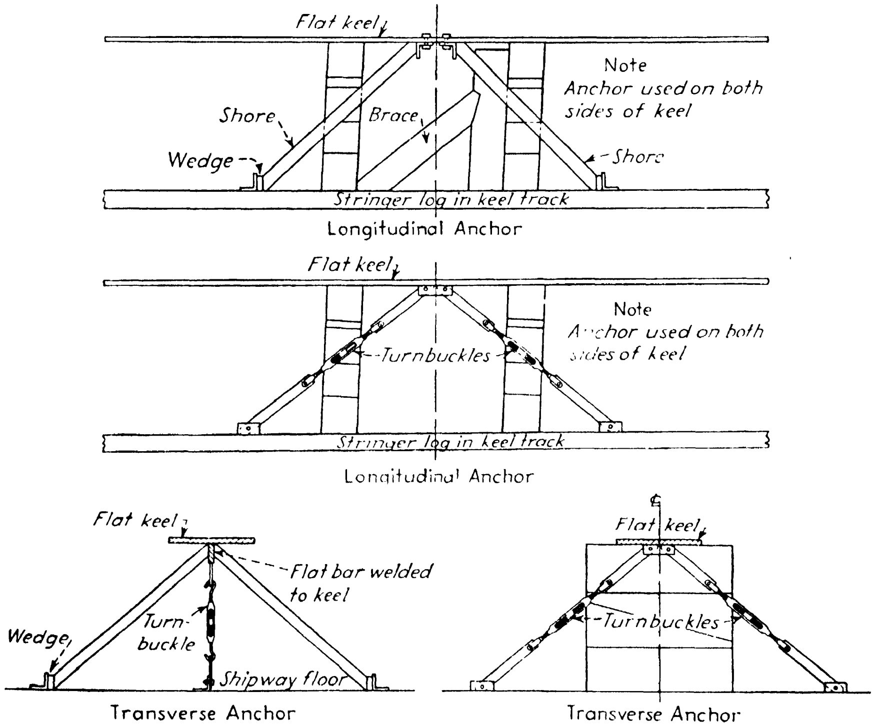


FIG. 305.—Method of securing flat keel in position.

The laying is done in the same manner as for the flat keel except that the bar keel will be landed in a vertical position. The same procedure is used in landing it as close to the frame station as possible until final setting takes place.

Setting the Keel. After the keel has been laid, the next procedure is to set the keel plates in their final position ready for making up. The setting of these plates should be started at the first plate that is laid. This plate, after being set in exactly its right position, should be spur shored in such a manner that it can be used as an anchor for pulling and adjusting the adjoining plates.

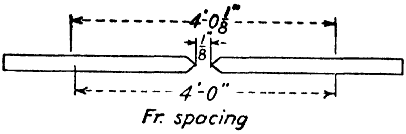


FIG. 306.—Root opening of welded keel butts.

Various methods of securing the plates can be used, the method shown in Fig. 305 being the most common. One type is tension bracing, with the use of flat bars and turnbuckles. Another is by means of timber shoring against clips on the stocks and the flat keel.

In riveted keels no allowance for welding shrinkage is necessary at the ends of the plates, which should be cut to their exact lengths in order to obtain fair holes in the garboard strake of shell plating.

In the welded type of butts in the flat keel a root opening must be held between the butts of the keel plates so that a minimum amount of chipping will be necessary to ensure proper fusion of the welding on both sides of the plates. The size of the root opening is generally ⅛ in. for mild steel and $3/16$ in. for special-treatment steel. In setting the keel plating for welded butts, the space of root opening should be added to the designed frame spacing where the butt occurs, as shown in Fig. 306. After the keel-plate butts have been welded, it will be found that the distance between frame stations where the butt occurs will be very close to its designed measurement, owing to the contraction during welding.

As each keel plate is set, the forward end of the keel plates working forward from the starting point and the after end of the plates working aft of this point should each be anchored or shored on the center line in order to hold the plate in position during the welding of the butt and until such time as sufficient structure has been welded above the keel to resist movement from the center line (see Fig. 307).

At the forward and after ends of the vessel, it is well to add tie straps and turnbuckles in a vertical position in order to create resistance against the tendency of the keel plates to lift during the process of welding. This is shown in Fig. 308*a*. After the keel plates have been set in their proper fore-and-aft position, a flat-bar strongback should be welded across the butts in order to hold it until the shipfitter makes up the butts.

Figure 308 shows the keel of a vessel with the keel plating set and properly shored to hold it in position.

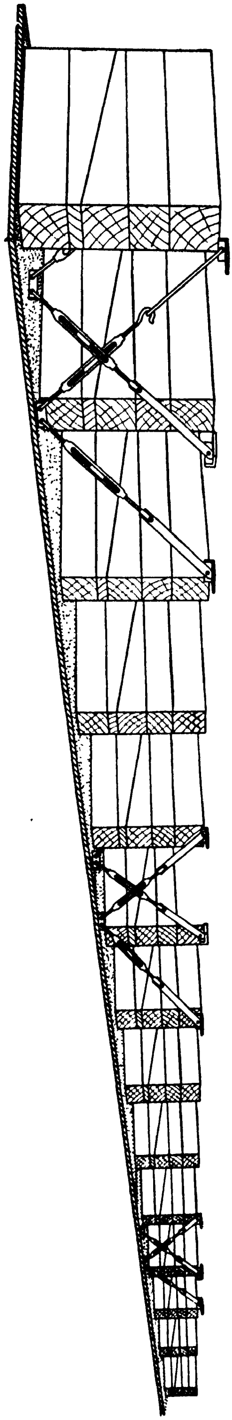


FIG. 307.—Keel track braced and tied down with turnbuckles.

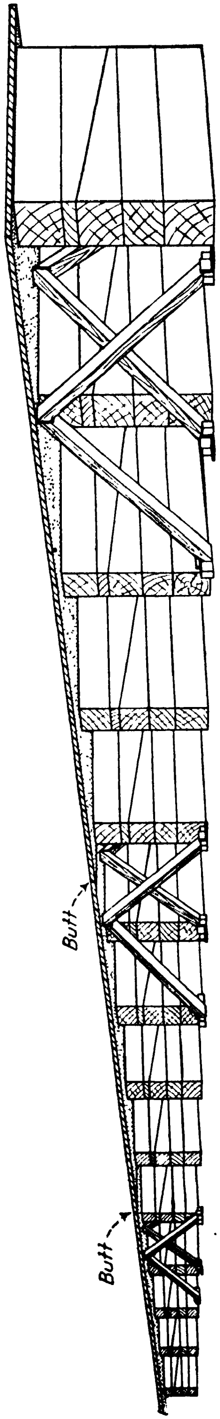


FIG. 308.—Keel of a vessel set and properly shored.

FIG. 308a.—Keel tied down with tie straps and turnbuckles to resist tendency to rise during welding.

TRADE TERMS

Keel. Bottom plate or base, which rests on the keelblocks.

Frame stations. Designed spacing and points at which framing is located.

Fore. The forward part of a ship.

Aft. Toward the stern, or rear, of a ship.

Sternpost. A casting upon which the rudder hinges.

Furnaced plates. Plates that have to be shaped at the furnace to suit designed lines.

Root opening. Space between two plates secured together with a V-butt weld so that fusion of the welds on each side at the center is ensured.

Tie straps. Flat bar used for holding or pulling.

Turnbuckle. Threaded sleeve with right- and left-hand threads for screws used for tightening.

SAFETY PRECAUTIONS

Keep clear of cranes with plates that are being carried overhead.

Keep the hands clear when plates are being landed in place.

See that clips are welded with welds of the proper size.

Use pin mauls, pneumatic machines, crosscut saws, and wrenches properly.

CHAPTER XVII

ERECTING, SETTING, AND ALIGNING THE VERTICAL KEEL

After the flat keel has been set and welded, the ship is ready for the vertical keel. The connections at the top and bottom may be the all-riveted type with angles at the top and bottom; it may be a combination riveted and welded type (with riveting strips welded at the top and

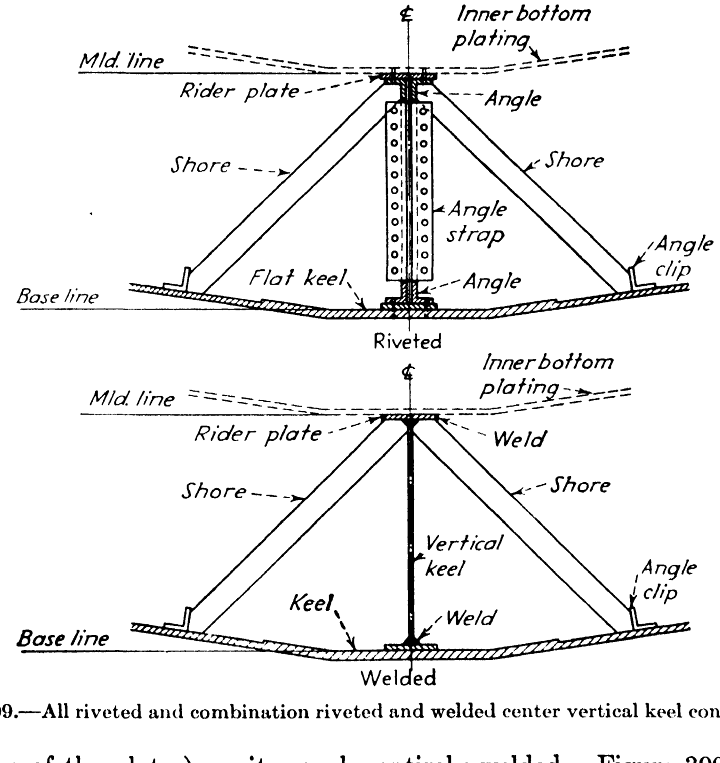


FIG. 309.—All riveted and combination riveted and welded center vertical keel connections.

bottom of the plates); or it may be entirely welded. Figure 309 shows an all-riveted type and a combination riveted and welded connection.

Erecting the Keel. The vertical keel may be subassembled regardless of whether it is all-riveted or all-welded. This means that it can be brought into the ship in assemblies of two to three or possibly four plates. On some types of ships for which it is practical to subassemble the inner-bottom structure, it may be included in either the port or the starboard assembly, if the subassembly can be so built.

With the riveted type of vertical keel, it is necessary that it tie in with the flat keel in order to secure fair rivet holes. When being erected into the ship, it is temporarily braced in position and made ready for setting.

Setting the Vertical Keel. The shipfitter and shipwright usually work together on the job of setting the vertical keel. The shipwright

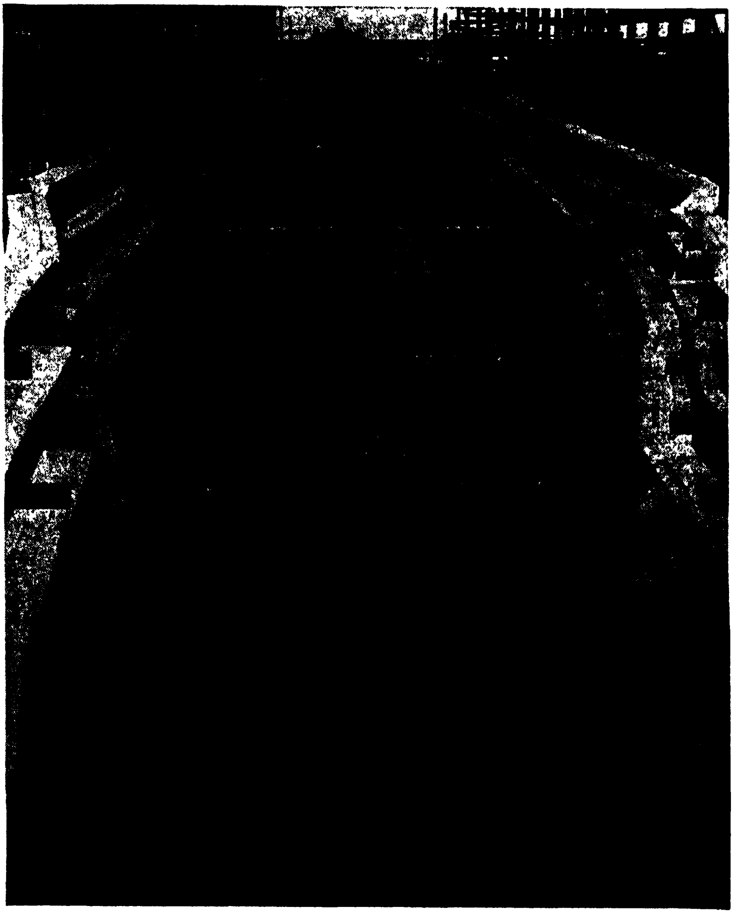


FIG. 310.—Vertical keel erected in the ship.

sets it so that it will tie in with the frame stations on the flat keel (also shoring it in a true vertical position on the center line). The shipfitter makes up the butts, lays off rivet holes, and makes the job ready for reaming and bolting.

With the welded type, it is also necessary for the vertical keel to tie in with the flat keel insofar as the frame spacing and length are concerned.

If the keel is to be subassembled in two or three plate sections, additional material of at least 1 in. should be allowed at the time of fabrication. This material is left on the forward end of each assembly in the forward body of the ship, and the same allowance is made on the afterend of the assembly in the afterbody of the ship. This will permit any adjustment that may be necessary to compensate for welding shrinkage during subassembly and in the event that the flat keel has shortened more than was anticipated. If there is no subassembly of the center vertical keel, the same allowance for added material should be made on every third plate, to permit adjustment.

The vertical-keel plates must be shored plumb on the true center line of the ship.

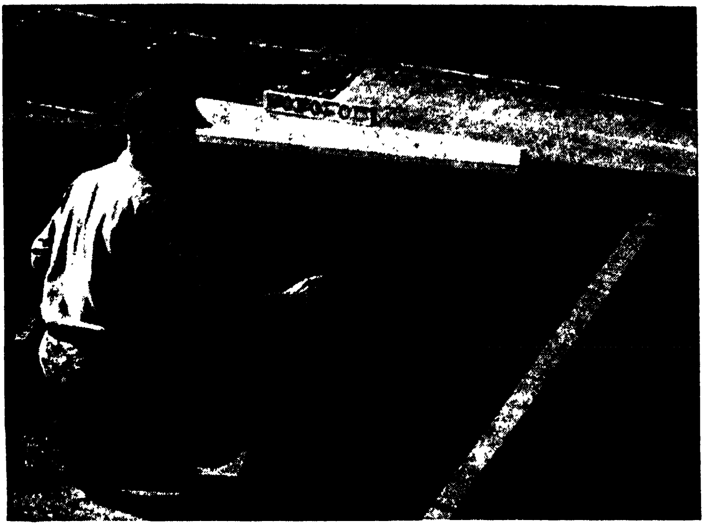


FIG. 311.—Shipwright installing spur shores to plumb up vertical keel.

Aligning the Keel. After being set in position by the shipwright, the job can then be turned over to the ship fitter for making up the butts in the plating and the riveting strips ready for final welding. Shores should be installed at approximately 8-ft. intervals and should be out of the way of frame lines where connections are made to the vertical and flat keel. Care must be taken that the vertical keel is held on the center of the ship at all times; otherwise, a crooked keel may develop from distortion caused by welding.

Figure 310 shows the vertical keel erected in the ship with some of the subassembled inner-bottom sections already in place. Figure 311 shows the shipwright installing spur shores to plumb up the vertical keel and checking the declivity of the top of the keel.

Large Assemblies. Where it is possible to build large subassemblies, a large assembly may include both the flat and the vertical keel, some of the frames or floors, and the shell and inner-bottom plating. In such cases it is necessary to follow the same procedure on the subassembly skids as on the ship, when setting the flat keel to a straight line and also maintaining the vertical keel, floors, and longitudinals in their true position.

When such an assembly is completed and ready for the ship, the entire assembly can be laid on the keelblocks and shored and set on the center line, as in laying the flat keel. Some additional shoring may be required to support the weight overhanging the keel track, depending on the size and type of assembly. Such an assembly is shown in Fig. 312.

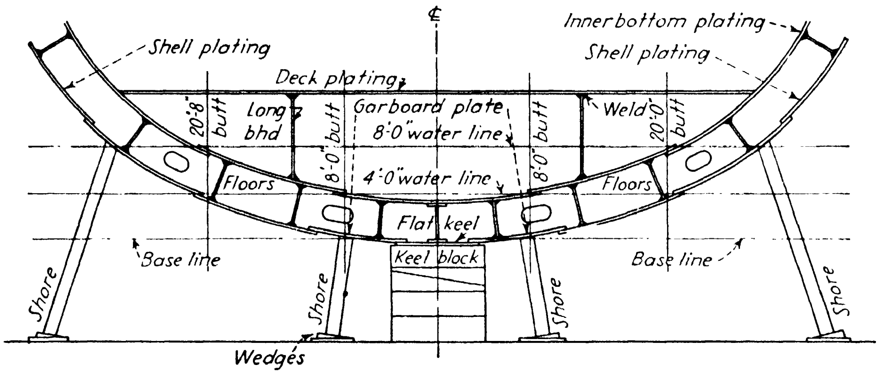


FIG. 312.—Bottom assembly with longitudinals, inner bottom, and deck plating assembled in one section.

TRADE TERMS

Vertical keel. The vertical member to stiffen the flat keel of a vessel.

Riveting strips. A flat plate welded to the bottom or top of a vertical member and then riveted.

Plumb. To make perpendicular to the base line.

Tie in. To key up or make even with any line or hole.

SAFETY PRECAUTIONS

Stay clear of plates while the crane is handling them until they are landed approximately in position.

Be careful to avoid injury when moving plates.

CHAPTER XVIII

SETTING BOTTOM AND SIDE SHELL PLATING AND ESTABLISHING FRAME STATIONS

When the flat and vertical keels have been laid and set into the ship, the work of building the bottom portion can proceed. To a large extent, the flat and vertical keels will govern the setting and fitting of the other parts of the ship as they are erected.

As previously stated, the true length of the riveted type of flat and vertical keel must be maintained as closely as possible in order to procure fair holes in the adjacent shell and inner-bottom plating.

Shrinkage. Where floors and plates are welded to the shell plating, compensation must be made to take care of welding shrinkage. In such cases, where the seams and longitudinal angles are riveted to the shell, it is well to leave some of the holes in the seams and longitudinals blank at convenient points, as shown in Fig. 313. The holes left blank should not be drilled until the welding has reached a point near them.

To compensate for the shrinkage caused by welding butts of shell plating and the bottom floors to the shell and also to ensure fewer difficulties with subassemblies as they are brought into the ship, an allowance of $\frac{1}{64}$ in. per ft. is made, which will adequately take care of the shrinkage. However, it may be necessary to reduce this amount considerably if shrinkage is not taking place as was anticipated.

An example of this condition is found where the frames are spaced rather far apart. That is (depending on the type of inner-bottom structure), more shrinkage will develop with the frame spacing of 30-in. centers than where frames are spaced 4- to 8-ft. centers, as in longitudinally framed ships.

As the construction of the ship advances from amidships toward the ends, the welding will be done in the same manner. A point near the midship part of the ship should be used as an initial, or zero, point. From this point frame stations should be established on the flat and vertical keels, the allowance of $\frac{1}{64}$ in. per ft. of length being included in them. The frame stations should be used in the setting of floors, regardless of any rivet holes in the shell plating.

Figure 314 shows the floors in relation to the designed frame stations before welding (the arrows indicating the designed frame stations), while

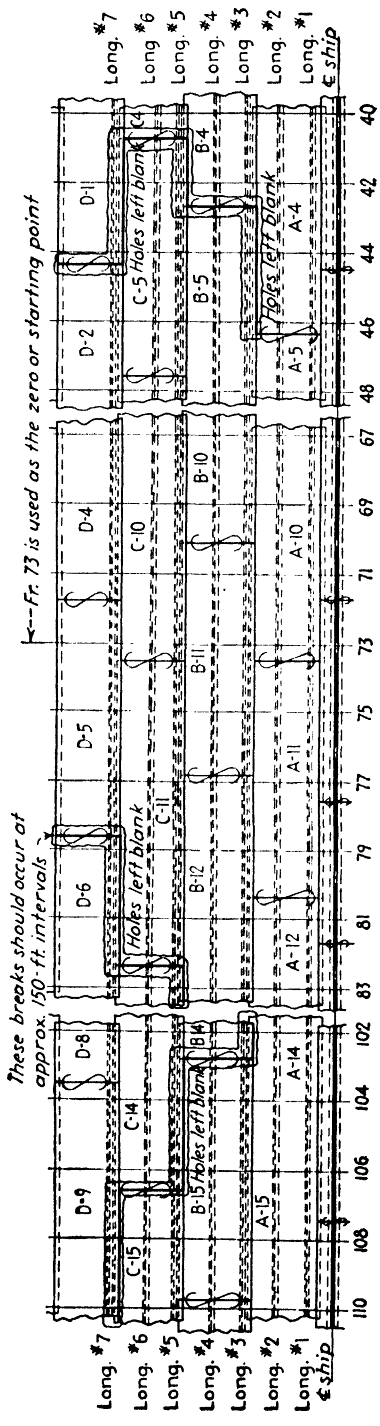


FIG. 313.—Bottom shell plating with holes left blank for adjustment.

the floors have been set to the stretch allowance line.

Figure 315 shows the shipwright installing the frame line and a 6-in. working line from the frame line on the flat keel plates. It must be remembered that the same stretch allowance has been put into the center vertical and flat keel prior to the welding of the butts in order that all the plating shall have a uniform allowance.

When the structure is of the all-welded type and, because it cannot be subassembled, is being assembled in the ship, compensation for welding shrinkage should be increased to $\frac{1}{32}$ in. per ft.

To revert to the holes left blank in the shell plating, after the welding has reached this location it is desirable to make a check of what is going on, since the greater part of the welding shrinkage up to this point will have taken place. It will now be safe to make any necessary adjustment, and after this the holes can be drilled. From this point the same procedure as that used amidships can be followed. This will ensure fewer bad holes and a much better arrangement for readjustment.

The foregoing may appear to be laborious. However, where accuracy and a good structure are desired, the procedure is well worth while.

On some types of ships for which exacting dimensions are not required, this method should not be necessary. However, on large combat ships in which the structure from the bottom up ties in with heavy armor, it is *positively essential* that the finished structure be as near to design as possible in order that the armor boxing will receive its proper support and connections.

Setting Bottom Shell Plating. After the flat-keel plating has been set, the bottom shell plating can be erected by the cranes and landed on

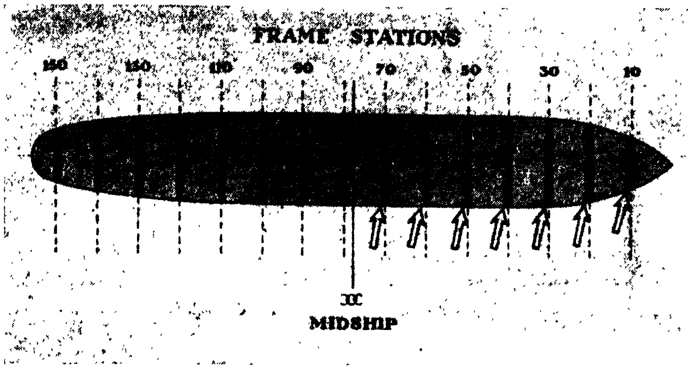


Fig. 314.—Floors in relation to the designed frame stations.

the spauls, which support it until the bottom structure is erected and set. The plating is landed on the bottom spauls as closely as possible to its permanent position. Later, it will have to be set and regulated in its proper position.

Fig. 315.—The shipwright establishing frame lines and 6-in. working line.

In setting the bottom shell plating, a square line is brought out from the center line of the ship by plumbing down to the monuments set on the shipway stocks. The monuments were installed at the time the keel track was laid down. A monument is usually located at the starting point used on the keel, or about the midship part of the ship. A wire is stretched from the vertical keel to an upright brought up from the monument, and the process of setting the first shell plates can begin.

The garboard strake, or the first strake of plating next to the keel, is the first to be set. In Fig. 313, it will be noted that the afterend of shell plate A10 crosses the zero, or starting, frame. This will be the first plate to be set.

Start with driftpins and a pinch bar to fair up the holes in the seams connecting to the flat keel. Using frame 73 (which has been put on from the layoff template), adjust the shell plate so that the frame line will come directly in line with the wire stretched at 90 deg. to the center line of the ship.

If it is found that the holes in the seams do not fair up by holding the frame stations it may be necessary to compromise slightly between the seam holes and the frame stations, particularly if frames are welded to the shell. However, if frames are riveted to the shell, it will be best to favor fair holes in the seams and ignore to some extent any variance in the frame lines.

After the first plate has been set, it can be tacked with bolts so that it will not move and the next plate aft, or A11, can then be set, the seam holes in the flat keel being used as a guide.

When the two A plates have been set, the setting of the next strake can follow. This will consist of plates B10 to B12.

From Fig. 313, it can be readily seen that B11 will be the first plate to set. Using frame 73, the plate is brought under the wire and regulated to suit the seam holes at the outer edges of A10 and A11. When this has been done, B10 at the forward end of this plate and B12 at the afterend can be set. Then, the setting of plates C10 and C11 in the C strake can proceed. The shell plate C10 should be set first from the zero point, frame 73, and the plate regulated to suit seam holes in plates B10 and B11. When this has been done, shell plate C11 can be set.

When plates C10 and C11 have been set, the setting of the next strake, or plates D4 and D5, can be done. This is accomplished as was done for the other strakes, frame 73 being held each time.

When the foregoing procedure has been completed, it will be observed that a block of the bottom shell plating has been set to the square line from which the entire bottom can be set and regulated. When this block has been set and securely tacked with bolts or by welding, two sets of spur shores in both a fore and an aft direction should be installed on each side of the keel. The shores should be located at the outer edge of A and C strakes. They will prevent any movement of this plating when the remainder of the shell plating is being pulled and regulated into position and will form a rigid anchor for the setting of adjoining shell plates by the regulators.

Gaining or Losing Dimension in Setting Shell Plating. To prevent gaining or losing in the width of the plating, a check from the offsets should be made at 20-ft. intervals throughout the bottom of the ship. This may be done by measuring from the center line parallel to the base line and plumbing down to the point of the outer edge of D strake, as shown in Fig. 316.

Frequent checks must also be made from the square line, and parallel to the base and center lines, particularly on the outer strakes, so that the framing will set at right angles to the center line of the ship. This may be done with a tape or batten secured from the mold loft. This batten

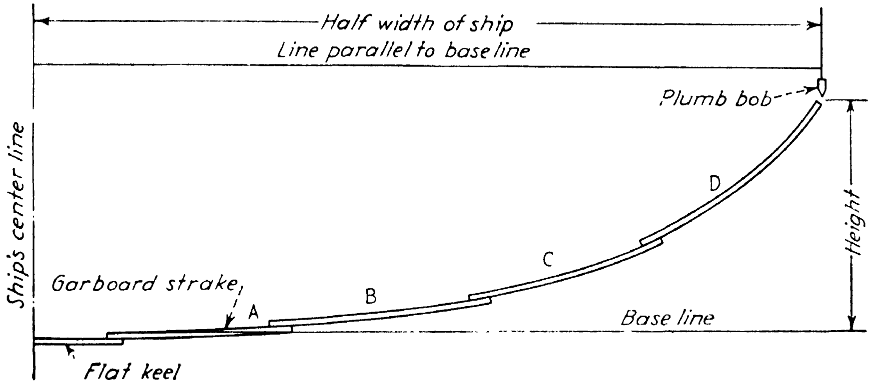


Fig. 316.—Method of plumbing down to half width of shell plates.

has been developed so that it can be laid along the seam of a strake of plating when approximately in its designed position.

As the regulating of the bottom shell advances toward the forward and afterends and when the point of adjustment where holes have been left blank is reached, continue the regulating, ignoring entirely this slip joint.

Some slight readjustment will be necessary after the welding to the shell plating has been completed. However, this does not require a great deal of labor and can usually be taken care of with a slight adjustment of one or two plates in each strake after the welding has proceeded to this point.

In making adjustments on riveted plating, care must be exercised in spreading the adjustment over two or more plates so that holes will clean up when reamed out for riveting. Where plating is fabricated with the holes a size small, it is possible to move a plate as much as ¼ in. in either direction where ¾-in. diameter rivets are used.

Setting Side Shell. In setting the side shell the same principle is used as for setting the bottom shell except that the shell, being vertical, will have a tendency to drop as well as to slip aft. This is true of shell

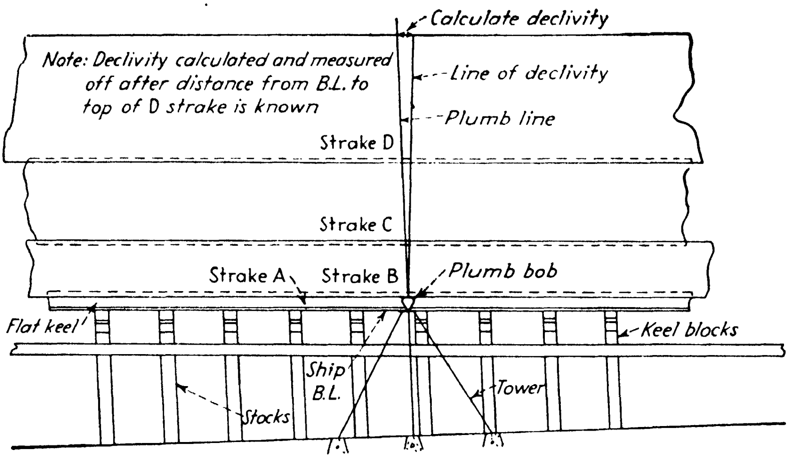


FIG. 317.—Method of erecting a perpendicular to the square line for setting side shell.

that is subassembled and brought into the ship in units as well as of shell that is set as individual plates.

Before an attempt is made to set the shell, some definite line and height must be established as a starting point. This should be the same point as that used on the bottom shell and inner bottom.

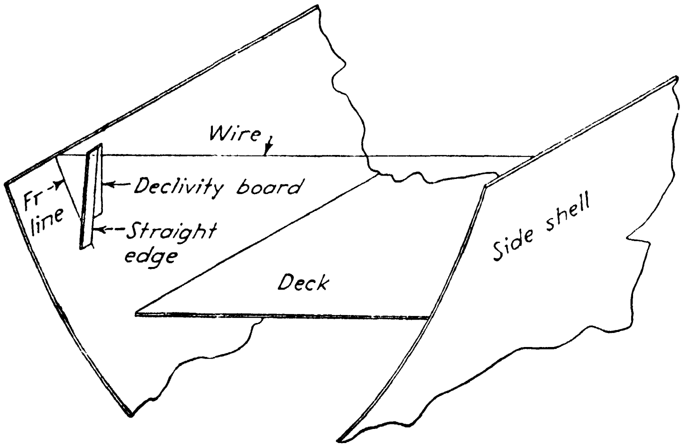


FIG. 318.—A wire stretched from the side with a straightedge and declivity board projected from the wire to establish the position of the frame stations on the side shell.

From the monuments a square line at right angles to the base plane of the ship, as shown in Fig. 317, can be erected with the use of a plumb bob. The amount of declivity can be figured and this point established on some fixed location at the side of the ship and clear of the shell. A wire is then stretched from one side of the ship to the other and a straightedge applied vertically with the aid of a declivity board to give the position of the frame station, as shown in Fig. 318. If the side shell is subassembled as shown in Fig. 319, the assembly can be brought into the proper fore-and-aft position by moving it until it is in line with the frame station brought up square from the base line.

The subassembled units of a shell may be set in a vertical direction by checking from the base line to a height established on the framing of

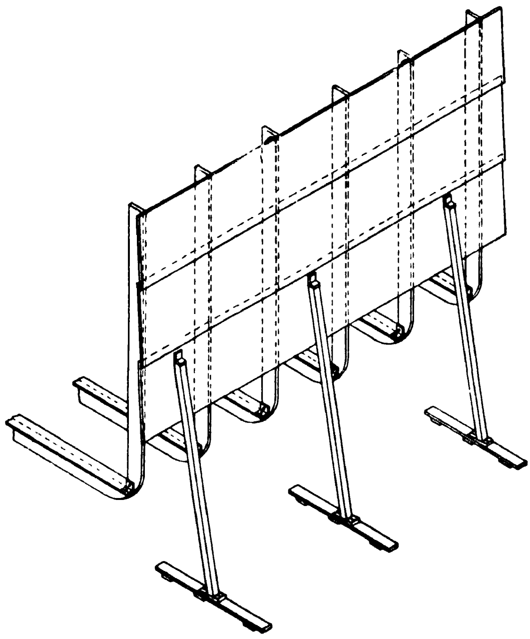


FIG. 319.—Subassembled section of side shell with framing erected in the ship.

the section and the shell then raised or lowered until it is the proper height above the base line. The fore-and-aft position should also be rechecked after the assembly has been established to the proper height to see that it has not moved from the fore-and-aft position line.

If the side shell plating is set in individual plates, the same procedure is used for bringing the frame line up from the base line of the ship.

If the bilge strake of plating is to be lifted from the ship, a height batten obtained from the body plan giving the height of the plate edge above the base or a convenient water line should be applied and marked on the side framing. The shell plating can then be shored up to these spots. Jointly with this operation the first plate should also be set in its proper fore-and-aft position by means of spur shores or turnbuckles secured to some of the framing forward and aft of this plate for the purpose of pulling the plate in its proper position. After the first plate has been set, it should be spur shored in position so that other adjacent plates may be set, this plate being used as an anchor for pulling or pushing other plates, as shown in Fig. 320.

No effort should be made to regulate forward and aft of the starting point until sufficient plates that cross the starting frame line to reach a deck have been regulated. This is because the decks will have a bearing on the height of the shell plating, particularly if riveted angles are used for attaching the shell and deck together.

If the shell plating is set too high or too low at the bottom, resulting in bad holes at the deck angles, it will be necessary further to regulate the plating by compromising between the holes through the deck angles

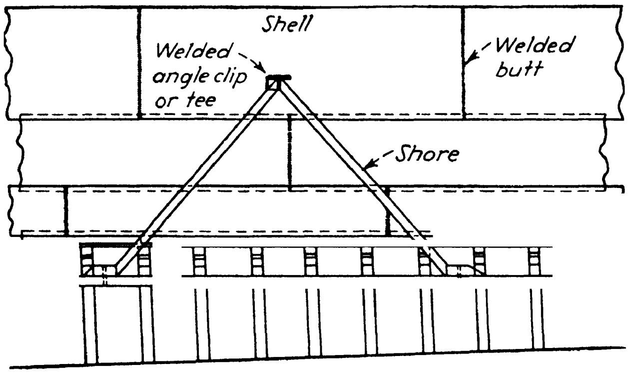


FIG. 320.—Section of side shell spur shored on declivity to be used as an anchor for setting other plating.

and the height of the lower strake of shell in order to bring both as close to their proper position as possible.

REVIEW AND COMMENTS

Each shell plate is developed to fit in only one place on a ship, particularly where the shell is riveted. For the shell plates to fit correctly, each should be set in exactly the position for which it was developed during fabrication.

Starting from the keel plate and going up and outward, each line or row of plates is called a *strake*. Starting next to the keel the strakes of plating are designated alphabetically, A strake being next to the keel, B next, C next, etc. Starting at the forward end, each plate in each strake is given a number, No. 1 being forward, No. 2 next, etc.

Each plate has the frame station punched on it near the lower and upper edges. These stations are struck in with a chalk line and keyed up with those on the adjoining plate.

Each plate is set to its proper position by means of sheet lines and welded on the adjoining strake of plating already set. After each plate has been set, it should be securely tack bolted or welded in place to prevent it from moving when adjoining plates are being regulated.

Install sufficient shoring to prevent shell from slipping aft and, where the side shell is concerned, from settling or sagging below the designed heights of the sheet lines.

SAFETY PRECAUTIONS

Keep clear of plates when they are being erected.

Keep fingers out of rivet holes or from between butts of plating.

Do not lay tools on the staging where they are likely to be knocked off, possibly striking workmen below.

CHAPTER XIX

SETTING AND ALIGNING INNER-BOTTOM STRUCTURE AND PLATING

After the bottom shell plating has been regulated and set and the stretched frame stations projected from the center vertical and flat keels, the erection and setting of the inner-bottom structure can proceed. If the vessel being built is a type for which inner-bottom plating (together with floors and longitudinals) can be subassembled on the skids and brought into the ship in units, a much quicker job of setting will result. This type of subassembled construction can be brought into the ship and landed on the bottom shell plating in its approximate permanent location.

Setting in Transverse and Fore-and-aft Position. With the use of jacks and turnbuckles the shipwright will place the assembly at the frame station marked on the shell plating. When this has been done, he will proceed to set the assembly in its proper transverse position by measuring from the center of the vertical keel to a buttock line from which the assembly was constructed or to a convenient girder if the floors do not extend out to the side, or bilge, of the ship. If the floors do extend out to the bilge, a check from the offsets can be made from the center line to the molded line of the shell at the level of the inner-bottom plating. When this has been accomplished, the assembly will be set in a longitudinal as well as in a transverse position.

Setting to Height. The operation of setting to the proper height still remains. If the inner bottom of the ship is parallel to the base line, a straightedge set on leveling or parallel blocks under each of its ends can be used. A spirit level is placed on top of the straightedge to determine whether or not the section is level. It is important for the straightedge to be set parallel to the inner-bottom plating. Care must also be exercised to see that it is set *at right angles, or* 90 *deg., to the center line of the ship;* otherwise, a discrepancy will result because of the declivity of the base line (see Fig. 321). If it is found that the section is not level, it can be brought into a level plane by easing down on the wedges under the bottom shores if it is too high or driving them up harder if the section needs to be raised.

Another method (particularly useful when the inner bottom is parallel to the shell of the ship) is by means of a straightedge secured with thumb clamps to pieces of scrap flat bar tack-welded on the frame line at the center line and at the outboard ends of the straightedge. If rechecking is necessary, the straightedge can always be placed back in the same position (see Fig. 321*a*).

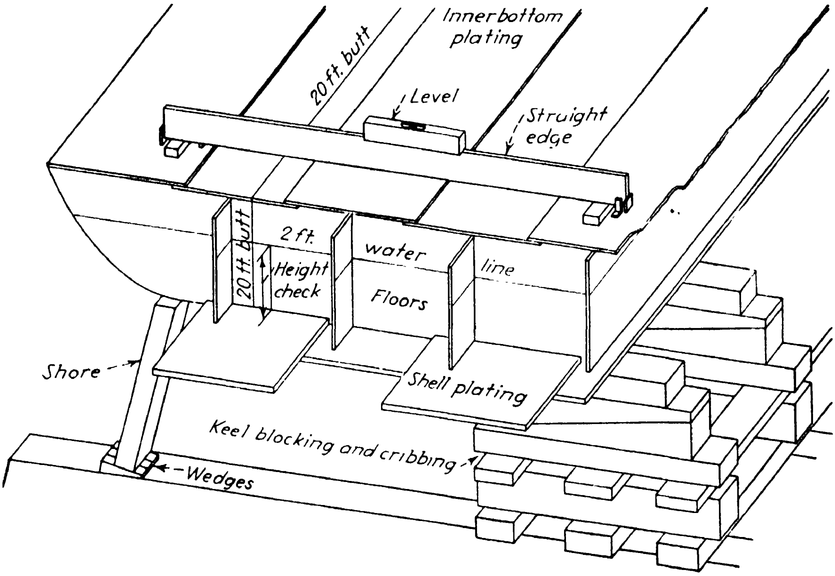


Fig. 321.—Subassembled section of inner bottom being leveled with a straightedge and spirit level.

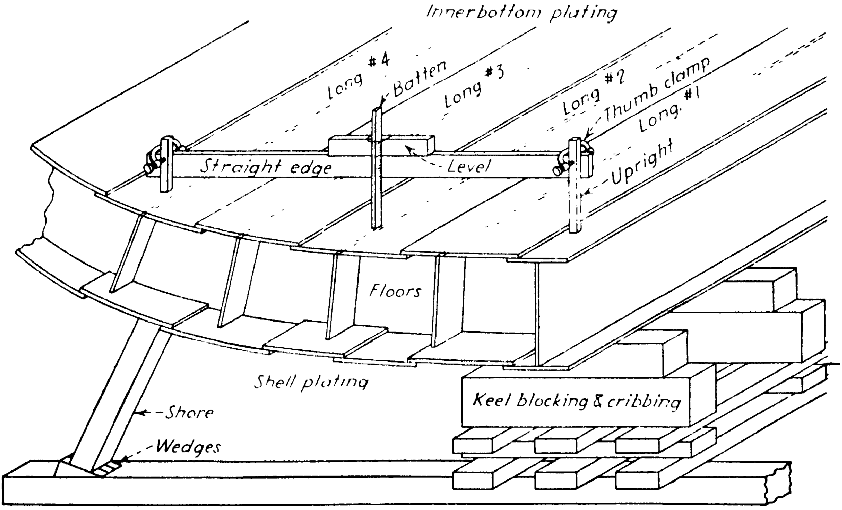


Fig. 321*a*.—Checking height of subassembled inner-bottom section where necessary to use height battens from offsets.

In discussing the setting of the bottom-shell spauls (Chap. XV) it was stated that it is always good practice to set them at the outer ends at least ½ in. lower than design. The reason for this is that it is much easier to shore up a section than to lower it. Therefore, when the spirit level is applied on the straightedge, the section will be slightly lower at the outer ends and it will be necessary to go below and use shores to raise up the section until the spirit level is brought level. This should be done at each end of the assembly. After the ends have been brought into a plane, a check should be made through the middle of the assembly.

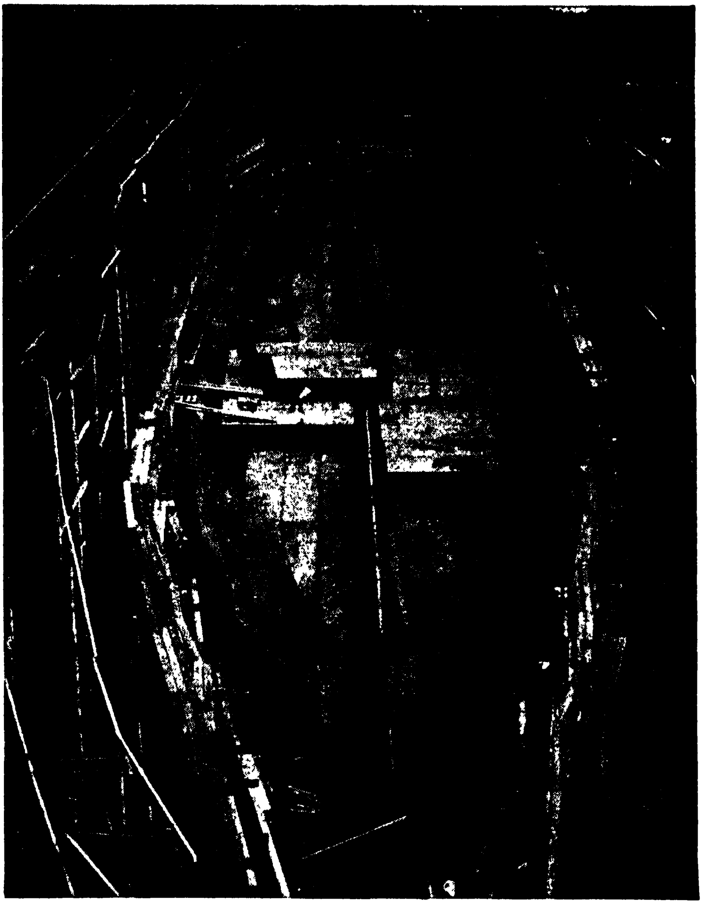


FIG. 322.—Subassembled section being brought into the ship and set on the bottom shell preparatory to setting in place.

When this has been done, the assembly is ready for making up at the center vertical keel and shell.

If it is desirable to keep the bottom low to compensate for any tendency to lift during welding, it will have to be set low at the outer end by the desired amount from the level line. It is not necessary to set each section before bringing in the connecting section; however, it is good practice, if possible, to set the first section definitely on each side of the ship. This affords an anchor point for setting the remainder of the sections. The initial section can also be set with much less interference and more accuracy.

In the setting of successive sections throughout the ship, it may be found that some trimming or cutting will be required at the intercostal longitudinals and inner-bottom plating in order to place them in the proper position. It is also well to check from the offsets the height of the water line on the subassembled section to the molded line of the bottom shell plating. This practice is an insurance against the possibility of the shell being high or low where no allowances have been made for doublers or lap strake plating. This is illustrated in Fig. 321.

In Fig. 322 are shown subassembled sections being brought into the ship and set on the bottom shell preparatory to setting in place.

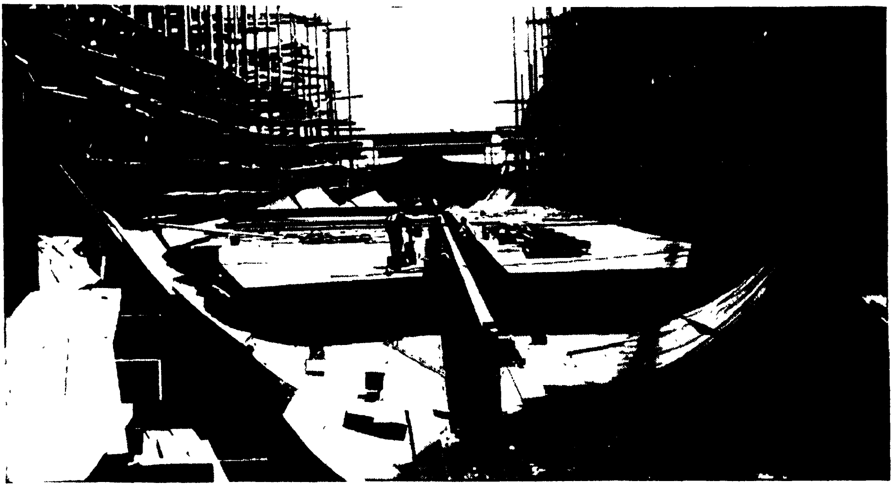


FIG. 323.—Some of the inner-bottom subassemblies in position ready for production welding.

Making Up Connections. If all inner-bottom section connections at the shell are to be welded, it will be necessary to bring the shell plating hard up against the floors and longitudinals where the shell may be low. Where the structure is comparatively light, this can be done by the use of 6- by 6-in. shores. The permanent bottom shores can also be used for this purpose. However, the 6- by 6-in. shore is much easier to move around from one point to another to bring up the shell plating against the inside structure. Where shell plating is heavy, it may be brought up against the inside structure by the use of hydraulic jacks set on a base block.

The work of making up the connections is usually done by the shipfitter with the assistance of the shipwright. As each shell section is brought up hard against the inner-bottom structure, it can be tack-welded to the floors and longitudinals. This operation should be started next to the flat keel, working out toward the bilge of the ship in order to avoid buckles in the shell plating.

Figure 323 shows some of the inner-bottom assemblies in position, ready for production welding.

Riveted Connections. In the type of construction where the floors and longitudinals are riveted through the shell, all such connections

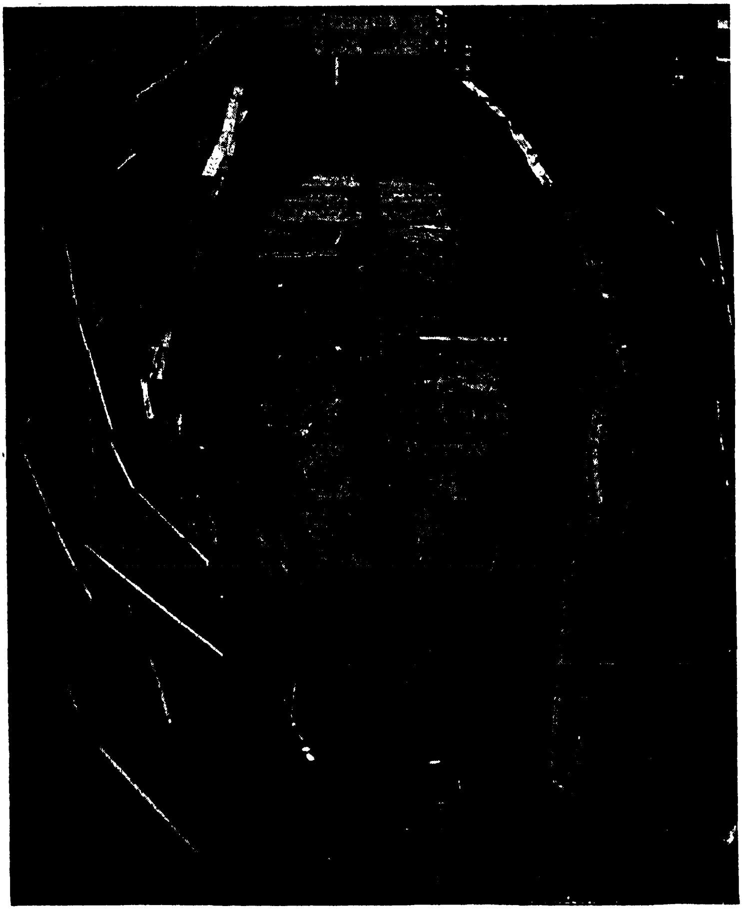


FIG. 324.—A number of subassembled sections of the inner bottom set into the ship and aligned.

should be regulated for fair holes before the unit is finally welded up. The method for setting the welded sections can also be used in this case. Before connections are tack bolted to the shell plating, the subassembly should be set very close to its permanent position and then rechecked after the shell is tack bolted to the inner-bottom structure.

With the exception of the extreme forward and after end assemblies, Fig. 324 shows the subassembled inner-bottom sections set and aligned in the ship. The dark area along the center of the ship shows the absence of the rider plate, which has been left off until the inner-bottom sections have been set and completely welded. This affords easy access and ventilation during welding.

Inner-bottom Structure Built in the Ship. If the construction of the inner bottom is such that subassembly is not practical, then it will be necessary to set floors and longitudinals into the ship in individual pieces.

If the floors are the strength members and the longitudinals intercostal, each floor will have to be leveled up and set on declivity in the same manner as that practical in leveling subassembled sections. However, if the floors are intercostal and the longitudinals are the strength members, a much more difficult job of setting must be undertaken.

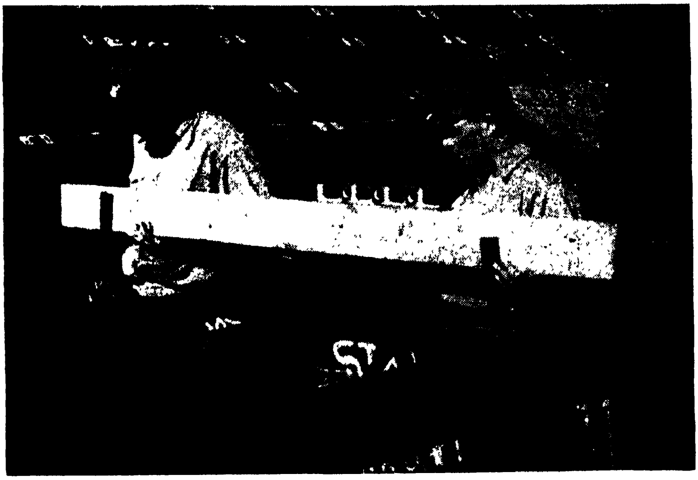


FIG. 325.—Setting floors by checking the top from offsets.

Setting Floors. Since the vertical keel has been plumbed up and shored in a vertical position, the first operation will be to set the floors between the center vertical keel and the No. 1 longitudinal. These floors should be set from the water line established on them from the mold-loft templates. They can also be set from the offsets to the top of the floors, as shown in Fig. 325. If any difficulty is experienced in making the floors check to the proper heights, a recheck should be made from the water line to the inside of the shell plating before any attempt is made to cut the floors for fitting.

Setting Longitudinals. After a sufficient number of floors have been set throughout the ship to span the length of one or more longitudinal plates, the longitudinal plates can be brought in.

Various methods of checking may be used in setting the inner-bottom structure. Usually height battens taken from the mold-loft body plan can be used to check the shell from a water line or the top of the center vertical keel.

Before setting the longitudinal to its proper height, it must first be established in its proper fore-and-aft position. After this has been done, it can then be brought up to its proper height by shoring against the shell. Then, the end of each longitudinal plate should be checked and brought up to its proper height and half width at the molded line of the inner bottom. The reason for doing this is that there may be a slight discrepancy in the cutting of the floors during fabrication and if so an

FIG. 326.—Shipfitters and shipwrights aligning and setting inner-bottom floors and longitudinals.

accumulated error will occur as the process of working out toward the bilge of the ship develops.

Care must be exercised in checking the measurements at the correct half widths, particularly if the inner-bottom plating has a dead rise or is parallel to the shell. This condition would tend to increase the amount of error if the longitudinal were not in its correct half-width position.

In Fig. 326, ship fitters and shipwrights are shown aligning and setting inner-bottom floors and longitudinals.

After the first longitudinal has been set to its proper position, the next step is to install the floors outboard in the same manner as the floors between the center vertical keel and the No. 1 longitudinal, that is, to the straightedge brought out from the center vertical keel. The height at the outboard end of the floor should be checked to the point on the underside of the inner-bottom plating. This will also act as a recheck on the No. 1 longitudinal, which has just been set. Some slight trimming may be necessary from time to time where it is found that the floors project above the top of the longitudinal or do not fit the faired shell. An examination should be made to see that the shell is fair before trimming any floors at the bottom.

After the floors have been set outboard of the No. 1 longitudinal, the next longitudinal can be brought into the ship and set in the same manner as the other longitudinals. It will be found that as in the subassembled sections some points along the shell will have to be brought up against the inner structure, and an effort should be made not to raise the shell above its designed height by excessive shoring.

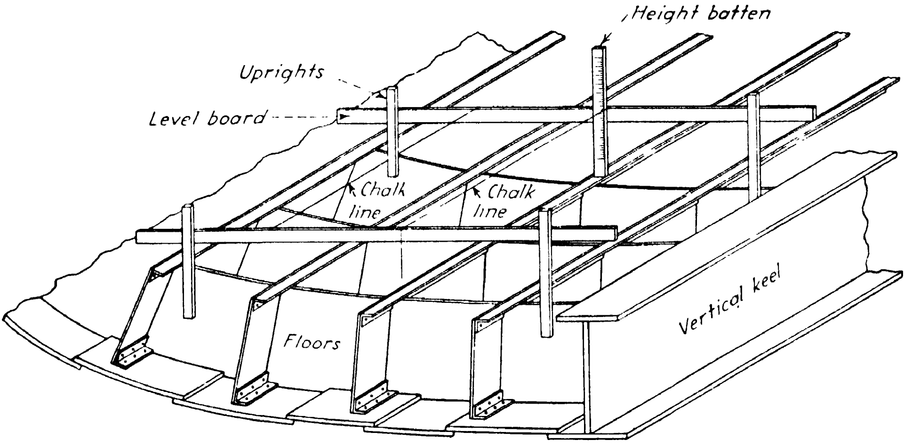


FIG. 327.—Checking longitudinals in the inner bottom.

The same procedure is used throughout in the setting of the floors and longitudinals. Various examples of checking are shown in Fig. 327. In Fig. 328 shipwrights are shown checking floors and longitudinals with height battens.

It has been found good practice to set the bottom structure of the ship slightly lower than design to compensate for any tendency to rise caused by shrinkage during welding. This is done by leaving a slight opening at the top inboard edge of each floor where it connects to the longitudinal.

Vertical Inner Bottoms. On certain types of vessel the inner bottom may continue parallel to the side of the ship up to or above the lower deck. This is particularly true of some of the medium-sized combat ships, for example, cruisers.

Figure 329 shows an inner bottom of a freighter that is parallel to the shell of the vessel. The inner-bottom sections were subassembled on the skids with the shell and inner-bottom plating welded to the framing and longitudinals. After being erected in the ship, they were brought up to the correct height at the deck by means of shores on the outside of the

FIG. 328.—Shipwrights checking floors and longitudinals with height battens.

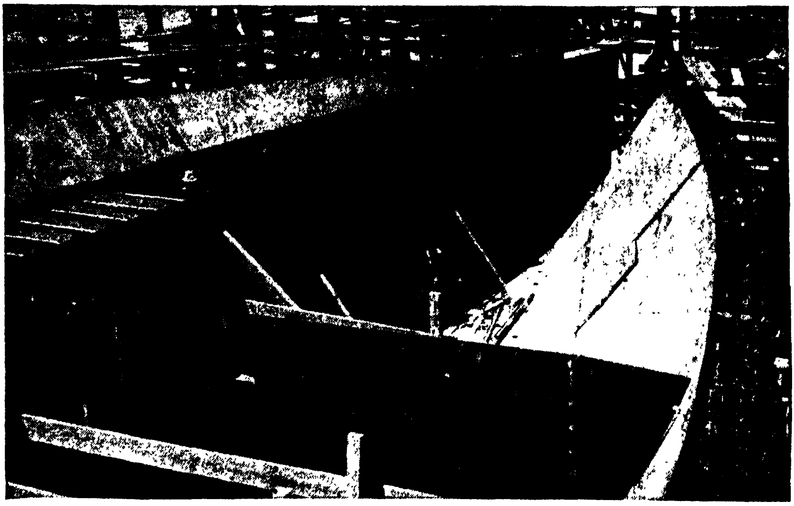


FIG. 329.—An inclined inner bottom of a freighter.

shell. The half widths at each end and the middle of each section were also checked from the center line of the ship.

On this type of construction, particularly if the decks are to be subassembled, it is good practice to set the inner-bottom structure slightly greater in half width than design to afford easier erection of the deck sections. After the deck sections have been erected in the ship, the sides can then be pulled in to the proper half width against the deck.

On some types of ship the inclination of the inner bottom may be the reverse of the one shown because of a tumble home on the side of the ship. In such cases, it may be necessary to install spreaders to prevent the side assemblies from drawing inboard during the process of welding, thus reducing the half breadth of the ship and resulting in difficult installation of the deck sections.

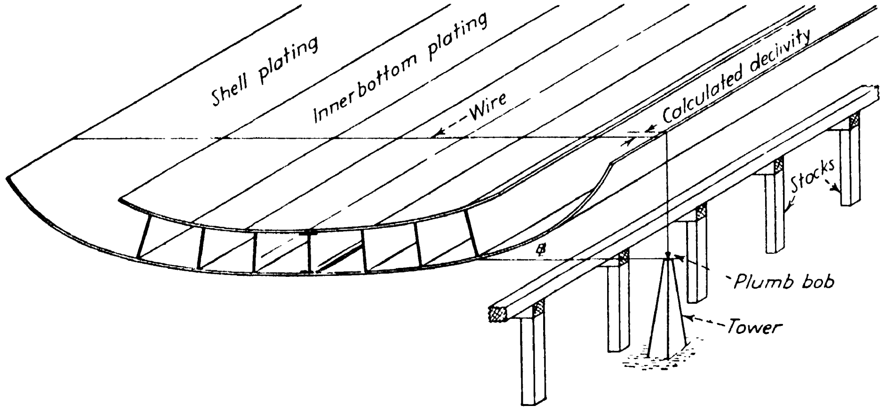


FIG. 330.—Square line brought up from the base line and out to each side of the ship with a wire stretched across the ship for setting inner-bottom plating.

Setting Inner-bottom Plating. In the type of construction in which the inner-bottom plating is not subassembled with the inner-bottom structure, the next operation in the construction of the ship will be to install the inner-bottom plating. The first operation before any plating is brought into the ship should be to check the center line and center vertical keel throughout the length of the ship to ensure a straight working line for building the structure above the inner bottom. Slight distortions that may draw the vertical keel from the true center line of the ship may occur during the process of welding. This can readily be taken care of in the setting of the inner-bottom plating so that no difficulty will be encountered in plumbing up bulkheads should the center line be slightly off the true center.

After the center line has been established, a buttock line should be installed at a convenient distance from the true center line. This is done so that the center strake of the inner-bottom plating can be set and the center line reestablished on these plates after setting. Once the center line has been established, it should be used as the center until the next level of the structure is reached, even though it may vary slightly from the true center because of the movement of the structure of the ship.

The operation of setting the inner-bottom plating is very much the same as that of setting the bottom shell plating. The square lines should be stepped up by declivity from the base line of the ship and brought out to each side. From these points a wire can be stretched for the setting of the plating (see Fig. 330).

The same arrangement of leaving blank holes is also good practice on a large ship where combination riveting and welding are used. If the inner bottom is of the welded type of construction, a slip joint or added material should be left at approximately the same locations as recommended on bottom shell plating so that adjustments of shrinkage caused by welding may be made.

Since the frame lines on the shell have been the means of setting the position of the floors and longitudinals, no attempt can be made to establish permanent frame stations until after the inner-bottom plating has been welded. The proper procedure for welding the structure to the inner-bottom plating is to make the welds to the inner-bottom plating slightly in advance of the welds to the shell plating. This, to some extent, reduces the tendency for the inner-bottom structure to lift after being welded.

REVIEW AND COMMENTS

Make frequent checks of frame stations and working lines.

Do not permit the structure to get out of square (one side ahead of the other).

If the structure is welded, it should be anchored down with turnbuckles and straps to create resistance against movement.

Keep the various members keyed together as closely as is practicable.

Watch the plans for doublers, increased plate thickness, and changes in design or dimension. Work closely with the shipfitter.

Study the offsets.

Have you checked your tape and spirit level?

SAFETY PRECAUTIONS

Keep clear of loads on cranes.

Keep the hands clear of steel until it has been landed and turned loose from the cranes.

In making tack welds, be sure they will hold.

CHAPTER XX

BULKHEADS

There are three types of steel bulkheads used in a ship, namely, transverse, longitudinal, and miscellaneous and other divisional bulkheads. Transverse and longitudinal bulkheads may be watertight, oiltight, nontight, or swash. Their purpose is to give transverse and longitudinal strength to the vessel and to partition holds and compartments as may be required by the purpose for which the vessel is to be used.

Bulkheads also ensure additional safety in the underwater portion of the vessel. In the event of accident, damage can be localized through the closing of compartments in the way of damage.

In most shipyards bulkheads are subassembled on the skids before they are brought into the ship. For the purpose of assembling bulkheads according to their design, water lines and buttocks taken from the mold-loft templates are center punched on the plating at the time it is laid off for fabrication.

If bulkheads are fabricated on the skids, the center line, water lines, and buttocks must be established so that they can be used for the installation of stiffeners and other connections making up to the bulkhead, as well as for the purpose of installing the bulkhead on the ship.

There is very little work required of the shipwright in the subassembling of bulkheads unless an assembly containing several bulkheads is being put together as a unit on the skids. In this case it may be necessary to do certain shoring and lining up for the shipfitter to make up the assembly. Ribbands for the purpose of keeping bulkheads fair during welding and for the stiffening necessary for handling them from the skids to the ship will be required. This work is usually performed by the shipwrights.

The setting and fitting of main transverse and longitudinal bulkheads are done by the shipwright. These bulkheads are often watertight and oiltight and are the main athwartship strength units of both cargo and combat vessels. Because they are solid and strong, the hull of the ship is usually faired to them, and for this reason they must be securely set and fitted.

Setting and fitting are divided into two steps. First, the ship is made ready to receive the bulkhead. The structure on which the bulkheads are to be set should be lined up according to plans for their proper location. Whether they are on designed frame stations, given distances from the frame stations, or given distances from the center line, the lines after being struck in on the plating should be center punched and a working line established at any convenient distance from the actual line of the bulkhead for the convenience of setting in the proper location. This distance can be 3 to 6 in. or greater if desired (see Fig. 331).

If the bulkheads have riveted connections through the shell or deck, they may be fastened temporarily by the use of bolts through the rivet holes. Some additional bracing will also be necessary. If the bulkheads are of welded construction, clips must be set up to hold the bottoms temporarily in position. The tops in both cases, however, must be braced temporarily with shores or turnbuckles and straps until they are permanently set.

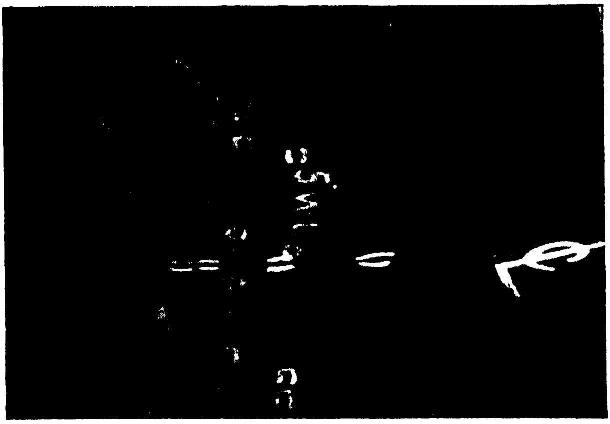


FIG. 331.—Establishing working line for setting transverse bulkhead.

Flat bars and clips for erecting the bulkhead should be installed before it is brought into the ship.

If wooden shores are used, their tops should be at least *three-fourths* the distance to the top of the bulkhead.

The second step in setting a main transverse or longitudinal bulkhead is to line it in its proper position relative to the lines struck in on the ship.

TRANSVERSE BULKHEADS

Erection. After the ship has been made ready, bulkheads may be brought into the ship and erected.

The transverse watertight bulkhead shown in Fig. 332 is being lowered into the ship to be erected by the shipwright. Wooden ribbands have been bolted to its forward side to hold it fair, as well as to stiffen it for handling. The stiffeners are on the after side.

After the bulkhead has been landed in the ship, shores and turnbuckles to hold it temporarily in position are installed so that it can be turned loose from the crane. In Fig. 333 shipwrights are shown installing a tension brace consisting of flat bar straps and turnbuckles. In Fig. 334

FIG. 332.—Transverse bulkhead being lowered into the ship.

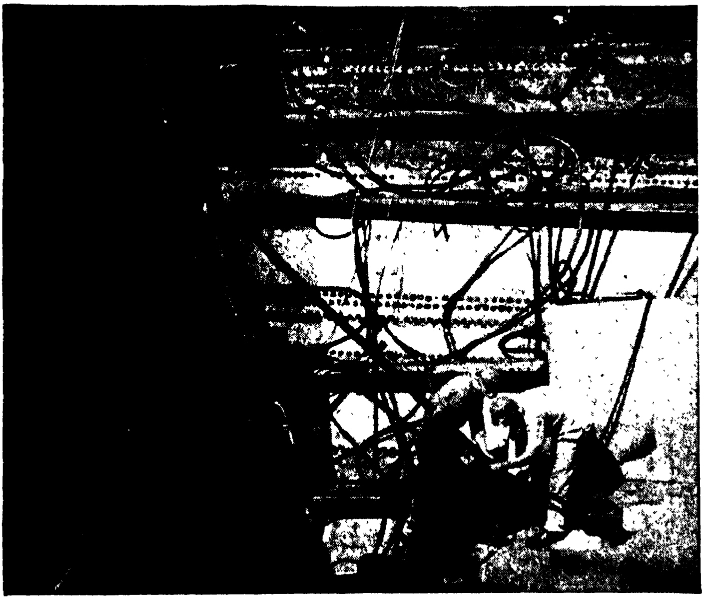


FIG. 333.—Shipwrights installing tension braces with flat bar straps and turnbuckles.

the bulkhead has been cut loose from the crane and secured temporarily in place by means of shores and tension braces.

Aligning and Setting on Center. Since its center line was established at the time the bulkhead was being subassembled on the skids,

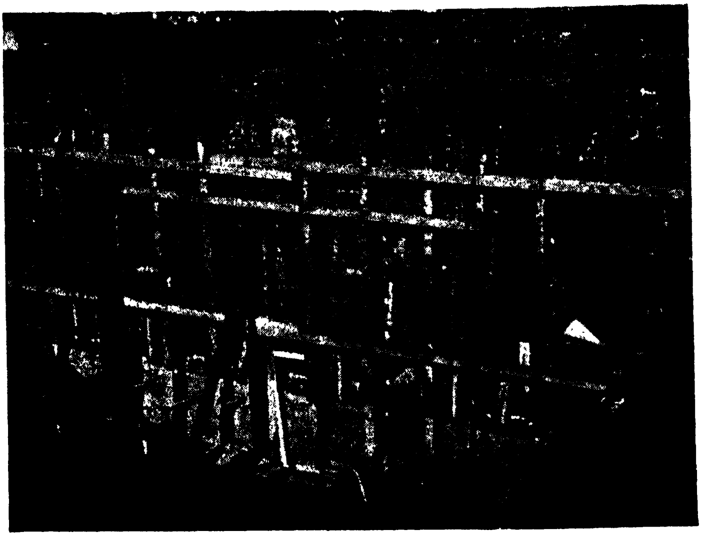


FIG. 334.—Transverse bulkhead erected in the ship and secured temporarily by means of shores and tension braces.

the former can now be used to place the bulkhead on the center line of the ship. This is done by swinging a plumb bob from the center line at the top of the bulkhead and moving the latter by means of shores or jacks until the plumb bob swings directly over the center line on the keel

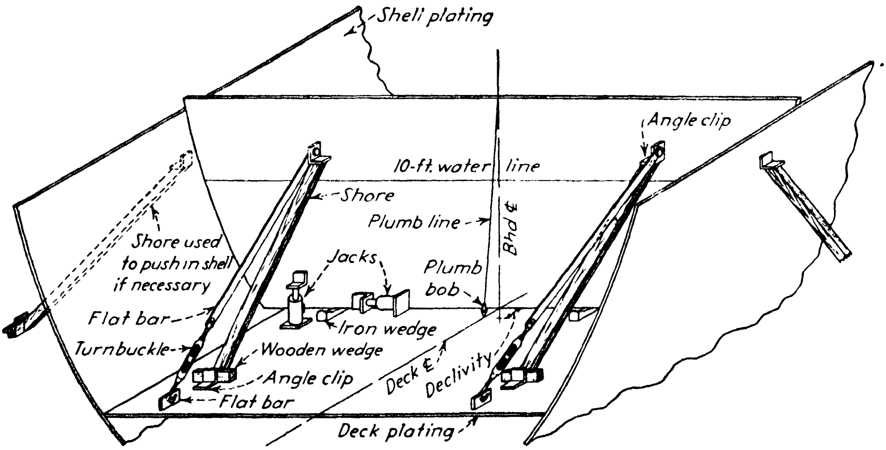


FIG. 335.—Transverse bulkhead being leveled up by means of jacks and wedges.

plate or deck at the bottom. Setting conditions and the construction will govern to a great extent whether the bulkhead can be shored on the center line from the sides or jacked and wedged at the bottom until it is brought into proper alignment. In lining up heavy bulkheads a combination of both may have to be used. This condition is shown in Fig. 335.

Setting Athwartship. In Fig. 336 the shipwright is shown using a steamboat jack to pull a bulkhead to the center line on the deck. After the bulkhead has been plumbed to the center line of the ship, the next operation will be to see that the water lines are level.

If the bulkhead has not been distorted during the process of welding on the skids, the water lines should check and be at right angles to the

Fig. 336.—Using steamboat jack to pull a transverse bulkhead to the center line of the deck.

center lines. However, should it be distorted, it may be necessary to change the water line so that this will be at right angles to the center line, or it may be necessary to reverse the process by checking the half width of the bulkhead from the center line to determine whether or not the latter is in the center of the bulkhead.

If it is found that the center line does not check with the half width of the bulkhead from each side of the ship, then it will have to be changed. Before water lines are changed, the height from the water line to the top of the bulkhead should also be checked. If it is found that the water line is parallel to the top of the bulkhead (which must be level), a compromise between the center line and the water lines may be necessary. If the center line is plumb and the water lines are level, the operation of setting the bulkhead in its fore-and-aft position can commence.

Figure 337 shows shipwrights checking the water line of a bulkhead.

With very few exceptions, bulkheads are usually set at right angles in a vertical direction to the fore-and-aft base line of the ship. The exceptions are those in way of machinery and uptake spaces and where companionway divisions may be designed to have an inclination to suit the conditions for which they are intended.

Setting Fore-and-aft Position. Assume that the bulkhead is to be built at right angles to the base line of the ship. First, set the bulkhead on declivity at the center line of the ship. To do this, multiply the height of the bulkhead in feet by the declivity per foot on which the ship is being built. This will give the point from the line at the bottom of

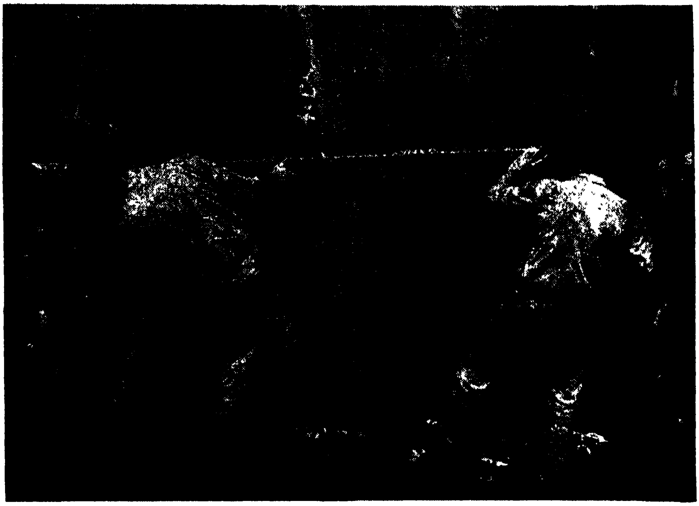


Fig. 337.—Checking the water line of a bulkhead.

the bulkhead where the plumb bob should intersect to bring the bulkhead to its proper declivity. For example, if the distance from the top of the bulkhead to the point of the plumb bob is 22 ft. 8 in., or $22\frac{2}{3}$ ft., and the ship is being built on a declivity of $\frac{5}{8}$ in. per ft., then the plumb bob should intersect at a point approximately $14\frac{3}{16}$ in. ($\frac{5}{8} \times 22\frac{2}{3} = 14\frac{3}{16}$) aft of the line at the bottom of the bulkhead to place it at right angles to the base of the ship, or on declivity.

Shores or straps with turnbuckles can be used to adjust the bulkhead and bring it into its proper position, as shown in Fig. 338.

After the center of the bulkhead has been set, the same procedure should be used at its outer ends, whether at the shell or at a longitudinal bulkhead to which the transverse bulkhead may be fastened. After the sides have been brought into the same line as the center, the bulkhead is then in its fore-and-aft location with the exception of some sagging in between these points. This sagging can be corrected when the bulkhead is secured at the top.

Setting to Correct Height. In the welded type of construction, where the structure is distorted by shrinkage and heat during welding and where accurate work is desired, added material is usually left at the bottom of the bulkhead (or sometimes at the sides) for the purpose of taking care of any irregularities that may exist in the ship. Therefore, if added material has been left on the bottom of the bulkhead, it will be necessary to cut some of this material off to give the bulkhead its proper height and half-width dimensions.

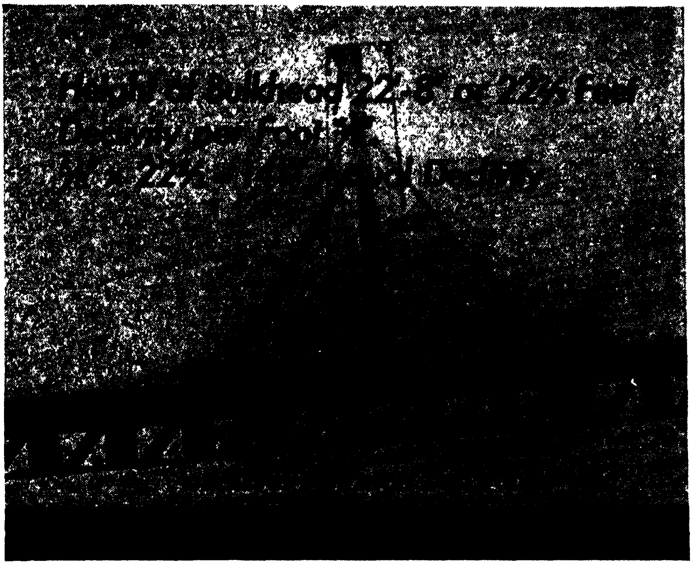


FIG. 338.—Shores or straps with turnbuckles used to adjust the bulkhead to its proper position.

From the water line that was checked to ensure its being at right angles to the center line when the bulkhead was placed on the center of the ship, check the height to the top of the bulkhead at the center and at each side to determine whether or not this height is correct.

If, for example, the deck at the top of the bulkhead is straight and is 32 ft. above the base line of the ship, then, from an 8-ft. water line, this distance should be 24 ft. If this distance is correct and there is an inner bottom that is 4 ft. from the base line of the ship, then the distance from the 8-ft. water line to the top of the inner bottom should be 4 ft. less the thickness of the inner-bottom plating. Consequently, if 1 in. of added material has been left at the bottom of the bulkhead and the bulkhead is resting hard on the inner-bottom plating, there should remain 1 in. of added material to be scribed and cut off the bottom of the bulkhead to bring it down to its proper height above the base line. However, it will be found that in most welded vessels there is a tendency for the bottom to rise slightly during welding or that irregularities due to buckling may exist in the inner-bottom plating. Therefore, the amount of material to be cut off may vary.

Cutting and Fitting. As previously mentioned, the bottom of the ship is usually built about ½ in. lower than design at the bilge to take care of the tendency to rise. The added material left on the bulkhead

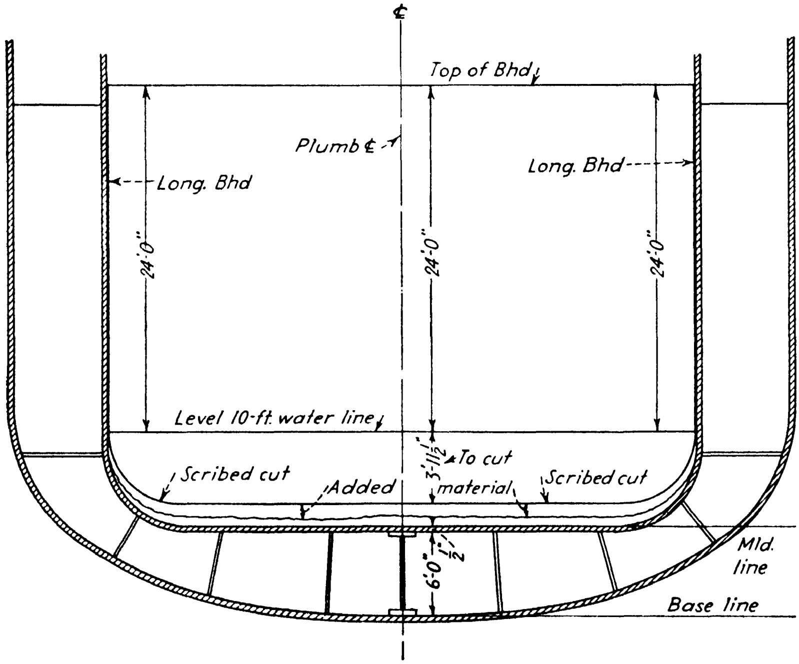


FIG. 339.—Added material left at the bottom of a transverse bulkhead to take care of irregularities.

will be sufficient to take care of any irregularities that may develop if the bottom does not lift as much as anticipated (see Fig. 339).

If the bulkhead is cut to fit the side of the ship as shown in Fig. 340, it will be necessary to mark perpendicular lines with soapstone around the edge of the bulkhead, a spirit level being used as a guide. With a 1-in. template parallel to the perpendicular lines, mark the boundary by running the template along the tank top scribed with soapstone.

After the additional material has been removed from the bottom of the bulkhead, it can be lowered down to rest hard on the inner bottom. It will then be necessary to recheck the bulkhead, the same procedure being followed as that used in setting it for cutting down. It should be braced and shored accurately in order to hold it plumb and on its proper declivity. When this has been done, the bulkhead can be tack-welded to the proper lines for production welding, as shown in Fig. 341.

Stiffeners should not be fastened or welded at the bottom until the bulkhead has been set in its permanent position at the top. Some slight change may have to be made at the time the top is set; and if the stiffeners

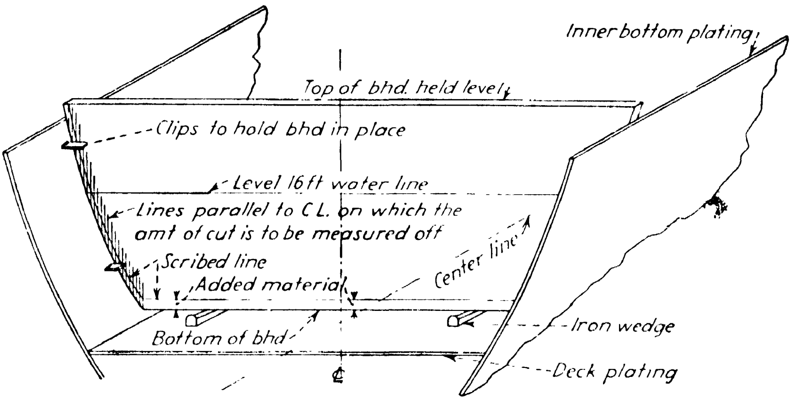


FIG. 340.—Vertical lines marked on transverse bulkhead for scribing off excess material at the sides of the bulkhead.

FIG. 341.—Bulkhead being set and tack-welded to proper lines for production welding.

are welded, this may not be possible. In Fig. 342 shipwrights are shown jacking a bulkhead on the frame line.

Where bulkheads are fitted between sides of an inner bottom that is parallel to the shell of the vessel, care must be exercised in scribing for cutting. If, for example, a bulkhead must be brought down 1½ in. vertically to bring it to its proper height, care must be exercised to see that the scribe is held parallel to the center line at all times; otherwise, a bad fit will result (see Fig. 343).

The same procedure must be followed in scribing stiffeners, which may be welded to an inner bottom that is not parallel to the base line

FIG. 342.—Shipwrights jacking a bulkhead on the frame line.

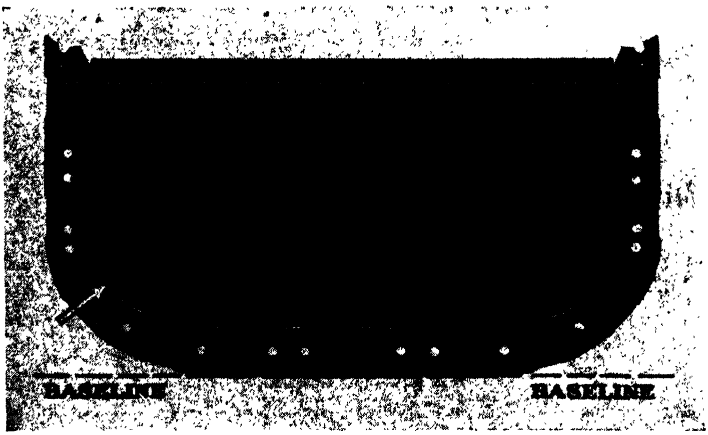


FIG. 343.—Improperly scribed badly fitting transverse bulkhead.

of the ship. In this case a declivity board should be used to install perpendicular lines for the purpose of scribing off the desired amount of material.

BETWEEN-DECK BULKHEADS

Bulkheads between decks are set in the same manner as the bulkhead just mentioned except that the deck heights will have to be used in conjunction with water lines.

Because of the fact that transverse bulkheads to a large extent govern the fairness of the shell of the ship, it is important that they be set and cut as nearly to designed dimensions as possible so that no unfairness will be evident in the shell of the ship. This will also result in the better fitting of the other members of the structure attached to the shell of the vessel. It is therefore evident that the shipwright's work in setting up the main structure of the ship and aligning it so that structure subsequently being brought into the ship will fit properly and so that a fair-line shell will result is of the utmost importance.

MAIN LONGITUDINAL BULKHEADS

In the setting of main longitudinal bulkheads somewhat the same procedure is followed as that used for the transverse bulkheads with the exception that added material for adjustment is usually left at the top of the bulkhead instead of the bottom, particularly where such bulkheads extend to the shell of the vessel. If the bottom is cut to the mold-loft lines, this will be found of assistance in fairing the shell between the main transverse bulkheads. Any adjustment or corrections can then be made at the top. If the bulkheads are set on the inner bottom of the ship where irregularities may exist, then the added material should be left at the bottom as in the case of the transverse bulkheads so that irregularities in the inner bottom can be taken care of.

The first operation in setting a longitudinal bulkhead is to place it in its proper fore-and-aft position, that is, to the proper frame stations. It must then be brought into the proper half-width position. If the bulkhead is parallel to the center line of the ship, it must be set to the proper designed half width both top and bottom; after this, the operation of setting it to the proper height and declivity can be performed. After it has been set on approximately its proper half-width position, beginning on the end of the section, it must be brought to its proper height with respect to the water lines on the main transverse bulkheads. This can be done by means of shoring on the outside of the shell plating, care being taken not to shore transverse bulkheads out of plumb. After one end has been brought to its desired height, the same operation should be performed on the opposite end. A check can then be made to determine whether or not the frame lines are on declivity. This is done by suspending a plumb bob from the top of the bulkhead as for the transverse bulkhead.

If the bulkhead is inclined, that is, farther from the center at the top than at the bottom, two points will have to be checked. In this case two operations will be necessary. (1) The bulkhead should be set approximately at the proper distance from the center line. (2) It should be brought up to the proper height and placed on declivity by means of jacks or shores. A recheck must be made of the position from the center line after the bulkhead has been brought up to its proper height.

In the setting of main longitudinal bulkheads, it is important that they should tie in with the shell and decks of the ship. That is, it is possible to gain or lose length if care is not exercised in tying in with the frame stations on the shell and the decks.

If bulkheads are of welded construction, it is important that the same stretch should be used in subassembling and setting as that for the center vertical keel, so that the frame lines will tie in with the remainder of the structure. If the butts of the plating are welded, the same root openings will have to be held as those in the butts of the center vertical and flat keels.

Difficulty is sometimes encountered where a combination of riveting and welding is used in the area of such bulkheads. Hence, if the top of the bulkheads is to be riveted to the deck and the remainder of the bulkhead welded, it is good practice to use only tack holes in the connections through the deck and then resort to drilling on the ship after the greater part of the welding has been completed. Otherwise, bad rivet holes will result in a great many instances.

Frequent checks should also be made from the square line at the midship part of the ship to ensure against one side of the ship being ahead of the other, thus causing difficulty when deck plating is laid and set.

MISCELLANEOUS AND OTHER DIVISIONAL BULKHEADS

The setting of miscellaneous and other divisional bulkheads is usually performed by the shipfitters' department, which works from working lines installed on the deck plating and the shell of the ship by the shipwrights. These bulkheads, after being brought into the ship by the cranes, are temporarily supported in place by wooden shores or steel strap braces until such time as they are set in their final position.

In many shipyards, shipwrights are called upon to perform service work for the shipfitter in aligning this structure, particularly where shoring and bracing may be necessary to bring it into alignment. In Fig. 344 a number of bulkheads are shown set up in the ship preparatory to the erection of side framing and decks.

REVIEW AND COMMENTS

Preparing to Set the Bulkhead

One of the most important jobs in ship construction is the setting of bulkheads. After bulkheads are set, they are constantly used as points of reference in building the remainder of the ship to correct dimensions. Great care, therefore, must be exercised to be sure that each bulkhead is set correctly and secured in that position.

Strike in frame stations where the bulkhead is to be set. Check to be sure this line is square athwartship.

When bulkheads are set on stretched frame stations where welding has been completed and shrinkage has taken place, it will be found that they cannot be plumbed in a fore-and-aft position and will consequently be thrown out of plumb away from the midship part of the ship until such time as the upper structure has been set and welded and subsequent shrinkage has taken place. In this event, brackets at the bottom of

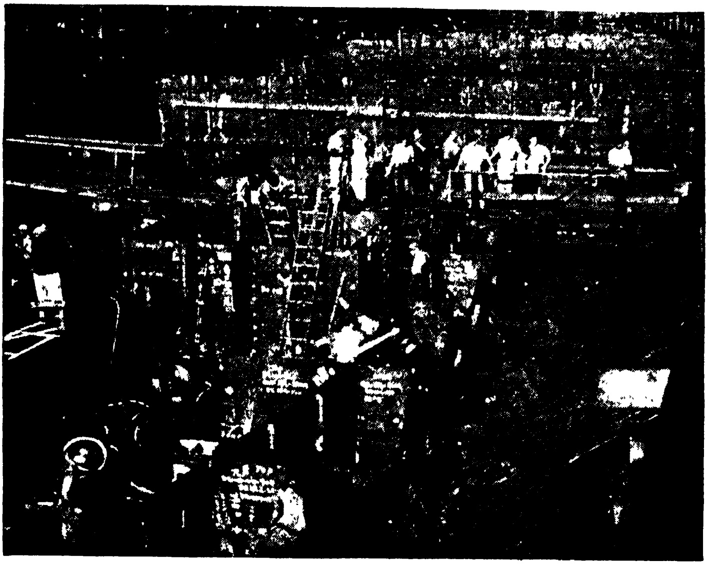


FIG. 344.—A number of bulkheads set in the ship preparatory to erection of side framing and decks.

stiffeners should be left off until the bulkhead has been pulled back approximately plumb. After this the brackets can be installed and welded.

PROCEDURE OF SETTING THE BULKHEAD

1. After the bulkhead is landed in place by the crane, secure it in its approximate position by means of two or more braces fastened on each side.

2. Establish the center line on the bulkhead and set the bulkhead to the center line on the keel plate or deck, as the case may be.

3. Using a plumb bob suspended from the center line at the top of the bulkhead so that it will hang over the established center line below, plumb the center line of the bulkhead.

4. Set the bulkhead on the proper declivity. The plumb bob is used for high bulkheads and the declivity board for between-deck bulkheads.

5. Fasten a wire across the top of the bulkhead to uprights at the sides and set it to a straight line, holding points previously set. Shore the bulkhead to suit so that longitudinals may be secured to it.

6. Strike in a convenient water line. If possible, use the same water line consistently through each level of the ship.

7. When a bulkhead is very wide, it is good practice to use a surveyor's level for leveling. Almost all shipyards now use an engineer's level and transit for running lines, as the work can be done more quickly and accurately.

8. Check the height of the bulkhead at each side at the established base line on the deck, using a steel tape or batten, thus determining the amount of excess material that must be removed.

9. Scribe the amount to be cut off along the bottom or top of the bulkhead, following accurately the shape of the shell or deck as the case may be.

10. After the bulkhead has been cut and lowered into place, check again to be sure it is properly set.

11. There are two methods used in establishing a line square from the center line. (1) Plumb up a square line established on the stocks. (2) Measure an equal distance on each side of the center line, and establish a spot. Measure forward or aft along the center line any convenient distance, and establish a spot on the center line. Measure diagonally from this spot to each of those established off the center line. If the diagonal measurements are equal, the line is square, provided, of course, that all measurements are made accurately.

SAFETY PRECAUTIONS

Do not stand in way of the bulkhead until it is landed.

Be sure that it is secured before releasing it from the crane.

Do not use timber with large knots for bracing because of the possibility of its breaking at these points if subjected to strain.

CHAPTER XXI

SIDE FRAMING

The side framing of a vessel acts as ribs to support it. The spacing of the framing varies according to the size of the vessel to be built.

Frames usually extend from the bilge of the ship to the first strength deck, but they may extend through one or more decks, depending on the length of the frames necessary. In designing the proper-sized framing for a vessel the framing at the bottom must be considerably heavier than the framing toward the upper part of the ship. At the points where the size of the framing changes, frames are usually cut where it is possible to butt and secure them together at a beam knee or where they penetrate the deck.

There are two types of frame. One is a standard structural shape. The other is a built-up web frame to give additional strength to the side of the vessel between the bulkheads. Web frames are usually located opposite the ends of hatches and may also be installed between these points when it is necessary to provide additional stiffening.

Unless it is possible to subassemble sections of side shell including side framing and to install these subassemblies in the ship in units, the side framing from the inner bottom to the first deck will be the next structure erected in the ship. Before this can be done, however, some temporary means of supporting these frames must be provided. This consists of a ribband near the top of the frames located opposite an outside lap strake of plating, so that the skin strake can be erected and secured to the frames while the ribband holds them approximately in their proper position.

Framing Ribband. The ribband for erecting side framing can be either a solid piece of timber or a built-up adjustable ribband as shown in Fig. 345.

The framing ribband usually extends from the forepeak bulkhead to the afterpeak bulkhead unless framing forward and aft of these bulkheads is erected individually instead of in subassembled units (which is usually the case). If a ribband is necessary beyond these points, it must be banked to suit the shape of the ship. This ribband can be of wood or a steel flat bar.

If wood is used, it must be cut out and shaped to suit the shape of the ship. A steel ribband must be bent so that it will hold the framing in approximately the correct position.

After the location or height of the ribband has been determined, a support, or outrigger, from the stage standards should be erected. The ribband can then be laid on this support.

To establish the height of these supports for the ribband, the base line of the ship can be projected out to the side and marked on the staging standards. When this has been done, with the use of a height batten obtained from the body plan or a steel tape and the offsets, the desired height of the ribband is established on the staging standards so that the

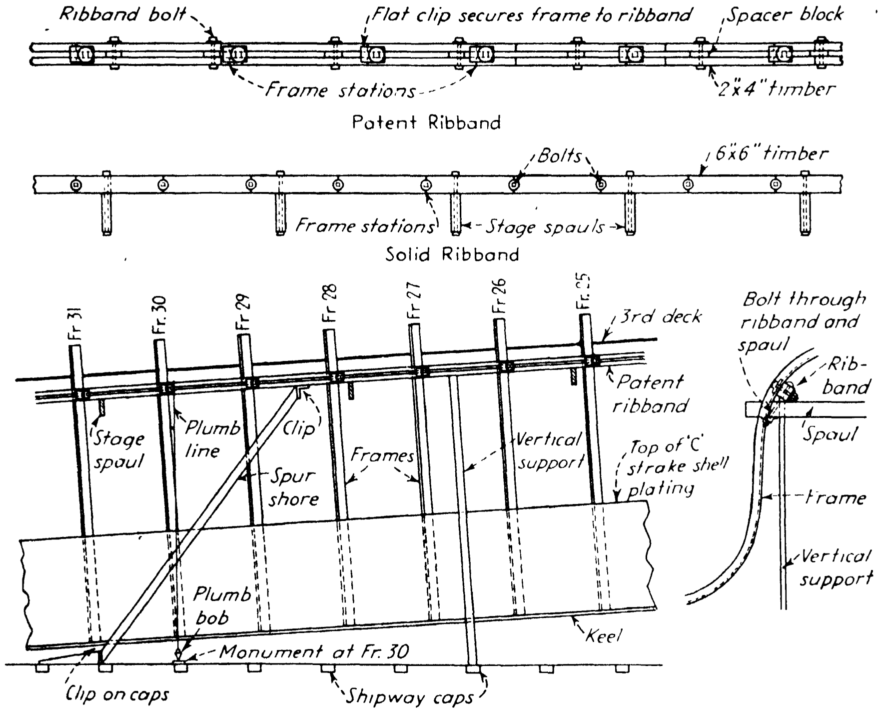


FIG. 345.—Ribband for erecting side framing.

ribband support or the outrigger can be adjusted to these lines and made ready for the ribband.

The outrigger should be long enough to extend from the stage standard to the actual side of the ship so that it can support the ribband, which must be set to this point, or approximately at the true half width of the ship. This can be done by plumbing down from the ribband support to the proper distance measured from the center line of the ship and marked on the shipway.

When the half width of the ribband has been established on the ribband support and after the height of the ribband has been determined, it can then be laid on the supports and connected together, set to the proper half width and "chocked" so that it will not move outboard when frames are secured to it. After it has been erected and secured together, at least one set of spur shores should be installed to hold it in a fore-and-aft position. The spur shore should be footed on the shipway caps or on the ground on a solid footing and then cut in at the top against a clip secured to the ribband.

When the structure is particularly heavy and the ship long, it may be necessary to erect two sets of spur shores to offset the tendency of the weight to move aft because of the declivity on which the ship is being built. It may also be necessary to erect some vertical shores under the ribband to support the weight of the frames when the framing is of a heavy nature and particularly when the ship at the forward and after ends overhangs the bottom. The latter condition throws a greater part of the weight of the framing on the ribband, causing it to sag and probably break if shores are not erected to help support the weight on the ribband.

Establishing Frame Stations. In order to erect the frames and secure them to the ribband in their proper location, frame stations must be established along the ribband as a guide. A template secured from the mold loft and giving the frame stations as applied to the outside of the shell at the given height of the ribband is used to mark the stations. The height is usually given from a sight edge of shell plating or a convenient distance below some deck.

Generally, ribbands are set 18 in. below a deck since staging is provided 3 ft. 6 in. below the deck. This provides suitable working conditions for securing frames and setting the ribband.

To apply templates on the ribband it is first necessary to establish a starting point. This is done by suspending a plumb bob down to the monument that was used for setting the bottom shell plating.

By using the height of the ribband above the base line, the declivity on which the ship is being built can be figured. The amount of declivity can then be marked off from the plumb-bob line and the starting point established so that the frame stations will be at right angles to the center line of the ship, as well as perpendicular in a fore-and-aft direction to the base line of the ship. Frame-station templates can now be applied and the frame stations marked on the ribband and either notched in with a handsaw or marked across the ribband with a race knife.

Frames can be secured to the ribband by means of flat-bar clips with bolts extending through the ribband. The bolt can be tightened when the flat-bar clip has been placed over the toe of the frame and the frame held in position on the frame station marked on the ribband. These clips should be provided and installed at each frame before the work of erecting the framing begins.

Figure 345 shows spur shores, ribband clips supporting shores, and the frame stations plumbed up and marked on the ribband. In the foreground of Fig. 346, the ribband can be seen lying on the outrigger just below the level of the top of the bulkheads, with bulkheads, framing, and deck beams aft of this bulkhead already erected.

When transverse bulkheads extend between the sides of the shell, the usual practice is to install the framing ribband before the transverse bulkheads are erected, as this will be an aid in holding them in place.

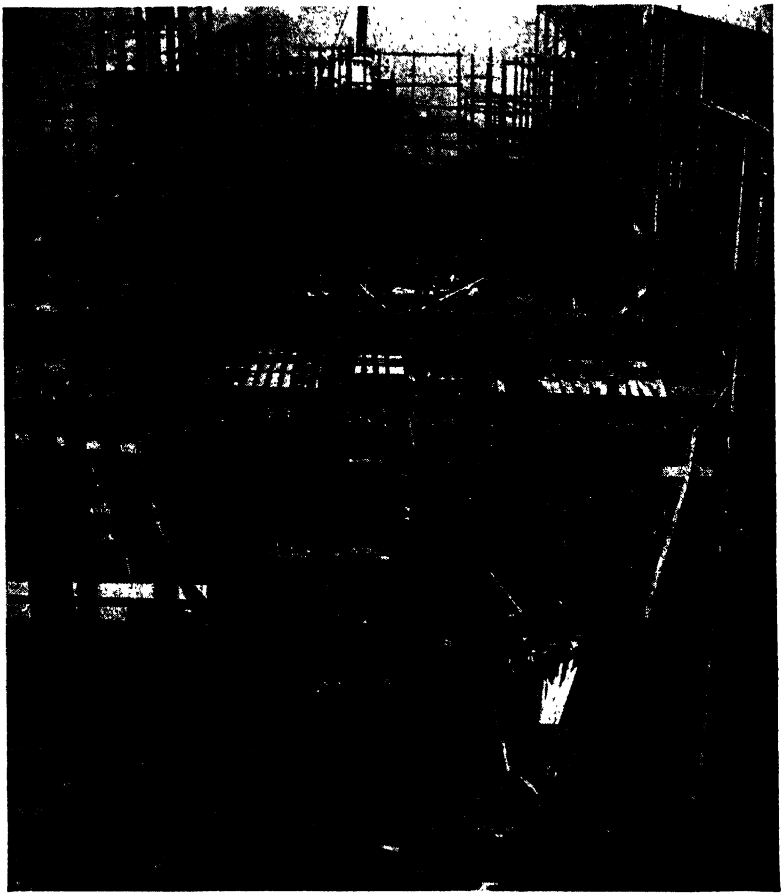


FIG. 346.—Ribband lying on outrigger set below level of bulkheads.

Setting Frames. The setting of the framing will, of course, form the shape of the ship and, if properly done, will create a fair shell between the main transverse bulkheads. As the frame is being lowered into place by the crane, it must be held on the correct frame station at the bottom and at the top. The top is set approximately by fastening it at the frame station to the framing ribband. The bottom of the frame must be cut at the correct distance from the center line. This is done by means of buttock lines center punched on the frame when it was laid off for fabrication.

As the frames are set in the space between the bulkheads, which have already been set, a wire can be stretched at a water line between the bulkheads and the water line on each frame checked from this wire. This will definitely set the framing in a vertical direction. The framing will be definitely set on its proper halfwidth at the top at the time that the deck beams, girders, and deck plating are erected and set in position.

By sighting over the frames it can readily be determined whether or not they are fair. If unfair frames are discovered, they must be checked and regulated until they are fair with adjacent frames.

Web Frames. As previously stated, web frames are designed to give additional strength where necessary and where regular-sized frames

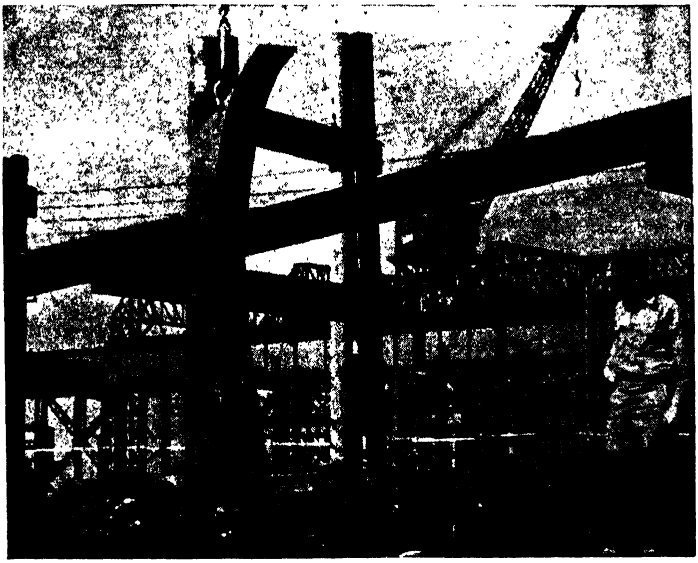


Fig. 347.—Between-deck web frame being erected in the ship.

are not sufficiently strong, particularly in the area of the large hatch openings or in large holds.

In Fig. 347 a between-deck web frame is shown being erected in the ship. To the right the shipwright will be observed stationed at the clip located on the framing ribband to which the web frame will be temporarily secured until set.

After the frame has been erected in the ship, the work of setting it can begin. In Fig. 348 the web frame is marked with a 28-ft. water line and 28-ft. buttock. The first operation to be performed will be to set the frame in its proper athwartship position so that the 28-ft. buttock on the web frame will intersect the buttock line marked on the deck. After this has been done, the water line will be brought to a level plane with the spirit level. If the height above the base line of the deck at this point is known, the frame can then be checked for height from the 28-ft. water line. Added material is usually left on the bottom of web frames to take care of irregularities; therefore, some of this added material will have to be removed by burning. When the amount of material to be removed in order to bring the web frame to its proper height has been determined and the water line on the frame made level, the web can be scribed and burned off.

The web can then be lowered down so that it will rest on the deck. Both the buttock and water lines are rechecked for plumb and level. After this, the web can be tack-welded to the deck ready for welding. However, before being welded, the frame must also be set in proper declivity.

Fig. 348.—Web frame being set.

REVIEW AND COMMENTS

Framing ribband is used to hold frames temporarily in position until they are regulated and set. To serve this purpose it must be set accurately and well braced.

In projecting the square line of the starting frame to the ribband that rests on the staging spauls and standards, it is necessary to project the square line out to the staging standards from under the ship.

First, nail a piece of 2- by 4-in. timber in a fore-and-aft direction between two of the stage standards coming in way of the square line. This timber should be nailed at the level of the base line of the ship.

With a plumb bob project the starting frame from a monument established on the stocks to the 2 by 4 on each side of the ship.

From this point the frame station can be projected up to the ribband by figuring the declivity from the distance between the 2 by 4 to the position of the ribband.

Stage spauls should be set along each side of the ship to the designed height of the ribband and the approximate half width.

Using a plumb bob, establish half widths on alternate spauls along each side of the ship, so that the ribband can be set on its proper half width.

Have the crane lay sections of ribband in their approximate position. The sections of ribband can then be connected together and while this is being done should be placed on the half widths marked on the outriggers, or spauls.

Cut one or more spur shores on each side running from the stocks to the ribband. These are fastened at the top and bottom.

When spur shores have been installed, the starting frame station can be established on the ribband. From this point, templates can be applied to the ribband and the frame stations marked on the ribband.

Ribbands should be made fast to bulkheads as they are set into the ship before attempting to erect frames.

A $\frac{3}{4}$-in. bolt of suitable length with a flat-bar clip should be provided where frames are designed to occur.

SAFETY PRECAUTIONS

Examine ribband to see that there are no weak spots, particularly at the coupling joints.

Keep clear of the crane when ribband is being erected on the spauls.

Be sure when erecting frames that each frame is landed at the bottom before being secured to the ribband, so that the latter will not be subjected to any more weight than necessary.

CHAPTER XXII

DECK GIRDERS AND BEAMS

Deck beams and girders which support the deck plating generally are erected after the side framing.

Deck girders which support the deck plating and deck beams usually run in a fore-and-aft direction. However, where large deck openings are provided for shipping cargo or equipment, transverse girders are ordinarily located at the hatch ends to compensate for and to strengthen the structure in way of these large openings. Stanchions may be provided to assist in supporting the load around the hatch corners. Sometimes, additional stiffening is provided by means of deep brackets.

Transverse girders may also be used where the longitudinal framing type of design is called for. When this is the case, the transverse girders may be recessed for the longitudinals to pass through them (see Fig. 349).

In designs in which deck framing is run in an athwartship direction, longitudinal girders are provided to help support the transverse beams and are usually cut so that the latter pass through them. They are also intercostal between the transverse bulkheads and the transverse girders.

Erecting Transverse and Longitudinal Girders. After the side framing has been erected, the transverse girders can be brought into the ship and connected to the web frames with the necessary shores to hold the transverse girders in their temporary position until they are set. The longitudinal girders can then be erected and shored temporarily in the same manner. So that no great amount of difficulty may be experienced in erecting the longitudinal girders, the transverse girders should be placed very close to their permanent location.

Because the web frames and deck girders support transverse beams and plating, it is important that they be set in their proper position so that the deck plating of the ship can be attached to its support as designed and fabricated.

Setting Transverse Girders. When the transverse and longitudinal girders have been erected in the ship, the next operation will be to set the transverse girders in position. If the deck plating is of the all-welded type, the same consideration must be given to welding shrinkage of girders and also the deck as was given to the shrinkage of the bottom shell and inner-bottom structure.

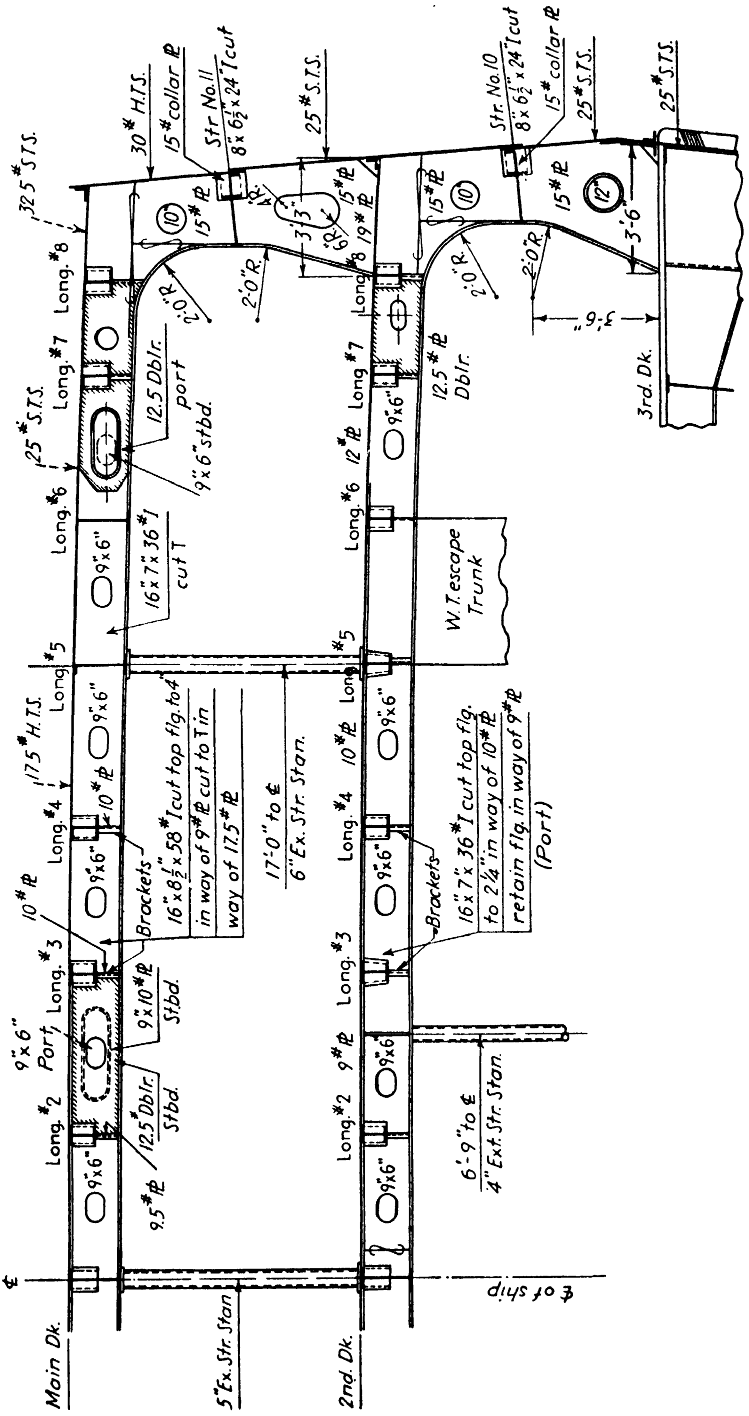


FIG. 349.—A transverse web frame and girder.

The transverse girder should first be set to its proper height above the base line. This height should be checked at both the center line and each side and is obtained from the book of offsets or the body plan.

FIG. 350.—Shoring up a transverse girder.

FIG. 351.—Setting transverse girder on center line.

If the girder is found to be low, it should be brought up to the proper height, as shown in Fig. 350. If it is high, easing up on the wedges under the shores will lower it.

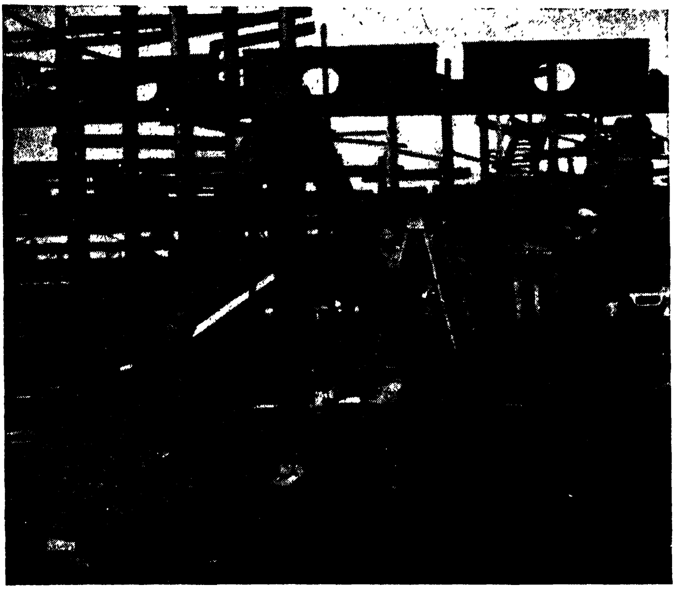


Fig. 352.—Spur shoring transverse girder at center line.

Fig. 353.—Shipwrights rechecking a transverse girder.

The next operation is to place the girder on the center line of the ship. To do this, either wooden spur shores or steel straps can be used.

With a line and plumb bob suspended from the center line laid off on the girder for fabrication, shore or pull the girder until the point of the plumb bob falls over the center line of the deck or structure below, as shown in Fig. 351.

After this the girder must be placed in its proper fore-and-aft position. To accomplish this, spur shores or turnbuckles and straps should be placed on the center line and at each end of the girder, as shown in Fig. 352. At points where longitudinal girders connect to the transverse girders, spur shores should also be installed in order to maintain them

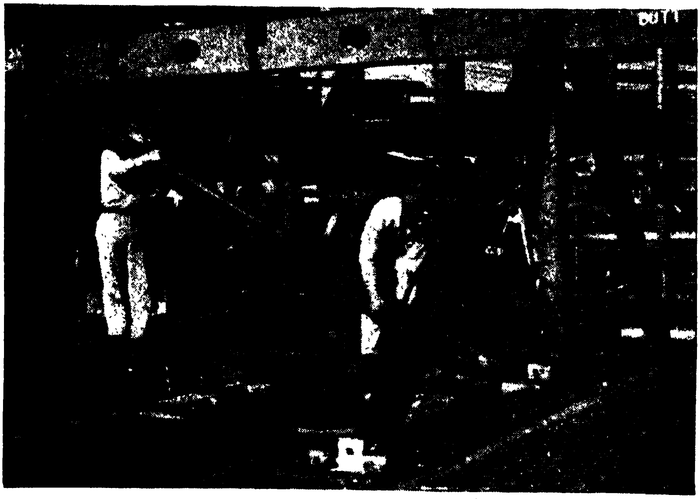


FIG. 354.—Transverse girder properly spur-shored.

in their proper position and to guard against movement when connections are being made at these points.

After the girder has been set in both the transverse and the fore-and-aft position, the height should be rechecked to see that no movement has taken place (see Fig. 353).

Extreme care must be exercised in all the foregoing operations because all work will be aligned between the main bulkheads and these girders. Figure 354 shows a transverse girder properly braced and shored after being set so that the other parts of the structure can be pulled and regulated from this point.

The web frames connecting to these girders can next be secured at the proper half width of the ship and the job turned over to the ship fitter for making up the connections (see Fig. 355).

Setting Longitudinal Girders. In setting longitudinal girders the proper distance from the center line of the ship should first be established and marked on the transverse girders. As the transverse girders have already been set, it will simply be necessary to cut in the longitudinal girders between the transverse girders after due consideration has been given to the connections of the transverse beams to the longitudinal girders, so that these beams will intersect at their proper frame station.

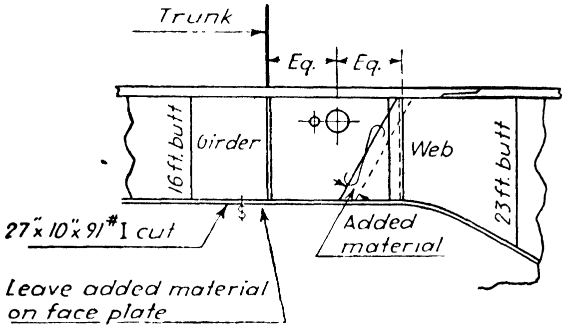


FIG. 355.—Web frame set at proper half-width of the ship and connected to a transverse girder.

The longitudinal girders can then be set in their proper transverse position to the marks made on the transverse girders.

At the ends of the longitudinal girders connecting to the transverse bulkhead, it is always good practice to install spur shores to prevent movement when the connections to the transverse girders are welded together or when the other part of the structure is being regulated and made up (see Fig. 356).

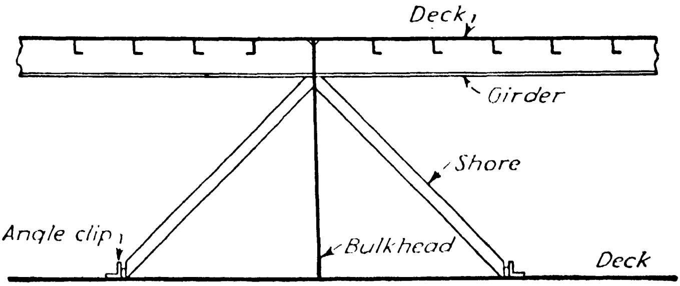


FIG. 356.—Longitudinal girder spur-shored at bulkhead connections.

If the deck plating, together with beams and girders, is subassembled and brought into the ship in units, the same setting procedure must be followed, with one exception. Instead of setting each web and transverse or longitudinal girder separately, these members, already being welded to the deck plating, will be set jointly; and, if they are properly built, after one of the members has been set, the units should be set automatically in all directions.

Since all the welding, except that which connects the sections together, has been completed, the amount of stretch to be allowed will be reduced to the root openings between the joint welds, as has already been explained.

TRANSVERSE BEAMS

Since the framing ribband will, to a large extent, hold the framing in its proper half width, no difficulty should be experienced in erecting and making up the connections of the deck beams at the shell. Some regulating will be required when the deck plating is laid on the beams, but these beams should be almost in their permanent position. If they are off center, they can be pulled with draw clips if the plating is welded to them; or if they are riveted to the plating, they can be lined up by means of driftpins driven into the holes to fair them up.

Where beams are welded to the deck plating, they are usually set at the shell and at the connections to the longitudinal girders. Between these points, they may be properly spaced by means of a flat-bar spacer tack-welded to their underside. Should any of the beams be very much out of position, it may be necessary to resort to spur shores to put them on their proper center line or in their correct fore-and-aft position. Spur shores for supporting and bracing transverse beams and girders should be cut in accordance with the instructions given for cutting spur shores in Chap. X.

REVIEW AND COMMENTS

Check the book of offsets to determine the height of deck above base line; or if one deck has already been set into the ship, obtain between-deck heights and amount of camber, if any.

Heights should be marked on a wooden rod or template, which can be easily applied by setting it up plumb in a transverse direction and on the approximate declivity in a fore-and-aft direction.

Consideration must be given to the thickness of deck plating above the molded line of the deck, particularly if between-deck heights are used. If the thickness of deck plating varies, care must be exercised in applying height battens at the proper location so that the bottom of the batten will be at the proper distance above the molded line of the deck on which the batten is set. All shores used for bracing and shoring up should be secured at the top so that they will not be dislodged through vibration, and thus possibly injure workmen.

Do not apply any more welding than is necessary to clips for bracing and shores, for this means waste in time and material in applying and removing. However, a little too much is far better than not enough.

CHAPTER XXIII

REGULATING AND SETTING DECK PLATING

With the deck beams, girders, and bulkheads set in position, the job of laying, regulating, and setting the deck plating is begun (see Fig. 357). The deck plates are placed by the shipwright, who checks all operations to see that they are set according to designed lines, particularly

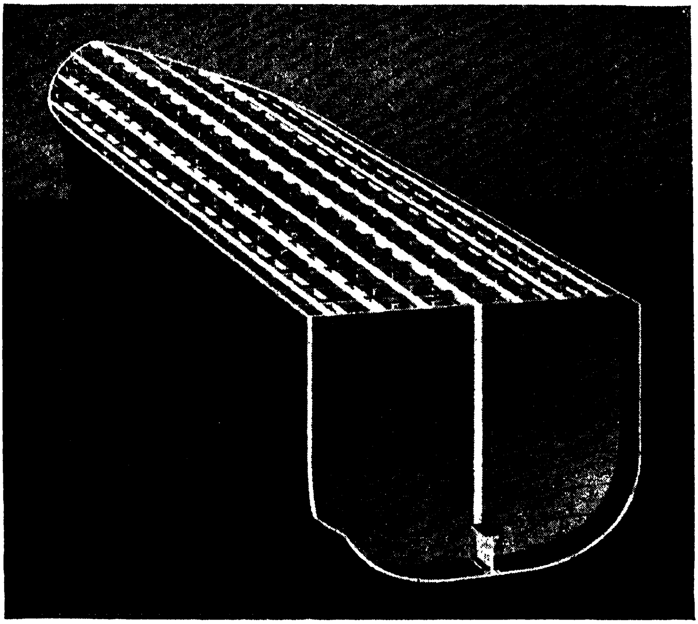


FIG. 357.—Deck beams, girders, and bulkheads ready for erecting deck plating.

the stringer and centerline strakes. Making up and fitting the plates is the responsibility of the ship fitters.

Once the deck plates of a ship are riveted or welded in position, the entire hull becomes a rigid unified structure. Therefore, before they are laid, the shipwright must check the centers of all transverse girders and bulkheads with the center line of the ship. The exact center of the top of each transverse girder and bulkhead must be lined up with this center line. The distance between the frame lines is checked at the top where the transverse girders join the side frames. Once the center line, buttock lines, and frame lines are checked and marked on the girders, they serve as accurate guides by which the deck plates must be aligned.

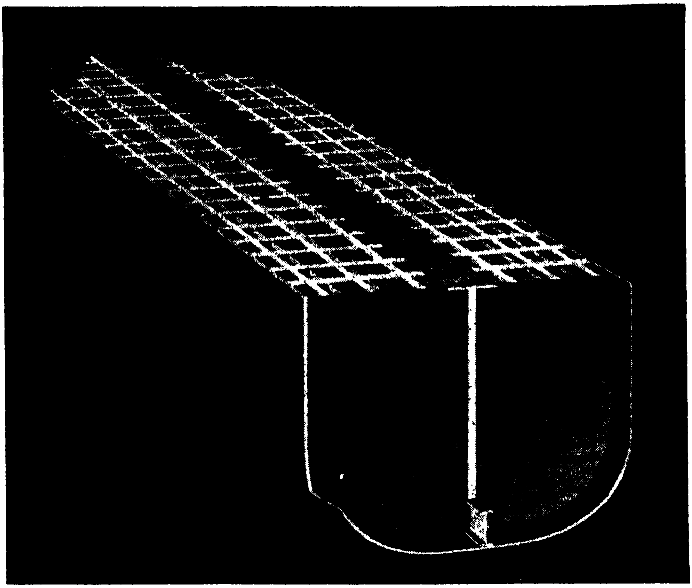


FIG. 358.—First strake of deck plating laid.

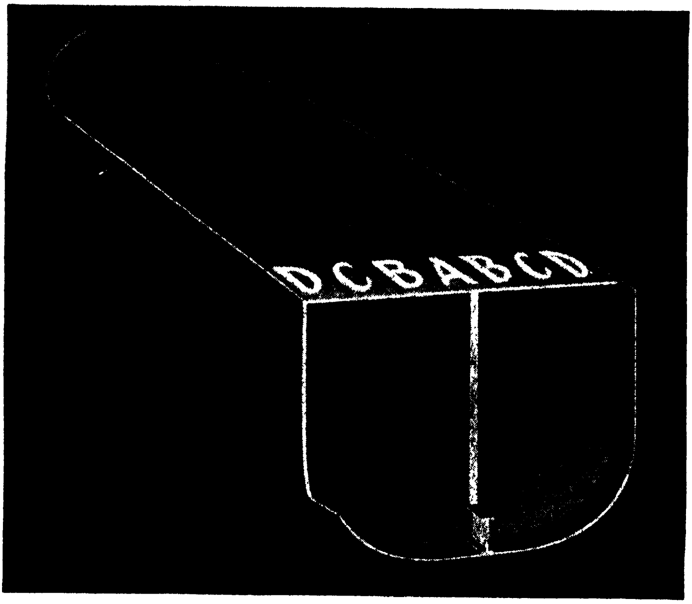


FIG. 359.—Strakes of deck plating numbered alphabetically.

The first row of plates to be laid is always set on the center line. This row is known as the *A strake* (see Fig. 358).

As each plate is laid, its position must be checked carefully. Its center line must be laid to the center line of the ship. All buttock lines and frame lines must be absolutely true.

The two outside strakes are known as the *stringer strakes.* They follow the shape of the ship and must be set to the frame lines and buttock lines.

Only when the A strake and the stringer strakes are laid and set should the intermediate strakes be placed in position. These strakes are identified alphabetically by their position from the A strake port or starboard (see Fig. 359).

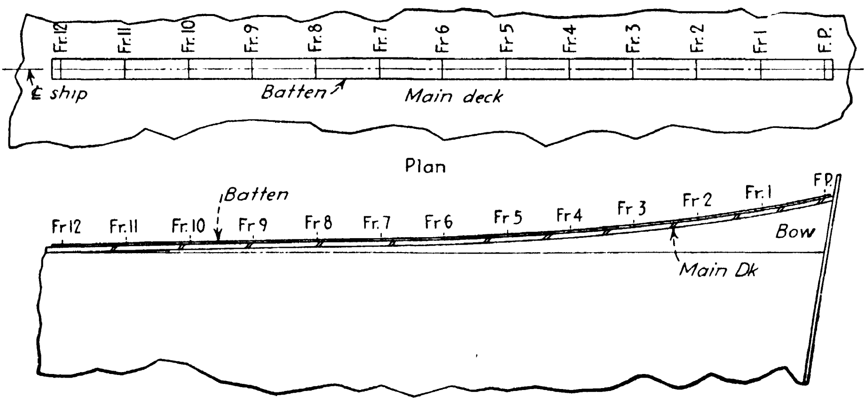


FIG. 360.—Batten secured from mold loft with frame stations on deck with sheer.

Setting a Riveted Deck. In setting a riveted deck, flat-bar uprights can be erected at the sides and center of the ship and a wire stretched across these uprights. The plates that cross the location of the wire can then be set so that the frame station on the plates used for setting them will fall under the wire.

As the work of setting these three strakes progresses from the square line toward the forward and after ends, frequent checks should be made from the square line to determine whether or not the deck plating may be gaining so that it will tie in with the remainder of the deck plating and shell plating when it is erected and set. Some chipping of butts or regulating of seams and butt laps may be necessary if the length is not running as designed.

If the deck is straight and has no sheer, a tape may be used for this purpose and a check should be made at both the center line and the sides. In making the checks at the sides, the tape should always be held parallel to the center line, so that the proper dimension is maintained.

If the deck is designed with a sheer, a batten should be secured from the mold loft that has the frame stations, as applied to the sheer of ship, marked on it. This batten can be applied like the tape and will give the proper distance between the frames more accurately than measuring parallel to the base line and using a declivity board (see Fig. 360).

At the time that the first three strakes are being set in their proper fore-and-aft position, they must also be set in their proper transverse position. This can be done by using a convenient buttock line that was center punched on the plate at the time when it was laid off for fabrication. By setting the buttock line to its proper half breadth on the ship, the plating should line up with the width of the main transverse bulkheads.

The centerline strake must also be set to the true center line of the ship throughout, for it is possible to develop a lopsided deck if the center line and buttock lines are not considered.

After the setting of the center line of the stringer strakes has been advanced to a point at which the remainder of the plating on the deck can be set, this work will begin. By starting at the same square line and starting point, begin regulating plates that fall across the square line, setting one strake at a time until the stringer strakes have been reached. When this has been done, the plates forward and aft of this point can be regulated and set. Care must be exercised in the setting of the other strakes of plating so that beam holes will line up square across the ship and so that no difficulty will be encountered when hatch openings and trunks are connected. Care should be taken so that trunks and hatches are not thrown out of declivity where the deck plating may either gain or lose length (see Fig. 361).

There is a peculiar knack in knowing how to "steal," or gain, length in the setting of a deck, regardless of whether it is riveted or welded; this cannot be explained in words but comes from experience and practice. It will be found that, whereas one man has regulated a deck in such a manner that bad holes develop where the deck has been allowed to steal, or gain, slightly in each plate, the same plating may be regulated with perfect holes by an experienced man who adjusts the proper plates to accomplish this purpose.

Setting Combination Riveted and Welded Decks. In the setting of deck plating in which seams are riveted but butts are welded, the same method of setting can be followed as described in the foregoing. However, certain considerations must be given to root openings and other welded connections to the deck.

If the seams and beams are all riveted and the butts and strength girders welded, a certain amount of shrinkage should be allowed for, so that openings for hatches and trunks will line up with the lower part of the ship's structure and be lined up in proper declivity with the deck connections made up. Experience has shown that the stretch of $\frac{1}{100}$ in. per ft. will usually compensate for welding shrinkage in this type of construction.

On extra-heavy plating, another type of butt joint is sometimes used. This is called a *scarfed butt.* Scarfs are milled into the steel. Since they

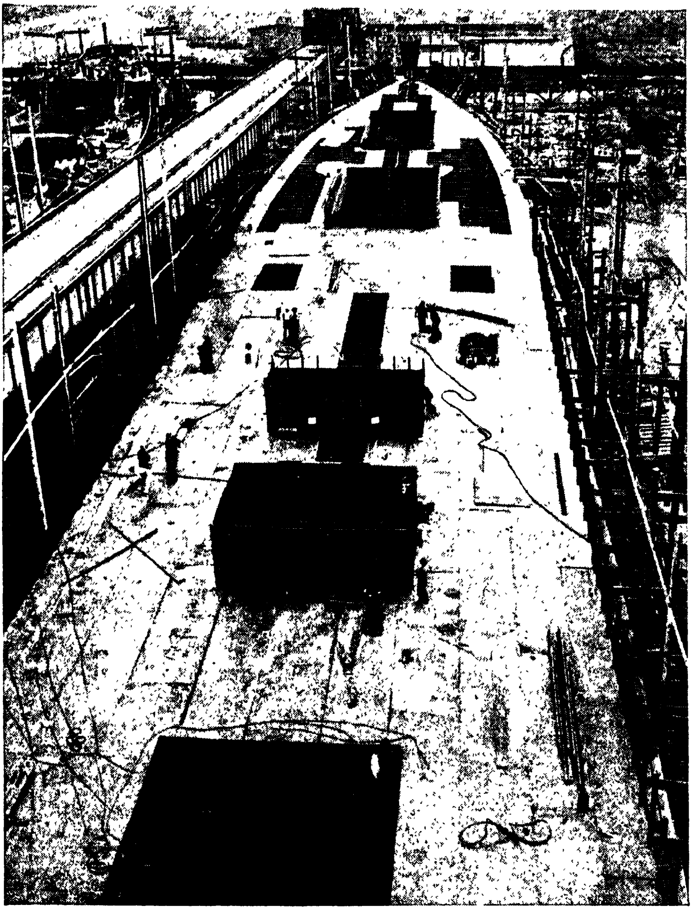


FIG. 361.—Trunks and hatches projecting through decks.

are quite wide, they must be riveted and welded. Root openings are left at the top and bottom of these joints. In order to draw these heavy plates together, large clips are tack-welded to the plates and a steamboat jack is bolted to the clips (see Fig. 362).

A strain is taken on the plates by working the handle of the jack against the ratchet. The use of a pipe over the jack handle will supply the leverage necessary to move the largest plate.

In setting deck plating where scarfed seams and butts are used, some chipping may be necessary in order that the deck may be set to its desired length and frame stations. Figure 363 shows shipwrights setting a stringer plate with the scarfed type of butt.

FIG. 362.—Heavy deck plates being pulled together with steamboat jack.

Setting All-welded Deck Plating. In setting deck plating with the all-welded type of construction, stretch should be allowed for, to compensate for welding shrinkage. Through experience it has been found that, with a shrinkage allowance of $\frac{1}{64}$ in. per ft., the deck will be somewhere near

FIG. 363.—Shipwright setting stringer plate with scarfed type of butt.

the proper length after the welding has been completed. This stretch includes root openings at the butts of the plating.

In Fig. 364 erectors and shipwrights are shown erecting an all-welded heavy deck plate. In Fig. 365 shipwrights are shown striking in the center line of the ship preparatory to the erection of the centerline strake of deck plating.

FIG. 364.—Erectors and shipwrights erecting all-welded heavy deck plating.

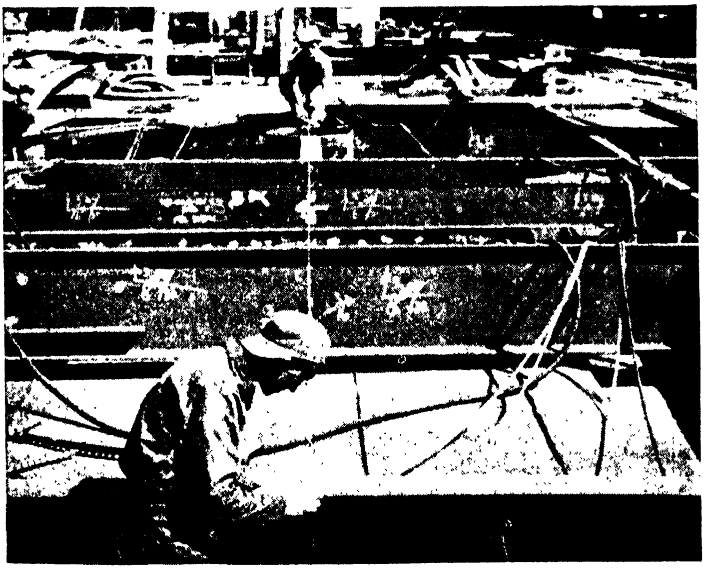


FIG. 365.—Striking in center line of deck.

For pulling and regulating, because of the absence of holes in all-welded construction it is necessary to resort to bolts and clips welded to the deck plating. In Fig. 366 a shipwright is shown lining up and pulling heavy all-welded deck plating. In Fig. 367 an all-welded butt is shown made up and ready for production welding, with center lines and frame lines of adjoining strakes matching.

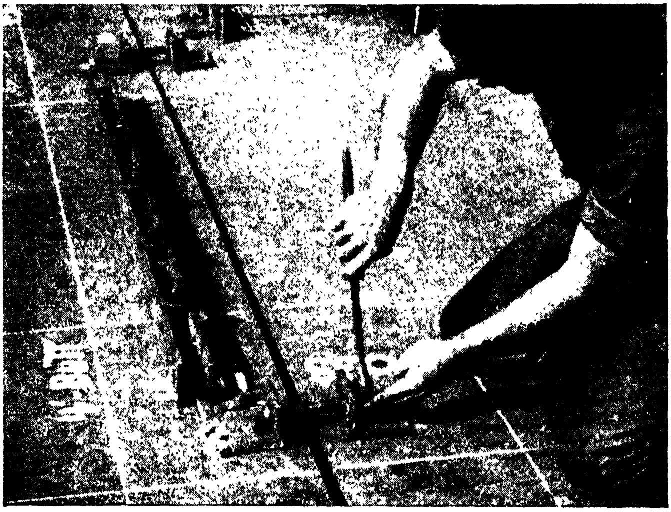


Fig. 366.—Lining up and pulling all-welded heavy deck plating.

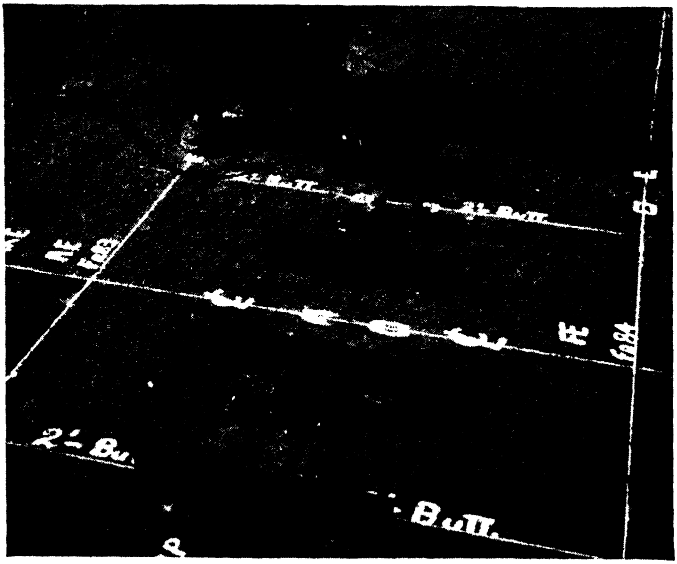


Fig. 367.—All-welded butt made up and ready for production welding.

In making allowances for the compensation of welding shrinkage on all-welded decks in a transverse direction, an allowance of $\frac{1}{100}$ in. per ft. has been found to be adequate.

In Fig. 368 shipwrights are shown erecting a square line alongside of a hatch opening, to check it for position.

Setting Subassembled Deck Plating. The deck plating of a ship may be subassembled in sections, with beams and girders welded to the plating during the subassembly. The section will be set as the girders were set (see Chap. XXII), but in this case the deck plating will be set simultaneously with the structure supporting it.

Care must be exercised in determining the amount of stretch allowance between sections, since the greater portion of the welding has already been performed and the shrinkage due to welding will already have taken place with the exception of the butts where each section joins to the other.

A *stretch of 1/8 in.* or the required root opening across the butts for such assemblies is found to be adequate to take care of shrinkage when

FIG. 368.—Erecting square line alongside of a hatch.

the butt is welded. It is important in subassembling deck plating in sections that the same stretch should be used in lining up for connections to the deck plating as for the subassembling of the other longitudinal members of the structure below, so that all connections will member up in the ship.

It is good practice to leave 1/2 to 1 in. of added material at the sides of the deck at connections to the shell so that an opportunity for fairing it in between the transverse bulkheads may be had after these sections have been set. It is also good practice to leave some added material at one end of every fourth section so that any forward or aft adjustment may be made if necessary.

In the erection of a subassembled deck it may be necessary in certain locations to provide temporary support until the time when beam connections are made up and stanchions installed. When temporary supports are installed, it is good practice to leave them slightly lower than design and to provide wedges under the shores so that they may be wedged up to the desired height when the work of setting the deck is being done. A temporary support for subassembled decks is shown in Fig. 369.

Setting Deck Stringer Angles. Deck stringer angles are used to connect the shell plates to the stringer plates of the deck. These angles are used where the deck is designed to be riveted at the shell.

After the deck plating has been erected and set, the general practice is to erect the shell plating so that the stringer angles can be regulated and set to suit both deck plating and shell and, at the same time, create fair holes.

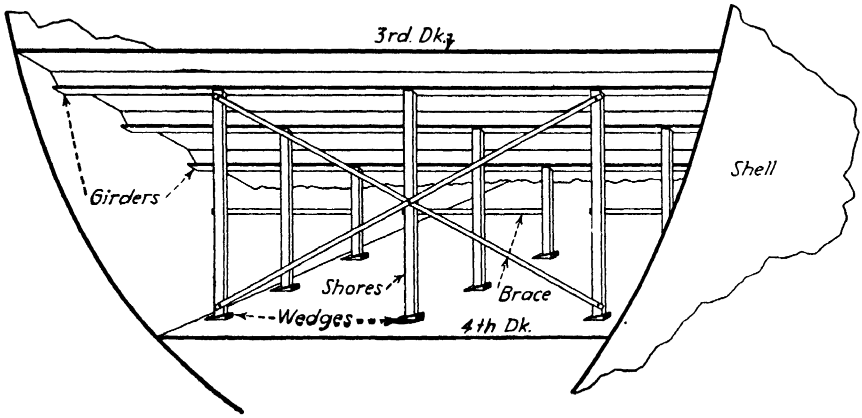


FIG. 369.—Temporary support for subassembled decks.

Before the stringer angles are reamed and bolted and made ready for riveting, the deck should be faired. Stringer angles should be pulled forward or aft until frames on deck plating key up with frame stations on them. The fairness of the deck should be checked with a deck batten and low spots shored up until the line of the deck is fair.

The flange of the angle connected to the deck should be set first. After this has been done, shell plating should be regulated to suit the holes in this angle. Some compromising may be necessary to obtain fair holes, by turning the deck flange loose and resetting the angles to suit both deck and shell.

Fairing the Deck. After the deck plating has been regulated and set, there are generally high and low places in the deck that must be removed so that a fair deck will result. It is essential that all decks be made fair throughout, and to achieve this one of two methods may be used.

The first method uses a deck batten laid in a fore-and-aft position parallel to the center line and reaching from one bulkhead to another.

This batten is laid on parallel blocks about 2 in. thick, which should be spaced at intervals of about 8 ft. By sighting along the batten it may usually be determined whether or not the deck is fair. Low spots may be corrected by shoring until the 2-in. block touches the batten, and high

Fig. 370.—Shipwright fairing a deck stringer plate.

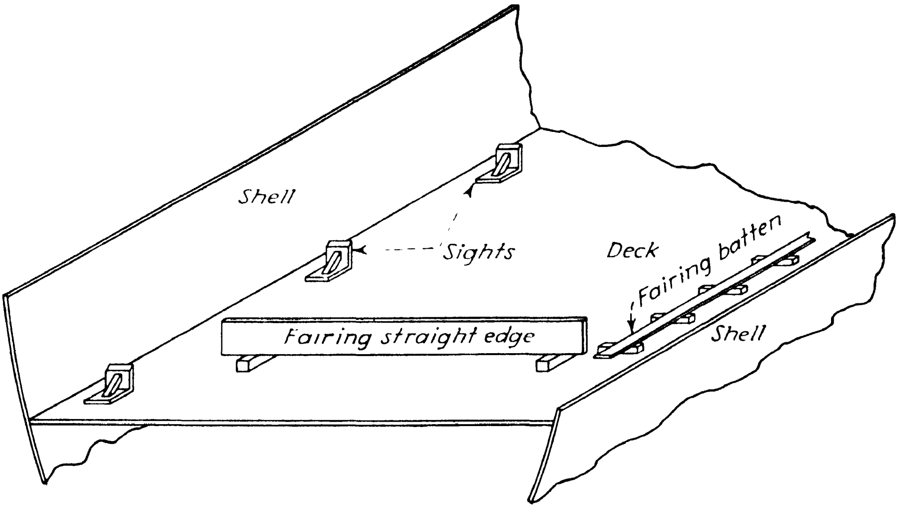


Fig. 371.—Fairing batten and sight, used for fairing decks.

spots may be pulled down with the use of turnbuckles. This fairing should be done along each strake of plating.

In fairing the stringer plates they may be wedged up or pulled down at the connections to the frames at the shell. In Fig. 370 shipwrights are shown fairing a deck stringer plate.

The second method may be employed when the distance between bulkheads is great enough to make the use of a deck batten impractical.

Three or more pieces of wood of the same width can be used for sights. One sight can be placed on each of two bulkheads and other sights at intermediate points between. By moving one sight from one frame to another and then sighting across the other sights each time, the fairness of the deck may be determined and low and high spots removed.

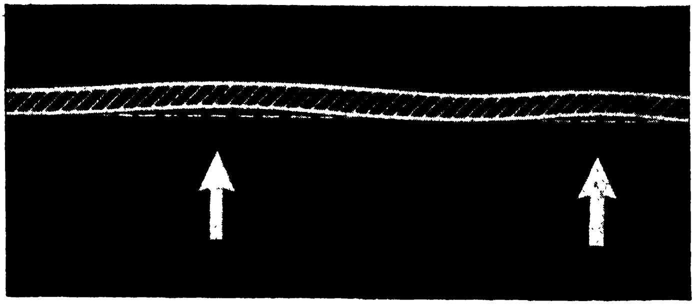


Fig. 372.—Buckled heavy deck plate.

When connection to the shell is made after the deck has been set in a fair line, the shell should be faired by pushing in or out so that it is fair in a plan view.

In Fig. 371 are shown the fairing batten and a sight used for fairing decks.

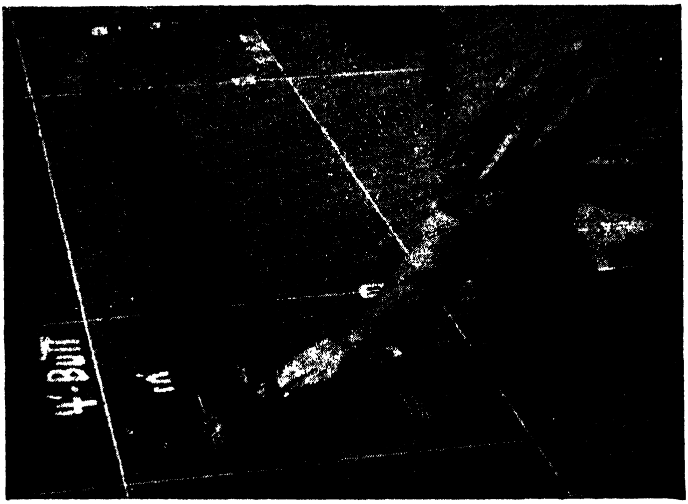


Fig. 373.—Strongback for removing buckles from buckled deck plating.

In fairing heavy deck plating it sometimes happens that the plating is buckled, after being rolled, to the point at which buckles will have to be removed in order to create a fair deck (see Fig. 372). Before fairing such deck plating with a fairing batten, the buckles must be removed by means of strongbacks, as shown in Fig. 373. The strongbacks are left in

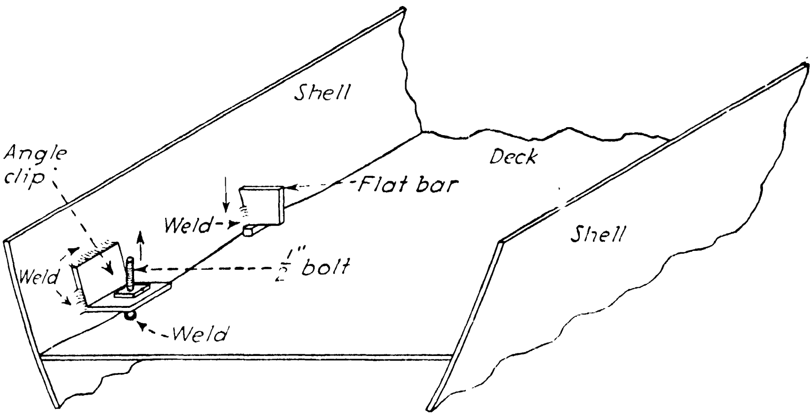


FIG. 374.—Method of fairing deck at connection to shell.

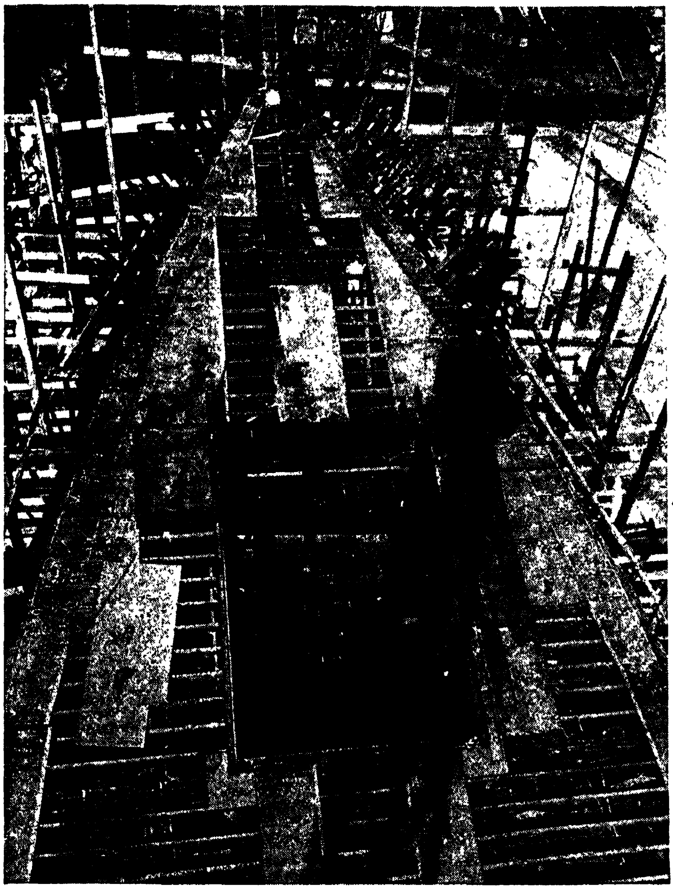


FIG. 375.—Faired sheer strake of shell plating.

place until after the welding has been completed, and spot-heat straightening may be necessary after the strongback has been removed.

In Fig. 374 is shown the method of fairing the deck at connections to shell.

Making Up the Connection of the Deck Stringer Plate at the Shell on Welded Decks. After the deck stringer plate has been faired in a fore-and-aft direction, the half width of the stringer plate can be laid off to designed dimensions, provided that extra material has been left on the outboard edge of the stringer plates. When the designed half widths have been established on the stringer plates, a fairing batten may be used to fair through these spots and mark the cutting line.

If no added material has been left on the stringer plates and any irregularities occur in the half width of the deck, these may be removed by fairing between the main transverse bulkheads, so that no humps or hollows will occur in sighting along the sheer strake of the shell plating (see Fig. 375).

REVIEW AND COMMENTS

Preparation and Procedure

1. Install the center line, buttock line, and square line on the deck so that the deck plating may be set from these.
2. Erect the center and stringer strakes of deck plating in approximately their permanent location. Set the center and stringer strakes of deck plating to lines established on the structure supporting the decks.
3. Set the remainder of the strakes of deck plating between the centerline and stringer strakes.
4. Make frequent checks of the deck plating to see that it does not gain or lose length.
5. A pinch bar, maul, steamboat jack, and wrench are essential tools in setting deck plating. When decks are riveted, driftpins must also be carried.

SAFETY PRECAUTIONS

Keep out of the way of cranes when plates are being erected.

Never put fingers through rivet holes since there is danger of their being struck from below or cut off if plates are not securely fastened.

If decks are set on temporary supports until connections are made up, these supports should be securely braced so that there is no danger of collapsing.

CHAPTER XXIV

SHELL STRINGERS

A shell stringer is a heavy steel channel structural shape or flanged plate used to strengthen the ship at the shell and to tie the framing together.

Stringers are designed to run in a horizontal fore-and-aft direction but not necessarily parallel to the base line. The position of longitudinals and stringers is usually center punched on the framing in way of the stringers.

In some cases stringers are continuous, extending through web frames where the ship is longitudinally framed. On the transversely framed

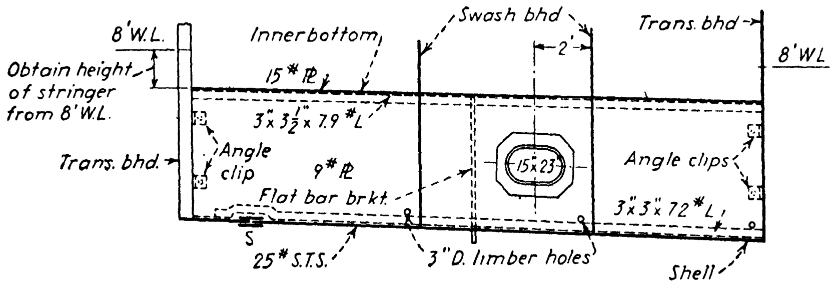


FIG. 376.—Providing support for erecting stringers, together with the method of applying heights of stringers from water line established on the framing.

ship, stringers are cut out to permit frames to run through them, or they may be intercostal between the frames. In a longitudinally framed vessel the transverse framing is cut out to permit the stringers to pass through them.

The work of the shipwright in connection with stringers consists principally in providing means for erecting and holding them in position. It is also sometimes necessary to establish the position of stringers on the framing. This may be done by obtaining heights from convenient water lines from the body plan and transferring them to the framing of the ship, together with the angle at which the stringer will set.

In Fig. 376 are shown one means of providing support for erecting stringers, together with the method of applying heights of stringers derived from a water line established on the framing.

CHAPTER XXV

BILGE KEEL AND PACKING

The bilge keel is a fore-and-aft member fitted to the outside of the shell plating along the bilge, to prevent excessive rolling of the ship. It may be a single flat plate welded to the bilge strake of plating or a T bar, as shown in Fig. 377. Another type of bilge keel is a double-plate V type secured to the shell with angles or by welding the plates directly to the shell. A wooden filler is usually installed in this type of keel, as shown in Fig. 378. However, sometimes this space is left void with only the web brackets installed between the plates to secure stiffening.

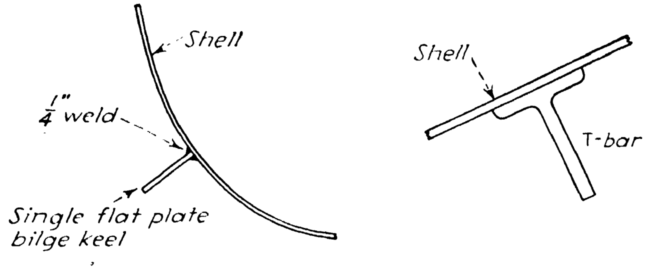


FIG. 377.—Single flat-plate bilge keel and a T-bar bilge keel.

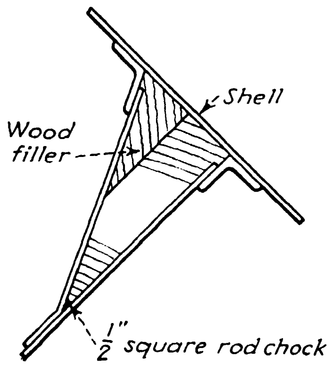


FIG. 378.—V-type bilge keel with wood filler.

The Use of Battens. The work that the shipwright performs in connection with the bilge keel, regardless of type, is to establish the line of the keel on the shell with battens obtained from the body plan in the mold loft. The batten is usually applied from the sight edge of the bilge strake of shell plating and is a girth against the outside of the shell plate. In Fig. 379 is shown the batten for establishing the line of the bilge keel, together with its application from the sight edge of the bilge strake of shell plating.

Frame lines must also be established on the outside of the shell so that the spots for the line of the bilge keel can be placed in their proper position. Frame lines will also be used for applying the templates for the angles connecting the bilge keel to the shell, so that tack holes may be drilled for setting the angles on the shell.

After the spots for the line of the bilge keel have been installed, a sheet-line fairing batten is used to develop a fair line that will intersect them. Where the line of the bilge keel is straight, a chalk line may be used to strike through the spots.

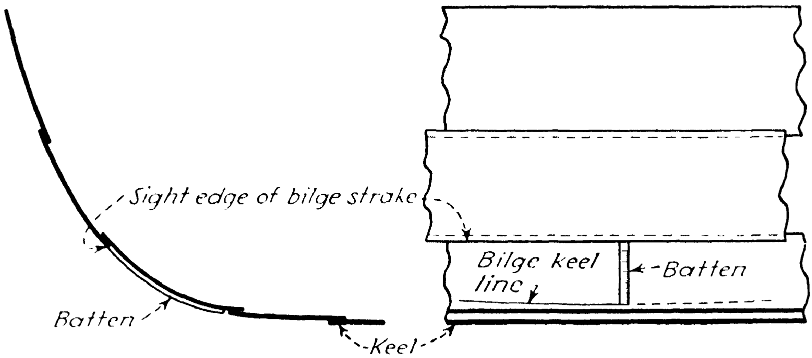


FIG. 379. Batten for establishing the line of the bilge keel.

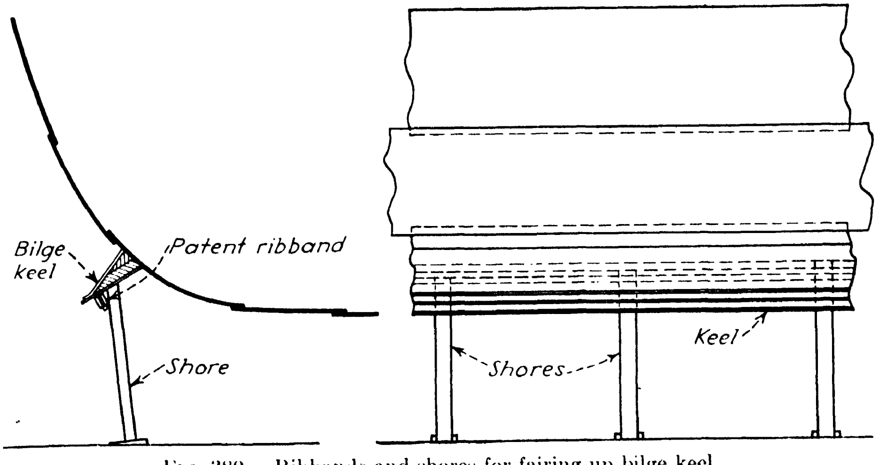


FIG. 380.—Ribbands and shores for fairing up bilge keel.

Templates for Angles. After the line of the bilge keel has been established on the shell, the ship fitters will take templates used in laying out the angles that fasten to the shell. These templates will then be applied on the line established by the shipwrights and tack holes drilled in the shell until such time as the angles themselves are set and faired in position.

Erection of Plating. After the tack holes are drilled, the angles are erected and bolted to the shell, and then are faired. After the angles are faired and bolted to the shell, plating can be erected and regulated. However, before this plating is set up, small brackets made of scrap plate should be set in line with the flange of the angle to which the plate is fastened to help in supporting it in its proper position.

When the lower plate has been put on the angle and brackets and regulated and set, the upper plate is installed, regulated, and set. The outer edge of the bilge keel is then faired up by means of ribbands and shores, as shown in Fig. 380. After this, the upper plate, together with the angle, is removed so that the wood filling can be installed.

The lower angle and plate are left in place and reamed, bolted, and riveted. The upper angle and plate are removed in sections and set on the staging vertically, and the connection to the angle is reamed, bolted, and riveted.

After the wood filling has been installed, the upper plate is set in position and the connections are made through the shell. The remainder

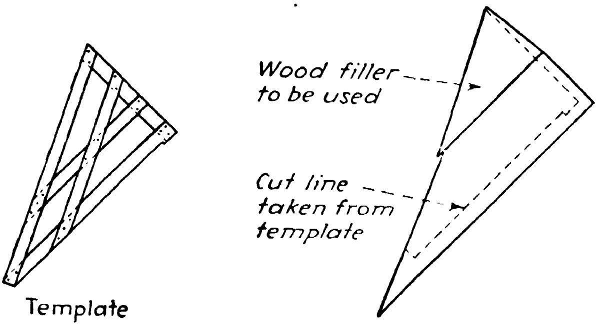


FIG. 381.—Templates used for fabricating bilge keel wood fillers and their method of application.

of the holes are then drilled through the shell and the structure riveted together with the seam of the two plates at the outer edge of the bilge keel.

Installing Wood Filling. The wood filling for the bilge keel usually consists of pieces of wood 3 in. in thickness, set with the grain running vertically and cut to the shape of the bilge keel.

Templates may be obtained from the mold loft to give the shape of the bilge keel filling, with the cut at the inboard side to fit the shell. These templates are made at intervals depending on the shape of the bilge keel. They are then fitted on the ship itself to take care of any slight irregularities. Through the midship portion of the ship one template may be used for a considerable distance. However, toward the forward and after ends it will be found that different templates will have to be used at closer intervals because of the change in the shape of the keel. Extra templates may be made, if necessary, on the job.

After the templates have been fitted in place, the wedge-shaped filler blocks can be fabricated in the shop, ½ to ¾ in. of added material being left on the top.

A chock consisting of a ½-in.-square steel rod is welded close to the seam of the two plates, but far enough away so that it will not foul and prevent the plates from being bolted tightly together. This chock provides a means of holding the wood filling in place until such time as the upper plate is put in place.

In Fig. 381 are shown the templates used for fabricating the wood fillers and their method of application.

At the ends of the bilge keel a template is usually made to conform to the shape. After the wedge-shaped filler blocks have been roughed out, they can be laid edgewise on a flat surface and this template applied to mark the cut at the outer ends of the filler pieces.

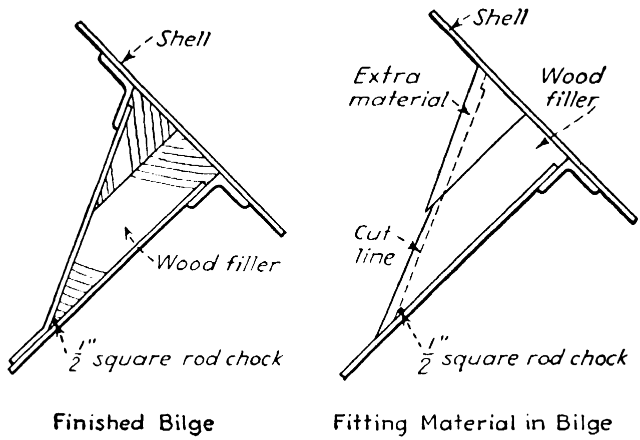


Fig. 382.—Fitting and finishing bilge keel filler.

In installing the wood filling in the bilge keel a band saw should be placed at a location convenient to the work. Filler blocks are then fitted into position, and the extra material is marked as shown in Fig. 382 and cut off with the band saw. After the blocks have been fitted and the high spots worked off, they should be smoothed off and faired by means of a coarse sanding machine so that the upper plate will fit tightly against the wood.

The wood filling is then removed so that the plates can be treated with some rust-resisting solution and the wood dipped in hot bitumastic. After the filling has been dipped, it is replaced in the position in which it was fitted. Care must be exercised not to mix up the pieces after fitting and dipping; otherwise, much trouble will result, for it will be difficult to identify the many pieces making up the filling after it is coated with bitumastic. Because the bitumastic will take up some extra space, it may be necessary to drop out two or three pieces when the filling is being installed after dipping.

If butt straps are designed at the butts of the plating, a filling must be notched out in way of the butt straps before the upper plates are erected.

After the wood filling has been reinstalled, the upper plate of the bilge keel can be erected and the remainder of the work completed. The strongbacks on the underside of the bottom plate are usually left in place until after riveting has been completed.

CHAPTER XXVI

HATCH CASINGS AND TRUNKS

Hatch casings and trunks may be subassembled in sections that extend through several decks. The subassembled sections will be set into the ship when the deck that supports them at the bottom has been

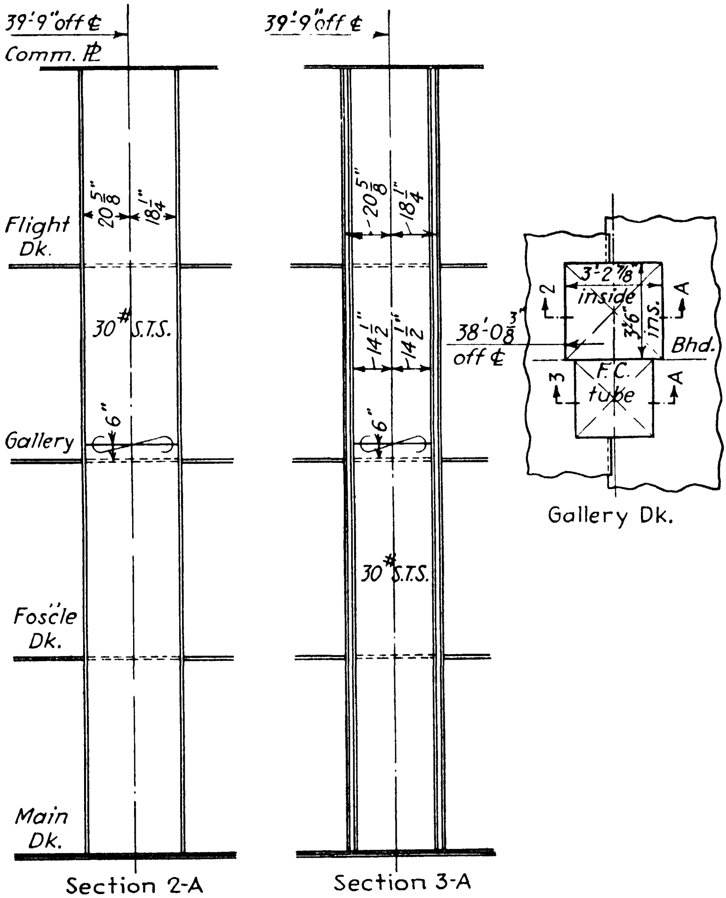


FIG. 383.—Trunk hatch extending through three decks.

set and riveted or welded to a degree at which it is capable of supporting them.

Like longitudinal and transverse bulkheads, trunks are set to their proper height by means of the water lines from which they were subassembled. By checking from offsets to the height of the deck on which they will set, the distance between the deck and the water line on the trunks can be checked and the amount of material, if any, that will have to be removed can be scribed and burned off and the trunk set down on the deck. Since various trunks enclose elevators and ammunition hoists, it is important that they shall be plumb and in their designed positions.

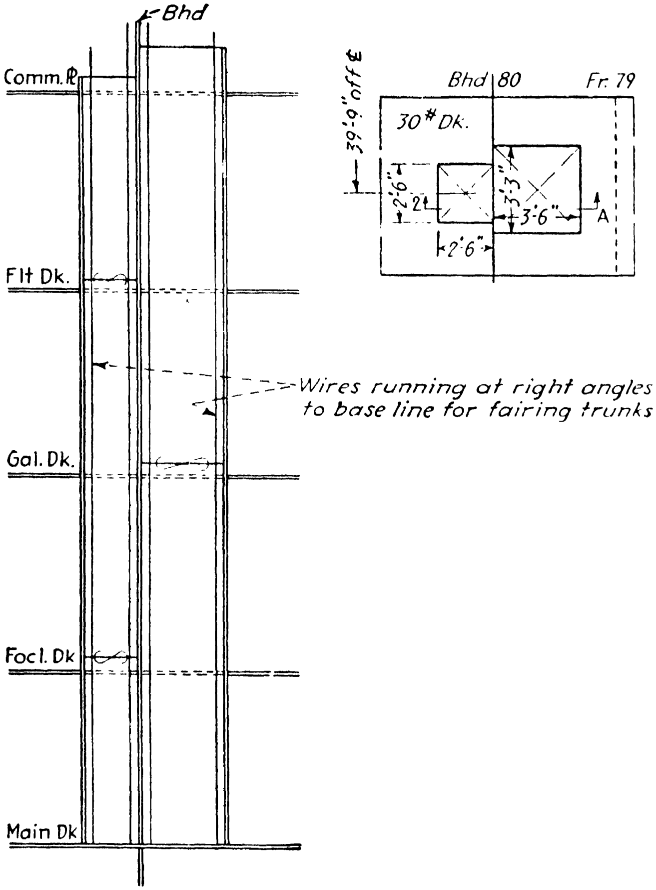


FIG. 384.—Ammunition-handling trunk with wires extending from top to bottom at right angles to the base line.

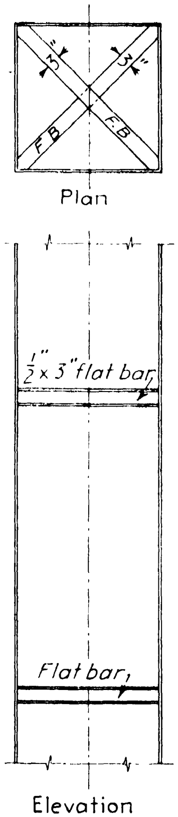


FIG. 385.—Horizontal X-bracing in hatches.

If hatches and trunks are properly set plumb and on declivity, they will aid materially in the setting of the successive decks that are attached to them (see Fig. 383).

When hatches and trunks extend up through the ship for a considerable height, it thus being necessary to erect them in two or more pieces, they must line up with each other, particularly if elevator guides are to be secured against the sides. When this occurs, steel wires set on the correct declivity of the vessel are run from the top to the bottom of all sections of trunks before these sections are connected together, in order that they will line in to a straight line, even though provisions are made for liners behind the elevator guides.

In Fig. 384 is shown an ammunition-handling trunk extending up through several decks, with wires extending from top to bottom that are at right angles to the base line in both a transverse and fore-and-aft direction, to which the sections of the trunk will be lined up before they are connected together and before any of the decks through which they extend are made fast to them.

Extreme care should be exercised in erecting high trunks to see that they are properly and sufficiently braced before being turned loose from the cranes. If they are not adequately braced there is danger of their being blown over by high winds or knocked down if accidentally struck with heavy loads on the cranes. Flat-bar or wire-rope guys incorporated with turnbuckles are the best type of brace to use for this purpose.

When casings or trunks are so large that they cannot be assembled together but must be erected in the ship one side or end at a time, care must be exercised to see that each side lines up with the other and particularly that the sides are square with each other and not racked.

If the sides have a tendency toward being racked when fastened together, horizontal X-bracing may be installed, as shown in Fig. 385. When the hatch structure has been made square, it should be securely anchored on the outside with turnbuckles and straps, so that it will not move or rack before it is securely fastened to the adjoining structure.

CHAPTER XXVII

SUPERSTRUCTURE

The superstructure of a vessel is that part above the main deck which includes deckhouses, navigating bridges, bulwarks, and curtain plates. This structure is usually subassembled in sections suitable for handling and erection. In small vessels it may be possible to subassemble the entire superstructure in one, two, or three units. On large vessels it is necessary to break up the assemblies to suit handling facilities.

Deckhouses. In some deckhouse assemblies, numerous miscellaneous bulkheads and possibly the engine and boiler casing are included. This

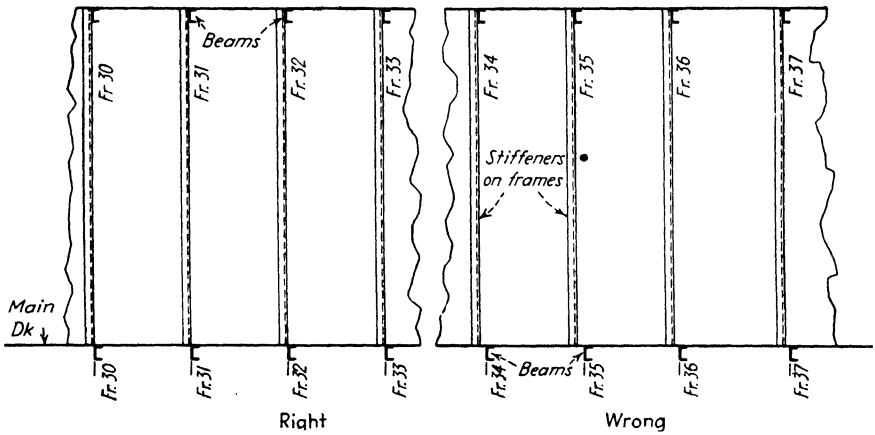


FIG. 386.—Frame lines not matching up under stiffeners of deck houses.

means that the deckhouse may be too large or too heavy to subassemble in one unit, and it may be necessary to subassemble and to erect it in smaller units more suited to the crane capacities. Added material is usually left at the bottom of such deckhouses to take care of irregularities in the deck plating.

When such an assembly is put together on the subassembly skids, the shipwright will brace and plumb up the sides and ends in the same manner in which this would be done on the ship. The sides and ends, together with the miscellaneous bulkheads contained in them, will all have to be set to a water line or plane so that they will conform to the designed sheer of the ship and so that the ends and miscellaneous bulkheads will be plumb when set to the correct height in the ship.

From the water line used in assembling the deckhouse on the skids, the height is checked from a water line already established on the completed structure of the ship. By means of jacks, shores, or wedges, the deckhouse should then be brought up to the proper height and set on declivity with the sides plumb. The height to the water line from the base line is then checked, and the amount of material to be removed is scribed and burned off to bring the deckhouse to its correct height. After this has been done, the assembly can be lowered by means of jacks, set to the proper lines, and tack-welded. If there are miscellaneous bulkheads inside the house, they too must be lined up in the same plane as the deckhouse, so that the proper height of the house is maintained and that it is fair, whether it is straight or cambered. Before the work of erecting the deckhouses in the ship begins, the boundaries and locations of the various bulkheads should first be established on the deck. This will aid in placing the assembly in approximately its permanent position when brought in with the crane and thus eliminate much unnecessary pulling and jacking.

Erecting and Setting the Deckhouse on the Ship in Sections. As mentioned previously, when deckhouses are too large they will, of course, have to be erected in the ship in suitable units. After the lines of the deckhouse have been established on the deck, the sides and ends can be brought in and braced temporarily in position on the ship. The water lines used for subassembling the deckhouse will be used for the purpose of checking the height and amount of material to be removed from the bottom.

The same principle is used for setting the deckhouses as for setting transverse and longitudinal bulkheads. It must be remembered, however, that due consideration will have to be given to the amount of stretch

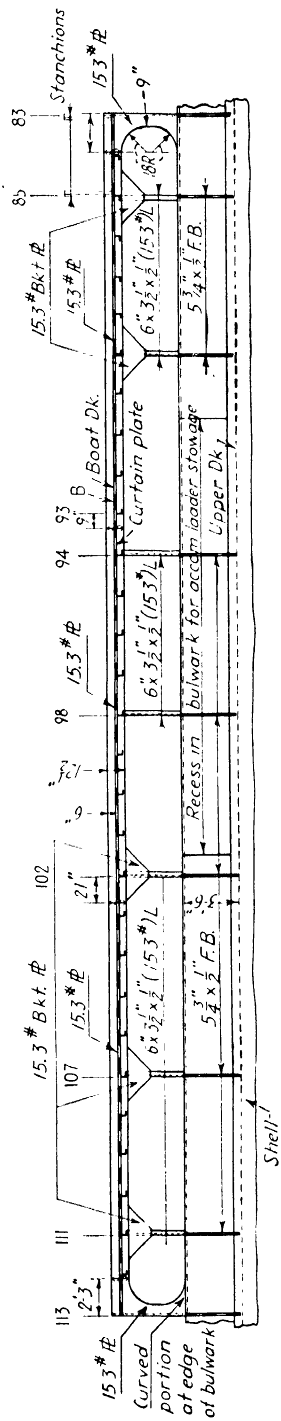


FIG. 387.—Bulwark and curtain plates at the side of the ship.

put into deckhouses at the time when they are subassembled so that the various stiffeners and frames will tie in with the frame stations of the ship itself; otherwise, bad fitting will result. This is particularly true of the longitudinal bulkheads and sides of the deckhouse. It is therefore good practice to leave added material on the ends of some of the sections, depending on their length, so that adjustment may be made where the deckhouse stiffeners are not tying in at the bottom over the beams on which the house rests (see Fig. 386). This is important; for, if frame stations do not match up, difficulty will be experienced when the top of the deckhouse is being set in its proper position.

The principle used for setting decks is also used for setting the top of the deckhouses. Shores and braces can be made ready for shoring up

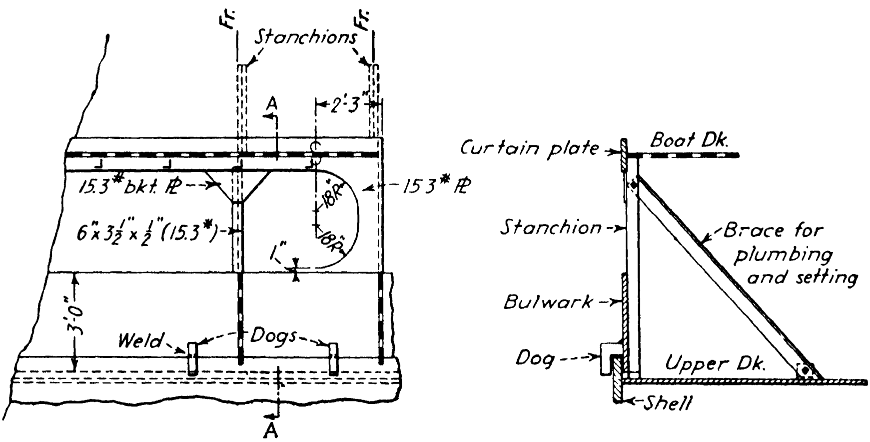


FIG. 388.—Dogs welded at bottom of bulwark for holding the bottom in position.

and bracing the deckhouse structure and the top of the deckhouse itself by referring to the plans to obtain the height of girders and decks above the main deck of the ship.

Bulwark and Curtain Plates. Included in the superstructure of a vessel are the bulwark and curtain plates at the side of the ship, as shown in Fig. 387, which shows the superstructure side between the upper and boat decks. This part of the structure must be set plumb to the base line in both the fore-and-aft and transverse directions. The stanchions must be plumb and the curtain plate must be shored and faired so that it will present a fair appearance.

Dogs can be welded at the bottom of the bulwark at approximately the correct height above the seam for the purpose of holding the bottom in position (see Fig. 388). Braces leading inboard should be provided at each end and in the center to hold it temporarily in a vertical position.

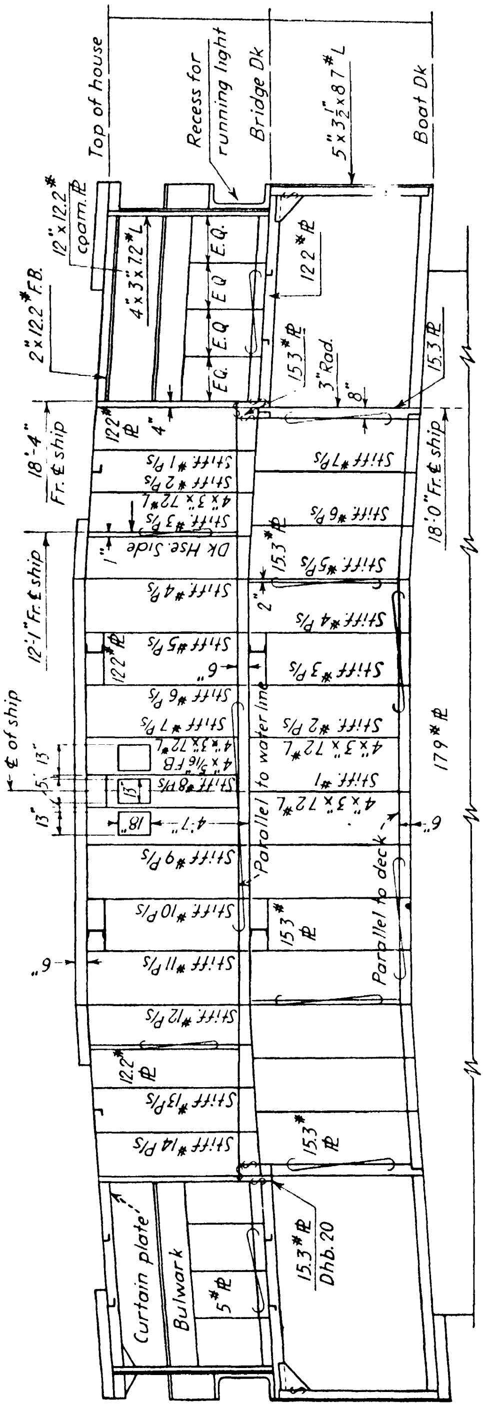


FIG. 389.—Front of the superstructure, including deckhouses and bulwark at wings.

After the structure has been turned loose from the cranes, the work of setting it in its final position can be performed with the use of the spirit level, declivity board, and straightedge.

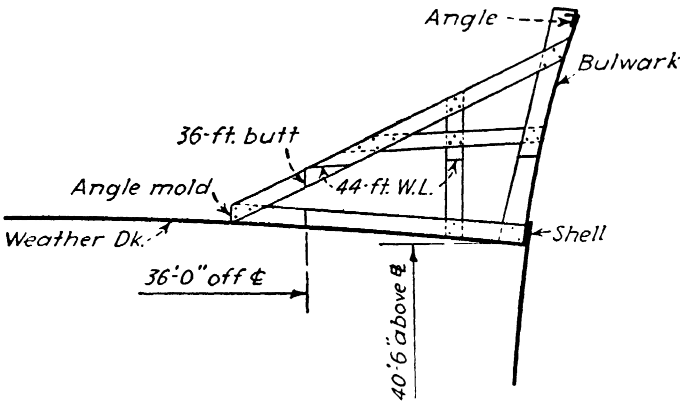


FIG. 390.—Angle molds for setting flared bulwark in proper position.

In Fig. 389 is shown the front of the superstructure, which includes the deckhouses and the bulwark at the wings. For the front of the house to present a good appearance, it is evident that the camber of the bulwark must be fair and symmetrical about the center line and the stanchions

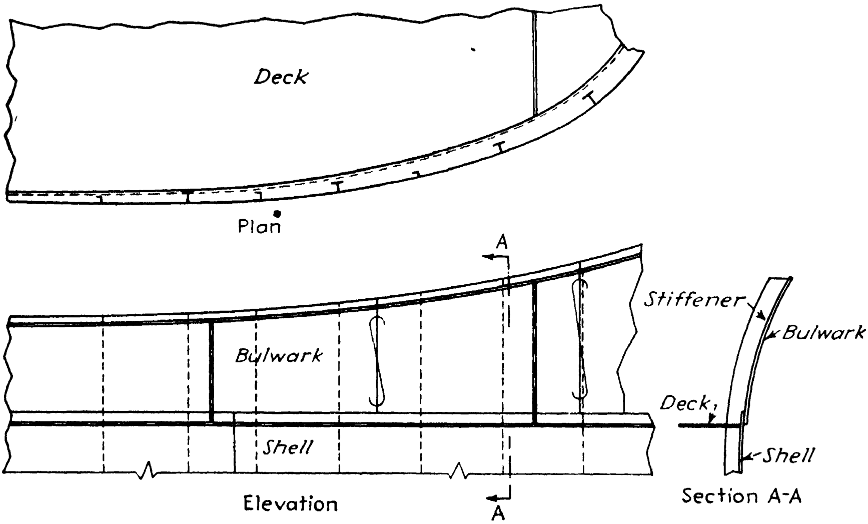


FIG. 391.—Faired bulwark in plan and elevation.

plumb. In order to have a fair camber on the front of the house, it is good practice to secure from the mold loft a camber mold built to the camber of the ship on top of the deck. Have a level line parallel to the base line marked on the mold, so that a spirit level may be applied and the mold brought level to give the true camber of the deck. The manner of erecting and setting the bulwark front is similar to that used for the side, and the same fundamentals of checking heights and plumbing are employed as those used for the other structure of the ship.

Flared Bulwarks. In setting a bulwark that is flared, particularly at the ends of the ship, it is always set at a given distance above the deck of the ship rather than from a water line. In erecting it, dogs are welded at the bottom so that it will catch over the edge of the shell plate and thus hold the bottom in place. The top may be fastened by means of braces to the deck, these being set so that the bulwark will have approximately the designed amount of flare.

Angle molds should be obtained from the mold loft to give the proper angle of the bulwark with respect to the deck, as shown in Fig. 390. By applying the mold to the deck the bulwark may be set in or out to its correct position. Molds should be applied at approximately 10-ft. intervals.

At the top of the mold there should also be marked the point of the top of the bulwark. If the deck to which the mold is being applied is in a fair line, this will also place the top of the bulwark in a fair fore-and-aft line.

After templates are applied and the bulwark set, temporary braces consisting of scrap flat bar or plate can be used for holding it in its correct position.

After the points at the locations of the templates have been set, the bulwark is faired between these points with the eye. The top of the bulwark, after being completed, should present a fair appearance both in plan and elevation, as shown in Fig. 391.

CHAPTER XXVIII

FOUNDATIONS

The work of the shipwright in connection with foundations is confined to the establishing of working lines, such as water lines, buttock lines, and frame lines, in the spaces where foundations are specified. From these lines ship fitters can then build foundations according to plan, doing their own plumbing and leveling. In some yards, however, shipwrights establish all lines necessary for the construction of the foundations, furnishing the proper transverse position of the foundation as well as the fore-and-aft position, together with a height above the base line on some of the adjacent structure, from which the ship fitter can build the foundation.

Ballast and General Service Pump. In Fig. 392 is shown the foundation for the ballast and general service pump. It sets against bulkhead 108, and its center is specified to be 13 ft. 3 in. from the center line. It is located on the port side only.

Because the foundation sets against bulkhead 108, this establishes it in its fore-and-aft position. Referring to Fig. 392 again, it can be seen that the height of the foundation is specified to be 6 ft. 2¼ in. above the base line. Therefore, the distance from the center line is established on the inner bottom and the height of the foundation on the bulkhead from a water line already established for the purpose of measuring heights.

Fuel-oil Transfer Pump. In Fig. 393 is shown a foundation for a fuel-oil transfer pump. It sets against bulkhead 88, which establishes it in its fore-and-aft position. The center of the foundation is designed to be 4 ft. off center line on the port side only. The height of the foundation is designed to be 5 ft. 8¼ in. above the base line to the top of the chock. The same procedure is used in establishing these working lines as was explained in the foregoing.

Boiler. In Fig. 394 is shown a boiler foundation. The fore-and-aft center is designed to be 13 ft. 6 in. aft of frame 88. This line is installed from frame 88 and checked so that it will be at right angles to the center line of the ship.

The transverse position of the foundation is designed to be 6 ft. 6¾ in. from the center line of the ship to the inboard edge of the inboard chock. The center of the chock is 9 in. outboard of this line. The outboard end of the outboard chock is designed to be 14 ft. 4⅛ in. from the inboard edge of the inboard chock.

By establishing these lines on the inner bottom the ship fitter can set his foundation, which is generally preassembled, in its proper position.

To set the foundation at its proper height above the base line, four angle uprights can be set, tack-welded and braced about 12 in. outside the

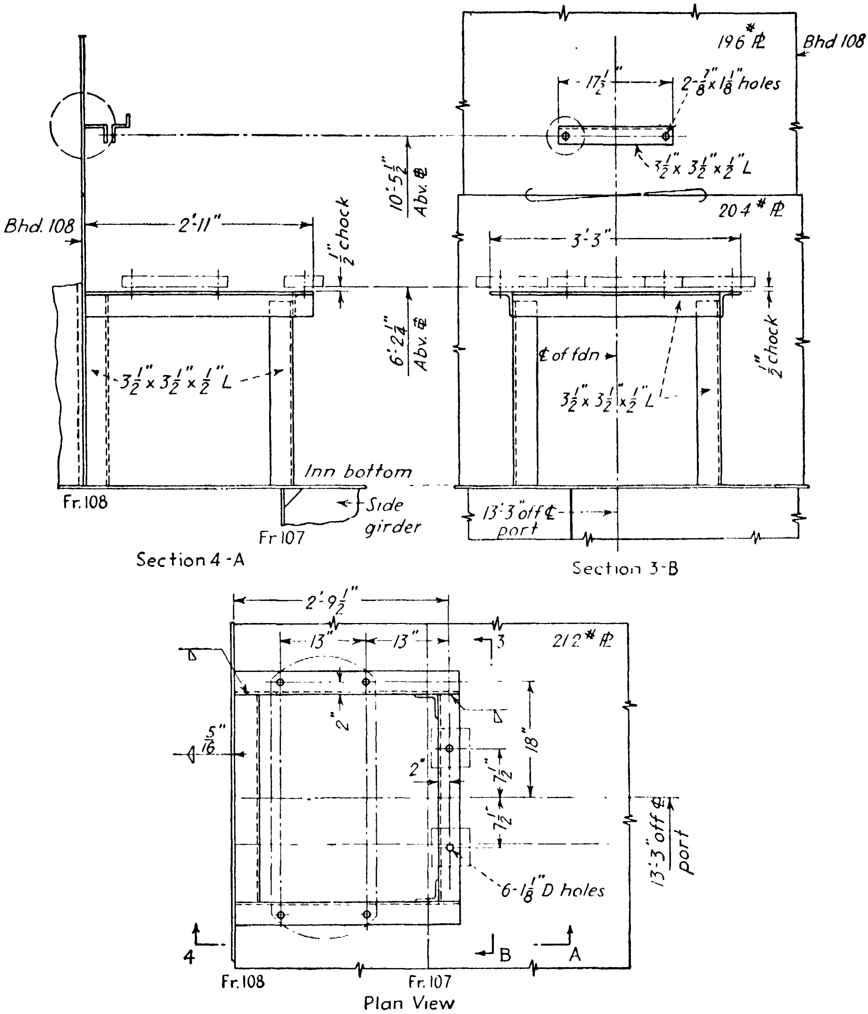


Fig. 392.—Foundation for ballast and general service pump.

boundary of the foundation. The height to the top of the foundation, which is 2 ft. 6 in. above the top of the inner bottom, can then be marked on the angle uprights.

After the height has been established on one of the uprights, a straightedge with a spirit level can be used to level out the height to the opposite upright, giving the transverse height of the foundation. With a straightedge and declivity board and spirit level, the height is then set on the remaining two uprights to give the fore-and-aft line of the top of the foundation.

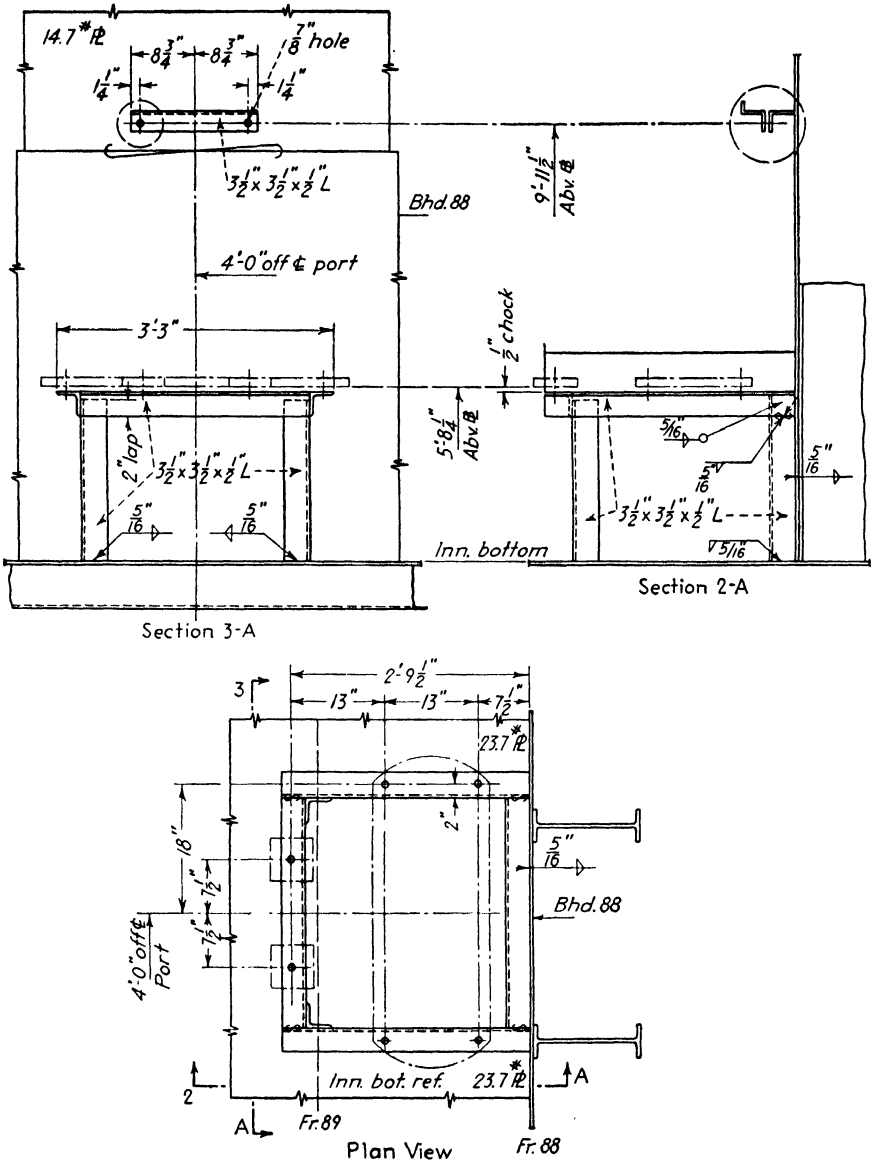


FIG. 393.—Foundation for fuel oil transfer pump.

By stretching a chalk line to intersect the points on the angles, the ship fitter may determine the amount of trimming necessary to fit the foundations to the inner bottom.

Steering Gear. In Fig. 395 is shown a steering-gear foundation, designed to straddle the center line of the ship. Its fore-and-aft position is 4 ft. 8⅝ in. forward of the center of the rudder-stock, which is located 1½ in. forward of frame 175. This is the location of the after edge of the foundation. The forward edge of the foundation at the center line is 4 ft. 5⅛ in. forward of the after edge of the foundation.

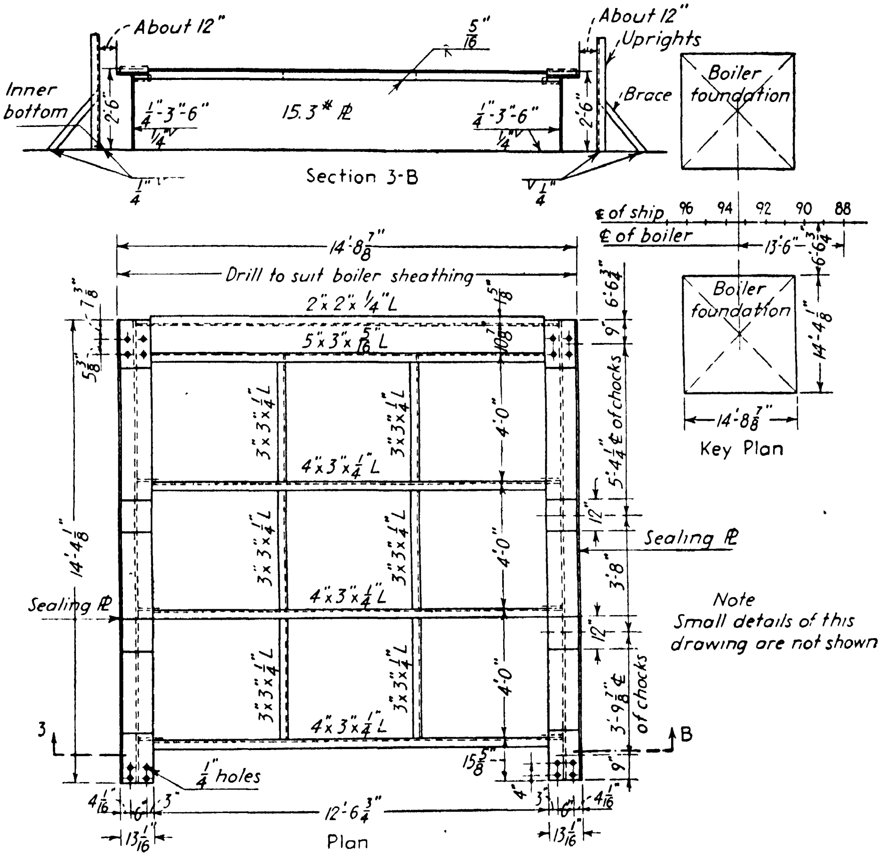


FIG. 394.—Boiler foundation.

From these working lines all dimensions shown in the plan of the foundation can be established.

The height of the foundation is designed to be 32 ft. 5¼ in. above the base line. It can be obtained by dropping a steel tape down through the opening for the rudderstock to the base line of the ship on the stern casting. Then with a declivity board and spirit level the designed height is projected forward to the location of the foundation. These heights are established on short pieces of flat bar tack-welded outside the boundary of the foundation.

Windlass. The windlass foundation is illustrated in Fig. 396. It consists of wood, the boundaries of which are confined by a flat bar welded to the deck, as shown in the plan. It will be observed that all the dimensions in a fore-and-aft direction are given from the center of the chain pipes, which are located 12 in. aft of frame 10 and 2 ft. 2¾ in. from the center line on each side of the ship.

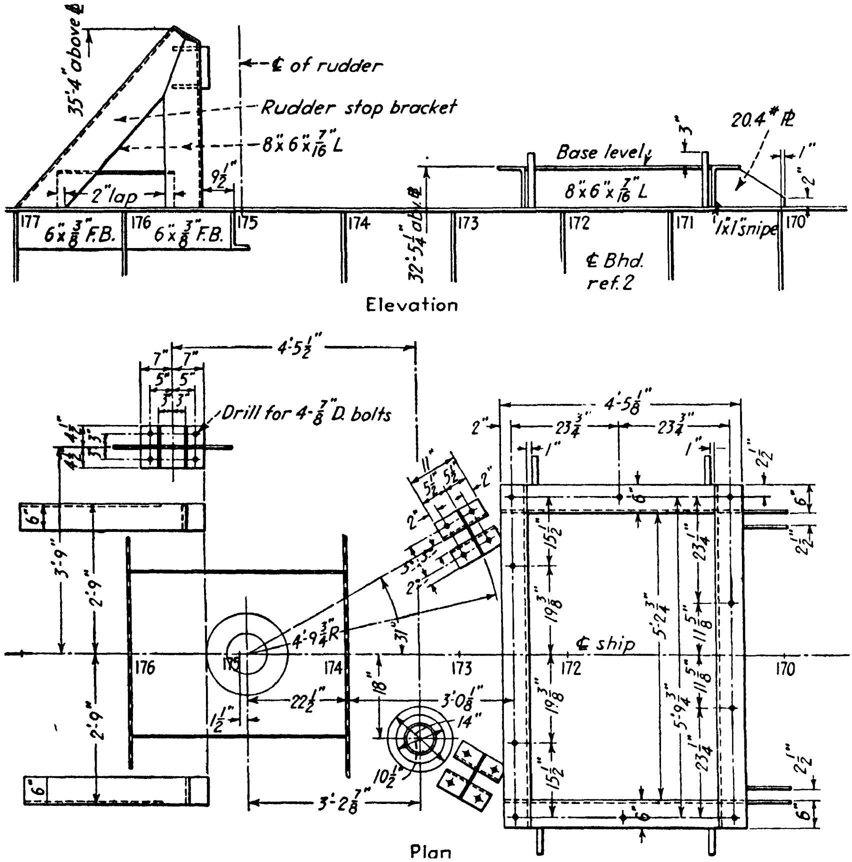


FIG. 395.—Steering-gear foundation.

After the boundary of the foundation has been lined in on the deck, the flat bar is set up plumb and tack-welded ready for production welding. When this has been done, a template is made within the boundaries of the flat bar for the purpose of laying off and fabricating the wood pieces in the shop.

Planking. Planking, specified to be 4 in. thick, is laid on the floor of the shop edge to edge, in sufficient quantities to make up the entire foundation. If the planking is beveled to allow for calking, it can be butted up hard, one piece beside the other; however, if the butts of the planking are square, sufficient space must be allowed between the planks to permit calking. Spacers the thickness of the space allowed for calking can be dropped between the planks. The boundary and the opening for the chain pipes are then marked on the planking, which is then sawed to these lines.

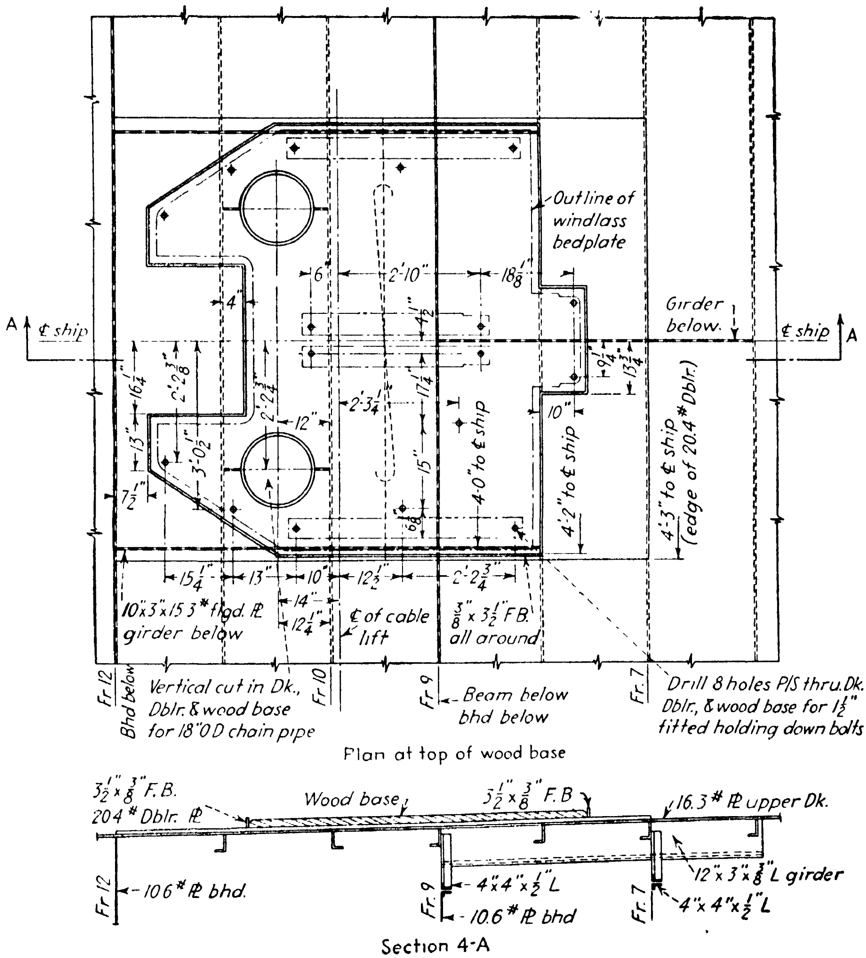


FIG. 396.—Windlass foundation, including wood plank foundation.

Before taking the planking apart for sawing, it should be marked with identification numbers, so that its location can easily be determined when it is brought to the ship. It must be remembered that sufficient space must be left at the boundaries of the foundation to permit calking.

After the wood base has been placed within its boundaries, a template, made on the windlass foundation and showing the locations of holding-down bolts, is laid on the wood planking. The position of these holding-down bolts is marked on the wood, so that the bolts that secure the wood base to the deck plating will not foul any of them.

Boltholes. After the centers of the holding-down bolts of the windlass have been marked, the bolts for holding down the wood base can be laid off and drilled on 24-in. centers, as specified on the drawing. Holes are then drilled into the wood down to the deck plating. If decking bolts extending through the deck plating are to be used, an indentation should be made in the deck plating after the holes have been bored through the wood, so that the plating can be drilled after the wood is removed, for cleaning out shavings. Before the wood is taken up, the holes should also be drilled with a plug bit to the depth below the surface of the decking to which it is desired to place the nuts.

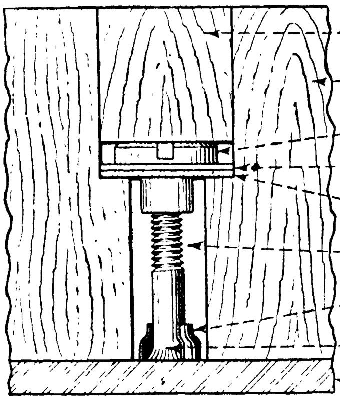


FIG. 396*a*.—Stud bolts for securing wood decking.

After all the drilling has been performed on the wood, this is removed, the shavings are cleaned out, and the holes are drilled through the deck plating. Then the deck is treated with a rust preventive, and the wood planking is again put in place. Deck bolts are used to secure the wood base to the deck plating, with washers and grommets on the underside of the deck.

Stud Bolts. Another method of securing wood decking is by stud bolts welded to the deck by means of a stud welder. A section of wood plank is fitted and wedged into place. Holes are drilled and counterbored to the desired depth and the plate is cleaned and the wood replaced. The stud is welded through the hole to the steel deck.

A lampwick grommet and washer are first placed on the stud. Then, the slotted nut is applied and tightened by means of an air drill with a screw-driver bit. To complete the wood decking job, a wooden plug is driven into the counterbored hole, as shown in Fig. 396*a*.

After the bolts have been tightened and the counterbored holes plugged up, the planking can be planed down to a flush surface if any irregularities exist. The seams of the planking are then calked and pitched.

CHAPTER XXIX

THE RUDDER

The work the shipwright performs in connection with the construction and installation of the rudder is building the jig, or cradle, on which it is constructed and after this, when it has been made ready for installation on the ship, building a skidway to support it in a vertical position and to skid it into place, so that it can be connected to the rudder bearer.

There are various types of rudder. Some are the single plate, the spade type, the contraguide, the pilot, the balanced, and the semibalanced.

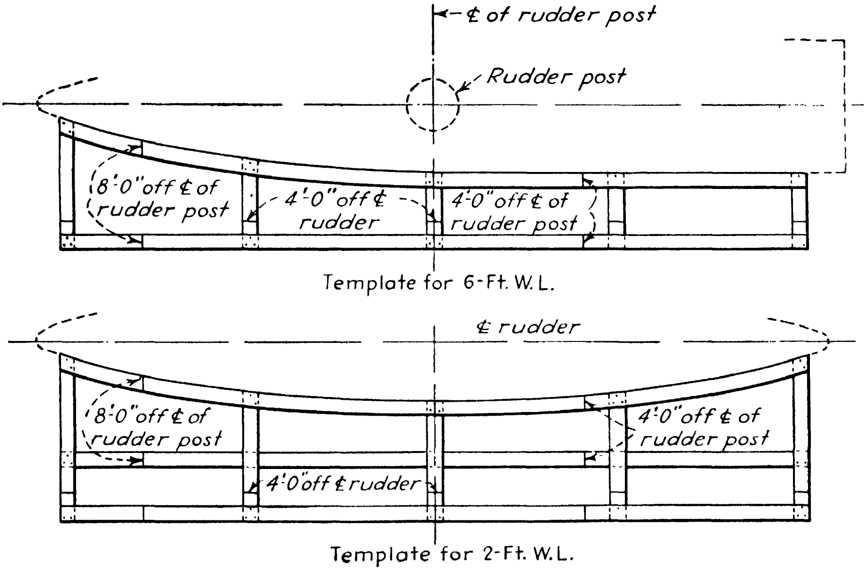


FIG. 397.—Templates for building jig for rudder.

Construction of the Rudder. In constructing the jig for the rudder, which is usually built in a horizontal position, templates are first obtained from the mold loft. These are built to the outside of the rudder plating and have established on them a line parallel to the center of the rudder from which the jig can be constructed, as shown in Fig. 397.

Scrap plate is used to make the jig by cutting the shape of the rudder from the templates. When this plate is laid off for cutting, the working line established on the template should also be center punched on the plating for the purpose of establishing it at the proper height when it is set up. When the plates have been cut out to the shape of the rudder, the floor on which the jig is to be built can be lined off, with the vertical center of the rudder established at right angles to the position of the templates.

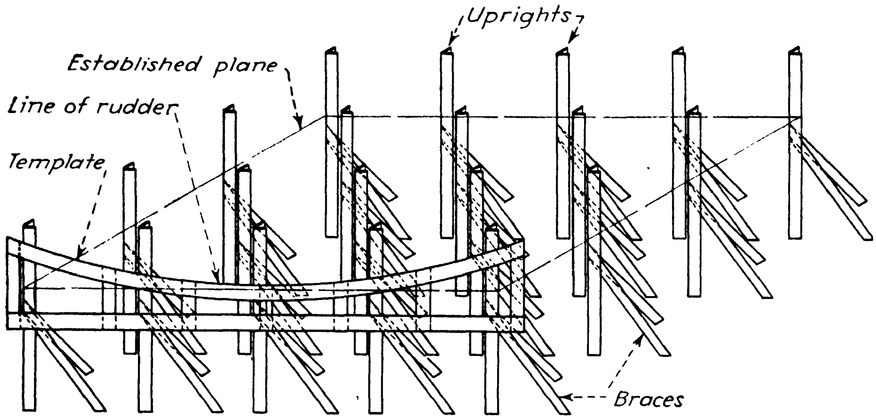


FIG. 398.—Templates secured to uprights for rudder jig.

The position of the templates can now be established by using a water line or the base line of the rudder. When these lines have been established, uprights made of scrap wood can be set up and temporarily braced and the templates, in turn, nailed to the uprights to a plane established

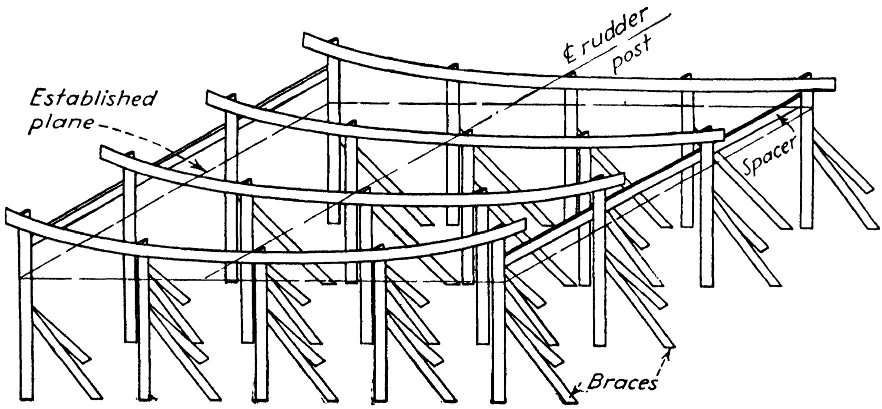


FIG. 399.—Uprights with planes established and uprights braced in both directions for rudder jig.

on them with a level and straightedge or an engineer's level, as shown in Fig. 398.

Steel angle uprights can be set up and braced along the line of the templates. A level plane is now established on all uprights, and the wooden templates are clamped to the uprights. Adjusted to the level plane, the uprights are cut so that the top does not project above the templates.

From a vertical center line, frame line, or center of the rudderstock established on the layout, the plates can now be set up and secured to the

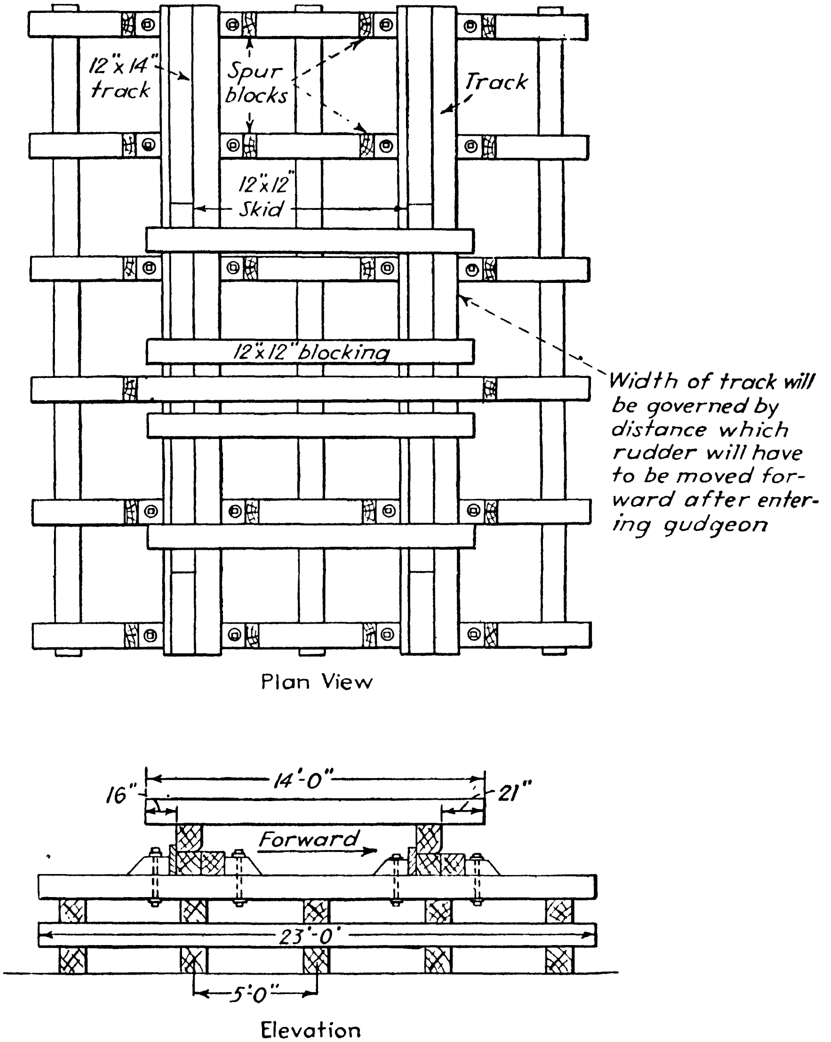


FIG. 400.—Track for skidding in rudder from side of shipway.

uprights, holding them at the proper distance from the working plane established on both the uprights and the plates (see Fig. 399).

After the plates have been set up and secured to the uprights, they should be sighted across the top to see that they are fair. If necessary, they should be made fair with a fairing batten.

When all the plates have been set up, spacers consisting of scrap plate are installed between the plates near the top to hold them in their proper position. Water lines, frame lines, and the center of the rudderstock can now be established on the jig so that the ship fitters can regulate the plating in its proper position in the jig.

The bottom plating is first laid on the jig. The rudder casting is then laid on this plating and fitted to it. The shipwrights generally set and shore this casting to its proper position.

The internal structure of the rudder is then built on top of the plating and around the casting. After this has been completed, the top plate is placed on this structure. Because of the fact that most rudders are almost entirely welded, it is important that the shipwright should check

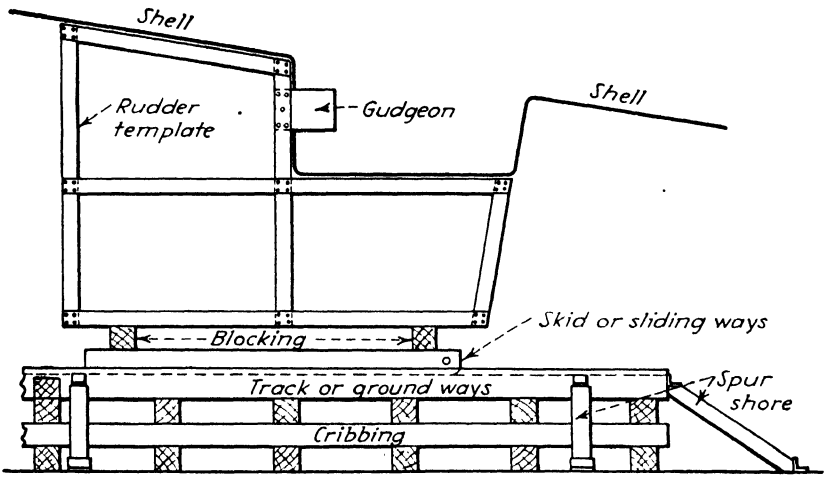


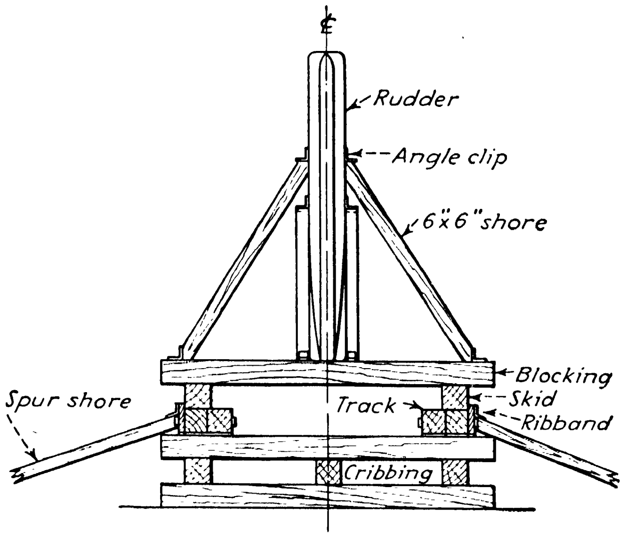
FIG. 401.—The construction of rudder skid for a large rudder with a template set on top.

the alignment of the center of the rudder at frequent intervals, particularly during welding, so that it will not twist off center.

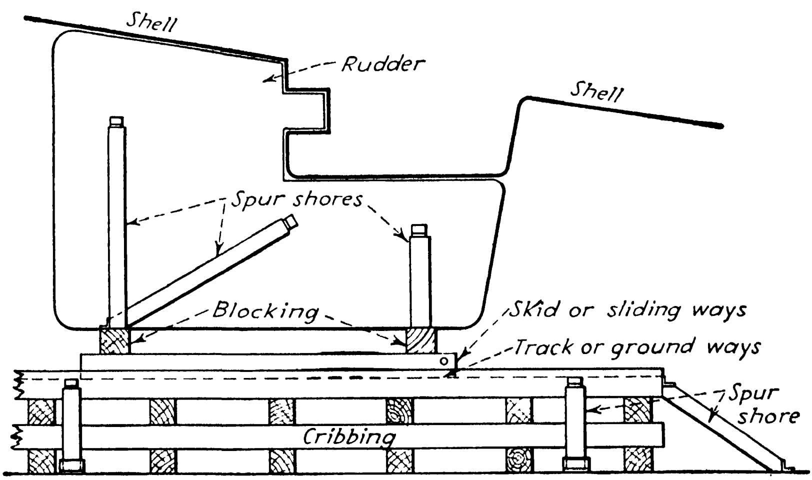
Installation of the Rudder. When the rudder is ready to be installed in its position on the ship, and its size and location under the ship is of such nature that it cannot be handled with chain falls or with the cranes into its proper position, it is necessary to build a skidway for this purpose. Like the skids for shafting, the rudder may be installed from the side of the ship or from the stern, depending, of course, on the obstructions and the best possible means of access. The better method of installing the rudder is from the side, as this requires shorter skids and less skidding.

Since there is very little clearance between the top of the rudder and the rudder gudgeons, the skidway must be built to a height such that the rudder will enter the gudgeon without any jacking or lowering. If anything, it is best to have the rudder skidway a little low than too high, since it can be more easily jacked up than lowered.

After the track has been built and braced in position, as shown in Fig. 400, the skid is constructed on top of the track. A template built to conform to the outside boundaries of the rudder should be made from the rudder itself and set up on top of the skid to see that it is at the proper



End looking forward.



Fore-and-aft elevation.

FIG. 402.—Rudder setting on skidway with bracing to hold it in position.

height, so that the rudder will enter the gudgeon. In Fig. 401 is shown the construction of a rudder skid for a large rudder with a template for checking it set on top. It is always good practice to allow for ½ in. settlement when the rudder is placed on the skid.

When the skid has been completed, it is pulled out to the side or to the stern of the ship and the track greased with launching grease. The rudder is then brought in with the crane and set up vertically on the skidway.

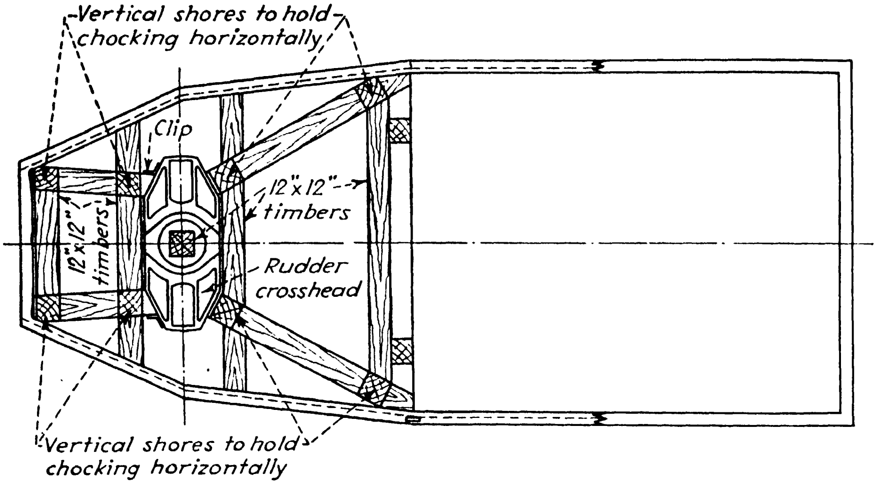


Fig. 402a.—Typical arrangement of rudder chocking.

After being landed on the skids, the rudder is braced in a transverse direction at both ends and also in a forward direction to prevent it from tipping aft. Temporary clips are welded at the top of the shores holding the rudder. When these clips have been welded and the shores wedged

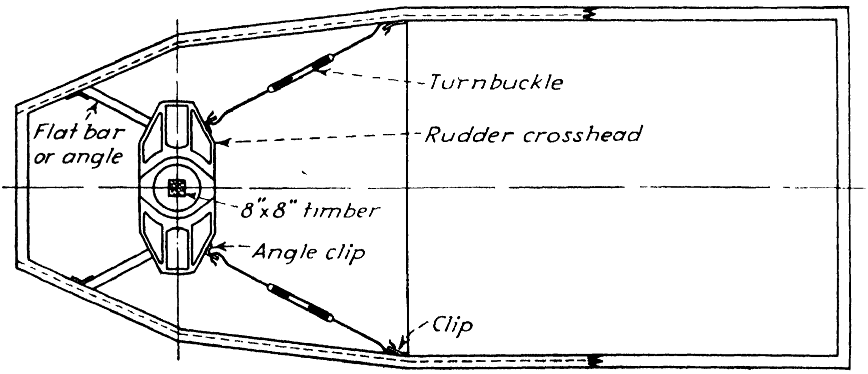


Fig. 402b.—Chocking for small rudder.

up tight, the crane can be turned loose from the rudder. The skid with the rudder is then pulled into its position under the ship.

In Fig. 402 is shown the rudder setting on the skidway with bracing to hold it in position.

Chocking Rudder for Launching. When the ship is being made ready for launching and after the rudder crosshead, or quadrant, has been installed and set, it will be necessary to chock the rudder securely to ensure against any possibility of its turning during the time that the ship is sliding into the water. On large rudders this chocking must be extremely heavy, being generally 12- by 12-in. oak timbers fitted to convenient adjacent structure.

The chocking should be installed with shores running fore and aft on each side of the crosshead. To prevent any transverse displacement of the shoring, spacers are installed between the inboard sides and the structure of the ship. To prevent vertical displacement, shores are also installed at the ends, on the top and bottom sides, and extending to the decks. A typical arrangement of rudder chocking is shown in Fig. 402*a*.

On small rudders it is sometimes possible to install chocking and shoring by using steel plate or structural shapes and welding this type of chocking to the structure of the ship, so that the crosshead cannot possibly move (see Fig. 402*b*).

CHAPTER XXX

FITTINGS AND CASTINGS

To a large extent, welding has reduced the number of castings that are built into the hull of a ship. However, there still remain a few, such as the lower portion of the stem, the sternpost for single-screw ships, and some types of struts.

On large vessels designed with heavy stern frames for supporting the rudder, only a portion is cast, the remainder of the structure being built up of structural plates and shapes and welded together. Small bitts and chocks may be cast, but the larger types are built up of steel plates and shapes. Large hawsepipes are still cast, but on the smaller types only the bolster and upper part are castings, while the pipe is rolled plate with the castings welded at each end.

THE STEM

No part of the ship is more noticeable than the stem. If it is lined up and set properly, it gives the ship the trim appearance that it should have, but if poorly set and allowed to kink, it gives an otherwise perfect hull an untidy appearance. Therefore, setting and lining up the stem constitute a very important job.

Fitting Stem Sections Together. The stem is usually composed of two or more pieces, which should be fitted together and faired on the ground before they are erected in place on the ship. This should also be done if the stem is to be included in a bow that is subassembled on the skids.

A mold giving the contour of the stem should be obtained from the mold loft. It should be made to a line 2 in. from the actual line of the stem, so that it will not foul any part of the casting or plating in the event of any irregularities.

The mold is laid on the ground where the stem is to be put together and a rough outline marked on the ground. This line will be used as a guide in placing the blocking on which the stem is to be laid.

Blocking should be built up to a height so that the stem will be clear of the ground for its entire length (see Fig. 403). The stem can then be laid on the blocking preparatory to lining it up. It is not necessary to set the stem level, but it must be set in a plane.

In order to avoid a twist in the upper part of the stem, the forefoot and the keel plate attached to the stem should be made level. In doing this, it will be possible to plumb across the bow of the plating forming the stem.

To line up the front of the stem in a straight line, straightedges can be leveled out from the center of the stem and set on 2- by 4-in. stakes driven into the ground near the butts of the sections of the stem. By sighting across the top of the straightedges it can readily be seen whether

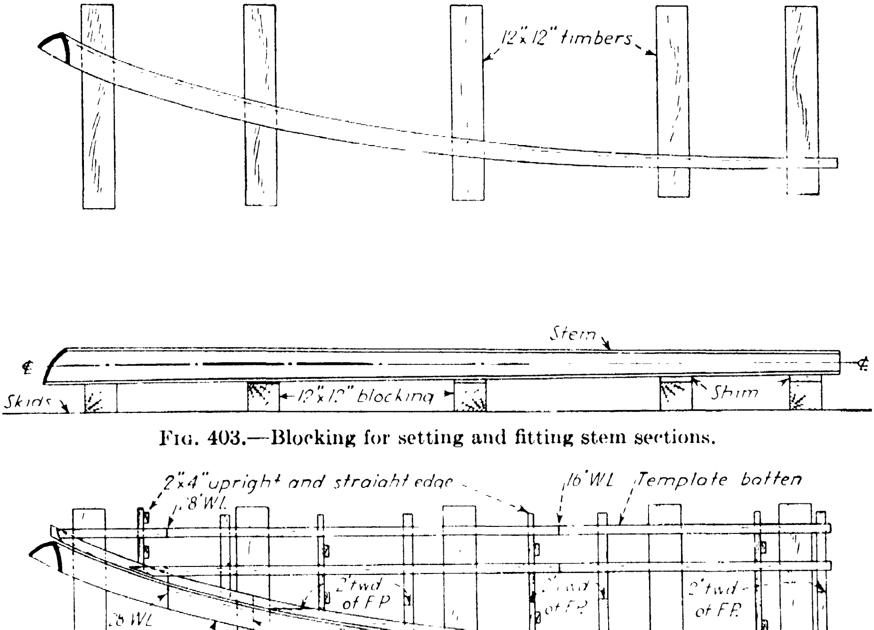


FIG. 403.—Blocking for setting and fitting stem sections.

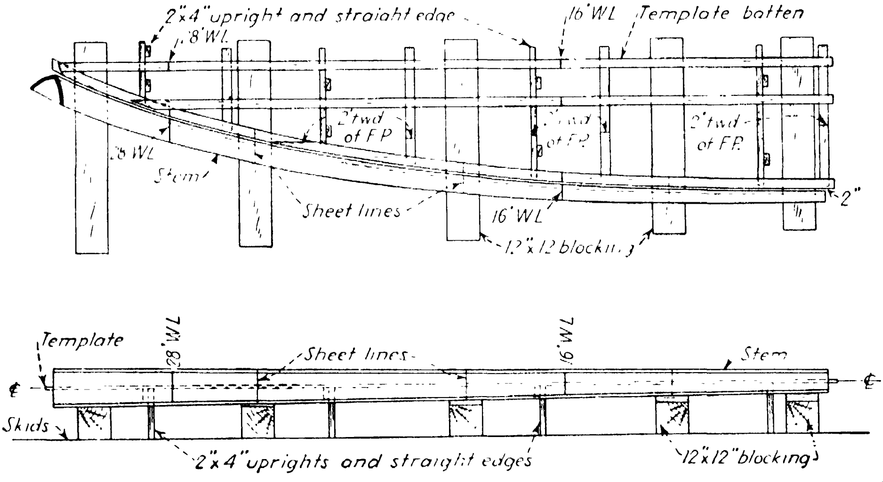


FIG. 404.—Stem with template laid on straight edges for lining up to proper contour and sheet lines marked on the stem.

or not they are in a straight line. Any straightedges not lining up with the two end straightedges can then be brought in line and the stem wedged up until all straightedges are in line. The template is then laid on top of the straightedges and the stem lined up to its proper contour. All necessary water lines, frame lines, and sheet lines are then center punched and marked on the stem (see Fig. 404).

Another method of lining up the stem is to erect uprights by driving stakes into the ground and stretching a chalk line around the uprights. One side of the chalk-line rectangle may then be brought up to approximately the line of the stem. The remainder of the line can then be moved up or down until a plane is sighted across all four lines. When the lines have been brought into a plane, sights can be taken over the chalk line to the line of the stem, which can be moved until it is in the same plane with the chalk line. Figure 405 shows the method of lining up the stem with the plane set up on uprights.

The forefoot of the stem should be set level in either case to avoid any twisting in the sides in the stem. Temporary supports must then be

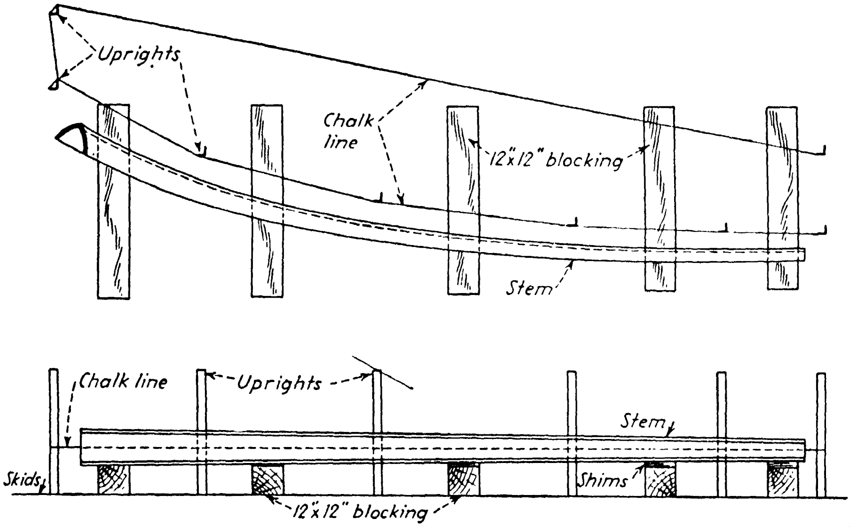


FIG. 405.—Method of lining up the stem from a plane established on uprights.

installed at the center line of the stem so that the contour template can be laid on them for the purpose of shaping the stem to its designed lines.

After the sections of the stem have been lined up, any butts that may have to be welded can be made up and braced for welding. Where butts are left loose so that the stem can be placed in position either in the subassembly or on the ship in sections, erection clips and pitching spots can be installed at these points, so that it will be possible to set the stem back in the same manner in which it was lined up.

Setting the Stem. If the bow of the vessel is to be subassembled, it will include the stem. It is generally subassembled with the stem at the top; in other words, with the framing and stem setting horizontally.

The breasthooks and deck levels are then set up vertically. After this, measurements may be taken from a frame line for setting the stem on the forward ends of the breasthooks and decks.

Two perpendiculars are set up at the top and lower ends of the bow assembly, and a line is stretched between them. The stem can be lined up by plumbing down to the center from this line, after being set approximately in its proper fore-and-aft position, by taking measurements from a frame line to the inside of the stem. The forefoot and keel plate attached to it will be set up plumb and in line, with the upright used for a straightline.

After the stem has been lined in its proper position, it should be securely shored and braced from inside the assembly so that it will not move during the process of setting other members and when being

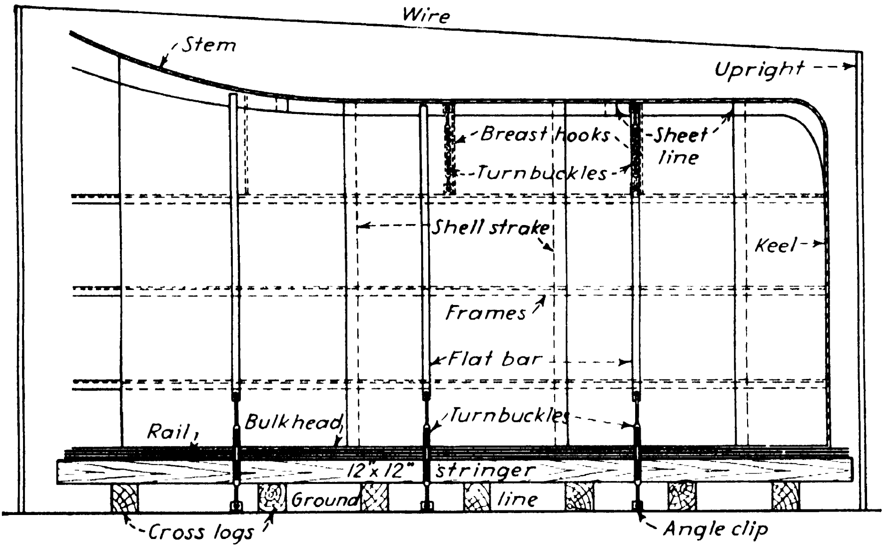


FIG. 406.—Stem set up in a bow assembly in an inverted position.

welded. Additional outside bracing may be used after the structure has been erected and before welding is started.

The stem set up on a bow assembly is shown in Fig. 406. Regardless of whether the stem is to be set into the ship with the subassembled bow or separately when the bow is not subassembled, the same procedure for setting is used.

Before the bow assembly or stem is erected into the ship, an approximate location of the shores that will support it in a vertical position should be established. Clips should be welded to the stem or bow assembly for the purpose of chocking the head of the shore. Measurements can then be taken from the point of the head of the shores to the base line, to which should be added the distance from the base line to the stocks on which the bottom of the shores will be set. The shores are then cut to the proper length to support the stem on each side.

Good judgment is essential in properly placing the shores. They should be strutted at a rake of about 2 in. per ft. and fastened to clips at the top. Before the stem or bow assembly is brought into the ship, they should be set up and lashed to the staging at approximately their proper location.

While the assembly is being held by the crane, it should be set in its proper fore-and-aft position. Using a steel tape, measure from the established base line to a water line punched on the stem for the purpose of setting the assembly to the proper height. Set shores in place, and wedge up so that the crane can be turned loose. Install two straps and

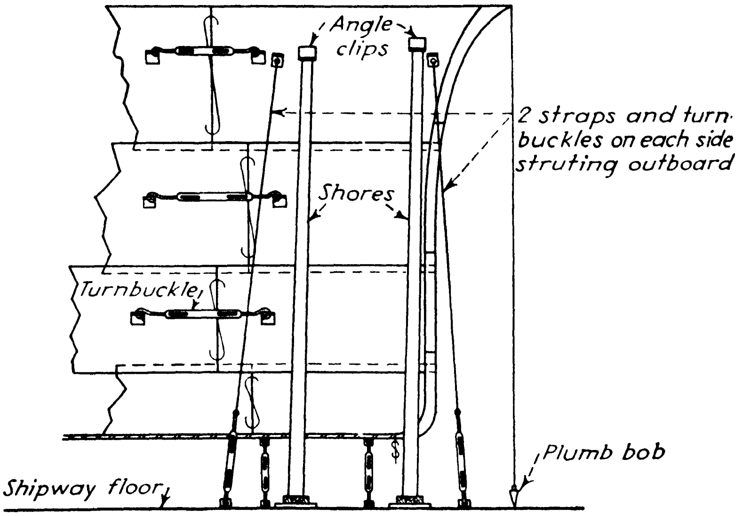


FIG. 407.—Bow set in ship with turnbuckles and shores to hold it in position.

turnbuckles on each side of the assembly for the purpose of holding it on the center line of the ship.

After the assembly has been cut loose from the crane, a heavy plumb bob should be suspended from the top of the stem to the center line established on the stocks. The assembly can then be moved until the plumb bob falls directly over the center line.

The lower part of the bow assembly should be secured on the center line by means of turnbuckles and straps fastened to the stocks, so that there is no possibility of its moving to any large extent during the process of welding. A bow set with turnbuckles and shores is shown in Fig. 407.

STERN CASTING

Before the stern casting can be set into the ship, it is necessary to check it with a stern-frame template to ensure its being straight and to designed lines. If the stern frame is made up of more than one piece, the pieces making up this assembly must be lined up to a straight plane before being fastened together. Some chipping or heating may be necessary if these sections do not line up after being put together. In checking the sternpost for alignment it is generally set up level. Straightedges supported on stakes driven into the ground, or uprights welded to the platen on which the frame is being put together, are then set up. Then straightedges are brought out from the center of the frame and made level.

By sighting across the straightedges, it can be determined whether or not they are in a plane; straightedges not in line must be adjusted. When the straightedges have all been brought into a plane, the stern

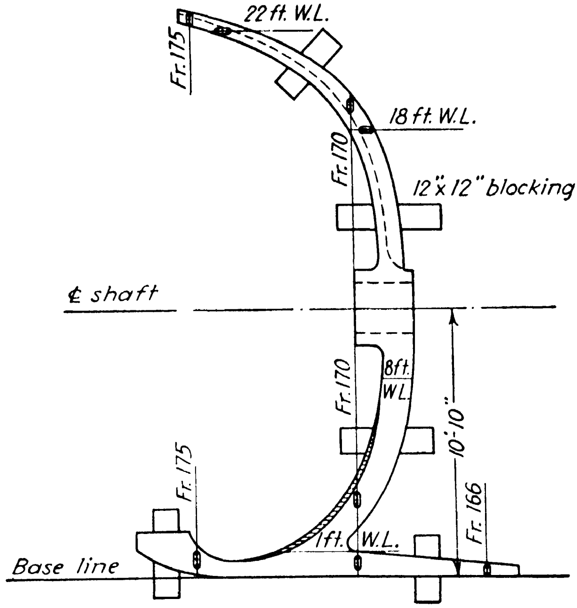


FIG. 408.—Stern frame casting laid on blocking lined up and marked ready for erecting in the ship.

frame is adjusted to line in with them. The template is then laid on them and the contour of the frame checked for correctness.

In checking the stern frame, consideration must be given first to the hub, or bore, for the shaft. This must line in with the center of the ship and must also be the proper distance above the base line of the vessel.

After all governing factors have been taken into consideration and the pieces making up the stern assembly have been secured together, all frame lines, water lines, and the center line are marked and center punched on the casting. The casting is then ready for erection on the ship as shown in Fig. 408.

Erecting and Setting the Stern Frame in the Ship. When the stern frame is ready for erection in the ship, the location of the shores and guys should be determined so that they will be available when the stern frame is lowered in place. Since the keel plate to which the stern frame is attached at the bottom is generally fitted and drilled before the casting is brought into the ship, the stern frame may be secured at this point.

The upper part of the stern frame will, of course, have to be shored in somewhat the same manner as the stem casting. That is, shores should be headed under clips near the top of the casting but not high enough to interfere with erection and working the shell plating attached to it.

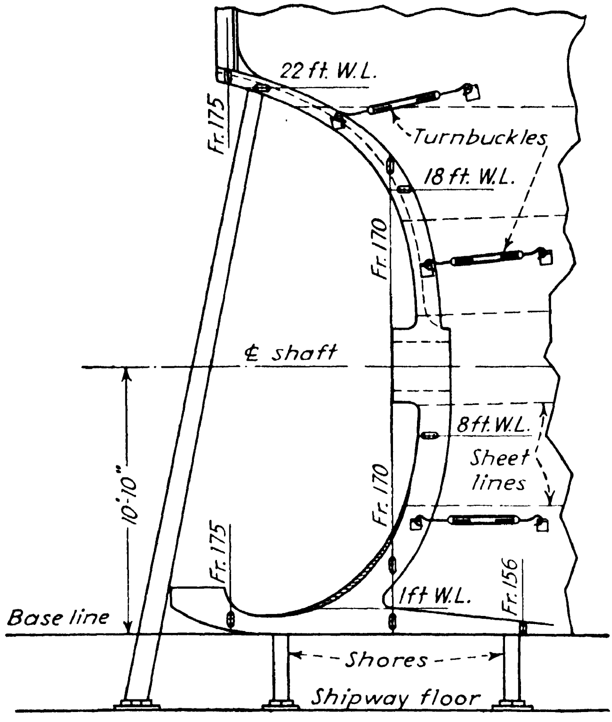


FIG. 409.—Stern post set and shored in its proper position in the ship.

The length of the shores can be determined by measuring from the bottom of the casting to the clips and adding to this dimension the distance from the top of the keelblocks to the stocks or shipway on which the shores will rest.

Allowances must also be made for strutting the shore in a transverse direction of about 2½ in. per ft. Flat-bar and turnbuckle guys may also be used in holding the casting in a vertical position. Clips for attaching the flat bar to the casting should be welded before the casting is brought into the ship.

Shores should be lowered and set in their approximate positions before the casting is brought into the ship.

When the casting is lowered into place, it should be set as close to its permanent position as possible to avoid having to move it any more than necessary. As previously mentioned, the keel plate that is attached to the casting in the ship has already been fitted and drilled and affords one means of setting the sternpost in a fore-and-aft position.

The center line that has been marked on the casting should be placed on the center line of the ship and shores and guys installed. After this, the crane may be turned loose from the casting.

After the casting has been cut loose from the crane, a plumb bob should be suspended from the center line at the top of the casting and this should be moved until the plumb-bob point falls over the center line of the ship. This may be done by tightening up on the turnbuckles on each side of the casting and tightening up or easing off on the shores.

To set the casting to its proper height above the base line, it is necessary to project the latter out to the vicinity of the casting. From the base line, measurements can then be made up to the water lines that have been marked on the casting, and this can be raised or lowered as necessary to bring it to the proper height.

Figure 409 shows the sternpost set and shored in its proper position, together with the points that have had to be checked.

When the structure that is attached to the stern-frame casting is being worked, frequent checks should be made to prevent any movement of the casting from its proper position, since this will affect the height of the shaft above the base line as well as its alignment from the center line.

STERN WELDMENTS

The difference between the stern-frame casting and the stern weldment is that the latter consists partly of castings and welded structure and generally does not incorporate any support for the shafting, acting only as a support for the rudder. The method of setting the stern weldment is exactly that used for setting the stern-frame casting except that closer attention must be given to the proper height for the rudder gudgeons. Figure 410 shows the stern weldment in position and braced against the possibility of movement.

The stern weldment is usually subassembled in a jig or cradle. After welding has been completed and the weldment annealed, the necessary working lines for setting it are rechecked and established.

HAWSEPIPES

Hawsepipe castings differ in type and construction according to the type of vessel in which they are being installed. On small and medium-sized vessels, hawsepipes are sometimes made up of three pieces, the upper and lower portions being castings and the pipe a rolled plate attached to the castings when the pipe is being installed in the ship.

Templates are usually furnished by the pattern shop or mold loft from the *mock-up* made of the bow framing for fitting the pattern for the hawsepipe casting. A template is made, with the outline of the bolster and the opening that will be cut into the shell. It is marked with a water line and frame line so that it can be applied on the shell

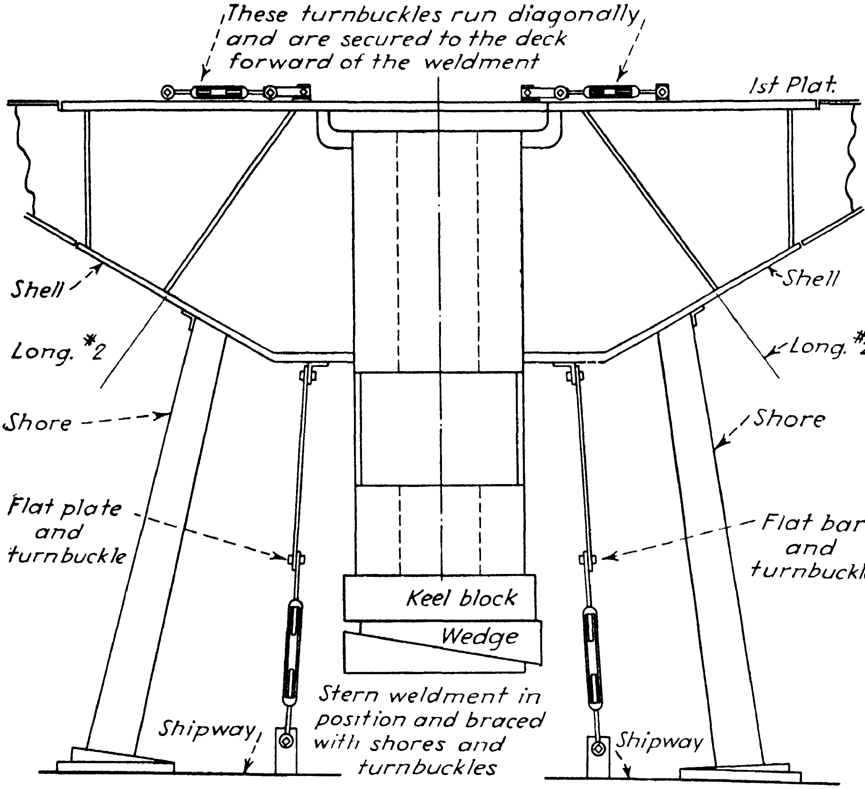


FIG. 410.—Stern weldment in position and braced with turnbuckles and shores.

of the ship (see Fig. 411). A template is also made at the deck, with the outline of the upper part of the casting and the cut in the deck plating that will permit the installation of the casting itself.

If the hawsepipe is of the built-up type, it is possible to cut the openings neat enough in the decks and shell to avoid the necessity for having a collar at the deck. However, if the hawsepipe is in one piece, it is, in most cases, impossible to cut the opening in the deck to a neat size because of the difficulty of installing it. Collars on the shell are not permitted; therefore, care is used in laying off the opening in the shell.

On large hawsepipes it is generally necessary to remove the structure surrounding the hawsepipe, including the deck beams, plating, and girders through which it penetrates at the top, and then to reset them after the hawsepipe has been put into its correct position and set.

When the hawsepipe is ready to be erected into the ship, the shipwright should obtain the drawing showing its exact location and, with the template for the cut in the shell, check the casting at the top by passing the template over the casting to determine the size of the hole that will be necessary in order to install the casting through the shell.

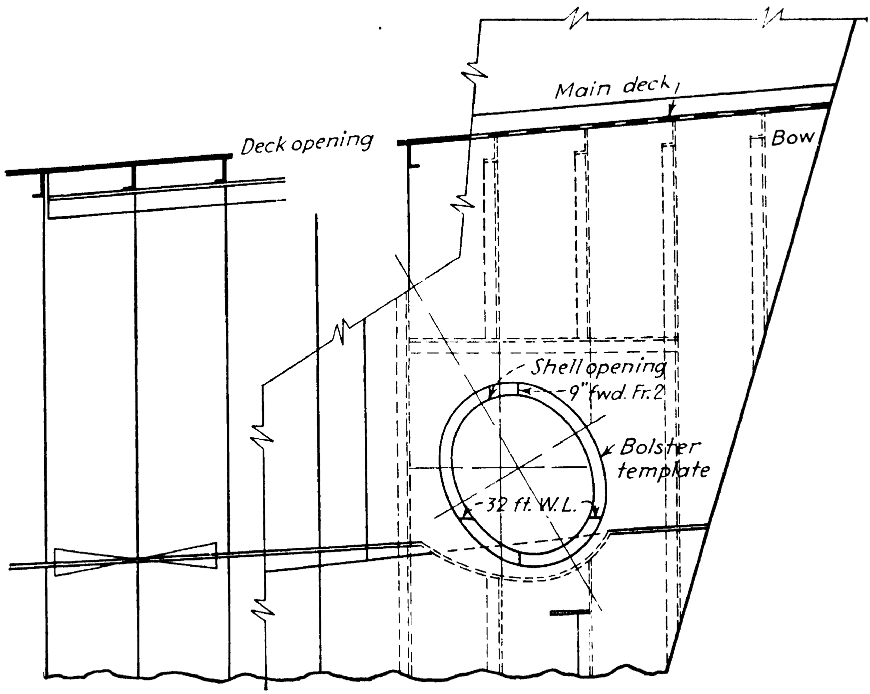


FIG. 411.—Template of outline of the bolster and opening cut in the shell for a hawsepipe.

Generally, this opening can be much smaller than will be the case after the bolster has been fitted against the shell and excess material burned off. The reason for making the opening in the shell no larger than absolutely necessary to enter and erect the casting is that an opportunity for adjusting the bolster is made possible, so that the upper part of the casting will be at the proper distance from the center line and also with respect to the windlass for anchor-handling gear without danger of getting the opening in the shell too large.

Figure 412 shows the openings cut in the deck and shell ready for the installation of the hawsepipe.

After the hawsepipe casting has been erected in the ship, it must be set according to the plan. This can be done by jacking and shoring on the upper part of the casting and using steamboat jacks attached

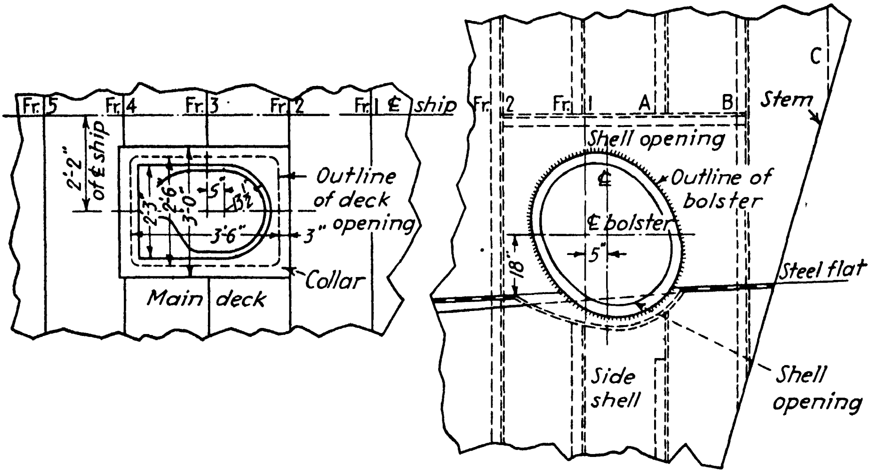


FIG. 412.—Opening cut in deck and shell ready for installation of hawsepipe.

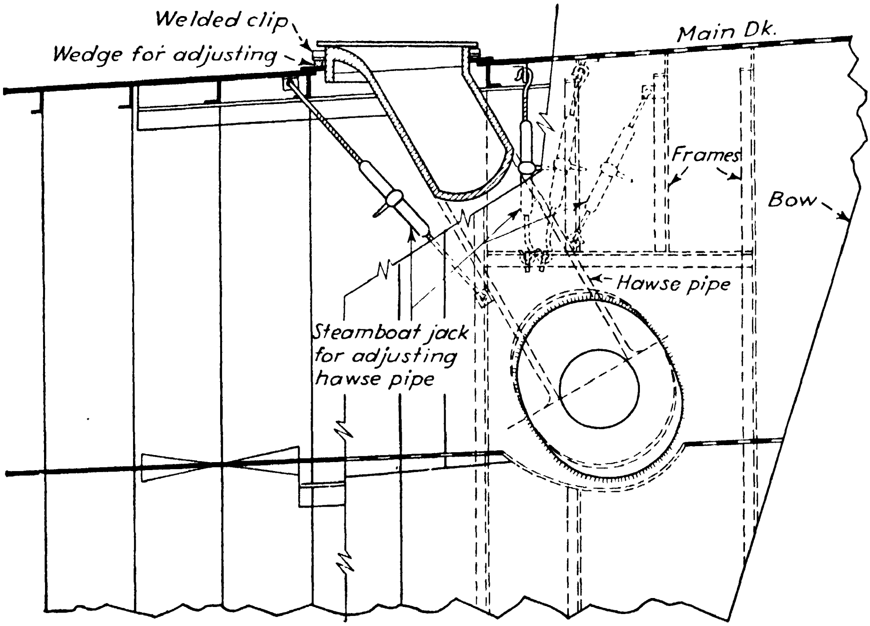


FIG. 413.—Four steamboat jacks being used to set hawsepipe casting in any direction desired.

to the bolster or to the tube and to clips on the inside of the shell for the purpose of raising or moving it. Figure 413 shows four steamboat jacks being used to move the hawsepipe casting in any direction desired.

After the casting has been set in its proper position, it should be tack-welded with a sufficient number and size of tack welds to prevent it from moving.

To remove the excess metal between the bolster and the pipe itself, some trimming may be necessary after the former has been fastened to the shell. After it has been pulled up hard and the shell faired as necessary, the bolster can be welded permanently to the shell.

At the same time, the work can be started, attaching the structure around the top of the casting or, if this is not necessary, fitting collars and making up the connections at the deck.

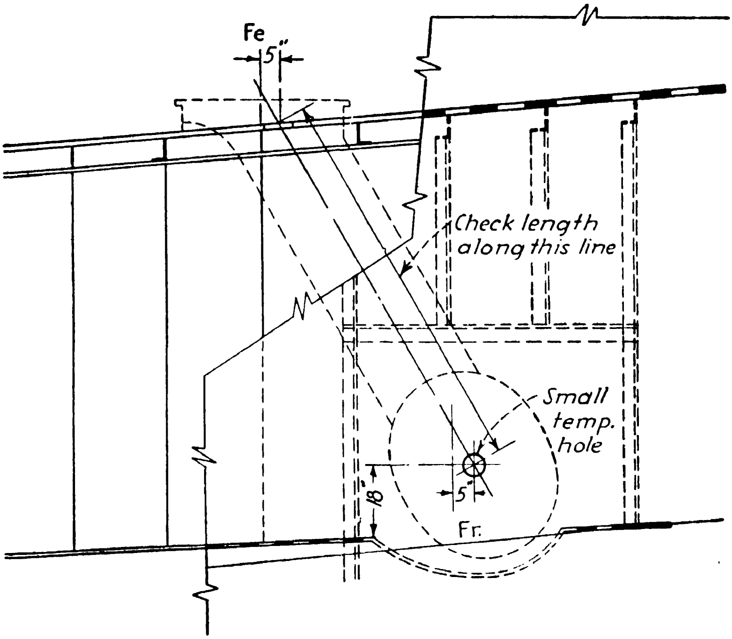


FIG. 414.—Method of checking length of hawsepipe to the center of openings in the deck and shell before cutting.

The shipfitter usually makes up all connections after the hawsepipe has been set and welded in place so that it cannot be moved.

When it is not possible to obtain templates for the cuts in the shell and decks, they can be made from the casting itself and the necessary working lines marked on them from the plan showing the location of the casting. When this is the case, always work on the safe side by not removing any more of the deck and shell than is absolutely necessary to erect and install the casting.

Before the openings are burned in the deck and the shell itself, it is a good plan to make a check from the center of the opening in the deck to the center of the opening through the shell with a tape and to apply this to the casting itself as a measure of safety. If any great variance is shown, it is well to recheck the openings from the drawing as well as the casting itself (see Fig. 414). A good policy to follow in the installation of the hawse and chain pipes or any other fittings in connection with the anchor-handling equipment is to use a point on the windlass foundations

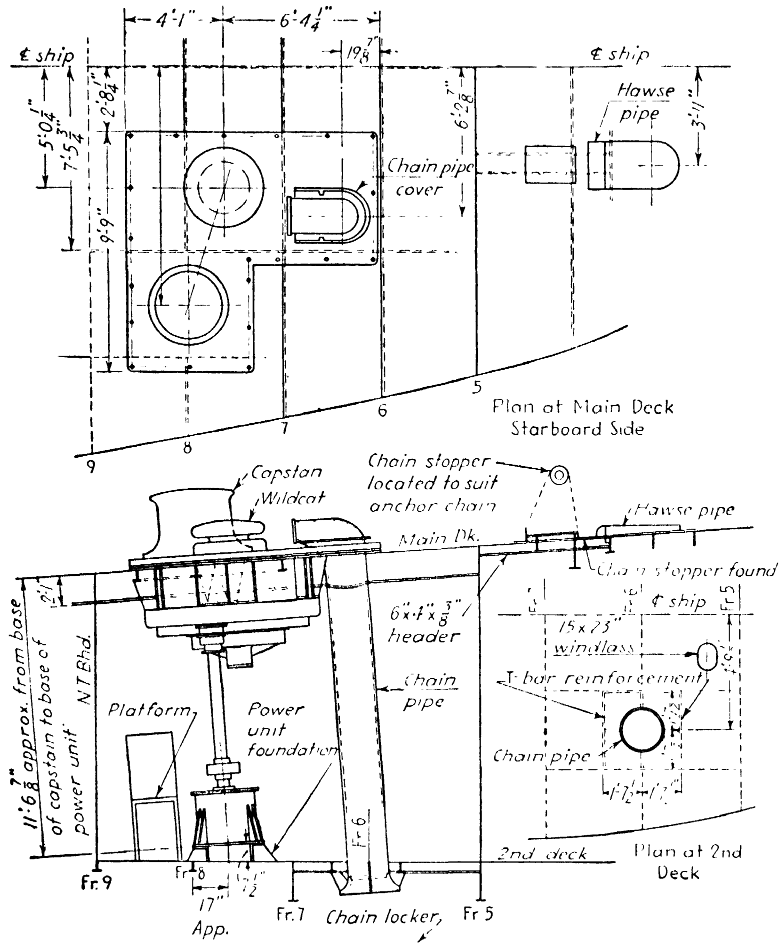


Fig. 415.—Chain pipe layout.

as a working point at all times. This will ensure the proper lead from the hawsepipe to the wildcat and chain pipe.

CHAIN PIPES

The chain pipe is a long pipe through which the anchor chain passes from the anchor windlass to the chain locker. It must be set so that the anchor chain will pass through without fouling or hanging against its side. A drawing for it usually gives its exact location with respect to the anchor windlass, and these openings can be cut into the deck according to this plan or as shown in Fig. 415.

Before the openings are cut through the decks for the pipe, it is good practice to measure its diameter and shape. This is because the pipe is usually rolled plate welded together, not always circular in shape, and sometimes either slightly larger or smaller than specified. Aside from its being not exactly to dimension, there is no reason why the openings through the decks cannot be cut fairly neat, with enough clearance for it to pass through, but still not large enough to necessitate a collar. After the openings have been cut into the deck, the chain pipe can be installed through the openings by the cranes.

The opening is made by making a template to fit the pipe at the point at which it will penetrate the deck and then passing this template over the chain pipe, thus ensuring the opening in the deck being large enough for the pipe to pass through.

A small chock should be welded at the top of the pipe on two sides to prevent it from passing through to the deck and to assist in keeping it at the proper distance above the deck plating.

Chain pipes are usually fitted with a bellmouthed casting at the top and bottom. If such castings are specified, they can then be attached to the pipe after the pipe is inserted through the decks. Some slight trimming may be necessary for fitting the castings so that they will be at the specified dimensions above and below the ends of the pipe.

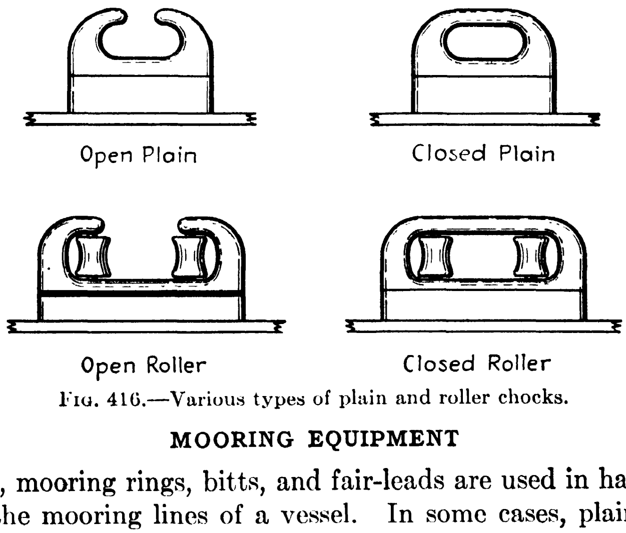


FIG. 416.—Various types of plain and roller chocks.

MOORING EQUIPMENT

Chocks, mooring rings, bitts, and fair-leads are used in handling and fastening the mooring lines of a vessel. In some cases, plain, open, or closed chocks are used. These are shown in Fig. 416.

Chocks and Mooring Rings. Closed chocks are used where the pull would tend to lift the lines out of open chocks. Roller chocks reduce the

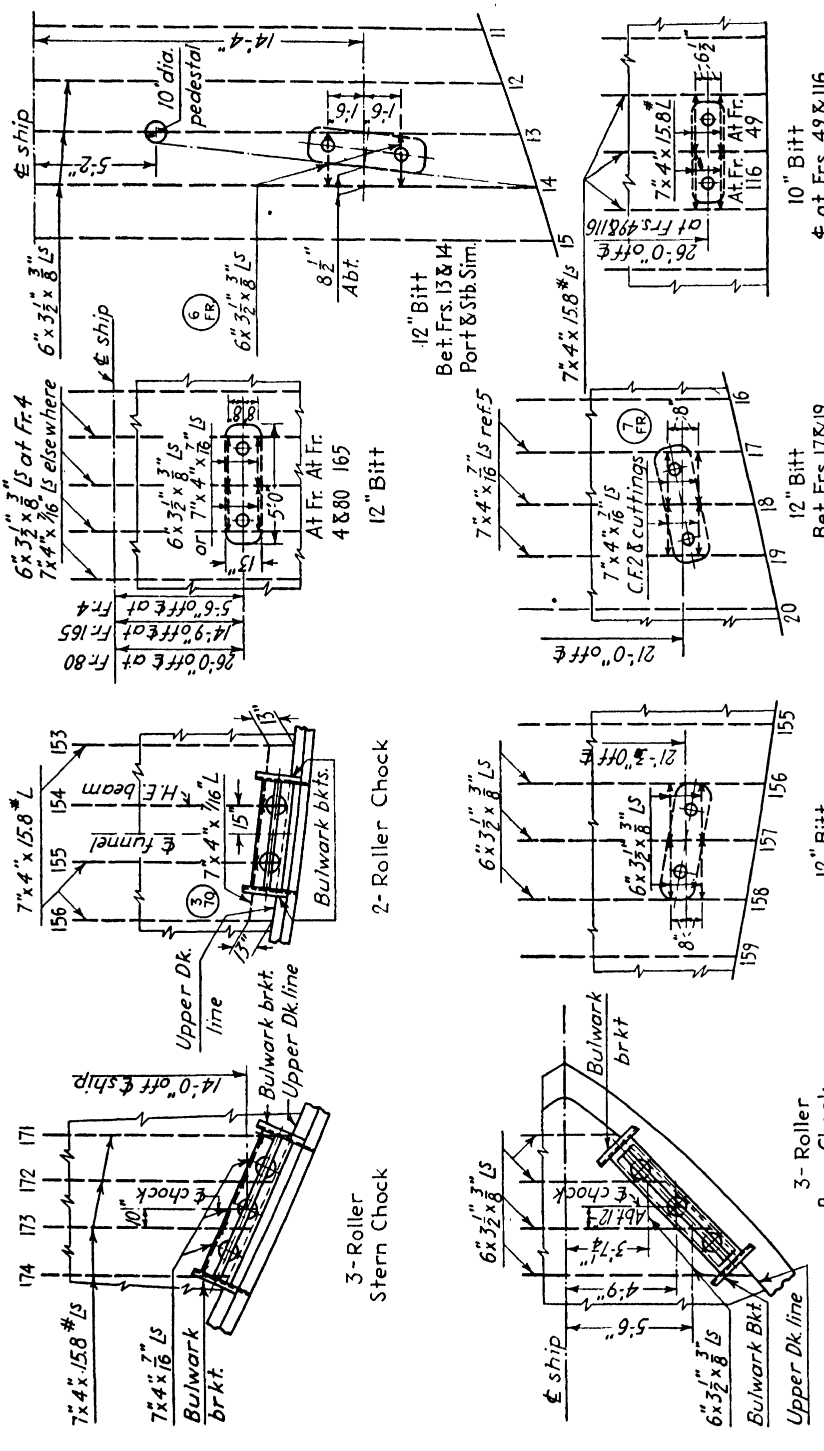


FIG. 417.—Various types of chocks and their arrangement and dimensions for installing on the ship.

wear on the lines and are located at points at which lines are used to warp the ship into the piers with the aid of capstans on the ship.

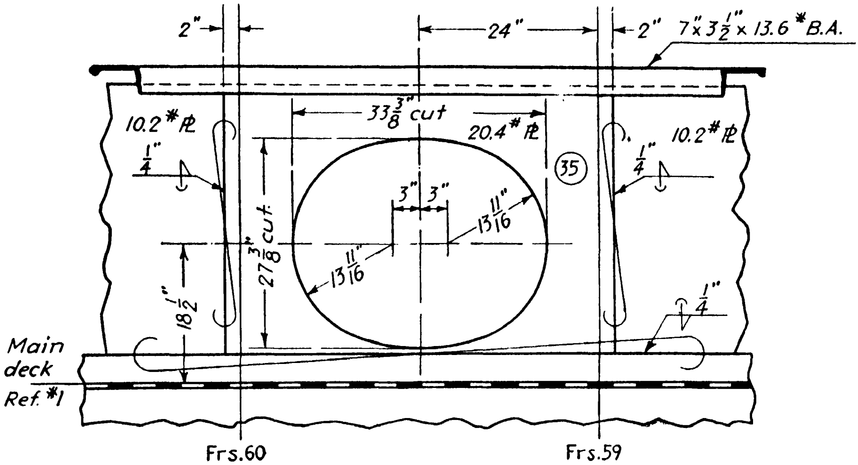


Fig. 418.—The location and opening in the bulwark for mooring rings.

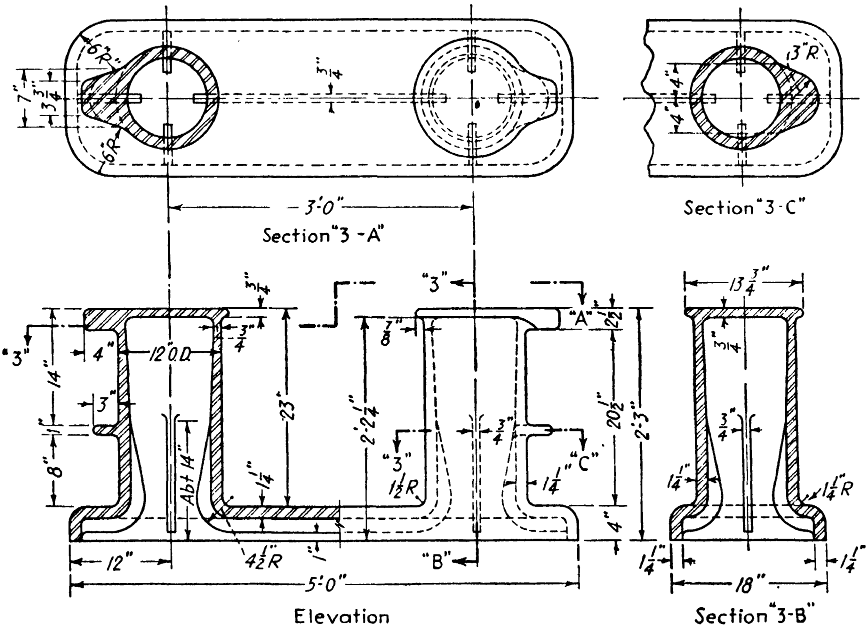


Fig. 419.—A cast bitt.

Mooring rings are used to pass lines through the bulwark or through shell plates and consist of half-round bars shaped to the specified size. In some cases, they are castings welded or riveted to the bulwark or shell plating to prevent chafing the lines.

In Fig. 417 are shown various types of chocks and their arrangement and dimensions for installing on the forward and afterends of a ship. In Fig. 418 are shown the location and opening in the bulwark for mooring rings.

Bitts. Bitts, which are vertical posts used in making fast the lines of a vessel, may be cast in the smaller sizes, as shown in Fig. 419, or may be built-up welded construction, as shown in Fig. 420.

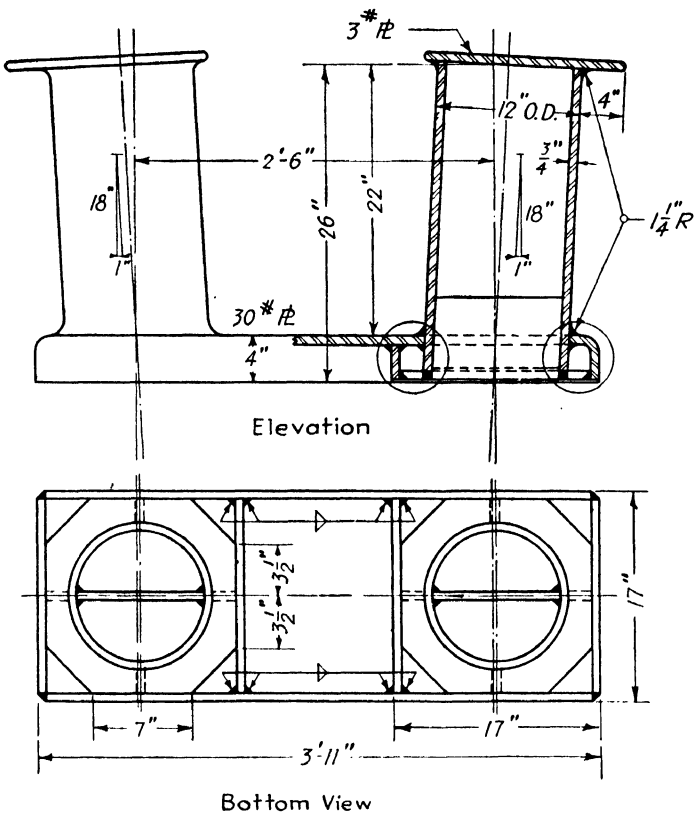


FIG. 420.—A built-up welded bitt.

The casting types are usually secured to the deck by means of bolts through the deck. They are laid off by lifting templates from the bitts themselves and applying them to the deck for drilling.

The welded type is usually attached to the deck by means of welding, as shown in Fig. 420, which specifies the height of the base of the bitt above the deck plating.

No great amount of difficulty need be experienced in setting this work if drawings and dimensions are closely followed. In Fig. 421 are shown the arrangement and location of bitts at the forward and after ends of the ship.

Fair-leads. Fair-leads must be set in line with the drums of the winch to keep the lines clear of possible obstructions and to ensure a straight lead of the lines to the drum. If lines are being hauled tight with a winch, they usually pass over a fair-lead between the winch and the bitt.

The method of setting the fair-lead foundation and fair-lead is shown in Fig. 421. Fair-leads are usually set after the winch and bitts are in place. A chalk line is passed over the winch drum and bitt and held off from each by one-half the diameter of the hawser to be used. That is, if a 3-in.-diameter hawser is to be used, the chalk line is held $1\frac{1}{2}$ in. from the drum, the bitt, and the fair-lead.

The figure gives the approximate location and angle of the fair-leads. Some slight adjustment may be necessary after the chalk line is tried, so that there will be no possibility of the line slipping or binding.

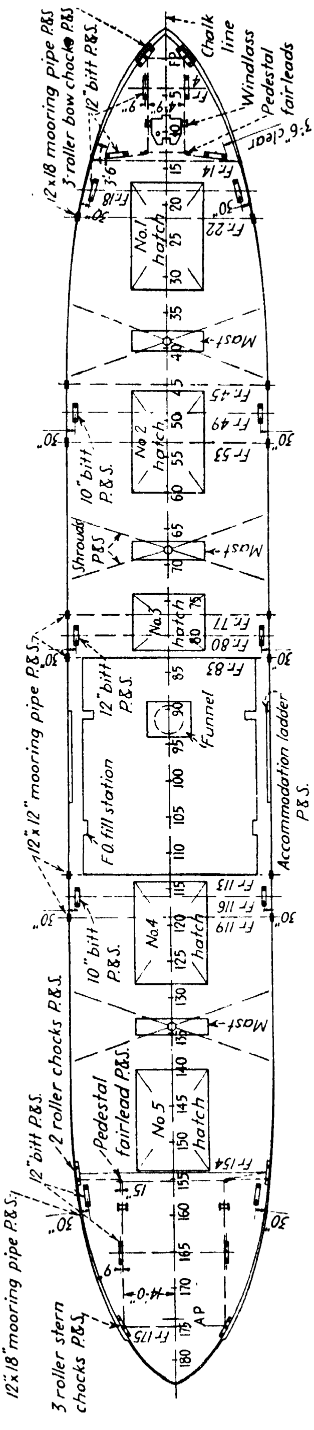


FIG. 421.—Arrangement and location of bitts and fair-leads.

SHAFT STRUTS

Vessels having more than one shaft usually require the use of castings called *struts* for the purpose of supporting the shafting after it leaves the hull of the ship. Struts must be set to the proper line of the shafting. They are secured to the hull of a ship by arms extending from the barrel of the strut to webs, or foundations, provided on the inside of the hull for attachment.

Some struts are cast in one piece. Other types are designed with the arms welded to the barrel, as shown in Fig. 422. In either case, box molds are made from the body plan to fit between the strut arms. The box molds are applied on the castings for the purpose of machining the strut palms to the designed lines, or to fit the structure of the ship.

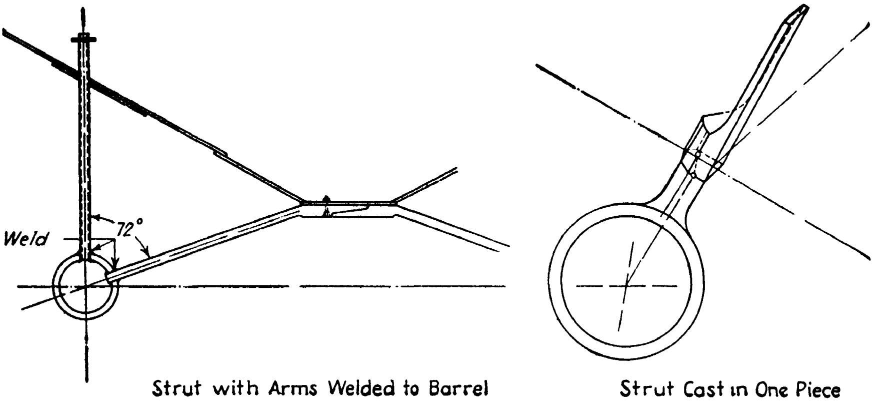


FIG. 422.—Struts cast in one piece and strut designed with arms welded to the barrel.

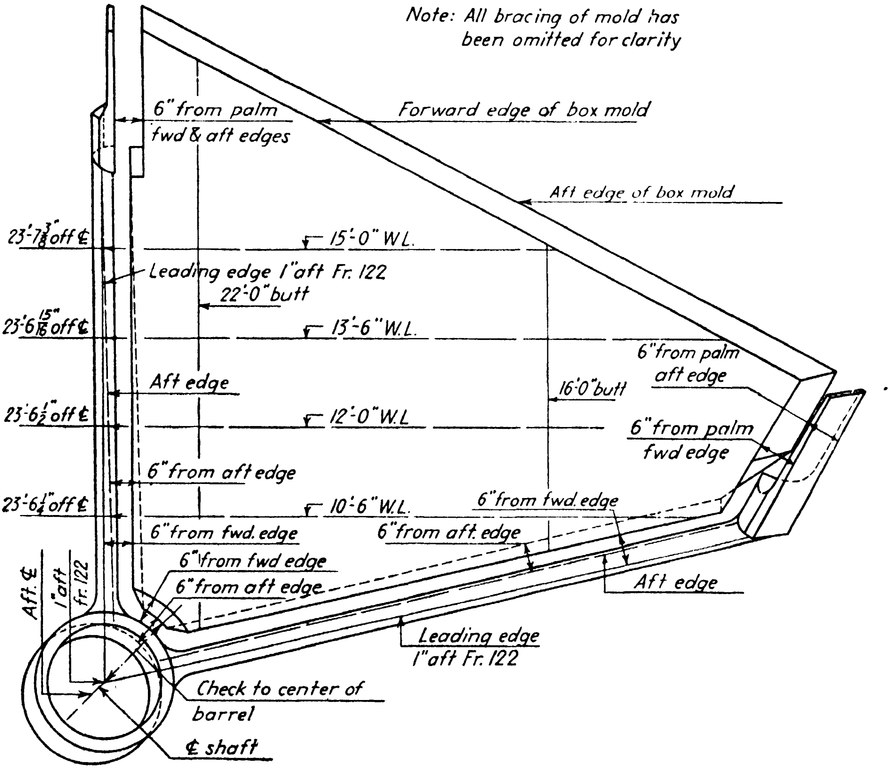


FIG. 423.—Box mold applied to welded and cast types of struts.

On welded struts the box mold is used for setting and bracing the strut arms in their proper position for welding so that these will fit the structure of the hull after the barrel has been set to the line of the shaft. In Fig. 423 is shown the box mold applied on a strut.

Where the strut palms are machined off to fit against webs provided inside the hull of the ship, it is much more difficult to hold the barrel to the line of the center of the shaft and, at the same time, to create a good fit on both palms.

The welded type of strut is much easier to set than the one-piece casting, mainly because of the type of structure used for securing it on the inside of the hull. This type of structure can be readjusted to suit the strut arms much more easily than that used for the riveted type of connection.

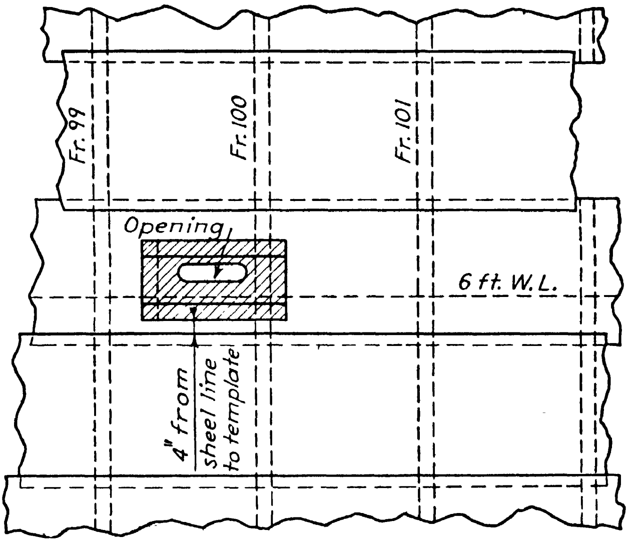


FIG. 424.—Template used for cutting openings in the shell for strut arms.

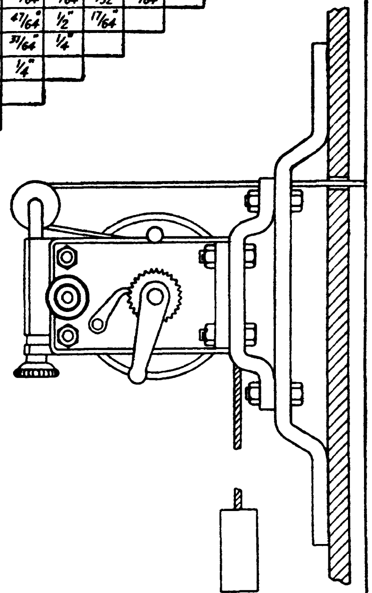
The line of shafting is generally provided by the steam engineers or outside machinists from the base line of the ship, furnished by the shipwrights. The openings where the strut arms penetrate the shell are laid off by the shipwright from templates secured from the mold loft and applied from the water line and frame line, together with a pitching spot from a convenient sheet line or shell-plate edge (see Fig. 424).

Figure 424*A* is a sag chart of steel line used for alignment of shafting and other work on which steel lines are used. It shows the amount of sag in various lengths of line which have to be used.

In Fig. 425 is shown the arrangement of shafting in a vessel with the locations of the struts and tube castings.

Before or during the time when the openings are being laid off for burning in the shell, a foundation must be provided under each opening for the struts. This foundation is built so that the barrel, when landed

10'	20'	30'	40'	50'	60'	70'	80'	90'	100'	110'	120'	130'	140'	150'	160'	170'	180'	190'	200'	210'	220'	230'	240'	250'	260'	270'	280'	290'	300'	310'	320'	330'	340'	350'
5/16"	19/32"	7/8"	1 1/8"	1 23/64"	1 37/64"	1 25/32"	1 61/64"	2 1/8"	2 17/64"	2 25/64"	2 1/2"	2 19/32"	2 43/64"	2 23/32"	2 3/4"	2 25/32"	2 25/32"	2 3/4"	2 23/32"	2 43/64"	2 19/32"	2 1/2"	2 25/64"	2 17/64"	2 1/8"	1 61/64"	1 25/32"	1 37/64"	1 23/64"	1 1/8"	7/8"	19/32"	5/16"	
19/64"	37/64"	27/32"	1 3/32"	1 5/16"	1 33/64"	1 23/32"	1 57/64"	2 3/64"	2 11/64"	2 19/64"	2 25/64"	2 15/32"	2 17/32"	2 37/64"	2 39/64"	2 5/8"	2 39/64"	2 37/64"	2 17/32"	2 15/32"	2 25/64"	2 19/64"	2 11/64"	2 3/64"	1 57/64"	1 23/32"	1 33/64"	1 5/16"	1 3/32"	27/32"	37/64"	19/64"		
19/64"	9/16"	13/16"	1 3/64"	1 17/64"	1 15/32"	1 21/32"	1 13/16"	1 61/64"	2 5/64"	2 3/16"	2 9/32"	2 23/64"	2 13/32"	2 29/64"	2 15/32"	2 15/32"	2 29/64"	2 13/32"	2 23/64"	2 9/32"	2 3/16"	2 5/64"	1 61/64"	1 13/16"	1 21/32"	1 15/32"	1 17/64"	1 3/64"	13/16"	9/16"	19/64"			
9/32"	35/64"	25/32"	1 1/64"	1 7/32"	1 13/32"	1 19/32"	1 47/64"	1 7/8"	2"	2 3/32"	2 11/64"	2 15/64"	2 9/32"	2 5/16"	2 5/16"	2 5/16"	2 9/32"	2 15/64"	2 11/64"	2 3/32"	2"	1 7/8"	1 47/64"	1 19/32"	1 13/32"	1 7/32"	1 1/64"	25/32"	35/64"	9/32"				
17/64"	17/32"	49/64"	63/64"	1 11/64"	1 23/64"	1 33/64"	1 43/64"	1 51/64"	1 29/32"	2"	2 1/16"	2 1/8"	2 5/32"	2 11/64"	2 11/64"	2 5/32"	2 1/8"	2 1/16"	2"	1 29/32"	1 51/64"	1 43/64"	1 33/64"	1 23/64"	1 11/64"	63/64"	49/64"	17/32"	17/64"					
17/64"	1/2"	47/64"	15/16"	1 9/64"	1 5/16"	1 29/64"	1 19/32"	1 23/32"	1 13/16"	1 57/64"	1 61/64"	2"	2 1/32"	2 3/64"	2 1/32"	2"	1 61/64"	1 57/64"	1 13/16"	1 23/32"	1 19/32"	1 29/64"	1 5/16"	1 9/64"	15/16"	47/64"	1/2"	17/64"						
1/4"	31/64"	45/64"	29/32"	1 3/32"	1 1/4"	1 25/64"	1 33/64"	1 5/8"	1 23/32"	1 51/64"	1 27/32"	1 57/64"	1 29/32"	1 29/32"	1 57/64"	1 27/32"	1 51/64"	1 23/32"	1 5/8"	1 33/64"	1 25/64"	1 1/4"	1 3/32"	29/32"	45/64"	31/64"	1/4"							
1/4"	15/32"	11/16"	7/8"	1 3/64"	1 13/64"	1 21/64"	1 29/64"	1 35/64"	1 5/8"	1 11/16"	1 47/64"	1 49/64"	1 25/32"	1 49/64"	1 47/64"	1 11/16"	1 5/8"	1 35/64"	1 29/64"	1 21/64"	1 13/64"	1 3/64"	7/8"	11/16"	15/32"	1/4"								
15/64"	29/64"	21/32"	53/64"	1"	1 9/64"	1 17/64"	1 3/8"	1 15/32"	1 35/64"	1 19/32"	1 5/8"	1 21/32"	1 21/32"	1 5/8"	1 19/32"	1 35/64"	1 15/32"	1 3/8"	1 17/64"	1 9/64"	1"	53/64"	21/32"	29/64"	15/64"									
15/64"	7/16"	5/8"	51/64"	61/64"	1 3/32"	1 13/64"	1 5/16"	1 25/64"	1 29/64"	1 1/2"	1 33/64"	1 17/32"	1 33/64"	1 1/2"	1 29/64"	1 25/64"	1 5/16"	1 13/64"	1 3/32"	61/64"	51/64"	5/8"	7/16"	15/64"										
7/32"	27/64"	19/32"	49/64"	29/32"	1 1/32"	1 9/64"	1 15/64"	1 5/16"	1 23/64"	1 25/64"	1 13/32"	1 13/32"	1 25/64"	1 23/64"	1 5/16"	1 15/64"	1 9/64"	1 1/32"	29/32"	49/64"	19/32"	27/64"	7/32"											
13/64"	13/32"	37/64"	23/32"	55/64"	63/64"	1 5/64"	1 5/32"	1 7/32"	1 17/64"	1 19/64"	1 5/16"	1 19/64"	1 17/64"	1 7/32"	1 5/32"	1 5/64"	63/64"	55/64"	23/32"	37/64"	13/32"	13/64"												
13/64"	3/8"	35/64"	11/16"	13/16"	59/64"	1 1/64"	1 3/32"	1 9/64"	1 11/64"	1 13/64"	1 13/64"	1 11/64"	1 9/64"	1 3/32"	1 1/64"	59/64"	13/16"	11/16"	35/64"	3/8"	13/64"													
3/16"	23/64"	33/64"	21/32"	49/64"	7/8"	61/64"	1 1/64"	1 1/16"	1 3/32"	1 3/32"	1 3/32"	1 1/16"	1 1/64"	61/64"	7/8"	49/64"	21/32"	33/64"	23/64"	3/16"														
3/16"	11/32"	31/64"	39/64"	23/32"	13/16"	57/64"	15/16"	63/64"	1"	1"	63/64"	15/16"	57/64"	13/16"	23/32"	39/64"	31/64"	11/32"	3/16"															
11/64"	21/64"	15/32"	37/64"	11/16"	49/64"	53/64"	7/8"	57/64"	29/32"	57/64"	7/8"	53/64"	49/64"	11/16"	37/64"	15/32"	21/64"	11/64"																
5/32"	5/16"	7/16"	35/64"	41/64"	45/64"	49/64"	51/64"	13/16"	13/16"	51/64"	49/64"	45/64"	41/64"	35/64"	7/16"	5/16"	5/32"																	
5/32"	19/64"	13/32"	1/2"	19/32"	21/32"	45/64"	23/32"	47/64"	23/32"	45/64"	21/32"	19/32"	1/2"	13/32"	19/64"	5/32"																		
9/64"	17/64"	3/8"	15/32"	35/64"	19/32"	41/64"	21/32"	21/32"	41/64"	19/32"	35/64"	15/32"	3/8"	17/64"	9/64"																			
9/64"	1/4"	23/64"	7/16"	1/2"	35/64"	37/64"	37/64"	37/64"	35/64"	1/2"	7/16"	23/64"	1/4"	3/64"																				
1/8"	15/64"	21/64"	13/32"	29/64"	31/64"	1/2"	1/2"	31/64"	29/64"	13/32"	21/64"	15/64"	1/8"																					
1/8"	7/32"	19/64"	23/64"	13/32"	7/16"	7/16"	7/16"	13/32"	23/64"	19/64"	7/32"	1/8"																						
7/64"	13/64"	17/64"	21/64"	23/64"	3/8"	3/8"	23/64"	21/64"	17/64"	13/64"	7/64"																							
3/32"	3/16"	1/4"	19/64"	5/16"	21/64"	5/16"	19/64"	1/4"	3/16"	3/32"																								
3/32"	5/32"	7/32"	1/4"	17/64"	17/64"	1/4"	7/32"	5/32"	3/32"																									
5/64"	9/64"	3/16"	7/32"	15/64"	7/32"	3/16"	9/64"	5/64"																										
5/64"	1/8"	5/32"	3/16"	3/16"	5/32"	1/8"	5/64"																											
1/16"	7/64"	9/64"	9/64"	9/64"	7/64"	1/16"																												
3/64"	3/32"	7/64"	7/64"	3/32"	3/64"																													
3/64"	5/64"	5/64"	5/64"	3/64"																														
1/32"	3/64"	3/64"	1/32"																															
1/32"	1/32"	1/32"																																
1/64"	1/64"																																	



Dia. drum for steel line - $3\frac{1}{2}$"
Dia. center to center of weight rope - $6\frac{3}{4}$"
Weight - 30.25 lb.

Tension in steel line = $30.25 \times \frac{6.75}{3.5} = 58.34$ lb.

No. 7 music wire - Dia. 0.018" - weight per ft. 0.00088 lb.

FIG. 424A.—Sag chart of steel line for alignment of shafting.

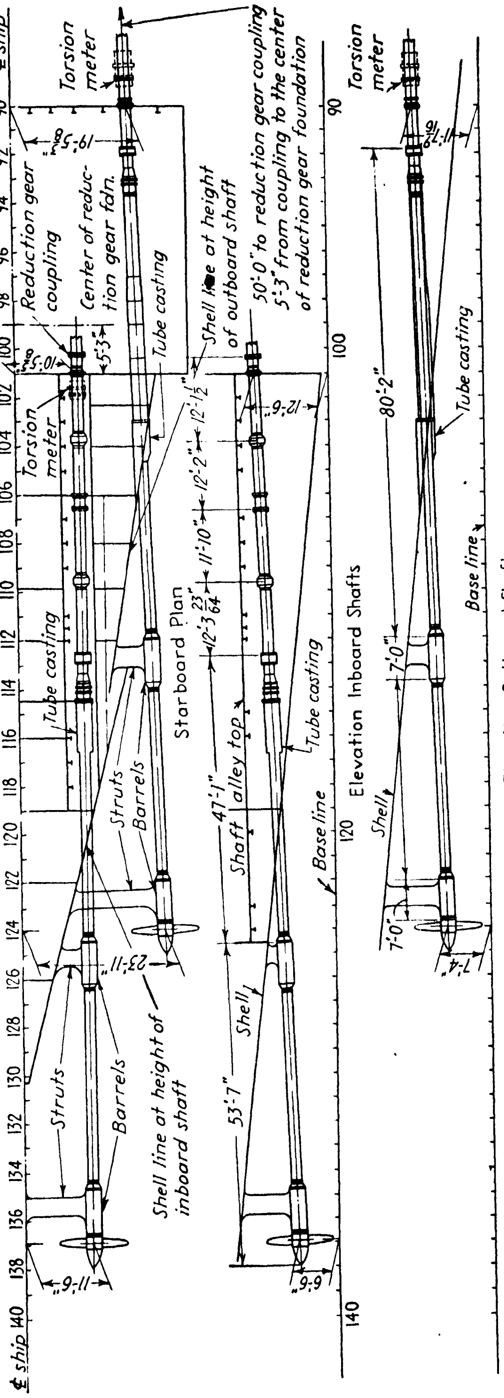


FIG. 425.—Arrangement of shafting in a vessel with locations of struts and tube castings.

on it, will center approximately at the center of the shafting. The foundation is usually built with the top parallel to the line of the shaft, but 42 in. below its center. This provides sufficient room for blocking and wedges under the barrel, as shown in Fig. 426.

When the openings have been cut in the shell and foundations for the struts have been completed, the struts can then be placed in position.

No attachments are made to the strut arms in the hull of the ship until all welding on the hull has been completed to the weather deck, so

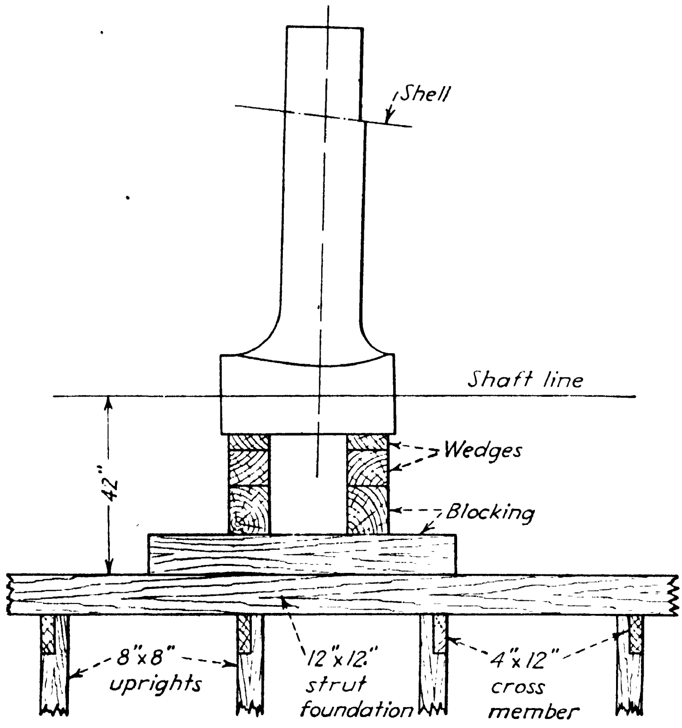


Fig. 426.—Foundation for supporting shaft strut temporarily in position.

that there will be no danger of the struts moving to any extent after they have once been set.

After all welding in the area of the struts and tube casting has been finished, the final wire along the center line of the shafting can be run.

For the struts to be set in their proper fore-and-aft position to suit the length of a shaft, the shaft rod is installed parallel to the centerline wire. This rod is marked with the location of the strut barrels so that they will be set in their proper fore-and-aft position. This is to ensure that the bearings will be located in the proper position on the shaft. The shaft rod is applied from a point on the reduction-gear foundation, which must be at right angles to the center line of the shaft, as shown in the arrangement of shafting in Fig. 425.

Setting the Strut Casting. After the shaft line and rod have been placed in position, the shipwright can begin work in the final setting of the struts. The after struts are usually set first, then the intermediate, and finally the tube casting.

To adjust and to assist in holding the struts after they have been set to the shaft line, four steamboat jacks with flat-bar straps of lengths to suit are attached to clips welded to the strut barrel and shell, as shown in

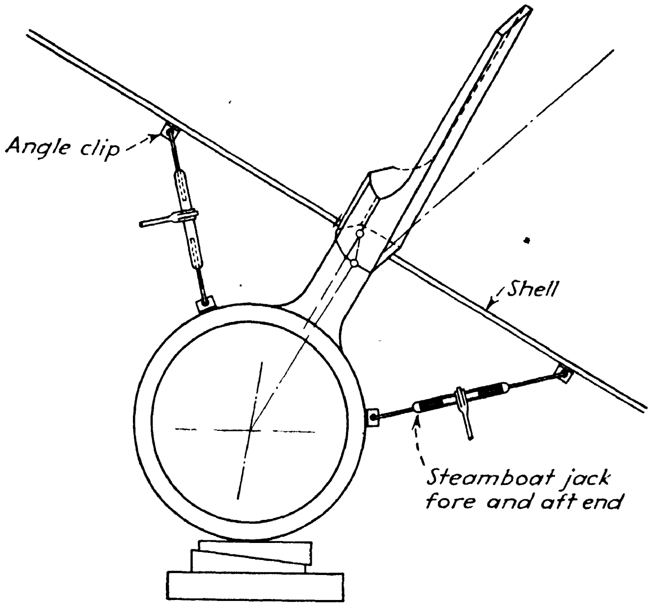


FIG. 427.—Steamboat jacks being used with flat-bar straps to set struts.

Fig. 427. In adjusting the strut to the proper height, one strap and turnbuckle should be led up and aft and another up and forward. In adjusting the strut in a transverse direction, one steamboat jack and strap should be led inboard and aft and one inboard and forward.

A hydraulic jack and wedges may also be used under the barrel for raising the strut barrel.

It will be found that in setting the strut barrels to the shaft line it is best to set the struts to the correct horizontal center first, and then to set them to the vertical center. After this the strut is then adjusted to suit the shaft rod to set it in its fore-and-aft position. It will be found that some slight adjustment will have to be made on all the straps and jacks until all points check. When the struts have been set to the shaft line, they should be securely braced with heavy structural shapes, as

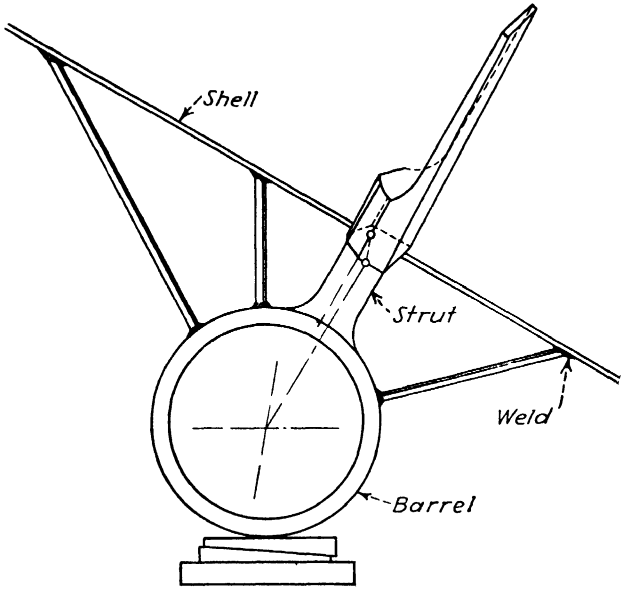


FIG. 428.—Bracing struts after they have been set to the shaft line.

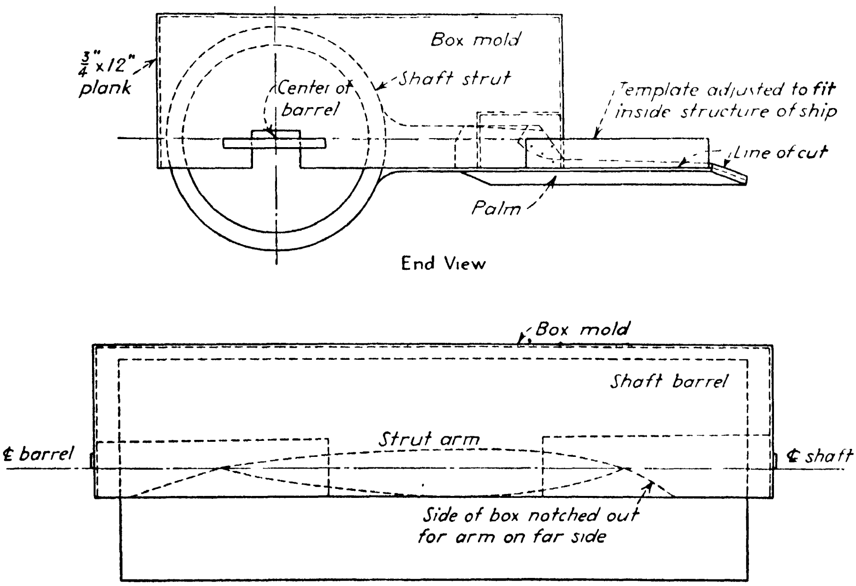


FIG. 429.—Template applied to one-arm strut for the purpose of machining off palm.

shown in Fig. 428, so that they will not move while the connections are being made up and riveted or welded.

The same procedure is used in setting both the after and intermediate struts.

Single-arm Struts. On some ships the intermediate struts have only one arm instead of two. The method for setting these is fundamentally the same as for the two-arm struts, though the process is generally much easier. In Fig. 429 is shown a template applied to a one-arm strut for the purpose of machining off the face of the palm to fit the inside structure of the ship.

After the struts have finally been set and the structure fitted around them, welding and riveting can be performed to secure them permanently in position. However, while this work is being done, the shipwright should closely observe the position of the strut with respect to the wire along the center of the shaft to see that it does not move to any great extent.

If any considerable difficulty is experienced in lining up the strut and tube castings, it is sometimes possible to make a slight adjustment in the height of the line at the after strut to create a better opportunity for adjustment of the two remaining castings. This movement of the line cannot, however, be much more than $\frac{1}{4}$ to $\frac{1}{2}$ in. in either direction, and the line should not be moved unless absolutely necessary.

THE TUBE CASTING

In preparing to set the tube casting, which partly penetrates the hull of the ship, with the other portion extending on the inside of the hull, extreme care must be exercised not to cut too large an opening for the tube. The tube casting is usually installed in the ship through an opening cut in the shell from a template obtained from the mold loft. This is applied in somewhat the same manner as for the openings for strut arms, after the shell plating has been set on the cradle and before the inside structure of the ship is put into place. The opening should be no larger than is necessary for the tube to pass through the shell, so as to afford opportunity for adjustment of the casting to the shaft line and to allow sufficient material left around the casting to fit the rabbet provided in the casting for the setting of the shell.

When the casting is to be fitted to the shaft line, the shell plating should be wedged off and away from the casting, so that it can be moved to suit the shaft line without fouling the shell. Long straps will, of course, not be necessary with the steamboat jacks for setting the tube casting. It is sometimes possible to jack and shore the casting from the inside structure of the ship, which has already been secured into place.

When the casting has been set to the center of the shaft line, the shell is cut in to suit the rabbet in the casting. After this, the shell can be brought up hard against the casting. The casting can then be braced so that it will not move, and the work of setting the interior structure and connections to the tube can be done.

Where it is not possible to place the tube castings in the ship at an early date, it may be necessary to remove some of the shell plating in way of the tube casting before it can be installed. When this is done, the plating can be cut to fit around the tube casting after it has been set, by making a mold for each plate and fitting it to the casting.

CHAPTER XXXI

STANCHIONS

In large open spaces on a ship where there are few or no bulkheads to assist in supporting the deck structure, stanchions are placed to carry the load. These vary in type and construction, depending on the load

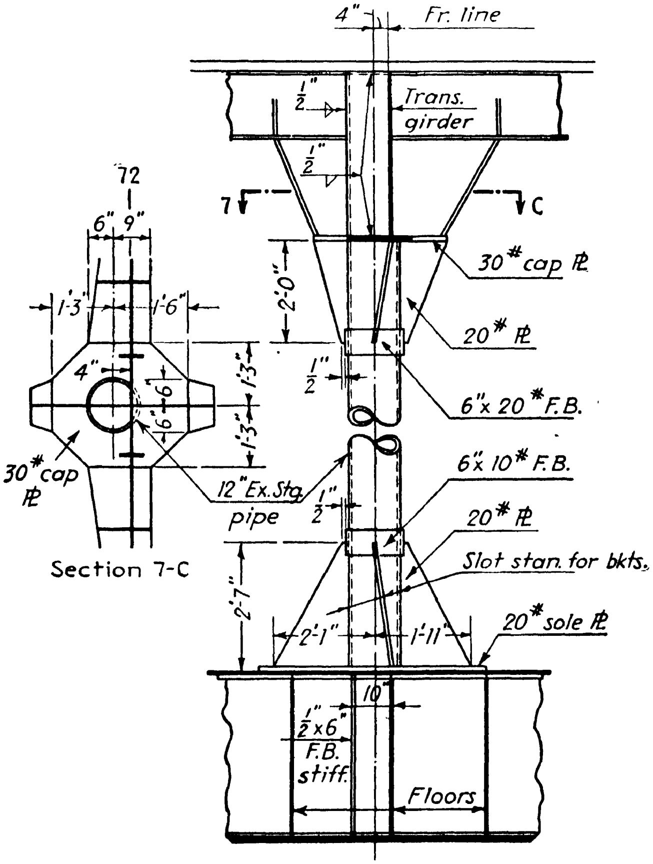


FIG. 430.—Stanchion with base plate and stiffening brackets.

that they are designed to carry. Structural H sections of various sizes are used, as well as heavy or extra-heavy pipe of varying diameters.

Construction. Either type is designed with stiffening at the top and bottom to suit the type of connection to be made at the top. The bottom usually consists of a base plate and stiffening brackets, as shown in Fig. 430.

All stanchions are not square to the base line, some being inclined in a transverse direction to clear machinery or structure.

Stools are generally used where stanchions are footed on inclined or radial surfaces, as on inner bottoms parallel to the shell at the side, or on the top of the shaft or pipe tunnel.

Laying off Location. From the plan, first establish the position of the stanchion at the top and bottom. If the structures supporting the decks have been built plumb one over the other, the stanchion should seat properly over any stiffening designed for it and, at the same time, be plumb.

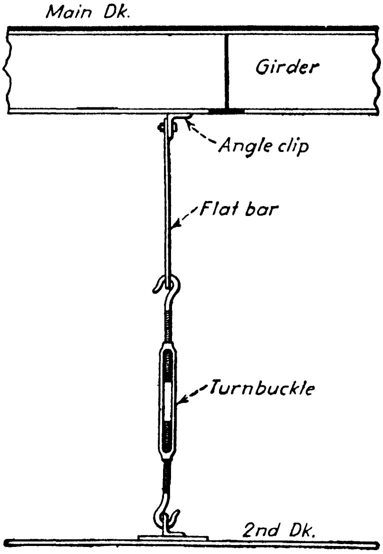


FIG. 431.—Deck pulled down with strap and turnbuckle to proper height.

Next, check the height of the deck from the offsets, also taking into consideration the thickness of the deck plating, which must be deducted from the between-deck heights. If the deck is low, it will have to be shored up to its correct height. If too high, it can be pulled down with a strap and turnbuckle, as shown in Fig. 431.

Since it is important that stanchions fit properly, one end of the stanchion is usually left with added material for fitting, so that any irregularities can be taken care of.

Installation. In some yards stanchions are set and completed by shipwrights. In others the shipwrights line up the location of stanchions and set the deck to the correct height, and then the stanchions are fitted into place by the ship fitters.

Stanchion at Right Angles. Figure 432 shows a stanchion at right angles to the base line of a ship and extending from the inner bottom to the deck above. A plumb bob should be used to check the stanchion because of its height. From the figure it can be observed that a doubling plate has been designed under the bottom of the stanchion. At the top the stanchion is fitted under a heavy transverse girder; therefore, if this has not been set plumb over the doubler provided at the bottom, it will not be possible to set the stanchion plumb, as both the top and bottom points are fixed.

With a steel tape or a piece of batten, measure the height from the top of the doubler on the inner bottom to the underside of the transverse girder. It is assumed that the stiffening brackets at the top have been left loose until after the stanchion has been fitted.

If the brackets at the bottom have been cut to fit the designed lines of the top of the inner bottom, it may be assumed that they will fit when the

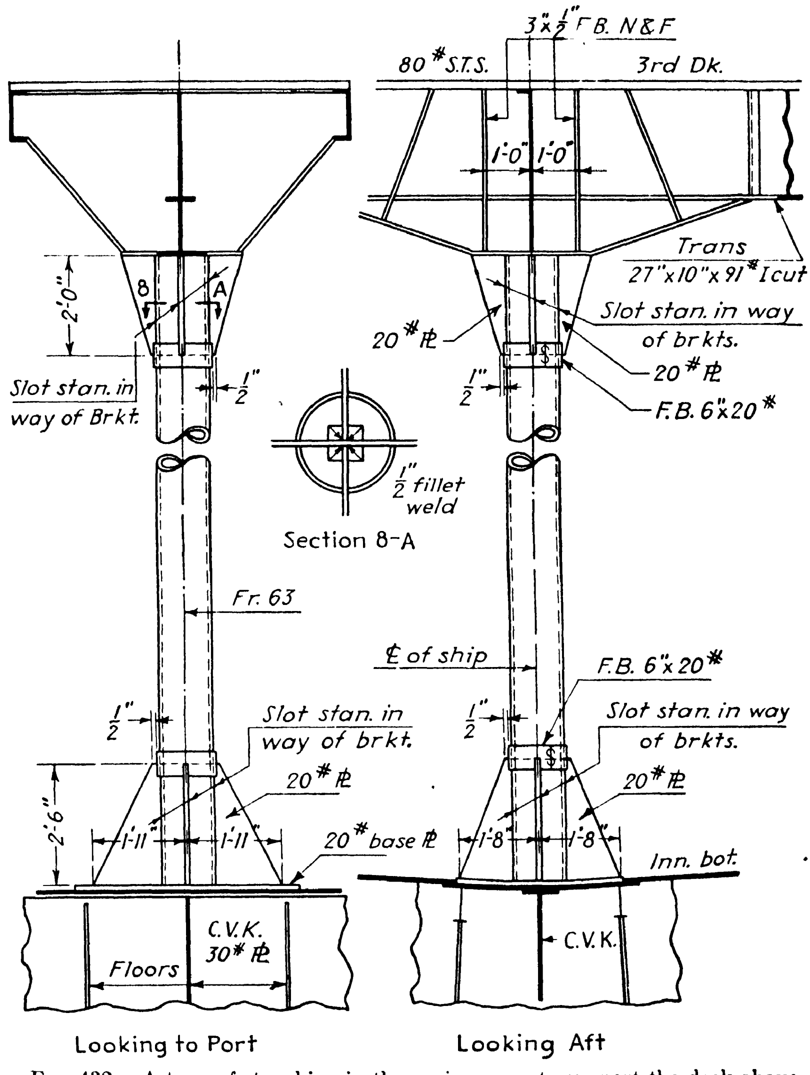


FIG. 432.—A type of stanchion in the engine room to support the deck above.

stanchion is in place, as there is sufficient stiffening at this point to prevent any great amount of distortion. This can be checked from observation. If the fit looks questionable, it may be well to fit a mold on the top of the tank top and then check this against the bottom cuts of the bracket. The tape or batten may then be applied from the bottom of the stanchion to the cut at the top. As a measure of safety, it is well to cut the stanchion at least ¼ in. long. After it has been placed into position, any irregularities or bad fits at the bottom may be taken care of by scribing and burning. If the brackets at the bottom do fit, the additional ¼ in. may be removed by burning after the stanchion has been placed in its proper location. It will, of course, be necessary to shore the transverse girder up a little higher than the correct height to permit placing the stanchion in position.

The stanchion should now be checked for plumb. Some slight compromise may have to be made in order to fit the stiffening provided at the top and bottom and, at the same time, be at right angles to the base line. When the stanchion has been definitely set, it is tack-welded at

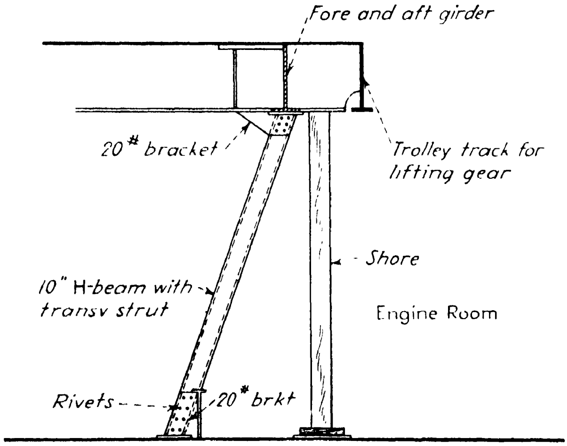


FIG. 433.—A stanchion in the engine room space inclined to clear machinery.

the top and bottom and turned over to the ship fitters for the fitting of the brackets at the top.

Inclined Stanchion. Another type of stanchion is shown in Fig. 433. It is located in the engine room but is inclined in a transverse direction toward the center to give support to the girder located under the engine-room hatch casing. Since a point plumb under the girder came directly over one of the units of machinery, it was impossible to set the stanchion plumb.

In setting this type of stanchion it is first necessary to check the height of the girder for correctness. The girder should then be shored to hold it at its proper height.

On this stanchion (which is an H-bar section) all rivet holes were laid off and punched when it was fabricated. However, the holes in the bottom, which were connected to the web provided for stiffening the bottom, were left blank. After the stanchion is placed in position, erection bolts to hold it in place are installed at the top. It is then set in its proper position and wedged up until it bears hard against the bottom of the girder. It is then tack-welded on each side, the holes are drilled into the web at the bottom, and the job is turned over to the ship fitters for the remainder of the fitting.

Stanchion Footed on a Stool. Figure 434 shows a stanchion that is footed on a stool on top of the shaft alley on the center line of the ship. The stool, which is fabricated and cut to the proper radius of the shaft alley, is first set in position on top of the shaft alley. The top of the stool is designed to be 15 in. above the top of the shaft alley and is level in both a fore-and-aft and a transverse direction. When the stool has

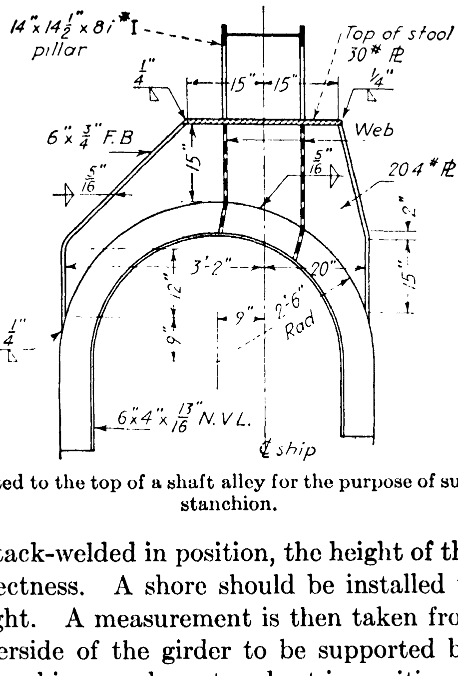


FIG. 434.—A stool fitted to the top of a shaft alley for the purpose of supporting the foot of a stanchion.

been placed and tack-welded in position, the height of the deck should be checked for correctness. A shore should be installed to hold the deck to its proper height. A measurement is then taken from the top of the stool to the underside of the girder to be supported by the stanchion. After this, the stanchion can be cut and set in position and made plumb with the use of the plumb bob. Then it should be tack-welded at the top and bottom and the job turned over to the ship fitters for the remainder of the fitting.

Between-deck Stanchion. In Fig. 435 is shown a between-deck stanchion. This is a very simple type, being a 5-in. standard pipe fitted with a sole plate at the bottom and cut in under the transverse girder at the top. After checking and shoring the deck to the correct height, a measurement is taken of the length of the stanchion and the pipe cut and placed in position. It is than tack-welded and made ready for production welding.

In laying off the cut line for a pipe stanchion after the height has been established at one point on the pipe, wrap a piece of cardboard that has a straight edge tightly around the pipe at the point of cutting, and trace in with soapstone, provided that the top of the stanchion is to be cut square. On between-deck stanchions a spirit level and declivity board may be used for plumbing.

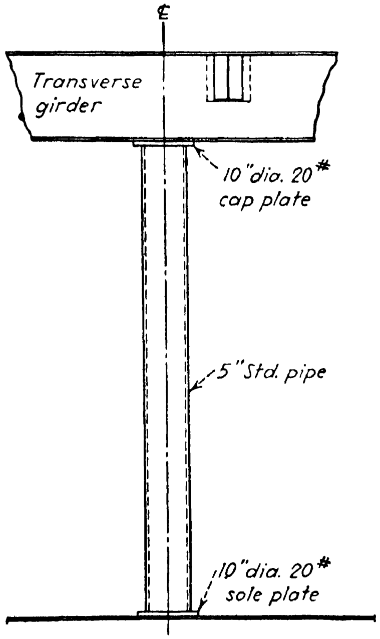


Fig. 435.—A simple form of between-deck stanchion

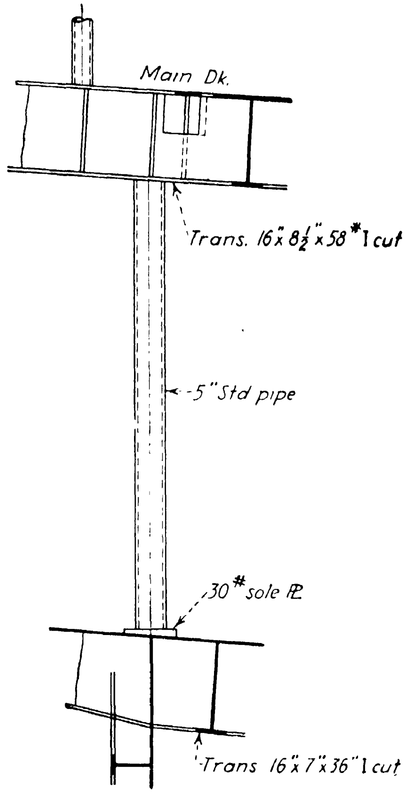


Fig. 436.—A stanchion fitted under a deck which is inclined

Installation on an Inclined Deck. On stanchions that are fitted under deck girders where the deck is inclined and not parallel to the base, as shown in Fig. 436, it may be necessary to fit a template, made the full width of the stanchion, in the exact position in which the stanchion will be placed. The template is then laid on the stanchion and the stanchion marked and cut.

CHAPTER XXXII

DRAFT FIGURES AND LOAD AND PAINT LINES

All vessels, regardless of type and size, require draft figures as well as load and paint lines, which indicate the depth to which the vessel extends in the water when loaded.

DRAFT FIGURES

Draft figures are usually read from the lowest point of the keel of a vessel. They are used to determine the amount of water that the vessel is drawing. Ships are also provided with internal draft gauges, which can be read from the inside of the ship. They should coincide with the outside draft figures.

From Fig. 437 study the point from which figures are to be applied, together with their position on the hull.

Draft figures are usually provided at the bow and stern of the ship. On particularly large ships a set of draft figures may be required at the midship part.

Draft figures should be established from a straight line extended from the lowest point of the keel plating. This is particularly true if three sets of draft figures are to be installed. Otherwise, when the ship is in the water, the figures will not coincide.

First, establish the vertical position and then the point from which the figures will be applied. The vertical position is usually given from a frame station.

To establish the straight line under the ship, erect straightedges 6 in. below the bottom of the keel at intervals of 50 ft. from the forward to the after perpendicular. Now, sight across the top of the straightedges. If the ship is particularly long, a transit, or dumpy level, may be used for this purpose. Set the instrument at either of the end straightedges. The hairline in the telescope should be set at the same height as the straightedge. By working the adjusting screws the telescope can then be tilted until it is in line with the other end straightedge. Check at each straightedge to determine its alignment with the two end straightedges. If any of the straightedges do not check within a reasonable amount, say $\frac{1}{4}$ to $\frac{3}{8}$ in., move straightedge forward or aft, reset at another point the same distance below the keel, and then check for alignment. Where irregular settlement of the keel occurs, it may be necessary to ignore one or two of the straightedges, as it will be impossible to set them all in a straight line.

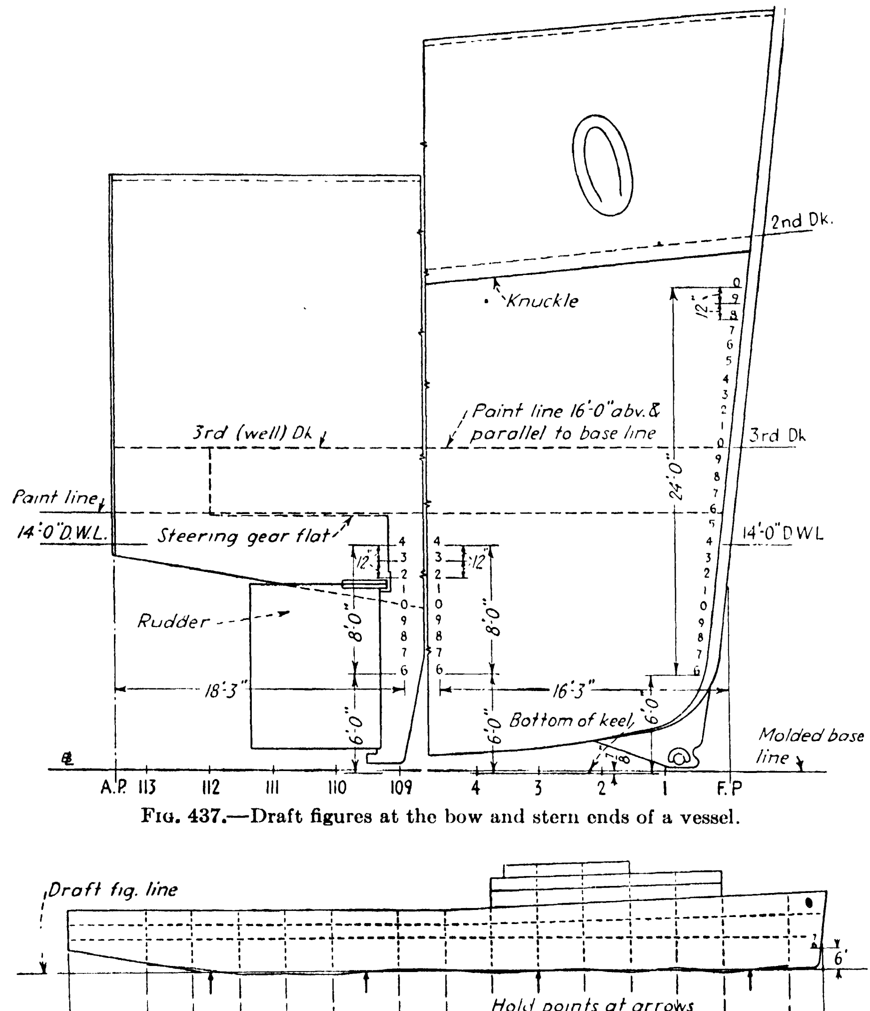


FIG. 437.—Draft figures at the bow and stern ends of a vessel.

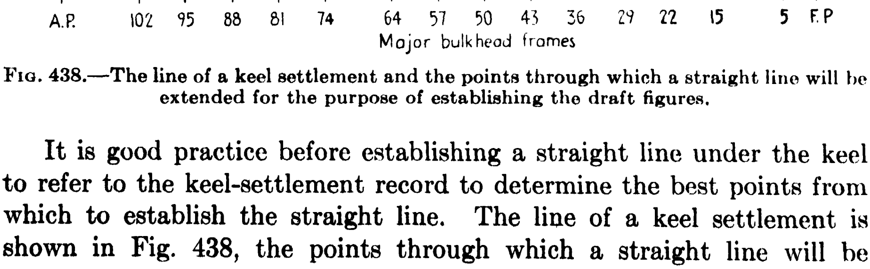


FIG. 438.—The line of a keel settlement and the points through which a straight line will be extended for the purpose of establishing the draft figures.

It is good practice before establishing a straight line under the keel to refer to the keel-settlement record to determine the best points from which to establish the straight line. The line of a keel settlement is shown in Fig. 438, the points through which a straight line will be extended being denoted by the arrows. Straightedges are then erected at these points and adjusted as above. This will be the plane from which the draft figures will be established.

Draft Figures at the Bow. If the shape of the hull in way of the figures is fairly straight, a template the width of the draft figures can

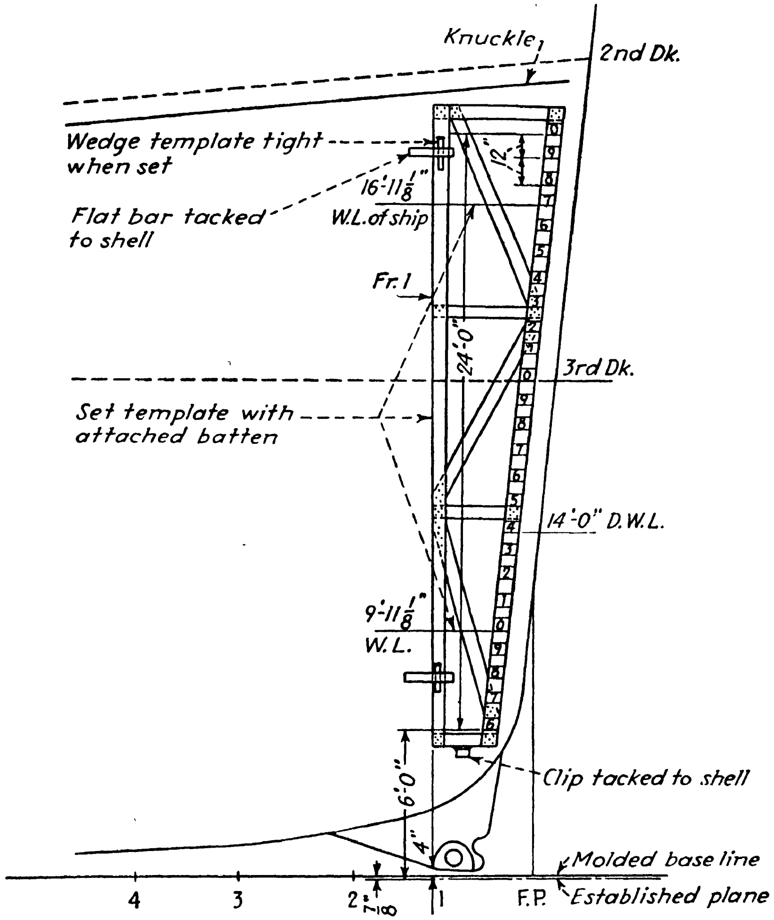


FIG. 439.—Template for applying draft figures where the shell is straight in the location of the draft figures.

be developed from the mold-loft body plan to be applied along the outside of the shell and the figures marked as shown in Fig. 439. This is the most accurate method to use when draft marks follow the contour of the stem.

If the draft figures are perpendicular to the base line and are located where the ship begins to take shape, they may be applied with a batten on which the figures have been marked with a tape.

First, erect two flat bars at each edge of the draft figures. This flat bar should be long enough to permit the batten to be clamped so that it will be parallel to the center line of the ship.

With a spirit level and straightedge, project the marks from the batten to the shell of the vessel, first at one edge of the draft figures; then, moving the batten to the other edge, repeat the procedure. With a short straightedge, mark lines through the spots on the shell, and center punch them ready for painting.

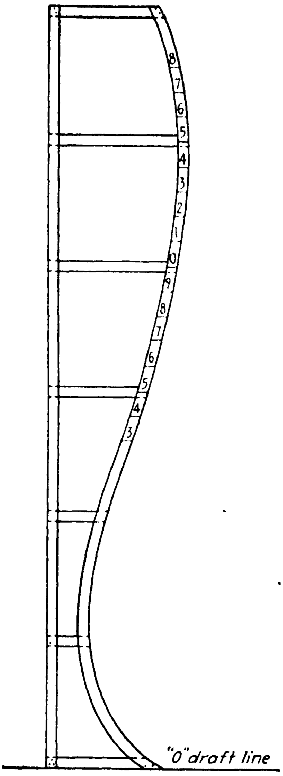


FIG. 440.—Template for establishing draft figures on a bulbous bow.

Another method recommended when figures have to be accurate and the shape of the ship makes it difficult to apply them, particularly in the case of ships with bulbous bows, is based on the use of a template (Fig. 440), procured from the mold loft, with the figures marked on it.

From the point from which the draft figures are to be applied, erect two straightedges 8 in. below this point and about 5 ft. each side of the location of the draft figures, as shown in Fig. 441.

Now, set two straightedges 8 in. in width in a fore-and-aft direction on top of the straightedges just erected. On top of these two, set the template at approximately the location of the figures, at right angles to the center line. It should then be plumbed up so that it will be at right angles to the fore-and-aft straightedges and then braced to them as shown.

Now, move the straightedges on which the template is set fore and aft until the template is opposite to the forward edge of the location of the figures, and mark the top and bottom of each figure on the shell plating. Move the template to the line of the after edge of the figures and mark on the shell in the same manner. Draw a line to intersect each of these points, and center punch the boundaries of the figures.

The same rig can be used on the opposite side of the ship, except that the figures will appear on the after side of the template when it is reversed.

The forward and aft edges of the figures should always be established first, so that the template can be applied as close to the figures as practicable.

Midship Draft Marks. When draft marks, or figures, are specified amidships, their location is first established in their fore-and-aft position. From the straight line established under the bottom of the ship, level out with a surveyor's level or straightedges to the side of the ship.

Temporary uprights may have to be erected for the purpose of supporting the straightedges when they are projected out from under

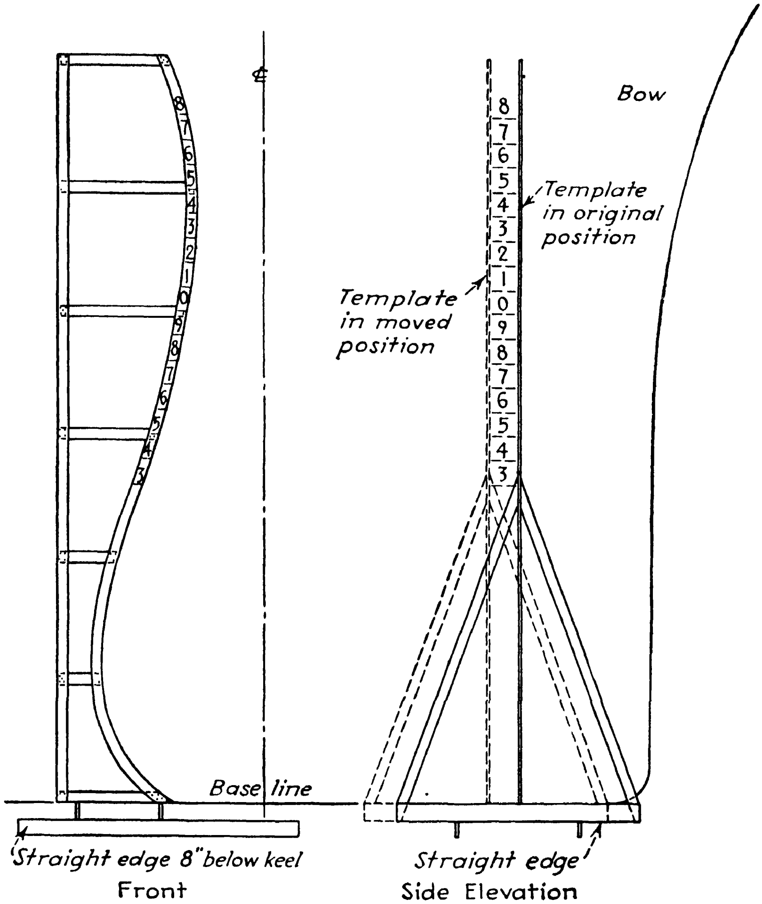


FIG. 441.—Method of applying template for draft figures on a bulbous bow.

the keel of the ship. These straightedges must, of course, be at right angles to the center line of the ship, and they can be erected approximately 3 ft. on each side of the location of the draft figures. When the straightedges have been set up and leveled, a fore-and-aft straightedge can be set across them. This should be parallel to the center line of the ship and in line with the side of the vessel.

A steel tape may be used in applying the points of the draft figures, the ring end of the tape being held to the bottom of the fore-and-aft straightedge and, at the same time, at right angles to the straight line under the bottom of the ship. This line, of course, is on the same declivity as that used in building the ship. Spots may now be marked on the forward and after edges of the draft marks and lines intersecting the spots marked on the shell and center punched.

After Draft Marks. The after draft figures are generally the easiest to install, particularly when they are designed to be placed on the rudder-

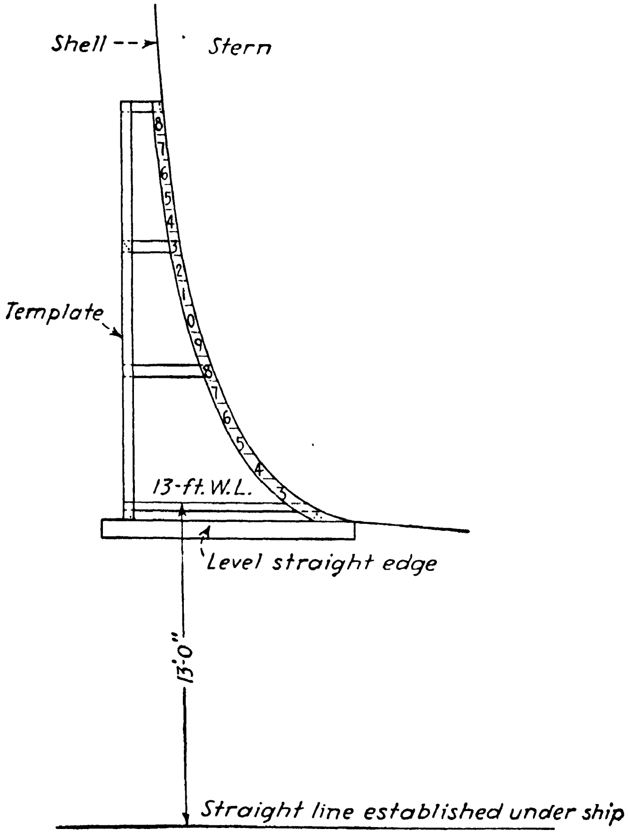


FIG. 442.—Method of applying draft marks at the afterend of a vessel.

post. They may be installed with a steel tape from a straightedge brought out level from the straight line established under the vessel in the same manner as the amidships draft figures.

On some vessels draft marks are located under the counter of the ship where there is considerable shape due to the rise of the keel. In this case, they are difficult to install accurately if care is not exercised. When draft figures are specified in such locations, straightedges are erected. To establish these draft marks a template may be obtained from the mold loft at a convenient frame each side of the location of the draft marks, as shown in Fig. 442. This template will extend to the bottom of the lowest figure specified. This may be 10 to 15 ft. above the bottom of the keel.

Straightedges similar to those erected forward should be set up in the same manner, but at a height that will clear the bottom of the ship at the location of the draft marks.

If, for example, the first draft figure specified is 15 ft. and the bottom of the template obtained from the mold loft is built to a point 15 ft. above the bottom of the keel, then the transverse straightedges, if they are 8 in. in width, should be set with the top 14 ft. 4 in. above the straight line. Straightedges 8 in. in width are then set fore and aft across the transverse straightedges and templates set at their proper frame station and on declivity. When the inside edge of the templates is bearing against the shell plating, the outside edge of the template, which should be built to a convenient buttock line, should check plumb and be at the proper distance from the center line of the ship. However, some slight variation will not greatly matter, the most important consideration being that the straightedges set fore and aft shall be parallel to the straight line under the bottom of the keel.

When the spots on the templates have been marked on the shell of the ship, the templates can be removed and set up on the opposite side. A chalk line may then be used to strike in lines intersecting the point at each frame. After this, the boundaries of the draft figures are center punched on the shell.

In obtaining the templates for applying the draft figures from the mold loft, the position of the straight line from the base line must be known and furnished to the mold loft, so that the bottom of the template will be the correct distance below the base line of the ship.

Some shipwrights resort to the declivity board and framing square when installing points for draft marks. With men experienced in the work, this is a much quicker method; but, with the inexperienced, it is much less accurate. It is therefore recommended that these short cuts be avoided by the beginner.

LOAD AND PAINT LINES

From the drawing shown in Fig. 443, study the requirements. Take the drawing to the mold loft so that the desired lines can be laid in on the body plan and battens lifted to be applied on the outside of the shell from a convenient working point. When the lines have been applied on the body plan, the loftsman will pick up from a convenient sight edge of shell plating or line of a deck a girth batten at intervals of 10 to 20 ft. at frame stations and establish on this batten the point of each line at given frames. This batten will be taken on the outside of the

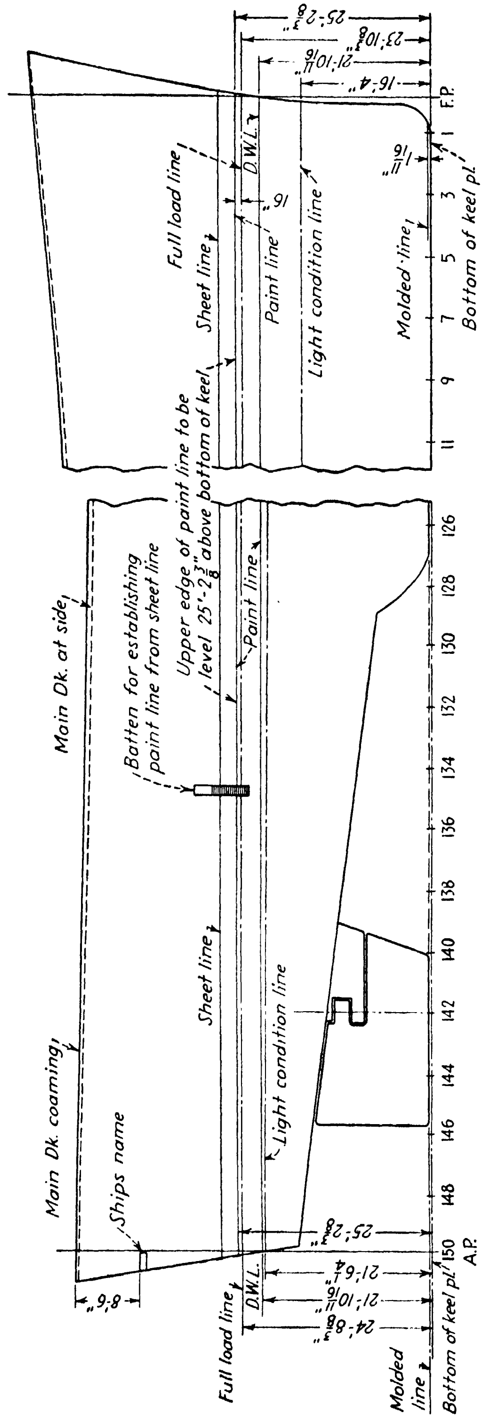


FIG. 443.—Load and paint lines.

shell plating and is to be applied on the ship in the manner shown in Fig. 444.

In applying the girth batten on the ship from a sight edge of shell plating, first sight the edge of the plating by the eye to see that it is fair. If the batten is applied to an unfair plate edge, the unfairness will be reflected in the lines being installed. If the sight edge of the plate is not fair, sight along the edge, and establish points that are fair. Have someone hold a pencil or soapstone at points not fair and raise or lower

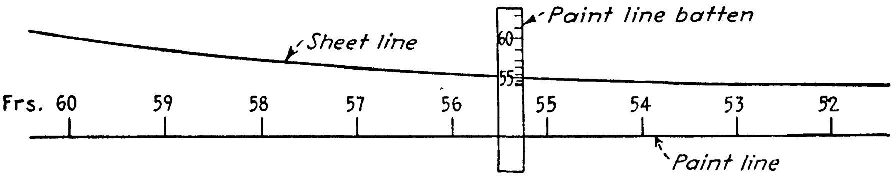
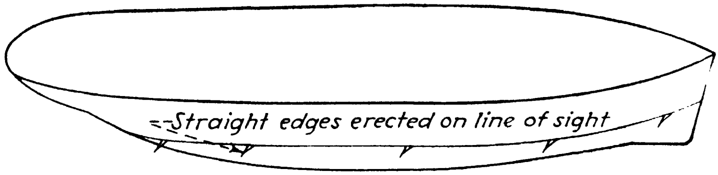


FIG. 444.—Method of applying batten on the outside of the shell plating for establishing paint lines.

them until they are fair to the eye. Then apply the batten from the fair line and put in spots at the frames corresponding to the batten.

If a deck line is used, the line of the deck will first have to be struck in on the shell with a chalk line. It should then be sighted and made fair and the batten applied in the same manner as from the sheet lines.

After all spots have been put in, they are sighted in for fairness. It may be necessary to strike through the spots with a chalk line before fairness of the line can be judged.



Note: Paint and load lines are faired in between straight edges by eye

FIG. 445.—Straightedges for fairing in paint and load lines.

On vessels with fine lines, it may be necessary to erect several straightedges from the spots in order to sight along the line for any distance (see Fig. 445).

If the bow or stern has lifted to any extent from welding shrinkage, the amount of lift will have to be considered in order that the line shall be straight as designed. That is, the line may have to be dropped from the spots by the amount that the bow or stern has lifted from the straight keel. If the amount of lift is great, the drawing room may have to be called in to make some adjustments in order that the lines shall tie in with the draft figures.

Care must be exercised, particularly at the ends of the ship, in developing a fair line. In order to fair in lines at the ends of the ship correctly, the shipwright must place himself in position with the plane of the line when sighting, for lines at this part of the ship will appear fair only when sighted on the plane of the line.

CHAPTER XXXIII

ESTABLISHING WORKING LINES

One of the most important parts of shipwright work is establishing working lines on the ship. As has already been stated (page 246), all lines are established from the monuments on the building ways.

The base line is checked from the base-line monuments at each side of the stocks. The center line is established from the centerline monuments on the shipway or from the datum monuments at the side of the shipways.

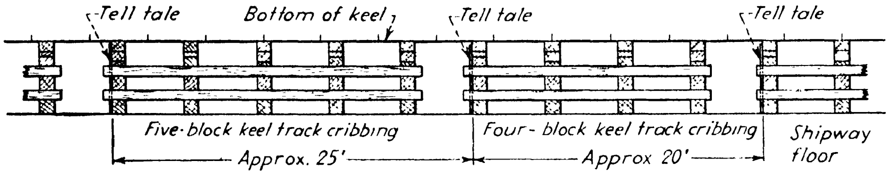


FIG. 446.—Arrangement of settlement telltales along the keel track.

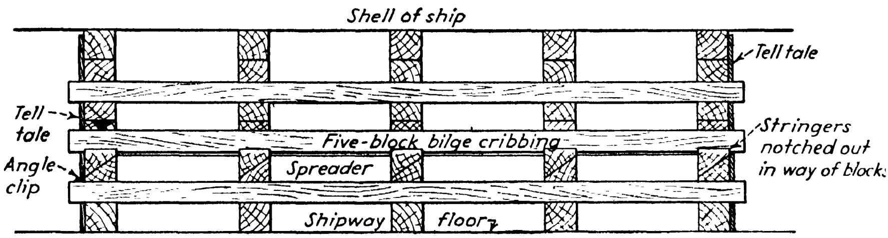


FIG. 447.—Settlement telltales at bilge cribbings.

Settlement of Vessel during Construction, Affecting Lines. As the steel is erected in the ship during construction, the blocks and shores under the ship tend to compress, thus causing the ship to settle. Because the greater portion of the weight of the ship is supported on the keel track, more settlement naturally occurs on the keel track than at the sides of the ship.

The space between the blocking closing together, as well as the compression of the flat-grained timber itself, produces settlement. This settlement is not always uniform and if not closely observed and corrected will become serious insofar as the alignment of the vessel is concerned.

Before the keel is laid, for the purpose of determining the amount of settlement and to prevent undue settlement at concentrated points, telltales are erected along the keel track at intervals of 20 ft. Telltales are shown in Fig. 446. On extremely large and heavy vessels, telltales are also established at the bilge cribbings to record settlement, as shown in Fig. 447.

The telltale rods consist of a 1¼- by 1¼- by ⅛-in. angle set on the shipway caps and held in a vertical position by a loose-fitting U clip, as

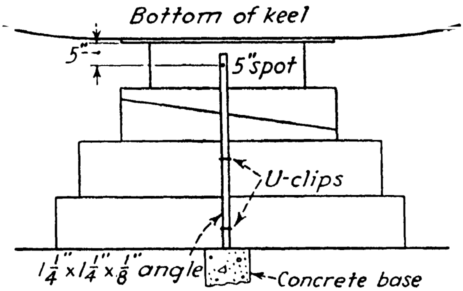


FIG. 448.—A typical form of telltale rod.

shown in Fig. 448. The top of the telltale is extended to within 3 in. of the keel of the ship.

After the telltale has been placed in position, a pitching spot 5 in. from the top of the keelblock is marked and center punched on the angle rod. Settlement can then be observed by measuring from the bottom of the keel to the pitching spot from time to time and can be recorded in a graph, as shown in Fig. 449. As successive checks are made of the keel

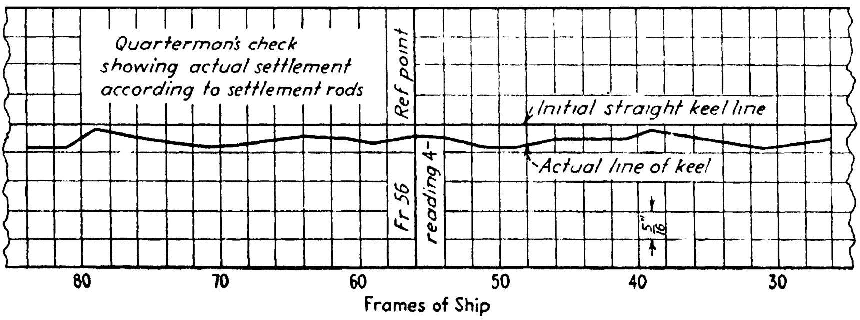


FIG. 449.—Graph showing keel settlement.

settlement, they can be plotted on the graph and any undue settlement quickly recognized.

Where undue settlement occurs, keelblocks should be hardened up by driving up the wedges, and additional shores should be installed on each side of the keelblocks to retard further settlement. As more weight is erected into the ship, further settlement will be revealed in the high spots. If this is greater than is thought desirable, shores can also be placed at these points.

It must be remembered that there must be no tendency to transfer the weight of the ship from the keel track to shores, thus possibly tripping the ship. However, the shores are changed from time to time to complete work under them, and settlement on the keel track is thus allowed.

The same principle is true with telltales at the bilge of the ship, where the weight is jointly supported by the shores and bilge cribbings. Should irregular settlement occur at these points, wedging up on the cribbings and additional shoring will tend to retard points of undue settlement similar to that on the keel track.

Another purpose that the bilge telltales have is as follows: From their readings it can be determined whether or not there is any tendency for the ship to list to one side or the other. However, if shores are installed symmetrically about the center line with the same amount of driving up on the wedges, this is not likely to occur.

After all the necessary telltales have been installed under a vessel, an elevation should be established on the telltales from a bench mark clear of the shipway to determine whether or not there is any settlement of the shipway foundations themselves. Should there be such settlement, this must be added to the amount of settlement recorded on the telltales from the keel of the ship to give a true picture of the actual shape of the ship.

Elevations should be established on the foremost and aftermost telltales on the keel track. Then a straight line can be shot through with a transit and measurements taken from the straight line to spots on the telltales, the end elevations being used as a reference point in determining whether or not any settlement of the telltales themselves has occurred.

Effect of Settlement in Establishing Heights from the Base Line. Because the settlement of a ship is not uniform on the keel track, the establishment of heights from the keel or the monument is checked by the extent of settlement at each side along the keel. From past experience it has been found that establishing the heights at the main transverse bulkheads and then intersecting these points with straight lines (which will then conform nearly to the shape of the keel) will cause the least possible trouble.

Owing to settlement, together with atmospheric temperature changes that affect the steel structure of the ship, the hull is constantly moving. Welding distortion and shrinkage also tend to add to this movement; therefore, *the only time when the base line of the ship is on the true grade on which the ship is being built is when the keel is laid.* Thereafter, points from the base line of the ship at the main transverse bulkheads are used, and any measurements between main transverse bulkheads are taken from a straight line intersecting the points at these bulkheads. That is, even though a deck is designed to be parallel to the base line of a ship, and if the deck were made so by cutting all the structure down to a straight plane, owing to the change in the hull this plane could not be held long enough to complete the deck, for it would be more than likely to change to some extent overnight.

In Fig. 450 the effect that settlement has in establishing heights for building the structure of the ship can be seen.

In combat ships where side-belt and internal armor are specified, and especially if this armor comes from the manufacturer machined to designed lines, a straight line must be adhered to regardless of the settlement, in order that the armor may fit. Any adjustment in the structure must be made at the top or bottom of the connecting parts, but the

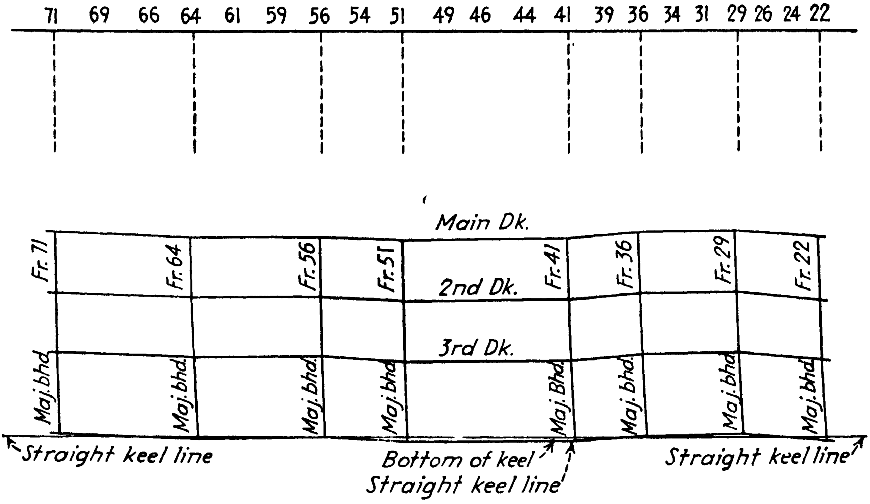


FIG. 450.—Effect of settlement in establishing heights for building the structure of a ship.

armor must be worked to a straight line, or true grade, of the ship; otherwise, much difficulty will be experienced, particularly at the ends of the armor.

Establishing the Center Line. When the keel is laid, the center line is established from monuments on the shipways and the keel laid to this line. The keel plating is then set to the center line and shored so that it will not move from it. When the keel is welded, a new center line is established on the keel plates from the monuments because, owing to welding distortion, some of the points may have been pulled slightly off center.

The structure above the bottom shell and keel is then erected and set to this center line. During the process of welding the structure, there may be other points that are distorted from the center line. Therefore, after the inner bottom has been laid and set, the true center line of the ship is again established by plumbing down to the monuments and sighting with a transit through these points.

In the sequence of construction the transverse bulkheads are now installed and are set to the center line established on the inner bottom.

In discussing the setting of the transverse bulkheads into the ship (page 298), it was stated that they were plumbed from the center line at

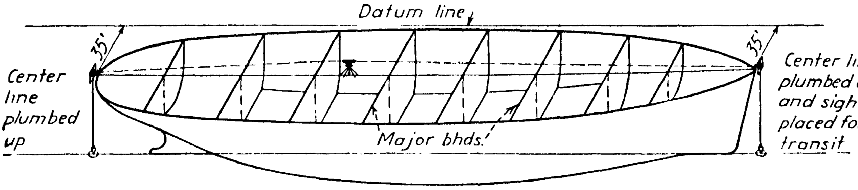


FIG. 451.—Establishing center line at the top of bulkheads from the datum line.

the top of the bulkhead to the center line on the inner bottom. Therefore, the center line at the top of the bulkhead follows the line of the center line on the inner-bottom plating.

The construction of the vessel up to the top of the bulkheads then progresses to the point at which it is necessary to establish the center line of the deck at the top of these bulkheads. The same method is used in plumbing up from the monuments or datum line as was used in establishing the center line on the inner bottom (see Fig. 451).

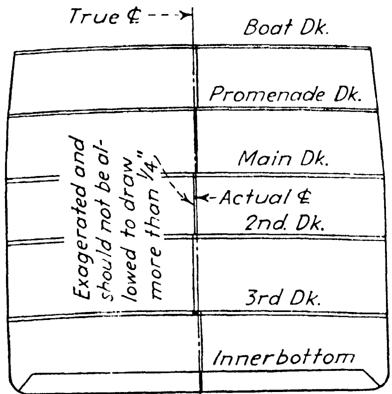


FIG. 452.—Actual center line of a vessel with respect to the true center line.

When the center line is brought up from the monuments and shot through with the transit throughout the length of the deck, it will be found that the centers of the bulkheads will not always intersect the straight line being established from the monuments, owing to the distortion of the ship and, in some cases, uneven settlement. However, the true center line is marked on all the bulkheads, and the necessary measurements are taken from it.

After the center line, which has been brought up from the monuments, has been established and marked on the bulkheads of the ship, it should not be moved again, for there will be further movement in the structure of the ship from the same causes explained in the foregoing. If an effort is made to change the center line each time a check is made, it will be necessary to shift it every day, which will greatly retard work in progress.

The same practice is used from deck to deck until the top of the ship is reached (see Fig. 452).

Establishing Square and Declivity Lines. For the ship to be built with the structure at right angles to the base line, or plumb, and for the structure in a transverse direction to be at right angles to the center line, it is necessary to work from a square declivity line at the declivity on which the ship is being constructed. To do this a starting, or initial, point that is marked with monuments is used. This line is carried up from the bottom of the stocks on the declivity on which the ship is being constructed and then established on each deck as it is erected and set. All fore-and-aft dimensions are then taken from this line.

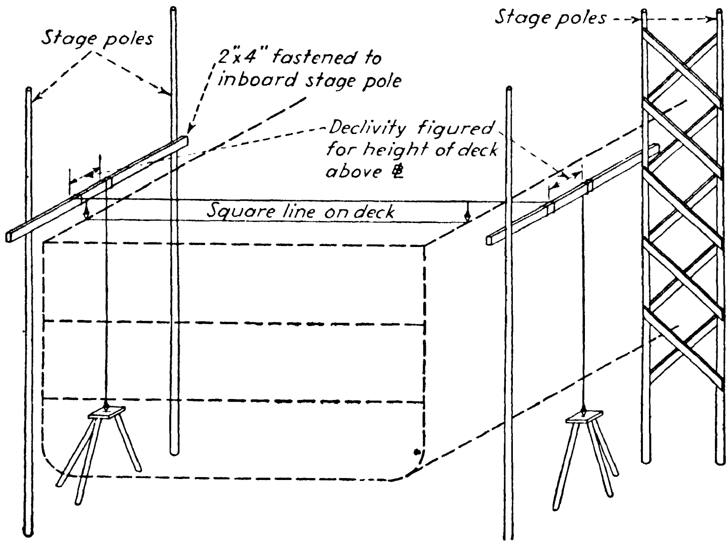


FIG. 453.—Method of projecting the line square to the base line from monuments.

Various methods of projecting the line up from the monuments are used. One uses a 2- by 4-in. timber nailed between the staging standards parallel to the base line and at the height of the deck on which the square line will be established. The measurement is then made from the monument to the timber and the amount of declivity in this distance calculated. A plumb bob is suspended by a wire from the timber so that it will intersect the point on the monument and the amount of declivity established from the wire. The same operation is performed on both sides of the ship.

A wire is then stretched across the ship to intersect the points on the 2 by 4, giving the position of the square line (see Fig. 453).

Another method is sometimes used on shipways that are designed with trestle-structure bridge cranes. One of the trestle columns may be used for the purpose of establishing a line square to the center line, and perpendicular to the fore-and-aft base line of the ship (see Fig. 454).

A flat bar 3/8 by 5 in. can then be secured to the trestle column for the purpose of stretching a wire from one side of the ship to the other or for use as a point that can be intersected with a transit set on the center line of the ship. Water lines may also be established on the flat

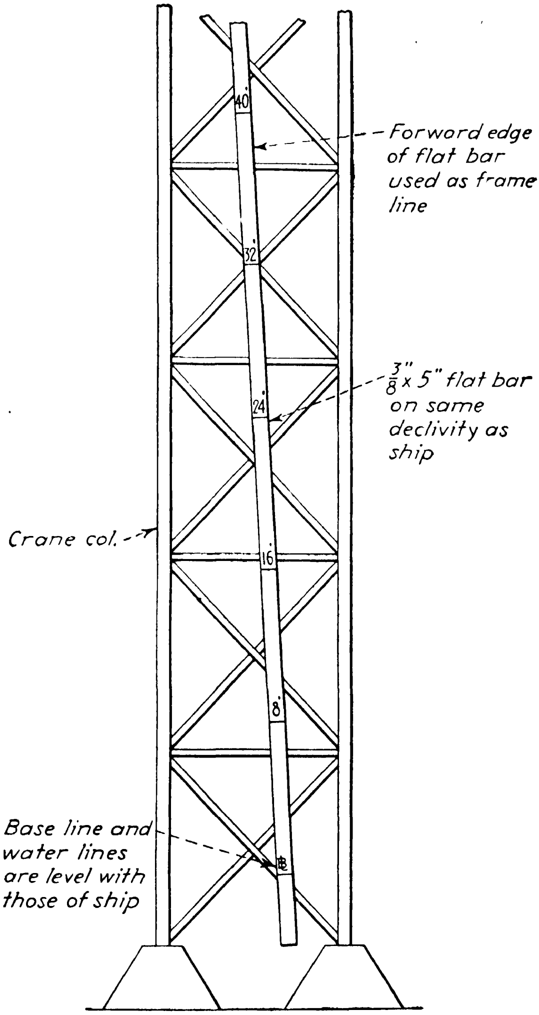


FIG. 454.—Another method of establishing the perpendicular to the base line on crane trestle columns.

bar from the original keel line of the ship. A wire stretched from one side of the ship to the other at the edge of the flat bar and parallel to any water line will give the position of the square and perpendicular line at any height desired.

Care must be exercised to remove as much of the sag from the line as possible. Otherwise, this may throw the line aft (see Fig. 424A, sag chart of steel line).

Establishing Water Lines and Buttocks. For the convenience of all workmen on the ship, water lines and buttocks are established at convenient points by the shipwright.

Water Lines. In all compartments and engine and boiler rooms, water lines are established on bulkheads, as shown in Fig. 455. These will, of course, be affected by the settlement of the ship but will be at the proper height above the base line of the ship at each of the main transverse bulkheads. In the engine and boiler rooms and in deep holds, it is well to establish a convenient water line about 4 ft. above the bottom and 4 ft. below the top of these holds for the convenience of workmen working from the upper water lines, so that it will not be necessary for them to measure to the bottom each time. Water lines should be established on

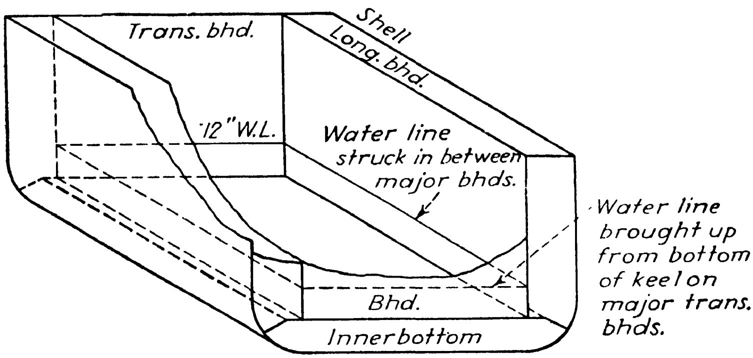


FIG. 455.—Water lines established on bulkheads in engine and boiler rooms.

the entire boundaries of each compartment where it is necessary to work from them.

Buttock Lines. For the convenience of workmen measuring from the center line, buttock lines are established at 6- to 10-ft. intervals on the decks. They are established from the center line on each particular deck and therefore are not exactly plumb over each other but are nevertheless sufficiently accurate for all work other than machinists' work.

All lines established by the shipwright should be center punched at intervals of not more than 10 ft. with three center-punch marks, indicating that these are working lines which are established from the structure of the ship which has been completed but which do not necessarily conform to the lines established by the mold loft for fabrication. The punches should be encircled with paint, so that they can readily be found by those desiring to use them. Lines center punched for fabrication are indicated by two punch marks.

Many other types of working lines, too numerous to mention in detail, must be furnished by the shipwright. The principle already explained is used in establishing them all.

CHAPTER XXXIV

RUNNING SHEET LINES

Sheet lines, as they are commonly known, are the edges of the various strakes of shell plating. It is the duty of the shipwright to see that they have a fair appearance from all angles.

In cases where some of the shell plating is taken from work, the edges will have to be established for the ship fitter lifting the shell plates, so that he can mark them on the plate for cutting. When a strake of plating is not fabricated but is taken from work after the remainder of the shell plating has been regulated and set, there may be some difference in its width from the designed lines in the body plan, particularly at the after-end, where the ship has a great deal of shape. In view of this, before establishing the edges it is good practice to obtain a girth batten for this strake of plating from the mold loft for the purpose of determining whether or not the plates ordered will be wide enough to suit the sheet lines established. Some slight adjustment may be necessary so that the plate will be wide enough.

Establishing the Sheet Line. In establishing the sheet line, first obtain from the plan of the shell plating the width of the lap at various points. It is immaterial which seam is faired first. Now, establish spots, giving the specified amount of lap and keeping it as neat as possible. Next, with a sheet-line fairing batten and mold clips install the fairing batten so that it will intersect the spots established. When the batten has been placed on all these spots, sight along it and fair up any unfair spots, checking it from each end for fairness.

After the batten has been made fair, mark the edge of the plating on the shell with soapstone. Next, apply the girth batten, holding the sheet line just faired in, and mark the other edge of the plate for the entire distance of the strake.

From the shell-plating plan, next check the width of the plate lap to see that it is within the boundary of the girth batten spots. If found to be sufficient to take care of the specified lap, the upper edge of the plating may then be faired in with a sheet-line fairing batten in the same manner as the lower seam.

If, on the other hand, it is found that the material ordered is scant, it may be necessary to steal a little material from the lower seam, together with some at the top, so that there will be a sufficient amount of material to lay off the plate. An example of fairing in sheet lines is shown in Fig. 456.

On some vessels, around the bossing for the shafting where the plating is extremely heavy and difficult to fit, sufficient material is allowed on some of the edges for the purpose of fairing and adjusting. In such cases, it is also the practice to leave two or three strakes of plating to be taken from work. In this case, girth battens for each strake should be obtained from the body plan, so that they can be applied on the frames and faired sheet lines run through the spots from them.

Difficulty is seldom experienced from not having sufficient material to take care of shell plating. However, this sometimes does occur. Therefore, it is good practice to check the width of the available material with a girth batten to ensure having sufficient material and to avoid the necessity of realigning the sheet lines.

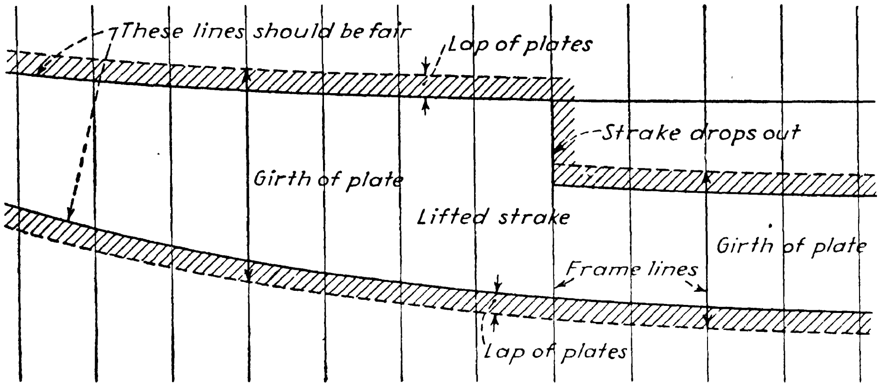


Fig. 456.—Fairing in sheet lines.

Fairing Fabricated Shell Sight Edges. On all the sight edges of plating, that is, the edges of the plating visible from the outside of the ship, some irregularities are found due to poor shearing or careless center punching in lining off the edges of the plating for fabrication. It is thus necessary to check the sight edges for fairness so that they will create a good appearance when the ship is in the water.

Sheet lines that are run in a straight line from one butt of the plate to the other do not give the shell the fair appearance that slightly easy-curved sight edges do. While such lines do not detract from the strength of the vessel, they do detract from the fairness of the shell even when the shell framing is absolutely fair.

The shipwright, who is responsible for the fairness of the shell, takes great pride in pointing out the fairness of the sheet lines after a good job of fairing has been done. On the other hand, when sheet lines are not fair, they "stick out like a sore thumb" to those who are professionally interested.

CHAPTER XXXV

MACHINIST'S BORING STANDS AND SHAFT SKIDS

MACHINIST'S BORING STANDS

After the shaft struts and boss castings have been set and welded in their proper position and the structure of the ship has advanced to the point where it is safe for the steam engineers, or outside machinists, to run their final shafting line preparatory to boring out for the shaft, platforms

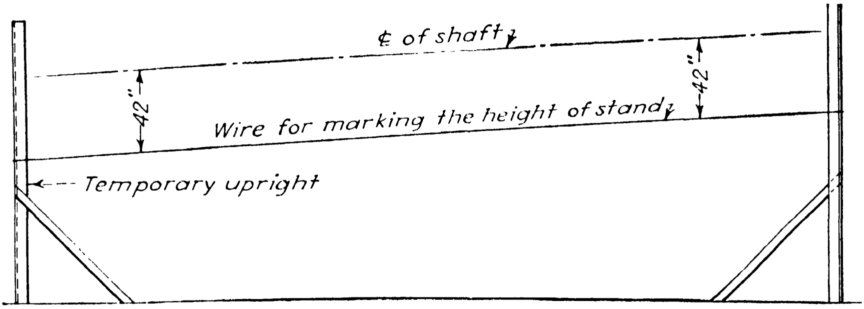


FIG. 457. Establishing the line for the machinist's boring stands from the center of the shafting.

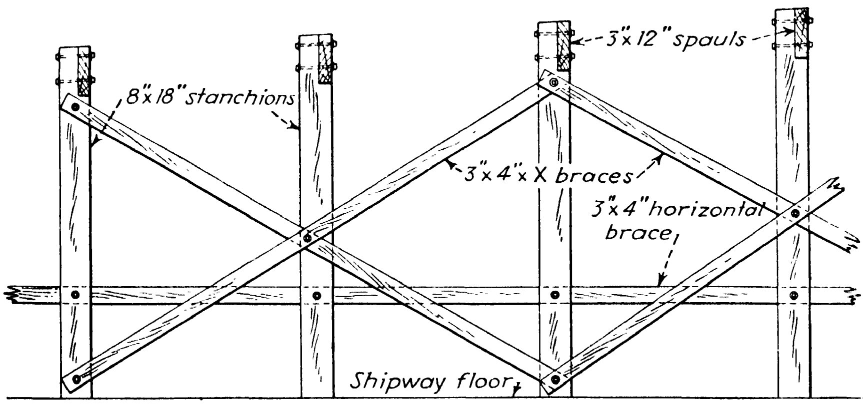


FIG. 458.—Method of building and bracing a boring stand.

must be set up to support the boring bars and machinery. These platforms, or stands, are built parallel to the shaft line, and the height is governed by the type of machinery used for boring out.

When the wire for the final line of the shaft has been run, the top of the spauls supporting the stand can then be established. Since this platform is also used for the purpose of skidding the shafting in place when the boring has been completed, it is necessary that it shall be well braced in all directions.

Boring platforms are generally built 42 in. below the center of the shaft. Therefore, by setting up uprights braced temporarily in position, the height of the stand can be established from the wire or center of the shaft, as shown in Fig. 457.

When the height of the platform has been established, the location of the spauls and uprights can be determined. The spauls are generally set on 5-ft. centers on 8- by 8-in. uprights, notched out at the top for 4- by 12-in. spauls. These uprights are set up plumb.

After the uprights have been cut and the spauls bolted to them, they may be set up with temporary 2- by 4-in. bracing until the entire stand is

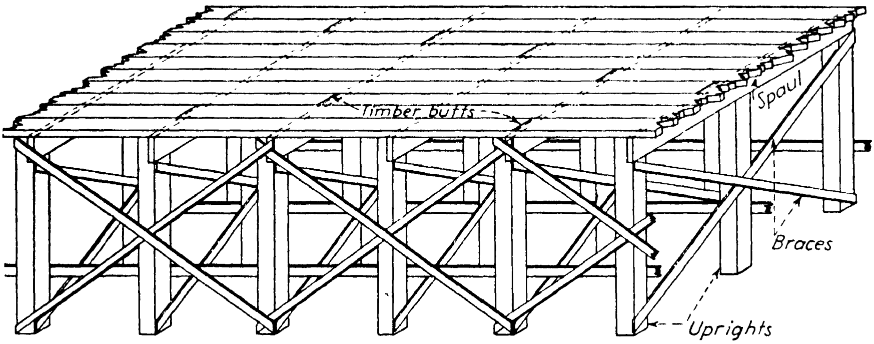


FIG. 459.—A completed machinist's stand ready for boring machines.

set up. After this, the permanent bracing is done, consisting of 3- by 4-in. or 4- by 6-in. timbers (Fig. 458).

When these uprights and spauls have been braced, the decking, consisting of 3- by 12-in. stage plank, is put in place, the butts in each strake being staggered.

Figure 459 shows a completed machinist's stand ready for boring machines.

SHAFT SKIDS

On large ships where the shafting is extremely heavy, and particularly on ships designed with twin or quadruple shafting, it is necessary to build a skidway for this installation, owing to the extent of the overhang of the ship, which makes it impossible to handle the heavy shafting with the cranes.

Shaft skids are generally built of 12- by 12-in. timber bolted together and having on each side a 3- by 12-in. ribband, as shown in Fig. 460. The height of the shaft skids is usually such that, with the saddle set on top of the skids and the shafting bearings removed from the struts, the cou-

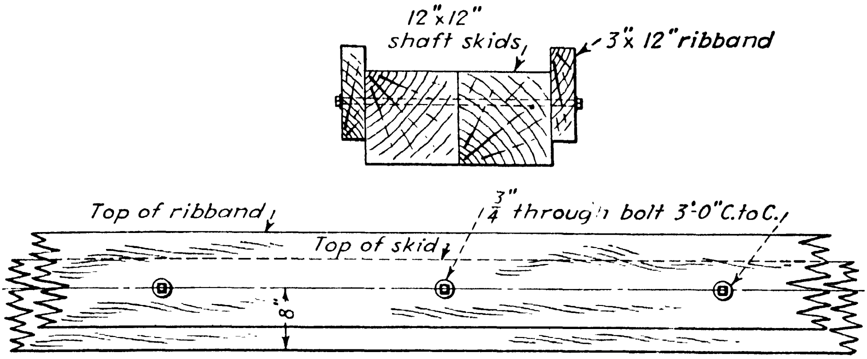


FIG. 460.—Method of construction of track for skidding in shaft.

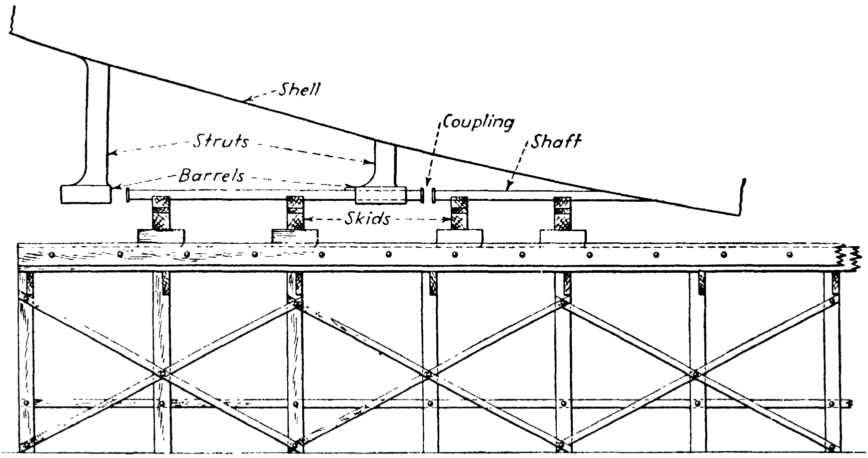


FIG. 461.—Shaft being skidded through strut barrels.

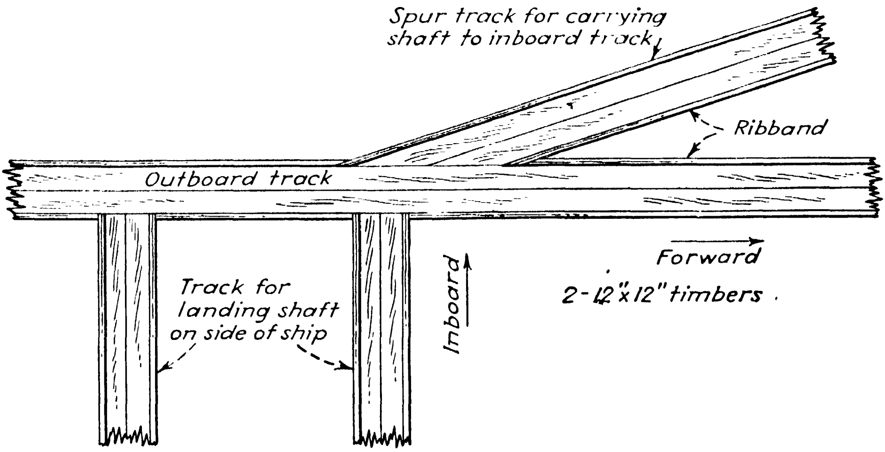


FIG. 462.—Track for skidding shafting under the ship.

plings on the ends of each section of shafting will pass through the struts and boss casting and into the ship, as shown in Fig. 461.

The location at which the shafting can be landed on the skids will determine the method by which the shafting is skidded into place. In some cases, if it is possible, with the removal of two or three sections of staging, a skidway is built from the side of the ship straight into the skid on which the shafting can be skidded forward. In other instances, it may be necessary to install the shafting from the extreme afterend of the

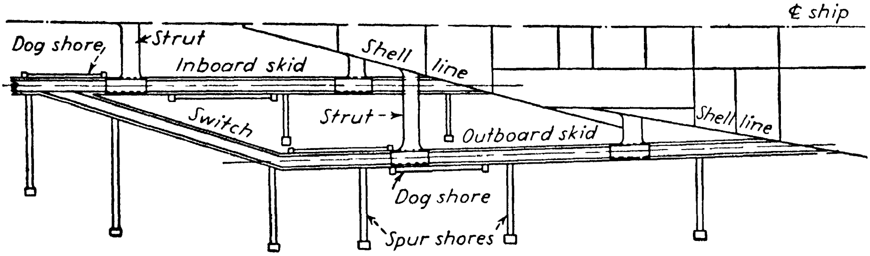


FIG. 463.—An arrangement of shaft skids for a large ship.

ship. To save labor and material, a single track is used on each side for the purpose of landing the shaft on the skids with the cranes; and after it has been hauled up under the ship, it is switched from the outboard to the inboard track, as shown in Fig. 462.

Shaft skids should always be braced securely in a fore-and-aft position, as well as a transverse direction, to prevent them from displacing when the shafting is being pulled and jacked into position.

An arrangement of shaft skids for a large ship is shown in Fig. 463. This also shows the fore-and-aft strut braces, together with the chocks holding them in a transverse position.

CHAPTER XXXVI

ARMOR

Certain parts of the structure of some types of combat ships are designed with protective armor. The type and design of the ship will, of course, govern the thickness and amount of armor to be used. The setting and aligning of armor are fundamentally the same as for other structure of the ship; however, heavy armor is usually *keyed* together with a tapered, dovetail, or square key. It is therefore necessary that these keys be fitted before the armor is brought into the ship, so that no difficulty will be experienced when the keys are being driven.

Transverse Armor Bulkheads. Transverse armor bulkhead plates are butted and welded together in the lighter-sized armor and keyed together and welded when the armor is of considerable thickness.

The plates making up armor bulkheads are laid off and fabricated from templates developed in the mold loft. The edges that will be affected by distortion in the structure of the ship may be left to be finished from templates lifted from the actual work.

When all the machining that is required for these plates has been finished, they can be brought to a skid and pulled together, the keys fitted, and the butts proved. At this time, if the ship has been made ready in way of the location of the bulkheads, the template can be lifted from the ship and the water line installed on it. The template can, in turn, be set to a water line on the bulkhead. Any irregularities at the bottom or sides of the bulkhead can then be marked and the plates machined or burned, so that they will bear firmly on the structure on which the bulkhead is set. Care should be exercised to ensure the top of the bulkhead being at its proper height, since the plates are generally rabbeted out so that the deck plating will fit into this rabbet.

When the plating is being erected, the method of bracing used for other structure is followed, except that heavier turnbuckles and shores are used to brace this armor. As each plate is brought into the ship, it should be set in its correct position before the adjoining plate is brought in, so that jacking and pulling will be reduced to a minimum.

After the plates have been installed, steamboat and hydraulic jacks are used in jacking the butts together. If dovetail or taper keys are used, it will be necessary to jack the butts together before the keys can be put in. When keys are straight or slightly tapered, they may be inserted in the keyway as each plate is erected. The adjoining plates can then be jacked in over the key, thus eliminating the necessity for driving the key, particularly when it is extremely long.

When all the plates have been erected in the ship and pulled together, the bulkhead should be shored in its proper alignment at several points across the ship.

No attempt should be made to set the bulkhead definitely until all welding has reached the point at which any distortion due to welding will not affect the bulkhead.

Steering-gear Armor. Steering-gear armor is laid off from templates developed in the mold loft. It is then machined at the butts and top, and the keyways are cut. The bottom is left with all material possible for fitting to the ship. When the ship is ready, the armor is erected in the ship and set. It will be necessary to block it up clear of the structure on which it is to be set, owing to the added material.

After the entire box has been pulled together, set, and leveled, it is scribed for cutting, so that it will attain its proper height after cutting. It is also possible to burn the armor while it is in place with a burning torch attached to a motor-driven burning machine that travels along the deck or armor support and follows the exact line of the armor support, making almost a machine-fitting job. If the support for the armor is inclined, this torch can be adjusted to the same angle as the armor support.

After the surplus material has been burned off, the armor is lowered, a plate at a time, by means of wedges or jacks and then finally reset, and the keys are driven.

Side-belt Armor. The side-belt armor is usually machined on all four edges. It is therefore necessary to use extreme care in maintaining the support for it as close to designed dimensions as possible. This means that constant vigilance must be maintained.

Since this armor is machined to a straight line at the bottom and the butts at right angles to the bottom, it is necessary that the supporting structure shall be maintained in the same line. Otherwise, the butts will not make up.

It is sometimes possible to leave some of the structure loose for final adjusting after the remainder of the work has been done. Some liners may be necessary even though a great deal of care has been taken.

The side-belt armor is secured to the structure of the vessel by means of holding bolts, extending through the shell plating. When the armor is laid off for machining, holes for these bolts are laid off and drilled. After the holes are drilled and the plates machined, these are proved by laying them down and blocking them up so that they will attain the same relative position as when erected vertically in the ship.

At this time, the keys are fitted. After being fitted, the key is secured in the keyway of one of the plates with countersunk-head tap bolts. Keys are usually secured to the forward keyway of the plates forward of amidships and in the after keyway of the plates aft of this point.

Laying Off Holes for Holding Bolts. Before the plates are brought to the ship, templates are made from each plate. On these all holding bolts are marked from their actual position in the plate. The templates are then taken to the ship and applied to the shell. The armor is usually installed beginning amidships and then working forward and aft from this point; therefore, the templates are applied in the same manner.

Small spring clips are tack-welded to the shell for the purpose of holding the templates in place. After the template has been set, the location of all holding bolts is center punched on the shell plating and the holes are drilled. The butts of the plating are also scribed on the shell to act as a guide when the plates are set in position on the ship. No trouble is generally experienced through the midship part of the ship. However, toward the ends, where the ship begins to take shape, care must be exercised in applying the templates in their exact position; otherwise, bad holes will result, and it will be difficult to install the holding bolts.

Barbette Armor. Barbette armor, after being machined, is set up on the ground and proved before it is brought into the ship.

The keys in barbette armor are usually of the interlocking type and must therefore be driven after the plates have been set. A weight attached to a small motor-driven winch is generally used for driving the keys. This is guided by running it through a pipe of suitable size, placed over the top of the key.

The support is sometimes machined on the ship, so that the armor will seat properly on its support. However, where this is not the case, much care must be taken in setting the structure and holding it so that the armor will fit as closely as practicable. Some shim liners may be necessary where it does not fit hard up.

In erecting barbette armor, turnbuckles and straps are generally used to hold it in position until all the plates have been installed. Each plate, as it is brought into the ship, should be set as close to its true position as practicable.

When all the plates have been erected, a heavy wire rope is passed around the entire outside of the barbette and the ends are fastened in the eyes of the steamboat jacks, for the purpose of pulling the plates together. When the plates have been pulled together, the keys can be driven.

Armored Decks. Armored deck plates are set in the same manner as ordinary deck plating that is butted. Since the armored deck is generally laid on a course of plating, it is first necessary to line off the butts and frame stations. If the plating is to be keyed together, it is good practice to lay out sections of the plating for fitting the keys and proving the butts.

The laying of the plating is started amidships and progresses forward and aft of this point. Should the structure of the ship vary from design because of welding shrinkage or poorly-set work, some recutting of the butts will be necessary, so that openings in the deck for trunks, hatches, and gun mounts will line up. It is therefore important that the structure be built as close to designed dimensions as possible.

CHAPTER XXXVII

ESTABLISHING AND CHECKING DIMENSIONS

In establishing measurements, it is frequently necessary to resort to offsetting because of obstructions. In offsetting measurements, care

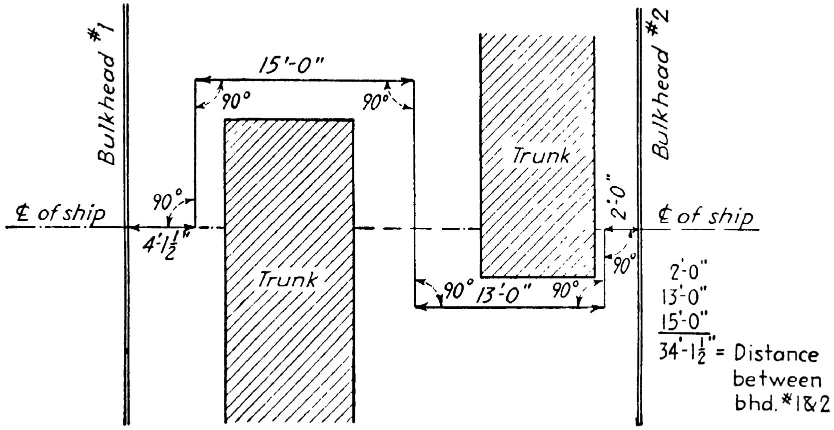


Fig. 464.—Method of offsetting dimensions because of obstructions.

must be exercised in the addition and subtraction of figures lest errors occur (see Fig. 464).

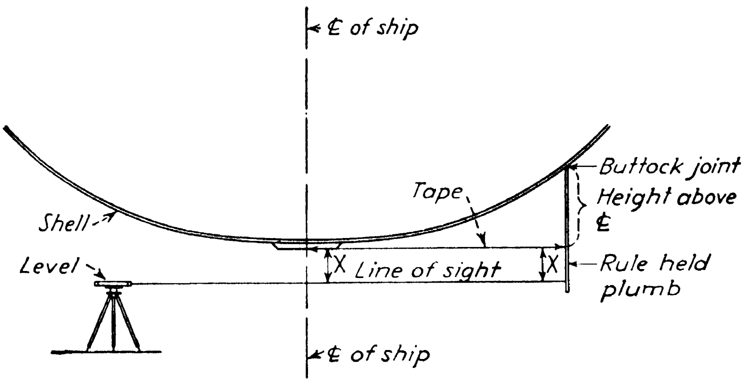


Fig. 465.—A method of making measurements on the bottom of the hull with a surveyor's level.

Measurements for points on the rounded surface of the hull are taken by holding a rule plumb at the desired distance (measured parallel to the base line by means of a tape) and sighting with a level. Such measurements may also be taken with a level set up in one particular position where it is possible to see the rule held at all the points (see Fig. 465).

The rule must be held in the same position relative to the center line when the other dimensions are read to obtain the correct dimension with respect to the center line of the ship.

Where obstructions prevent taking measurements of height and half breadths, they may be taken as shown in Fig. 466. Points 6 to 12 in.

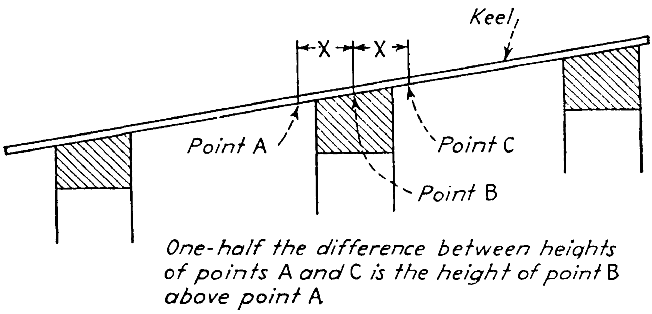


FIG. 466.—Taking measurements on the hull by interpolation.

forward and aft of the points desired can be taken, an interpolation between these two measurements made, and the dimension established.

In checking vertical dimensions, the tape should always be held at right angles to the base line of the ship. Otherwise, the dimension will be in error.

In establishing the buttock lines on a cambered deck, the tape should always be held parallel to the base line and the buttock plumbed down with a plumb bob, as shown in Fig. 467.

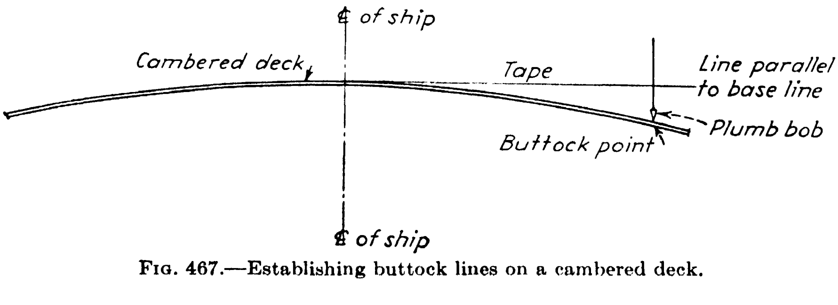


FIG. 467.—Establishing buttock lines on a cambered deck.

If longitudinal measurements on the deck from a square line across the ship are to be precise, small holes should be drilled in the bulkheads for the purpose of extending the tape through them. When the tape is being offset, the offset line should be projected at right angles to the center line or to the line at which the measurement is being taken, as shown in Fig. 468.

In establishing or checking dimensions from the datum line to the top of the ship where it is impossible to plumb down to the centerline monu-

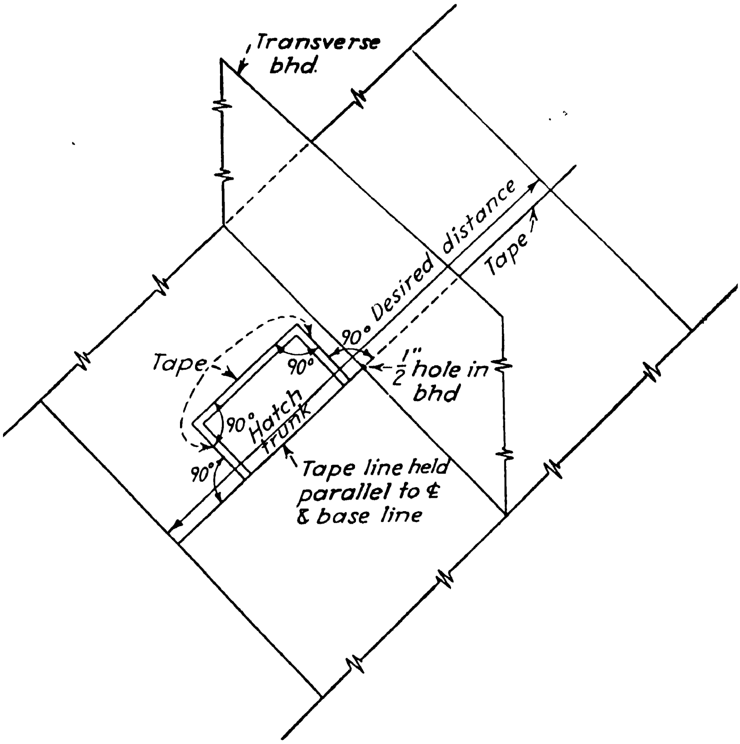


FIG. 468.—Making longitudinal measurements in way of hatches and bulkheads.

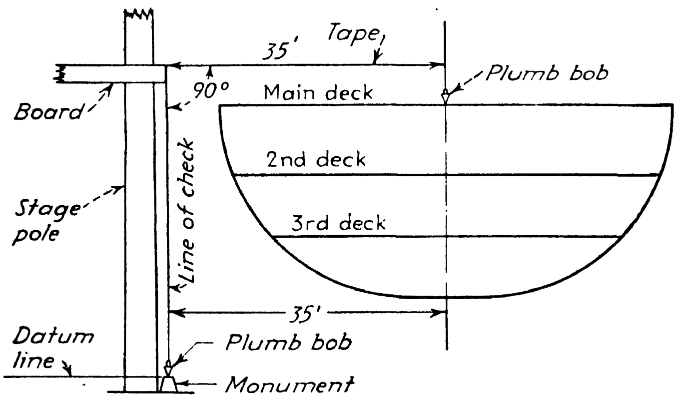


FIG. 469.—Establishing or checking dimensions from the datum line to the top of the ship.

ments, a plumb bob is suspended from a temporary support on the staging, which will clear the structure of the ship. The support is moved until the point of the plumb bob falls over the center of the monument.

A steel tape is then held at right angles to the wire supporting the plumb bob in order accurately to establish a measurement from this plumb line (see Fig. 469).

Measurements made along a deck having sheer must also be made with the tape held parallel to the base line. Otherwise, the dimension will not be accurate (see Fig. 470).

There are many measurements to be taken on the ship that are sometimes difficult to obtain and will require rechecking to ensure their accuracy. The engineer's level and transit can be used to good advantage

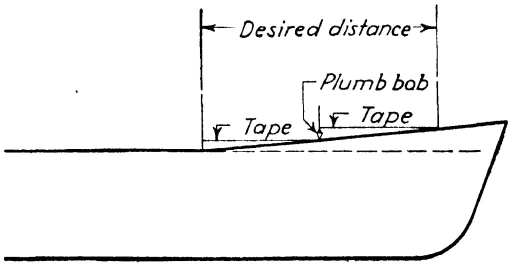


FIG. 470.—Measurements made along a deck having sheer.

in many of the places where to install lines with a tape would result in much loss of time.

USE OF INSTRUMENTS

Dumpy Level. The dumpy level shown in Fig. 471 is generally used by the shipwright for leveling. It consists of a telescope *A* attached to bar *B* and carrying a level bubble *C*. The bar *B* is attached to a spindle, which is partly supported by a ball-and-socket joint. The bearing plate on the spindle carries the upper leveling plate *P*. The lower half of the joint forms the leveling plate that is attached to the tripod head.

By leveling the screws *S*, the upper part of the instrument may be tipped in any direction with respect to the lower leveling plate.

In the telescope *A*, whose objective is at *O* and eyepiece at *E*, there is a ring carrying two fine hairs at right angles to each other. The ring may be adjusted so that the intersection of the wires is in the optical axis of the telescope and one wire may be made vertical when the other will be horizontal. When the axis of the bubble tube and the line of sight of the telescope are parallel, the latter will be horizontal when the bubble is brought to the center of its tube.

In setting up the level, the legs should be planted firmly, with the lower leveling plate as nearly horizontal as possible. In setting on the deck of a ship, the points of the tripod may be set into the holes of ¾-in.

nuts tack-welded to the deck plating to hold them firmly in position. The telescope is then swung over one pair of leveling screws and the bubble brought to the center of the tube. The telescope is then brought over the other pair of leveling screws and leveled. A recheck is made by revolving the telescope in a complete circle and adjusting the leveling screws until the bubble is in the center of the tube at all times.

Terms Used in Leveling. The purpose of the level is to establish a horizontal plane which for convenience is always above some imaginary plane called the *datum plane,* the elevation of which may be actually referred to some known plane of reference or may be assumed. If assumed, it is generally given an elevation slightly below the lowest point required, thus eliminating the inconvenience of minus elevations.

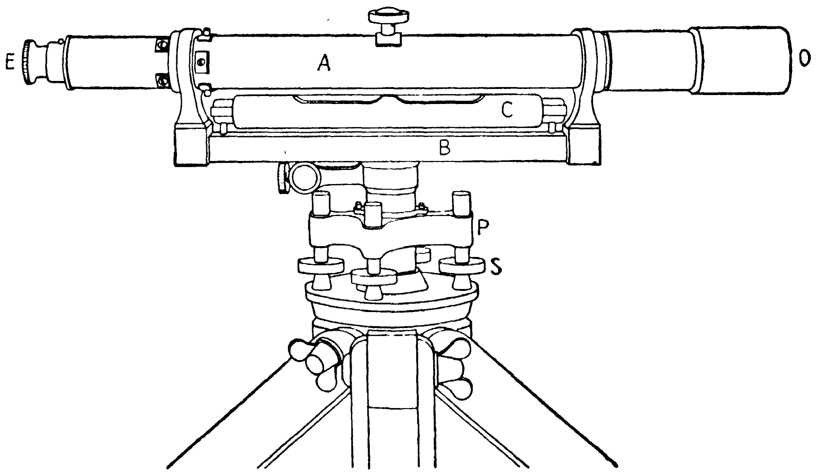


FIG. 471.—The dumpy level.

A rod reading taken on a point of known elevation in order to obtain the height of the instrument is known as a *back sight* or *plus sight.*

Permanent bench marks are usually established about the shipyards with reference to mean low water (M.L.W.), which is considered elevation 100.00. From a record of these bench marks, the elevations above mean low water can be established at any time. A reading above mean low water on the rod of 7.84 would be recorded as elevation 107.84. An elevation below mean low water would be the rod reading deducted from elevation 100.00, or 92.16.

When a point is used merely to determine the height of the instrument for the next position of the level or transit, it is called a *turning point.*

A rod reading that is taken on a point of unknown elevation in order to determine that elevation from a height of the instrument is called a *fore sight* or *minus sight.*

Obtaining Difference in Elevation. To obtain the difference in elevation between two points, the level can be set midway between the points by sighting through the telescope and reading a rod held on one of the points and then by reading the rod held on the other point. The difference in elevation may be determined by taking the difference between the two readings.

In cases where it is not possible to see both points with a single setting of the level, two or more intermediate points, called *turning points*, may be used. The readings taken on these points are *assumed elevations*, called *plus sights* and *minus sights*. The elevation of a point plus the rod reading gives the elevation of the line of sight; the elevation of the line of sight above a point of unknown elevation gives that elevation. In Fig. 472 is shown an example of obtaining elevation in which three setups are

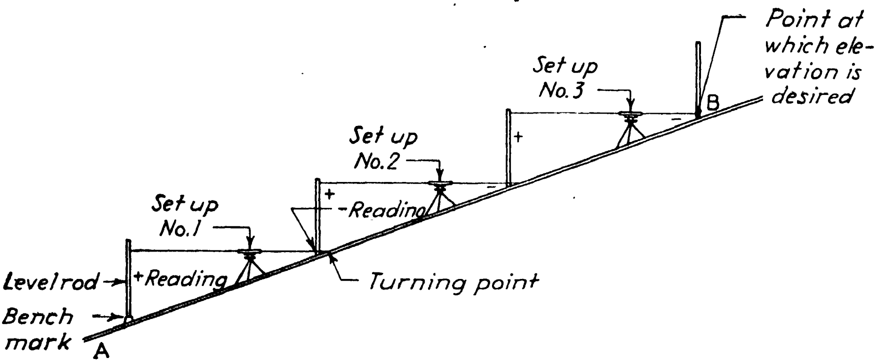


FIG. 472.—Obtaining difference in elevation between two points with three setups of the level.

required. The sum of the plus and minus sights between points A and B is the difference of level.

To Establish a Working Point from a Bench Mark. To establish an elevation from an established bench mark of known elevation, the instrument is first set up at a position where it will be possible to see both the known elevation and the point to be established.

The leveling rod is set up on the bench mark and the height of instrument (H.I.) determined.

If the elevation of the bench mark is 107.00 and the rod reading is 2.75, the height of instrument is 107.00 + 2.75, or 109.75.

The rod can then be set up on the point of unknown elevation and a reading taken on the rod. This rod reading is subtracted from the height of instrument, and the result is the elevation of the point desired (see Fig. 473). It may be necessary to make two different setups in order to obtain the elevation, particularly if it is below the top of the rod reading (in this case the plus and minus readings would have to be made similar to that already explained in the foregoing).

To establish a plane to a definite elevation from a bench mark, as shown in Fig. 474, the instrument is first set up in a position where the bench mark and all points can be sighted. The telescope is leveled and the rod set up on the bench mark to determine the height of the instrument. Stakes can then be driven into the ground at the boundary points of the plane. The rod is set up on each of these stakes, and the

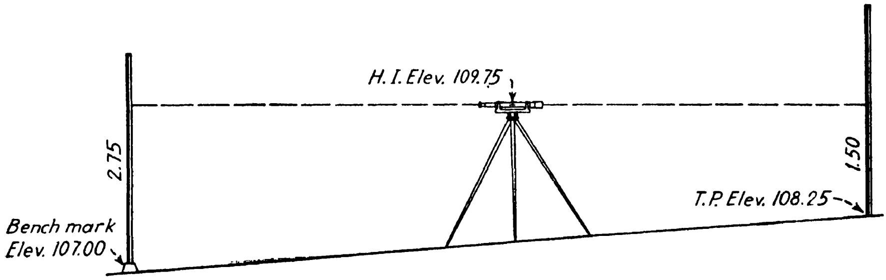


FIG. 473.—Establishing a working point from a bench mark.

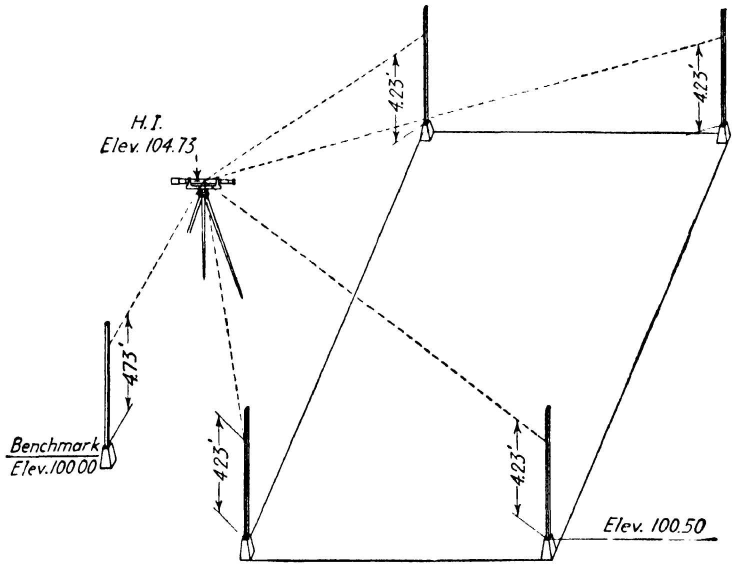


FIG. 474.—To establish a plane to a definite elevation from a bench mark.

stakes are driven into the ground so that the tops of all of them will be at the level of the same elevation. A plane can then be established at the desired elevation from these points with a rule or rod.

The Transit. The transit is an instrument somewhat similar to the dumpy level, except for the head (see below). The telescope may be rotated not only in the horizontal plane, as on a level, but also in the vertical plane. Both these movements can be measured to degrees and minutes by a vernier scale. Consequently, the instrument will do all the work of the dumpy level, plus the determination of any angle in any direction.

The transit is fitted with a hook for centering the head directly over a point by means of a plumb bob. The instrument is set up and leveled in the same manner as the dumpy level.

Its use in shipbuilding is principally on the ship itself. With the plumb bob, the instrument may be set up over the datum line at one end of the ship, and by sighting through the instrument at a monument at the other end a point may be located plumb over the base line at any location on the ship that is visible, by simply moving the telescope in the vertical plane. In this operation, after the instrument is set, any horizontal motion of the instrument is prevented by locking the two plates together.

If it is desired to locate lines that are square to the base line, the instrument is set up, as in the foregoing, and the reading taken on the horizontal scale when the instrument is sighted along the datum line. The instrument is then turned horizontally exactly 90 deg. and locked in position. Now, all points in the vertical line of sight will be square with the base line.

If the instrument is leveled as just described, a perpendicular to any point may be located by sighting on the datum point and, after locking the horizontal adjustment, moving the telescope vertically to obtain a line of sight on the desired height.

CHAPTER XXXVIII

TIMBER JOINTS

The shipwright is often called upon to perform heavy timberwork, such as the building and maintenance of piers, shipways, heavy timber racks, frames, and trestles. Details will not be discussed; however,

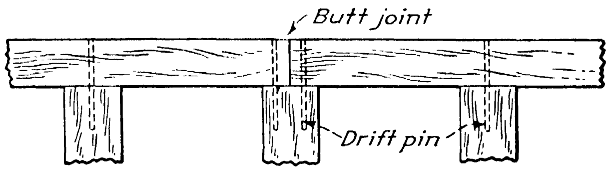


FIG. 475.—A square-butt heavy-timber joint.

every shipwright should have a knowledge of some of the many joints required in such work.

Joints may fall into one of three classes, plain or butt joints; lap joints; and mortise joints. The various kinds of butt joints are the straight miter, rabbeted, and spliced.

BUTT JOINTS

Figure 475 shows a square butt joint on a heavy timber stringer secured with driftbolts. In Fig. 476 is shown the miter butt with a reinforcing fishplate.

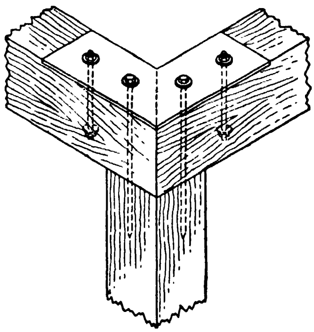


FIG. 476.—A heavy-timber miter butt.

Wood butt straps are also used in connection with the square butt. These should be one-half the thickness of the main timber and six times the width of the main timber in length (see Fig. 477).

Where timbers are to be subjected to tension stresses, a wedge-shaped wood key of seasoned white oak may be inserted, as shown in Fig. 478. Where only one key is used, it may be made in one piece. Where more than one key is desired, it is not always possible to cut the keyways in such a manner that each key will be fitted to carry a uniform part of the load. Therefore, to overcome this, keys are usually cut wedge-shaped, so that they can be driven hard up, giving each key solid bearing in the keyway.

When bolts are used in timber butts, the diameter of the bolt should be one-twelfth the thickness of the timber. Bolts should be spaced no closer than four times the diameter of the bolt from the end of the timber.

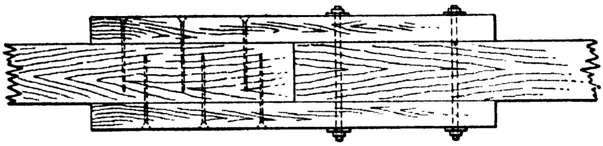


FIG. 477.—Square timber butt with wood butt straps.

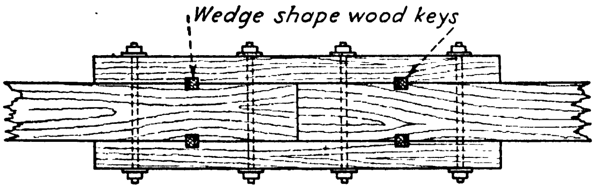


FIG. 478.—Reinforced timber joint fitted with keys to resist tension stresses.

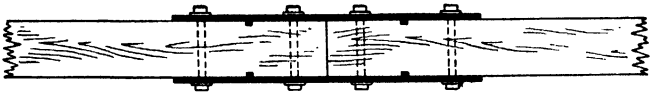


FIG. 479.—Steel-plate butt straps used with a square-butt joint.

Another form of butt strap used with a square butt joint is shown in Fig. 479. This is a steel-plate butt strap, or fishplate; its thickness should be one-sixteenth the width of the timber. If the timber is subjected to tension, square keys may be welded to the strap and the timber notched out for the key as shown. If the timbers are subjected to compression stresses only, these keys are omitted.

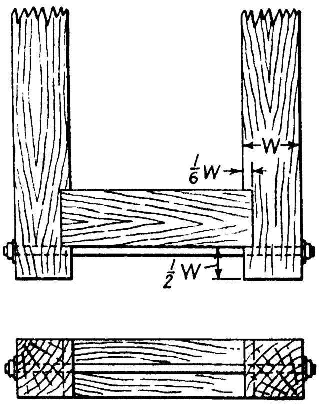


FIG. 480.—Rabbeted butt joint.

Rabbeted Butt Joints. The rabbeted butt joint is used in the construction of pickling tanks, where it is necessary to make the joints watertight. A rabbet slightly less than the thickness of the adjoining timber is cut from one side of the timber, and is fitted tightly into the complementary rabbet. The rabbet should be one-sixth the thickness of the timber in depth (see Fig. 480).

LAP JOINTS

There are various forms of lap joints, to suit the nature of the stresses to which the timbers will be subjected.

Shiplap. When timber is shiplapped, it is cut away for a portion of the width on both edges, but on opposite sides (see Fig. 481).

Compression Scarf Joint. Figure 482 shows one form of compression scarf joint. The timber is halved and fitted together for a distance of six times the thickness of the timber. The addition of steel butt straps adds greater strength to the joint.

FIG. 481.—Ship lap joint.

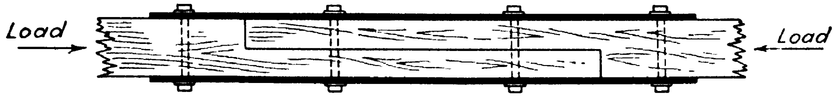


FIG. 482.—A compression scarf joint.

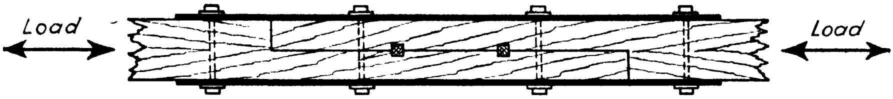


FIG. 483.—A compression and tension scarf joint.

FIG. 484.—Tapered scarf joint with square end.

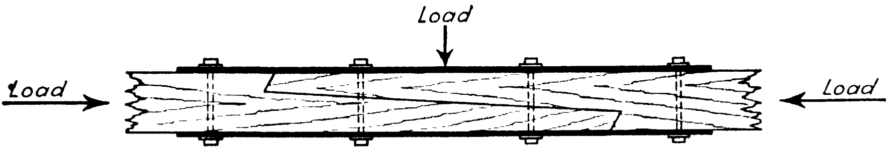


FIG. 485.—Tapered scarf joint with beveled ends.

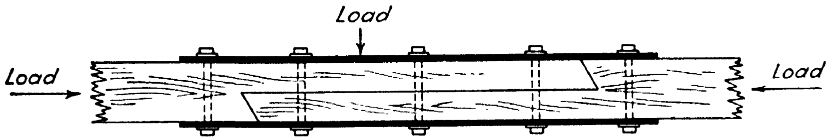


FIG. 486.—Compression and bending scarf joint.

Compression and Tension Scarf Joints. This type of joint is made in the same manner as the compression scarf joint, with the exception of the square keys, which are fitted in the scarf to create a resistance when the timber is in tension, as shown in Fig. 483.

Tapered Scarf Joints. On timbers whose thicknesses make it impractical to halve the timber, tapered scarf joints, as shown in Figs. 484 and

485, may be used. The tapered scarf has greater resistance against splitting than the halved scarf.

Compression and Bending Scarf Joints. When timbers are to be subjected to compression and bending loads, the timbers are halved with the ends mitered, as shown in Fig. 486. The mitering of the ends prevents the scarf from opening up when the load is applied. The addition of the steel butt straps prevents the timber from splitting at the root of the scarf.

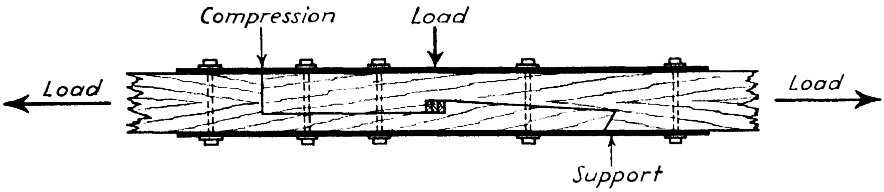


FIG. 487.—Tension and bending scarf.

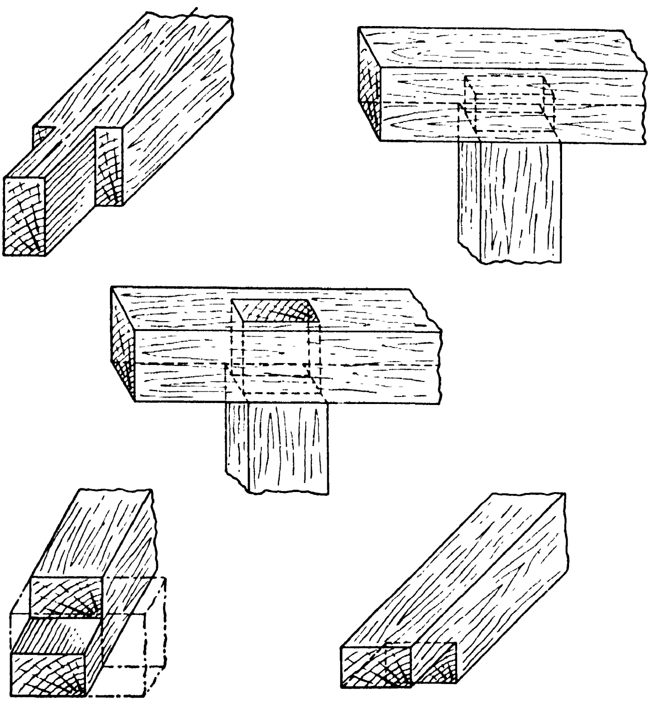


FIG. 488.—Various forms of mortise and tenon joints used on heavy timbers.

Tension and Bending Scarf. This joint is similar to the compression and bending scarf except that a key is added and the scarf tapered, as shown in Fig. 487.

MORTISED JOINTS

A mortise is a space hollowed out in a timber to receive a *tenon*, which is a projection made to fit the mortise in another timber to make a joint.

Various forms of mortise and tenon joints used on heavy timber are shown in Fig. 488.

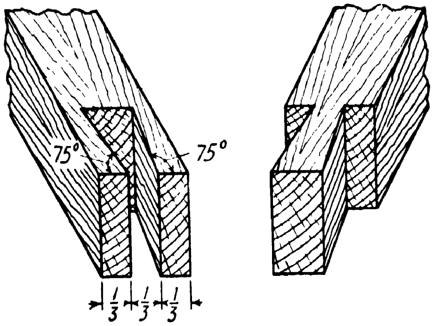


FIG. 489.—Dovetail joint.

Dovetail Joint. Another form of mortise joint is the dovetail joint shown in Fig. 489. The taper of dovetails is generally 75 deg. The socket is generally one-third the thickness of the timber at the bottom and then is tapered out 75 deg.

CHAPTER XXXIX

LADDERS, STAIRS, RAMPS, AND GANGWAYS

Some means for boarding a vessel while it is under construction on the shipways must be provided. Aboard the ship, ladders, walkways, and stairways are required until the vessel's permanent means of access are in place. This temporary access must be moved, rearranged, and maintained with the progress of the construction of the vessel.

Many man-hours of work can be lost by poor access for workmen; therefore, good access is money well spent.

LADDERS

Temporary ladders used during construction are generally of a built-up type. They are made up of side rails; rounds, or treads; and

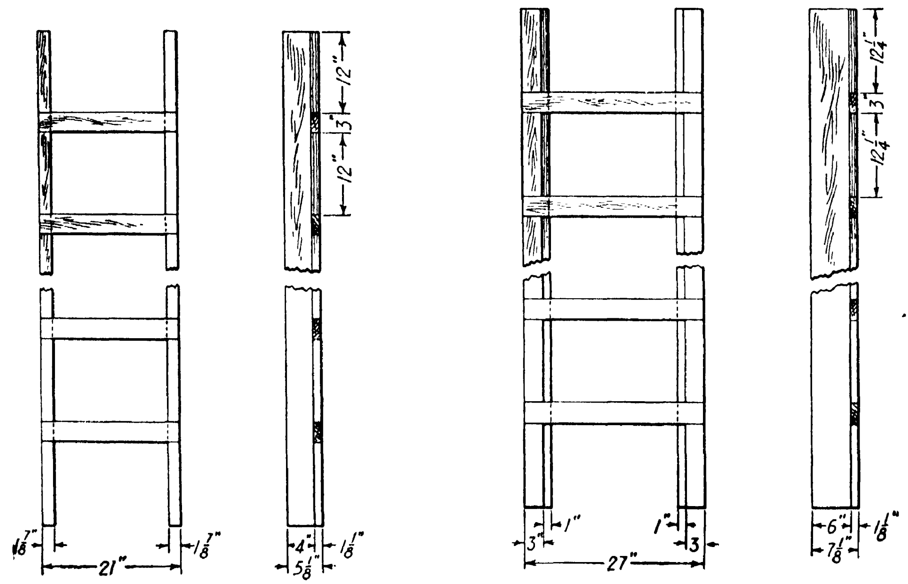


FIG. 490.—Construction of ladders generally used on board the ship as well as for access to staging.

spacers used between the rounds. All material for ladders should be free of large knots.

Ladders should project above the landing at the top not less than 4 ft. to enable them to be boarded safely. They should be secured at the top by lashing with baling wire to prevent them from slipping.

Length of Ladders. Ladders up to 16 ft. long are generally constructed of 2-in. by 4-in. yellow or Oregon pine. The side rails of ladders 16 to 24 ft. long should be of timber not less than 3 by 5 in. Ladders in excess of 24 ft. in length should be constructed of side rails 4 by 6 in. in cross section.

Width of Ladders. The width of ladders up to 24 ft. in length is generally 21 in. Ladders above 24 ft. in length are 27 in. wide.

Ladder Rounds. Ladder rounds are usually made of straight-grained Oregon pine $1\frac{1}{8}$ in. thick and 3 in. wide.

Spacers. The spacers used between the ladder rounds are nailed to one edge of the side rails. They are usually made up from 2-in. scrap stage plank and are cut $1\frac{1}{8}$ by 2 by 12 in.

For details, see Fig. 490.

STAIRWAYS

Because of the large number of men using stairways on the ship, particularly during quitting time, side stringers are generally of the

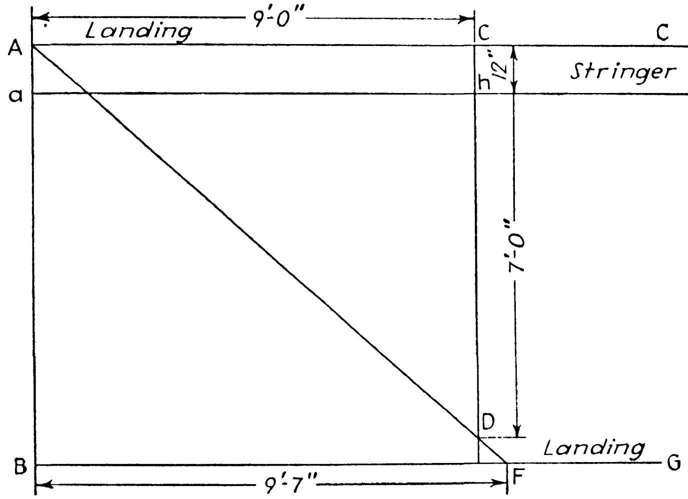


Fig. 491.—A layout for stairs.

built-up type to accommodate greater loads. However, the conventional, or saw-tooth, type of stringer is sometimes used.

Since areas for stairways are confined, it is frequently necessary to resort to the winding type of stairways with platforms, or landings, at each flight of stairs.

The principal dimensions used in designing stairs are (1) *rise* and (2) *run*.

The run is determined not only by the rise but also by the headroom. When these are agreed upon, the proportions of the tread and rise can be determined.

Example. The distance between landings for a straight flight of stairs is 8 ft. 6 in. The stairs must be laid out so that there will be a headroom clearance of not less than 7 ft.

From Fig. 491, draw line *BG* to represent the lower landing and *AC* parallel at a distance of 8 ft. 6 in. (the rise) to represent the upper landing.

The distance between the upper landing and the landing stringer is 12 in. Now, measure down from *AC* 12 in., and draw the line *ah*. Since the headroom is to be not less than 7 ft. at *h*, draw a line perpendicular to *BG* at *h*. Next drop perpendicular *AB* to *BG*, and draw through points *A* and *D* the line *AF*. The distance *BF* is the approximate run for the headroom *hD*.

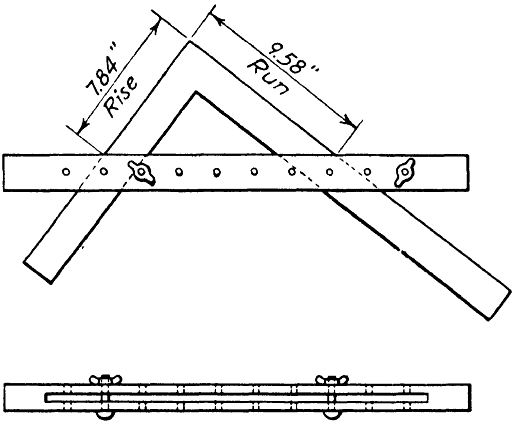


FIG. 492.—A fence attached to a framing square.

Rise and Treads. For ordinary purposes the rise per step, or riser, should be 7 in. and the tread 10 in. Some variation may have to be made in both to suit conditions. Therefore, proportion of 7 and 10 may be for trial purposes. Hence, $8.5 \times 12 = 102$ in.;

$$102 \div 7 = 14.57.$$

As there cannot be a part of a step, it can be assumed that there will be 14 risers, or slightly more than 7 in. per rise.

The run can now be divided by the *number of risers less* 1 to obtain the width of the tread. Therefore, 9 ft. 7 in. = 115 in.;

$$115 \div 13 = 8.84 \text{ in.}$$

This is less than the width of the tread desired; so a slightly wider tread can be tried by reducing the number of risers by 1. Hence, $115 \div 12 = 9.58$ in., or the width of the tread. $102 \div 13 = 7.84$ in., or the height of risers.

Although this is not an ideal height of riser, it is the best condition obtainable since the length of the stair well is fixed, thus limiting the run due to the specified headroom.

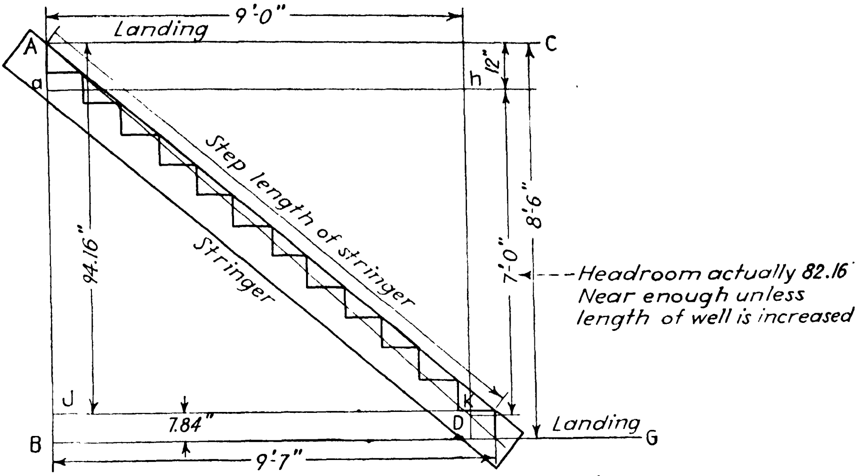


FIG. 493.—The layout for the stair stringer.

To Lay Out Stringers. The laying out of the stair stringers may be done with a fence attached to a framing square (see Fig. 492). However, for more accurate work, the stringers may be laid off with dividers.

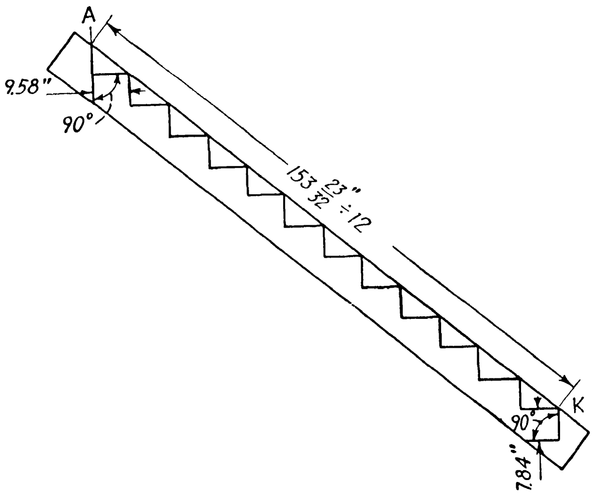


FIG. 494.—Layout of stringer.

The ordinary method used for laying out stringers is to take the rise per step on one leg of the square and the tread on the other. To secure accuracy in laying out, the work should be done with great care.

The fence attached to the square is set at 7.84 in. on the tongue and at 9.58 in. on the body, and the thumbscrews on the fence are tightened so that it will not move.

While the fence ensures a constant setting, it is not accurate for neat work, for there is a possibility of gaining or losing when moving the square.

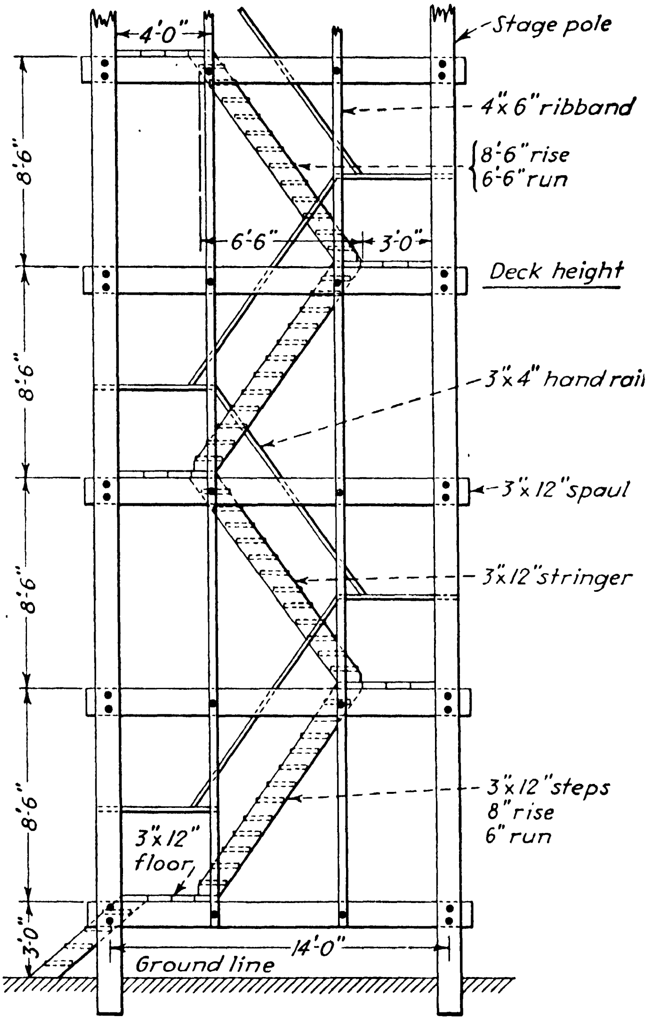


FIG. 495.—Layout for winding stairway.

For work where precision is necessary, it will be found more satisfactory to divide the entire distance into the required number of divisions with dividers and then apply the square with the fence clamped at the proper rise and run, these points being made to intersect the points established with the dividers. This entire distance along the edge of the stringer corresponds to the hypotenuse of a triangle of which one leg is the rise and the other the run of the stairs, as shown in Fig. 493.

From the layout shown in Fig. 493, lay out line *JK* 7.84 in. above the parallel to *BG*. This is the top of the first riser.

Now, to obtain the step length of the stringer, subtract the height of the first step from the rise. That is, 8 ft. 6 in. = 102;

$$102 - 7.84 = 94.16 \text{ in.};$$

therefore, the rise equals 94.16 in. and the run 115 in.

$$\text{Step length of stringer} = \sqrt{\text{rise}^2 + \text{run}^2} = \sqrt{94.16^2 + 115^2}$$
$$= \sqrt{10{,}404 + 13{,}225} = \sqrt{23{,}629} = 153\tfrac{23}{32} \text{ in.}$$

The distance is then divided by 12, or the number of treads, as shown in Fig. 494.

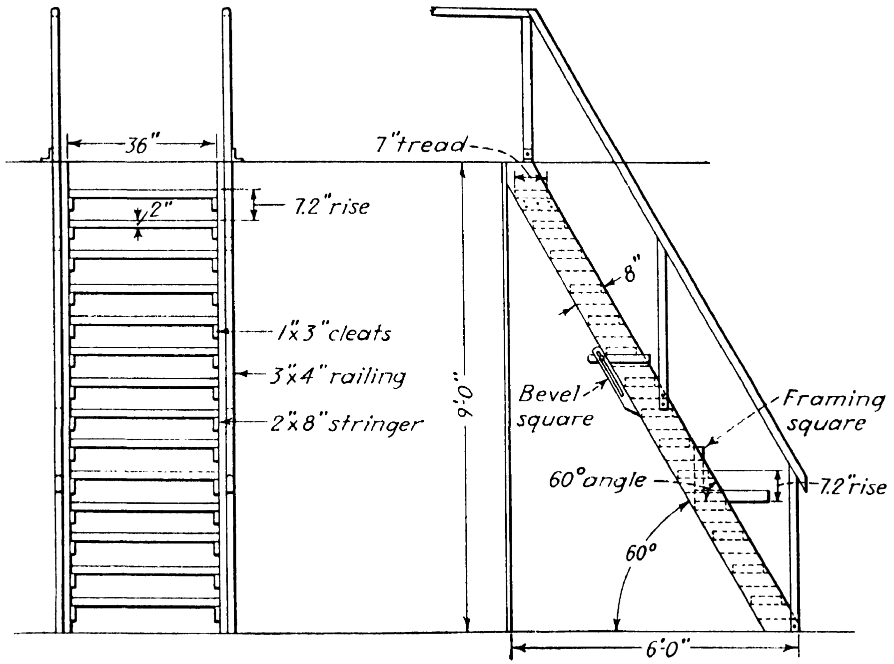


Fig. 496.—Companionway stairs.

The distance of $153\tfrac{23}{32}$ in. can now be laid off on the edge of the stringer, leaving as much stock at the ends as may be thought necessary, and with the dividers the distance is divided into the same number of parts as there are treads.

The ends of the stringer are laid out as shown in Fig. 494.

Figure 495 shows a winding stairway with various landings, together with the rise and run for each flight of stairs.

Companionway Stairs. Companionway stairs, as shown in Fig. 496, are sometimes used as a temporary means of access between decks.

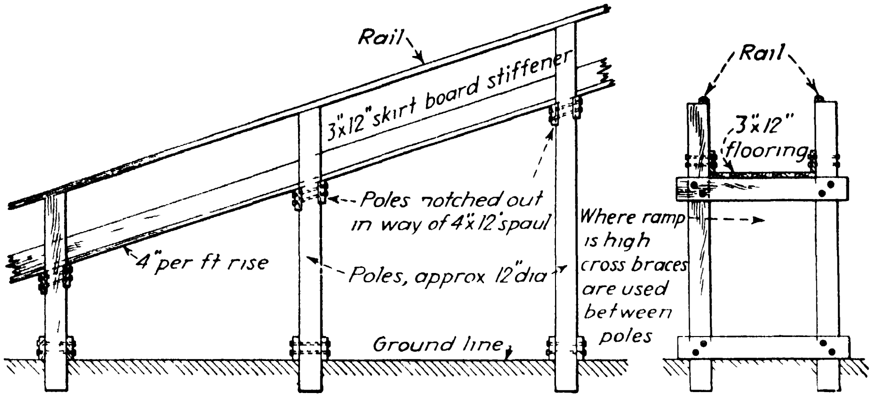


FIG. 497.—Construction of a ramp.

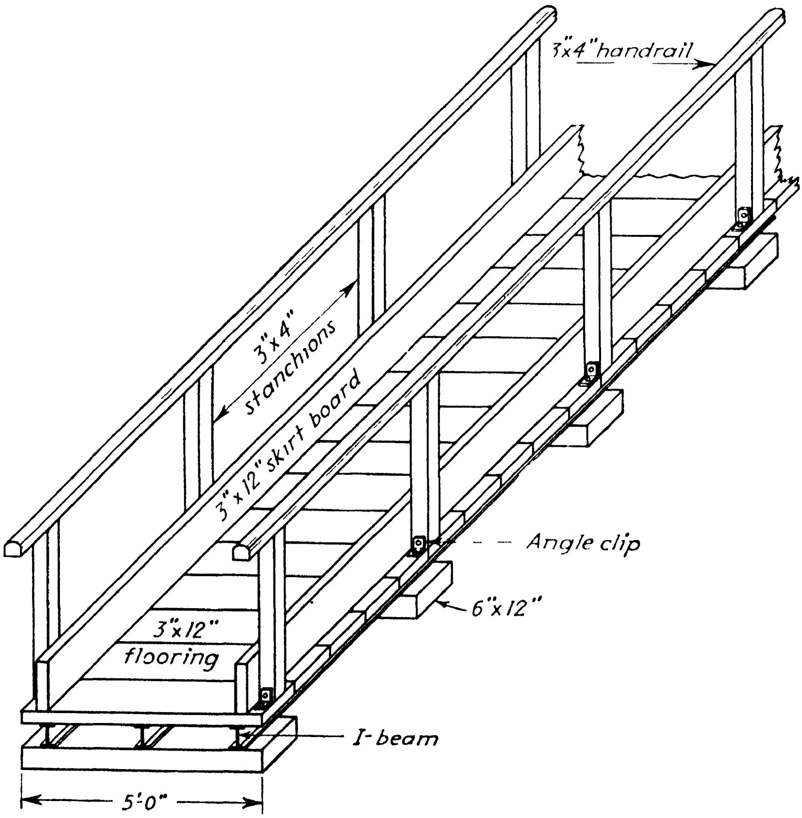


FIG. 498.—A type of heavy gangway.

In constructing this type of stairs, the height between decks is considered the rise, and the run may be figured out to a suitable degree of an angle, for example, 60 deg. After this the stringer can be laid off with a bevel square as illustrated.

RAMPS

Where long flights are necessary, particularly on the outside of the ship, a ramp is used instead of stairs. This is much safer for the use of workmen and much easier to climb. It should not exceed 4 in. rise per foot and must be well supported and braced.

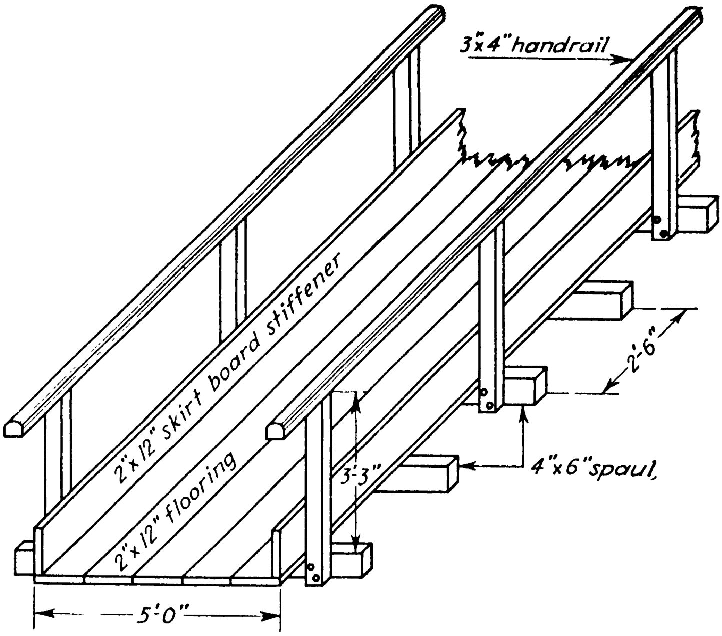


FIG. 499.—A light type of gangway.

Uprights supporting handrails should be well braced and should be not less than 4- by 4-in. cross-sectional timber, approximately 39 in. high.

Cleats should be installed on 15-in. centers. These usually consist of oak straps 1 in. thick and 2 in. wide, running the full width of the ramp.

Figure 497 shows a suitable form of ramp.

GANGWAYS

Gangways are used to extend from ramp and stair platforms to the ship. They must be built substantially owing to the large numbers of men using them, particularly at quitting time. Figure 498 shows a safe form for gangways up to 30 ft. in length. In Fig. 499 is shown a method of constructing a short, light gangway for use where traffic is relatively light.

CHAPTER XL

LAUNCHING

The work of launching a vessel is without doubt the most interesting part of the shipwright's work. There is a grave responsibility attached to the safe launching of a ship of any size. To those who are responsible, it is a time of anxiety and worry, which increases with the size of the vessel to be launched.

There must never be any doubt or question as to suitable stiffening and strengthening to be used in connection with the construction of the launch-way foundations, the launch ways, the launching cradle, or the structure of the vessel in the bearing area on the cradle where excessive strains are likely to occur during launching.

In respect to engineering, launching is a feat without parallel, consisting as it does in transferring literally thousands of tons of ship from the foundations on which it was built to the cradle and ways which carry it into the water, the entire operation taking but a few hours.

PRELIMINARY WORK

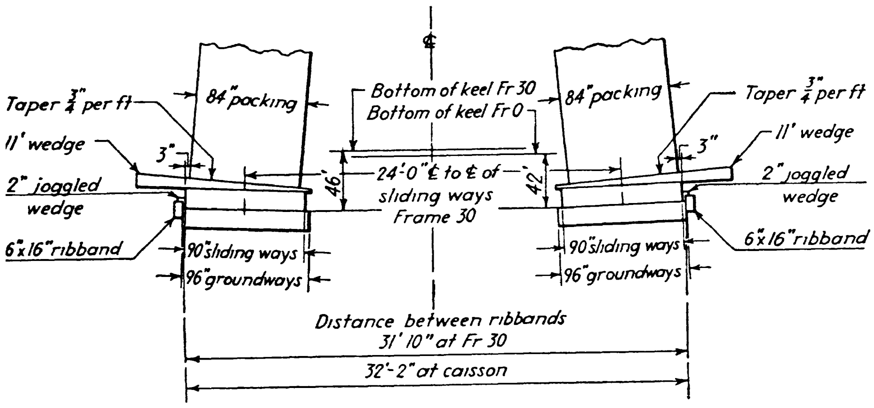
Launching begins with the setting of the keelblocks. These have to be set at the proper location, height, and grade to satisfy certain conditions for launching.

The keelblocks are located so that the vessel will be as close to the high-water mark as possible and still afford unhampered opportunity for the men to work around and under the stern.

Consideration must be given to the location of the launching triggers and trigger pit. If feasible, the ship should be located so that approximately one-half the length of the sliding ways will be forward of the trigger. While this is not always possible, it is desirable from the standpoint of reducing as much as possible the drag, or pulling effect, on the after part of the cradle.

As far as height is concerned, the keelblocks must be kept as low as possible, but at the same time sufficiently high so that when the ground and sliding ways are in position under the vessel there will be at least 12 in. clearance between the sliding ways and the hull at the closest point, in order to afford a sufficient thickness of packing above the setting-up wedges.

The grade is determined jointly with the height and must satisfy similar conditions; that is, the vessel must be kept as low as possible



General Notes

1	Transverse slope of groundways	3/8" per ft
	Inclination of groundways	9/16 per ft
2	Inclination of keel	½" per ft
3	Distance from keel to groundways FP	42"
4	Distance from trigger to push block	295-6"
	Total length of groundways	826'-6"
5	Width of groundways	96"
6	Total length of sliding ways	588' 6"
7	Width of sliding ways	90"
8	First saddle located at frame	30
9	Forward end of groundways at frame	17
10	Width of packing	84"
11	Trigger located at frame	135
12	Distance between ribbands at frame 30	31'-10"
	Distance between ribbands at caisson	32'-2"
13	Estimated weight of ship at launching LT	16,150
	weight of men and dunnage LT	350
	weight of ways and packing LT	1,000
14	Estimatea total weight on grease LT	17 500
15	Probable effective area of slidways	8,700 sq ft
16	Estimated pressure on grease, per Sq Ft	1 9 Lt.

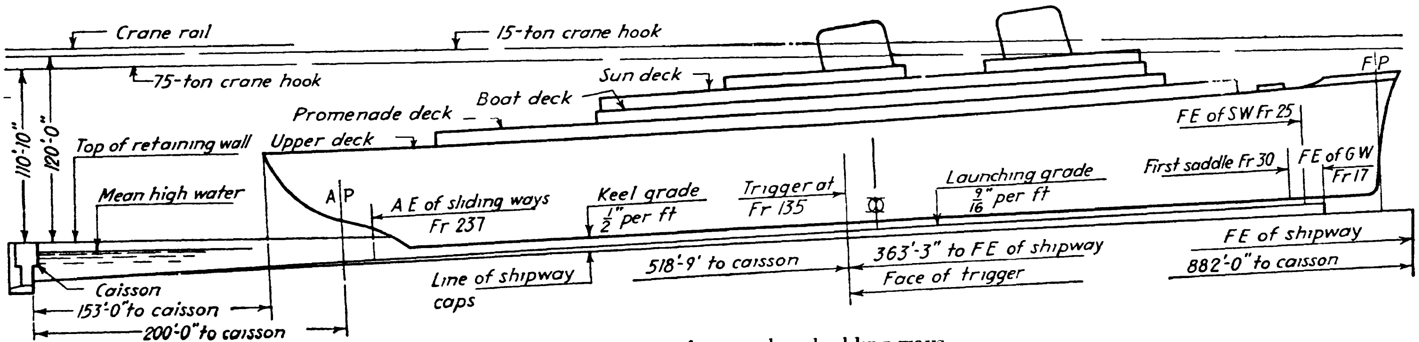


FIG 500 —Location of a vessel on building ways.

and, more important, with the proper relation to the ground-way inclination, so that the bottom of the keel at the stem will never drop below the level established at the top inside edges of the ground ways during the passage of the ship toward the water, particularly when pivoting occurs. If the forefoot is allowed to penetrate the plane of the top inside edges of the ground ways, the vessel is apt to foul the keel-track cribbing on the center line and ride over the timber or concrete foundations and cause considerable damage.

The grade of the launching, as well as the width of the sliding ways and width of packing, is determined from the estimated launching weight of the vessel. The shape and structural characteristics themselves determine the location of the sliding ways and packing and their probable effective lengths. These characteristics are so regulated as to create pressure per square foot on the grease ranging from 1½ tons up to 2½ tons for heavy vessels.

The preceding paragraphs are simply a brief outline of the considerations given to launching a vessel before the keel has been laid. We shall now proceed in detail with a discussion of the first part of the launching preparations.

SETTLING THE DETAILS

Let us assume that the preliminary plans for a vessel to be constructed have already been developed. The drawing room sends to the yard plans for consideration for laying down the keel of the vessel. These usually include the outboard profile, midship section, transverse sections, decks, shell plating, and bossing, together with the estimated weight of the ship at launching. From these plans there is developed a plan in section and profile showing the location of the ways and packing under the vessel (see Fig. 500).

This plan will give all necessary yard information to enable the drawing room to make its preliminary calculations and will include the following data:

1. Declivity of launch ways, inches per foot.
2. Declivity of keel.
3. Height of keel above top inside edges of ground ways at the forward perpendicular.
4. Distance between launch ways.
5. Length and extent of ground ways.
6. Width of ground ways.
7. Length and extent of sliding ways.
8. Width of sliding ways.
9. Location of fore-poppet saddle.
10. Width of packing.

11. Location of triggers.

12. Estimated weight of ways, packing, men, dunnage, and ballast, long tons.

13. Estimated total weight on grease.

14. Probable effective area of sliding ways on grease, square feet, both sides.

15. Estimated pressure on grease, long tons per square foot.

Declivity, or Slope, of Launching Ways. The first requirement in connection with the launching is that the ship must start. Starting depends primarily upon the weight per square foot on grease and the declivity, or slope, of the ways; and secondarily on the atmospheric temperature at the time of launching and the kind of launching lubricant used.

The method of determining the weight per square foot on the grease is to divide the total weight on the grease, which includes the weight of the ship, sliding ways, packing, men, and dunnage, by the effective area of the sliding ways. The effective width of the ways should be such as to produce a pressure of 1.5 to 2.5 tons per sq. ft. With heavy ships it may be found that extremely high unit pressures exist unless the sliding ways are excessively wide; in this case four narrow ways may be used instead of two.

If the launching is to occur during warm weather when the temperature is likely to be high, it is feasible to estimate a lower pressure, as the grease is likely to be softer and more easily squeezed out from between the ways during the slide. During cooler weather the pressure may safely be estimated up to 2.5 tons. With pressure running above 2.5 tons, the grease is likely to squeeze out, causing the ways to come together, wood to wood, and probably burn or stick. Cool weather also tends to slow the launching.

It is not always possible to obtain pressures as high as 1.5 tons per sq. ft. in launching small ships, because the width of the sliding ways should be not less than 12 in. owing to the possibility of tipping sideways if too narrow. Therefore, as the pressure decreases, the declivity must necessarily be increased to induce the tendency to slide. The greater the declivity, the faster the launching; yet this, also, increases the strain on the ship and fore poppets unless the declivity of the keel is made suitable. This can be done by giving less slope to the keel of the vessel than to the ground ways.

Launch-way declivities are somewhat in accordance with the following inclinations *for endways launchings:*

Small vessels, $\frac{7}{8}$ to $1\frac{1}{8}$ in. per ft.
Moderate-sized vessels, $\frac{11}{16}$ to $\frac{3}{4}$ in. per ft.
Large vessels, $\frac{1}{2}$ to $\frac{5}{8}$ in. per ft.

From the foregoing considerations the declivity of the launch ways is decided upon.

Most vessels are launched with straight ways, but occasionally ways are cambered, giving them a constant-radius curve getting steeper near the way ends.

The radius of the arc for cambered ways for large ships is usually between 40,000 and 50,000 ft. The camber may also be stated to be 12 in. in 700 ft., the 12 in. being the height of the arc and 700 ft. the length of the chord of the ground ways.

Cambered ways should have a mean declivity in the length of the sliding ways of ½ to ⅝ in. per ft. They have the advantage that they permit an increasing declivity so that, while the upper part of the ways may drop only about ½ in. per ft., the lower part may drop ¾ in., or 50 per cent more. It is advantageous that the declivity at the upper part should not exceed ½ in. to the foot, for this is sufficient to start the ship. The tendency is for the vessel to start off slowly but to increase in speed more rapidly as it enters the water than if straight ground ways are used.

Cambered ways are also used when the depth of the water over the way ends is limited by the extent of the ground-way foundations, and a considerable final declivity is necessary to prevent tipping and to maintain the motion of the vessel as the stern enters the water, so that it will not slow up during the critical stage when the cradle is about to leave the end of the ground ways. There is, however, the disadvantage of increasing the strain on the vessel and the poppets when the stern lifts.

Declivity and Height of Keel. The location of the vessel relative to the ways is important. With ways sloping ⅝ in. per ft., the ship's keel usually slopes about ½ to ⅝ in. per ft., while a vessel requiring a ¾ in. per ft. launching grade may have a keel slope of ⅝ in. per ft. Extremely heavy vessels are usually given a keel grade of $\frac{1}{16}$ in. per ft. less than the launching grade. If excessive way-end pressures are expected and the ship is lightly constructed, so that the structure will not withstand excessive pressure, it is advisable to give the keel the same slope as the ground ways in order to invite quicker buoyancy, or lifting effect, as the stern enters the water. This consideration is decided upon by the drawing room when calculations are made.

The author prefers the keel parallel to the launching grade, since the only disadvantage is an increase in pivoting pressure, and if this is not too great it can be offset by stiffening the structure in way of the saddle straps and increasing the size of saddles. The smaller slope decreases the pivoting pressures by delaying the time the stern begins to lift but has the disadvantages that it increases the danger of tipping and increases the strains on the ship when weight is concentrated near the way ends (way-end pressure).

The height at the stem must be such as to prevent the bow from tipping down and striking the ways or bottom when the fore poppet clears the way ends. The distance from the keel to the top inside of the ground ways is established so that the keel will be as low as possible to avoid excessive height of keelblocks and launching cradle. But, at the same time, it must be high enough to accommodate the sliding ways, setting-up wedges, and at least a 6-in. strake of packing between the hull and the wedges at the lowest point. The allowances made, the underside of the ground ways being used as a base in arriving at this height, are as follows:

1. Thickness of ground ways.
2. Thickness of sliding ways.
3. Thickness of wedges.
4. Minimum thickness of packing.

As the bottom of the vessel usually has a dead rise, it will be found that the height of the shell at the location of the packing will be above the bottom of the keel. From the line, or transverse-section plane, this height may be established by running a buttock, or vertical fore-and-aft plane, of the bottom of the ship and applying this against the normal base line, thus ensuring a sufficient and a minimum height above the keel.

Consideration must also be given to the amount of drop of the bow, or forefoot, at pivoting. Roughly, it may be assumed that the vessel will trim by the stern approximately $\frac{1}{16}$ in. per ft. of its length when afloat. The amount of overhang forward of the fore poppet, or pivoting point, will govern the amount of dip, or drop; therefore, if the vessel has an overhang of 60 ft. and the keel grade is $\frac{5}{8}$ in. per ft., the amount of dip must be $\frac{5}{8}$ in. per ft. minus $\frac{1}{16}$ in. per ft. times 60 ft., or 0.5625×60, which is $33\frac{3}{4}$ in. dip. Therefore, the keel should be no less than this distance above the top inside edge of the ground ways; that is, the grade of the keel per foot, minus the trim per foot, multiplied by the amount of overhang is the amount of drop, or dip. This dimension is checked at the time calculations are made and is largely dependent upon the buoyancy and distance slid to pivoting.

Distance between Launch Ways. From the midship and transverse sections at the ends, we shall now establish the transverse centers of the ways and packing.

The distance between the ways, center to center at the forward end, is usually about one-third the vessel's beam. The precise distance should be decided by the structural arrangement of the hull, for the ways should be so placed that longitudinals, or keelsons, may take the pressure of the ways. Consideration must also be given to the position of the outboard caps and piling.

The closer together the ways, the more extensive the support received from the cradle, because the cradle may be carried farther forward and aft before it leaves the flat part of the ship's bottom; and by placing the fore poppets near the bow this will reduce the tendency to premature pivoting and the amount of overhang of the ship unsupported by the cradle.

In long fine-lined vessels a considerable portion of the hull at either end may overhang the cradle, in some cases as much as 80 ft.; therefore, it can readily be seen that the shape of the vessel, together with the distance between centers, governs the effective length of the sliding ways and packing. Consideration must aiso be given to obtaining and securing proper bearing of the hull upon the cradle, at the same time that the possibility of efficiently housing the after packing about the bossing, or shaft struts, is observed.

In establishing the distance between the ribbands of the ground ways, allowances should be made for slight clearance between the outside of the sliding ways and the ground-way ribband. The ground ways do not run parallel, the distance between ribbands at the extreme afterend being about 4 in. greater than this same distance at the forward end. This is done so that, if there is any slight lateral movement of the sliding ways and packing during the passage down the ways, there will be little opportunity for the sliding ways to jam hard against the ground-way ribbands, thus possibly splitting them off.

Length and Extent of Ground Ways. The length and extent of the ground ways are governed at the forward end by the extent of the sliding ways and at the afterend by the extent of the outboard piling and caps, or ground-way foundations, of the shipway. In some instances where the depth of water may be insufficient for certain types of vessel, it may be necessary to extend the outboard foundations to give the desired depth.

On semisubmerged shipways the ground ways are usually extended to the inboard sill of the caissons, or cofferdam, where the depth of water is usually sufficient for safe launching.

When small or medium-sized vessels are launched from semisubmerged shipways designed for large ships, it is not necessary to extend the ground ways to the caissons, for these ships require much less water to become water-borne and are therefore afloat before reaching the available depth of water at the ends of the shipways. In such cases the ground ways are extended only far enough into the water to prevent a drop off of the cradle as it leaves the ends of the ground ways. At the forward end the ground ways are extended far enough forward of the ends of the sliding ways to allow room for emergency starting jacks and the push block on which they bear.

Width of Ground Ways. The width of the ground ways should be not less than the width of the sliding ways plus 3 in.

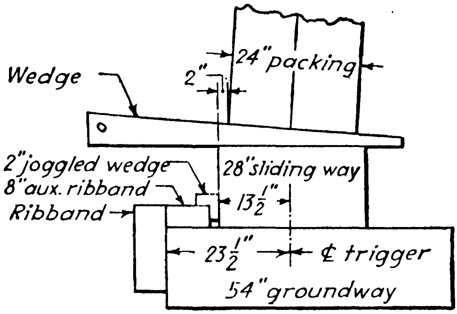


FIG. 501.—Section in way of 54 in. ground ways, using 28 in. sliding ways and auxiliary ribband.

Occasionally, ground ways left in place from a previous launching are utilized, and these may be considerably wider than necessary. In this case an auxiliary ribband is fitted inside the side ribband to center the sliding ways with the trigger, which is usually located about the center of the ground ways (see Fig. 501). However, in extreme cases, it may be necessary to move the ways laterally to suit the desired distance between ribbands.

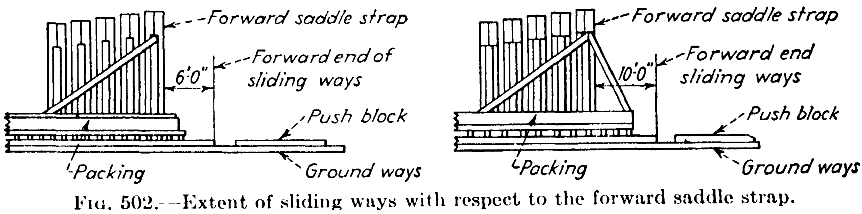


FIG. 502.—Extent of sliding ways with respect to the forward saddle strap.

Length and Extent of Sliding Ways. The length and extent of sliding ways is governed at the forward end by the location of the center of the foremost saddle strap. The sliding ways should be extended no farther forward than necessary, because of the excessive strain thrown upon them as the vessel pivots, which may result in breaking them if they are extended too far forward of the poppets.

If there is to be a diagonal shore fitted between the top of the fore poppet and the crushing section, the ways are usually extended far enough forward to give sufficient strut to this diagonal shore. If there is no diagonal shore, they are usually extended 6 ft. forward of this same point. Diagonal shores are fitted only when the poppets are unusually high and require stiffening from the forward end (see Fig. 502).

At the afterends the sliding ways are usually extended about 6 ft. aft of the end of the packing.

Width of Sliding Ways. The width of the sliding ways is governed by the possible effective length of the ways, the weight expected on the grease, and the desired pressure per square foot on the grease.

For example, let us say that we have a total of 16,000 tons on the grease. The time of launching is January, when the temperature is relatively low. A pressure of 2 to 2.5 tons per sq. ft. on the grease is desirable, owing to a high coefficient of starting friction. For safety we shall use a mean of the two pressures, or 2.25 tons. The effective length of the sliding ways is 500 ft. The width of the sliding ways is then figured as follows:

$$P = \frac{W}{L \times 2w} = \frac{\text{weight}}{\text{area}}$$

$$w = \frac{W}{P \times L \times 2}$$

$$w = \frac{16{,}000}{2.25 \times 500 \times 2} = 7.11$$

where W = 16,000 tons = weight on grease.
L = 500 ft. = length of sliding ways (one side).
P = 2.25 tons per sq. ft. = allowable pressure on grease.
w = width of sliding ways (one side).
$2w$ = width of sliding ways (both sides).

The width of the sliding ways should be 7 ft. 0 in.

The effective length, width, and area of sliding ways is the portion of the sliding ways bearing on the grease that will actually support the weight of the cradle.

At the forward and after ends where the ways project beyond the ends of the packing, there is little weight on this area. Consequently, it is subtracted, as it is not affected. In the width of the way it is roughly estimated that the effective width is 1 in. less than the actual width of the ways, owing to the worn edges of the sliding ways.

Location of the Fore-poppet Saddle. The center of the fore-poppet saddle strap should be located under a bulkhead or suitable transverse strength member, if possible, to give proper support during pivoting. If this is not feasible, some suitable stiffening must be made to the ship's structure to withstand the pressure against the hull. Consideration must also be given to the amount of unsupported overhang of the hull forward of the saddles, as there is a possibility of the forefoot striking the caps during pivoting or in dropping off the way ends. It may be desirable to move the fore poppet farther forward in addition to adding water ballast aft to prevent this.

Width of Packing. Packing is customarily made not more than 4 to 6 in. narrower than the sliding ways in order to permit a uniformly distributed load at the grease. Standard-sized timbers are used where practicable.

Location of Triggers. The triggers should be located, if possible, to suit the available trigger pits so as to afford unhampered opportunity for working around them on the day of launching. On the semisubmerged type of ways a pit is usually provided to give ample headroom under the groundway foundations. This, however, fixes the location of the trigger pit and must therefore be considered in locating the ship on the stocks. On the wooden type of stocks it is possible to shift the trigger pit, but this should not be resorted to unless absolutely required as it necessitates cutting out some of the timbers and bracing of the stocks.

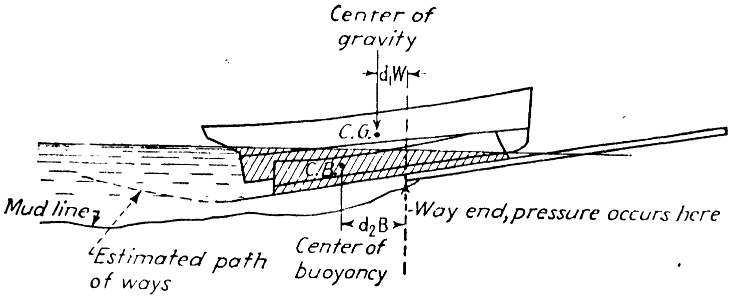


FIG. 503.—The tendency toward tipping.

As has already been stated (page 448), the triggers should be located about midway of the length of the sliding ways.

Calculations. After a preliminary sketch of the proposed location of the vessel on the stocks has been developed, it is submitted to the hull department for its consideration. Complete launching calculations are not made if the vessel is similar to some vessel previously launched. However, if the vessel is a new type, complete calculations are made before the keel is laid to ensure a safe and successful launching. It may be found necessary according to these calculations to extend the outboard ground-way foundations to obtain the necessary amount of water over the way ends where parts of the vessel are subjected to excessive pressure or it may be found that the ship's structure will require internal stiffening. This work can be done more easily in advance of its actual need and along with the hull structure.

At this time the slope of the keel and its height above the top inside edges of the ground ways are also checked to avoid any possibility of the fore poppet striking the keel track during pivoting.

Complete launching calculations will not be discussed. However, the shipwright who works on the preparations for launching a vessel should understand at least some of the factors that must be provided for in order to launch a ship safely.

Factors to Be Allowed For. While the vessel is sliding down the ways, as long as the entire length of the sliding ways is still on the ground ways stability is maintained. As the stern enters the water, the sliding ways overhang the ground ways and displacement gradually increases, as shown in Fig. 503. When this occurs, there is a tendency for the stern to tip down over the way ends. This is offset by the rapidly increasing buoyancy at the afterpart of the ship.

In order to prevent any possibility of tipping it is essential that the moment of buoyancy about the afterend of the ways shall be greater than the moment of weight about the way ends. If the moment of weight exceeds the moment of buoyancy, there will be a tipping moment,

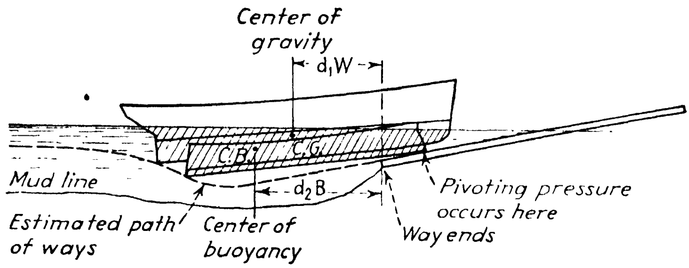


FIG. 504.—Pivoting.

which can be overcome either by increasing the length of the ground ways, thus increasing the water over the ways, or by placing ballast at the forward end. This would ensure a safe moment against tipping.

During the time when the stern of the ship is still supported by the ends of the ways and with little buoyancy, there is also a concentration of weight, or pressure, on the afterends of the ways that must be withstood by the structure of the ship. This is called *way-end pressure.*

As the vessel continues to slide into the water, the buoyancy continues to increase and there comes a time when this is sufficient to lift the stern (see Fig. 504). When this occurs, all the remaining weight is thrown on the ways at the extreme forward end, or on the fore poppets. This is called *pivoting.* The pressure on the grease in way of the fore poppets at the instant of pivoting is known as *pivot pressure.*

After the vessel has pivoted, it continues to slide along supported by the buoyancy and the fore poppets until the ends of the sliding ways come to the end of the ground ways and drop; or if the ground ways are of sufficient length, they simply float off without any drop. At this point the ship becomes completely water-borne and dependent on her own stability to remain upright.

RELEASING THE SHIP

Various methods of releasing the ship are employed, such as sawing off solepieces, burning off plates, and releasing various types of mechanically and hydraulically operated triggers.

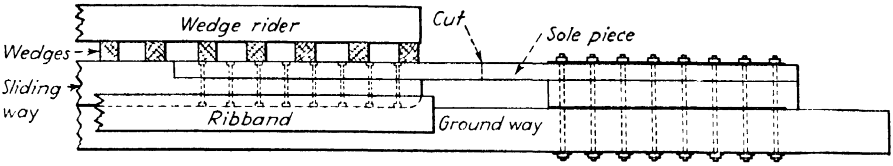


FIG. 505.—Solepieces.

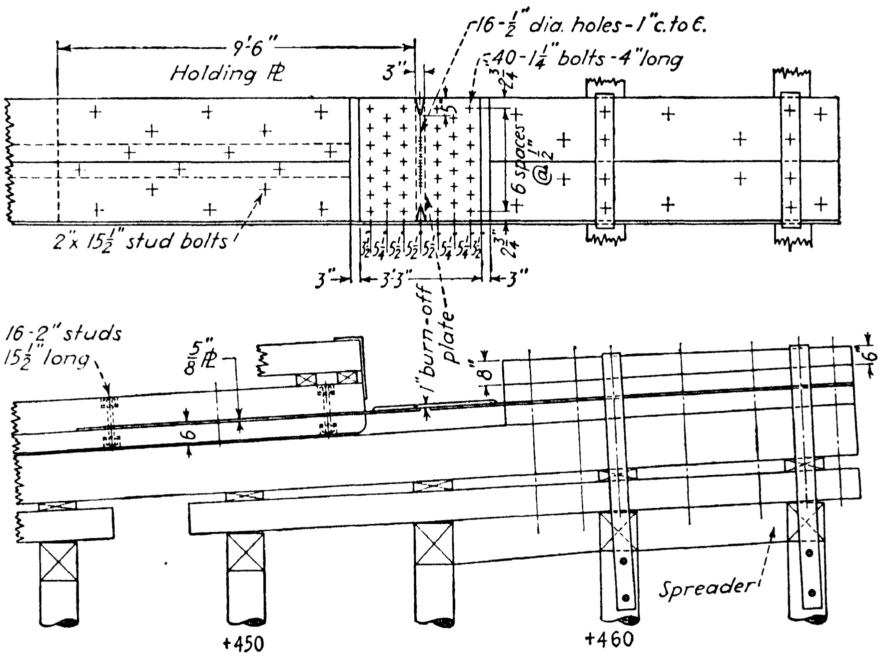


FIG. 506.—Burn-off plates.

Solepieces. Small vessels are usually released by sawing through oak solepieces, one at the forward end of each sliding way. These are merely pieces of timber securely bolted to the sliding ways and to the ground ways. One type of solepiece is shown in Fig. 505.

Burn-off Plates. Another method of releasing small and medium-sized vessels is by means of the burn-off plate. These are attached to the sliding ways and secured to the ground ways in somewhat the same manner as solepieces but are burned off with acetylene torches when the ship is to be released. A type of burn-off plate commonly used for launching a vessel weighing 5000 to 6000 tons is shown in Fig. 506.

Triggers. For releasing heavy vessels hydraulic or mechanical triggers are generally used. Hydraulic triggers consist of an assembly made up of heavy structural shapes and plates on the underside of which are mounted a latch, hydraulic cylinder, and piston, together with a lever, or trigger, that is fulcrumed on a bearing and projects up through a recess in the ground ways. This whole assembly is securely bolted to the ground ways as shown in Fig. 507.

The section of sliding ways that bears against the trigger projecting through the ground ways is fitted with a steel *shoe*, or bearing plate,

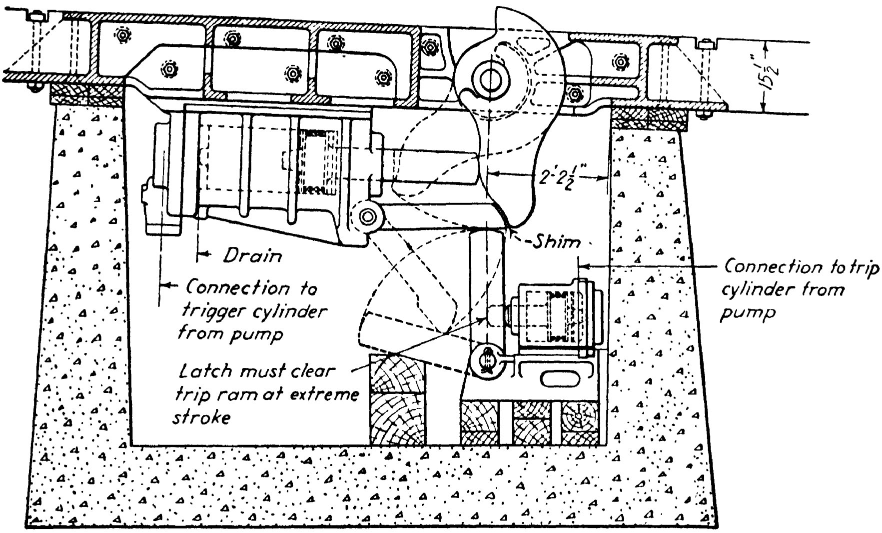


FIG. 507.—A type of hydraulic trigger.

which bears against the trigger, preventing any tendency for the sliding ways to move aft until the trigger is released.

The piston in the hydraulic cylinder bears against the lower portion of the trigger. Thus, any tendency for the ship to pull, that is, of the ways to move toward the water, is counteracted by pumping pressure on the cylinder with a hydraulic pump.

A heavy steel keeper block, which is beveled where it bears against the trigger, is fitted between the cylinder casting at the bottom and the lower end of the trigger. Between the beveled end of the keeper block and trigger a thin metal plate, or shim, is fitted. At the bottom of the trigger and under the keeper block there is a latch, which holds the keeper block in place until it is released. The latch is necessary because, with the bevel on the end of the keeper block, the latter could easily drop out; but the latch prevents this until it is released. A shore set up on wedges is usually installed under the latch to assist in keeping the keeper block in place, also. If all goes well, this shore is removed when the bottom of the ship has been cleared as far forward as the trigger pit. After this, the catch on the latch holds the latch in place.

If the ship is pulling and there is sufficient pressure on the cylinder to prevent movement, that is, when the pull of the ship is balanced by the pressure on the cylinders, to release the ship it is necessary merely to release the latch and allow the keeper block and shim to drop away and then exhaust the cylinders.

If the hydraulic piping, or pump, should fail, the ship cannot be released until the keeper blocks have been dropped or burned out. This, of course, is not at all desirable.

An interesting feature of hydraulic triggers is the function of the shim between the trigger and the keeper block, for the pull of the vessel can always be sensed and furthermore may be equalized by pumping sufficient pressure on the cylinders so that the shims will always be loose.

The clearance between the keeper block and the shim should be not greater than ⅛ in. This generally permits a clearance on both sides, should there be a slight inequality in the amount of clearance between the shim and the keeper block on both triggers.

Thus, through the use of triggers it may be definitely determined what is going on during the time the bottom of the ship is being cleared.

The coefficient of starting friction may be determined as follows:

$$W_n = W \cos \alpha$$
$$W_s = W \sin \alpha$$

where W = weight of ship.
W_n = normal component of the weight of the ship.
W_s = sliding component of the weight of the ship.
α = angle of inclination of the ways.

$$F = W_s - P$$
$$f = \frac{W_s - P}{W_n}$$

where F = force of friction.
f = coefficient of starting friction.
P = pull of ways against trigger.
p = unit pressure in trigger cylinders (tons per square inch).
A = area of trigger cylinder (both sides).
L = leverage of cylinders.
$P = ApL$

The coefficients may vary for different conditions of temperature and unit pressure on the grease. From past practice a coefficient may be assumed, and with the foregoing computation *the gauge pressure to be expected can be fairly accurately forecast.*

Mechanical Triggers. Another form of releasing device is the mechanical trigger shown in Fig. 508. This type requires no pumps, high-pressure hydraulic piping system, or releasing valves. It consists of a series of three levers, which holds the trigger until released. In

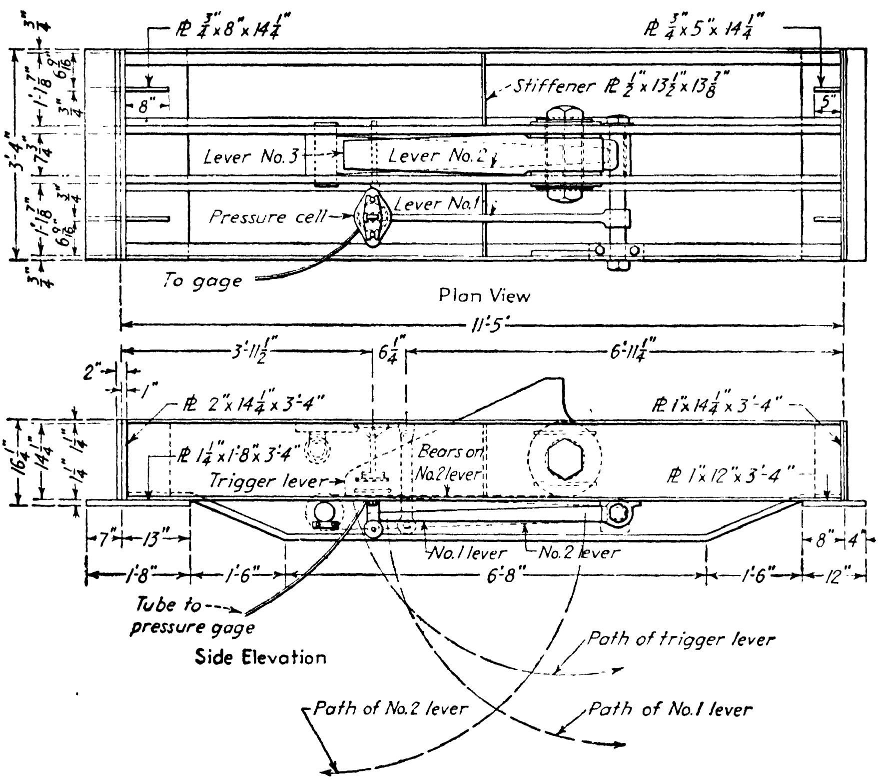


FIG. 508.—A type of mechanical trigger.

releasing, lever *A* is dropped by releasing the supporting latch, which can be operated from the launching stand or the central directing station. Upon releasing lever No. 1, lever No. 2 is permitted to drop, thus releasing the trigger, which, when dropped, completely clears the sliding ways.

Dogshores. On large vessels dogshores are sometimes used. They are chiefly a safeguard against possible faulty releasing devices. They are usually located aft of the midship part of the ship. More than one set may be used if necessary.

Dogshores are in themselves a releasing device and are sometimes used as such. But when used in conjunction with triggers, solepieces, or

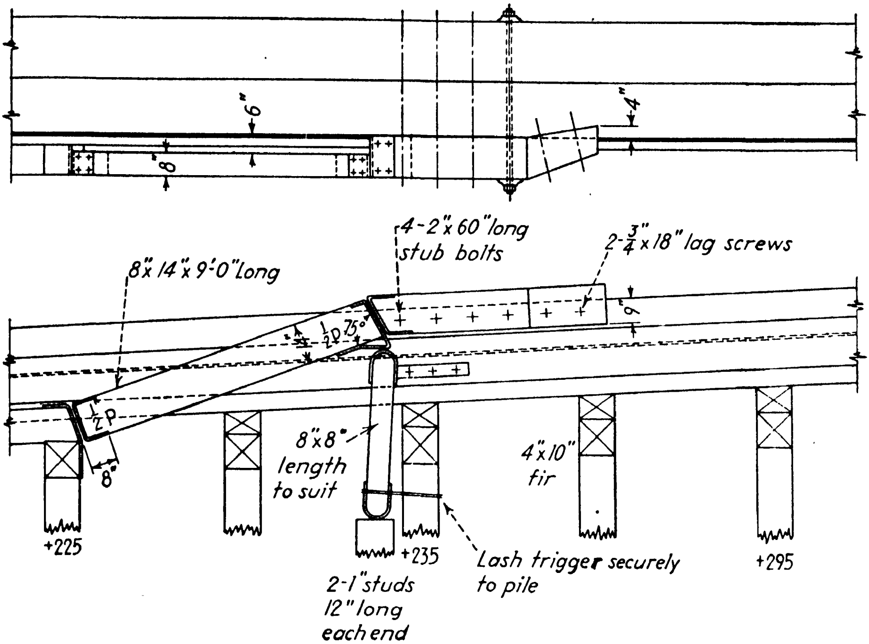


Fig. 509. -A type of dogshore.

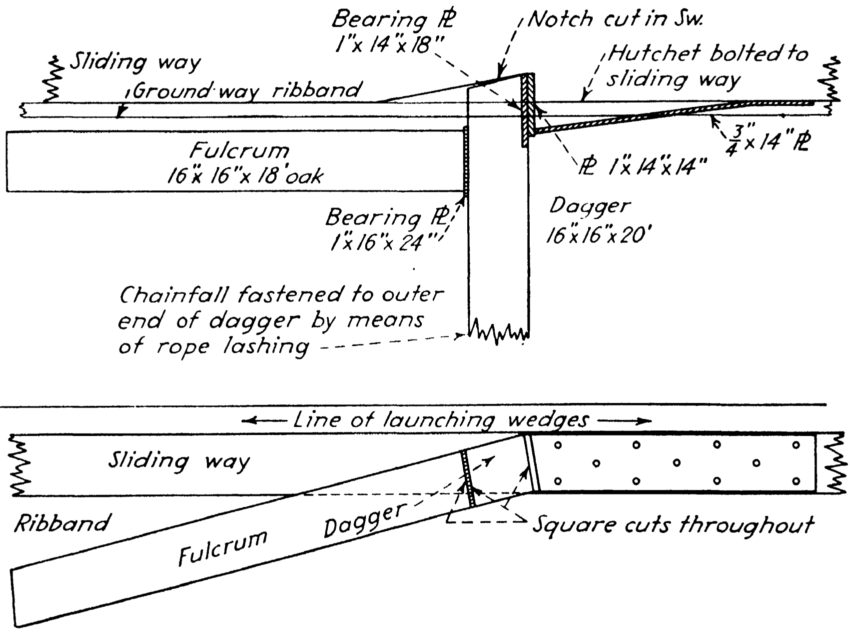


Fig. 510.—A type of dagger shore.

burn-off plates, they are released and cleared away just before the cutting off or the releasing of the triggers.

The dogshore is placed between two heavy timbers bolted to the sliding ways and the ground ways, respectively, as shown in Fig. 509. The timbers, together with the dogshore, are reinforced at the points of bearing with steel plate.

The forward end of the dogshore is beveled to an angle of 75 deg. to allow it to drop when the trip shore supporting it is removed. The trip shore should also be faced with steel plate; it is removed by striking it with a four-man ram either forward or aft.

It is good practice to install a jack between the top of the dogshore and the shell in the event that the shore should jam.

Dagger Shores. Another form of releasing device, or preventer, used in connection with launching is the dagger shore. One dagger is fitted on each side of the vessel, approximately one-fourth the length of the vessel forward of the after perpendicular. The dagger shore itself consists of a 14- by 14-in. or 16- by 16-in. oak timber about 20 ft. long laid in a horizontal plane with the inboard end set into a recess in the outside edge of the sliding ways (see Fig. 510). The recess is lined with steel plate, as are also the inboard end of the dagger shore and the top end of the pivot shore.

The dagger shore is fulcrumed against a heavy oak or pivot shore, which is canted downward at the afterend and seated hard against a footing in the shipway. When the dagger shore is placed in position, a strap consisting of 6-in. manila is placed on the outer end. A 15-ton chain fall is hooked into the bight of the strap, and the other end of the chain fall is secured farther aft to a suitable anchor. By tightening up on the chain fall, the dagger shore will lever the sliding ways in a forward direction, thus preventing them from going aft until released.

To release the daggers, it is necessary merely to cut the manila strap with an ax, which causes the dagger to jump forward and the pivot shore to drop. The dagger is then hauled clear of the sliding ways.

LAUNCHING PREPARATIONS

In the preparation for installing the ways, packing, and other launching gear under the vessel, all the necessary calculations for the safety of the vessel during launching will have to be made and drawings of the cradle furnished to the shipwright department by the drawing room. In old established shipyards, drawings for the cradle usually consist of those for the fore poppet, the after poppet, and packing through the midship section, as shown in Fig. 511. If internal stiffening or shoring of the hull structure is found necessary, drawings will also be furnished for details of these. Detailed drawings of the foundations for ground ways,

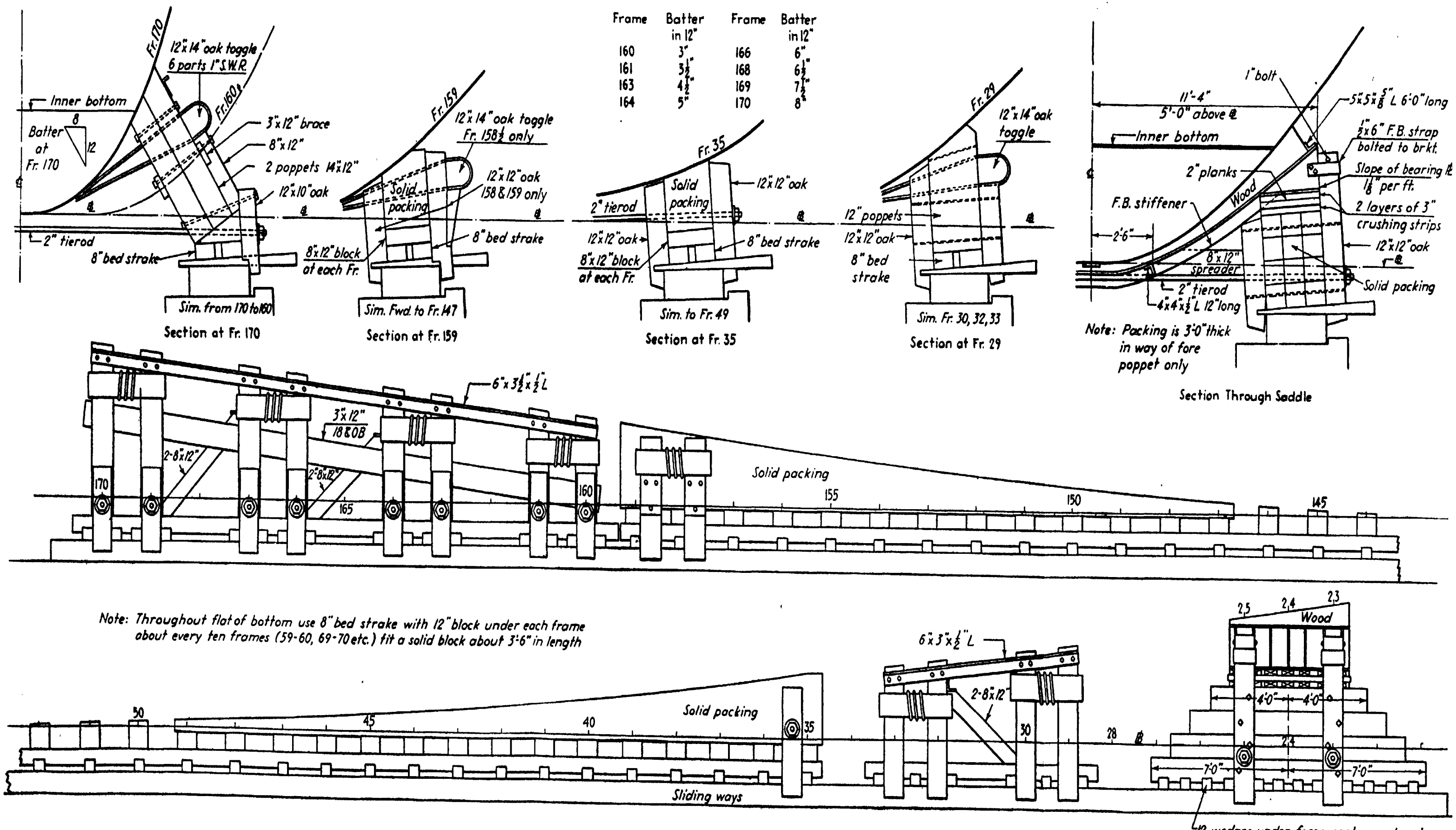


FIG. 511.—Launching cradle for a small ship.

construction of launch ways, arrangement of tricing and pulling lines, etc., are usually left up to the yard departments to develop from experience in previous launchings.

Construction of Ground Ways

Ground ways are constructed of heavy timbers, usually 12 by 12 in. in cross section, built up to the desired width. The timbers are generally sized by dressing one side and one edge, so that they will be uniform in size and will line up on both the top and the bottom.

Ground ways are usually built in standard-length sections of 60 ft. However, it is sometimes necessary to install a longer or shorter piece to make up the desired length. They should be built with standard connections, so that they can be used in any location except where special considerations have to be met. In assembling ground-way timbers, the butts should be staggered so that the ways can be handled without danger of buckling (see Fig. 512).

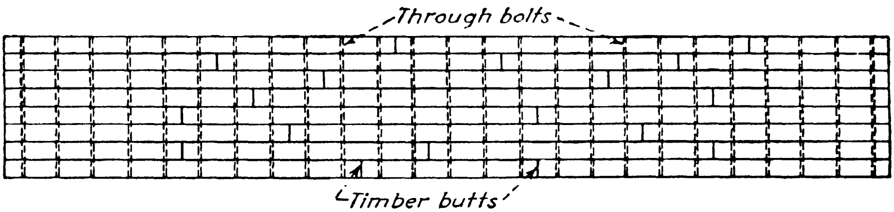


FIG. 512.—Arrangement of timber butts in constructing ground ways.

Timbers. Timbers should be laid on a series of level skids, preferably 12- by 12-in. timber suitable to accommodate the width of the way. Steel brackets or chocks are then fastened securely to the timbers, spaced at a distance 6 in. in excess of the width of the way including the ribband. When the timbers are placed on the skids, one edge can be placed hard against the brackets and, after all timbers have been placed in position, wedges or a jack may be used to bring the timbers hard up against each other. Holes for securing the timbers together can then be spaced and drilled to suit the ribband, which will be bolted to the side with the upper line of bolts. Bolts are usually staggered 4 in. from the top and bottom of the timbers and are spaced on approximately 2-ft. centers.

After the holes for the bottom bolts have been drilled, they are then counterbored, so that the nuts will set in flush with the timber, particularly on the ribband side. It is not necessary to counterbore holes for nuts on the inside; however, it is good practice to do this, because if the ends of the bolts are left projecting out over the side they can cause considerable damage by rubbing against other ways when in the water for moving or when in storage.

Bolts 1 in. in diameter are ordinarily used for securing way timbers together.

Where the building of ways is extensive, holes for bolts may be jigged in the timbers before they are put together, regardless of whether or not the boltholes extend through the ways parallel to the bottom of the timbers.

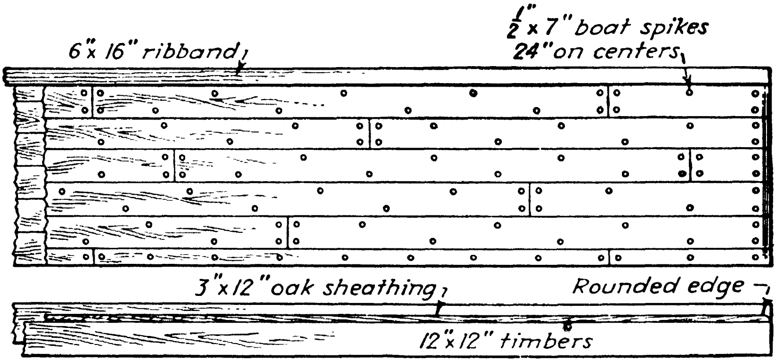


Fig. 513.—Sheathing on ground ways.

After the lower line of bolts has been placed through the timbers and tightened, the installation of the ribband can begin. However, if sheathing is to be used on top of the timbers, it should be installed before the ribband is put on.

Some ways are designed with sheathing. The use of sheathing on the way timbers is practical; for if any damage should occur to the bearing surface of the ways, the sheathing can be easily renewed. This, of course, is much easier than to renew the heavy timbers.

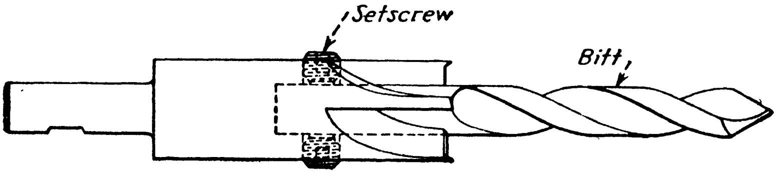


Fig. 514.—A counterbore drill used for boring holes for boat spikes to secure sheathing.

When the ways are sheathed, a few bolts should be installed in the upper line of holes in the timbers and the bolts tightened, so that the timbers will be drawn up hard together. Sheathing is then installed as shown in Fig. 513. Care must be exercised in making all butts and seams tight to prevent the launching lubricant from getting into the crevices and spreading off the sheathing, particularly at the edges.

Sheathing used for ground ways is usually 3- by 12-in. oak installed in 16-ft. lengths. The method for tightening the timbers by means of wedging between brackets is also used in pulling together the sheathing.

When the sheathing has been wedged hard up together, holes are bored for boat spikes, which fasten it to the timbers. Galvanized boat spikes ½ by 7 in. are used for this purpose, and they are staggered in the plank on 2-ft. centers, as shown in Fig. 513. In Fig. 514 a drill is shown for boring holes for boat spikes, together with a counterbore for the head of the boat spikes, so that they will not project above the top of the sheathing or split it when driven.

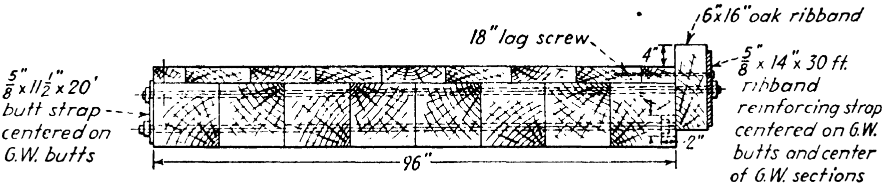


FIG. 515.—Transverse section of ground ways, showing reinforcing plate on ribband.

After the sheathing has been spiked down to the timbers, it is planed down with a deck planer to create an even surface. The work of installing the ribband can then be performed.

Ground-way Ribband. Ground-way ribband usually consists of 6- by 16-in. oak timber with as few butts as possible. The top of the ribband ordinarily extends 4 in. above the top surface of the ground ways, regardless of whether or not sheathing is used.

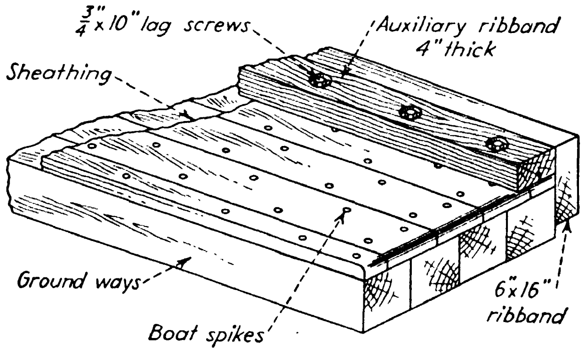


FIG. 516.—An auxiliary ribband secured to ground ways with lag screws.

If sheathing is used, it will be necessary to block under the ribband on top of the skids until it lines up the proper distance above the sheathing. The ribband can then be wedged up hard against the ground ways from the brackets. The top line of holes, which have already been drilled through the timbers, are run through the ribband, and after this the bolts for securing the ribbands to the ground ways are installed and tightened up.

Owing to the strain at the top of the ribband in the event that the sliding ways bear hard against the ribband during the passage of the ship down the ways, it is good practice to install additional stiffening by means of flat-bar clips, near the top of the ribband, secured to the ways with lag screws driven into the sheathing. In some instances a con-

FIG. 517.—Sliding ways being utilized as ground ways with the use of auxiliary ribband.

FIG. 518.—Shipwrights driving lag screws into auxiliary ribband with a bolting machine.

tinuous steel plate the width of the ribband is used for some distance at the lower end of the ways, generally in the area between the high-water mark and the ends of the ground ways. This is shown in Fig. 515.

Ground-way Auxiliary Ribband. When ground ways have been left in place on a shipway from a previous launching but when the distance between ribbands must be closed up, but to no great extent, to suit a different type of ship, an auxiliary ribband is sometimes used instead of moving the ways. However, consideration must also be given to the transverse location of the trigger in the ways, so that the sliding ways will bear approximately in their transverse center against the trigger.

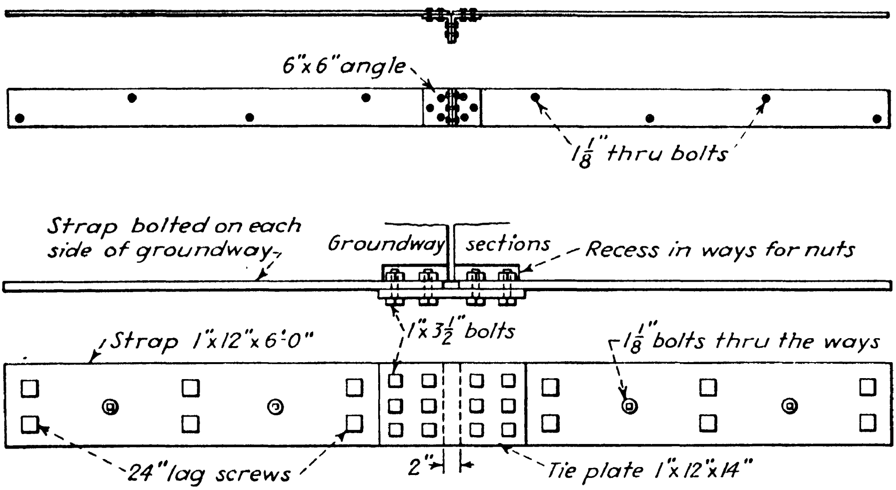


FIG. 519.—Ground-way butt strap.

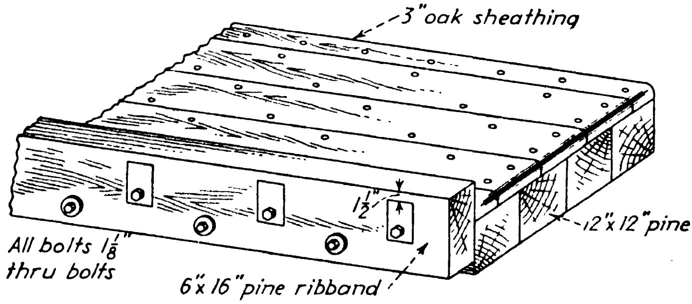


FIG. 520.—The general construction of a section of ground ways.

The auxiliary ribband consists of timber 4 in. thick and of the desired width to give the desired distance between the auxiliary ribbands. It is secured to the top of the ground ways by means of lag screws ¾ in. in diameter and 10 in. in length, spaced on 3-ft. centers, as shown in Fig. 516.

Figure 517 shows a set of sliding ways being utilized as ground ways with the use of auxiliary ribband. In Fig. 518 shipwrights are shown driving lag screws into an auxiliary ribband with a bolting machine.

Ground-way Connections. The connection for making up the ground-way sections consists of a plate strap extending for a distance of

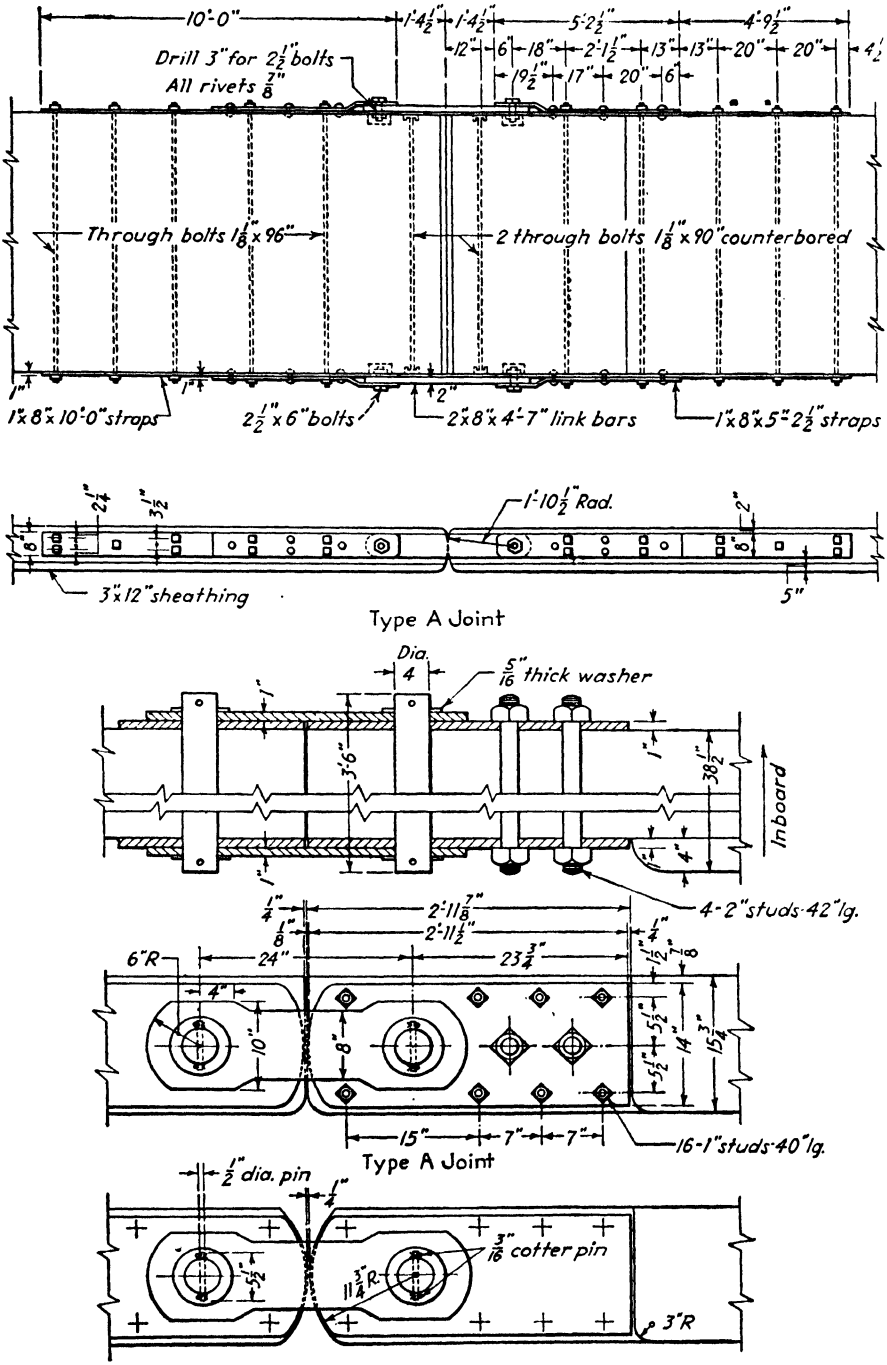


FIG. 521.—Sliding way couplings.

6 ft. on either side of the butt. These strips are also designed to be standard to fit on any butt, taking the regular bolts that hold the ground-way timbers together.

The straps on the outside of the ribband are located in its center and take the through-bolts in the ways, a 24-in. lag screw being staggered between these bolts at the top to give further reinforcing. This butt strap is shown in Fig. 519.

Figure 520 shows the general construction of a section of ground ways. The butts of the ground-way sections at the top are rounded off as shown, so that in the event one section projects above the top of the other to some slight extent, there will be no tendency to damage them when the sliding ways pass over the butts.

Sliding Ways

Sliding ways are constructed in the same manner as the ground ways, but without the ribband. However, couplings are provided at each end for connecting the ways together, as shown in Fig. 521.

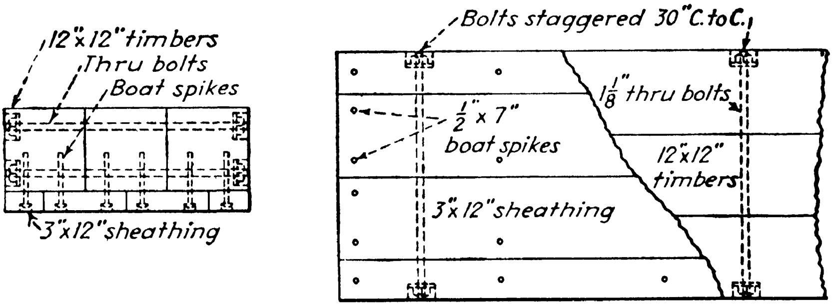


FIG. 522.—The general construction of the sliding ways.

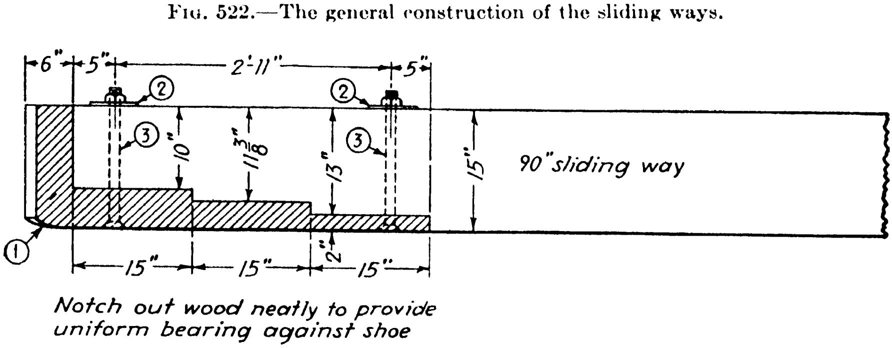


FIG. 523.—Steel trigger shoe.

In Fig. 522 is shown the general construction of the sliding ways, which are sheathed with 3- by 12-in. oak sheathing. The section of sliding ways on each side of the ship that bears against the trigger is fitted with a steel shoe, as shown in Fig. 523. The section immediately aft of the section bearing against the trigger must be recessed at the bottom for the trigger will set immediately below this, as shown in Fig. 524.

Another type of shoe for bearing against the trigger may be used when it is not desirable to place the butt of the sliding ways against the trigger. In this case, a casting similar to that shown in Fig. 524*a* may be fitted in the center of a section of sliding ways, thus eliminating a weak spot of a coupling at the trigger.

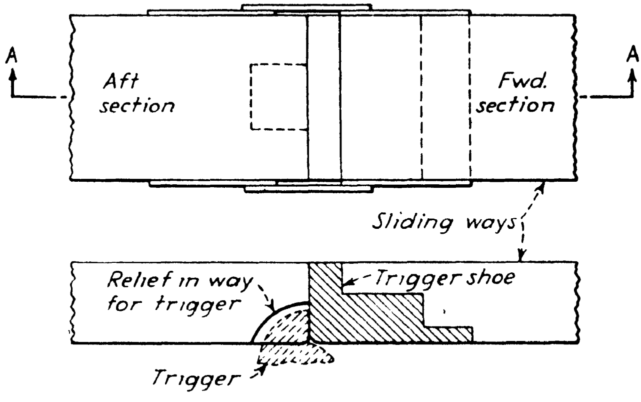


FIG. 524.—Recess at butt of sliding ways for the trigger.

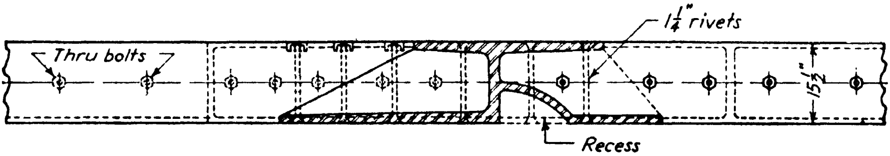


FIG. 524*a*.—Recess off butt of sliding ways for the trigger.

Launching Lubricants

Base and Slip Coats in Their Relation to Launching Problems. Before the development of the all-weather base and slip coats, each master shipwright had his own secret formula, which he varied in different seasons of the year according to his experience. These formulas consisted of various mixtures of beef tallow and oleostearin. The mixtures differed in certain areas of the ground ways, one mixture being used at the forward part of the ship, another mixture aft of this point to the pivoting area, etc. Soft soap and lard oil were used for the slip coat.

With the development of the all-weather base coat and slip coat that could be used over any portion of the ways, and at any season of the year, all of these secret formulas were gradually discarded for the more reliable all-weather launching lubricants. There are numerous firms which manufacture launching lubricants by various trade names. Opinions differ as to which product is the best.

The important factors involved to ensure the greatest possible safety include the slope and elevation of the ground ways and keel, initial and way-end pressure, the energy of the ship absorbed by buoyancy, water resistance, drag resistance, and friction of the launching grease with respect to the distance traveled. It is necessary, of course, to know accurately the starting and sliding friction, which is mostly controlled by the slope of the ways under the ship's center of gravity and which must always be less than the sliding component (W_s) of the weight of the vessel.

Under the pressure of current conditions the best launching grease is none too good when the tremendous value of the ship and the reputation of the shipyard for successful launchings are considered in comparison with the trifling cost of grease. Undoubtedly an all-weather and all-petroleum launching grease gives the safest and most economical launching.

Base Coat. The base coat should have a melting point of not less than 150°F. and should be an all-petroleum product free of fillers. It must be waterproof in salt or fresh water.

Slip Coat. The slip coat should have a melting point of not less than 180°F. It should be smooth and nonfibrous, free of fillers, and waterproof in either salt or fresh water.

Establishing Grade of Ground Ways

When the work of establishing the grade and transverse position of the ground ways is to be started, the plan of the location of the ship on the stocks must be referred to first. This is the plan that was submitted to the drawing room at the time when the keel was laid, showing the height of the vessel above the top of the ground ways and the point from which the ground-way grade will be started. In the plan shown in Fig. 500, the transverse position should first be lined off on the stocks.

All blocking and shoring in this area should be moved, as it will have to be entirely clear. When this has been accomplished, the transverse position of the foundations for the ground ways can be marked off on the shipway caps. This is, of course, assuming that there are no foundations in place. Again referring to the plan shown in Fig. 500, the approximate height of the foundations for the ground ways may be established by leveling out from the bottom of the keel and building the ground-way cribbing to within shimming distance of the actual bottom of the ground ways or top of the foundations.

The construction of the ground-way foundations will, of course, depend on the size of the ship to be launched. For ground ways up to 6 ft. in width three longitudinal stringers are ordinarily used. For ground ways 6 ft. in width, four longitudinal stringers should be used. On extremely heavy ships for which ground ways are 9 ft. or over, the number of stringers should be increased accordingly.

Preparation. When the grade of the ground way's exceeds 2 ft. in height above the shipway caps, the foundations should be cribbed with fore-and-aft stringers and cross blocks. For foundations set on concrete caps transverse filler blocks should be grouted on top of the caps to afford a solid bearing for the stringer logs. These transverse blocks should be of similar thickness to bring each set of fore-and-aft stringers into a level plane when they are laid on top of them.

The length of the cribbing can vary to suit available lengths of timber. Where caps are spaced on 5-ft. centers, the timbers should not exceed 22 ft. in length, each longitudinal timber thus bearing on five caps. Figure 525 shows the method of obtaining the size of filler blocks neces-

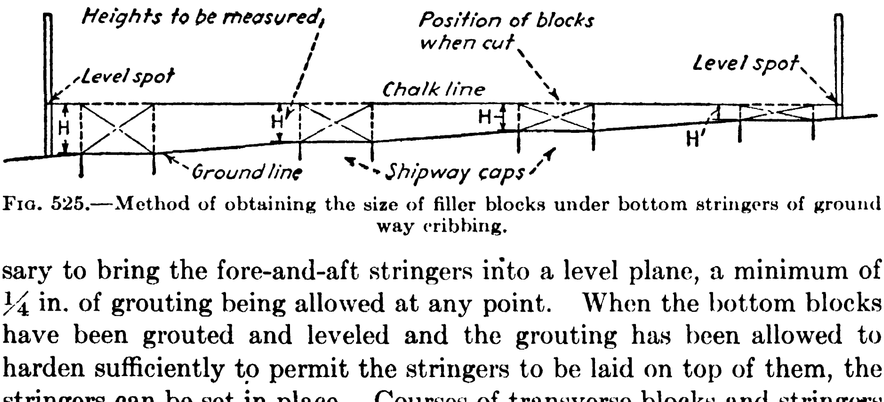


FIG. 525.—Method of obtaining the size of filler blocks under bottom stringers of ground way cribbing.

sary to bring the fore-and-aft stringers into a level plane, a minimum of ¼ in. of grouting being allowed at any point. When the bottom blocks have been grouted and leveled and the grouting has been allowed to harden sufficiently to permit the stringers to be laid on top of them, the stringers can be set in place. Courses of transverse blocks and stringers may then be brought up to the desired height, or to within shimming distance of the bottom of the ground ways.

When it is not necessary to crib the foundations in the area, that is, where the ground ways are less than 2 ft. above the shipway caps, only transverse blocks need be fitted. The bottom block, which rests on the shipway caps, should also be grouted and the grouting allowed to harden.

In way of the pivoting area the blocking under the ground ways should be doubled up as a measure of safety, if the shipway foundations permit. That is, if blocking under the shipways is 12 in. in width, it may be doubled up to give a 24-in. bearing on each cap, provided that the cap is wide enough. If, on the other hand, the shipway foundations permit the installation of a block midway of the regular 5-ft. center-to-center space, this may be done, a bearing area on 2-ft. 6-in. centers being thus obtained in this pivoting area.

The reason for the extra reinforcing in way of the pivoting area is that excessive loads are concentrated here when the ship pivots. If no extra reinforcing is provided, the regular blocking may not withstand the load and therefore may tend to crush.

Running Grade. After the blocking for supporting the ground ways has been set in and lined up to approximately the desired grade, uprights are nailed to the blocks and cribbings at 20-ft. intervals. The inboard line of uprights should be placed at the inboard edge of the ground ways, as this is the working point for the line of the grade. From the starting point of the grade the engineer will then set up elevations at three or four points along the length of the ship. After one side has been set up, the same should be done on the opposite side. The engineer should then level from one side to the other to see that both lines are in a plane. When this has been proved, the transit can be set up at the forward

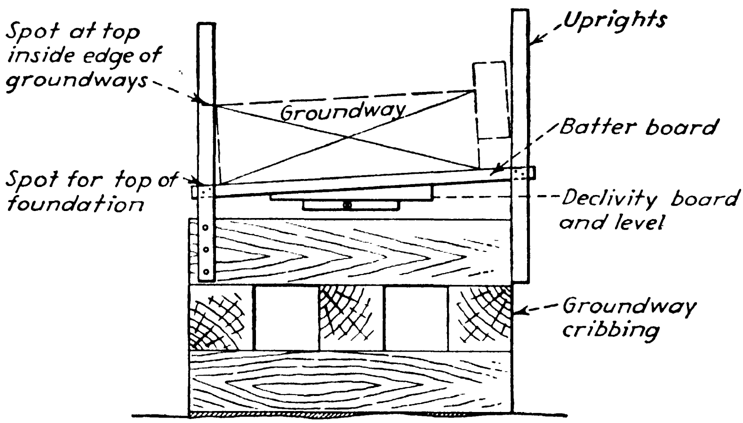


Fig. 526.—Batter boards for obtaining line of top blocks on ground way foundations.

upright, the instrument brought into alignment with the spots established by the use of elevations, and the points on the remainder of the uprights established throughout.

After the grade of the inboard edge of the ground ways has been established, a check can be made from this line to the bottom of the keel to determine its accuracy against the grade that was run for the keel of the vessel. There will, of course, be the difference of the settlement of the ship on its blocking from the original keel grade.

When the grade has been checked and definitely established for the inboard edge of the ground ways, batter boards can be set up from the inboard upright to the outboard line of uprights. If the ground ways are to have a transverse inclination, a declivity board with the amount of inclination per foot can be used in conjunction with a spirit level for establishing the position of the outer end of the batter boards. Care must be exercised to see that the batter boards are at right angles to the center line of the ship. Otherwise, they will not line up. This procedure is shown in Fig. 526.

Cambered Ground Ways. If cambered ways are decided upon, consideration must be given to the fact that, at the afterend of thé ways, the distance from the caps to the top of the ground ways should be 5 or 6 in. more than the thickness of the ways, to allow for sufficient shimming to the underside at the closest point from the chord of the arc to the shipway caps.

The distance from the line of the arc to the top of the ground ways should be such that, when the camber is put in the ways, the minimum distance from the keel to the top of the ground ways will be greater than the thickness of the sliding ways, to allow for packing up.

Assuming that the distance from the line of the keel to the top of the ground ways at the forward end of the fore poppet is 12 in., that the distance from the shipways to the ground ways at the afterend is 16 in. for a way 12 in. thick, and that the camber is 10 in. in 512 ft., the full length of the ground ways, the declivity of the keel ½ in. per ft., and the declivity of the chord of the ground ways 36.5/64 in. per ft., we proceed as follows:

The declivity of the way being 36.5/64 in. per ft., or 4.5/64 in. more than the declivity of the keel, we start on the keel at the line of the forward end of the fore poppet. For every foot measured horizontally, and aft of this point, the line of the ways will be 4.5/64 in. below the line of the keel.

Divide the distance between the forward end of the fore poppet and the afterend of the ways into any number of equal parts. Assuming that each of these sections equals 64 ft. (if eight equal parts are used), the first station from the forward end will be 4½ in. below the keel, the second 9 in., the third 1 ft. 1½ in., etc.

A line sighted through these points should be 28 in. above the shipway at the afterend of the ways, as we have started from the keel line at the forward end of the fore poppet, while the top of the ground ways is 12 in. below the keel at that point. If the height at the afterend of the ways is found to be correct, the line can be lowered bodily 12 in. and the new line, which will be the chord of the ways, can be marked on the blocks for future reference.

Camber of Ways. The foundations for the ways are built in the form of an arc, and the camber is stated by comparing the height of the arc in relation to its chord, as, for example, 10 in. in 512 ft. The 10 in. is the height of the arc, and 512 ft. is the length of the chord of the ground ways. The original idea of building camber in the ways was to provide against the vessel's settling down on the ways when the weight was transferred from the keelblocks to the launch ways, which is not improbable in some building ways. The effect of camber on the ways may also be regarded as giving small initial velocity and accelerating the final velocity of the vessel during her run down the ways.

Camber on the ways also has an important effect in reducing way-end pressure on the bottom of the ship, by getting the stern water-borne sooner.

If the camber is 10 in. and the length of the ground ways, as in the example, is 512 ft., we take the quadrant of a circle of 10 in. radius and divide the arc and base into half the number of equal parts into which

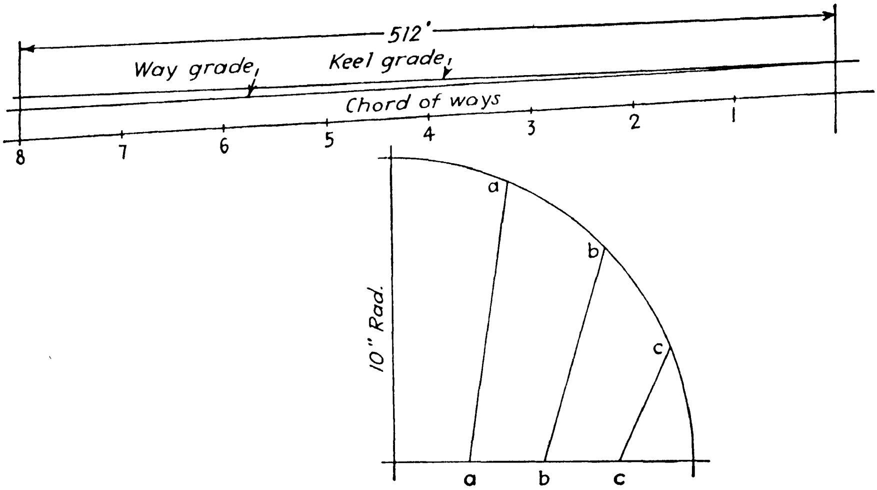


FIG. 527.—Method of laying out camber for cambered ground ways.

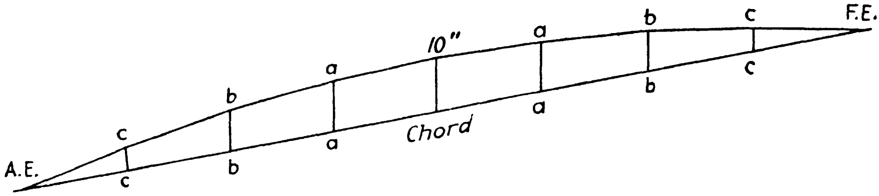


FIG. 528.—Camber line of ground ways.

we divided the length of the ways when laying off the chord of the ways, as shown in Fig. 527.

If the length of the ways is divided into eight equal parts, the height at the center of the way will be 10 in. above the chord of the ways, and the first division on each side or center of the ways will be a distance equal to lengths *a,a* above the chord of the ways. The second division on each side will be the distance equal to lengths *b,b* above the chord of the ways. The third division on each side will be the distance equal to lengths *c,c* above the chord of the ways. The fourth division will be the afterend of the ground ways on one side and the forward end of the fore poppet on the other side.

This line will now appear as shown in Fig. 528.

In building up the cribbing of the ground ways for cambered ways the same procedure can be followed as that for straight ground ways. However, the locations of uprights for batter boards will be in accordance with the foregoing instead of at intervals of 20 ft.

After the camber line has been established at intervals of 64 ft., additional straightedges may be installed for the purpose of more easily fairing in the necessary blocks and shims to build the foundations to the desired camber curve.

Installation of Ground Ways

After the cribbing foundation for the ground ways has been built up to the desired grade, the work of installing the ground ways on their foundations can begin. If the ship is being built in a semisubmerged shipway where it is possible to install the ground ways in the dry, all the ground ways can be installed in one operation.

If there is sufficient room at the stern of the ship, the ground ways can be brought in with the cranes and landed on their foundations. If not, they will have to be brought in from the forward end on a runway constructed at the level of the forward end of the foundations, so that they can be hauled under the ship after being landed on the runway by the cranes.

So that the ground-way foundations may be undisturbed and not knocked out of alignment when the ways are being installed under the ship, a plank runway is built on top of the foundations. This usually consists of 3- by 12-in. plank doubled up and laid from 6 to 12 in. from each edge of the foundations. Gumwood rollers 6 in. in diameter and long enough to span the width of the track are then laid on the plank runway and the ways landed on the rollers by the cranes.

Regardless of whether the ways are being pulled in from the bow or the stern, they may be hauled into position under the ship by means of a winch at either end of the ground-way foundations. If the ground ways are being hauled aft and downgrade, a snubbing line should be attached to the forward end of each section as it is hauled into place.

The location of each section of ways should be marked on the ground-way foundations before the ways are placed under the ship, as a guide in pulling them in position. As each section of way is brought in, it is jacked up, the rollers and track are removed from under, and the ways are lowered down on the foundations themselves as close to their exact position as possible. After all the ground ways have been hauled in under the ship, the work of lining them up can be started.

Shipways Having Submerged Outboard Ground-way Foundations. On shipways in which portable outboard ground ways are used, only the ground ways under the ship are installed in the first operation. In this case, the position of the butt of the outboard section of ways must be known, so that the ways under the ship can be properly located. On this type of shipway, the ground ways can be floated in from the stern and pulled forward on the type of track and rollers mentioned in the foregoing.

Installing Outboard Ground Ways. Approximately 10 days to 2 weeks before launching, the outboard ways are usually set into place. Various methods are used in connection with installing and placing them.

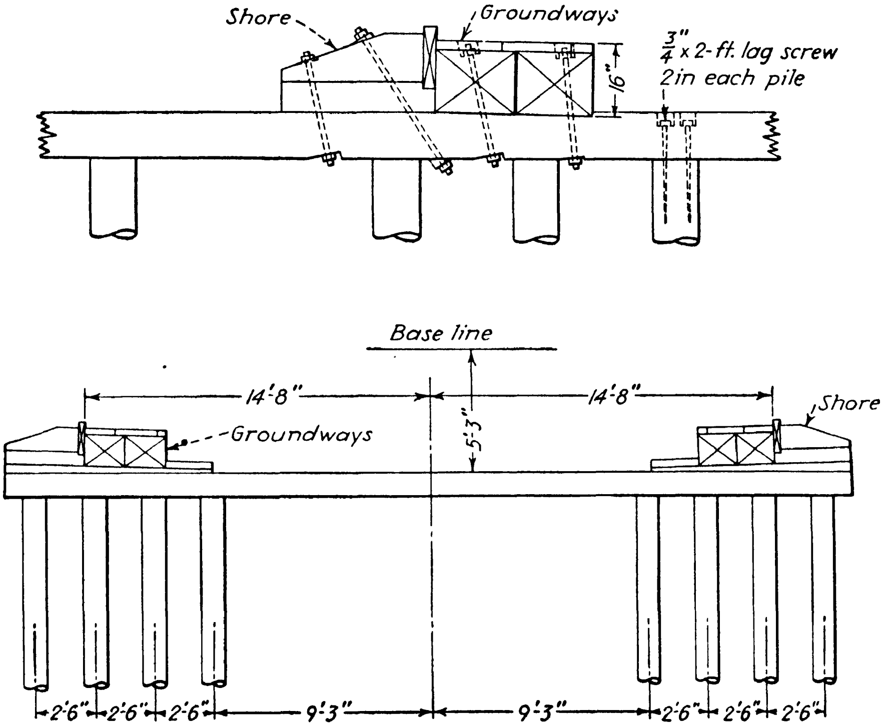


FIG. 529.—Arrangement of permanent outboard ground ways.

Because of the fact that these ways are under water, some means of holding them down in place must be provided. In some instances they are ballasted with steel plate spiked or lag-screwed to the bottom and sides to the extent that they will have a negative buoyancy necessitating moving with a floating derrick or pontoons when being placed in position. Another is to provide ballast pockets on each side, which may be filled after they have been floated and lined up in position.

The lining up of these ways will be discussed further in connection with lining up the ground ways (page 483).

Shipways with Permanent Outboard Ground Ways. In some shipyards permanent, or fixed, outboard ground ways are used, which eliminates the necessity for removing and lining them up. On such shipways the distance between ground-way ribbands cannot be varied to any extent. This distance may be closed up with the use of an auxiliary ribband installed by a diver but cannot be opened up without altering all the arrangements made for holding down and keeping in line the

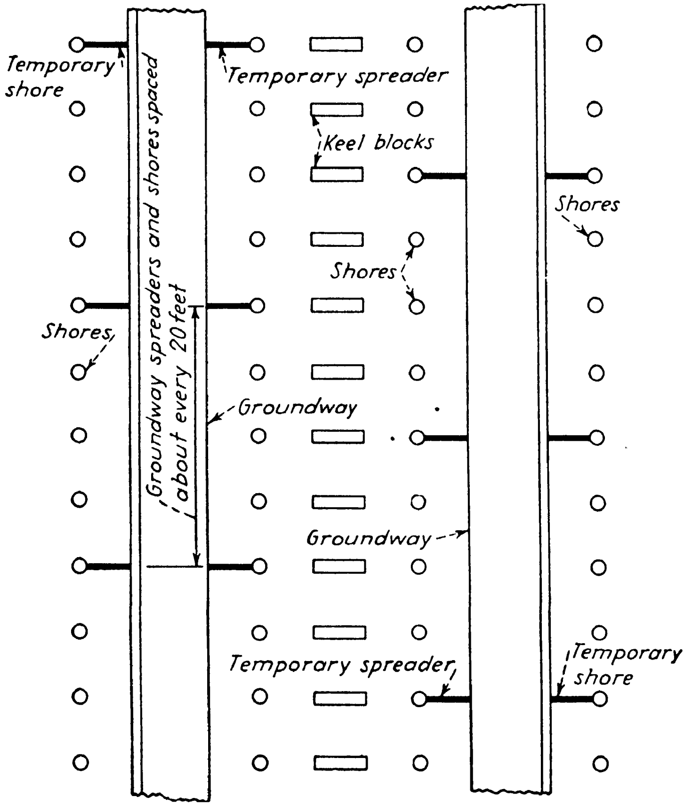


FIG. 530.—Ground ways lined up and temporarily shored in position.

permanent ground ways (see Fig. 529). In such cases, when the ground ways are installed under the ship they may be floated in from the stern and the connections immediately made up to the permanent outboard ways.

Lining Up Ground Ways

After the ground ways have been installed under the ship, preparations may be made for lining them up. From the plan of the location of the ship on the ways, giving the distance between ribbands at the forward and after perpendicular, uprights are set up at these points on each side of the ship. The ground ways are then jacked and shored to this line and temporarily shored in position, as shown in Fig. 530.

If the ground-way foundations are in perfect alignment and the ground ways are uniform in thickness, there should be no necessity for checking the horizontal alignment unless some discrepancy is observed. In this case, sights can be set on the edge of the ways where the irregular-

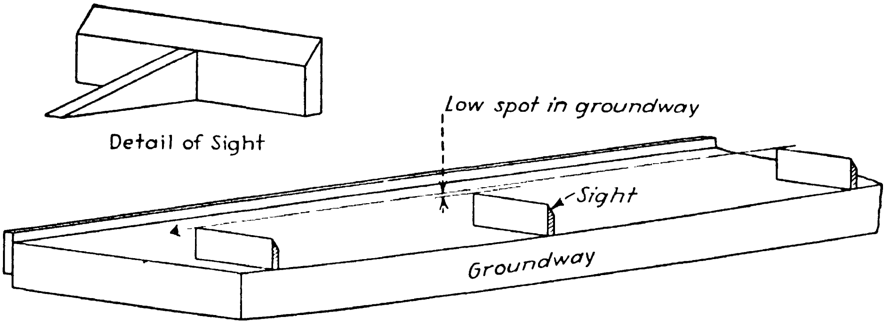


FIG. 531.—Sights used for checking inboard edge of ground ways.

ity is observed, as shown in Fig. 531, and the irregularity removed to create a fair line.

When all the sections of ground ways under the ship have been set to the proper half width and the top has been checked for fairness, they can be permanently shored in place.

Transverse Spur Shores. To prevent outboard displacement of the ground ways, shores are placed against the ribband at approximately

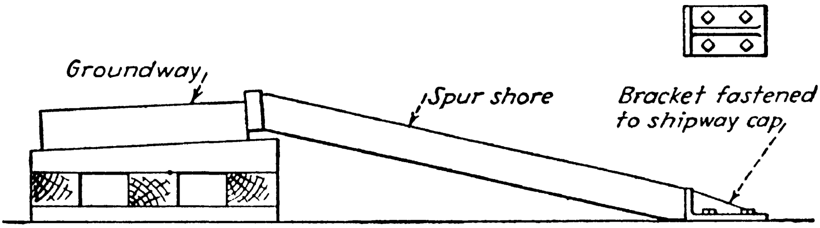


FIG. 532.—Transverse spur shore and backing brackets.

20-ft. intervals. A suitable backing should be provided for the footing (see Fig. 532).

Either round timber or square 8- by 8-in. timbers may be used for spur shores.

To be effective, these should be installed at an angle of less than 45 deg.

To prevent the ground ways from moving inboard when the spur shores are installed, spreaders are provided opposite each set between the inboard edges of the ground ways. The spreaders can be installed between the inboard edge of the ways and the keel-track blocking in most cases (see Fig. 533).

Longitudinal Spur Shores. To prevent the ground ways from moving aft, spur shores are installed at 100-ft. intervals, beginning at the location

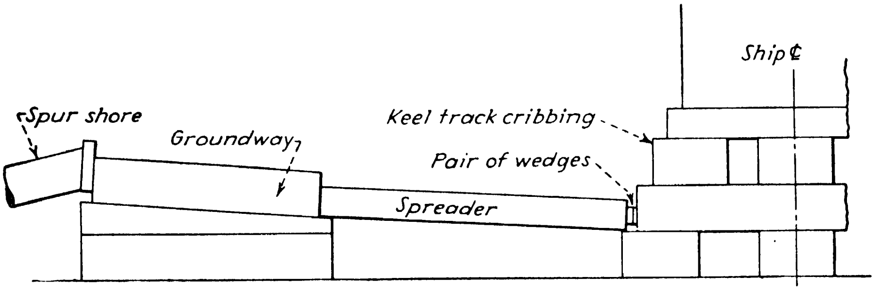


FIG. 533.—Spreaders between inboard edges of ground ways.

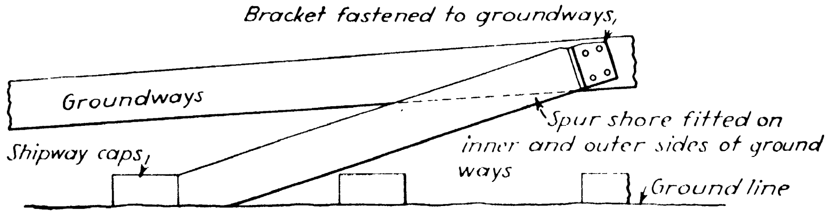


FIG. 534. Longitudinal spur shores.

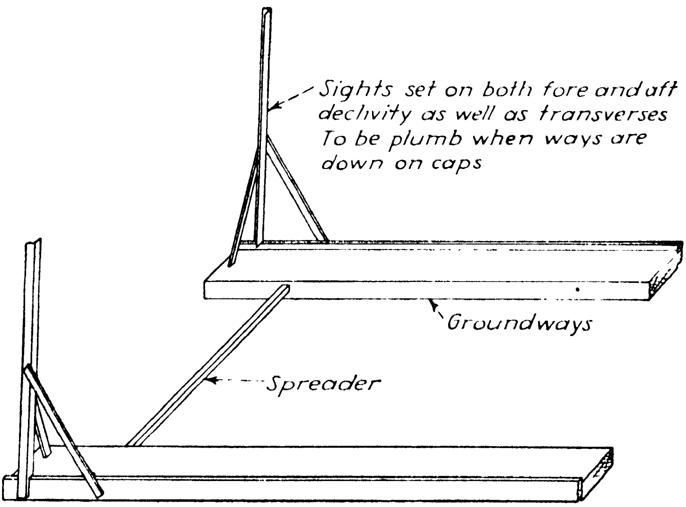


FIG. 535.—Sights for lining up portable outboard ways.

of the afterend of the sliding ways and extending for two-thirds the length of the ship to the forward end. The spur shores generally consist of timbers 6 by 12 in. in cross section. The 12-in. dimension is vertical. They are installed as shown in Fig. 534.

Lining Up Portable Outboard Ways. When the portable outboard ways have been placed in position with the floating derricks, the work of lining them up can begin. After the ways have been connected to the inshore sections, vertical sights are erected at the afterend of the ship and amidships, as well as a sight on the extreme end of the portable ways and long enough to project above the surface of the water after the ways have been lowered into position, to determine whether or not they are in proper alignment (see Fig. 535). Since the distance between the ground-way ribbands is known at the after perpendicular and at the extreme outer ends of the ways, spreaders are installed at intervals of 20 ft., so that the distance between the ribbands will be as designed and the ribbands will be in a straight line.

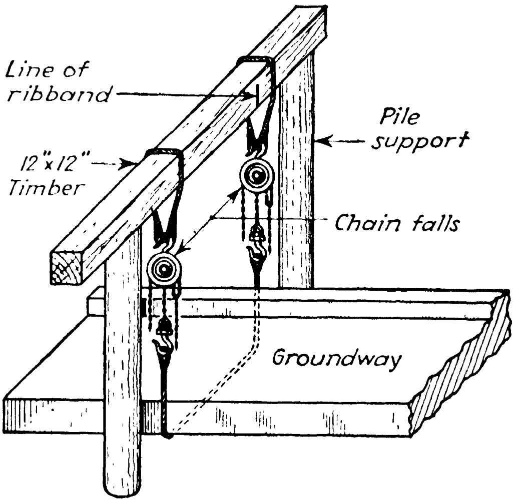


FIG. 536.—Arrangement for raising up for greasing and lining up outboard ground ways with permanent ballast.

Ground Ways with Permanent Ballast. If the ground ways have been ballasted so that they will not float, it will be necessary to raise them to the surface of the water for the purpose of installing the spreaders and spur shores and for greasing.

If the ways are extremely long, where it will be necessary to provide means of support other than the floating derricks at the extreme outer ends, temporary A frames are ordinarily used by driving piling on each side of the way, high enough to provide working space from a staging clear of the water. Timbers 12 by 12 in. are then laid across the top of the piling, and suitable chain falls are attached to the timbers on each side of the way, as shown in Fig. 536. Strong wire straps passed under the ways for the purpose of raising them above the surface of the water are then hooked to the chain falls.

So that no great difficulty will be experienced in placing the ways in proper alignment, it is good practice to project a line of ribband to the top of the A frames for the purpose of properly locating the chain falls.

After the ways have been raised to the surface and the spreaders between them installed, spur shores are installed opposite the spreaders to hold the ways in their proper alignment when they are lowered on their foundations. Fixed brace piling is usually provided at the location of the spur shores. Spur shores should be long enough to extend from the ground-way ribband to the brace piling after the ways have been lowered in position.

When the ways have been greased, they are checked and set in their proper alignment and lowered. The spur shores are then cut in against the brace piling, as shown in Fig. 537. The staging and A frames are then removed.

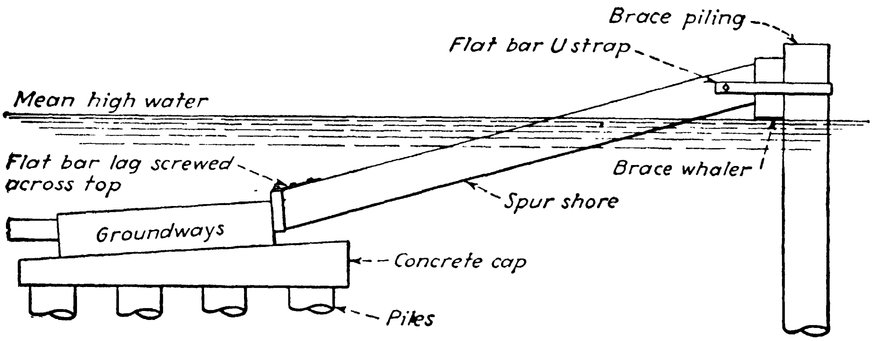


FIG. 537.—Spur shores on outboard ground ways.

Setting Outboard Ways with Portable Ballast. Outboard ground ways are also designed so that they may be floated into position and then submerged by the addition of portable ballast. The arrangement for holding them the proper distance apart and in their proper transverse position is the same as that described for ways with permanent ballast.

For this type of way to be sunk in its proper alignment, guides are provided along the sides of the way that will set into sockets secured to the outboard-foundation caps. The guides will have to be set to a line that will give the proper distance between the ground-way ribbands and must be designed substantially enough to prevent buckling if there should be any tendency of the ways to sink unevenly (see Fig. 538).

When the spreaders have been installed between the ways, the spur shores have been secured, and greasing has been completed, the ballast pockets can be filled; or if ballast blocks are used, they can be set in position to sink the ways.

It will be found that, after the ways have been sunk below the surface of the water, it will be necessary for the diver to assist in placing the remainder of the ballast blocks or in filling the ballast pockets.

Ballast blocks have been found to be the more practical because there is no danger of the ballast spilling on top of the ground ways to an extent that might damage the sliding ways if the ship passes over them (see Fig. 539).

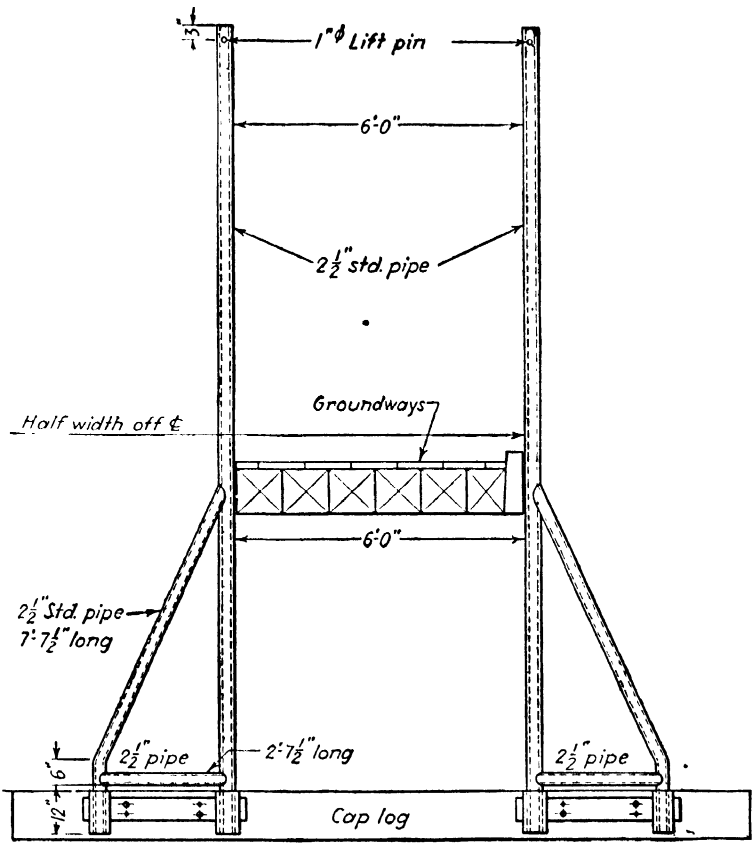


FIG. 538.—Guides for sinking outboard ground ways with portable ballast.

Lining Up Exposed Ways. On ships built in a semisubmerged shipway, the lining up of the exposed ground ways, or that portion between the ends of the sliding ways and the gate, is not usually done until just prior to launching, principally because of obstructions such as staging, shaft, and rudder skids that may be in the way of lining them up.

When the time arrives for the ways to be lined up on their foundations, the distance between ribbands is first checked at the after perpendicular, because this was the point used in lining up the ground ways under the ship. The distance between ribbands at the extreme ends of the ways is also established and uprights erected at these points.

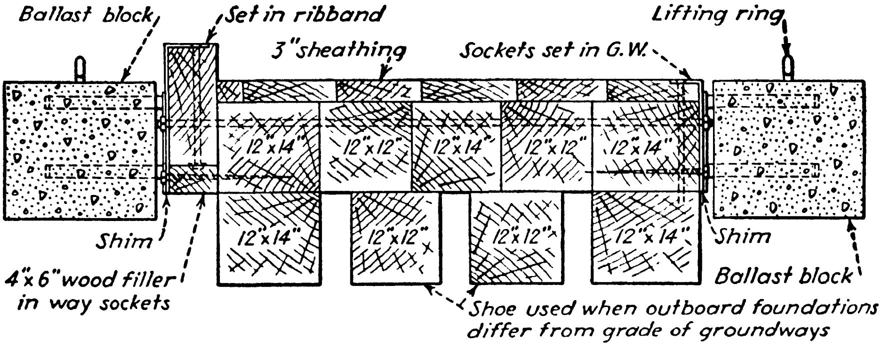


Fig. 539.—Portable ballast blocks for sinking outboard ground ways.

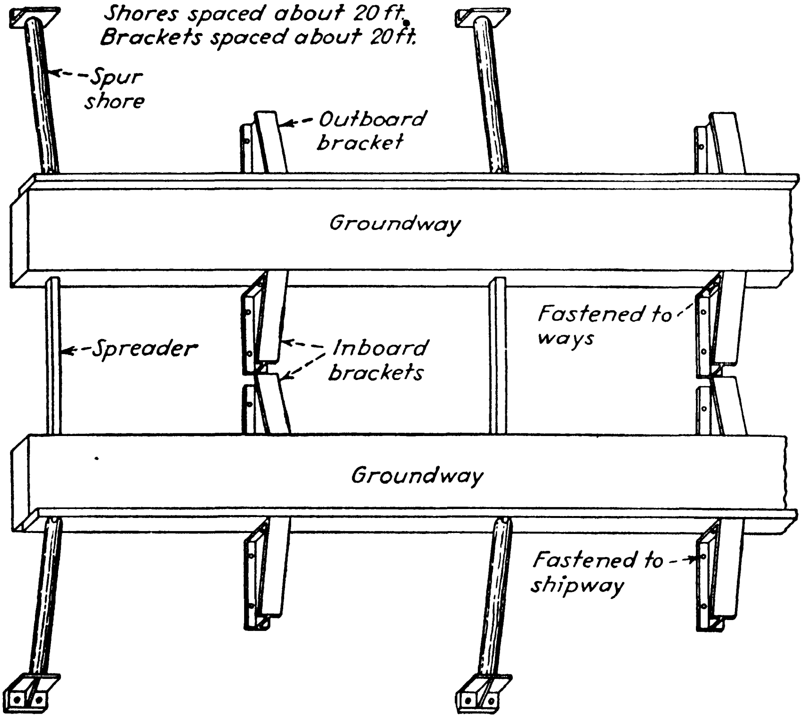


Fig. 540.—Exposed ground ways lined up and spur shored in position.

The ways are then jacked and shored, so that they will line in with these two points. After this, they are spur shored, as shown in Fig. 540.

Installation of Triggers and Other Releasing Devices

After the ground ways have been installed and lined up under the vessel and before the sliding ways are installed, the means to be used for releasing the vessel should be made ready for installation. If triggers are to be used, the position of the triggers should be located and the openings cut in the ground ways before these are installed.

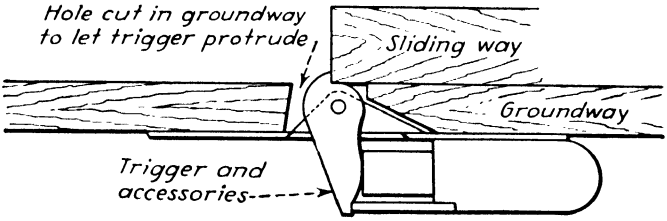


Fig. 541.—Trigger secured to underside of ground ways.

Some types of triggers are designed to bolt to the underside of the ground ways, necessitating the extending of the opening for the trigger arm through the ground ways, as shown in Fig. 541. In other types of trigger construction, they are designed as a complete unit, with the ground ways fitted into the ends of the trigger structure, as shown in Fig. 542. In setting such triggers, they should be installed at the same time as the ground ways, since it is not possible to install them later without moving out of position either the forward or the after sections of the ground ways. If the ground ways have to be fitted into the trigger structure, a template should be made from this and applied to the ground ways for cutting and fitting, as shown in Fig. 543.

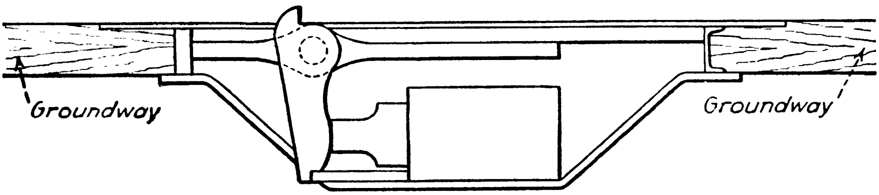


Fig. 542.—Ground ways fitted into end of trigger structure.

The general practice followed in installing this trigger, when ground ways are being installed from the afterend, is to install all the ground ways forward of the location of the trigger. The trigger is then installed by skidding it into place from the side of the ship and setting it over the ends of the ways into which it has been fitted. The sections of ground ways aft of the triggers are then pulled in and set into the afterend of the trigger structure.

After the ways have been lined up together with the triggers, so that the triggers will set square off the center line of the ship, the connections are made up to the ends of the ways and the ribband is installed at the side of the trigger.

Because of the pressure exerted against the afterend of the trigger structure when the weight of the ship is bearing against the trigger, it is well to reinforce this point with additional shores or blocking to prevent any deflection that might cause the ways not to bear squarely against the trigger, thus producing a tendency for the ways to ride over the trigger, particularly if the trigger does not extend up through the ways to any great extent.

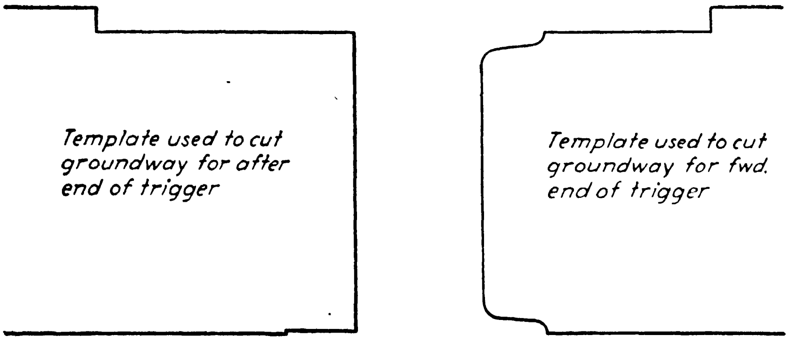


Fig. 543.—Template for fitting ground ways into trigger structure.

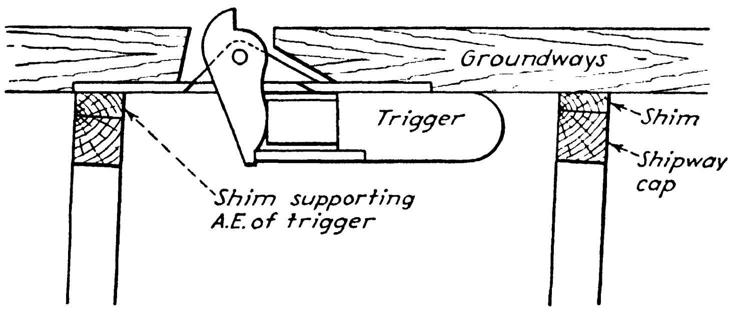


Fig. 544.—Support under trigger structure.

Triggers Bolted to the Underside of Ways. Triggers that bolt to the underside of the ground ways may be installed after these have been set into position for lining up. A template is usually made from the trigger structure for drilling the holes for the bolts to fasten it to the ground ways before these are installed. The triggers are then skidded to the underside of the ways and shored and jacked up into position until they bear hard against the ways. After this, the bolts may be installed and tightened up.

Bearing at the afterend of the structure should also be provided on this type of trigger, by locating it in such a manner that the end will bear at least partly on the shipway caps, as shown in Fig. 544.

Solepieces. If solepieces are to be used for releasing, they should be installed on the sliding ways before the latter are installed. Solepieces should consist of oak timbers of proper design to hold the component (Ws) of the ship's weight. The length, number, and size of bolts to secure the solepieces to the sliding ways will, of course, depend on the size of the ship to be launched. The heads and nuts of the bolts are set into the wood with the head side down and below the bearing surface of the sliding ways, so that they will not cut into the ground ways during launching. The nuts at the top of the solepieces are also set in so that they will not obstruct or foul any of the wedges under the wedge rider. In Fig. 505 is shown a typical solepiece used when vessels are to be released by sawing off.

In determining the sizes of solepieces and their fastenings, the following formula is used:

$$F = W \sin \infty$$

where F = force down the ways.
W = weight of the ship and cradle, long tons.
∞ = angle of slope of the ground ways.

If the ways have a slope of $\frac{5}{8}$ in. per ft., the maximum pull on the solepieces will be about one-twentieth the launching weight.

For the working stress of oak at 1600 lb. per sq. in., the necessary cross-sectional area of each solepiece can be determined. For example, with a ship weighing 5000 tons on the grease at a zero coefficient of friction, the pull on the solepieces would be 250 tons, or 125 tons each side. The minimum cross-sectional area required would be 175 sq. in. on each side; and if the ways were 36 in. wide and the solepieces 5 in. thick, this would give a cross-sectional area of 180 sq. in., or a sufficient amount to hold the ship. However, solepieces are usually made somewhat heavier than necessary to allow for a greater factor of safety.

Burn-off Plates. Where burn-off plates are used instead of timber for releasing, somewhat the same installation is used as that for wooden solepieces.

The ship is released by burning through the burn-off plates with acetylene torches, simultaneously from each side toward the center. A line of holes $\frac{1}{2}$ in. in diameter and spaced on 1-in. centers is usually drilled in the plate where it will be burned off. Each space remaining between the holes is then numbered, together with the space at each edge, as shown in Fig. 506. When the ship is to be released, the burners will burn the numbered spaces in numerical order simultaneously.

When a point is reached at which the cross-sectional area is not sufficient to hold the pull of the ship, spaces not burned will break and the ship will be released.

To determine the size of the plate, a working stress of 15,000 lb. per sq. in. is generally used. The same method is used for calculating the necessary sectional area as that for the wooden solepieces.

The design of the fastenings that connect the solepieces and burn-off plates to the sliding and ground ways is important because their strength is governed by the crushing strength of the wood in front of the bolts and sufficient bearing area should be provided so that the bolts cannot be pulled through. The holes in the wood for the bolts should be bored the neat size of the bolts. Large washers placed under the heads and nuts will increase the strength considerably.

Installation of Sliding Ways

The sliding ways, like the ground ways, can be installed from either end of the ship, whichever is most convenient. Since the ground ways are in position and shored, so that they cannot move, the top can be used as a track for pulling the sliding ways into position.

The same means may be used for pulling the sliding ways as that for the ground ways.

When sliding ways are installed, consideration must be given to greasing operations, which are affected by the space available for skidding the sliding ways out of the area of greasing. This space is sometimes very limited.

No particular effort is made to place each section of sliding ways definitely in position when they are hauled under the ship, the only consideration being that they shall be installed in their proper order and approximately in their proper location.

Greasing

In preparing for the application of the launching lubricant, the sliding ways are usually skidded inboard alongside of the ground ways and clear of the area to be greased. The possibility of doing this will depend on whether or not there is sufficient room between the keel track and the ways, particularly if a line of shores has been installed in this area.

If there are no shores in this area, a skid to support the sliding ways is installed, as shown in Fig. 545. This consists of 6- by 6-in. timbers set into sockets on the inboard edges of the sliding ways, with the top of the skids 1 in. higher than the top of the ground ways, so that the sliding ways can be skidded over on top of the grease irons without scraping off any of the launching lubricant.

After the skids have been installed, the sliding ways are pulled over on the skids. The ground ways are then thoroughly cleaned off preparatory to applying the launching grease.

If the arrangement under the ship does not permit the ways to be pulled over on the skids, it is sometimes possible to jack up the sliding ways high enough above the ground ways to permit the application of

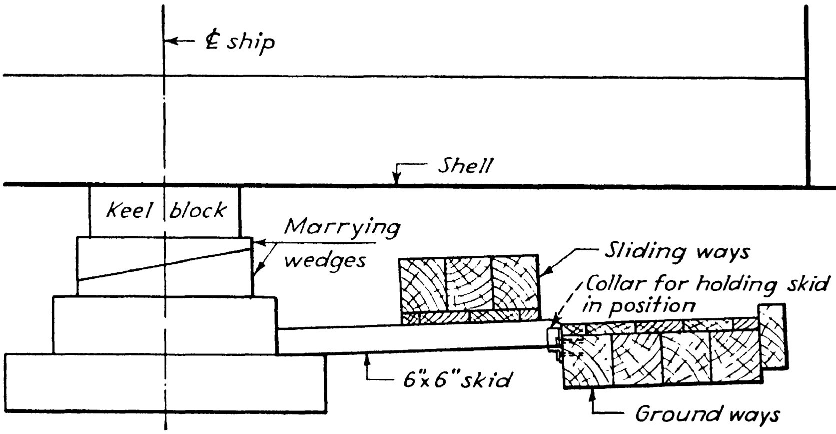


FIG. 545.—Skid for supporting sliding ways during greasing.

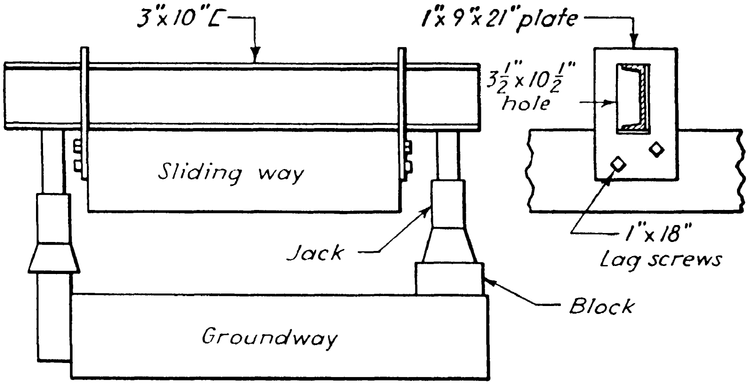


FIG. 546.—Strongbacks for raising sliding ways.

the launching lubricants. This, of course, depends on the height between the top of the ground ways and the ship. Crosspieces consisting of heavy timbers or structural shapes are lag-screwed to the top of the sliding ways, as shown in Fig. 546. After this, jacks are installed under the crosspieces on blocking at each side of the ground ways and the ways raised up and blocked until greasing has been completed.

A second and perhaps better method is to combine the greasing operations and the installation of the sliding ways with the use of the cam block, as shown in Fig. 546*a*.

Most of the sliding ways can be installed under the ship, with the exception of possibly one or two sections. The ground ways are then greased, the grease irons installed, and the sliding ways rolled down over the greased area on rollers, one end of which will bear on the ground-way ribband and the other end will be blocked up to the same height with timbers 4 in. thick. As each section is rolled down into an approximate location, cam blocks are secured to the ground-way ribband and the filler timber on which the rollers bear; the cam blocks are located and secured so that when the way is pulled down off the cam block, it will be in its approximate correct location on the grease. A set of these blocks should be installed at each end of each section of sliding ways and also about midway between the two ends. Cam blocks, as shown in Fig. 546a, consist of a radial oak timber 4 in. in width and faced with a steel

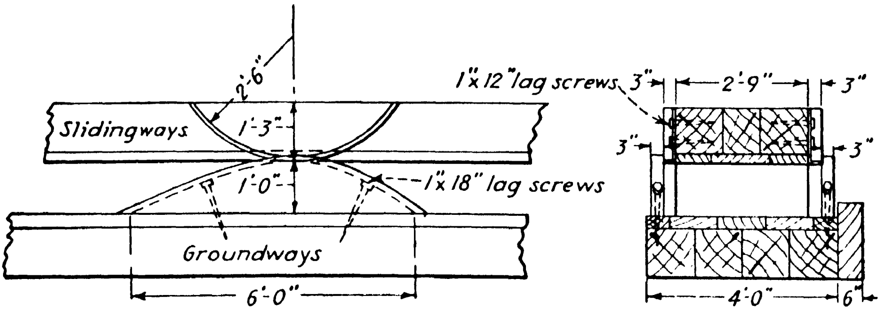


FIG. 546a.—Cam blocks used for lowering ways on grease irons.

flat bar to prevent wear. The height should be approximately 1 in. greater than the diameter of the rollers being used so that the rollers can be free when the ways are resting on the peak of the cam.

The cam attached to the sliding ways is constructed of 5- by 5-in. angle, lag screwed to the side of the ways, and located in the same relative position as the blocks on the ground ways. When it is desired to remove the rollers and lower the ways down on the grease, the ways are pulled up on the peak of the cam, the rollers removed, and the ways then pulled down on the grease and the cam blocks removed. By the use of standard lengths of ways and spacing of the cams, the same holes for the lag screws may be used each time that the cams are used.

After the aftermost section of ways is lowered down on the grease, it should be chocked on the lower end to prevent the sliding ways from slipping aft until they are definitely placed in their proper location. The area to be greased ahead of the installation of the sliding ways will, of course, depend on the number of pieces of sliding ways that have been installed under the ship. That is, sufficient area may be greased at a time to take care of one section of sliding ways, or the application of lubricants may be extended over two or three sections of sliding ways. These can then be placed in position and greasing operations extended farther forward.

Grease Irons (Draw Irons). Grease irons, or draw irons, are used to keep the weight of the cradle off the grease until launching. They are usually spaced approximately 12 ft. apart, except in way of the butts of the sliding ways, where one iron is located about 4 ft. from each end of each section.

The thickness of the irons is determined to some extent by the combined thickness of the base and slip coats of launching lubricants. They should be thick enough to keep the ways entirely clear of the top of the slip coat; for example, if the base coat is to be ½ in. thick and slip coat ¼ in. thick, they should be ⅞ to 1 in. thick.

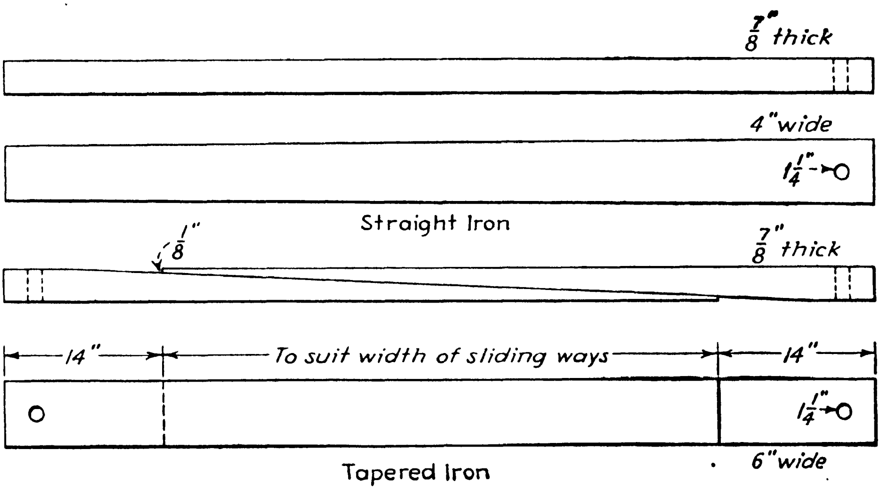


FIG. 547.—Straight and tapered grease irons.

Grease irons are usually 4 to 6 in. wide, the wider one being used on extremely heavy ships. The irons should be made long enough to project over the inside of the groundways to permit pulling arrangements to be attached.

On extremely heavy ships, particularly at the afterend and in way of the engine-room spaces where most of the settlement is likely to occur, split irons are sometimes used. These are tapered to a thin edge at each end and, when married together, should give the desired thickness (see Fig. 547).

One objection to split irons is that it is necessary to cut holes through the ribband for the grease irons to pass through, and this tends to weaken the ribband. Another objection is that double the amount of work is required to pull them. However, they have the advantage that, once they are started, they are much easier to pull, or draw, out. For grease irons to pull more easily, it is important that they should be freed from the base coat and well greased before the sliding ways are pulled over on them.

Wooden pieces are sometimes used that conform to the width and thickness of the iron. These are placed in the locations of the grease irons and left in until after the base coat has been applied. They are then removed and the grease irons installed in their places.

Grease irons should never be installed bearing on the wood of the ground ways. One or two coats of base coat should be applied to the ground ways to prevent this. Slip coat should be applied liberally in the opening provided for the grease iron before it is installed.

Each grease iron should be numbered in order from the afterend of the ship, and the number corresponding to the iron should be painted immediately beneath it on the side of the ground ways. This will positively identify the location of each iron, so that, in the event that one of the irons is missing, after the others have been pulled, its location can be found and assurance made that it has been removed from between the ways.

Pulling Grease Irons. Grease, or draw, irons are usually pulled at the beginning of the preparations for launching the vessel on launching day. Two 6-ton ratchet chain hoists at each set of six pairs of grease irons are employed for pulling them.

Grease irons are usually installed in pairs, or opposite each other, port and starboard, to facilitate their removal. Each iron is provided with a hole in the end to accommodate a shackle to which the chain hoist can be hooked. A wire-rope choker or a chain of the desired length may be used between the two chain hoists. Pull exerted on one or both of the chain hoists will tend to draw the irons one at a time.

A heavy clip should be located immediately beneath each draw iron, and this clip should be securely bolted with through bolts to the inside of the ground ways. When one or the other of the grease irons is withdrawn, the pulling rig can then be attached to the clip for the purpose of withdrawing the other iron. On large heavy ships shackle bolts should be not less than 1 in. in diameter, and the hole in the grease iron should be so located that it cannot pull through, that is, not too close to the end. The time allotted for pulling grease irons in the launching program is usually 5 min. for each iron, or 10 min. for the pair. The number of gangs to remove the irons can be governed by this time.

Application of Launching Lubricants. *Preparation of Ways.* Before the launching lubricants are applied, the ways must be thoroughly cleaned and dried. They are first scraped off with spade scrapers to remove all old base coat and dirt and then are swept off clean.

An acetylene heating torch is generally used for drying off any moisture on the ways. Under the ship, where the ground ways are not so likely to be wet, no great amount of heating is necessary. However, the outboard ways, particularly if they have been under the water for some time, when raised for greasing will require considerable drying off before the launching lubricant is applied.

After the ways have been thoroughly cleaned and dried off, they are ready for the application of the base coat. When the work of applying the base coat is ready to begin, the heating torch should be applied again just ahead of the brush-coat application. The ways should be heated until they are quite warm to the hand. This will create better adhesion of the base coat to the ways.

Base Coat. The base coat must be melted to apply. A portable type of heating kettle using about 2½ gal. of kerosene per hour at maximum operation and with a built-in thermometer will be found most convenient and safe in respect to eliminating the fire hazard of wood-burning kettles, which must be kept a considerable distance from the ways.

According to the season of the year, heat the base coat to a temperature high enough above its melting point to allow for a loss of heat while carrying it from the kettle to the ways.

In the summertime, with clear weather and normal temperature, heat the base coat about 50°F. above its melting point. In the wintertime or in cold rainy weather, owing to more rapid loss of heat as it is being carried to the ways, it is necessary to compensate for this condition and heat to 100°F. above its melting point. In treating ways that have been water-soaked, after they have been dried off by heating to secure good adhesion the base coat should be heated to about 150°F. above the melting point.

If the launching conditions require more than 3⁄16 in. thickness, first apply a 1⁄16-in. brush coat as mentioned in the foregoing, and lengthwise along the two edges on top of the ground ways temporarily nail wood strips of the thickness it is desired to make the base coat.

Most manufacturers of launching lubricants specify a thickness of ¼ to ⅜ in. for moderate-sized vessels and of ½ in. for large heavy vessels.

Gauge Strips. For the purpose of applying the desired thickness of base coat, gauge strips are used. These strips are usually 1 in. in width. When the ways are extremely wide, a strip is also used down into the center of the ways, in order that the thickness of the base coat will be uniform for the entire width of the ways.

The wooden strips are nailed at each edge on top of the ways, provided that the ground ways are to be greased for the entire width.

If the ground ways being used are wider than the sliding ways, it is necessary to grease only for a width of 1 in. greater than the width of the sliding ways plus the width of the joggled wedges. In this case the inboard gauge strip will confine the base coat to the desired area.

The brush coat of base coat is then applied to the ways. After this, the melted base coat can be poured on from pails and spread with an upward motion toward the forward and outboard edges of the ground ways. A piece of template wood about 2 ft. in length is used for this purpose. In this way, the melted base coat will have a chance to set as it starts to run back down the ways. Each coat applied in this manner

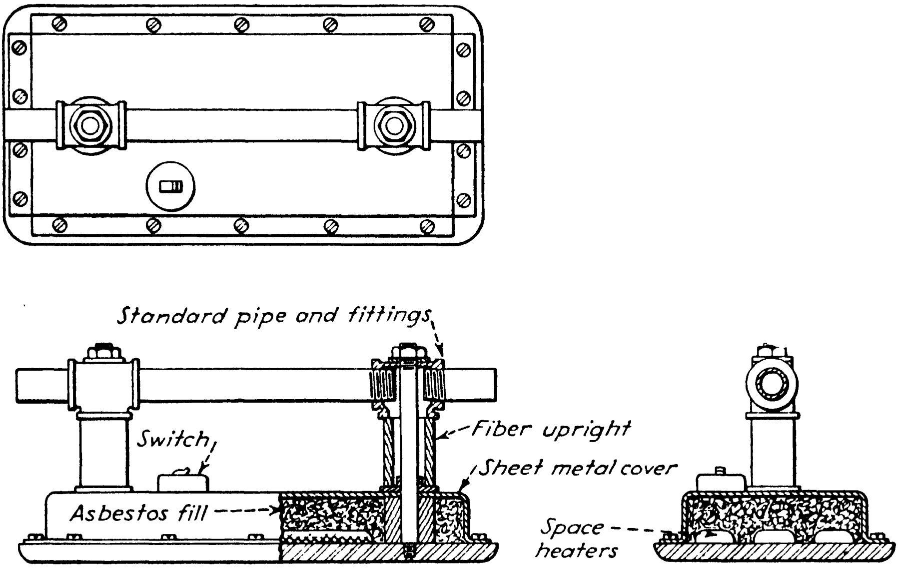


FIG. 548.—Electric smoothing iron.

will be approximately ⅛ in. thick. Successive coats can be applied until the base coat has been brought up to the top of the gauge strip.

Care must be exercised not to work over too large an area at a time, that is, not to allow each coat to cool to the extent where the successive coats applied will not bond and will be laminated. Only enough area should be worked on at a time to retain the heat and pliability of the base coat between each coat. As each coat is applied on top of the other, it should still be warm to the hand; otherwise, it may be laminated and roll off as the ship passes down over the base coat, possibly causing the ground and sliding ways to come together, wood to wood.

After the base coat has been applied to the level of the gauge strips, these can be removed. If a gauge strip has been used in the center, this area will have to be filled up with base coat.

Ironing. After the base coat has been applied and allowed to set, it is customary to iron off the surface to remove lumps and excess and to create a smooth surface for the slip coat. By the elimination of depressions in the surface of the base coat, the slip coat can be more readily removed without mixing with the base coat when this is to be reused. If the base coat is mixed with the slip coat to any extent, it will tend to soften and render its bearing qualities useless.

Electric heating irons similar to that shown in Fig. 548 are generally used for smoothing off and ironing out the base coat. If an electric iron is not available, rectangular steel plates 8 by 12 in. with a handle attached may be used. These are heated in some sort of coke fire, and the base

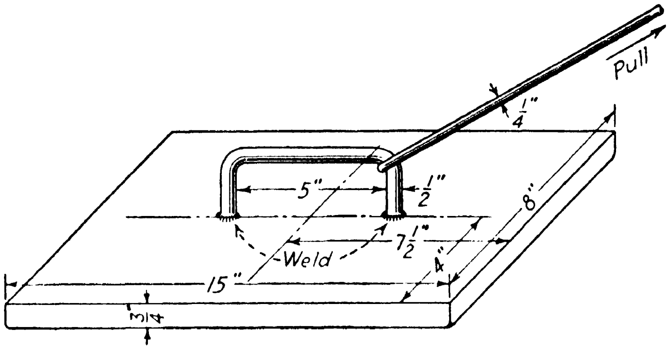


Fig. 549.—Plate smoothing iron.

coat is ironed out with a hooked rod, which can be attached to the handle of the heated plates, as shown in Fig. 549.

Slip Coat. The slip coat does not have to be heated. It is ready to apply as it comes from the barrel. Slip coat is usually applied to a thickness of ¼ in. In extremely cold weather, this thickness may be increased.

Slip coat is applied by hand to approximately the desired thickness; if desirable, a gauge may be used for scraping and leveling off excess. This gauge is simply a wooden strip notched out to fit on top of the ribband to the desired distance below the top of the ribband. A wooden strip is used on the inboard edge of the ways on which this gauge can bear.

The advantage of gauging and smoothing out the slip coat is that it creates a uniform thickness of slip coat.

After the grease irons have been installed, slip coat should be applied liberally to the top of the grease irons to facilitate their removal.

Base Coat on Sliding Ways. Always apply a brush coat 1/16 to ⅛ in. thick to the sliding ways to prevent the wood sheathing from absorbing the slip coat.

Placing Sliding Ways in Position

After the greasing operations have been completed and the grease irons installed, the sliding ways can be pulled over on the grease and set in position. If they have been pulled aside on a skid, a leg of a timber hook attached to a block and tackle secured to some of the shoring can be used for pulling them over on the grease.

To prevent wiping off any of the slip coat when this is being done, a shore wedge is usually inserted between the top of the grease iron and the bottom of the sliding ways. The wedge is driven up in such a manner that the sliding ways will be at least ½ in. above the top of the slip coat.

When the ways have been pulled over to the point at which the wedge begins to jam against the ribband, a pinch bar is used to remove the wedge, as well as to keep the ways clear of the slip coat until they are in their proper transverse position.

Where solepieces or burn-off plates are used, it is customary to install the sliding ways on the grease from the afterend forward. A chock is first installed at the point of the afterend of the sliding ways. This is secured to the ground ways by means of lag screws to prevent the sliding ways from slipping aft. When the chock has been installed the afterpiece is pulled over on the grease and pulled aft until it bears against the chock. Successive sections forward of this section are then installed until the forward end is reached.

As each section of sliding ways is being pulled over on the grease, a snubbing line should be attached to the forward end to keep it from slipping aft and to help in setting the end making up the connections.

Making Up the Forward End. After all the sections of sliding ways have been pulled over on the grease, the connection of the solepieces or burn-off plates may be made at the forward end. If holes have already been drilled in the ways for the bolts, some slight forward or after adjustment may be necessary in order to fit these holes. This may be done by jacking down from the forward end or up from the chock at the afterend of the sliding ways until the holes are fair. The bolts are then installed, the connections between the various sections of sliding ways checked, and toggle bolts installed.

Next, the chock at the afterend of the sliding ways should be removed, so that any play in the connections between the sliding ways will be allowed to straighten out, thus eliminating any possibility of the ways creeping aft after the packing has been installed. The chock is then reinstalled at the afterend of the sliding ways to assist in holding them in position. If any great amount of movement has taken place, new holes will have to be drilled for the lag screws. The chock usually consists of pieces of 8- by 12-in. timber 3 ft. in length.

Setting Sliding Ways against the Trigger. When triggers are used for releasing, the procedure generally followed, in installing the sliding ways on the grease, is to install the section that bears against the trigger first. The trigger keeper block and latches are first set, and the section that bears against the trigger is placed against it. Then the sections forward are installed in the manner described in the foregoing.

When the sliding ways forward of the trigger have been installed, the sections aft of the trigger can be placed in position, starting with the section that connects to the trigger bearing section and proceeding aft to the afterend.

When all the sections have been placed on the grease, the connections are definitely made up and a chock is installed at the afterend of the

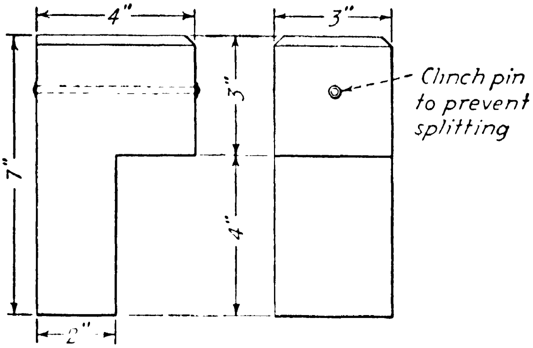


Fig. 550. Joggled wedge.

sliding ways to hold them in position in the event that the trigger is tripped.

Joggled Wedges. Joggled wedges serve the purpose of maintaining the proper clearance between the ground-way ribband and the sliding ways.

They are made in the shape of an inverted L and are 1 to 3 in. thick and made of oak. The leg of the joggled wedge that fits between the ribband and the sliding ways varies in thickness according to the clearance designed between the sliding ways and the ribband (see Fig. 550). This distance is generally 1 to 2 in.

Joggled wedges are spaced about 20 ft. apart. They are installed after the greasing has been completed and the sliding ways have been lowered on the grease irons.

Shoring the Sliding Ways in Their Transverse Position. After the sliding ways have been lowered on the grease irons and the connections made up and joggled wedges installed, the ways are shored hard over against these by means of 4- by 6-in. spreaders placed between the inboard sides of the sliding ways and the keel-track blocking (see Fig. 551).

At this time, if the ship is to be released with triggers, the sections of sliding ways forward of the triggers should be jacked down to bear hard against the triggers and a chock installed at the forward end. This will eliminate any difference in the clearance between the trigger and the keeper block on each side of the ship when pressure is applied on the triggers and the ship is actually being held by them during the launching operations.

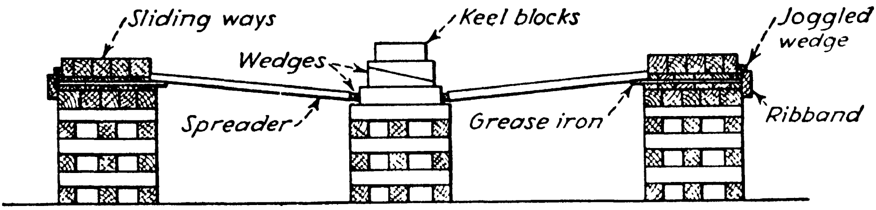


Fig. 551.—Spreaders to hold sliding ways in position.

Grease Covering. To prevent trash and debris from falling into the clearance space between the ground-way ribband and the sliding ways, this space is covered with strips of wood ½ in. thick and 3 in. wide between the joggled wedges for the entire length of the sliding ways.

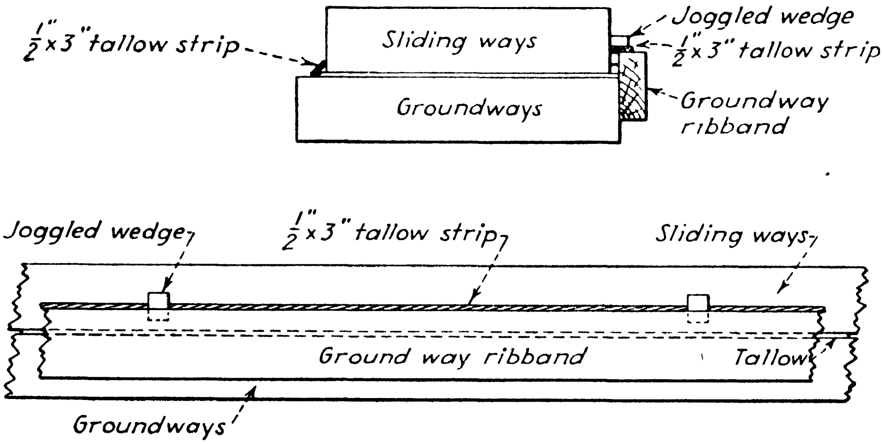


Fig. 552.—Covering strips for launching lubricants.

To prevent trash and dirt from accumulating along the inside edge of the sliding ways, grease covering strips similar to those used on the outboard side of the sliding ways are also used on the inboard edge. The inboard covering strips are installed at an angle, as shown in Fig. 552, and are notched out where they pass over the grease irons.

Jacks. *Precaution for Insuring Starting of the Ship.* Against the possibility that the ship will not start when the releasing devices have been released, jacks are usually installed at the forward end of the sliding ways on each side of the ship.

The jacking power is customarily about one-tenth to one-twentieth the weight of the vessel. This amount is adequate to overcome any reasonable coefficient of starting friction.

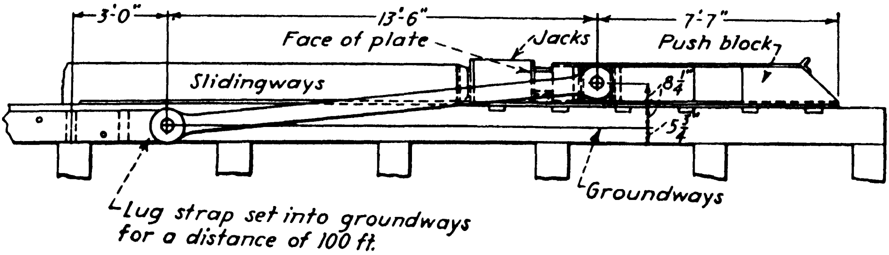


FIG. 553.—Backstop for jacks.

Backstop for Jacks. The backstop for the footing of the jacks can consist of 12- by 12-in. oak timbers bolted together horizontally and then in turn bolted to the ground ways through holes bored the same diameter as the bolts. It should be placed to suit the length of the jack when in a closed position.

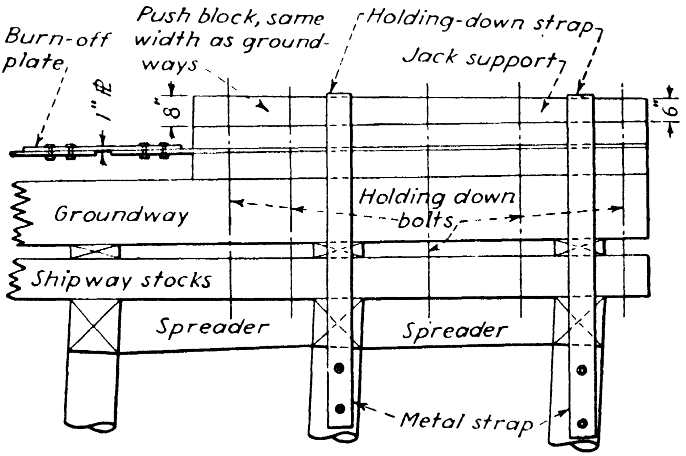


FIG. 554.—Backstop and holding-down strap for solepieces and burn-off plates.

On large heavy ships where pressures will run high, should jacking be necessary the backstop should be built up of structural shapes and plating designed to withstand the thrust of the jacks, as shown in Fig. 553. When solepieces or burn-off plates are used for releasing the ship, the backstop should be high enough above the top of these devices to give sufficient footing for the jacks.

If solepieces or burn-off plates are used for releasing, there will be a tendency for the forward end of the ground ways to lift when the pull of the ship is transferred to them. Consequently, it is necessary to install holding-down straps on top of the backstops to offset this. The straps should be securely anchored to the shipway piling or caps, as shown in Fig. 554.

LAUNCHING CRADLE

When the preparations for launching the ship have advanced to the point where the cradle is ready to install, that is, after the sliding ways have been set and shored in place, the plan foi the launching cradle of the ship is studied in preparation for its installation. The plan shown in Fig. 511 is the launching cradle for a moderate-sized freighter and will be used as an example.

The time for launching a vessel from its release until it is water-borne is 45 to 75 sec. All the work necessary in connection with launching a ship is performed during this short interval of time, in which it is impossible to make any readjustment or repair any bad work. Therefore, each part of the launching cradle should be fitted and secured in the best manner possible, no question or doubt being left in connection with any part.

Pivoting Pressure

One factor over which everyone responsible for the successful launching of a ship is much concerned is the pivoting pressure, or the reaction on the ways when the stern begins to lift. Concentration of pressure at the fore poppets is sometimes actually visible when the ship pivots. Pivoting pressures sometimes run over 5000 tons. Naturally, suitable provisions must be made for taking care of these, and some means must be found for distributing them over as great an area as possible, thus allowing the undersurface of the sliding ways to remain in contact with the upper surface of the ground ways for a considerable distance during pivoting.

Crushing Strips. This is probably best accomplished through the use of crushing strips between the layers of the fore-poppet packing, as shown in Fig. 511. These strips are usually of clear, straight-grained white pine or spruce and are 2 by 3 in. or 3 by 3 in. in section, being laid transversely across the packing. If 2- by 3-in. crushing strips are used, the 3-in. dimension is placed vertically. These strips are spaced at what appears to the casual observer about 12 in. apart, but in reality the spacing varies more or less uniformly, being close under the fore poppets and gradually widening out.

The spacing and arrangement are shown on the plan developed by the drawing room and are pretty definitely calculated through an analysis of the reaction and the change in grade of the vessel or sliding ways for several positions after pivoting. There is also a further crushing action that occurs in the division planking between the rows of crushing strips. The number of rows of crushing strips used will, of course, depend on the amount of the fore-poppet pressure.

Frequently, telltales are fitted at a number of places to measure the crushing, so that actual results may be analyzed. These are designed and fitted so that, after the amount of crushing is actually recorded by them, they are salvaged after launching and measured.

On large heavy vessels crushing has been observed to be as much as 5 in. through six rows of crushing strips.

Crushing strips may also be necessary throughout the length of the launching cradle, particularly on vessels that are longitudinally framed and light in construction. They tend to relieve some of the stress against the hull of the ship caused by way-end pressures.

Crushing strips are sometimes installed in the after-poppet section. They help to distribute the weight on the cradle uniformly to prevent any concentrated loads at the afterend that might tend to bed the sliding ways into the base coat after the grease irons have been removed, for it is the afterend that sits on the grease longer than any other part.

Cradle Construction

The cradle for launching the vessel consists of three main parts, the fore-poppet section, the main section, and the after-poppet section. Each may be made up into one or more pieces, depending on the size of the vessel.

The number and length of the fore-poppet and after-poppet sections are dependent on the design of the cradle and the type of ship for which it is used. The main section of packing, which extends through the flat part of the ship between the fore-poppet and after-poppet sections, is made up into lengths that will be convenient to handle after it has been removed from under the ship, and particularly if it is to be used again under successive ships. In the latter case, shorter sections would be more practical as there is less chance of their becoming racked and distorted when being hauled in under the ship.

In making up these sections, consideration should be given to straddling the butts of the sliding ways and to using standard lengths of timber, wherever possible.

Installing Main Section. The main sections of packing are generally the first to be installed, for this part of the ship is usually ready for packing before either of the ends. In some yards the main sections of packing are fabricated, except for the top blocks, which are fitted after the lower section has been installed and lined up on the wedges. If there is sufficient room available at the stern of the ship, the main sections of packing may be put together here and then hauled up under the ship in their proper locations.

The wedge rider, that is, the strake of packing that rests on the driving-up wedges, is the first to be assembled and bolted together. If more than one length of timber is necessary in each line, the butts of the timber should be staggered to create rigidity.

From the plan shown in Fig. 511 it will be observed that there is very little detail in connection with the main section of packing. The bed strake, or wedge rider, consists of two 8- by 12-in. timbers with a 6- by 8-in. piece between them to make up the width of 30 in. The sections making up the main section of packing on this particular ship were made 40 ft. long; timbers 16 ft. in length were used and the butts staggered by cutting one timber in two and using a piece at each end. The method of holding the timbers together was by 1-in.-diameter bolts spaced on 4-ft. centers through the centers of the timbers, the bolts at the ends being 2 ft. from the end of the section.

After the sections of wedge rider have been made up and bolted together, they are pulled under the ship in their proper location on top of the sliding ways. The wedges are installed, and the packing is set in a transverse position 3 in. from each edge of the sliding ways. The wedge rider is chocked in this position by nailing blocks to the top of the sliding ways against each of its sides.

In installing the wedges under the wedge rider, the thin end of the wedge should be set even with the inside edge of the wedge rider. This permits a sufficient length of the wedge to project outside for driving up the packing hard against the ship on the day of launching.

Dummy wedges are generally used only for setting the wedge rider in its proper position. They are not placed at the location of every driving wedge. They are simply scrap pieces of stage plank ripped out to the same taper as the driving-up wedges, but extending only to the sides of the sliding ways. This permits easy working around the packing until it has been fitted, which is not the case with the regular driving wedges, which project over the outside edge of the ways for some 3 to 4 ft.

Setting the Filler Blocks. After the wedge rider is set in its proper position and the dummy wedges are installed, the setting of the filler blocks between the shell of the ship and the wedge rider can then be performed.

Since a filler block is shown fitted under every frame between frames 40 and 146, the frames on the vessel will first have to be located and marked on the shell, so that the blocks will be set directly under each frame. This may be done by definitely locating one frame station and then measuring from this point at designed frame spacings. A check may be made from time to time by tapping on the shell to determine the correctness of the position of the frame.

Filler blocks may be cut to their proper shape at the ship; or *spilings* may be taken 6 in. on each side of the frame, the block being 12 in. wide, for fabricating these blocks in the shop. Spilings are taken even if

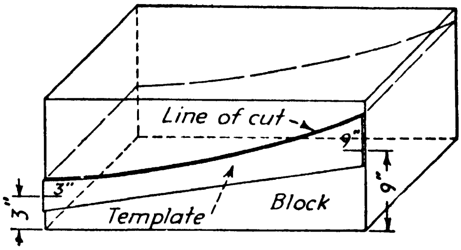


Fig. 555.—Template for working filler blocks.

filler blocks are cut at the ship, for they can be conveniently applied to the blocks themselves for marking off and cutting. When blocks are short enough to be handled conveniently a band saw can be used for rough cutting them out.

Spilings are measurements taken from the wedge rider to the shell at the inboard and outboard ends of the block and at each side, provided that the bottom of the ship is straight.

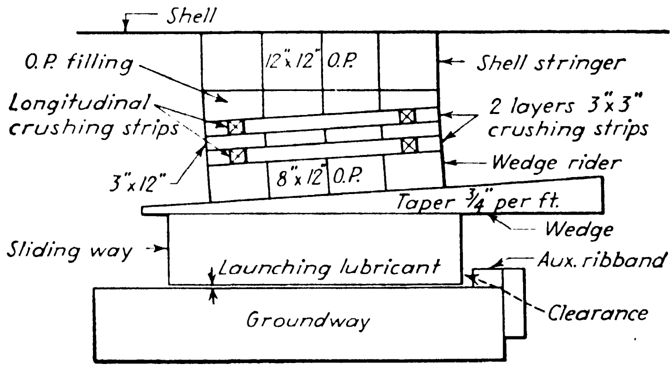


Fig. 556.—Midship packing designed with crushing strips.

If the shell of the ship is rounded, a template is then cut out to fit the shell of the ship and a height taken from the template to the top of the wedge rider at each end. After this, the template can be applied on the block as shown in Fig. 555.

Filler blocks should be fitted to the ship after rough cutting with a foot adz, so that the entire surface of the block bears against the shell.

Where the midship packing is of considerable height and where crushing strips are designed to be fitted as shown in Fig. 556, the crushing strip and separators and all parts of the packing except the filler block can also be fabricated clear of the ship and then pulled under it into position. Figure 556 shows an 8- by 12-in. wedge rider with two rows of transverse crushing strips and two lines of fore-and-aft crushing strips, together with a solid timber ribband consisting of four 12- by 12-in. Oregon-pine timbers bolted together and fitted to the shell. Between the top row of crushing strips and the shell ribband, the necessary filler to make up the distance between the wedge rider and the shell consists of four fore-and-aft pieces. Spilings for these were taken after the ribband had been wedged up hard against the shell above the lower section. The spilings were then taken at 2-ft. intervals in a fore-and-aft direction on the inboard and outboard sides. Since the shell of the ship was straight, a straight line could be struck from any of the spiling points.

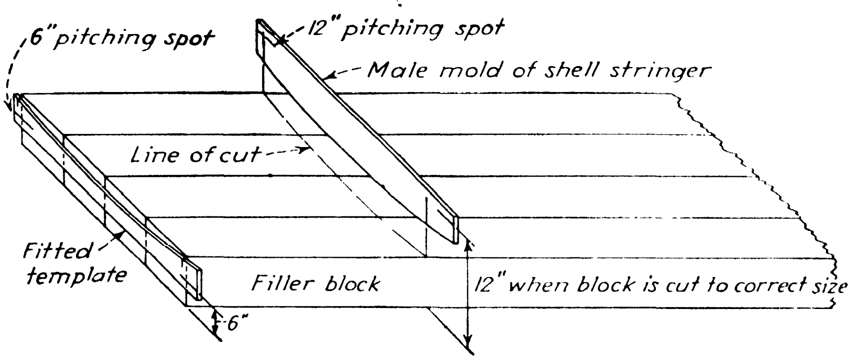


FIG. 557.—Spilings and templates for fitting fore-and-aft packing.

Timbers of the necessary thickness were then laid down on a skid and lined off for cutting, as shown in Fig. 557. If there was any change in the spiling due to change in the shape of the shell, a template was made at points 4 ft. apart to fit on the crushing strips and against the shell ribband. If any shape was necessary in the filler timbers, a male template was made at the top of the fitted template so that it could be fitted on the top of the timbers for working.

A complete section of filler timbers can be laid out at one time and worked to fit by chocking them together on working skids or a platform. After being worked to the templates, the timbers are taken apart and placed individually in position. Some slight readjustment may be necessary where the timbers do not fit.

In Fig. 511, it will be observed that, at the forward end just forward of frame 35 and just aft of frame 51, the plan calls for solid packing. This can be made up of any convenient-sized timbers and is fitted to the ship by taking spilings at every frame as each strake of packing is fitted to the ship.

A broad ax and foot adz are generally used for shaping the timbers. The broad ax is used for rough cutting and hewing to the line. The foot adz is used for the final trimming and fitting. Where any great amount of timber has to be removed, it is general practice to saw cut the timbers vertically at intervals of 8 to 12 in. close to the cutting line and then to shape out these blocks with a broad ax, care being taken not to split the timber out below the neat-cut line. The timbers are then worked neat to the line with the foot adz, a cross-grain cut being used. Spilings necessary for picking up a solid section of packing using timbers 8 by 12 in. are shown in Fig. 558.

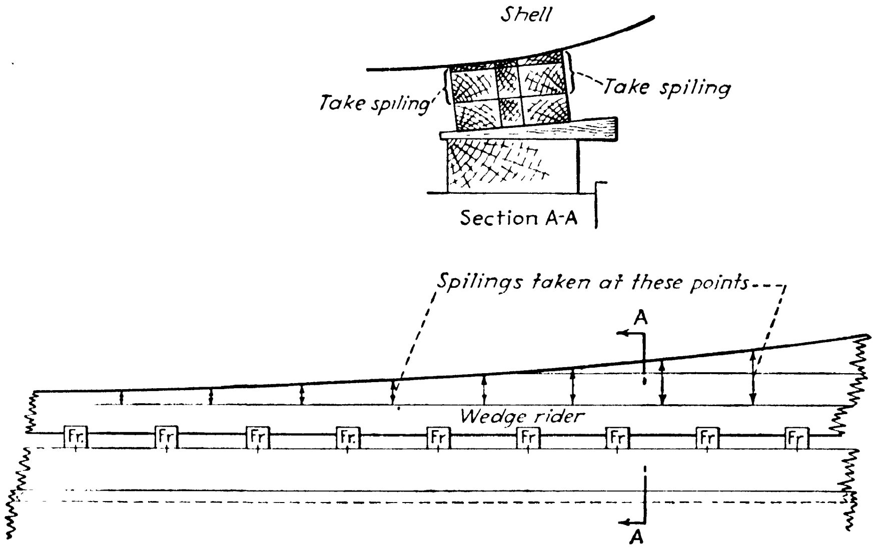


FIG. 558.—Spilings for a solid section of packing.

The same principle of the solid packing is used at the afterend of the main section of packing from frame 147 to frame 157. The same fundamentals are used in fitting this packing as those used forward.

Installation of the Fore-poppet Section. The fore-poppet section as shown in the plan is designed in two pieces. On this particular ship, the section usually considered the fore-poppet section requires no poppets, the saddle straps resting on a series of crushing strips set on fore-and-aft timbers as shown.

Two sets of poppets are shown at frames 29 and 30 and frames 32 and 33.

In fitting the poppets under the ship, it will be necessary for the shipwright to make a template at the after side of each poppet that will fit between the wedge rider and the shell of the ship. After the mold has been fitted at this position, it is moved to the forward side of the poppet and spilings are marked on the template at intervals of 6 in., to give the proper angle of the cut.

The templates are then laid on the timbers to be used for this purpose and the cutting lines marked as shown in Fig. 559. The timbers making up the width of the poppet can be laid on the skids and temporarily tacked together for marking. After this, they can be taken apart, cut, and installed.

In installing the fore-poppet section shown, including the saddle straps, the saddle will be the first part to be installed. It will be observed from the plan that this saddle is fitted with a flat-bar strongback, or stiffener, to prevent buckling and to hold its shape.

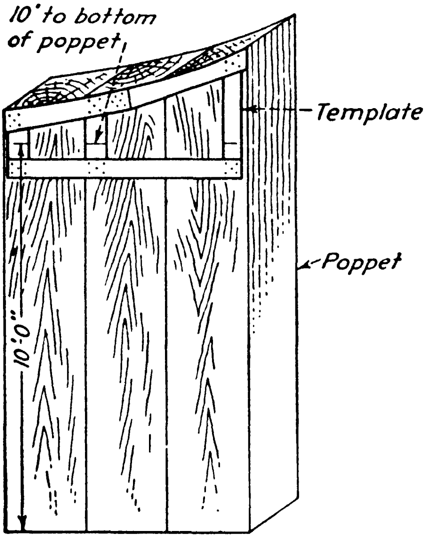


Fig. 559.—Template for cutting poppets.

Temporary shores are placed under the saddle brackets, and clips, holding the saddle at the proper distance above the sliding ways, are welded to the shell and saddle.

Then, both the crane and block and tackle can be turned loose. A shore is also installed underneath the bottom of the saddle at the center line after a block the desired thickness of the packing between the ship and the saddle has been placed at this point. The shore is then wedged up hard against the saddle.

The packing between the wedge rider and the crushing strips can now be installed as shown, on both sides of the ship. After being built up to the point of the location of the crushing strips, the saddle can be definitely adjusted and set and the crushing strips, with their separating planks, installed and fitted.

It will be observed that this section of packing differs from the main section in that it is 36 in. in width, better to distribute the pivoting load, whereas the main section is only 30 in. wide.

For the purpose of reviewing the fore-poppet section more thoroughly, let us refer to the fore-poppet section shown in Figs. 560 and 560*a*. This section is quite extensive, owing to the shape of the ship and the pivoting load.

Before definitely deciding to build the lower section before installing the saddles, a check should be made to determine whether or not the saddles can be passed under the bottom of the ship, from one side to the other, with the lower section in place. If this is possible the lower section can be built and placed in position.

The wedge-rider timbers are laid on the dummy wedges, lined up, drilled off, and bolted together. Then the crushing strips and the separating plank between them are installed according to the plan.

When the separating planks between the rows of crushing strips are placed in position, the butts of the various lines of planking should be staggered to create rigidity.

Crushing strips are held in position by toenailing with tenpenny common wire nails at each end. The separating planks are toenailed

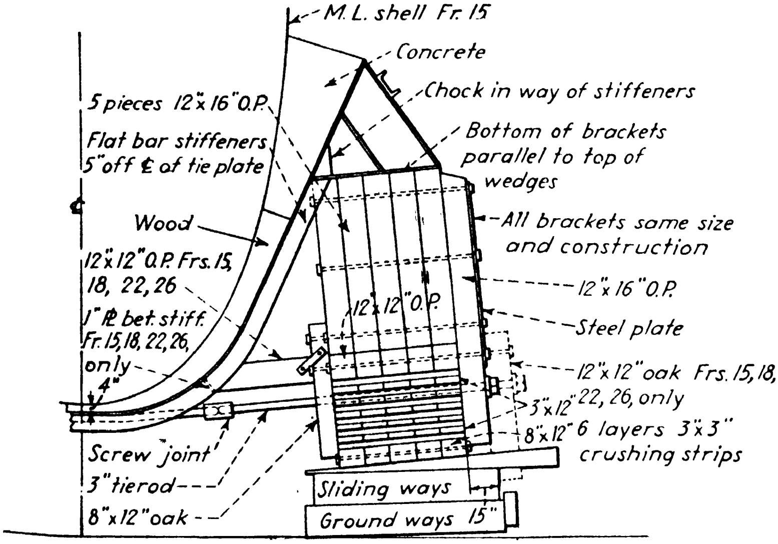


FIG. 560a.—Transverse section of fore poppet shown in Fig. 560.

in turn to the crushing strips, etc. After all the crushing strips have been installed, the footing timbers for the poppets are installed, lined up, and bolted together. When tie rods project through the crushing-strip section, provision must be made for them to pass through the crushing strips and separators. A chalk line extended from the keel at the position of the tie rod and extended to its proper distance above the wedge rider at each side will determine the amount of opening necessary for the tie rod. Since the tie rod projects through the lower section at a level plane, while the crushing-strip section is inclined to be square off the wedge, it would be difficult to attempt to cut a hole at this angle through this type of construction.

Installing Saddles. After the crushing-strip section has been completed, the saddles can be installed in the manner already described for the single saddle. They should then be plumbed up and centered under each frame, as designed, by the use of shoring under the saddle brackets. When the entire section of saddles has been lined up, it should be checked for appearance and correctness. Clips are then welded from each side of the saddle at the top to the shell of the ship to hold it in position until the poppet timbers have been installed under the brackets.

All saddles should have a 4-in. minimum thickness of packing between the saddle and the shell of the ship.

When the saddles have been installed, the tie plates, which fit immediately underneath the saddle and out over the top of the poppet footing timber, as shown, are installed.

Installing Poppets. The poppet timbers are fitted and cut from templates made between the top of the tie plate and the underside of the saddle bracket. These templates may be made for individual timbers or for the set of four as shown.

In setting the timbers in individual pieces, a template consisting of a ¾- by 12-inch board is set in line with the location of the inboard timber. The template is fitted on top of the tie plate and the cut marked at the underside of the bearing plate on the bracket on both the forward and after edges. It is then laid on a timber of suitable length, and the cuts are marked and made. The timber is installed and set in its correct position, and the length and cut of the adjoining timber are made.

Some shipwrights prefer to make one template for each set of poppets. This is built of regular ¼- by 6-in. template wood and lined up across the top under the bearing plate and at the bottom on top of the tie plate, together with the vertical boundaries of the poppet. This rectangle is then braced diagonally to prevent it from racking.

Next, timbers of suitable length are laid on skids and wedged tightly together. The template is laid on the timbers, and the cut lines are marked off; after which, the timbers are cut and installed and set perpendicular to the base line in a fore-and-aft direction and at right angles to the tie plate in a transverse direction. Poppet timbers are usually toenailed and braced temporarily in place to hold them in position until the permanent bracing and bolting is done.

Wood Packing in Saddles. After the poppets have been installed and the bracing and bolting completed (this will be discussed later under Fastenings), the shores under the center of the saddle are removed. The saddle plates are then wedged away from the shell at the minimum distance, so that they will be pulled down tight on top of the poppets.

The fitting of the wood packing between the saddle and the shell can now be started. For this filling, 4- by 6-in. or 6- by 6-in. scrap lumber is used. The saddles are first marked off with the butts or edges of this filling, beginning at the center line of the ship. If the packing to be used is 6 in. in width, these spots will be 6 in. apart. Dimensions are then taken at each of the spots and applied to the packing to be used and the cut lines marked.

This wood packing is usually cut at the job with a band saw. Any necessary fitting is done with the use of the foot adz.

The wood packing should extend at least 2 in. past the side of the saddle to permit fastening the wood to the saddle after it has been fitted.

In some locations where it is difficult to install the wood packing because saddles are particularly close together, it is sometimes necessary to install the wood packing in two pieces, cutting it diagonally so that it can be driven up hard and then trimmed off to create a good appearance.

Concrete Packing in Saddles. The area between the saddle strap and the shell of a ship in way of the brackets supported on the poppets is generally filled with concrete, consisting of two parts sand and one part cement.

On large, heavy ships, where the pivoting load runs high, concrete is used over the entire area of the saddle in order to create a more solid bearing between the saddle strap and the hull of the vessel.

Installing After-poppet Section. The design of the after-poppet section shown in Fig. 511 is comparatively simple. The after poppets are canted inboard at the top with the use of a cant block set on top of the wedge rider between it and the foot of the poppets.

In making the templates for these offsets, the line of the top of the poppets should first be laid off and marked on the shell of the ship, so that the top will line up for the fore-and-aft angle braces which will be secured to it.

It will be observed that the poppet at frame 160 is not canted in so much as the poppet at frame 170. Therefore, each cant block will have to be cut at a different angle.

The poppets are designed to follow the line of the inner bottom. Thus, this line will be the first to be established. From this line the outside line of the top of the poppets can then be established. After this, a line projected from this point to the top of the wedge rider will indicate the outside edge of the poppet. The cant block should be cut to a minimum thickness of 1 in. on the inboard end, and from this point the bottom of the poppets should be square to the side. This will determine the shape and size of the cant block.

After the cant blocks have been installed and toenailed in position, a template is made to fit on top of the cant block and against the shell, holding the outside line of the poppets. Owing to the shape of the ship, it may be necessary to build a template from both the forward and after sides of the poppets in order that the proper fit may be made.

After the templates have been made, they are laid on timbers of suitable length, the cut lines marked, and the timbers cut and installed.

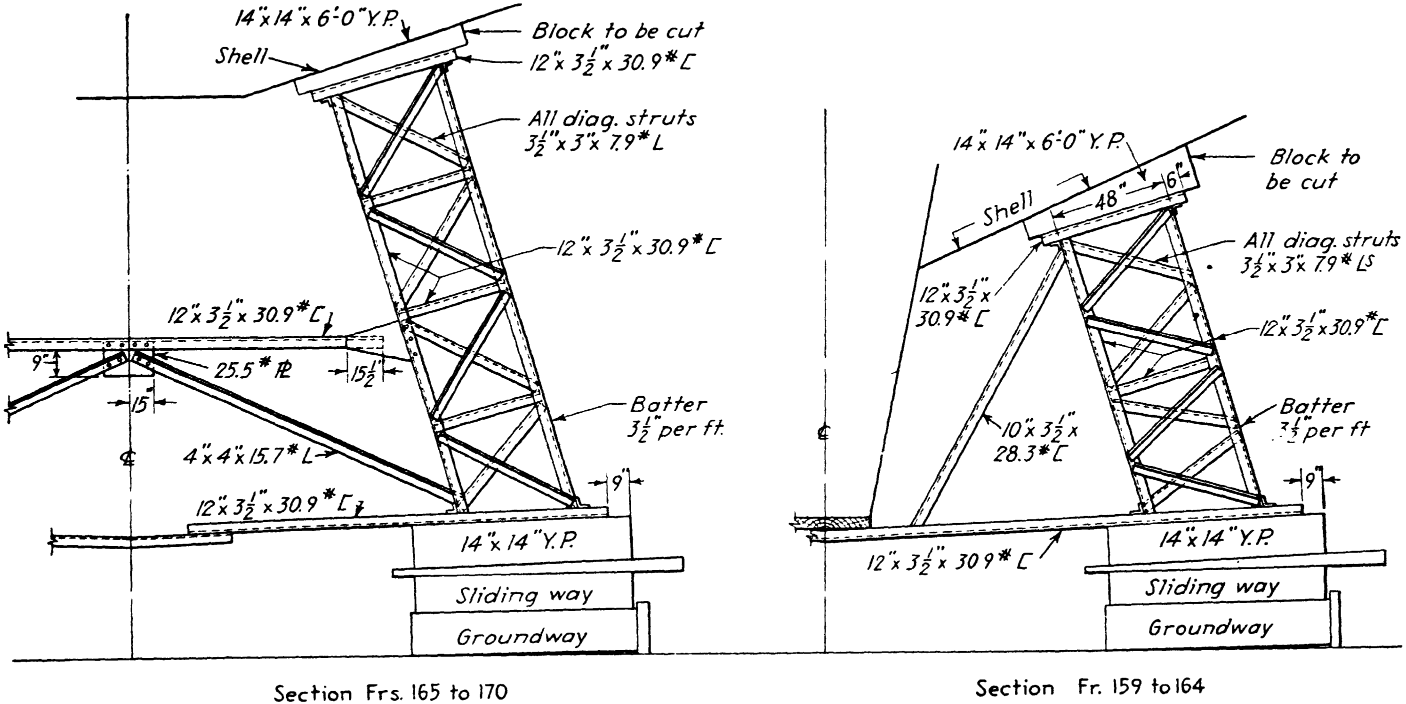


Fig. 560b.—Transverse section of a launching cradle constructed of structural plate and shapes.

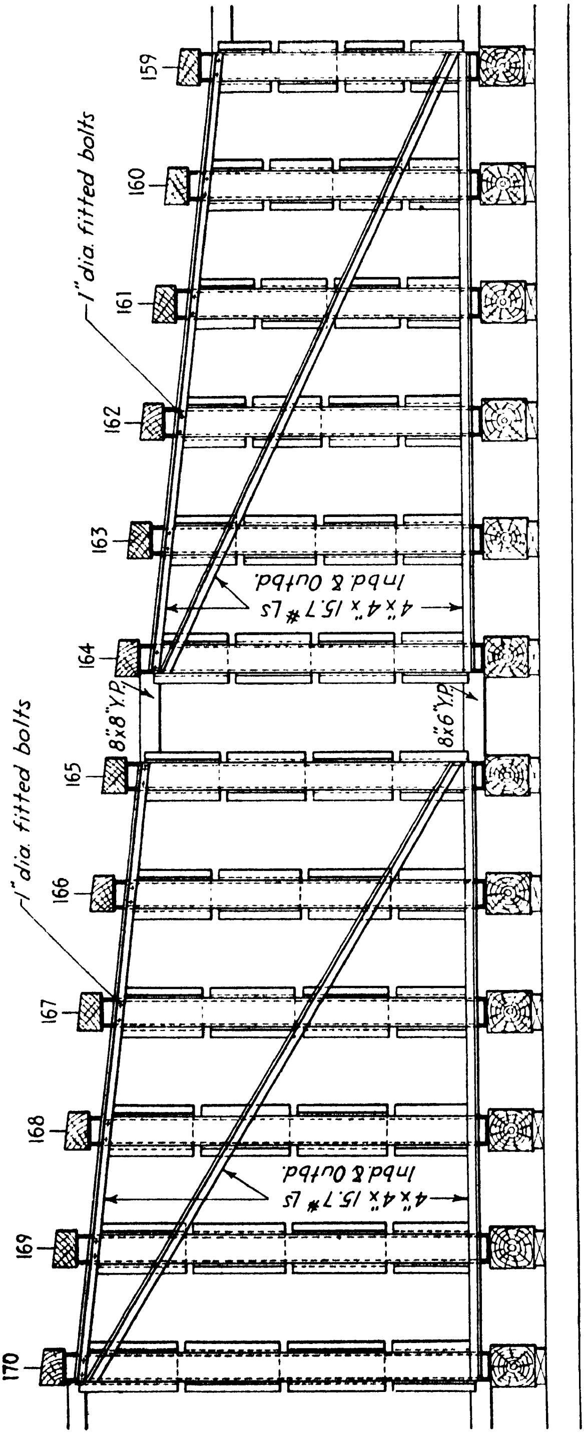


FIG. 560c.—A portion of a launching cradle constructed of structural plate and shapes.

Cradle Constructed of Structural Shapes

When a number of ships of the same type are being constructed, it is good practice to construct the cradle at the forward and after ends of structural shapes, in order that it may be used repeatedly without being damaged when removed from under the ship, as generally happens when wood timbers are used. For the purpose of making adjustments the top and lower blocking on this steel framework is usually wood, since this can be fitted to the ground ways and the ship to suit any slight difference that may occur.

Part of a built-up steel cradle is shown in Fig. 560*b* and 560*c*. It consists of channels and angle, which can be fabricated from templates developed in the mold loft and then assembled somewhere adjacent to the ship. They can then be placed in position under the vessel on top of the wedges and blocks on the sliding ways. After they are properly located, the top blocks can be fitted between the top of the steel framework and the hull of the vessel.

The conventional type of wood packing is generally used in the flat portion of the ship; but where the shape of the ship attains a height at which it is practical to use the built-up cradle, this part is constructed of steel. It must be remembered, however, that, when only a few ships of the same type are to be constructed, the wood cradle is much cheaper. A wood cradle will usually last for about four launchings without any extensive overhauling. After this, overhauling is required from time to time, and split and broken timbers must be renewed.

In assembling the steel cradle on a flat skid, either it can be blocked up to the same declivity as the launch ways, or the bottom may be set flat on the skids and the uprights inclined on the declivity of the ship, so that they will be plumb when they are set on top of the ways. Any transverse struts or bracing from one side to the other are generally installed after the poppets are set in position under the ship, since it would necessitate removal of keel blocking if the entire assembly were to be put under the ship in one piece.

Tie Rods

Owing to the height of the packing at the forward and after ends, tie rods are installed to prevent it from spreading when the weight of the ship is transferred to it during the removal of the shores and blocking.

In some cases where the packing at the forward and after ends is extremely high, two tie rods may be used at one location—for the purpose of holding, one the lower part of the cradle and the other the upper portion.

The size of tie rods will, of course, depend on the pivoting and way-end loads and the strain to which the rods will be subjected during launching. They are generally 1½ to 3 in. in diameter.

The threaded ends and nuts of the tie rods should be well coated with a mixture of one part beef tallow and one part white lead to facilitate their removal and to prevent rusting when in the water. The nuts should be well tightened so that the tie rods will be taut and any tendency for the packing to spread will be reduced to a minimum when the weight of the ship is transferred to the cradle.

Strongbacks

For the purpose of stiffening up the cradle at the forward and after-ends, vertical timbers known as *strongbacks* are used in conjunction with tie rods, toggles, and frapping. Strongbacks are installed on both the inner and outer sides of the packing. This prevents any lateral movement of the packing on top of the ways.

From the plan of the saddle shown in Fig. 511, it will be observed that two strongbacks are fitted at frames 23 and 25, the outside strongbacks extending from 6 in. below the top of the saddle to within 7 in. of the ribband.

Sufficient clearance must always be allowed for settlement on the packing, particularly at the forward end in way of crushing strips, so that during the settlement and crushing period there will be no possibility of the strongbacks coming down on the ribband, causing damage.

The same consideration is given to fastening strongbacks through the packing. Bolts extending through the strongbacks should not be installed in such a manner as to prevent crushing from taking place. A bolt is generally installed through the bottom wedge rider. A U clip or strap fastened to the crushing rider at the upper end of the strongback will allow the rider to move down by the strongback during crushing.

Holes through the strongbacks for tie rods are laid off and bored before the strongbacks are installed.

As the packing is narrower than the sliding ways, it is generally set 3 inches inboard of the outboard edge of the sliding ways and the strongbacks are notched out 3 in. to fit down over the side of the sliding ways. Sufficient material will remain to prevent splitting off. If the sliding ways are considerably wider than the packing, as shown in Fig. 560, the inside strongbacks extend only to the bottom of the wedge rider. An auxiliary strongback is installed to project below the top of the sliding ways, the bolt for securing this strongback extending only through the wedge rider.

Strongbacks Used in Way of Toggles and Frapping. Where strongbacks are installed in way of toggles and frapping as shown in the plan at frame 29, they are usually cut just below the toggle to act also as a seating for the toggle; however, this is not true in all cases. As shown in Fig. 561, strongbacks sometimes are extended for a considerable distance above the toggle; in this case a toggle seat is fitted and installed on the outside of the strongback. The inside strongback, however, is cut in the same manner as that used with tie rods.

In Fig. 511, it will be observed in the section at frame 170 that a double strongback is used on the outside of the packing only, one strongback consisting of a 12-in. by 10-in. timber through which a 2-in. tie rod is extended. This prevents the lower portion of the cradle from displacing

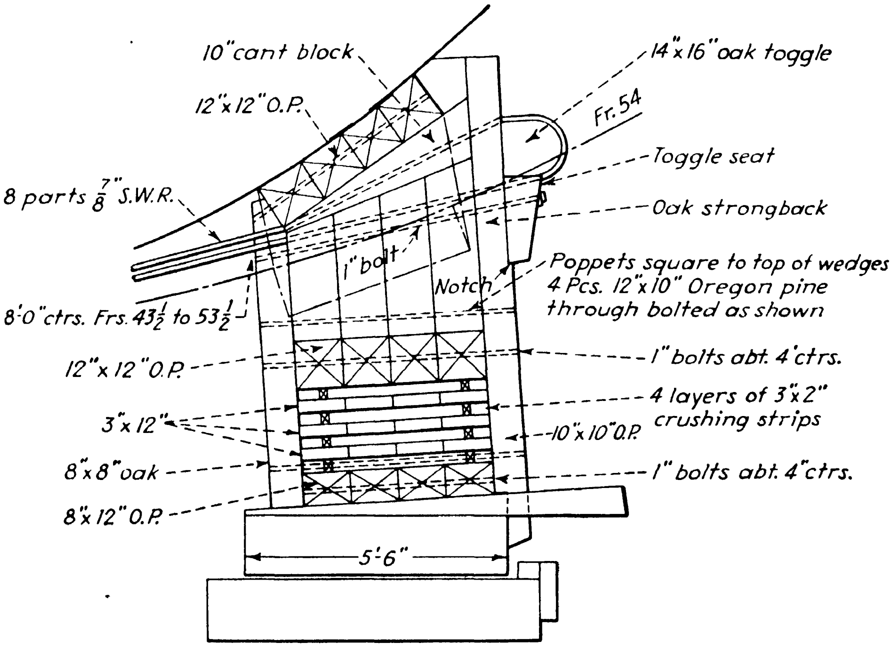


FIG. 561.—Section of packing showing toggle seat secured to strongback.

outboard. Above this strongback and fitted against it is another strongback bolted to the upper portion of the cradle on top of which is rested a toggle for the frapping. Since no crushing strips are necessary in this portion of the cradle, the entire assembly is securely bolted together as shown.

Laying Off Strongbacks. In laying off strongbacks, a template mold is made to the side of the strongback for the purpose of obtaining its length and the position of the tie-rod holes, as well as for cutting the outline and shape of the strongback.

After the strongbacks have been laid off, cut, and bored, they are toenailed to the packing in their proper position. Holes for the bolts are then drilled and the bolts installed.

Frapping

Where it is necessary to prevent the top of the packing from displacing but it is impracticable to use tie rods, wire-rope frapping passed around timber toggles is generally used. The size of the wire frapping and the number of turns necessary depend on the load to which it will be subjected. It will be observed from the plan that the frappings at both the forward and after ends consist of six parts of 1-in. steel wire rope.

This frapping is first wrapped around one toggle and the end secured to the standing part of the wire rope by means of wire-rope clamps. When this is secure, the wire is passed to the other side and around the toggle and back to the opposite side until the desired number of turns have been made.

Each part is then pulled taut by means of a block and tackle secured to the drum of a winch or with a ratchet chain hoist. As each part is pulled taut, it is secured to one of the taut parts until all parts have been pulled taut and the end secured to one of the standing parts.

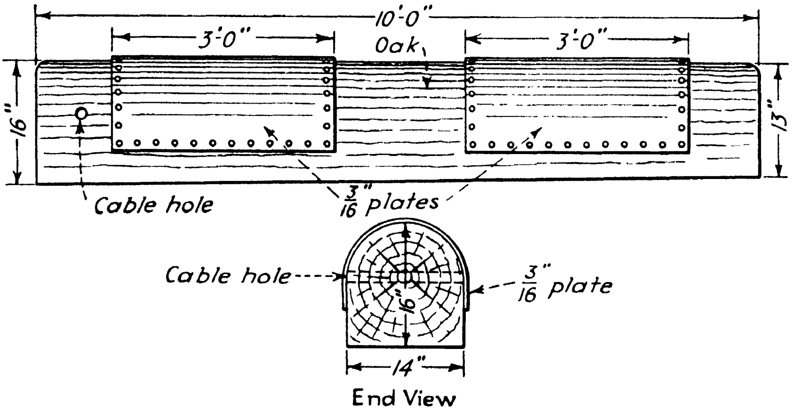


Fig. 562.—A frapping toggle.

Toggles

Toggles usually consist of oak timbers with two of their corners rounded off as shown in Fig. 562. The length of the toggle will depend on the span it will have to bridge.

Toggles run parallel to the sliding ways but are made wedge-shaped, with a taper of 3 in. in the length. The purpose of tapering is so that they may be pulled from beneath the frapping after launching to facilitate the removal of the cradle.

At the forward end of the ship the thick end of the toggle is placed forward so that the toggles can be pulled forward. At the after end of the ship the thick end of the toggle is generally placed aft so that the toggles can be pulled aft.

Toggles are usually fitted with a $\frac{3}{16}$-in. plate in the area where the frapping bears against the rounded portion of the toggle, to prevent the wire rope from cutting into the wood.

A hole is provided at the thick end of the toggle so that a wire rope can be passed through it for the purpose of drawing the toggle (see Fig. 562).

Driving-up Wedges

Wedges for the purpose of driving the packing hard against the ship after the grease irons have been removed may be located under each of the bearing blocks. They are generally located to suit the design of the cradle and differ accordingly. In some instances, they are placed clear of the center both fore and aft of the bearing block in order to distribute the weight more uniformly on the sliding ways. In the fore-poppet and after-poppet crushing sections, wedges are installed to suit the position of the crushing strips.

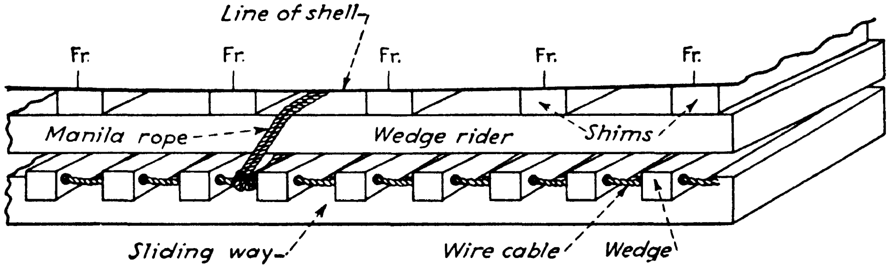


FIG. 563.—A section of launching wedges secured after driving up.

Driving-up wedges are of oak timber 6 in. in width and tapered $\frac{3}{4}$ in. per foot. The length of the wedge is governed by the width of the ways and packing, and the thin end is located even with the inboard side of the packing and is generally $1\frac{1}{2}$ in. thick. This thickness may, however, have to be reduced to a featheredge if insufficient space has been allowed between the top of the sliding ways and the hull of the ship. This is not desirable owing to the fact that the ends of the wedges will be easily damaged if too thin.

On the outside of the packing, the wedges are extended at least 3 ft. outside the outboard edge.

A 1-in.-diameter hole is drilled through the outer end of the wedge for the wedge-securing wire. The latter is made taut after the wedges have been driven up on the day of launching and is lashed to the packing at intervals to prevent the wedges from going adrift after launching (see Fig. 563).

Fastenings

Fastenings on the cradle consist of all bolts, clips, flat-bar straps, etc., that secure the packing and cradle together. They also include straps used in holding the ground ways in position to prevent them from floating, particularly when they are located in semisubmerged shipways that are flooded on the day of launching.

Packing Bolts. During the process of the construction of the cradle, the wedge rider and shell stringer (if one is used) are generally bolted together before being installed. The remaining members of the packing are fitted and toenailed in position until all the strongbacks, spreaders, and component parts that make up the cradle have been put in place so that the entire cradle can be bored off and bolted together.

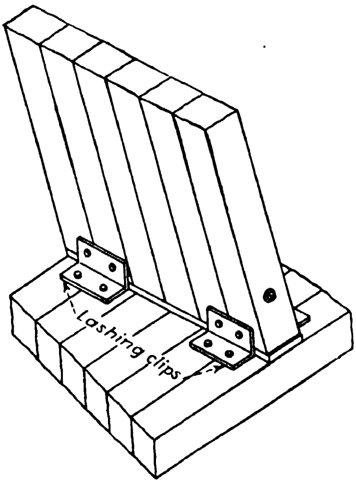


Fig. 564.—Angle-bar lashing clips.

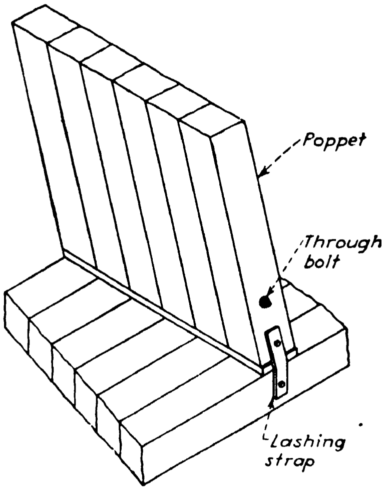


Fig. 564a.—Flat-bar lashing straps.

The size of the bolts will, of course, depend on the size of the ship. Generally, $\frac{7}{8}$-, 1-, and $1\frac{1}{8}$-in. bolts are used throughout the cradle. Securing bolts in the packing are generally installed on 4-ft. centers, except at the ends of timbers, where additional bolts may be required.

Bolts through strongbacks and braces are first laid off. After this, the intervening bolts are spaced off and drilled.

In the fore-poppet section on large ships, the locations of bolts and diagonal bracing are generally shown on the plan, as shown in Fig. 560. In other sections of the packing the location of the bolts is left to the discretion of the foreman shipwright. The bolts should be installed in such a manner that there will be no danger whatever of racking the cradle during the launching or during the removal of the cradle from under the ship.

Clips and Flat Bar. Where the poppet type of packing is used, it is necessary to secure the poppets to the lower portion of the packing by means of angle clips installed on each side of the poppets as shown in Fig. 564. Flat-bar straps may be also used for this purpose, as shown in Fig. 564*a*.

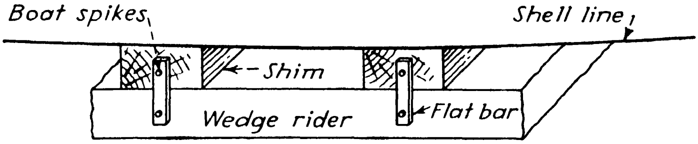


FIG. 565.—Flat-bar lashing straps.

Where only filler blocks are used on top of the wedge rider, a flat-bar clip with a hole in each end is used for securing its block to the wedge rider. Boat spikes are driven into the hole in the clip and into the wedge rider and filler block on both the inboard and outboard sides (see Fig. 565).

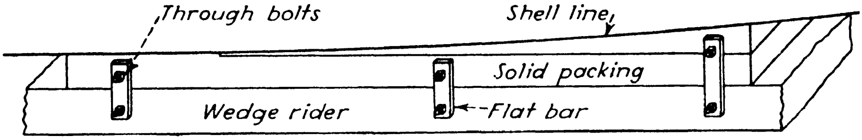


FIG. 566.—Flat-bar lashing on solid packing.

With the use of solid packing, fastening clips, consisting of flat bar, are placed in a vertical position at intervals governed by the length of the timbers. Holes are drilled through the solid packing through which bolts are installed from one side to the other through a flat bar on each side of the solid packing, as shown in Fig. 566.

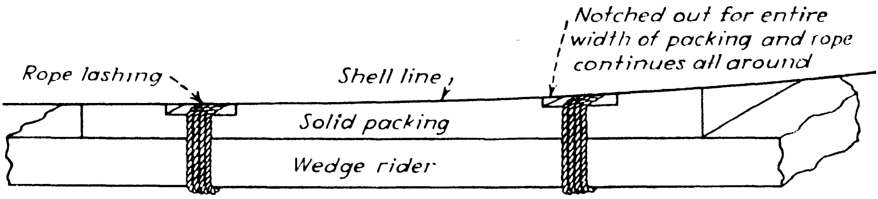


FIG. 567.—Rope lashing on solid packing.

Manila-rope lashing is often used for lashing together the solid packing. Slots are provided in the packing between it and the ship for the purpose of passing the lashing around the top. The lashing is also installed at intervals governed by the length of the timbers used and is so lashed that there will be no danger of any of it coming loose (see Fig. 567).

Securing Ground Ways in Semisubmerged Shipways. Fastening clips for securing the outboard ground ways, particularly to prevent them from floating during flooding operations, are installed as shown in Fig. 568. The size and type of this fastening will, of course, be governed by the size of the ground ways. If these are extremely large, 3½- by 3½-in. angles are used, one end being attached to the sides of the ground ways by means of 1-in.-diameter lag screws and the other secured to the shipway by means of a clip fastened to a bolt set in the shipway caps, as shown in Fig. 568.

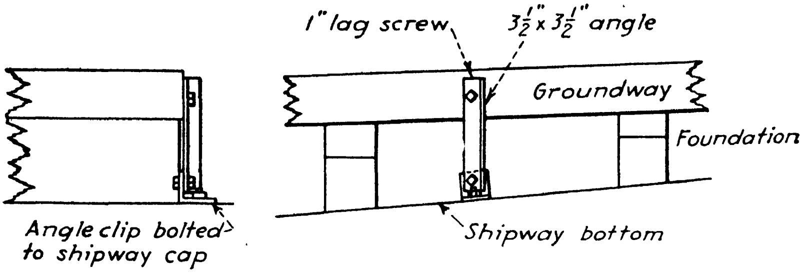


FIG. 568.—Method of securing ground ways in place in semi-submerged building shipway.

Flat bar is used where the ways are not large, bar being secured to the ways and shipway caps in the same manner as the angles.

Extreme care must be exercised to ensure against any possibility of the ground ways floating when the shipways are flooded. This would be disastrous, possibly causing postponement of the launching.

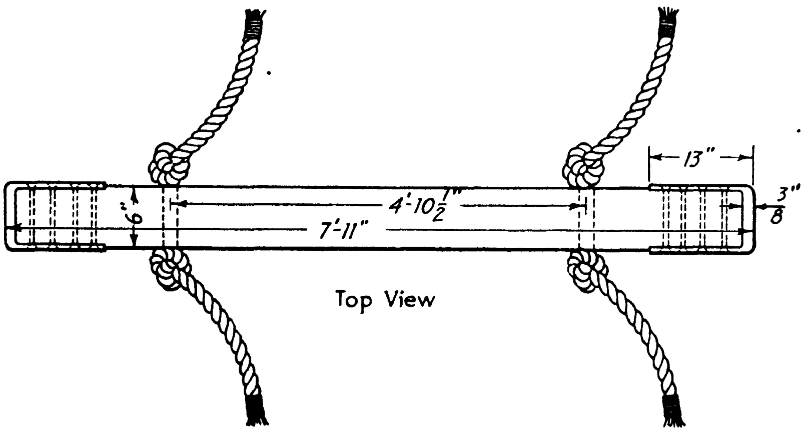


FIG. 569.—A 4-man-wedge ram.

RAMS

Various sizes and types of rams are used during the process of removing support from under the ship during the preparation for launching and the launching of the vessel.

Driving-wedge Rams. Driving-wedge rams are usually 6- by 6-in. oak timbers 6 ft. long, with a rope through the ram near each end to accommodate a four-man gang. They are usually fitted with steel heads to prevent the ends from splitting (see Fig. 569).

Cribbing Rams. The rams used for knocking out the collapsible cribbings are made of 4- by 8-in. oak timber 12 ft. long, with ropes to accommodate 10 men. They are fitted with a steel cap on each end to prevent splitting.

Keel-track Ram. The ram used on the keel track for the purpose of battering out any keelblocks that may be found difficult to remove is made of 4- by 6-in. oak timber 14 ft. long, with ropes to accommodate 14 men. It is of a size to fit between the parts of collapsible blocks, which are sometimes difficult to remove after one side has been freed.

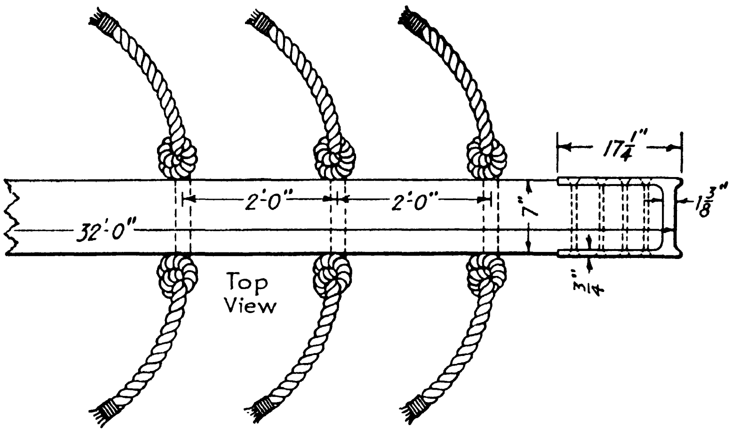


FIG. 570.—A 30-man shore ram.

Shore Rams. Rams for knocking out shores differ in size depending on the size of ship to be launched. For light ships a 20-man ram consisting of 6- by 7-in. oak timber 22 ft. long, with ropes to accommodate 20 men, may be used.

On heavy ships, where shores are extremely large, a ram of 6- by 7-in. oak 32 ft. long, with ropes to accommodate a 30-man gang, is used. Shore rams are provided with a steel head to prevent splitting (see Fig. 570).

TRICING LINES AND PULLING ARRANGEMENT

Lines for securing and removing the sliding ways are generally installed as follows: A 1¼-in.-diameter wire rope is located on each side of the ship at the forward and after ends of the ways. These wires extend through a 3-in.-diameter hole 3 ft. from the end of the ways at the forward and after ends. After being passed through this hole in the ways, the end of the wire is secured to the standing part by means of wire-rope

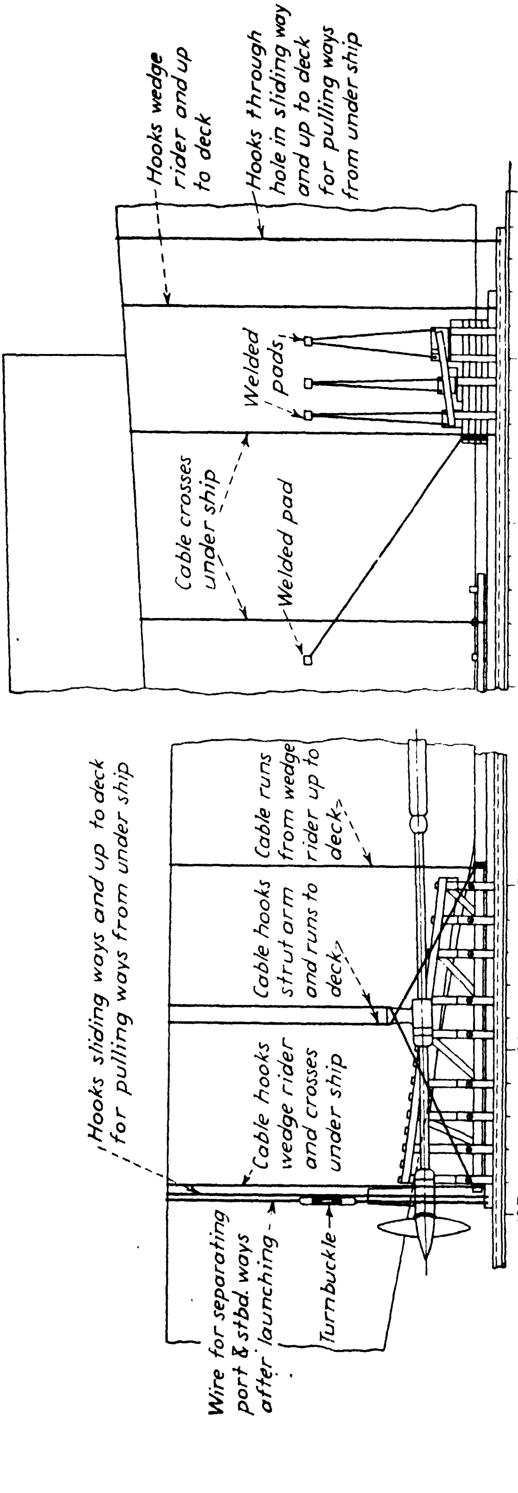


FIG. 571.—Method of securing tricing lines.

clamps. Then the wire is extended to the deck of the ship and secured on bitts or other available structure (see Fig. 571).

To prevent the wires from cutting into the ways when they are pulled from under the ship, a ½- by 10- by 30-in. reinforcing plate is generally installed on each side of the ways. A 3-in.-diameter hole is burned into the plate, the edges of which are chamfered to prevent chafing the wire.

Sliding-way Tie Wire. At the afterend of the sliding ways, in addition to the pulling wires a 1¼-in. tie wire having a turnbuckle at one end for adjusting is generally installed. The wire is shackled to the ways to a 1- by 1½-in. eyebolt through the sliding ways, and one end is fastened to the eyebolt with a toggle pin, from which a ½-in.-diameter wire is extended to the deck. This wire can be drawn from above the water after launching, thus separating the port and starboard sliding ways.

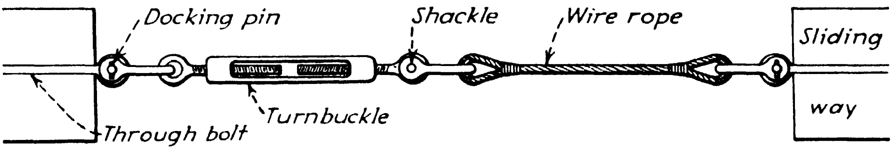


FIG. 572.—Sliding-way tie wire.

The purpose of the tie wire is to prevent the sliding ways from being dislodged owing to the force of the water between the packing as the ship enters the water (see Fig. 572).

Cradle-support and Pulling Lines. For the purpose of holding the cradle in position during launching and for pulling the packing after launching, wires are generally installed as follows:

Fore-poppet Section. Two wires should be installed at the forward and after ends of this section. They are passed through a 3-in.-diameter hole bored through the wedge rider and then are lashed around the lower section of packing twice, with the standing part of one wire on the outboard side of the packing extended and secured to the deck above. The standing part of the other wire should be located at the inboard edge of the packing and passed under the keel of the ship, up to the deck on the opposite side of the ship, and secured.

The same procedure is followed on the other side of the ship and at the afterends of these sections on each side of the ship.

These wires, crossed X-fashion under the ship, will prevent any lateral displacement of the packing during the time when the cradle enters the water and when the ship is being warped in to the pier.

Main Section. Two wires should be installed at the forward end and two wires at the afterend of each of the sections making up the main section. They are generally ⅞-in.-diameter wire rope and are passed through a 3-in.-diameter hole drilled through the lower strake of packing and then lashed around the lower section for two turns. They are treated in the same manner as the wires on the fore-poppet section; that is, one wire is extended from the outside of the packing to the deck above on that side, while the other wire on the inside is passed under the keel of the ship and up to the deck on the opposite side.

After-poppet Section. Holding and pulling wires in the after-poppet section are installed like those in the main section, with two wires at each end of each section installed cross-fashion.

Saddle-support Wires. The wires for supporting saddles are usually ⅞-in.-diameter wire rope, with one wire on each side of the saddle on each side of the ship. They are secured to the saddles by means of shackles and then extended to the deck above, where they are secured to some suitable support, or they may be secured to clips attached to the shell above the water line.

Toggle Wires. Wires for the purpose of pulling toggles are generally ⅞-in.-diameter wire rope. They are installed on the forward end of the toggles on the forward toggles and on the afterend of the toggles at the afterend of the ship. Toggle-pulling wires are usually installed on one side of the ship only, the opposite toggle being secured to the frapping through the hole in the end of the toggle.

Tie-rod Wires. Wires for pulling the tie rods are installed on one side of the ship only. They should be installed on the side of the ship away from the pier and are generally ⅞-in.-diameter wire rope.

Frapping Wires. The wires for recovering the frapping, after the toggle on one end has been removed, consist of ½-in.-diameter wire rope, which is extended to the deck on the opposite side of the ship from which the toggle was pulled.

Wedge-securing Wires. Wires for securing the launching wedges usually consist of ½-in.-diameter wire rope for the entire length of each section of packing. Such wire is secured to the lower section of packing with ½-in.-diameter eyebolts at intervals of 20 ft.

Removing Ways and Packing after Launching

On small ships it is possible to withdraw the ways and packing from under the ship immediately after launching by means of a hawser attached to the forward end of the sliding ways and packing and in turn securing this hawser to a dolphin. After this, the ship may be pulled off the cradle by the tugs. In such a case, flat-bar clips with slotted holes are provided along the sides of the ways and packing for the purpose of holding the packing and ways together when these are being pulled from under the ship.

When the after packing is extremely high and it is not possible to pull it out from under the ship to the forward end, it is pulled separately. It is secured to the ship with tricing lines and is entirely free of the main section of the packing. The ship is then pulled off the fore-poppet and main sections. After this, the high after sections can be removed by hauling them aft after the tricing lines have been turned loose.

When ways and packing are pulled from under the ship as explained in the foregoing, pulling lines need not be quite so extensive. Cross wires should be provided at the ends of the various sections, but the number of these wires can be reduced by one-half by utilizing one set of wires at each butt of the packing instead of the customary set at the forward and after ends of each section.

Before the ship is hauled off the launching ways and packing, all these wires will have to be turned loose from the deck. To prevent them from becoming entangled or fouled on the river bottom, floats are secured to the ends to keep them on the surface of the water and to enable them to be identified. When the wires are turned loose, they are dropped overboard with the floats attached to the ends. The floats may be numbered; and those on the starboard side may be painted green and those on the port side red.

Removing Ways and Packing at the Pier. On large ships where the ways and packing are removed at the outfitting pier, the sliding-way wires are first turned loose, including the tie wire at the afterend.

If the sliding ways are extremely long, it may be necessary for a diver to break them in the center of their length by removing the toggle bolts, or a toggle bolt may be provided which can be pulled with wires above the surface of the water. The sliding ways are then pulled from each end of the ship. This is generally done with a winch on a floating derrick or a towboat.

The fore-poppet section together with the saddles is next to be removed. As this section, owing to the weight of the saddle straps and concrete filling, will not float, it will be necessary to provide some means of supporting it until it can be removed from the water. Generally, a small barge of sufficient size to support the fore-poppet section can be lashed to the top of the saddles on each side.

After the support wires have been turned loose, the section can be floated clear of the bow of the ship to the point at which it can be removed from the water with the cranes. The removal of the main and after sections of packing can then follow, proceeding from forward to aft. This can be done after the tricing lines and pulling wires have been turned loose from their fastenings and toggles, frapping, or tie rods removed.

Extreme care should be exercised not to snag the packing on any of the underwater part of the structure, such as the bilge keel, shafting, or struts. Where tricing and pulling lines pass over the bilge keel, a guard is usually provided as shown in Fig. 573.

Where the packing is likely to foul the shafting, guards must be provided.

In some instances where the packing is extended aft to a point at which it is impossible to pull the packing without fouling the shafting, particularly on twin- or quadruple-screw ships, it is necessary to ballast the packing and to sink it to a point at which it will clear the shafting and can be hauled from under the ship. After this, it is raised to the surface and the ballast removed.

When it is necessary to ballast packing before launching in order to sink it clear of the ship's appendages, wires are usually passed under the packing to the deck on each side of the ship for the purpose of holding

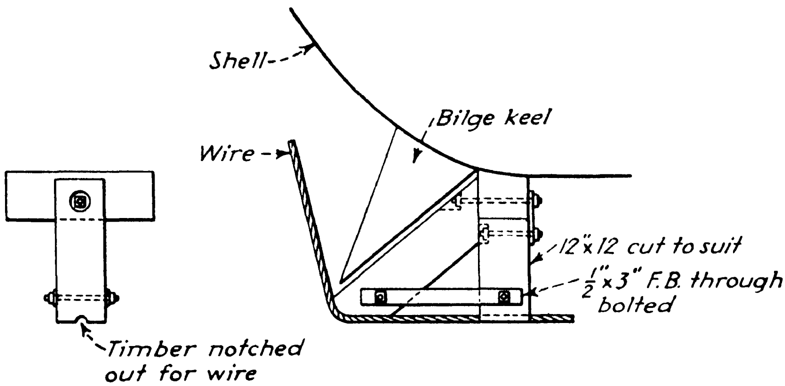


Fig. 573.—Bilge-keel guard.

it in position, particularly during the time when the diver is removing tie rods and frappings, when there is danger of shifting the packing, possibly injuring the diver.

Pulling Packing from under Ships during Launching. On small ships it is possible so to arrange packing that the entire cradle and sliding ways can be snatched from under the ship as it is moving out into the water immediately following pivoting. When this is done, spreaders are installed between the inboard sides of the sliding ways and also the packing to hold it together during launching.

On larger ships, even when the bottom is quite flat, removing the cradle from under the ship by this method is not advocated because of the risk involved.

Crushing Telltales

In order to obtain information for future launchings, telltales are sometimes installed to record the actual deformation of the crushing strips at various points in the fore-poppet section. Telltales are generally of the rod and stick type, consisting of a 3- by 3-in. length of yellow pine. A hole is drilled in the lower end lengthwise of the stick, and a $\frac{5}{8}$-in.-diameter steel rod is inserted in it. The hole is drilled $\frac{1}{32}$ in. smaller than the rod to offer sufficient resistance to the movement of the rod when it is pushed into the hole. It is also drilled sufficiently deep so that it will take the entire length of the rod, which projects outside of the stick if necessary. Rod length is generally determined by assuming $1\frac{1}{2}$ in. of crushing for each layer of crushing strips.

In its vertical position, the top of the stick bears against an angle clip bolted to the packing above the crushing strips, while the end of the rod is set to bear against another angle clip bolted to the packing below the

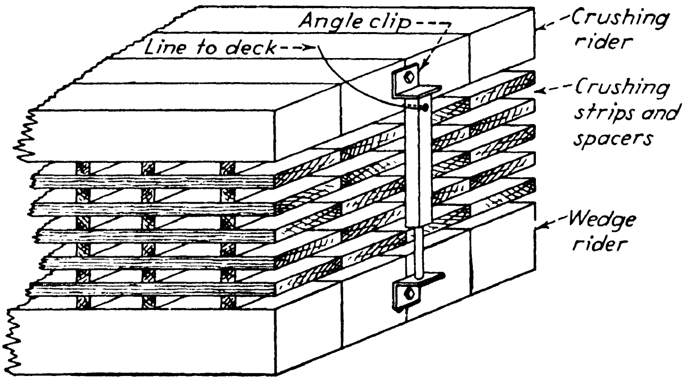


Fig. 574.—Crushing telltale arrangement.

crushing strips. The telltales are fitted tightly between the two clips and are then toenailed to the packing with small nails to ensure their being held in place. The amount by which the rod is forced up into the stick is the measurement of the crushing, an initial reading being taken of the amount of rod projecting from the stick prior to launching.

For the purpose of recovering the telltale after launching, a hole is drilled in the upper end of the stick through which a $\frac{1}{2}$-in. line is passed and the end secured. The line is extended to the deck and tagged for its location. Immediately after launching the telltales can be pulled up on deck and the amount of crushing recorded and tabulated; Fig. 574 shows this type of telltale arrangement.

Internal Shoring

To withstand the pressure against the hull of the ship during launching, it is frequently necessary to install stiffening to reinforce the hull in the area of these pressures.

If the calculations for the thrust against the shell in way of the fore-poppet saddles during pivoting show a load that is likely to buckle and damage the structure, suitable internal stiffening must be provided.

In way of transverse bulkheads that may be too light to withstand the thrust, transverse stiffeners are sometimes used, as shown in Fig. 575.

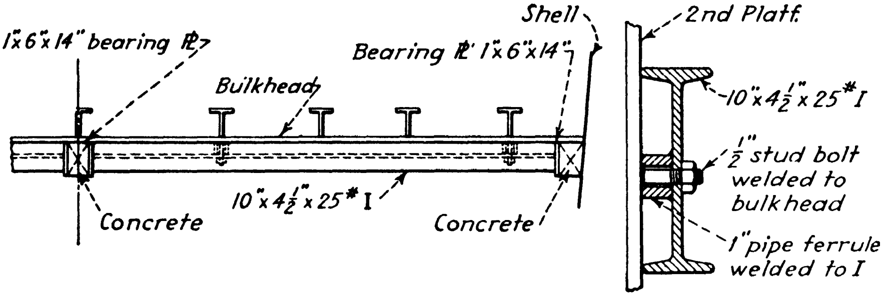


FIG. 575.—A form of internal stiffening.

In open compartments where there are no bulkheads between the sides of the ship, structural I beams or extra-heavy pipe spreaders are fitted between the sides of the hull at the locations of the saddles, as shown in Fig. 576. The spreaders are fitted clear of the hull of the ship, with sufficient room between the ends and the shell to permit easy removal

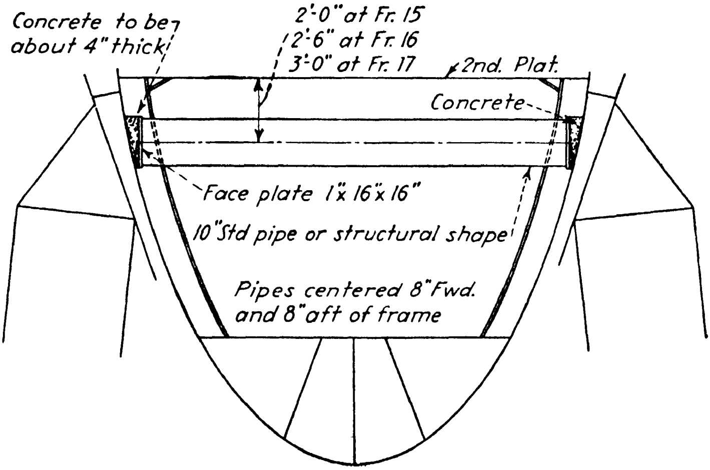


FIG. 576.—A form of internal shoring.

after launching. The space between the shell and the spreader is then filled with concrete to create a good bearing.

To Withstand Way-end Pressure. To withstand the way-end pressure and to prevent buckling the floor plates and shearing off rivets, the lightening holes in the floor plates are sometimes reinforced with double angles at each side in order to distribute the load as much as possible.

In extremely heavy ships where the way-end pressures run high, it is sometimes necessary to resort to extensive shoring between the inner bottom and the decks above to withstand this pressure and to prevent damage to the hull. However, this should be avoided if possible.

ARRANGEMENTS FOR CHECKING

Some shipyards are located on small bodies of water, the boundaries of which are built up with piers, warehouses, etc. This makes it impossible to do further dredging in order that the ship when launched will not ground, possibly causing considerable damage to the hull. In such locations, it is necessary to resort to checking in order to stop the ship within a safe distance of the opposite shore.

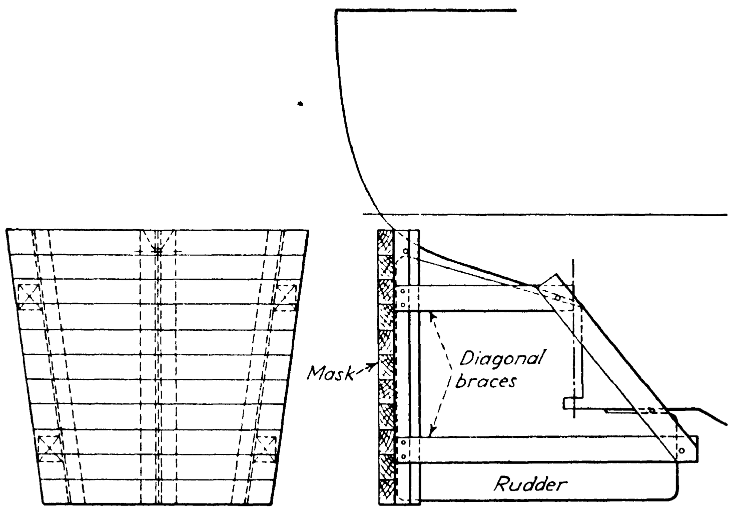


FIG. 577.—A checking mask.

Masks. A structure consisting of heavy timbers secured at the stern of the ship and known as a *mask* is a common form of checking arrangement. The mask creates a resistance when pushed against the water as the ship is sliding down the ways, thus reducing the energy developed by the motion of the ship. Since the amount of resistance created by a mask is proportional to the square of its area, it should be as large as practicable. Figure 577 shows a suitable type of mask as a form of checking.

Snubbing. On some small ships a suitable arrangement for checking is snubbing the ship by means of manila hawsers, extended from the bow of the ship through a wooden brake, as shown in Fig. 578. After the hawser has been placed through the brake, it is laid out on the stocks at the bow of the vessel so that it will play out freely without entangling. When the ship has slid approximately one-half the distance to the water, pressure is applied to the handle of the brake by men throwing their weight on the lever, while a stream of water is played on the hawser where it passes through the brake.

The same principle is also used with spring-load brakes. Spring-load brakes consist of an upper and lower casting through which a wire rope

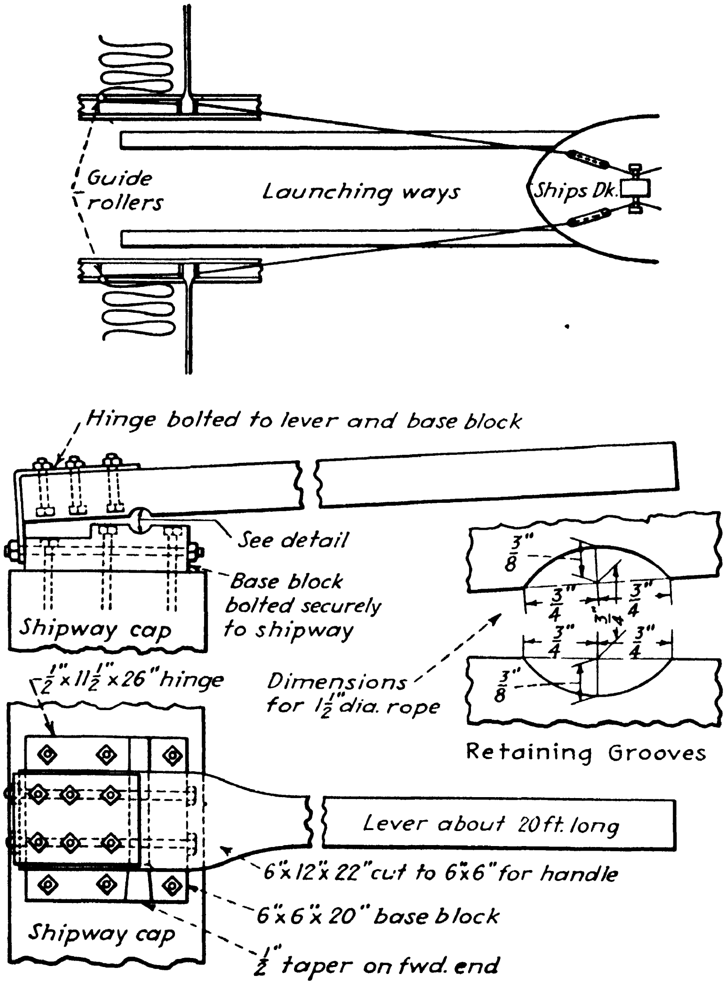


FIG. 578.—A lever brake method of checking.

is drawn by the ship. Springs can be tightened by screws and handwheels to provide the necessary pressure on the rope.

Drags. The method of stopping ships by dragging weights is commonly used. Various forms of weights are used for this purpose.

The weight of the drags and the point at which the first drag begins to act depend upon the launching weight and length of the ship, the declivity, and the distance in which the vessel must be stopped. If the river is very narrow, it is usual for the first load of drags to act when the fore poppet is immediately over the afterend of the ways or even immediately after pivoting has occurred. Where the breadth is not so limited, it is usual to allow a good margin of travel to avoid any possibility of the vessel coming back on the ways after being checked.

The next thing to be decided is the size and distribution of the drags that make up the total weight. The drags should be so arranged that the total load on each wire will not exceed two-fifths the breaking strength. When the total weight on each wire is divided into two or three bundles, the initial shock load is very much reduced as each one of the bundles begins to act.

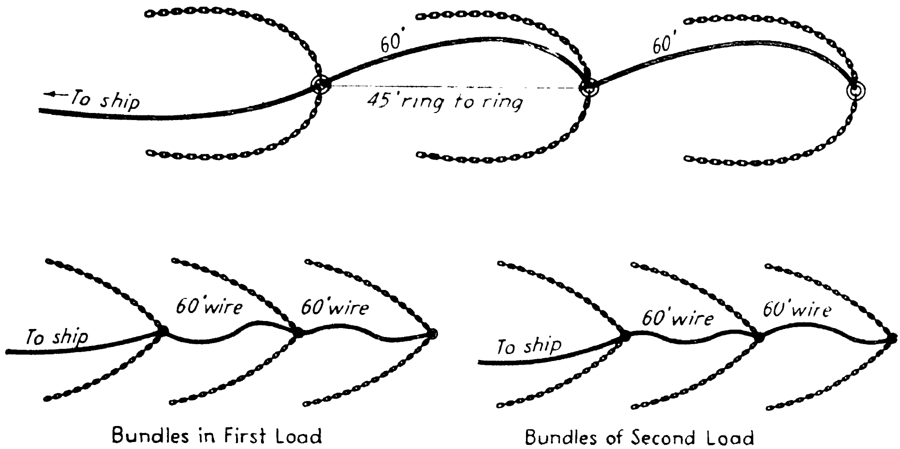


FIG. 579.—An arrangement of chain drags.

Where the load is divided, there is a wire or chain attaching each bundle, with about 15 to 20 ft. of slack to allow the after bundle to travel that distance before the next bundle comes into play.

If the total load is divided into three bundles and the distance between the crowns of adjacent bundles is 45 ft. and the amount of slack 15 ft., the length of the wire would be 60 ft., as shown in Fig. 579.

Another point that must be considered is the starting position of the lowest bundle of drags on the shipway. To determine this, it is necessary to know the approximate travel of the drags down the shipway during the launching operations. This can usually be obtained from the data available from previous launchings in the same yard, provided that the general details are the same in each case. For example, it would be useless to compare the travel between drags of two vessels if one was built on a shipway having a concrete floor, with the drags consisting of concrete blocks, and the other on natural ground, with the drags consisting of bundles of chains and allowed to plow into the earth, for the effect of friction in each case would be very different.

The arrangement of the drags on the berth depends on their weight and the work expected from them, together with the space available for stowage. Under ordinary circumstances, the drags are arranged so that half the weight is on each side of the ship when the ship is checked and so that the drags will be clear of each other.

Assuming that the length of each bundle is 45 ft. and the length of the wire 60 ft., the distance between the crowns of adjacent bundles in the same load will be 60 ft. when the drags come to rest. If it is desired to have the same distance between the crown of the last bundle in the

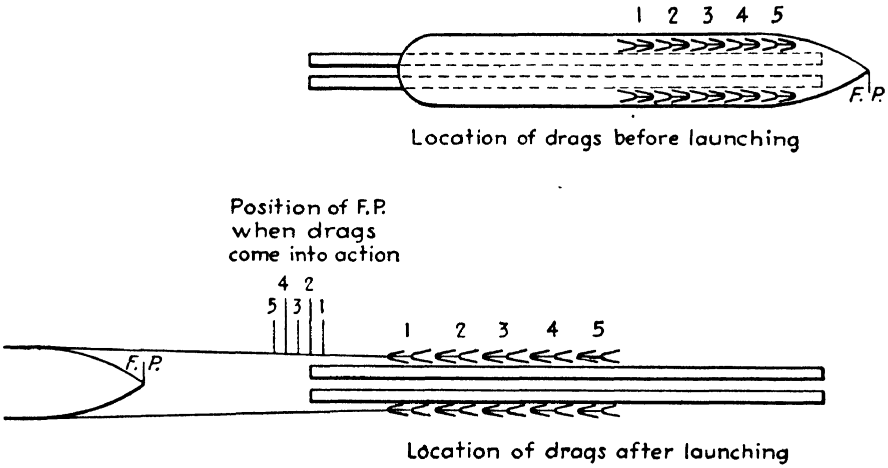


FIG. 580.—Location of drags before and after launching.

first load and the crown of the first bundle in the second load when the drags come to rest, the drags must be arranged so that the distance between these points will be 90 ft., so that the bundles will turn over without fouling. This will leave a distance of 15 ft. between the tail of the last bundle in the first load and the crown of the first bundle in the second load, and the bundles will appear as shown in Fig. 580 when they stop moving.

It is sometimes necessary to perform much experimental work in order to ensure a good job of checking, particularly when a large ship is being checked for the first time.

Figure 581 shows a releasing device attached to the side of the ship for the purpose of attaching the drag wires. As soon as the ship has stopped, the levers may be pulled by means of a wire extended to the deck and the drag wires released, so that the ship can be moved into the outfitting berth.

Slewing. Sometimes vessels are launched where the breadth of the river on the center line of the shipway is very limited and, in order to prevent the stern from fouling the bank on the opposite side, the vessel must be slewed around by means of checking on one side of the ship. This is sometimes done by dropping an anchor into the river bed at the proper location and attaching it to a manila or wire-rope hawser and then securing the other end near the stern of the ship.

The proper length of wire and the location of the anchor, together with the location for the securing of the wire to the ship, are obtained by means of a model of the vessel under actual launching conditions

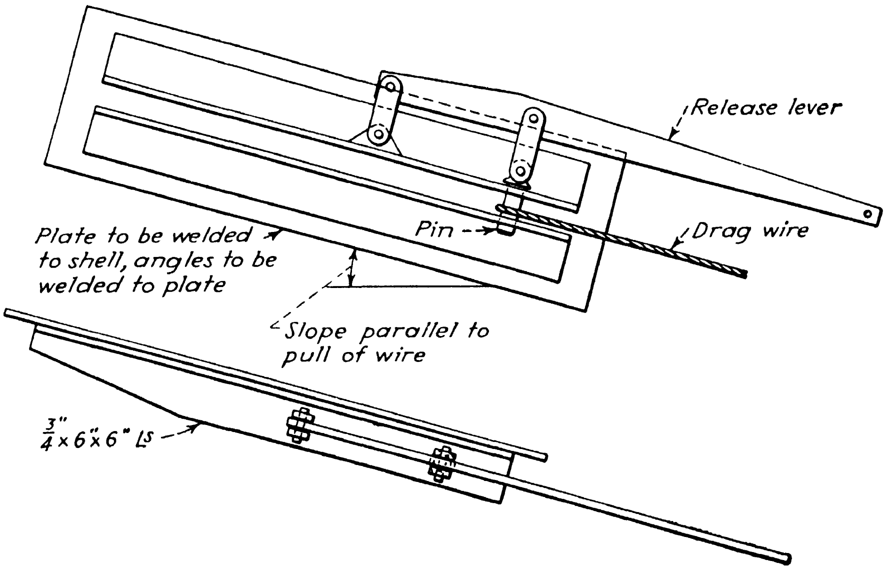


Fig. 581.—Drag release.

and a model of the breadth and contour of the river with respect to the location of the ship. String may be used to represent the wires, and pieces of metal may represent the anchor.

The anchor is placed at the approximate location in the river bottom and the wire secured to the afterend of the ship, sufficient slack being allowed for readjustment. When all appears to be satisfactorily arranged, the model is launched and the line on the ship allowed to play out until the point is reached at which it is desired to slew the ship. At this point the free end of the line should be tightened and its length noted. The location for securing the hawser near the stern of the ship should also be observed, as it may be necessary to shift it forward or aft to obtain the desired results.

After the necessary adjustments have been made and the length of the hawser has been established, together with the point at which it is

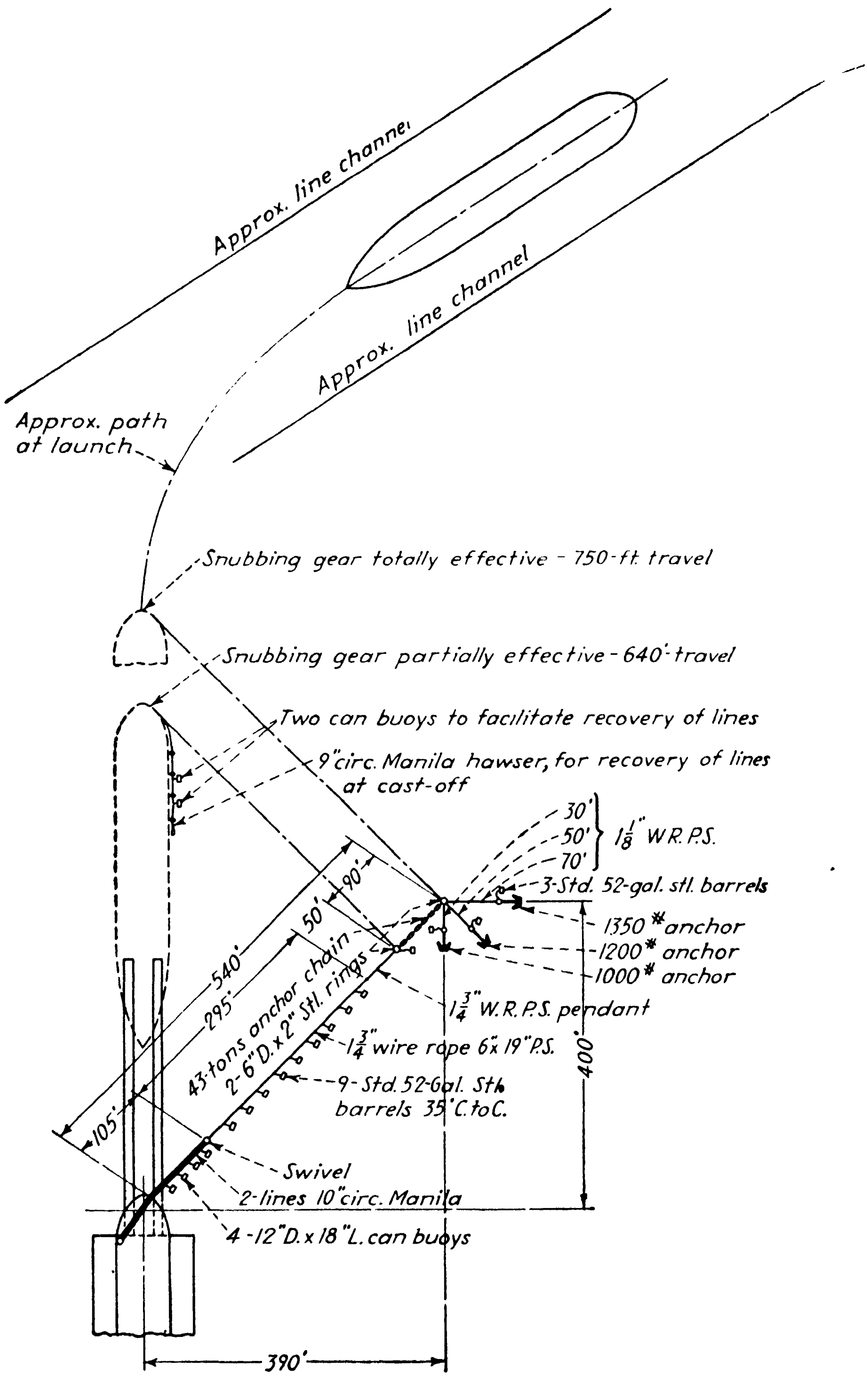


Fig. 582.—A method of slewing arrangement.

secured on the ship, the procedure is repeated, it being noted whether or not the ship is slewing at the proper time.

Consideration must be given to the size of the anchor and the type of river bottom, to determine the amount of drag that will occur when the hawser comes into play.

A slewing arrangement is shown in Fig. 582. Chain drags may also be used for slewing.

PREPARATIONS FOR LAUNCHING DAY

During the weeks prior to launching hundreds of other details have to be arranged. Soundings have to be taken and possibly dredging performed in the way of the path of the vessel. Divers have to examine the sills outside the caisson gates and free them of mud so that they can be removed. Outboard ways must be examined to see that they are properly seated, that spur shores and spreaders are in place, and that there is no trash present.

Arrangements have to be made for the removal of all light and welding lines and gas, air, and water hose at all points where these systems enter the vessel.

Inspection must be made to see to the positive closing of manholes, cargo port doors, air ports, bleeders, sea chests, and other openings through the hull of the vessel.

The flooding equipment, such as the pumps and caissons, has to be inspected and tested. Trigger tests are conducted. Staging is removed from around the ship to prevent fouling as the ship slides down the ways, it being necessary sometimes to remove all staging in closely confined shipways. Gangways and access aboard the ship must be examined and arrangement made for their removal at designated times, together with many other items too numerous to mention.

During the week prior to launching the ramming stage and ramming rail are built; tumble, or trip, shores and sand blocks are installed; lines for handling shores, together with all rams that may be required, are placed in position; and the launching stand is constructed.

Approximately 2 days before launching all shores in the way of driving wedges, together with those which are thought unnecessary, are removed. Jacks and pumps are placed at the jacking station at the forward end of the sliding ways; wedges and wrenches are placed at all collapsible keelblocks and cribbings; and the area for spectators is fenced or roped off.

Schedule of Launching Preparations

In order that all work on the hull of the vessel that affects the installation of the cradle and launching gear shall be finished in sufficient time

SCHEDULE OF LAUNCHING PREPARATIONS

Operations	Scheduled		Actual	
	Start	End	Start	End
1. Run grade line for ground ways	......	......	Apr. 17	Apr. 17
2. Install missing and renew bad caps outboard	......	....	Apr. 3	June 16
3. Install shims and line up cribbing for ground ways to the proper grade	......	.	May 1	May 15
4. Install ground ways, with the exception of the outboard section	.....	......	May 16	May 18
5. Connect up ground ways	......	......	May 16	May 23
6. Install spur shores	May 18	May 23	May 18	May 25
7. Install triggers and push blocks	May 19	May 27	May 19	May 26
8. Install and couple up outboard section of ground ways	May 24	May 31	May 29	May 31
9. Build skids for shifting sliding ways for greasing	May 24	May 26	May 23	May 24
10. Install sliding ways and shift for greasing	May 25	May 26	May 24	May 26
11. Install grease gauge strips	May 25	May 26	May 26	May 26
12. Locate position of grease irons	May 25	May 26	May 26	May 29
13. Grease ground ways for extent of sliding ways	May 29	May 30	May 29	May 29
14. Grease sliding ways	May 29	May 29	May 29	May 29
15. Shift sliding ways on grease, couple up, and set triggers	May 30	May 31	May 29	May 31
16. Install joggled wedges and shore sliding ways in position	May 30	May 31	May 30	May 31
17. Install grease covering strips	May 31	May 31	May 30	May 31
Section 3 (Frames 45½ to 70½)				
18. Install in one piece entire section of packing, frames 45½ to 70½, port and starboard, and rework wedge blocks where necessary	June 1	June 3	May 31	June 6
Section 4 (Frames 70½ to 96½)				
19. Install in one piece entire section of packing, frames 70½ to 96½, port and starboard, and rework wedge blocks where necessary	June 1	June 5	May 31	June 7
Section 5 (Frames 96½ to 121½)				
20. Install in one piece entire section of packing, frames 96½ to 121½, port and starboard, and rework wedge blocks where necessary	June 2	June 6	May 31	June 8

SCHEDULE OF LAUNCHING PREPARATIONS.—(*Continued*)

Operations	Scheduled		Actual	
	Start	End	Start	End
Section 6 (Frames 121½ to 152)				
21. Install in one piece entire section of packing, frames 121½ to 152, port and starboard	June 5	June 7	June 5	June 8
22. Install strongbacks and toggles	June 7	June 8	June 9	June 12
Section 7 (Frames 152 to 163)				
23. Install in one piece entire section of packing, frames 152 to 163, port and starboard	June 9	June 12	June 8	June 9
24. Install tie rods and strongbacks	June 12	June 12	June 12	June 15
25. Install toggles	June 12	June 12	June 15	June 15
Sections 1 and 2 (Frames 17 to 45½)				
26. Install in one piece entire section of packing, frames 17 to 45½, port and starboard	June 12	June 13	June 5	June 9
27. Install crushing strips and solid packing under saddles	June 12	June 13	June 7	June 9
28. Install saddles	June 12	June 12	June 6	June 9
29. Install tie rods, strongbacks, and spreaders	June 13	June 16	June 7	June 13
30. Install wood packing between shell and saddle straps	June 15	June 29	June 7	June 14
31. Install rope lashings	June 15	June 20	June 12	June 16
General and Final Operations				
32. Install flat-bar lashings on packing and wedge blocks	June 1	June 16	June 7	June 16
33. Make up sand blocks	June 5	June 9	June 5	June 9
34. Inspect, clean, grease, and reset trigger keeper blocks	June 7	June 7	June 15	June 15
35. Install piping, and connect up pumps in trigger pit	June 9	June 20	June 12	June 13
36. Install saddle-supporting wires	June 9	June 14	June 15	June 16
37. Install launching wedges throughout	June 15	June 16	June 9	June 16
38. Install support and pulling wires on ways and packing	June 15	June 16	June 13	June 16
39. Grease outboard ways, install spreaders, spur shores, and lower into place	June 14	June 15	June 12	June 16
40. Install sand blocks	June 14	June 15	June 14	June 15
41. Complete shimming up ground ways above low water	June 14	June 19	June 16	June 19
42. Install temporary spreaders in way of frappings	June 16	June 19	June 13	June 15

SCHEDULE OF LAUNCHING PREPARATIONS.—(*Continued*)

Operations	Scheduled		Actual	
	Start	End	Start	End
43. Install frappings forward and aft.	June 16	June 20	June 13	June 16
44. Set up and complete launching stand.	June 16	June 20	June 6	June 20
45. Build ramming rail, and complete ramming stage.	June 16	June 19	June 19	June 20
46. Grease exposed ways—between low-water mark and end of slidingways.	June 19	June 19	June 19	June 19
47. Install jacks, pumps, and piping at forward end.	June 19	June 20	June 16	June 20
48. Install trip shores.	June 19	June 20	June 16	June 20
49. Dress up launching stand.	June 20	June 20	June 20	June 21
50. Remove cribbings 1 and 3.	June 20	June 20	June 20	June 20

before launching, a schedule is usually made up so that all departments will be informed as to the limiting dates at which work in various sections must be completed. This schedule should tie in with the master and other schedules for compartment completion, which is, in some cases, not on time because of lack of material, etc. Consequently, when compartments are behind schedule to the point at which this will affect the installation of the cradle, it is necessary to complete the work on the shell and to test the shell so that the cradle can be installed, the testing being completed on the other boundary compartments at a later date.

The preceding table is a typical schedule of launching preparations for a moderate-size freighter, launching being contemplated on June 21. It will be observed from the schedule that operations 1 to 5 have no scheduled starting and completing dates, owing to the fact that this work was performed in advance of what would be a normal schedule, at some opportune time when men were available.

The foregoing schedule of preparations will, of course, depend on the number of men being used on the job. The lapsed time may be increased or decreased as desired.

SOUNDINGS AND DREDGING

Owing to the fact that rivers usually have silt that is continually shifting, it is necessary to take soundings and to dredge, if necessary, in the area in which the ship will be launched, in order to ensure sufficient depth.

Soundings are recorded, as shown in Fig. 583, in the path of the ways and at points on each side of the center line to afford ample clearance for the hull of the ship. The soundings are then plotted on the plan of the path of the ways with respect to mean low water to determine clearance for the vessel, as shown in Fig. 584.

Ramming Stage and Ramming Rail

On some types of building ways a staging is required for workmen when ramming up the wedges and removing outside supports from under the ship on the day of launching. A ramming stage is usually con-

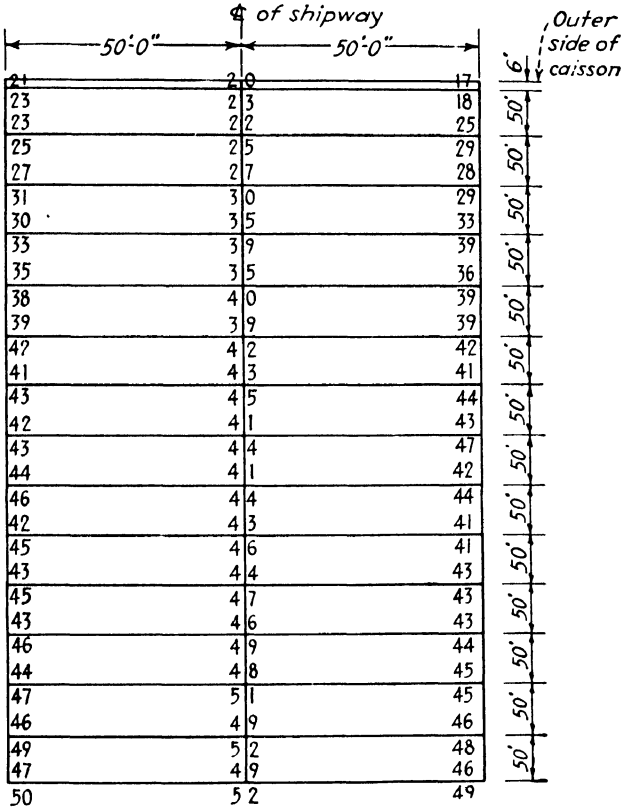


Fig. 583. A record of soundings.

structed 5 ft. 6 in. below the hull of the ship, because this is the most suitable height for the rams in wedging the cradle up to the ship.

The ramming stage consists of stage plank used on the outside of the ship during its construction. It is laid on spauls spaced on 15-ft. centers supported on 6- by 6-in. uprights and then braced as shown in Fig. 585.

The ramming rail used to support the rams in wedging up consists of 3- by 4-in. to 4- by 6-in. timber supported on uprights and braced both in a transverse and fore-and-aft position, as shown in Fig. 586.

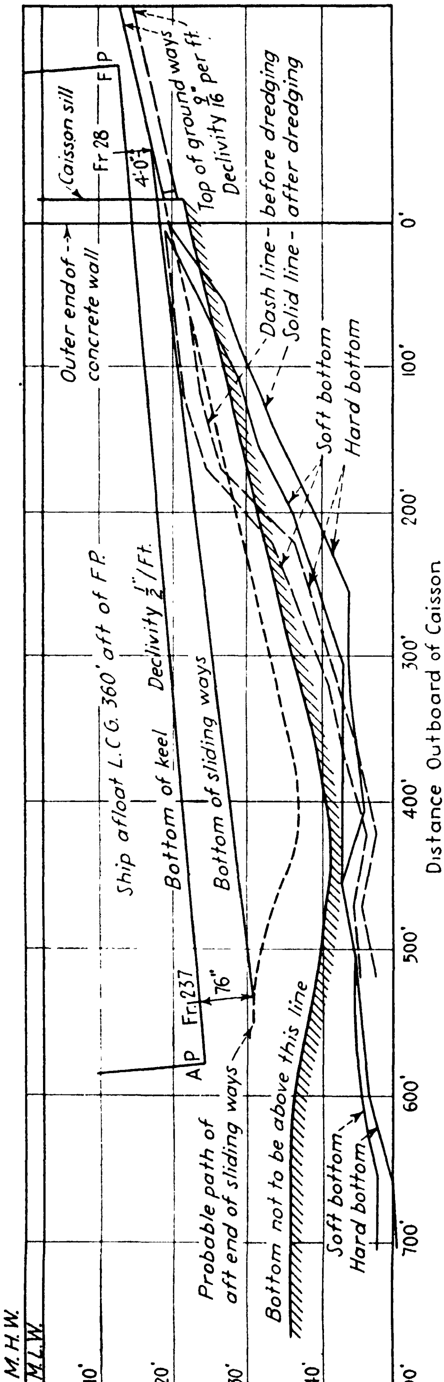


FIG. 584.—Soundings plotted on path of ways diagram.

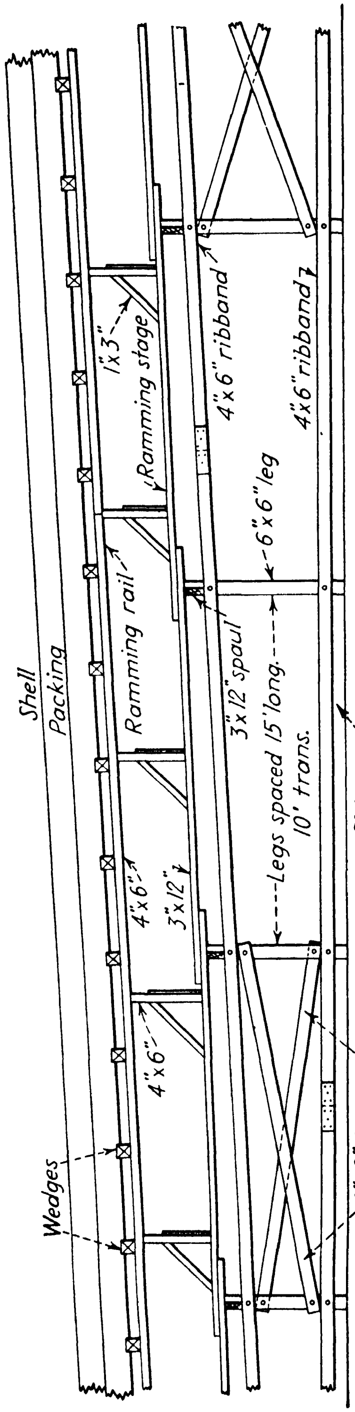


FIG. 585.—An arrangement of ramming stage.

In a transverse position the ramming rail is located 3 ft. 6 in. from the ends of the wedges.

TUMBLE, OR TRIP, SHORES

Since the afterend of the ship and cradle sit on the grease for a considerably longer period than the remainder of the cradle, *trip shores*, or *tumble shores* as they are sometimes known, are installed under the keel to assist in supporting some of the weight up to the time of launching.

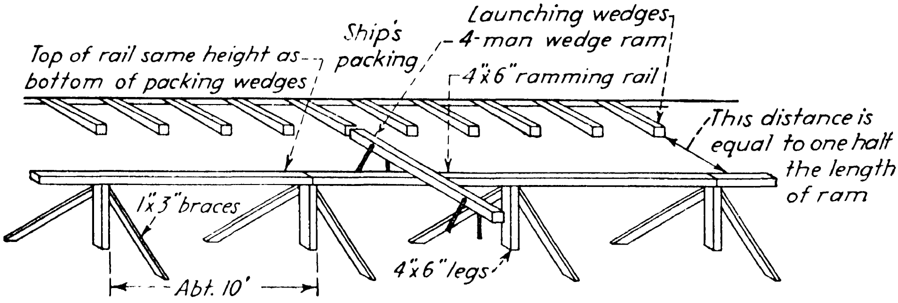


FIG. 586.—Ramming rail.

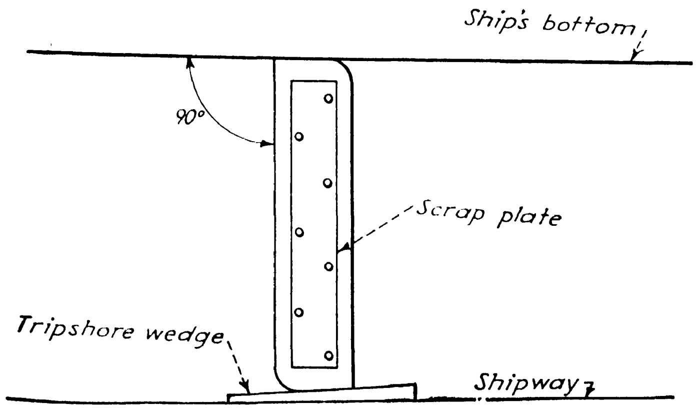


FIG. 587.—A trip, or tumble, shore.

They are installed after the keelblocks and cribbings have been removed in the area below high water, on approximately 10-ft. centers. The timber used for constructing trip shores is generally oak of varying sizes, depending on the size of the ship being considered.

Trip shores are roughly calculated to carry one-third the weight of the ship over the area supported. For example, a ship 400 ft. long and weighing 4000 tons will weigh roughly 10 tons per ft. of length. Therefore, if the length supported on trip shores is 60 ft., the weight of the ship in this area will be 600 tons and the weight supported by the trip shores will be one-third of 600 tons, or 200 tons. If a total number of seven shores is used in this area, each shore will carry about 30 tons. The length of the shore will, of course, have some bearing in determining the size of the timber to be used. The size of the trip shore may be easily determined from tables.

The shores are generally set at right angles to the line of the keel, as shown in Fig. 587. The top is rounded, with a radius of one-half the thickness of the timber on the forward edge. The bottom is rounded, with a similar radius on the after edge of the shore.

If the weather is extremely warm, it may be desirable to set the tops of the shores slightly forward at the rate of ⅛ in. per ft. from a line at right angles to the keel. In colder weather, the exact reverse is true: the strut is set aft by the same proportion.

Trip-shore Wedges. The wedges used for tightening up trip shores are also of oak, tapered ½ in. per foot and generally 14 in. wide, 2 ft.

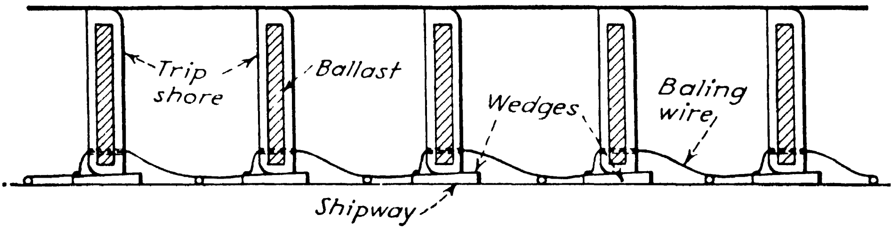


FIG. 588.—Arrangement of trip shores under a ship.

long, and tapered 4 to 3 in. The wedges are driven up hard between the shipway caps and the bottom of the trip shore with a heavy eight-man ram, driving from the forward end.

Sufficient scrap plate is nailed to the sides of the shores to prevent the shores and wedges from floating after they have been tumbled aft when the ship is released. The wedge is secured to the bottom of the shore with baling wire extended through a hole drilled in the wedge and at the bottom of the shore. In addition, a ½-in. wire rope is also extended fore and aft through holes in the bottom of the trip shores to prevent their going adrift because of the backwash after launching. Figure 588 shows an arrangement of trip shores under a ship.

Sand Blocks

In order to reduce the time during which the ship will sit on the grease and to transfer the weight of the ship from the keel track to the cradle more uniformly, the long and arduous job of splitting out solid keelblocks is eliminated by the use of sand blocks, as shown in Fig. 589.

Construction of the Sand Block. Sand blocks are steel frames made up of 6-in. channel, with one portable side fitted with a lever to which draw wedges are attached for the purpose of releasing the sand when blocks are removed. The sand block is assembled by first setting in a block 3 in. thick to fit the frame to a depth of 1 in. from the heel. The block is then nailed in position through the small holes observed in the sides of the frame.

Sand, which has been thoroughly dried by heating, is then placed in the frame to within 1 in. of its upper heel. A block of the same dimension as the bottom block is set into the frame on top of the sand, and nails are driven into the holes to hold it in place.

Installation of the Sand Block. Sand blocks are generally installed about 1 week prior to launching. At this time solid blocks on the keel

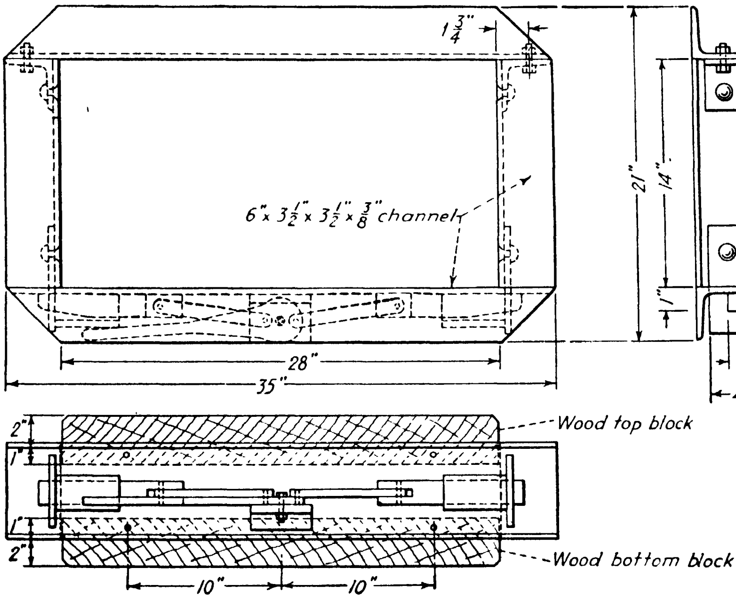


Fig. 589.—A type of sand block.

track are split out, beginning at the forward end and working aft, and are replaced with sand blocks, together with the necessary fillers to place their tops against the keel of the ship.

After the solid keelblock has been split out, the filler of the necessary thickness is placed beneath the lower marrying wedge. The marrying wedges are then pulled back, and the sand block is installed on top of them. The nails that hold the blocks in place are then drawn, so that they will not prevent the blocks from bearing hard on the sand when they are being wedged up.

These wedges are driven up with the ram and slide generally used for wedging up keelblocks during the construction of the ship.

To release the sand blocks, the lever is pulled out from the side of the block, which draws back the tapered wedge from the holes in the

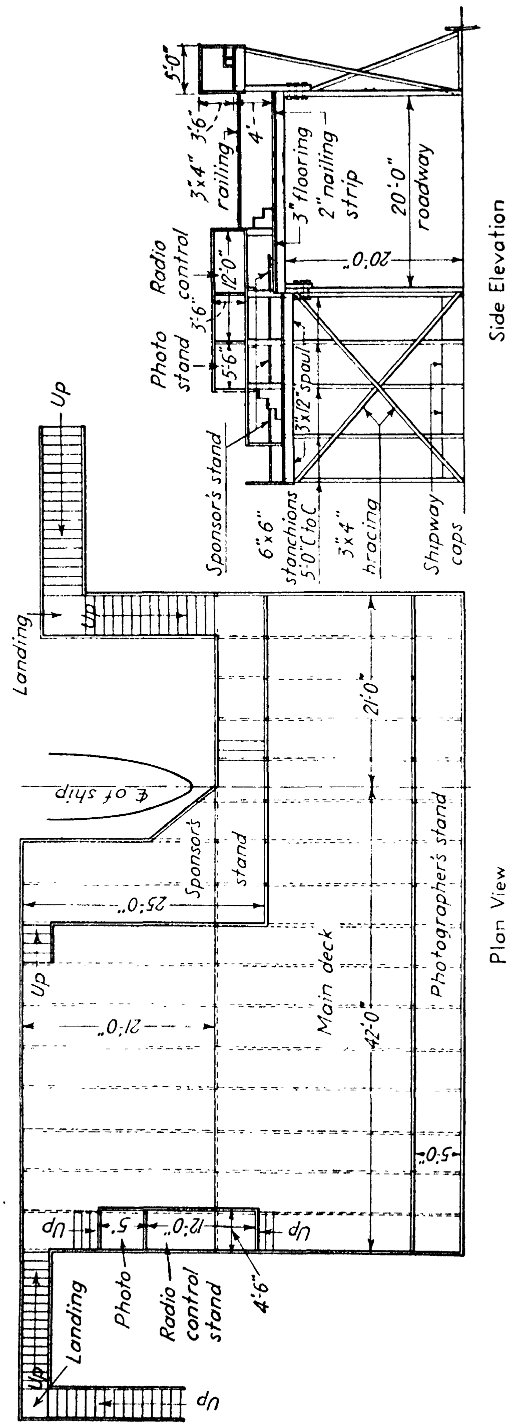


FIG. 590.—A large launching stand.

ends. The portable side can then be removed by hitting each end with a pin maul. The handle of the pin maul is used for raking out the sand between the upper and lower blocks, thus collapsing the block.

Sand blocks are also used as a form of collapsible cribbing block. This type of block consists of a steel pan of the same width as the blocking of the cribbing, the length being the same as the width of the cribbing. The ends of the sand block are provided with a bolted plate, which is

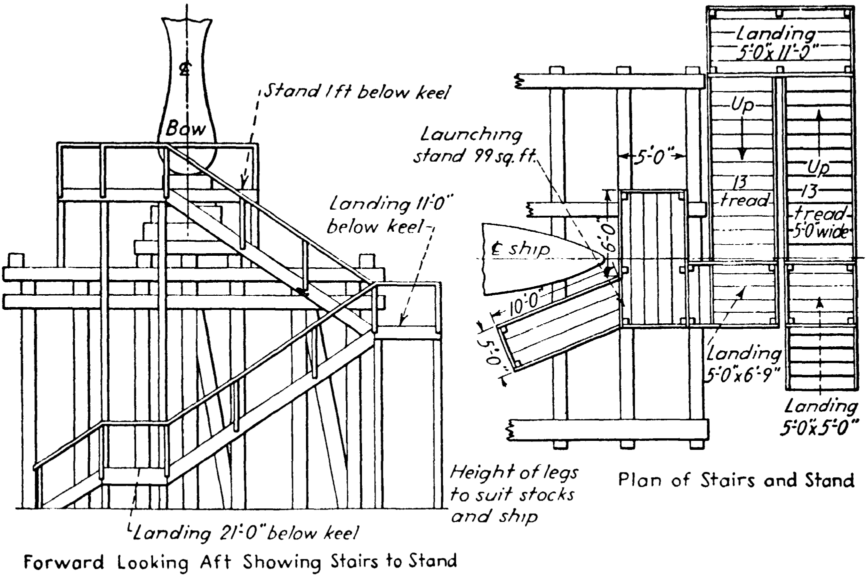


FIG. 591.—A small launching stand.

removed and the sand raked out with a round rod flattened out and turned at one end.

The Launching Stand

The construction and size of the launching stand depend on the size of the launching party and the accommodations required for guests. In some cases, launching stands are quite extensive, as shown in Fig. 590, some accommodating as many as 2000 persons. Other stands (Fig. 591) are large enough to accommodate only the sponsor and her immediate party, space being provided for the remainder of the party and guests on the ground surrounding the bow of the ship.

To determine the size of the stand, the area usually allowed per person is 3½ sq. ft. The supports of the stand should be designed to support the weight of 200 lb. per sq. ft., including the safety factor of 4.

Racks for Grease Irons

When the grease irons are removed from under the ship, a rack must be provided for hanging them on each side. This usually consists of 3- by 12-in. timber set on 6- by 6-in. uprights high enough above the ground to suit the length of the grease irons. The uprights are notched out on a shoulder and securely braced in a vertical position.

The racks should be long enough to accommodate the number of irons under the ship. Spikes on which the irons are hung are spaced on 8-in. centers and driven into the rack. The spikes should be numbered with numbers corresponding to those on the grease irons so that any iron missing from the rack may be readily located and removed from between the sliding and ground ways.

Placing Rams

Two days before launching, all rams should be put in their proper position.

Driving Up Wedge Rams. The four-man rams used for driving up the wedges should be placed at each wedge station, which is generally an area taking in 10 to 12 wedges.

Cribbing Rams. The rams to be used in ramming out the collapsible cribbings should be located at the first cribbings to be removed. If all cribbings are scheduled to be removed simultaneously, one ram should be provided at each cribbing on each side of the ship.

Keel-track Rams. The rams to be used in connection with ramming out keelblocks, should this be necessary, should be placed in on the keel where operations will begin.

Shore Rams. If shores are to be removed on launching day between the keel track and the sliding ways on each side, one ram should be provided on each side of the ship at the afterend, where the operation of removing these shores is scheduled to start.

The rams used in the removal of shores outboard of the packing should also be placed where the operations begin. An extra shore ram should be available on each side of the ship in case one of the rams is broken during removal.

Wrenches and Wedges

Where collapsible blocks are used, wrenches that must fit the nuts should be provided, one on each side of each block. Wrenches must also be placed at the cribbings for the removal of the bolts that hold the clips in place at the afterends of the cribbing.

In anticipation of the possibility of having to split out solid blocks on the day of launching, four steel bursting wedges should be placed on each side of each block. In addition, two oak shore wedges should be placed on each end of each solid block.

At each of the collapsible blocks there should be available four oak shore wedges for the purpose of driving into the vertical opening to collapse the block.

Central Tool Station

Tools should be placed where they will be needed. In addition, however, a central tool station should be provided on each side of the ship about midway of its length.

This should have on hand a number of poleaxes, heavy mauls, extra wrenches, steel bursting wedges, crosscut saws, pinch bars, and timber hooks and an assortment of nails and spikes.

THE LAUNCHING PROGRAM

In developing the launching program, the first consideration is the time of launching. This is decided upon by the time of high tide and minimum current. Generally, launchings occur at high tide because a greater depth of water over the way ends reduces the way-end pressure and the drop off at the bow and thus provides a greater margin of safety for the ship. A lack of sufficient water below the calculated water over the way ends increases way-end pressures and delays the time of pivoting and the period when the ship is water-borne.

However, in launching extremely long ships, particularly in rivers having a strong current, consideration must be given to this factor, lest the current force the ship from a straight course out of the shipway before it has cleared the ground ways, when it might shear off the ribband and possibly cause considerable damage. In such cases, a time between flood and ebb tide known as *high-water slack* is generally used. This varies in different localities of the country. At high-water slack, when the current is zero, the height of the water may be less than at high tide, resulting in a reduced depth of water over the way ends. This, of course, must be considered when the launching calculations are made.

After the time of the launching has been decided, the work of developing the launching program can be started. The primary factors in developing a launching program are (1) to cover all operations in as short a period of time as practicable, so that the ship will not sit on the grease any longer than is absolutely necessary; (2) *to coordinate the time of operations in proper sequence so that there is sufficient time to perform them properly without endangering the lives of workmen.*

Launching day was at one time a day of great confusion and hard work. When difficulties were encountered, particularly in the removal of keelblocks, the ship was sometimes released 1 to 2 hr. after the time set.

If solepieces started to give way, any support remaining under the ship was crushed and rolled over, frequently causing damage to the hull, and the ship was released prematurely. With the development of collapsible oak and sand keelblocks and various devices for releasing, much of the uncertainty and hazard has been eliminated from launching.

Credit should be given Harold T. Bent, Superintendent of Hull Construction at the Newport News Shipbuilding and Dry Dock Company, who is a pioneer in the development of *precision launchings.*

It was once a custom of the foreman shipwright to station himself at the bow of the ship with three or four messengers at his call. From past performance, he would fix in his mind or set down a few notes as to when the various operations should be started in order to launch the ship at a set time. He would then dispatch messenger boys to the different leaders with instructions. Sometimes supervisors on the launchings were handed a list of scheduled operations, but invariably these operations were not performed until instructions were passed along by messengers from the foreman, who was obliged to assume the directing of each detailed operation, in addition to his responsibility of successfully launching the ship.

Planned Launchings

With the development of planned launchings the entire job is broken down into a number of operations, which are performed in the order, or sequence, desired. A time interval is allowed for their execution, and they are then assigned to supervisors in certain areas according to type of work. The supervisors are handed a work sheet for the operations that they will perform with the men assigned to them. They will be provided with a general program as a matter of information, but they will perform their tasks at the designated times. That is, each move made by each gang is known, and instructions are prescribed in each supervisor's work sheets.

In order that the supervisors can all work to the same time, their watches should be synchronized with the timepiece to be used in releasing the ship. This should show exact standard time.

With the exception of the wedge rallies, which are performed on whistle signal so that wedging up will be done simultaneously, all other operations will be executed at the designated times according to the supervisors' watches and work sheets. Only if the launching is delayed owing to accident, bad weather, or the failure of the launching party to arrive will supervisors fail to perform their tasks at designated times. In this event, definite instructions are given as to the amount of delay.

Time Intervals

In determining the time intervals for performing the various operations, it is always a good policy to allow a little extra time in case difficulties are encountered, as well as to give the men a resting period.

The number of men used in connection with the launching operations must constitute a well-balanced force on each side of the ship and on the keel track. Too large a force of men will invite confusion through men being in one another's way. An insufficient number of men will add confusion through the need to rush the job to keep on schedule.

The following time is usually allowed for the performance of major operations:

Grease Irons. In removing grease irons six pairs of irons are usually assigned to each gang, with an allowance of 10 min. per pair.

Shores. In removing shores on light moderate-sized vessels, a 20-man ram gang is used.

On large heavy ships a 30-man ram should be used. In removing long shores aft, 1 to 2 min. per shore is generally allowed. In the removal of shores amidships, two shores per minute is generally allowed. Forward of amidships, an allowance of 20 sec. per shore is generally sufficient.

Cribbings. In removing the cribbings of a solid collapsible-block type, 5 min. per cribbing is allowed. Where sand blocks are used for collapsing the cribbing, 10 min. per cribbing is allowed.

Blocking. When it is necessary to split out solid keelblocks, 15 min. is allowed for each block, with four men assigned.

Collapsible Blocks. With two men on each block, 5 min. is allowed for the removal of the straps and bolts, collapsing the block, and then clearing the keel-track cribbing to below the level of the top of the ground ways.

Sand Blocks. To release sand blocks, 3 min. is allowed for two men at each block for collapsing the block and reducing the keel track to below the level of the top of the ground ways.

Number of Men

Keel Track. The number of men assigned to the keel track will, of course, depend on the length of the ship to be launched and whether or not there are any solid blocks to split out.

Solid Blocks. Where it is necessary to split out solid blocks, four men are usually assigned to a block. The number of blocks to be split out and the time interval allowed determine the number of gangs necessary for splitting out these blocks.

Collapsible Oak and Sand Blocks. The number of men required in removing collapsible oak and sand keelblocks is two men to a block.

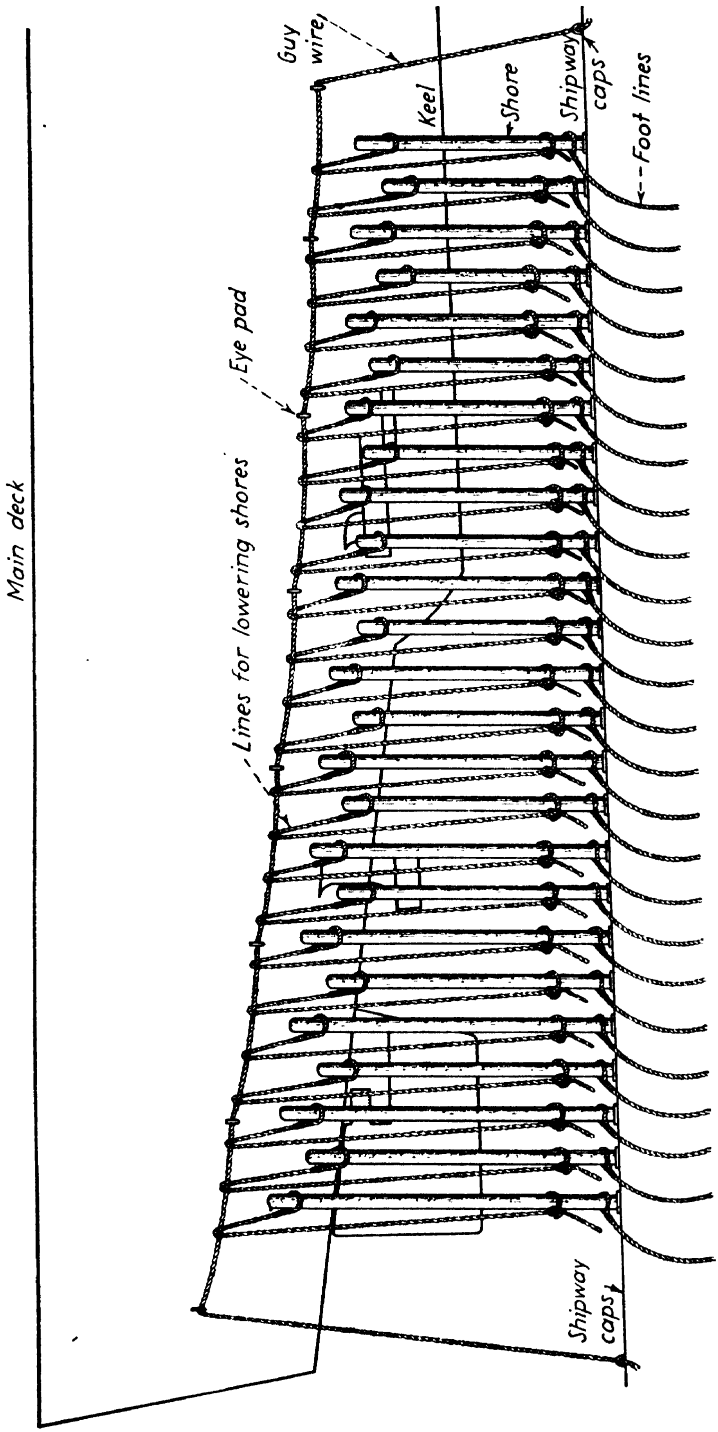


FIG. 592.—Method of lowering long shores to the ground during launching operations.

Cribbings. In the removal of cribbings, 12 men are generally used on a cribbing.

Two men are assigned to the task of removing the angles at the after-end of the cribbing that hold it in position. Ten men are assigned to the ram to collapse the cribbing after they have removed the spreaders between the blocks.

The same men will clear away the cribbing material to a point at which it will not foul the bottom of the ship during its passage down the ways.

Where cribbings are extremely high, it may be necessary to add a gang of laborers to assist in getting this extra material out of the way in time.

Removing Shores. In removing shores the size of the ram to be used determines the number of men necessary. In addition, a gang of men is assigned to clearing away the shores after they have been knocked out. There are usually 12 to 16 men per ram gang.

Where shores are exceptionally long, it is necessary to lower them to the ground by means of ropes or wire lines so that they will not fall on the ram gang when they are being knocked free. This is done in the manner shown in Fig. 592, by means of a wire stretched through eye pads welded to the side of the ship, ropes being passed over the wire and tied to the top of the shores, with the free end coiled up at the bottom. Where shores are extremely long and heavy, 12 men are used to hold the lines and lower the shores to the ground.

In addition a gang must be provided with a snatch line to pull the foot of the shores clear as they are being lowered down with the head lines. Six men are ordinarily used for this purpose.

Grease Irons. The number of men usually assigned to each gang drawing grease irons is five, four doing the drawing and one carrying the irons and hanging them on the racks.

Wedging Operations. During the wedging operations it may be necessary to commandeer all the men to make up the ram gangs. Four men are assigned to each ram, and each gang takes in approximately 12 wedges.

Men for Miscellaneous Items. Men usually have to be provided for various miscellaneous items, as one man on each side of the ship to look after tools; two men on each side of the ship, with axes, to cut out any shores that may require this; the necessary water boys to supply drinking water to the men on the keel track and on each side of the ship, so that it will not be necessary for them to leave their jobs; and one man on each side to remove tallow covering strips and joggled wedges.

Men will also have to be assigned to the job of removing the remainder of air and power lines going aboard the ship, together with any electrical grounds, which are generally welded to the hull of the ship and which must be chipped off. During the removal of the outside supports, men must be assigned to the inspection of the hull, for these supports are removed to see that all work has been done in the way of shoring and blocking, such as calking or welding. Painters must follow up behind the gang making removals, to paint out the area bearing on shores and blocking.

Electricians should be assigned to the ship to see that power for lighting under the ship is maintained, and to arrange for making up power connections at the outfitting pier after the ship is launched. A force of men must also be on board the ship to handle lines to the tugs for warping in and tying up the ship at the pier. Finally, men must be assigned to the last means of access aboard the ship, so that they can remove the gangway just prior to launching.

Extra Men. A force of men is assigned to check and close sea connections, together with a force of men to open up and inspect tanks immediately following launching. Extra men must also be provided in case some of the regular gang fail to show up for work or if it is necessary to call on additional help to relieve the regular gang.

Only the actual launching operations under the ship are covered in the launching program. However, instructions for other parts of the work mentioned in the foregoing are covered in separate memoranda to the various departments involved.

Procedure for Removals

The procedure for removals under the ship in preparations for launching from semisubmerged shipways is usually divided into three periods, as follows: first period, operations below high-water mark; second period, flooding operations; third period, operations above high-water mark.

The *first period* covers all operations within that portion of the ways under water after flooding.

The *second period*, or the period of flooding operations, includes the opening of the flooding valve, pumping down the caisson, and the removal of the caissons, thus opening the shipway to the sea.

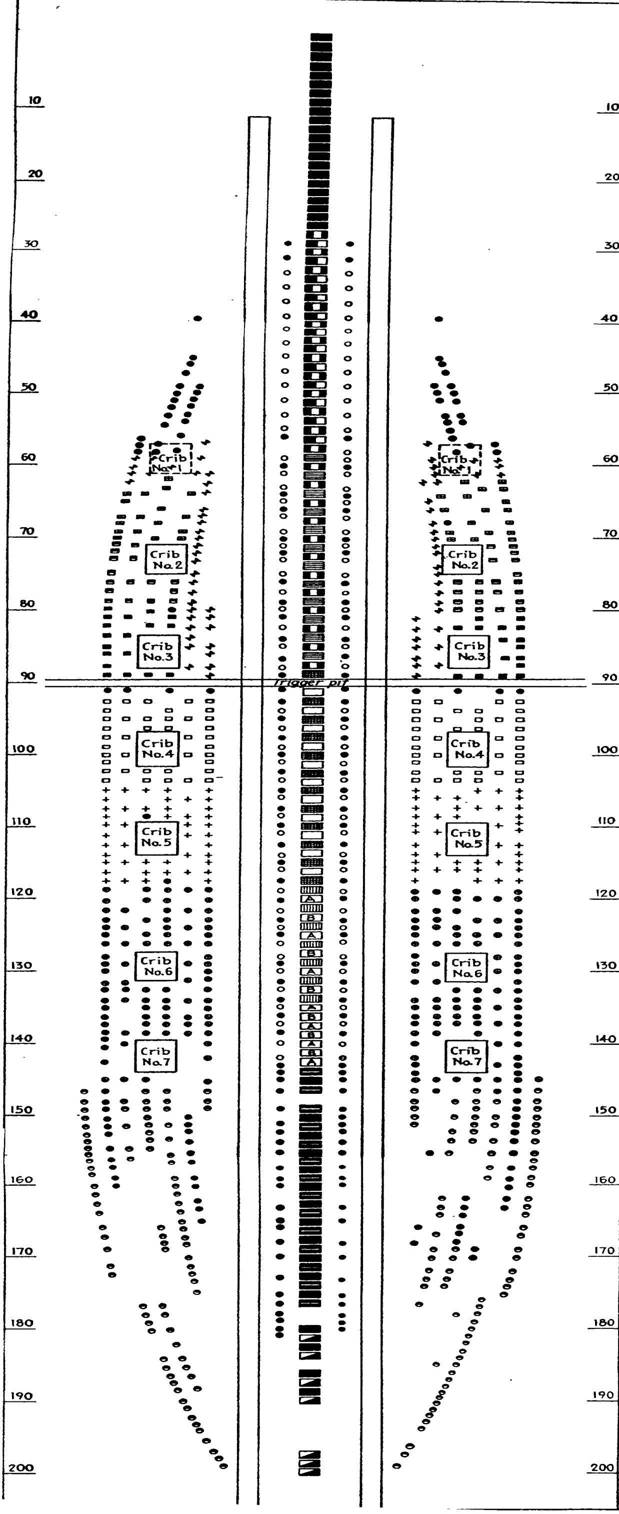
The *third period* covers all remaining work from the flooded area to the forward end.

In launching from the conventional type of building ways, operations usually begin with the drawing of the grease irons. The removal of the outside supports is generally started at the afterend and worked to the forward end.

If it is desirable, some variation of the removals may be made. For example, shores and blocking may be removed from the afterend toward amidships, or to the flat portion of the ship, and then removals made at

LAUNCHING U.S.S. YORKTOWN H393

ARRANGEMENT



NOTES

KEEL TRACK

Blocks	Fwd.	Aft	Total No.
Sand	25	11	36
Collapsible	25	18	43
Trip shores	0	14	14
Solid	0	13	13
Preliminary	22	16	38
Long shores	0	7	7
Total	72	79	151

SHORE REMOVAL

	Fwd. of trigger		Aft of trigger		Total		Total P&S
	P	S	P	S	P	S	
Launching day row No. 1	7	7	44	47	51	54	105
2	21	17	32	27	53	44	97
3	14	16	43	36	57	52	109
4	11	13	33	39	44	52	96
5	14	14	33	28	47	42	89
6	27	27	71	77	98	104	202
7	0	0	22	24	22	24	46
Keel track	28	28	21	21	49	49	98
Total	122	122	299	421	421	421	842
Preliminary row No 1	1	0	1	1	2	1	3
2	0	0	1	0	1	0	1
3	0	0	3	1	3	1	4
4	6	6	2	0	8	6	14
5	9	8	0	7	9	15	24
6	2	1	1	3	3	4	7
7	0	0	0	0	0	0	0
Keel track	12	13	45	42	57	55	112
Total	30	28	53	54	83	82	165
Summary of all shores row No. 1	8	7	45	48	53	55	108
2	21	17	33	27	54	44	98
3	14	16	46	37	60	53	113
4	17	19	35	39	52	58	110
5	23	22	33	35	56	57	113
6	29	28	72	80	101	108	209
7	0	0	22	24	22	24	46
Keel track	40	41	66	63	106	104	210
Total	152	150	352	353	504	503	1007

CRIBBING

	Date	Time	Location
No. 1	Dec. 24,43		Frs. 56-61
No. 2	Jan. 21,44	10:05 A.M.	Frs. 70¾-75¾
No. 3	Jan. 21	10:05 A.M.	Frs. 83½-88½
No. 4	Jan. 21	10:05 A.M.	Frs. 96¾-101¾
No. 5	Jan. 21	10:05 A.M.	Frs. 109¾-114¾
No. 6	Jan. 21	4:25 A.M.	Frs. 127-131
No. 7	Jan. 21	4:25 A.M.	Frs. 139-144

LEGEND

- (Black) solid blocks removed previous to launching
- (Yellow with red band) collapsible blocks removed 11:45 A.M.
- (Yellow with white band) collapsible blocks removed 11:35 A.M.
- (Yellow with blue band) collapsible blocks removed 6:55 A.M.
- (Red) sand blocks removed 12:36 P.M.
- (White) sand blocks removed 12:30 P.M.
- (Blue) sand blocks removed 12:05 P.M.
- A B Solid blocks A-4:25 A.M. B-5:10 A.M.
- (Green) trip shores
- "A" frames removed 4:00 A.M.

- ● (Black) shores removed previous to launching
- ○ (Yellow) shores removed 4:00 A.M.
- (Green over blue) shores removed 5:40 A.M.
- (Green over yellow) shores removed 5:40 A.M.
- (Green) shores removed at 8:25 A.M.
- \+ (Green over white) shores removed) 11:45 A.M.
- □ (Green over red) shores removed 12:05 A.M.
- (Blue) Shores removed 12:25 P.M.
- (White) shores removed 12:30 P.M.
- ⊞ (Red) shores removed 12:36 P.M.

the forward end to the flat portion of the ship, thus leaving the supports under the midship part to be removed last.

Another variation can be made in connection with the removal of the cribbings. These may be removed before the shores are removed or after the shores are removed. That is, it may be felt that the steadying effect under the ship of leaving the bilge cribbings in place until all the rest of the ship has been cleared and then releasing the cribbings just before launching would be desirable.

This is pointed out to show that the sequence of removal from under the ship in a fore-and-aft direction is a flexible one. However, removals in a transverse direction should be carried on at the same time so that the ship will be transferred to the packing uniformly athwartship. Regardless of what procedure is followed in the various areas, *the support under the ship in a transverse direction should be removed simultaneously on each side of the ship and on the keel track.*

Planning the Program

Before the launching program is made up, an arrangement of the blocking, shoring, and cribbing under the ship should be drawn up. This will give the necessary information as to the number and location of the various outside supports that will be left under the ship to be removed on the day of launching.

Figure 593 shows an arrangement of the blocking and shoring under an aircraft carrier. It gives the number of sand, collapsible oak, and solid keelblocks; the locations of trip shores; the number of shores in the various rows forward and aft of the trigger pit; and the location of the bilge cribbings.

After the arrangement of the outside supports under the ship has been made, the program can be developed from this information. The method and sequence of removals will, of course, first have to be decided upon. When this has been done, each operation is listed in the sequence in which it is desired until the entire job is covered. No starting or limiting times are listed at this time.

After the entire launching procedure has been listed and tabulated, it is rechecked to see that nothing has been missed. The time of release is then inserted in the last operation on the schedule.

From this point the time consumed for each operation is inserted in the starting and limiting columns and worked back until the beginning of the operations has been reached. Some revising may be necessary after the time covering the entire program has been set down—which may be either too short or too long. Figure 594 shows the program after it has been smoothed out, giving the starting and limiting times and the time allowed for each operation.

HULL 393
LAUNCHING OPERATIONS
WORK SHEET—SHIPWRIGHTS DEPARTMENT
PORT SIDE
GANG LEADER—MR. R. H. HURST
30-MAN RAM GANG

Assisted by

Mr. T. O. Carmines with 16 laborers piling and clearing away shores
Mr. E. C. Allen with 12 shipwrights on lines
Mr. C. M. Staley with 6 shipwrights to follow up and install spur shores if they are knocked out

Also assisted by

Mr. George Fox with 30-man auxiliary ram
Mr. W. A. Blackwell with 12 laborers piling shores
Mr. R. B. Melton with 12 shipwrights on line

The auxiliary ram gang will remove shores between frames 118 and 145, working from the forward to the after end until such time as the ram gangs begin to interfere with one another. At this time the auxiliary gang will drop out and assist with the removal of shores from the shipway.

In the removal of shores above high water, your ram gang will remove shores between frames 104 and 118. The auxiliary gang will then take over the ram and remove shores between frame 104 and the trigger pit with your main gang clearing away shores and assisting as necessary. The auxiliary ram gang will also remove the shores in the wedge row forward of the trigger pit.

Operation No.	All times A.M.		Operation
3	4:00	4:45	Remove all shores (YELLOW) between the ways and the keel track on the port side for the entire length of the ship, beginning at the stern and working toward the forward end NOTE: Mr. Carmines with 16 laborers will clear away shores as they are knocked out
18	5:40	8:10	Remove all shores (GREEN over YELLOW) from under the bottom of the ship aft of frame 146, beginning at the stern and working forward NOTE: The ram gang will back up as each shore is knocked out, and men handling lines will lower the shores and put them into the trough for transport to the afterend of the shipway, where they will be removed with a floating derrick. The 8 men handling lines for lowering the shores will lead the lines aft, while 4 men with lines on the foot of shores will guide the shores into the slide trough, where a gang of laborers will haul them aft Extreme care should be exercised to avoid rushing, as 2 min. has been allowed for the removal of each shore. This has been done to avoid possible injury to workmen because of the extreme length of these shores and the difficulty in handling them from the shipway

Operation No.	All times A.M.		Operation
27	10:05	10:35	Remove cribbings 2, 3, 4, and 5—the remainder of all cribbing NOTE: In particular, you will take charge of cribbing 4 and see that it is removed from under the ship and piled neatly alongside of the retaining wall clear of high water. You will receive for this operation 4 shipwrights from Mr. Melton and 4 shipwrights from Mr. Staley. These 8 shipwrights will see that the bolts and angles are removed. After cribbing 4 has been removed, take your men aft to cribbing 5 if it is not yet removed
29		10:50	MEN TO ASSEMBLE at wedging stations forward of frame 118. NOTE: Owing to the confined area of the ship on the stocks, an uneven settlement on the grease is not desirable, particularly on the port side. It is therefore important for the port side to be wedged up as tightly as possible and for the available men to be on hand to perform various operations, 5 men being assigned to each ram rather than the usual 4 Mr. Fox and the other leaders on the port side of the ship will assist you in stationing men at the various ramming stations, and these leaders should see that plenty of power is put on the ramming up on this side of the ship. Your men need not work on the wedge rallies unless there is an insufficient number of men available. Your men are to take this opportunity to rest before proceeding with the shore removals
30	10:55	11:00	First rally on wedges forward of frame 118
31	11:05	11:10	Second rally on wedges forward of frame 118
32	11:15	11:20	Third rally on wedges forward of frame 118
34	11:20	11:35	Remove the remainder of all ramming rail forward of Frame 118 NOTE: As soon as the ramming rail has been removed, you will take all your men aft to prepare to remove shores forward of frame 118. Mr. Wiseman with 2 axmen will stand by ready to cut away any shores that may require cutting. Mr. Carmines and Mr. Blackwell with their men will help to clear away shores as they are knocked out
37	11:45 A.M.	12:05 P.M.	Remove all shores (GREEN over WHITE) aft of frame 104

Operation No.	All times P.M.		Operation
			NOTE: When this operation is finished, Mr. Fox and his ram gang will take over the ram to remove shores between frame 104 and the trigger pit
			NOTE: Work of removing side shores aft of the trigger pit will STOP as soon as the trigger pit is reached by the ram gangs working on each side of the ship
			Your men will take over the ram and, ON SIGNAL,
42	12:25	12:30	Remove the after one-third of all shores (BLUE) forward of the trigger pit
44	12:30	12:36	Remove the second one-third of all shores (WHITE) forward of the trigger pit
46	12:36	12:41	Continue the removal of the remainder of all shores (RED) under the ship until STAND BY.
47	12:41		FIRST WHISTLE—All men to get clear of the ship
			NOTE: In knocking out shores forward of the trigger pit, you will closely follow the instructions of the staff supervisor, who will work with you; he will give the signal to stop or to go ahead as each telltale light is reached
			Under no circumstances should there be any rushing or racing by the ram gangs; they should go at a normal pace and endeavor to keep abreast of each other. As soon as all shores are knocked clear forward of the trigger pit, or AT THE FIRST WHISTLE SIGNAL FOR THE MEN TO GET CLEAR OF THE SHIP, INSTRUCT THEM TO GET CLEAR OF THE SHIP IMMEDIATELY REGARDLESS OF WHETHER OR NOT ALL SHORES HAVE BEEN KNOCKED CLEAR
			Your close cooperation and study in connection with the foregoing schedule will be greatly appreciated and will result in the successful launching of this ship on time

In the program (Fig. 594) it was found after launching that ample time was allowed for all operations. In some cases, the time could have been cut down, but this was not done because much material had to be removed from below high-water mark before flooding operations could be started and the removal of this material depended on the cranes and car movements, which are subject to breakdown.

Oper. No.	Schedule			Operation	Notes
				First period—3:00 A.M. to 8:55 A.M.	
				Operations below high-water mark	
1	3:00	4:00	1:00	Pull all grease irons for the entire length of the sliding ways, port and starboard; remove irons from under the ship and hang on their respective numbered racks (38 irons each side)	
2	3:00	4:00	1:00	Final trigger test and inspections, and the removal of testing gear	
3	4:00	4:45	45	Remove all shores (*yellow*) between the ways and the keel track, port and starboard for the entire length of the ship beginning at the stern and working toward the forward end (47 shores each side)	
4	4:00	5:00	1:00	Remove three aftermost A frames (*orange*).	3 A frames—at frames 198, 199, and 200
5	4:10	4:40	30	Remove all grease covering strips throughout, port and starboard	
6	4:10	5:40	1:30	Tighten up all wedges throughout following behind the removal of grease irons	
7	4:25	4:45	20	Remove cribbings 6 and 7, port and starboard	
8	4:25	4:55	30	Cut out and remove 7 alternate solid keel blocks (A) on the keel track aft.	7 blocks—at frames 120, 125, 130, 135, 137½, 140, and 142½
9	4:50			Men to assemble at wedging stations aft of frame 118 (13 stations)	
10	4:55	5:00	5	First rally on wedges aft of frame 118	
11	5:05	5:10	5	Second rally on wedges aft of frames 118	
12	5:10	5:45	35	Cut out and remove 6 alternate solid keel blocks (B) on the keel track aft.	6 blocks—at frames 122½, 127½, 132½, 136½, 138¾, and 141¼
				NOTE: Remove all keel track cribbing in way of these blocks to below the level of the grease surface and clear of high water	
13	5:15	5:20	5	Third rally on wedges aft of frame 118	
14	5:20	5:35	15	Remove ramming rail aft of frame 118 and all ramming shape aft of frame 126, port and starboard	
15	5:20	5:35	15	Remove all temporary spreaders between the sliding ways aft of frames 118	
16	5:20	5:35	15	Remove all joggled wedges aft of frame 118, port and starboard	
17	5:40	6:10	30	Remove the four aftermost long shores on the keel track	4 long shores —at frames 181¼, 183¾, 187½, and 190
18	5:40	8:10	2:30	Remove all shores (*green* over *yellow*) from under the bottom of the ship aft of frame 146 (86 shores each side)	
19	5:40	8:10	2:30	Remove all shores (*green* over *blue*) from under the bottom of the ship aft of frame 118 (86 shores each side)	
				NOTE: When all solid blocks on the keel track aft of the trigger pit have been cut out and removed then	
20	6:55	7:10	15	Remove all collapsible oak blocks (*yellow* with *blue band*) on the keel track aft of frame 118.	7 blocks—at frames 118¾, 121¼, 123¾, 126¼, 128¾, 131¼, and 133¾
				NOTE: Remove all keel track cribbing in way of these blocks to below the top of grease surface and clear of high water.	
21	8:25	8:55	30	Remove all shores (*green*) in the wedge row forward of the trigger pit (29 shores each side)	
				Second period—7:55 A.M. to 10:25 A.M.	
				Flooding operations	
22	7:55	8:07	12	Open flooding valve to flood shipways (on verbal instructions)	
23	9:35	9:50	15	Pump down gate 9 for removal	
24	9:50	10:05	15	Gate 9 afloat, removed, and shipways 9 open to the sea	
25	9:55	10:10	15	Pump down gate 8 for removal	
26	10:10	10:25	15	Gate 8 afloat, removed, and both shipways open to the sea	
				Third period—10:05 A.M. to 12:42 P.M.	
				Operation above high-water mark	
27	10:05	10:35	30	Remove cribbings 2, 3, 4, and 5, port and starboard (the balance of all remaining cribbing)	
28	10:35	10:45	10	Straighten up ramming stage and ramming rail forward of frame 118	
29	10:50			*Men to assemble* at wedging stations forward of frame 118 (16 stations)	
30	10:55	11:00	5	First rally on wedges forward of frame 118	
31	11:05	11:10	5	Second rally on wedges forward of frame 118	
32	11:15	11:20	5	Third rally on wedges forward of frame 118	
33	11:20	11:35	15	Remove the balance of all joggled wedges, port and starboard	
34	11:20	11:35	15	Remove the balance of all ramming rail forward of frame 118, port and starboard	
35	11:20	11:35	15	Remove the balance of all temporary spreaders between the sliding ways	
36	11:35	11:45	10	Remove the balance of all collapsible oak blocks (*yellow* with *white band*) on the keel track aft of the trigger pit (11 blocks)	
37	11:45	12:05	20	Remove all shores (*green* over *white*) aft of frame 105, port and starboard (43 shores each side)	
38	11:45	12:05	20	Remove all collapsible oak blocks (*yellow* with *red band*) on the keel track forward of the trigger pit 25 blocks	
				NOTE: When all solid and collapsible oak blocks have been removed from under the ship for the entire length of the keel track, then	
39	12:05	12:15	10	Release and remove all sand blocks (*blue*) aft of the trigger pit together with one sand block at frame 89 (12 blocks)	
				NOTE: Remove all keel track cribbing to below the level of the grease surface together with any floating timber aft of the trigger pit	
40	12:05	12:20	15	Remove all shores (*green* over *white*) aft of the trigger pit (39 shores each side)	
				NOTE: Work of removing side shores aft of the trigger pit will *stop* as soon as the trigger pit is reached by the ram gangs working on each side of the ship	
41	12:20	12:25	5	*Silent period*	
				NOTE: As soon as the entire bottom of the ship is completely cleared of blocks and shores aft of the trigger pit and as soon as all collapsible oak blocks on the keel track forward of the trigger pit have been removed, and on signal, then	
42	12:25	12:30	5	Remove the after one-third of all shores (*blue*) forward of the trigger pit, (18 shores each side)	
				NOTE: As soon as one-third of all shores (*blue*) forward of the trigger pit on each side have been removed, then	
43	12:30	12:35	5	Release and remove the after one-half of sand blocks (*white*) on the keel track forward of the trigger pit (12 blocks)	
				NOTE: Remove all keel track cribbing to below the level of the grease surface	
44	12:30	12:36	6	Remove the second one-third of all shores (*white*) forward of the trigger pit (17 shores each side)	
				NOTE: As soon as two-thirds of all shores (*blue*) and (*white*) forward of the trigger pit on each side have been removed, and as soon as the after one-half of sand blocks (*white*) on the keel track forward of the trigger pit has been removed, then	
45	12:36	12:41	5	Release and remove all remaining sand blocks (*red*) on the keel track forward of the trigger pit (12 blocks)	
				NOTE: Remove all keel track cribbing to below the level of the grease surface	
46	12:36	12:41	5	Continue the removal of the remainder of all shores (*red*) under the ship (16 shores each side) until	
47	12:41:45			*Stand by—first whistle*—All men to get clear of the ship	
48	12:42			*Second whistle*—Keeper blocks *out*—release keeper block latches; drop keeper blocks; exhaust trigger cylinders	

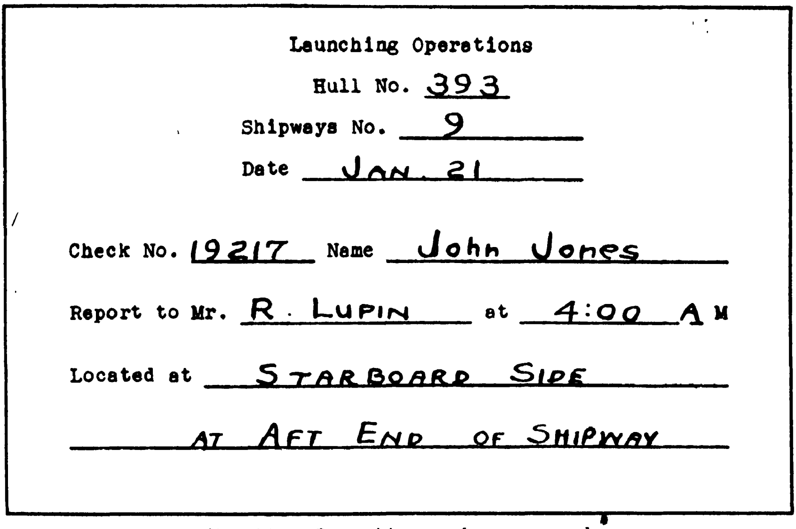
LAUNCHING U.S.S. YORKTOWN H 393

OPER. NO.	STARBOARD LABOR	STARBOARD CHG.	STARBOARD DP.	KEEL TRACK LABOR	KEEL TRACK CHG.	KEEL TRACK DP.	PORT LABOR	PORT CHG.	PORT DP.
	SHIPWRIGHT DEPT. 11 MEN TO REPORT AT 2:45A.M. 217 MEN TO REPORT AT 3:45A.M.			MR. H.F. GARYANTES 20 LEADERS 118 LABORERS					
	ERECTORS DEPT. 62 MEN TO REPORT AT 2:45A.M. 123 MEN TO REPORT AT 3:45A.M.			90 SHIPWRIGHTS MR. W.W. MAC NICHOLL 9 LEADERS					
				176 LABORERS					
	2 WATER BOYS 2 AXE MEN 1 TOOL MAN 20 CLEANERS	WISEMAN WISEMAN WISEMAN HARDY	S.W. S.W. S.W. ER.	1 WATER BOY 20 CLEARING 6 LABORERS ON GATE	WISEMAN GARY BURCHER	S.W. ER. S.W.	2 WATER BOYS 2 AXE MEN 1 TOOL MAN 20 CLEANERS	WISEMAN WISEMAN WISEMAN POWELL	S.W. S.W. S.W. ER.
1				58 ERECTORS ON GREASE IRONS	WILLIS	ER.			
2 3	30 MAN RAM GANG 16 CLEANERS	FETNER GWALTNEY FURMAN	ER. ER. S.W.	6 LABORERS IN TRIGGER PIT	LINKOUS	S.W.	30 MAN RAM GANG 16 CLEANERS	HURST CARMINES	S.W. S.W.
4 5	1 SHIPWRIGHT	G.FUTRELL	S.W.	16 SHIPWRIGHTS 13 LABORERS (AFTER REMOVAL OF "A" FRAMES)	LINKOUS EVANS	S.W. S.W.	1 SHIPWRIGHT	STALEY	S.W.
6 7 8	12 SHIPWRIGHTS 24 SHIPWRIGHTS 70 CLEANERS	G.FUTRELL WILLIS JACKSON THOMAS	S.W. ER. S.W. S.W.	16 SHIPWRIGHTS 13 LABORERS	LINKOUS	S.W.	12 SHIPWRIGHTS 24 SHIPWRIGHTS 42 CLEARING	STALEY ALLEN MELTON BLACKWELL	S.W. S.W. S.W. S.W.
9 10	52 MEN NEEDED (64 MEN) 52 MEN	BURROUGHS BEGGER	S.W. ER.		EVANS	S.W.	52 MEN NEEDED (66 MEN) 52 MEN	G. FOX	S.W.
11 12	52 MEN	WILLIS JACKSON THOMAS BEGGER	ER. S.W. S.W. ER.	16 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.	52 MEN	ALLEN G. FOX	S.W. S.W.
		FURMAN BURROUGS G.FUTRELL GWALTNEY	S.W. S.W. S.W. ER.					MELTON BLACKWELL	S.W. S.W.
13 14	52 MEN 52 MEN (64 MEN)			13 LABORERS	LINKOUS EVANS	S.W. S.W.	52 MEN 52 MEN (66 MEN)		
15 16 17	1 SHIPWRIGHT	G.FUTRELL	S.W.	13 LABORERS	LINKOUS	S.W.	1 SHIPWRIGHT	STALEY	S.W.
18	30 MAN RAM GANG 16 PILING 12 ON LINES 6 FOLLOW UP	G.FUTRELL WILLIS JACKSON FURMAN	S.W. ER. S.W. S.W.		EVANS	S.W.	30 MAN RAM GANG 16 PILING 12 ON LINES 6 FOLLOW UP	HURST ALLEN CARMINES STALEY	S.W. S.W. S.W. S.W.
19	30 MAN RAM GANG 12 PILING 12 ON LINES 6 FOLLOW UP	GWALTNEY FETNER THOMAS BURROUGHS	ER. ER. S.W. S.W.				30 MAN RAM GANG 12 PILING 12 ON LINES 6 FOLLOW UP	G.FOX MELTON BLACKWELL STALEY	S.W. S.W. S.W. S.W.
20		BEGGER G.FUTRELL	ER. S.W.	16 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.			
21	30 MAN RAM GANG	FETNER	ER.				30 MAN RAM GANG	G.FOX	S.W.
	12 PILING 12 CLEARING 12 FOLLOW UP	THOMAS BURROUGHS BEGGER G.FUTRELL	S.W. S.W. ER. S.W.				12 PILING 12 CLEARING 12 FOLLOW UP	MELTON BLACKWELL STALEY	S.W. S.W. S.W.
22 23 24									
25 26									
27	36 SHIPWRIGHTS 88 CLEARING	WILLIS	ER.				36 SHIPWRIGHTS 88 CLEARING	G.FOX	S.W.
28 29	36 SHIPWRIGHTS 80 MEN NEEDED (94 MEN)	JACKSON FURMAN GWALTNEY	S.W. S.W. ER.				36 SHIPWRIGHTS 80 MEN NEEDED (94 MEN)	HURST ALLEN	S.W. S.W.
30 31 32	80 MEN 80 MEN 80 MEN	FETNER THOMAS BURROUGHS BEGGER G.FUTREL	ER. S.W. S.W. ER. S.W.				80 MEN 80 MEN 80 MEN	CARMINES MELTON BLACKWELL STALEY	S.W. S.W. S.W. S.W.
33 34	1 SHIPWRIGHT 80 MEN (86 MEN) 8			8			1 SHIPWRIGHT (86 MEN) 80 MEN		
35 36				16 SHIPWRIGHTS 13 LABORERS 32 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS LINKOUS	S.W. S.W. S.W.			
37 38	30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP	WILLIS FURMAN GWALTNEY BURROUGHS	ER. S.W. ER. S.W.	32 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.	30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP	HURST CARMINES BLACKWELL STALEY	S.W. S.W. S.W. S.W.
		BEGGER G.FUTRELL	ER. S.W.						
39				32 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.			
40	30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP	FETNER FURMAN GWALTNEY BURROUGHS	ER. S.W. ER. S.W.				30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP	G. FOX CARMINES BLACKWELL STALEY	S.W. S.W. S.W. S.W.
41		BEGGER G.FUTRELL	ER. S.W.						
42	30 MAN RAM GANG 16 CLEARING 12 CLEARNG 28 FOLLOW UP 30 CLEARING						30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP 30 CLEARING		
43				32 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.			
44	30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP 30 CLEARING	FETNER FURMAN GWALTNEY WILLIS BURROUGHS BEGGER G. FUTRELL	ER. S.W. ER. ER. S.W. ER. S.W.				30 MAN RAM GANG 16 CLEARING 12 CLEARING 28 FOLLOW UP 30 CLEARING	HURST CARMINES G. FOX BLACKWELL STALEY	S.W. S.W. S.W. S.W. S.W.
45				32 SHIPWRIGHTS 13 LABORERS	LINKOUS EVANS	S.W. S.W.			
46	30 MAN RAM GANG						30 MAN RAM GANG		
47 48	16 CEARING 12 CLEARING 28 FOLLOW UP 30 CLEARING						16 CLEARING 12 CLEARING 28 FOLLOW UP 30 CLEARING		

Gang Routing and Work Sheets

After the program has been developed, the gang routing diagram from which the work sheets are developed is made up, as shown in Fig. 595. This gang routing diagram is laid beside the launching program so that the number of men required for each operation can be listed beside each of the operations. As the gangs complete their operations, they may be assigned to other work in their area in successive operations, as shown by the arrows.

For example, the shifting of men from the outside of the ship to the keel track can be readily traced by observing the transfer of eight ship-


Launching Operations

Hull No. 393

Shipways No. 9

Date JAN. 21

Check No. 19217 Name John Jones

Report to Mr. R. LUPIN at 4:00 AM

Located at STARBOARD SIDE

AT AFT END OF SHIPWAY

FIG. 596.—Launching work report card.

wrights from each side of the ship after operation 32 has been completed who will assist the men on the keel track with operation 36 and thereafter until the work on the keel track has been completed.

The foregoing procedure requires some study and effort but is well worth while from the standpoint of covering each part of the work that the various supervisors will have to perform.

The work sheet for the supervisor and his gang is developed from the gang routing sheet, which shows all operations that each gang will perform throughout the launching procedure. On page 556 is shown a typical work sheet for the 30-man ram gang, which shows the gang leader for one side of the ship, together with his assistants and the work that they are to perform.

Assignment of Men. When the number of men required in each gang has been determined, their selection will be governed by the type of

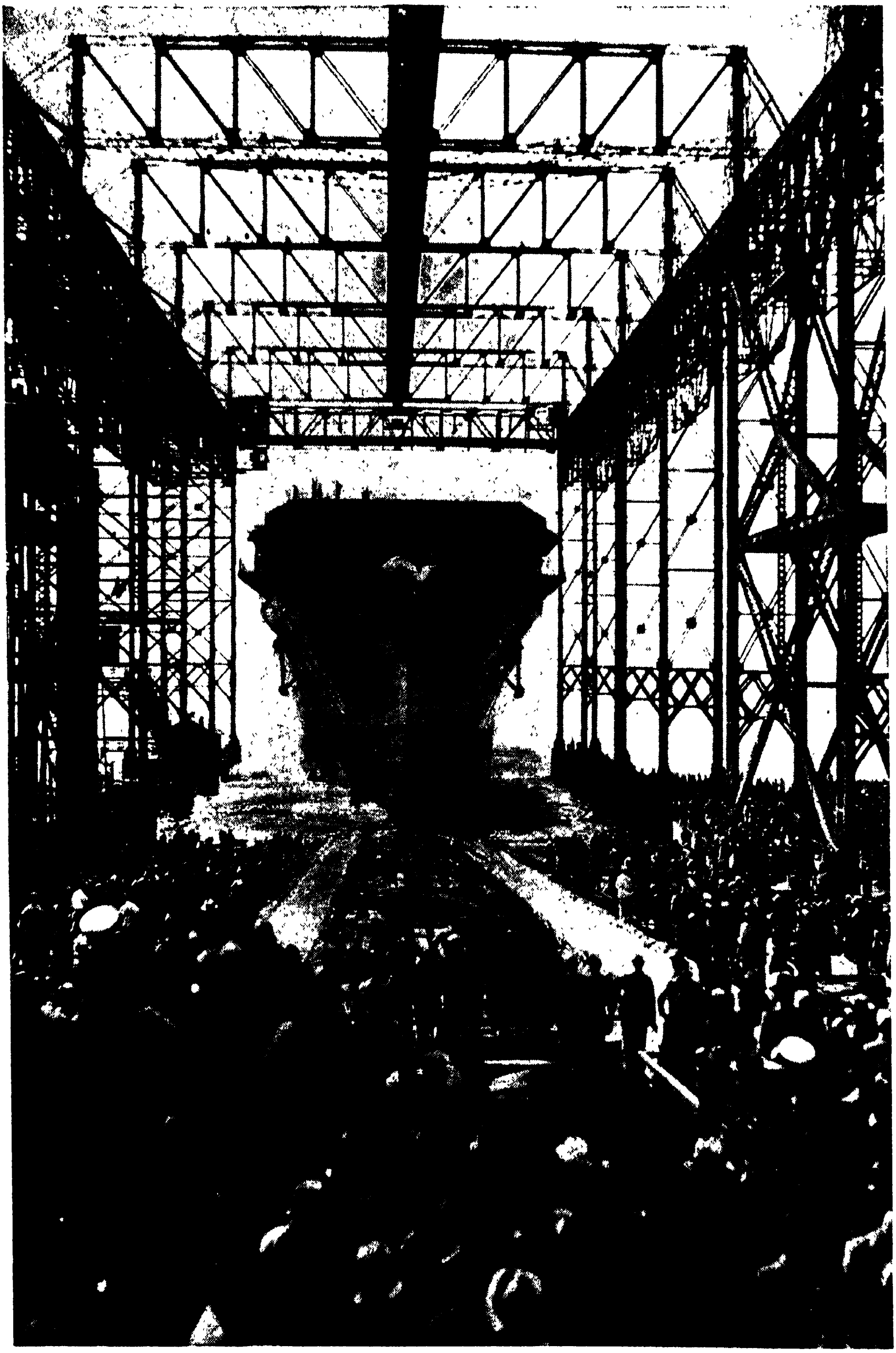


FIG. 597.—A successful launching.

work to be performed. For example, shipwrights will do all shipwright work in connection with the keelblocks and cribbing removals, with any other carpentry work that may be necessary. Stage builders and erectors are generally used for ramming out shores and wedging up. Clearing away is done by laborers. When the number and type of men have been decided in each group, they are then picked and their names and check numbers attached to the work sheets, so that the supervisor will know which men are to work in his group.

About 2 days before launching, each man working on the launching is given a report card, as shown in Fig. 596. This card contains the necessary information as to his supervisor and the scheduled time and place to report for work. It also ensures his attendance on the correct job. This eliminates confusion, as men coming to work immediately report to their supervisor, whose whereabouts are clearly shown on the card.

When the launching program and work sheets are developed in the foregoing manner, the foreman shipwright is relieved of all the work of organizing and performing the various operations on the day of launching. His work will be confined to locations where difficulties might be encountered and where he can give instructions and directions to overcome them. The remainder of the work is left to his organization, who, with the men assigned, launch the ship from instructions, while he reaps the benefits of a well-planned launching (see Fig. 597).

LAUNCHING DATA

Various data are collected during the launching of each ship, for use on future ships. A record is also made of any difficulties encountered

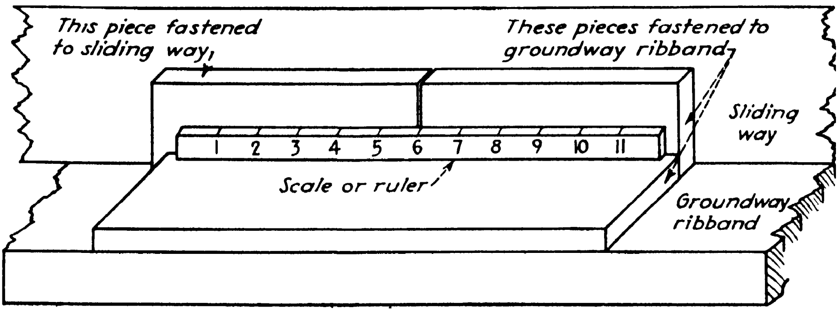


FIG. 598.—Typical creep gauge.

so that these may be taken into account in the launching of a similar ship.

As each supervisor completes his particular operation, he should jot down beside this operation the actual starting and finishing time, so that this can be incorporated in the launching report and used for future reference.

Data on Releasing Devices. Data are also collected in connection with the releasing devices, such as the creep gauges used in connection with the solepieces or burn-off plates. Records of the amount of creep are made at the times when major removals are made from under the ship. In Fig. 598 is shown a typical creep gauge.

DATA ON TRIGGERS

Time	Operation	Lb. per sq. in.
7:00 A.M.	Trigger pumped out	150
8:45 A.M.	End of first period	150
10:25 A.M.	At finish of wedge rallies	150
10:44 A.M.	After removal of all solid and collapsible blocks aft of the trigger pit	950
10:50 A.M.	Removal of all oak collapsible blocks forward of the trigger pit	1100
11:12 A.M.	After removal of all shores aft of the trigger	1800
11:17 A.M.	After removal of all sand blocks aft of the trigger pit	1850
11:44 A.M.	Removal of all shores forward of the trigger pit and one-half of the sand blocks removed	2400
11:48 A.M.	After removal of all sand blocks	3250
11:49 A.M.	After removal of all shores	3400
11:50:29 A.M.	At exhaust of triggers releasing the ship	3600

Temperature on the Day of Launching. On the day of launching a record is made of the temperature under the ship and the temperature of the water at various time intervals, as follows:

Time	Air under ship, °F.	Water, °F.
5:00 A.M.	70	72
6:00 A.M.	70	72
7:00 A.M.	71	72
8:00 A.M.	70	72
9:00 A.M.	71	72
10:00 A.M.	72	74
10:30 A.M.	73	74
11:00 A.M.	74	74
11:30 A.M.	74	74

WIND, WEATHER, AND SEA ON THE DAY OF LAUNCHING

Time	Wind direction and force, m.p.h.	Weather	Sea
6:00 A.M.	Northwest, 5	Clear	Smooth
7:00 A.M.	Northwest, 5	Clear	Smooth
8:00 A.M.	Northwest, 6	Clear	Smooth
9:00 A.M.	Northwest, 6	Clear	Smooth
9:56 A.M.	Northwest, 6	Clear	Smooth
10:00 A.M.	Northwest, 6	Clear	Smooth
11:00 A.M.	Northwest, 6	Clear	Smooth
11:50 A.M.	Northwest, 7	Clear	Smooth
11:56 A.M.	Northwest, 7	Clear	Smooth

HEIGHT OF TIDE ON DAY OF LAUNCHING

Time	Water over way ends		Elevation on tide board
	Ft.	In.	
6:00 A.M.	17	8 7/16	99.1
7:00 A.M.	18	10 7/8	100.3
8:00 A.M.	19	3 5/8	100.7
9:00 A.M.	20		101.4
9:56 A.M.	20	3 5/8	101.7
10:00 A.M.	20	3 5/8	101.7
11:00 A.M.	20	2 1/2	101.6
11:50 A.M.	19	9 5/8	101.2
11:56 A.M.	19	9 5/8	101.2

PUMPING DOWN AND FLOODING

Operation	Scheduled		Actual	
	Start	Finish	Start	Finish
Start to open valve	6:45 A.M.	6:57 A.M.	6:34 A.M.	6:45 A.M.
Start to pump down caisson	8:35 A.M.	8:50 A.M.	7:51 A.M.	8:09 A.M.

HEIGHT OF TIDE

	Inside gates	Outside draft board
At opening of valve	85.0	100.1
At start to pump down caisson	100.6	100.6
When shipway was open to the sea	101.2	101.2
Height of water over way ends at time of launching	19.8	

TERMS AND DEFINITIONS

A

A frames. Frames forming the letter A.
abaft. Toward the stern; aft.
access opening. Openings in any part of ship's plating used for a passageway while the ship is under construction.
adz. A tool with a blade set at right angles and a long curved handle used by the shipwright in shaping timbers.
aft. At, or toward, the stern.
after perpendicular. A line perpendicular to the base line at, or near, the after edge of the rudderpost at the designed water line.
after poppet. Upright members used to support the afterend of the ship during launching.
afterbody. Hull form aft of the midship section.
afterend. At stern, or part nearer stern.
aftermost. Nearest the stern.
afterpeak. The compartment at the stern, aft of the last watertight bulkhead.
afterpeak bulkhead. Aftermost watertight bulkhead.
air port (port hole). A circular window, in the ship's side or deckhouse, for light or ventilation.
align. To adjust or form to a line.
alteration. Modification, or change.
amidships. The middle portion of a ship, as distinguished from the ends.
anchor. A heavy device for holding the ship at rest in the water. It is designed with a hook shape, which grips the ocean bottom, and is fastened to the ship with a heavy chain.
angle. A figure formed by two meeting planes or lines; a rolled steel bar, L section.
angle clip. A short piece of angle bar used for attachment.
angular distortion. Distortion caused by heating, in which stresses are set up at right angles to the neutral axis of the base metal.
anneal. To soften metal by heating and then gradually cooling.
appendages. Such parts of the ship as shafting, struts, bilge keel, propellers, and rudders extraneous to the hull.
aperture. The opening between rudder post and propeller post for the propeller.
arc. A portion of a curved line.
arc-welded. Welded with an electric arc.
armor boxing. Compartment enclosed with armor.
assemble. To collect, or build, the fabricated parts entering into construction in their proper positions before erection.
athwartship. Across the ship, perpendicular to the fore-and-aft center line of a ship.
auxiliaries. Various pumps, motors, and other small machinery required on a ship.
auxiliary ribband. A ribband alongside the main ribband.

B

backing angle. A short piece of angle for reinforcing the butt or splice of two angles.
baling wire. A light flexible wire about 1/8 in. thick, generally used for baling purposes.
ballast. Sea water or any weight, or weights, used to keep the ship from becoming top-heavy or increase its draft or trim; also, weights used in the launching cradle.
ballast pocket. A pocket built into the cradle for ballasting and sinking the cradle clear of the hull.
ballast tank. Watertight compartments to hold ballast.
ballistic bulkhead. A protective bulkhead against gunfire.
balsa. A form of light wood used by the shipwright to pack the bilge keel.
base block. The block at the base of a column or shore.
base line. The main line taken, or representing the base.
battens. Narrow strips of wood used in making templates or molds and for fairing lines. Also used as protection strips in cargo holds.
batter board. Horizontal boards nailed to posts as a fastening for stretching strings to form outlines.
beam. An athwartship member supporting a deck or flat. Also used in referring to the extreme width of the ship.
beam knee. A piece of plate forming a bracket for connection to side frame.
below. Below a deck or decks.
bending slab. Heavy cast-iron perforated slabs arranged to form a large floor on which plates and shapes are bent after heating in a furnace.
between decks. The space between any two continuous decks; also referred to as *'tween decks.*
bevel. The angle between the flanges of a frame or other member. (When greater than a right angle, *open bevel;* when less, *closed bevel.*) Also pertains to chamfer.
bevel board. A board with degree divisions of a right angle, similar to a protractor.
bilge. Curved portion between the bottom and the side of a ship; also the recess into which all water drains.
bilge cribbing. Blocks used under bilge for supporting the ship during construction or dry docking.
bilge keel. A fin on the ship at the turn of the bilge to reduce rolling.
bilge strake. Strake of plating at the bilge.
bilge well. A low place or sump to which bilge water drains.
bitt. Tie post for making lines fast on deck.
bitumastic. A black tarlike composition, largely of bitumen or asphalt, used in packing the bilge keel.
bleeders. Plugs screwed into the bottom of the ship which may be unscrewed to allow drainage of compartments when the ship is in dry dock.
blueprint. A blue photograph.
body plan. A drawing showing frame lines in elevation.
boiler. A chamber in which water is heated to form steam for power.
boiler chocks. Braces that prevent fore-and-aft movement of boiler.
boiler foundation (boiler saddle). Lower support for a boiler.
bolster of a hawse pipe. The built-up portion outside the shell, to prevent chafing by the anchor chain.
booby hatch. Watertight covering over a deck opening that is used as a companionway.
boom. A spar pivoted at one end, used for hoisting cargo.
boom rest. A support for the boom when it is not in use.
boring stand. A stand used for boring out shaft struts and stern frames and tubes.

bosom piece. A short piece of angle bar used as a butt strap or connecting piece.
boss. The curved portion of the ship's hull around the propeller shaft.
boss frame. Side frame that is bent for clearing the propeller-shaft tube.
boss plate. Shell plate covering curved portion of hull where propeller shaft passes outboard.
bottom shell. The shell plating on the bottom of a ship.
bow. The forward end of a ship.
bracket. A triangular plate used to connect rigidly two or more parts that meet at some angle with one another, as a deck beam to a frame or a frame to a margin plate.
breakwater. A guard plate that prevents a solid thrust of water from sweeping the decks.
breasthook. A flanged plate bracket joining port and starboard stringers at their forward end in the bow.
bridge. Deck on which the pilothouse is located; an amidships superstructure.
bucking brace. A brace pulling against another brace pushing in the opposite direction.
buckling. Act of crumping.
building way. Place where the ship is built before launching; shipway.
built-up timber. A timber made up of two or more pieces and secured together.
bulb angle. An angle shape reinforced at one toe.
bulb plate. A narrow plate reinforced on one edge.
bulb tee. Tee bar with toe of web reinforced.
bulkhead. A vertical steel partition between compartments, extending athwartship or fore and aft.
bulwark. A strake of shell plating above the weather deck. Serves to keep deck dry and as a guard against losing cargo and men overboard.
buoyancy. Ability to float; upward force of water pressure equivalent to the weight of liquid displaced.
bursting wedges. Steel wedges used for splitting timber.
butt. The joint formed when two parts are placed edge to edge; also, the end joint between two plates.
butt strap. A connecting strap between the butted ends of two parts.
buttock. A vertical plane running fore and aft at right angles to the transverse base line of the ship.

C

caisson. A hollow floating box or boat used as a flooding gate for a dock or basin.
calk. To make a joint watertight.
camber. The athwartship rise or crown of a deck.
camber curve. Line of camber or curve.
cambered ground ways. Ground ways shaped with a convex curve.
cant. To tilt.
cant block. A wedge-shaped block used for tilting purposes.
cant frame. A frame not square to the center line.
cap. A top piece.
capstan. A revolving device used for heaving in lines.
cargo. The freight carried by a ship.
cargo batten. Wood strips used to keep cargo from bearing against steel bulkhead or hull.

cargo boom. Boom used in handling cargo.
cargo hatch. Opening in a deck to permit loading of cargo into holds.
cargo port. Opening in a ship's side for loading and unloading cargo.
casing. Bulkheads enclosing portion of vessel, such as engine or boiling casing.
casting. A part made by pouring molten metal into a mold and allowing it to cool.
ceiling. Wood sheathing used to protect cargo.
center line. The fore-and-aft middle line of a ship, extending from stem to stern.
center to center. From one center to another center.
center vertical keel. The vertical keel at the center of a vessel.
chafing plate. Radial plate for minimizing chafing of ropes.
chain locker. Compartment in which anchor chain is stowed.
chain pipe. A pipe for the passage of anchor chain from windlass to chain locker.
chain stopper. A device that prevents anchor chain from running out. It is set in place after lowering the anchor or after it has been stowed.
chamfer. To cut or reduce an angle or a corner; to bevel.
channel. An iron bar of channel section (⊏). The deeper part of a river, which affords the best and safest passage for vessels.
chock. A block to prevent movement; also castings fitting at the sides of a ship through which mooring and towing lines are passed.
chord. A right line intersecting a curve.
cleat. A fitting having two arms or horns around which ropes may be made fast; also, a clip on the frames of a ship to hold the cargo battens in place.
clinch pin. Pins with both ends riveted.
clinkered plating. Plating of which one edge is lapped under another, while the other edge laps on top of another plate.
coaming. The vertical boundary of a hatch or skylight.
coefficient. A number commonly used in computation as a factor expressing the amount of change or effect under certain conditions of temperature, length, volume, etc.
cofferdam. A narrow empty space between watertight or oiltight bulkheads to prevent leakage into adjoining compartments.
cold press. Hydraulic press to bend steel in a cold state.
collapsible block. A block made to collapse by a releasing device.
collision bulkhead. The watertight bulkhead nearest the bow of the ship.
companionway. An access hatchway in a deck, with a ladder leading below, generally for the crew's use.
compartment. A subdivision of space in a ship; a room.
contour. The outline of a figure or body.
corrugated. Having a series of folds or furrows used to produce stiffness.
corrugated bulkheads. A bulkhead made of corrugated plating, which eliminates the need for many welded stiffeners.
counter. Overhang of the stern of a ship.
counterbore. To enlarge a hole; to recess by boring.
countersink. To cut the sides of a drilled or punched hole into the shape of a frustum of a cone.
cradle. A form on which furnaced plates are shaped. The support in which a ship lies during launching, called launching cradle. Also cradle used for subassembling shaped sections.
cribbing. A framework of timbers for supporting heavy loads.
cross grain. Across or at right angles to the grain.
cross section. A section at right angles to an axis, especially the longer axis.
cut nail. Nails cut out of thin sheets of metal.

D

dagger shore. A heavy horizontal timber lever, having one end set against a shoulder on the sliding ways and the opposite end pulled taut with a chain fall and fulcrumed against a diagonal shore for the purpose of preventing the ship from moving during the time that blocking is removed for launching the ship.

datum line. A horizontal line from which heights and depths or points are reckoned; a plane or level assumed or used as a basis of reckoning.

davit. A crane arm for handling small boats and other stores.

dead flat. The portion of a ship's form or structure that has the same transverse shape as the midship section.

dead rise. Rise or athwartship slant of the bottom of a ship from the keel to the bilge.

deadman. A buried log, or the like, serving as an anchor for something, as a guy rope; also, any stout timber or log used as an anchorage.

deadweight. The total weight of cargo, fuel, water, stores, passengers, and crew and their effects, that a ship can carry.

deck. A deck on a ship, corresponding to the floor in a building.

deck beam. Athwartship support for deck.

deck, bulkhead. The uppermost continuous deck to which all the main transverse bulkheads are carried.

deck height. The height of the deck above the base line of the ship.

deck line. The designed line of the underside of the deck plating.

deck plating. The plating forming the deck.

deck stringer. The strake of plating that runs along the outer edge of a deck.

deckhouse. A shelter built on deck.

declivity. Deviation from a horizontal plane; gradual descent of a surface; inclination downward; a sloping place. Inclination of shipways to provide for launching.

declivity angle. The angle of slope with respect to a horizontal plane.

deep tank. A deep compartment, usually extending from tank top to lower deck.

deflection. The amount of bending.

derrick. A device for hoisting heavy weights, cargo, etc.

diagonal shore. A shore set at an angle of about 45 deg. with the keel.

diameter. A line passing through the center of any object or figure, especially a circle or conic section.

dished. Resembling a dish in form. Applied to the end of a cylinder or drum when it is concave or to the sides of flat keel, as bent to fit the dead rise.

displacement. The total weight of the ship when afloat, equals the weight of the water it displaces.

distortion. Act of distorting; a twisting motion resulting in a misshapen condition.

docking keel. Keel on each side of ship used to distribute the weight in dry dock in the case of large ships.

dog. A device, usually of simple design, for holding, gripping, or fastening something, consisting essentially of a spike, rod, or bar of metal.

dog shore. One of several shores used to hold a ship firmly and prevent her from moving while the blocks are knocked out before launching.

dolphin. Several piles that are bound together, situated either at the corner of a pier or out in the stream, and used for docking and warping vessels.

double bottom. Compartment at bottom of ship between inner and outer bottoms, used for ballast, fuel, oil, and water tanks.

doubling plate. A plate fitted inside or outside another to give additional strength or stiffness.

double shear. A stress that tends to cause adjacent parts to slide over one another; to cut at two points rather than one.

doubler. A plate fitted inside or outside another to give additional strength or stiffness.

draft. The vertical distance from the lowest point on the ship's bottom to the water surface when the ship is afloat.

draft board. A board graduated in feet and tenths of a foot, to give the depth of water.

draft figures. The numbers on the bow and stern of a ship to indicate the depth of water she draws.

draftsmen. Men engaged in the preparation of the general and detail plans from which are built the ship's hull, machinery, fitting, etc.

drag. The amount the stern end of a ship is below the bow when the ship is afloat.

draw clip. A short structural angle or shape welded to a member and used for drawing members together.

driftpin. A small tapered tool used to draw adjoining plates or shapes into alignment.

driving-up wedges. The wedges used in tightening up the cradle against the hull of the ship.

drop bolt. An unfastened bolt dropped into a vertical hole to act as a chock.

dummy brace. A brace used for bracing a dummy stage standard.

dummy stage pole. An auxiliary stage pole augmenting the main staging standards.

dumpy level. A level having a short telescope rigidly fixed to a table, capable only of rotary movement in a horizontal plane.

E

electrode. Filler metal used in welding by the metal arc process. It is usually covered but sometimes bare.

elevation. Height above the level of the sea; a geometric projection of an object on a plane perpendicular to the horizon; orthographic projection on a vertical plane.

end launching. The launching of a vessel endways into the water.

engine room. The space on a ship provided for the operating machinery and propelling engines.

erect. To set upright.

erecting. The process of hoisting into place and bolting the various parts of a ship's hull.

erection clips. Short angle clips used to facilitate the erection of the steel structure of a vessel.

even keel. When the keel is level or parallel to the water surface.

expansion trunk. Upper portion of tank on an oil tanker, used to allow for the expansion of the oil when the temperature rises.

exposed ways. The portion of the ground ways between the end of the sliding ways and the water.

eyebolt. A bolt whose head is in the shape of a ring or eye.

F

fabricate. The process of assembling material prior to assembly or erection. In hull work, it consists of shaping, punching, drilling, countersinking, scarfing, rabbeting, shearing, beveling, etc.

factor of safety. A design factor such that when multiplied by the allowed working stress for a given material it will give a product equivalent to the ultimate strength of that material.

fair curve. A curve that is fair and regular.
fair line. A line without irregularities or unevenness; smooth.
fair up. To make fair.
fairing. Correcting or fairing up a ship's lines or structural members, that is, without kinks, bumps, or waves.
fairing ribband. A long narrow strip of timber or plate used for fairing the shell plating or framing for the purpose of making fair.
fair-lead. A fitting through which a rope, line, etc., may be led so as to change direction without excessive friction.
fairwater. Plate or casting used to preserve streamline flow past the hull structure.
fantail. Plates forming overhang at stern.
fastening. Anything that binds, makes fast, secures, or confines, as a bolt, band, or buckle.
fathom. A linear measure; 6 ft.
faying surface. The surface of contact between two adjoining parts.
fender. Heavy strip of wood or steel attached to the side of a ship about the water line to prevent rubbing or chafing of the hull.
fiddley. Casing top over boiler room.
fiddley hatch. A hatch over boiler room.
filler block. A block of varying thickness, used between the main blocks to obtain the desired height of the blocking.
fittings. A term applied to pipe connections and outlets; cleats, chocks, and other miscellaneous castings used in securing equipment on deck.
flange. Portion of a plate or shape at, or nearly at, right angles to the main part.
flare. The sudden widening of the shell at the top near the bow.
flat. A small partial deck without curvature.
flat bar. A rolled steel plate varying in width and thickness but not more than 6 in. wide.
flat keel. The center bottom plate of a vessel, which forms the keel, or backbone of the ship's framing.
floor. A transverse plate placed vertical in the double bottom of a ship, running from bilge to bilge.
flush. Unbroken or even surface; on a level with the adjacent surface.
fore. The forward section, or section from amidships to the bow of the ship.
fore and aft. In line with the length of a ship longitudinally.
fore poppet. Any of certain upright timbers at the forward end, used to support the vessel in launching.
forebody. A hull form forward of the midship section.
forecastle. The forward upper portion of the hull.
forefoot. The part of the stem that curves under to meet the keel.
foremast. The mast nearest the bow.
forepeak. A large compartment, or tank, at the bow in the lower part of the ship.
forepeak bulkhead. Collision bulkhead or bulkhead nearest to the bow.
forging. The result of hammering, bending, or pressing a hot piece of metal into shape.
forward. Near, at, or toward the bow of a ship.
forward perpendicular. A vertical line perpendicular to the base line intersecting the forward edge of the stem at the load water line.
forward quarter. Side of ship just aft of bow.
foundations. Supports for boilers, engines, and small machinery.
frame line. The fixed position or point of a frame; the frame station.
frame, side. Frame inside a ship, above and connecting to margin plate or floor plates.

frame spacing. The fore-and-aft distance between adjacent frames.

frame station. The designed fore-and-aft position of the frame with respect to the forward and after perpendiculars.

frame, web. Heavy side or continuous frame, made with web plate between its members.

frames. Transverse ribs that make up the skeleton of a ship. They act as stiffeners, holding the outside plating in shape and maintaining the transverse form of the ship.

frames, continuous. Frames combining side frames and floors.

framing. Ribs forming the skeleton of a ship. Process or style of putting together a frame or of constructing anything.

framing ribband. A long narrow strip of timber or plate, especially in one band, and bolted longitudinally to the frames of a vessel to hold them in position while the vessel is building.

framing square. A large steel carpenter's square provided with tables for cutting the framing of a building.

frapping. A lashing for binding tightly together.

freeboard. The vertical distance from the water line to the top of the weather deck at side, at the lowest point.

fulcrum. The support, as a wedge-shaped piece or a hinge or shore, about which a lever turns.

G

gaining dimension. Measurement in excess of the desired or designed dimensions.

gangway. Means for boarding a ship; a ladder, platform, etc.

garboard strake. The section or strake of plating next to the keel.

gauge strip. A strip used for gauging the thickness of launching lubricants.

girder. A continuous beam running fore and aft under the deck for the purpose of supporting the deck beams that are not directly over a pillar.

girth. Any expanded length; distance around ship's frame from gunwale to gunwale; the outside dimension of anything; the circumference.

grab rods. Bent rods welded to the side of a ship or bulkhead, to form a ladder.

grade line. Degree of incline or angle.

grating. A light platform or walkway built up of metal bars, used for access to machinery.

grease iron. Irons of varying thickness and thicker than the thickness of the launching lubricants, to hold the sliding ways off the grease until the day of launching.

grommet. A washer of twisted hemp cotton coated with red-lead putty and used to stop leaks.

ground ways. Timbers fixed on the ground under the hull on each side of the keel, on which the ship slides during launching.

gudgeons. Bosses on sternpost drilled for pins for rudder to swing on.

gunwale. Junction of deck and shell at top of sheer strake.

gunwale bar. Angle bar that connects deck stringer plate and shell plates at weather deck.

guys. Wire or hemp ropes or chains attached to anything to steady it.

H

H beam. A structural rolled shape in the form of an H.

half breadth. One-half the full width of any object; also, the distance from the center line to the sides.

half width. One-half the full width of any object.
hatch. Opening in deck for passage of cargo, etc.
hatch battens. Flat bars that are wedged against hatch coamings to secure tarpaulins.
hatch beam. Portable beam across the hatch to support covers; also, strong beam at end of hatch.
hawse pipe. Casting extending through decks and side of ship at bow for the passage and stowage of anchor chain and stock less anchor.
hawser. Large rope for towing, mooring, and securing a ship.
header. A framing; a piece fitted between two girders usually in the way of openings. A pipe or casting into which several smaller pipes are led.
heeling. The listing of a vessel to one side.
height batten. A batten obtained from the body plan for the purpose of establishing heights of the ship structure on the ship.
hogging. Straining of the ship that tends to make the midship section higher than the bow and stern.
hold. Below deck; space used for the stowage of cargo.
hold beams. Beams in the hold for adding strength to ship's structure. Similar to deck beams, but having no plating on them.
horn. To line or square up.
hull. The body of the ship, including shell plating, framing, decks, and bulkheads.

I

I beam. A structural shape whose cross section resembles the letter I.
inboard. Toward the center line; inward.
inboard profile. Longitudinal section through center of ship.
inclination. A direction tendency from the true vertical or horizontal, as the inclination of a column or of a roadbed; hence, the amount of deviation from the vertical or horizontal plane.
innerbottom. The tank top. The upper surface of the double bottom, making right angles with the floors below.
inside staging. Staging used on the inside of the ship.
intercostal. Short lengths of plate or bar between frames, beams, etc., not continuous.
internal stiffening. Stiffening designed and installed on the inside of the hull, especially in connection with launching.
interpolate. To insert intermediate terms, as a series according to the law of the series; to calculate intermediate values from observed values, according to some assumed law or change in value.

J

jack. A portable machine variously constructed for exerting great pressure or lifting or moving a heavy body to a small distance; may be designed to be operated mechanically or hydraulically.
jack staff. A flagpole at bow of vessel.
jig. A form or frame used as a guide or pattern in construction or manufacturing; a form of mold.
joggle. To offset a plate or shape to avoid the use of liners.
joggled wedge. An offset spacer block used to maintain clearance between the sliding ways and the ground-way ribband.
joint. To join or fit together.
jointing a saw. Act or process of making the saw teeth even.

K

keel. The backbone of the ship's frame, running on the bottom along the center of the vessel in a fore-and-aft direction. Frames of the ship are attached to the keel.

keel, bar. Keel that protrudes through the bottom.

keel, flat. A row of flat plating along the ship's center line. The middle bottom-shell strake.

keel grade. The grade or declivity upon which the ship is being constructed.

keel track. A series of blocks on the center line of the shipway on which the keel of the ship is laid; thereafter, the main means of support during the construction of the ship.

keel, vertical. Vertical plating running on top of flat keel for reinforcement.

keelblocks. Heavy blocks on which the ship's keel rests during her construction.

keelson, side. Fore-and-aft plating on each side; similar to the vertical keel.

keeper block. A block of steel inserted between the trigger and the trigger latch; locks the trigger in position until the latch is released.

keyed together. Put together by means of keys or pitching spots; membering together two pieces in their proper relation to one another.

king post. Samson post. A stub mast outboard from the center line, used to carry cargo booms.

kink. A bend or turn; a twist or doubling in a rope caused by doubling or winding upon itself.

knuckle. A sharp bend in the plate or shape.

knuckle plate. A plate bent to form a knuckle.

L

lap. A joint in which one part overlaps the other, the use of butt straps being thus avoided.

lap strake. A strake of plating that is lapped on top of adjoining strakes.

launch-way foundation. The foundations or cribbing on which the ground ways are laid and set.

launch ways. The ground, or standing, ways and sliding ways used in connection with launching a vessel.

launching. The operation of placing the hull in the water by allowing it to slide down greased launching ways. During launching the weight of the hull is borne by the cradle and sliding ways, which are temporarily attached to the hull and slide with it down the ground ways.

launching grade. Grade or inclination of the ground ways.

lay (of a rope). The amount of twist put into a rope and its direction.

laying off. Marking shapes, plates, etc., for shearing, punching, etc.

length between perpendiculars. The ship's length measured from the forward perpendicular to the after perpendicular parallel to the base line.

length over-all. The length of the ship measured from the extreme forward end to the extreme afterend.

leveling up. To make level.

lift. To make a template from measurements taken on the job.

line up. To align.

liner. A filler used to bring one member in line with another, which it overlaps.

liner wedge. A tapered steel wedge generally used for wedging apart plating for the installation of liners.

lines. Plans of a ship that show its form.
lines plan. A plan showing the lines of form for a vessel.
listing. Heeling; leaning to one side.
load line. A line painted or marked on the hull of the vessel, denoting the depth to which she can be safely loaded.
loftsman. A mold-loft workman who lays off the ship's lines and develops templates from them.
longitudinal. A structural member running fore and aft, parallel or nearly parallel to the vertical keel.
longitudinal bulkhead. A bulkhead extending in a fore-and-aft direction in a vessel.
losing dimension. Measurement less than desired or designed dimensions.

M

main deck. The principal deck, usually occurring immediately below the shelter or weather deck.
male and female. Two engaging pieces, one of which is raised and the other recessed, as templates used in fitting the packing under the ship.
manhole. A round or oval-shaped hole in deck or bulkhead to allow the passage of a man.
margin plate. The outer row of plates of the inner-bottom connecting to the shell plating at the bilge.
marker. A brass pipe dipped into paint used in marking rivet holes.
marrying wedge. Wedges used in pairs, one on top the other, for lifting in a vertical direction; generally refers to wedges used on the keel track and bilge cribbings for adjusting.
mast. A large long spar extending nearly vertical on the center line of the ship.
mean low water. The intermediate level of low water between extremes of low tide.
midship. Of, pertaining to, or in the middle of a ship.
midship section. A cross section of a ship at midship point.
mock-up. A form constructed of light template wood and made to full size for the purpose of fitting patterns and templates to ensure their accuracy.
mold. A template or light pattern of a ship's part, usually made of paper or thin wood battens.
mold clamp. A spring-steel U-shaped clamp coming together at the ends, used for clamping templates in position.
mold clips. Spring clips used for fairing in.
mold loft. A shed or building with large smooth floors for laying off the lines of a ship to actual size from which templates are made for the structural work entering into a hull.
molded. The form of a ship without plating or planking.
molded breadth. The greatest breadth of a ship measured horizontally, exclusive of the outside plating.
molded depth. The vertical distance from the base line to the underside of the main deck; this is also registered depth.
monument. A stone or other permanent object erected to indicate a limit or to mark a boundary or line.
mooring. Holding a ship in position with the use of lines and cables to prevent moving or swinging.
mooring ring. A round casting located on the bulwark plating to prevent the chafing of mooring lines and cables passing through the plating.
mushroom. To spread out at the end so as to resemble a mushroom.

N

nonwatertight. Subdivisions or partitions in the interior of a ship not designed to retain water.

O

oakum. Material used to fill seams in wood decks, etc., usually made of untwisted fibers of old rope treated with a composition of resin and pitch.

offset. To set off out of line or position.

offsets. A table of molded dimensions for ship's lines made up from the mold-loft body plan.

oiltight. A sealed joint made by calking, riveting, or welding. (Closer than watertight.)

ordinate. One of the equally spaced vertical divisions between the forward and after perpendiculars, used for calculating volume, displacement, or form.

outboard. Toward the ship's sides from the center line.

outboard bulkhead. A line of piling used as a retaining wall at the water's edge at the sides of the shipway.

outboard foundations. The outboard piling that supports the outboard ground ways.

outboard profile. A plan representing the longitudinal exterior of a vessel showing the starboard side of the shell, all deck erections, masts, yards, rigging, rails, etc.

outboard ways. The portion of ground ways at the outboard end that extends away from the hull.

outrigger. Any spar or projecting timber beam run out for temporary use or, less commonly, as a permanent fixture.

outside staging. A platform from which workmen work on the outside of the ship.

outside supports. The keel track, cribbing, and shores that support the weight of the hull during its construction.

overboard. Outside, over the side of the ship; in the water.

overhang. The portion of the hull not supported by the water.

P

packing. Material placed between joints to make them watertight; also, wooden blocks and wedges used to contact the ship with the sliding ways.

paint line. A line in the area of the load line of a vessel used for painting the underwater portion of the shell with a type of paint to resist corrosion.

palm. Flat coupling of rudderstock; also, a flat surface at the end of struts or stanchions.

panting. In-and-out movement of ship's plating, caused by movement in water or engine vibration.

panting stringer. A fore-and-aft plate, angle, or built-up girder fitted between the side stringers in the bow and stern to reduce the in-and-out vibrations, or panting, of the frames and plating.

peak. Compartment at extreme bow or stern.

piling. Posts of wood, metal, or concrete driven into the earth along the bank of a body of water to support piers or outboard ground ways.

pillar. Stanchion; vertical column providing support.

pitching spot. A match mark or key mark for setting two members in their proper relation to one another, or an arbitrary mark from which a dimension may be taken.

pivoting point. The time during the launching of a vessel at which the moment of buoyancy about the fore poppets becomes equal to the moment of the vessel's weight. At this point the stern begins to lift, the vessel pivoting about the fore poppet.

plane. Level, flat. Also, a tool used by the shipwright for smoothing surfaces of wood.

planking. Wood covering.

plate. Steel or other metal rolled or cast into a constant thickness small in relation to its length and breadth.

platen. A flat platform on which subassemblies are built.

plating. Plates for hull, deck, bulkhead, etc.

Plimsoll mark. Mark on the side of a ship designating the depth to which a ship may be loaded.

plumb. Vertical; hanging perpendicularly.

plumb bob. A bob or pointed weight of a plumb line.

plumb up. To make plumb from the base; to cause to be perpendicular.

pontoon hatch cover. Steel box-shaped member used to close in cargo hatch.

poop. The after upper portion of the hull, usually containing the steering gear; also, the deck above the shelter deck.

port. The left-hand side of a ship looking forward; also, an opening in the ship's side.

porthole. A circular opening in the ship's side.

profile. Side elevation of ship.

propeller. A rotating device with three or four blades that drives a ship through the water.

propeller shaft. Rotating bar running from engines to propeller by means of which the engines turn the propeller.

push block. A structure secured to the ground ways at forward end of the sliding ways for the purpose of footing launching jacks in the event that the ship does not start when released.

Q

quicken. To lessen the radius of a curve to make it sharper; to snub. To quicken a water line is to make its curvature more pronounced.

R

rabbet. An offset designed to take or hold some other part.

race knife. A cutting tool with a blade that is hooked at the point for marking outlines on timber or material.

rail. The rounded section at the upper edge of the bulwarks.

rake. An inclination from vertical of a shore, mast, smokestack, etc.

rally. Men uniting in driving wedges when launching a vessel.

ram. A heavy oblong timber with reinforced metallic ends, used for exerting hard blows against the ship's underpinning.

reaming. Enlarging a punched or drilled hole.

regulate. To adjust.

reverse frame. A shape fastened to the inner edge of a transverse frame for reinforcement.

ribband. A wooden strip running fore and aft, used temporarily to align the transverse frames. (See also fairing, framing, and auxiliary ribband.)

ribbanding. Installing ribbands.
riveting. Fastening two pieces of metal together with rivets.
riveting strips. Flat-bar strips riveted to the deck and shell for securing bulkheads and other structure where it is not expedient to weld directly joining members.
roll. To put curvature in a plate. Alternate raising and lowering of the sides of deck.
rolled plate. Plate that can be shaped by rolling through a plate roll.
rubbing bar. A plate riveted to the bottom of a keel to give protection in docking and grounding.
rudder. A large, flat, heavy fitting hinged to the stern frame, and used for steering the ship.
rudder stop. Lug on stern frame or shell to limit the swing of the rudder.
rudderpost. Sternpost. After post of stern frame to which the rudder is hung.
rudderstock. Shaft of rudder, which extends from rudder upward to steering gear.

S

saddle straps. Steel-plate bellybands used at the forward end of the ship for support during launching.
sag. The dropping or tendency to droop of the midship portion of a vessel relative to the ends.
sagging. When the middle portion of a ship is lower than the bow and stern.
sand block. A box filled with sand that replaces the solid keelblocks under the ship prior to launching. When the sand is released from the box by pulling a lever, the top of the box will collapse, thus clearing the keel track.
scantlings. The dimensions of various parts of a ship's structure, such as frames, girders, or plating.
scarf. A connection made between two fitting parts by tapering their ends so that they will mortise together with the same thickness as the pieces connected.
screen bulkhead. A dustproof bulkhead usually placed between engine and boiler rooms.
scribe. To make a mark; to write. Also, a pointed tool used for marking steel or other hard surfaces.
scrive board. A portable platform made of soft, clear, planed lumber on which a full-sized body plan of a ship is drawn, the lines being cut into the surface of the wood in small U-shaped grooves by means of a scriving knife, to prevent them from being obliterated. The scrive board is placed in some convenient place as a ready reference for shapes of frames, floors, etc.
scupper. A deck drain.
sea chest. A compartment open to the sea through which sea water may be admitted or discharged.
seam. A plate-edge overlap. Riveted edges must overlap, forming a seam. Welded joints may or may not overlap. Also, any lengthwise or side joint.
seam strap. A strap connecting plates, thus forming a flat seam.
semi-submerged shipway. A foundation, designed with the lower end below water level, for the construction of ships. It is provided with a floodgate so that the shipway can be pumped dry during ship construction.
set. Metal mold for use on a bending slab.
set iron. A bar of soft iron used on a bending slab to give shape to the frame.
shaft alley. A casing covering the propeller shaft from engine room to afterpeak to protect and provide access to shaft.
shape. A bar of constant cross section through its entire length, such as a channel, T bar, or angle bar.

shear. A stress that tends to cause adjacent parts to slide over one another. Also, to cut.

shear line. A line to which a shearing cut is to be made.

sheer. Fore-and-aft curvature of a deck.

sheer line. The longitudinal curve of the rail or decks, which shows the variation in height above water or freeboard, throughout the vessel's entire length.

sheer strake. The top full course of side shell plating.

sheet lines. Lines indicating the edges of the shell plating which run fore and aft.

shell expansion. A drawing showing both the bottom and the side shell expanded and drawn as a flat surface.

shell plating. The outer skin of the hull.

shelter deck. A continuous superstructure deck above the freeboard deck.

shim. A wedge used for truing up shores.

shipway. A foundation for supporting ships during their construction.

shore. A brace or prop.

sight edge. Visible edge of outside shell plating.

skeg. The afterend of the keel.

skids. Timbers on which structural parts are moved to desired positions.

skin. The outside planking or plating forming the watertight envelope over the framework. The inner-bottom plating is called the *inner skin.*

skylight. Opening in deck to give air and light to compartments below.

sliding way. That part of launching way which slides over the ground ways with the ship when it is launched.

spar. A long round mast or boom used to carry rigging.

spaul. A support shaped to fit the designed hull at given frames. It forms a cradle for supporting the bottom shell until the internal structure is secured sufficiently to be supported by shores and bilge cribbings. Also, an arm or limb projecting from staging standards for supporting stage planking.

spile. A long light measuring rod or rule notched to hold a pencil.

spiling. Figures showing the distance of a curved beam or surface from the edge of a template or curve; act or process of measuring or marking off with a spile.

splice. A method of uniting two ropes by first unlaying, then interweaving and tucking the strands.

spur shore. A diagonal brace or support.

stability. The ability of a ship to remain upright.

stage planking. Timber plank used for staging.

staging. Scaffolding on which to stand in working on outside of ship or high places on board the ship.

staging standard. Wooden or steel structures used to support the outside staging in the construction of a vessel.

stanchion. A vertical post or pillar.

starboard. The right-hand side of a ship looking forward.

stay. A guy line.

stealer. A plate extending into the end of an adjoining strake; this usually occurs near the bow or stern.

steering gear. Apparatus for controlling rudder.

stem. The extreme bow of the ship, extending from keel to forecastle deck.

step. To put in place.

stern. The afterend of a ship.

stern frame. A large casting or forging attached to afterend of the hull to form the ship's stern. Includes rudderpost and propeller post.

stern tube. A bushing through the stern to support the propeller shaft.
sternpost. The main vertical post in a stern frame upon which the rudder is hung.
stiffener. A shape used to stiffen plating.
stiffening. Structural angles or shapes and plates secured to the ordinary structure for the purpose of strengthening at points found weak when calculated for design.
stocks. A common name for the elevated shipway.
stool. A support for the propeller-shaft bearing in the shaft alley.
stowage. Everything for support and fastening of articles to be stowed.
strake. A continuous row of plates. The strakes of shell plating are usually lettered, starting with A at the bottom row; thus, A strake, B strake, etc.
stress. The intensity of the force per unit area that tends to alter the form of a solid body.
stringer. A fore-and-aft member used to give longitudinal strength to the shell.
stringer plate. Deck plate at outboard edge.
strongback. Supporting girder for hatch covers. Rig used for strengthening bent plates.
strut. Outboard support for propeller tail shaft.
strut arm. A steel member extending from the side of the strut barrel for the purpose of supporting and securing the barrel in its proper alignment.
strut of a shore. The inclination of a shore from a vertical line.
stylus. A sharp-pointed tool for scribing steel plates.
subassembly. The assembling of portions of ship structure on the platens before it is brought into the ship.
superstructure. That part of a ship's structure extending above the uppermost complete deck.
swash plate. A plate fitted athwartship or fore and aft in tanks for preventing excessive flow of the liquid that the tanks may contain.
sweet line. A smooth line without humps or abrupt breaks; a fair line.

T

tackbolt. A temporary holding bolt.
tack weld. A weld used for assembling purposes only.
tail shaft. That portion of the propeller shaft extending through the stern tube and carrying the propeller.
taken from work. Measured from actual conditions.
tank top. The inner-bottom plating.
tanks. Compartments for liquids or gases.
tarpaulin. A waterproof canvas covering.
T bar. A structural shape whose cross section resembles the letter T.
telltale. A device that indicates the keel settlement of a vessel or the crushing of the crushing strips during launching.
template. A pattern made to full size; a mold.
tension. Stress caused by pulling.
tension brace. A brace installed to pull; to be in tension.
thrust bearing. A bearing to resist thrust. A bearing on the propeller shaft that relieves the engine from the driving force of the propeller and transfers it to the structure of the ship.
tie plates. Long narrow plates used to tie deck beams together where there is no steel deck plating. Also used for securing the cradle together at the forward end.
toggle. A device for fastening frapping or cables to be used on packing at the time of launching for holding the packing in place.

transit. A surveyor's instrument to measure angles.
transom. The aftermost transverse frame.
transverse. At right angles to the keel; athwartship.
transverse bulkhead. A bulkhead across the ship, from side to side.
transverse frames. Athwartship members forming the ship's ribs.
trigger pit. A pit under the ground ways in which triggers for releasing the ship at the time of launching are located.
trim. To make a ship change its position in the water by shifting ballast. Drag.
trunk. A casing passing through a deck used for ladders, ventilation, elevators, etc.
tumble home. An inboard slant of a ship's side above the bilge.
turnbuckle. A loop or sleeve with a screw thread at one end and a swivel at the other; or a right-and-left screw link, used for pulling the ship structure to the proper position.

U

U clip. A clip or plate cut in the shape of the letter U.
Unionmelt welding. A trade name for a type of automatic welding.
upset metal. Metal upset by heating.
uptake. Casing between boiler and smokestack.

V

V butt weld. Two plates butted together and welded after the edges have been chamfered off to form a V.
vertical keel. A row of vertical plates extending along the center of the flat keel.

W

water line. The intersection of any horizontal plane with the molded form of a ship. Any one of certain lines of a ship parallel with the base line.
water-borne. A vessel afloat in the water immediately after launching.
watertight. Waterproof. To prevent the passage of water.
waterway. A gutter; a narrow passage along the edge of a deck for the drainage of the deck.
way-end pressure. Pressure at the ends of the ground ways, both on the ways and against the hull during launching.
ways. Timbers, etc., on which a ship is built or launched.
weather deck. A watertight deck exposed to the weather.
web. The vertical portion of a beam; the athwartship portion of a frame, etc.
web frame. A frame with a deep flange or web.
wedge rider. Timbers of the launching cradle laid on driving-up wedges.
wedges. Pieces of wood or metal shaped in the form of a V, used for driving up or for separating work.
welding. Making a joint of two metal parts by fusing the metal in between them or by forging together at welding heat.
welding sequence. The order in which welding is performed.
weldment. An assembly consisting of members welded together.
well. A sump in the inner bottom or bottom of a ship to which bilge water runs, so that it may be pumped out.
whipping. To bind up the ends of ropes to prevent unraveling.

winch. A hoisting engine used in pulling lines and handling cargo.
windlass. A machine for hoisting anchors by winding the anchor chain.
wood screws. Threaded nails with slotted heads.

X

X bracing. Bracing in the form of the letter X.

Y

yard grade. Ground line or grade of shipyard.

Z

Z bar. A structural shape whose cross section resembles the letter Z.

APPENDIX

Measures of Extension

Measures of extension are used in measuring lengths, distances, surfaces, and solids.

12 inches = 1 foot
3 feet = 1 yard
$5\frac{1}{2}$ yards, or $16\frac{1}{2}$ feet = 1 rod
(3 feet = 1 pace; 5 paces = 1 rod—used in pacing distances.)
320 rods = 1 mile
6 feet = 1 fathom
1.15 statute miles = 1 nautical mile, or 1 knot
3 geographical miles = 1 league
5280 feet = 1 mile
6080.20 feet = 1 nautical mile

Square Measure

144 square inches = 1 square foot
9 square feet = 1 square yard
$30\frac{1}{4}$ square yards = 1 square rod
160 square rods = 1 acre
640 acres = 1 square mile

Cubic Measure

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
128 cubic feet = 1 cord

Surveyor's Lineal Measure

7.92 inches = 1 link
25 links = 1 rod
4 rods or 100 links = 1 chain
80 chains = 1 mile

Liquid Measure

4 gills = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
7.480 gallons = 1 cubic foot

Avoirdupois Weight

16 ounces = 1 pound
100 pounds = 1 cental
2000 pounds = 1 short ton
2240 pounds = 1 long ton

Board Measure

1 board foot = 144 cubic inches = volume of board 1 foot square and 1 inch thick

Circular Measure

60 seconds = 1 minute
60 minutes = 1 degree
90 degrees = 1 quadrant
360 degrees = circumference

LAYING OFF ANY ANGLE WITH A STEEL SQUARE

The table below gives values for measurements on the tongue and body of the square so that by joining points corresponding to the measurements, any angle from 1 to 45 deg. may be laid out.

Angle, Deg.	Tongue	Body	Angle, Deg.	Tongue	Body
1	0.35	20.	24	8.13	18.27
2	0.7	19.99	25	8.45	18.13
3	1.05	19.97	26	8 77	17.98
4	1.40	19.95	27	9.08	17.82
5	1.74	19.92	28	9.39	17.66
6	2.09	19.89	29	9.7	17.49
7	2.44	19.85	30	10	17.32
8	2.78	19.81	31	10.3	17.14
9	3.13	19.75	32	10.6	16.96
10	3.47	19.7	33	10.89	16.77
11	3.82	19.65	34	11.18	16.58
12	4.16	19.56	35	11.47	16.38
13	4.5	19.49	36	11.76	16.18
14	4.84	19.41	37	12.04	15.98
15	5.18	19.32	38	12.31	15.76
16	5.51	19.23	39	12.59	15.54
17	5.85	19.13	40	12.87	15.32
18	6.18	19.02	41	13.12	15.09
19	6.51	18.91	42	13.38	14.86
20	6.84	18.79	43	13.64	14.63
21	7.17	18.67	44	13.89	14.39
22	7.49	18.54	45	14.14	14.14
23	7.8	18.4			

By measurement, it will be found that the distance from the outside of the blade to the outside of the tongue will be 20 in. for any angle in this table. This is because the distance from the heel of the square to the point indicated by the table is, respectively, the natural sine and natural cosine multiplied by 20.

TABLE XVI.—DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH

Fraction		Decimal	Fraction		Decimal
	1/64	.015625		33/64	.515625
	1/32	.03125		17/32	.53125
	3/64	.046875		35/64	.546875
1/16		.0625	9/16		.5625
	5/64	.078125		37/64	.578125
	3/32	.09375		19/32	.59375
	7/64	.109375		39/64	.609375
1/8		.125	5/8		.625
	9/64	.140625		41/64	.640625
	5/32	.15625		21/32	.65625
	11/64	.171875		43/64	.671875
3/16		1875	11/16		.6875
	13/64	203125		45/64	.703125
	7/32	.21875		23/32	.71875
	15/64	.234375		47/64	.734375
1/4		.25	3/4		.75
	17/64	.265625		49/64	.765625
	9/32	.28125		25/32	.78125
	19/64	.296875		51/64	.796875
5/16		3125	13/16		.8125
	21/64	328125		53/64	.828125
	11/32	34375		27/32	84375
	23/64	.359375		55/64	859375
3/8		375	7/8		.875
	25/64	.390625		57/64	.890625
	13/32	.40625		29/32	.90625
	27/64	.421875		59/64	.921875
7/16		.4375	15/16		.9375
	29/64	.453125		61/64	.953125
	15/32	.46875		31/32	.96875
	31/64	.484375		63/64	.984375
1/2		.50	1		1

TABLE XVII.—INCHES AND FRACTIONS OF AN INCH IN DECIMALS OF A FOOT

	0	1	2	3	4	5	6	7	8	9	10	11
1/16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1/8	.0104	.0938	.1771	.2604	.3438	.4271	.5104	.5938	.6771	.7604	.8438	.9271
3/16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1/4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5/16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3/8	.0313	.1146	.1979	.2813	.3646	.4479	.5313	.6146	.6979	.7813	.8646	.9479
7/16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1/2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9/16	.0469	.1302	.2135	.2969	.3803	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5/8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11/16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3/4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13/16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7/8	.0729	.1563	.2396	.3229	.4063	.4896	.5729	.6563	.7396	.8229	.9063	.9896
15/16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
1	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167	1.000

TABLE XVIII.—½ IN. PER FT. DECLIVITY TABLE

24′	12	12 1/16	12 3/32	12 1/8	12 5/32	12 3/16	12 1/4	12 5/16	12 11/32	12 3/8	12 13/32	12 7/16
23′	11 1/2	11 9/16	11 19/32	11 5/8	11 21/32	11 11/16	11 3/4	11 13/16	11 27/32	11 7/8	11 29/32	11 15/16
22′	11	11 1/16	11 3/32	11 1/8	11 5/32	11 3/16	11 1/4	11 5/16	11 11/32	11 3/8	11 13/32	11 7/16
21′	10 1/2	10 9/16	10 19/32	10 5/8	10 21/32	10 11/16	10 3/4	10 13/16	10 27/32	10 7/8	10 29/32	10 15/16
20′	10	10 1/16	10 3/32	10 1/8	10 5/32	10 3/16	10 1/4	10 5/16	10 11/32	10 3/8	10 13/32	10 7/16
19′	9 1/2	9 9/16	9 19/32	9 5/8	9 21/32	9 11/16	9 3/4	9 13/16	9 27/32	9 7/8	9 29/32	9 15/16
18′	9	9 1/16	9 3/32	9 1/8	9 5/32	9 3/16	9 1/4	9 5/16	9 11/32	9 3/8	9 13/32	9 7/16
17′	8 1/2	8 9/16	8 19/32	8 5/8	8 21/32	8 11/16	8 3/4	8 13/16	8 27/32	8 7/8	8 29/32	8 15/16
16′	8	8 1/16	8 3/32	8 1/8	8 5/32	8 3/16	8 1/4	8 5/16	8 11/32	8 3/8	8 13/32	9 7/16
15′	7 1/2	7 9/16	7 19/32	7 5/8	7 21/32	7 11/16	7 3/4	7 13/16	7 27/32	7 7/8	7 29/32	7 15/16
14′	7	7 1/16	7 3/32	7 1/8	7 5/32	7 3/16	7 1/4	7 5/16	7 11/32	7 3/8	7 13/32	7 7/16
13′	6 1/2	6 9/16	6 19/32	6 5/8	6 21/32	6 11/16	6 3/4	6 13/16	6 27/32	6 7/8	6 29/32	6 15/16
12′	6	6 1/16	6 3/32	6 1/8	6 5/32	6 3/16	6 1/4	6 5/16	6 11/32	6 3/8	6 13/32	6 7/16
11′	5 1/2	5 9/16	5 19/32	5 5/8	5 21/32	5 11/16	5 3/4	5 13/16	5 27/32	5 7/8	5 29/32	5 15/16
10′	5	5 1/16	5 3/32	5 1/8	5 5/32	5 3/16	5 1/4	5 5/16	5 11/32	5 3/8	5 13/32	5 7/16
9′	4 1/2	4 9/16	4 19/32	4 5/8	4 21/32	4 11/16	4 3/4	4 13/16	4 27/32	4 7/8	4 29/32	4 15/16
8′	4	4 1/16	4 3/32	4 1/8	4 5/32	4 3/16	4 1/4	4 5/16	4 11/32	4 3/8	4 13/32	4 7/16
7′	3 1/2	3 9/16	3 19/32	3 5/8	3 21/32	3 11/16	3 3/4	3 13/16	3 27/32	3 7/8	3 29/32	3 15/16
6′	3	3 1/16	3 3/32	3 1/8	3 5/32	3 3/16	3 1/4	3 5/16	3 11/32	3 3/8	3 13/32	3 7/16
5′	2 1/2	2 9/16	2 19/32	2 5/8	2 21/32	2 11/16	2 3/4	2 15/16	2 27/32	2 7/8	2 29/32	2 15/16
4′	2	2 1/16	2 3/32	2 1/8	2 5/32	2 3/16	2 1/4	2 5/16	2 11/32	2 3/8	2 13/32	2 7/16
3′	1 1/2	1 9/16	1 19/32	1 5/8	1 21/32	1 11/16	1 3/4	1 13/16	1 27/32	1 7/8	1 29/32	1 15/16
2′	1	1 1/16	1 3/32	1 1/8	1 5/32	1 3/16	1 1/4	1 5/16	1 11/32	1 3/8	1 13/32	1 7/16
1′	1/2	9/16	19/32	5/8	21/32	11/16	3/4	13/16	27/32	7/8	29/32	15/16
0′	0	1/16	3/32	1/8	5/32	3/16	1/4	5/16	11/32	3/8	13/32	7/16
	0″	1″	2″	3″	4″	5″	6″	7″	8″	9′	10″	11″

Table XIX.—9/16 In. per Ft. Declivity Table

24′	13 1/2	13 17/32	13 19/32	13 5/8	13 11/16	13 23/32	13 25/32	13 13/16	13 7/8	13 15/16	13 31/32	14
23′	12 15/16	12 31/32	13	13 1/16	13 1/8	13 5/32	13 7/32	13 1/4	13 5/16	13 3/8	13 13/32	13 7/16
22′	12 3/8	12 13/32	12 15/32	12 1/2	12 9/16	12 19/32	12 21/32	12 11/16	12 3/4	12 13/16	12 27/32	12 7/8
21′	11 13/16	11 27/32	11 29/32	11 15/16	12	12 1/32	12 3/32	12 1/8	12 3/16	12 1/4	12 9/32	12 5/16
20′	11 1/4	11 9/32	11 11/32	11 3/8	11 7/16	11 15/32	11 17/32	11 9/16	11 5/8	11 11/16	11 23/32	11 3/4
19′	10 11/16	10 23/32	10 25/32	10 13/16	10 7/8	10 29/32	10 31/32	11	11 1/16	11 1/8	11 5/32	11 3/16
18′	10 1/8	10 5/32	10 7/32	10 1/4	10 5/16	10 11/32	10 13/32	10 7/16	10 1/2	10 9/16	10 19/32	10 5/8
17′	9 9/16	9 19/32	9 21/32	9 11/16	9 3/4	9 25/32	9 27/32	9 7/8	9 15/16	10	10 1/32	10 1/16
16′	9	9 1/32	9 3/32	9 1/8	9 3/16	9 7/32	9 9/32	9 5/16	9 3/8	9 7/16	9 15/32	9 1/2
15′	8 7/16	8 15/32	8 17/32	8 9/16	8 5/8	8 21/32	8 23/32	8 3/4	8 13/16	8 7/8	8 29/32	8 15/16
14′	7 7/8	7 29/32	7 31/32	8	8 1/16	8 3/32	8 5/32	8 3/16	8 1/4	8 5/16	8 11/32	8 3/8
13′	7 5/16	7 11/32	7 13/32	7 7/16	7 1/2	7 17/32	7 19/32	7 5/8	7 11/16	7 3/4	7 25/32	7 13/16
12′	6 3/4	6 25/32	6 27/32	6 7/8	6 15/16	6 31/32	7 1/32	7 1/16	7 1/8	7 3/16	7 7/32	7 1/4
11′	6 3/16	6 7/32	6 9/32	6 5/16	6 3/8	6 13/32	6 15/32	6 1/2	6 9/16	6 5/8	6 21/32	6 11/16
10′	5 5/8	5 21/32	5 23/32	5 3/4	5 13/16	5 27/32	5 29/32	5 15/16	6	6 1/16	6 3/32	6 1/8
9′	5 1/16	5 3/32	5 5/32	5 3/16	5 1/4	5 9/32	5 11/32	5 3/8	5 7/16	5 1/2	5 17/32	5 9/16
8′	4 1/2	4 17/32	4 19/32	4 5/8	4 11/16	4 23/32	4 25/32	4 13/16	4 7/8	4 15/16	4 31/32	5
7′	3 15/16	3 31/32	4	4 1/16	4 1/8	4 5/32	4 7/32	4 1/4	4 5/16	4 3/8	4 13/32	4 7/16
6′	3 3/8	3 13/32	3 15/32	3 1/2	3 9/16	3 19/32	3 21/32	3 11/16	3 3/4	3 13/16	3 27/32	3 7/8
5′	2 13/16	2 27/32	2 29/32	2 15/16	3	3 1/32	3 3/32	3 1/8	3 3/16	3 1/4	3 9/32	3 5/16
4′	2 1/4	2 9/32	2 11/32	2 3/8	2 7/16	2 15/32	2 17/32	2 9/16	2 5/8	2 11/16	2 23/32	2 3/4
3′	1 11/16	1 23/32	1 25/32	1 13/16	1 7/8	1 29/32	1 31/32	2	2 1/16	2 1/8	2 5/32	2 3/16
2′	1 1/8	1 5/32	1 7/32	1 1/4	1 5/16	1 11/32	1 13/32	1 7/16	1 1/2	1 9/16	1 19/32	1 5/8
1′	9/16	19/32	21/32	11/16	3/4	25/32	27/32	7/8	15/16	1	1 1/32	1 1/16
0	0	1/32	3/32	1/8	3/16	7/32	9/32	5/16	3/8	7/16	15/32	1/2
	0	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11′

TABLE XX.—5/8 IN. PER FT. DECLIVITY TABLE

24′	15	15 1/16	15 1/8	15 5/32	15 7/32	15 9/32	15 5/16	15 3/8	15 7/16	15 15/32	15 17/32	15 19/32
23′	14 3/8	14 7/16	14 1/2	14 17/32	14 19/32	14 21/32	14 11/16	14 3/4	14 13/16	14 27/32	14 29/32	14 31/32
22′	13 3/4	13 13/16	13 7/8	13 29/32	13 31/32	14 1/32	14 1/16	14 1/8	14 3/16	14 7/32	14 9/32	14 11/32
21′	13 1/8	13 3/16	13 1/4	13 9/32	13 11/32	13 13/32	13 7/16	13 1/2	13 9/16	13 19/32	13 21/32	13 23/32
20′	12 1/2	12 9/16	12 5/8	12 21/32	12 23/32	12 25/32	12 13/16	12 7/8	12 15/16	12 31/32	13 1/32	13 3/32
19′	11 7/8	11 15/16	12	12 1/32	12 3/32	12 5/32	12 3/16	12 1/4	12 5/16	12 11/32	12 13/32	12 15/32
18′	11 1/4	11 5/16	11 3/8	11 13/32	11 15/32	11 17/32	11 9/16	11 5/8	11 11/16	11 23/32	11 25/32	11 27/32
17′	10 5/8	10 11/16	10 3/4	10 25/32	10 27/32	10 29/32	10 15/16	11	11 1/16	11 3/32	11 5/32	11 7/32
16′	10	10 1/16	10 1/8	10 5/32	10 7/32	10 9/32	10 5/16	10 3/8	10 7/16	10 15/32	10 17/32	10 19/32
15′	9 3/8	9 7/16	9 1/2	9 17/32	9 19/32	9 21/32	9 11/16	9 3/4	9 13/16	9 27/32	9 29/32	9 31/32
14′	8 3/4	8 13/16	8 7/8	8 29/32	8 31/32	9 1/32	9 1/16	9 1/8	9 3/16	9 7/32	9 9/32	9 11/32
13′	8 1/8	8 3/16	8 1/4	8 9/32	8 11/32	8 13/32	8 7/16	8 1/2	8 9/16	8 19/32	8 21/32	8 23/32
12′	7 1/2	7 9/16	7 5/8	7 21/32	7 23/32	7 25/32	7 13/16	7 7/8	7 15/16	7 31/32	8 1/32	8 3/32
11′	6 7/8	6 15/16	7	7 1/32	7 3/32	7 5/32	7 3/16	7 1/4	7 5/16	7 11/32	7 13/32	7 15/32
10′	6 1/4	6 5/16	6 3/8	6 13/32	6 15/32	6 17/32	6 9/16	6 5/8	6 11/16	6 23/32	6 25/32	6 27/32
9′	5 5/8	5 11/16	5 3/4	5 25/32	5 27/32	5 29/32	5 15/16	6	6 1/16	6 3/32	6 5/32	6 7/32
8′	5	5 1/16	5 1/8	5 5/32	5 7/32	5 9/32	5 5/16	5 3/8	5 7/16	5 15/32	5 17/32	5 19/32
7′	4 3/8	4 7/16	4 1/2	4 17/32	4 19/32	4 21/32	4 11/16	4 3/4	4 13/16	4 27/32	4 29/32	4 31/32
6′	3 3/4	3 13/16	3 7/8	3 29/32	3 31/32	4 1/32	4 1/16	4 1/8	4 3/16	4 7/32	4 9/32	4 11/32
5′	3 1/8	3 3/16	3 1/4	3 9/32	3 11/32	3 13/32	3 7/16	3 1/2	3 9/16	3 19/32	3 21/32	3 23/32
4′	2 1/2	2 9/16	2 5/8	2 21/32	2 23/32	2 25/32	2 13/16	2 7/8	2 15/16	2 31/32	3 1/32	3 3/32
3′	1 7/8	1 15/16	2	2 1/32	2 3/32	2 5/32	2 3/16	2 1/4	2 5/16	2 11/32	2 13/32	2 15/32
2′	1 1/4	1 5/16	1 3/8	1 13/32	1 13/32	1 17/32	1 9/16	1 5/8	1 11/16	1 23/32	1 25/32	1 27/32
1′	5/8	11/16	3/4	25/32	27/32	29/32	15/16	1	1 1/16	1 3/32	1 5/32	1 2/32
0′	0	1/16	1/8	5/32	7/32	9/32	5/16	3/8	7/16	15/32	17/32	19/32
	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″

TABLE XXI.—RIGHT-ANGLE TRIANGLES COMPOSED OF WHOLE NUMBERS

Height	Base	Hypotenuse	Height	Base	Hypotenuse
3	4	5	14	48	50
5	12	13	15	20	25
6	8	10	15	36	39
7	24	25	15	112	113
8	15	17	16	30	34
9	12	15	16	63	65
9	40	41	17	144	145
10	24	26	18	24	30
11	60	61	18	80	82
12	16	20	19	180	181
12	35	37	20	21	29
13	84	85	20	48	52
			20	99	101

INDEX

C

F

G

M