INTERNATIONAL LIBRARY OF TECHNOLOGY

A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

THE FORMATION OF LETTERS
MECHANICAL DRAWING
STRUCTURAL DRAFTING
SKETCHING

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, help one to select the proper formula, method, or process and in teaching him how and when it should be used.

This volume includes the following four titles: Mechanical Drawing, Structural Drafting, Sketching, and The Formation of Letters. The paper on Mechanical Drawing is the most thorough, practical, and up-to-date treatise on this subject in print, and every possible care has been taken to make the text correspond in every respect to the best modern drafting-room practice. Structural Drafting is a special application of mechanical drawing to the details of structural engineering, and is the only thorough presentation of this subject in print. Sketching is a small but complete treatise on the making of freehand drawings of machinery, etc., which are intended to be worked up into, or to take the place of, finished working or mechanical drawings. In style and manner of treatment, this paper is unique. The sketches illustrated are exact reproductions, both in size and execution, of the original pencil sketches, which were made under the same conditions that would prevail in actual practice. The Formation of Letters treats on all the various standard alphabets used in lettering and in sign painting. Full directions are given for each letter, and all possible care has been taken to secure correct outlines.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part is complete in itself; hence, to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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THE FORMATION OF LETTERS

ALPHABETS

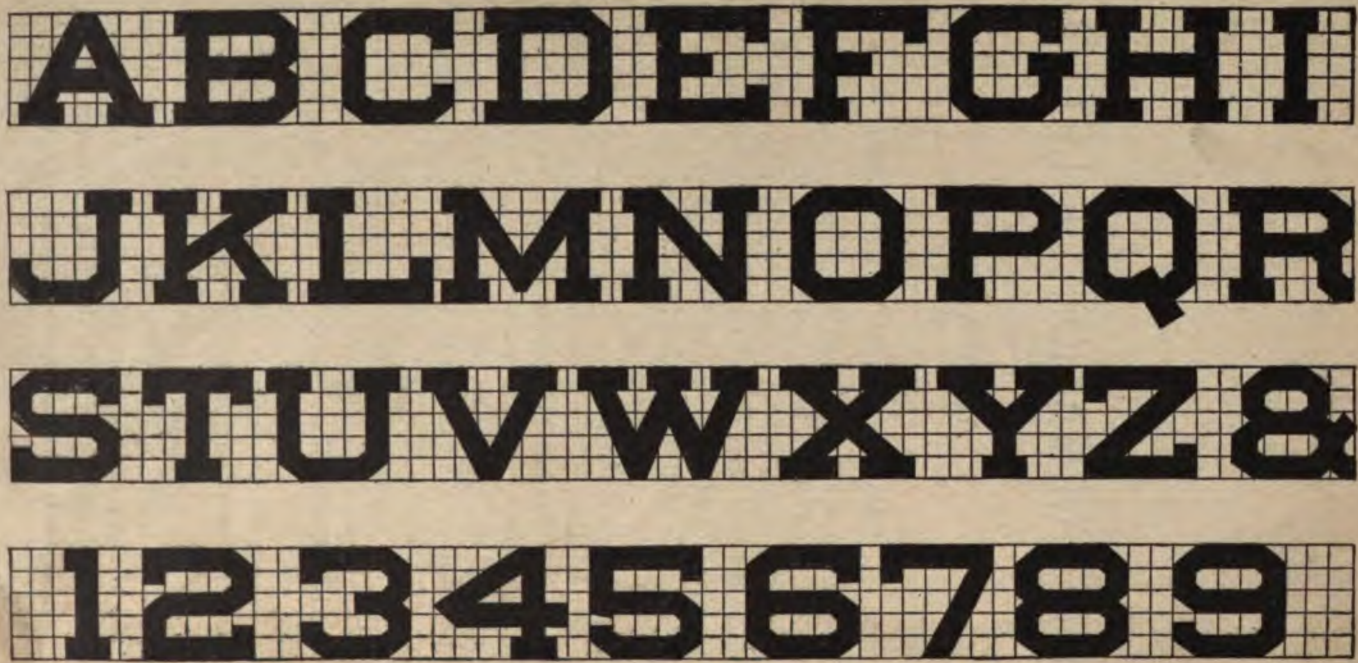
PLATE, TITLE: FULL BLOCK

1. Fasten a sheet of drawing paper 15 inches wide and 20 inches long on the board with thumbtacks, being careful to keep the edges of the paper parallel with those of the drawing board. Then, with a sharp-pointed lead pencil, draw a rectangle 15 inches long and $8\frac{1}{4}$ inches wide, which allows a margin of $2\frac{1}{2}$ inches on either side, and $3\frac{3}{8}$ inches above and below the figure. These pencil lines will be erased when the work of drawing the plate is completed. Beginning on the left vertical line, at the base of the rectangle, measure off the height of the letters, making four spaces $1\frac{1}{4}$ inches high, allowing a space of $\frac{3}{4}$ inch between the four lines of letters. This brings the top of the first line of letters 1 inch from the top pencil line. The height of the title is $\frac{1}{2}$ inch, and is $\frac{1}{2}$ inch above the first line of letters.

Horizontal lines are then drawn with the **T** square from the points marked on the left vertical border line, and extended to the right border line. Each of the $1\frac{1}{4}$-inch spaces is now divided into five smaller spaces of $\frac{1}{4}$ inch each, and vertical lines are drawn through the spaces, dividing them into a number of $\frac{1}{4}$-inch squares as shown.

2. On this plate, the stroke of each letter and numeral occupies the width of one square (or $\frac{1}{4}$ inch), and in giving the proportions of any part of a letter it is measured in strokes and fractions of a stroke. For instance, the letter

FULL BLOCK



A is 5 strokes wide, and the spurs project beyond the width of the letter ½ stroke (or ⅛ inch in this case) on each side.

The lines forming the vertical sides of the square are assumed to be numbered separately for each letter, according to its width. Thus, the lines between which the letter A is drawn, exclusive of spurs, are numbered from *1* to *6*; W occupies seven spaces, and is limited by lines *1* and *8*; M lies between lines *1* and *7*; etc. All the letters being of the same height, they are included between the same horizontal lines; therefore, the spaces between the lines *a*, *b*, *c*, etc. to *f* are each one-fifth the height of a letter. In referring to any particular point in a letter, it is necessary simply to name the two lines that intersect at or near that point. For example, *6 d* would be the intersection of vertical line *6* and horizontal line *d*, and would refer in the letter L to the extreme upper right-hand corner of the lower extremity of the letter; while in the letter W it would refer to the intersection of the interior slanting outlines of the right portion of the letter. These matters must be borne in mind as the plates are studied.

3. The Full Block shown on this plate, and the Half Block, which is the title of the next plate, are the only styles of letters given here that can be classified as strictly mechanical. Nearly all letters are somewhat mechanical, as their straight lines are drawn with a ruling pen, though the curved portions may be drawn freehand with the point of the red-sable brush. The style shown on this plate, however, is strictly mechanical, as no curves or irregular lines enter into its construction, and it can be drawn exclusively with a straightedge and pencil. The slightest curve or irregular line would require the free use of the hand, and call on the judgment of the eyes to make the lines symmetrical and true. This plate is a simple one, but to remember the comparative width of all the letters and the exact position of every detail of each letter will require close attention and study.

The **Full Block letter** is made square, occupying, exclusive of the spurs, five spaces in width and five in height. The middle bars of all the letters and numerals occupy the middle space between the lines, excepting those of the letter A and the numeral 4, which, in each case, is dropped one-half a space (or $\frac{1}{8}$ inch). The width of the letter is always measured between lines *1* and *6*, thus excluding the spur. Of all the slanting strokes in the various letters, those of the N, V, and W are the only ones that extend to the bottom line, and are finished without a spur on the lower extremity.

Full Block letters do not possess any rounded corners, but such letters as would possess rounded lines in other styles, as B, C, D, etc., are beveled on the angles with a line drawn diagonally through the corner block (as shown in the letter S) from point *a 2* to a point one-fourth the width of the stroke (or $\frac{1}{16}$ inch) above *b 1*, and from *f 5* to a point $\frac{1}{4}$ stroke below *e 6*. With few exceptions, the width of the stroke should be the same in all parts of the letter. A slanting line is therefore drawn on the inside of the letter, parallel with the outside beveled corner, and never more than the width of the stroke from it, and occasionally less, as shown in the letter B at *c 5* and *d 5*, where the thickness of the slanting line is only $\frac{1}{8}$ inch, which makes it appear better than when given the full width.

4. There are many irregular features in letters of every style, and it is well to become familiar with them, as they assist in learning the characteristic features of each letter. The extremities of the C are longer than those of the E or F, on account of the inside bevel line of the C, which would make the extremity of that letter appear too short, while the corresponding point on the G is the same length as the E and F, in order to allow as much space as possible between this and the lower extremities of the letter. The lower extremities of the J and L are carried up to line *d* on account of the open space within these letters.

5. To determine the proper slant of the strokes in such letters as N, V, X, and Y when two given points are on opposite sides of the stroke, as well as on opposite ends, as in the letter N, for example, at *2 a* and *5 f*, carry an imaginary line, as nearly the proper slant as possible, in opposite directions from each of these points and $\frac{1}{4}$ inch apart. Point off, to the left of *2 a* at right angles with the imaginary line drawn from *2 a* to a corresponding point at the right of *5 f*, the width of the stroke; this gives the true line from this point to *5 f*. After the first line is established, measure the width of slanting stroke at the point opposite *5 f* and draw a line to *2 a*, which gives both lines for the slanting stroke.

6. The four points of contact, which give the position of the slanting strokes of the letter K, are as follows: From the point half way between *c* and *d* on *2* to *4 b*, also from *6 e*, to a point half way between *4* and *5* on *c*. The slanting strokes of the letter M are joined at the base line *f*, and are $\frac{1}{2}$ stroke in width at base, equally divided by vertical line *4*. The tail, or projection, of the Q is two and one-half times the width of the stroke, and begins in its right outline at line *4* and passes through the intersection of lines *5* and *f*.

The letter R is 5 strokes in width, but the tail is properly located $\frac{1}{2}$ stroke to the left of line *6*, and is beveled less than other letters, or from a point $\frac{3}{8}$ stroke below *e*.

The letter V occupies a full-stroke space on the bottom line, while the lower extremities of W are but $\frac{3}{4}$ stroke, $\frac{1}{4}$ stroke on the left and $\frac{1}{2}$ stroke on the right of line *3*, and $\frac{1}{2}$ stroke on the left and $\frac{1}{4}$ stroke on the right of line *6*. This letter occupies in width 7 strokes, while the M occupies but 6, with the effect of being the same or of even greater width. The other letters are of regular width, except the single stroke I and the numeral 1.

The points that govern the construction of the character & are simply the position of the points on line *d* $\frac{1}{2}$ stroke to the left of line *1*, which gives the extension of the lower part of the character, also the points at *4 e* and *6 c* that give the position of the slanting stroke.

7. The numeral 4 is 1 stroke wider than the other numerals, the middle bar being $\frac{1}{2}$ stroke longer on the right of the vertical stroke than the spur at the bottom. From the point where it touches line *1* in the middle of the side of the block to the point where it touches line *2* in the middle of the side of the block below, gives the slant of the stroke, forming the numeral on the left end of the middle bar.

The numeral 5 is not cut off or beveled inside of the stroke on the upper portion of the figure. The line from *1 d* to *2 d* is dropped at *2 d* about $\frac{1}{4}$ stroke (or $\frac{1}{16}$ inch).

The figure 7 is the full width, although this may be sometimes shortened $\frac{1}{2}$ stroke. The slanting stroke is from points *4 f* to *6 b*.

After studying carefully the instructions and characteristic features of each letter, practice these letters on Manila paper, using only the horizontal lines *a* and *f*. This will familiarize you with the relative width of the letters, before you attempt the plate that is to be sent in for correction, and also show how much of the instruction has been retained.

After drawing all the letters on the plate, outline the letters of the title Full Block and then proceed to ink in the work, using the **T** square and triangles, to ink the horizontal and vertical lines, and the two triangles together for the parallel diagonal lines, as explained in *Elements of Lettering*.

8. The small squares forming the guides for the lettering may be inked with clean fine lines, perfectly uniform in thickness throughout the entire plate. The outlines of the letters may be inked with a rather heavy line, as it will then be simpler to fill them in with a brush. The outline of the title Full Block will not be blacked in, and the pencil lines or squares that were drawn to aid in forming the letters will be erased.

After all the outlines and other work has been inked in, and the pencil lines and other marks have been erased, take a No. 4 red-sable brush and black the letters in solid. The utmost care is here required so as not to run the brush over the lines. Take plenty of time, and see that the ink in the brush is not too thick and that there are no hairs or pieces of lint to catch and smear the plate. Fill in each letter carefully, and complete it before you start the next. By paying careful attention to these points, a great deal of future trouble is saved. Do not hurry your work.

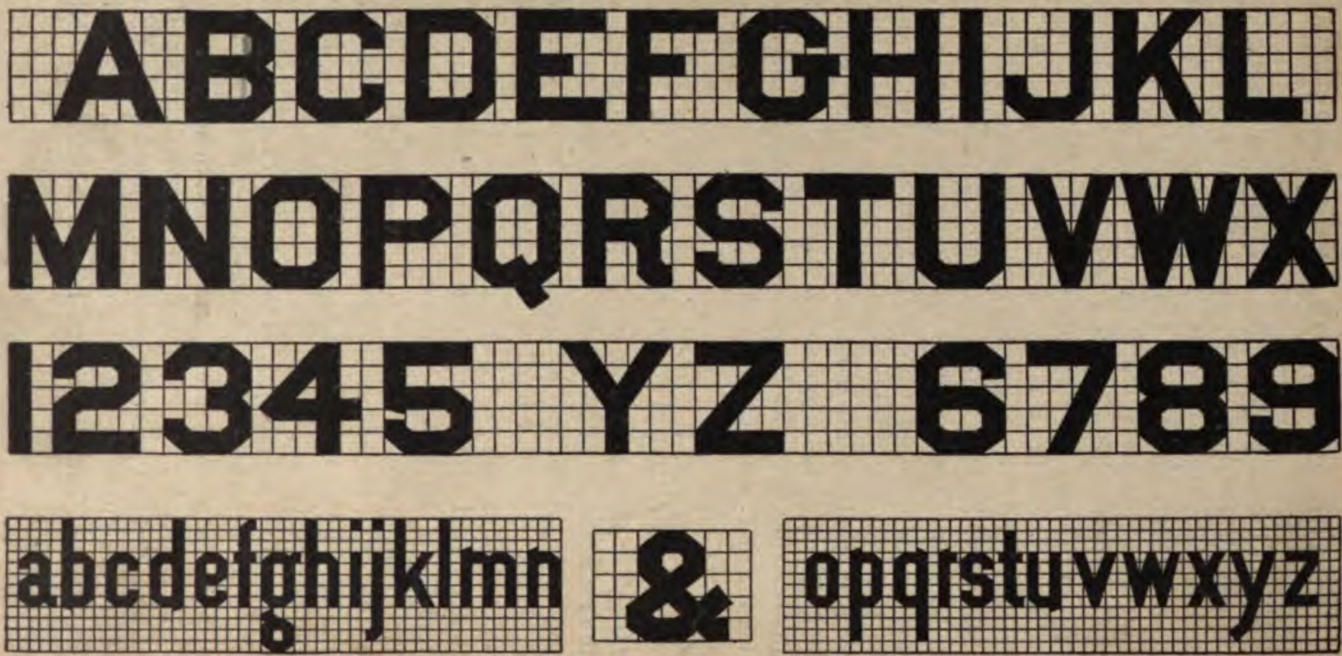
9. First ink in all the light lines and light dotted lines (which have the same thickness); then ink in the heavy required lines after the pen has been readjusted. The student's name, followed by the words "Class" and "No.," and after this the class letters and number should be printed in the lower right-hand corner $\frac{3}{8}$ inch below the border line, as shown. Thus, John Smith, Class No. 4529. The date on which the drawing was completed should be placed in the lower left-hand corner below the border line. All of this lettering is to be in capitals $\frac{1}{8}$ inch high. Erase the division lines, and clean the drawing by rubbing very gently with the eraser. Care must be exercised when doing this, or the ink lines will also be erased. If any part of a line has been erased or weakened, it must be redrawn. Then write with a lead pencil your name and address in full on the back of the drawing, after which put the drawing in the tube in which the plate was sent you, and send it to the Schools.

PLATE, TITLE: HALF BLOCK

10. The **Half Block letter** is, in many respects, similar to the Full Block, though the omission of the spurs necessarily changes the characteristic appearance of the letter. The Half Block is only 4 strokes in width, while its height is equal to the width of 5 strokes, as was the Full Block. Another detail of difference, particularly noticeable in the letters C, G, and S, and in the numerals 2, 3, and 6, is the finish of the extreme corners of certain letters. The Full Block letter C, for instance, is carried to the point *6 a*, while in the Half Block it is cut off at an angle corresponding with the opposite side.

On this plate are also given the small, or *lower-case*, letters of the alphabet, to draw which it will be necessary to divide the space occupied by the letters into $\frac{1}{8}$-inch squares, instead of $\frac{1}{4}$-inch, as with the capital, or *upper-case*, letters. Upper case and lower case are technical terms used in the printing trade to designate the capital and small letters, respectively, of any style. The partitioned tray in which the individual

HALF BLOCK


ABCDEFGHIJKL
MNOPQRSTUVWX
12345 YZ 6789
abcdefghijklmn & opqrstuvwxyz

pieces of type corresponding to each letter are kept is called a *case*, and the one containing the small letters is set in front of the compositor, while the case containing the capitals is placed above and back of this. Hence the names upper case and lower case. The old technical names were *majuscules* for the capital letters and *minuscules* for the lower-case letters, but we will confine ourselves to the simpler terms.

11. On a sheet of drawing paper 15 inches by 20 inches draw a rectangle 15 inches long and $8\frac{1}{4}$ inches high as required in the previous plate. These pencil lines serve as the lines from which all measurements are to be taken. Begin at the lower left-hand corner of the border line and measure off on the left-hand line $1\frac{1}{2}$ inches for the lower-case line, $\frac{3}{4}$ inch space, and $1\frac{1}{4}$ inches for the three lines of upper-case letters with $\frac{5}{8}$ inch space between them. The title Half Block will then be $\frac{1}{2}$ inch above the top line of letters and $\frac{1}{2}$ inch high. Divide the space for upper-case letters into squares $\frac{1}{4}$ inch each by means of a triangle and **T** square, and similarly divide the space for the lower-case letters into $\frac{1}{8}$-inch squares.

The corners of the letters are beveled at the same angle as in the Full Block; that is, in the letter B, for instance, the bevel line extends from *4 a* to a point $\frac{1}{4}$ stroke above *5 b*, but the proportionate widths of some of the letters differ greatly from those in the previous plate. The letters A, M, W, and Y are each 1 stroke wider, and the character & and the numeral 4 are each $\frac{1}{2}$ stroke wider than the other letters of this alphabet, while the L is $\frac{1}{2}$ stroke narrower. It is well to bear these facts in mind, to compare the two plates closely, and to study the points wherein these letters differ. The left extremity of the J is the same as the Full Block, while the L is left plain. The middle strokes of the M on line *f* are finished one-half the width of 1 stroke.

12. The points of contact in the tail of the Q are $\frac{1}{2}$ stroke below and $\frac{1}{4}$ stroke to the right of *3 d* and *4 f*. The length of tail below the line, from *4 f* is three-fourths the width of 1 stroke. The tail of the R is $\frac{1}{2}$ stroke to the left of line *5*, and the bevel of the tail is one-half that of other letters. A bevel also occurs in the tail near *3 d* to the vertical stroke. The vertical stroke of the T is one-half on each side of line *3*. The middle strokes of the W are $\frac{3}{4}$ stroke wide on *a*, equally divided by line *3*. On *f*, these strokes are also $\frac{3}{4}$ stroke wide, divided by line *2*, $\frac{1}{4}$ stroke to the right and $\frac{1}{2}$ stroke to the left, and on *4 f* this is correspondingly reversed, as likewise the outside strokes on *a* are 1 stroke wide, $\frac{1}{4}$ stroke within the letter at lines *1* and *5*, and $\frac{3}{4}$ stroke outside these lines.

The horizontal bar in the numeral 4 is dropped $\frac{1}{2}$ stroke below the center, while the horizontal bar of the A is 1 stroke below. The two points that govern the left-hand outline of the numeral 4 are $\frac{1}{2}$ stroke to the left and $\frac{1}{2}$ stroke below *1 d*. The character & is entirely different in outline from that of the previous plate, the points of contact being *1 c* to *4 f*. The upper cross-stroke is guided by points *1 d* and *4 c*. The other stroke parallel with this is made from points *4 d* and *3 f*.

13. The lower-case letters are $\frac{5}{8}$ inch high and $\frac{3}{8}$ inch wide, and their stroke is one-half the stroke of the capitals, in this case $\frac{1}{8}$ inch. All letters that extend above line *a* are $\frac{3}{8}$ inch higher, except the letter *t*, which is only $\frac{1}{4}$ inch above; all other letters extend below line *f* $\frac{3}{8}$ inch, except the g, which is $\frac{1}{2}$ inch below *f*.

The beveled end, which occurs in the vertical stroke of the numeral 5, is also used on the lower-case letters b, d, m, n, p, q, r, and u. The same rule that applies to the capitals is also observed in the lower-case letters in regard to the beveled corners. The points of contact in the lower portion of the letter g are $\frac{1}{2}$ stroke below *1 f* to *2 f*, and 1 stroke below *1 f* to 2 strokes below *2 f*. The points of contact in the letter k are $\frac{1}{2}$ stroke to the right of *3 a* to *2 c*, and from $\frac{1}{2}$ stroke to the right of *4 f* to *3 c*. The m occupies 5 stroke spaces. The w is identical with the capital letter. The x is equally divided on lines *1* and *3*. The y occupies 4 stroke spaces; the points of contact in this letter are *5 a* to 2 strokes below *3 f*, and from there to a point $\frac{2}{3}$ stroke to the right and

3 strokes below *1 f*, then from *1 a* to *3 f*, intersecting the other stroke.

After the letters of this plate have been drawn, proceed, as directed in the first plate, to ink and fill them in, observing the same directions regarding the name, class letters and number, and date, after which the work should be carefully cleaned from all pencil marks.

PLATE, TITLE: ANTIQUE HALF BLOCK

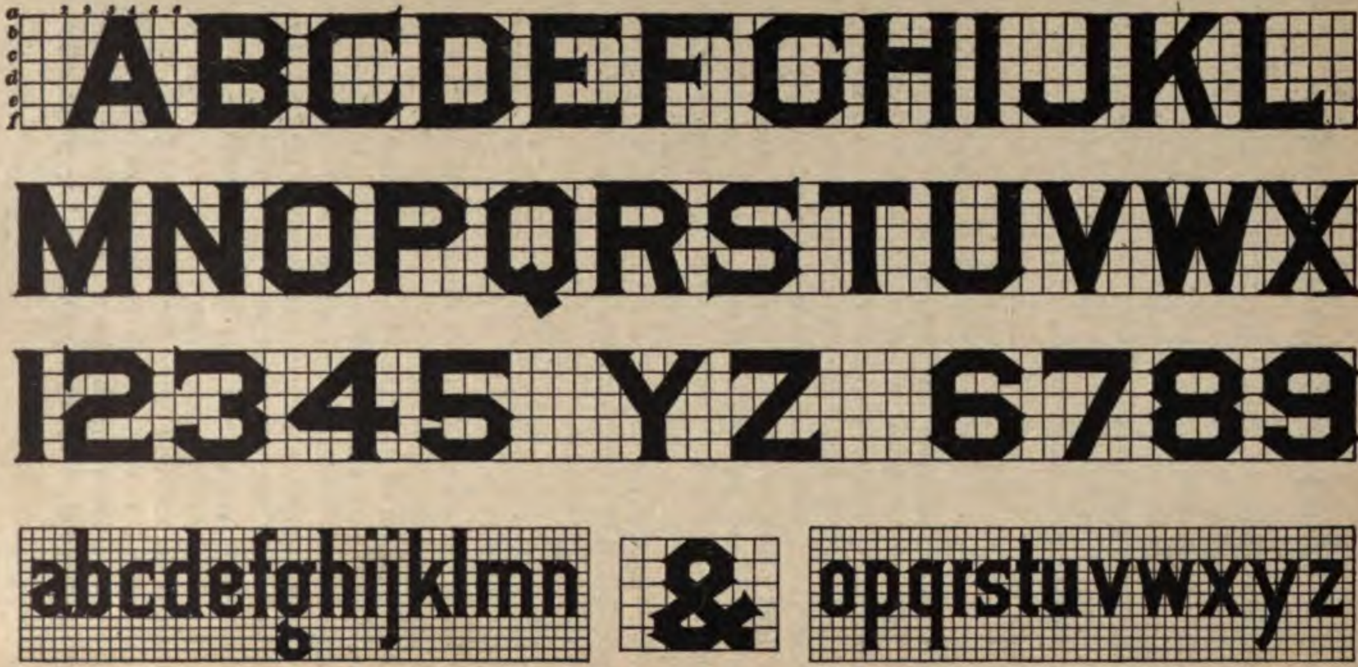
14. The **Antique Half Block** differs from the simple Half Block in very few points, the principal one being the addition of a triangular spur to every corner on the side of each letter. The preparatory work of dividing the lettering spaces into $\frac{1}{4}$-inch squares is identically the same as in the previous plates, with the exception of the line for the title, which is $\frac{7}{16}$ inch high. The corners of the letter are beveled, following the same rule as in the previous plate, but the line of the bevel is carried to *b* and *e*, from which points it is brought back to the body of the letter at as sharp an angle as possible, thus forming an acute spur on those sides of the letter that are beveled.

15. The spurs on the strokes at lines *a* and *f* are carried $\frac{1}{4}$ stroke to the right and left of the stroke of the letter, and are brought back to the stroke of the letter $\frac{1}{4}$ stroke above the line *f* or below the line *a*.

The character of the letters C, G, and S and the numerals 2 and 3 is slightly changed, which gives rise to an important change in the classification of this style of alphabet. This change, though slight, causes the Antique Half Block to be classed in the list with freehand alphabets. These letters and numerals have a spur extending above the line *a*, and a spur on the S extending also below the line *f*. These particular spurs are curved back to the lines *a* and *f*.

The letter C is carried $\frac{2}{3}$ stroke below the point *5 b*, from which point a line is carried toward *3 d*, which gives the proper angle to the end of the spur. On this line, point off about

ANTIQUE HALF BLOCK



$\frac{1}{4}$ stroke to the left of line *5*, which will give the width of the spur, and with a radius of $\frac{3}{4}$ stroke draw a quarter circle tangent to line *b*. The lower extremity of this letter is carried in the same manner to *5 d*.

16. The spur on the letter L is $\frac{1}{2}$ stroke above line *e*, joining back to the stroke at an angle of 45°. The M is finished without the spur, at points *2 a* and *5 a*, as is also the N at *2 a*, and the numerals 1 at *2 a*, 4 at *4 a*, 5 at *1 a*, and 7 at *2 f* and *3 f*.

The character of the R is changed in this style, the change occurring in the tail of the letter, the points of contact being $\frac{1}{4}$ stroke to the right of *4 d* and *5 f*.

The lower extremity of the numerals 3, 5, and 9, and the upper extremity of the numeral 6 are finished the same as were the simple Half Block letters, and show a full width of stroke at this point.

17. The only difference in the lower-case letters from those of the plain Half Block style is the spur, which is about $\frac{1}{4}$ stroke long, and the finish of the vertical stroke letters, which are not beveled on the end as on the previous plate. These letters, as well as letters m, n, o, p, q, r, and u, are not carried above line *a* or below line *f*, but are beveled parallel with the spur. The extremities of the lower-case letters a, c, e, and s are finished in the same manner as are the capitals C, G, and S.

18. In drawing this plate, bear all these points of comparison well in mind, and refer frequently to the previous plate, in order to note and compare the differences. Lay off the measurements from the lower left-hand corner of the border line, precisely the same as on the previous plate, and divide the lines for letters into squares, representing in each dimension the width of the stroke of the capital letters and the lower-case letters. Draw the letters in as usual, outline the letters of the title in the center of the plate according to the measurements given, and erase the border line or such parts of it as do not enter into the formation of the lower spaces.

Insert the date, name, and class letters and number as in previous cases, and send plate in to the Schools for correction.

PLATE, TITLE: RAILROAD BLOCK

19. Railroad block, as its name implies, is designed to fill spaces, such as the frieze and dado of railroad coaches, that are too long in proportion to their height to admit of the use of any other style. It is an elongated block letter, with only such changes in certain of its details as are necessary to make the elongated form practical. The height of the letters of this plate is $\frac{7}{8}$ inch, while the breadth is $2\frac{3}{16}$ inches, or two and one-half times its height, with the exception of the letters A, I, K, M, V, X, and Y; while the general characteristics of the letters are the same as those of the Full Block, assuming that the Full Block were designed in rectangles whose longitudinal dimensions were greater than their height in the same proportion as is the breadth to the height of these letters. Railroad Block letters can be elongated to three and sometimes even four times their height without becoming distorted or badly proportioned.

20. To design this plate, begin at the lower left-hand corner of the border line, as before, and point off on the vertical line of the margin six spaces of $\frac{7}{8}$ inch each for the lines of the letters, and five spaces of $\frac{7}{16}$ inch each between the lines of the letters. The title is $\frac{1}{4}$ inch high and $\frac{9}{16}$ inch above the upper line of letters. The horizontal strokes of the letters in this style are $\frac{3}{32}$ inch wide; in locating them, lay off $\frac{3}{32}$ inch below line *a* and above line *f* and draw lines *b* and *e*; then locate line *c* $\frac{1}{2}$ inch above line *f*, and draw line *d* $\frac{3}{32}$ inch below *c*. The vertical strokes are all $\frac{5}{8}$ inch wide, and the slanting strokes are all $\frac{1}{2}$ inch wide; but, on this plate, when reference is made in connection with any part of a letter being proportional to its stroke, the $\frac{5}{8}$-inch stroke is always intended. Each letter is drawn within a rectangle, the height of which is equal to the height of the letter, and the length of which is equal to the length of the letter between two vertical lines passing through its extremities, exclusive of the spur. With the exception of nine letters, all these rectangles are $3\frac{1}{2}$ strokes wide; of these, W is the widest, being $5\frac{2}{5}$ strokes, and N is

RAILROAD BLOCK

the narrowest, being $3\frac{2}{5}$ strokes. The others are as follows: K, 4 strokes; T, $4\frac{1}{3}$ strokes; A and V, $4\frac{2}{5}$ strokes; M, $4\frac{1}{2}$ strokes; and X and Y, $4\frac{4}{5}$ strokes each.

21. Commencing on the first line of letters, draw a vertical line $\frac{1}{2}$ stroke to the right of the left-hand border line, and $4\frac{2}{5}$ strokes to the right of this draw another vertical line, thus completing the rectangle within which the letter A is to be drawn. Draw the rectangle for each of the other letters on the top line in the same manner, leaving a space of 1 stroke between the B and C, and spaces of $1\frac{1}{3}$ strokes between the A and B, and $1\frac{1}{4}$ strokes between the C and D, the width of all the other letters on top of the line being $3\frac{1}{2}$ strokes. If these rectangles are proportioned properly, there should be a space of $\frac{1}{3}$ stroke between the right-hand end of the rectangle containing the E and the right-hand border line. In a similar manner, draw the rectangles containing the letters in the second line, making the first vertical line of the rectangle containing the F $1\frac{3}{5}$ strokes from the left-hand border line. In spacing the other letters, leave 1 stroke between F and G and between I and J, $1\frac{4}{5}$ strokes between G and H, and $1\frac{4}{5}$ strokes between H and I. On the third line of letters, the rectangle containing the K is 2 strokes from the left-hand border line, while the space between it and the rectangle containing L is $1\frac{1}{2}$ strokes. Between L and M, and between M and N, are spaces of 1 stroke and 2 strokes, respectively. The rectangle containing the O and T on the next two lines below are each started $\frac{1}{2}$ stroke to the right of the left-hand border line. The space between O and P is $1\frac{3}{5}$ strokes; between P and Q, a space of 1 stroke exists; the space between Q and R is $1\frac{1}{2}$ strokes; between R and S, a space of $1\frac{1}{4}$ strokes; between T and U, a space of $1\frac{1}{4}$ strokes; between U and V, a space of $1\frac{3}{5}$ strokes; and the space between V and W, $1\frac{3}{5}$ strokes. On the lowest line of letters, a rectangle containing the X is started $1\frac{1}{5}$ strokes to the right of the left-hand border line, and between this and Y is a space of $1\frac{1}{5}$ strokes, while between Y and Z there is a space of but $\frac{4}{5}$ stroke. The character & is $3\frac{1}{3}$ strokes wide in its upper part and $3\frac{4}{5}$ strokes wide in its lower part. The rectangle containing it is, therefore, $3\frac{4}{5}$ strokes long, and is located $2\frac{1}{2}$ strokes to the right of the Z.

22. Proceed to draw the letter A, making the top of it on line *a* $\frac{3}{5}$ stroke in width, and draw the outside slanting strokes to the lower right and left corners of the rectangle. The horizontal stroke of the A is equal in width to the other horizontal strokes of the letters, and its upper edge is on line *d*. The general length of spurs is two-thirds the width of the stroke; equal to the distance from line *d* to *f*. Spurs on slanting strokes should be twice the length on the inside to that of the outside, and they should always be made in proportion to the length of spurs on vertical strokes, measuring on line *a* or *f*. Exceptions to this rule occur in letters K, W, etc., which will be overcome by proportion, in allowing proper space between spurs. In joining the strokes of B to the horizontal lines that form the spurs on the left-hand side, the compass may be used, and a quarter circle described, the radius of which is equal to half the distance between lines *b* and *c*, and the center of the quarter circle located below the top or above the bottom and to the left of the stroke of the letter a distance equal to the radius, as shown in the letter B. The bevel in this letter extends from *a* to *b* and from *e* to *f* the full width of the stroke. In drawing C, E, G, S, T, and Z, a full width of one of the horizontal strokes (which in this case is $\frac{3}{32}$ inch) is left between the upper extremity of the letter and the line *c*. On the letters C, G, and S, a slight spur is extended above the line *a*, and on the S, below the line *f*. The letter F has its upper extremity resting on line *c*, and the lower extremities of the letters J and L extend to line *d*. The middle strokes of the letters E and F are equal in length to one-half of the space inside these letters. The widths of A, M, N, V, and W, where their smaller extremity rests against the line *a* or *f*, vary considerably. In A, it is $\frac{3}{5}$ stroke; in M, but $\frac{1}{2}$ stroke; in N, $\frac{3}{5}$ stroke; in W it is $\frac{2}{5}$ stroke; and in V, $\frac{4}{5}$ stroke. In drawing K, the light slanting stroke joins the body stroke midway between *d* and *e*. The heavy slanting stroke joins the light slanting stroke on the left side at line *d*.

23. The slanting strokes of M and N start on the left from a point on the vertical stroke the width of the narrow stroke above line *c*. The light slanting stroke of M is joined to the top of the letter at the intersection of the heavy stroke on line *a*. Observe that the heavy slanting stroke in all letters, with the exception of the Z, inclines in the same direction, and that where two slanting strokes come together, one of which is heavy and the other is light, that the heavy stroke is on the left side in the U, V, W, and Y, and on the right side in the A, K, and M. The tail of the R is nearly $\frac{1}{2}$ stroke to the left of the line of the rectangle enclosing the letter. The spaces between the heavy strokes of the letter T each equal the distance from line *d* to line *f*. The center of the letter V where it rests on line *f* is the middle of the base of the rectangle containing the letter.

24. To draw the W, extend the rectangle containing it the width of the narrow stroke to the right, or to four times the height of the letter, and divide this increased rectangle vertically into four squares. A line drawn from points $\frac{1}{4}$ stroke to the left of *4 f* and *5 a* will give the right outline of right narrow stroke, and from points *3 a* to *2 f* will give the left line of the left narrow stroke. The only points to be observed are those of the three spaces within the letter, or the points where the narrow and heavy strokes intersect; the middle point is the width of the narrow stroke above *c* and the others are the same distance below *d*. With a knowledge of the width of the slanting strokes, these points are all that are necessary to complete the letter. The letter X is drawn so that the upper line of the heavy stroke and the lower line of the light stroke extend into the corners of the rectangle on the right side of the letter; and the lower line of the heavy stroke and the upper line of the light stroke extend into the corners of the rectangle on the left side of the letter.

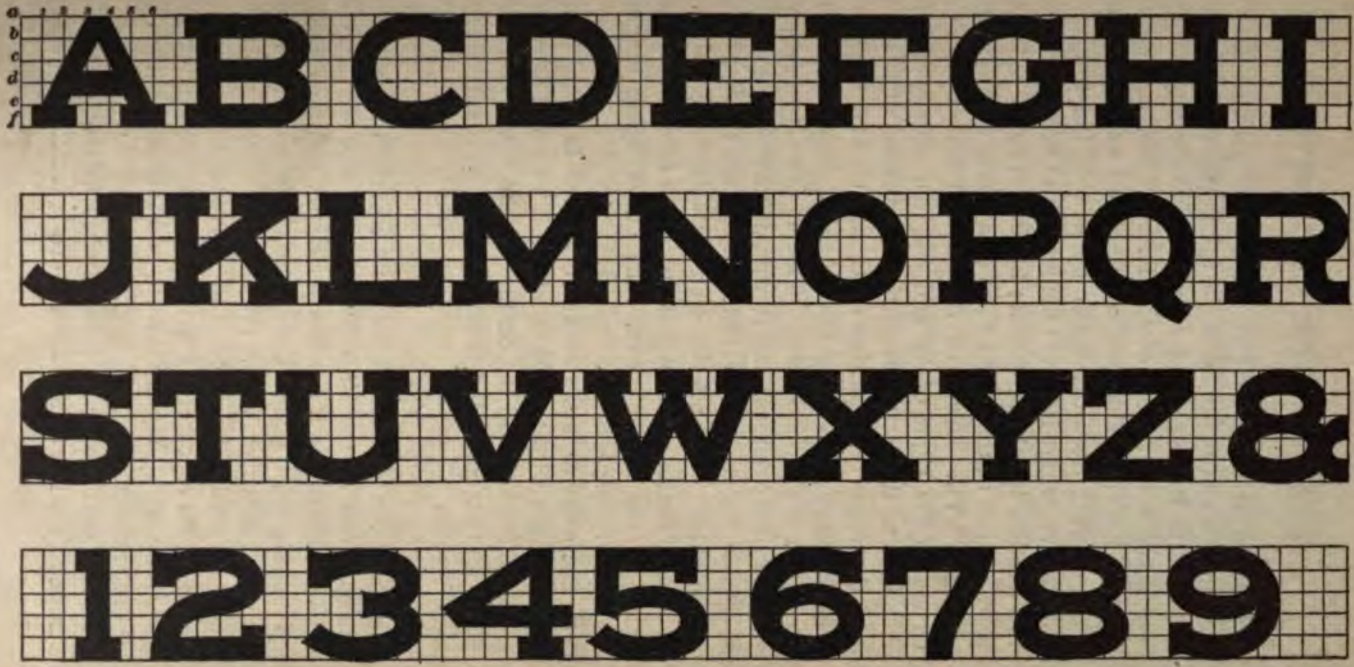
25. The method of keeping the outlines of these strokes parallel is the same as in the case of the diagonal stroke of the letter N described in connection with the Full Block alphabet. In drawing the Y, the upper point of contact between the diagonal heavy stroke and the vertical stroke is on line *c*, and the direction of the lower line of the heavy stroke carries it into the upper left-hand corner of the rectangle containing the letter. The vertical stroke is exactly in the center of the rectangle. The upper and lower widths of the character & have already been given, but, in order to secure the correct outline of the character, observe that the lower left-hand stroke is one-half the narrow stroke less in height on the end than the lines *de*. The slanting stroke on the right-hand side of the letter begins on line *f* at a point equal to the width of the narrow stroke to the right of the inside of the letter, and the slant of this stroke is such as to render it parallel with the upper right-hand beveled portion of the letter and keep it distant the width of the narrow stroke from that point. It is necessary to use much care in connecting the slanting stroke with the spur and to make the curves as small and symmetrical as possible, so that their apparent length is equalized.

26. Having drawn in all the letters in pencil, the title should be drawn to correspond with the letters of this alphabet, and should not exceed $\frac{1}{4}$ inch in height. Ink in the whole plate carefully according to the rules laid down for drawing the body of the plate, leaving the inking of the title until the completion of the plate otherwise; using the drafting pen, **T** square, and triangle when inking the horizontal and perpendicular lines, and using the triangle alone for the bevel lines at the corners of the letters, but turning all the curves from the strokes to the spurs on the insides of the letters with the brush, freehand. The letters should then be filled in with a brush, as with the previous plates, and all construction marks erased from the plate, except the six horizontal lines *a*, *b*, *c*, *d*, *e*, and *f*, and the vertical lines closing the ends or each line of letters. In the left-hand corner the date, and in the right-hand corner the name and class letters and number, should then be carefully printed, as usual.

PLATE, TITLE: ROUND FULL BLOCK

27. The **Round Full Block** letters are precisely the same as the Full Block, except that the corners are round, instead of beveled. The proportions of the letter are identical with those of the first plate. With the exception of the letters O and Q, the curves should all be drawn freehand. To draw this plate, begin at the lower left-hand corner of the border line, and divide the space for the lettering lines and numerals in the same manner as for Drawing Plate, title, Full Block. The stroke of the letter will then be the same as in the first plate, and, though all letters are to be drawn, only such letters will be here described as possess in some of their parts curved outlines. Information for drawing straight letters, if required, can be obtained by reference to the Full Block plate. The letter A on this plate is all straight lines, as in the former plate, but the letter B is rounded from the points *4 a* to *6 b*, overlapping line *6* slightly, in order to give full width to the rounded stroke. The bottom of the letter is rounded in the same manner to *4 c*, where the curve stops. The inside of the letter is rounded from *4 b* to *4 c*, conforming with the outline above described, in order to give equal width to the entire stroke. The middle bar of this letter is exactly in the center of its height, the lower rounded stroke thereby making a duplicate of the upper one. The letters C and G are not circular, but slightly elliptic, the points through which the curves of the C pass being *6 a*, ½ stroke to the right of *3 a*, ½ stroke below *1 c*, ½ stroke to the right of *3 f*, to ⅓ stroke below *6 d*. The line from here to the finish of the letter at *5 d* should be somewhat curved. The hollow curve at the top of the letter from *6 a* to the point *4 a* should be but a slight depression, just sufficient to show that there is a curve there. At a point ¼ stroke above *5 c* begin the inside curve, keeping it perfectly parallel to the line of the outside. In the letter G the rounded stroke intersects the lower half of the vertical straight stroke at *6 e*. This is done in order to leave sufficient space on the inside between the end of the curve and the horizontal stroke.

ROUND FULL BLOCK



28. The letters O and Q are perfect circles, and their entire outline can be drawn with a compass. The letter R and the letter P are precisely the same in their upper portion as the letter B. The tail of the R, however, is 1 stroke to the left of the right side of the letter, and extends to line *6* without curving from the upper portion of the letter. The smaller curve, where it leaves the letter and bends toward line *6*, has a radius equal to $\frac{1}{2}$ stroke; the larger curve in the under side of the tail of the R is an arc of a circle with a radius of $1\frac{1}{2}$ strokes. The curves of the S are joined at a point $\frac{1}{2}$ stroke to the right of *3 c* and *3 d*; the upper and lower extremities of the letter are curved somewhat after the manner of the upper extremities of C and G, and the letter is carried slightly above the line, making it about $\frac{1}{10}$ stroke higher than the other letters. This is done to preserve an appearance of evenness, as it would otherwise look short. The inside curve of the letter U extends from a point $\frac{1}{2}$ stroke below *2 d* to a point $\frac{1}{2}$ stroke below *5 d*; the outside curve of the letter extends from point *1 e* to point *6 e*, and is parallel to the inside curve, each curve being tangent to lines *e* and *f*, respectively.

The character & is somewhat distorted in order to correspond in width with the other letters. The middle stroke is but $\frac{3}{4}$ stroke wide, and the outline of the upper half is parallel on its two sides, but tapers slightly as it approaches the middle stroke.

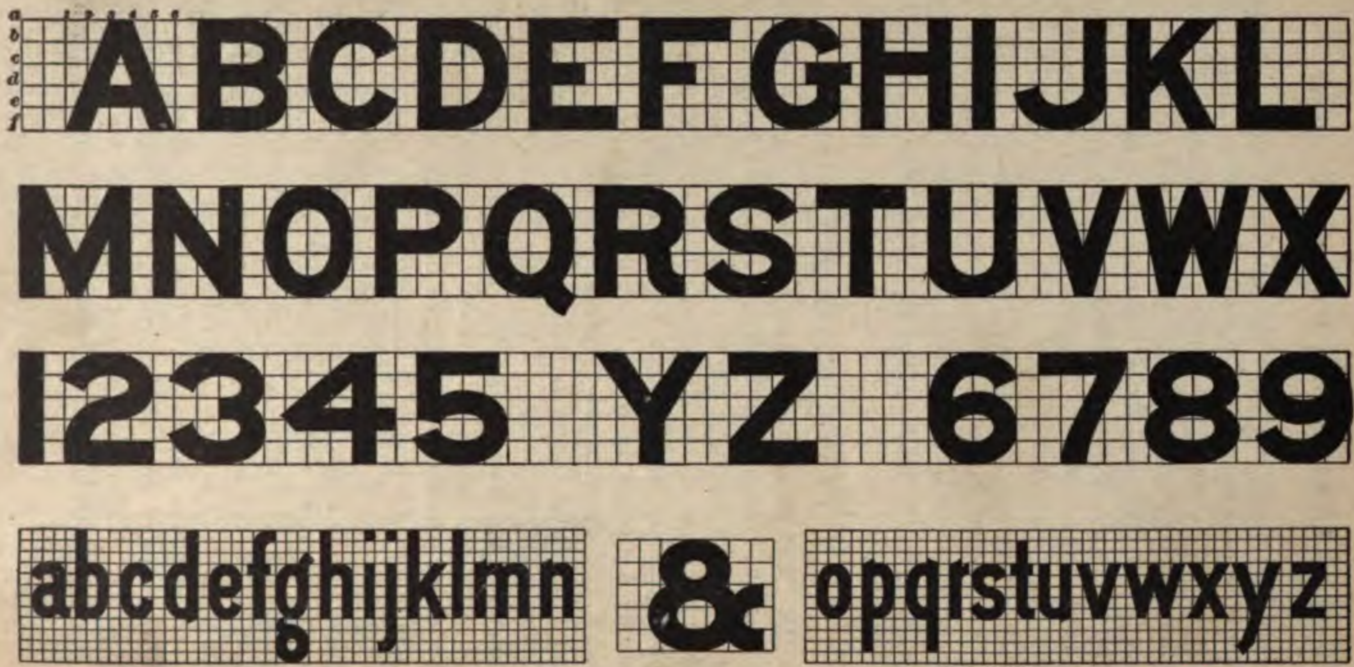
29. In the numerals, the only figures that remain the same as those of the Full Block are 1 and 4. The lower left-hand side of the 2 is a quarter circle, and may be drawn with a compass, if desired, with the center at point *4 f*. The upper part, however, is not the arc of a circle, and must be drawn, carefully, freehand. In drawing the other curved figures, observe carefully points where they intersect the squares in which they are drawn, and follow the lines of the plate accurately.

Observe that the figure 5 terminates in the lower portion $\frac{1}{2}$ stroke to the left of line *1*. Figure 7, instead of possessing a straight stem, has a compound curve, which at the top and bottom is perpendicular to the horizontal guide lines of the letter. Draw these letters carefully and ink them in, using the **T** square and the triangle for the horizontal and perpendicular lines, and the triangle alone for the slanting lines. The O and Q should be inked with the compass, but the curves of the other lines must be carefully drawn freehand with pen, making each line form an even stroke without ragged edges or appearance of overlapping. Draw in the title as shown, blacking in the letters with a brush, as heretofore described. Place the date in the lower left-hand corner, and the name, class letters and number in the right-hand corner.

PLATE, TITLE: EGYPTIAN

30. The **Egyptian letter** is very frequently referred to as Gothic—a name incorrectly given. The general formation of the letter is very similar to the Half Block, with the exception that all the Half Block letters that are beveled on the angles are round in the Egyptian style. These letters occupy 4 strokes in width, with the exception of A, M, W, and Y, and the numeral 4, each of which is one space wider, and the letters L and I, which are $\frac{1}{2}$ stroke and 3 strokes narrower, respectively. The plate is lined in the same manner as the Half Block plate; the title $\frac{3}{8}$ inch high is $\frac{5}{8}$ inch above the top line of the letters. The round portion of all the letters partakes of the curve of an ellipse, and with the exception of a few special instances, the rules governing the letters O and P can be applied to the drawing of all the letters on the plate. The extreme outline of the letter O is a nearly perfect ellipse, the breadth of which is 4 strokes and the height 5 strokes. The curved portion of the letters B, P, and R, are also elliptic, the curve starting at the top of line *3* in each letter. The middle bar of the H is raised $\frac{1}{2}$ stroke above the center. The left-hand portion of the entire curve of the J is a quarter circle, extending from point *2d* to *3e*. The right-hand portion of this curve is elliptic, joining the straight stroke about $\frac{1}{3}$ stroke below point ***4d***.

EGYPTIAN


ABCDEFGHIJKL
MNOPQRSTUVWX
12345 YZ 6789
abcdefghijklmn
&
opqrstuvwxyz

The outside curve of the letter is parallel to the inside curve. The points of contact in the letter K are from *5 a* to ½ stroke below *2 d*; the other slanting stroke is from point *5 f* to the line *c*. The letter M extends to line *f* with its slanting strokes, and is ½ stroke wide on the line *f*, while the lower part of the slanting stroke of the N is slightly less than a full stroke in width. The curve of the tail of the R at *5 e* is a quarter circle, the radius of which is ½ stroke, the outside line being made parallel to it. The inside curve of the U is a semicircle; the outside curve is elliptic, and joins the upright strokes at points *1 e* and *5 e*. The V and W are ¾ stroke wide where they rest on line *f*. The central portion of the W is ½ stroke wide where it rests against line *a*. The angle of the left-hand portion of the numeral 4 is 45°, passing through the point *1 d*, the upper slanting stroke of the figure crossing line *1*, ½ stroke below the point *1 c*. The horizontal stroke of the figure is ½ stroke each side of line *d*. In making the figure 8, the stroke between line *c* and *d* is reduced about one-eighth of its regular width in order to prevent the letter from looking top heavy. The character & occupies three spaces in width above, and five spaces below its horizontal center line, and the middle stroke is reduced about one-eighth of the regular width. The lower-case letters are to be drawn as shown, following the same general directions as were given in connection with plate entitled Half Block.

31. The lower-case letters are three spaces wide by five high; they are, therefore, more elliptic in form than the capitals, and are drawn from a point midway between *2* and *3* in all rounded letters, as the o. An exception to this occurs in such letters as h, m, and n, in which case the curve forming the top of the letter touches *a* at line *3*. The horizontal strokes of the f and t extend ½ stroke on either side of the vertical. The vertical strokes of the letters m, n, p, q, r, are extended above the line *a* ⅓ stroke to the right, and are carried below the line in a corresponding manner on the letters b, d, and u. In the letters a, h, m, n, u, the curved outline of the letter joins the vertical stroke on lines *b* and *e*.

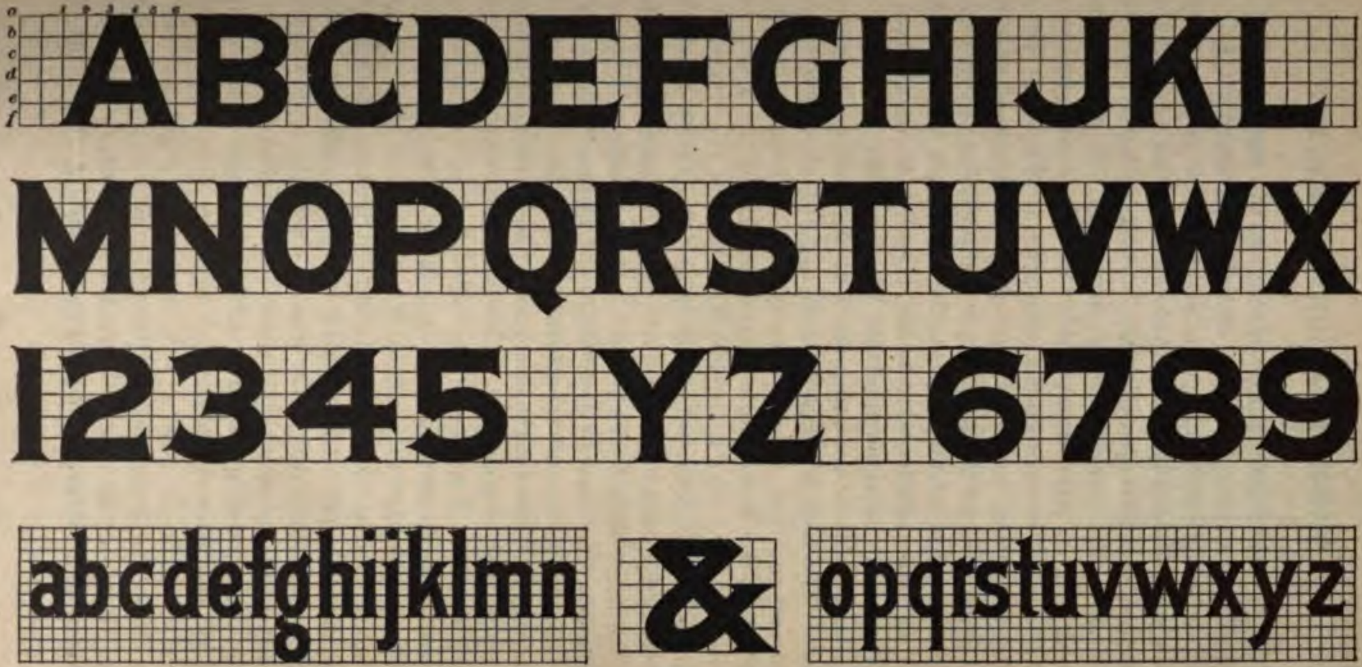
The letter g extends 4 strokes below *l*; the lower portion of the letter is ½ stroke below *l* at its center, while the upper extremity reaches a point 1 stroke above *a*. The curved end of the vertical strokes of the letters a, j, and t occupy but ½-stroke space, while that of the f occupies a full-stroke space.

Having finished drawing the letters in pencil, ink the plate carefully, drawing all horizontal lines with the T square and all vertical lines with the triangle, but turning all curves freehand, using a No. 3 red-sable brush, as none of the letters will admit of the use of the compass to advantage. Draw in the title; black in letters on the body of the plate; put the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner, as before.

PLATE, TITLE: ANTIQUE EGYPTIAN

32. The form of **Antique Egyptian letter** is almost identical with the plain Egyptian, the main distinction being observed in the addition of a spur at the angles of the letters, but no variation occurs in the proportion of the letter or its stroke. This style is very popular with sign painters and letterers, owing to the adaptability of the letter to a great variety of forms, to suit certain specific conditions. Some letterers make the spur much more exaggerated than shown on this plate, and others make it scarcely perceptible. The examples given herewith, however, may be taken as an average, wherein the spur projects about ⅓ stroke. All letters having a horizontal stroke, as the E, L, etc., have these strokes finished with a beveled end, on which the spur is added at the same angle. The ends of the strokes of the C and the upper stroke of the G and S, and figures 2, 3, 5, 6, and 9 are beveled at an angle opposite to that of the other letters referred to above. The bevel shown on the upper terminal of C is made by drawing a line from a point ¼ stroke to the right of *5 a* to a point ⅓ stroke to the left of *5 c*. The middle bar of the A is 1 stroke below the center; the middle bar of the H is ½ stroke above the center; while the middle

ANTIQUE EGYPTIAN



bars of the E and F are exactly in the center. The J is finished with a spur at *5 e*, as well as just above *1 e*. The points that determine the inclination of the strokes of the K are from *5 a* to $\frac{2}{3}$ stroke below *2 d*, and from *4 f* to the intersection of the upper slanting stroke with line *3* $\frac{1}{3}$ stroke above *d*. The two slanting strokes of the M meet in the center of the letter at a point on line *f*, and no spurs exist on the insides of the slanting strokes at the top. The end, though usually finished with a point at *5 f*, as on this plate, is often finished the same as in the plain Egyptian, to which the spurs are added. The tail of the Q is cut on an angle of 45°, the shorter side being 1 stroke in length and the longer side being equal to the distance from *2 e* to *3 f*. The tail of the R is a slanting stroke; the points of contact are *4 d* to *5 f*. The strokes of the W come to a point on line *a* to correspond with the M. The corner of the Z is beveled off at about the same angle as the interior of the 5 and top of character &. The long slanting stroke of the character & is drawn from a point $\frac{1}{2}$ stroke to the left and below *1 a* to a point $\frac{1}{2}$ stroke to the right of *4 f*. The corresponding, or upper, slanting stroke, from its top to the beginning of the curve, is made from a point $\frac{1}{2}$ stroke to the right and below *4 a* to a point *2 d*. The other slanting stroke intersects the long stroke 1 stroke below this point, and is parallel with upper stroke, finishing on line *c*. The curve by which these strokes are united is $\frac{3}{4}$ stroke to the left of line *1* at *e*. The middle bar of the numeral 3 is beveled at a slight angle, as shown. The character of the numeral 5 is changed at the point where the vertical stroke joins the curved bottom portion of the numeral 5. The point added below the line *d* is necessary to fill out the space to the line of the curve. The numerals 6, 8, and 9 are about $\frac{1}{3}$ stroke wider than the other characters, but are similar in other respects to the same numerals in the plain Egyptian alphabet.

33. The lower-case letters are in many respects the same as those in the plain Egyptian alphabet, although many exceptions occur. All strokes extending above the line *a* are cut at an angle of 60°, to which the spur is added at the same angle. This characteristic is also observable on letters of shorter height, such as the i, j, m, n, etc., but the ends of the strokes of all letters extending below the line are finished without this detail. Other information concerning the lower-case letters, as to their proportion, spacing, etc., will be found in the Drawing Plate, title, Egyptian.

Having finished drawing the letters in pencil, they should be inked carefully, drawing all horizontal lines with the T square and all vertical lines with a triangle, but making all curves freehand, using the red-sable brush, as none of the letters will admit of the use of the compass to advantage. Draw in the title, as shown; black in the letters in the body of the plate carefully, lettering the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner, as before.

PLATE, TITLE: ANTIQUE EGYPTIAN (LIGHT)

34. In drawing this plate, all guide lines will be omitted, except the lettering lines that limit the top and bottom of the letter. It will therefore be necessary to count the number of letters in each line, and to divide this line proportionately, so that each letter will fill its proper space. The capital letters and figures in this plate are $1\frac{1}{4}$ inches high, as in the previous plates, and the average width is 1 inch, but the letters A, M, O, Q, S, W, etc., are wider than the average, and the letters I, L, and N are narrower, as will be pointed out hereafter.

On the top line are twelve letters, the widest of which, A, is $1\frac{1}{4}$ inches; the narrowest, the I, being but $\frac{3}{32}$ inch, or equal to the width of 1 stroke. Commencing at the lower left-hand corner, divide the plate as follows for the first line of letters: $1\frac{1}{2}$ inches above the lower border line draw a line to limit the top of the lower-case letters; $1\frac{1}{8}$ inches above the lower border line, draw a line to limit the top of the body of the lower-case letters; and $\frac{1}{2}$ inch above the lower border line draw a line on which the bodies of the lower-case

ANTIQUE EGYPTIAN (Light)

ABCDEFGHIJKL

MNOPQRSTUVW

12345 .. XYZ & .. 6789

abcdefghijklmnopqrstuvwxyz

letters rest. The g, j, p, q, and y will then extend below this line on the lower border line. Three-fourths inch above the top line of the lower-case letters draw a horizontal line on which the numerals shall rest. The numerals, like the two lines of letters above, are $1\frac{1}{4}$ inches high, with a space $\frac{5}{8}$ inch between them and the line above. The title is $\frac{5}{8}$ inch above the top line of lettering, and its letters are $\frac{3}{8}$ inch high. This style of lettering is an extreme form of the Egyptian letter, and in many respects is the most useful form it assumes. The lines are extreme and do not follow the conventional regularity of the lines of letters on the Full Block or Half Block plates, but are governed, nevertheless, by certain rules that must be followed carefully to observe their proportions, particularly in this plate, as it is the first one to be drawn entirely freehand.

35. Begin this plate by drawing the letter A, which rests on the lower line, 5 strokes to the right of the left-hand border line. The width of the letter, exclusive of its spurs, is the same as its height, and the cross-bar is $2\frac{2}{3}$ strokes above the bottom line. In connection with this plate we meet with an entirely new detail in lettering, as seen at the top to the left of the letter A. This detail is called the *cyma*, from the Greek *Κυμα*, *kyma*, meaning "a wave." Its purpose, in most instances, is to fill the space between the slanting parts of the letter, or extremities, that are likely to cause wide openings when two letters are placed together. It is also used in some places to form the finishing stroke of a letter, as in the Q and Z. In subsequent plates, its use in the construction of letters will be observed, as it forms a component part in many letters in the German Text, Old English, and Church Texts. The cyma on the letter A is 8 strokes in length and 1 stroke to the left of the point of A.

The vertical stroke of the B is about 3 strokes to the right of A, but the length of the line should be so proportioned that the letters are evenly divided, and not lay off each letter by measurements taken from its neighbor. The middle bar of the B is 8 strokes above the bottom line; the upper portion of the letter is 5 strokes from top line, and the lower part projects 1 stroke beyond the upper part. The curves of the B are carried into the middle bar independently of each other, and start from the horizontal bars at about the center of the letter.

36. The C is a perfect circle as far as it goes, and the spur on the inside is about 2 strokes below the top line; the lower extremity of the letter projects a full stroke beyond the top, and finishes in a point 3 strokes above the lower line. The curved portion of the letter D is semicircular, and becomes tangent to the horizontal top and bottom lines 3 strokes to the right of the vertical line.

The middle bar of the E, F, G, and H are all on one line, 4 strokes below the top of the letter. This bar in the E and F extends to within 2 strokes of the right extremity of the letter. The slanting stroke of the K begins 3 strokes above the lower line, and extends to the top line, where the end is beveled at an angle of about 60°. The L is 1 stroke narrower than the other letters, and the cyma is placed over it so that its lower extremity is even with the right-hand portion of the letter.

The M is 2 strokes wider than the other letters and starts $\frac{1}{3}$ stroke to the right of the border line, to leave sufficient room for the spur. In some cases, the M is made precisely like an inverted W, except that at the union of the two slanting strokes the letter is finished flat with a spur, instead of being pointed, as in the W. On this plate, the middle slanting strokes of the M are brought to a point one-half the width of the letter below the top line. The slanting stroke of the N commences on the vertical stroke, one-fourth the width of the letter above the bottom line.

37. On this plate, there is a difference between P and R that was not seen on previous plates. The loops are entirely different in style, the middle bar of the P being $4\frac{2}{3}$ strokes from bottom line, while the same stroke of the R is $6\frac{2}{3}$ strokes above the bottom line. The tail of the R intersects the middle bar at a point where the curve becomes tangent. The letter S begins to curve each way from a point in the center of the letter on a line with the middle bar of R. The letter is narrower at the top than at the bottom, the proportions being about the same as in the numeral 3, hereafter described.

The W is practically two V's joined at a point $2\frac{2}{3}$ strokes below top line. The cyma over the W is so placed as to fill the space between its upper extremity in the same manner as the cyma is placed in the lower part of M. This is not a component part of the letter, however, and in many cases may be omitted with advantage.

The vertical stroke of the Y extends $6\frac{2}{3}$ strokes above the bottom line, the letter being 12 strokes wide on top. The X is 9 strokes wide on top and 4 strokes wider on the bottom. Z and the numeral 7 are of the average width on top, and the former may be finished in the same manner on the bottom, or with a cyma, as shown on the plate.

The character & is 10 strokes wide on the horizontal part of the letter, the longer slanting lines extending to the right 1 stroke beyond the line of top of letter. This line, divided into three equal parts, will give about the location where the other two slanting strokes intersect the longer one. These two strokes are parallel and joined with a semicircle, as shown.

38. The figures differ somewhat from the letters on account of their elliptic form. The numeral 2 curves in each direction from a point one-half its height. The numeral 3 is much narrower at the top than at the bottom, and its sides can be enclosed in an isosceles triangle whose height is about three times the height of the letter. The middle bar of the figure 3 is 7 strokes from the bottom line, and is carried to the left and beveled off in line with the bevel of the top stroke. The middle bar of the 4 is 7 strokes from the top line, and extends $9\frac{1}{3}$ strokes to the left and 4 strokes to the right of the vertical line. The upper curve of 5 is $4\frac{2}{3}$ strokes from top line, and upper portion of the elliptic curve of 6 is $1\frac{1}{2}$ strokes below the top line, which distance is the same between the lower curve of 9 and the bottom line, 6 and 9 being simply reversed.

The stem of the 7 extends below the line 4 strokes, and the figure is finished horizontally with a spur. The figure 8 is 12 strokes long on the top line, and the slanting strokes of the figure intersect $2\frac{2}{3}$ strokes below the top line and are joined on the loop, which is 12 strokes wide, and forms the lower portion of the figure.

39. The lower-case letters are similar in general outline to those of the Half Block, but in some respects are very different. It must be remembered that the lower-case letters should always be made so that the long strokes are the height of the capitals, and the others three-fifths this height, when they are used together. The letter a finishes on the bottom line by its vertical stroke coming to a point, as is also the case with the letters d and u.

In proportioning the lower-case letters, they should bear the same relations with reference to their height as do the capitals, that is to say, their width should be four-fifths their height, as shown on this plate. In measuring the height of a letter, measure only the body, not counting the part that extends above the line, as in b and k, or extends below the line, as with j and y. The strokes of the letters should also be in proportionate width to the stroke of the capitals, and those strokes that extend above and below the line should all extend to the same height, which was not the case with the Half Block. The cross-bars of the f and t are longer in this than in the previous plate, and are on a line with the body of the letter. The top of the f is about two-thirds the regular width of the letter. The upper portion of the g is identical with the letter o. The letters c and e finish their lower extremities with a point, and the right-hand portion of the r extends two-thirds the width of the letter, and is the width of a stroke above the top line. The s, v, and w are precisely the same as the capitals, the only difference being the size. Space these letters by the eye, drawing every outline lightly in pencil, in order to get them in their required positions on the plate.

40. Having accomplished this, start with the letter A and draw, exclusively in pencil, each individual letter, making the lines freehand, and complete each letter before the following one is started, although in spacing the top line it may be convenient to draw the L first, in order that the letters may be spaced evenly between them.

When the letters are completed, drawn in pencil, ink them in, using the T square and triangle for the vertical and horizontal lines, but turning all curves, except the capitals C, D, G, O, and Q, freehand. The letters may then be blacked in, solid, as shown; the title drawn on the top of the plate; the date on the lower left-hand corner; and the name and class letters and number on the lower right-hand corner.

PLATE, TITLE: ANTIQUE EGYPTIAN (HEAVY)

41. It would at first appear scarcely possible that the lettering on this plate is but a modified form of the style drawn in the two previous plates. This is the heavy extreme of the Antique Egyptian style, as the former plate was the light extreme, and it is fitted to fill certain needs in letter design that no other style can accomplish quite so effectively. The **Heavy Antique Egyptian,** however, is rarely used as a solid black letter, as shown on this plate, and it is here so printed in order to preserve uniformity in the lettering plates. In designs for lithographic work, show bills, book-covers, etc., it is largely used in a simple outline; and though extremely bulky on account of the weight of the stroke, it is considered most graceful and symmetrical when properly handled.

The three lines of letters and one line of figures in this plate are drawn between horizontal guide lines placed $1\frac{1}{4}$ inches apart, as in the previous plates, with $\frac{3}{4}$ inch between them. The title is $\frac{3}{8}$ inch high, and $\frac{5}{8}$ inch above the upper line of letters. On this plate, the width of the letter is $1\frac{3}{8}$ inches, and the stroke is about one-third of the width, or $\frac{7}{16}$ inch. As in previous plates, many of the letters exceed this width and others are narrower, as will be pointed out.

42. The A, B, C, E, G, and K are 10 per cent. wider, and the M about 20 per cent. wider; the W is over 50 per cent.

ANTIQUE EGYPTIAN (HEAVY)

ABCDEFGHI

JKLMNOPQR

STUVWXYZ &

123456789

wider, and the letter Z and the character & are about 25 per cent. wider. The numerals 2, 5, 6, 8, and 9 are each about 10 per cent. wider than the average width of the letters. It is not intended that all these dimensions and irregularities will be carried in the mind, but by paying attention to these proportions as the letter is drawn, and thereby accustoming the mind to nothing but letters of perfect proportions, one will soon be able to draw a letter that bears its proper relation of width to height and weight in stroke, without making any mechanical measurements to determine the stroke, and thus learn why each letter is given certain characteristic forms. The rapidity and ease with which this result is accomplished will depend entirely on the amount of practice given to the work, with strict attention to the rules set forth.

43. The spurs of these letters are about $\frac{1}{8}$ inch long, although in exceptional cases, such as the E or L, the spur is made much longer in order to balance the stroke. All vertical strokes are finished on their upper and lower extremities by a concave line. This line is the arc of a circle, the radius of which is $1\frac{1}{2}$ inches above and below each vertical stroke. Letters having three parallel horizontal strokes must have these strokes somewhat reduced in width, in order to leave a space within the letter, as in the B and E. In the letter S and the character &, this is accomplished by carrying the stroke above the line and thereby drawing the letter open. In the letter C, the lower portion of the stroke extends $\frac{1}{3}$ stroke beyond the upper portion of the inside point, and on the E, F, J, and Z, a slight spur is added to the outer extremity, which carries the letter above the line. The lower portion of the horizontal stroke of the E is not a straight line but a compound curve, the center of which, on the upper side, is on a line with the middle bar of the letter; the length of this middle bar is equal to the width of the stroke, or one-third the width of the letter. The middle stroke of the H is $1\frac{1}{4}$ strokes above the bottom line. The J is brought to a point at the left of its lower curve; the top of the curve rises to within 1 stroke of the top line of the letter. The upper slanting stroke of the K and the right strokes of V and W are rested about $\frac{1}{2}$ stroke above top line of letter. The right spur of this projecting stroke rests either on the top line, as in K, or $\frac{1}{7}$ stroke above it, as in V and W. The points from which the slanting strokes of the K are drawn are $\frac{4}{5}$ stroke from the bottom line on the right side of the vertical stroke and the same distance from this point on the right side of the upper slanting stroke. The horizontal stroke of the L is a compound curve similar to that of the E, except that it is about $\frac{1}{2}$ stroke shorter. The cyma added to this letter is about two-thirds the width of a stroke.

44. The letter M is brought to a point on the lower line. The letters O and Q are not perfect circles, as in the Light Egyptian, but are $\frac{3}{8}$ stroke wider than their height. The horizontal stroke of G, the tail of the Q, and the character & are curved somewhat in the shape of a horn. The point in each case rests within the letter. The outside end is terminated with a concave form, similar to the vertical strokes in the letters. The tail of the R is carried below the line in the same manner as the top of the K is carried above the line. The slant of the stroke of the R starts at a point $\frac{3}{7}$ stroke from the vertical line, and is carried so that the outside of the stroke is directly below the curve of the letter.

The letter S is drawn by means of 4 vertical lines 1 stroke apart. The third line will mark width of letter to upper spur, and fourth line will mark width of letter at extreme right-hand curve. The first line will mark curve of letter on left-hand side. The letter X is equal in width to the letter Y, and the point of intersection of its slanting strokes is $\frac{5}{7}$ stroke above the bottom line, and that of the Y the same distance from the top line. The lower stroke of the Z is similar to the letter E, except that it is cut off on the lower left side of the letter to form a beveled end. The character & is drawn with 4 vertical lines similar to those of letter S; the first line in this case determining the curved portion of the left-hand side of the letter; the fourth line determining intersection of under side of lower curve of the character and horizontal horn stroke; the second stroke will determine the point where top of character begins to extend above top line.

45. In drawing the numerals, little need be said in explanation. Attention is called only to a few points, such as that the 2 is straight on the bottom line and curved on the upper portion, similar to the reverse of the upper terminal of the C; the horizontal stroke is a compound curve on top. The 3 extends $\frac{1}{2}$ stroke above line, the point of the strokes being in center of inside space of letter.

The middle bar of 4 is $\frac{3}{8}$ stroke from the bottom line, and extends the width of the stroke of the letter to the right, and is carried to the left only far enough to give a small opening inside the figure. The figure 5 is carried $\frac{1}{2}$ stroke below the line. The point of the vertical stroke is $\frac{3}{4}$ stroke above the bottom line. The 6 extends $\frac{1}{2}$ stroke above the line and is $\frac{5}{7}$ stroke from the top line to upper side of curve.

The 7 extends $\frac{1}{2}$ stroke below line, and the right point is vertical below center of horizontal stroke. The figure 8 is composed of two ellipses, the lower one being $\frac{1}{4}$ stroke wider than the upper one. The 9 is just the reverse of 6.

46. In drawing the figures, it will be necessary in some places to diminish the the width of a stroke in order to leave sufficient space within. Draw all these letters with pencil, freehand, in precisely the same manner as the previous plates; then ink them in, freehand, without the use of the T square and triangle, other than to draw the pencil guide lines. The letters must then be filled in as in copy, the title drawn and blacked in, as shown, and the date, name and class letters and number put in their proper places, as heretofore. The student is not expected to produce absolute duplication of the letters on these sheets. By this time, he should have become familiar enough with the forms and proportions of the strokes, widths, and heights of all letters to vary them slightly from the dimensions given on this plate, without seriously impairing their proportions;

therefore, in drawing this exercise, the proportions of the strokes may be varied slightly in some places, if in the student's judgment this will improve the appearance of the letter.

PLATE, TITLE: FRENCH ROMAN

47. French Roman letters possess the same general proportion as the Full Block, that is, they have a width equal to their height. This width varies in some letters, however, precisely as it did in the Full Block style, and the details of such variation will be given as the letter in question is discussed. The characteristic difference between the Roman, Egyptian, and Half Block letters lies in the use of two separate but uniform widths of lines to form the letter. These are distinguished under the names of *stroke*, for the heavy portion, and *fine line* for the slender portions of the letter. On this plate, the four lines of letters and numerals are each $1\frac{1}{4}$ inches high, and $\frac{3}{4}$ inch apart, and the stroke is $\frac{5}{16}$ inch, or one-fourth the height, and the fine line is one-fifth the stroke. The title is $\frac{7}{16}$ inch high and $\frac{9}{16}$ inch above the line of letters. To draw this plate, divide the drawing paper above the lower border line, as in the previous example, and then lay out the letters lightly, in pencil (freehand), so as to space them equally along the lines.

48. The letter A is commenced $2\frac{1}{2}$ strokes from the border line, and is $4\frac{1}{2}$ strokes wide at the base. The apex of the A is the center of the letter (as is always the case in upright letters), and the top horizontal bar is $\frac{4}{5}$ stroke above bottom line. The spurs on the bottom make the foot of stroke 2 strokes wide, and the foot of the fine line 1 stroke wide.

The vertical stroke of B is about $1\frac{1}{4}$ strokes to the right of the A, and the intermediate bar is $2\frac{1}{4}$ strokes from the bottom, as are also the intermediate bars of E, F, and H. The width of the top of B is exactly 4 strokes, but the lower curved portion projects $\frac{2}{5}$ stroke more on the right side, and the spurs, top and bottom, extend an equal amount to the left. A vertical line drawn $1\frac{1}{5}$ strokes to the right of the upper

FRENCH ROMAN

ABCDEFGHI
JKLMNOPQR
STUVWXYZ&
123456789

curve of the B will be tangent to the left curve of C, and 4¼ strokes to the right of this line another vertical line will limit the fine lines of C. The lengths of each of the spurs, on the ends of the fine line of the C, is 1 stroke, the top one of which touches the top lettering line, while the bottom spur is ¼ stroke above the lower lettering line. One and one-half strokes to the right of C is the vertical stroke of letter D, which is 4 strokes wide. The curve of D commences ½ stroke to the right of the vertical stroke and the fine line gradually expands in an elliptic curve until it is a full stroke wide at the center. The spurs on D are the same as those on B. The letters E and F are each 4 strokes wide, the vertical stroke of the E being 1 stroke to the right of D, and the vertical stroke of the F 1¼ strokes to right of E. The spurs on these letters are each 1 stroke long, and incline from the letter at such an angle as would make either of them intersect the opposite lettering line about 1 stroke away from the letter; that is, if the line of the lower spur of E were carried to the top of the letter, it would intersect the top lettering line 1 stroke to the right of the letter. The intermediate bars of E and F are 1½ strokes long. With the exception of the vertical stroke, G is precisely like C; this extends ¼ stroke to the right of the fine line. The lower fine line joins the vertical stroke, on the outside, ⅘ stroke above the bottom, and the top of the vertical stroke is 2½ strokes above the bottom line. There is a space of 1½ strokes between G and H, and a space of 2 strokes between H and I. H is 4 strokes wide.

The letter J is 4 strokes wide, and its left extremity touches the left border line; the intersection of the curve and vertical stroke on the right is 1 stroke above the bottom line. The letter K is 4¼ strokes wide, and the fine line intersects the vertical stroke 1⅕ strokes above the bottom. The slanting stroke intersects the fine line 1⅕ strokes from the vertical stroke on the fine line. Excepting that the spur is 1¼ strokes in length, L is similar to E.

49. The letter M is 5 strokes wide. The intersection of the slanting stroke and fine line is on the bottom lettering line, exactly midway between the vertical stroke and vertical fine line. The lower side of the slanting stroke, where it intersects the vertical fine line, and the lower side of the slanting fine line, where it intersects the vertical stroke, is $\frac{4}{5}$ stroke below the top lettering line. The letter N is $\frac{1}{2}$ stroke narrower than the average 4-stroke letter, and the under side of the slanting stroke intersects the left vertical fine line $\frac{3}{4}$ stroke below the top line, and the right vertical stroke at its intersection with bottom lettering line. In outline, the O and Q are complete circles. The middle line of the P is $1\frac{1}{2}$ strokes above the lower lettering line, while the middle line of R is 2 strokes above, and the slanting stroke intersects the fine line 1 stroke to the right of the vertical stroke of the letter. The S is $3\frac{2}{3}$ strokes wide at the top and 4 strokes wide at the bottom; on the vertical center line of the letter the double-curved stroke is $1\frac{1}{5}$ strokes below the top line, and the spur on the end of the lower fine line is $1\frac{1}{4}$ strokes in its vertical length. The U is 4 strokes wide, as is also the Z, and the V is similar to an inverted A. The W is $6\frac{1}{2}$ strokes in width at the top, and its two lower points intersect the lower lettering line, 3 strokes apart. The point where the middle stroke and fine line meet on the top line is an equal distance from the inside of the left stroke and the inside of the right fine line; a vertical from this point drawn to the bottom letter line will give the position of the points reached by the strokes and fine lines on the bottom line. The right point is 1 stroke from the vertical line and the left point is 2 strokes. The X is $3\frac{4}{5}$ strokes on top and $4\frac{3}{5}$ strokes wide at the bottom. The Y is $4\frac{1}{4}$ strokes wide on top, and the vertical stroke is exactly in the center of the letter and $1\frac{1}{2}$ strokes high on the left side. The character & is $3\frac{1}{4}$ strokes wide on top. The curved portion of the character extends $\frac{1}{5}$ stroke to the left of the top fine line, while the center of the slanting stroke, where it rests on the bottom line, is directly beneath the right end of the top fine line. One slanting fine line intersects the slanting stroke 1 stroke below the top, and the other intersects the slanting stroke $\frac{4}{5}$ stroke from the bottom line, and then terminates in a horizontal spur $1\frac{1}{4}$ strokes from the top line.

50. In outlining the numeral 2, the space within the top of the figure must be as large and full as possible, without curtailing the space below. The horizontal stroke is $4\frac{1}{5}$ strokes long and is finished with a concave end and spur, as are also the 5 and 7. In each of these numerals, the point of spur is $\frac{1}{2}$ stroke from the end of the horizontal stroke to which it is attached. The numeral 3 is $3\frac{4}{5}$ strokes wide on top and $4\frac{1}{5}$ strokes wide on the bottom; the intermediate fine line is $2\frac{1}{5}$ strokes from bottom, and extends into the figure about two-thirds of the inside space. The horizontal fine line of numeral 4 is $1\frac{3}{5}$ strokes above the bottom of the figure, and extends $2\frac{4}{5}$ strokes to the left of the stroke and $\frac{4}{5}$ stroke to the right. The horizontal stroke of 5 is $3\frac{3}{5}$ strokes long, and the top of the intermediate fine line is $1\frac{2}{5}$ strokes from the upper lettering line. The figure is 4 strokes wide on the bottom, and finishes $\frac{1}{4}$ stroke to the left of the vertical fine line.

The 6 is $4\frac{2}{5}$ strokes wide, and the intermediate fine line is $1\frac{1}{5}$ strokes from the top. The upper fine line, with the spur, finishes $\frac{1}{2}$ stroke short of the full width of the figure. The 7 is 4 strokes wide on top and $1\frac{2}{5}$ strokes on the bottom, and its foot rests $1\frac{1}{2}$ strokes to the left of the end of the horizontal stroke. The 8 is $4\frac{1}{4}$ strokes wide on the bottom, and is identical with the right half of the duplicate on two sides of a center line. The 9 is an inverted 6.

Draw these letters in pencil, carefully proportioning each letter of both the plate and the title, measuring each stroke. The inking in must be done freehand with a red-sable brush, and the letters carefully blacked, as before. Insert the date in the lower left-hand corner of the plate, and in the lower right-hand corner put the name and class letters and number.

PLATE, TITLE: FRENCH ROMAN (LIGHT)

51. The **Light French Roman** letter fills the same position in point of variation to the normal alphabet as does the light Antique Egyptian to the normal alphabet of that letter. It is also an extremely modified form of the normal letter, applicable to certain specific purposes, where the mother style would be less desirable. The stroke of this style of letter can be made even lighter than on this plate, although, with such lightening, the fine line should remain about the same, unless the reduction in the stroke is such that it makes them too nearly the same size. The curved strokes of the letters appear more slender than the straight strokes if made the same width as the vertical, on which account some of the numerals, as well as the letters, are made heavier in stroke, and will be pointed out when the numerals are discussed. In making use of this alphabet, the stroke should never be made heavier, in proportion, than on this plate, as an increase will tend to bring it back to the original style of plain French Roman, wherein the stroke is one-fourth the height of the letter.

52. The cyma enters into the construction of some of the letters of this plate as it does in the light Antique Egyptian, and is also used in some instances to fill up the broad open spaces. It does not form a component part of any of the letters, except the A and Q, and under certain circumstances may be omitted entirely. Letters on this plate are the same dimensions in height and spacing as on the previous plate. The title is $\frac{3}{8}$ inch high, and $\frac{5}{8}$ inch above the top line of the letters. The stroke is $\frac{3}{16}$ inch; the fine line is one-third the stroke. The thickest part of the curved strokes is equal to the width of a stroke plus the width of a fine line; the spur projects one-half the stroke.

53. The letter A is $7\frac{2}{3}$ strokes wide and is started $3\frac{2}{3}$ strokes from the border line; the cyma, forming a cross-bar of the A, equally divides, and is itself equally divided by, the fine line.

FRENCH ROMAN (Light)

ABCDEFGHI

JKLMNOPQR

STUVWXYZ&

123456789

The B is 2 strokes to the right of the A, and $6\frac{1}{3}$ strokes wide at the top and 7 strokes wide at the bottom. The intermediate fine line is 4 strokes above the bottom line, and the lower space within the letter is $\frac{1}{2}$ stroke wider than the upper space.

The C is $1\frac{1}{2}$ strokes to the right of the B and is 7 strokes wide to the spur on the top line, but the lower fine line extends the width of 1 stroke, and finishes 2 strokes above the bottom line. The vertical stroke of the D is $1\frac{2}{3}$ strokes to the right of the C, the letter being 7 strokes wide, and the fine line commences to curve at a point twice the width of the stroke to the right of the vertical stroke. The middle horizontal fine lines of the E, F, G, and H are 2 strokes below the top line, and in E and F, 4 strokes long. The spurs on C, G, and S are rounded from the fine line, giving it an extra thickness at this point. The horizontal middle bar of the G is 4 strokes in length. The space between the D and the E and the E and the F is 2 strokes; between the F and the G only $\frac{1}{3}$ stroke; and between the G and the H and the H and the I is $2\frac{2}{3}$ strokes. The letters E and F are 6 strokes and the D, G, and H are 7 strokes in width. The curve of the J intersects the vertical stroke 1 stroke above the bottom line. The fine line of the letter K intersects the vertical stroke 2 strokes above the bottom line, and extends 1 stroke above the top line; the slanting stroke intersects the fine line $3\frac{2}{3}$ strokes from its lower end. The middle slanting strokes of the M are brought to a point 3 strokes above the bottom line; the top of the letter is 3 strokes narrower than the bottom, the full width on the bottom being 8 strokes. The slanting stroke of the N joins the vertical fine line on the right $1\frac{1}{3}$ strokes above the bottom. The O and Q are 8 strokes wide; the P and R are 7 strokes wide; and their middle fine lines are $2\frac{2}{3}$ strokes from the top line. The cyma of the Q rests on the bottom line on the right side of the letter, and on the left is 2 strokes above within the letter.

54. The intersection of the slanting stroke of the R with the middle fine line is 2 strokes to the right of the vertical stroke, and its lower end is cut off at an angle of 45°, the right spur resting on the bottom line. On a vertical center line drawn through the S, the middle stroke is $3\frac{2}{3}$ strokes from the bottom line; the fine line on top is cut off 1 stroke shorter than the projection of the curve beneath it, while the fine line at the bottom projects 1 stroke beyond the curve above it. The full width of the S at the bottom is $7\frac{2}{3}$ strokes. The T is 7 strokes at the top, and the U is $6\frac{1}{2}$. The fine line of the letter V extends above the lettering line in the same manner as the fine line of the K. The intersection of the interior lines of the W is equally divided between the stroke and fine line, and is $1\frac{1}{3}$ strokes below the top line. The space between the points of the letter on the bottom is 5 strokes, and the cyma is drawn about two-thirds of the space within the letter. In the letter X, the fine line intersects the stroke $2\frac{1}{3}$ strokes below the top line, and the letter is 8 strokes wide at the bottom. The fine line of the Y intersects the vertical stroke $3\frac{2}{3}$ strokes above the bottom, and the letter is $7\frac{2}{3}$ strokes wide on top. The character & is 7 strokes wide at the bottom, and the lower end extends 1 stroke to the right of the upper portion. The middle bar is 4 strokes from the bottom line. The cyma is so placed as to extend $1\frac{1}{2}$ strokes outside, and $2\frac{1}{2}$ strokes inside, the letter, and its lower end is $1\frac{1}{2}$ strokes above the line.

55. The numeral 1 is beveled on its upper end at an angle of 60°, the line of the bevel being equally divided by the top line of the letters. The upper parts of the numerals 2 and 3 are sickle-shaped, and the horizontal stroke of the 2 is straight on the bottom and curved on the top. The lower fine line of the 3 is finished similar to the upper fine line of G. The middle bar of the figure 4 is $2\frac{2}{3}$ strokes above the lower line, and extends $5\frac{2}{3}$ strokes to the left and 2 strokes to the right of the vertical stroke. The middle bar of 5 is 4 strokes above the bottom line; the upper horizontal stroke is 6 strokes long, and finished in the same manner as the bottom stroke of the 2. The middle bar of the 6 is 5 strokes above the bottom line, and the upper part of the figure diminishes to a point 1 stroke above the top line, the point being on a vertical line from the inside of the right-curved stroke. The slanting stroke of the 7 extends 1 stroke below the line, and is cut off parallel with the lettering lines; the horizontal stroke of the 7 is similar to the top stroke of the 5. The figure 8 is 6 strokes wide on top and $7\frac{1}{3}$ strokes below. The horizontal middle stroke is $2\frac{1}{3}$ strokes below the top line. The numeral 9 is similar to the 6, reversed, the middle line being 2 strokes above the bottom line, and the point of the letter below the bottom line being vertically beneath the outside of the left-hand curved portion.

These letters and numerals should be drawn in freehand, according to the directions herewith given, and the letters blacked in ink. Then put the date in the lower left-hand corner, and in the lower right-hand corner the name and class letters and number, as before.

PLATE, TITLE: FRENCH ROMAN (HEAVY)

56. The **Heavy French Roman** is the other extreme of the letter, as contrasted with the light style of the French Roman alphabet. The stroke in this style is increased to about twice what it is in the normal French Roman style, thus making the strongest contrast possible in the details of the letters. In general use, however, this heavy style of letter (as explained in connection with the heavy Antique Egyptian alphabet) is not usually blacked in solid as here shown, but it is drawn in outline only, the outline being about the same weight as the fine line. In designing any particular variation of a form or style of letter, such as heavy French Roman, it is important to observe that in each variation the characteristics of the letters should be maintained uniformly throughout the alphabet. For instance, the lower fine line of the E is in this case not terminated with the regular spur, as before, and to be consistent, the lower fine lines of the L and Z are similarly terminated, as these letters in any plain alphabet are alike in the lower fine line and finish. The same idea may be observed in the carrying of the fine line of the K, V, W, and Y above the line.

:FRENCH:ROMAN:(HEAVY)

ABCDEFG
HIJKLMN
OPQRSTU
VWXYZ &

57. The height of the letters in this plate, their size and position, the space between the lines, and also the title, are precisely the same as on the previous plate. The width of the stroke is $\frac{1}{2}$ inch. The average width of a letter is 3 strokes, but the alphabet abounds in exceptions, so that it is not surprising to find that the number of letters of standard width are in the minority. The spur is about $\frac{1}{4}$ stroke, and is joined to the fine line with a curve, except as pointed out in connection with the E, L, and Z, and also in the other fine lines of the letters E, F, T, and Z. The letter A is $3\frac{1}{2}$ strokes in width. The middle bar is $\frac{3}{8}$ inch from the bottom line, but the spurs at the top of the side end stroke are precisely the same as those at the bottom. The ends of the strokes are rendered concave by the arc of a circle whose radius is 4 strokes. The middle line of the B is $1\frac{1}{2}$ strokes above the bottom. The lower portion of the letter is $3\frac{1}{2}$ strokes wide and extends $\frac{1}{2}$ stroke to the right of the upper portion. The bottom fine line of the letter C extends 1 stroke beyond the spur at the end of the top line, and the cyma is inserted, as shown, to fill the space within the letter. Observe that the curve of the cyma becomes tangent, as though it were a continuation of the inner curve of the letter. The outlines of the B, D, E, L, P, R, and Z are formed, not of a straight line on top and bottom, as in previous styles, but in the form of a compound curve, making, thereby, a wavy fine line, terminating in the E, L, and Z with a heavy curl. The horizontal fine line in the middle of the E, F, and H, and the top of the vertical stroke of the G, are $\frac{3}{4}$ stroke from the top line. The intermediate fine line of the E and F is 2 strokes in length, and extends $\frac{1}{4}$ stroke beyond the end of the fine line. The fine line of the K meets the vertical stroke $\frac{3}{4}$ stroke above the bottom line. The slanting stroke of the K (measuring on the fine line) intersects the fine line 1 stroke from the vertical stroke. The left-hand stroke of the M is not given full width on the top line, in order to leave as much space as possible within the letter, and at the same time to avoid too great a projection beyond the left fine line. The intersection of the middle stroke and fine line is $\frac{1}{2}$ stroke from the bottom, and the letter is $5\frac{1}{4}$ strokes in width. The letter N is $\frac{1}{8}$ stroke narrower than the average width of the letters, and the slanting stroke intersects the fine line $\frac{1}{4}$ stroke above the bottom. The lower line in the slanting stroke intersects the left-hand vertical line 1 stroke below the top. The O and Q are $3\frac{1}{2}$ strokes wide. The tail of the Q is entirely outside of the letter in this style, and is somewhat of the form of a cyma, tangent to the outside of the letter below and to the right of the center line of the opening. The lower fine line of the P is $\frac{5}{8}$ stroke above the bottom line. Notice that the width of the stroke of the S where it joins the fine line diminishes very rapidly, and is not a gradual reduction, as in the previous slants. The upper fine line is $\frac{3}{16}$ inch within the outline of the letter, and the lower line projects $\frac{3}{16}$ inch. The letter U possesses two very small spurs in its lower portion, and is thickened to twice the width of the fine line at the point where the vertical and curved fine lines come together. The V, W, Y, and also the K carry their fine lines above the line about $\frac{1}{2}$ stroke, the spurs on the end of which are at right angles to the line of the letter. This feature is frequently added to the fine line of the letter A, carrying it below the line about $\frac{1}{2}$ stroke and finishing its spurs at right angles. The width of the W is 5 strokes. To proportion the W, lay out its full width of 5 strokes on the top line, and from the right end of the letter lay off, to the left, 2 strokes on the top line, which will locate the point where the middle strokes meet; $\frac{3}{4}$ stroke to the right of a point vertically opposite this, on the lower line, will give the point where the right stroke and fine line meet, and $1\frac{3}{4}$ strokes to the left will give the other corresponding point. The stroke and the fine line of the X intersect at a point $\frac{5}{8}$ stroke from the top line, the letter being 3 strokes wide on top. The vertical stroke of the Y intersects the fine line $1\frac{1}{2}$ strokes above the bottom, and the letter is $3\frac{3}{4}$ strokes wide on the top line. The lower left-hand angle of the letter Z diminishes to a point that projects from the letter about $\frac{1}{2}$ stroke. The character & extends $\frac{1}{2}$ stroke to the left of a vertical line drawn tangent to its upper curve on the left side, and the cyma forming the lower right termination, on its fine line, is equally divided above and below the point where it is joined to this line, the lower curve of the cyma being tangent to the bottom line, and the upper curve reaching $1\frac{1}{2}$ strokes above it.

58. The instructions for drawing this plate are much less detailed than the other plates, as by this time the student should be sufficiently familiar with the letter forms to readily design any of the characteristics without detailed explanation. Attention is particularly called, however, to the careful spacing of the letters, particularly those of the top line, as by getting these in their proper places it is a simple matter to locate others beneath them in their proper relative positions. Having drawn the letters carefully in outline, they should be inked in and then blacked, as usual, with a sable brush, after which the date should be placed in the lower left-hand corner, and the name and class letters and number in the right-hand corner, as before.

PLATE, TITLE: ROMAN (NEW YORK)

59. There are no styles of lettering more generally used, with more convenient application for various purposes, than the Roman letter. Three general styles of the Roman letter will be given here, and attention is called, particularly, to the principal characteristic differences in the styles as well as to the general formation and construction of the letters. In the **New York Roman**, the main characteristic is the thinness of the fine line, and the symmetrical proportions of the letters; for, though the upper and lower halves of such letters as the E, H, and S are not identically the same in size and proportion, they are arranged to appear so to the eye, and the actual difference is difficult to discern, unless the letter is turned upside down.

60. In drawing this plate, make the four lines of letters $1\frac{1}{4}$ inches high, as before, with the spaces between them $\frac{3}{4}$ inch,

ROMAN
(NEW YORK)

ABCDEFGHI
JKLMNOPQR
STUVWXYZ&
123456789

the main line of the title $\frac{3}{8}$ inch high, and $\frac{5}{8}$ inch above the top line of the letter; the second line of the title $\frac{1}{8}$ inch high, and $\frac{3}{8}$ inch above the top line of the letters. The stroke of this letter is $\frac{5}{16}$ inch, or one-fourth of the height; the spurs are $\frac{4}{5}$ stroke on all letters, except the E, F, L, T, and Z, where they are larger, as will be described later. The curve of the spur from the fine line to the stroke is, in most cases, a quarter circle, the radius of which is $\frac{4}{5}$ stroke, and the center $\frac{4}{5}$ stroke from the vertical stroke and the fine line, to both of which the quadrant must be tangent.

61. The letter A is located at the foot of its fine line 2 strokes from the left-hand border; the middle fine line is $1\frac{1}{5}$ strokes above the bottom line, and the spurs on the end of the fine line increase its length to 2 strokes at the base, and that of the slanting stroke to 3 strokes. The lower portion of the B extends $\frac{1}{4}$ stroke to the right of the upper portion. The letter C is designed so that its interior outline forms a perfect ellipse 3 strokes in width and the height of the letter, the crescent-shaped portion of the stroke to the left of the letter being $\frac{1}{5}$ stroke thicker at its center than the vertical strokes in the same alphabet. The spurs on the E, F, L, T, and Z, extending 1 stroke at right angles to the fine line, are returned to the fine line at an angle of 45°, and are rounded into it with a slight curve. The middle fine lines of the B, E, F, and H are $\frac{1}{5}$ stroke above the center of the letter. The top of vertical stroke of the G is $\frac{2}{5}$ stroke above the center of the letter.

The letter J is terminated at its left extremity with a ball, or disk, the top of which reaches to the center of the letter, the small spur at the right extremity marking the intersection of the vertical stroke with the expanding curved fine line at a point $\frac{4}{5}$ stroke above the bottom line. The fine line of the K intersects the vertical stroke at a point $1\frac{1}{2}$ strokes above the bottom line, and the slanting stroke intersects the fine line $1\frac{1}{5}$ strokes from the latter starting point.

62. The space within the lower part of the M is equally divided on the lower lettering line by the intersection of the slanting stroke and the slanting fine line. The top of the vertical stroke is reduced one-fourth its width where the fine line bevels its corner. The main point to be observed in this letter is to be sure that the intersection of the vertical fine line and slanting stroke, and of the vertical stroke and slanting fine line, are the same distance from the top of the letter. The N is $\frac{2}{5}$ stroke narrower than the other letters. The intersection of its slanting stroke and left fine line are the same distance from the top line as in the letter M. The ellipses that form the interiors of the letters O and Q are 1 stroke narrower than that of the C, owing to the fact that a heavy crescent-shaped stroke on either side of the ellipse so increases the letter as to give it proper proportions. The exterior outlines of the O and Q are perfect circles. The lower fine line of the letter P is $1\frac{3}{5}$ strokes from the bottom line. The tail of the R is located $\frac{1}{2}$ stroke to the left of the right outline of the letter, and is a perfect cyma equally divided by a horizontal line one-fourth the height of the letter. The crescent above it is 1 stroke wide at a point 1 stroke from the top line. The middle bar is located exactly in the center of the letter.

63. A center vertical line through the letter S will divide the stroke $1\frac{3}{5}$ strokes above the bottom line. The finish of the left spur is vertically under the curve of the stroke above, but the finish of the right spur is $\frac{1}{4}$ stroke within the letter, and but two-thirds the length of the lower spur on the side. The letter U is drawn with the lower inside curve a semiellipse, and an increase in the thickness of the spur marks the point where the vertical fine line becomes tangent to the curve. The W is $6\frac{1}{5}$ strokes wide, its lower points being 3 strokes apart, 1 stroke to the right and 2 strokes to the left of a point vertically opposite the middle point on the top line, which divides equally the space between the inside of the left slanting stroke and the right fine line. The intersection of the stroke and fine line of the X is practically in the center of the letter, so as to make the enclosed triangles of equal area above and below. The fine line of the

Y intersects the vertical stroke exactly in the center of the letter. The character & possesses, for its heaviest stroke, a compound curve, the inclination of which is the same as the slanting stroke of the letter N. The width of this character on top is 3 strokes, and its lower portion projects $\frac{1}{2}$ stroke to the left of the upper portion. The intersection of the right fine line and heavy stroke is $1\frac{3}{5}$ strokes above the bottom line, and the top of the ball terminating the fine line is $2\frac{2}{5}$ strokes above the bottom line and $1\frac{3}{5}$ strokes to the right of the point of intersection. The light strokes of the character are about $\frac{3}{5}$ the width of the heavy stroke.

64. The lower stroke of the numeral 2 is a perfect cyma, and the top is precisely the same as that of the 3. The stroke tapers off again to a fine line where it joins the left end of the cyma. The balls terminating the fine lines of the Roman figures are $\frac{2}{5}$ stroke wider than the straight strokes of the figures, while the curved strokes of all the figures are $\frac{1}{5}$ wider than the straight ones. The space between the two balls at the end of the fine line of the figure 3 is about one-half their diameter. The top of the figure 4 is finished in the same manner as the right stroke of the letter M. The horizontal fine line of the 4 extends $2\frac{4}{5}$ strokes to the left and 1 stroke to the right of the vertical stroke, and is $1\frac{3}{5}$ strokes above the bottom line. The horizontal stroke of the figures 5 and 7 is different from that of any other alphabet, and consists of a double compound curve, the concave and convex portions of which are opposite each other. The lower portion of the 5 is similar to the 3, and the vertical fine line is $\frac{2}{5}$ stroke to the right of the left outline of the ball. The width of the lower stroke of the 7, on the bottom line, is $1\frac{3}{5}$ strokes, and rests on the bottom line 1 stroke to the right of the end of the horizontal stroke. The top line of the lower portion of figure 6 is $2\frac{2}{5}$ strokes above the bottom line. The ball is about $\frac{1}{5}$ stroke within the figure. The stroke of figure 8 is precisely the same as that of the letter S, the fine line being reduced where it is brought around and intersects the stroke near the center of the figure. The maximum thickness of the lighter stroke in the 8 is about one-half that of the main stroke. The figure 9 is a reversed 6, except that the ball extends to the outside line of the letter.

65. The New York Roman letter is used largely by some sign painters where the work is to be done in gold or in black letters on a white ground, and the fine line is so thin that a strong contrast is required to bring it into prominence. Some designers vary the forms of the figures 2, 3, and 6 in a manner that, though not strictly classical, adds highly to the effect. Instead of terminating the upper fine line with a ball, it is finished in a point, as shown in Fig. 1, or sometimes equal in width to the stroke, as shown in Fig. 2.

FIG. 1

FIG. 2

Draw these letters as on the previous plates, being careful to space the letters in the top line uniformly, and making the letters in the three lower lines of the plate proportionately; then place the date, name, and class letters and number in their proper places.

PLATE, TITLE: ROMAN (BOSTON)

66. The **Boston Roman letter** possesses a much heavier fine line than does the New York Roman, the spurs of the letters being cut off on the end to form a fillet the thickness of a fine line. These spurs are one-fourth circle, as described in the previous plate, the radius being the additional width of the fine line nearer the center of the letter. In the earlier form of the Boston Roman (the style from which our present style sprung), the fine line was much longer on the spur, and triangular corners, instead of quarter circles, marked the connection of the spurs to the vertical strokes. The early form is now obsolete; only occasionally on a very old sign is seen an inscription making use of these letters. The application of this style of letter fills a

ROMAN
(BOSTON)

ABCDEFGHI
JKLMNOPQR
STUVWXYZ&
123456789

field wherein the practice of the New York Roman would be impossible, such as the cutting of letters in stone or marble, and the working of letters in leaded glass or sheet metal, where the fine line of the New York style of letter could not be executed. The letters are in precisely the same proportion as those on the previous plate, and are placed $\frac{3}{4}$ inch apart—the lettering lines being $1\frac{1}{4}$ inches high, as before, the larger letters of the title being $\frac{3}{8}$ inch and small letters $\frac{1}{8}$ inch high, and $\frac{5}{8}$ inch and $\frac{5}{16}$ inch above the top line of letters, respectively. The width of stroke in these letters is $\frac{5}{16}$ inch, and though the fine line is here designed as $\frac{1}{5}$ stroke, it may be varied somewhat, according to the material in which the letters are to be worked. As, for instance, the marble, metal, or glass worker may use a heavier fine line on some special work than the normal text, while the sign painter often reduces the fine line, especially if the letters are to be gilded.

67. In the first line of letters, there is no characteristic difference between this and the alphabet of the previous plate, except as already pointed out in the thickness of the fine line and the termination of the ends of the spurs. The top of the A and the bottom of the V and W, the middle strokes of the M and the slanting stroke of the N, are not terminated in a point, but in a fillet the width of the fine line, for the same reason as above described.

The spurs of the middle fine line of the E and F are joined to the fine line in a curve, as is also the spur on the end of the horizontal fine line of the figure 4. The other horizontal fine lines, however, do not join the spurs in a curve.

The letters W and R are somewhat different from those of the previous alphabet, as the middle of the top of the W is finished a full stroke in width, with spurs, instead of being brought to a point, as in the previous plate.

The tail of the R is carried out in a slanting stroke from a point the width of 1 stroke from the vertical stroke, extending the width of 2 strokes from the vertical stroke, where it intersects the bottom line with a spur on the right side.

68. In the numerals, there is little change from the other style of Roman letter, except in the horizontal strokes of the 2, 5, and 7.

Draw this plate under the same rules and conditions observed in the previous plate, as all the proportions and details of the letters are identically the same, except where herein pointed out as different. Draw these letters as on the previous plate, inserting date, name, and class letters and number, as before, being careful to space the letters uniformly, and making the letters in the three lower lines of the plate proportionately.

PLATE, TITLE: MEDIEVAL ROMAN

69. The **Medieval Roman letter,** termed by some authorities *Antique Roman*, belongs to the historic period that its name indicates. There are three features shown in this style of letter. The first of these is a small spur added above and below the lettering lines; another is a projection of the inside line of the stroke beyond the fine line a distance of about $\frac{1}{3}$ stroke, as in the top of the letter A and the bottom of the N; and the third is the rounding of every angle of the letter where two fine lines or a fine line and a stroke intersect. The width of the stroke of these letters is $\frac{1}{4}$ inch, or one-fifth the height. The spur is 1 stroke long, and is joined to the letter 1 stroke above the bottom, or below the top line, thus making the curve on the inside an exact quarter circle. All letters on this plate are 5 strokes in width, with the exception of such letters as have been heretofore described as always exceeding or falling short of these limits.

70. In the letter A, the fine line intersects the stroke at the point of the letter, and though the stroke on its inside is carried past the fine line, the intersection takes place precisely as though this peculiarity did not exist. The horizontal fine line of the A is $1\frac{1}{4}$ strokes above the bottom of the letter. The lower curved portion of the B extends

MEDIEVAL ROMAN

ABCDEFGHI
JKLMNOPQR
STUVWXYZ&
123456789

$\frac{1}{4}$ stroke beyond the upper curve, and the middle bar is $2\frac{3}{4}$ strokes above the bottom line. The spurs of the C, G, and S, and of the numerals 1, 2, 3, 5, and 7, are finished with a fine line or secondary spur above or below the lettering line. In these three letters, this little spur is opposite the point of the main spur; it should not exceed $\frac{1}{4}$ stroke in length, and is not vertical, although nearly so. The middle fine lines of E, F, and H, and the top of the vertical stroke of the G are $2\frac{3}{4}$ strokes from the bottom line.

The letters E and F are $\frac{1}{2}$ stroke narrower than the regular width of the letters. The L is one stroke narrower, the N $\frac{1}{2}$ stroke narrower, the M 1 stroke wider, and the W is $3\frac{1}{4}$ strokes wider than letters of regular width. The Y is $\frac{1}{2}$ stroke, and the character & is 2 strokes wider than the average width ,of the letters. The vertical stroke of the letter G has a spur added at the point where the curved line and the bottom of the letter intersects with it. This spur is about $\frac{1}{4}$ stroke in length. The letter J is $4\frac{1}{2}$ strokes in width, and extends 1 stroke below the line, the ball being 1 stroke in diameter and crossing $\frac{1}{3}$ stroke over the line. The curved portion is tangent to the ball of the left-hand portion, and intersects with the vertical stroke of the letter on the right side 1 stroke above the bottom line.

71. The K, like the letter A, has the inside of the slanting stroke projecting across its fine line; the intersection of the slanting stroke of the fine line is 2 strokes from the vertical stroke, and the fine line joins the vertical stroke $1\frac{1}{4}$ strokes above the bottom. The spur on the end of the fine line of the L, as on all other horizontal fine lines of this alphabet, extends outwards as shown, though on this letter the incline is somewhat more than on the E, F, or T.

The slanting stroke and the fine line of the M intersect midway between the fine line and vertical stroke of the letter, both intersections of the fine line and stroke at the top of the letter being 1 stroke below the top line. The projection of the upper side of the slanting stroke on the right fine line of the N makes this letter the full width of 5 strokes.

The letters O and Q are circles on the outside, and the ellipses within, instead of being vertical, are inclined to the left, so that the longitudinal axis of the ellipse is about 1 stroke to the left on the top line.

The lower fine line of the letter P is $2\frac{3}{4}$ strokes from the bottom line of the letter. The fine line of the R is $2\frac{1}{2}$ strokes above. The tail of the R begins $1\frac{1}{4}$ strokes from the vertical stroke of the letter and extends to twice this distance on the bottom line.

The spurs of the letter S are unequal in length, and the lower one is largely under the upper curve of the letter, while the upper one is $\frac{1}{2}$ stroke within a line of the lower curve. The horizontal stroke of the letter is $2\frac{1}{2}$ strokes from the bottom line.

The letter W is $8\frac{1}{4}$ strokes wide on top and $3\frac{3}{4}$ strokes wide on the bottom, and the intersection of the inside fine line and the right side of the stroke is 4 strokes from the left side of the letter. The interior triangles of the letter should all be of the same area.

The fine line of the X intersects the stroke $\frac{1}{2}$ stroke above the center of the letter, and the fine line of the Y joins the stroke exactly in the center of the letter.

72. The character & is designed so that the interior of the upper and lower portions of the letter incline the same as the elliptical interior of the O and Q, and some authorities carry this feature in the inside line of the C and G, but it is difficult to accomplish this without producing a distorted appearance, and has therefore been here omitted. The top of the & is $\frac{1}{4}$ stroke wide above the top line, and the right fine line expands to a width $\frac{3}{4}$ stroke at a point almost on the top line. The fine line intersects the lower outline of the stroke half way between the top and bottom lines. The horizontal line of the spur is $\frac{1}{4}$ stroke above the center of the letter.

73. The fine line forming the top of the numeral 1 is at an angle of about 60°, and the broadest point extends above the top lettering line about one-half the width of a stroke, the fine line extending the width of a stroke beyond the vertical stroke of the letter. The curves of the 2, 3, and 5 are somewhat sickle shaped, the top of the 3 being the only one with a spur above the top line. The 3, 5, 6, and 9 terminate in a point 1 stroke above or below the line. This characteristic feature of the figures 3 and 4 in this style is the fine line, which is inclined at an angle of about 50°. The curved stroke of the 3 begins on the fine line at a point about $\frac{1}{2}$ stroke above the center of the figure. The figure 4 extends 1 stroke below the bottom line, and the horizontal bar is 1 stroke above the bottom line, $\frac{1}{4}$ stroke in thickness, and extends $1\frac{1}{4}$ strokes to the right and $3\frac{3}{4}$ strokes to the left of the horizontal stroke. The vertical fine line of the figure 5 is one-half the height of the letter.

The upper fine line of the figure 6 is $\frac{3}{4}$ stroke below the top line. The slanting stroke of the figure 7 extends 1 stroke below the bottom line, and its lower right end is vertically below the center of the horizontal stroke of the figure on the top line.

The lower inside space of the figure 8 is made as large as possible, in conformity with the other letters of its style, the lower portion of the letter being 6 strokes in width and $\frac{3}{4}$ stroke wider on each side than the upper portion. The horizontal portion of the stroke is $2\frac{3}{4}$ strokes above the bottom line. The figure 9 is a reversed 6, the lower fine line being $\frac{3}{4}$ stroke above the bottom line.

Execute all the work on this plate as in the previous plates, paying particular attention to the distinguishing characteristics of the letter, completing the plate with the date, name, and class letters and number in their proper places.

PLATE, TITLE: LOWER-CASE ROMAN

74. The **lower case** of the four varieties of Roman letters are given on this plate, in order to show the comparative differences in their general design. The plate is divided somewhat differently from the previous ones, the lowest line being $\frac{3}{8}$ inch above the lower border line.

Lower Case Roman

NEW YORK AND BOSTON ROMAN

abcdefghijklmnopqrstu
abcd vwxyz rstu

FRENCH ROMAN

abcdefghijklmnopqrstu
vwxyz

ROMAN NUMERALS

I II III IIII IV V VI VII VIII IX X XX·L·C·D·M·

MEDIEVAL ROMAN

abcdefghijklmnopqrstu
vwxyz

Another line drawn $\frac{5}{8}$ inch above will mark the space for the last five letters of the alphabet. A similar $\frac{3}{8}$-inch space and a line $\frac{5}{8}$ inch above this will mark the first letters of the alphabet. The upper strokes of these letters extend $\frac{3}{8}$ inch above this line, and $\frac{1}{4}$-inch space is left between their tops and the numerals.

The line containing the numerals is $\frac{1}{2}$ inch high. Resting on the line forming the top of the Roman numerals are the last five letters of the French Roman alphabet. These are $\frac{5}{8}$ inch high. Allow $\frac{3}{8}$ inch space between lines of letters and draw the upper French Roman letters $\frac{5}{8}$ inch high. All letters above it, except the titles, are $\frac{5}{8}$ inch high. The space between the top of the French Roman and the lower line of letters above is $1\frac{3}{16}$ inches; the space between the upper letters is $\frac{3}{8}$ inch. The projection of the letters above the top, or below the bottom, lettering line is the same as in all three alphabets.

75. Only eight letters of the Boston Roman alphabet are shown, as this alphabet is practically the same as the New York style in every respect, excepting the proportionate widths of stroke and fine line, and any such other details as would arise from a difference of fine line and the way it finishes. These details have been explained in connection with the plate containing the capital letters in previous alphabets, and need not be repeated here. The bottom part of the vertical stroke of the a curves to a point in the New York alphabet, and finishes with a fillet at the end of a quarter circle in the Boston. The same difference will be observed in the finish of the vertical strokes of all letters in these two alphabets.

76. In the French Roman, this termination in the letters is different, branching off at an angle from the vertical stroke and carrying both sides parallel, making a spur on one side and a bevel on the other side of the stroke.

The curve of the a is the same in the New York and Boston alphabets, bending downwards to its intersection with the vertical stroke, while in the French Roman alphabet it intersects with the vertical stroke in an upward direction.

In the New York and Boston alphabets, the ball on the terminal of the upper fine line of the a and other letters is the same, but in the French Roman these letters are finished with a thickening of the fine line.

The width of the stroke in the first three alphabets is $\frac{1}{8}$ inch, but that of the Medieval Roman is one-third less. The top stroke of the b, as well as that of all vertical strokes, except the t, in the New York and Boston alphabets, is horizontal, while the bottom stroke in each case is the reverse of the letter a.

The top of the c is the reverse of the top of the a; the letter d is the reverse of the b in each alphabet, except the Medieval Roman, the fine line of which intersects the stroke at the top of the body of the letter. The stroke of the e is cut off at a bevel in the first two alphabets, and brought to a point in the fine line in the lower two. The curved stroke of the latter is crescent-shaped.

The cross-line of the f in the first two alphabets is finished as a spur, but in the lower two it is a bar $\frac{1}{2}$ stroke wide, extending two-thirds the width of the letter.

The letter g of the first alphabet extends four-fifths its height below the line. The top part of the g is equal to the o and the bottom is a cyma, the right point of which continues in a fine line to the line below. The extreme lower portion of the g is the same in the first two and in the Medieval alphabet, except as to proportion, the latter being broader and more elongated, while the French alphabet differs in this respect by the omission of the return of the fine line.

There is little variety in the h, i, or j of any of the alphabets, except as to width and weight of the stroke. The tail of the r in the first two alphabets is practically the same; in the third, it forms a half cyma, but in the fourth one it meets the fine line, terminating in a ball. The s of the Medieval Roman alphabet thickens at the ends of the fine line, and terminates with a fine-line spur in the same manner as the capital letter of that alphabet.

The last five letters, with the exception of the y, are closely allied in design to the capitals of the same alphabet, and the letter y is similar to the letter v with its fine line carried below the bottom lettering line and finished as shown.

77. There are no set rules governing the width of the stroke, the space between the strokes in the Roman numerals always depending on the circumstances under which the characters are used. On a circle, such as a clock dial, the stroke is light and the space does not greatly exceed the fine line in this case. The numerals V and X are condensed as much as possible. The line at the top and bottom of the letter in many cases does not extend across the points of the V, as shown in the plate, but are cut off in the form of a spur for each individual numeral.

The numeral 4 in some cases is written IIII, and in others IV. There is no rule governing which shall be used, although custom has made the former almost universal in dialing. In nearly all cases where these letters occur to represent numerals, they are condensed much more than any other letters of the same style on the same tablet or in the same inscription.

In the use of the Medieval Roman alphabet, it was formerly customary to leave no space between the various words of the inscription, but to separate the words merely by a period, in the same manner as the numerals.

Draw this plate according to the directions given, proportioning the letters as directed, inserting the small titles over each alphabet, and observing particularly the characteristic differences existing in each one. After the plate is inked, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: COLOR SHADING

78. In shading letters with colors, there are several important points to observe. To give the shading the touch of a master hand, one must first select such colors as are in harmony or contrast. Discordant colors should, therefore, be studiously avoided. Weakness in coloring is always characteristic of the work of a beginner. Black or dark colors should be freely employed to give strength to the shading. Pure rich colors may be easily destroyed by using a brush that has not been thoroughly cleaned, or they may be ruined by carelessness in mixing. This is especially true with regard to oil or varnish colors, as water colors are pure in their prepared state, and require only pure water to reduce them to the consistency and strength where they may be applied.

79. To draw the plate, use regular T. S. Co.'s cold-pressed drawing paper 15 inches by 20 inches. Measuring from the bottom edge of paper, draw the bottom line for the letter B exclusive of shade 3 inches from the edge; the letter C, $2\frac{3}{4}$ inches, and the letter E, $3\frac{1}{8}$ inches. The letter B is 2 inches from left edge of paper and $3\frac{3}{4}$ inches wide, exclusive of spurs. The letter E is $\frac{3}{4}$ inch fróm right edge of paper, and $4\frac{3}{4}$ inches wide, exclusive of spurs. Locate the letter C $3\frac{1}{8}$ inches to the left of E, making it 3 inches wide, extreme width. The widths of the strokes of these letters are: B, $\frac{7}{8}$ inch, including black outline in each case; C is $\frac{3}{4}$ inch, and E, 1 inch.

Beginning at the top edge of paper, measure downwards and draw a line for the top of title $1\frac{7}{16}$ inches from edge. The height of title is $\frac{5}{16}$ inch. Locate this in center of plate by finding center, which is 10 inches from right or left edge of paper. Locate the black panel containing the letter W $1\frac{1}{4}$ inches from right edge of paper and $2\frac{1}{4}$ inches from top; the height of panel is $3\frac{5}{8}$ inches and the length $4\frac{7}{8}$ inches. The height of letter W is $2\frac{7}{16}$ inches and the letter is $\frac{3}{4}$ inch from bottom edge of panel. The letter I is $2\frac{1}{8}$ inches from top edge of paper; $4\frac{5}{8}$ inches high and $1\frac{1}{4}$ inches from left edge; exclusive of spurs. The letter E is $2\frac{9}{16}$ inches from top edge; $4\frac{1}{4}$ inches high, and 4 inches from left edge of paper. The panel to the back of letter E is $2\frac{1}{8}$ inches from top, $3\frac{1}{2}$ inches from left edge, 3 inches high, and $3\frac{1}{8}$ inches wide. The letter S is $2\frac{1}{8}$ inches from top edge of paper, $8\frac{3}{16}$ inches from right edge, and $8\frac{1}{8}$ inches from left edge measuring to the extreme curve of the main stroke of letter.

The letter T is $3\frac{1}{4}$ inches high. The width of strokes is as follows: I, $\frac{15}{16}$ inch; E, $\frac{5}{8}$ inch; S, 1 inch; T, $\frac{3}{4}$ inch, including black outline; W, $\frac{9}{16}$ inch.

80. Draw the shade from all letters by first drawing light pencil lines from every point of the letter at an angle of 45°. Always keep the shade uniform in width and the space between the shade and the outline of letter likewise uniform in width. The space between the shade and the stroke in the letter W is $\frac{3}{16}$ and the shade $\frac{3}{8}$ inch wide, condensing this on left slanting strokes. The width of the yellow, crimson lake, and vermilion shades in the letter S is $\frac{1}{4}$ inch; that of the two gray shades is $\frac{3}{16}$ inch. The letter T being smaller, the width of shades are in proportion to the height of letter. The top portion of letter I is $\frac{5}{16}$ inch on its black face and $\frac{5}{16}$ inch wide in its bevels. The beveled edge of the lower portion is $\frac{3}{16}$ inch. The strokes of the letter E are equally divided by a center line.

The width of the shades in the lower letters are as follows: B black shade next to letter, $\frac{1}{4}$ inch; blended shade, $\frac{3}{8}$ inch; black shade, $\frac{3}{16}$ inch; dark-gray shade, $\frac{3}{16}$ inch; and light-gray shade, $\frac{1}{4}$ inch. C yellow, dark and light purple shades are $\frac{1}{4}$ inch wide; and the natural shade beyond these, $\frac{5}{16}$ inch wide. The shades of the letter E are all $\frac{1}{4}$ inch, with the exception of the black, which are $\frac{3}{16}$ inch and $\frac{1}{8}$ inch, the wider being the nearer to the stroke of the letter.

Before coloring the face of the letters and shading them, use a soft eraser and reduce the pencil marks to visible lines only, entirely erasing any superfluous pencil marks and otherwise clean the drawing. It will impair the work to attempt this after the water colors have been applied. Execute all the black work of the plate before beginning to shade and color the letters.

81. Beginning at letter I, color the entire lower portion with a medium shade of Prussian blue. Lighten the blue with white for the light bevel and darken it for the dark bevel with the same blue. The yellow bevels of the top portion of the letter are an orange-chrome tint for the light, darkened with burnt sienna for the darker bevel; for deepest shade, Indian red is used. The light-gray panel at back of letter E contains a little orange chrome yellow, while the gray shades of the letter are made of charcoal gray tempered with blue. More blue is added to this gray to produce the color used in blending the face of the letter S. The face of the letter T is sepia, burnt sienna, and charcoal gray. To shade the letters S and T, first run on the vermilion shade $\frac{1}{2}$ inch wide and subsequently split this by covering the half nearest to the letter with crimson lake. Gold color may then be run in the space between the shade and the letter. The gold color of the letter W is made of orange chrome and lemon chrome yellow. The darker shade of yellow is the gold color with burnt sienna added. In coloring the W, cut in the letter with waterproof India ink, cutting in the shade also, then flow the water colors over the white, which insures a clear color.

To shade the three lower letters, begin on the B and outline the letter, then run on the heavy black shade next to the letter and the other black shade $\frac{1}{2}$ inch from the first. The blending should then be done beginning with the lightest yellow, which is a tint of chrome yellow. Blend into this a little orange chrome, following with vermilion, then with the dark shade, which is the pure color, in the darkest part. The two gray shades are charcoal gray only. The tint on the face of the letter is made of Indian red. Use Mauve purple in shading the C, orange chrome yellow and burnt sienna for the shade nearest the letter, and charcoal gray and orange for the natural shade. The various shades of green in the letter E are obtained by adding gamboge to the new green for the yellow green, and Prussian blue for the blue green. Burnt sienna is used for the brown shade, orange and sienna for the shade within the face of the letter. The vine is Indian red with crimson lake added. Use gold color for outline of letter. Sufficient space is allowed at the bottom of this plate for the name, class letters and number in the right corner and the date of its completion in the left.

PLATE, TITLE: GERMAN TEXT

82. The **German Text** is a style of letter originated toward the end of the Medieval period, and is closely allied to the Old English in many of its details. The identity of the letters themselves are somewhat more obscure than the Old English letters, as their general outlines are intended to conform more closely to the earlier styles. Some of the letters, such as the O, Q, S, etc., are scarcely recognizable as being the same characters with which we are familiar in the Roman type. This alphabet, like the Old English, is composed almost exclusively of combinations of cymas and crescents. The letters are not sufficiently regular to permit of a detailed description of each of their numerous proportions, and the student must use his judgment and measure by the eye to determine if the proportions of a letter are or are not in accordance with the plate. Draw the lower line of the lower-case letters $\frac{5}{16}$ inch above the lower border line. Make the lower-case letters $\frac{11}{16}$ inch high, with a space of $\frac{1}{2}$ inch between the bottom line and the line for the long strokes above, which is $\frac{5}{16}$ inch from the bottom of the upper line of letters. The long letters extend above the line $\frac{5}{16}$ inch. Between the tops of the long letters and the bottom of the last line of capital letters is a space of $\frac{3}{8}$ inch, and the capitals are 1 inch high and $\frac{1}{2}$ inch apart. The title is $\frac{9}{16}$ inch above the top line of letters, its capitals being $\frac{7}{16}$ inch high, while its lower-case letters are $\frac{5}{16}$ inch, or in the same proportion as the lower-case letters below in the plate. In this alphabet, the vertical strokes are $\frac{3}{16}$ inch, and the curved strokes at the point of maximum width are $\frac{1}{3}$ stroke wider. The vertical strokes of nearly all the letters in the capitals and lower case are cut at an angle of 45°, their bottoms terminating in two spurs on the sides, to which is added a fine line on the right end, while the fine line is added to the left at the top. The proportion of this may be more clearly seen by a reference to Fig. 3,

FIG. 3

German Text

A B C D E F G H I K L M

N O P Q R S T U V

W X Y Z U &

a b c d e f g h i j k l m n o p q r ſ s t

u v w x y z

which shows the vertical stroke together with the diagonal stroke, showing the relative position of each if they were separated. At a of the lower-case letters is shown the characteristic of the vertical stroke terminating on the bottom line with its point to the right of the center of the stroke. It will be observed that the points of this stroke, to the fine lines extending from them, are but the angles of a small rectangle, the width of which is equal to the stroke and the length of which is equal to about 1¼ strokes. This small rectangle is set with a point on the left of the center line of the stroke of the letter, diagonally opposite the point resting on the lower line of letters and its sides inclined at an angle of 45°. This rectangle is changed to suit the width of letter and the part with which it is to be united. In the lower case i and j, it is set with its principal angle on the center line of the stroke; in the p, it is set with its right angle on a line with the outside of the vertical stroke. This brings the projection of the stroke sufficient to the left to cause it to intersect with the vertical stroke on the left of the letter, when the upper left-hand angle is slightly extended. In the capital letter A, it will be observed that the cyma and crescent-shaped stroke, forming its upper left side, are both repeated in several letters, while either one or the other stroke is to be found in all of the letters. The width of these capital letters is about equal to their height, with the usual variation in letters that are always exceptions, such as the M, W, etc. The M and W are 50 per cent. wider than the other letters in both the upper and lower cases.

83. The principal thing in laying out this German Text is to give all the curved strokes the proper angle. Inaccuracy in proportion, either as to length or thickness, does not mar the appearance of the letter to such an extent as does the placing of the strokes at an improper angle. Many of the letters, when closely examined, will be found to be very much alike, and the stroke of the curved formations, once mastered, has only to be changed around and its size altered to make it a simple matter to combine it in any of the letters. Draw the vertical stroke of the A $\frac{13}{16}$ inch to the right of the left border line. Draw the slanting part of the stroke, with its point and spur, as above described. Construct the half cyma of a sufficient length to make the letter 5 strokes wide, and draw the vertical cyma and crescent stroke, the latter to within $\frac{2}{3}$ stroke of the vertical and the former $\frac{2}{3}$ stroke from the latter. The upper left strokes of the V are similar in outline, but different in proportion, to those of the A. A half cyma forms the lower right curve of the B, and a full cyma, terminating in a ball, forms the lower stroke of the B. A short thick cyma forms the top stroke of the letter and finishes at a point directly over the extreme outside curve of the lower portion. The C is in outline a crescent, within which is hung from the fine line a cyma, the bottom of which is continued in a fine line and curved parallel to, and $\frac{2}{3}$ inch from, the lower stroke of the letter. The top of the letter is finished on the top line with a half cyma. The lower stroke of the D is similar to that of the B, but longer and thinner. It rests on the bottom line and swings around to the left again, similar to the stroke of the B, but continues past the vertical stroke at the top of the letter and curls up on the left side. The vertical stroke is then drawn as a cyma; its point pierces the top stroke, and its curved fine line is tangent to the bottom stroke. The letter E is similar to the C, except the addition of its ball and fine line. The letter F combines the two curves of the lower parts of two cymas, and is crossed at the top with a horizontal cyma, a ball and fine line similar to the E completing the characteristic of the letter. The left stroke and interior of the G is similar to the C, except that its interior cyma does not hang from the fine line, but crosses it, and its lower right fine line is continued around, deepening into a heavy semicyma, the inside line of which touches the vertical stroke and the top of which continues outwards and upwards, terminating in a ball at the top line. The letter H is composed of a vertical cyma, with a ball on its lower end and a semicyma on its upper end. The right stroke is a crescent, the left end of which terminates in a small hollow-sided rectangle, 1 stroke in each direction.

84. The letters I and J, combined in one character here, are very similar to the F except that the lower strokes are much more inclined and there is no ball and fine line. In the letter K, the left-hand vertical stroke does not begin with a ball, but starts from a small rectangle, and curves, tangent to the lower line, into a fine line and thence into a broad stroke at its center, and diminishes at its top line, where it again becomes tangent and returns to the front of the letter as a part of the fine line. Under this fine-lined arch, which is $\frac{1}{2}$ stroke above the line, is drawn a small semicyma; and under the semicyma are drawn the fine line and lower slanting stroke of the letter. The letter L is similar to the letter J reversed, but not quite so large. Its vertical cymas, too, are not inclined. The letter M is composed of the two crescent strokes terminating at the bottom in two semicymas, the points terminating below the line and finishing on the right side with a cyma and vertical stroke. The left stroke of the N is similar to the left stroke of the A, except that the crescent stroke is brought down full to the bottom line and the semicymas grow out of it to the left, as in the M.

85. The letter O combines the strokes of the letter D in a somewhat different manner. The vertical cyma inside the D is moved to the exterior edge, so that its center rests just to the right of the ball on the lower line. The right-hand top stroke is carried over, intersecting the vertical cyma at a point directly over the right-hand side of the ball of the lower stroke. The letter Q is precisely similar to this, except the tail. The letter P possesses a long vertical stroke, terminating below the line 2 strokes and tapering off to within one-third of its width at the center. The upper left half of this stroke is precisely the same as that in the N, the upper right half supporting a semicyma, the lower point of which is tangent to the end of a semicyma resting on the lower line. There is considerable similarity between the letter R and the letter K, though careful observation shows that their details are entirely different in arrangement. The right lower stroke of the R is a vertical stroke terminating in a curve; the left stroke is a duplicate of the left stroke of the N, the difference being that where the vertical stroke intersects the top stroke the R reaches a horizontal line, which extends from its vertical stroke to its crescent stroke, while the N has no such detail. The stroke of the S is a horizontal cyma on top, a horizontal crescent at the bottom, and a horizontal cyma of reversed curves in the middle. The characteristics of the strokes in the T are readily understood, but a strong resemblance would be observed in the general outline of the U and that of the A, and on this account many German printers use a letter identical with the lower-case u. The V is also similar to the B, except that its right stroke is a cyma supporting a small cyma, and its bottom stroke is a cyma attached to a ball. The letter W is very irregular. The upper left stroke is the upper left stroke of the A and the lower left stroke is the lower left stroke of the B. The vertical, or nearly vertical, intermediate stroke is joined to the crescent after terminating into a looped fine line; the extreme right stroke is a cyma supporting another cyma similar to the right half of the U, but of different proportions. The middle stroke is then proportioned to conform itself to these other two. The X is simply a vertical stroke crossed by a horizontal stroke. The Y is a combination of the left strokes of the U and A, with a vertical cyma and fine-line curve. The Z is composed of two crescents and a cyma, the middle stroke of which is 3 strokes above the lower line.

The character & is shown in two forms, the first one, composed of a vertical cyma, terminating in its upper end with a ball, and with two tangent cymas for its right stroke, being essentially the original German character, which is rarely used except in signs and inscriptions involving firm names essentially of a German character. The second & is a modification of the Old English form of the letter applied to this text for modern use in such places where the German text will be used to write English words or express English names.

86. The lower-case letters are similar in many respects, in regard to their formations, to the lower-case letters of the Old English alphabet. The stroke of these letters is three-fourths that of the capitals, and the space enclosed between the vertical strokes of the a, b, g, m, n, etc. is about 1 stroke. The letters p, v, w, and y finish above the line with a semicyma; the top of the letter f finishes horizontally with a cyma, while a crescent-shaped stroke is inserted between the crossing of the k and the vertical line. Give the closest attention to the proportioning of these letters, comparing the details of each lower-case letter with those of the Old English alphabet and observing the strong points of similarity between different letters and this alphabet. For instance, observe that the d and o are precisely the same in outline, except that the former letter is continued above the line with a semicyma. The c and e are very nearly alike, with the exception of the fine line. The r and the x are identical, with the exception of the finish on the bottom line. The middle stroke of the z is in the center of the body of the letter, and the inclined stroke at the top is at an angle of 45°.

Having completed laying out the alphabet, ink in this plate, as before, inserting the title in its proper place, and placing the date in the lower left-hand corner and the name, class letters and number in the lower right-hand corner.

PLATE, TITLE: CHURCH TEXT

87. Church Text is seen in many of the old English cathedrals, and was originated in the monasteries of the Medieval period. It has been used in all church work, for stained-glass inscriptions and ecclesiastical decorations, and is seldom used for other purposes. It bears a strong resemblance to the Old English letter, which will be discussed later on, but in many respects it is simpler. In drawing this plate, the first line is $\frac{5}{16}$ inch above the margin line, and the lower-case letters are $\frac{11}{16}$ inch high in the body and project $\frac{5}{16}$ inch above and below the line. The space between the body line of the lower-case letters is $\frac{5}{8}$ inch,

Church Text

A A B C D E F G H H I K

L M N O P Q R R S S

T T U V W X Y Z

a b c d e f g h i j k l m n o p q r s

t u v w x y z

and between the topmost line of the lower-case letters and bottom line of the capitals is $\frac{5}{8}$ inch. The three lines of capitals are each 1 inch high and are spaced $\frac{1}{2}$ inch apart. The title is $\frac{5}{8}$ inch above the top line of letters, and its capitals are $\frac{3}{8}$ inch high, while its lower-case letters are two-thirds this height. It is practically impossible, in an alphabet of this character, to give a direct proportion of the various parts of the letter in terms of its stroke and fine lines. The vertical strokes are $\frac{5}{32}$ inch in width and $\frac{1}{32}$ inch wider in all curved strokes. In manuscript and inscriptions, either painted or drawn, the fine line is usually as thin as it can be made. In carved work and stained-glass work the fine line is governed by the material in which it is executed. The widtns of these letters vary largely, but, like many of the more geometrical alphabets, the average width is about equal to the height. The letters A, H, R, S, and T are each shown in two forms, the choice of which is left entirely to the tastes and desires of the letterer, as either style belongs to this alphabet. The stroke forming the upper right-hand finish of the B occurs in a more or less curved form in the letters H, N, O, P, Q, and R, and is a combination of cymas and semicymas. The cyma has been used in the other alphabets, but forms an actual component part of the letter in this, as well as in the Old English and German Texts, and forms one of the most important characteristics of the letter. It should therefore be practiced separately until its form is so familiar that it can be drawn in any position and in any direction.

88. In the first form of the letter A, the cyma occurs three times, and each time, with but one exception, in a different position. The stroke at the bottom of the B is a cyma, the terminals of which are continued, to form a fine line, and again spread into semicymas, constituting the lower curved portion of the letter. The heavy curved stroke of the C is crescent-shaped, its interior vertical stroke being another reproduction of the cyma. In drawing these letters, gauge carefully by the eye the space between the strokes and also between the fine lines. The two vertical strokes of the B, and all other letters where vertical strokes are used together, are spaced about $\frac{1}{4}$ stroke apart, whereas the vertical cyma, as it occurs in the C and G, is 1 stroke from the inside of the crescent stroke, and the vertical strokes inside the O and Q are spaced 1 stroke away from the point on the top line forming the outline of the letter. The lower finishing stroke of the D is similar to the B, whereas the upper stroke, starting at the left extremity of the letter, sweeps down as an elongated cyma and diminishes to a fine line at the same point as did the same detail in the B. The two points, or spikes, that project from the left of some of the letters are located about the middle of the vertical stroke, except in the A, where they are raised to clear the fine line. The vertical strokes from which they project, as well as the fine lines that extend from these strokes in some letters, such as the C and N, are beveled off top and bottom at an angle of about 30°.

89. All, except the curved lines of the letters, should be drawn with the triangle; those being at the 30° angle can thus be easily rendered parallel. The letter E is a combination of vertical strokes, cymas, and semicymas. The middle semicyma and the fine line that intersects it with the semicyma at the top, intersects the vertical stroke at the center. The lower stroke of the F carries this letter $1\frac{1}{2}$ strokes below the line. The letter G is very similar to the C, except that the crescent forming its left stroke is vertical, and its right stroke is brought around and finished as a semicyma with a like detail inside, as occurs on the bottom of F. The two styles of H are almost identical in their vertical strokes and top, the main difference being in the character of the curve that forms the right projection of the letter. The letters I and J are combined in one character in this alphabet, the vertical strokes of which are similar to the F, except that the right one finishes with a curve at the bottom instead of a straight line, as in the former letter. The K is similar to other letters in detail, except in its right strokes, one of which is a compound curve and the other straight, inclining to the left at an angle of 60°. The lower stroke of the L finishes on one end with a curve, and on the other with a beveled and fine line at an angle of 45°. The vertical strokes are the same as those of similar letters, and two fine lines are attached to the horizontal stroke, which, with that of the T, by the way, are the only straight horizontal strokes in the entire alphabet.

90. The middle stroke of the M differs somewhat from the previous details of the alphabet, its upper end bending in full width to meet the fine line, while its lower end is finished with a spur on each side projecting $\frac{1}{2}$ stroke, coming to a point at the bottom. The extreme right stroke of the M is a cyma. The right stroke of the N is similar to the stroke of the second H, but with less curvature. The O, P, Q, and R project $\frac{3}{4}$ stroke above the top line, in the O and Q the point where this projection occurs being $\frac{1}{2}$ stroke to the right of the center of the letter. This gives the exterior of the letter a pear shape; the left stroke forms a crescent, and the right one a compound curve, between which the vertical stroke intersects the top of the letter with one of the lower fine lines. There are no new details in the letter P, the stroke being simply a combination of the previous curves. The first variety of R resembles the B in its upper portion, and the K in its lower portion. The second variety possesses that peculiarity of twist at the upper end of its right vertical stroke that somewhat resembles the middle stroke of the M, and finishes like the top stroke of the D. The letter S will be found a difficult one to make; the fine lines of the second one and the lower part of the first one, being at an angle of 45°, may be drawn first and used as guides to proportion the letter. The letter in either of its forms is very similar; the first one is finished at the right of the half cyma with a ball, the lower fine line also terminating with a ball, somewhat after the manner of the Gothic style, though this and the T are the only two letters in the capitals of this alphabet that are so decorated. The first T is similar to the C in regard to its crescent stroke, while that of the second is carried its maximum width to the right, where it is cut off with a fine line and ball. The right stroke of the U is the reverse of the middle stroke of the M. The V is a combination of cymas and straight strokes directly proportionate, and the W is similar to the V in its right portion, with the addition of the vertical stroke on the left side. In drawing the X, make the compound-curved diagonal stroke first. Through its center draw the cyma. The fine lines will then intersect with the diagonal stroke at the angles between it and the cyma on the left-hand side, and are 1 stroke apart if carried parallel. The two strokes, or half cymas, of the Y are identically alike, and are spread apart sufficiently to make their two points 4 strokes apart on the top line. The crescent finish of the letter extends 3 strokes below the line. The diagonal stroke of the letter Z is at an angle of 45°. Its full length over the break is 3½ strokes. The break is 1 stroke wide on its inside, and the two fine lines intersect on the top line 2 strokes to the right of the diagonal stroke. The bottom of the letter, where the right point intersects with the bottom line, is directly below the corner of the lower side of the upper part of the diagonal stroke.

91. The stroke in the lower-case letters of this alphabet is the same as the vertical stroke of many of the capitals; the bottoms of the letters are in nearly every case terminated with two spurs extending to the right and left ¾ stroke above the bottom line. These lower spurs vary slightly in their projections, according to the letter, and are either a full stroke or a half stroke, the difference being readily discernible at a glance. The enclosed letters, such as a, b, and g, are 2 strokes wide on the inside. The letters m and w have their vertical strokes 1¾ strokes apart. The letters r and x are precisely alike, except the cross-bar of the x and curled terminal below the line. The letter t is crossed by a similar terminal, which extends from the upper line of the body of the letter to a point 1½ strokes below the line. There is nothing about this alphabet that should cause any difficulty in its execution. Close attention should be given to each individual letter, noting all its peculiarities before an attempt is made to draw it. If your design of the letter appears in any way unlike the original, study the above, learn the point of error and correct it. In this letter, as in the previous alphabets, the curved strokes are somewhat heavier than the straight strokes, particularly the crescent-shaped strokes, the long compound-curved strokes not being so much so as the crescents, but at the same time heavier than the straight strokes. These variations are slight, but the fact that they exist must be noted in each case.

After drawing the plate, insert the title, as shown, place the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: GOTHIC

92. The **Gothic** alphabet was created during the closing centuries of the Medieval period, and is associated historically, as well as in its outline, with the ogival, or pointed arch, which at this time existed in the Gothic architecture. The letter in modern use is applied to church decoration, for the purpose of writing religious quotations, and in printing certain kinds of church literature, for which it is appropriate on account of its origin in the ancient monasteries. It is more legible than the regular Church Text, and therefore more often used, both for church work and in the province of the commercial letterer. In dividing the plate with lettering lines, the bottom line of the lower-case letters is $\frac{3}{8}$ inch above the lower margin line, and the height of the body of the lower-case letters is $\frac{5}{8}$ inch; the stroke of the long letters extends $\frac{3}{8}$ inch above and below the line. From the top line of the body of the lower-case letters to the bottom line of the numerals is $\frac{5}{8}$ inch, and the numerals are $\frac{13}{16}$ inch in height, with a space $\frac{1}{2}$ inch between them and the lowest line of capitals. The capital letters are 1 inch high, with $\frac{5}{8}$ inch between them, and the title is $\frac{7}{16}$ inch high; the lower case of the title is $\frac{3}{16}$ inch from the top margin line. The stroke of the letters in this alphabet is $\frac{3}{16}$ inch, and the fine line is $\frac{1}{4}$ stroke. The width of the letters average closely to

Gothic

ABCDEFGHIJ

KLMNOPQRST

UVWXYZ

1234567890

abcdefghijklmnopqrstuvwxyz

5 strokes, though there are many variations, owing to the eccentricities of outline. All the curved strokes of a letter are $\frac{2}{3}$ stroke wider than the straight strokes. In the capital letters A, G, J, P, and T, and in the lower-case letters a, h, j, y, and z, there is a fine line terminating in a round ball at the end of the letter; the diameters of these balls being 1 stroke in the capital letters, and somewhat more than 1 stroke in the smaller letters.

93. In the letters A, E, and F, where a middle bar extends entirely through the width of the letter, this bar is $\frac{1}{2}$ stroke. On the top line, the letter A measures 6 strokes in width between the small knobs, which are equal in thickness to the fine line. This horizontal fine line, at the top of the letter, extends only $1\frac{1}{2}$ strokes to the right of the vertical stroke, and the curved line of the letter rounds out from the vertical stroke to a point 2 strokes distance at the horizontal bar, terminating in a ball $1\frac{3}{4}$ strokes below the line. The vertical stroke of the A is 6 strokes from the border line, and between it and the B are 4 strokes. The vertical stroke of the B is but 4 strokes in length, and the fine lines curving from the center of the letter at the top and bottom line cut the ends of the stroke in a slanting direction, projecting beyond and terminating in a ball $\frac{1}{2}$ stroke in diameter, the center of which is 1 stroke to the left of the letter. The inside space of the B, at the top, is $2\frac{1}{2}$ strokes, the bottom is $\frac{1}{4}$ stroke wider, and the points in the center of the curved strokes are $1\frac{1}{2}$ strokes above the bottom, and below the top, lines. Between the B and C is a space of 2 strokes, and from the point of the C to its vertical fine line is $5\frac{1}{3}$ strokes. The left half of the interior of the C is a semiellipse, and the curved fine lines, top and bottom, are thicker as they approach the vertical fine line and become nearly tangent on the inside. Between the fine line of the C and the stroke of the D is a space of $3\frac{2}{3}$ strokes, and the latter letter is $5\frac{1}{2}$ strokes wide in the center. The left half, including the stroke and its termination, is precisely the same as the left half of the letter B, and the right half the same as the letter

C reversed. The general outline of the E is a duplication of the C, except that the vertical fine line extends $1\frac{1}{4}$ strokes above and below the letter, and terminates in small knobs the thickness of the fine line. The clear space between the E and the F is 4 strokes, and the vertical full stroke of the F is the same as that of the A reversed. The diminishing stroke on the right of the F can be readily recognized as an exaggerated spur, the origin of which has been seen in the previous alphabets. The inside of the letter is $2\frac{2}{3}$ strokes wide at the horizontal fine line, which horizontal line is 2 strokes below the top of the letter. The width of the letter on the top line is $6\frac{1}{2}$ strokes, and the finish below the bottom line is 1 stroke. The space between the F and G, at the intermediate horizontal line, is 2 strokes, and the left half of the G is constructed in the same manner as the left half of the C, while the right half is similar to the lower half of the B. The distance from the lower line to the top of the inside curve is $3\frac{1}{2}$ strokes, and the greatest width of the letter from point to point is $6\frac{2}{3}$ strokes.

94. Between the G and the H is two strokes, the vertical stroke of the latter being the same as that of the F, except as to its right finish on the top line. The curved stroke of the H makes the letter $5\frac{1}{2}$ strokes wide and carries it 2 strokes below the bottom line. The letter I is $3\frac{1}{2}$ strokes wide on the top and bottom lines, 3 strokes from the H at the point of the curved stroke of the H, and 2 strokes from the J on the top line. The letter J is $4\frac{1}{2}$ strokes wide on the top line, and its upper horizontal stroke reaches its greatest thickness $1\frac{3}{4}$ strokes from the left-hand end. The left-hand fine line, which is nearly vertical, terminates in a knob 3 strokes below the top line. The ball on the bottom of the J has its center on the bottom line and its left side directly under the end of the top horizontal stroke. The letter extends $1\frac{1}{4}$ strokes below the line, is $3\frac{1}{3}$ strokes wide on the bottom line, and its curved stroke at the intermediate point reaches a thickness of $1\frac{1}{2}$ strokes, $3\frac{1}{2}$ strokes below the top line. The vertical strokes of the letters K, L, N, P, and R are formed precisely as the vertical strokes of the other letters, variations being made in their terminations, but those variations in no way differ from similar ones in letters on the top line. The upper left-hand finish of the P and R is precisely the same as that of the B; the lower horizontal stroke of the L is the same as the upper horizontal stroke of the J, except that the letter is $5\frac{1}{2}$ strokes long. The curved stroke of the N is, in its lower portion, similar to that of the H, while its upper portion, where it joins the vertical stroke, is more like the D; the width of the letter at the center is $5\frac{1}{3}$ strokes. The curved strokes of the K reach a point on the top and bottom lines that makes the letter 6 strokes wide. The irintersection and juncture with the vertical stroke takes place 3 strokes above the bottom line.

95. The letter M is $8\frac{1}{3}$ strokes wide at the center, and about $\frac{1}{2}$ stroke less at the bottom line. Its two points on the top line are about 3 strokes apart, and its right- and left-curved strokes are similar to those of the C, except that the enclosed ellipse is narrower. The middle stroke divides 1 stroke below the top line. The middle stroke of the letter at its center is 1 stroke wide, and the two interior ellipses are each 2 strokes wide. The letters O and Q are, in outline, a duplication of the left portion of the letter C, the tail of the Q being added, as shown, tangent to the center of the letter and extending to the right to within $\frac{1}{2}$ stroke of the outside. These letters are 7 strokes wide. The curved stroke of the letter P projects from the vertical stroke sufficient to make the letter $5\frac{1}{2}$ strokes wide, and extends below the top line 3 strokes. The upper part of the R is precisely similar, except that the ball on the interior is only the thickness of the fine line, in diameter, instead of the full stroke, as in the former letter. The tail of the R is nearly a straight line on its inside, with only enough curvature to prevent its becoming straight; this stroke is $1\frac{1}{2}$ strokes wide, and its length between the lower ball, 1 stroke below the line, and the ball in the inside of the curve of the R is exactly 7 strokes.

96. The letter S is almost entirely included in a rectangle 7 strokes wide; the spur at the right-hand end on the top line extends to within $\frac{1}{2}$ stroke of the corner of the rectangle, while the spur on the opposite end of the letter on the lower left-hand corner extends the full width of the rectangle. The point on the heavy curved stroke touches the right side of the rectangle $1\frac{1}{2}$ strokes above the line, while the point on the left side of the rectangle comes within $\frac{1}{3}$ stroke of the side, and is also $1\frac{1}{2}$ strokes below the line. The letter T is similar to the letter G, except that both of its curved strokes are of smaller dimensions. The top of the intermediate fine line, as it curls into the letter, is 3 strokes above the lower line. The horizontal stroke at the top of the letter is $5\frac{3}{4}$ strokes, and at its greatest thickness is 1 stroke wide. The intersection of the fine line of the body of the letter, with the crossing stroke at the top, is at the center of the letter. The letter U consists of a combination of the vertical stroke of the A and the curved stroke of the C, and is 6 strokes wide. The letter V is 7 strokes wide on the top line. The right slanting line of the V diminishes in width from a full stroke at the top to about $\frac{1}{2}$ stroke at the bottom, where it joins the left slanting stroke. The W is 8 strokes wide on the top line and the right portion is the same as the letter U, which is $5\frac{1}{2}$ strokes in width, to which is added a crescent-shaped curve and intersecting fine lines, this bringing the entire width of the letter up to 8 strokes. The letter X is $7\frac{1}{2}$ strokes wide, and the intersection of its curved strokes with the slanting stroke is just above the center of the letter. The letter Y is 7 strokes wide at the top line, and consists in a combination of the left stroke of the V and the right stroke of the N. The top and bottom strokes of the Z are similar to the bottom stroke of the L. The letter is $5\frac{1}{2}$ strokes wide. The spur on the bottom of the vertical stroke is 3 strokes long, while that on the top is $2\frac{1}{2}$ strokes long.

97. In the numerals, the strokes are but $\frac{1}{8}$ inch in thickness, in the straight characters, but extend to twice this thickness in the widest part of the curves. The top corners of the 3, 4, 5, and 7 extend slightly above the line, as do also the lower corners of the 2 and 7, as well as the spur on the end of the 1 and 4. The curves forming the sides of the 3, 5, 6, 9, and 0 are similar to the curves forming component parts of the capital letters. The bottom stroke of the 2, the upper stroke of the 3, the left stroke of the 4, and tops of the 5 and 7 are each a semicyma. The horizontal fine line of the 4 entends 4 strokes to the left and $1\frac{1}{4}$ strokes to the right of the vertical stroke, the width of the stroke of the numerals being used for measurement. The intermediate stroke of the 5 is 4 strokes above the bottom line; of the 6, $4\frac{1}{2}$ strokes above the bottom line; of the 8, $3\frac{1}{2}$ strokes above the bottom line; while the 9 is $2\frac{1}{2}$ strokes above the bottom line.

The stroke of the lower-case letters is $\frac{3}{32}$ inch wide. The width of all letters, except the w and m and the single-stroke letters, is $4\frac{1}{2}$ strokes. The spurs forming the terminations of the strokes, at the top and bottom of the letters, are carried from the center of the stroke on the top and bottom lines, either way, to a point about $\frac{1}{2}$ stroke from the line and $\frac{1}{2}$ stroke from the vertical stroke, and are given a slight curve to these points. The student should be able to design the other details of this lower-case alphabet from the general proportions of the original plate, being careful, if necessary, to measure each detail in the original, and proportion its length or thickness according to the stroke of the letter.

After executing the work on this plate in pencil, ink it in, using the **T** square and triangle on the straight lines of the letters desired, and outlining all the curves and forming all the points on the curves of the strokes freehand, excepting the circles on the concave sides of the stroke of the capitals and numerals, which may be drawn with a compass if desired. The diameter of these little circles on the capital letters is $\frac{1}{8}$ inch, and on the numerals three-fourths that of the capitals. The balls on the h, j, y, and z of the lower-case letters are two strokes in diameter. The ball on the lower-case a is but 1 stroke in diameter. After the plate is inked in and the titles put in place, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

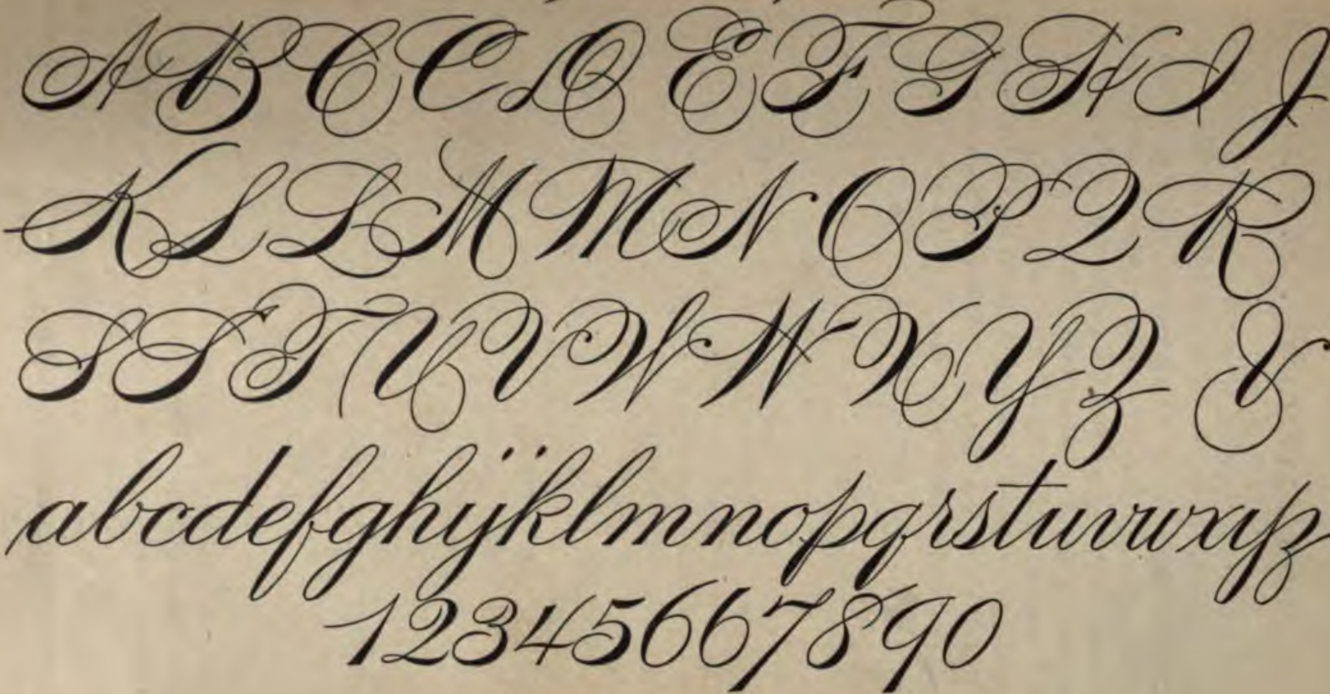
PLATE, TITLE: SPENCERIAN SCRIPT

98. The term *script*, in its broadest and earliest application, included all styles of writing and printing, but custom has reduced the application of the term simply to that form of writing executed with the pen, which was formerly called *pen text* or *text hand*. The reduction to its present classification was caused more by the classifying of the other styles and leaving the term script to the pen text, rather than setting aside the pen text under the name of script, as was done with certain forms of early alphabets, such as the Medieval and Church Text. The earliest form of pen text was very simple in its construction, but it gradually grew complicated with the desire for elaborate lettering.

About the middle of the 19th century, the form of alphabet shown on this plate was originated by Spencer, and gave to the world an entirely new and artistic form of text hand. This is the form that is used almost exclusively by the letterer and sign painter, and for all practical purposes where a shaded letter and accurate form is desired. In drawing this plate, as before, outline all letters in pencil, forming the strokes of the capitals and small letters of two individual lines, and so inking them with a pen, but blacking them in afterwards with a No. 3 red-sable brush. In inking the lines, attention must be given not only to the formation of the curved fine lines and strokes, but also to the location and finish of these curves. When the letters are inked, it is of more importance to secure the proper position for each line than to be able to form the curves with evenness and perfection. Bear in mind that in executing this plate the letters are not to be written; it is not expected that any one of the strokes or curves made with a clean, even sweep of the hand will be perfect, but, on the contrary, every detail of every letter must be carefully located and drawn, in order that the finished character may be a reproduction of the one on the lettering plate.

99. In dividing the plate, make the bottom line of the figures ¼ inch above the lower border line. Draw lines

Spencerian Script



limiting the top of the figures $\frac{3}{4}$ inch above the lower one; leave a space of $\frac{5}{8}$ inch between the top of the figures and the bottom of the lower-case letters, and draw the lower-case letters $\frac{7}{16}$ inch high. The loops of the lower-case letters, such as the g or h, extend $\frac{5}{8}$ inch below and $\frac{11}{16}$ inch above the lettering lines. Between the top of the long letters and the bottom of the capitals leave $\frac{1}{2}$ inch. Capital letters are 1 inch high—the spaces between them, $\frac{5}{8}$ inch. The capitals of the titles are $\frac{3}{8}$ inch high, and $\frac{3}{8}$ inch above the top line of letters. The small letters are $\frac{5}{32}$ inch high.

100. In executing this plate, it will be practically impossible to give any idea of the exact location of each letter. Judgment of the eye in comparison with the lettering plate and close attention to the details of the copy are the only guides that can be depended on for the completion of the details. Bear in mind that the slant, or inclination, of the letters is always 35°, and in such strokes as those of the lower-case letters this angle can be easily kept; but the stroke that governs the capitals cannot be so easily determined. In Fig. 4 is shown a main stroke, such as forms the body of the letters F, L, N, etc., and its relative position to the 35° inclination line of the letter. The line of the angle is tangent to the stroke at the point where the shading begins, and passes through the shaded stroke on the bottom line. The divergence of the stroke from the line of inclination of the letter is the same in its upper and lower portions.

FIG. 4

101. The drawing of these letters by means of inclined-angle lines will be found absolutely necessary at first in order to secure satisfactory results, but as the eye becomes trained this angle can be readily judged with great accuracy and the work executed entirely freehand. The stroke of the lower-case letters is $\frac{1}{16}$ inch, and that of the capitals $\frac{3}{32}$ inch.

The shaded stroke of the capitals should, in such letters as have the stroke shown in the A and L, be below the center of the letter, the maximum width of the stroke being at a point 1 stroke above the bottom line. While it is necessary to avoid the shading of all fine lines, there are cases, as in the letter E, where two shades are necessary in order to balance the letter and give it a more graceful appearance; but the shaded portion of a letter always represents the downward stroke of a pen or brush, and the shading of any of the upward fine lines would be in opposition to the characteristic formation of the letters. Every stroke of these letters is based on a combination of the crescent and cyma. In the lower-case letters, the maximum thickness of the stroke of a, d, g, o, and q is above the center of the letter. In some alphabets, the tops of the letters formed similar to the a have their fine lines carried above the top line, as shown in Fig. 5, in which case the maximum width of the crescent stroke is above the center of the letter, and the general effect of the letter is oval. The points at the top of the r and s, and also the upper part of the loop of the k, extend above the top line. In executing the lower-case letters of the script in sign writing, one of the most difficult details is the joining of the fine lines and strokes in such letters as a, n, u, etc.

FIG. 5

102. In Fig. 6, the stroke of the letter is shown to be practically a straight line until it nears the top or bottom lines at the left or right, as shown at *a*, *a*, when it commences to curve and at the same time to diminish to a fine line, which finishes the top or bottom of the stroke. This stroke and its accompanying fine lines, will be found to exist in the letters a, d, etc. In Fig. 6, the left stroke is practically the reverse of the letter i, while the wide

FIG. 6

stroke is the other characteristic stroke that extends through the entire lower case. The dotted line through the center of the letter shows that the top and bottom of the stroke are duplicates one of the other, and that the fine line, where it curves to join the vertical stroke, joins it in exactly the center of the letter. Comparison of this detail with the letters h, m, n, etc. will show its application to the lower-case alphabet. The fine line should never intersect a stroke at a point above or below the center of the letter.

103. The two forms of strokes used in some of the capital letters are shown in the letters A and B. There are no rules governing which of these forms shall be used in the letters P, B, and R, under different conditions, this being left entirely to the taste of the letterer. The A stroke is used in P on this plate. The stroke shown in the letter A takes up a trifle less room than the one used in the B, and on that account is sometimes to be preferred.

104. Another variation of the capital letters, practiced by many expert letterers, is shown in Fig. 7, wherein the lower part of the C is carried below the line and the first lower-case letter of the word is inserted somewhat within the letter. This treatment is applicable to the letters C, E, K, L, and R, and may be used in some places where the space is limited and the writing must be condensed, or to give an inscription a more graceful and freehand appearance.

FIG. 7

105. Particular attention must be paid to the spacing of the inclined lines in the lower case. As said before, the proportions of strokes cannot well be given, but the horizontal width of most of the letters on a line through their centers will make them equal in this dimension to their height, with the exceptions of the letters pointed out in other alphabets. Careful observations of this, and the inclination of the letter at an angle of 35°, causes little trouble in the finishing of work. A simple method of laying off the letters at the required angle is to make a small triangle of cardboard, one angle of which shall be 35°; this may be done by taking a square card, and from one of its corners measuring off a distance of 4 inches; at right angles to this, measure off a distance of $2\frac{3}{4}$ inches, and join the points so sought with a line on which the cardboard may afterwards be cut. The two angles opposite the long and short sides adjacent to the right angle will then measure 55° and 35°, respectively. After drawing the plate and inking it in, as described, insert the title in its proper place, place the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: ITALIC SCRIPT

106. The **Italic Script** may be generally characterized as a Roman letter, the strokes of which incline to the right at an angle of 30°, or occasionally to the left at an angle of 20°. It is a letter that, after practice, can be executed with great rapidity, and is of great value to both the plain letterer and the draftsman. The capital letters are almost identical with the New York Roman, excepting as to the finishing of the spur on the fine lines of the A, K, and V, and occasionally as to the letters M, N, W, and Y, when these are finished in the same manner. The tail of the R is sometimes dropped one-third of its length below the line, but in all other respects the rules governing the proportioning of the New York Roman letters will apply to these capitals. In drawing this plate, draw the line for the top of the numerals $1\frac{3}{8}$ inch above the lower border line and make the numerals $1\frac{3}{8}$ inch high. The lower-case letters are $\frac{9}{16}$ inch high in the body of the letter and the first row of letters is $\frac{9}{16}$ inch above the top line of the numerals. The five last letters of the alphabet are even with the top line that limits the height of the numerals.

Italic Script

ABCDEFGHIJKL
MNOPQRSTUV
WXYZ &
abcdefghijklmnopqrsstuw
12345 wxyzz 67890

107. The long letters of the lower case extends $\frac{1}{2}$ inch above and below the bodies of the letters, and the space from the top of the long letters and the first line of capitals above them is $\frac{5}{16}$ inch. The capitals are 1 inch high and $\frac{3}{4}$ inch between each line. The long letters and capitals of the title are $\frac{7}{16}$ inch high and $\frac{9}{16}$ inch above the top line of letters. The proportion of the capitals and lower-case letters in the title is the same as those in the body of the plate. Draw the capital letters, as shown on this plate, spacing them by the judgment of the eye and proportioning them according to the rules laid down in the plate for New York Roman letters. The lower-case letters have a $\frac{3}{32}$-inch stroke and average about 5 strokes in width, with the variation heretofore pointed out in other alphabets.

The tops of all the long letters are finished with a fine line and curved, as are also the tops of such small letters as i, m, and n. The letter f is reduced to a fine line and finished with a ball similar to the top of the letter c, the fine line appearing above the ball again as though a continuation of its outline. The bottom of the letter has an oval form, finishing with a small ball similar to the bottom of the letter g. Where the letters f f occur in the middle of the word, the first reaches only to the bottom line of the regular letters and is given a slight curve and cut-off at the bottom, in the same manner as the letter p in this alphabet. The second letter f is then drawn as the one on the plate, its curved lower portion extending under the first one and the cross-line, or horizontal fine line, made continuous with the two letters, as shown in Fig. 8. The letters j and y are finished with a loop below the line, as in the ordinary script, the size of the loops varying slightly, according to the letter adjacent to them. The p and q are carried below the line with a full width of stroke, which is finished horizontally, though on the q the fine line is returned

Fig. 8

to the lettering line to distinguish it from the g. Either of the two forms of s and z shown in this plate is admissible in ordinary Italic lettering. The first form of the letter s is the one usually made where there is much lettering to be done, as its form is simpler and it can be made quicker. The same rule applies to the second form of the letter z. Where two s's occur at the end of a word, the first form is used and the first letter made a trifle smaller, its top reaching only to the top line of letters. The second, however, reaches above the line, as is shown on the plate.

108. The numerals in this style of letter are precisely the same as those in the New York Roman, their width being equal to their height. Should it be desired to lay out these letters by means of guide lines other than those for the tops of the letters, proportion them in the same manner as the letters of the New York Roman plate, drawing such horizontal lines through the letters as may be necessary to locate their essential characteristics, and spacing what would be the vertical lines in the New York strokes at an angle of 30° from the perpendicular for this plate. After drawing the letters, figures, and title, the student will black them in, as shown, inserting the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: RENAISSANCE

109. Renaissance letters are of a great variety, the genuine characteristic of most of them being a lack of purity of style. The period of the invention of their design was about the middle of the 15th century, when great advancement was made in all art and architectural forms, and the discovery of ancient manuscripts and illuminated letters, embellished with classical ornaments, caused a divergence in the customs and styles in practice up to that time. In the capital letters of this plate are shown the style of Renaissance alphabet prevailing in Germany and its dependencies; it is known as the German Renaissance. The origin of the letter will be found in Italian writings, the Germans at this

Renaissance

time occupying Northern Italy. The simplest style next to it is what is known as the French Renaissance, being more sober in its construction and less likely to be confusing in forming an essential part of an inscription. A peculiarity of the letter, in its German form, is the shape of a stroke strongly resembling the cyma, observable in many of the letters, but more particularly in the F, K, M, N, S, U, and X. This stroke was also adopted by the French when they modified their alphabet according to the German style. This stroke had its origin in the shape of a cutlas that was used by the Germans at about the middle, or close, of the 15th century. It is most conspicuous in the French Renaissance in the top strokes of E, F, and H, although both the strokes of the O and the right fine line and the finish of the W and Y, as well as the crossing of the T, and details of other letters, show the influence of this characteristic. The other style of alphabet, as shown in this plate, is the modern adaptation of the German style or modern Renaissance, and is generally known among painters and in the printing trades as the Bradley text. The stroke is much heavier than in either of the former styles, and it is generally governed by rules derived from other alphabets, which did not influence either the French or German styles.

110. Many details show the influence of the Gothic alphabet, such as the tails of the R and K, while the T follows closely on the structural lines of the Old English or German text; however, this alphabet for modern use is much better suited to all styles of plain lettering than either of the former, but for elaborate initial letters or illuminated manuscript, the style of capitals used in the German or French text, with an elaborate fine-line background used with the former, makes a highly artistic design. In the lower-case letters, only two alphabets are represented—the German and the Bradley text. The German a is readily seen to be composed of two of the cutlas-shaped strokes and a small cyma, while the a of the Bradley text combines the vertical curved stroke of the Egyptian letter with the cutlas stroke of the German. These points may be studied throughout the alphabet, and are too evident to require individual explanation. The letters of the Bradley text in the lower case, are as follows: 2–4–5–7–9–10–12–13–16–17–19–21–22–24–26–27–29–30–32–33–35–37–38. The three letters omitted are the i and j, which are made heavier than the German and dotted with a ball instead of a cyma, and the w, which is but two v's joined together. In drawing this plate, locate the bottom line of the lower-case letters $\frac{3}{8}$ inch from the margin line, the lower-case letters being $\frac{9}{16}$ inch high. The long strokes of the letters reach $\frac{3}{8}$ inch above or below the line, and their stroke in both alphabets is $\frac{3}{32}$ inch. From the body of the lower-case letters to the bottom line of the last row of capitals is a space of $\frac{1}{2}$ inch, the French and Bradley text capitals being $\frac{3}{4}$ inch high. The German letters are 1 inch high, exclusive of line work, with a space of $\frac{5}{8}$ inch between each line of letters.

111. The ornamental work behind the German letters is not an essential part of the letter, but is shown here simply as a background that is usually applied when the lettering is used, in order to set it off and make it appear more rational. The lines of this background work radiate, in most cases, from the same central point, following very closely the stroke of the letter that is nearest them and spreading off outside of the letter a comparatively uniform distance from it, but preserving the identity of its general shape. In designing this plate, work almost entirely from observation of the details of the original letter. It is impossible to give any direct information toward the comparative heights or different details, or the amount of projection of each letter above or below the line. In following the design of this plate, use your ingenuity, measuring such details of the original with the compasses, and transferring their proportions to your plate, as you may consider necessary and would be compelled to do were you designing an inscription in this style of letter. Experience, by this time, with previous plates, should enable you to handle the pencil, pen, and brush with sufficient dexterity to execute all that is required without further preliminary instruction. The date should be inserted in the lower left-hand corner as usual, and the name and class letters and number in their proper places.

PLATE, TITLE: SHIPPERS' BOX MARKING

112. The letter entitled **Shippers' Box Marking** is used largely by shipping clerks for marking packages and boxes, and is executed almost entirely with a brush. Occasionally, for some purposes, the same letter is used on drawings or price tickets, where a similar letter is designed with a pen. The stroke of the letter is the natural swell made by the drawing of the brush as it is pressed down on the marked surface, charged with the marking fluid.

113. Two styles of brush are used for the marking of boxes. One, a soft camel's-hair brush with short hair, for marking the planed wood and smooth surfaces, while for rough wood and other irregular surfaces, a long-hair bristle brush is used. These brushes, when not in use, are usually allowed to stand in the marking pot, but in such a manner as not to rest on their points. In executing this plate, make the lower-case letters $\frac{5}{8}$ inch high, and $\frac{9}{16}$ inch above the lower margin line, leaving a space of $1\frac{1}{16}$ inches between the tops of the lower-case letters and the under side of the numerals and last letters of the alphabet. Draw the numerals $\frac{7}{8}$ inch high, and the capital letters $1\frac{1}{8}$ inches high. The space between the lines of capital letters is $\frac{7}{8}$ inch. The capitals of the title are $\frac{3}{8}$ inch high, the small letters $\frac{3}{16}$ inch, and are $\frac{1}{2}$ inch above the top line of letters. Although there is no specific proportion for the width of these letters, the capitals average about 1 inch in width, and the lower-case letters about $\frac{1}{2}$ inch.

114. The majority of the letters of the alphabet have for the right side of the stroke a straight line, the exceptions being in the J, where the straight line is on the left of the stroke, and in the M, N, V, and W, where both sides of

Shippers' Box Marking

ABCDEFGHIJKL

MNOPQRSTUV

12345 WXYZ & 67890

abcddeffghijklmnopqrstuvwxyz

the stroke are curves. In the S, the stroke is a compound curve on both sides, and in the Z, a straight bar, as in the Roman. In drawing these letters with the brush, the stroke is almost invariably drawn first, inclining at an angle of about 30°. The fine lines are then put in place with the point of the brush, and afterwards the spurs on such letters as they are required. The line drawn for the top of these letters is put there as a guide to determine their relative height, and seldom forms an essential outline for the letter, as the experienced letterer never has lines to govern the heights of his letters and must mark each by eye measurement and comparison with the previous one. On this account, many eccentricities are permissible in this style of letter. The carrying of the stroke of the G and the tail of the R below the line is a characteristic feature peculiar to this style, adding to its graceful and freehand effect. The heaviest part of the stroke of the letters is about $\frac{5}{16}$ inch, though the middle stroke of the M, the left stroke of the V, and the straight stroke of the Z, are each but $\frac{1}{4}$ inch. The tops of the letters are in but few cases finished with a straight fine line, as the compound curve used in its place tends more to give an appearance of uniformity, and at the same time hides any errors in the alinement. The spurs on such letters as E, F, L, etc. are curved on the inside, within the letter, opposite to the angle at which the curve exists in the regular Roman letter. The peculiar shape of the spurs on the end of the middle fine line of the E and F is due to the fact that they are made with one stroke of the brush. The stroke of the letter S is peculiar to itself, being a compound curve made with one stroke of the brush and the first stroke of the letter made, the fine lines being afterwards applied to its top and bottom, each in a separate stroke. The heavy stroke of the letters O and Q is on the left side, and though the right side is heavier than the fine line, it is usually made about half as heavy as the stroke. In making the letter A, the shaded fine line is made in the same manner as the first line of the M and N, somewhat resembling the J.

115. The long strokes of the lower-case letters, as they extend above the line, are given a slight curve to the left and finished with a short horizontal fine line. The bottom of the letters, however, is never finished with this fine line, in most cases being finished below the line with a scroll and ball, that of the j being somewhat similar to the lower part of the capital J, and the p and q finished plain, or with a fine-line flourish, as shown. When f f occurs in the middle of a word, the first letter reaches only to the lower line, and the other one is carried down to finish with a scroll and ball. A fine cross-line engages both letters.

At the end of a word, the letter d, shown on the plate with a looped finish above the line, is sometimes used, and although the first d is often used in a similar position, the second one is never used in the middle of a word. The letter t may be crossed with a straight line, or with a compound curve as in the copy. Do not execute these letters on the plate with a brush, though it is not likely that occasion will ever arise in practical work where you will be called on to execute them as large as this with a pen, but, in reproducing this plate, draw the letters in outline with a pen, as in previous cases, blacken them in with a brush, and send the plate in for correction. The object of this is to insure familiarity with the forms of the letters of this alphabet, so that in any subsequent practice you may not be handicapped in the endeavor to form a style of letter that is not well adapted to the use of the marking brush.

After completing the plate, insert the title, as shown, put the date in the lower left-hand corner and name and class letters and number in the lower right-hand corner, as heretofore.

PLATE, TITLE: OLD ENGLISH

116. This lettering plate, the modern form of the **Old English letter,** is far different from the alphabet bearing this name in its original use. The stroke is considerably heavier than the Church Text in proportion to the height of the letter, but varies in different letters to such an extent

Old English

ABCDEFGHIJKL
MNOPQRSTUV
WXYZ &

abcdefghijklmnopqrs
tuvwxyz

that it is almost impossible to give definite proportions of the letter in terms of its stroke. The present form of the letter adheres more closely in outline to the letter characters we are in the habit of seeing in our every-day reading matter, and therefore it is much more legible than the antique style. In Fig. 9 are shown two letters, I and S, partaking of the characteristics of the original Old English style. The comparison of these styles with the I and S in the drawing plate will show scarcely sufficient resemblance to identify the characters shown in the figure as being the parent letters of this style. The principal application of the Old English letter is in ecclesiastical decorating and engrossing. Occasionally, the letter is used singly, as in an initial letter, or forms the principle of an illuminated capital, as often seen in ecclesiastical literature.

FIG. 9

117. To draw this plate, make the line governing the lower part of the body of the lower-case letters $\frac{5}{16}$ inch above the lower border line; the lower-case letters are $\frac{11}{16}$ inch high, with a space of $\frac{9}{16}$ inch between them. The strokes of the letters extend, in some cases, $\frac{5}{16}$ inch above or below the lettering lines, as indicated. Between the top of the lower-case letters and the bottom of the lower row of capitals leave a space of 1 inch. Make the capitals 1 inch high, and a space of $\frac{1}{2}$ inch between each line. The title is $\frac{5}{8}$ inch above the top line, and its capital letters are $\frac{3}{8}$ inch high, the small letters being two-thirds this size. The characteristic features of the alphabet consist of a number of cymas, half cymas, and crescent-shaped strokes. The straight strokes, where used, usually terminate at one or both ends with a spur on each side about $\frac{1}{2}$ stroke above the bottom line. The letters bear approximately the same proportion of width to height as did the Full Block letters, with the many variations necessary on account of their irregular form. The stroke of this letter is $\frac{3}{16}$ inch, though it is not uniform in all parts, the crescent strokes in many of the letters being $\frac{1}{16}$ inch wider. Where two cymas are adjacent, or a cyma stands near the vertical stroke, one of the cymas is usually made $\frac{1}{2}$ stroke wide at the thickest part; also, where a vertical stroke curves on the inside of the letter, as in the C, T, and U, the vertical stroke is a trifle less and the curved stroke is a trifle more in width than the full stroke.

118. In proportioning the letter A, draw the fine line from a point on the lower line $2\frac{1}{2}$ strokes to the right of the left-hand border to a point $5\frac{1}{3}$ strokes to the right on the top line. Then make the letter 5 strokes wide on the bottom line, and draw the fine horizontal line $2\frac{1}{4}$ strokes above the bottom; the heavy horizontal line being $\frac{1}{2}$ stroke in width, is drawn the thickness of the fine line below. The half cyma on the bottom of the fine line is $2\frac{1}{3}$ strokes in length, measured from its point on the line, and the return of its fine line after curving 2 strokes below is directly under the point of the letter. The letter B is $4\frac{1}{2}$ strokes in width to the outside of the cyma, exclusive of the spurs. The cyma, in its upper left-hand corner, is $3\frac{1}{2}$ strokes in length, and its right-hand point is over the center of the fine lines on the interior of the letter. The right stroke of the B, where it joins the curved fine line, is thinned down to $\frac{2}{3}$ stroke in width, and the upper stroke at this point curves around suddenly to form the fine line, terminating in a small ball. The crescent shape of the letter C is $5\frac{2}{3}$ strokes wide from the point to its left-hand side, the upper end extending $3\frac{1}{2}$ strokes to the right, and stopping over the center of the interior of the letter, the vertical stroke being $2\frac{2}{3}$ strokes long and terminating with a half cyma, which measures $1\frac{1}{2}$ strokes on the top line. The fine line joining the vertical stroke of the cyma and the bevel on the bottom of the vertical stroke, as well as all the diagonal lines at the ends of the letters in this alphabet, except as otherwise pointed out, inclines at an angle of 30°, but the line is not straight and always curves toward the interior of the letter. The letter D is $5\frac{1}{3}$ strokes in width to the outside of the spur of the cyma. The right vertical stroke and the top horizontal stroke are joined together at the angle by a sharp curve. The two fine lines in the center of the letter are $\frac{1}{4}$ stroke apart and $\frac{1}{4}$ stroke from the cyma. The letter E is composed entirely of cymas and half cymas. The space between the fine line and the first cyma of the letter is 1 stroke, between the fine line and the second cyma is $\frac{1}{3}$ stroke, and between the right-hand fine line and the projecting end of the top of the letter is 2 strokes, which is directly over the half cyma on the bottom of the line, exclusive of fine-line projection; the middle half cyma projects from the fine line $1\frac{2}{3}$ strokes. The F is drawn similar to the B, except that its middle stroke is finished like the E and its top stroke like the C. The G also resembles the C strongly, being precisely the same as that letter, with the exception of the right stroke, which is carried around and finished, as shown, coming to a point 3 strokes above the lower line; the lower corresponding point is 1 stroke above.

119. From the vertical stroke of the letter H to its fine line is $1\frac{2}{3}$ strokes, from the vertical stroke to the cyma is 2 strokes, and from the vertical line to the outside of the second cyma, exclusive of the spurs, is $3\frac{1}{2}$ strokes. The horizontal line of the H is $\frac{3}{4}$ stroke in width, and its top is 2 strokes from the top line. The letters I and J are similar to E in their upright cymas, the difference being in the position of the heavy and light cymas, which are reversed. These letters, as the H, terminate on the top line where they are joined to the fine lines. The single fine line on the letter J is $\frac{1}{3}$ stroke to the right of the main cyma, which terminates in a heavy cyma at the bottom of the letter. The letter K is developed from the letter I, the slanting fine line leaving the vertical fine line of the letter at a point 2 strokes above the lower line, and intersecting the top line at a point $2\frac{2}{3}$ strokes to the right of the fine line. The lower heavy stroke intersects the fine line at a point 1 stroke from the first double fine line. The letter L is similar to the letter E, with the middle stroke left out and with the vertical cymas reversed, the heavy one being to the right. The left part of the letter M is similar to the letter I, and its middle and right portions consist of two vertical strokes, separated by a space of $1\frac{1}{4}$ strokes and $1\frac{1}{4}$ strokes from the heavy cyma. The fine lines within the letter are $\frac{1}{4}$ stroke apart and $\frac{1}{4}$ stroke away from the vertical cyma.

120. The letter N is $3\frac{2}{3}$ strokes wide between its fine lines, the slanting stroke intersecting with the left fine line 1 stroke below the top. The letters O and Q are identical in every part, except as regards the tail of the latter. The left crescent-shaped stroke forms a semiellipse on its inside, and its outside is 3 strokes from the nearest inside fine line. The other side of the letter extends $2\frac{1}{3}$ strokes beyond this fine line, and the inside vertical stroke is midway between the fine line and the crescent stroke of the letter. The letter P is similar in construction to the letter L, its main cyma being carried nearly to the top line and its right stroke carried $\frac{1}{4}$ stroke above the line and to the right sufficiently to make the letter $4\frac{2}{3}$ strokes wide. The vertical fine line of the letter falls from the point of intersection of the cyma and the right stroke. The left half of the R is similar to the I, though a trifle shorter; the upper right stroke is similar to that of the B, though care must be taken to keep the tail of this letter vertical and not confuse it with the slanting stroke of the K, although they may appear somewhat similar. In drawing S, the point at the lower portion of the letter, where the half cyma joins the fine line from the full cyma above, is exactly midway between the convex curves of the cymas forming the body of the letter. The half cyma extends $3\frac{1}{3}$ strokes to the left of this point. The right cyma extends $2\frac{1}{2}$ strokes to the right of this point, and its greatest convexity is $2\frac{1}{2}$ strokes above the bottom line. The left cyma reaches its greatest convexity $1\frac{1}{2}$ strokes below the top line. The space between the cymas is $\frac{1}{4}$ stroke, the right one being a trifle less and the left one a trifle more than $\frac{3}{4}$ stroke in width. The cyma at the top of the letter T is 5 strokes long; the inside vertical fine line is $1\frac{1}{4}$ strokes from its right-hand end. The inside vertical stroke is $\frac{2}{3}$ stroke from the fine line and also 1 stroke from the crescent-shaped curve that forms the body of the letter, the right finish of this curve being directly under the end of the horizontal cyma at the top.

121. The crescent spur at the end of the letter U is somewhat distorted in shape, in order to admit the insertion of the interior stroke, which is 3 strokes long and $\frac{3}{4}$ stroke from the crescent. The letter is finished on the right side with a vertical stroke, as shown, the entire width of the letter being $4\frac{2}{3}$ strokes. The vertical strokes of the V make the letter 2 strokes wide inside, the point on the top line of the letter being on a line with the inside of the right vertical stroke. The extreme right and the extreme left strokes of the W are but slight modifications of the right and left strokes of the V. The middle stroke, however, is a plain straight stroke terminating as shown. In the letter X the space between the diagonal stroke and diagonal fine line, if both were carried through to the lettering lines, would be $2\frac{2}{3}$ strokes on the top and $3\frac{2}{3}$ strokes on the bottom. The intersection of the stroke and fine line is $1\frac{3}{4}$ strokes below the top and $2\frac{2}{3}$ strokes above the bottom. The cross-bar of the X is $3\frac{1}{3}$ strokes long. The intersection of the fine line and vertical stroke of the Y is 3 strokes above the bottom line, and the width of the letter on the top line, if the fine line were carried through, would be 4 strokes, the vertical stroke being in the center of this width. The strokes of the Z are modifications of similar strokes existing in the S, the half cyma at the bottom being $4\frac{1}{2}$ strokes long in the bottom line, the diagonal cyma being drawn to finish with the former almost tangent at a point $1\frac{1}{3}$ strokes from its left-hand end. The cyma on the top line does not reach to the left limits of the letter within 1 stroke, but is 3 strokes long, as it stops to the right side within $\frac{1}{2}$ stroke of a vertical line drawn through the center of the ball and the end of the lower half cyma. The diagonal strokes of the character & incline at an angle of about 35°, the two upper strokes being 1 stroke apart, and the two lower strokes, $1\frac{1}{2}$ strokes apart. The diagonal strokes can be gauged by the eye and the character drawn in, as shown.

122. In drawing the lower-case letters, the interior space of all the enclosed letters is 2 strokes; the strokes of the small letters are $\frac{1}{8}$ inch in width. In designing the small letters, draw all the vertical strokes first; then the diagonal fine lines that form the enclosures at the top and bottom of the letter are drawn at an angle of 30°. The spurs at the tops and bottoms of the vertical strokes are similar to those on the large letters and on the long strokes extending above or below the line. These spurs project $\frac{3}{4}$ stroke to the right and left of all the vertical strokes, finishing on the top and bottom lines, with the exception of the right-hand strokes of the m and n, which terminate with a curve. The vertical stroke of the j is carried $2\frac{1}{2}$ strokes below the line and is beveled off to the left in a curved stroke at an angle of 60° and terminates in a short and abrupt semicyma. A little study of this alphabet will show that there is a great similarity in the construction of all the letters of the lower-case alphabet. It is essentially a straight-line alphabet, there being only sufficient curved strokes to emphasize the characteristics of certain given letters.

123. In drawing this plate, give particular attention to the proportioning of the spacing of the letters on the plate, as well as to the drawing of the letters themselves. Owing to their irregularity in outline, no definite rules can be given as to the location of each individual letter, and as the alphabet is a difficult one and likely to require considerable practice before it can be satisfactorily done, each letter should be drawn on a separate piece of paper until you are familiar with it, and then redrawn carefully after its proper spacing has been located on the drawing paper. The first line of letters once properly spaced, the second and the third line can be located according to the relative position of their letters with those of the line above. It is not required that exactly the same proportion and spacing given in the original plate be maintained, but whatever spacing is adopted must be uniform, so that the letters will not appear crowded in one part of the sheet nor spread apart in another, and that the spacing between the two ends of each line of letters and the vertical border lines shall be uniform.

After drawing the plate, insert the title at the top, put the date in the left-hand corner and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: ENGROSSING

124. The style of letter known as **Engrossing,** generally referred to as German Roundhand, is usually executed with a writing pen designed specifically for this purpose. It is more of a pen alphabet than a brush alphabet and but rarely enters into any of the work required by the sign painter and general letterer. It is largely used for the body of the information contained in engrossed resolutions or conventional forms, and before the invention of the typewriter was the letter exclusively used for engrossing wills, deeds, and other legal documents. In executing this plate, draw the letters in outline and fill in the strokes with a brush, but

FIG. 10

the characteristics of the construction of the letter should be understood in order that the stroke and its diminution to the fine line may be properly proportioned. The pens used by the draftsman to do this work are of two forms—one with a plain flat point like an ordinary stub pen, and the other style shown in Fig. 10, with which the shaded-letter alphabet is drawn. The latter style possesses a double point, which at one stroke draws both a heavy stroke and a fine line, as in the open-outlined letters and the shaded ones on the plate. In form, these pens are not unlike an ordinary stub, and are held in the hand, almost perpendicularly with the breadth of the

Engrossing

ABCDEFGHIJKLMNOPQRST
12345 UVWXYZ 67890
abcdefghijklmnopqrstuvwxyz

ABCDEFGHIJKLMN
OPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz

point, at an angle of about 45°. The position of the point of the pen is not changed in forming any of the letters, the direction of its movement determining entirely the width of each stroke, and the points of its taper or diminution to the fine line. In the letter A, for instance, the pen is set in position to draw the interior crescent stroke to the left of the vertical stroke of the A. The pen is then moved to the left of this crescent, and the upper crescent is drawn so that the terminals of each come together. The lower crescent of the A is then drawn as a continuation of the second one, thereby forming a curve somewhat like the letter C. The pen is again placed in position at the top of the second crescent, drawn vertically downwards within 1 stroke of the bottom line, and then in a slanting direction to the right, until it touches the bottom line, and then in the direction of the inclination of the point, upwards, making the terminal fine line. This operation, in varying forms, is repeated with every letter of the alphabet. Where the scroll curve occurs in any letter, each crescent or line of the curve is drawn separately, and terminated so that the fine end of one joins on to the fine end of another, except in the letter C, where at the top these lines are permitted to pass each other.

125. When the letterer desires to use this alphabet on a large scale, he usually outlines the letter, thickening the stroke and tapering it to a fine line in such places as would naturally occur if he were using a pen. The letters have no absolute proportions of width; they are based, in general, on the script alphabet, with a slight tendency toward the eccentricities of the German Text, but with sufficient latitude to enable the letterer to vary considerably in establishing proportions, without seriously impairing the symmetry and smoothness of the appearance of the work. In designing this plate, locate the bottom of the lowest line of letters $\frac{1}{4}$ inch above the lower border line. Make this line of letters $\frac{7}{16}$ inch high and leave $\frac{3}{4}$ inch space between it and the line of shaded capitals. The top capital letters and numerals are $\frac{3}{4}$ inch high, and the space between the shaded capitals and the outlined letters above them is $\frac{1}{2}$ inch, while between the outlined capitals and the lower-case letters in black above them, is $\frac{9}{16}$ inch. The lower-case letters are $\frac{3}{8}$ inch high and the space from them to the capitals is $\frac{3}{4}$ inch. The two upper lines of capitals and numerals are $\frac{1}{2}$ inch apart, and the title is $\frac{1}{4}$ inch high and $\frac{9}{16}$ inch above the top line of letters.

126. In drawing these letters use the freehand pen entirely, outlining the letters, and completing the plate in outline before starting to shade or blacken in any of the characters. The upper alphabets of capitals and lower-case letters may then be blacked in. One half of the second alphabet, and all of its lower-case letters may then be shaded, as shown on the plate, and the second half shaded and tinted with horizontal freehand lines, drawn about $\frac{1}{32}$ inch apart. If desired, you may draw the letters with an engrossing or round writing pen, after you have had sufficient practice with this instrument on a separate sheet of paper. The width of the pen at the point should be $\frac{1}{8}$ inch for the capital letters, and $\frac{3}{32}$ inch for the small letters. This, when inclined at the angle of 45°, will give a stroke somewhat narrower than either of these measurements, which is the proper stroke, as shown on the plate. The main thing to be observed in letters of this plate is their characteristics, due entirely to the position of the pen, and the direction of its movement in their execution. The general proportion of each letter is more or less dependent on this; the amount of curve and the direction to be given each stroke will be determined by the position of the pen and the direction of the stroke.

After completing the pages shown, insert the date in the lower left-hand corner and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: ARCHITECTS' PEN STROKE

127. This plate exhibits three forms of the **Pen Stroke alphabet** and their corresponding lower case, used under varying circumstances, but almost exclusively for architectural drawings. The letter is constructed so that it may be easily drawn without the use of any instrument save an ordinary pen or a drafting pen. The letters should be made perfectly clear and legible, expressing its words without study necessary on the part of the observer. The letters are free from any conventional proportion, there being no rule for stroke or width of letter other than those prescribed, according to the circumstances of each case. The stroke should usually be made heavier when drawn on tracing cloth, in order to produce a clear print, but in the lettering of the details of a paper drawing the stroke can be as fine as the draftsman may desire. The general proportions for the letters in alphabet No. 1 require that their width shall be four-fifths their height, while the width of alphabet No. 2 is equal to the height. In alphabet No. 3 the letters vary, the main purpose being to produce a letter by the use of the triangle and T square that can be completed in straight lines without freehand additions.

128. In drawing this plate, the lower-case letters of the alphabet at the bottom are $\frac{1}{8}$ inch above the lower margin line. The letters are $\frac{5}{16}$ inch high, and the long letters extend $\frac{3}{16}$ inch above and $\frac{1}{4}$ inch below the lines. The bottom line of capitals corresponding to this lower case is $1\frac{3}{8}$ inches from the margin line. The letters are $\frac{1}{2}$ inch high. The lower-case letters of alphabet No. 2 are 1 inch above these capitals, and are the same height, and extend the same distance above and below the line as do the other lower-case letters. From the second line of capitals to the lower-case letters of alphabet No. 1 is 1 inch, with a space of 1 inch between them and the capitals, and a space of $\frac{1}{2}$ inch to the title, the capitals of which are $\frac{3}{8}$ inch high. The capitals and the small letters, alphabets No. 1 and No. 2, are the same height as those in

Architects Pen Stroke

1
ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefgghijklm — & & & — nopqrstuvwxyz

2
ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefgghijklm — & & & — nopqrstuvwwxyz

3
ABCDEFGHIJKLMNOPQRSTUVWXYZ&B

abcdefghijklmnopqrstuvwxyz

the lower alphabet. The inclination of the letters in alphabet No. 1 is 30°.

129. The strokes of the letters are frequently projected beyond the limits of the normal letter, either as a scroll, such as occurs in the C and E, or as a compound curve, observed in the G and R. Wherever the scroll occurs, the end should be finished with a dot. The regular straight strokes of the letter are usually finished with a spur in the form of a short, straight line, which crosses the stroke at about an angle of 30° with the horizontal line. In some cases, the stroke of one letter is carried over to interfere with another, as may be observed in the tail of the Q, the middle stroke of the R, etc.

130. Occasionally, the initial letter will be extended to cover over or extend under an entire word, as shown in Fig. 11, but in the use of any such eccentricities, legibility, the chief object of the letter, must never be overlooked. While these conditions apply to all the alphabets, it is more particularly to No. 1 on this plate that we refer. Alphabet No. 2 is a modified form of the French Roman, without any distinction between the stroke and fine line. The spur should be very small, the tendency of the draftsman usually being to make it excessive. There are no spurs in the lower-case alphabet. Alphabet No. 3 is made entirely with the T square and the triangle, and requires no freehand penciling before laying it out.

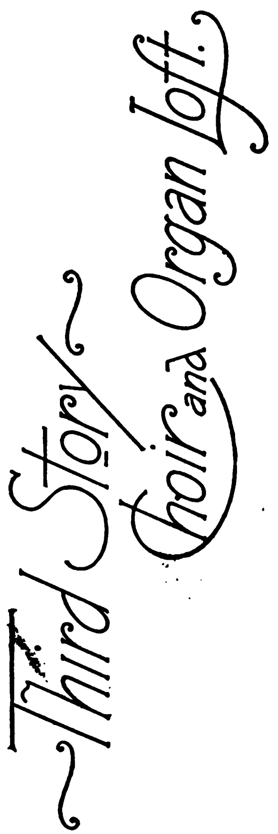


Fig. 11

131. The upper and lower lines confining the letters should be drawn first, the letter A located in its proper place and drawn in ink, and then, after approximately spacing the distances, the vertical lines of the letters B, C, D, E, etc. should be drawn in ink without further instructions.

When this plate is finished, make a careful comparison of each letter of your own plate with that of the copy, and endeavor to criticize and detect for yourself any irregularity or error that may exist. If this error is in the proportioning of the letter, correct it before your plate is sent in for correction; if it is simply an error of location or spacing, let it stand, and, unless very serious, it will not be counted. When satisfied that every detail is up to the standard, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: DRAFTSMEN'S STYLES

132. Many topographical and mechanical draftsmen, as well as civil and mechanical engineers, contend that the style and quality of lettering on a map, survey, or drawing is of little importance so long as it expresses what is intended in the parts referred to. With some, there is a feeling that extensive lettering, or even careful and accurate lettering of a map or drawing, is time wasted, and that the real effort of their work should end with the finishing of the drawing itself. That this is a grievous and serious mistake, for any finished draftsman needs no further proof than the fact that the government of the United States has recognized the importance of accuracy in map lettering to such an extent as to establish certain rules that shall govern the lettering of each individual part of a map, using a certain sized letter for certain objects or localities of importance, and larger and smaller letters for localities of greater or less importance. Each style of the letter is used uniformly, to indicate the character of the surface or division of the country lettered. For instance, all waterways, lakes, etc. are lettered in various sizes of Italic letter; railroads and engineering improvements are lettered in an inclined block letter; cities are lettered in Roman capitals; smaller towns

1 ABCDEFGHIJKLMNOPQR

2 ABCE STUVWXYZ

8 Backhand, Pen-Stroke Letter

3 ABCDEFGHIJKLMNOPQR

4 ABCE STUVWXYZ

9 *Shaded Italic Script*

5 *ABCDEFGHIJKLMNOPQRSTUVWXYZ-123456789*

abcdefghijklmnopqrstuvwxyz

6 abcdefghijklmnopqrstuvwxyz

7 ABCDEFGHIJKLMNOPQRSTUVWXYZ

12345 abcdefghijklmnopqrstuvwxyz 67890

in capitals and lower-case letters; etc. All of the principal letters used in this work, as well as several other styles, are given in this Course of instruction for draftsmen, but their specific application is a matter of separate study and does not form a part of this Course.

133. In drawing this plate of letters, draw the bottom line of numerals $\frac{7}{16}$ inch high and resting on the lower border line. Between this and the letters above is a space of $\frac{5}{8}$ inch, and the letters themselves are $\frac{9}{16}$ inch high. The lower alphabet of lower-case letters is $\frac{5}{16}$ inch below the capital letters of that alphabet, or about $\frac{1}{8}$ inch above the bottom line, and $\frac{5}{16}$ inch high.

The line of letters numbered *6* is $\frac{3}{8}$ inch above the line numbered 7, the lower case of alphabet No. 5, to the left, being $\frac{5}{16}$ inch high in the body of the letters, and the alphabet to the right, $\frac{5}{32}$ inch high. From the top of the former to the letters in No. 5 is $\frac{1}{2}$ inch, and the letters are $\frac{7}{16}$ inch high. Above this, a distance of $\frac{3}{8}$ inch, the heavy line containing the last eight letters of the alphabet is $\frac{5}{8}$ inch high, and all the heavy lines above this are spaced $\frac{1}{2}$ inch apart and $\frac{5}{8}$ inch high. The four letters in lines *2* and *4* are $\frac{3}{16}$ inch below the line immediately above them, while the small lines of letters numbered *8* and *9* are each $\frac{1}{8}$ inch high, and located with their small letters in the center of the space occupied by the alphabet immediately to the left. The panel containing the title, the length of which is 5 inches, is $\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch above the top line of letters. The height of the letters in the panel is $\frac{1}{4}$ inch, the stroke is one-fifth their height, and the white outline border is 1 stroke in width. Beginning with the top line of letters, the stroke of which is one-fifth the height, locate the center of the top of the A 3 strokes from the left border line. The letters of this alphabet are all 5 strokes in width, except the L, which is only $4\frac{1}{2}$ strokes; the M, which is 6 strokes; and the W, which is 7 strokes in width. It will be observed that this alphabet is very similar in many of its details to the Half Block alphabet drawn on the second plate, with two exceptions:

one, that the width of the letter is equal to its height, and the other, that the letters with beveled corners do not possess that bevel on the inside of the stroke. The first of these exceptions may be varied according to the conditions in which the lettering is to be done. Certain drawings may require that the letters shall be elongated or condensed, thus destroying the proportion of width to height; but the condition regarding the bevel existing on the outside of the letter only should never be altered, as omitting the bevel on the inside of small letters contributes to the sharpness and clearness of the outline, as may be seen in the letters of the title.

134. Alphabet No. 2 shows an alphabet, or at least a portion of it, the proportions and general outlines of which are similar to No. 1, with the addition of the spur, as in the Antique Half Block plate. No difficulty should be experienced in executing this alphabet, should it be desired, in any of your work, as the general principles of the letters are precisely the same as in alphabet No. 1. In designing the other letters, no spur should be placed on the left extremity of the J nor on the tail of the R, and the small spur that exists on some letters where the bevel stroke intersects with the vertical stroke should never exceed in size one-half the regular spur. No spurs on any of the letters should project above the line, except on the letters C, G, and S. Alphabet No. 3 is a repetition of the Egyptian letter already drawn in that plate, excepting in the letters having rounded strokes. The O and Q in this alphabet are perfect circles, while the strokes of the other rounded letters are all elliptic curves. The letters are somewhat similar in many respects to alphabet No. 1, the left extremity of the J, however, extending higher above the lower line, and the rounded letters, such as the C, G, O, etc., having their convex edges a little above and a little below the lettering line. This protuberance of the letter is only noticeable when horizontal lines are drawn limiting the top and bottom; but if it is not done, these letters will appear shorter than the others when a line of lettering exists alone. Alphabet No. 4 is similar to the Antique Egyptian plate, and in this is embodied some features referred to in the previous alphabet. The spur is added precisely as in alphabet No. 2, excepting in the letters C and E, all letters of a similar character partaking of the same peculiarity.

135. Alphabet No. 5 is one of the most important alphabets with which the draftsman is required to be familiar. This style of letter is used in descriptive matter on all classes of drawings. It is a single pen-stroke letter drawn rapidly, freehand, and when executed at a uniform angle and properly spaced, presents a line of very neat work. The principles on which these letters are constructed are shown in the oval of Fig. 13, and the characteristic curve by which

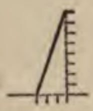


Fig. 12

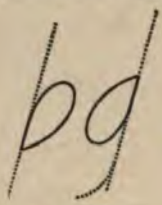


Fig. 13

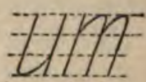


Fig. 14

such letters as the m and u are joined is shown in Fig. 14. The angle of these letters is three parts base to eight of height, as shown in Fig. 12. The round letters of the lower case, which are shown to the left of alphabet No. 6, are not elliptic, but oval, and the curve should be practiced repeatedly before executing the plate. If the capitals of alphabet No. 5 are drawn perpendicular, instead of at the angle shown in Fig. 12, then the lower-case letters shown to the right of those belonging to alphabet No. 5 will be used. These lower-case letters, alphabet No. 6, are elongated, and made to fill a space often occurring in drawings, which is too narrow for the regular proportion, as shown in the line above. When this style is used, the capitals and long letters of the lower alphabet should be twice the height of the small letters of the lower alphabet.

136. Alphabet No. 7 is an engrossing alphabet, or, as it is sometimes called, Round Writing, and is made with a shading pen especially designed for this writing, and used with ordinary writing fluid or India ink. The angle of the up stroke, or fine line, of the pen should be about 45°; the heavy strokes should always be made with a downward movement of the pen, and the fine lines either united or, as in the R and S, terminated with a slight space between the points. The letters in No. 8 are backhand pen-stroke letters, as indicated, and are used for similiar purposes with alphabet No. 5, and can be executed with great rapidity where time in the lettering of a drawing is of importance. This letter must always be of uniform angle and somewhat condensed.

137. The shaded Italic Script shown in No. 9 is a letter in general use for important lettering of drawings, such as titles, etc., where it is especially beneficial in giving a variety and thereby improving the appearance of the drawing. The title of the drawing shows the letter treated in a different manner, but proportioned precisely the same as the other letters in alphabet No. 1. The letter is carefully outlined, as in the previous cases, and then the background is blacked in, leaving the letter in relief instead of blacking the letter itself. The shaded strokes of alphabet No. 7 and letters in No. 9 may be either outlined with a fine pen and blacked in subsequently, or they may be made with a single stroke of the fine soft pen, the strength of the line being altered by the pressure, or, in the case of alphabet No. 7, with a round writing pen previously described. Execute the plate as shown, paying particular attention to the spacing and proportioning of each of the strokes in each of the letters. There is nothing in this plate that is essentially new, but there is much in the arrangement, location, and proportioning of details that will test the attention given to, and the knowledge derived from, the work on previous plates. After the plate is completed, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner, as usual.

PLATE, TITLE: HEBREW

138. The **Hebrew alphabet,** though not considered until nearly the end of this Course, is, in point of chronology, the earliest form of letter with which we have so far had to deal. It is not the intention here to give instruction as to the sound represented or the names given to the different characters, but to familiarize one with the forms and principles that govern the different letters, so that he can execute the same from a rough copy, when required to design an inscription for the stone cutter, marble worker, metal worker, or the engrosser.

139. In executing this plate, locate the lower lettering line $\frac{5}{16}$ inch above the lower margin, which gives the bottom of M only. Make these letters $1\frac{1}{8}$ inches high throughout the alphabet, with a space of $\frac{7}{8}$ inch between the two lower lines, and $\frac{3}{4}$ inch between the upper lines. The title is $\frac{3}{8}$ inch high, the word Final, $\frac{3}{16}$ inch. The average width of the stroke of these letters is about $\frac{1}{4}$ inch, and the fine line about $\frac{1}{16}$ inch. The English characters, for which the letters stand, are marked by the side of them, and the following names in their regular order will show to which ones we refer to in the subsequent descriptions: *Aleph*, *Beth*, *Gimel*, *Daleth*, *He*, *Vav*, *Zayin*, *Cheth*, *Teth*, *Yod*, *Kaph*, *Lamedh*, *Mem*, *Nun*, *Samekh*, *Ayin*, *Pe*, *Tsadhe*, *Qoph*, *Resh*, *Shin*, *Tav*. The final letters are *Kaph*, *Mem*, *Nun*, *Pe*, and *Tsadhe*.

140. Some of these letters resemble each other so closely that the closest attention is necessary in order to distinguish the characteristic points. The cyma, which is the main stroke of the first letter Aleph, is more pronounced in this than in some other Hebrew alphabets, thus showing that there is opportunity for variation in this detail. The lower stroke of the second letter, corresponding with B, extends to the right of the fine line $\frac{1}{4}$ stroke, while in the next letter, G, it is but $1\frac{1}{2}$ strokes in length, and does not quite reach the fine line. The character corresponding to D and that corresponding to R are very similar, the distinguishing

HEBREW

QUIESCENT

א בּ b ג g ד d ה h ו u ז z ח ch ט t

י y כּ k ל l מ m נ n ס s

QUIESCENT

ע פּ p צ ts ק q ר r שׂ s שׁ sh תּ t

FINAL

ך k ם m ן n ף f ץ ts

characteristic being that the former is carried almost to a point at its upper right-hand side, while the latter curves off to the fine line. The vertical stroke of the H does not reach to the cyma at the top of the letter. The letter Y is cut off short, finishing 2 strokes above the bottoms of the other letters. The dot inside the letters B, K, T, etc. must never be omitted, as the letter will not then possess its proper value. In the character corresponding with M, a space of ½ stroke is left between the fine line and the bottom horizontal stroke. The quiescent Ayin somewhat resembles the letter Y, and the tail of the letter extends from the bottom line, at an angle of about 60°, to a point vertically under the top. The short stroke of the P is finished ½ stroke above the horizontal stroke, with a short fine-line spur toward the left. The dot of the letter rests on what is really the lettering line, which extends practically through the center of the letters, a characteristic in which this alphabet differs from all others.

141. In forming these letters, pay particular attention to the proportion of each, according to the width of its stroke. Notice the position of the cyma, with regard to the lettering lines, between which the characters are drawn, and also the location of other details, with respect to the horizontal lines, on which the script letters rest and below which the Hebrew letters, in nearly every case, extend. Note the combination of similar details existing in different letters, as was the case in the Old English and German text alphabets; the T, for instance, possessing, as its right stroke, the same character as stands for the letter R, the upper stroke of the B, and the right stroke of the final F. Note also that in general appearance the letters T, M, S, P, and final M are very much alike, but when analyzed, as to the shape and proportion of their strokes, are entirely different. On the other hand, observe that the character standing for Ts in the middle of a word is totally different from the character standing for the same letters at the end of a word. The only difference in the characters standing for S and Sh is the position of the dot.

Lay out this plate in outline as in the previous ones, black in the letters with a brush, and print in the title in a Roman letter $\frac{5}{8}$ inch above the top line of the Hebrew letters. The word Final over the last line of Hebrew letters is $\frac{5}{16}$ inch above them. After the completion of the plate, write the date in the lower left-hand corner and the name and the class letters and number in the lower right-hand corner.

PLATE, TITLE: UNCIAL GREEK

142. The **Uncial Greek alphabet** is distinguished from the alphabet of minuscules in the same sense that capitals are distinguished from lower-case letters in the Roman alphabet. The minuscules, however, are not always used in the exact relation of lower-case letters to the Uncial Greek, nor are the latter used entirely as capitals. The uncial letter is always used at the beginning of proper names and the first word of a sentence, whether the whole sentence is written in this style letter or not.

143. In designing this plate, draw the line limiting the bottom of the letters $\frac{1}{4}$ inch from the lower border line. The minuscules are then made $\frac{3}{4}$ inch in height, with a space of $\frac{3}{4}$ inch between them. From the top of the minuscules to the bottom of the uncial letters, a space of 1 inch is left. The uncial letters are 1 inch high, with a $\frac{1}{2}$ inch space between them, and the title is $\frac{1}{4}$ inch high and $\frac{1}{2}$ inch above the top line.

144. There are but twenty-four letters in the Greek alphabet, and as their forms are in many respects different from the Roman letters, it is well to know them by name in their regular order, that proper comparisons with them and other alphabets can hereafter be made.

The names are as follows: *Alpha*, *Bēta*, *Gamma*, *Delta*, *Epsilon*, *Zēta*, *Ēta*, *Thēta*, *Iōta*, *Kappa*, *Lambda*, *Mu*, *Nu*, *Xi*, *Omicron*, *Pi*, *Rho*, *Sigma*, *Tau*, *Upsilon*, *Phi*, *Chi*, *Psi*, *Omega*.

The stroke in this form of letter is a trifle less than $\frac{1}{4}$ inch wide; the general width of the letter is about 4 strokes,

UNCIAL GREEK

Α Β Γ Δ Ε Ζ Η Θ

Ι Κ Λ Μ Ν Ξ Ο Π

Ρ Σ Τ Υ Φ Χ Ψ Ω

α β γ δ ε ζ η θ ι κ λ μ

ν ξ ο π ρ σ τ υ φ χ ψ ω

excepting round or extended letters, which are wider and can only be judged by their relative proportions. The average width of the minuscules is $\frac{9}{16}$ inch, and their form can best be reproduced by drawing the lettering lines at the top and bottom of the letters on the plate, and judging the proportion of the Greek letter in the copy as it projects above or below this line.

145. The letters Alpha and Beta are similar to the Roman characters A and B, with the exception of the spur, which is $\frac{1}{2}$ stroke in length and but $\frac{1}{4}$ stroke in width where it joins the letter. There is no letter C, and the Gamma (G) is similar to an inverted L. The Delta (D) and Lambda (L) are similar in outline to the Alpha, except that the former has a horizontal stroke and the latter possesses no horizontal fine line. Epsilon is similar to the Roman letter E, and Zeta corresponds with the Roman letter Z. The Eta is very similar to the Roman letter H, but is the character used in the Greek for the long sound of the letter E. The Theta (Th) is similar in outline to the Omicron (O), except that it has a cross-bar in the middle, which is $\frac{1}{2}$ stroke wide and reaches to within $\frac{1}{4}$ stroke of the curved outline. The Iota and Kappa are similar to, and correspond with, the Roman letters I and K. There is no letter J in the Greek alphabet. Lambda, the equivalent of the Greek letter L, is similar to an inverted V, or an A without the horizontal fine line; and Mu and Nu correspond with, and are similar to, the Roman letters M and N. Xi, corresponding somewhat to the letter Z, is drawn with three horizontal strokes, the intermediate one being 1 stroke shorter on each end than the two outside strokes. Omicron, as said before, is similar to the letter O of the Roman alphabet. Pi is similar to the Eta, or the letter H, without the horizontal fine line. Rho, the Greek letter R, is identical with the Roman letter P, except as to the spurs. Sigma, the Greek letter S, is unlike, in its general appearance, anything in the Roman alphabet, but its slanting stroke and fine line are the same inclination as those of the X. Tau is similar to the Roman T. In the Greek, Upsilon is the character that stands for the Roman letter Y, to which it is closely related in outline. Phi, Chi, Psi, and Omega, the last four letters of the Greek alphabet, correspond to Ph, Ch, Ps, and the long sound of O, respectively. The Phi is similar to a letter I passed through a low, broad ellipse; the Chi is similar to the Roman X. The Psi is a character entirely different from anything we have heretofore met, but its middle stroke is the same as the middle stroke of the Phi. The Omega in its upper half is similar to the O, but its lower portion is finished with horizontal strokes and spurs, as shown.

146. Among the minuscules, there is less resemblance to the Roman characters than we find in the uncial letters, and many letters that bear a resemblance to certain Roman characters do not correspond with those characters in sound. The Sigma is very similar to the Omicron, and closely resembles an inverted Q, totally different from the same character in the uncial alphabet, or to the letter S in the Roman alphabet, for which it stands. Upsilon closely resembles an Italic v, while Omega is not greatly different from w, and these characters themselves are entirely different from those of the same name in the uncial alphabet. The letters Beta, Delta, Zeta, Theta, Lambda, Phi, and Psi extend their lines about one-half their height above the line. The letters Beta and Chi extend $\frac{1}{3}$ stroke below the line, while Gamma, Mu, Phi, and Psi extend one-half their height below the line.

147. It is not necessary to remember the details of the shape of each of these letters, but you should be able to proportion them, when called on, according to the rules laid down, and should also know when and where to apply the uncial letter or the minuscule.

The upper and lower lines confining the letters should be drawn first, the letter A located in its proper place and drawn in ink, and then, after approximately spacing the distances, the vertical lines of the letters B, G, D, E, etc. should be drawn in ink, without further instructions. After this plate is finished, make a careful comparison of each letter of your plate with that of the copy, and endeavor to criticize and detect for yourself any irregularity or error that may exist. If this error is in proportioning of the letter, correct it before your plate is sent in to the Schools for correction; if it is merely an error of location or spacing, let it stand, unless very serious, and it will not be counted. When satisfied that every detail is up to the standard, insert the date in the lower left-hand corner and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: HENRY VII

148. The **Henry VII letter** dates back to the beginning of the 16th century, and takes its name from the Chapel in Westminster Abbey, London, which was built for King Henry VII, and in which his dust now lies. The letter was designed to conform to the style of architecture prevailing at that time, and was used for carvings and inscriptions throughout the Chapel. Its modern use is associated more with engrossing and ecclesiastical work; it is never used for carving in stone, though it is especially applicable for designs in pyrography, or etching on cork, leather, bone, and ivory.

149. The letters of this plate are divided into four lines, each $1\frac{1}{8}$ inches high and spaced $\frac{3}{4}$ inch apart, and the lower line but $\frac{3}{16}$ inch above the lower border. The title is $\frac{7}{16}$ inch high and $\frac{13}{16}$ inch above the top line of letters. The average width of these letters is $1\frac{1}{2}$ inches, a characteristic that did not exist in the original designs in Westminster Abbey. A peculiarity of Gothic art and architecture was that not the slightest attention was ever given to symmetry or uniformity in detail, and consequently the lettering at the close of this period is singularly marked with irregular eccentricities. Modern taste, however, demands a certain amount of decorous uniformity, and these letters have been modernized to that extent, in order to make a serviceable alphabet.

HENRY VII
(WESTMINSTER ABBEY)

A B C D E F G H

I J K L M

N O P Q R S T U

V W X Y Z

150. The letters M and W are $1\frac{7}{8}$ inches and **2** inches wide, respectively, B, C, E, and F are $1\frac{1}{4}$ inches wide, and the letter L is $1\frac{1}{2}$ inches wide over all. The round strokes at their maximum thickness are $\frac{3}{8}$ inch, and the fine line is $\frac{1}{16}$ inch. The dots at the ends of the stroke are $\frac{1}{8}$ inch in diameter, as are also the circular white openings at the point where the stroke reaches its maximum width. The balls used in the center of the concave strokes are $\frac{1}{4}$ inch in diameter; the only case where one of these ball forms is used at the end of a stroke is in the letter U, this detail being there but $\frac{3}{16}$ inch in diameter. In the middle of the letters A, B, and M, a floral device is used, varying somewhat in the different letters, but all based on the trefoil, or fleur-de-lis, ornament characteristic of the period. It will be observed that a short flat spur projects each side of the white disks or balls entering into the broadest parts of the strokes. The straight lines, or beveled ends, of these spurs are drawn from a point in the center of the white disk.

151. This alphabet naturally has wide exceptions from the general rules laid down for the conventional alphabets heretofore described. These eccentricities are permitted simply because the letter had its origin in a class of work where the information conveyed to the reader was secondary to the ornament of the letter itself. For instance, the title Henry VII carved elaborately on a tablet, was put there to ornament that tablet, and the information that it is the name of the dead king is secondary, because the observer has time to decipher its meaning from the beauty of the detail. The letters D, O, and Q are precisely alike in this alphabet, with the exceptions of the tail added to the bottom of the Q and the ball at the top of its fine line, and the tail added to the top of the D. The vertical strokes of all letters that possess such are identical, and the middle strokes of the letters F and H are made thicker than the fine lines.

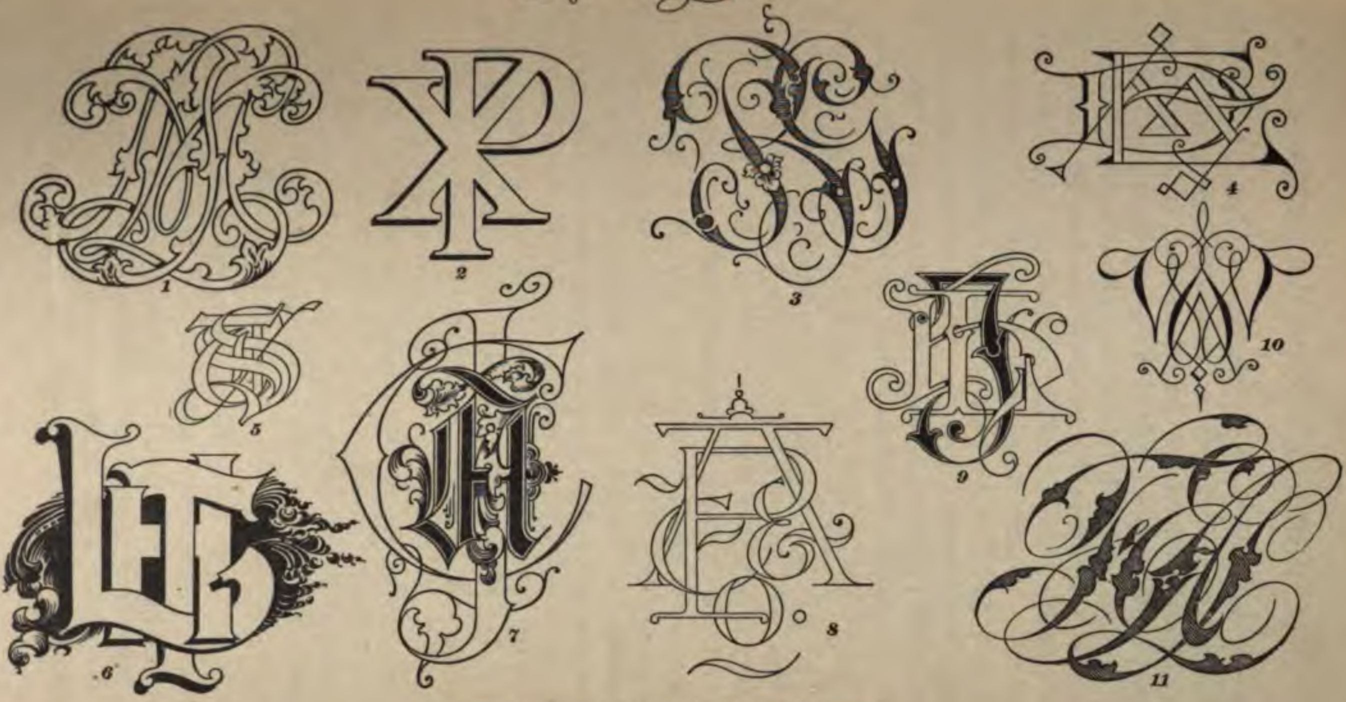
152. In drawing this plate, first outline the letters in pencil, omitting all attempts at ornamentation, and rounding the curves as evenly as possible to their joints with the stroke and fine line, in the same manner as if he were laying out a Medieval alphabet. The balls, hollows, foliated work, and other ornamentation can then be added, and when all is in place the plate may be inked. In inking the plate, it is advisable to ink in all the balls and ornamental work first, and draw the plain and simpler parts of the letters afterwards, as it is much easier to connect straight or evenly curved lines to a detail than it is to plant this detail on the lines in question. After the plate is complete and blacked in, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner.

PLATE, TITLE: MONOGRAMS

153. The origin and date of letters woven together in the form of a monogram cannot be exactly located. It is of most ancient origin, however, the earliest record on which we can place any reliability being about the 3d or 4th century. As far back as the time of Constantine, the monogram of the two Greek letters, shown in No. 2 of this plate, were carried on the banners in warfare. This device, taken from the *labarum*, may be classified as an ideogram as well as a monogram. The two Greek letters Chi and Rho stand for Christ, being the first two letters of the name. It was usually employed in connection with other designs.

154. The monogram shown in No. 1 is a text-hand letter, interwoven in a somewhat florid style, so as to be suitable for embroidery. The form observed at No. 3 is a backhand script used largely by engravers and coach painters. No. 4 is a straight-line design, more especially adaptable for work in gold, as gold lines appear so much heavier to the eye than any color, and the lines of this alone are particularly fine. In No. 5 is shown a monogram laid in Old English letters, used to illustrate the fact that, complicated as these letters are in themselves, they are, nevertheless, susceptible of being interwoven into a monogram. In No. 6 is shown the opposite of No. 4, an interlacing of heavy letters, and is usually applied to such form of monogram as will

Monograms



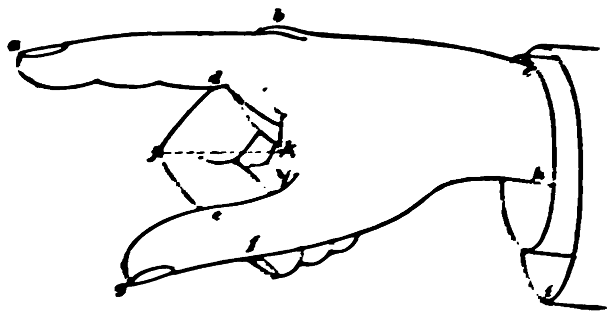
permit of the letters being drawn in outline. In No. 7 is an illuminated capital letter A surrounded by another letter with which it does not even come in contact, and though smaller than either the C or J in the same monogram, it is the most prominent letter in it. No. 8 is a light-faced letter combined to form a monogram suitable for a firm name—A. P. & Co. No. 9 is a design very elaborately carried out by an interweaving of three letters, showing how compact a design may be made. No. 10 is a design of the letters W W A, the second letter being reversed, which is permissible in some cases for this style of design. No. 11 is similar to No. 3, except that the inclination of the letters is in the opposite direction.

155. In executing this plate, first study the letters and determine to what style each particularly belongs. For instance, in No. 8 you will observe, in the light stroke and heavy fine line, a resemblance to the light French Roman letter. In No. 6 a resemblance to heavy Egyptian can be seen, while No. 2 is essentially a Roman letter. It may be desirable to divide each monogram of the plate into a number of squares (making very light pencil lines only), then draw your own plate in a similar number of larger squares, and note the point in each square where the most lines of each letter occur, thereby outlining the whole. For instance, to draw monogram No. 1, draw its bottom line $4\frac{3}{8}$ inches above the lower border line. Then make a rectangle, the left side of which is $\frac{1}{4}$ inch from the left border line, the height of which is 3 inches, and the width $3\frac{1}{2}$ inches. If this rectangle is divided into squares of $\frac{1}{4}$ inch each, the extreme left-hand portion of the monogram will touch the left-hand line in the fourth square above the bottom, as also will the right extreme curve touch the line in a corresponding location.

156. By dividing the rectangle that encloses monogram No. 1, of the plate, into small squares, fourteen horizontally and twelve vertically, it is possible to proportion every detail of the monogram by locating its position in each square, and so locating it on the plate. Do this with No. 1, using this method in drawing each of the succeeding monograms, locating them on the plate according to their relative positions on the original design, and drawing them all in outline. After completing the work, clean all pencil marks and guide lines from the plate. Though it is desirable that as much of the work as possible be done freehand, it is perfectly permissible to use the triangle and ruling pen to execute any portion of this work, as it is essentially a work of precision, and from a practical standpoint is of no value unless neatly, accurately, and systematically carried out. Therefore, it is wise to draw each monogram separately on a piece of paper, where it can be altered and erased as many times as necessary to insure its perfection, after which, with the practice and experience gained, it may be reproduced on the drawing plate. After completing the plate, insert the date in its usual place, and the name and class letters and number in the lower right-hand corner.

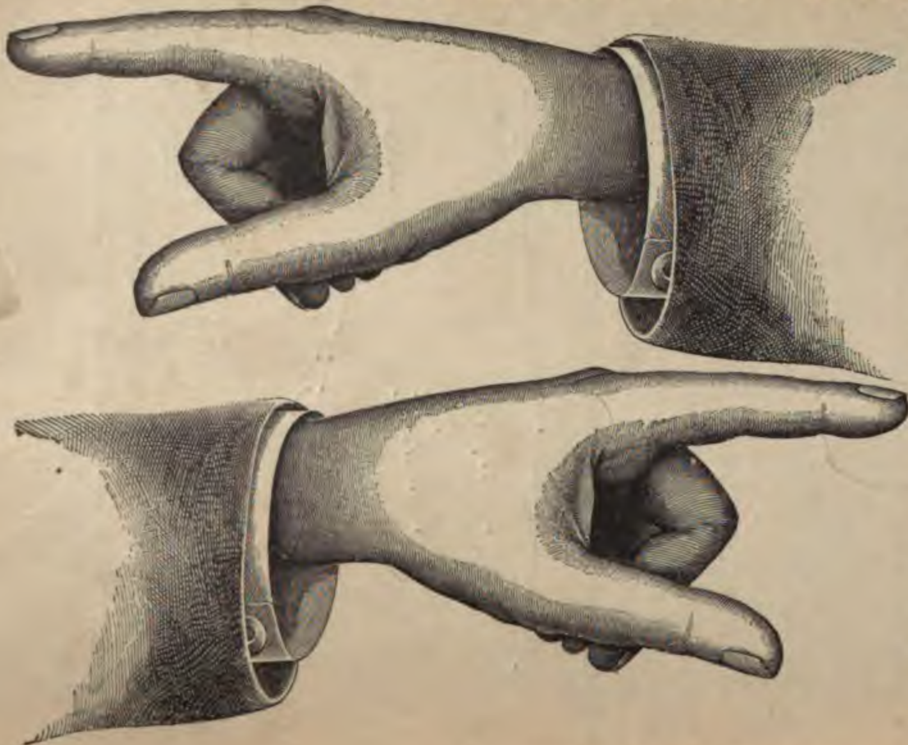
PLATE, TITLE: INDEXES AND BANDS

157. The principal figures shown on this plate are right and left index hands, the proportions of which are here given in such simple terms that no difficulty should be experienced in laying them out at any time from memory, by locating the



principal points hereafter described. [illegible] just touches the top border line and the [illegible] the left border line. [illegible] right [illegible] halfway between the [illegible] and the lower border line.

INDEXES AND BANDS



1
2
3
4
5
6
7
8

158. In proportioning the indexes, make the distance from the end of the first finger to the top and center of the knuckle of the second finger the same as from the latter point to the edge of the cuff, or, in other words, make *a b*, Fig. 15, equal to *b c*; make the distance from *a*, the end of the finger nail to *g*, the end of the thumb nail, equal to *a b*. This distance should be 3½ inches on your drawing, which is also the distance from the top of the cuff to the coat sleeve, or from *e* to *f*. The distance from *d* to *e*, *g* to *h*, *i* to *k*, and *k* to *l* is 1¼ inches, as is also the distance from *j* to *k*. With these measurements fixed in mind, it will always be a simple matter to lay out a well-proportioned index hand.

159. It is not always necessary that the index should be shaded, but where such is imperative, full strength should be given, where necessary, in order to bring out the drawing in relief. The lower side should always be shaded much stronger than the top, and the shade of the coat sleeve should fade out softly toward the edges, where it disappears into the white of the paper. Be careful not to show the joints of the finger and thumb too prominently, as they only require the mere suggestion. The right index is approximately the same as the left in every respect, but both should be practiced with equal attention, as it frequently happens that a designer is capable of drawing a right-hand index extremely well, and is utterly unable to execute the same figure in the opposite direction.

160. The bands on this plate are extremely simple and require very little explanation. They may be used as borders to tablets or signs, or, in some cases, may be stenciled and afterwards filled in, or, with slight variation, may be used as dividing parts in an inscription, provided suitable foliated or geometrical ends form their terminals. In laying them out, the top line of No. 1 is but ⅜ inch below the upper border line, and the bottom line of No. 8 is ¼ inch above the lower border line. Nos. 3, 4, and 5 are each ⅝ inch high, while Nos. 2, 6, and 7 are only ⅜ inch high. No. 8 is but ⅜ inch high. They should be drawn to reach to within $\frac{1}{4}$ inch of the right-hand border, and may be finished in an irregular manner when the motive is shown. The length of these bands is $4\frac{3}{8}$ inches.

In drawing these, the **T** square and triangle may be used to execute the straight lines, as well as the compasses for carrying out the curves, with the exception of Nos. 3, 5, and 6, which must be executed entirely freehand. Proportion each part carefully; no matter how simple, do not hurry the work, and, when complete, shade the indexes and black in the borders like the original plate, insert the date in the lower left-hand corner, and the name and class letters and number in the lower right-hand corner of the plate.

PLATE, TITLE: INSCRIPTION DESIGN

161. In the example of **Inscription Design** chosen, a variety of treatment has been introduced to exemplify a harmony in the coloring of the design, and to illustrate the several methods used to embellish various parts that will add strength and legibility to the whole. It should not be understood that colored designs require extensive treatment in all cases, as broad washes and few colors make a design that is often preferable to one that is overloaded with carefully studied coloring and an abundance of detail in its composition.

162. To draw the plate, use only T. S. Co.'s cold-pressed drawing paper 15 inches by 20 inches, and a 4H lead pencil. Make as few pencil marks as possible, as these must be lightly erased before the water color is applied. Beginning at the top edge of drawing paper, locate the palette, which is 1 inch from top edge and $\frac{5}{8}$ inch from side. The extreme width of the top of palette, measuring from the left edge of paper, is $5\frac{7}{8}$ inches, the lower portion is $5\frac{5}{8}$ inches. The title is 1 inch from top edge and $\frac{3}{8}$ inch high. The top edge of panel is $2\frac{3}{8}$ inches from top edge of paper, the bottom of panel is 6 inches. The band at top and bottom of panel is $\frac{1}{2}$ inch wide. The letters of the panel are $1\frac{3}{8}$ inches. The end of panel is $1\frac{1}{2}$ inches from right edge of paper. The yellow panel is $\frac{5}{8}$ inch from right edge, $10\frac{5}{8}$ inches long, and 4 inches wide in center. The word Composition is $3\frac{3}{16}$ inches from bottom edge of paper. The letters are $1\frac{1}{8}$ inches high. The word Utility is $5\frac{9}{16}$ inches from bottom edge, and $\frac{7}{8}$ inch high. The green panel is $2\frac{1}{4}$ inches from bottom edge and $3\frac{1}{8}$ inches high, $6\frac{1}{2}$ inches from left edge and $10\frac{3}{8}$ inches from right edge to short vertical line. With these measurements, the general arrangement of the design may be accurately followed. To space the letters and follow their formation as shown in the copy should not require instruction on this final plate.

163. Colors should not be applied until the black lines are drawn and lettering is done as far as possible. First, cut in the letters on the palette, and outline the long panel; then letter the words The Utility in the Composition. Now begin on the color work by blending the long panel, beginning with the mauve purple. The pink should be an opaque color, made so by the addition of white. The colors of the band of the panel are orange chrome, burnt sienna, and black blending into Prussian blue. The shade of the letters on this panel blend from pure mauve purple to Indian red, then to orange vermilion. The space between the shade and the letter is filled in with gold color and burnt sienna, ending with clear white. The rococo panel should be blended before the ornamental edge or the lettering is done. Orange chrome in white should be used for the light, and burnt sienna for the dark portion of the panel. For the darkest shades of the ornamental edge add black to burnt sienna. For the darkest shade on the word Design use crimson lake. The ornamental border of panel should now be executed and the lettering of the design completed. The green panel should be first laid in with a medium shade of green, the lightest shade should then be applied, using a little white in combination with the green. The darkest shade is changed from a green shade to a reddish tone by the addition of burnt sienna. The shading of the letters and panels should now be done, using a natural shade made of charcoal gray and a slight amount of orange chrome.

The second shade is produced with the addition of charcoal gray only. The second shade in the word composition is made by adding Indian red to the natural shade, strengthening this with crimson lake on the first two letters of the word. White is then run in between the shade and the letter on the green panel, as well as between the shade and the letters of the two large panels. In extending the ornament from the green panel, care should be exercised to make the curves of the ornament symmetrical, and to keep the shade of the green light rather than dark, as in the latter case it will tend to confuse the ornament with the lettering.

On the completion of the design, sign your name in small neat letters either printed or written. Also attach your class letters and number as usual in the right corner, and the date of the completion of the work in the left.

MECHANICAL DRAWING

INTRODUCTION

DIVISIONS OF THE SUBJECT

1. While every drawing executed by means of the T square, triangles, and other drawing instruments, is a *mechanical drawing*, this term is usually restricted to drawings representing machines, machine parts, and objects used in the mechanic arts. In recognition of this restricted meaning of mechanical drawing, the term "geometrical drawing" was used in the preceding paper to signify that the subjects treated dealt with those general geometrical principles that form the foundation of all instrumental drawing.

A **mechanical drawing** is the language employed by the designer of machinery to convey his ideas to others; as, for instance, to the workman who is to construct the part or machine represented.

2. A workman that constructs a machine or machine part from drawings is said to "work to drawings," and requires not only a true representation of the object to be made, but all its dimensions as well. The drawing must also give other instructions, such as the material to be used, method of manufacture, etc. A mechanical drawing of this kind is called a *working drawing.*

3. While the systems used in the drawing offices of the leading manufacturing companies for producing drawings vary in many important details, it should be noted that good drawings made in one office can be read in others, and that the parts represented can be made in other shops, even when office and shop practice differ to a marked degree. In general all mechanical drawings are made as plain as possible, shading and other aids to the eye being omitted except on complicated drawings, when shading is occasionally resorted to in order to bring out the important features of the design. The shading of surfaces, lines, and holes is becoming less and less common, but when used, the instructions given in *Geometrical Drawing* will be followed.

It is not good practice to spend time on elaborate titles or figures. Plain letters, easily read, serve all purposes and do not waste the time of the draftsman.

The methods here described are those which have been found to be the most representative and complete, and the student can easily adapt himself to any local regulation, if the principles here explained do not agree in every particular with the practice in the office in which he first starts as draftsman.

WORKING DRAWINGS

KINDS OF WORKING DRAWINGS

4. Working drawings are divided into two general classes, namely: *assembly*, or *general*, *drawings* and *detail drawings*.

Assembly, or general, drawings show the workman the relation between, and the places or positions occupied by the component parts of a structure, machine, device, fixture, implement, etc. If any dimensions are given, they are usually only the leading ones.

5. Detail drawings show the exact shape and size of each integral part. For this purpose they are supplied with all the dimensions required by the workman and any additional explanatory notes that the draftsman may consider necessary.

Detail drawings may be made so complete that they will answer for the patternmaker, blacksmith, and machinist, and they are usually so made in the smaller shops. In the large shops, however, separate drawings are often made for these men; the detail drawing for the use of the patternmaker then contains only the dimensions and notes needed by him to make the pattern; that for the blacksmith contains only the dimensions needed for making the forging; and, finally, that for the machinist contains only the dimensions needed by him.

6. Attention is called to the fact that practice varies in regard to the dimensions given on detail drawings, at least as far as drawings for the patternmaker and blacksmith are concerned. In some places, the dimensions given represent the size the object is to be when finished; hence, the blacksmith or patternmaker must make necessary finishing allowances himself. In other places the finishing allowance is made by the draftsman; the dimensions given are then those of the pattern or forging. If in doubt about the practice followed in a particular drawing office, find out by inquiry what system is used.

In the drawings which follow, the finished dimensions only are given, the necessary allowances being made by the patternmaker or blacksmith.

SCALES

7. It is seldom convenient to make the drawing of a part full, or life, size, it being more often necessary to show the part as reduced in size. Thus, supposing it is desired to make a drawing $\frac{1}{4}$ size, then 12″ on the object will be represented by 3″ on the drawing, hence if 3″ is laid off and divided into 12 equal parts, each of these parts will represent 1″ on the object. If these parts are subdivided into 2,

FIG. 1

4, or 8 parts, each will represent $\frac{1}{2}''$, $\frac{1}{4}''$, or $\frac{1}{8}''$ on the object. A scale of this kind is called a $\frac{1}{4}$ **scale, or a scale of 3″ to the foot.** A $\frac{1}{8}$ **scale, or a scale of $1\frac{1}{2}''$ to the foot,** is constructed in the same way, except that $1\frac{1}{2}''$ would be laid off instead of 3″.

In some cases, the scale is increased as in small machines, such as instruments, etc.

8. The dimensions given on a drawing are always followed and it is seldom necessary to state the scale to which drawings are made, although this may be done if it in any way adds to the clearness of the drawing. It is common practice to have parts on the same detailed sheet drawn to different scales, the more complicated parts being drawn as near full size as possible, and the less complicated parts being drawn to a much reduced scale.

9. Fig. 1 shows a scale which is convenient for the student, inasmuch as it combines eleven systems of subdivision and may be used for all the work ordinarily done in a drafting room. This scale is triangular in section and 12 inches in length, and on each of its edges there is laid off a scale, as shown at *A*, *B*, and *G*. The scale at *G* is "full size"; that is, this edge of the scale is divided into inches and fractions of an inch down to sixteenths, and is used for drawings in which an object is represented in its natural size. On its opposite side, at *B*, is shown the quarter-size scale of 3″ = 1 ft. The first 3-inch (actual size) division, from *B* to *C*, is subdivided into 12 parts representing inches, and each inch is then divided into proportional fractions of an inch, generally eighths. From *C* to *D*, *D* to *E*, and *E* to *F*, the scale is marked in its main divisions of 1 foot each, each foot being 3″ long, actual size. From *A* to *B* the scale is independently divided into spaces of $1\frac{1}{2}$″ (actual size) to form an eighth-size scale, or $1\frac{1}{2}$″ = 1 ft., the divisions of the latter occurring on and between the marks for the 3″ = 1 ft. scale.

The other sides and edges of the instrument are divided into scales of 1″ and $\frac{1}{2}$″, $\frac{3}{4}$″ and $\frac{3}{8}$″, $\frac{1}{4}$″ and $\frac{1}{8}$″, and $\frac{3}{16}$″ and $\frac{3}{32}$″ to the foot. Different makers do not always arrange their scales in the same manner. Thus, instead of having a full-size scale and scales of 3″ = 1 ft. and $1\frac{1}{2}$″ = 1 ft. on one side, as shown in Fig. 1, some makers have the full-size scale and $\frac{3}{16}$″ = 1 ft. and $\frac{3}{32}$″ = 1 ft. on one side. It will be observed that the numbering of the feet on these scales does not start at the end of the instrument, but at the first main division from the end. Thus, on the quarter-size scale the zero mark is placed at *C* and the first foot is measured to *D*. This is done so that the feet and inches may be laid off independently and with one reading of the scale.

The figures indicating the number of feet on this scale are placed along the inside edge at *D*, *E*, and *F*, the numbers running in a direction away from the part containing the inches. The numbers indicating inches run in an opposite direction from those defining the feet.

10. To lay off 2 ft. $3\frac{3}{4}$″ on a scale of 3″ = 1 ft., and from a given point, place the scale on the point so that the 2-foot mark will be directly over it; then from the zero mark *C* lay off $3\frac{3}{4}$″, as shown, locating a second point. The length of the distance thus laid off between the two points represents 2 ft. $3\frac{3}{4}$″. The scale of $1\frac{1}{2}$″ = 1 ft. is used in a similar manner to lay off the same distance. The figures indicating feet on this scale are placed nearer the edge, in order to prevent confusion in reading.

To draw to half size, or to a scale of 6″ = 1 ft., use the full-size scale, and remember that every $\frac{1}{2}$″ on that scale corresponds to 1″ on the object; that is, that every dimension is only one-half of the real length. To lay off $5\frac{7}{8}$″, lay off 5 half inches and $\frac{7}{16}$″ over; the result is a line $5\frac{7}{8}$″ long to a scale of 6″ = 1 ft.

11. It may happen that a draftsman is obliged to make a scale, when the size of his plate is limited and a general drawing of some object is desired. In such a case, one scale may be too large to enable the drawing to be made on a sheet of the required size; another scale may make it too small to show up well. For example, a $\frac{1}{8}$ scale may be too large and a $\frac{1}{16}$ scale too small; a $\frac{1}{12}$ scale may be just right. If the draftsman has no $\frac{1}{12}$ scale (that is, a scale of 1 inch to the foot), he may make one by taking a piece of heavy drawing paper and cutting out a strip about the size of an ordinary scale and laying off the inch divisions on it. Each division or part will represent 1 foot on the object. Divide one of the end parts into 12 equal parts and each will represent 1 inch on the object. Lines indicating half and quarter inches may be drawn if considered necessary.

Fig. 2 shows part of a scale made in this manner, giving

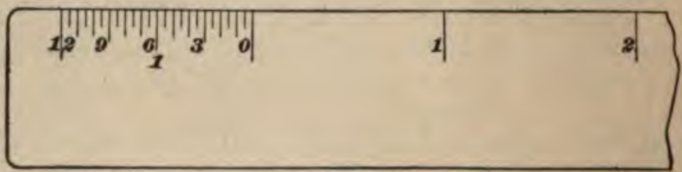


FIG. 2

feet, inches, and half-inches—the quarters, eighths, etc. of an inch being judged by the eye.

To make a $\frac{1}{5}$ scale, lay off 12″ and divide this distance into 5 equal parts, using one of the methods described in *Geometrical Drawing*. Using the same method, divide one of the end divisions into 12 equal parts, to represent inches, and then divide each of these parts into halves, quarters, eighths, etc.

DUTIES OF DRAFTSMEN

12. A brief description of the duties of the draftsman, according to his rank and experience in the modern drafting room, is given herewith. There are usually three, and sometimes four, grades of men:

1. The *designer*, who, as his name indicates, designs the apparatus.

2. The *leading*, or *head*, *draftsman*, who takes the ideas of the designer and works them up into practical form. Very often the designer does his own laying-out work, and in such case, fills both the position of leading draftsman and designer.

3. The *detailer*, who works either directly or indirectly for the leading draftsman, takes his assembly drawings and makes up the details, calling for proper material, parts, and quantities. His work approaches more and more nearly to that of the leading draftsman, as he gains in skill and familiarity with the machine designed.

4. The *tracer*, who takes the pencil detail drawings, and makes tracings for reproduction, his work in turn approaches more and more nearly the work of the detail draftsman as he gains in skill and experience. It is probable that the young man who starts work without previous practical experience will start work as a tracer. If he does this work neatly and intelligently, he can count upon promotion to the more responsible position of detail draftsman, if opportunity offers, from which position he can then advance himself higher and higher.

13. The necessity of carefully following all instructions in making tracings cannot be too forcibly presented. Slovenly work will at once create a bad impression, while painstaking work, and carefully made and presentable tracings, will immediately place the tracer in favorable standing with his employers At the start it is better to work slowly until the subject presented is well in hand and perfectly understood. While speed is important, accuracy must come first.

DRAWING PLATES

GENERAL INSTRUCTIONS

14. The general instructions which follow, apply to all the mechanical-drawing plates treated in this Section.

From the start, the student should remember that it is essential to do neat and accurate work; that all lines, figures, and letters must be clear cut and distinct; that there must be no doubt as to the meaning of limits or dimensions; that mistakes made on drawings are often more serious than errors in the shop, for they may not be located until the various parts of the machine are to be assembled. He must also keep in mind the necessity of making drawings concise, but not needlessly complicated; that dimensions are not to be duplicated; that when working drawings once leave his hands marked "complete" it should not be necessary to refer to him for further particulars.

15. Size of Plates.—The plates are to be of the same size as those drawn in connection with *Geometrical Drawing*, 14″ × 18″, with border lines drawn $\frac{1}{2}$″ from edge, making working limits of drawing 13″ × 17″.

16. Title and Number of Drawing.—The title or name of drawing is to be placed in the lower right-hand corner of sheet, and a space of $1\frac{1}{2}$″ × 4″ is to be reserved for this title; the height will vary, but the length will always be 4″. In addition to the title there will be given in this space the number of the drawing, the draftsman's name, and the date when the drawing was finished. If desired, the date can also be given when drawing was started.

17. Fractions.—Fractions are to be written with dividing line horizontal, thus: $\frac{3}{4}$″, $\frac{7}{16}$″; never thus: 5/16″, with dividing line inclined.

18. Abbreviations. — Abbreviations are only used on drawings when lack of space prevents use of complete word, although there are a few abbreviations which can be used without hesitation, having been practically fixed by long practice, thus: D. or "Diam." for diameter; R. or "Rad." for radius; "Thds." for threads; f. for finish.

19. Definitions.—The word **drill** placed near a dimension or hole is always taken to mean that a hole is put through the object by drilling.

Ream or **reamed** placed near a hole means that the hole is finished by reaming.

The word **tap** following a dimension and a number always means that the hole is to be finished by tapping with a tap of the dimensions given; that is, "$\frac{1}{2}$–13 tap" would mean that the hole is to be tapped with a $\frac{1}{2}''$ tap, 13 threads to the inch.

The word **cored** implies that finish is unnecessary, the hole being produced by a core, which is placed in the mold when the casting is made. Cores are arranged for by the patternmaker.

The terms **shrinking fit, driving fit, forced fit,** and **turning fit,** always imply that the workman is to make allowance for the kind of fit called for, all holes being made to nominal dimensions, and the allowance necessary made on the part which goes into the hole.

F all over means machine or part is to be finished all over.

When wishing to convey special information, write your note in plain English so that it cannot be misunderstood.

20. Dimensions.—All dimensions above 24″ are to be given in feet and inches, the inches being designated by accent (″) mark, and feet by abbreviation ft., thus 6 ft. $4\frac{1}{2}''$; never use accent mark for feet, as there is then danger of confusion.

When micrometer or gauge measurements are required, all dimensions are given to three decimal places; thus, 1.000″ would indicate one inch measured with gauge or micrometer; 6.250″ would indicate $6\frac{1}{4}$″, and 0.250″ would indicate $\frac{1}{4}$″ measured in the same way. Note that a zero should always be placed ahead of the decimal point when dimensions are less than one inch; this avoids all confusion as to value of decimal.

Where possible all dimensions should be given so as to read from bottom and right-hand side of drawing.

Intermediate dimensions always start from some finished surface, or center line, this giving a base from which work can be checked.

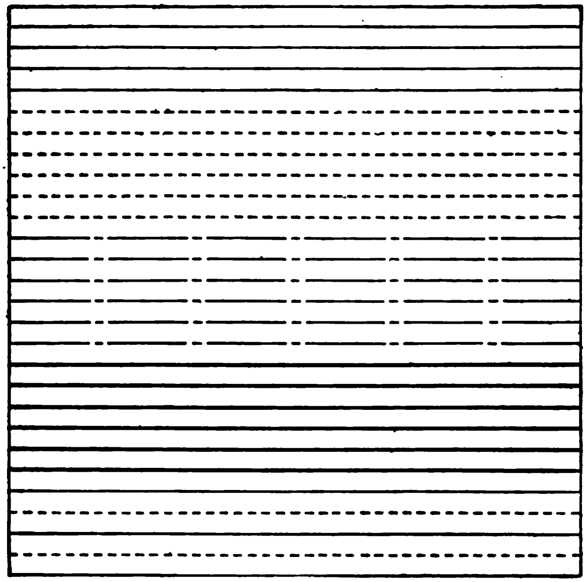
PENCIL DRAWINGS AND TRACINGS

21. The method of making working drawings differs from the method which has been followed in *Geometrical Drawing*, the pencil drawing not being inked in. In modern shop practice, original drawings are not sent to the shop, but reproductions, called **tracings**, are made on **tracing cloth**, which is a cloth made semi-transparent by sizing, and then blueprints are made from the tracings. A description of the blueprint process will be given farther on. Since the tracing can be made to serve as an original drawing, it is not necessary to ink in the pencil drawing, although it may be retained as a record.

Following the above general shop practice, the drawings made in connection with the study of this subject will first be made in pencil and afterwards traced. The methods to be followed in making the pencil drawing will be those which have been used in penciling the plates in *Geometrical Drawing*.

22. For the pencil drawing a good grade of Manila paper upon which lines can be easily drawn and erased is sufficient. The tracing cloth is then placed over the paper drawing and the lines inked in on the cloth. All ink lines on tracings must be uniformly black without regard to the width of these lines. In general, the lines will be made

Fig. 1.



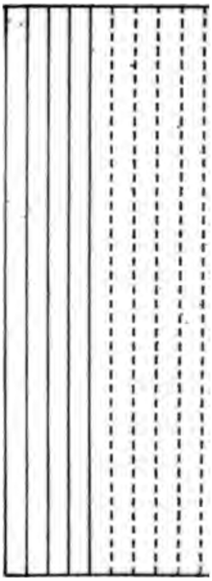
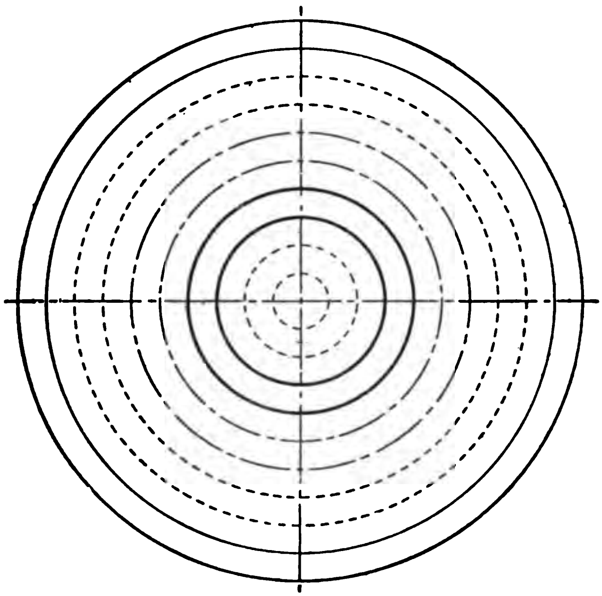
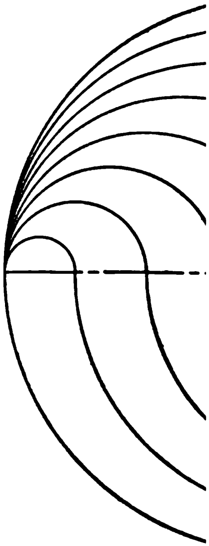


Fig. 4.





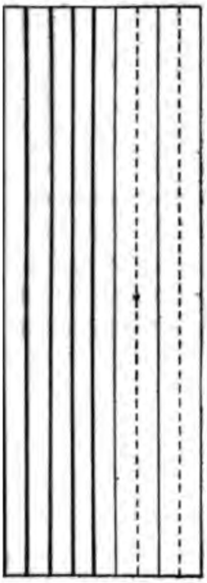
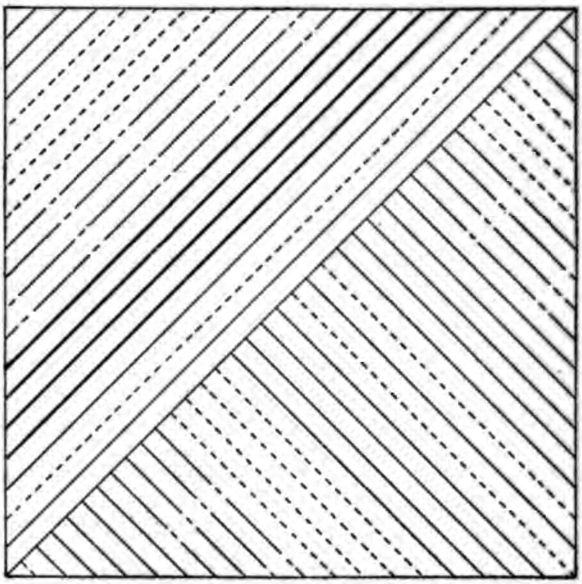


Fig. 3.



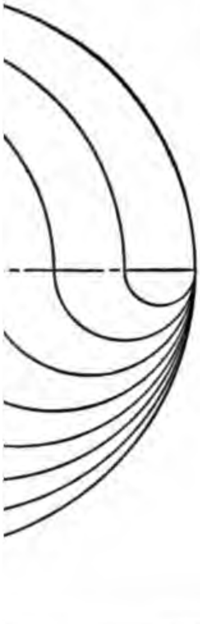
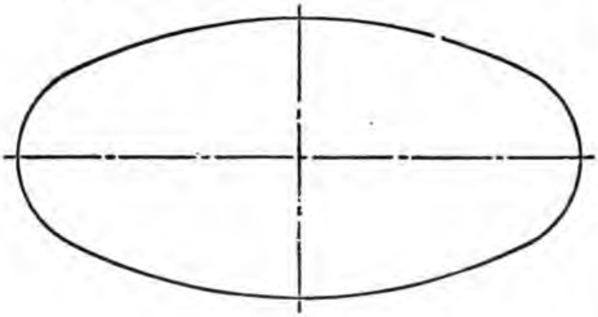


Fig. 6.



PRACTICE SHEET

DRAWN BY..................

DATE..................

1001

TATES.
XTBOOK COMPANY.
London.

about 50 per cent. heavier than they would have been if inked in on the original paper drawing.

At first it will be found very difficult to get lines that are distinct and uniformly black, but by strictly following directions, it will become quite as easy to make a good tracing as it is to ink in the drawing on drawing paper.

The plates to be drawn in connection with this subject all have numbers, which begin with 1001. They are to be drawn in the order of their numbers.

PLATE 1001, TITLE:

PRACTICE SHEET

23. Plate 1001 is intended for a practice sheet in tracing and is introduced to give the student an opportunity to familiarize himself with the methods of making lines on tracing cloth, and will not serve in any way as a working drawing. We would suggest that after having carefully penciled the drawing on Manila paper, it be traced several times before submitting the tracing to the Schools for criticism.

In order to distinguish readily between references to figure numbers on the drawing plates and to those in the text, the former will be printed in heavy-face type and the latter in ordinary type.

24. Suggestions for Making the Pencil Drawing. Figs. **1**, **2**, and **3** are squares $5\frac{1}{16}''$ on a side, and the lines drawn in them are $\frac{3}{16}''$ apart, some being full lines, some dotted, and some heavy lines; the positions of all parallel lines are to be fixed by scale measurements, care being used to place them symmetrically. All lines should be a trifle heavier than is shown on the engraved plate, as the engraving is somewhat smaller than the tracing. In locating the squares let their top sides be $\frac{3}{4}''$ below the upper border line, leaving a space of $\frac{5}{16}''$ between first and third squares and their adjacent border lines and a space of $\frac{13}{32}''$ between each of the squares.

Fig. 4 is a series of 10 concentric circles, $\frac{1}{4}''$ apart, of lines varying in thickness, the outside circle being 5″ in diameter. When drawing these circles—and at all times when several arcs are described from the same center—be careful to keep the leg of the compass that contains the needle point perpendicular to the plane of the paper and press the compasses as lightly as possible against the paper; otherwise, a hole will be made in the paper at the center from which the arcs are struck, which will wear larger all the time. It will then be difficult to ensure accuracy, and the hole will present an unsightly appearance. This caution is particularly necessary when inking in a tracing, as the hole enlarges much more rapidly than on paper and will be reproduced in all blueprints taken from the tracing.

Fig. 5 is a combination of semicircles enclosed in an outer circle 5″ in diameter.* Place the horizontal diameters of these circles $3\frac{1}{4}''$ above the lower border line and their vertical diameters $2\frac{13}{16}''$ and $8\frac{1}{2}''$ from the left-hand border line.

In order to draw this latter figure, first draw the horizontal and vertical diameters, as shown, which are 5″ long. Divide the horizontal diameter into 8 equal parts, then draw the outer circle. Bisect each of these main divisions and with the points of bisection as centers draw the semicircles as shown, first describing the two smallest semicircles —one above and one below the horizontal diameter—then the two next larger; and so on, until the figure is completed.

In drawing this figure the student should take very great care to make the semicircles meet accurately, as this is the object of this exercise.

25. Fig. 6 represents an ellipse whose major axis is 5″ and minor axis is $2\frac{1}{2}''$, located respectively 4″ above the lower border line and $2\frac{7}{8}''$ from right-hand border line. The ellipse may be constructed in one of the ways described in

* The distances for locating the various views on this or any of the succeeding plates are always to be measured with a full-size scale.

Geometrical Drawing, or by the following approximate method, which is rapid and is accurate enough for practical purposes:

Draw the two axes a, a' and b, b', Fig. 3, and join a and b by the line ab; lay off bc equal to $oa - ob$ and bisect ac by the perpendicular de, which intersects bb' produced in e and oa in g. Lay off $oe' = oe$, and $og' = og$, and draw $e'f$, $e'f'$, and ed'. With e and e' as centers, and $eb = e'b'$ as a radius, describe the arcs dbd' and $fb'f'$; and with g and g' as centers, and $ga = g'a'$ as a radius, describe the arcs daf and $d'a'f'$.

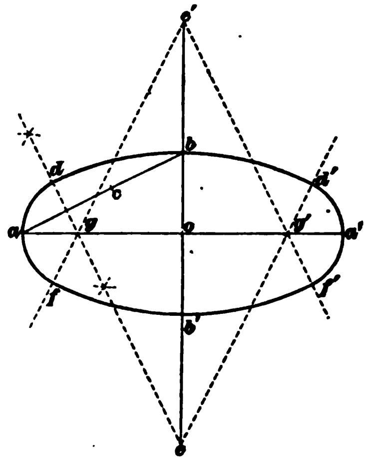


FIG. 3

The points e and e' may lie within or without the ellipse, according to the difference between the axes.

26. In the lower right-hand corner of the sheet is a space reserved for the title with lines drawn as shown. Make this space 1½" high and 4" long and subdivide it by a line ½" above and parallel with the lower border line. In the lower space draw a vertical line 1¾" from the right-hand border line. The title and number should be centrally located in their respective spaces, and the letters and figures should be ¼" high. Fill in the title with the type of letters indicated.

The tracing can now be begun.

27. Tracing the Drawing.—The two sides of the tracing cloth are known as the glazed side and the dull side. Place the tracing cloth over the carefully prepared pencil drawing, glazed side up, putting extra thumbtacks in each corner, and smoothing out all wrinkles. Either side of the tracing cloth may be used for inking in. The glazed side takes ink much better than the dull side, the finished drawing looks better and will not soil as easily, and it is also easier to erase a line that has been drawn on this side. Pencil lines can be more satisfactorily drawn on the dull side, and if it is desired to photograph the drawing, it is better to draw on this side. The draftsman uses either side, according to the work he is doing and to suit his individual taste, or to follow the practice of the drafting room in which he is employed.

Care must be taken to remove all dirt and grease, otherwise the ink will not flow well from the pen. This is done by taking a knife or file and scraping or filing chalk upon the tracing cloth; then with a soft rag (cotton-flannel, or chamois) rub it over the tracing cloth, being sure to rub chalk over every part. The chalk powder must be fine and must be rubbed off gently after being spread on the surface. The use of the powdered chalk makes it possible to ink the drawing satisfactorily and prevents the ink running, as it sometimes does when chalk is not used.

28. Now take the **T** square and with the right-line pen draw all the horizontal lines, starting at the top and working down, drawing the light lines first, and gradually spreading the pen until the heavier lines are taken care of.

Next, draw the vertical lines, then the inclined lines, then the circles, and finally the ellipse, which will be drawn by the method just described.

29. Before fixing the width of the line, draw your pen on the edge of tracing cloth outside the bounding lines on which the tracing is cut or else on a separate piece of tracing cloth; until your pen works freely and smoothly, and produces lines of the right weight, do not attempt to draw any lines on the tracing cloth. You need not expect to make a good tracing at the first trial, but will be surprised at the rapid improvement after one or two practice sheets have been drawn.

LETTERS & FIGURES

TYPE I ABCDEFGHIJKLMNOPQR
STUVWXYZ
1234567890

TYPE II *ABCDEFGHIJKLMNOPQR*
STUVWXYZ
1234567890

TYPE III *ABCDEFGHIJKLMNOPQRSTUVWXYZ &c.*
1234567890-

DECIMALS 0.025 0.075 1095 FRACTIONS $\frac{1}{8}$ $\frac{9}{16}$ $\frac{33}{61}$

TYPE IV *abcdefghijklmnopqrstuvwxyz &c.*

Note THE OVAL IN TYPE IV IS SHAPED THUS 0 AND WHEN INVERTED THUS D THIS OVAL OR PART OF IT IS USED IN THE FOLLOWING LETTERS IN MANNER INDICATED

a b c d e g h j m n p q r

LINES

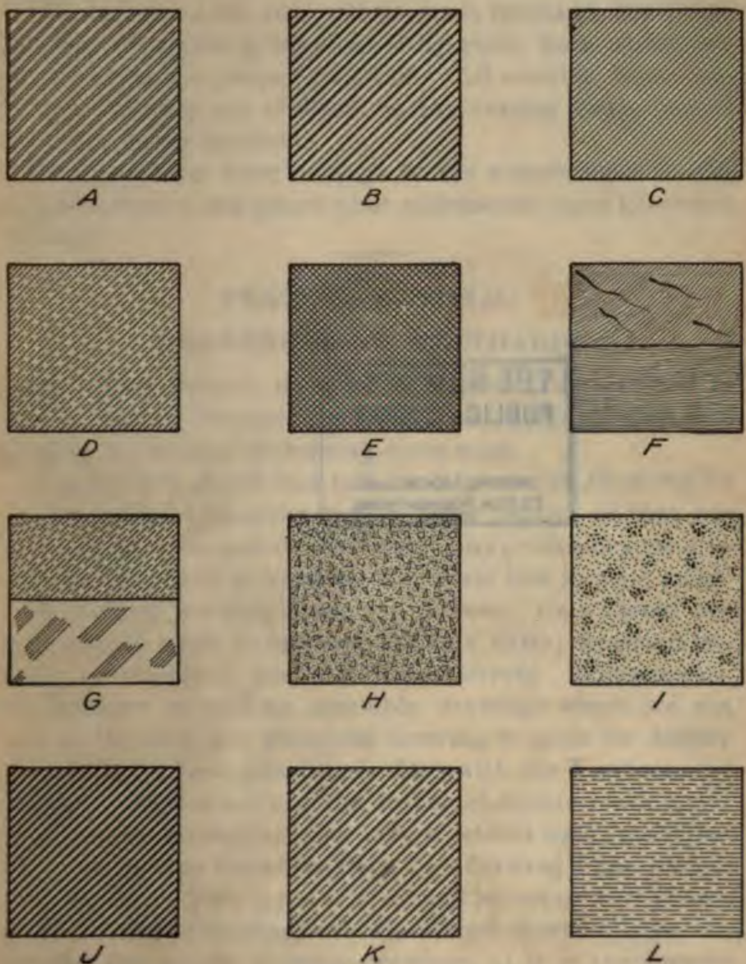
SURFACE & CUTTING PLANE LINES

HIDDEN SURFACE LINES

DIMENSION LINES

CENTER LINES

STANDARD CROSS SECTIONS



DRAWING ROOM STANDARDS

DRAWN BY........................

DATE..............................

1002

D STATES.
TEXTBOOK COMPANY,
ALL, London.

When the lines are all drawn, put in the title and the designation of figures. In tracing, remember that ink dries slowly and care must be taken to avoid smearing.

The letters in the title will be made freehand, the shape and size of letters being limited by guide lines which you will draw in the proper positions. All working lines used on the drawing are omitted on the tracing cloth, center lines only being retained.

Before mailing your tracings to the schools write on the dull side with a lead pencil your address and class letter and number.

PLATE 1002, TITLE:

DRAWING-ROOM STANDARDS

30. This Plate is intended as another practice sheet in tracing, and at the same time serves as an introduction into the regular routine of drawing-room work.

Considerable stress was laid in *Geometrical Drawing* on the necessity of learning how to letter neatly; all that has been said there is endorsed here, and any proficiency the student has acquired in lettering will stand him in good stead.

In making working drawings, however, time should not be uselessly spent in making elaborate titles; freehand lettering is, therefore, used almost exclusively. Sometimes—for instance in making assembly drawings which are not sent to the shop and where the drawing is made for display or other purposes—lettering is done with the **T** square and triangle. But even then the rather elaborate block letter described in *Geometrical Drawing* is seldom used; a simpler alphabet, as that shown as Type I on drawing Plate 1002, is used instead. Two types of freehand lettering were shown in *Geometrical Drawing*, only the second of which is recommended for use on working drawings, as it is the simpler of the two. It is repeated as Types II, III, and IV on Plate 1002, differ only in size.

31. It is important that all sheets of drawing for the same shop have uniform lettering, and that the various types of lettering are used always for one and the same purpose. In this work the following plan will be adopted:

Letters shown under head of Type II are the style of letters which will be used in the **main title** of all the drawing sheets which follow. These letters are $\frac{1}{4}''$ in height and are spaced as shown.

Capitals shown under head of Type III will be used for all **capitals** except the main title.

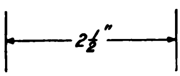
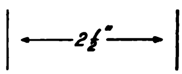
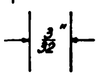
Type IV will be used for all **lower-case letters in body of drawing,** and in **bill of materials,** and the figures in all **dimensions.**

Types III and IV are made freehand, but it is advisable at all times to draw guide lines on the pencil drawing before the work is started, these guide lines not appearing on the tracing, of course.

It is recommended that the lettering be done on the pencil drawing as well. It will serve to nicely locate the words, etc., and when lettering the tracing, any misplacement can then be remedied. Any good, sharp, steel writing pen, not too hard, may be used in lettering, but a so-called *crow quill pen,* especially adapted for this work, is recommended.

DEFINITIONS OF LINES

32. Surface Lines.—**Surface lines** refer to those lines which limit or bound the delineation of a part and should be of the same weight all about the figure.

33. Dimension Lines. — **Dimension lines** are lines drawn to show limits to which dimensions apply and are ended with an arrowhead, put in freehand, the arrowheads should always touch the lines which limit the dimension, thus:  Never thus:  A short dimension may be indicated thus:  Placing arrowheads outside of limiting lines.

Do not put dimension lines in or over delineation of parts, or place figures where they cannot be easily read.

34. Center Lines.—Center lines are usually drawn at the working center of the object shown, and are extremely important as indicating the point from which work is to be laid out. Dimensions are frequently given from the center lines and they serve as a guide for all dimensions even when not used to limit them. In making working drawings it is important that one of the center lines should be first located, as this will immediately fix the starting point of drawing. This working point is not necessarily the geometrical center of the figure, but is fixed by some important point about which the delineation begins and which is relatively important in the complete object.

This line is also used to indicate where a section has been or is to be taken. If, however, a partial section is indicated, the remainder of the view being in elevation or plan, the full (surface) line is used, except where there is an opening appearing in both parts of the view; in this case, the dash and dot would be used where the line crosses the opening, and the full line where it crosses the solid portion.

35. Hidden Surface Lines. — Hidden surface lines are lines drawn to show the surfaces of hidden parts, and it will be noticed that the part hidden in one view is sometimes drawn full in the other views, indicating that from one position the part cannot be seen, while from the other position it is in view.

36. As was stated in Art. **22**, all lines on tracings should be fully 50 per cent. heavier than the lines used on the plates drawn in connection with *Geometrical Drawing*. The only case in which a fine line should be used is when locating points by intersecting lines, and even then they are not actually needed, since the points can be located by fine pencil lines, and being once located the lines passing through the points may be as heavy as desired. Fine lines on tracings render it very difficult to obtain a good blue-print.

It will be noticed that the broken and dotted line, here used for center lines and to indicate where a section is to be or has been taken, consists of a repetition of long dashes, each followed by *one* dot. In *Geometrical Drawing* two dots were used. Both forms of this line are widely used, but the student is recommended to use the one here shown, as it is simpler. When working in a drafting room, however, he must conform to the standards in force there.

SECTIONS AND SECTION LINING

37. In order to show the interior of hollow objects, they are often drawn in section, and the kind of material is then usually indicated by certain combinations of lines. Unfortunately, there is no universally adopted standard; thus, a certain combination of lines may indicate that the material is cast iron if drawn in one office; in another office this same combination may have been adopted to represent brass; and so on. As far as working drawings are concerned, there is usually no difficulty experienced on account of this diversity of practice, since as a general rule the material is, and should always be, distinctly specified on the drawing in order to prevent any mistake on the part of the workman.

38. The most commonly used combinations of lines for different materials are shown in Plate 1002, under heading Standard Cross-Sections. Steel of all kinds is indicated as shown at *A*; *B* shows the sectioning employed for wrought iron. Cast iron is usually sectioned as shown at *C*, and this type of cross-sectioning will be used for *all* materials unless it is deemed advisable on complicated drawings to designate kind of material by character of cross-section, in which case the standard sections here shown will be used. Brass and other similar copper alloys are sectioned in the manner shown at *D*. For lead, Babbitt, and similar soft metal, the sectioning shown at *E* is extensively used. Wood, when cut across the grain, is usually sectioned as shown in the upper half of *F*, and when cut along the grain, as shown in the lower half. Wood is also frequently indicated on a drawing by section lines, even when it is not a section. Glass and stone, when in section, are often indicated in the manner shown by the upper half of *G*; when not in section, they are frequently drawn as shown in the lower half. Concrete may be indicated as at *H*; *I* gives a common representation of leather. Rubber and wood fiber are sectioned as shown at *J*; firebrick, as shown at *K*; and water, as shown at *L*.

The squares inside which the various kind of cross-sections are to be drawn should be 1½" square; a space of 1" should be left between each square in a horizontal row and of ¾" between those in a vertical row. The square *C* should be 2¼" below upper border line and 1" from right-hand border line.

All section lines are spaced without the use of a scale or special instrument, the eye being the only guide in placing them evenly, and the student will follow this plan in drawing the sections shown. With practice, great skill can be acquired in spacing the lines evenly, and the work can be done very rapidly.

39. Sections of material that appear too thin on a drawing to be conveniently sectioned, or when it is desired to make the section very prominent, are often blackened in, as shown in Fig. 4. In order to separate different pieces, a white line is then usually left between them. Black sections are most frequently employed for sectional views of structures composed of plates and rolled sections, such as **I** beams, angle irons, bulb angles, rails, **Z** bars.

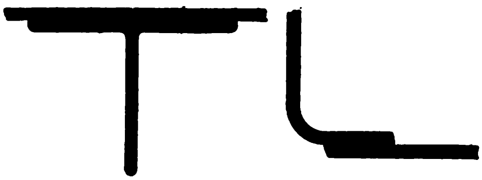


FIG. 4

40. On many sectional views, it will be noticed that the section lines do not run in the same direction. This invariably means that there is more than one piece in the section given. Thus, referring to Fig. 5, it will be seen that the section lining shown at *b*, *b* is at a right angle to the other section lining. It is the general rule among draftsmen that all parts of the same piece shown in section must be section-lined in the same direction, irrespective of the continuity of the section. Thus, referring again to Fig. 5, the fact that all section lining marked *A* is in the same direction immediately establishes the fact that this part of the view is a section of the same piece. Likewise, since the sectioning shown at *b* and *b* runs in the same direction, it follows that *b* and *b* are sectional views of one piece, which is separate from *A*.

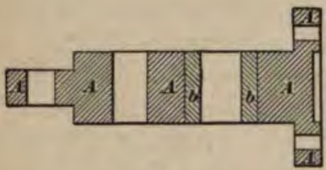


FIG. 5

The above rule governing the direction of section lines is always adhered to when possible; when any departure is necessary, care is taken to prevent ambiguity. Where only the sectional view is given, it is often very difficult to understand the drawing, and sometimes a violation of the above rule will cause an erroneous conclusion to be drawn. Referring to (*a*), Fig. 6, cover up the front view shown at (*b*). Then, since the section of *a* and *a*′, and also that shown at *b* and *b*′, are respectively in the same direction, any one would be perfectly justified in assuming that *a* and *a*′ was a sectional view of a rod fitted with a solid bushing *b b*′. Furthermore, since *c*, *c* and *c*′, *c*′ are sectioned the same way, the conclusion that they were the jaws of a forked rod would be justifiable. Referring now to view (*b*), it is seen that *b* and *b*′ are separate brass boxes; the part *a*′ is seen to be separate from the cap *a*, and the note "*Rods Removed*" indicates that *c* is separate from *c*′. The way the sectional view should have been section-lined to correspond to the front view shown at (*b*) is given in Fig. 6 (*c*).

41. When a cutting plane passes through the axis of a shaft, bolt, rod, or any other solid piece having a curved surface and located in the plane on which the section is taken, it is the general practice not to show such solid pieces in section, but in full. Thus, in Fig. 6 the sectional view (*a*) is taken on the plane represented by the line *x y*, in view (*b*), which passes through the axis of the pin *d*. This pin is shown in full, however, in views (*a*) and (*c*). The practice here shown is rarely departed from by experienced draftsmen, since it makes a drawing easier to read and also saves considerable time in making the drawing.

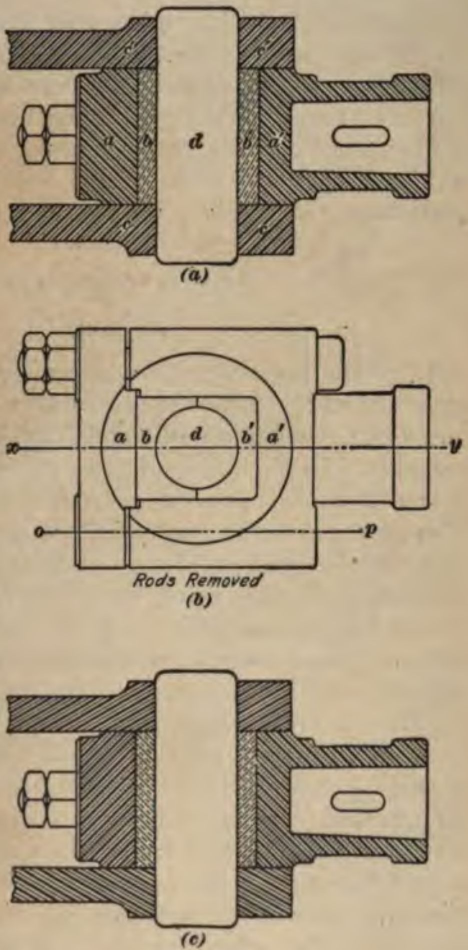


Fig. 6

42. Fig. 6 also shows another feature that is frequently met with in shop drawings. Referring to the illustration, it is seen that no bolt is shown in the lower half of the object in so far as the front view (*b*) is concerned. A center line *op* is drawn in, however, which indicates to the workman—who reasons from the symmetry of the object in respect to the center line xy—that the lower half of the object is to be supplied with a bolt placed in the plane given by the center line op. In case of symmetrical work, draftsmen will frequently complete only one half of the view and merely indicate the other half by a few lines or not at all, trusting to the judgment of the workman for a correct reading of the drawing. In the best practice, a note is made on the drawing calling attention to the fact that the indicated portion of the view is a duplicate of the completed portion.

PLATE 1003, TITLE:

DETAILS

43. The majority of the succeeding text illustrations are supposed to represent the preliminary pencil drawings to be made by the student and from which he is to make the final tracings. In these pencil drawings little use is made of dotted lines, as the main purpose of such drawings is that of indicating the *location* of the various lines; the distinction between full and dotted lines and such that are to be omitted altogether being made during the process of tracing. In the pencil drawing distinction is made to some extent between those lines that are merely construction lines and those that constitute the real outlines of a view, in so far that at first all lines that are not sure to be one of the outlines are drawn faintly. After the length and location of the outlines have been definitely determined they are strengthened and in this manner distinguished from mere construction lines or such that are to be shown as dotted lines. The first eight figures of this Plate show the conventional methods of representing screws; they are drawn full size. The actual projection of a screw thread will be similar to the projection of a helix; but in order to save the time required to locate the points and trace in the curves, the following methods are universally used, except, perhaps, in the case of screws of very large diameter and pitch.

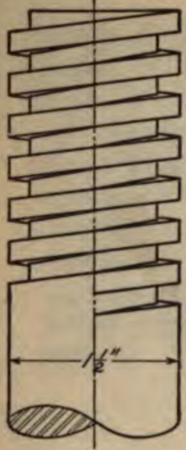


Fig. 1

Fig. 2.

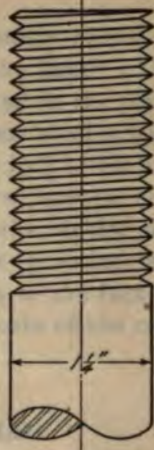


Fig. 3.

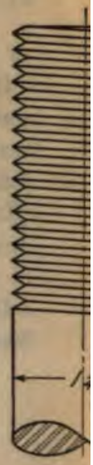


Fig.

Methods of

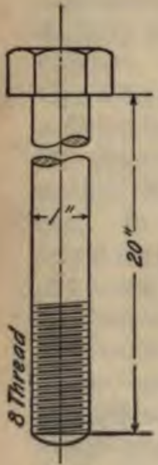


Fig. 9.

Fig. 11.

Fig. 13.

Fig. 15.

Fig. 10.

Fig. 12.

Fig. 14.

Fig. 16.

Methods of Representing Standard

Fig.5.

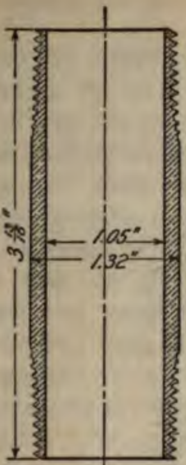


Fig.6.

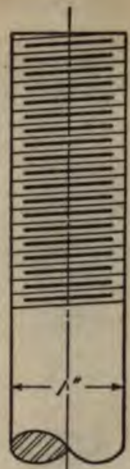


Fig.7.

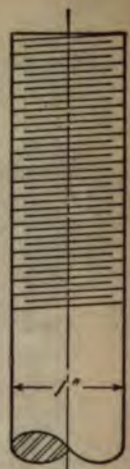


Fig.8.

resenting Screws.

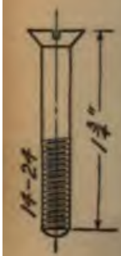


Fig.17.

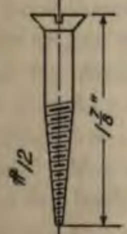


Fig.19.

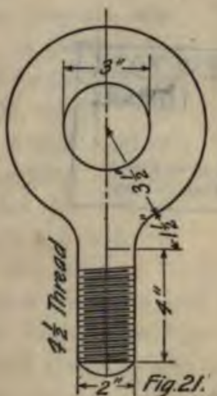


Fig.21.

Fig.23.

Fig.24.

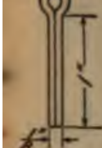


Fig.18.

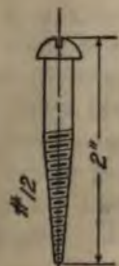


Fig.20.

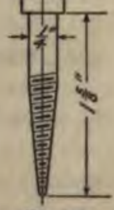


Fig.22.

ls.

DETAILS

DRAWN BY..............

DATE..............

1003

United States.
onal Textbook Company.
rs' Hall, London.

44. To locate the upper row of views on this Plate, draw a horizontal line 1⅛" below the upper border line and locate the top sides of the views along this line. Draw another horizontal line 4$\frac{11}{16}$" below the same border lines to limit the lengths of these views. Leave a space of ¾" between Fig. 1 and the left-hand border line and the same space between each of the views in that row. Fig. 1 represents a single square-threaded screw 1½" in diameter and ⅜" pitch. To draw the screw follow the directions given herewith in connection with Fig. 7. First draw the center line *m n* and a line *a b* at right angles to it. Make the distance *a b* equal to the diameter of the screw, or 1½", and through the points *a* and *b* draw lines *a d* and *b e* parallel to the center line *m n*. Also lay off on the line *a b* distances *a f* and *b g* equal to one-half of the pitch ($\frac{3}{8}" \times \frac{1}{2} = \frac{3}{16}"$), and through the points *f* and *g* draw lines *f h* and *g i* parallel to the center line *m n*. These lines show the depth of the thread. On the line *a d* lay off the width of the groove and of the thread, *a c*, *c j*, *j k*, etc., each equal to one-half of the pitch, or $\frac{3}{8}" \times \frac{1}{2} = \frac{3}{16}"$. Draw the line *b c*, and through the points *j*, *k*, *l*, *o*, etc. draw lines parallel to *b c* intersecting line *b e* at points *x*, *q*, *r*, *s*, etc. Draw faint pencil lines joining the points *c* and *q*, *j* and *r*, *k* and *s*, etc., to represent the back edges of the threads and make the parts that are seen full lines. Draw faint horizontal lines from points *j*, *l*, *p*, etc., to the line *f h* and from the points of intersection draw lines to the center points of the lower side of the threads, such as *v t*, these lines representing the visible bottom lines of the threads. Likewise draw horizontal lines from the

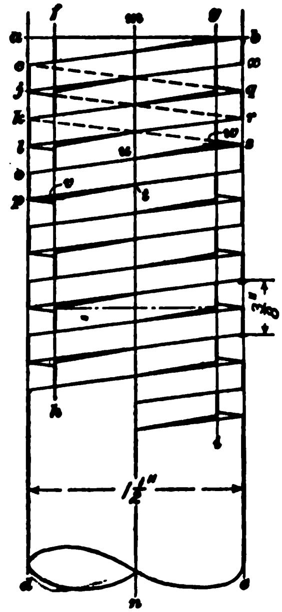


FIG. 7

points q, s, etc., to the line $g\,i$ and from the points of intersection draw the lines $u\,w$, etc. The method of drawing the remainder of the screw should be apparent.

In some drawing offices this conventional method of representing screw threads is further simplified by omitting the lines indicating the back edges of the threads as well as those that represent the bottom lines. The threads will then be indicated by a series of parallelograms, such as $c\,b\,x\,j$, $k\,q\,r\,l$, etc. The screw *17* in Fig. 43 has been drawn in this manner.

It will be noticed that the width of the thread and of the groove, measured parallel to the center line $m\,n$, and the depth of the thread are all exactly the same; that is, they are each equal to one-half of the pitch. If a section were taken through the center line $m\,n$, the thread and groove would look like, Fig. 8, a series of squares; hence the term *square thread*.

FIG. 8

When a long and comparatively slender object is to be drawn, such as these screws, it often happens that when drawn to a scale sufficiently large to make the drawing intelligible, the length is so great that the outline extends beyond the space available. In that case part of the object is broken away, taking care to let the place of break be at such a point that the remaining part will indicate the transverse dimension and shape of the part removed. An object is also frequently broken off when it is unnecessary to show it complete, as in the case of Fig. **1**, where it is simply a question of showing the construction of the threaded part and where the other part may be a straight rod of any desired length.

The fact that part of an object is broken away is indicated by a so-called **break.** Breaks may be indicated in various ways; most commonly the break is given an outline that will reveal the shape of the object. The conventional method of indicating the break on a round rod is that shown at the lower end of Fig. **1.**

An example of a break where the central part of an object is removed is shown in Fig. **9**. Here the removed part is simply part of a straight rod, and therefore it need not be drawn, especially when it is a question of saving space. The remaining parts are pushed together and the true length of the screw indicated by the adjacent dimension, here 20″. Conventional methods of indicating breaks are shown in Fig. 9. Wood is usually shown broken in the manner illustrated at (*a*), angle irons as at (*b*), **T** irons as at (*c*), **Z** bars as at (*d*). Cylindrical objects are occasionally broken as shown at (*e*), but most frequently in the manner shown at (*f*). Pipes and similar hollow cylindrical objects may be broken as shown at (*g*); but more frequently the break is made as shown at (*h*). Rectangular objects may be broken in the manner shown at (*i*); plates and objects other than those included between views (*a*) and (*i*) are often shown broken off by drawing a wavy freehand line as in (*j*) and (*k*). As a rule the break is indicated by section lines, as in Fig. **1**. On small objects, or in views drawn on a small scale, it is sufficient to show the break in black, as in Fig. 9.

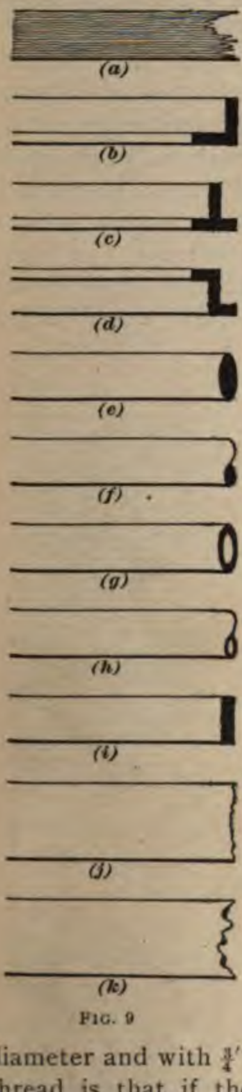


FIG. 9

45. Fig. **2** shows a **double square-threaded screw** $1\frac{1}{2}''$ in diameter and with $\frac{3}{4}''$ pitch. The reason for using a double thread is that if the single square thread were used, the depth would be so great as to weaken the bolt or rod on which it was cut and render it unsafe for the purpose for which it was intended. To prevent this, either the diameter of the rod must be increased or the thread must be cut of the same depth and thickness as a thread of half the pitch, or, in this case, as if the pitch were $\frac{3}{4}'' \times \frac{1}{2} = \frac{3}{8}''$, as in the preceding problem; another thread of the same size and pitch ($\frac{3}{4}''$) must be cut half way between these first threads, thus giving a double thread. The pitch, or distance that the screw would advance in one turn, would be $\frac{3}{4}''$, the same as if it were a single-threaded screw of $\frac{3}{4}''$ pitch, while the depth of the thread is only half as great. To draw it, proceed exactly as in the last figure, and follow the directions given herewith in connection with Fig. 10. To get the direction of the line *b c*, Fig. 10, which in this figure represents the projection of the bottom edge of the top of the thread, lay off *a c* equal to one-half the pitch, or $\frac{3}{4}'' \times \frac{1}{2} = \frac{3}{8}''$, and draw the line *b c*. The width of the threads and grooves, and also the depth of the threads, is one-fourth of the pitch, or $\frac{3}{4}'' \times \frac{1}{4} = \frac{3}{16}''$.

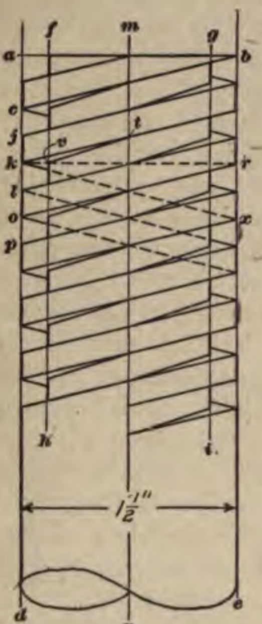


Fig. 10

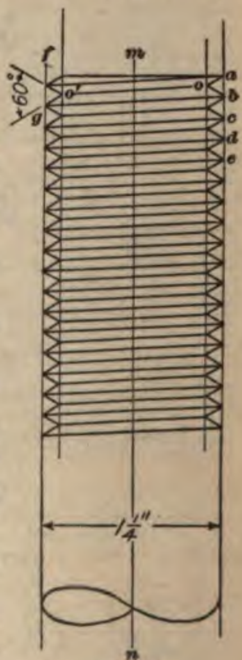
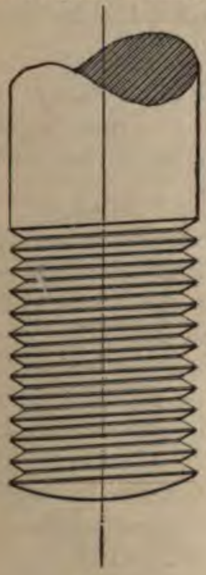


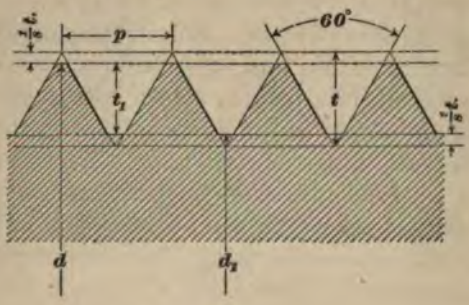
Fig. 11

Through the points *k*, *l*, *o*, etc., draw faint pencil lines *k x*, etc. to represent the back edges of the threads, and make the parts that are seen full lines. Through the point *k* draw a faint pencil line $k r$ at right angles to the center line $m n$, intersecting the line $f h$ in v, and draw the line $t v$, which represents the bottom of the thread. The remainder of the screw should be drawn without trouble.

46. Fig. 3 and Fig. 11 show a **single V-threaded screw** $1\frac{1}{4}''$ in diameter and having 7 threads to the inch; that is, the pitch is $\frac{1}{7}''$. Draw a cylinder $1\frac{1}{4}''$ in diameter, having $m n$ for the center line. Lay off $a b$, $b c$, $c d$, etc. each equal to the pitch, or $\frac{1}{7}''$. Do the same on the left-hand side. With the aid of the **T** square and 60° triangle make the angles $a o b$, $f o' g$, etc., 60°. The rest of the thread can be drawn by referring to the figure.

47. Fig. 4 represents a screw exactly like the preceding one, except that the thread is left-handed instead of right-





(a) (b)

FIG. 12

handed. To ascertain whether a thread is left-handed or right-handed, hold the screw in such a position that its axis is horizontal. If the thread is right-handed, as it usually is, the angle that the edge of the thread makes with the horizontal on the right-hand side is obtuse; if left-handed, it makes an acute angle with the horizontal on the right-hand side. No further instruction should be necessary for drawing the thread.

The **Seller's triangular** or **V thread,** commonly called the **American thread,** or **United States Standard,** which is used in the United States, is shown in Fig. 12 (*a*). Fig. 12 (*b*) is an enlarged section of the thread. The *angle* between the sides of the thread is 60°. The distance p indicates the pitch of the screw. As shown in the figure, a section of a single thread is an equilateral triangle, the altitude of which is t; to form the United States Standard thread one-eighth the altitude of the triangle is cut off from the apex, and the angle at the root is filled in to a like depth. Hence the *real depth* of the thread t_1 is three-quarters the altitude of the triangle, that is, $t_1 = \frac{3}{4}t$.

48. Fig. **5** represents a **double V-threaded screw** $1\frac{1}{4}''$ in diameter. It has $3\frac{1}{2}$ threads per inch; that is, the pitch is $1'' \div 3\frac{1}{2} = \frac{2}{7}''$. The remarks made in connection with Figs. **2** and **3** apply here.

49. Fig. **6** and Fig. 13 represent a section of a **brass nipple.** When the diameter of a nipple is given, the inside diameter is always meant, unless otherwise stated. The actual diameter of a nipple or pipe is very rarely given, but must be taken from printed tables. The *nominal diameter* of the nipple shown in the figure is 1″, but the actual inside diameter is 1.05″; from the table, the outside diameter is found to be 1.32″, making the thickness .135″. Owing to the thinness of the shell, pipe threads are finer than the threads on the same sized rods. The coarsest pipe thread is 8 threads per inch. The number of threads per inch on the nipple shown is $11\frac{1}{2}$. The thread is tapered 1 in 16; that is, the diameter of the threaded part is increased by $\frac{1}{16}''$ for each inch in length, to make a tight fit, and the length of the threaded part on each end is $0.51'' + 0.52'' = 1.03''$, of which length the distance between a and b, Fig. 13, represents the perfect thread, while from b to c the thread is imperfect. On account of the small size of the thread and the crowded condition of the lines, Fig. 13 is drawn on a larger scale and only one end of the nipple is shown, the construction of the other end being identical. To draw the nipple proceed as follows: Draw a cylinder 1.32″ in diameter and with *m n* as a center line; lay off the inside diameter equal to 1.05″ and draw *d e* and *f g*. When decimal parts of an inch are required, lay off the dimension in the nearest 64ths of an inch by consulting Table V at end of this paper. Draw a horizontal line, through point *a*, across the cylinder, and lay off the points *h*, *k* (indicating the minimum outside diameter of the threaded part) 1.28″ apart. Draw a second

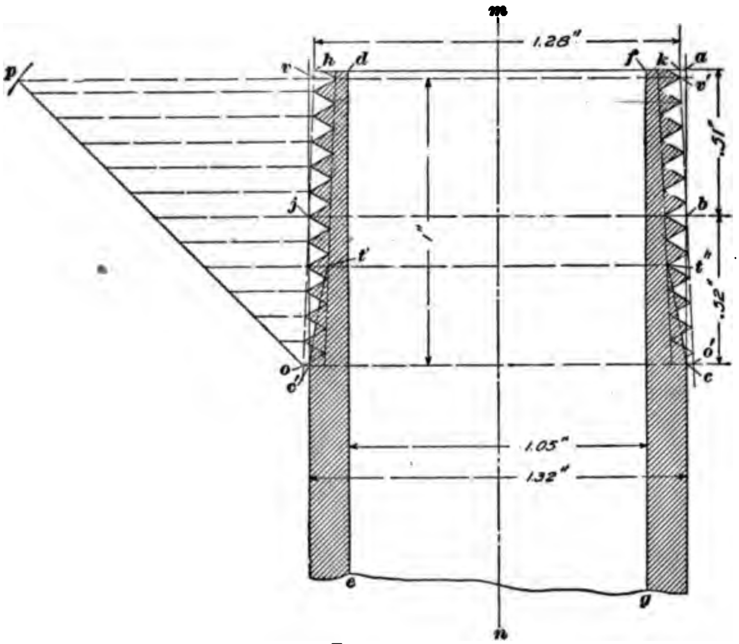


FIG. 13

horizontal through *b*, intersecting the other side of the cylinder at *j*, and a third horizontal through *c* intersecting the other side at *c*′. Join the points *h*, *j* and *k*, *b* by straight lines and produce them until they intersect the line *c c*′ at *o* and *o*′. These lines indicate the position of the tops of the threads.

Draw a horizontal line 1″ above *c c*′, intersecting the lines *h o* and *k o*′ at points *v*, *v*′. Prolong the line *v v*′ indefinitely toward the left, then divide the distance *v o* into 11⅛ parts by means of the method given in *Geometrical*

Drawing, as follows: Apply the compasses to the scale and open them until they span 23 divisions (in this case sixteenths), and then with this length as a radius and with the center at *o*, strike an arc intersecting the line $v v'$ at *p*. Connect *o* and *p* by a straight line and, starting at *o*, mark off eleven-eighths by means of a scale and a sharp-pointed pencil. From these points, with the aid of the T square, draw horizontal lines to the lines *h o* and $k o'$, the intersection with the former line locating the tops of the threads and with the latter the bottom of the threads. By means of the T square and the 60° triangle draw a couple of threads, beginning at *v* and also a few threads at *k*, remembering that the divisions on $k o'$ are to be advanced half a thread, as shown; that is, the top of one thread and the bottom of the preceding thread on the other side will both be on one horizontal line. Through the bottoms of the threads thus found, draw lines parallel with *h o* and $k o'$; these lines will indicate the bottom of all the threads. Complete the threads along *h o* and $k o'$ as if they were perfect, and continue the threads above $v v'$ to the upper end of the nipple.

Counting from *o*, draw a horizontal line through the top point of the fourth thread and extend said line until it intersects the bottom lines of threads at t' and t''. Join the points t', c' and $t'' c$ by straight lines, which lines will indicate the bottoms of the imperfect threads. It will be noticed that from points *b* and *j* downwards the tops of the threads, as drawn, extend beyond the sides of the cylinder and consequently these parts will also be imperfect. When inking in the drawing only those parts of the threads should be shown that lie *inside* the outer edges of the cylinder and *outside* the lines $t' c'$ and $t'' c$. As the size of the threads, when drawn on the plate, are very small, it is not expected that the student will be able to draw them correctly in their minute details, but it is necessary that the total number of threads shall be correct. Table IV, giving the dimensions of standard threads for gas and water pipes, is found at the end of this paper.

50. Fig. **7** shows another method of representing a V-threaded screw. This method has the advantage of making a neat-looking drawing and of being very rapid in delineation. The pitch is laid off as in the three preceding figures. The heavy lines represent the bottom of the thread and their lengths are determined by constructing an equilateral triangle on the pitch distance, as shown in Fig. 14, and limiting the line to distances between two corresponding vertexes of the triangle. The diameter of the screw is 1″ and the number of threads per inch is 8.

FIG. 14

51. Fig. **8** represents the screw shown in Fig. **7**, but with the heavy lines replaced by light ones. This method has many advantages in making tracings, as it makes the resetting of the pen unnecessary, and the ink does not take so long to dry. Fig. **7** will be used for ordinary work; Fig. **8**, when there are a number of details of the same sort, making complete representation inadvisable.

When screws are represented, as shown in Figs. **7** and **8**, it is not customary to lay off exact distances to represent the tops and bottoms of threads. The distances between the lines are made even and of any length that presents a good appearance. This adds, of course, to the rapidity with which a drawing can be made.

The right-hand **V** thread is considered as a standard and is always furnished unless some other is specifically called for. When left-hand, double, or multiple threads are wanted, it is customary to place a note near the part detailed calling attention to the fact.

52. When a screw thread is hidden by part of the object and it is deemed necessary to show its location, dotted lines are drawn in one of the three ways illustrated in Fig. **15**. Of these methods, (*a*) is the most complete, but (*b*) is the form generally used and is clear. Fig. **15** (*c*) should not be used unless supplemented by a note, "$\frac{3}{4}''$ stud" or "$1\frac{1}{8}''$ bolt," etc.

53. Draw a horizontal line $6\frac{1}{4}''$ below the top border line and locate the tops of Figs. **9, 11, 13, 15, 17,** and **19** along this line. Lay off on it a point $1\frac{1}{4}''$ from the left-hand

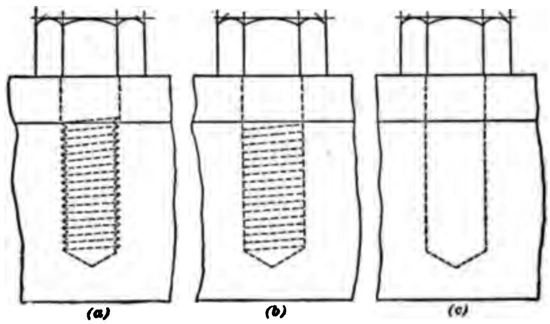


FIG. 15

border line, and through this point draw the center line of Figs. **9** and **10**. From this point, also, lay off other points $1\frac{29}{32}''$ apart, through which draw the center lines for Figs. **11** to **22** inclusive, excepting Figs. **23** and **24**, which are drawn separately.

Figs. **9** and **10** of the plate represent the ordinary and conventional method of representing a hexagon bolt and nut. The example selected is a bolt 1″ in diameter and 20″ long, with the thread portion cut 8 threads to an inch, head $1\frac{5}{8}''$ across flats; the curve at the lower end of the bolt is drawn with a radius equal to diameter of bolt. By $1\frac{5}{8}''$ across flats is meant $1\frac{5}{8}''$ between parallel sides, that is, twice *o k*, Fig. 16.

That the student may fully understand the method of laying out the nut and the head of the bolt, the method which is to be followed will be described in detail. It is not common practice to show more than one view of either a bolt or nut, the shape being determined by the delineation.

To lay out the nut, first draw two horizontal lines *a c* and *b d* across center line *m n* (see Fig. 16) 1″ apart, this being the diameter of the bolt, and the proper thickness of the nut corresponding. The head of the bolt is somewhat thinner, being, as shown, $\frac{13}{16}$″ thick. In order to determine the proper point at which the lines *a b*, *c d*, *e f*, and *g h* are drawn, draw a semicircle $1\frac{5}{8}$″ in diameter (the width of the nut across flats) with the intersection *o* of the lines *a c* and *m n* as the center; draw a tangent *i j* to this circle, perpendicular to the center line. Draw two other tangents to the circle, using the 60° triangle. The intersecting points *i* and *j* of the tangents will locate the lines *e f* and *g h*, *e* being the projection of *i* and *g* the projection of *j* on *a c*; the intersection of the tangents with the perpendicular *a c* will locate the lines *a b* and *c d*.

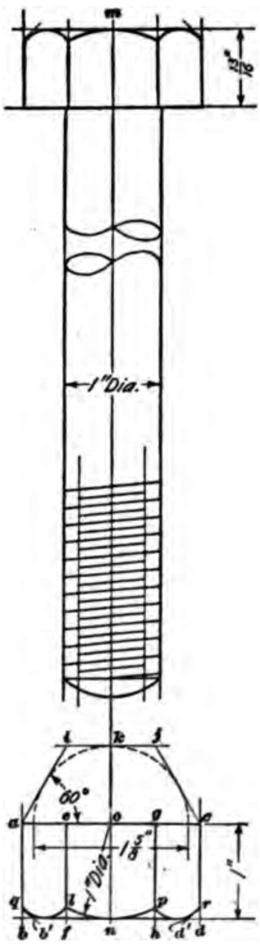


FIG. 16

To construct the curves which form the top of the nut draw a circular arc from *o* as a center, with a radius equal to the diameter of the bolt (in this case 1″), tangent to the perpendicular *b d*, which limits the thickness of the nut, until it intersects *e f* in *l*, and *g h* in *p*; find by trial a radius such that arcs can be struck from *l* to *q*, and from *p* to *r*, and be tangent to *b d*; the centers for these arcs must lie on lines parallel to the center line *m n* and half way between *a q* and *e l* and *g p* and *c r*. Draw curves for the head of the bolt in same manner.

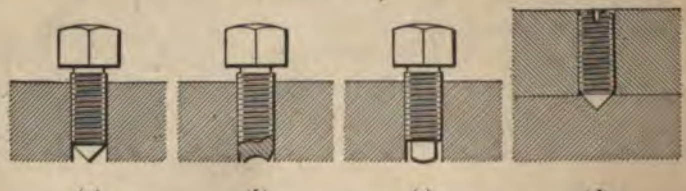
Instead of indicating the corners *b d*, Fig. 16, as parts of a spherical surface, they are often drawn as being parts of a conical surface, the side of which forms an angle of 45° with its axis. Lines $q\,b'$ and $r\,d'$ are then drawn tangential to the curves $q\,l$ and $r\,p$. Fig. 23 is also drawn in this manner. Where it is the purpose of representing a nut or head in a conventional manner, it is a saving of time to omit these additional lines.

54. Figs. **11** and **12** show the conventional method of representing a square-head bolt and nut. Their curves are constructed in much the same manner as those of the hexagonal-head bolt, except that they are drawn with a radius twice the thickness of the bolt. Dimensions correspond to those given in Fig. **9**, except length, which is 6″; the width of the head is 1⅝″ across flats.

Complete information as to the construction of standard bolt heads, nuts, screw heads, etc., is given in Fig. 64. Any dimensions not given in the instructions referring to Plate 1003 will be found there.

55. Fig. **13** is a hexagonal-head capscrew; the head of the capscrew is smaller than a corresponding hexagonal-head bolt, being 1¼″ across flats. The dimensions given will be followed, and are standard dimensions for a bolt of this size. Curve of head is drawn by taking radius 2 times diameter of bolt.

Fig. **14** represents a ½″ 13-thread setscrew, 1⅜″ long. Head is ½″ across flats, and the two curves on same are struck



(a) (b) (c) (d)
FIG. 17

with a radius equal to twice the diameter of screw. Draw the curves at neck of screw with a radius of ⅛″. The information needed for drawing the lower end is given in Fig. 64.

The form of setscrew shown in Fig. **14** is the one most in use. Some other forms are represented in Fig. **17**, in which (*a*) is called a **cone-point setscrew**, (*b*) a **cupped setscrew**, (*c*) a **round, pivot-point setscrew**, and (*d*) a **headless, cone-point setscrew.**

Figs. **9**, **10**, **11**, **12**, and **13** are drawn to $\frac{1}{2}$ scale or 6″ = 1 ft., while Figs. **14**, **15**, **16**, **17**, **18**, **19**, **20**, and **22** are drawn full size.

56. Fig. **15** represents a round-head, $\frac{14}{24}$ machine screw, $1\frac{3}{4}$″ long; 14 is the gauge of the body of the screw; 24 gives the number of threads per inch. The screw is drawn by drawing a center line and laying off the parts as shown. No. 14 gauge practically corresponds to $\frac{1}{4}$″, and measurements may be made with this as a basis; thickness of the head is $\frac{3}{16}$″; width of head is $\frac{7}{16}$″.

The outline of the head should be a compound curve, but on account of the small size of the view it is difficult to show it in this form; it will suffice if in its place a circular arc is drawn with a radius of $\frac{7}{32}$″.

57. Fig. **16** is a fillister-head machine screw of the same dimensions as that shown in Fig. **15**. The head is $\frac{3}{16}$″ thick below the round and $\frac{23}{64}$″ in diameter. The radius of the round top is equal to the diameter of head.

58. Fig. **17** is a machine screw of corresponding length and diameter, except that it has a flat head; thickness of head is $\frac{9}{64}$″; diameter of head, $\frac{15}{32}$″.

It will be noticed that the dimensions for length of screws are given under the head in Figs. **15** and **16**, and including head in Fig. **17**.

59. Fig. **18** represents a cotter pin 1″ long and $\frac{1}{8}$″ in diameter. This pin is split and is put through the ends of bolts or studs to prevent nuts or washers working off. Make the eye $\frac{1}{4}$″ in diameter.

60. Figs. **19** and **20** are conventional methods of representing round-head and flat-head wood screws. Dimensions previously given apply to these screws, except the gauge of body is No. 12, which approximately corresponds to $\frac{7}{32}''$. Diameters of heads of Figs. **19** and **20** are approximately $\frac{7}{16}''$ and $\frac{3}{8}''$, respectively. Make the straight parts of the screws $\frac{5}{8}''$ long, and the rounded points $\frac{1}{16}''$ thick.

61. Fig. **21** shows a 2″ eyebolt, $4\frac{1}{2}$ threads to the inch, with a 3″ hole in the eye and corresponding dimensions outside. This part is drawn to $\frac{1}{4}$ scale, or 3″ = 1 ft.

62. Fig. **22** shows the representation of $\frac{1}{4}''$ lag bolt, $1\frac{5}{8}''$ long. Lag bolts have square heads. The head is $\frac{3}{8}''$ across flats and the curve drawn with a radius of $\frac{1}{2}''$. The body of bolt is drawn similar to Fig. 19.

63. Figs. **23** and **24** give conventional methods of representing keys drawn to $\frac{1}{2}$ scale or 6″ = 1 ft.; they are plainly dimensioned and will need no detailed description of method of drawing them. These figures also indicate a convention quite frequently employed to show a section in a view other than the one the section should appear in, the little squares showing the depth of the keys and the shape of a cross-section.

64. Parts represented in Figs. **9** to **24** are standard parts which are seldom, if ever, drawn on detailed drawings. They are called for, however, in the title, and they are frequently shown in assembly drawings, in which case they will be drawn as represented, and with the principal dimensions only, if any, given.

Additional information on the construction of standard nuts and bolts, machine and wood screws, together with the standard gauges for Morse drills, and steam, gas, and water pipes are found at the end of this paper under Useful Tables.

INSTRUCTIONS AND DEFINITIONS

65. Before starting work on the next plate, further instructions and definitions are necessary.

Part Numbers.—When a detailed working drawing is completed, letters or numbers are placed near the parts delineated so that they may be easily identified, and this practice will be followed on all future plates, a number being placed near the part and enclosed by a circle $\frac{3}{8}''$ in diameter, thus ①

Part numbers start at 1. Be careful to place them at a point where they will not interfere with dimensions, center lines, or surface lines. These part numbers will be referred to in the material list, as explained later.

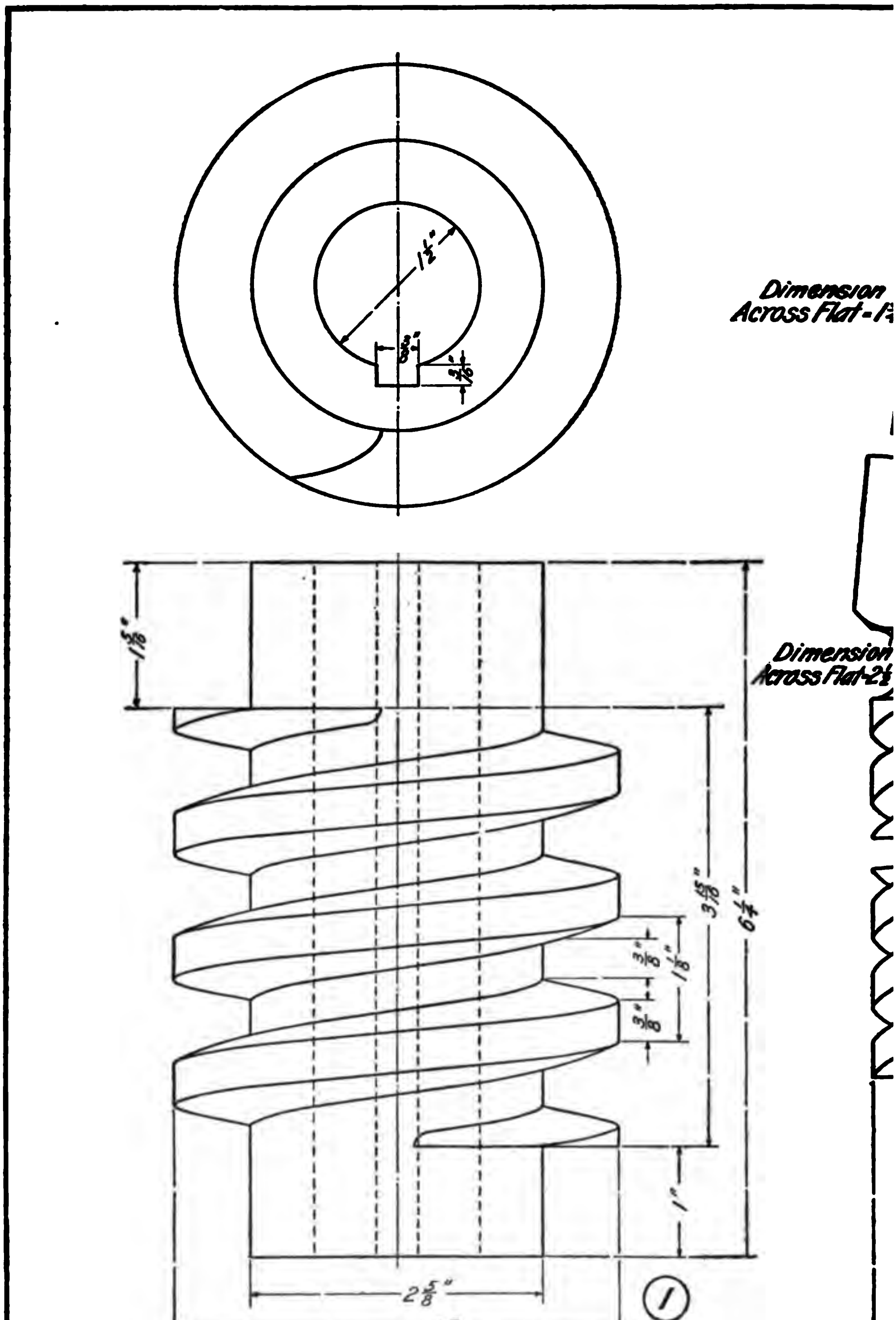
66. Pattern Numbers.—All machine details which are made from castings must first have a pattern, and it is common practice to have the draftsman call for these patterns, giving them the proper number by which they can be known and referred to. The first time a part which requires a pattern is shown on a drawing, it will have a pattern number assigned to it, which will be the number of the drawing with a letter annexed, thus: Part 1, Plate 1004, is made of cast brass and its pattern number will be 1004–A. This number serves as an immediate means of identification and gives any person who handles the pattern the number of drawing upon which all dimensions can be found. This pattern number is called for in the material list of which an explanation follows.

67. Material List. — All detailed working drawings have a list of materials placed at some convenient part of the drawing, which is a list of parts shown on the drawing, the number of parts necessary to complete the apparatus shown, the material from which they are made, and a note calling for patterns when they are necessary. This material list is best placed above—and is practically an extension of—the title. The list is divided into six columns which, taken together, are 4" wide, the same width as the main title previously described. Starting at the left-hand side, column 1 is made $\frac{1}{4}$" wide and is the quantity column, showing the number of parts required in order to complete the part detailed; column 2 is made $1\frac{5}{8}$" wide, and gives the common shop name of the part; column 3 is $\frac{1}{4}$" wide, and shows the part number; column 4 is made 1" wide, and shows the material from which the part is to be made; column 5 is made $\frac{5}{8}$" wide, and is reserved for the word "pattern" when one is necessary; column 6 is made $\frac{1}{4}$" wide, and contains the letter by which the pattern will be known when called for, it being preceded by the number of the drawing. It frequently happens that patterns made for one machine can be used to produce castings for another machine under construction. In such cases the pattern would be designated in the material list by the number and letter first assigned to it. It is not at all necessary to put a heading over these columns, as the use which is made of them soon fixes their object in the mind of the draftsman.

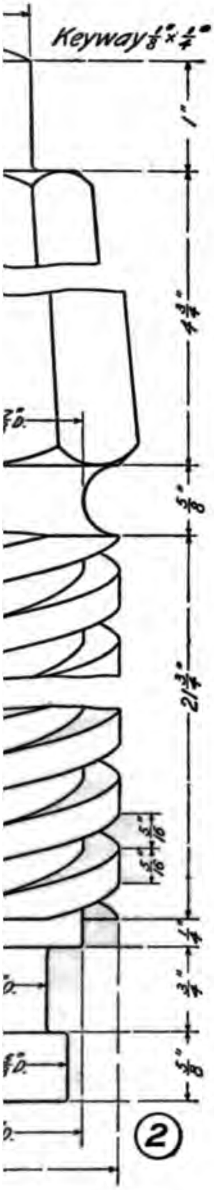
The material list is divided into sections by horizontal lines $\frac{3}{16}$" apart. Standard details, such as machine screws, bolts, nuts, washers, keys, and similar parts, have part numbers assigned to them, but are seldom detailed on the drawing, the material list giving all the information that is necessary in order to supply them to the person who is to assemble the part.

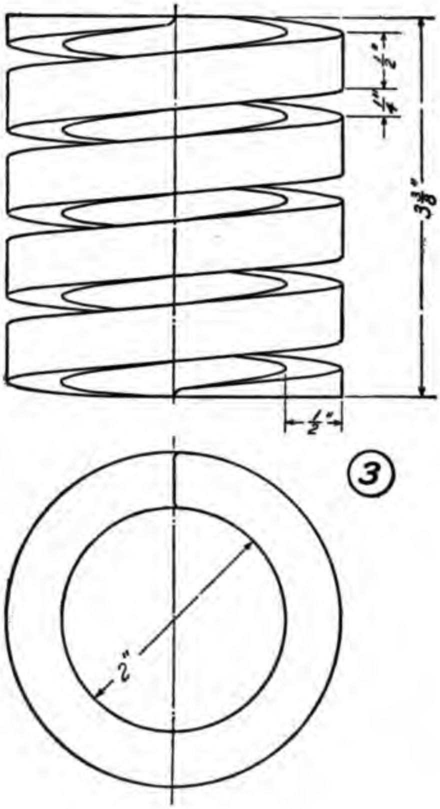
The material list is best arranged in such a way that the lowest number is put at the bottom of the list. The reason for this is to permit the adding of another detail, if such should become necessa y, or, in other words, placing the parts in this order in the title permits the extension upwards of the space occupied by the latter as desired, some titles being short (vertically) and others long, according as the machine drawn is more or less complicated.

68. Position of Views.—The main view or elevation once having been located, the right-hand view of object will



Dimension
Across Flat
Dimension
Across Flat
1⅝"
3 15/16"
6¼"
3/8"
1⅛"
3/8"
1"
2⅝"
4"
1





1	Spring	3	Spring Steel		
1	Adjusting Screw	2	Machine Steel		
1	Worm	1	Brass	Pattern	A

MACHINE DETAILS

DRAWN BY..........
DATE..........

1004

TATES.
XTBOOK COMPANY,
London.

be shown at the right of the elevation, the top view at the top, bottom view at the bottom, etc. This method of location of views is technically known as *third-angle projection* and is more generally used than *first-angle projection*, which differs from it by having the right-hand view of the object placed on the left-hand side of the main plan, the bottom at the top, etc. An explanation as to the use of the first-angle and third-angle projection, is given fully in *Practical Projection*. Either plan may be used, but each drawing office has a standard practice which must be followed. In the plates which follow, third-angle projection is adopted as standard.

PLATE 1004, TITLE:
MACHINE DETAILS

69. This Plate is intended to give the student practice in drawing helical curves. In the previous plates screw threads have been represented by straight lines, and this conventional plan is followed whenever possible to save time. When, however, the dimensions of a threaded piece are large, especially when the pitch of the thread is steep and the scale used is large, the true projection of the screw thread is often drawn; this the draftsman should do with as little loss of time as possible. The necessary directions are given below for each of the three parts represented on this plate.

It is often difficult for a beginner to form a clear idea of the appearance of an object from a mechanical drawing, and there is, therefore, shown in Figs. 18, 19, and 20 half-tone reproductions of photographs of the parts represented by the drawing. The attention of the student is particularly called to the method of drawing the adjusting screw, **2**, it being broken at two points, in order to permit it to be drawn within the limits of the drawing.

70. Draw border lines and lines for the title as shown, allowing space above the title for the material list of the

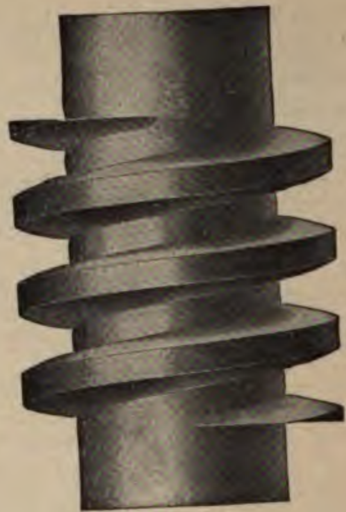


Fig. 18

Fig. 20

Fig. 19

three parts which are to be described and drawn. Do not letter the title until the drawing is completed. All the parts shown on this plate are to be drawn full size.

Part 1 is a single-threaded worm with a $1\frac{1}{4}''$ hole through it; its over-all length is $6\frac{1}{4}''$; the hub diameter is $2\frac{5}{8}''$, which is also the diameter of the worm at the bottom of the thread. The length of the threaded portion is $3\frac{15}{16}''$, the hub being $1''$ long at one end and $1\frac{5}{16}''$ long at the other end. The worm has a diameter of $4''$ over the outside of the threads.

The method of drawing the worm is as follows, referring to Fig. 21. Draw a center line mn, $3\frac{1}{2}''$ from the left-hand border line. Parallel to this line draw two other lines pq and rs, each $2\frac{5}{8}'' \div 2 = 1\frac{5}{16}''$ from it; these lines determine the bottom of the thread, and also the diameter of the hub. Then draw two lines tu and vw parallel to the center line, and $4'' \div 2 = 2''$ from it; they determine the top of the thread.

Locate two points a and a' on the center line $6\frac{1}{4}''$ apart, a being $1\frac{3}{4}''$ from the lower border line. Through both of these points draw with the **T** square a perpendicular to the center line, thus defining the length of the hub. Locate two other points b' and b on the center line, one $1\frac{5}{16}''$ below a' and the other $1''$ above a. Through these points draw perpendiculars to mn; these lines are to limit the length of the threaded portion of the worm.

71. Now proceed to construct the thread. This will necessitate a number of construction lines being drawn that are not, however, to appear on the final tracing; they are made on the pencil drawing only. The pitch, that is, the distance between the top of one turn of the thread and the corresponding point on the next turn, is $1\frac{1}{8}''$, and since the length of the threaded portion of the worm is $3\frac{15}{16}''$, there will be $3\frac{15}{16}'' \div 1\frac{1}{8}'' = 3\frac{1}{2}$ turns of the thread; hence, the number of equal spaces representing the tops and bottoms of the thread is $3\frac{1}{2} \times 2 = 7$; therefore, divide the line bb' into seven equal parts bI, $I\,II$, etc. The thread itself is to have approximately the shape of a **V** thread, except that instead of making the angle x 60°, this angle is determined from the pitch of the thread and the amount of flattening at the top and bottom. Referring to the Plate, the dimen-

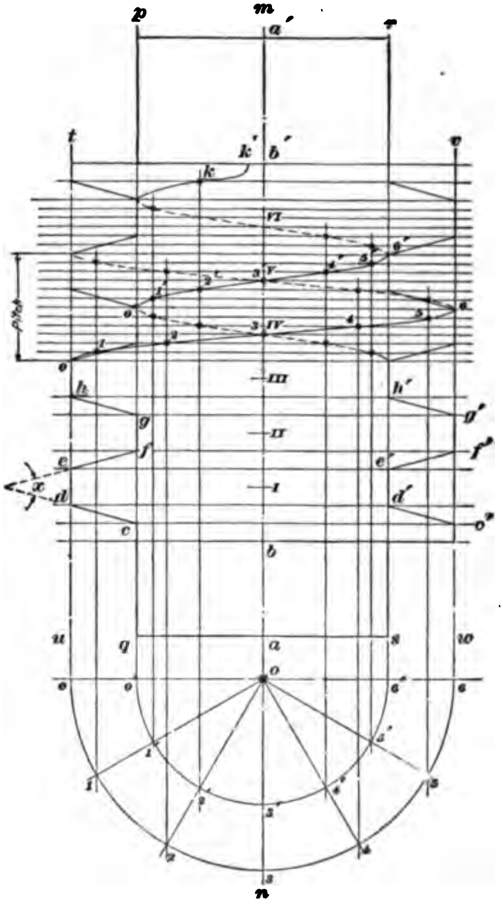


FIG. 21

sions show that the flattening at the top, and also at the bottom, is $\frac{3}{8}''$; that is, *de* and *fg*, Fig. 21, are each equal to $\frac{3}{8}''$. Hence, on each side of the division points *b*, *I*, *II*, *III*, etc., just obtained, lay off $\frac{3}{8}'' \div 2 = \frac{3}{16}''$, and draw *cc'*, *dd'*, *ee'*, *ff'*, *gg'*, etc., perpendicular to *mn*, which, intersecting with the lines *tu*, *pq*, *rs*, and *vw* locate the points defining the tops and bottoms of the thread. Draw the straight lines *cd*, *ef*, etc., and *c'd'*, *e'f'*, etc., as shown. Note herewith that the top of the thread on one side corresponds to the bottom of the thread on the other side of the center line.

72. To construct the curves defining the helixes, locate some point *o* on the center line, and with *o* as a center, draw two semicircles whose diameters are equal to the top and bottom diameters of the threads; that is, 4" and $2\frac{5}{8}$", respectively. Divide the semicircles into any convenient number of equal parts. This is done by first dividing the exterior semicircle into the required number of parts, as *0*, *1*, *2*, *3*, *4*, *5*, and *6*, then drawing radii to each point from *o*; this divides the interior semicircle into the same number of equal parts at the points *0'*, *1'*, *2'*, *3'*, *4'*, *5'*, and *6'*. The division of the circles is most quickly effected by the use of the 60° triangle. If, as in this particular case, six divisions are chosen for reasons now to be explained, the pitch must be divided into twice the number of equal parts that the semicircles have been divided into, that is, into 12 parts, in order to also delineate the rear part of the thread. As the pitch is $1\frac{1}{8}'' = \frac{18}{16}''$, these divisions are $\frac{18}{16}'' \div 12 = \frac{3}{32}''$ apart. The lines *cc'*, *dd'*, *ee'*, *ff'*, etc. are either $\frac{3}{16}''$ or $\frac{3}{8}''$ apart, and those that are $\frac{3}{8}''$ apart already have the distance between them halved by the points *I*, *II*, *III*, etc.; hence, these divisions can be utilized at once, and it is only necessary to halve them again to get the required 12 divisions. Draw perpendiculars to *mn* through the division points. From points *1*, *2*, *3*, *4*, *5*, and *1'*, *2'*, *3'*, *4'*, *5'*, of the semicircles, draw lines to intersect the aforesaid perpendiculars. The intersections are points of the helixes, those made with lines *1–1*, *2–2*, *3–3*, *4–4*, *5–5*, belonging to the top of the thread, those made with lines *1'–1'*, *2'–2'*, *3'–3'*, *4'–4'*, *5'–5'*, belonging to the bottom of the thread, as shown in Fig. 21. Through the points which have thus been located, draw a curve, as shown, using for this purpose the irregular curve. The remaining outlines of the thread can be drawn in the same manner; but an easier and quicker method is to cut a curve, of the same shape as those already drawn, out of bristol board or cardboard and use it as a templet. It will be noticed that the part of the curves between points *2* and *4*, and *2'* and *4'*, respectively, is very flat; it is so nearly a straight line that it may be so considered and drawn, so that the irregular curve will have to be used only to delineate the parts *0–1–2*, *0'–1'–2'*, *4–5–6*, and *4'–5'–6'* of the helix. The student will do well to draw the straight portions of the helixes first, and to employ in doing so his two triangles in the manner shown in *Geometrical Drawing*, the lines being parallel, and then to join on the curved portions.

Draw two other lines (see Plate) parallel to the center line and $1\frac{1}{2}'' \div 2 = \frac{3}{4}''$ from it; these lines will be dotted and determine the location of the hole through the hub.

73. The top view of the worm is shown above the figure just constructed, and consists mainly of circles, the center one showing the hole, the next one the diameter of the hub, and the outer one the outside diameter of the screw. This view is located with its center on the extended center line of the lower view, letting the center of the concentric circles be $2\frac{1}{4}''$ below the upper border line. When the thread is cut in the lathe it runs out, on both ends naturally, into thin edges which are afterwards rounded off more bluntly. This is shown conventionally by the curves in the plan and elevation; see *k k'*, Fig. 21.

A keyway $\frac{3}{16}''$ deep and $\frac{3}{8}''$ wide is cut through the central part of the worm in order to keep it from turning on the shaft on which it will be placed. This keyway is plainly shown in the plan, and is indicated in the elevation by dotted lines.

74. Part **2** on Plate 1004 is a triple-threaded, adjusting screw with a tapered hexagonal head, and is drawn full size.

It is also shown broken at two points, since if shown in its full length, a smaller scale would be necessary.

Draw a center line parallel to and 9″ from the left-hand border line. The method of constructing the screw is the same as that shown in connection with the worm, except that the thread is square instead of V-shaped. The pitch or distance between corresponding points of the same thread is $1\frac{1}{8}$″; the depth of the thread is $\frac{5}{16}$″, and the width of the thread at base and root is $\frac{5}{16}$″. Three separate curves are constructed, there being three separate threads. (If the screw had been a double or a quadruple one the number of divisions chosen for the semicircles would properly have been 8, for in laying out the tops and bottoms of the threads one would have obtained already 4 or 8, respectively, of the required divisions of the pitch, as shown in the accompanying sketch, Fig. 22, where the dotted lines indicate the paths of the two threads.) A templet can be made as before, after one of the threads has been fully constructed.

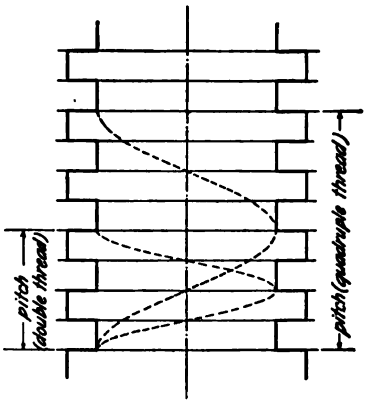


FIG. 22

In order to properly construct the tapered hexagonal head, it should be noticed (see Plate 1004) that the dimension given is $1\frac{3}{4}$″ across flats at a point 1″ from the end of the adjusting screw, the rounded top portion not being considered in dimensioning. Locate the point *c* on the center line, Fig. 23, 3″ below the upper border line, and draw through it a perpendicular *a b*. With the point *c* as a center, draw a semicircle $1\frac{3}{4}$″ in diameter, this being the dimension across flats, and using the 60° triangle and T square, draw tangents to the semicircle to locate points *a*, *b*, *x*, and *y*; through the points *x* and *y* draw lines parallel to center line and intersecting *a b*. These points determine the points in which the lines defining the edges of hexagonal head intersect $a\,b$.

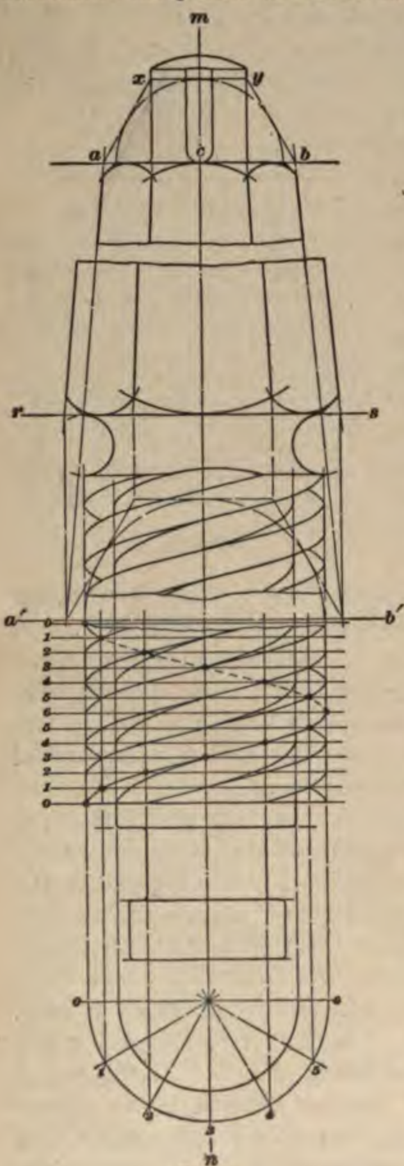


FIG. 23

To determine the proper taper, draw a line $a'\,b'$, Fig. 23, $4\frac{3}{4}''$ (see Plate) from and parallel to $a\,b$, and proceed as before, in the present instance drawing a semicircle on the line $a'\,b'$, with a diameter of $2\frac{1}{8}''$, that being the distance across the lower sides of the flats. Find the points of intersection in the same manner as the points of intersection at top are determined, and corresponding to a, x, y, and b. The tapered portion being so long that it cannot be conveniently shown upon the drawing, it is broken; consequently, the lines that have been penciled will not be fully drawn, the top portion only of the tapered lines being drawn.

In order to draw the lower portion, locate the line $r\,s$ perpendicular to the center line and at some convenient point, for instance $2\frac{5}{8}''$ below $a\,b$. Project the points already located for the lower portion of the hexagonal portion of the adjusting screw; then draw lines through these points parallel to the tapering lines already determined for the top portion.

The methods of constructing curves at the head and base of this hexagonal portion of this screw will be the same as those used in the preceding plate in laying out the hexagonal bolts and nuts.

75. Part 3 on Plate 1004 is a helical spring, drawn full size. It is made of $\frac{1}{2}''$ square steel wound around a $2''$ mandrel in such a manner that $\frac{1}{4}''$ space remains between the turns for the play of the spring. The curves formed by the edges of the twisted steel bar are helixes, as in a screw thread, and have a pitch equal to the height of the bar plus the clearance, or $\frac{1}{2}'' + \frac{1}{4}'' = \frac{3}{4}''$. To draw the spring proceed in a manner similar to that employed in drawing the worm, laying out, Fig. 24, the top and bottom lines, *g h*, *k l*, *o p*, etc. of the coil, the distance *h l* being $\frac{1}{2}''$, *l p* being $\frac{1}{4}''$, *p r* being $\frac{1}{2}''$, etc., and then constructing the helixes. The latter are very flat, and it will be sufficient to determine just one point of the curves on each side near the extreme right and left, the rest being indicated by straight lines. To determine these points, draw in the plan, the center of which is located $4\frac{7}{16}''$ above the lower border line, two radii *o a* and *o b*, Fig. 24, with a

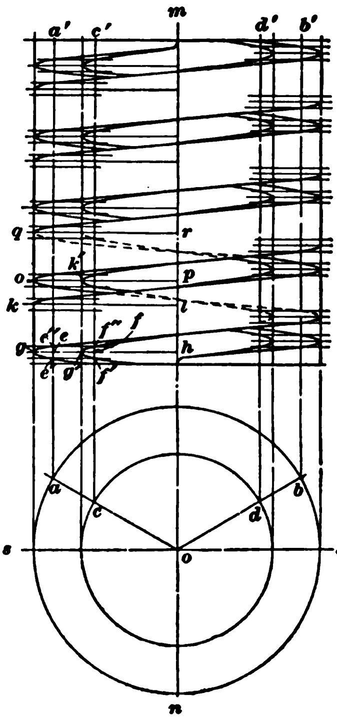


FIG. 24

30° triangle, and draw parallels *a a'*, *c c'*, *d d'*, and *b b'* to the center line *m n* from the intersections of the radii with the circles. Since the angles *a o s* and *b o s'* are $30° = \frac{30}{360} = \frac{1}{12}$ of a circle, the pitch would be divided into 12 equal parts, were the helixes drawn exactly correct. Hence, on each side of the top and bottom lines of the coil lay off points *e'*, *e''*, *f'*, *f''*, etc., the distances *e e'*, *e e''*, etc., being $\frac{1}{12}$ of the pitch, or in this case, $\frac{3}{4}'' \div 12 = \frac{1}{16}''$. Draw the curves *e' g e''*, *f' g' f''*, etc. freehand, making them look well and uniform in outline. Do the same on the right-hand extremities of the helixes and connect the proper curves by straight lines, as shown.

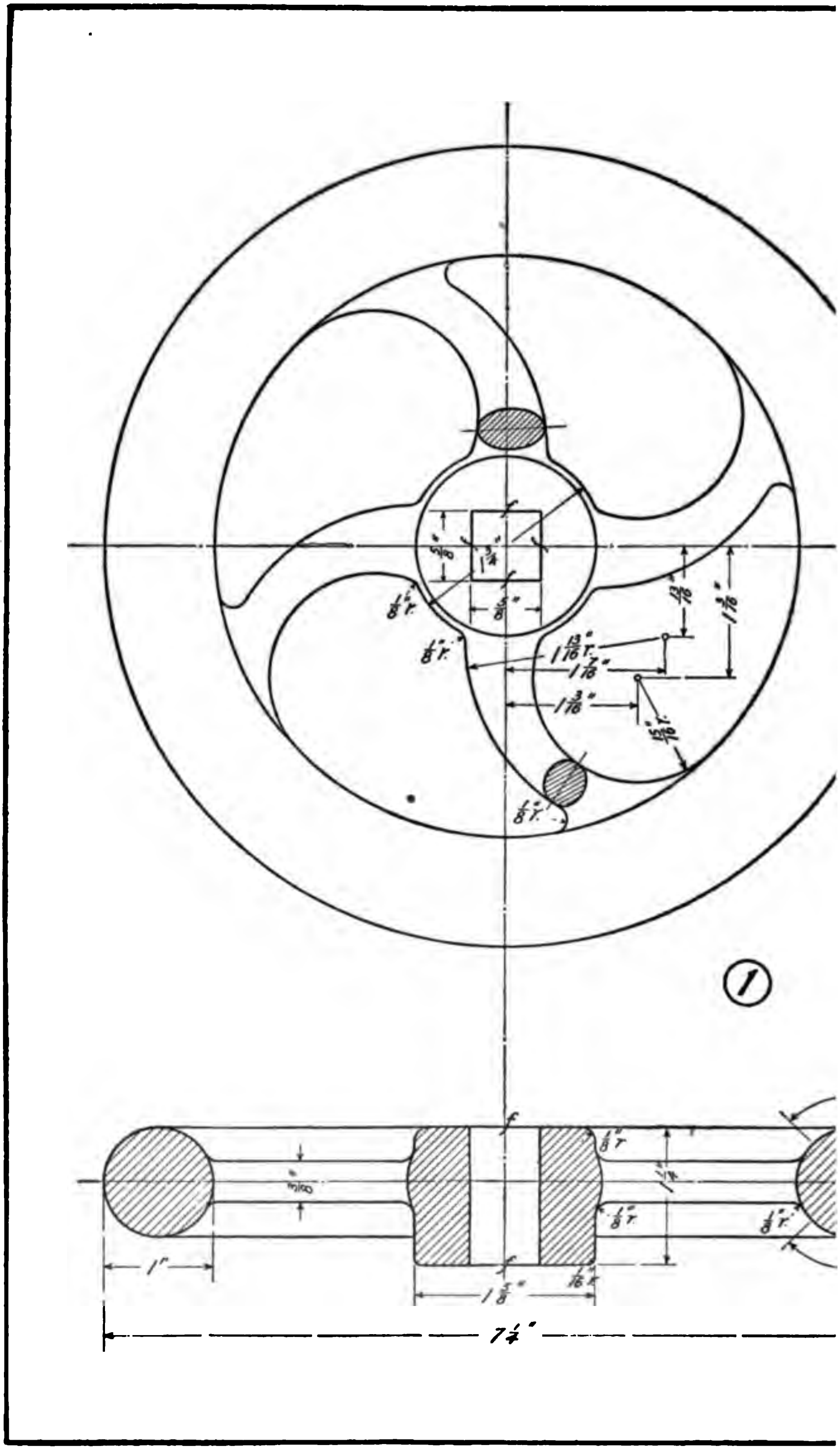
76. This Plate serves to give practice in representing helixes. It would not be bad practice, however, to represent the curves wholly by straight lines, especially if the drawing must be quickly made, and particularly in the case of parts **1** and **3**, in which the curves are very flat. In the case of part **2**, the substitution of straight lines for the curves would look somewhat awkward on account of the large pitch.

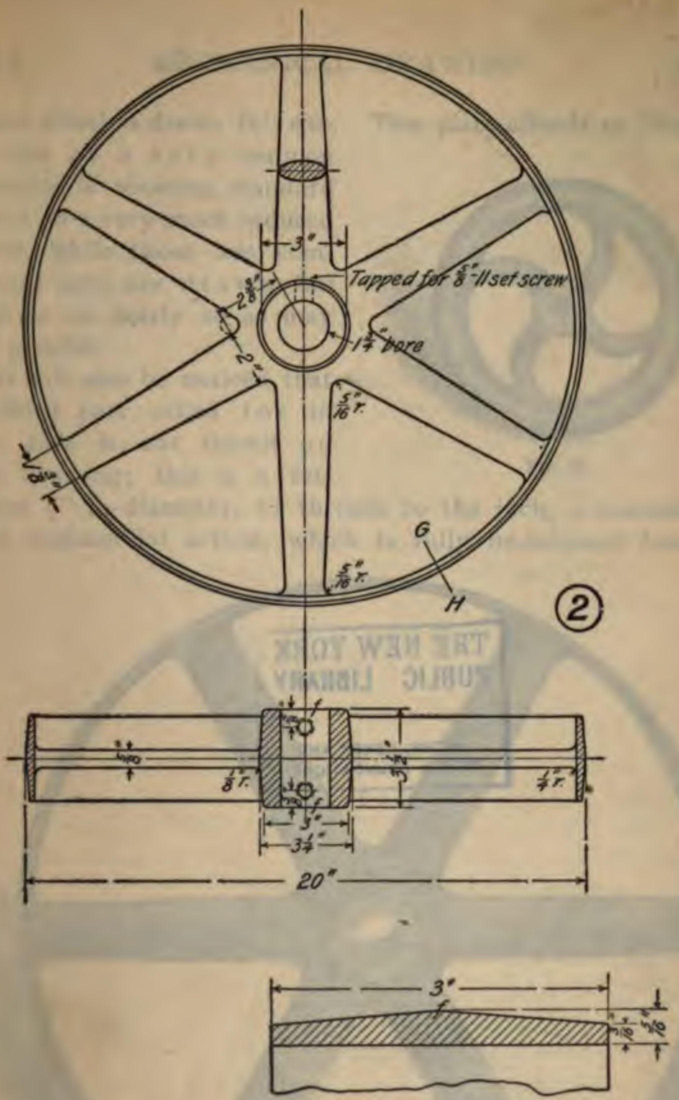
In a hurried drawing, one would then perhaps draw this part to a smaller scale, when the substitution of straight lines for the curves would be less objectionable; or the thread may be represented in the conventional form shown in Fig. **1**, Plate 1003, and a note added calling for a triple thread.

PLATE 1005, TITLE:

HAND WHEEL AND PULLEY

77. The objects to be drawn on this Plate are shown in half-tone reproductions of photographs, Figs. 25 and 26. Attention is called to the relative size of the hand wheel, part **1** on Plate 1005, and the pulley, part **2**. The latter, it will be noted, is much larger than the former, but appears smaller in the drawing, being drawn to $\frac{1}{4}$ scale, while the


1
1 13/16" r.
1 7/16"
1 3/16"
15/16" r.
1/8" r.
1 5/8"
7 1/4"
1"



Section on line G.H.

2	5/8"-11 Set screws 1" long for part 2	3	Machine steel		
1	Pulley	2	Cast iron	999 E	
1	Hand wheel	1	Cast iron	Pattern	A

HAND WHEEL AND PULLEY

DRAWN BY........................

DATE........................

1005

ınd wheel is drawn full size. This plate affords an illus-ation of a very common ·actice of showing standard ırts on a very much reduced ale, while those less com-only used are drawn full ze or as nearly so as may : possible.

Fig. 25

It will also be noticed that third part called for in ıe title is not shown on ıe drawing; this is a set-rew $\frac{5}{8}''$ in diameter, 11 threads to the inch, a common ıd commercial article, which is fully understood from

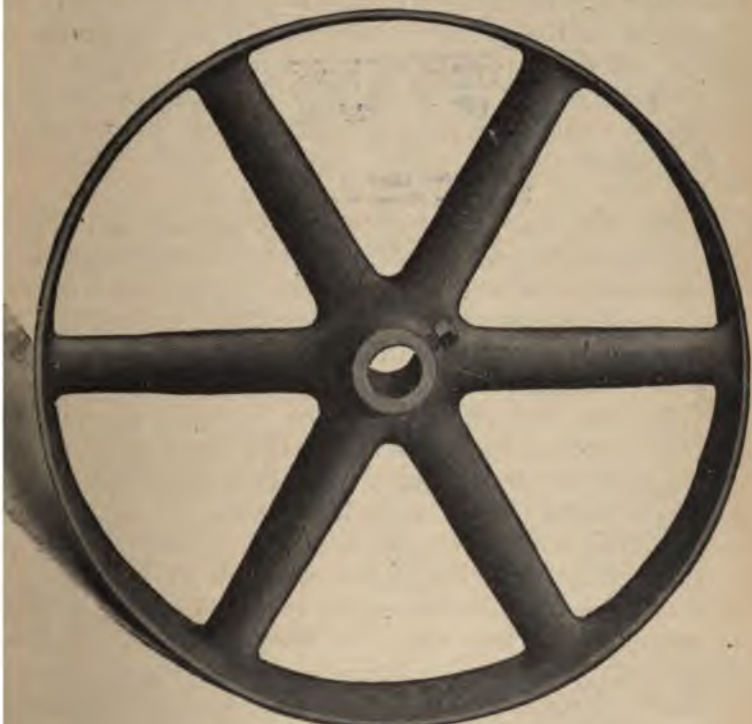


Fig. 26

the description in the bill of material given thus: "$\frac{5}{8}$"-11 setscrew."

78. On this Plate finish marks are introduced, being indicated by the letter *f*, showing that the surfaces are to be machine finished where the marks appear.

Where it is desired to show a finish for a portion of a surface only, as on the rim of the hand wheel, the finished portion is limited by lines between which the finish line is drawn, as shown on the right of the lower figure representing a sectional view of the hand wheel.

79. It is also frequently desirable or necessary to show some portion of an object more in detail than is necessary on the rest of the figure; this is illustrated in the cross-section of the pulley at the point *G H* and drawn full size below. A section of this sort when not shown as a regular part of a drawing, may be put at any convenient place on the sheet, near to main views of the part drawn, if possible.

80. On the plan (top view) of parts **1** and **2**, cross-sections of the arms are indicated at points near the hub and rim in the hand wheel and midway between hub and rim in the pulley; these sections show that the arms are oval in shape, the thicknesses being given in the lower views—$\frac{3}{8}$" in the hand wheel and $\frac{5}{8}$" in the pulley.

To draw the Plate proceed as follows: Starting with part **1**, draw a horizontal center line *m n*, Fig. 27, 5" from the upper border line, and a vertical center line *p q*, 4$\frac{1}{2}$" from the left-hand border line. With the point *o* of the intersection of these two center lines as a center, draw a circle 1$\frac{5}{8}$" in diameter, showing the end view of the hub; next draw a circle 1$\frac{3}{4}$" in diameter; this indicates the enlarged portion of the hub where the arms join it. Next draw a square $\frac{5}{8}$" on each side, whose center corresponds with the center of the hub; this indicates the end view of the hole that is put through the hub. Draw the external outline of the hand wheel, which is a circle $7\frac{1}{4}''$ in diameter, and then the internal outline, a circle $5\frac{1}{4}''$ in diameter. Then

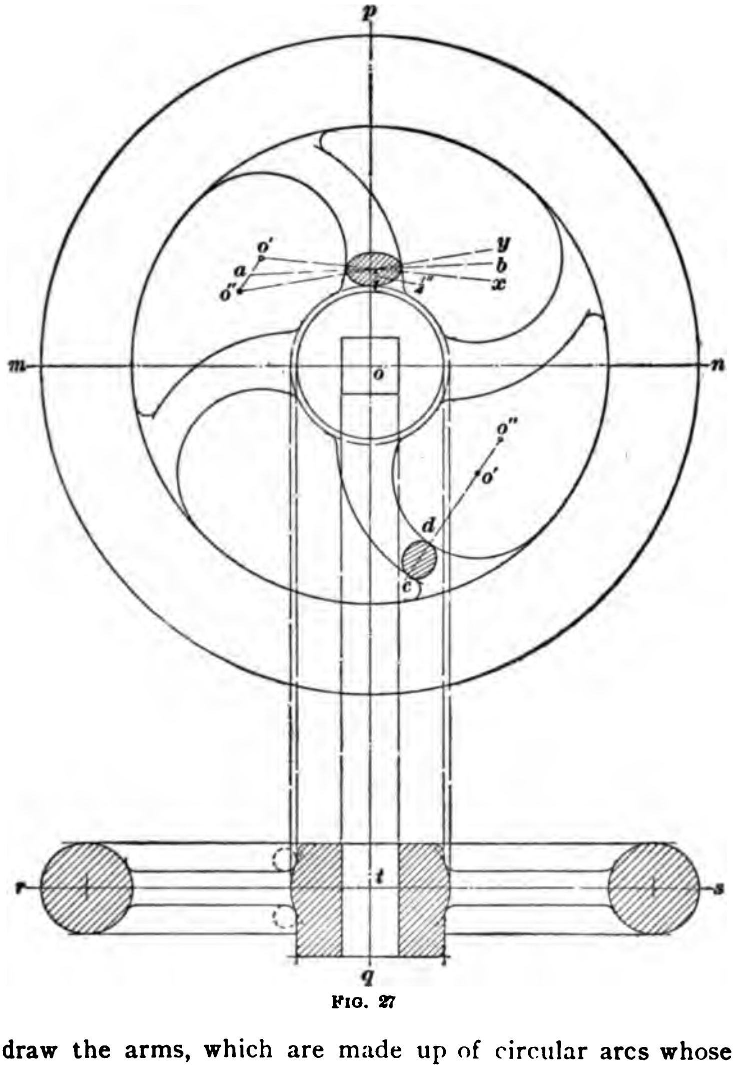


FIG. 27

draw the arms, which are made up of circular arcs whose centers are located by giving their distances from the center lines. Leave the plan for the present and proceed to draw the lower view, which is a section taken on the center line *mn*.

The lower view is what is called a *conventional section*, and the sectioning indicates that the material is cast iron; this is verified by reference to the bill of materials. The rim is cut on the horizontal center line, and so is the square hole in the hub, but the hub itself is represented as being cut on a line passing between and free of the arms. This is done to avoid drawing the curves that would result in cutting the arms by a true central section, which would entail useless labor. Moreover, the conventional section allows the round outline of the hub to be shown at its enlarged central portion between the arms.

Draw a horizontal center line *rs*, Fig. 27, $2\frac{3}{8}''$ from the bottom border line. On this center line lay off to the right and left of the point of intersection *t* with the vertical center line *pq*, $7\frac{1}{4}'' \div 2 - 1'' \div 2 = 3\frac{1}{8}''$, locating the centers of the circles representing the sections of the rim. Draw horizontal lines tangent to the 1″ circles; lay off from the upper line $1\frac{1}{4}''$ downwards, the length of the hub, and draw the bottom line of the hub. From the upper figure or plan carry down vertical projection lines representing the square hole; also draw similar lines tangent to the circles representing the hub. Next lay off $\frac{3}{8}'' \div 2 = \frac{3}{16}''$ each side of the center line *rs*, and draw the horizontal lines, limiting the thickness of the arms.

81. Round Corners and Fillets.—The figures are now completed except the sections of the arms in the plan, or upper figure, the curves representing the enlarged portion of hub in the lower figure, and the various small circular arcs rounding off the corners. The latter will be drawn first, using the radii given on the Plate. Sharp corners are always avoided in machinery, especially in castings, unless called for by special reasons. Corners are, therefore, rounded off. In the case of concave corners the patternmaker often resorts to the use of some plastic material, such as putty, strips of leather, or even lead to fill in the corner so as to round it. From this practice the rounding out of a concave corner is called a **fillet**, and this term has come to be applied to the little circular arc used by the draftsman to represent it.

82. Next draw the rounded outlines of the enlarged portion of the hub. Through the points of intersection with the horizontal center line *r s*, and the tangents to the circles in the plan defining the hub, draw circular arcs tangent to the fillets, circles joining the arm to the hub, as shown in Fig. 27. The drawing of these circular arcs will require a little trying before the proper radius is found; the centers lie on *r s*, of course.

Lastly, draw the cross-sections of the arms in the upper figure. As said above, the arms are elliptical or oval in section. They are so, however, only the greater part of their length; at their ends they are smoothly joined to the rim and hub respectively, the ovals thus gradually flaring out to run over into the surfaces of the rim and hub. This joining need not be shown further than indicated by the fillets; the patternmaker will know how to proceed. The cross-sections are taken in the portion of the arm where they are sure to be truly oval.

The section in the lower part of the figure is taken on a line *c d* (see Fig. 27) passing through the centers o' and o'' of both circles outlining the shape of the arms. The cutting plane is thus perpendicular to both these curved outlines. The other section in the upper part of the figure near the hub is taken $\frac{1}{4}''$ from the hub (where it is sure to be truly oval). This section cannot be perpendicular to both outlining circles, as the cutting-plane line cannot be made to pass through both centers. Therefore, a cutting plane *a b* is chosen midway between a plane $o'x$ passing through center o' and a plane $o''y$ passing through the center o''.

83. It will be noticed that for some circles the radii are given, and for others the diameter. No general rule can be made to apply to the choice of dimensions of this sort except the general one that dimensions that will be of service to the machinist will be given in diameters, and those that will be of service to the patternmaker should be given as a radius; machinists use calipers to determine correct diameters, while the patternmaker lays out his work from a

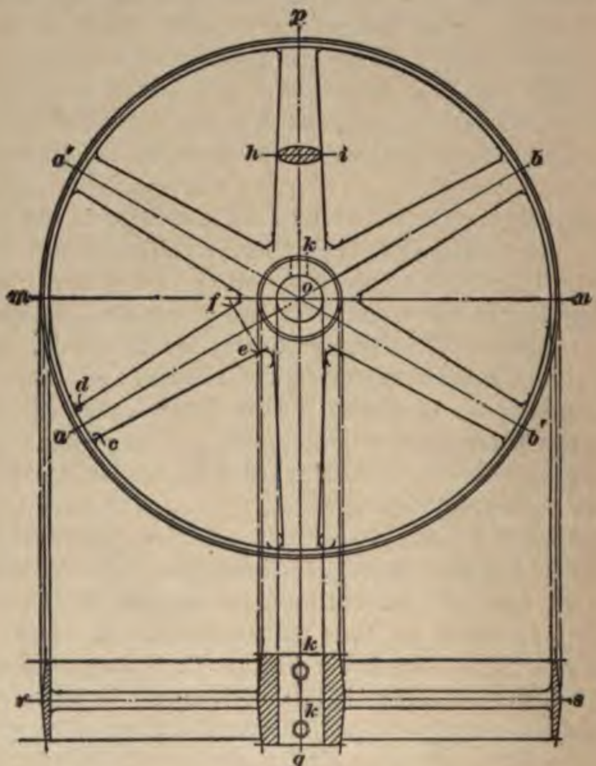


FIG. 28

radius dimension. It will be noticed also that the dimension for the bore of the pulley is written in a manner different from the others; that is, it is not indicated by means of a line with arrowheads on both ends. The word *bore* indicates that the pulley pattern provides for a hole much smaller, so that it can be bored out for smaller shafts, if so desired. The dimension given ($1\frac{1}{4}''$) is for the machinist.

84. Part **2** is very similar in shape to part **1**, except that it is much larger, that the rim is flat—because it is intended to carry a driving belt—and that the arms have straight outlines. Being much like the hand wheel otherwise, the pulley is drawn in much the same manner. The scale used is $3'' = 1$ ft.

Locate the horizontal center lines *m n* and *r s* (see Fig. 28) $3\frac{3}{8}''$ and $7\frac{1}{4}''$, respectively, from the upper border line, and the vertical center line *p q* $4\frac{3}{8}''$ from the right-hand border line. Draw circles about *o* representing the outside and inside of the rim and hub. The outside of the rim will be represented by two circles, an outer one 20″ in diameter giving the outline of rim at the center, and an inner one with a radius $\frac{1}{8}''$ smaller giving the outline at the edge. Making the rim higher in the center is for the purpose of keeping the belt from slipping off. The amount of rise in the center, that is, the difference between the radius at the edge and that at the middle, or what is the same thing, the difference between the thickness of the rim at those two points is called the *crown* of the rim, which is seen from the small section at the right-hand lower corner of the drawing to be $\frac{5}{16}'' - \frac{3}{16}'' = \frac{1}{8}''$. The inside of the rim is perfectly straight and appears therefore in the plan as a single circle drawn with a radius $\frac{5}{16}''$ smaller than that of the outermost circle. The outside of the hub is also represented by two circles, 3″ and $3\frac{1}{4}''$ in diameter. The diameter of the bore is $1\frac{3}{4}''$.

Now draw the arms. Lay out the center lines *a b*, *a′ b′* of the four arms not vertical, by means of the 60° triangle. They are tapered, and the small end of each at the rim is $1\frac{3}{8}''$ across on tangent to the inside circle of the rim; the large end is 2″ across at a point $2\frac{3}{8}''$ from the center. By these dimensions the taper of the arms is established. Hence, draw a perpendicular to the center line of an arm, tangent to the inside circle of the rim and lay off on it points *c* and *d* $1\frac{3}{8}'' \div 2 = \frac{11}{16}''$ from the center line on each side. Draw another perpendicular $2\frac{3}{8}''$ from the center and lay off on it points *e* and *f* 1" from the center line. Draw the lines *c e* and *d f*. The limiting lines of the arms are joined at the inner ends by circles of $\frac{5}{16}''$ radius, lines of adjacent arms being tangent to them. The outer ends of the arms are joined to the rim by fillets of $\frac{5}{16}''$ radius. Draw in all these fillets. Draw the oval section of the arm at *h i*, Fig. 28, midway between center of pulley and rim.

Next draw the lower figure, a sectional elevation, by projecting from the plan the various diameters of rim, hub and hole, and then laying out the width of the rim, the length of the hub, and the thickness of arms, exactly as was done in the case of the hand wheel.

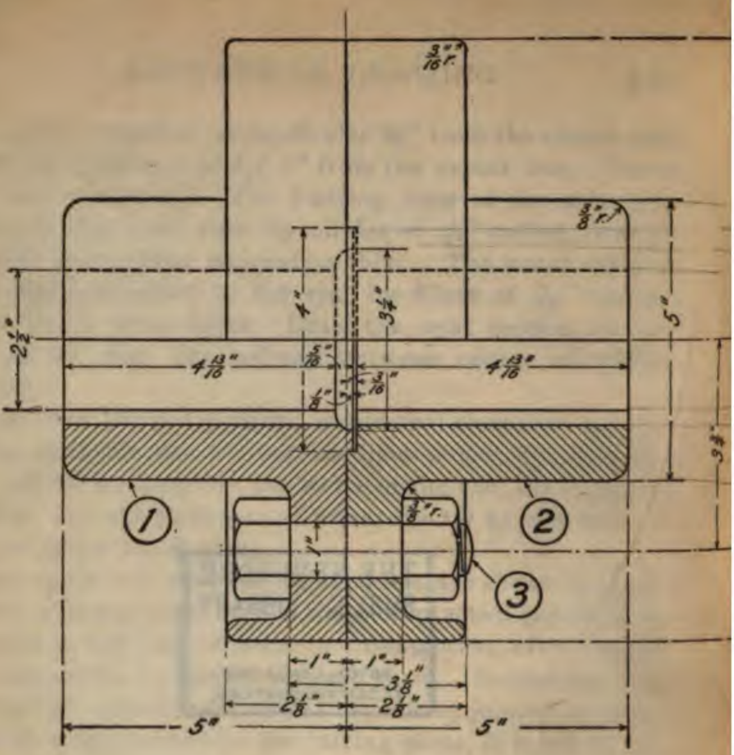
Note again that only the hub and rim are shown in cross-section on lower view, as it is common practice not to show the arms or any part of them in cross-section, even though a cutting plane be passed through them. Notice also that although the web formed around the hub by joining the arms by fillets is intersected by the cutting plane, it is not shown in the section, the outer lines of the hub being drawn straight across.

There should be no difficulty in drawing the large detail section *G H* of the rim.

The holes *k*, *k* indicate the positions of the two $\frac{5}{8}''$ set-screws mentioned in the bill of materials, which fasten the pulley to the shaft. The full circles indicating these holes are surrounded by circles in dotted lines, this being the conventional method to indicate that the holes are tapped.

When finishing the title and bill of materials, note that part 3 is called for, but is not shown on the drawing, it being a standard piece.

Part 1 requires a pattern to be made. Hence, the pattern is designated by the number of the drawing, and being the first on the list in the bill of materials is marked *1005–A*. This fact is indicated in the bill of materials by the word *Pattern*, and being the first on the list it is marked *A*.


3/16" r.
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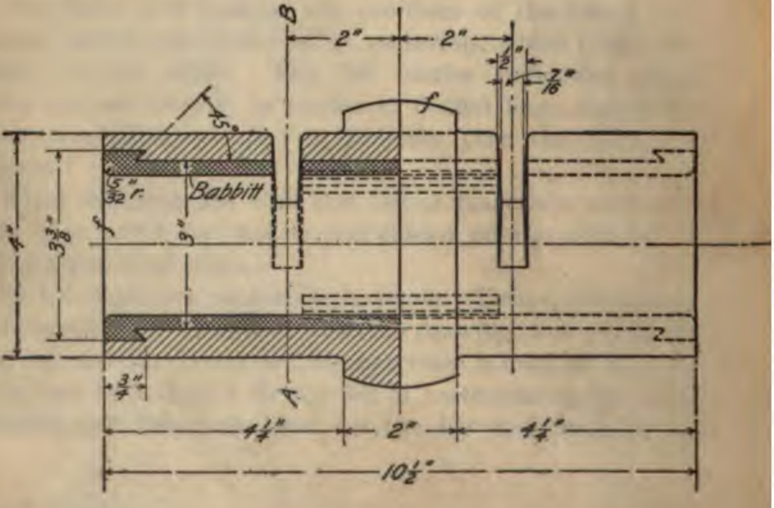
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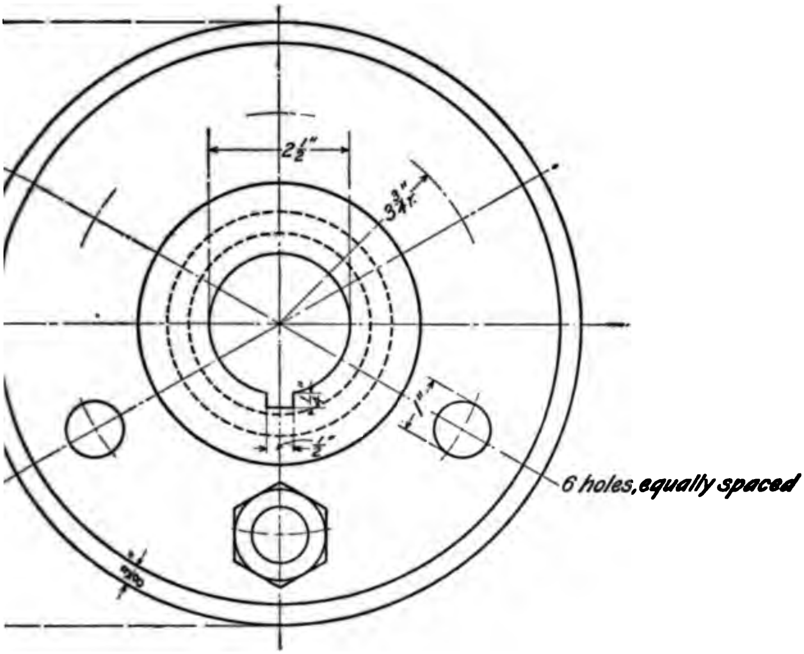
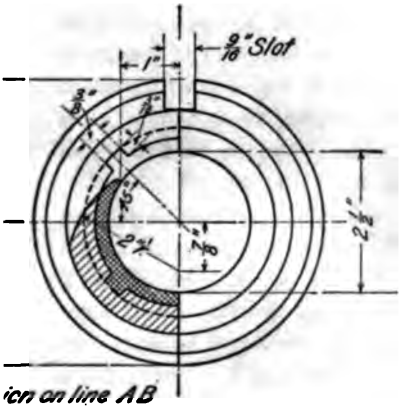


'all over



'icn on line AB

1	Bearing	4	C.I. and Bab. M.	Pattern	C
6	1" Hex Hd. bolt				
	3¼" long with nut	3	Machine steel		
1	Coupling (female)	2	Cast iron	Pattern	B
1	Coupling (male)	1	Cast iron	Pattern	A

COUPLING AND BEARING

DRAWN BY..............

DATE..............

1006

The pattern itself is designated by the number of the drawing and the letter given it, hence it is marked *1005–A*.

Part **2** can be cast from another pattern drawn from specifications furnished on drawing numbered 999 and marked *Pattern E* in the bill of materials. Therefore, in the space left for the word "pattern" in the bill of materials and on the same line as the piece referred to, insert *999–E*, thus indicating that a new pattern is not required.

PLATE 1006, TITLE:
COUPLING AND BEARING

85. The upper figure shows an elevation and side view of a flange coupling used to connect two lengths of shafting. For example, suppose that in a shop or factory there are many machines to be driven from an engine. A belt is carried from the driving pulley of the engine to a pulley on a shaft overhead, which in turn is supported in bearings. This shaft is strung along the whole length of the shop over all the machines to be driven, and pulleys are carried on it from which belts transmit motion to the various machines. It is evident that such a long shaft cannot be made in a single piece and, therefore, it is put up in certain lengths that are connected by couplings. Such a coupling invariably consists of three principal parts, one that is securely fastened to the end of one shaft, a second that is similarly fastened to the end of the other shaft to be connected to the first, and a third part consisting of means to firmly fasten the first two parts together.

In the flange coupling drawn on Plate 1006 these three principal parts are the flange numbered **1**, the flange numbered **2**, and the bolts, of which there are six, numbered **3**. The flanges are fastened to the shafts by keys, which prevent them turning thereon, and the bolts in turn fasten the two flanges together, so that the whole structure becomes a solid piece. The coupling is intended for two 2¼" shafts, and both flanges are, therefore, bored out to that size.

The lower part of the elevation shows the coupling in cross-section with a bolt in position. The upper part shows the external view of the coupling, the dotted lines indicating the position of the raised boss on part **1** which fits into the recess in part **2**, recess and boss insuring true alinement when the two parts which have been previously keyed to the shaft are bolted together.

The two parts of the coupling are first bored and then faced up on the abutting surfaces; they are then clamped together, and the keyway is cut. In the side view it will be noticed that but one bolt is shown, and but two bolt holes in addition, a note being added stating that there are six holes equally spaced; this is common practice on a working drawing, repeated parts being indicated only and not drawn in full. An idea of the appearance of the coupling when finished will be got from the half-tone view in Fig. 29.

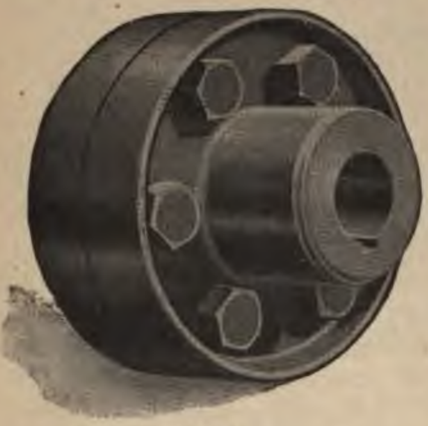


FIG. 29

86. To begin, draw the center lines: a horizontal center line *m n*, Fig. 31, $3\frac{1}{4}''$ (full size) from the upper border line across the whole sheet, serving for both the left-hand and right-hand views; a vertical center line *p q*, $4\frac{1}{2}''$ from the left-hand border line, representing the joint of the two halves of the coupling; and a third center line *r s*, drawn vertically $5\frac{3}{8}''$ from the

FIG. 30

right-hand border line for the right-hand figure, or side view. The scale to be used is 6" = 1 ft.

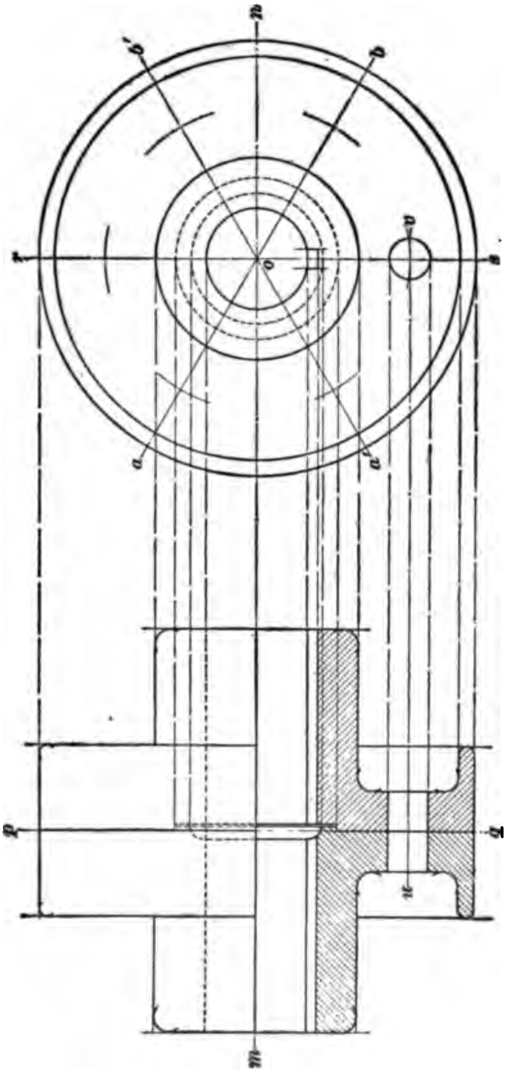


FIG. 31

Draw the side view first. Describe a circle with a radius of $2\frac{1}{2}'' \div 2 = 1\frac{1}{4}''$ from the intersection *o* of the center lines *m n* and *r s* as a center; this represents the bore for the shaft. Next draw in the keyway, ½″ wide and ¼″ deep. Two circles described from the same center and having radii of 5″ ÷ 2 = 2½″ and 10¾″ ÷ 2 = 5⅜″, represent the side view of the hub and the outside of the flanges, respectively. By reference to the lower half of the elevation it will be seen that the flanges are recessed, leaving a rim of only ⅜″ in thickness. Hence, with a radius of 5⅜″ − ⅜″ = 5″ and a center *o*, draw a circle concentric with the outside circle, to represent the inside edge of the rim. By means of the 60° triangle draw the remaining center lines *a b*, *a′ b′* of the bolt holes and intersect them by circular arcs having a radius of 3¾″. Draw in the bolt holes in the lower half of the figure by drawing circles 1″ in diameter. Draw the end view of a nut on the middle one of the lower three bolt-hole centers, according to directions given in connection with Plate 1003.

The elevation is now to be drawn. On either side of the vertical center line *p q* lay off 5″, the length of hubs of the coupling, and draw vertical lines through the points obtained. Lay off similarly 2⅛″ and 1″ on either side of the vertical center line and draw vertical lines to represent the edges of the flanges and the thickness of the webs of the flanges, respectively; the latter lines may, however, be quite short, as they appear only in the lower half of the figure. Now carry over from the side view, by means of the T square, two horizontal lines tangent to the outside circle intersecting the vertical lines limiting the width of the flanges. Carry over similarly horizontal lines tangent to the circle representing the side view of the hub. These will intersect the vertical lines limiting the lengths of the hubs; the lower horizontal will also intersect the verticals that limit the thickness of the webs of the flanges. A tangent carried over horizontally from the bottom point of the circle representing the outer outline of the rim will also intersect the verticals in the elevation completing the sectional outline of the coupling. Carry over the horizontal center line *u v* of the bolt from the end view and complete the drawing of the bolt in the usual manner. Round off all sharp corners, using radii as given on the plate. The right-hand half of the coupling has a circular recess 4″ in diameter and $\frac{3}{16}$″ deep bored in it; draw this by laying off on either side of the horizontal center line *m n*, 4″ ÷ 2 = 2″, and on the right of the vertical center line *p q* (or, what is the same thing, the face of the flange), lay off $\frac{3}{16}$″, and draw the horizontals and a vertical, respectively, through the points. Represent this recess in the side view also, by drawing a dotted circle with a 4″ ÷ 2 = 2″ radius. Into the recess of the right-hand half of the coupling just drawn fits a boss projecting $\frac{1}{8}$″ from the face of the left-hand half of the coupling; represent this by drawing a vertical line $\frac{1}{8}$″ to the right of the vertical center line *p q*. The verticals representing the bottom of the recess and face of the boss are dotted in the upper half of the figure, as they are hidden there. The left-hand half of coupling has also a circular recess turned in, smaller in diameter than the boss, namely $3\frac{1}{4}$″; it is $\frac{5}{16}$″ deep measured from the face of the boss. Draw in this recess and round its bottom corners; also represent it in the side view by a dotted circle of proper diameter. Next carry over the top line of the shaft bore horizontally from and tangent to the circle representing the bore in the end view; this line must be dotted in the upper half of the elevation, as it is hidden from view. Finally carry over the bottom lines of the shaft bore and the keyway, shown in full in the lower half of the elevation. Put in the section lining and dimensions.

87. Part 4 on this drawing is a self-alining, self-oiling, dynamo bearing for a $2\frac{1}{2}$″ shaft. In Fig. 30 a half-tone reproduction of a photograph of this piece is given to enable the student to form a correct idea of its actual appearance. A shaft bearing, generally speaking, is a stationary machine part having a hole into which fits, and in which turns, a movable cylindrical piece, the shaft. Upon a shaft are carried other machine parts designed to turn with it, as, for instance, the armature in a dynamo. There are generally two bearings to a shaft of a machine, one on each side of the part carried by the shaft. In order that the shaft may turn freely, the two bearings must be exactly

FIG. 32

in line all the time. To insure this against any possible distortion of the machine frame or bending of the shaft, bearings are often made, as the one here represented, self-alining; that is, they are so located in the frame that they

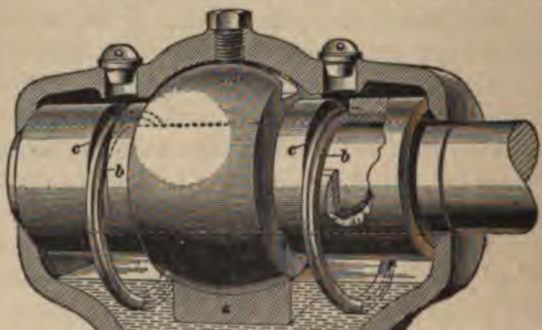


FIG. 33

can adjust themselves to any slight variations. The bearing here shown has for the purpose a spherical* boss *a*, called

* Strictly speaking, the boss is not spherical, being only a part of a sphere. However, for practical purposes, it is very convenient to refer to any part of a sphere, except half a sphere (hemisphere) as a sphere or ball, and this practice will be followed throughout this paper in cases of this kind, unless some other designation is considered advisable.

the *ball*, Fig. 32, the center of which rests in a correspondingly hollow seat, called the *socket*, in the machine frame, shown in Fig. 33. As it rests there, movable of course, friction would be liable to cause the bearing to turn with the shaft. To prevent this, a slot is cut across the boss at *a*, Fig. 32, into which fits a pin projecting from the stationary frame, Fig. 33.

When two surfaces move, one on the other, they necessarily rub each other, producing friction, and this not only consumes power, but creates heat and is liable to injure the surfaces. The amount of friction varies between different materials, certain combinations offering less friction than others. It has been found that steel shafts move with a comparatively small amount of friction on a softer metal. So bearings are usually lined with Babbitt or similar material. The great expedient, however, to reduce friction, is lubricating the surfaces with oil, which lubrication must be kept up constantly. To reduce the necessary labor of the attendant and to insure constant regular lubrication, bearings are often made self-oiling; that is, are provided with means by which the oiling is done automatically. In the bearing shown this is done by hanging over the shaft loose rings *b* that dip into a reservoir of oil, as indicated in Fig. 33. When the shaft turns the rings turn with it by adhesion and carry enough oil from the reservoir to the top of the shaft to properly oil it. In order that the rings may rest on the top of the shaft, the bearing proper must have slots *c c* cut into it, as shown in Figs. 32 and 33, and on the plate. The bearing shown is made of cast iron and is babbitted inside, the Babbitt being held in place by dovetailed circular recesses at the ends, shown in the left-hand half of the elevation, and longitudinal recesses $\frac{3}{8}$" wide and $\frac{3}{16}$" deep, shown in the side view; the babbitting is ordinarily done on a mandrel smaller in diameter than the finished bore of the bearing. After being babbitted the bearing is accurately bored and finally finished on the outside.

The left-hand half of both views is shown in section, the right-hand half giving the external view. Oil grooves are not shown in the drawing and are omitted from all working drawings when regular shop practice is to be followed, only being added to drawing if special instructions are to be given.

88. In delineating the bearing, which is drawn half size, proceed in much the same manner as with the coupling. Draw the center line mn (Fig. 32) $2\frac{5}{8}''$ from bottom border line and two vertical center lines, one pq $4\frac{5}{8}''$ from the left-hand border line for the elevation, and another rs $10\frac{3}{4}''$ from the left-hand border line for the side view. Begin with the end view, completing it as far as possible, before starting the other view. Thus draw circles with o as a center, $5\frac{1}{8}''$, $4''$, $3\frac{3}{8}''$, $3''$, and $2\frac{1}{2}''$ in diameter to represent, respectively, the circular outlines of the spherical boss in the center of the bearing, of the body of the bearing, of the outside of the Babbitt lining, and the bore. Next lay off $\frac{7}{8}''$ from o downwards and draw, with o' as a center, a circular arc with a radius of $2''$. This circular arc cuts into the circles representing the body of the bearing and the bore at c and d. Round off the sharp corner at d. Draw the $\frac{9}{16}''$ slot on top of the rounded boss. Draw the longitudinal recesses for the Babbitt $\frac{3}{8}''$ wide and $\frac{3}{16}''$ deep, their centers 45° from the horizontal center line mn. Section-line the Babbitt and bearing section. This view is now complete with the exception of one circle, namely, that representing the edge of the boss, the radius of which will have to be obtained from the other view, now to be drawn. Carry over horizontally from the end view the lines limiting the diameters of the boss, bearing, Babbitt lining, and bore, tangent to the circles representing these parts in the end view. Lay off right and left from the center line pq the various distances limiting the length of the body of the bearing, the boss in the middle, and the lengths of the dove-tails of the Babbitt lining. Likewise, lay off $2''$ on either side of pq for the center lines tu and vw of the oil-ring slots. Lay these out next. It will be noticed that they are narrower inside, near the shaft by $\frac{1}{16}''$ than at the surface of the bearing. Carry over from the side view a horizontal line through *d*, which will intersect *t u* and *v w* at *x* and *x'*, respectively. Lay out the bottom width of the slots at this point, $\frac{7}{16}''$, thereby finding the points *k*, *l*, *k'*, and *l'*. Carry over a horizontal from the side view through *c*, which intersects *t u* and *v w* at *y* and *y'*, respectively. Lay off the width of the slots at this point, $\frac{1}{2}''$. Draw verticals from the points *f*, *g*, *f'*, and *g'* to the upper limiting line of the bearing and intersecting it; from the points of intersection *h*, *i*, *h'*, and *i'* draw lines to the points *k*, *l*, *k'*, and *l'*; also, lines *f k*, *g l*, *f' k'*, and *g' l'*. With *z*, the intersection of the center lines *m n* and *p q*, as a center, draw circular arcs limiting the outside of the spherical boss, the radius being obtained by carrying over from the side view or by measurement, $5\frac{1}{8}'' \div 2 = 2\frac{9}{16}''$. The arcs intersect the verticals limiting the length of the boss in points which finally give the radius for a circle to be drawn in the side view to represent the edge of the round boss. Put in the section lining, using the proper lines for cast iron and Babbitt. Notice that the boss is section-lined all through in the bottom half of the figure, but only up to the bottom line of the slot *a* in the top half, showing that the slot runs all the way through the boss.

In completing the drawing, fill in the title and note that two patterns are necessary for the coupling, pattern for **1**, being *A*, and for **2**, *B*. Also note that six 1" bolts $3\frac{1}{4}''$ long with nuts are required and are called for in title or bill of material.

The part numbered **4** is made of cast iron, from pattern *C*, the Babbitt afterward being melted and poured about the mandrel previously spoken of, this mandrel being held in position inside of the casting while the bearing is being babbitted.

PLATE 1007, TITLE:

COMMUTATOR

89. This Plate shows the detail drawings and the assembly drawing of an electric railway-motor commutator. It is composed of a shell, part **1**, a clamping ring, part **2**, these two parts being drawn together by eight bolts, thereby clamping the 100 commutator bars shown by the part **3**. The latter are separated from each other by mica insulation sheets .03″ thick and are also insulated both from the shell and the clamping ring by mica rings $\frac{3}{32}$″ thick. An idea of the general appearance of the commutator may be had from Fig. 34.

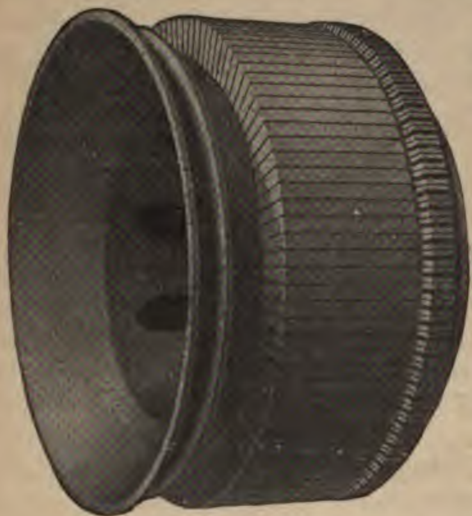
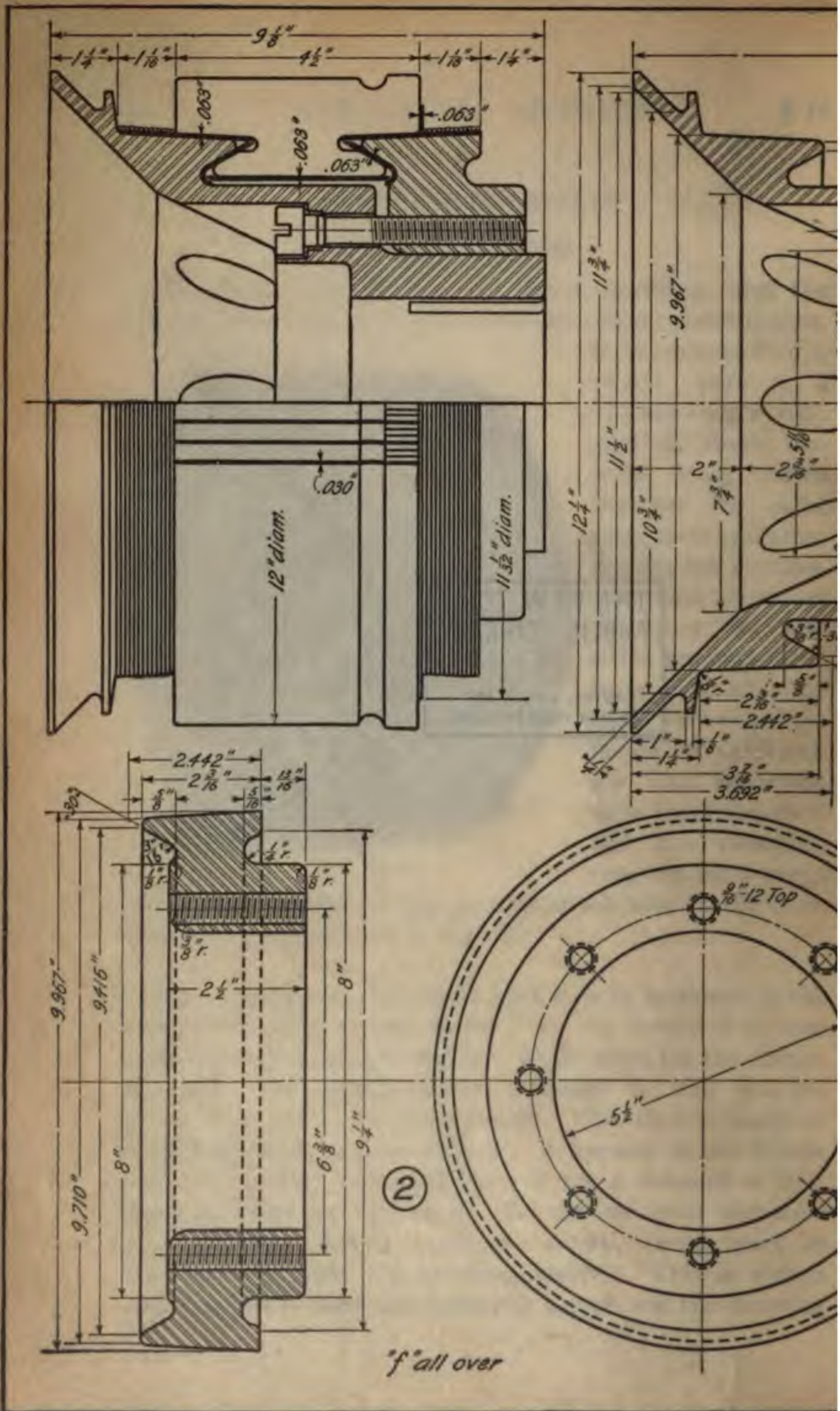
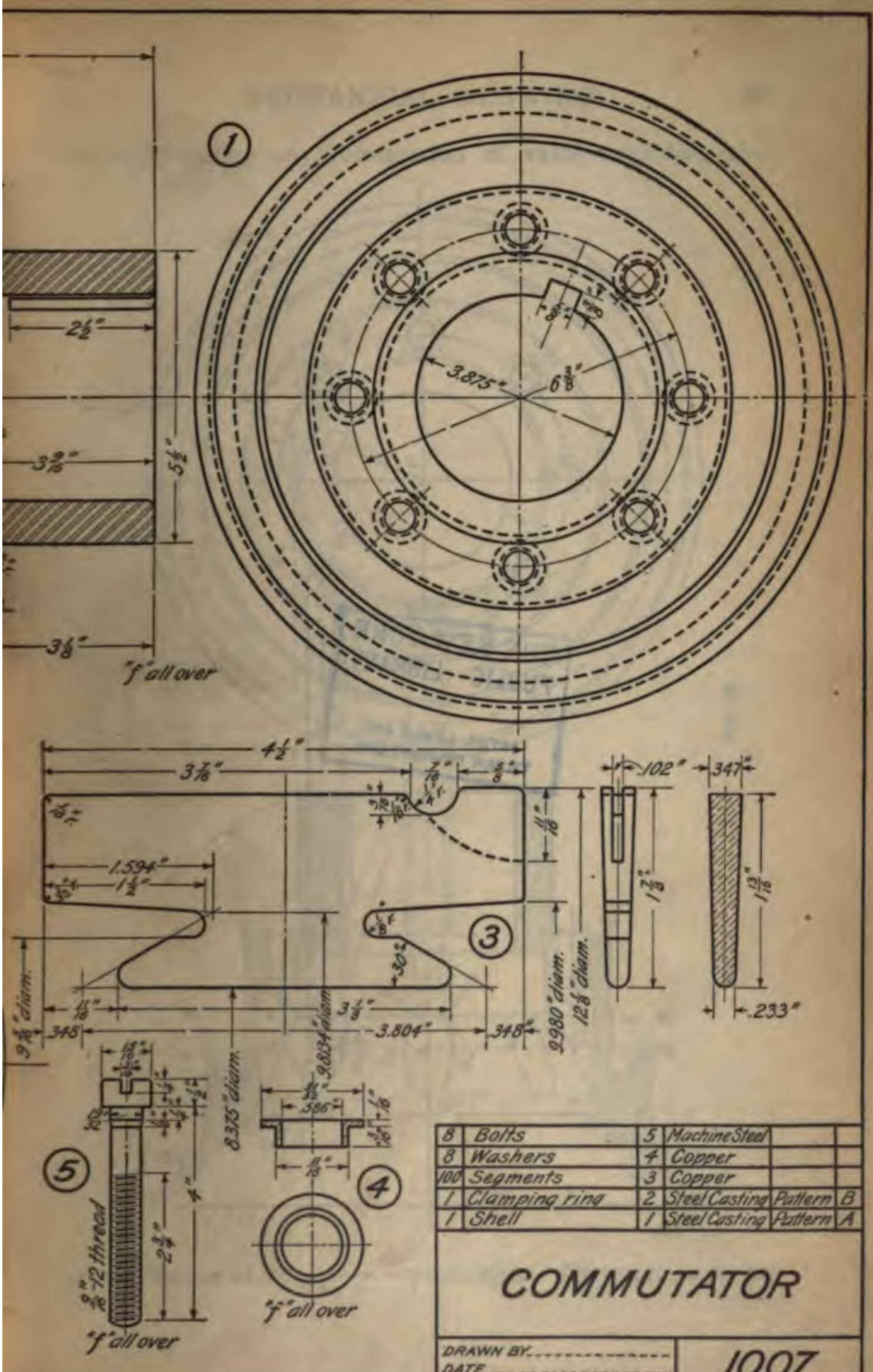


FIG. 34

90. The commutator shell, part **1**, is to be shown in the right-hand upper corner of the Plate by means of an end view and a sectional elevation. Eight holes for the clamping bolts are symmetrically arranged in the manner shown and are to be countersunk. The shell is made of steel, cast from pattern *1007–A*. A keyway is cut in one end of the shell, extending into it for a distance of $2\frac{1}{2}$″, being $\frac{3}{8}$″ deep and $\frac{5}{8}$″ wide. In the sectional elevation no outlines of hidden parts are shown, except such as may serve to make the drawing clearer. This is always desirable when lines unnecessarily complicate the drawing


9 1/8"
1 1/4"
1 1/16"
4 1/2"
.063"
.030"
12" diam.
11 1/32" diam.
11 3/4"
11 1/2"
12 1/4"
10 3/4"
9.967"
7 3/4"
2"
2.442"
3.692"
9.416"
9.710"
8"
6 3/8"
9 1/4"
2 1/2"
9/16" 12 Tap
5 1/2"
2
"f" all over



8	Bolts	5	Machine Steel		
8	Washers	4	Copper		
100	Segments	3	Copper		
1	Clamping ring	2	Steel Casting	Pattern	B
1	Shell	1	Steel Casting	Pattern	A

COMMUTATOR

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... TEXTBOOK COMPANY.
...all, London.

without adding any information of value regarding the

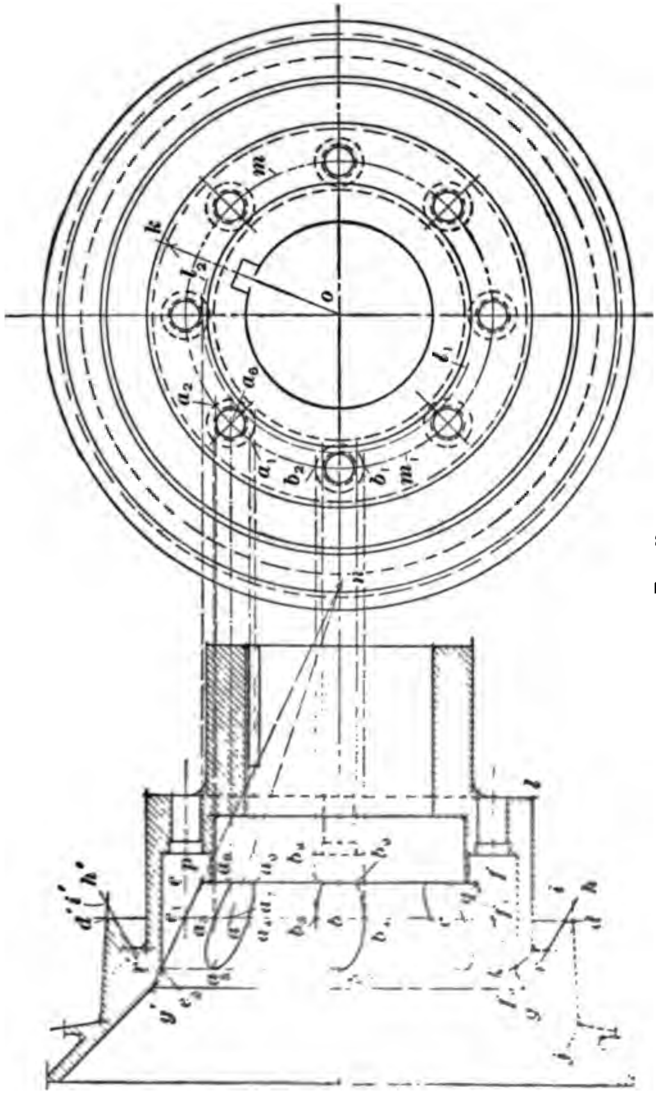


FIG. 33

construction of the piece represented. This part is to be finished all over, as indicated by the note between the two views.

91. Begin by drawing a horizontal center line $3\frac{5}{8}''$ below the upper border line, extending across the whole width of the Plate. Draw the vertical center line of the end view $3\frac{1}{4}''$ from the right-hand border line and with the intersection *o*, Fig. 35, of these lines as a center draw the various circles outlining the bore and the receding surfaces of the shell, with the diameters given in the sectional view of the drawing. The scale to be used is $6'' = 1$ ft. With a radius of $6\frac{3}{8}'' \div 2 = 3\frac{3}{16}''$, draw a circle, around which the centers of the eight holes for the clamping bolts are to be symmetrically located and which are spaced equally distant apart, as indicated. The position of the center line *o k* for the keyway is obtained by drawing two circular arcs with a radius greater than half the distance between two adjoining holes and connecting the point of intersection *k* with the center *o*. It will be noticed that each full-line circle representing a bolt hole is concentric with two dotted circles, which represent the outlines of the countersunk parts of the holes.

92. Next proceed to draw the sectional elevation of the shell by drawing a vertical line, representing its right-hand end, $\frac{3}{8}''$ to the left of the end view. Draw another vertical line $9\frac{1}{8}''$ to the left of the first, thus obtaining two lines that limit the length of the shell. Parallel with these lines draw others that pass through the various external edges of the shell. By projecting horizontal tangents from the top and bottom points of the circles in the end view which represent similar edges, and letting them intersect corresponding verticals in the sectional elevation, the exact locations of the edges are determined. Proceed to outline the internal surfaces of the shell, the bore, and the keyway in a similar manner.

93. It will be noticed that on this Plate several dimensions are given to thousandths of an inch. Most of these dimensions refer to the clamping surfaces of the shell, clamping ring, and commutator bars. These parts are turned to fit gauges prepared by the toolmaker, who lays out the gauges and makes them suit the dimensions given. The purpose of giving these dimensions so exactly is to call attention to the fact that great accuracy is required and that measurements at these places are to be determined either by gauges or with micrometers. This practice of giving *accurate* dimensions in decimals and *approximate* dimensions of a machine part in halves, quarters, eighths, sixteenths, etc., of an inch, is now largely adopted in the better class of drafting rooms, the purpose of its adoption being to show the workman at a glance which parts of a machine part require to be very accurate and which do not, thus tending to prevent the waste of time incidental to needless accuracy.

In regard to laying off on the drawing dimensions given in decimals, lay off to the nearest 64th inch, actual measurement. This is ascertained in the following manner: Consider the dimension 9.416″ in the sectional elevation of part **1**. As the scale used for drawing this is 6″ = 1 ft., or one-half size, the actual distance to be laid off using a full-size scale is $9.416'' \div 2 = 4.708'' = 4'' + .708''$. But .708″ expressed in 64ths is $.708'' \times \frac{64}{64} = \frac{45.312''}{64} = \frac{45}{64}''$ to the nearest 64th inch. Hence, the actual distance, measured with a full-size scale, is $4\frac{45}{64}''$. Again, part **3** is drawn full size; hence, the dimension 1.594″ expressed to the nearest 64th inch is $1\frac{38}{64}''$, since $.594'' = .594'' \times \frac{64}{64} = \frac{38.016''}{64} = \frac{38}{64}''$ to the nearest 64th inch.

To find the nearest 64th inch corresponding in value to a dimension given in thousandths of an inch consult Table V, found at the end of this paper under Useful Tables.

94. Among the parts demanding great accuracy is the clamping surface indicated by the lines *r h* and *r′ h′*, Fig. 35. The correct position and inclination of this surface is determined in the following manner: Draw a vertical line at a distance of 3.692" from the left-hand end of the shell and intersect this line with two horizontal lines 9.710" apart and equidistant from the horizontal center line, thereby locating the two points i, i'. From these points draw lines $r h$ and $r' h'$ at angles of 30° with the axis of the shell or with a line parallel to the axis, such as the line $k l$. Now draw a vertical line $d d'$ $3\frac{1}{16}$" from the left-hand edge of the shell and find by trial a radius and center such that an arc can be described tangent to $d d'$, $h r$, and $i j$. Also, draw a line parallel to and $\frac{5}{8}$" to the left of $d d'$ and with a radius of $\frac{3}{16}$" find a center from which an arc may be described tangent to this line and tangent also to $h r$ and $l k$. So proceed with the upper half.

95. As the countersunk parts of the holes intersect the inside of the shell where it is cone shaped, the outlines of the holes will appear elliptical instead of circular, as indicated by the curves a, b, and c.

The outlines of the apertures a, b, and c have been carefully defined by a number of points found by the principles of projection. It is not necessary for the student to repeat this construction; he may limit himself to a few points only and by means of these draw the curves, approximately, freehand. The method of laying out the curve for the aperture a is identical with that for b and c. Connect the points e_2 and f_2 by a straight line; the extreme points of the curves will be situated on this line. Likewise connect points e_1 and f_1, on which line, points limiting the width of the various curves are to be located. The line $e_1 f_1$ is the end view of the circle $m m_1$. From the points a_1 a_2, where this circle intersects the largest of the circles representing the hole a, draw perpendiculars to the line $e_1 f_1$. The points of intersection a_3, a_4 are two points on the curve, limiting its extreme width. To find the point a_5 at the extreme end of the curve, produce the line $e_1 e_2$ until it intersects the horizontal center line of the two views at n. Project the center a_6, in the end view, on the line $e_1 f_1$; the points of intersection a_7 will be the center of the curve. Draw a line through n and a_7, intersecting line $e_2 f_2$ at a_8; this point is the extreme end of the curve. Assuming that the corner at point p is a sharp corner, project this point to the vertical center line of the end view, and through the point thus found draw the circular arc $l_1 l_2$ with o as a center. This is part of the end view of a circle represented by the line $p q$. From the points where this arc intersects the circle $a_1 a_2$, draw perpendiculars to the line $p q$; the points of intersection a_6 and a_9 will then locate the inner ends of the curve. Connect the points a_6, a_3, a_8, a_4, and a_9 by a curved line, drawn freehand; the result is the outline of the aperture a.

The location of the curve representing aperture b is somewhat easier to find. From the points of intersection b_1 and b_2 between the circle $m m_1$ and the circle indicating the hole b in the end view, draw perpendiculars to the line $e_1 f_1$, thereby locating the points b_3, b_4. The point of intersection between the line $e_2 f_2$ and the horizontal center line of the views gives point b_6. To locate the points b_8, b_9, draw perpendiculars, intersecting the line $p q$ from the points of intersection between the arc $l_1 l_2$, and the circle $b_1 b_2$.

It should be noted that while the lines $e_2 p$ and $f_2 q$ are here represented as straight lines, they should in reality be flat curves with their convex sides toward the horizontal center line of the view, because the elliptical curve, here shown in side view, is not located in a plane, but on a conical surface.

Attention is also called to the fact that while in this case the left-hand part of the end view has been used for projection, it is really the right-hand half that is represented in the sectional elevation. The left-hand half was used to avoid drawing projection lines across the whole of the end view.

Outlines of holes, as the above, or curves indicating the junction between intersecting parts, are generally drawn in the manner just described, partly to save time and also because such curves are bound to appear with the proper outlines and in the correct positions on the finished part, as a result of the process of manufacture, irrespective of how they are indicated on the drawings. But there are occasions when the draftsman desires to project such curves in their true form, and he should therefore be prepared to do this with ease and accuracy.

96. The clamping ring, part 2, is also made of steel, cast from pattern *1007–B*, and slips over the shell at *d*, as shown in Fig. 38. It is shown in a sectional elevation and an end view, and the horizontal center line, common for both, should be $3\frac{1}{16}''$ above the lower border line. First

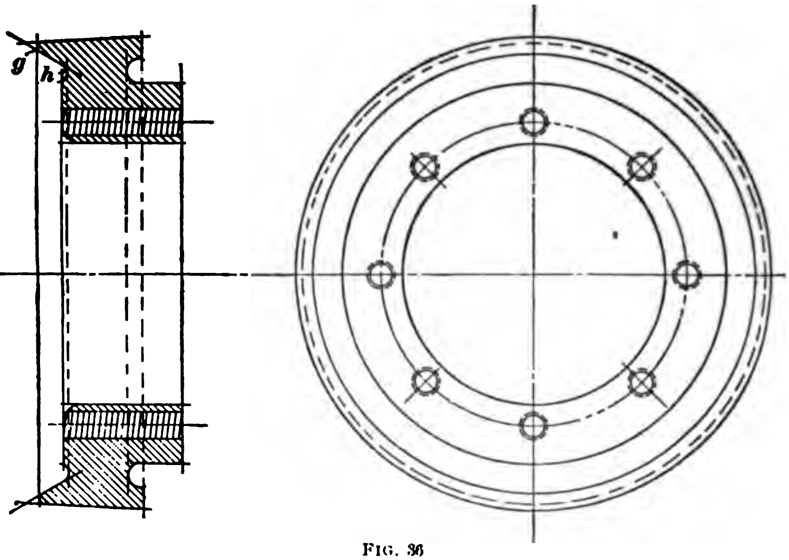


FIG. 36

draw the end view, locating its vertical center line $6\frac{7}{16}''$ from the left-hand border line. It is noticed that the circles in full lines, indicating the holes, are surrounded by circles in dotted lines. The latter indicate the diameter at the bottom of the thread in the hole, here $\frac{9}{16}''$, or what is the same thing, the diameter of the bolts at the top of the thread. The full-line circles indicate the top of thread in the hole or the diameter of the drilled hole, which is .454", or about $\frac{11}{16}$". A space of $1\frac{3}{16}$" (full size) should be left between the end view and the sectional view of the clamping ring. In the latter view the tapped holes, shown in cross-section, should in reality have 12 threads per inch, but owing to the small scale to which they are drawn, it is difficult to represent the full number, and they were therefore drawn as shown. The method of laying out the surface *g h*, Fig. 36, with an inclination of 30° to the horizontal center line, is similar to the one described with reference to Fig. 35.

97. The commutator bar, part 3, is shown in an elevation, an end view, and in a sectional view taken on line *k l*,

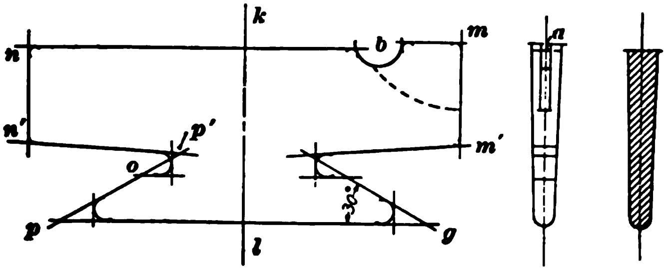


FIG. 37

Fig. 37; it is drawn full size. These commutator bars are made in long strips and are sawed off to proper length. After being assembled mica strips are placed between the bars, and then the ends of the assembled bars are turned to fit the clamping ring and shell. The majority of the dimensions are very important and are therefore indicated by inches and decimals. Locate the bottom, or base, line *pg* of the commutator bar $3\frac{1}{4}$" (full size) above the lower border line and draw the vertical center line *k l* $5\frac{7}{16}$" from the right-hand border line. Locate the center lines of the end view and sectional view [illegible] and [illegible], respectively, from the right-hand border line. The commutator bar is provided with [illegible] required by the toolmaker for making the gauges [illegible] turning it to size; [illegible] required for drawing it [illegible] by calculation

The height of the bar along the line kl, Fig. 37, is given in the sectional view as $1\frac{13}{16}''$, but the length of the side mm' and the distance of the point m above the line pg must be found by calculation. The point m' is located on a circle the diameter of which is 9.980″; as pg is tangent to a circle of 8.375″ diameter, the distance of m' above pg is: $\frac{9.980'' - 8.375''}{2} = .8025''$. The length of the side mm' is found in the same manner and is: $\frac{12.125'' - 9.980''}{2} = 1.0725''$. With the exception of the side mm' and the recesses a and b, the two parts of the bar, as divided by the center line kl, are alike. The point o is located on the line pp', drawn at an angle of 30° to pg, and its distance above pg is found by means of the diameters given on the Plate. Other points, such as p', are found by means of intersecting lines, the location of which are determined either by a diameter or a distance from one of the boundary lines. The dotted bottom line of the recess in the side mm' is drawn with a radius of $1\frac{5}{32}''$ from a center located on mm', the lower edge of the recess being $\frac{11}{16}''$ below the point m.

98. Part 4 is one of the copper washers that fit under the heads of the clamping bolts, thereby making the commutator oil-tight and preventing oil getting from the bearing back of the commutator into the armature. The washer is shown in a plan view and a sectional elevation. The vertical center line, common for both, should be $5\frac{3}{16}''$ from the right-hand border line and the center of the plan view should be laid off on this line $1\frac{3}{8}''$ above the lower border line. A space of $\frac{7}{16}''$ should be left between the two views.

The construction of parts 4 and 5 is not explained by means of any text illustrations, as the student should be able to complete the drawings of both without any supplementary instructions.

99. Part 5 is one of the clamping bolts, the heads of which fit into the holes a, b, c, e, f in the shell, as shown in

Fig. 35. These bolts screw into the clamping ring, and the remarks made about the threaded holes, as to threads per inch, apply also to the bolts. The center line should be $6\frac{15}{16}$'' from the right-hand border line and the under side of the head should be $2\frac{5}{8}$'' above the lower border line.

100. The assembly drawing is to be located in the upper left-hand corner of the plate, on the same center line as the

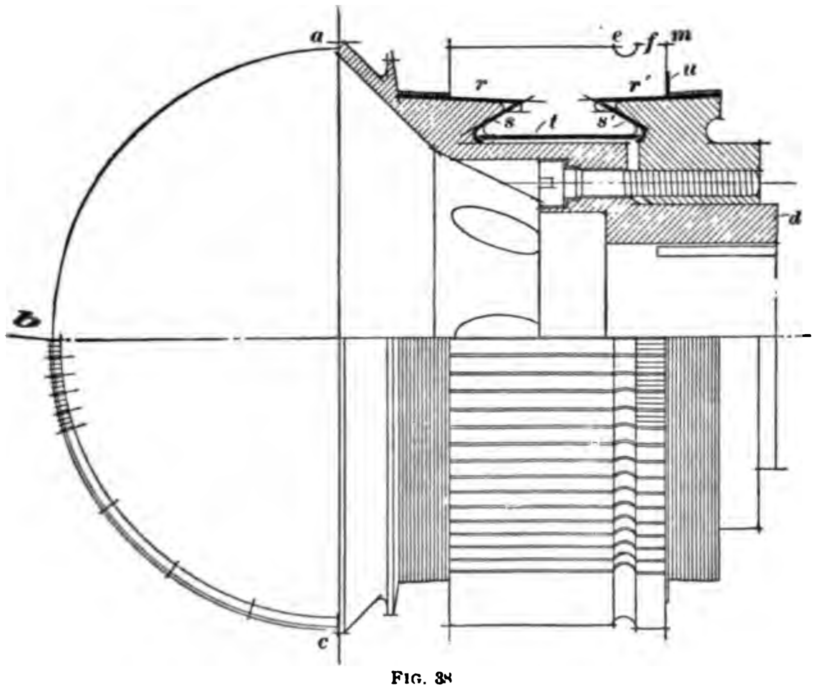
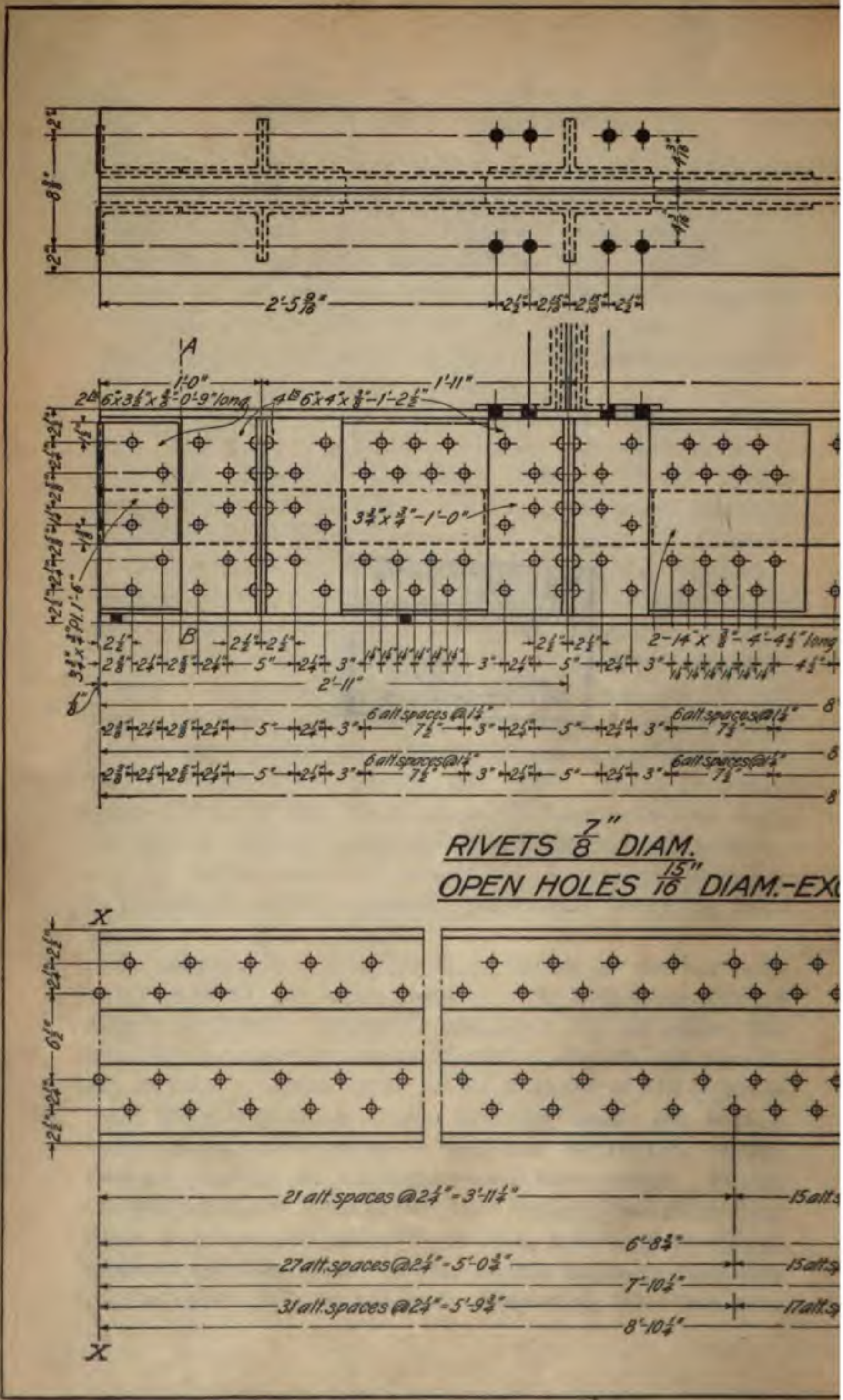


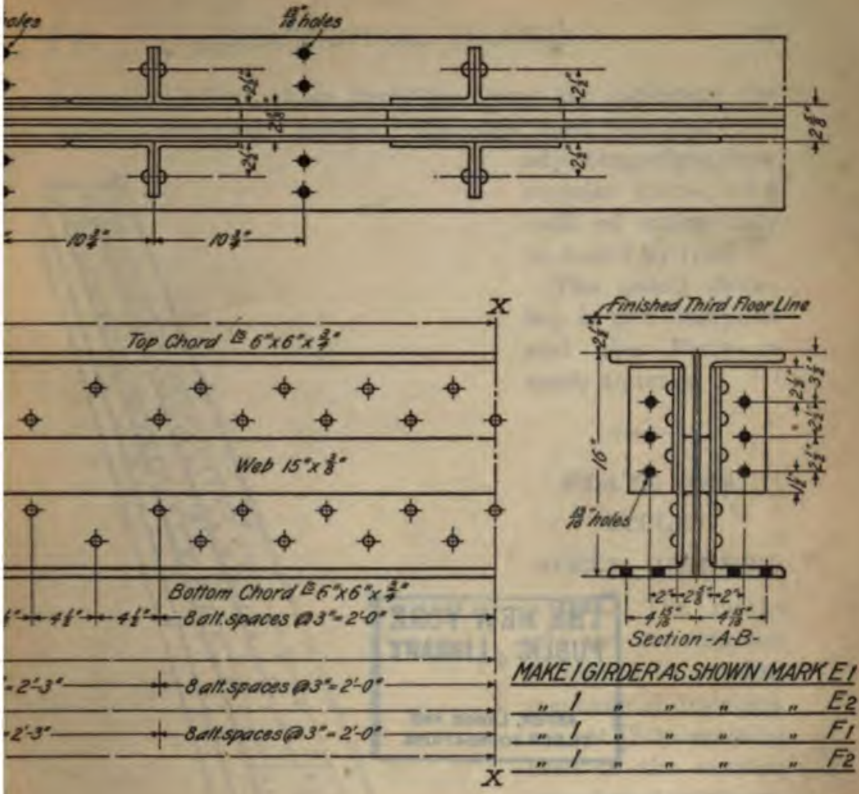
FIG. 38

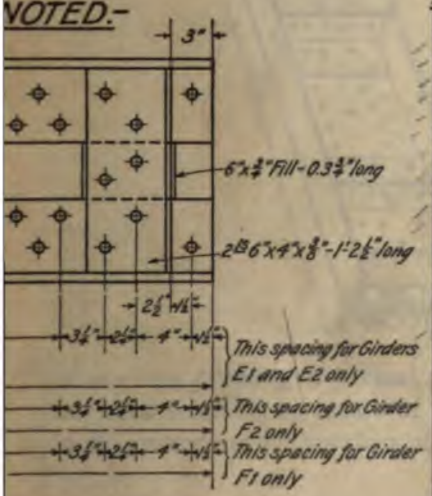
shell, with a space of $\frac{3}{8}$'' between its left-hand boundary line and the left-hand border line. The upper half of this assembly drawing is shown in cross-section. Begin by drawing the shell in the upper half, projecting the various diameters over from the adjoining sectional elevation; then draw the clamping ring and the clamping bolt. The relative positions of these parts are clearly indicated by the dimensions given in the assembly drawing. In Fig. 38 the various mica rings, required for insulating the commutator bars from the shell and clamping ring, are indicated by letters *r*, *r'*, *s*, *s'*, *t*, and *u*. Each of these rings has a thickness of .063"; this dimension has been slightly exaggerated on the drawing, which is permissible on working drawings. Those parts of the two mica rings *r*, *r'* that extend beyond the ends of the commutator bars are securely fastened in place by twine, well shellaced.

The lower half of this view, in which the vertical outlines may be obtained by projection from the upper half, may now be drawn. But few commutator bars are shown in this assembly drawing, as it is not customary to spend the time required to indicate the position of all the bars. To properly space the latter draw the semicircle *a b c*, Fig. 38, with a diameter of 12", that being the diameter of the commutator at the middle of the commutator bars. Divide the quarter circle *b c* in 5 equal parts, and the part next to *b* again in 5 parts. At either side of these division lines, lay off one-half of the insulation thickness which leaves in each division a space equal to one bar. At the middle of this space mark off the width of the recess; viz., .102". Lines projected across from the first 12 divisions will locate the first three bars in the assembly drawing. The projection of the arcs *e* are flat curves near the center line, gradually increasing in curvature as the segments get farther away, as indicated.

In cases where it is desirable to lay off all the bars and every part of the same correctly, the following method may be pursued: Draw the semicircle *a b c* as before, but add the two quarter circles, shown in Fig. 38, the outside one having a radius equal to the distance of the point *m* from the commutator center, and the inside one with a radius equal to the distance between the bottom of the recess *e*, near the ear *f* and the commutator center. Divide the quarter circle *b c* as before, but continue the subdividing down to point *c* and make the dividing lines long enough to intersect all three arcs. In Fig. 38 this has been done only in the upper fifth of the arc. Projecting lines are now


2'-5 9/16"
A
B
1'-0"
1'-11"
2 L^s 6"x3 1/2"x 3/8"-0'-9" long
4 L^s 6"x4"x 3/8"-1'-2 1/2"
3 3/4"x 3/4"-1'-0"
2-14"x 3/8"-4'-4 1/2" long
2'-11"
6 alt. spaces @ 1 1/4"
RIVETS 7/8" DIAM.
OPEN HOLES 15/16" DIAM.-EX
X
21 alt. spaces @ 2 1/4" = 3'-11 1/4"
6'-8 3/4"
27 alt. spaces @ 2 1/4" = 5'-0 3/4"
7'-10 1/2"
31 alt. spaces @ 2 1/4" = 5'-9 3/4"
8'-10 1/4"





Bill of Materials for 4 Girders Mark F1-F2-E1-E2

No. Pcs	Pcs	Section	Length	Remarks	Location
4	Ls	6"x6"x 3/4"	15'-2"	Top Chord R+L	For Girder E1-E2
2	Pls	15"x 3/8"	15'-2"	Web	" " " "
4	Ls	6"x6"x 3/4"	15'-2"	Bott. Chord R+L	" " " "
2	Ls	6"x6"x 3/4"	16'-3 1/2"	Top Chord R+L	" Girder F2
1	Pl.	15"x 3/8"	16'-3 1/2"	Web	" " "
2	Ls	6"x6"x 3/4"	16'-3 1/2"	Bott. Chord R+L	" " "
2	Ls	6"x6"x 3/4"	17'-3 1/2"	Top Chord R+L	" " F1
1	Pl.	15"x 3/8"	17'-3 1/2"	Web	" " F1
2	Ls	6"x6"x 3/4"	17'-3 1/2"	Bott. Chord R+L	" " F1
32	Ls	6"x4"x 3/8"	1'-2 1/2"	Stiff R+L	" Girders E1 E2 F1 F2
8	Ls	6"x3 1/2"x 3/8"	0'-9"	R+L	" " " " " "
8	Ls	6"x4"x 3/8"	1'-2 1/2"	Stiff R+L	" " " " " "
8	Pls	6"x 3/4"	0'-3 3/4"	Fill	" " " " " "
8	"	14"x 3/8"	4'-4 1/2"	Stiff	" " " " " "
8	"	3 1/2"x 3/8"	1'-6"	Fill	" " " " " "
8	"	" "	1'-0"	Fill	" " " " " "

STRUCTURAL STEEL GIRDERS

DRAWN BY................

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drawn, as before, those from the inner arc indicating the lowest points in the groove. Through these points and the adjoining edges draw circular arcs, the radii of which may be found by trial.

The pencil drawing is now complete and the Plate is ready to trace.

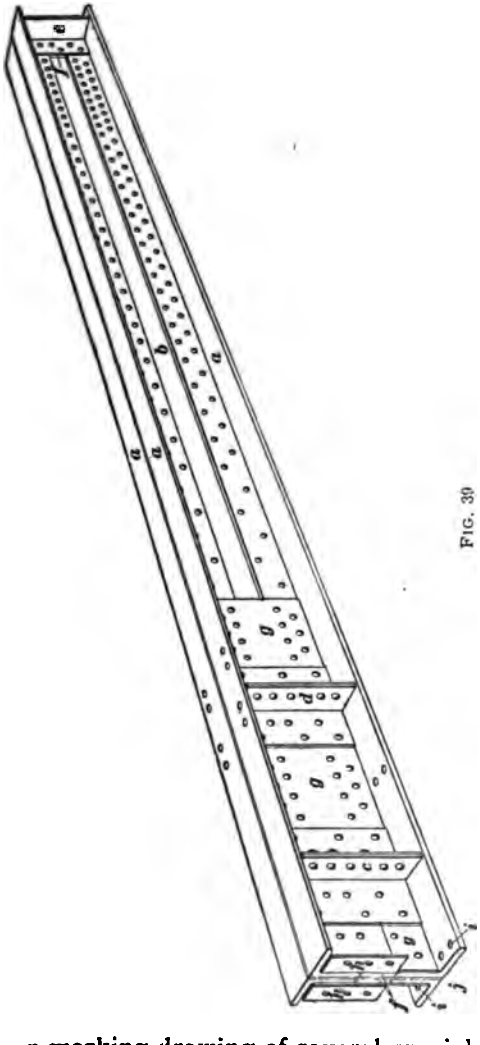

FIG. 39

PLATE 1008,
TITLE:
STEEL GIRDERS

101. The methods and conventions employed in making mechanical drawings are not all universally used in the various branches of engineering, as, for instance, in structural engineering, which concerns itself mainly with the construction of columns, girders, braces, etc. used in the construction of bridges, modern office buildings, etc. As an example of structural construction, the shop or working drawing of several special, built-up steel girders has been selected, by means of which the methods employed in the execution of this class of drawings will be shown.

Before proceeding with the drawing the student should familiarize himself with the names and purposes of the several parts, as given in the following description.

102. Referring to Fig. 39, a perspective view of a girder, the angles marked *a*, *a* are the **flange angles**, the upper pair forming the **top chords** and the lower the **bottom chords** of the girder. Connecting these chords is the **web-plate** *b*, while the vertical angles *c*, *d*, and *e* are known as **stiffeners.** The latter are required at the ends of the girder at *c* and *e* for the purpose of strengthening the web at the points where the girder is supported. At *d* stiffeners are also placed to reenforce the web, because at this point the upper chord of the girder is supporting the concentrated load presented by a column. At *f*, *f* are shown packing pieces, commonly called **fillers**, from the fact that they are used to fill a space otherwise open, which is undesirable where a compactly built-up part is required. These fillers are used wherever it is necessary to rivet through a space that would otherwise be vacant. **Reenforcing plates,** such as *g*, are frequently used to further stiffen the web of a plate girder, at the places adjacent to the points of support and beneath concentrated loads. The end *j* of the girder is to be secured to a structural steel column, and for this purpose the angle-iron **clips** *h*, *h* and the holes *i*, *i* through the lower flange angles are provided.

The structural girder under consideration is peculiar in that its depth is very small in comparison with its span, in consequence of which the girder is heavy for the load it is required to support. The necessity for keeping the girder shallow is that it may not diminish the **headroom** or height of the room beneath.

103. All the little circles shown on the chord and stiffeners (see Plate 1008) represent rivets. Attention is called to the fact that some of these are shown black. Whenever a blackened circle is shown it indicates a hole and not a rivet and that the rivets belonging to these holes are to be

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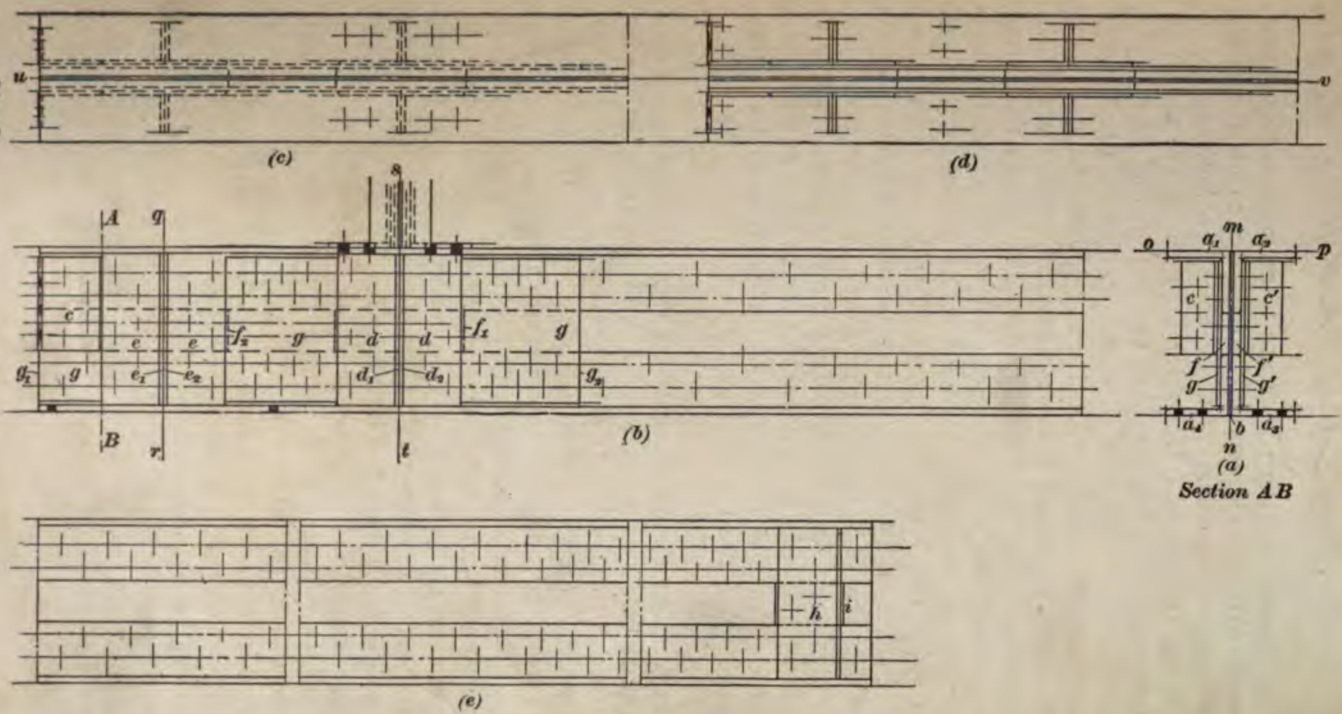


FIG. 40

driven during erection; they are therefore known as **field rivets.** All other rivets are to be driven in the shop. When shown in elevation these holes are indicated by a blackened rectangle. Holes for field rivets are shown in the upper chord, Fig. 39, over the stiffener *d* and in the lower chord to the left of *c* and *d*; also in the clips *h*. Wherever the field-rivet holes are hidden behind some other parts the holes are not blackened. For instance, in the main elevation of the girder, Fig. 40 (*b*), four rivet holes are shown above the stiffener *d*. Of these the two central ones are partly hidden by the angles of the post resting at this place; one-fourth of each hole is therefore not blackened. As these four holes are not shown in section they should in reality be indicated by dotted lines; but in order to make the field rivets more conspicuous to the workmen the ordinary rules are departed from and the conventional method here shown is adopted, to indicate simply the *position* of the rivets.

104. The Plate represents the working drawings of four separate girders, the shortest being 15 ft. 2″ and the longest 17 ft. $3\frac{1}{2}$″ in length. It would evidently be impossible to show each of these girders complete and at the same time to a scale large enough to make a readable drawing, without requiring an unnecessarily large sheet. To obviate this the girders have been divided into several sections and some parts broken away, as being simply duplicates of the part remaining. In this manner one drawing may be made to represent four different girders. The method of indicating the places where breaks occur differs from that heretofore described. It is here indicated by drawing a line consisting of a long dash and a dot along the adjoining parts of the break. Adjoining sections need not necessarily be arranged in one row, but may be placed in several rows, in this manner making the drawing still more condensed. On this Plate the first section is placed by itself and the line of break marked with the line *XX*. The remaining three sections are placed in a row below, in which the first section also has a line *XX* indicating that this end is to be considered as contiguous to the one similarly marked. The parts removed by the two breaks in the lower row contain a number of rivet holes, which are spaced similarly to those in the remaining parts; it would therefore be superfluous to show them. The scale to be used is $1\frac{1}{2}'' = 1$ ft.

105. The distance between the centers of two rivets is called their **pitch,** commonly designated on the drawing by the word **space.** The space need not necessarily refer to the spaces between rivets in one row, but may also refer to spaces between alternate rivets in two parallel rows. For instance in the upper elevation, near the middle, are shown several spaces marked $4\frac{1}{2}''$, meaning the spaces between two alternate rivets in separate rows. In the lower elevation, beginning at the left, is found the note "31 alt. spaces @ $2\frac{1}{4}'' = 5'\text{–}9\frac{3}{4}''$"; this means that the drawing should show thirty-two rivets alternating in two rows and spaced $2\frac{1}{4}''$ apart. The rivets in each row have a pitch of $4\frac{1}{2}''$. The saving in length by this method is evinced by the fact that the drawing shows only nineteen spaces of the thirty-one required. It is customary to indicate not alone the space between the rivets and the total number in each series, but also the total distance between centers of the first and last rivet in one series, the note "$5'\text{–}9\frac{3}{4}''$" in above note referring to this distance. Each series is made up of as many rivets as possible without including rivets of a different pitch. As soon as a change takes place in the pitch a new series is arranged, as found, for instance, to the right of the note just referred to, where the following note is found: "17 alt. spaces @ $1\frac{1}{2}'' = 2'\text{–}1\frac{1}{2}''$," meaning that the spacing has been reduced from $2\frac{1}{4}''$ to $1\frac{1}{2}''$.

106. In the drawing, the four girders are designated by the marks *E 1*, *E 2*, *F 1*, and *F 2*, but these marks are only to be found under the lower three sections, at which place all changes have been made both as to spacing of rivets and difference in length of girders. The left-hand parts of all four girders, Fig. 40 (*b*), are alike and no distinction need therefore be made between them at this point. The marks *E 1*, *E 2*, *F 1*, and *F 2* are shop marks and are usually painted on the work in white lead before they leave the mill. To them the erector refers in placing the work in position, as the marks correspond with similar marks on an assembly drawing used in erecting the work in the field.

107. The dimensions of the various angles used in constructing the girder are not given in detail, they being unnecessary on a working drawing. All that is required is to give the size of the angles. The note on top of the left-hand part of the girder, "2 **Ls** 6" × 3½" × ⅜"—0'-9" long," means that the part indicated is made up of two angles, or **Ls**, having legs 6" and 3½" long, respectively, each of which is ⅜" thick. These angles come in lengths of about 15 to 20 feet and can afterwards be cut in smaller lengths, to one of which the length "0'-9"" refers.

The fillers are also cut from long bars varying in width and thickness according to the space to be filled. For instance, the note "3¾" × ¾" Pl 1'-6"" at the head of the girder means that the filler plate is to be cut from a bar 3¾" wide by ¾" thick, and to a length of 1 ft. 6".

It will be noted that the manner of indicating dimensions given in feet and inches on this Plate differs from that used on the other Plates described in this paper. Thus, instead of expressing 5 feet 6¼ inches as 5 ft. 6¼", it is here expressed 5'-6¼", in conformity with the working drawing from which the Plate was made. The former method is to be preferred (see Art. **20**), but if the latter is used, never omit the short dash between the feet and inches.

In order to aid the student in drawing the angles in the chords, the dimensions of which are not fully given on the Plate, a sectional view of one, fully dimensioned, is given in Fig. 41. The radii of the fillet and corners are more or less arbitrary, the various rolling mills having their own standards.

The rivets used in this girder have ¾" and ⅞" shanks with heads 1¼" and 1 7/16" in diameter and 9/16" and 39/64" high, respectively. The holes for the rivets are generally punched $\frac{1}{16}''$ larger than the shank, the size of a rivet being indicated by the diameter of the shank *before* the rivet is driven. All $\frac{3}{4}''$ rivets require holes $\frac{13}{16}''$ in diameter. The rivets when driven fill these holes; consequently the *driven* size of a rivet = nominal size + $\frac{1}{16}''$. At the places where field rivets are to be driven, the notes "$\frac{15}{16}''$ holes" are to be found, indicating that $\frac{7}{8}''$ rivets are to be used.

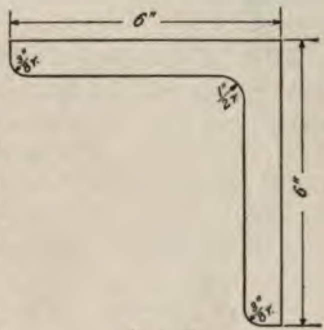


FIG. 41

108. To draw the Plate, begin by drawing the sectional elevation of the girder, Fig. 40 (*a*). This section is taken along the line *A B*, Fig. 40 (*b*), and shown as it would appear when looking along the girder from the right-hand end. Locate the center line *m n* $1\frac{11}{16}''$ from the right-hand border line, and the top line *o p* $3\frac{3}{4}''$ below the upper border line. Lay off one-half the thickness of the web-plate *b* to either side of center line and draw the four angles a_1, a_2, a_3, and a_4, according to the dimensions given in Fig. 41.

Between the upper and lower angles insert the two fillers *f*, *f'*; then add the reenforcing plates *g*, *g'*, and, finally, the clips *c*, *c'*. It should be noted that the reenforcing plates extend only to where the curve of the fillets on the chord angles begin, while the stiffeners have to extend clear to the angles of the top and bottom chords, and for this reason have their inner corners chipped off. Draw the center lines of the rivet holes, and indicate their location by blackened rectangles or circles (see Plate) where field rivets are to be indicated. Where the rivet heads are shown in side view indicate them by means of semicircles with diameters, as given above. On structural drawings it is not customary to indicate cross-sections by section lines; they are usually left blank or filled in entirely, either with ink or some dark color. If thus filled in, the spaces indicating field rivets are left white.

The note "Finished Third-Floor Line," found over the sectional elevation, means that the floor above the girder, when laid, will come to a height indicated by the line of dashes.

109. Next draw the elevation of the first section of the girder, locating its left end $\frac{3}{8}''$ from the left-hand border line. The limiting lines of the top and bottom angles may be projected from the section just drawn, likewise the lines limiting the width of fillers and reenforcing plates. Next locate the center lines *q r* and *s t* of the stiffeners *d* and *e*, Fig. 40 (*b*), and lay off their total width; also the sides of the legs d_1, d_2, e_1, and e_2, which project outwards at right angles to the plane of the paper. Lay off the clips *c*, one leg of which is seen to project a distance of $\frac{1}{8}''$ beyond the end of the girder. By referring to the sectional elevation, it will be noticed that the top of the clips is 1" below the upper side of the chord. Draw the reenforcing plate *g* extending from g_1 to g_2. The note "$2 - 14\frac{1}{2}'' \times \frac{3}{8}'' - 4'\text{-}4\frac{1}{2}''$ long," just below the lower chord, refers to this part. Indicate the fillers f_1 and f_2, the first being of a length equal to the width of *d*, and the latter of a length equal to the combined width of *c* and *e*. These fillers are covered both by the stiffeners and the reenforcing plates, and must therefore be indicated by dotted lines, which are shown beyond the edges of the stiffeners in order that they may be seen, though in reality they coincide with the edges of the stiffeners. Lay off the section line *X X* at a distance of 8 ft. $5\frac{1}{4}''$ from the left-hand end of the girder.

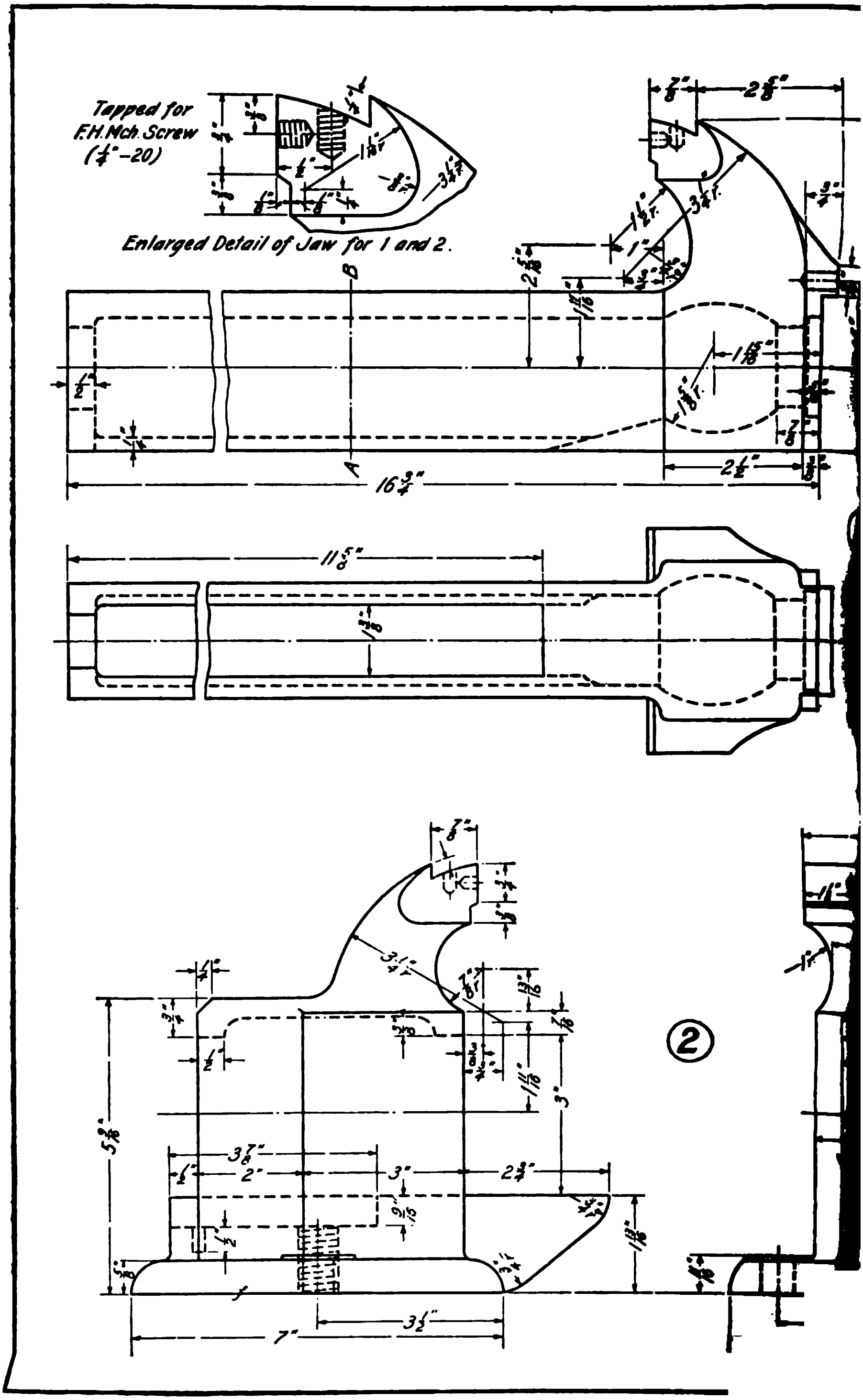
All the rivets are located in six horizontal rows at the distances from upper side of girder indicated on the Plate. Draw these horizontal center lines. Select any one of these lines, as for instance the lowest, and lay off on same the distance between centers of rivets, as given in any one of the rows below the girder, all of which are seen to be alike. From the lowest center line, verticals are drawn by means of the T square and triangle to the other center lines, intersecting them at the proper places and thereby locating the centers of the various rivets. It is unnecessary in the pencil drawing to draw the circle representing the rivets; this may be postponed to the making of the tracing, when the intersections of the rivet center lines will indicate the positions of the centers around which to draw the little circles. In some shops it is customary to omit these circles altogether and simply indicate the positions of the rivets by their center lines.

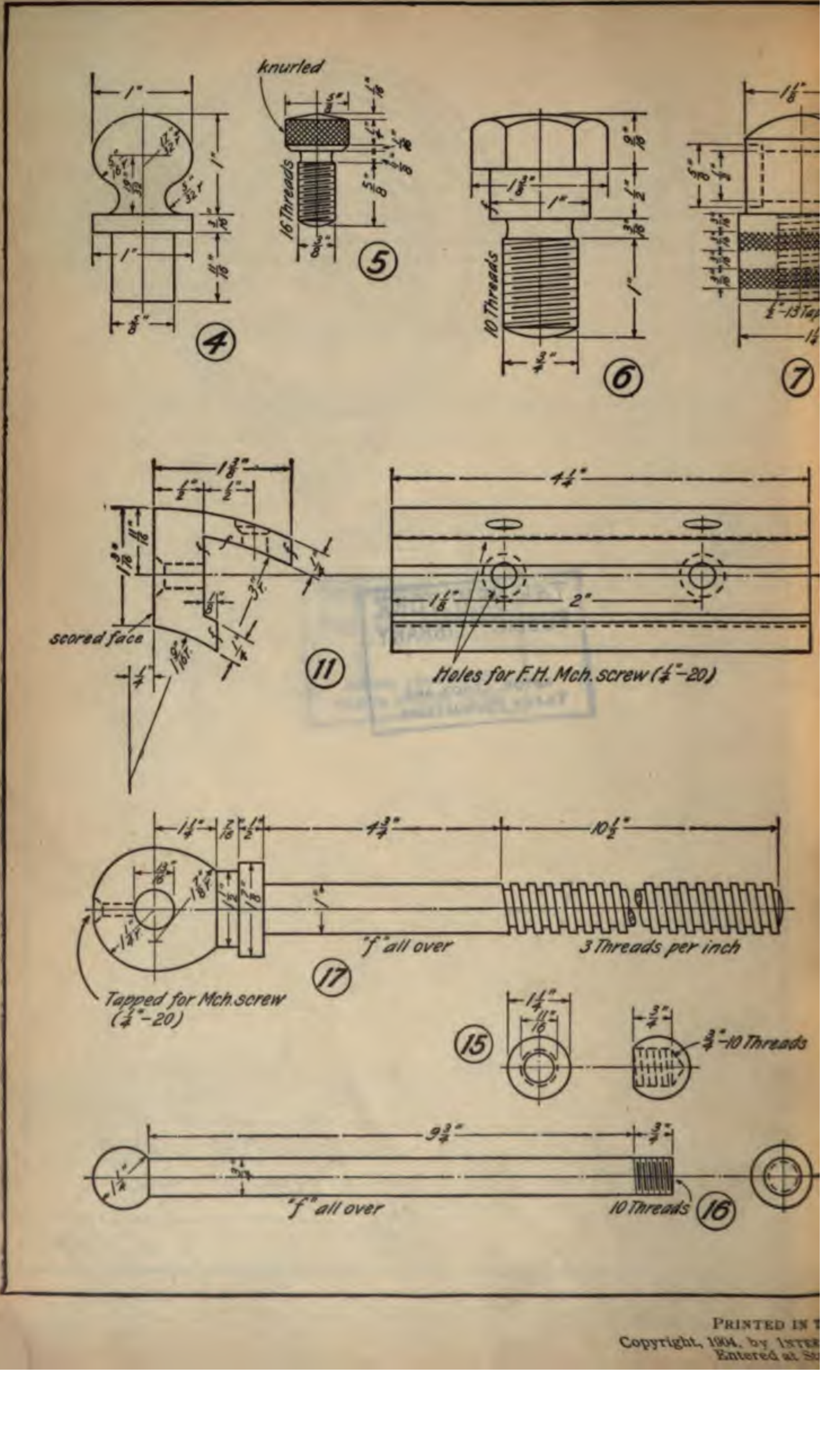
110. The first of the two plan views of the girder, shown in the upper part of the Plate and in Fig. 40 (*c*) may now be drawn by first laying off the center line *u v* $1\frac{1}{8}''$ below the upper border line. Locate the left-hand end by drawing a vertical line from the corresponding end in the elevation and locate the section line at its right-hand end, 8″ from the left-hand border line. The length of those angle legs which stand at right angles to the center line *u v* may be found by consulting the notes in the elevation. The holes for the field rivets will in this view appear as circles which are to be blacked in. The locations of the other limiting lines are found partly by projection from the elevation and partly by transferring the measurement from the sectional end view, Fig. 40 (*a*).

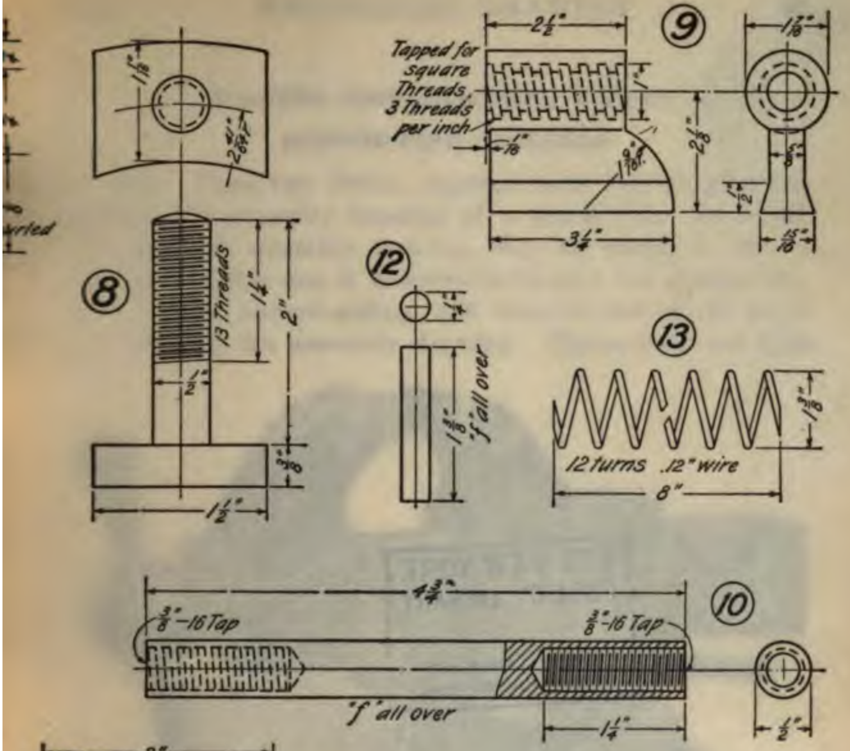
111. The other plan view, see also Fig. 40 (*d*), shows the girder in a sectional view taken along an imaginary horizontal center line in the elevation. The view is similar to the one previously drawn, except that some of the parts are shown in full instead of dotted lines. Most of the limiting lines are found by projecting horizontals from the other plan view, the position of the remaining limiting lines being determined by direct measurement; all dimensions extending in a horizontal direction are found in this manner. Those field rivets in the lower chord that are not visible in the other plan are here indicated, likewise those in the end stiffener.

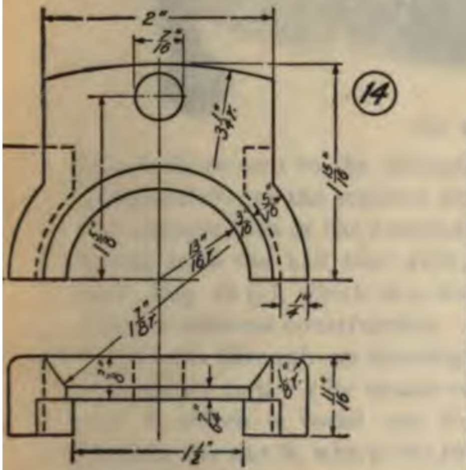
112. Next proceed to draw the right-hand parts, see also Fig. 40 (*e*), of the four girders. Locate the lower side of the same $2\frac{3}{8}''$ above the lower border line, letting the left-hand end lie in a line with the same end of the other elevation. This elevation is divided in three sections. Make the first section 3″, the second $3\frac{15}{16}''$, and the third $2\frac{25}{32}''$ long, leaving a space of $\frac{5}{32}''$ between each section. In other respects this elevation is drawn in the same manner as the one immediately above it. Locate the stiffener *h*, 3″ from the right-hand end and add the filler *i*, here shown in full lines.

113. The dimensions may now be added to the various views, attention being given to the method of arranging the dimension lines that indicate the lengths of the complete girder and girder sections. Between the break line *XX* of the lower elevation and its right-hand end there are found three pairs of dimension lines, the first of which refers to the girders marked *E 1* and *E 2*, the second to girder *F 2*, and the third pair to girder *F 1*. In each pair the upper line refers to the spacing of rivets and the lower to the total length of the section. Locate the first dimension line $\frac{1}{2}''$ below the girder, the second line $\frac{7}{16}''$ below the first, and leave a space of $\frac{3}{16}''$ between each of the remaining lines. The dimension lines found under the other elevation of the girder, represented by Fig. 40 (*b*), are supposed to be continuations of these six lines and should be located in the same manner. Draw the other dimension lines and insert corresponding dimensions, following closely the method used on the Plate as to their location and style of lettering. Add the notes referring to rivets and holes and the one referring to number and marks on girders. Lay off the space required for bill of materials and divide it into the necessary number of vertical and horizontal spaces. The abbreviations "Fill" and "Stiff" refer to fillers and stiffeners, respectively. *R* and *L* means right and left. When parts symmetrically placed are marked in this manner, it calls attention to the fact that they are not alike and that care should be exercised in order to put them in their proper places.


Tapped for
F.H. Mch. Screw
(1/4"-20)
Enlarged Detail of Jaw for 1 and 2.
16 3/4"
11 5/8"
7"
3 1/2"
5 3/8"
②


knurled
16 Threads
10 Threads
4
5
6
7
scored face
Holes for F.H. Mch. screw (1/4"-20)
11
"f" all over
3 Threads per inch
Tapped for Mch. screw (1/4"-20)
17
15
3/4"-10 Threads
"f" all over
10 Threads
16





1	1/4"-20-F.H.Mch.screw for 17.	20	Machine steel		
1	Fill.F.H.Mch.screw 3/8"-16-5/8" long	19	Machine steel		
8	1/4"-20-F.H.Mch.screw for 1,2 & 11	18	Machine steel		
1	Vise screw	17	Cast iron	Pattern	G
1	Rod for 17	16	Machine steel		
1	Nut for 16	15	Machine steel		
1	Guard for 1	14	Cast steel	Pattern	F
1	Spring for 9 & 17	13	Steel		
1	Stop Pin for 2 & 9	12	Machine steel		
2	Jaw Facing for 1 & 2	11	Cast steel	Pattern	E
1	Rod for 7	10	Machine steel		
1	Nut for 17 & 2	9	Cast iron	Pattern	D
1	Clamping Bolt for 7	8	Machine steel		
1	Sleeve Nut for 8	7	Machine steel		
1	Clamping Bolt for 2 & 3	6	Machine steel		
2	Screw for 10	5	Machine steel		
1	Pin for 2	4	Machine steel		

BENCH VISE DETAILS-II.

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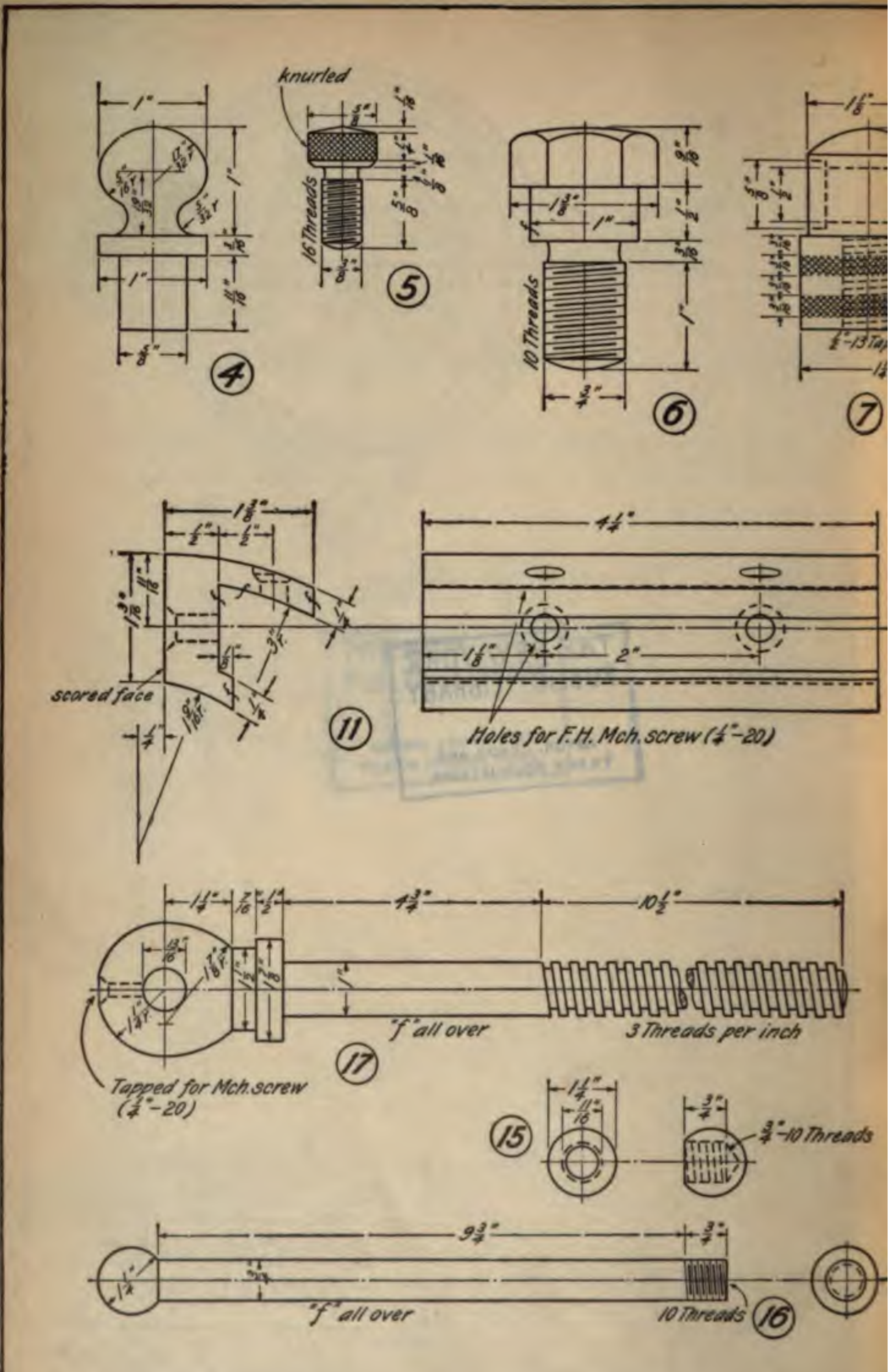
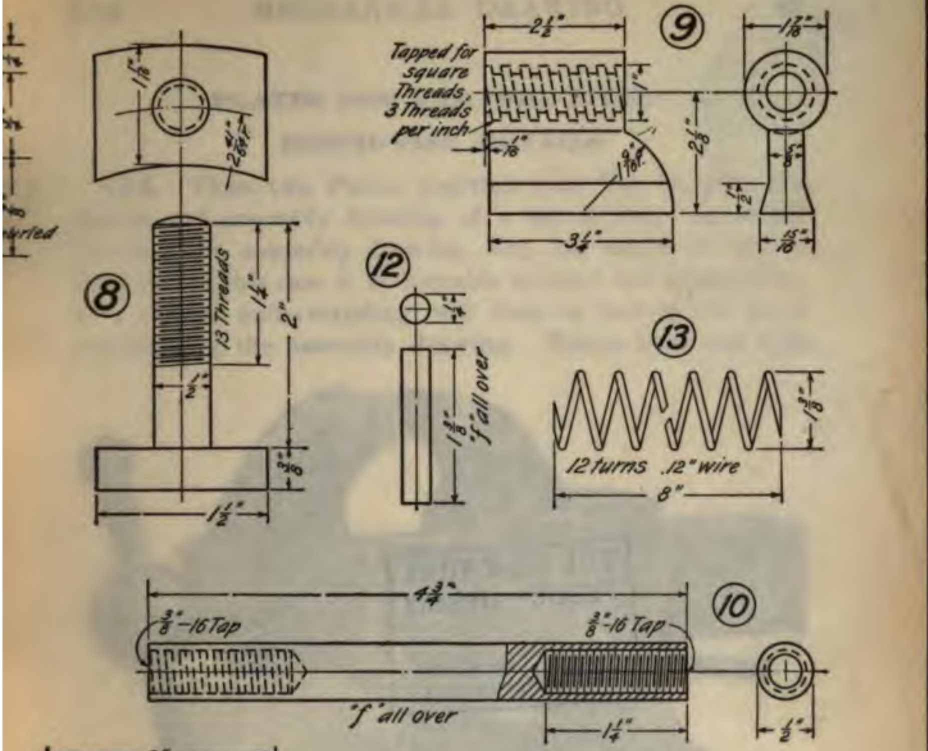
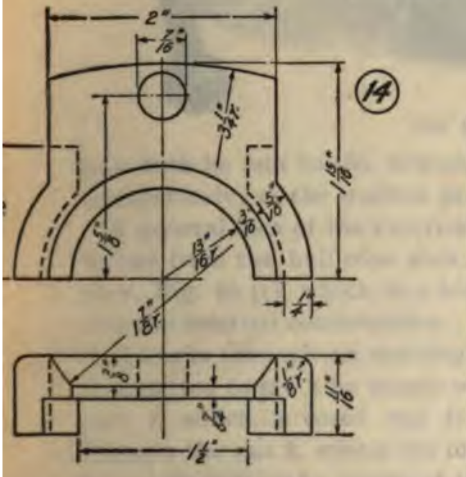
1010



knurled
16 Threads
10 Threads
scored face
Holes for F.H. Mch. screw (1/4"-20)
"f" all over
3 Threads per inch
Tapped for Mch. screw (1/4"-20)
3/4"-10 Threads
"f" all over
10 Threads





1	1/4"-20-F.H.Mch.screw for 17	20	Machine steel		
1	Fill.F.H.Mch.screw 3/8"-16-5/8" long	19	Machine steel		
8	1/4"-20-F.H.Mch.screw for 12&11	18	Machine steel		
1	Vise screw	17	Cast iron	Pattern	G
1	Rod for 17	16	Machine steel		
1	Nut for 16	15	Machine steel		
1	Guard for 1	14	Cast steel	Pattern	F
1	Spring for 9 & 17	13	Steel		
1	Stop Pin for 2 & 9	12	Machine steel		
2	Jaw Facing for 1 & 2	11	Cast steel	Pattern	E
1	Rod for 7	10	Machine steel		
1	Nut for 17 & 2	9	Cast iron	Pattern	D
1	Clamping Bolt for 7	8	Machine steel		
1	Sleeve Nut for 8	7	Machine steel		
1	Clamping Bolt for 2 & 3	6	Machine steel		
2	Screw for 10	5	Machine steel		
1	Pin for 2	4	Machine steel		

BENCH VISE DETAILS-II.

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1010

...TED STATES.
...AL TEXTBOOK COMPANY.
...Hall, London.

PLATES 1009 AND 1010, TITLE: BENCH-VISE DETAILS

114. These two Plates, together with Fig. 43, give the details and assembly drawing of a bench vise. In actual practice the assembly drawing, Fig. 43, would be drawn first, but in this case it is desirable to draw the details first, as a clearer understanding will then be had of the parts constituting the assembly drawing. Plates 1009 and 1010

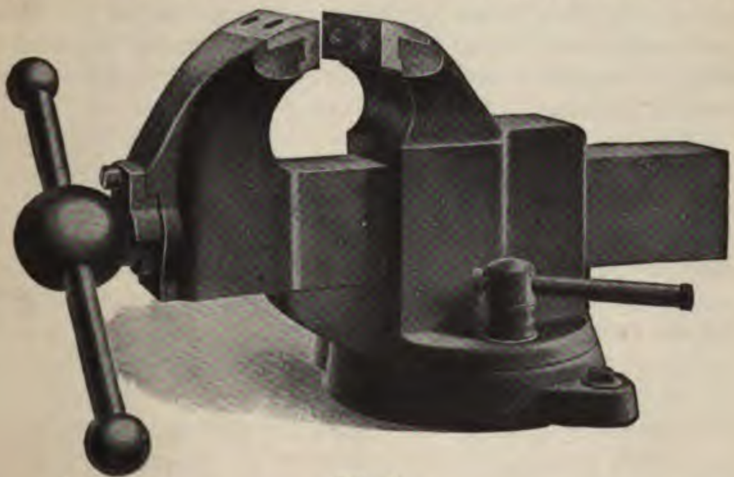


FIG. 42

may both be sent to the Schools for correction at one time, or separately, as the student prefers.

A general idea of the external appearance of the vise may be had from the half-tone view, Fig. 42, while the assembly view, Fig. 43 (*c*), which is a longitudinal section, will indicate the internal construction. It consists of the front jaw *1*, that works through an opening in the back jaw *2*. Motion is imparted to jaw *1* by means of the screw *17*, located inside part *1*, which is cored out for this purpose. The screw engages the nut *9*, which lies in a groove in part *2*, where it is held in position by means of the pin *12*. When an outward motion is given to the jaw *1* by turning screw *17* to the left, the jaw is assisted in its motion by the expanding spring *13*, while the screw is held in position, relative to the jaw, by the guard *14*. Both jaws are provided with steel facings *11*, secured by screws *18*.

The back jaw *2* rests on the base *3*, to which it is clamped by bolt *6* in such a manner as to leave it free to swing around the latter. A sleeve nut *7* engages with a clamping bolt *8*, whose head is held in a circular **T**-shaped groove in the base. A loosening of the nut by means of handle *10* allows the whole vise to be swung into any position desired, in which it may be retained by tightening the nut 7. The advantage of this arrangement is that it enables the workman to turn any side of the work in the vise to the front without having to rearrange it in the jaws.

115. Begin by drawing the front jaw *1* on Plate 1009, shown in four views: A side elevation, an end elevation, a plan, and a section taken on line *A B* of the side elevation. Lay off the horizontal center line, common to the two upper views, $3\frac{3}{8}''$ from the upper border line, and the vertical center line of the end elevation $9\frac{1}{2}''$ from the left-hand border line. This center line, if produced, will also serve for the sectional view. Another horizontal center line, $5\frac{15}{16}''$ from the upper border line, will define the positions of the lower views. Allow a space of $\frac{3}{4}''$ between the two upper views. All the views on this Plate are drawn half size.

Draw the end elevation first, then the side elevation, defining some of the dimensions in the latter by projection from the first view. The radii of the curves defining the sides of the jaw in the end view are not to be inserted in the drawing made by the student, as they are given simply to aid him in constructing them. Ordinarily the determination of curves of this nature is left to the judgment of the patternmaker, unless there are special reasons why they should be exactly defined. Next draw the plan view, which is a bottom view showing the groove in same. Some of its dimensions will have to be taken from the side elevation and some from the sectional view, which is to be drawn last. It is seen that the horizontal part of the jaw is cored out along its whole length, and that this cavity is partly rectangular and partly circular in section. The full-size view of the jaw proper, shown in the upper left-hand corner of the Plate, will apply to both jaws. Draw the vertical side of the jaw $2\frac{1}{2}''$ from the left-hand border line, and its upper corner $\frac{3}{4}''$ below the upper border line.

116. To draw the rear jaw, part *2*, shown in a side and a front elevation, lay off their horizontal center lines $2\frac{5}{8}''$ from the lower border line, and the vertical center line of the front elevation $8\frac{3}{8}''$ from the left-hand border line. The extension of the front jaw is to fit the cavity of the rear jaw, but it is observed that part *1* is made slightly narrower to allow it a freer motion.

It will be observed that the hole in the center of the base is threaded as is further shown by the note, "Tapped for $\frac{3}{4}''$ bolt." On working drawings, a thread is rarely shown in a hole which is to be tapped; the general rule is to draw two lines at a distance apart equal to the outside diameter of the thread, and to place a note on the drawing stating the size of tap to be used. It has been shown on this Plate, however, for the sake of completeness.

117. The base, part *3*, is shown in two views: a plan view and a side view, the latter being half in section and half in elevation. Lay off their vertical center line 3″ to the left of the right-hand border line, and the horizontal center line for the plan view $2\frac{1}{2}''$ below the upper border line. Leave a space of $\frac{3}{4}''$ between the two views. The square hole indicated in the upper part of the plan view serves the purpose of allowing the insertion of the bolt *8* from below into the **T** slot.

118. The parts on Plate 1010 are drawn full size, except those numbered *9*, *13*, *15*, *16*, and *17*, which are drawn half size. Locate the tops of the views in the upper row

$1\frac{1}{8}''$ from the upper border line, and equalize the spaces between them, similar to those on the Plate. In drawing the knurled portion of part *7*, draw, first, horizontal lines indicating the upper and lower borders, thereby making sure that the borders will appear even.

The lower part of the nut *9* is dovetailed into the groove situated in the base of part *2*, but this groove is made $\frac{1}{16}''$ wider to give a certain amount of play to the nut.

119. Draw the center line of the jaw facing *11*, $5\frac{3}{4}''$ below the upper border line, and draw the end view $1\frac{1}{2}''$ from the left-hand border line, leaving a space of 1″ between this and the rear elevation. The note "scored face" indicates that the face of the jaw is to be provided with a series of shallow grooves cut at right angles to each other. The appearance of this surface is indicated in Fig. 42. It should be noted that the arcs outlining the upper and lower surfaces of this part are not concentric. The center for the arcs of the lower surfaces is found by drawing a line parallel with the face at a distance from it of $\frac{1}{4}''$, then, with a radius of $1\frac{9}{16}''$ and the lower edge of the face as a center, draw an arc intersecting the parallel line. The point of intersection is the center of these arcs. The center of the upper arcs is found if the vertical line, indicating the face, is produced and intersected by an arc having a radius of $3\frac{1}{4}''$, and its center in the upper edge of the face.

120. The horizontal center line for the two views of the handle *10* is located $6\frac{5}{8}''$ below the upper border line, leaving a space between the end view and the right-hand border line and between the two views, of 1″ and $\frac{5}{8}''$, respectively. The right-hand end of the handle has been drawn in section, to show the threaded hole. In the free space above these views, locate the views of parts *8*, *12*, and *13*.

121. Draw the horizontal center lines of parts *16* and *17*, $1\frac{3}{8}''$ and $3\frac{7}{8}''$, respectively, above the lower border line, and leave a space of $\frac{7}{8}''$ between them and the left-hand border

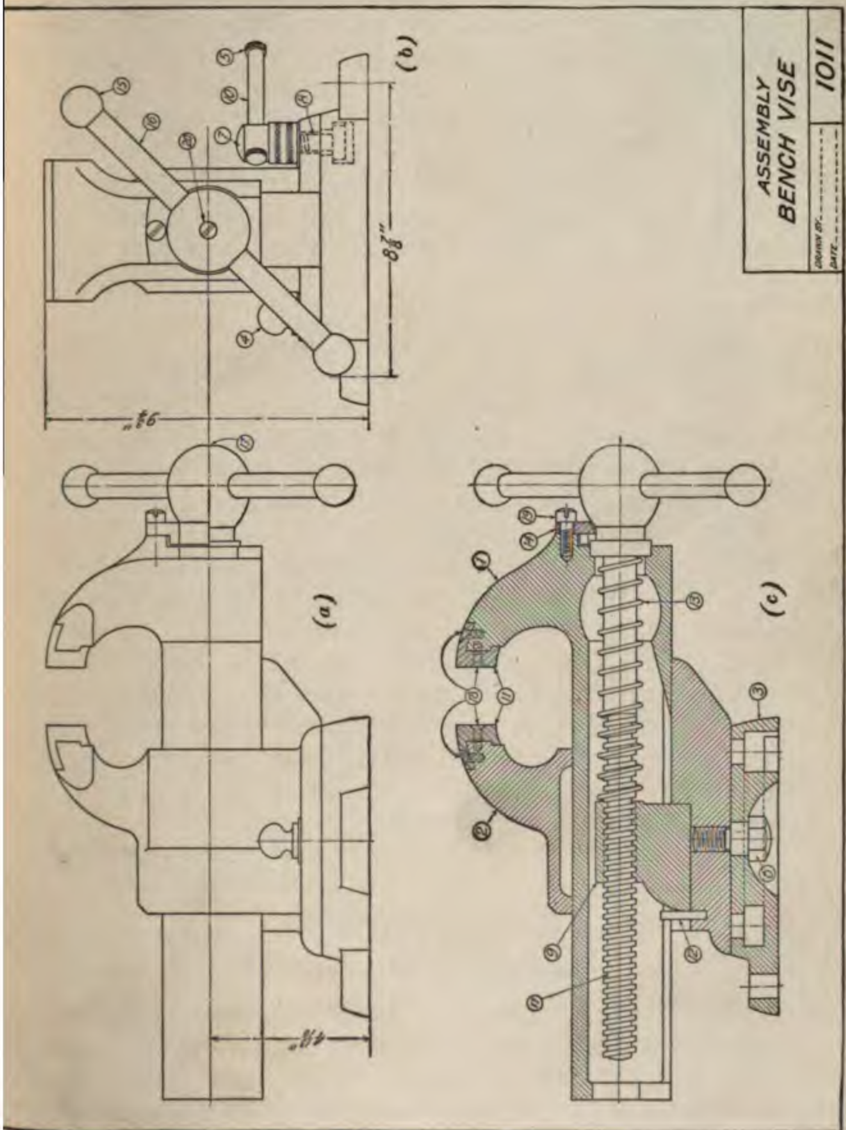


FIG. 43

line. The head of part *17* is not spherical, as the left-hand half is outlined by a semicircle with a radius of $1\frac{1}{4}''$, while the right-hand part is outlined by two arcs of $1\frac{7}{8}''$ radius. The extreme end of the head is flattened for a distance of $\frac{1}{2}''$, corresponding to the diameter of the countersunk part of the hole for screw *20*. The thread on the vise screw is made in a conventional manner, somewhat similar to Fig. 7, with the exception that the rear parts of the thread are not shown. Locate the end and side view of part *15* as indicated.

122. Before drawing the guard, part *14*, it should be carefully studied, for its shape is somewhat difficult to ascertain from the two views given. The upper view is a front elevation and the lower a bottom view. The parts difficult to locate are the two shoulders on the rear surface. These are shown in dotted lines in the elevation, but appear in the lower view as continuations of the sides. By consulting Fig. 44, where the guard is shown in perspective as it appears when seen from the rear, the student should be able to interpret the two views correctly. Draw their vertical center line $6\frac{3}{4}''$ from the right-hand border line and locate the base lines of the views $3\frac{1}{4}''$ and $1\frac{7}{8}''$ from the lower border line.

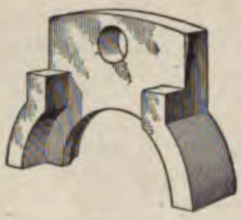
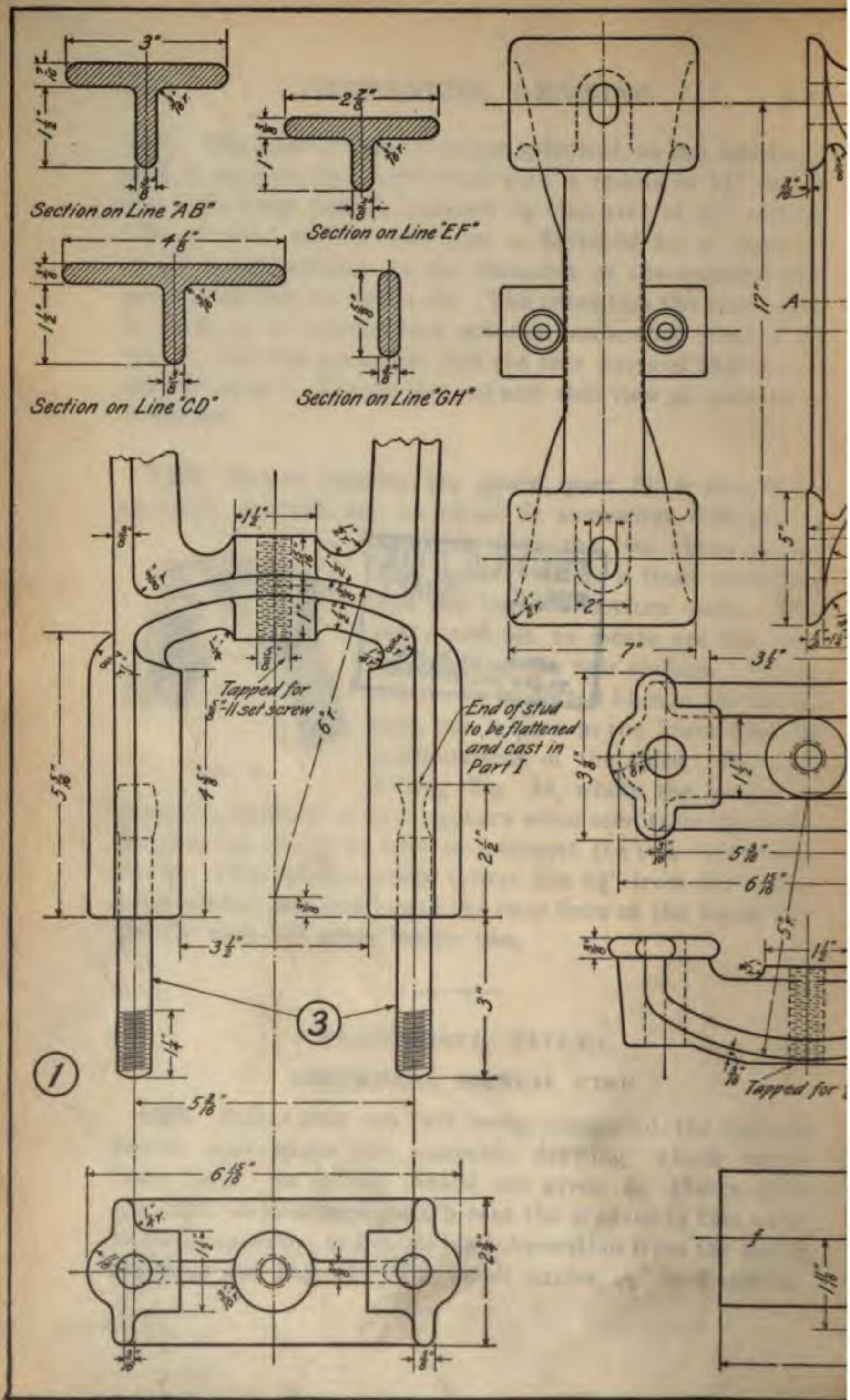


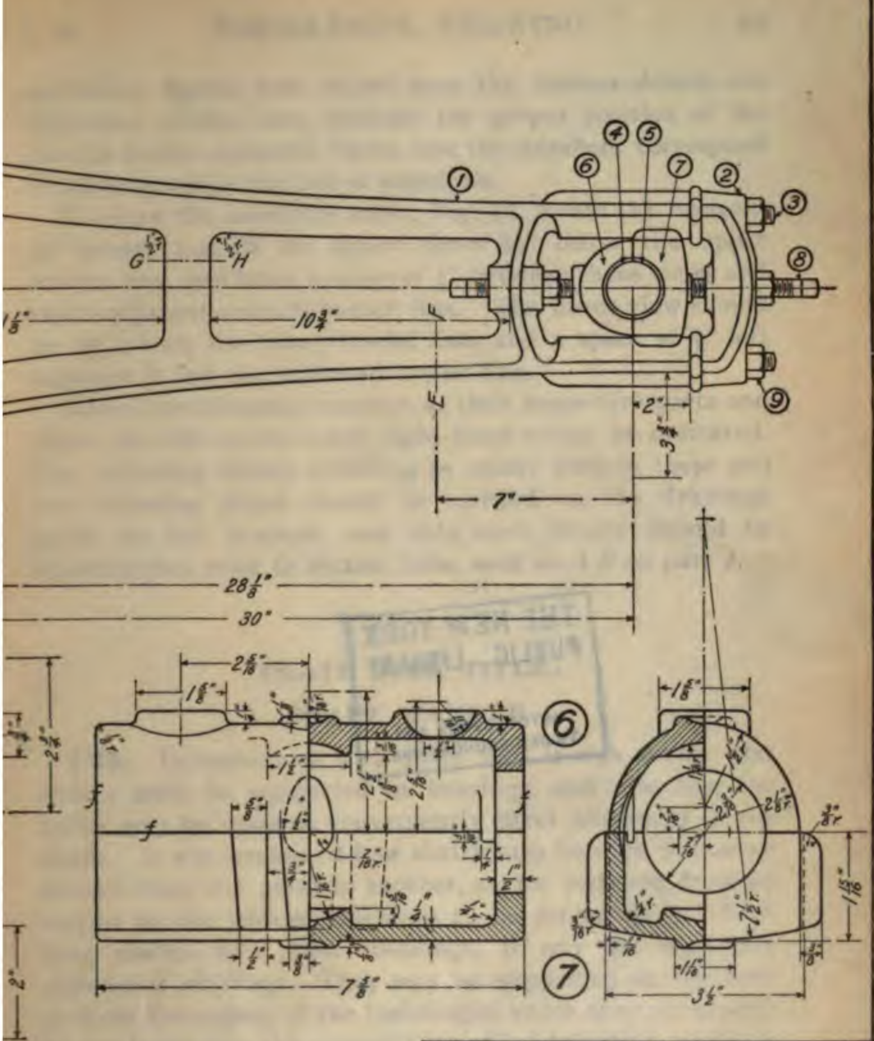
FIG. 44

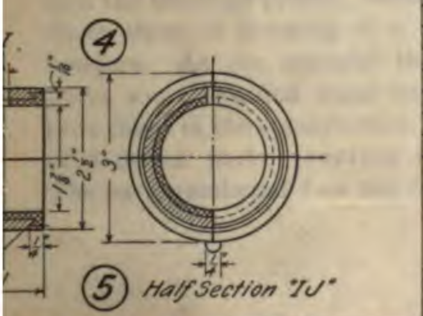
PLATE 1011, TITLE:

ASSEMBLY, BENCH VISE

123. Plates 1009 and 1010 being completed, the student should next make the assembly drawing, which forms Plate 1011. As all the details are given on Plates 1009 and 1010, no specimen plate is sent the student in this case, he being expected to get all his information from the detail drawings and Fig. 43. The small circles, $\frac{3}{16}''$ in diameter,


Section on Line "AB"
Section on Line "EF"
Section on Line "CD"
Section on Line "GH"
Tapped for 5/8"-11 set screw
End of stud to be flattened and cast in Part I
3
1
Tapped for





4	$\frac{5}{8}$" Hexnuts for parts 3 & 8	9	Machine steel		
2	$\frac{5}{8}$"-11 set screw 4" long for 1 & 2	8	Machine steel		
1	Sleeve (Bottom Half)	7	Cast iron	Pattern	F
1	Sleeve (Top Half)	6	Cast iron	Pattern	E
1	Bearing (Bottom Half)	5	Cast iron & babbit	Pattern	D
1	Bearing (Top Half)	4	Cast iron & babbit	Pattern	C
2	$\frac{5}{8}$"-11 stud $5\frac{1}{2}$" long for 1	3	Machine steel		
1	Cap	2	Cast iron	Pattern	B
1	Hanger	1	Cast iron	Pattern	A

SHAFT HANGER

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1012

enclosing figures and placed near the various details are reference circles; they indicate the proper position of the details in the assembly views, and the numbers correspond to those given in the bill of materials.

To draw the assembly views, Fig. 43, locate the horizontal center line of the upper views $3\frac{1}{2}''$ below the upper border line, and leave a space of $\frac{1}{2}''$ between these views and their adjacent vertical border line. The lower view should be $3\frac{3}{8}''$ above the lower border line, and a space of $\frac{1}{2}''$ left between it and the left-hand border line.

Insert the reference numbers at their respective parts and place the title in the lower right-hand corner as indicated. The reference letters referring to center lines in these and the following plates should be omitted on the drawings made by the student, and only such letters should be inserted that refer to section lines, such as *A B* on part *1*.

PLATE 1012, TITLE:
SHAFT HANGER

124. In connection with Plate 1006 it was shown that shafts must be supported in bearings, and also how the latter may be made to conveniently effect alinement of the shaft. It was explained how shafts may be used to convey motion from one point to another, as, for instance, from an engine to the various machines to be driven by it. Such long shafts—with their couplings, if any are used—are called *line shafting*. They may be supported on the floor or from the ceiling of the building in which they are placed. In the latter case the supports are called **hangers**, and contain the bearings proper, which may easily be alined. This Plate shows a drawing of a common form of such shaft hangers. As the material list shows, it consists of nine parts, some of which occur but once, others twice, and one four times in the construction, so that the structure consists of fourteen parts, counting every single piece by itself. The part numbered *1* on the drawing is the hanger proper, which is fastened to the ceiling by strong bolts passing through holes in the base. Extending downwards, this

FIG. 45

hanger terminates in a square-shaped frame open at the lower end, in which is placed a *shell* made in halves, parts *6* and *7* on the Plate. Within this shell is located the bearing proper, numbered *4* and *5*, also made in halves. The aforesaid square-shaped frame is closed, after the shell with the bearing is inserted, by a *cap*, part *2*, secured by two studs, part *3*, and nuts, part *9*. The studs are cast into the hanger, first having been flattened at the end, as directed by the note near the detail of the hanger. Two setscrews, part *8*, serve to adjust the shell containing the bearing proper to correct alinement with the other hangers used to support the same line of shafting. The whole structure put together appears as shown in the half tone, Fig. 45. The student will notice that there are very few finish marks on the drawing, from which it is plainly evident that a large portion of the dimensions are for the foundry, and that there is very little machine finish. The bearing proper, parts *4* and *5*, and the shell, *6* and *7*, are finished where they join together, parts *6* and *7* being also faced off at the ends. Parts *1* and *2* are drilled and tapped for the $\frac{5}{8}''$–11 setscrew used to adjust the height of the bearing, and oil holes are drilled in part *4*. With these exceptions there is no machine work to be done on the hanger. Parts *4* and *5* are lined with Babbitt, the same process being followed as that described in connection with the bearing shown in Plate 1006, although the absence of finish marks indicate that the bearing is not to be bored.

125. All the parts are drawn on the Plate in detail, by themselves, except the setscrews, the nuts, and the main frame or hanger proper, which is represented in two views drawn to a scale of 3″ = 1 ft. This figure shows the whole structure assembled.

The dimensions given on the assembly are leading dimensions only, the few detail dimensions of the main frame given and placed near the foot being added because the size of the sheet did not permit the portion of part *1* being shown in detail in any other position. The other dimensions of the main frame, or part *1*, are given in the two views located in the lower left-hand corner of the Plate.

126. All the details are to be drawn first, and to a scale of 6″ = 1 ft. Start with the bearing proper, parts *4* and *5*. The student will readily perceive the similarity of this piece with the one drawn on Plate 1006. There are these differences, however: In the present case the bearing consists of two parts, while the former was one piece only. The present bearing is not self-oiling, so that there are no slots for oil rings, little oil holes being provided instead. The means for preventing the bearing from turning in its seat is in the

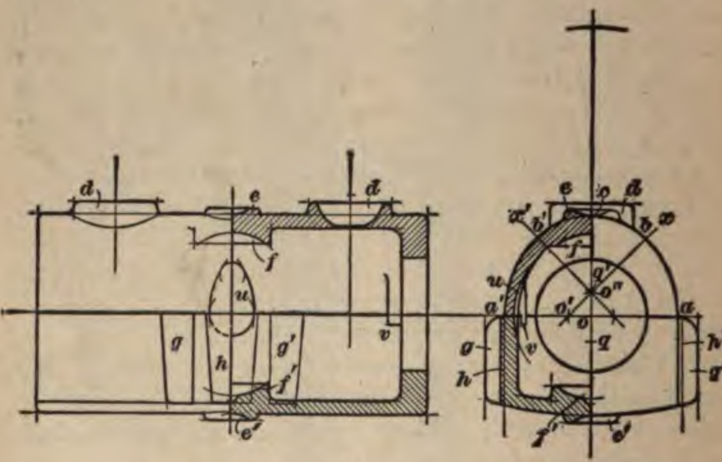

FIG. 46

present case a small boss, or teat, at the bottom of the rounded central portion, which is also called the *ball.* This small teat fits into a recess provided for it at the bottom of the lower shell, part *7*. For convenience the two halves of the bearing are drawn together, the finish mark placed on the dividing line indicating that both surfaces are to be finished. Both halves are shown half in section. With the instruction given for the similar piece on Plate 1006, the student should have no difficulty in drawing the bearing. Place the center lines $1\frac{1}{2}''$ from the bottom border line, and the vertical center lines $8\frac{3}{8}''$ and $5\frac{3}{8}''$ from the right-hand border line, respectively.

127. The shells *6* and *7*, Fig. 46, are drawn in much the same manner as the bearing. The two halves are also shown together, as were those of the bearing; they are also shown in a perspective view, Fig. 47, partly broken away. Draw the horizontal center lines $5\frac{1}{8}''$ from lower border line, and the vertical center lines $5''$ and $1\frac{1}{2}''$ from right-hand border line, respectively. Begin with the right-hand, or end, view. Draw the circular opening from the center o (see Fig. 46). Next draw the outline of the shell, which is dome-shaped

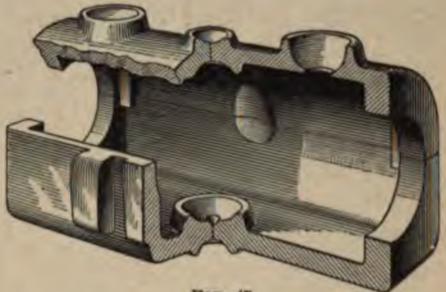

FIG. 47

in the upper half and box-shaped in the lower half. The outline of the upper half is composed of circular arcs of different radii, one drawn with a radius of $2\frac{1}{8}''$ from a center o' and $\frac{7}{16}''$ from o on the horizontal center line; the other with o'' on the vertical center line as a center, $\frac{7}{16}''$ from o, with a radius of $1\frac{1}{2}''$. Lay off o' and o'' first. Draw a line $o'\,o''$ through these points and prolong it, say, to x. When curves of different radii are joined together, as in this instance, their point of junction should lie on a line passing through the centers of the arcs, such as line $o'\,x$. Draw one arc from a till it intersects $o'\,x$ at b; then draw the other arc from b to c. Draw similar arcs on the left-hand side of the figure.

On top of the upper shell place the boss for the oil cup d, whose diameter is $1\frac{5}{8}''$ and whose top line is $\frac{1}{4}''$ above the crown of the shell, as seen in the other view. The boss is cupped, the cup having a radius of $\frac{11}{16}''$ and being $\frac{1}{2}''$ deep. Next add, in similar manner, the boss e for the end of the setscrew to bear against, $1\frac{1}{16}''$ in diameter and $\frac{1}{8}''$ high. This boss is also cupped, the cup having a radius of $\frac{9}{16}''$ and being $\frac{1}{8}''$ deep. This cup is not visible in the right-hand half of the end view, as the whole boss is hidden by the oil-cup boss and must be shown in dotted lines.

The outline of the lower, box-shaped half of the shell is now to be drawn. Carry straight lines down from *a* and *a'*, one full and one dotted, as shown, the latter being hidden by a projecting lug. The bottom line of the lower shell is a circular arc having a radius of $7\frac{1}{8}''$. Its center is obtained by laying out the bottom point $1\frac{11}{16}''$ below the horizontal center line, and from there going up $7\frac{1}{8}''$ on the vertical center line. Draw the boss *e'* at the bottom. The lower shell has on each side three projections *g*, *g'* and *h*, the lugs *g* and *g'* protruding $\frac{3}{8}''$, and the raised surface *h* only $\frac{1}{16}''$. The outlines of the lugs appear in the end view in full, in both halves of the figure, while the raised surface *h* appears as a full line on the sectional, or left, side and as a dotted line on the right side, being there hidden by the lug *g'*. Round off the lugs with the proper radii. The projecting lugs *gg'* just drawn, together with the raised surfaces *h*, hold the shell in proper position in the main frame, keeping it from moving endwise and sidewise respectively.

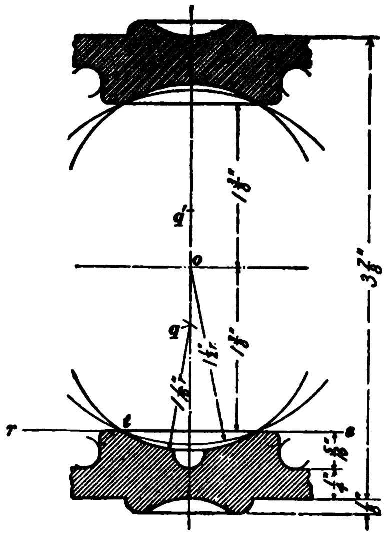

FIG. 48

Next define the thickness of the shell in the left-hand side of the figure by drawing concentric arcs and parallel lines to the outlines already drawn. The thickness is $\frac{1}{4}''$, as given in the other view at the bottom, it being understood that the general thickness of shell is the same throughout. On the inside of the shells are placed bosses *f* and *f'*, cupped to receive the ball, or rounded middle, portion of the bearing. These cups have, however, a smaller radius than the ball, for the following reason: As has been said, these surfaces are not finished. It would, therefore, not be practical to cast them so as to make them exactly coincide. By making the cups of smaller radius, the surfaces will be in contact only at the rim of the cup, as shown in Fig. 48. The radii of the cups are given as $1\frac{1}{16}''$; to find their centers, *q* and *q'*, proceed as follows: With *o* as a center draw a circle with a radius of $1\frac{1}{2}''$, as shown in Fig. 48; next lay off $1\frac{3}{8}''$ from *o* downwards along the vertical center line, and draw a horizontal line *r s* marking the top of the cupped boss. With the point of intersection *t* as a center and a radius of $1\frac{1}{16}''$, strike an arc cutting the vertical center line at *q*; with *q* as a center, draw the arc defining the bottom of the cup. Draw the upper cup in the same manner. Draw the little recess in the lower cup for the teat referred to in Art. **126.** The thickness of the shell is changed at two other places, namely, at *u*, Fig. 46, and at the corresponding point opposite, being recessed $\frac{1}{16}''$ deep and $\frac{7}{8}''$ wide to accommodate the ball, as the shell is only $2\frac{7}{8}''$ wide in the clear, while the ball is 3″ in diameter. The top sleeve *6* is held in position, in relation to bottom sleeve, part 7, by four projections *v*, one placed at each corner of the top half and slipping into the bottom half.

128. The other view is now easily drawn. Carry over from the end view horizontal lines limiting the inside and the outside of the shell, the tops and bottoms of the bosses for the oil cups and ball cups, keeping in mind the fact that the line representing the inside of the top of part *6* is not found by projecting horizontally from the end view, as the top point there represents the bottom point of the cup *f*. The inside top line in the side view must be found by laying off a point $\frac{1}{4}''$ below the outside of the shell, and through this drawing a horizontal. Lay off the center lines and centers of the oil cups and draw their outlines. Carry over the centers of the ball cups and draw their outlines, also those of the setscrew cups. Lay out the lugs *g* and *g'*, the raised surface *h*, the recess *u*, and the projections *v*, the latter visible only in the right-hand or sectional half of the figure. Round off the corners and draw the fillets

The outlines of the recess *u* is found by ascertaining the intersection between the ball of the bearing and the inside of the shell. The student is not required to determine the intersecting points by means of projection, but may draw an approximate curve in the following manner. With the intersecting point of the two center lines as a center, draw an arc with a radius of $\frac{7}{16}''$. Lay off another center $\frac{3}{4}''$ above the first and draw another arc with a radius of $\frac{1}{4}''$. By means of the irregular curve draw two curves tangential to the two arcs.

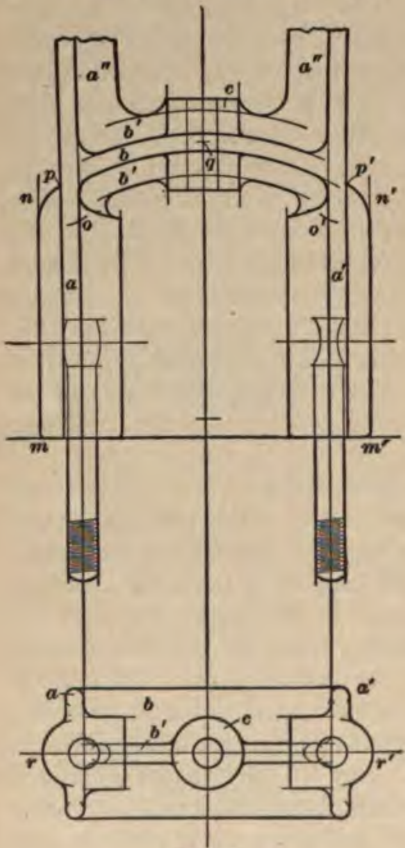

FIG. 49

129. Now draw the detail numbered *1* and *3* (see also Fig. 49), which is the lower portion of the main frame, with its bolts cast into it. It will be noticed that the detail drawing of parts *1* and *3* shows only a portion of the frame, and that it is drawn to a larger scale than the frame shown in the assembly drawing. This is another illustration of the practice referred to in the description of the enlarged cross-section of the pulley rim, Plate 1005. The size of the Plate would not permit of drawing the entire frame to the scale used for the details; hence, the upper part only is shown, drawn to the enlarged scale, the dimensions necessary for the foot of the frame being given on the assembly. Commence with the top view or elevation. Draw a vertical center line $2\frac{7}{16}''$ from left-hand border line. Draw parallel to it the center lines of the bolts $5\frac{3}{16}'' \div 2 = 2\frac{19}{32}''$ from it, on either side. Draw a horizontal line *m m'*, Fig. 49, which determines the bottom, and is $4\frac{1}{8}''$ (actual measurement) from the lower border line. Lay out the inside and outside dimensions ($3\frac{1}{8}''$ and $6\frac{15}{16}''$) of the uprights and draw their vertical outlines *m n*, *m' n'*. The uprights have ribs *a* and *a'*, the inside edges of which coincide with the center lines of the bolts; the ribs are $\frac{3}{8}''$ thick. These ribs extend to the upper part of the frame, while the thick parts of the uprights terminate on the outside in caps which are partly spherical and have a radius of $\frac{7}{8}''$, with centers on the inside edges of the ribs. To locate these centers, lay off from *m m'* the height $5\frac{5}{16}''$ on the outside edges of the ribs to *p* and *p'*; with these points as centers cut the inside edge line of the ribs with arcs struck with a radius of $\frac{7}{8}''$, obtaining centers *o* and *o'* of the caps. A ribbed bridge *b b'*, having a cylindrical boss *c* in the center for the setscrew, connects the two uprights. This bridge is curved to a circular arc, the upper edge of the central horizontal rib *b* having a 6″ radius, whose center is located $\frac{3}{8}''$ from the line *m m'*. The lower edge of the central rib *b* is $\frac{3}{8}''$ away from the upper, and is struck from the same center. The remainder of the bridge should be readily drawn. Draw the cylindrical boss *c* by locating a point *q* in the middle of the rib *b* and laying off points $\frac{3}{4}''$ to the right and left of the vertical center line, and $1\frac{5}{16}''$ above and 1″ below point *q*. Now put in the fillets joining the various parts, and round off the corners. Next draw in the hole for the setscrew in the boss *c*, and finally the studs *S*. The flattening of the studs is shown in a conventional manner without dimensions, this being safely left to the blacksmith.

Begin now with the bottom view. Carry down vertically the center lines of the studs, having previously drawn a horizontal center line of the whole figure $1\frac{3}{16}''$ (actual measurement) from the lower border line. Draw the circles representing the studs, the threaded setscrew hole, and the cylindrical boss *c*. Carry down the outside edges *m n* and *m′ n′* of the uprights from the upper figure to the lower, intersecting the horizontal center line in *r* and *r′*, through which points draw arcs of circles with a $\frac{11}{16}''$ radius to represent the plan of the uprights. Carry down the inside edges of the uprights and lay off their width, which is $1\frac{1}{2}''$. Carry down the edges of the ribs *a* and *a′* and make their width $2\frac{3}{4}''$. Finally, draw the rib *b′*, $\frac{3}{8}''$ thick. Round off corners and put in fillets.

130. The next part to be drawn is the cap *2*, also shown in Fig. 50. Draw center lines $7\frac{3}{8}''$ from the left-hand border line and 6″ from the bottom border line, respectively. It is best to start with the upper view or plan. Establish the stud-hole centers; draw the circles representing the stud holes, the setscrew boss, and the setscrew hole. Lay out the outside and inside dimensions of the body and rib of the cap as well as their width; the dimensions $6\frac{15}{16}''$, $3\frac{1}{2}''$, $2\frac{3}{4}''$, and $1\frac{1}{2}''$ will be found to be the same as the corresponding dimensions of the uprights of part *1*. These outlines will be partly dotted lines, being hidden by a half-round molding *a a* $\frac{3}{8}''$ wide carried all around. In the plan, this molding shows in parallel lines and concentric circles to the outlines of the body proper and $\frac{3}{16}''$ away from them. Now draw the lower view or elevation. It is drawn in a manner similar to the bridge portion in part *1*. Notice that the body tapers on the sides *b* and *b′* and that it is flattened at the bottom

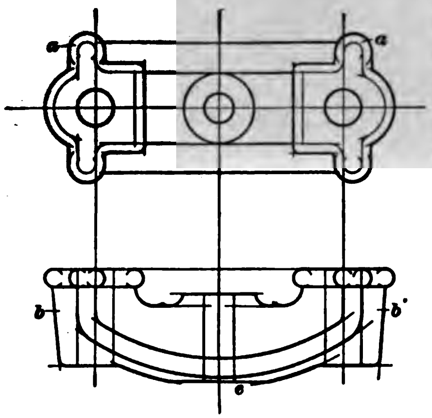

FIG. 50

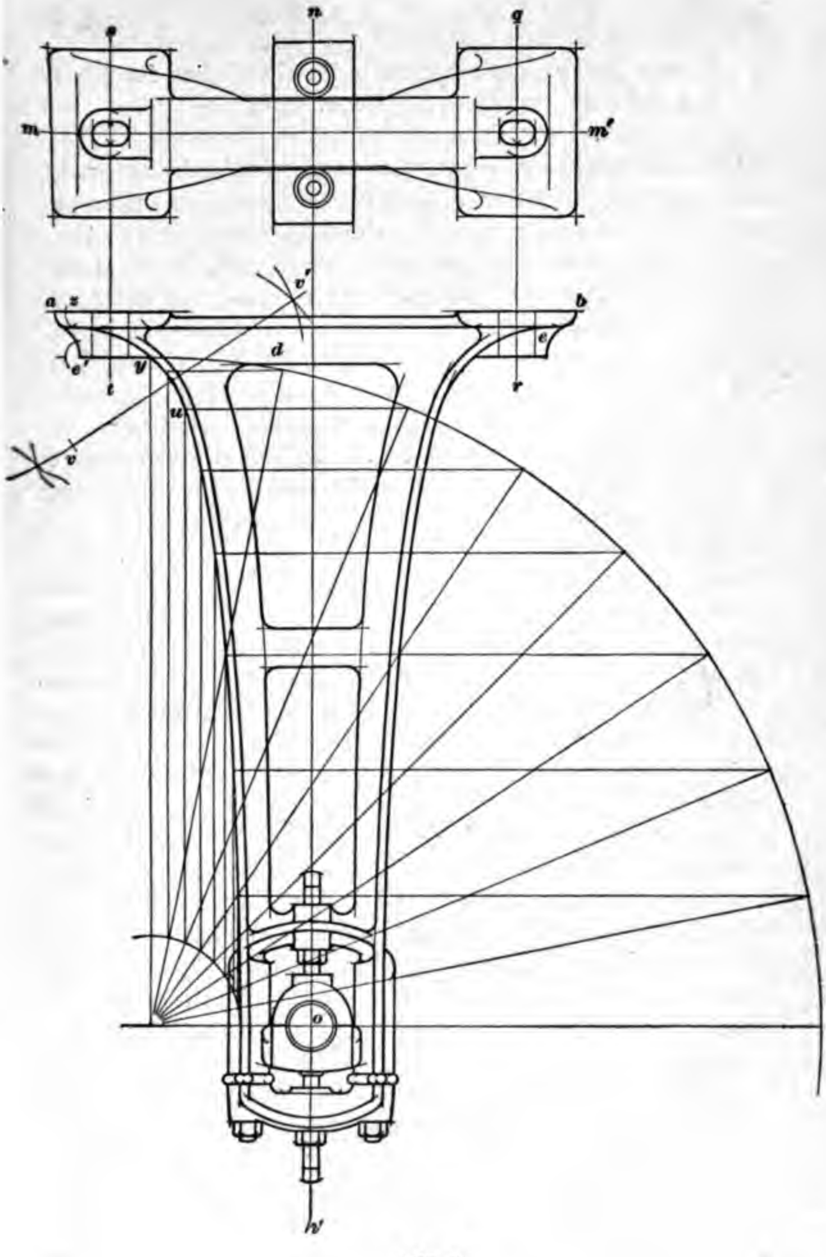

FIG. 51

at *c* for the nut of the setscrew. Put in circles for fillets and round off the corners with proper radii.

131. All that now remains to be drawn is the assembly shown in two views and in four sections through the frame and web. Start with the elevation, beginning at the left. Draw the horizontal center line *n n'*, Fig. 51, 3" from the upper border line, and a base line *a b* 7⅜" from the left-hand border line, draw center lines *q r* and *s t* for the bolt holes; lay out the thickness of the base and of the bosses *e* and *e'*, and draw in the bolt holes. The top of the rib *d* is parallel to the base line; the rib itself is 1¼" high, as indicated on the section along *A B* shown at the left-hand upper corner of the Plate. Lay off 30" from the base line to locate the center of the shaft; this distance is called the *drop* of the hanger. Draw a vertical center line through *o* and complete this end of the hanger from dimensions on the details previously drawn. The scale to be used is 3" = 1 ft. The curve of the side of the hanger is partly that of an ellipse, half the diameters of which are 3¾" and 28⅛". Use for its construction the first of the two methods given in *Geometrical Drawing*, as shown in Fig. 51. From *u* to *z* the curve is a circular arc tangent to the ellipse at *u* and to the bottom of the base at *z*, and passing through the end *y* of the long diameter of the ellipse. If the circles used for the construction of the ellipse are divided into the same number of parts as shown in *Geometrical Drawing*, then the point *u* is located at the end of the third line from the left in Fig. 51. The center of the curve *u z* may be found in the following manner: Draw a perpendicular *v v'* that will bisect an imaginary straight line connecting points *u* and *y*, in the manner described in *Geometrical Drawing*. Any arc with its center on line *v v'* will pass through points *u y*. The center of an arc that will also pass through point *z* can be found either by trial or according to the method described in *Geometrical Drawing* for passing a circle through three points not in the same straight line, the three points here being *u*, *y*, and *z*. The other construction dimensions can

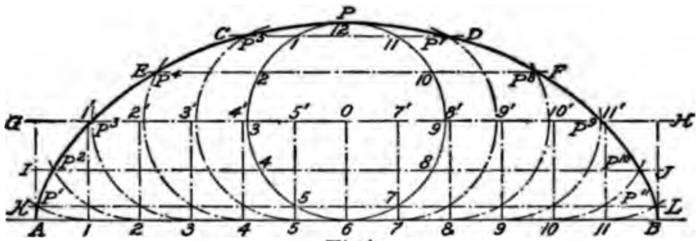

Fig.1.

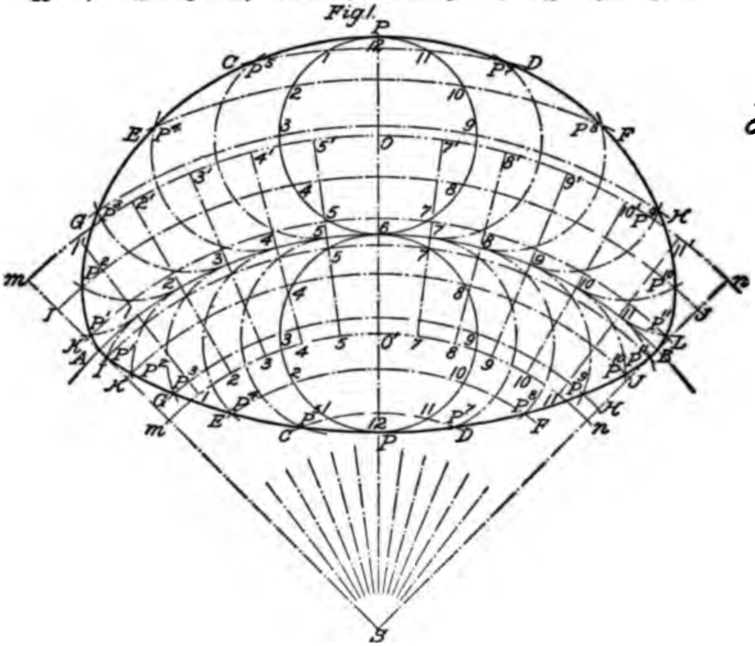

Fig.2.

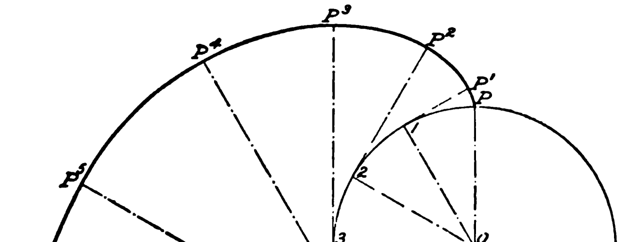

Fig.3.

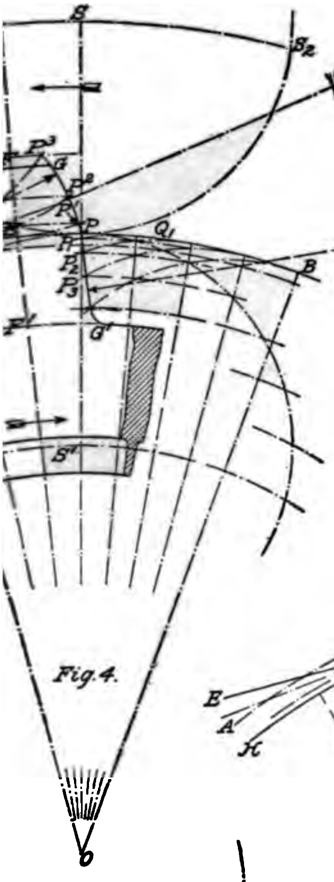

Fig. 4.

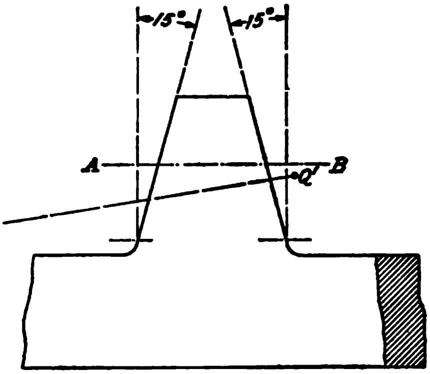

Fig. 7.

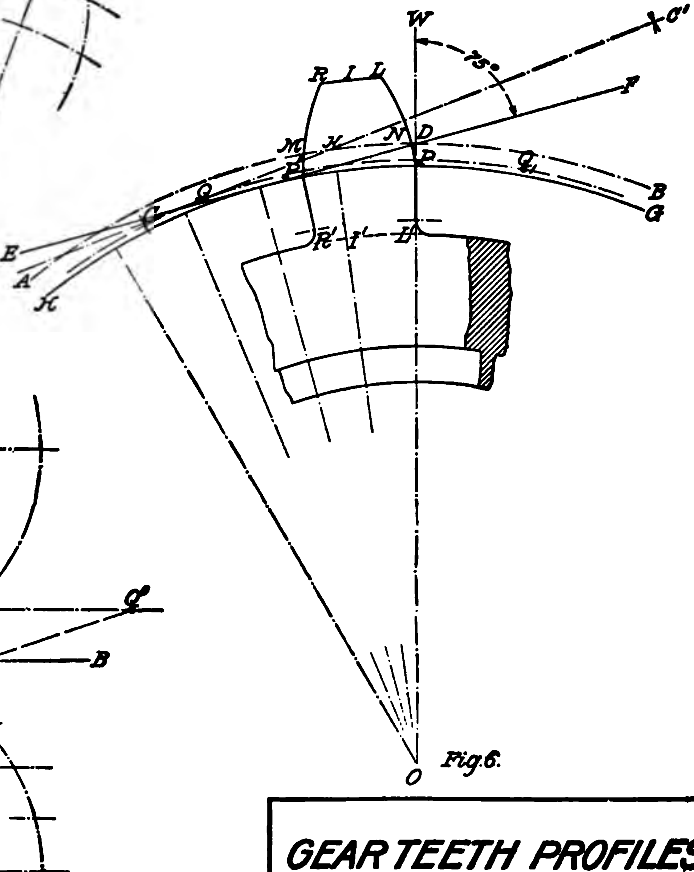

Fig. 6.

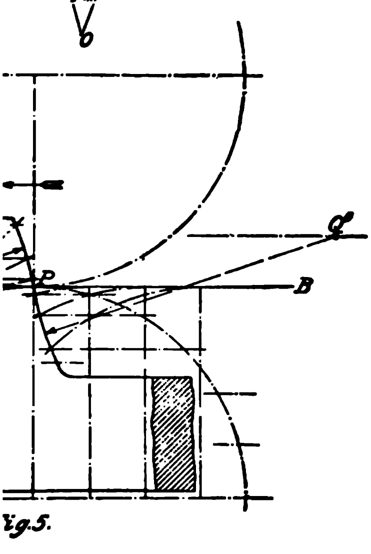

Fig. 5.

GEAR TEETH PROFILES

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1013

10231

be obtained from the cross-sections and the over-all dimensions given on the assembly. The bottom plan, to the left of the figure just drawn, is easily made by carrying over, horizontally, all dimensions from the elevation that can be so obtained, and laying off the others from center line $m m'$, $5\frac{1}{4}''$ from left-hand border line.

Finally draw the four sections of the main frame at the left-hand upper corner of the Plate. The student should have no difficulty with these.

In lettering the title, note that part *8* is called for twice, it being plainly evident from the assembly that two adjusting screws are necessary, and also that four hexagonal nuts, part *9*, are required for parts *8* and *3*. Six patterns are called for to complete the hanger, although part *4* could be produced from pattern *D*, which is made for part *5*. It is probable, however, that on standard parts of this sort, large numbers will be made, and it is therefore advisable to call for patterns for each part.

PLATE 1013, TITLE:

GEAR-TEETH PROFILES

132. The style of drawing shown in Plates 1013, 1014, and 1015 is somewhat different from that shown in the preceding Plates. Plate 1013 is more of a diagrammatic nature, its purpose being to show the theory and construction of gear-teeth in general, while Plates 1014 and 1015 are intended to illustrate the use of shade lines in drawings. When shade lines are used, the outlines of an object are given by means of two varieties of lines, one lighter and one heavier than that previously adopted as the standard. The function of shade lines is to differentiate between such surfaces that are illuminated by rays of light, assumed to come in a certain direction, and other surfaces not exposed to such rays. A detailed description of this subject has already been given in *Geometrical Drawing*.

While there is no doubt of the fact that drawings containing shade lines will greatly assist in giving a clearer idea of the shape of the objects represented, such lines are, however, going out of use more and more, principally because more care and time is required to execute a drawing in this manner. But as some drawing offices still continue their use and as there are cases when they *must* be used, as for instance in drawings intended for the U. S. Patent Office, it is well for the student to familiarize himself also with this method. The three Plates are drawn full size.

If a circle is rolled on a straight line without sliding, a point on the circumference of the circle will describe a curve called the **cycloid.** The circle is called the **generating circle.** The shape of the curve and the manner of drawing it are shown in Fig. 1. Let O be the center of the generating circle, which is $1\frac{3}{4}''$ in diameter, P the point on the circumference of the generating circle, and AB the straight line on which the generating circle is rolled and which is equal in length to the circumference of the generating circle, or $1\frac{3}{4}'' \times 3.1416 = 5.4978$, say $5\frac{1}{2}''$. The generating circle should be so placed that its center O lies over the center of the line AB, as shown. Divide the generating circle into any number of equal parts, in this case 12, or $P1$, 1–2, 2–3, 3–4, etc., and through these points draw lines CD, EF, GH, etc., parallel to the line AB. Through the center O of the generating circle draw the radius $O6$. Divide each half of the line AB into half the number of equal parts that the generating circle is divided into, as $A1$, 1–2, 2–3, etc., and through these points draw lines perpendicular to AB terminating in the line GH, as AG, 1–$1'$, 2–$2'$, 3–$3'$, etc. From the point $1'$, with a radius equal to the radius of the generating circle, as $O6$ or $1'$–1, describe an arc intersecting the line KL in the point P^1; from the point $2'$, with the same radius, intersect the line IJ in the point P^2; from the point $3'$, with the same radius, intersect the line GH; continue in a similar manner with the remaining points $4'$, $5'$, $7'$, $8'$, etc., intersecting the lines EF and CD in the points P^4, P^6, P^7, P^8, etc. The points A, P^1, P^2, P^3, etc. are points in the curve through which the cycloid may be drawn. It will be noticed that when the center O of the generating circle coincides with the point G, the point P on the circumference of the generating circle coincides with the point A; and that when the generating circle is revolved toward the right, without sliding, until the center O coincides with the point $1'$, the point P will coincide with the point P^1. Thus it is seen how the point P passes through all the points from A to B, namely, A, P^1, P^2, P^3, etc., when started at A and revolved toward the right to B.

133. If the generating circle is rolled, without sliding, on the outside of the circumference of an arc of a circle supposed to be at rest, instead of being rolled on a straight line, the curve described by a point P of the generating circle will be an **epicycloid.**

The manner of drawing such a curve is shown in Fig. **2.** AB is the arc upon which the generating circle is rolled, its center being at S and its radius being $3\frac{1}{2}''$. The diameter of the generating circle is in this case the same as in Fig. **1,** or $1\frac{3}{4}''$. Make the lengths of the arcs *6 A* and *6 B* equal to half the length of the circumference of the generating circle, by first calculating the length of half the circumference of the generating circle and drawing a straight line tangent to the arc *A 6 B* at *6*, making it equal in length to half the circumference of the generating circle. Then make the arc *6 A* equal to this line by means of the approximate method given in *Geometrical Drawing*. Divide the arc *A 6 B* and also the generating circle into the same number of equal parts, in this case 12, as *A 1*, *1–2*, *2–3*, etc., and *P 1*, *1–2*, *2–3*, etc., and draw radii from the center S to the points of division on the arc *A 6 B*. During the revolution of the generating circle, the center O will describe an arc *m O n* concentric with the arc *A 6 B* and having the same number of degrees in it as *A 6 B*. Produce the radii just drawn to the arc of center positions *m O n*, intersecting this arc in the points *m*, *1'*, *2'*, *3'*, *4'*, etc. Through the points of equal divisions, *1*, *2*, *3*, etc., of the generating circle pass concentric arcs having the center *S*, as *CD*, *EF*, *GH*, *IJ*, and *KL*. With the points *1'*, *2'*, *3'*, *4'*, etc. as centers and radii equal to the radius of the generating circle describe arcs cutting the arcs *KL*, *IJ*, *GH*, etc. in the points P^1, P^2, P^3, etc., which are points on the epicycloid.

134. When the generating circle rolls on the inside of the arc, the curve described by a point on the circumference is called a **hypocycloid.** The method of drawing it is similar in all respects to that just given for the epicycloid. The student should be able to construct it from the drawing without further explanation. The diameter of the generating circle is 1¾" as before.

135. Suppose that a string is wound on a cylinder and that the end of the string is at the point *P* in Fig. **3.** If this string is unwound from the cylinder, keeping it constantly tight, the end *P* will describe a curve known as the **involute of the circle,** or, more simply, the **involute.** To construct it geometrically, let *O* be the center of the given circle representing the cylinder, which, in Fig. **3,** is 2½" in diameter, and *P* the free end of the string when wound on the cylinder. Divide one-half of the given circle representing the cylinder into any number of equal parts, in this case 6, as *P 1*, *1–2*, *2–3*, etc., and through each of these points draw tangents to the circle, as P^1, P^2, P^3, etc. To draw these tangents, first draw the radii *O 1*, *O 2*, *O 3*, etc. and then draw the tangents $1\,P^1$, $2\,P^2$, $3\,P^3$, etc. at right angles to them. By means of the approximate method given in *Geometrical Drawing*, find the length of the arc 1 *P* and make the length of the tangent $1\,P^1$ equal to this length; of the tangent $2\,P^2$ equal to twice this length; of the tangent $3\,P^3$ equal to three times this length, and so on. The curve drawn through the points P^1, P^2, P^3, P^4, etc. will be the required involute. The use of these curves will now be explained.

136. On Plate 1014, in Fig. **1,** is shown one-half of two **spur gear-wheels** in mesh. The two dotted circles tangent to each other at P are struck from the centers of the gear-wheels and are called the **pitch circles.** The diameter of any gear-wheel is always understood to be the diameter of its pitch circle unless it is specified as **diameter at root,** or **diameter over all.** The length of that part of the pitch circle between the centers of any two consecutive teeth is called the **circular pitch,** or simply the **pitch.** Thus, in Fig. **1,** Plate 1014, the length of the arc $a\,b$ is equal to the pitch of either gear-wheel. When the gear-wheels are cut in a gear-cutter, the width of the tooth $c\,d$ on the pitch line is equal to the space $d\,f$; that is, the arc $c\,d$ is equal to the arc $d\,f$, and each is equal to half the pitch. When the gear-wheels are cast, that is, when they are not cut in a gear-cutter, clearance is given between the back of one tooth and the front of the tooth following, to allow for inequalities in casting. This clearance, or **backlash,** as it is usually termed, is generally made equal to 4 per cent. of the pitch. This is done by making the thickness of the teeth $c\,d$ equal to .48 of the pitch.

The part $C\,C_1$ of the tooth that lies beyond the pitch circle is called the **addendum,** and the part $C\,C_2$ that lies below it is called the **root.** The **face** of the tooth is the part $C\,C_1\,C'\,C$, Fig. **2,** of the tooth above the pitch circle, extending the whole width of the tooth. The **flank** is the part $C\,C_2\,C''\,C$, Fig. **2,** of the tooth below the pitch circle, extending the whole width of the tooth. The terms addendum and root mean distances only, while face and flank mean surfaces.

The usual practice is to make the addendum equal to $.3\,P$, and the root equal to $.4\,P$. $P =$ the circular pitch. The distance $C_1\,C_2$ is called the whole depth of the tooth. The method of describing the curves of teeth shown on the Plate 1013, Fig. **4,** is a convenient way of drawing the **cycloidal,** or **double-curved teeth.** Cycloidal teeth are constructed by making the outline of the face a part of an epicycloid and the flanks a part of the hypocycloid, hence the name double-curved teeth.

137. In Fig. **4**, Plate 1013, let AB be part of a pitch circle struck with a radius of, say, $5\frac{1}{2}''$. For convenience in drawing the tooth, let the pitch be $2''$. With O as a center, which is the center of the gear-wheel, and a radius equal to $5\frac{1}{2}''$, describe the arc AB, part of the pitch circle. Through O draw a straight line OS, cutting AB in P. Take the radius of the generating circles SP and $S'P$ equal to $1\frac{3}{8}''$ for this case and describe arcs having centers at S and S' on the line OS. With O as center and OS as radius describe the arc $S_2 S_1$. In connection with the gear-wheel teeth, the generating circles are frequently called **describing circles.** Roll the outer describing circle upon AB in such a manner that the center S will move in the direction of the arrow along the arc $S_2 S_1$. By means of the method given in Fig. **2**, find the points P^1, P^2, P^3, etc. on the epicycloid described by the point P. Trace a faint curve through the points just found and measure off on the pitch circle the thickness of the tooth.

$$PD = .48p = .48 \times 2'' = .96''$$

Make EF = the addendum $= .3 \times p = .3 \times 2'' = .6''$. With O as a center and OF as a radius describe an arc cutting the epicycloid in G. Now roll the inner describing circle on AB, so that its center S' moves in the direction of the arrow, and find the points P_1, P_2, P_3, etc. of the hypocycloid described by the point P, through which trace a faint curve. Make EF' equal the flank of the tooth $= .4p = .4 \times 2'' = .8''$, and with O as a center and OF' as a radius describe an arc cutting the hypocycloid in G'. PG' is the outline of the flank of the tooth and PG that of the face. Since it would be a tedious operation to draw all the tooth curves in this manner, it is usual to approximate the curves by means of circular arcs; that is, to find by trial a center Q and a radius QP such that an arc described from this center and with this radius will pass through the points on the curve GP and coincide with that curve as closely as possible; also, to do the same with regard to the curve PG', using the center Q' and the radius $Q'P$.

To find the center Q or Q' of these circular arcs proceed as follows: With P and G as centers and any radius describe arcs intersecting in C and C'. Draw a straight line through C and C'; the center Q must line on $C\,C'$ to the left of $G\,P$. Try different points *1*, *2*, *3*, *4*, etc. on this line as centers and *1* G, *2* G, etc. as radii, and see if one of the arcs struck with either one of these centers and radii will coincide with the epicycloidal curve $G\,P$. Make this circular arc fit the curve for a short distance beyond G—as far as P^2, for example; this will insure the arc being more nearly correct. This should be done in every case when finding an approximate radius of this kind. Continue in this manner until the point Q is found such that an arc struck with Q as a center and $Q\,G$ or $Q\,P$ as a radius will coincide as closely as possible with $G\,P$. If a circle were drawn with O as a center and $O\,Q$ as a radius, the centers of all the circular arcs of the faces of the teeth would lie in this circle, and the radii of these arcs would be equal in length to $Q\,P$. Hence, to find the center Q_1 of the arc $D\,H$ forming the back of the tooth, take D as a center and $Q\,P$ as a radius and describe a short arc cutting, in Q_1, the circle passing through Q. Then, with Q_1 as a center and the same radius describe the arc $D\,H$. In a similar manner find the center Q' and describe $P\,G'$, also $D\,H'$. Instead of letting the flank form a sharp corner at the bottom of the tooth, as shown dotted at G', it is usual to put a small fillet there, as shown by the full line. This makes the tooth stronger and less liable to break or to crack in casting. The entire tooth outline or curve $G\,P\,G'$ or $H\,D\,H'$ is called the **profile** of the tooth.

138. A **rack** is a part of a gear-wheel whose pitch circle is a *straight line;* the tops of the teeth all lie in the same plane.* A portion of a rack and one tooth are shown in Fig. 5. Take the pitch the same as before, then the addendum and root are also the same, that is, .6″ and .8″. Take

* As the radius of a circle is increased indefinitely, any arc of the circle approaches more and more to a straight line; and when the radius becomes infinite, the arc becomes a straight line.

the radius of the describing circles 1⅛", as before. It is evident that the tooth profile will be formed of parts of cycloids formed by rolling the describing (generating) circle upon the pitch line *A B*. Draw a small part of the cycloidal curves, as shown in the figure, by the method given in Fig. **1**; lay off the addendum and root and find the approximate radius in the same manner as in the last figure. The centers of the curves for the faces and flanks of all the teeth of the rack will evidently lie on the straight lines passing through *Q* and *Q'*, respectively, and parallel to the pitch line *A B*.

139. In Fig. **6** is shown the manner of drawing the **involute, or single-curve tooth.** The profile in this case is formed of a portion of an involute curve and a portion of the radius of the pitch circle. The circle from which the involute is constructed is called, in this case, the **base circle.** To find it draw the pitch circle, of which the arc *A B* is a part, with a radius equal to 5½" and having its center at *O*. Draw any radius *O W* cutting the arc *A B* in *D*. Through *D* draw the straight line *E F*, making an angle of 75° with *O W*. With *O* as a center and a radius to be found by trial, draw a circle tangent to *E F*. This circle, of which the arc *H G* is a part, is the base circle, and cuts *O W* in *P*. Upon this circle construct, in exactly the same manner as was shown in Fig. **3**, a portion of an involute curve passing through *P*. Lay off the addendum *I K* = .6", and with *O* as a center and *O I* as a radius describe an arc to form the top of the tooth, intersecting the involute in *L*. That part of the flank below the base circle is straight and is a part of the radius drawn to the point *P*. *K I'* is the root. The tooth has a fillet at *L'* and *K'*, as in cycloidal teeth. A circular arc is passed through the points *L* and *P*, coinciding as nearly as possible with the involute curve *L P*. Its center *Q* is found in the same manner as in Fig. **4**. For involute teeth it is only necessary to find the one center *Q*; the centers for all the remaining teeth lie on a circle having *O* as a center and passing through Q. To draw the other side of the tooth, lay off on the pitch circle $MN = .96''$, as before. With M as a center and $QN = QP$ as a radius draw an arc cutting, at Q_1, the circle passing through Q; with Q_1 as a center and the same radius describe the part $P'R$ of the tooth profile above the base circle. The part $P'R$ below the base circle is a part of the radius OP'.

140. In drawing any of the curves previously described, the greater the number of parts into which the describing or base circles are divided, the greater will be the accuracy obtained. The profile of the rack tooth used for involute gears is a straight line making an angle of 15° with a line drawn perpendicular to the pitch line. Its construction is shown in Fig. 7.

DEFINITIONS AND CALCULATIONS

141. When a revolving shaft transmits motion to another shaft parallel to it by means of gear-wheels or tooth-wheels in such a manner that two corresponding points, one on each gear-wheel, always lie in the same plane, the two gears are called **spur gear-wheels.** When the shafts are not parallel, but their axes intersect in a point, as O in Plate 1015, they are called **bevel gear-wheels.** If two bevel gear-wheels that work together have pitch diameters of the same size, they are called **miter gear-wheels.**

From what has preceded, it is evident that *the circular pitch multiplied by the number of teeth equals the circumference of the pitch circle.*

Let p = circular pitch of gear-wheel;
n = number of teeth;
d = pitch diameter;
$\pi = 3.1416$ (π is pronounced **pi**).

Then,
$$d = \frac{pn}{\pi} \qquad (1)$$

or, *the diameter of the pitch circle equals the circular pitch multiplied by the number of teeth divided by 3.1416.*

$$p = \frac{d\pi}{n} \qquad (2)$$

or, *the circular pitch equals the pitch diameter multiplied by 3.1416 divided by the number of teeth.*

$$n = \frac{d\pi}{p} \qquad (3)$$

or, *the number of teeth equals the pitch diameter multiplied by 3.1416 divided by the circular pitch.*

When constructing cycloidal teeth for gear-wheels, the diameters of the describing circles are usually made equal to one-half the diameter of the pitch circle of a gear-wheel having 12 teeth of the same pitch as those of the gear-wheel about to be made.

Let d' be the diameter of the describing circle; then,

$$d' = \frac{12p}{\pi} \times \frac{1}{2}, \text{ or } d' = \frac{6p}{\pi} \qquad (4)$$

Addendum = $.3p$; root = $.4p$; thickness of teeth for cast gears is $.48p$, and for cut gears $\frac{1}{2}p$.

PLATE 1014, TITLE:

GEAR AND PINION

142. This Plate shows the halves of two cast gear-wheels having cycloidal teeth, which work together, a cross-section of each gear being also given. The drawing is full size, the wheels not being shown entire for want of room; to have done so it would have been necessary to make the drawing to a reduced scale. The pitch is 1", the number of teeth in the large gear is 36, and in the small one 18. The pitch diameter of the large wheel is found by formula 1 to be

$$d = \frac{1 \times 36}{3.1416} = 11.46'', \text{ nearly}$$

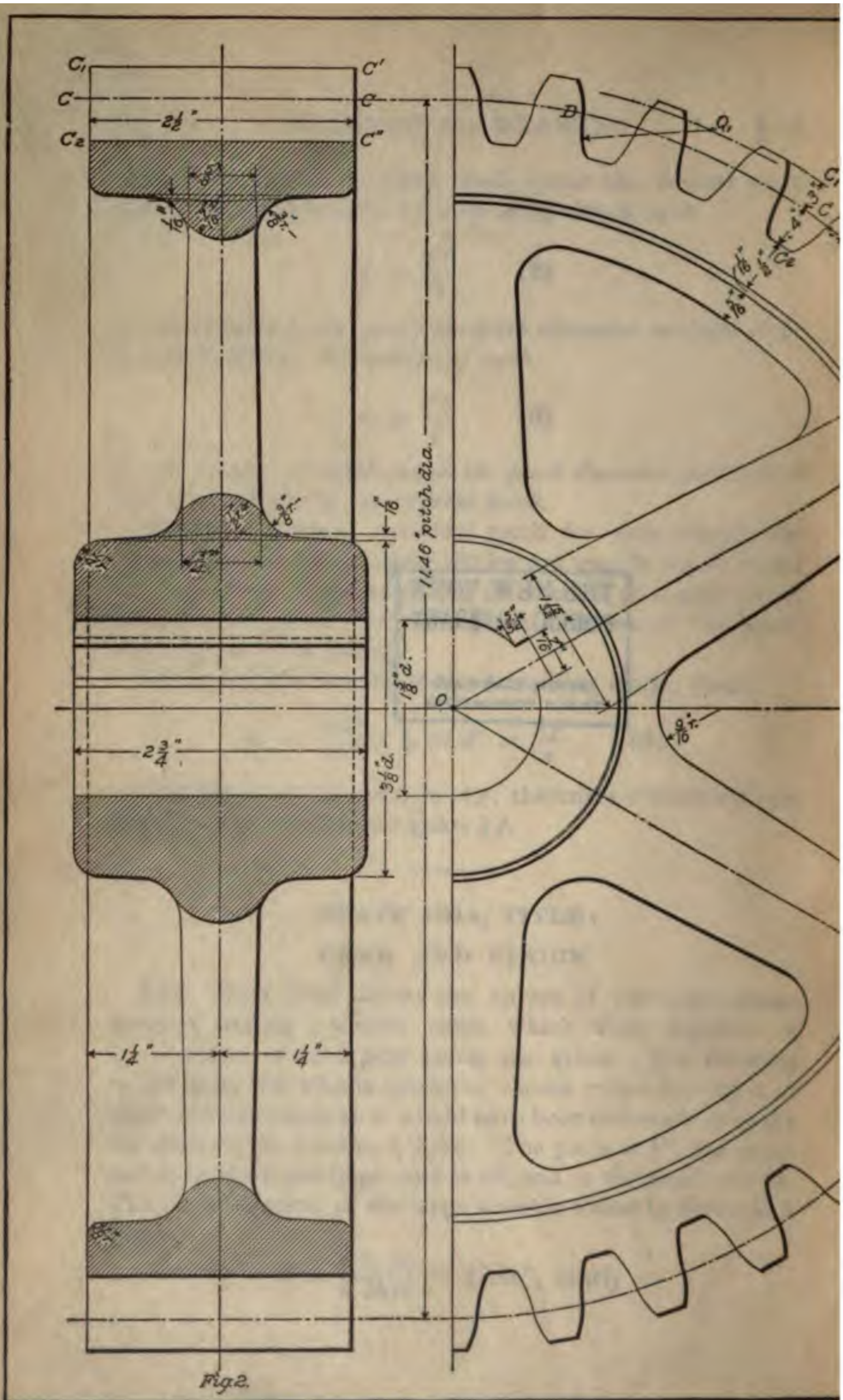
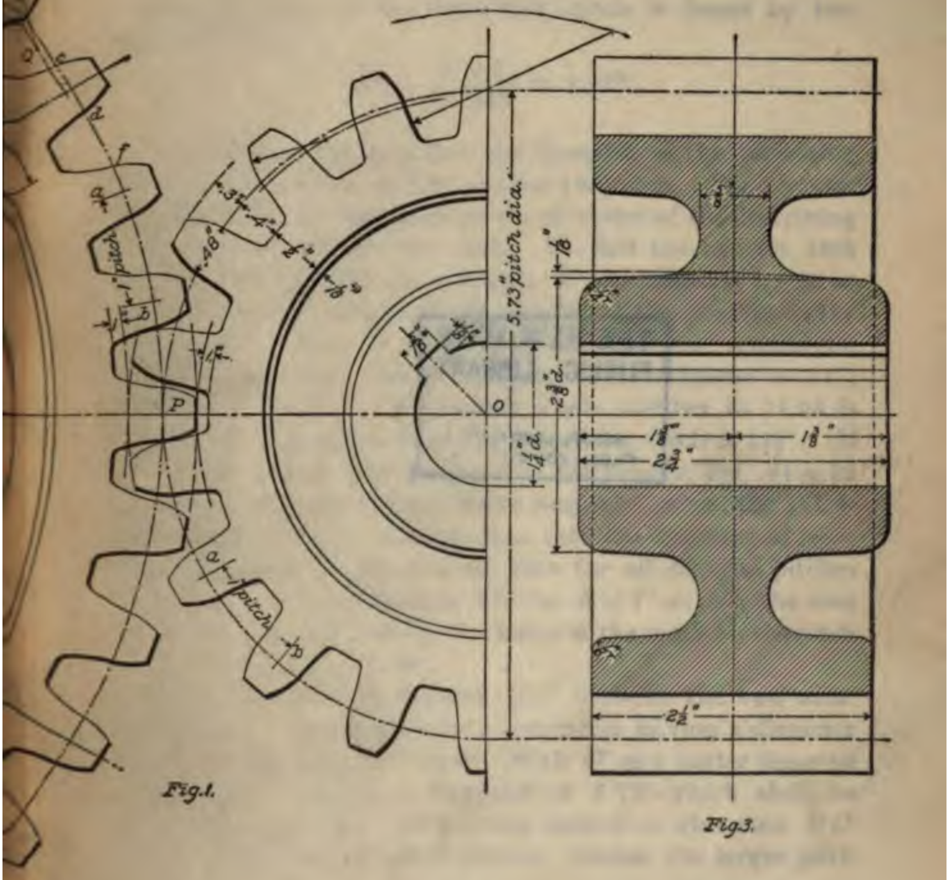


Fig. 2.



GEAR AND PINION

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red.

The pitch diameter of the small gear

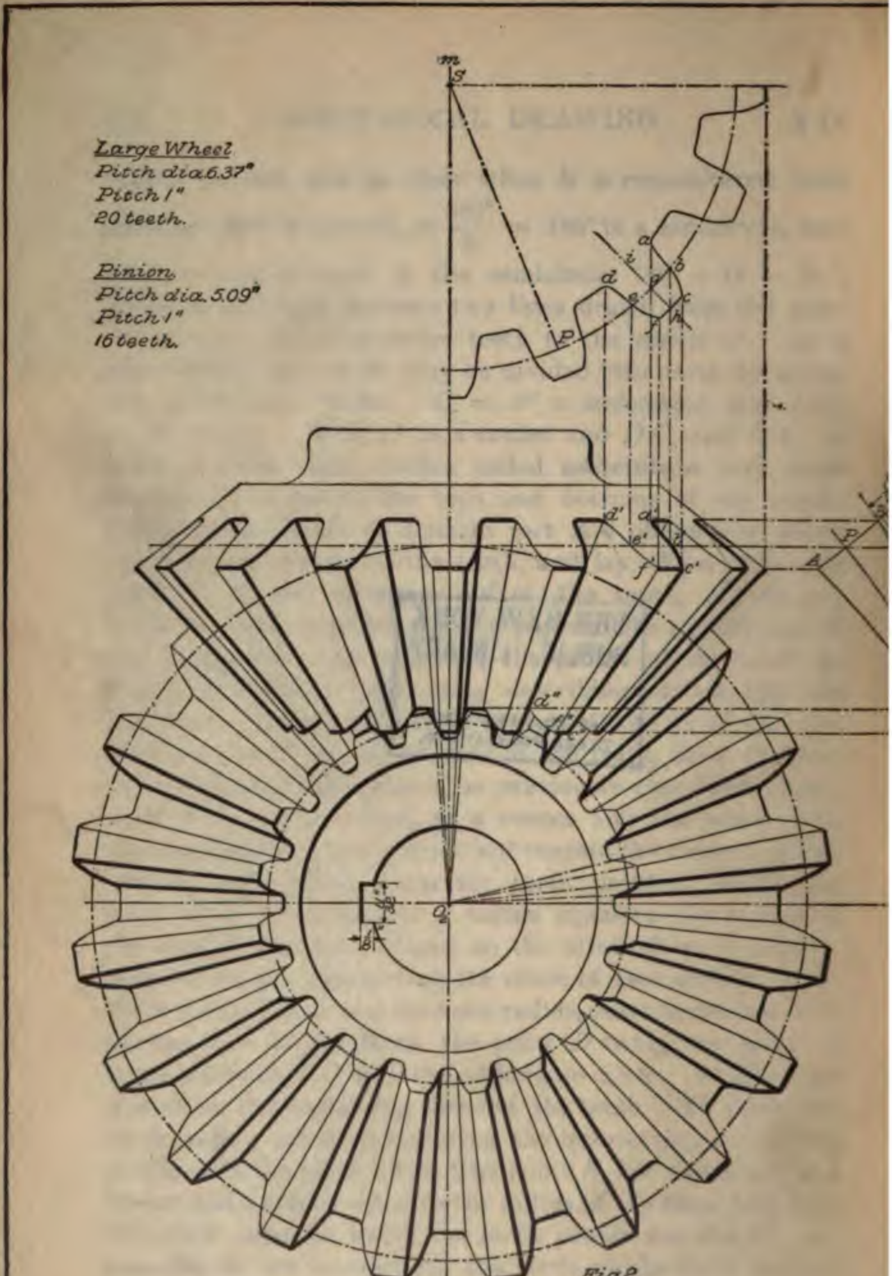
$$= \frac{1 \times 18}{3.1416} = 5.73'', \text{ nearly}$$

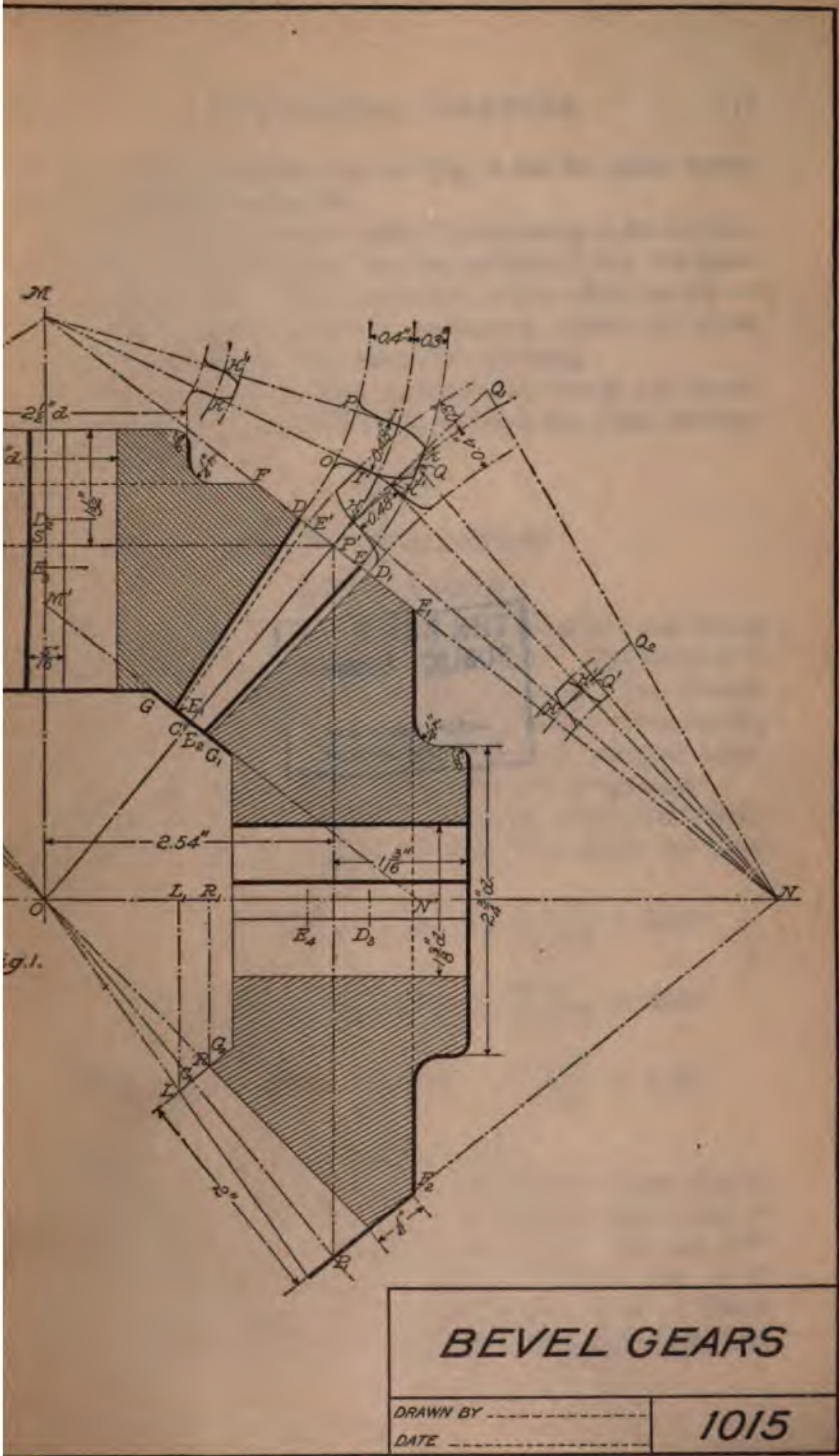
The diameter of the describing circle is found by formula **4** to be

$$d' = \frac{6 \times 1}{3.1416} = 1.91''$$

For all practical purposes, the diameter of the describing circle may be taken to the nearest 16th inch. For circular pitches under $\frac{1}{2}''$, approximate the diameter of the describing circle to the nearest 32d inch. To find the nearest 16th or 32d, multiply the decimal part of the diameter by 16 or 32 and take the nearest whole number of the product as the number of 16ths or 32ds that the decimal represents. Thus, in the above, the decimal part of the diameter is .91"; $.91 \times 16 = 14.56$. The nearest whole number to 14.56 is 15; hence, the diameter of the describing circle is $1\frac{15}{16}''$. If the diameter had been required to the nearest 32d, $.91 \times 32 = 29.12$; 29 is the nearest whole number; hence, the diameter would be $1\frac{29}{32}''$. In this case, take the diameter as $1\frac{15}{16}''$, approximating to the nearest 16th for all circular pitches above $\frac{1}{2}''$. The addendum will be $.3 \times 1'' = .3''$; the root $= .4 \times 1'' = .4''$; and the thickness of the tooth on the pitch circle $= .48 \times 1'' = .48''$.

Draw the line of centers $O\,O'$ between the two axes. With O as a center describe a semicircle having a diameter of 11.46", cutting $O\,O'$ in P. With O' as a center describe a semicircle having a diameter of 5.73" which shall be tangent to the first circle; this semicircle also cuts $O\,O'$ in P. These are the pitch circles. Divide the larger pitch circle into $\frac{36}{2}$, or 18 equal parts by using the protractor. This is accomplished by laying the protractor on the drawing in such a manner that the center of the protractor coincides with the center O of the gear-wheel and then laying off on the drawing 18 divisions, each equal to 10°. The reason for this will be clear when it is remembered that there are 360° in a circle, or $\frac{360°}{2} = 180°$ in a semicircle, and as there are 18 teeth in the semicircle, $180° \div 18 = 10°$, which is the angle between two lines drawn from the centers of any two consecutive teeth to the center O. In a like manner, any circle may be divided into parts by using the protractor. Make $C C_1 = .3'' =$ addendum, and $C C_2 = .4'' =$ root. With O as a center and $O C_1$ and $O C_2$ as radii, describe light circles, called **addendum and root circles**, to represent the tops and bottoms of the teeth. Consider the points of division just laid off on the pitch circle as the centers of the teeth, and lay off on each side one-half of the thickness $c d$ of the tooth, or $.48 \times \frac{1}{2} = .24''$. Upon another sheet of paper strike a short arc of the pitch circle and construct the profile of the tooth as described in Plate 1013, using describing circles $1\frac{11}{16}''$ in diameter. Having found the centers Q and Q_1 of the circular arcs used for the profiles of the teeth, draw circular arcs through these centers, as previously described; then, with O (see Plate 1014) as a center and the same radii describe circles; these circles will contain the centers of the circular arcs which form the teeth profiles. With the point A as a center and a radius equal to the radius of the face of the tooth (found on the other sheet of paper), describe an arc intersecting the circle of face centers at Q. With Q as a center and the same radius, describe the arc $A D$ for the face of the tooth, the point D being the point of intersection of $A D$ with the addendum circle. In the same way draw the remaining faces of the teeth. To draw the flanks take a point representing the intersection of a tooth profile with the pitch circle (the point B, for example) as a center and a radius equal to the radius of the flank found on the other paper on which the tooth profile was drawn, and describe an arc intersecting the circle of the flank centers in Q_1. With Q_1 as a center and the same radius, describe the flank curve, stopping at the root circle. Draw the flanks of the remaining teeth in the same way and then put in the


Large Wheel.
Pitch dia. 6.37"
Pitch 1"
20 teeth.
Pinion.
Pitch dia. 5.09"
Pitch 1"
16 teeth.
m
n
S
P
a
b
c
d
e
f
g
h
i
d'
e'
f'
c'
d"
A
O
Fig. 2.



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fillets. The remaining part of Fig. 1 can be easily drawn from the dimensions given.

Fig. 2 is a conventional method of drawing cross-sections of gears. The hubs and rims are sectioned, but the teeth and arms are not. This is similar to the wheel shown on Plate 1005. This method of sectioning makes the views clearer and saves the time spent in sectioning.

In Fig. 3 the entire gear is sectioned, except the teeth. The student should now be able to finish the Plate without further instructions.

PLATE 1015, TITLE:

BEVEL GEARS

143. To draw in section and projection two cast **bevel gears** whose axes intersect at right angles: The number of teeth in the large gear is 20, in the pinion 16. The circular pitch is 1″; the teeth are to be of the cycloidal form, having a face 2″ wide. In any kind of gearing, whether spur, bevel, or spiral, the smaller wheel is called the **pinion.**

Calculate the pitch diameters, addenda, roots, and describing circles by the same rules that were given for spur gears.

$$\text{Diameter of pinion} = \frac{16 \times 1''}{3.1416} = 5.09''$$

$$\text{Diameter of the large gear} = \frac{20 \times 1''}{3.1416} = 6.37''$$

$$\text{Diameter of describing circle} = \frac{6 \times 1''}{3.1416} = 1.91''$$

Take this as $1\frac{15}{16}''$, as in the last Plate.

Addendum = .3″; root = .4″. The sectional view, Fig. 1, must be drawn first. Draw PP' and through some point P' on this line draw $P'P_1$ perpendicular to it. Lay off PP' equal to the diameter of the pinion = 5.09″; also $P'P_1$ equal to the diameter of large gear = 6.37″. Bisect PP' and $P'P_1$, and draw OM and ON perpendicular to those lines at the point of bisection; they intersect in O. OM and ON are the axes of the two gears and intersect at right angles as required. Draw POP_1 and $P'O$. Through P draw APM perpendicular to OP. Through P' draw $MP'N$ perpendicular to OP' and through P_1 draw P_1N perpendicular to OP_1. PM and $P'M$ intersect at M on the line OM; $P'N$ and P_1N intersect at N, on the line ON. Lay off $P'C'$, PC, and P_1C_1, each equal to 2″, or the width of the face of the teeth; these lines are called the **pitch lines,** and the width of the face of the teeth is always measured on these lines. Lay off PA equal to .3″ = the addendum, and PB equal to .4″ = the root. Lay off $P'E$ and $P'D$ for the addendum and root of the other side, and $P'E'$ and $P'D_1$ for the addendum and root of the large gear. All these addenda and roots are each equal to .3″ and .4″, respectively. In bevel gears, all straight lines of the tooth profiles pass through the point of intersection O of the axes; hence, draw AO, and AA' will be the projection of the top of the tooth. Draw BO, and BB' will represent the bottom of the tooth, the line $A'CB'$ being perpendicular to OP. Make BF', DF, D_1F_1, etc. each equal to $\frac{1}{2}$″, according to dimensions. Join F', F, F_1, and F_2 with O, intersecting the perpendiculars through C, C', and C_1 (namely, the lines $A'CB'$, etc. produced) at G', G, G_1, and G_2. G', G and G_1G_2 will represent the bottom of the gears. The rest of the sectional part can be drawn from the dimensions.

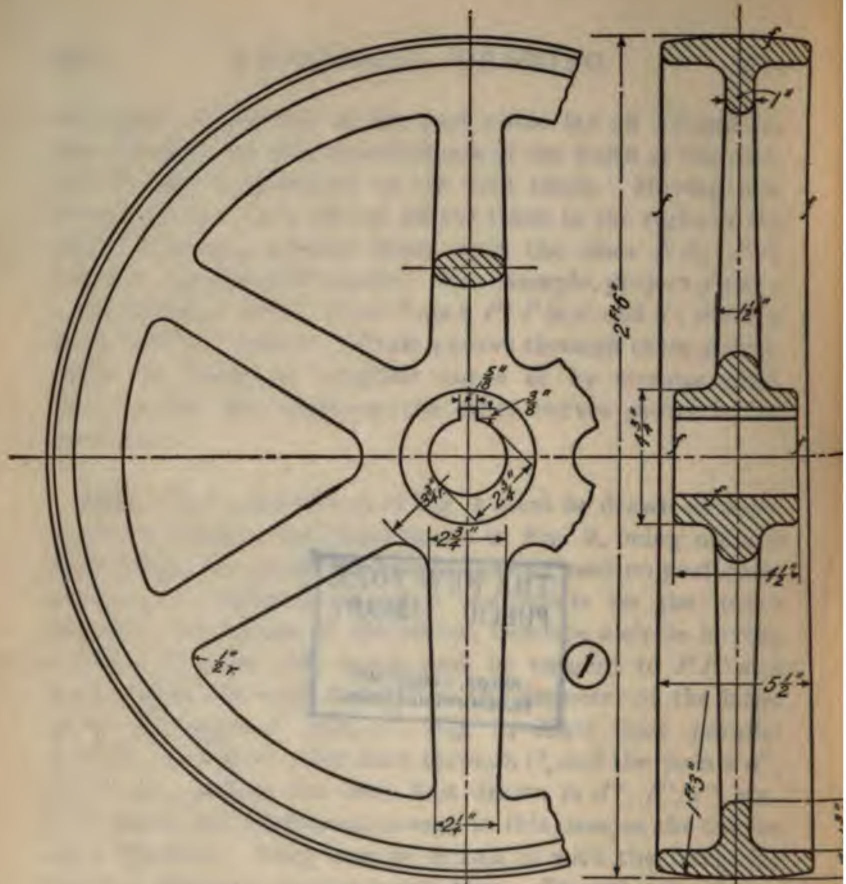
144. To show the shape of the teeth, proceed as follows: For the large gear, take N as a center, NP' as a radius, and describe an arc. Choose a point H and lay off HH' = .48 times the pitch = .48″, or the width of the tooth. With NE' and ND_1 as radii, describe the addendum and root circles. Roll the describing circles upon the arc whose radius is NP' and construct the tooth profile in exactly the same manner as in Fig. 4 of Plate 1013, QH and Q_1H' being the radii of the faces and flanks. To show the shape of the same tooth at C', draw $C'N'$ perpendicular to OP', or, what is the same thing, parallel to NP'. With $N'C'$ as a radius and N as a center, describe an arc. Draw NH and NH', and the distance between the points of intersection on the arc just drawn, measured on that arc, will be the pitch of the gear at the bottom of the tooth. With the same center and $N'E_1$ and $N'E_2$ as radii, describe arcs representing the addendum and root circles. Draw NQ and NQ_1, also QH and Q_1H'. Through K draw KQ' parallel to HQ, and through K' draw $K'Q_2$ parallel to $H'Q_1$; the points of intersection Q' and Q_2 of these lines with NQ and NQ_1 are the centers for the face and flank of the tooth at K and K'. Circles passing through these points concentric with N contain the centers of all the circular arcs forming the tooth profiles that may be laid off upon the arc whose radius is NK. The whole process is called **developing the teeth of bevel gears.**

In the same manner construct the tooth curves for the pinion, using the same describing circles, $1\frac{1}{16}''$ in diameter, and MP', $M'C'$ as radii, instead of NP' and $N'C'$.

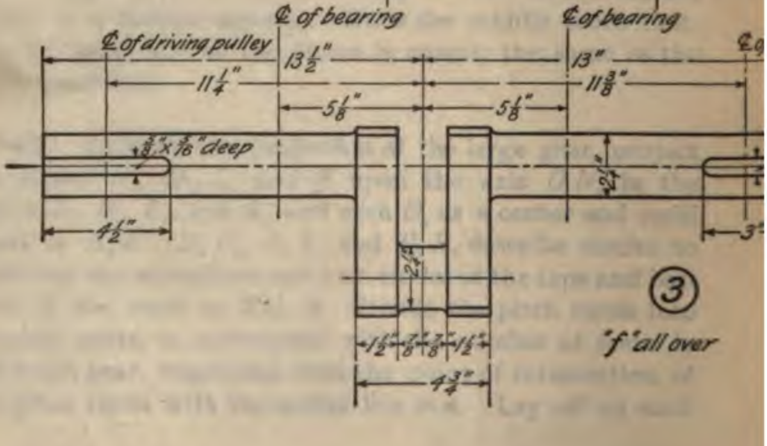
145. To construct the other view, draw first the projection of the pinion. Draw the center line mn. Produce the lines FF', DB, $P'P$, and EA across the drawing, as shown. Choose a point S on mn as a center and draw a quadrant with a radius equal to the radius of the pinion, as SP. Project the points D and E upon MO in D_2 and E_2. With S as a center and the distances E_2E and D_2D as radii, describe quadrants to represent the tops and bottoms of the teeth, that is, the projection of the addendum and root circles of the pinion in Fig. **2.** Since the whole pinion contains 16 teeth, the quadrant will contain 4 teeth; hence, divide the quadrant into 4 equal parts on the pitch circle to represent the centers of the teeth. Lay off on each side of the points of division distances ge and gb, each equal to one-half the thickness of the tooth. On each side of the points of division on the addendum circle lay off hf and hc, each equal to one-half the thickness of the top of the tooth JK, Fig. **1**, measured on the addendum circle. On each side of the points of division on the root circle lay off id and ia, each equal to one-half the thickness of the tooth at the root, as OP, Fig. 1, measured on the root circle. Having now three points on each side of all the teeth to the right of the center line mn, project them upon the lines EA, $P'P$, and DB, produced as shown. For example, project f and c upon EA in f' and c'; e and b upon $P'P$ in e' and b'; d and a upon DB in d' and a'. Draw a curve through these points, either by using an irregular curve or by circular arcs. This remark also applies to the other curves shown in the quadrant.

146. The tooth curves in Fig. 1 must be drawn as accurately as possible, but those shown in Fig. 2, being oblique projections, are drawn to satisfy the eye, and no particular accuracy is required. To find the points on the tooth curves at the bottom of the pinion, describe a circle having a center O_2 upon mn, which shall be tangent to PP' and have a diameter equal to 6.37″ = the diameter of the large gear. Through B' and A', Fig. 1, draw lines parallel to OO_2; also draw other lines through O_2 and the points d', f', c', etc., cutting the lines first drawn in d'', f'', c'', etc. Two points are considered enough in this case, as the curves are very short. They may be drawn in with the irregular curve in the same manner as the tops. The other teeth are drawn in a similar manner. Draw the middle tooth first. The left-hand half of the pinion is exactly the same as the right-hand half.

147. To draw the projection of the large gear, project the points E', D_1, L, and R upon the axis ON, in the points E_4, D_2, L_1, and R_1, and with O_2 as a center and radii equal to E_4E', D_2D_1, L_1L, and R_1R, describe circles to represent the addendum and root circles of the tops and bottoms of the teeth in Fig. 2. Divide the pitch circle into 20 equal parts, to correspond with the number of teeth in the large gear, beginning with the point of intersection of the pitch circle with the center line mn. Lay off on each

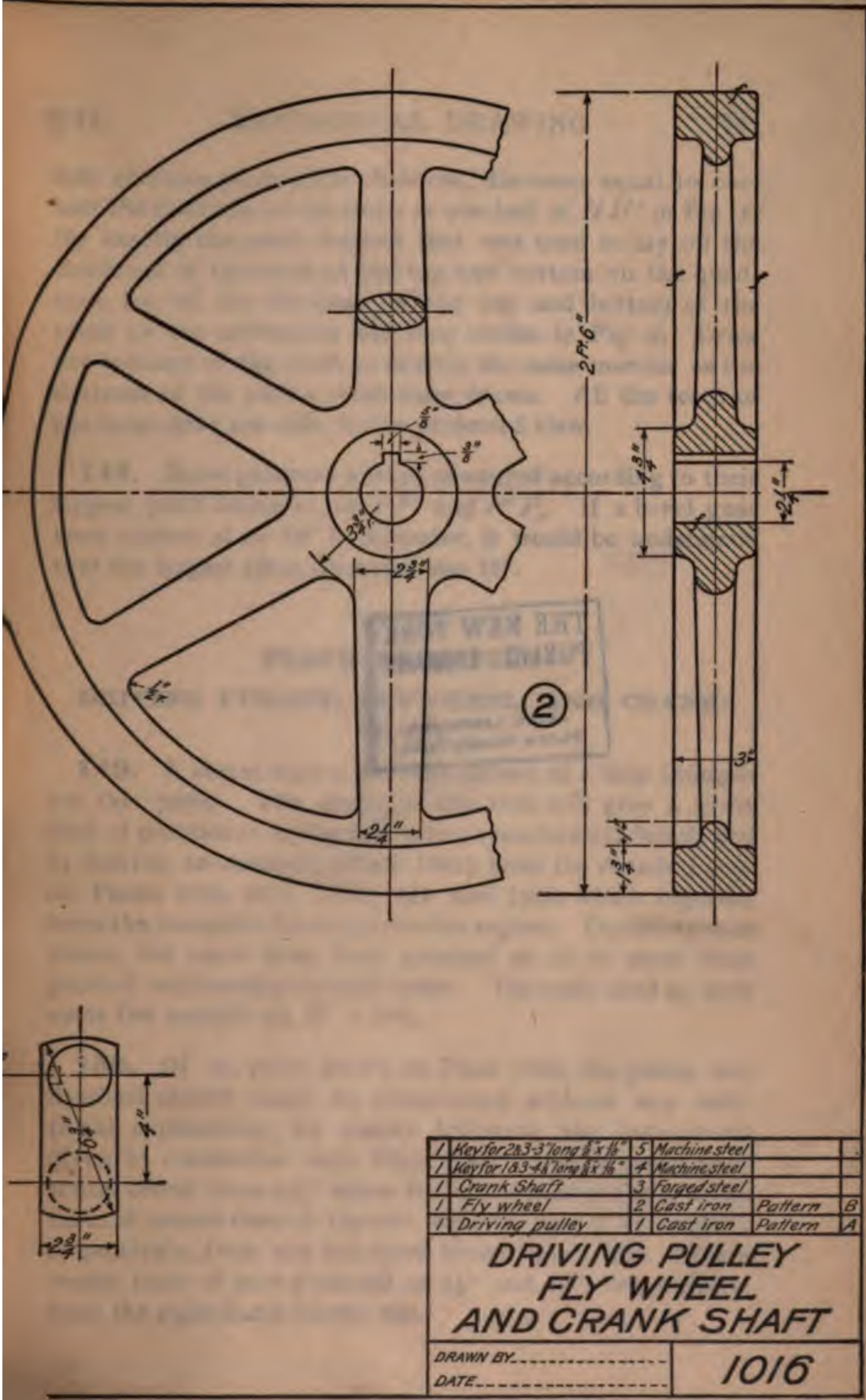

2 Ft 6"
1"
1½"
4¾"
1½"
5½"
1 Ft 3"
2¾"
2¼"
½" r
f

(1)


℄ of bearing
℄ of bearing
℄ of driving pulley
13½"
13"
11¼"
11⅜"
5⅛"
5⅛"
⅜" x 3⁄16" deep
2¼"
4½"
3"
1½"
⅞"
⅞"
1½"
4¾"

(3)

"f" all over



2 Ft. 6"
4¾"
2¼"
3¾"
2¾"
2¼"
3"
4"
2¾"
②
1 Key for 2 & 3-3" long
1 Key for 1 & 3-4½" long
1 Crank Shaft
1 Fly wheel
1 Driving pulley
5 Machine steel
4 Machine steel
3 Forged steel
2 Cast iron
1 Cast iron
Pattern B
Pattern A
DRIVING PULLEY
FLY WHEEL
AND CRANK SHAFT
DRAWN BY
DATE
1016

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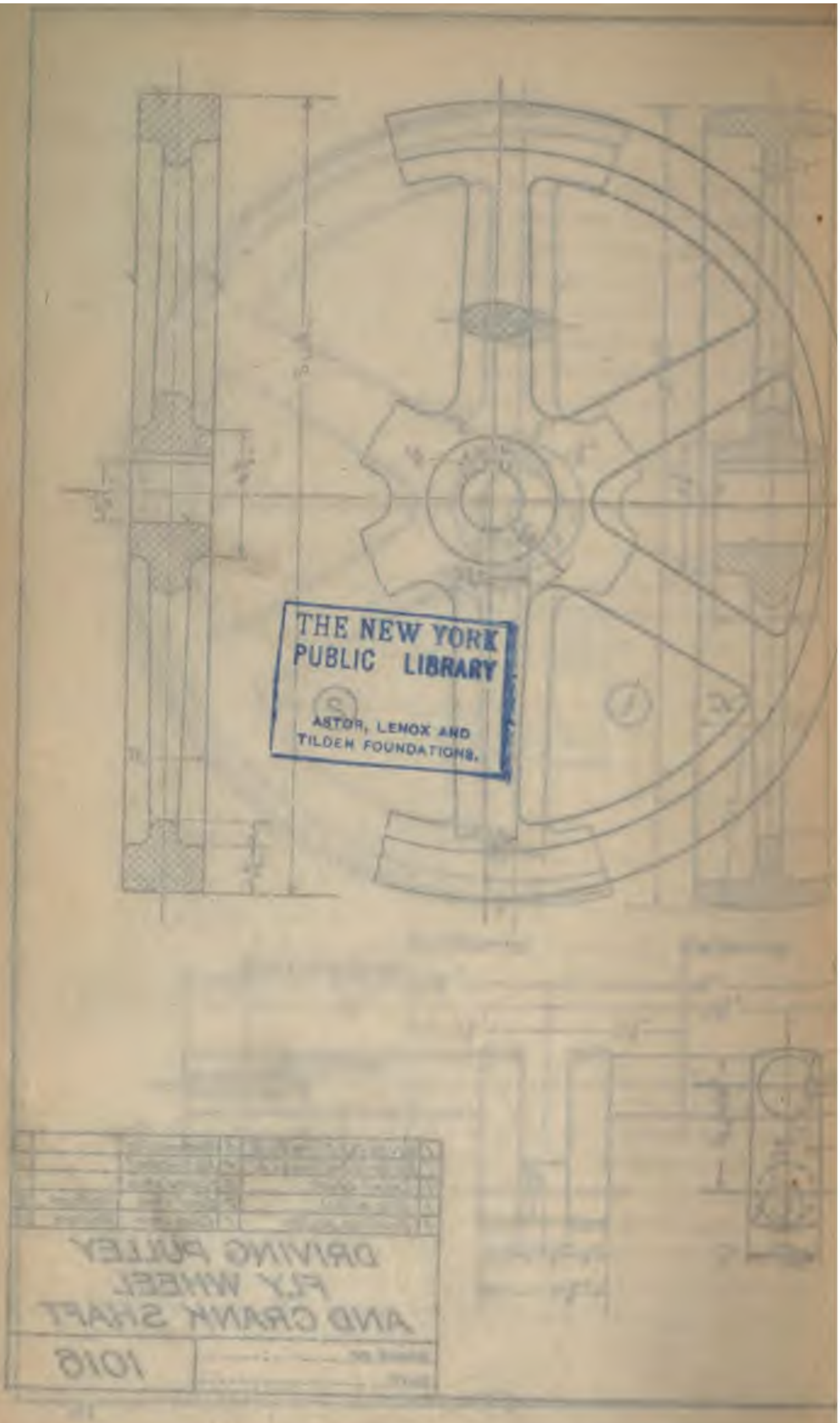


side of these pitch-circle divisions, distances equal to one-half the thickness of the teeth = one-half of HH' in Fig. 1. By exactly the same method that was used to lay off the thickness of the teeth at the top and bottom on the quadrant, lay off the thickness of the top and bottom of the teeth on the addendum and root circles in Fig. 2. Draw the bottoms of the teeth in exactly the same manner as the bottoms of the pinion teeth were drawn. All the teeth of the large gear are alike in the projected view.

148. Bevel gears are always measured according to their largest pitch diameter, as PP' and $P'P_1$. If a bevel gear were spoken of as 12" in diameter, it would be understood that the largest pitch diameter was 12".

PLATE 1016, TITLE:

DRIVING PULLEY, FLYWHEEL, AND CRANK-SHAFT

149. A steam engine has been chosen as a final example for this paper. The design is one that will give a great deal of practice in laying out various mechanical details and in making an assembly (Plate 1021) from the details found on Plates 1016, 1017, 1018, 1019, and 1020, which together form the complete drawings for this engine. On the various plates, the parts have been grouped so as to show their general relationship to each other. The scale used is, with some few exceptions, 3" = 1 ft.

150. Of the parts shown on Plate 1016, the pulley and flywheel should easily be constructed without any additional explanation, by simply following the instructions given in connection with Plate 1005. Locate their horizontal center lines $4\frac{9}{16}$" below the upper border line and the vertical center lines of the two views of part *1*, $4\frac{5}{8}$" and 7", respectively, from the left-hand border line. The vertical center lines of part *2* should be $4\frac{3}{8}$" and $1\frac{3}{8}$", respectively, from the right-hand border line.

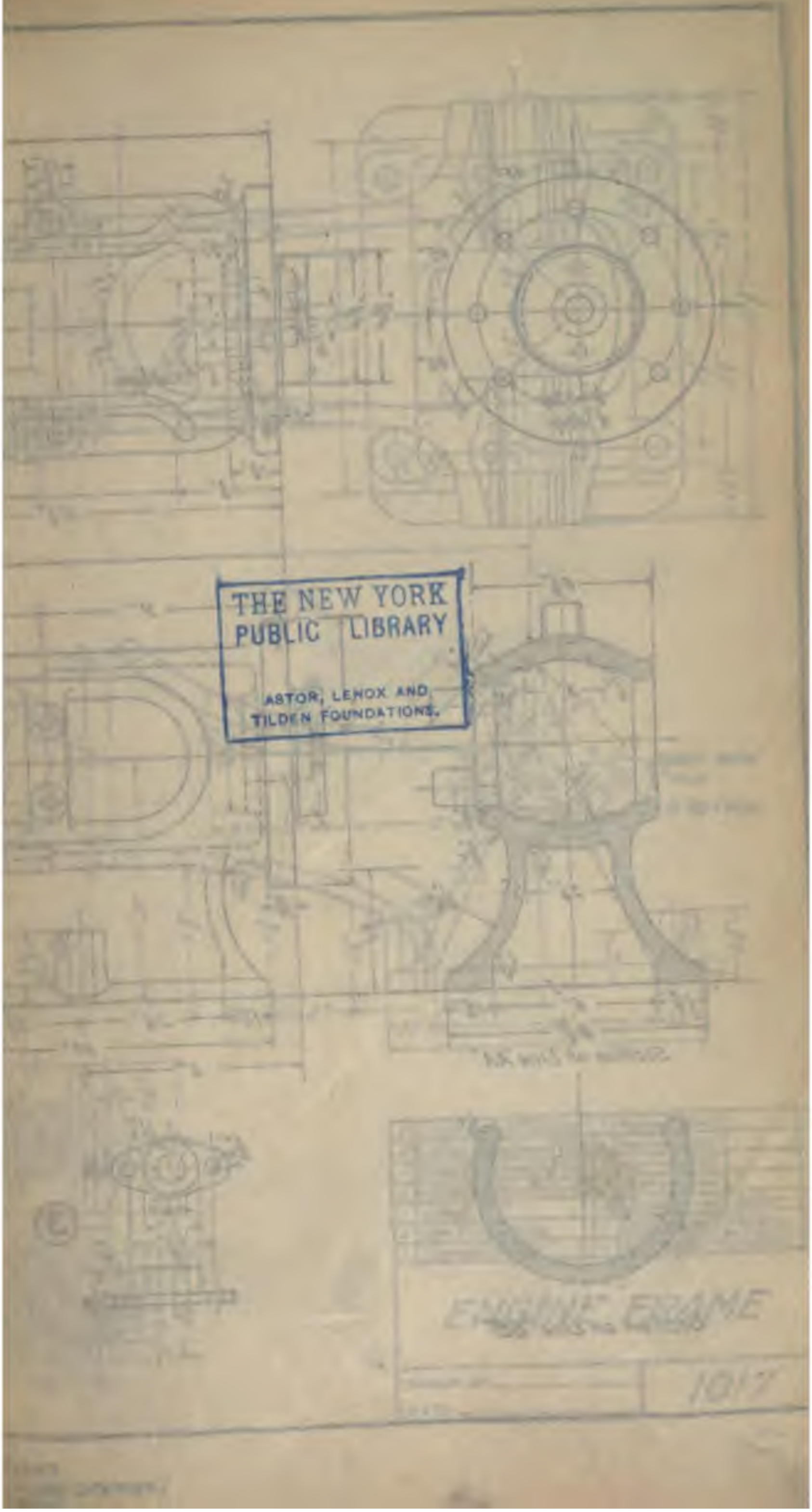
Part *3* is a forged-steel crank-shaft, on one end of which is to be mounted the driving pulley and on the other end the flywheel, both held in position by keys partly sunk into the shaft and partly into the hubs. The crank-shaft consists of the shaft proper and of two arms projecting at right angles, called the *webs*, which are connected by a short stud-like part, the *crankpin*. The vertical center line of the flywheel is $11\frac{3}{8}''$ (see Plate 1016) from that of the crankpin, the latter center being coincident with that of the cylinder and connecting rod, while the center line of the driving pulley is $11\frac{1}{4}''$ to the other side of the crankpin center. It should be noticed that on the Plate the abbreviation ℄ has been used for the term center line.

After the flywheel and driving pulley have been mounted on the shaft, the latter is placed in the bearings of the engine frame. The centers of these bearings are indicated as being $5\frac{1}{8}''$ to either side of the crankpin center. It will be noticed that the two keyways are not alike, the one for the driving pulley being cut clear to the end, while the one for the flywheel stops a short distance from the end. The stroke of the engine is determined by the distance between the horizontal center line of the crankpin and that of the shaft. This distance is here 4″ and the stroke will therefore be $4'' \times 2 = 8''$.

The shaft is $2\frac{1}{4}''$ in diameter; the web is $2\frac{3}{4}''$ wide by $1\frac{1}{2}''$ thick and rounded off to a radius of $6\frac{3}{4}''$. Locate the center line of shaft 3″ above the lower border line, and the vertical center line through the crank and end view of shaft $4\frac{15}{16}''$ and $9\frac{3}{4}''$, respectively, from the left-hand border line.

PLATE 1017, TITLE;
ENGINE FRAME

151. On this Plate are shown a plan, a side elevation, an end view, two cross-sections, and some details of the engine frame, all drawn to a scale of $3'' = 1$ ft. The elevation and plan are to be drawn together. Locate the center lines of these two views $2\frac{3}{4}''$ and $6\frac{3}{4}''$, respectively,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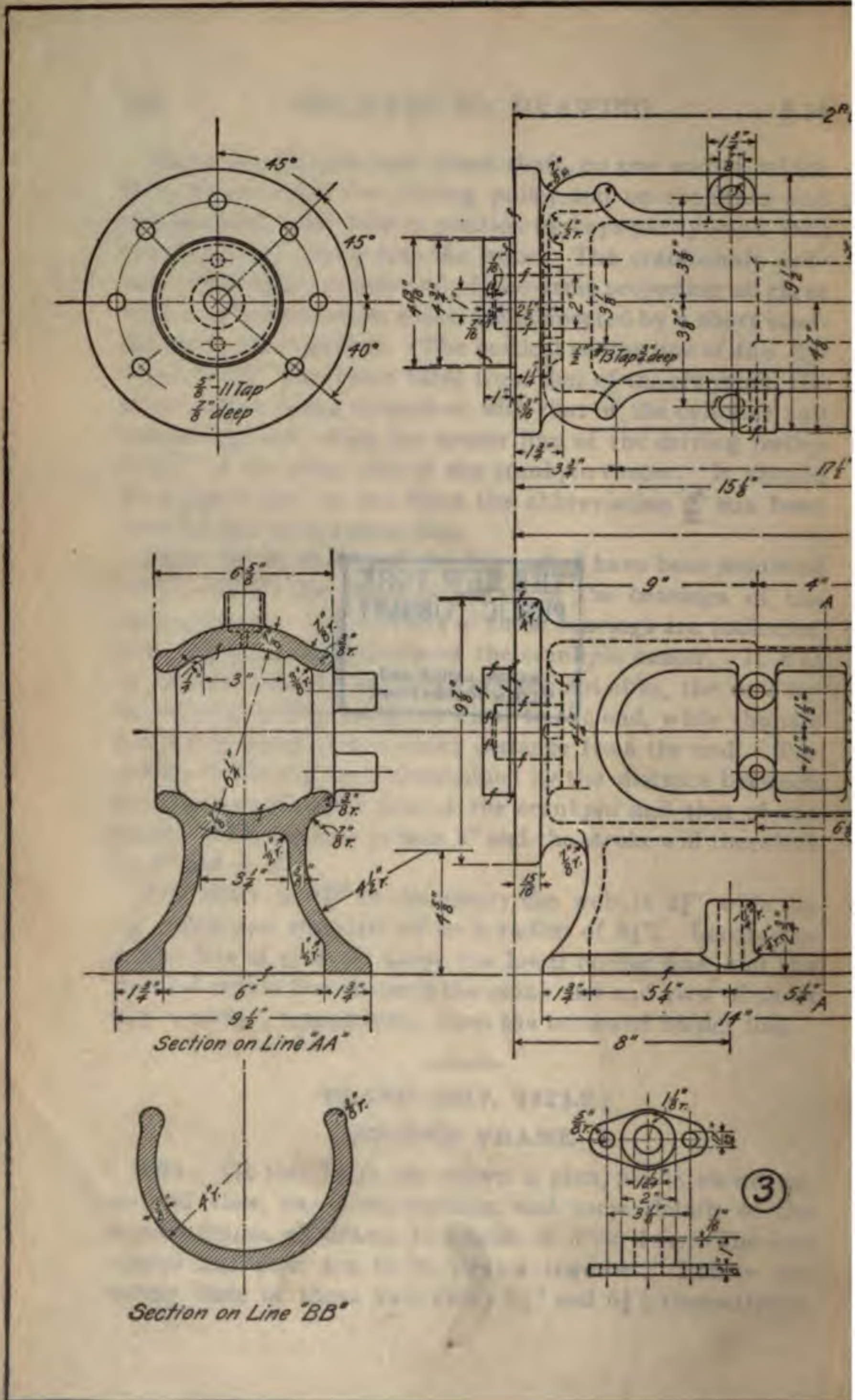
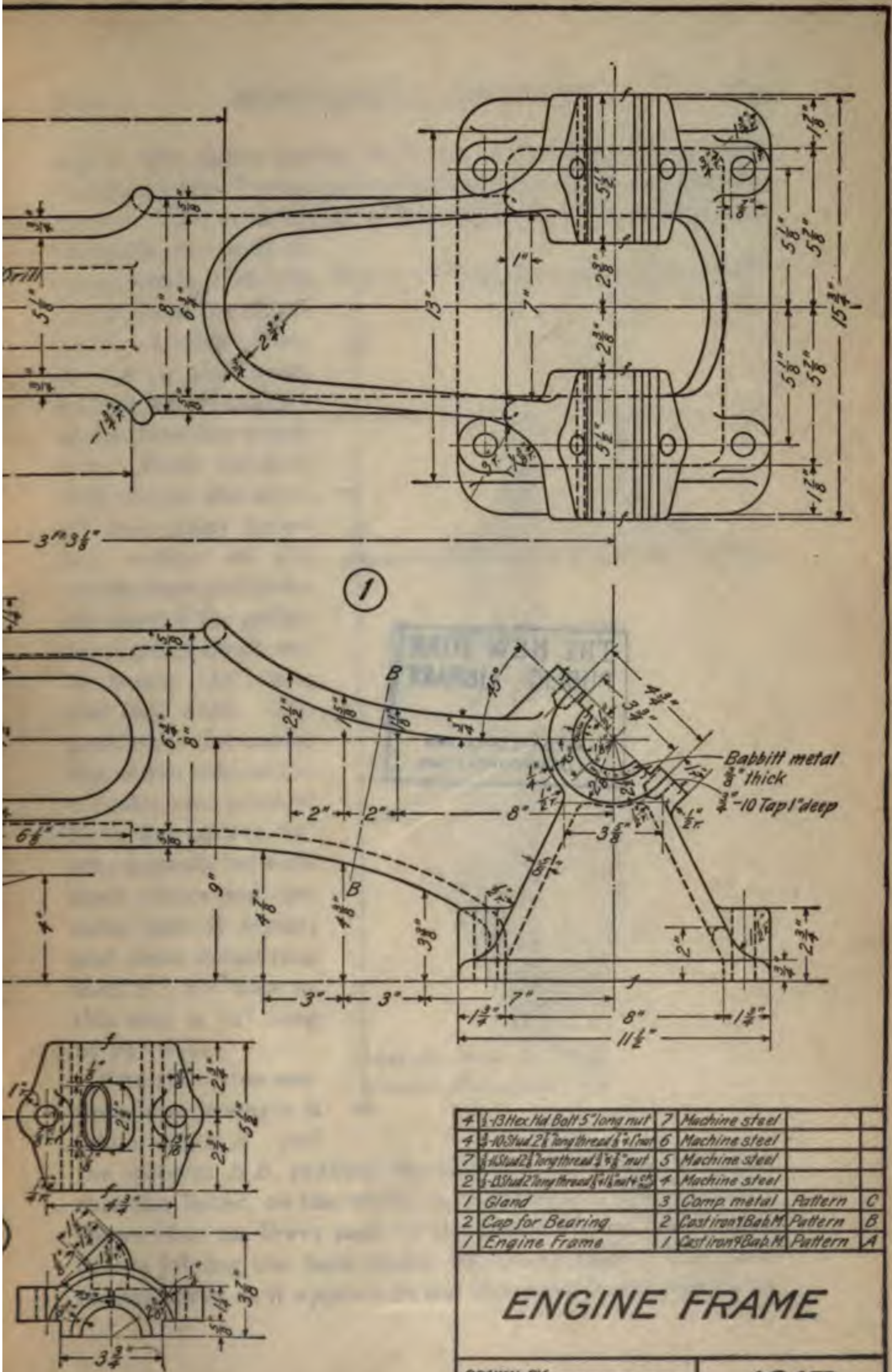


45°
45°
40°
5/8" -11 Tap
7/8" deep
13 Tap 3/4" deep
Section on Line "AA"
Section on Line "BB"
3



4	1/2-13 Hex Hd Bolt 5" long nut	7	Machine steel		
4	3/4-10 Stud 2 5/8" long thread 5/8" & 1" nut	6	Machine steel		
7	1/2-13 Stud 2 1/8" long thread 1/4" & 5/8" nut	5	Machine steel		
2	1/2-13 Stud 2" long thread 5/8" & 1 1/8" nut & ch. nut	4	Machine steel		
1	Gland	3	Comp. metal	Pattern	C
2	Cap for Bearing	2	Cast iron & Bab. M.	Pattern	B
1	Engine Frame	1	Cast iron & Bab. M.	Pattern	A

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below the upper border line and extend them the whole length of the Plate, as they are also to serve for the end views. The vertical center line, which in both views passes through the center of crank-shaft, should be 2½″ from the right-hand border line. Locate the main horizontal dimensions from this center line. Draw the base line of the elevation 9″ (to scale) below the center of the crank-shaft and make the base of the pedestal at crank-shaft end of frame 11½″ long and 15¾″ wide. The position of the center line of the base at the cylinder end is found by laying off 3 ft. 3⅛″ (the distance between shaft center and cylinder end of frame) and then measuring back 8″; the base at this end is 14″ long by 9½″ wide.

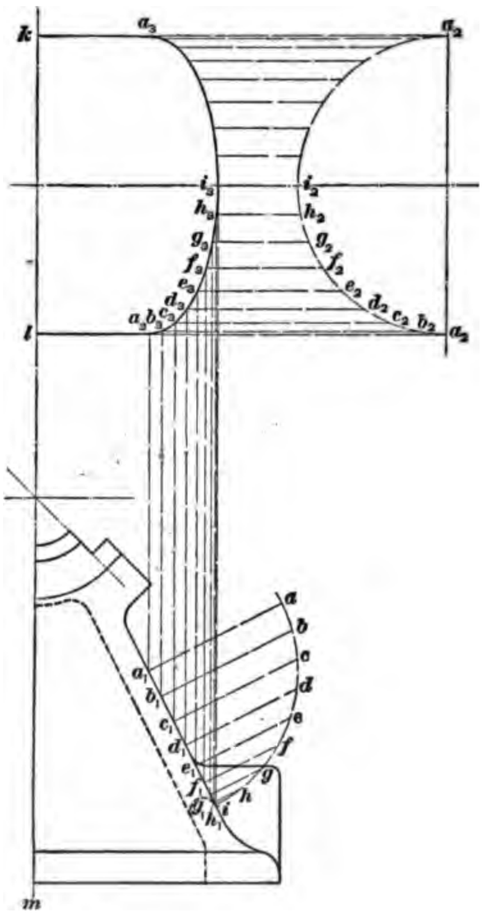


Fig. 52

The two cross-sections, one of which is taken at *A A* and the other at *B B*, indicate the shape of the frame, showing that the latter, on the whole, is cylindrical. The elevation shows that the lower part of the frame curves downwards before joining the base under the crank-shaft. The form of this curve as it appears in the elevation is determined by locating a number of points from the vertical and horizontal center lines and base line, as shown by the dimensions on the drawing. The points are then joined by lines drawn with the irregular curve. Before joining this curve to the cylindrical part of the frame, draw first the bead-like rib seen at this end, indicated by a circle $\frac{3}{4}''$ in diameter (see section on *BB*) and draw the curve tangential to this circle. The pedestal is pyramidal in shape, as seen in the elevation, with a semicircular opening in the top. To show this opening properly in the plan view, the special construction shown in Fig. 52 is required, in which the lower view represents the end of the frame in elevation. The semicircle, $6\frac{3}{4}''$ in diameter, representing the lower part of the opening, is supposed to have been turned at right angles about its vertical radius so as to lie in the plane of the paper. Only a quarter circle has been shown—the other part being symmetrical to it—and this has been divided into 8 equal parts, as shown at *a b*, *b c*, *c d*, etc. From these division points, projectors are drawn at right angles to side of frame, as indicated by lines $a\,a_1$, $b\,b_1$, $c\,c_1$, etc. A plan view of the opening is now to be drawn above the elevation by first drawing the semicircle $a_2\,i_2\,a_2$, representing a plan of the opening, and dividing it in 16 parts, since the whole semicircle is shown here. Draw horizontals from the points a_2, b_2, c_2, etc., letting them intersect verticals from the points a_1, b_1, c_1, etc., the points of intersection being points on the curve, as shown at a_3, b_3, c_3, etc. Draw horizontals through the two points a_3 toward the center line, when the lines $k\,a_3$ and $l\,a_3$ will indicate the outline of the opening as it will appear in the plan view. Verticals have been shown as only intersecting the horizontals from the lower half of the semicircle, but it is understood that they should be continued so as also to intersect those in the upper half, this part of the view being symmetrical to the lower half.

152. The face of the crank-shaft bearing is inclined at an angle of 45° with the horizontal, and has two $\frac{3}{4}''$ studs tapped into the frame for each cap. The lower half of the bearing and the cap are each lined with Babbitt $\frac{3}{8}$" thick. For aid in drawing these bearings in the plan view, the student should refer to Fig. 53. The method employed is

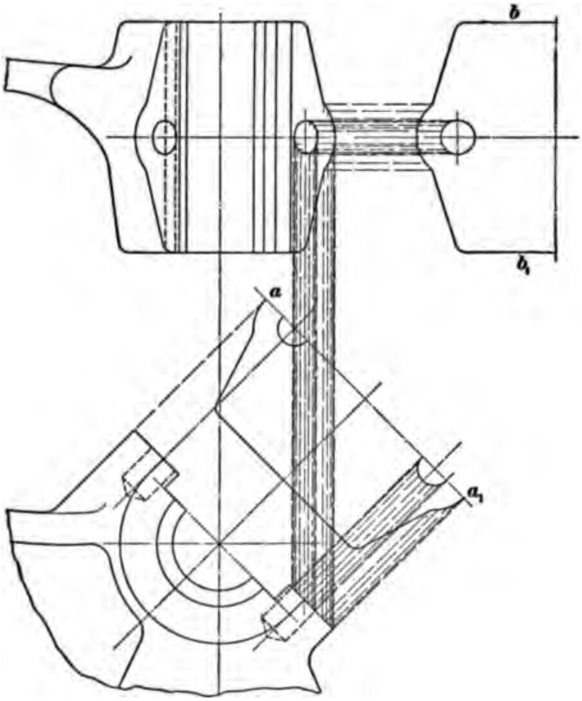


FIG. 53

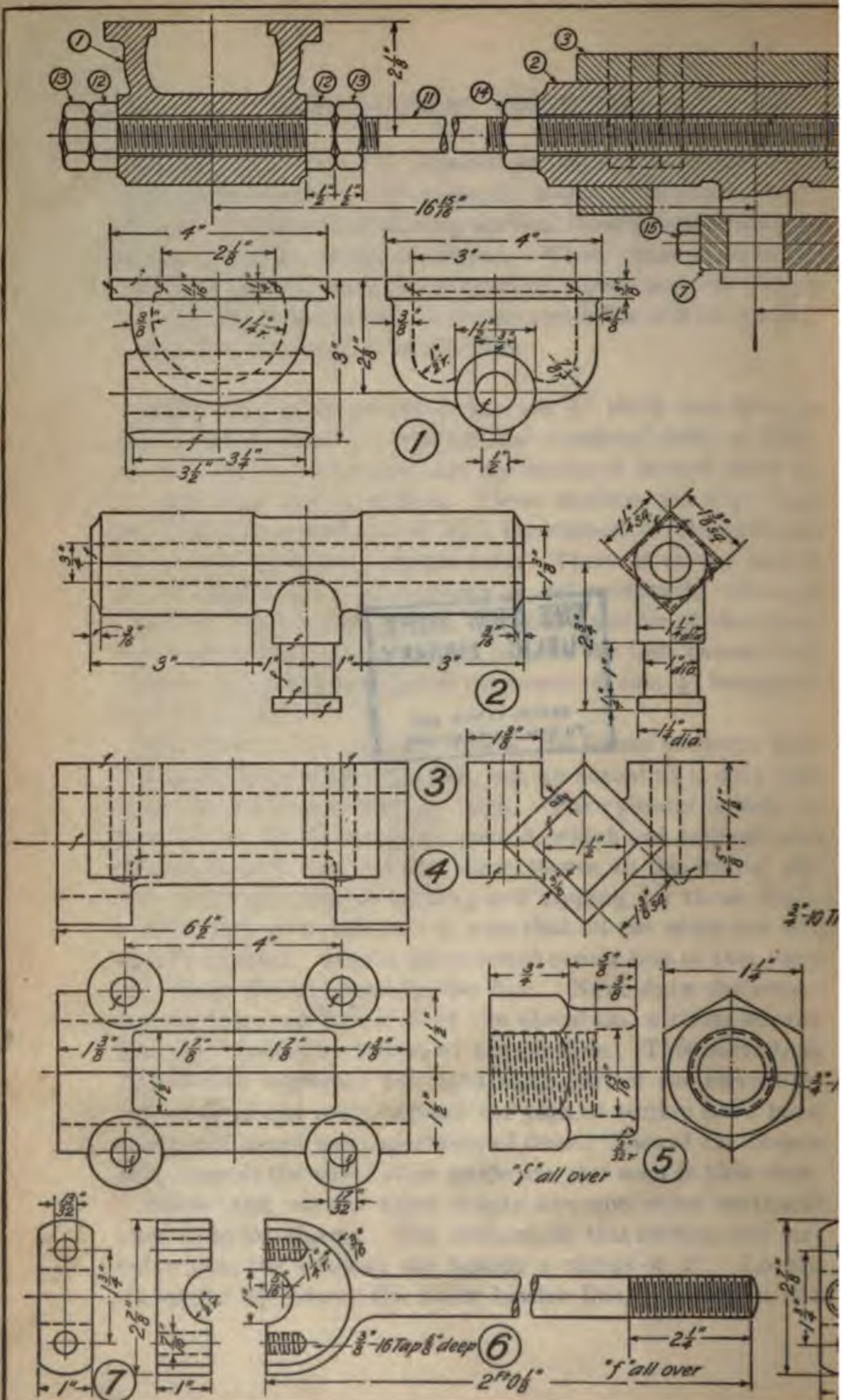
identical with that used in Fig. 52, and for this reason it was not thought necessary to supply it with reference letters or to enter into any detailed description of same. The dimensions of the plan view $a a_1$ shown in connection with the main elevation in Fig. 53, are derived from the plan view of the cap, part 2, the outlines being identical for both parts. The outlines of the stud holes and the curved parts of the frame adjoining same are divided into a certain number of parts, not necessarily as many as are indicated in the illustration, and these points are projected to the main elevation.

Another plan view $b\,b_1$ located as shown, is subdivided in a similar manner, and from the points of division, horizontals are drawn intersecting vertical lines drawn from the elevation at the points indicated. When these points are joined by circular arcs, the centers of which must be found by trial, the true outlines of frame and holes will be found, and as they will appear in the plan.

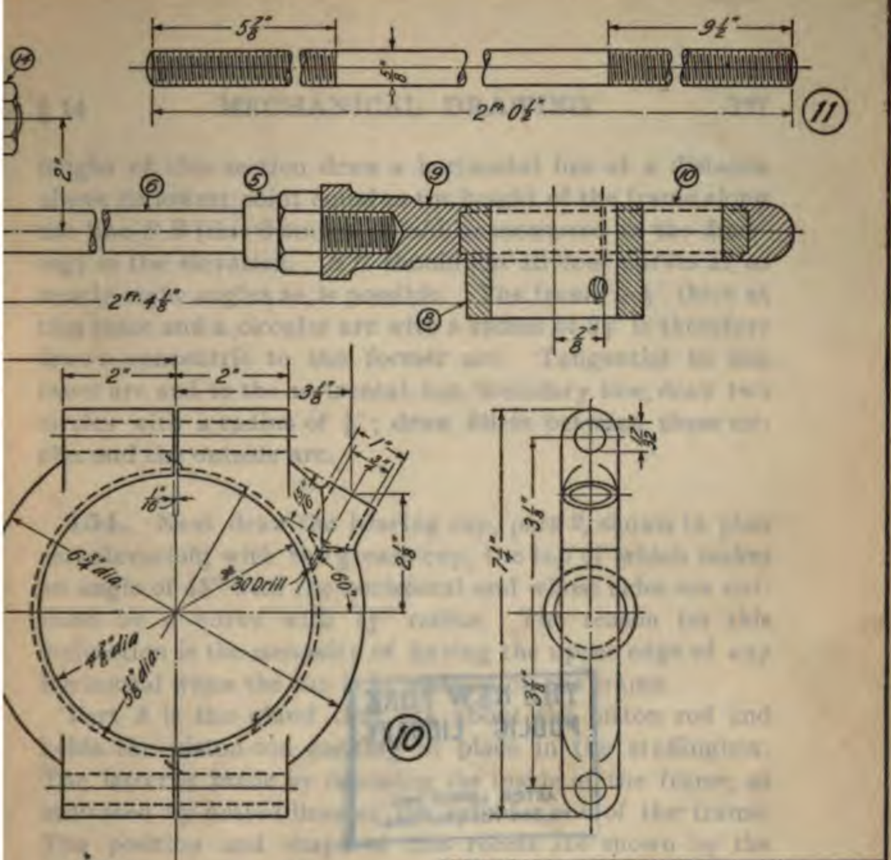
153. The walls of the frame are $\frac{5}{8}''$ thick and have a raised surface that is bored for the crosshead slide, as indicated in the cross-section, and by means of dotted lines in the plan view and elevation. These surfaces are $12\frac{1}{4}''$ long and bored to a diameter of $6\frac{1}{4}''$, the centers of the surfaces being $15\frac{1}{8}''$ from the cylinder face. There is at the center of the upper surface a grease or oil receptacle through which the crosshead is oiled. Near the middle of the opening in the side of the frame will be seen the four bosses that support the valve-stem guide by means of four $\frac{1}{2}''$ hexagon-head bolts, part *7*.

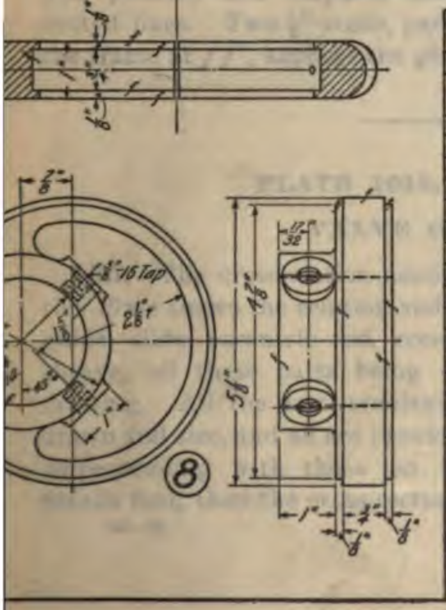
The boss on the cylinder end of the frame projects into the center bore of the cylinder, but an actual fit is only had along the small shoulder $\frac{1}{16}''$ high. The cylinder is held in position by the seven studs, part *5*, which are tapped into the frame end. In the end view, shown to the left of the plan view, the plan of drilling and tapping for these studs is indicated, from which it is seen that all the studs are not equally spaced. Locate the vertical center line of this view $1\frac{15}{16}''$ from the left-hand border line. Next draw the cross-section taken on line $A\,A$ of the elevation, with its center line $2\frac{3}{16}''$ from the left-hand border line. This section is intended to represent the right-hand part of the elevation, but most of the parts beyond the plan of section have been omitted to avoid any superfluity of lines. Two of the bosses that support the valve-stem guide are also seen in this view.

Below and on the same center line the other sectional view is to be shown. The outlines of this section are circular arcs, the exterior one having a radius of 4″. Locate its center $2\frac{1}{4}''$ above the lower border line. To define the



1
2
3
4
5
6
7
16 15/16"
6 1/2"
4"
3"
"f" all over
"f" all over
2 Ft 0 5/8"
2 1/4"





4	$\frac{1}{2}$"-13 Hex Hd Bolts 5" long and nuts for 3 & 4 & Frame	18	Machine steel		
2	$\frac{3}{8}$"-16 Sq hd set screw $\frac{1}{2}$" long for 8	17	Machine steel		
2	$\frac{1}{2}$"-13 Hex Hd Bolts 5" long with nut and ck. nut for 9 & 10	16	Machine steel		
2	$\frac{3}{8}$"-16 Hex hd bolt $1\frac{1}{2}$" long for 6 & 7	15	Machine steel		
2	$\frac{5}{8}$"-11 Hex nuts $\frac{5}{8}$" thick for 2 & 11	14	Machine steel		
2	$\frac{5}{8}$"-11 check nuts $\frac{1}{2}$" thick for 1 & 11	13	Machine steel		
2	$\frac{5}{8}$"-11 Hex nuts $\frac{5}{8}$" thick for 1 & 11	12	Machine steel		
1	Valve rod	11	Machine steel		
1	Eccentric strap half	10	Cast iron	Pattern	H
1	Eccentric strap half	9	Cast iron	Pattern	G
1	Eccentric sheave	8	Cast iron	Pattern	F
1	Eccentric rod strap	7	Forged steel		
1	Eccentric rod	6	Forged steel		
1	Nut for Eccentric rod	5	Comp. metal	Pattern	E
1	Top half Valve stem guide	4	Cast iron	Pattern	D
1	Bottom half Valve stem guide	3	Cast iron	Pattern	C
1	Valve stem slide	2	Com. metal	Pattern	B
1	Valve	1	Cast iron	Pattern	A

VALVE GEAR

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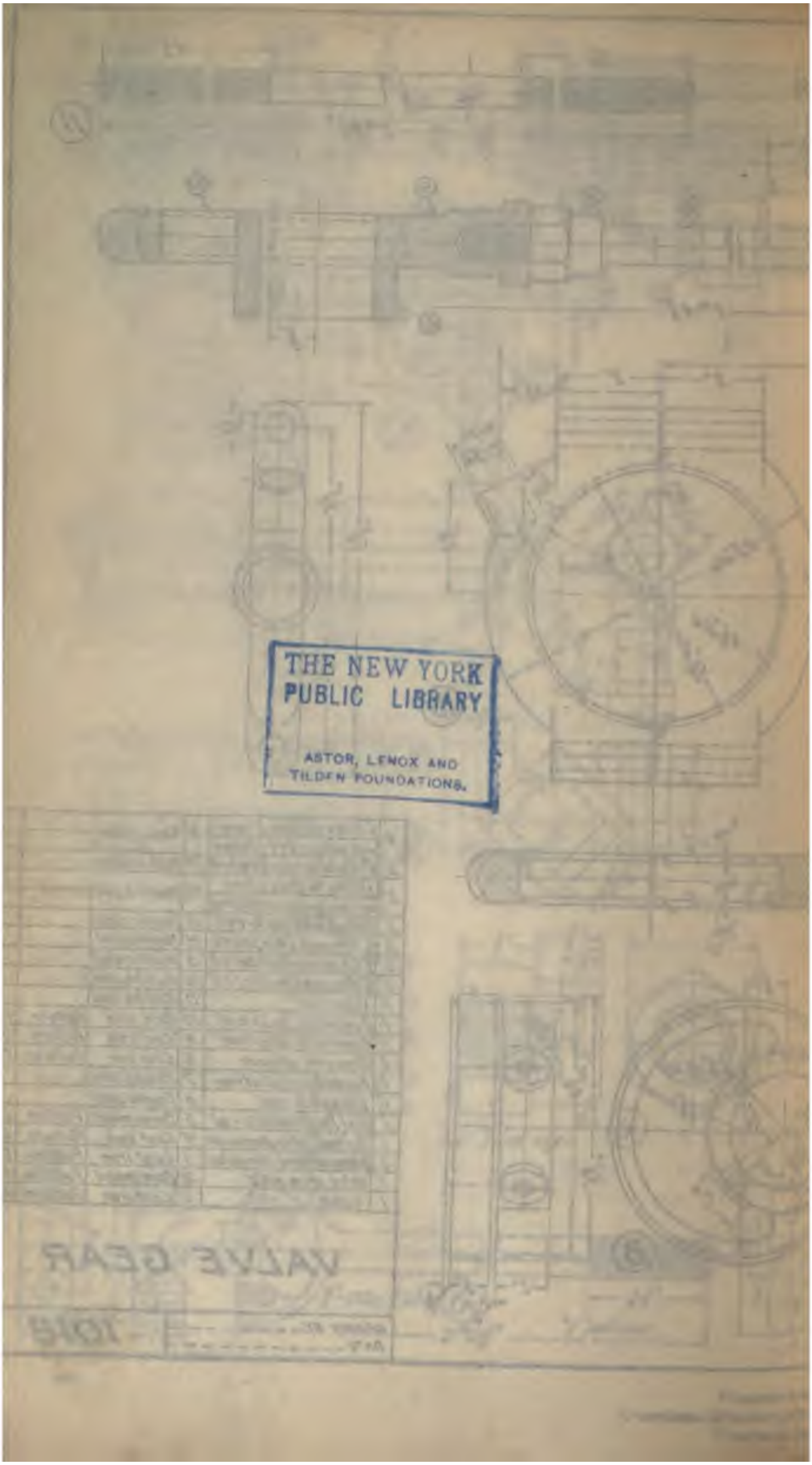
TATES.
XTBOOK COMPANY.
London.



height of this section draw a horizontal line at a distance above its lowest point equal to the height of the frame along the line *B B* (this distance should be measured on the drawing) in the elevation. *B B* should cut all four curves at as nearly right angles as is possible. The frame is $\frac{5}{8}''$ thick at this place and a circular arc with a radius of $3\frac{3}{8}''$ is therefore drawn concentric to the former arc. Tangential to this inner arc and to the horizontal, top, boundary line, draw two circles with a radius of $\frac{3}{8}''$; draw fillets between these circles and the outside arc.

154. Next draw the bearing cap, part *2*, shown in plan and elevation, with the grease cup, the top of which makes an angle of 45° with the horizontal and whose sides are outlined by a curve with $1\frac{3}{4}''$ radius. The reason for this inclination is the necessity of having the upper edge of cup horizontal when the cap is in position on the frame.

Part *3* is the gland that fits about the piston rod and holds the piston-rod packing in place in the stuffingbox. The latter is made by recessing the inside of the frame, as indicated by dotted lines at the cylinder end of the frame. The position and shape of this recess are shown by the dotted lines. Two $\frac{1}{2}''$ studs, part *4*, which are tapped into the frame at *f f'*, support the gland.

PLATE 1018, TITLE:

VALVE GEAR

155. The cross-section assembly in the upper part of this Plate shows the relation and connection between valve, guide, slide, eccentric rod, eccentric strap, and eccentric sheave, all these parts being detailed elsewhere on the drawing. All the parts are drawn half size, except part *5*, drawn full size, and all are provided with reference numbers corresponding with those on the assembly. Draw the details first, then the cross-section assembly.

156. Part *1*, the valve, is made of cast iron from pattern *1018–A*. It is a cup-shaped device, through the top of which the valve rod, part *11*, passes. Its position in the steam chest regulates the entrance of the steam through the ports that connect with the ends of the cylinder and permits also the exhaust steam to pass from these ports into the exhaust port, which connects with the exhaust pipe.

Locate the horizontal center line of the valve-rod boss $3\frac{9}{16}''$ (actual measurement) below the upper border line, and the vertical center lines of the two views $2''$ and $4\frac{9}{16}''$, respectively, from the left-hand border line. The left-hand view is a side elevation and the other an end view. On top of the boss is seen a rib-like projection; this slides on a corresponding rib on the steam-chest cover, which serves to hold the valve in place.

157. Part *2*, the valve-stem slide, is supported by parts *3* and *4* which, in turn, are bolted to the engine frame through the four holes in the bosses shown in the center of the opening in the elevation of the frame, Plate 1017. The slide is square shaped, with a stud at its center to which the eccentric rod is connected. Draw the horizontal center line for the two views at a distance of $5\frac{1}{8}''$ (full size) below the upper border line and the vertical center lines $2\frac{13}{16}''$ and $6\frac{3}{16}''$, from the left-hand border line.

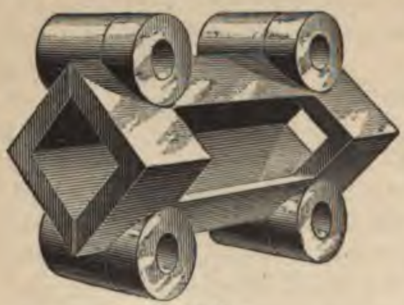


FIG. 54

Parts *3* and *4* are the two halves of the valve-stem guide, the exact shape of which is somewhat difficult to understand from the drawings alone. As an aid in gaining a clear conception of this part, the perspective view, Fig. 54, has been added. The junction of the parts is found along the center line common to the plan view and adjoining end view, part of each of the four bosses belonging to the front and part to the rear of the guide. The front of the guide has a rectangular opening $1\frac{1}{2}'' \times 3\frac{3}{4}''$. Locate the horizontal center lines of the two upper views $5\frac{1}{4}''$ and that of the lower view $3\frac{1}{8}''$ above the lower border line. Draw the vertical center lines $2\frac{1}{8}''$ and $5\frac{3}{8}''$, respectively, from the left-hand border line.

158. Part *5* is the clamping nut that locks the eccentric rod to the eccentric strap, part *9*. Locate the two views on the same center line as the lower view of part *4* and leave a space between the three views of $\frac{3}{4}''$ and $\frac{1}{4}''$ (full size), respectively. It is noticed that the hole in the nut is threaded only up to a distance of $\frac{3}{8}''$ from the outer end, this part being enlarged in diameter. According to a rule previously given, threads are to be omitted on tapped holes shown in elevation by means of dotted lines. Contrary to this rule threads have been added to some of the holes indicated on this Plate, as, for instance, on part *5*. Here the addition of threads brings out more clearly the fact that this hole is not threaded along its whole length.

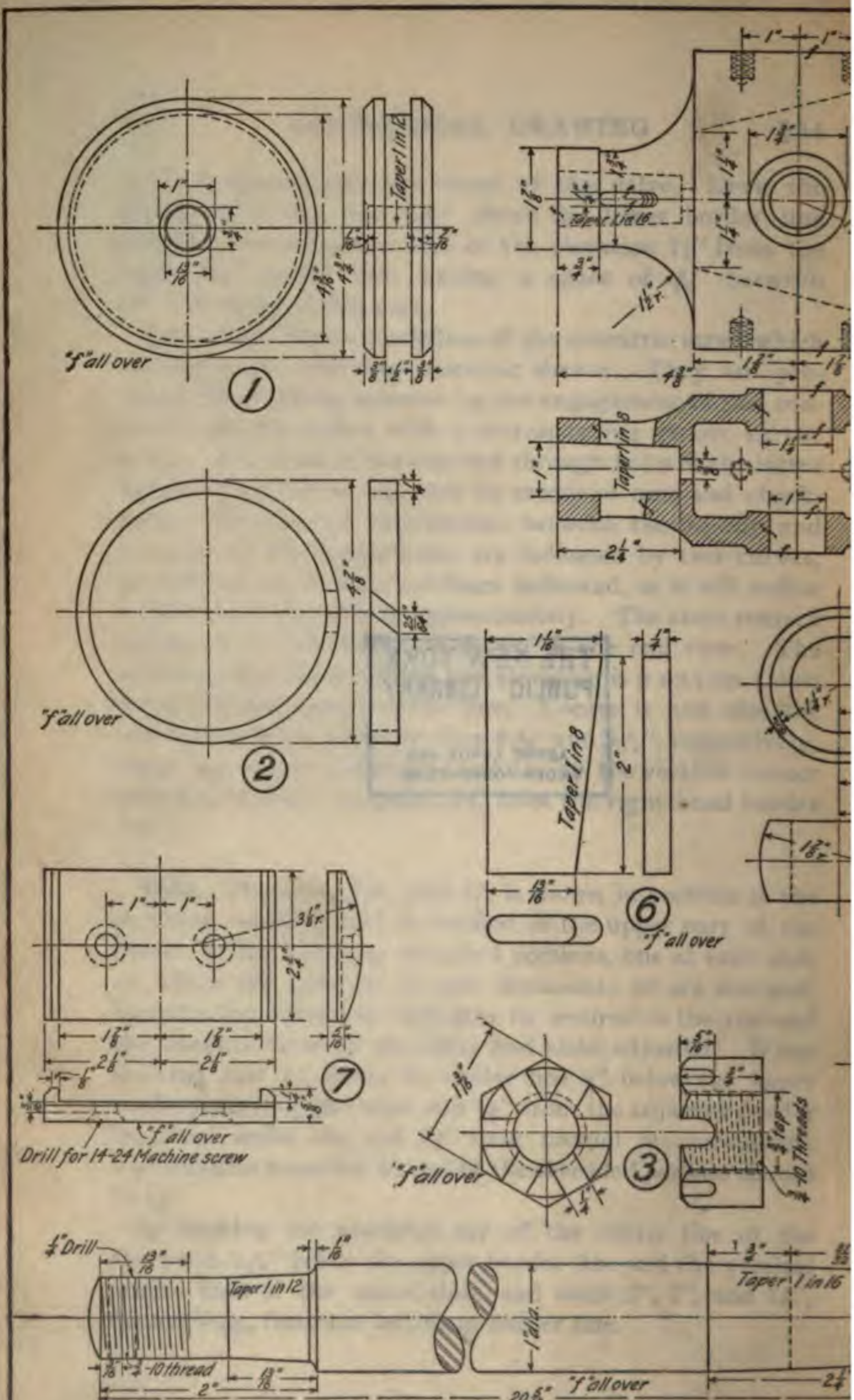
Parts *6* and *7* are the eccentric rod and strap, the threaded end of part *6* being screwed into part *9*, while the other end, together with part *7*, is clamped about the stud on part *2*. The bolts, part *15*, pass through the strap and screw into the threaded holes in the rod. Locate the horizontal center line $1\frac{1}{16}''$ (full size) above the lower border line and leave a space of $\frac{5}{16}''$ between the first view and left-hand border line, and spaces of $\frac{13}{32}''$ and $\frac{1}{2}''$ between the first, second, and third views; make the latter $4\frac{1}{2}''$ long and leave a space between this and the fourth view of $\frac{9}{16}''$.

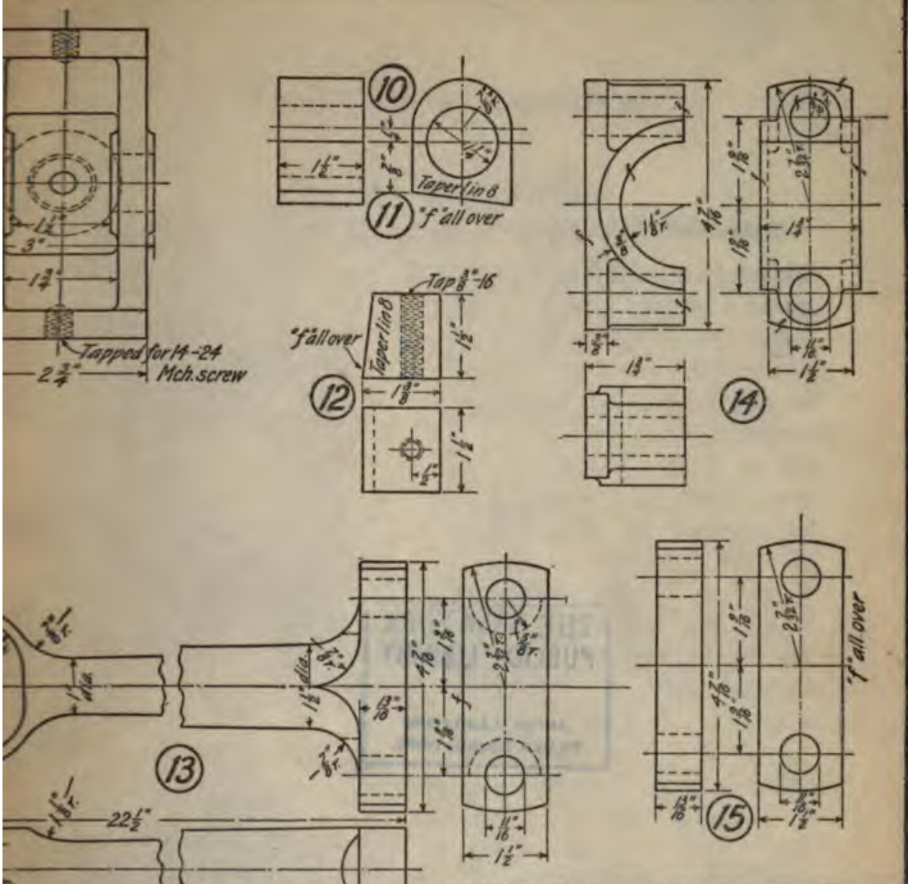
159. Part *8* is the eccentric sheave, which is fastened to the crank-shaft by means of the two setscrews *17* that pass through the tapped holes indicated. Its center is $\frac{7}{8}''$ to one side of the shaft center, this distance determining the *throw* of the eccentric and the travel of the valve. Draw the horizontal center line $2\frac{5}{16}''$ above the lower border line and the vertical center line of the elevation $7\frac{1}{4}''$ from the right-hand border line, leaving a space of $\frac{9}{16}''$ between the two views of this part.

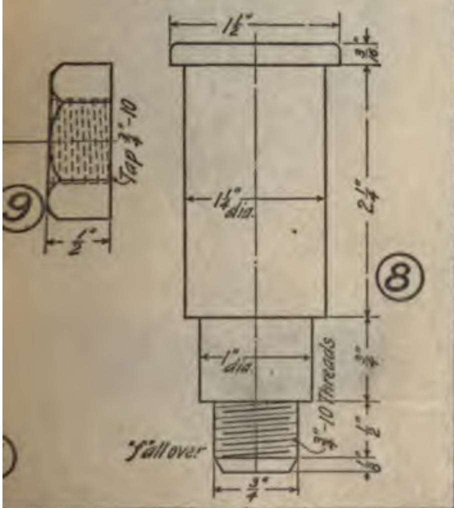
Parts *9* and *10* are the halves of the eccentric strap which embraces the revolving eccentric sheave. They are prevented from sliding sidewise by the engagement of the central rib on the sheave with a corresponding groove in the strap. Two bolts *16* are inserted through holes in the latter and hold the halves together by means of nuts and check-nuts. The lines of intersection between the oil cup and strap, as shown in elevation, are indicated by two curves, the radii of which have not been indicated, as it will suffice if the student draw them approximately. The same remark applies to the intersections shown in the end view. The sectional view shown below the elevation is a section taken along the horizontal center line. Locate it and also the center line of the sectional view $5\frac{9}{16}''$ and $8\frac{5}{16}''$, respectively, below the upper border line and lay off the vertical center lines $6\frac{5}{16}''$ and $2\frac{5}{8}''$, respectively, from the right-hand border line.

160. The valve rod, part *11*, is shown in position in the sectional assembly and is detailed in the upper part of the Plate. It has two long threaded portions, one at each end, on which the nuts *12*, *14* and check-nuts *13* are screwed, whereby the valve and slide may be secured to the rod and the distance between the valve and slide adjusted. When drawing part *11*, locate its center line $\frac{3}{4}''$ below the upper border line, its right-hand end $1\frac{3}{8}''$ from the adjacent border line, and make the rod $5\frac{3}{4}''$ long (actual measurement). The distance from end to end of the threaded portion should be $1\frac{5}{8}''$.

In drawing the assembly, lay off the center line of the valve rod $1\frac{3}{16}''$ below the upper border line and the vertical center lines of the valve, slide, and shaft 2″, 7″, and 14″, respectively, from the left-hand border line.


"f" all over
Taper 1 in 12
1
2
"f" all over
Taper 1 in 8
Taper 1 in 16
Taper 1 in 8
6
"f" all over
7
"f" all over
Drill for 14-24 Machine screw
"f" all over
3
"f" all over
1/4" Drill
Taper 1 in 12
1" dia.
3/4-10 thread
20 5/16"





2	$\frac{5}{8}$-11 Bolts-6$\frac{1}{4}$" long with nut & ch. nut	18	Machine steel		
2	$\frac{3}{8}$-16 Hex. Hd. Bolts $\frac{5}{8}$" long	17	Machine steel		
4	14-24 Flat head machine screws	16	Machine steel		
1	Connecting rod strap	15	Machine steel		
2	Connecting rod bearing	14	Comp. metal	Pattern	H
1	Connecting rod	13	Machine steel		
1	Wedge for 13	12	Comp. metal	Pattern	G
1	Half of Connecting rod bearing	11	Comp. metal	Pattern	F
1	Half of Connecting rod bearing	10	Comp. metal	Pattern	E
1	Nut for 8	9	Machine steel		
1	Cross head pin for 5 & 13	8	Machine steel		
2	Wearing strips for 5	7	Comp. metal	Pattern	D
1	Key for 4 & 5	6	Machine steel		
1	Cross head	5	Cast iron	Pattern	C
1	Piston rod for 1, 4, 3 & 5	4	Machine steel		
1	Crown nut with pin for 1 & 4	3	Machine steel		
1	Piston ring for 1	2	Cast iron	Pattern	B
1	Piston for 4	1	Cast iron	Pattern	A

PISTON, CROSS HEAD AND CONNECTING ROD

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PLATE 1019, TITLE:

PISTON, CROSSHEAD, AND CONNECTING-ROD

161. In the sectional assembly, Fig. 55, is seen the piston *1*, which is given a reciprocating motion in the steam cylinder by the steam acting alternately on either side of it. Its motion is conveyed by the piston rod *4* to the crosshead *5*, the latter containing in its interior one end of the connecting-rod *13* swinging around a pin *8*, while the other end has a bearing *14* that embraces the crankpin. In this manner the force acting on the piston is transmitted to the crankpin, where the reciprocating motion of the piston is changed into a rotary one. All the views on this Plate are drawn half size, except those of parts *3*, *4*, *6*, *8*, and *9*, which are drawn full size.

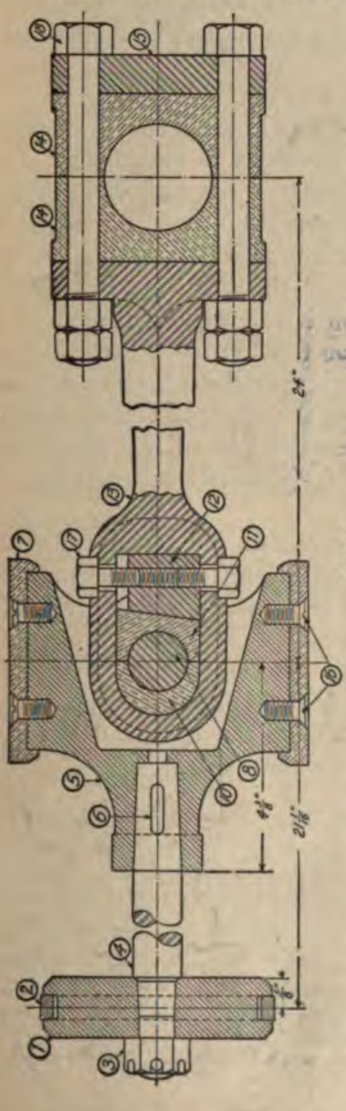


FIG. 55

162. The piston, part *1* (see detail numbered *1*) is made of cast iron and is provided on its outer edge with a groove for the piston ring, and with a central hole for the piston rod. The hole is composed of a straight and a tapered part, the straight part extending to a point $\frac{7}{16}''$ from one end. The diameter of the hole varies from $\frac{3}{4}''$ to $\frac{13}{16}''$, the latter dimension applying to a point $\frac{1}{16}''$ from end of hole at which place the hole is countersunk, enlarging the diameter to 1″. Locate the horizontal center line of the two views, 2″ from the upper border line, and the vertical center line $1\frac{1}{16}''$ from the left-hand border line, leaving a space of $\frac{7}{16}''$ between the two views.

163. The piston ring, part *2*, fits in the groove around the outside of the piston; it provides a steam-tight fit between the piston and the cylinder walls, and is for this reason made expansible by leaving an opening of $\frac{25}{64}''$ between its ends. It will be noticed that the ring is larger in diameter than the inside one of the cylinder; but when sprung into place in the cylinder it will adjust itself to the cylinder bore and the two ends will approach each other, until they nearly touch. The horizontal center line of the two views may be drawn $5\frac{9}{16}''$ from the upper border line, and the vertical center line of the elevation placed $1\frac{1}{16}''$ from the left-hand border line; a space of $\frac{5}{16}''$ is left between these views.

The crown nut, part *3*, fits the end of the piston rod and fastens the piston securely to the latter. To prevent an accidental turning of the nut, it is provided with a series of grooves into which fits a pin, which also passes through a hole in end of piston rod. The horizontal center line of these views is placed $2\frac{11}{16}''$ from lower border line, and the vertical one of the elevation 5″ from the left-hand border line, leaving a space of $\frac{5}{8}''$ between the views.

164. The piston rod, part *4*, is tapered at both ends, one to fit the piston and the other the crosshead. When the dimension of one end of a tapered piece is given, together with its length, the dimension of the other end may be found either by calculation or by construction. In the first case it is found by means of proportion. For instance: the taper at one end of the rod is 1 in 16, the full diameter of the rod 1″, and the length of the tapered portion $2\frac{1}{4}''$.

The proportion $1 : 16 = x : 2\frac{1}{4}''$ gives a value for x of .1406; by subtracting this value from 1″ it is found that the extreme end of the rod should be $1'' - .1406'' = .8594'' = .8594 \times \frac{64}{64} = \frac{55}{64}''$ in diameter.

If this diameter is found by construction, proceed as follows: A taper of 1 in 16 is, of course, equal to $\frac{1}{16}$ in 1. Multiply the fraction expressing the increase or decrease in 1″ by some convenient length, preferably by some number that will divide the denominator without a remainder, in this case, by 4, obtaining $\frac{1}{16}'' \times 4 = \frac{1}{4}''$; this represents the difference in the diameters 4″ apart. Hence, 4″ from where the taper begins draw a line at right angles to the center line and lay off on it on either side of the center line $\frac{1}{2}'' - (\frac{1}{4}'' \div 2) = \frac{3}{8}''$. Join the points as laid off with the extremities of the line defining the beginning of the taper by straight lines, and measure back from this line the length of the tapered part $2\frac{1}{4}''$, drawing through this point a line perpendicular to the center line. At the other end of the rod the diameter is $\frac{3}{4}''$, and the taper is 1 in 12. This end is to fit the hole in the piston, part *1*, and as the diameters and length of the hole is given in the views of the piston, the tapered part of the piston rod may be drawn by means of these dimensions.

Locate the center line of the rod 1″ above the lower border line; leave a space of $\frac{3}{4}''$ between the rod and the left-hand border line and make the rod 8″ long.

165. The crosshead, part *5*, is fitted to the piston rod by the tapered key, part *6*, which is driven through it and the piston rod, the hole in the piston rod being indicated by dotted lines at the right-hand end, part *4*. The crosshead receives the end of the connecting-rod, which is kept in place by the crosshead pin, part *8*. The upper and lower interior surfaces of the crosshead taper toward the closed end, while the vertical sides are parallel and provided inside and outside with bosses around the holes for the pin. On top and bottom of the head, holes are tapped for the screws that hold the wearing strips, part *7*, in place. Lay off the center line for the elevation and end view $1\frac{3}{4}''$, and that of the sectional plan $4\frac{1}{4}''$ below the upper border line. Let the vertical center line of the two left-hand views be $7\frac{1}{4}''$ from the left-hand border line, and place the remaining view $\frac{11}{16}''$ to the right of the elevation.

166. The connecting-rod, part *13*, is shown broken, the size of the Plate not permitting it to be drawn full length. The method employed in laying off the correct taper of the remaining parts is similar to that explained in Art. **164.** The places where the tapered portion of the rod begins and ends are found by drawing verticals through the centers of the fillets at either end, which are struck with a radius of $\frac{1}{8}''$; the points of intersection between the verticals and the fillet arcs are the initial points of the tapered part. It is found by calculation that the total length of the tapered part is $16\frac{9}{16}''$. Knowing this length and the diameter at either end of this part the student should be able to construct the taper.

One end of the connecting-rod receives the bearings, parts *10* and *11*, which fit over the crosshead pin, part *8*. The other end of the rod is attached to bearings *14*, for the crankpin. The bearing, parts *10* and *11*, is prevented from moving sidewise along the crosshead pin, because its width is just equal to the distance between the inside surfaces of the bosses on crosshead. The two parts of the bearing are forced toward the pin by means of the wedge, part *12*, which may be raised or lowered by turning the adjusting screws, part *17*, in the proper direction. Notice that the holes through which these screws pass are countersunk about $\frac{3}{16}''$ for the screw heads; hence the two slight curves in the outer line defining the outline of the small end of the rod in the elevation. Draw the horizontal center line of the elevation and end view $6\frac{3}{16}''$ and of the bottom view $7\frac{13}{16}''$ below the upper border line. The vertical center line corresponding to the center of the crosshead pin is $9\frac{3}{8}''$ and the one through the end view is $3\frac{9}{16}''$ from the right-hand border line.

167. Next draw the crosshead pin, part *8*, with its center line $5\frac{3}{4}''$ from the right-hand border line and its top $4\frac{3}{16}''$ above the lower border line. Also the nut, part *9*, that screws on its lower end and locks the pin to the crosshead. Draw the center line for the nut $3\frac{1}{4}''$ above lower border line and locate the center line of the elevation $8\frac{5}{8}''$ from the right-hand border line; a space of $\frac{1}{2}''$ is left between the two views. Both of these views are drawn full size.

Draw the bearings, parts *10* and *11*, and also the wedge, part *12*. The center line of the first two views should be $1\frac{3}{8}''$ below the upper border line, and that of the right-hand view $3\frac{15}{16}''$ from the right-hand border line, leaving a space of $\frac{7}{16}''$ between the two views. In locating the views of the wedge, leave a space of $4\frac{1}{8}''$ between them and the right-hand border line. The top line of the upper view should be $2\frac{3}{4}''$ below the upper border line and a space of $\frac{1}{4}''$ left between the two views.

168. The halves of the bearing for the crankpin, part *14*, are symmetrical and only one of them need be shown. Locate the center line of the two upper views $1\frac{15}{16}''$ below the upper border line and the vertical center line of the right-hand view $\frac{7}{8}''$ from the right-hand border line; leave a space of $\frac{11}{16}''$ between the views. The center line of the lower view should be $4''$ below the upper border line.

Draw the connecting-rod strap, part *15*. The bolts, part *18*, pass through this strap and the connecting-rod, holding the bearings, part *14*, in position and clamping them to the crankpin. Draw the center line of the strap $6''$ below the upper border line and locate the views $1\frac{13}{16}''$ and $\frac{9}{16}''$, respectively, from the right-hand border line.

169. Part 7, the wearing strip mentioned above, is somewhat peculiar in form and the three views should be studied carefully in order to obtain a clear idea of its true shape. Place the center line of the upper views $4\frac{3}{8}''$ above the lower border line and let the vertical center line of the plan be $1\frac{3}{8}''$ from the left-hand border line; leave a space of

$\frac{1}{2}''$ between the two views. Place the third view $\frac{5}{8}''$ below the plan view.

In drawing the remaining detail, part *6*, locate the upper side of the elevation $5\frac{15}{16}''$ below the upper border line. Leave a space of $4\frac{3}{8}''$ between the left-hand border line and the view next to same, and a space of $\frac{3}{8}''$ between the views themselves. The end view may be placed $\frac{3}{8}''$ below the others. The taper can be laid off directly from the dimensions; if, however, one of the dimensions, say the one marked $\frac{13}{16}''$ had been omitted, the extreme left-hand vertical line would be drawn first, next the line whose dimension is marked $1\frac{1}{16}''$ laid off, and a perpendicular drawn downwards through its right-hand extremity, then the length of the lower side may be found in the following manner: A taper of 1 in 8 is equal to $\frac{1}{4}''$ in $2''$; hence, lay off $2''$ downwards on the perpendicular last drawn, draw a horizontal line through point just laid off, and measure off to the left of this point $\frac{1}{4}''$; the point so determined is the other extreme point of the taper.

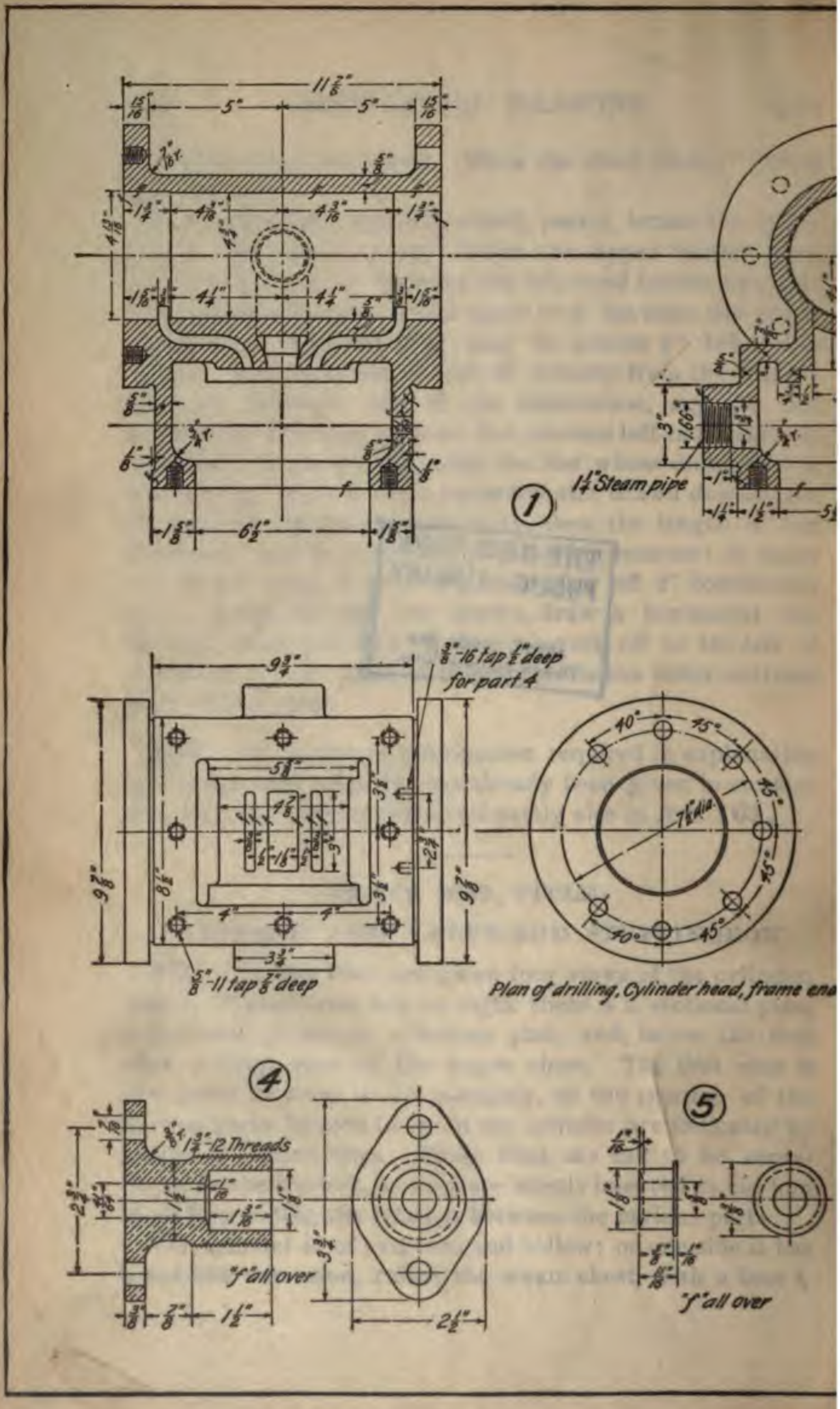
170. All necessary information required in explanation of the sectional assembly has already been given in connection with the various parts and partly also in Art. **161.**

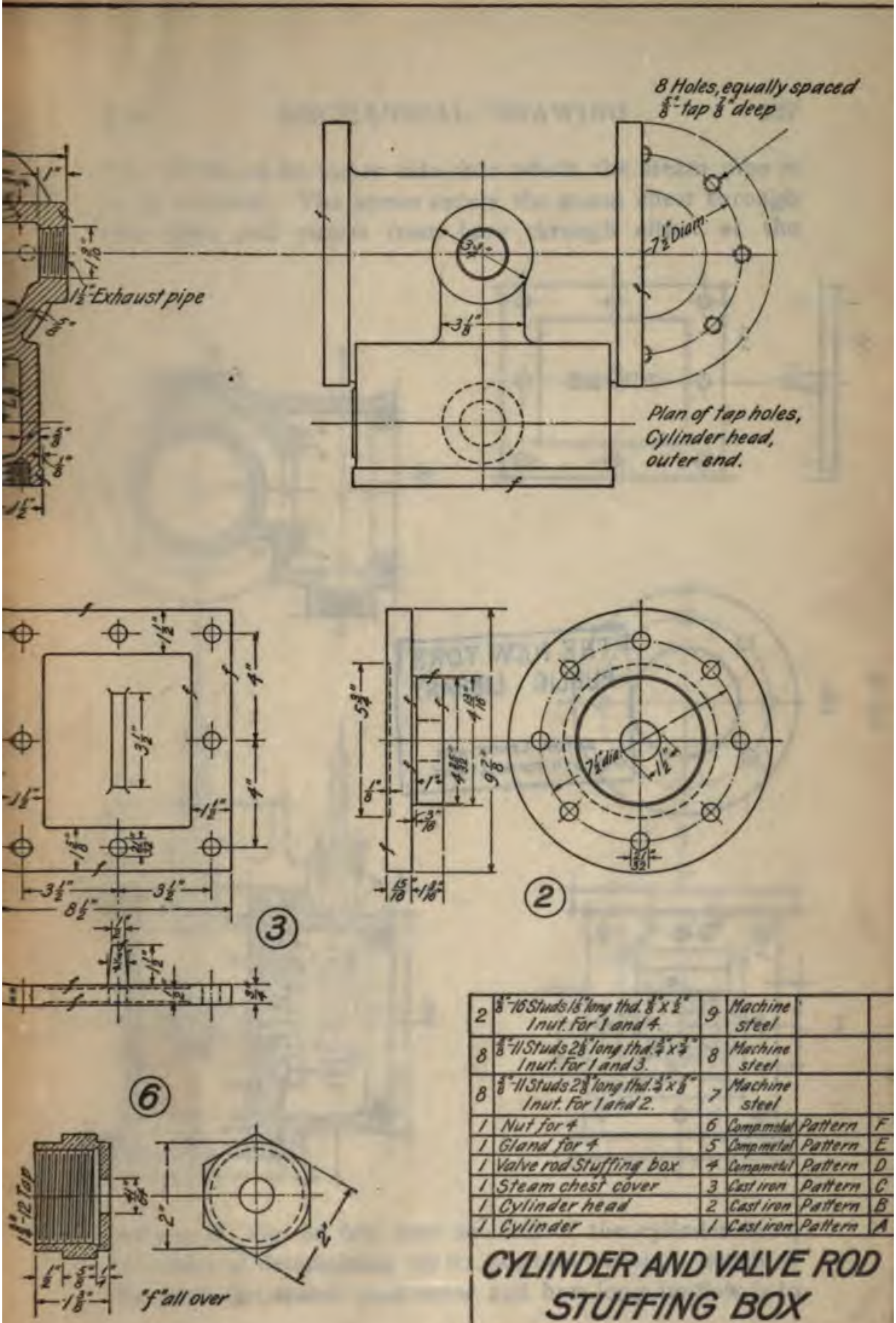
PLATE 1020, TITLE:

CYLINDER AND VALVE-ROD STUFFINGBOX

171. On this Plate are given four views of the cylinder, part *1*. Taken from left to right there is a sectional plan, a sectional elevation, a bottom plan, and, below the first view, a front view of the steam chest. The first view is also made to serve as an assembly, as the position of the various parts located in or on the cylinder are indicated by means of dotted lines. These lines are not to be reproduced by the student, as they are simply inserted to aid him in understanding the relation between the various parts.

The cylinder is of cast iron and hollow; on one side it has a box-like extension, called the steam chest, with a boss *i*,


1¼" Steam pipe
⅜"-16 tap ½" deep for part 4
⅝"-11 tap ⅞" deep
Plan of drilling, Cylinder head, frame and
1⅜"-12 Threads
"f" all over
"f" all over



2	3/8"-16 Studs 1 5/8" long thd. 3/8" x 1/2" 1 nut. For 1 and 4.	9	Machine steel		
8	5/8"-11 Studs 2 5/8" long thd. 3/4" x 3/4" 1 nut. For 1 and 3.	8	Machine steel		
8	5/8"-11 Studs 2 3/8" long thd. 1/2" x 5/8" 1 nut. For 1 and 2.	7	Machine steel		
1	Nut for 4	6	Comp. metal	Pattern	F
1	Gland for 4	5	Comp. metal	Pattern	E
1	Valve rod Stuffing box	4	Comp. metal	Pattern	D
1	Steam chest cover	3	Cast iron	Pattern	C
1	Cylinder head	2	Cast iron	Pattern	B
1	Cylinder	1	Cast iron	Pattern	A

CYLINDER AND VALVE ROD STUFFING BOX

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Fig. 56 (*b*), on its upper side, into which the steam pipe is to be screwed. The steam enters the steam chest through this pipe and passes from here through either of the

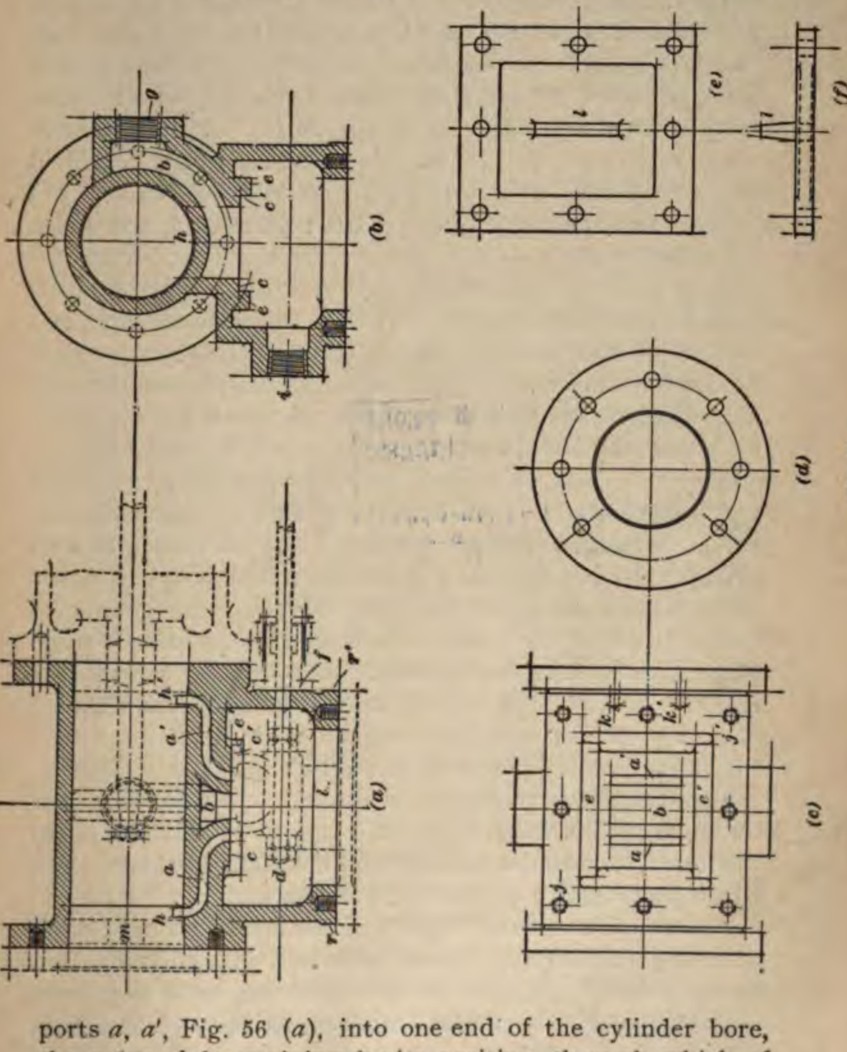


FIG. 56

ports *a*, *a'*, Fig. 56 (*a*), into one end of the cylinder bore, the valve *d* determining by its position through which of the ports the steam shall enter and how long its flow is to continue. In Fig. 56 (*a*), the steam has entered through port *a*, driving the piston to the right; but in the present position of the valve the latter has already advanced so far to the left as to shut off the steam, allowing it to expand. The steam that at the previous stroke has been acting on the right side of the piston is now escaping through port *a'* into the valve and out through the exhaust port *b* into the exhaust pipe, screwed on at *g*, Fig. 56 (*b*). The manner in which valve *d* receives its motion has already been described in connection with Plate 1018. Parts *1*, *2*, and *3* are to be drawn to a scale of 3″ = 1 ft.; parts *4*, *5*, and *6* to a scale of 6″ = 1 ft.

172. The sectional plan view is to be drawn first and located on a horizontal center line $2\frac{1}{4}''$ below the upper border line; draw its vertical center line $2\frac{9}{16}''$ from the left-hand border line. The bore of the cylinder is $4\frac{3}{4}''$ for $8\frac{3}{8}''$ of its length and is enlarged to $4\frac{13}{16}''$ at a distance of $1\frac{3}{4}''$ from either end. The walls are $\frac{5}{8}''$ thick and the flanges at each end $\frac{15}{16}''$ thick and $9\frac{7}{8}''$ in diameter. In the steam chest the valve travels on a seat *c c'*, $4\frac{1}{4}''$ from the center line of cylinder. The center line of the valve stem is $2\frac{1}{8}''$ from the valve seat, it being understood that the center lines of steam pipe and valve stem are located in the same vertical plane. The valve is prevented from moving sidewise by two ribs *e*, *e'*, $\frac{1}{2}''$ high and $5\frac{5}{8}''$ long. One of these is shown at *e'*, Fig. 56 (*a*), and both are shown in section at *e*, *e'*, Fig. 56 (*b*), and in plan at Fig. 56 (*c*).

The exhaust port *b* is $1\frac{1}{8}''$ wide and separated from the steam ports by webs $\frac{1}{2}''$ thick. It follows a path around the lower part of the cylinder and has walls $\frac{5}{8}''$ thick. The steam ports have a $\frac{3}{8}''$ opening 3″ wide, and follow a curved path through the walls of the cylinder. The straight parts of these ports are centrally located in said walls and are joined to the ends of the ports by curves having their centers in the valve seat and cylinder bore, respectively. The steam-chest walls are $\frac{5}{8}''$ thick, with an extension of $\frac{1}{8}''$ at *r* and *r'* to permit a machine finish to match steam-chest cover.

At *f* is a boss of equal thickness to be finished as a seat for the valve-stem stuffingbox, an opening being provided for the valve steam $\frac{41}{64}''$ in diameter. In the front of the steam chest is an opening $6\frac{1}{2}'' \times 5\frac{1}{2}''$. Dimensions for locating the stud holes in the cylinder flange for the cover are found on the drawing of part *2*, and the distance between the stud holes in the steam-chest flange is found on the elevation of the steam chest.

173. In the sectional elevation, to be drawn next, the section is taken through the vertical center line of the sectional plan. The bore of the cylinder, thickness of walls, and connections between the exhaust port and the exhaust pipe are clearly shown. The width of the valve seat and of ribs e, e' are also given, showing that the valve has a clear bearing on either side of the ports of $\frac{1}{8}''$. This and the following view are both located on the extended center line of the first view. Draw the vertical center line $7\frac{7}{8}''$ from the left-hand border line.

The bottom plan of the cylinder may now be drawn, locating its vertical center line $3\frac{7}{8}''$ from the right-hand border line. Little need be said in explanation of this view. The exhaust-pipe opening is shown by full-line circles and the steam-pipe opening by dotted circles. One half of the plan for drilling the cylinder head is shown to the right, the other half being symmetrical.

174. On a center line $7\frac{3}{4}''$ below the upper border line locate the fourth view of the cylinder, the longitudinal dimensions of which may be projected directly from the first view. Through the opening in the front of the chest the steam and exhaust ports may be seen, likewise a plan of the valve seat and the ribs $e\,e'$, Fig. 56 (*c*). The drilling plan for the eight studs, over which the steam-chest cover fits, is shown at $j\,j'$, also the drilling $k\,k'$ for the two studs, which hold the stuffingbox in place. The frame-end drilling plan is shown to the right of this view in Fig. 56 (*d*). The location of the holes corresponds with the position of the studs that are tapped into the engine frame and support the cylinder. Locate the center line of this plan $6\frac{1}{8}''$ from the left-hand border line.

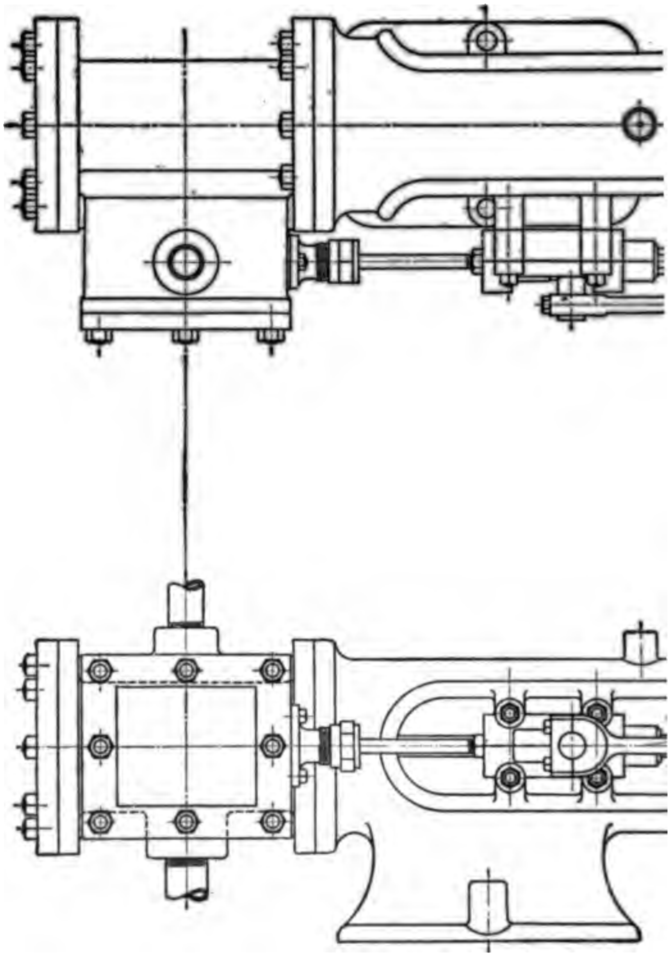
175. The steam-chest cover, part *3*, is next drawn in elevation and end view. Locate the vertical center line of these views $7\frac{5}{16}''$ from the right-hand border line and the horizontal center line of the elevation $6\frac{1}{16}''$ above the lower border line, leaving a space of $\frac{11}{16}''$ between the views. The projection *l*, Fig. 56, (*a*), (*e*), and (*f*), holds the valve in place. The cover is recessed inside and out to obviate the finishing of any part but those that fit the steam chest and on which the nuts for the studs are seated.

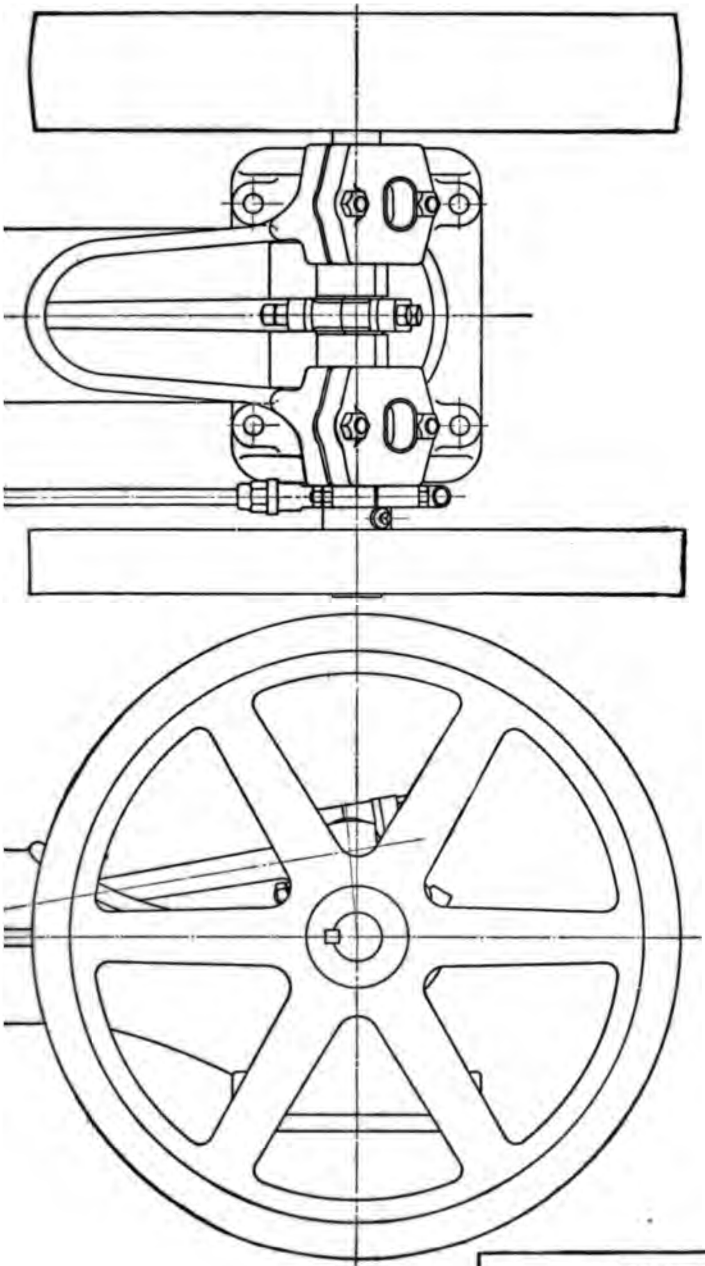
176. Part *2* is the cylinder head, which is bolted to the cylinder by means of the eight studs, part 7. The latter are fastened in the end of the cylinder before the cylinder head is put in place. The cylinder head is slightly recessed on the outside, the finish mark applying only to the raised portion. At *m*, Fig. 56 (*a*), is a recess in the cylinder head to make room for the nut on end of piston rod when the piston is at the end of its inward stroke.

177. The views along the lower border line are all located on a center line $1\frac{13}{16}''$ above same. Begin with part *4*, the valve-rod stuffingbox, and locate the two views at distances of $1\frac{1}{8}''$ and $3\frac{1}{4}''$ from the left-hand border line. The stuffingbox is bolted to the steam chest at *f*, Fig. 56 (*a*), by means of studs $\frac{3}{8}''$ in diameter, part *9*.

Part *5* is the gland that compresses and holds the packing in place in the stuffingbox, the purpose of the packing being to make the fit between piston rod and stuffingbox steam-tight. It should be noticed that those ends of the stuffing-box and gland that face each other are countersunk, the object being to force the packing toward the piston rod. Locate these views $5\frac{15}{16}''$ and $7''$ from the left-hand border line.

Part *6* is the clamping nut that holds the gland, part *5*, in position and by means of which the latter may be forced





ASSEMBLY
STEAM ENGIN

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102

more tightly against the packing. Let the center line of the right-hand view be 6″ from the right-hand border line, and leave a space of $\frac{7}{8}''$ between the two views.

The remaining parts, *7*, *8*, and *9*, are studs, the uses of which have been described. It will be noticed that the studs for *7* are specified as follows: $2\frac{3}{8}''$ long, thd. $\frac{3}{4}'' \times \frac{7}{8}''$, indicating that the studs are threaded for $\frac{3}{4}''$ at one end and $\frac{7}{8}''$ at the other end.

PLATE 1021, TITLE:

ASSEMBLY OF HORIZONTAL STEAM ENGINE

178. From the details given on Plates 1016 to 1020, inclusive, the student is required to make an assembly drawing giving a general view of the engine in a plan and a side elevation.

That he may have an idea of what he is expected to do, a reduced copy of the Plate is given in Fig. 57, in which all dotted lines indicating parts not visible have been omitted in order to simplify the work. In order to get the drawing within the same limits as were used on the preceding Plates, it is necessary to use a $\frac{1}{5}$ scale; that is, a scale of 2.4″ = 1 ft. It will be necessary, therefore, for the student to construct a scale of this kind, according to instructions given in Art. **11.**

When making an assembly view from several detail sheets, it is often possible to use the latter directly for tracing purposes, if both are drawn to the same scale. In that case the various detail views are successively laid under the tracing cloth and adjusted into such a position that their center lines will coincide with those of the views in the assembly in which they are to be inserted, after which they are pinned to the board. Considerable dodging is sometimes required in order that the tracing cloth may be so arranged, relative to the board, that overhanging parts do not interfere with the free use of the T square. Those parts of the tracing cloth that extend beyond the edges must be handled with care, so as not to tear or wrinkle it.

If the assembly had been drawn to a scale of 3″ = 1 ft. it would have been possible in the present instance to trace some of the details directly into the assembly, as, for instance, the engine frame, but being drawn to a scale differing from any of the details it is not possible in this case to make any direct use of the detail views in this manner.

179. Draw the two horizontal center lines $3\frac{1}{4}''$ and $8\frac{3}{8}''$ from the upper border line and lay off the vertical center line through center of cylinder $3\frac{1}{4}''$ from the left-hand border line. Locate the vertical through center of crank-shaft at a distance from the other vertical corresponding to that given in engine frame. Draw the side elevation of the bedplate with the bearing caps in position, from the dimensions given on the detail sketches, taking care to make the parts that are likely to be hidden by the flywheel, eccentric rod, etc. light so that they may be easily erased before tracing. The drawing may be traced without removing the unnecessary construction lines, but it is better to remove them,

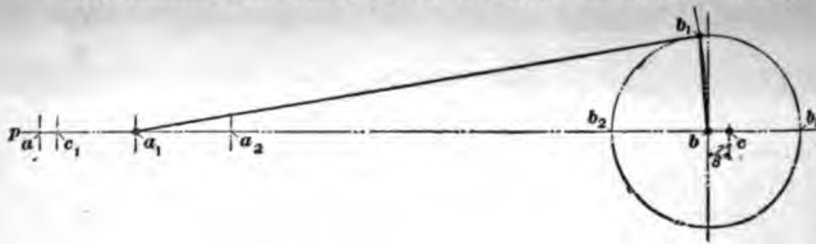


FIG. 58

since it lessens the liability of inking in lines that will have to be erased from the tracing. Draw the plan of the bedplate with the bearing caps, studs and nuts, foundation-bolt holes, etc. shown in their proper places and positions.

180. Returning to the elevation, draw the crank and crank end of the connecting-rod in the position shown in the general drawing. The method by which to determine the position of center of crankpin is shown in Fig. 58, where $b\,b_1$ represents the distance between centers of shaft and crankpin and $b_2\,b_3$, the two dead centers of the engine. The length of the stroke is indicated by the points a, a_2, the piston rod in this instance occupying a middle position at point a_1. To find the corresponding position of the crankpin, draw the circle $b_2 b_3$ with $b b_1$ as a radius; this radius is the length of the crank between center of shaft and center of crankpin, or 4" (see Plate 1016). Then with a radius equal to the length of the connecting-rod between its centers, and with b as a center, draw a small arc intersecting the line $a b_2$ at a_1; this determines the center position of the piston rod. With the same radius $a_1 b$, but with a_1 as a center, draw the arc $b b_1$; the point of intersection b_1 with the circle $b_2 b_3$ will be the point sought, viz., the center of crankpin, when the center of the crosshead pin is at a_1. A line connecting a_1 and b_1 will be the center line of the connecting-rod.

181. Draw the crosshead, obtaining the dimensions from the detail sketch. Complete the connecting-rod in both views, and draw the piston rod 1" in diameter. Draw both views of the cylinder with the nuts and the steam pipe in their proper position, getting all dimensions from the detail sketches.

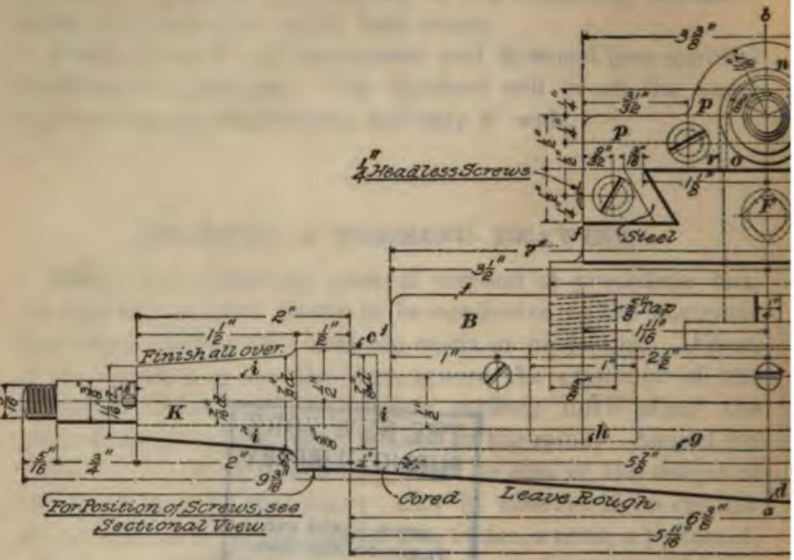
Draw the center line of the valve stem in the plan view, and draw the stuffingbox, valve stem, valve-stem slide and its guide in both views. In order to determine the position of the valve-stem slide, it is necessary to locate the center of the eccentric. Referring to the general drawing, it is seen that the eccentric is on the dead center farthest from the cylinder. The offset of the eccentric is given as $\frac{7}{8}$" in the detail sketch; hence, when in this position, the center of the eccentric strap will be situated at c, $\frac{7}{8}$" to the right of the crank-shaft center on the line pq, Fig. 58. With this point as a center, and a radius equal to the distance between the centers of the eccentric strap and the hole in the stud end of the eccentric rod (see detail sketch), in this case 2 ft. $4\frac{1}{8}$", describe an arc cutting the center line pq in c_1; c_1 will be the center of the pin on the valve-stem slide, which may be completed with the aid of the detail sketch. Complete the drawing of the eccentric, eccentric strap, and eccentric rod in both views.

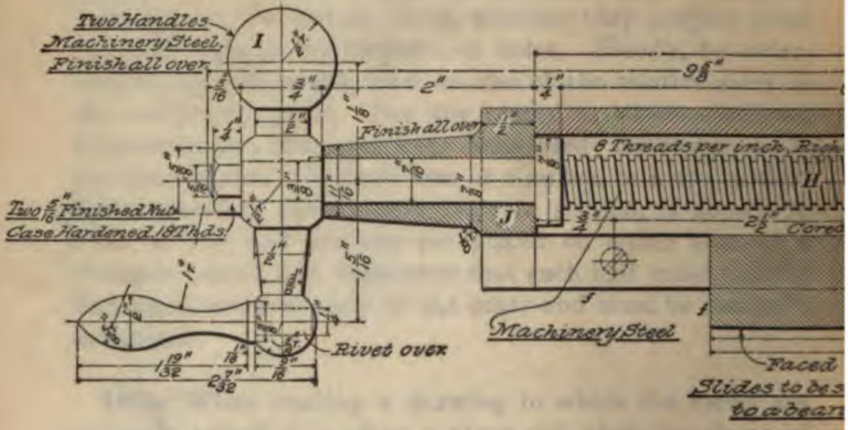
Finally draw in the bandwheel and flywheel (see general drawing for position). The flywheel will be of the same diameter as the bandwheel, but only 3″ wide.

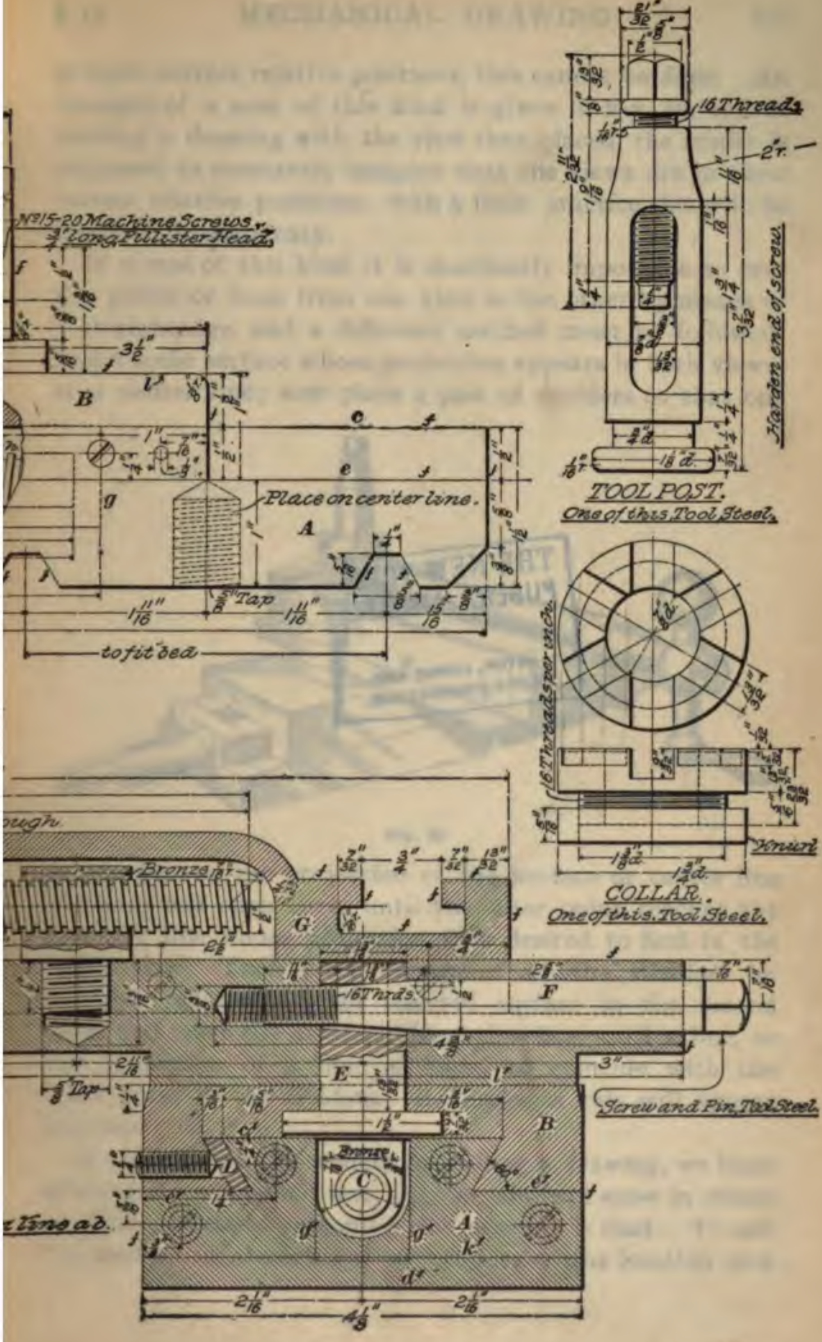
READING A WORKING DRAWING

182. The following general method of procedure has, by experience, been shown to be conducive to the accurate and rapid reading of a drawing made in projection. *First*, if the drawing is dimensioned, ignore the existence of the dimension lines and dimensions entirely until after the general shape of the object is fixed on the mind. *Second*, by referring to the several views, form an idea of the shape of the main body of the object; that is, observe if its outline shows it to be a cube, a sphere, a cylinder, a cone, a pyramid, etc., or a combination of several of these elementary forms. The shape of the main body having been impressed on the mind, observe how it is modified by details, determining, by reference to the several views, whether they project from the main body or are recesses, or holes. *Finally*, by referring to the dimensions, form an idea of the relative sizes of the component parts. Pay due regard to all conventional representations that may have been used; for instance, do not become confused if the arm of a pulley, or a rib, which, truly speaking, should have been in section, is shown in full. If two half sections are placed on either side of a common center line, remember that each half must usually be viewed independently of the other and must be mentally completed.

183. When reading a drawing in which the views are correctly placed, it is often a great aid, when the shape of some part is doubtful, to project with a straightedge points or edges of it over to another view, in order to find the location of the doubtful part. When the views are not placed


1/4" Headless Screws
Steel
B
5/8 Tap
Finish all over.
K
Cored
Leave Rough
For Position of Screws, see Sectional View.


Two Handles
Machinery Steel.
Finish all over
I
Finish all over
Two 5/8" Finished Nuts
Case Hardened, 18 Thds.
J
H
Machinery Steel
Rivet over
Faced



No. 15-20 Machine Screws, 3/4" long Fillister Head.
Place on center line.
to fit bed
16 Threads
Harden end of screw.
TOOL POST.
One of this, Tool Steel.
16 Threads per inch.
Knurl
COLLAR.
One of this, Tool Steel.
Bronze
16 Thrds.
Screw and Pin, Tool Steel.

in their correct relative positions, this cannot be done. An example of a case of this kind is given in Fig. 59, and in reading a drawing with the view thus placed, the reader is supposed to constantly imagine that the views are in their correct relative positions; with a little practice this will be found to be quite easy.

In a case of this kind, it is manifestly impossible to project points or lines from one view to the other by means of a straightedge, and a different method must be followed. Select some surface whose projection appears in both views, or a center line; now place a pair of dividers so that one

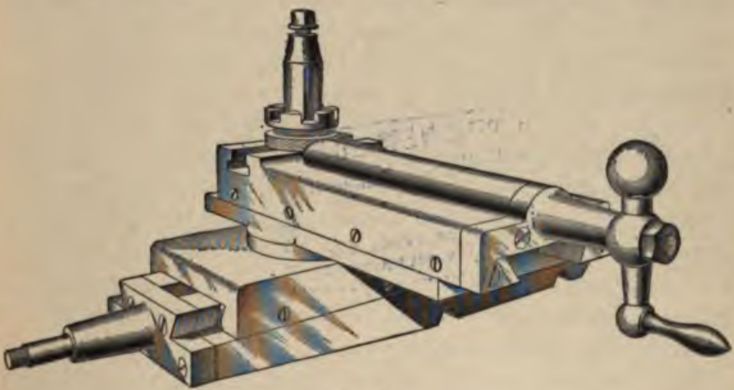


FIG. 60

point rests on the projection of the surface or center line selected, and open them until the other point reaches the point or line whose projection it is desired to find in the other view. Then place one point of the dividers on the line representing the selected surface in the second view, and move the dividers along this line until a line, or the projection of a line, is found to coincide with the other point of the dividers. Examples of this will appear later on.

In order to aid the student in reading a drawing, we have selected the compound rest, Fig. 59, and will show in detail by what process of reasoning this drawing is read. To aid the student in obtaining a correct idea of the location and shape of the various parts, a perspective view of the compound rest has been given in Fig. 60.

184. To find the shape of the different parts and also to discover, if possible, the relation between them, we must commence our investigation somewhere. Let us choose the bottom of the front view. Looking at this, it is noticed that a partial section is shown, from which, by reason of the section lining running in opposite directions, we conclude that *A* and *B* are separate parts. At the right and left of the front view, the full lines *c*, *c* show that some part of *A* is higher than the bottom of *B*, but we do not know whether these lines denote the top surfaces of projecting parts between which *B* is fitted, or if *c* is the top surface of a raised strip of some kind that extends clear through the inside of *B*. In order to settle this question, we note whether the top surface is continued somewhere. Looking at the front view it is seen that the line *c* is dotted clear through *B*, which settles conclusively that the part whose top surface is shown by the line *c* is a raised strip extending clear through *B*; this fact immediately implies that *B* has a groove of some kind running through it longitudinally in order to admit the raised strip.

Referring now to the sectional view, which, as previously stated, is a view taken on the line *a b* of the front view, and everything to the right of this line being removed, we may choose the bottom line *d'* of the sectional view as a base from which to make measurements. From the fact that the section is taken on the line *a b*, we know that the line just chosen is the projection of the intersection *d* of the plane represented by *a b* with the bottom of *A*. Measuring from *d'* upwards to the highest line *c'* of *A* in the sectional view, and placing one point of the dividers on *d* in the front view, it will be seen that the other point coincides with the dotted line forming a continuation of *c c*; this shows that *c'* is the projection of *c*. In a similar manner, we determine that *e'* is the projection of *e*, and tracing the outlines of *A* in the sectional view, we notice that the raised strip on *A* has inclined sides. We also notice that *B* is cut out to suit the profile of *A*, except that on one side a steel part *L* is interposed between the inclined sides of *A* and *B*; it is also seen that a screw rests with its point against *L*.

Referring now to the front view, and knowing from inspection of the sectional view that the upper and lower surfaces of the steel part *L* are flush with c' and e', or *c* and *e* in the front view, to determine the length of this part, notice if any dotted or full lines showing its length are shown anywhere at a right angle to *c* and *e*. None being found, the conclusion to be drawn is that either the steel part *L* is as long as *A* or has the same length as *B*. A person without any practical experience might conclude that the length is the same as that of *A*; but any one having engineering instinct or practical knowledge would immediately notice that, as the steel strip has setscrews which evidently push it against the inclined side of *A*, it would be unnecessary to make the strip the length of *A*, and hence would immediately conclude that its length is the same as that of *B*. This latter conclusion is the one the draftsman desired to convey.

185. Looking at the sectional view of *A* again, we notice that a groove, open on top, is cut into *A*. To find its length we must find lines corresponding to it in the front view. Measuring from d' upwards to the bottom of the groove and transferring the measurement to the front view, we find that the dotted line *g g* represents the bottom and end of the groove, which at the left is also shown to be open at the bottom, since the dotted line *g* curves around and continues to the bottom of *A*. This is also indicated by the dotted lines g' that form an extension of the sides of the groove in the sectional view; measuring from c' downwards to the horizontal dotted line joining the ends of g' g', and then passing along *c* in the front view, the point of the dividers will be found to coincide with the point where the dotted line *g* meets the bottom of *A*. From this the conclusion is drawn that the dotted horizontal line joining $g'g'$ in the sectional view is the bottom edge of the opening.

186. Looking at the front view we notice a left-handed screw C that is placed within the slot just investigated. Knowing that, in a view in line with its axis, the outline of a screw will be a circle, and knowing that this circle will be found inside of the slot, the screw is readily found in the sectional view. Now, experience teaches us that when a screw is shown in place in a machine drawing, there must also be somewhere along its axis a threaded hole (or a nut) to receive it. Looking at the sectional view we see the outline of something (marked "*Bronze*") that surrounds the screw. Now, this part, at first glance, appears to be a continuation of the pin E directly above it; there are two reasons, however, why this is not the case. In the first place, the part E is sectioned for steel; this immediately shows that E and the part under investigation are separate parts. Furthermore, when tracing out the shape and positions of the objects in the front view, they will be seen neither to be in line nor to have any connection with each other. To find the part under investigation in the front view, we may take, in the sectional view, a measurement from the center of the screw downwards to the lowest point of the part we are investigating, and then, referring to the front view, proceed along the center line of the screw C until we strike the dotted line h. Since the sectional view shows only things to the left of the line $a\,b$, we know that as the part being investigated shows in the sectional view, we must look for it to the left of $a\,b$ in the front view. At the ends of the horizontal dotted line h we notice two vertical dotted lines that show the length of the part under investigation; since these lines terminate against the line c we know that the part butts against the surface of B.

This latter conclusion is further confirmed by examining, in the sectional view, the full outline of the part. Referring again to the front view, we see a screw thread indicated in B right above the part we are discussing, and in the absence of any indication to the contrary may justly assume that it is a threaded shank by means of which the part is attached to *B*. By this time we are probably convinced that the part we have been investigating is the nut we are looking for, but are not sure of it. To find out, let us try to investigate the whole of the screw. In the front view, the dotted lines *i*, *i* show that the screw has a bearing and also has a collar butting against part of *A*; beyond the bearing the screw shows in full and apparently has a seat for some kind of an attachment which must cause the screw to turn, since a dowel-pin is shown in the seat. Inspecting the sectional view we find a screw similar to the one under discussion, with a ball handle and retaining nut on the end of it. As we find a note "*Two Handles Machinery Steel, Finish all over*," and as we cannot find any other place for the second handle, we naturally conclude that such a handle is to be placed on the end of the screw *C*. Now, from the fact that the screw is confined longitudinally by the collar and the ball handle, and that there is no thread on the part of the screw between them, we know that the nut must be to the right of the collar; since the part previously investigated is the only part we can find that directly surrounds the screw, we will now be justified in assuming that it is the nut we are looking for.

The fact that *A* and *B* are connected together by a screw provided with a handle for turning it will immediately suggest the idea that it is to be used for moving the part *B* along *A*, whence we conclude that *B* is a slide moving on *A*. Knowing this, the logical conclusion is that the piece *L* is a gib used for taking up the wear of the sliding surfaces, which view is proved to be correct when it is noticed, by reference to the sectional view, that a tightening of the setscrew will tend to draw the wearing surfaces together.

187. Looking now at the part *K*, at the left of *A*, in the front view, considering the part by itself, we cannot tell whether it is an integral part of *A* or a separate piece fastened to it. But as soon as we consider it in connection with the screw C, we see that the latter cannot be placed in position unless the part K is removable. From this we conclude that the part K is separate from A. The next question that suggests itself is: How is it fastened on? The note on the front view and the dotted screw heads in the sectional view show that screws with slotted heads are used.

As far as the shape of K is concerned, the front view shows that it is a cone joining some presumably flat part. Referring now to the sectional view, we discover by measuring successively from the center line and center of the screw C that the dotted horizontal line k' represents the lower surface of K, and the absence of any other dotted lines in this part of the sectional view indicates that the profile of the flat part of K is the same as that of A.

On examining the sectional view, it is seen that some part of D, which from the section lining we know to be separate from B, projects downwards from the main body of D and is in contact with the upper surface l' of the part B. Referring now to the front view and looking along l, we find that the part under discussion is cylindrical; this is inferred from the dimension "*4" turned.*" The main body of D, and also the parts G, H, and J, may now be investigated in a manner similar to that in which the relation of A, B, C, and K was traced; it will then be found that D is a part similar to A. Furthermore, the investigation will show that G is a slide; this slide is movable by means of the screw H, which turns in the bearing J.

188. Referring again to the sectional view, we see that B and D are connected together by a pin E, the object of which is unknown as yet. Examining this pin we notice that a hole is cut through its upper end and that a screw F, with a tapered shoulder to the right of its screw thread, passes through this hole. On close examination, we see that the hole in E is so placed that the tapered part of the screw F bears against the upper side of the hole. We further notice that the screw F is not used as a fastening device to hold any parts of D together; this conclusion is forced upon us by the fact that the sectional view shows *D* to be one piece. Now, we know from experience that a screw is used either as a fastening device or to transmit motion; as it obviously is not used for the purpose first mentioned, we conclude that it probably serves for the latter purpose. To make sure of this we trace out what will happen if the screw is rotated. We then notice that if the screw is screwed inwards, it will raise the part *E*; but as *E* cannot move upwards by reason of being confined by the collar on it, it shows to us that screwing *F* inwards will force *D* down on *B*. The logical inference is that *E* and *F* form a clamping device intended to clamp *B* and *D* together.

Examining the pin *E* again, we do not find anything that would definitely tell whether it is round or square. Here judgment must be used. An experienced person would know upon the first glance that the clamping arrangement shown is an expensive one to make and one not likely to be adopted when it is only required to fasten two pieces rigidly together, in which case *E* might be either round or square. The next inference would be that it is used in order to allow *D* to be rotated around *E* and to be clamped in any position. This supposition requires the pin *E* to be round and is correct in this case.

189. Referring now to the ball handle *I*, of which only one view is shown, the question of whether it is circular or square is immediately settled by experience teaching us that a handle having the shape shown is not likely to be anything else but round, and in the absence of any note or indication to the contrary, we would be justified in assuming it to be so.

190. As far as the part *G* is concerned, the sectional view shows it to be cored out in order to pass over the nut in which the screw *H* works. The width and profile of the coring must be obtained from the front view, which it will be remembered is a view at a right angle to the sectional view. The natural assumption to make is that the lines giving the width and profile of the coring will be found directly in the vicinity of the screw *H* in the front view. Measuring from the center line of this screw in the sectional view upwards to the line showing the height of the coring, and then transferring this measurement to the front view, we find the full circle *n*. Now, as the coring is beyond the bearing *J*, we know that its profile would show in dotted lines and conclude that the circle *n* represents some part of the bearing *J*. As this bearing has a conical projection, the inference is that the full circle represents the largest diameter of the cone, which is the case. Now, the absence of a dotted line showing the coring forces us to conclude that the dotted line would be directly behind the full circle *n* and is thus hidden. This conclusion is further strengthened by finding two vertical dotted lines *r*, *r* tangent to the circle *n*, and we finally decide that the groove has straight sides with a semicircular top, as given by the dotted lines *r*, *r* and the upper semicircle of *n*. By measuring again in the manner previously explained, we decide that the dotted line *o* is a front view of the nut in which *H* works.

At the right-hand end of the sectional view of *G* we notice a T-shaped opening. Referring to the front view we can easily discover, by transferring measurements, that the dotted horizontal lines *p*, *p* show the length of the slot, which is seen to extend clear across *G*.

191. Referring now to the drawing of the tool post, it will be observed that only one view is given. While this does not definitely settle that the post is circular in cross-section, common practice would justify a person in assuming, in the absence of any note or any other indication to the contrary, that such was the case. This view is strengthened by the fact that some dimensions are marked *d*, signifying diameter, which term is rarely applied to any but a round object.

192. The two views of the collar give its shape. Referring to the front view, while there is no definite note to that effect, it would be inferred from the fact that a thread is shown that the lower part is separate, being, in fact, a circular nurled nut threaded to receive the upper part.

193. While, generally speaking, any one can learn to determine the shape of objects from a drawing, there are cases that arise in practice where this is very difficult without further verbal or written instructions. The cases in which this usually happens are where coring has various odd-shaped curved surfaces that curve in different directions, as occurs, for instance, with the steam ports and other passages of steam-engine cylinders and other similar work. Practical experience with a certain line of work, and, frequently, a knowledge of the object of the doubtful part, will often enable the reader to form a correct idea of what the draftsman is trying to convey; when this experience or knowledge is lacking, *consult somebody who is likely to know.*

Furthermore, the shape of an object does not necessarily in itself always reveal its purpose. Ability to determine at sight what an object is to be used for involves either a thorough knowledge of a particular line of work—in which case the purpose of objects coming within its range can usually be determined at sight—or a very wide general knowledge of engineering construction.

BLUEPRINTING

194. Blueprinting is the process of duplicating a tracing by means of the action of light upon a sensitized paper. The following solution is much used for sensitizing the paper: Dissolve 2 ounces of citrate of iron and ammonia in 8 ounces of water; also 1¼ ounces of red prussiate of potash in 8 ounces of water. Keep the solutions separate and in dark-colored bottles in a dark place where the light cannot reach them. Better results will be obtained if ½ an ounce of gum arabic is dissolved in each solution.

When ready to prepare the paper, mix equal portions of the two solutions, and be particularly careful not to allow any more light to strike the mixture than is absolutely necessary to see by. For this reason it is necessary to have a dark room to work in. There must be in this room a tray or sink of some kind that will hold water; it should be larger than the blueprint and about 6 inches deep. There should also be a flat board large enough to cover the tray or sink. If the sink is lined with zinc or galvanized iron, so much the better. There must be an arrangement like a towel rack to hang the prints on while they are drying. For the want of a better name, this arrangement will be called a print rack. The paper used for blueprinting should be a good, smooth, white paper, and may be purchased of any dealer in drawing materials. Cut it into sheets a little larger than the tracing, so as to leave an edge around it when the tracing is placed upon it. Place eight or ten of these sheets upon the flat board before mentioned, taking care to spread flatly one above another, so that the edges do not overlap. Secure the sheets to the board by driving a brad or small wire nail through the two upper corners sufficiently far into the board to hold the weight of the papers when the board is placed in a vertical position. Lay the board on the edges of the sink, so that one edge is against the wall and the board is inclined so as to make an angle of about 60° with the horizontal. Darken the room as much as possible and obtain what light may be necessary from a lamp or gas jet, which should be turned down very low. With a wide camel's-hair brush or a fine sponge, spread the solution just prepared over the top sheet of paper. Be sure to cover every spot and do not get too much on the paper. Distribute it as evenly as possible over the paper, in much the same manner that the finishing coat of varnish would be put on by a painter. Remove the sheet by pulling on the lower edge, tearing it from the nail that holds it, and place it in a drawer where it can lie flat and be kept from the light. Treat the next sheet and each succeeding sheet in exactly the same manner, until the required number of sheets has been prepared.

Unless a large number of prints is constantly used, it is cheaper to buy the paper already prepared. It can be bought in rolls of 10 yards or more, of any width, or in sheets already cut and ready for use. There is very little, if anything, saved in preparing the paper, and better results are usually obtained from the commercial sensitized paper, since the manufacturers have machines for applying the solution and are able to distribute it very evenly.

195. In Figs. 61 and 62 are shown two views of a printing frame that is well adapted to sheets not over 17″ × 21″. The frame is placed face downwards and the back *A* is

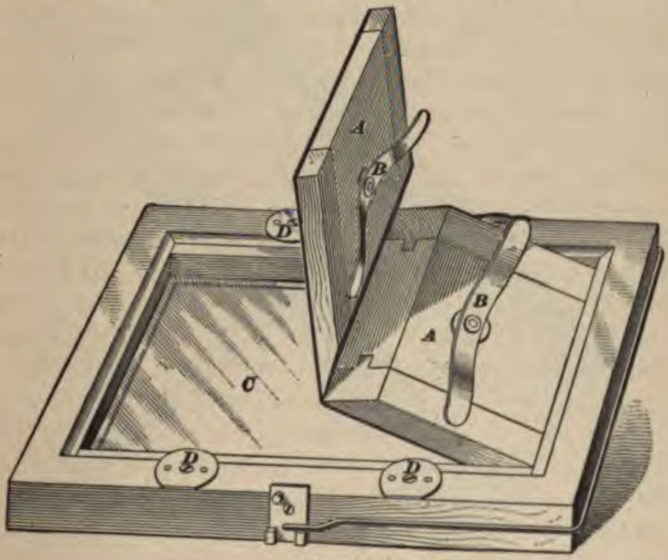


FIG. 61

removed by unhooking the brass spring clips *B*, *B*, and lifting it out. The tracing is laid upon the glass *C*, with the *inked* side touching the glass. A sheet of the prepared paper, perfectly dry, is laid upon the tracing with the yellow (sensitized) side downwards. The paper and tracing are smoothed out so as to lie perfectly flat upon the glass, the cover *A* is replaced, and the brass spring clips *B*, *B* are sprung under the plates *D*, so that the back cannot fall out. While all this is being done, the paper should be kept from the light as much as possible. The frame is now placed where the sun can shine upon it and is adjusted, as shown in Fig. 62, so that the sun's rays will fall upon it as nearly at right angles as possible. According to the conditions of the sky—whether clear or cloudy—and the time of the year, the print must be exposed from 3 to 15 minutes. The tray, or sink, already mentioned, should be filled to a depth of about 2″ with clear water (rain water if possible). The print having been exposed the proper length of time, the frame is carried into

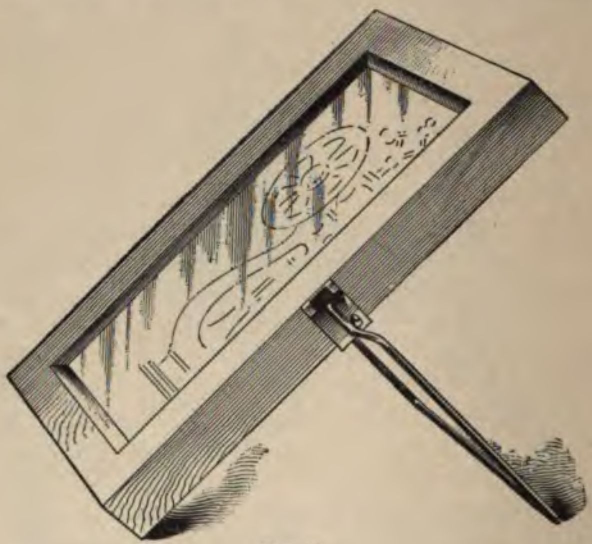


FIG. 62

a dark part of the room, the cover removed, and the print (prepared paper) taken out. Now place it on the water with the yellow side down and be sure that the water touches every part of it. Let it soak while putting the next print in the frame. Be sure that the hands are dry before touching the next print. The first print having soaked a short time (about 10 minutes) take hold of two of its opposite corners and lift it slowly out of the water. Dip it back again and pull out as before. Repeat this a number of times, until the paper appears to get no bluer; then hang it by two of its corners to dry on the print rack previously mentioned. If there are any dark-purple or bronze-colored spots on the prints, it indicates that the prints were not washed thoroughly on those spots. If these spots are well washed before the print is dried, they will disappear.

196. It is best to judge the proper time of exposure to the light by the color of the strip of print projecting beyond the edge of the tracing. To obtain the exact shade of the projecting edge, take a strip of paper about 12″ or 14″ long and 3″ or 4″ wide. Divide it into, say, 12 equal parts by lead-pencil marks, and with the lead pencil number each part 1, 2, 3, etc. Sensitize this side of the paper and, after it has been properly dried, place it in the print frame with the sensitized side and the marks and figures against the glass. Expose the whole strip to the light for 1 minute; then cover the part of the strip marked 1 with a thin board or anything that will prevent the light from striking the part covered. At the end of the second minute, cover parts 2 and 1; at the end of the third minute, parts 3, 2, and 1, etc. When 12 minutes are up, part 1 will have been exposed 1 minute; part 2, 2 minutes, etc., part 12 having been exposed 12 minutes. Remove the frame to a dark part of the room and tear the strip so as to divide it into two strips of the same length and about half the original width. Wash one of the strips as before described, and when it has dried, select a good rich shade of blue, neither too light nor too dark; notice the number of the part chosen, and it will indicate the length of time that the print was exposed. Examine carefully the corresponding part of the other strip, and the correct color of the edge of the print projecting beyond the tracing is determined. All prints should be exposed until this color is reached, no matter how long or how short the time may be; then they should be immediately taken out and washed.

197. In Fig. 63 is shown a patented frame which can be shoved out of the window and adjusted to any angle. When not in use, it can be folded up against the wall and occupies but little space. It is made in different sizes from 16″ × 24″ to 48″ × 72″. It is one of the best frames in the market,

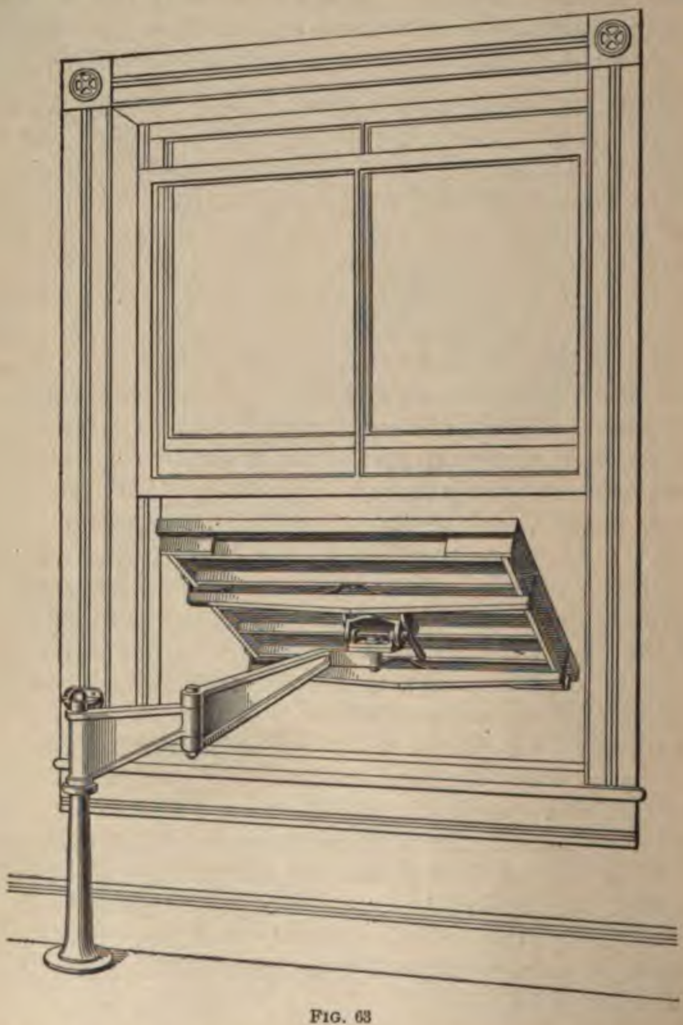


FIG. 63

and is placed in such a position relatively to the window that the window can be lowered to the top of the main arm, when it is desired to keep out the cold during the winter.

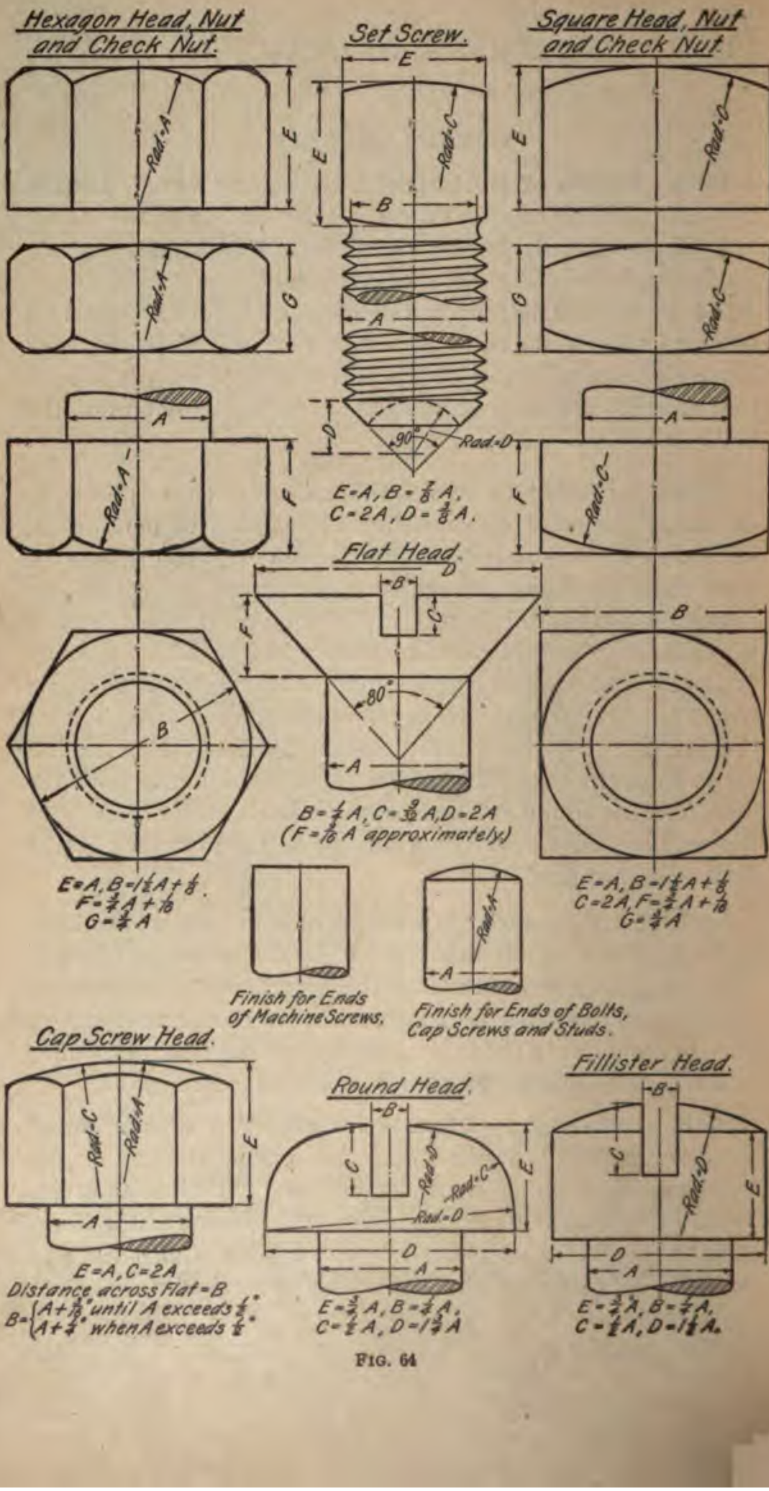
USEFUL TABLES

198. Forms of Bolt Heads, Nuts, and Screw Heads. The information required for the construction of the standard forms of bolt heads, nuts, and the principal screw heads is given in Fig. 64. The several dimensions are indicated by capital letters in the diagrams and the relations between these dimensions are stated either below each separate diagram or below each series of diagrams. It is seen that these dimensions are all based on the diameters of the bolts or screws.

199. In order to avoid the calculations required to use these diagrams, the standard dimensions of bolt heads, nuts, and screw heads have been given in Table I, for the sizes mostly in use. Dimensions, corresponding with those indicated by capital letters in the diagrams, are found in the table in columns headed by similar letters. For instance: It is required to find the height of a hexagon head for a bolt 1″ in diameter. In the diagram of a hexagon head the letter F represents its height. To find its numerical value from the table, descend along the column A until the diameter 1 is found. Then pass in a horizontal direction to the column F, where the value $\frac{13}{16}$ is found, which is the dimension required.

200. Small, standard, machine or wood screws are indicated by gauge numbers instead of by diameters. Table II gives the gauge numbers and the corresponding diameters of the sizes mostly used. To draw a screw of a certain gauge, find its diameter in the table, and lay out the head according to the instructions given with the diagrams in Fig. 64.

201. Diameters of Small Holes.—The sizes of small holes are generally indicated by the gauge number of the drills used in drilling them instead of by their diameters. Table III gives the gauge numbers and corresponding diameters of the Morse twist drills. The table will also serve to indicate the gauge numbers of ordinary steel wire.



Hexagon Head, Nut and Check Nut.
Set Screw.
Square Head, Nut and Check Nut.
Flat Head.
(F = A approximately)
Finish for Ends of Machine Screws.
Finish for Ends of Bolts, Cap Screws and Studs.
Cap Screw Head.
Round Head.
Fillister Head.
E=A, C=2A
Distance across Flat=B

FIG. 64

202. Pipe Threads.—The pitches and depths of the screw threads on pipes cannot be made according to the rules applying to ordinary screw threads, as in that case the depth of the thread would be greater than the thickness of the pipe.

Table IV gives the standard dimensions of pipe threads. By means of the data given under the head of Total Length of Thread and Length of Perfect Thread, it is possible to determine the length of the part containing imperfect threads. It should be noted that the number of the latter is a constant for all diameters; that is, according to the standard adopted, there should always be six imperfect threads, two of which are imperfect only at top, and four both at top and bottom. The number of perfect threads will vary according to the diameter of the pipe or nipple.

203. Decimal Equivalents of Parts of 1 Inch. Table V is intended to aid the student in finding the nearest 64th inch corresponding in value to a dimension given in thousandths of an inch.

The decimal fractions are printed in two sizes of type; the one in large type giving the exact value of the corresponding fractional part of an inch to the fourth decimal place. A given decimal fraction of an inch is rarely exactly equal to any of these values, but is either above or below it, and the question is then to decide to which of two values it is the nearest, whether to the preceding or succeeding one. For instance it is desired to lay off the fraction .1330″ in 64ths of an inch. The nearest decimal fractions are .1250 and .1406, and the question is which of these to choose. By means of the decimal fractions, printed in smaller type, this question may be answered at once, as the value of any one of these is the mean of the two adjacent fractions printed in larger type. If therefore any of the given decimal fractions is *above* the mean in value it belongs to the succeeding decimal fraction, if *below* to the preceding one. In this instance the mean fraction is .1328, and as .1330 is greater than this, .1406″ or $\frac{9}{64}$″ will be chosen. In the same manner the nearest 64th inch corresponding to the decimal fractions .3670″ and .8979″ are found to be $\frac{23}{64}$″ and $\frac{57}{64}$″, respectively.

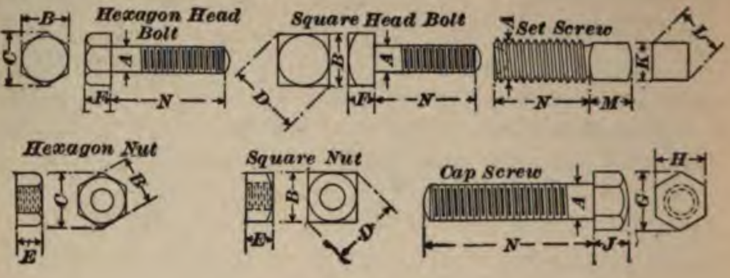


TABLE I

DIMENSIONS OF STANDARD-FINISHED BOLTS, NUTS, SET, AND CAP SCREWS

A	Threads Per Inch	Bolt Dimensions					Cap-Screw Dimensions			Setscrew Dimensions		
		B	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*L*	*M*
1/4	20	1/2	37/64	45/64	1/4	1/4				1/4	23/64	1/4
5/16	18	19/32	11/16	27/32	5/16	19/64	37/64	1/2	5/16	5/16	7/16	5/16
3/8	16	11/16	51/64	31/32	3/8	11/32	21/32	9/16	3/8	3/8	17/32	3/8
7/16	14	25/32	29/32	1 7/64	7/16	25/64						
1/2	13	7/8	1 1/64	1 15/64	1/2	7/16	7/8	3/4	1/2	1/2	45/64	1/2
5/8	11	1 1/16	1 15/64	1 1/2	5/8	17/32	1	7/8	5/8	5/8	7/8	5/8
3/4	10	1 1/4	1 7/16	1 3/4	3/4	5/8	1 5/32	1	3/4	3/4	1 1/16	3/4
7/8	9	1 7/16	1 21/32	2 1/32	7/8	23/32	1 5/16	1 1/8	7/8	7/8	1 15/64	7/8
1	8	1 5/8	1 7/8	2 19/64	1	13/16	1 7/16	1 1/4	1	1	1 13/32	1
1 1/8	7	1 13/16	1 15/16	2 9/16	1 1/8	29/32						
1 1/4	7	2	2 5/16	2 53/64	1 1/4	1	1 3/4	1 1/2	1 1/4			
1 1/2	6	2 3/8	2 3/4	3 23/64	1 1/2	1 3/16						
1 3/4	5	2 3/4	3 11/64	3 57/64	1 3/4	1 3/8						
2	4 1/2	3 1/8	3 39/64	4 27/64	2	1 9/16						
2 1/4	4 1/2	3 1/2	4 3/64	4 61/64	2 1/4	1 3/4						
2 1/2	4	3 7/8	4 15/16	5 31/64	2 1/2	1 15/16						
2 3/4	4	4 1/4	4 29/32	6 1/64	2 3/4	2 1/8						
3	3 1/2	4 5/8	5 11/32	6 35/64	3	2 5/16						
3 1/4	3 1/2	5	5 25/32	7 5/64	3 1/4	2 1/2						
3 1/2	3 1/4	5 3/8	6 13/64	7 19/32	3 1/2	2 11/16						
3 3/4	3	5 3/4	6 41/64	8 1/8	3 3/4	2 7/8						
4	3	6 1/8	7 5/64	8 21/32	4	3 1/16						
4 1/4	2 7/8	6 1/2	7 1/2	9 3/16	4 1/4	3 1/4						
4 1/2	2 3/4	6 7/8	7 15/16	9 23/32	4 1/2	3 7/16						
4 3/4	2 5/8	7 1/4	8 3/8	10 1/4	4 3/4	3 5/8						
5	2 1/2	7 5/8	8 13/16	10 25/32	5	3 13/16						

TABLE II

STANDARD MACHINE AND WOOD SCREWS

Gauge No.	Diameter Inches	Threads Per Inch	Diameter of Round Head	Diameter of Filister Head	Diameter of Flat Head
000	.0315				
00	.0447				
0	.0578				
1	.0710				
2	.0842	64	.1544	.1332	.1631
3	.0973	48	.1786	.1545	.1894
4	.1105	36	.2028	.1747	.2158
5	.1236	32	.2270	.1985	.2421
6	.1368	32	.2510	.2175	.2684
7	.1500	32	.2754	.2392	.2947
8	.1631	32	.2936	.2610	.3210
9	.1763	32	.3238	.2805	.3474
10	.1894	32	.3480	.3035	.3737
11	.2026	24			
12	.2158	24	.3922	.3445	.4263
13	.2289	22			
14	.2421	20	.4364	.3885	.4790
15	.2552	20			
16	.2684	18	.4866	.4300	.5316
17	.2816	18			
18	.2947	18	.5248	.4710	.5842
19	.3079	18			
20	.3210	16	.5690	.5200	.6308
21	.3342				
22	.3474	16	.6106	.5557	.6894
23	.3605				
24	.3737	16	.6522	.6005	.7420

TABLE III

MORSE TWIST-DRILL AND STEEL-WIRE GAUGE

Gauge No.	Diameter Inch	Gauge No.	Diameter Inch	Gauge No.	Diameter Inch
1	.2280	33	.1130	65	.0350
2	.2210	34	.1110	66	.0330
3	.2130	35	.1100	67	.0320
4	.2090	36	.1065	68	.0310
5	.2055	37	.1040	69	.02925
6	.2040	38	.1015	70	.0280
7	.2010	39	.0995	71	.0260
8	.1990	40	.0980	72	.0250
9	.1960	41	.0960	73	.0240
10	.1935	42	.0935	74	.0225
11	.1910	43	.0890	75	.0210
12	.1890	44	.0860	76	.0200
13	.1850	45	.0820	77	.0180
14	.1820	46	.0810	78	.0160
15	.1800	47	.0785	79	.0145
16	.1770	48	.0760	80	.0135
17	.1730	49	.0730		
18	.1695	50	.0700		
19	.1660	51	.0670		
20	.1610	52	.0635		
21	.1590	53	.0595		
22	.1570	54	.0550		
23	.1540	55	.0520		
24	.1520	56	.0465		
25	.1495	57	.0430		
26	.1470	58	.0420		
27	.1440	59	.0410		
28	.1405	60	.0400		
29	.1360	61	.0390		
30	.1285	62	.0380		
31	.1200	63	.0370		
32	.1160	64	.0360		

TABLE IV

U. S. STANDARD STEAM, GAS, AND WATER PIPE

Sizes of Pipes Inches	Threads per Inch	Actual External Diameter Inches	Actual Internal Diameter Inches	Total Length of Thread	Length of Perfect Thread	Tapping Size	Diameter at End of Pipe	
							Outside	At Bottom of Thread
$\frac{1}{8}$	27	.405	.270	.41	.19	$\frac{21}{64}$	.393	.342
$\frac{1}{4}$	18	.540	.364	.62	.29	$\frac{29}{64}$	.522	.445
$\frac{3}{8}$	18	.675	.494	.63	.30	$\frac{19}{32}$	.656	.579
$\frac{1}{2}$	14	.840	.623	.83	.39	$\frac{23}{32}$	.816	.717
$\frac{3}{4}$	14	1.050	.824	.84	.40	$\frac{15}{16}$	1.025	.926
1	$11\frac{1}{2}$	1.315	1.048	1.03	.51	$1\frac{3}{16}$	1.283	1.162
$1\frac{1}{4}$	$11\frac{1}{2}$	1.660	1.380	1.06	.54	$1\frac{15}{32}$	1.626	1.505
$1\frac{1}{2}$	$11\frac{1}{2}$	1.900	1.611	1.07	.55	$1\frac{23}{32}$	1.866	1.745
2	$11\frac{1}{2}$	2.375	2.067	1.10	.58	$2\frac{3}{16}$	2.339	2.218
$2\frac{1}{2}$	8	2.875	2.468	1.64	.89	$2\frac{11}{16}$	2.819	2.646
3	8	3.500	3.067	1.70	.95	$3\frac{5}{16}$	3.441	3.268
$3\frac{1}{2}$	8	4.000	3.548	1.75	1.00	$3\frac{13}{16}$	3.938	3.765
4	8	4.500	4.026	1.80	1.05	$4\frac{7}{32}$	4.434	4.261
$4\frac{1}{2}$	8	5.000	4.508	1.85	1.10	$4\frac{21}{32}$	4.931	4.758
5	8	5.563	5.045	1.91	1.16	$5\frac{15}{64}$	5.491	5.318
6	8	6.625	6.065	2.01	1.26	$6\frac{1}{4}$	6.546	6.373
7	8	7.625	7.023	2.11	1.36	$7\frac{5}{16}$	7.540	7.367
8	8	8.625	7.982	2.21	1.46	$8\frac{5}{16}$	8.534	8.361
9	8	9.625	8.937	2.32	1.57	$9\frac{5}{16}$	9.527	9.354
10	8	10.750	10.019	2.43	1.68	$10\frac{5}{16}$	10.645	10.472

NOTE.—The taper of the threaded part is 1 in 16.

TABLE V

DECIMAL EQUIVALENTS OF PARTS OF 1 INCH

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
	.0078		.2578		.5078		.7578
1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
	.0235		.2735		.5235		.7735
1/32	.0313	9/32	.2813	17/32	.5313	25/32	.7813
	.0391		.2891		.5391		.7891
3/64	.0469	19/64	.2969	35/64	.5469	51/64	.7969
	.0547		.3047		.5547		.8047
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
	.0703		.3203		.5703		.8203
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
	.0860		.3360		.5860		.8360
3/32	.0938	11/32	.3438	19/32	.5938	27/32	.8438
	.1016		.3516		.6016		.8516
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
	.1172		.3672		.6172		.8672
1/8	.1250	3/8	.3750	5/8	.6250	7/8	.8750
	.1328		.3828		.6328		.8828
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
	.1485		.3985		.6485		.8985
5/32	.1563	13/32	.4063	21/32	.6563	29/32	.9063
	.1641		.4141		.6641		.9141
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
	.1797		.4297		.6797		.9297
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
	.1953		.4453		.6953		.9453
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
	.2110		.4610		.7110		.9610
7/32	.2188	15/32	.4688	23/32	.7188	31/32	.9688
	.2266		.4766		.7266		.9766
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
	.2422		.4922		.7422		.9922
1/4	.2500	1/2	.5000	3/4	.7500	1	1.0000
	.2578		.5078		.7578		1.0078

STRUCTURAL DRAFTING

INTRODUCTION

27. Structural drafting is essentially mechanical drawing and is subjected to the same requirements with regard to accuracy and rendering. As it is necessary that the student should know something of the conventionalities of mechanical drawing, the plate entitled Details has been introduced in order to familiarize him with the elements of this subject. All other plates in this Section relate entirely to construction, and, besides offering the student practice in mechanical drawing, furnish him with a study of the details of construction. It is seldom that the structural draftsman can devote the time that is necessary to make a carefully executed and elaborate drawing, for the plans and details are often wanted in a hurry and they can seldom be used for any but the one piece of work. Therefore, all that is required of him is an accurate and complete drawing. Shade lines, as described in *Geometrical Drawing*, are seldom used, for they take time and are apt to destroy the accuracy of the drawing in scaling. Owing also to the fact that numerous notes are necessary, it is usual to adopt the simplest possible form of lettering—one that can be executed with rapidity; therefore, the common practice is to use, instead of the single-line Italic shown on the plates in *Geometrical Drawing*, the form of lettering called single stroke, which is used on the plates that follow.

DRAWING PLATES

DRAWING PLATE, TITLE: DETAILS

28. In laying out structural or mechanical drawings the draftsman is often called on to designate nuts and bolts. These parts have been given certain fixed proportions, known in this country as the *United States standard*, in order that all bolts and nuts throughout the country will be interchangeable. To make an accurate drawing of a bolt or nut would require considerable time, because the threads are in the form of a helix, which is somewhat difficult to lay out. It became necessary, therefore, to adopt some means by which a bolt with the threads and nuts could be readily shown, and the conventional methods designated on the plate in Figs. **1**, **2**, **3**, **4**, **5**, and **6** have been uniformly adopted by structural and mechanical draftsmen.

In order to distinguish readily between references to figure numbers on the drawing plates and to those in the text, the former will be printed in heavy-faced type and the latter in ordinary, or light-faced type.

29. Fig. **1** shows the simplest conventional method of designating the **threaded end of a bolt.** It consists of drawing single lines across the bolt at the same distance apart as the threads are located. These lines are inclined half the pitch in one diameter and represent approximately the top of the thread. The *pitch* of the thread is the distance from thread to thread and in this case is approximately equal to $\frac{9}{64}''$, because a $1\frac{1}{4}''$ United States standard bolt has seven threads to the inch. The conventional method shown in Fig. **2** is rather neater and more natural and is used on drawings of larger scale, though it is seldom attempted where it is necessary to show bolts in a drawing made to a $\frac{1}{4}''$, $\frac{1}{2}''$, or $\frac{3}{4}''$ scale.

D

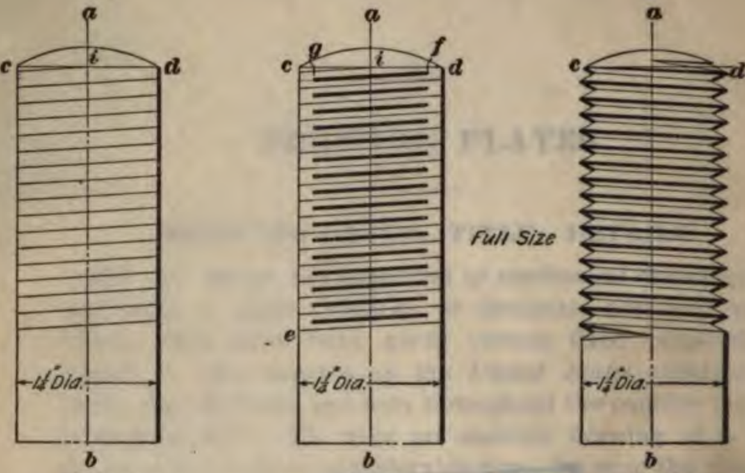
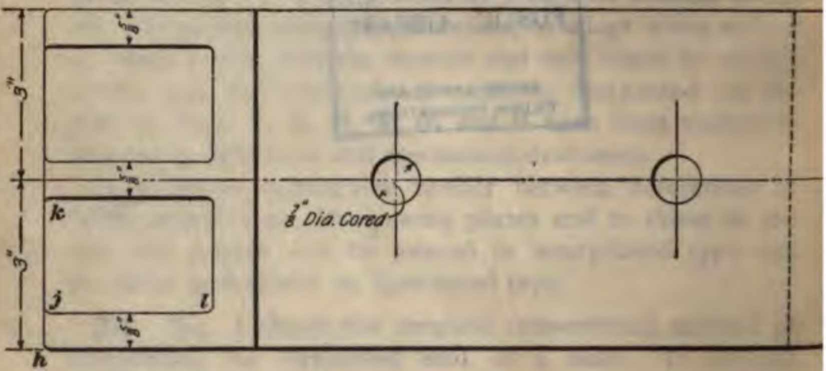


Fig.1. Fig.2. Fig.3.



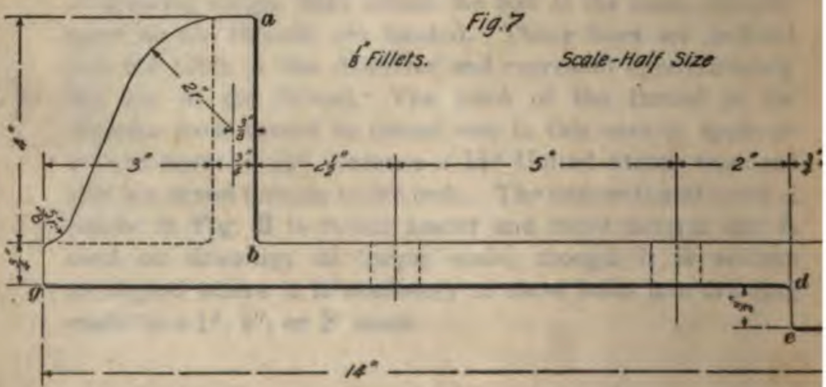


Fig.7

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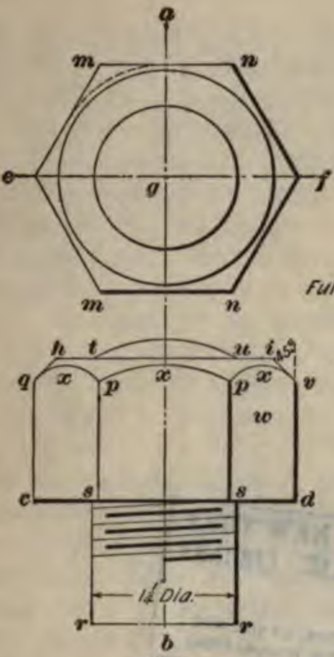


Full Size

Fig. 5.

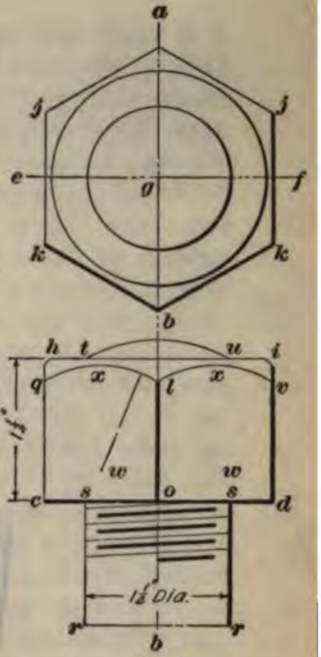


Fig. 6

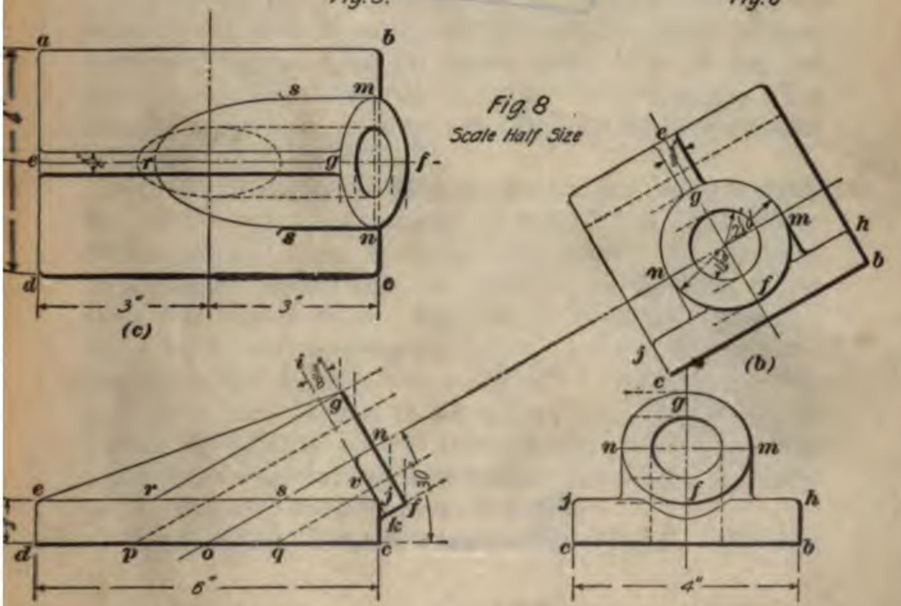
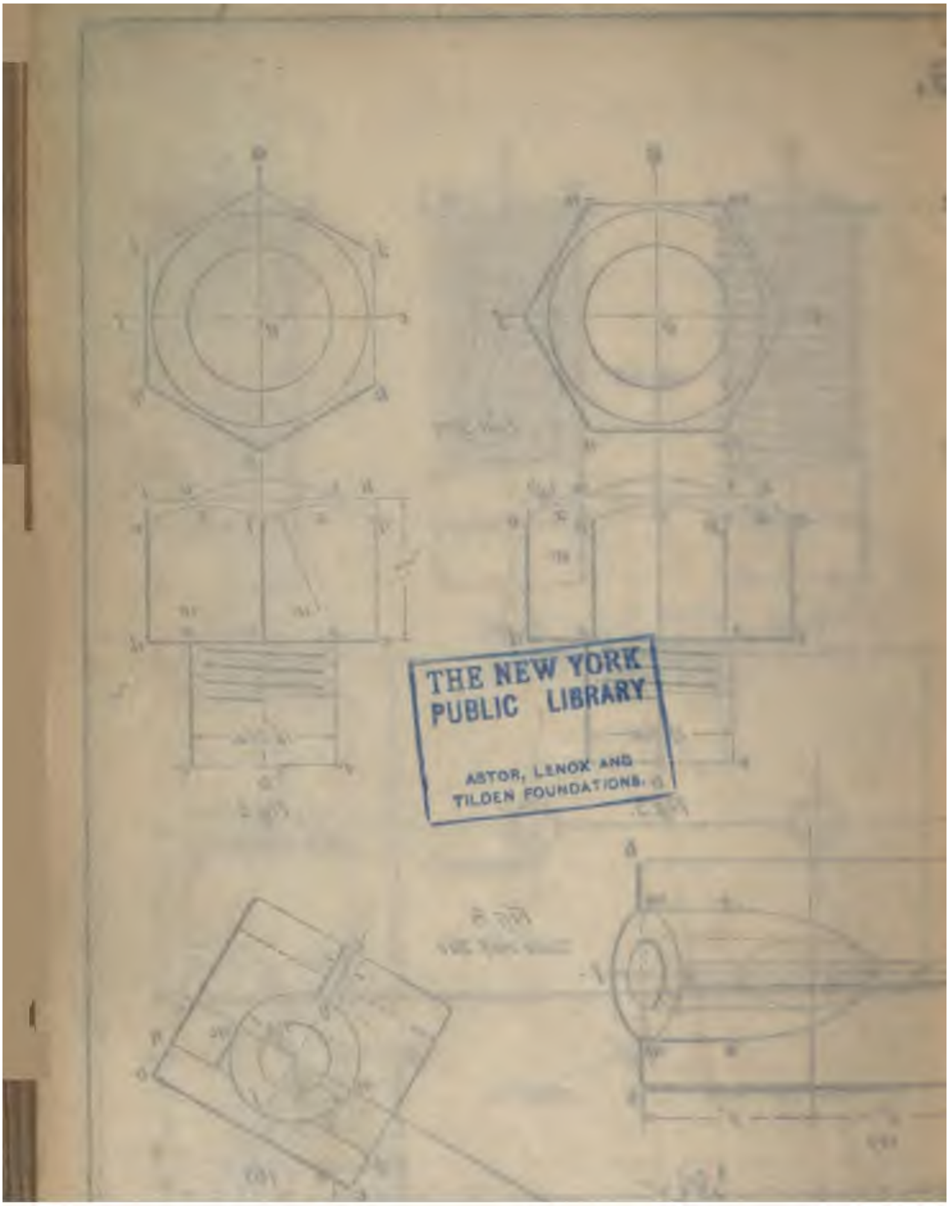


Fig. 8
Scale Half Size



In making large and accurate drawings and where it is desired to have the drawing possess a neat and finished appearance, it is usual to lay out the screw threads as shown in Figs. 3 and 4. The method of doing this is explained later. It will be noted that the threads slope in opposite directions in Figs: 3 and 4. This means is usually employed to designate whether the thread is *right* or *left hand;* that is, whether the nut can be screwed on the bolt by turning in the direction of the hands of a clock or opposite to their movement. A United States standard bolt cut with a right-hand thread is always tightened by turning the nut in the direction of the hands of a watch, while a bolt provided with a left-hand thread is tightened by turning the nut in the opposite direction, or reverse to the movement taken by the hands of a watch. Whether the threads on a bolt are right- or left-hand may readily be determined by placing the bolt in a horizontal position; if the threads slope from the top to the bottom toward the *right* the bolt is cut with a *right-hand thread*, while if the threads slant from the top to the bottom toward the *left*, the bolt is cut with a *left-hand thread*.

Figs. 5 and 6 show the end of the bolt provided with a hexagon nut, Fig. 5 having the nut turned with the longest diameter parallel with the sheet, while Fig. 6 has the shortest diameter lying in the plane of the paper. The threads are shown in these two views by the conventional method designated in Fig. 2.

Fig. 7 is a **cast-iron shoe** for the end of a rafter member in a roof truss; it is designed to transfer the thrust of the rafter member to the horizontal tie-member. The location of a similar casting may be observed on Drawing Plate, title: Mill Construction. The end of the rafter member is fitted to the casting along the lines *a b* and *b c*, while the projecting lip *d e f* is fitted into a cut in the tie-member. The bolt holes are necessary in the casting so that bolts may be passed through the tie and rafter member in order to hold them firmly together and in alinement, so that the shoe may act in its proper capacity as an abutment.

Fig. 8 shows, in detail, a **cast-iron washer.** This type of special washer is used where it is necessary to run a bolt or rod obliquely through the timber. If the washer were not used it would be necessary, in order to get a flat bearing for the nut, to cut into the timber at right angles with the direction of the bolt. For this reason a washer that has the shape of the casting shown in the figure is used. By this means the nut can be brought to a square bearing on the surface *g f*. The lower flange *a b c d* in (*c*) is usually set into the timber so that before the casting can move longitudinally it must shear the wood.

30. Commence the plate by drawing the vertical lines *a b*, Figs. **1**, **2**, **3**, and **4**, at distances of $1\frac{3}{16}''$, $3\frac{11}{16}''$, $6\frac{3}{16}''$, and $8\frac{11}{16}''$, respectively, from the left-hand border line. Draw a horizontal line $1\frac{5}{8}''$ from the upper border line, on which to locate the points *c*, *d*. Draw in the vertical lines representing the outline of the bolts and then describe the arc *c d* in each figure, these arcs being drawn with a radius equal to the diameter of the bolt. In Figs. **1** and **2**, the top of the thread is assumed to start at the intersection of the line *c d* and the center line. Lay off along the vertical line *a b*, from the point *i* in each of the figures, spaces equal to the pitch of the screw, or so many threads to the inch, according to the United States standard given in Table II. Through these points, which are spaced at a distance apart equal to $\frac{1}{7}''$, or approximately $\frac{9}{64}''$, since for a $1\frac{1}{4}''$ bolt there are seven threads to the inch, draw lines indicative of threads. In order to find the slant of these lines, lay off one-fourth of the pitch from *c* downwards and from the point thus found draw a line to *i*. Parallel with this line, draw lines through all the points laid off along line *a b*.

In Fig. **2**, the short heavy lines are drawn parallel to the light lines and represent the bottoms of the threads. Care should be taken to draw these lines the same length, as otherwise the drawing will present a ragged appearance. It is well, in order to stop these lines evenly, to draw light pencil lines, as through *g* and *f*, at a distance from the side lines slightly less than the pitch of the threads.

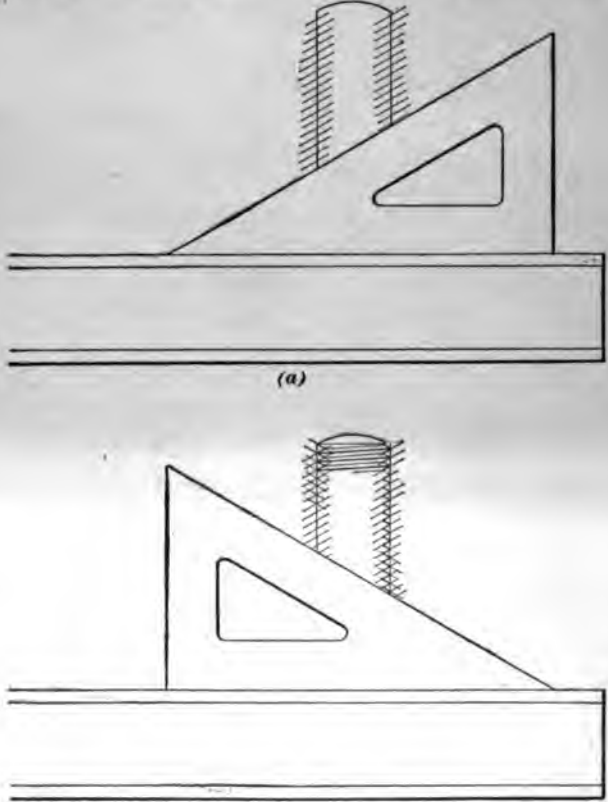
31. When drawing Figs. **3** and **4**, the verticals supposed to be drawn through the points *c* and *d*, locate the tops of the threads. The **V** cuts forming the threads subtend an angle of 60°, as shown in Fig. **4**, and may be conveniently drawn with a 30°–60° triangle, the long side of the triangle being against the **T** square.

In drawing the threads in these two figures, mark off the pitch of the threads on one side of the figure, as, for instance, from *c* downwards, in Fig. **3**. On the other side lay off a point at a distance of one-half the pitch below *d* and to the point thus located draw a line from *c*. Draw lines parallel with this line from the other division points. With the 30°–60° triangle, proceed to draw from each point so marked off as many sides of the thread as possible; then complete the outline of the thread by reversing the triangle. It is advisable to draw through the bottom of one thread, thus located, a line parallel with the side of the bolt in order to insure uniformity of the thread. Make the lines representing the tops of the threads heavy and those representing the bottoms of the threads light, as shown on the plate. Care should be taken to see that they slope in the same direction, as shown on the plate, for in Fig. **3** is represented a left-hand thread, while in Fig. **4** is shown a right-hand thread, the latter being the same as shown in Figs. **1** and **2**.

The method of drawing the **V**-shaped threads is illustrated in Fig. 27. In (*a*) is shown the relative position of the triangle and the **T** square in drawing one half of the thread, while in (*b*) is shown the triangle reversed, by which means the outline of the thread is completed. It will be observed that no vertical limiting line is required in this case.

Extreme accuracy in drawing these conventional designations is not necessary, for if the diameter of the bolt is given, the dimensions of the threads are determined, since all bolts in this country are cut according to the United States standard.

32. To proceed with Figs. **5** and **6**, lay out the vertical center lines *a b* $5\frac{1}{16}''$ and $1\frac{7}{8}''$, respectively, from the right-hand border line. Draw the horizontal center lines *e f* in the plan of each figure $2\frac{5}{8}''$ from the upper border line and lay off in each view the line *c d*, which represents the under surface of the nut, $5\frac{1}{2}''$ from the upper border line. From *g* as a center, in each case, describe the $1\frac{1}{4}''$ circle that represents



(a)

(b)

FIG. 27

the bolt. The smallest diameter of the nut is across the line *e f*, Fig. 6; this dimension for a $1\frac{1}{4}''$ nut is 2″, so that a circle having this diameter should be described in pencil, about the center *g*, in each figure. This circle, which is partially shown by the dotted line in the plan in Fig. 5, is necessary in order that the hexagon may be constructed. In circumscribing the hexagon in Fig. **6**, draw the two vertical lines *j k*, tangent to the circle at *e* and *f*, and with the 60° triangle draw the lines *k b* and *j a* tangent to the circle and at 30° with the horizontal. This completes the hexagon in Fig. **6**; the one in Fig. **5** is likewise circumscribed by drawing the horizontal lines *m n*, *m n*, tangent to the circle, and the lines *e m* and *f n* with the 60° triangle, making them tangent to the circle and at 60° with the horizontal. The circles on which the hexagons have been constructed are not necessary in the drawing and may be erased.

Having drawn so much of the plans, project downwards the vertical lines *r s* representing the outline of the bolt and the lines *q c*, *p s*, *v d*, and *l o* from the corners of the hexagon in each plan view. The standard nut is $1\frac{1}{4}''$ thick, and an indefinite horizontal line containing *h i* in both figures may be drawn. The arc *t u* in each view may be described by the compasses set to a radius equal to the diameter of the bolt, or $1\frac{1}{4}''$. In the plans, from the point *g*, describe the circle concentric with the bolt and $\frac{1}{16}''$ from the hexagon at the nearest point. This circle represents the outline of the flat circular surface of the top of the bolt, as designated by the lines *h i* in each view. Project the diameter of the circle just drawn and locate the points *h* and *i*, and from these points in Fig. **5**, draw the 45° lines *i v* and *h q*. By drawing a light horizontal line, in pencil, from *q* to *v*, which need not be shown in the drawing, the points *p*, *p* may be located; the points *q*, *l*, and *v*, Fig. **6**, are found by projecting across from the point *v*, in Fig. **5**. The highest points of the arcs, as at *x*, *x*, in each view are located $\frac{1}{16}''$ from the upper horizontal line *h i*; consequently, we have three points through which to pass an arc, which may be described as explained in *Geometrical Drawing*. Having located the centers *w*, *w*, the several arcs may be described and the slight bevel in Fig. **6** at *h* and *i* drawn; also, the threads on each bolt. Unnecessary construction lines may be erased and the figures finished.

By referring to Fig. 20, which is described under the heading Conventional Representation of a Nut, it will be observed that there is some difference between this figure and the plate. Both methods of designation are employed, the conventional representation being more common than the one shown on the plate. Complete information as to the construction of standard bolt heads, nuts, screw heads, etc. is given at the end of this Section.

33. Proceed with Fig. **7**, which offers no difficulty, as it is completely dimensioned, and all that is necessary to know is its location on the plate. The line *g d* in the lower view, or side elevation, is $1\frac{1}{2}''$ from the lower border line, while *c f*, the extreme right-hand line of the side view, or elevation, is $9\frac{1}{4}''$ from the right-hand border line. The line *h i* in the upper view should be $4\frac{3}{8}''$ from the lower border line. Sharp corners are always avoided in castings, unless called for by special reasons; corners are, therefore, rounded off. In the case of concave corners, the patternmaker often resorts to the use of some plastic material, such as putty, etc., to fill in the corner so as to round it. From this practice, the rounding out of a concave corner is called a **fillet**, and this term has come to be applied to the little circular arc used by the draftsman to represent it. Several of these fillets are found in this and some of the succeeding views, as at *j*, *k*, *l*, etc. As indicated on the plate, the fillets in Fig. **7** are to be drawn with a radius of $\frac{1}{8}''$. The word *Cored*, found in this view, implies that finish is unnecessary, the hole being produced by a core, which is placed in the mold when the casting is made. In case it is desirable to have the hole finished, the word *Drill* is placed after its diameter, which means that a hole is to be put through the object by drilling.

34. To draw the **check-washer** shown in Fig. **8**, it is necessary to draw the view shown in (*a*), or the side elevation, for all the other views are projections from this and have many dimensions that are foreshortened by the projection.

Commence by laying off the horizontal bottom line *c d* $1\frac{1}{8}''$ from the lower border line and then locate the point *o*, which is the intersection of the center line of the bolt with the bottom of the flange on the line cd. This intersection is $6\frac{3}{8}''$ from the right-hand border line. Draw the center line on with the triangle at an angle of 30° with the horizontal, and then after locating the points c and d lay off, from the latter, the vertical lines cj and de and draw the horizontal line ej. This finishes the lower flange. From j, with the 60°–30° triangle, draw ji lightly, as this is simply a dimension line. The diameter of the boss, or the distance from g to f in (a), is $2\frac{1}{4}''$, as shown in view (b). The bolt hole through the washer, shown by the dotted lines in views (a) and (c), is $1\frac{1}{4}''$ in diameter, as marked in view (b). Draw these dotted lines and gr, fk, and ge, putting in the necessary fillets. This practically completes view (a), so that it is possible to lay out the plan shown in (c). The lower flange $ejcd$ in (a) is designated in view (c) by $abcd$, and its center line ef is $4\frac{1}{2}''$ from the lower border line. The points f and g in (a) are projected to fg in view (c); it will be noted that the circular face of the boss when projected is foreshortened considerably, while the diameter of the boss on the line mn retains its true dimension. Thus, the circular boss and bolt hole, when projected to the plan, is elliptical. Likewise, the intersection of the bolt hole with the lower face of the flange, as at pq in view (a), is elliptical, as shown on the plan, because it is the oblique section through a cylinder. This ellipse, which is represented by dotted lines in view (c), is constructed on its major and minor axes, the major axis being projected from the view (a) and its minor axis being equal to the diameter of the bolt hole.

The three ellipses shown in view (c) can readily be drawn by the methods described in *Geometrical Drawing*, and in fact the whole view is a practical application of the principles set forth in connection with the Drawing Plates, titles: Projections II and Conic Sections. The point n in (a) may be projected to the plan (c) and the line mn thus found. As this is the center line, or major axis, of the ellipse, by marking off on it the distance mn equal to the diameter of the boss and projecting the points g and f from the same points in (a), the limiting points of the ellipse are found and it may be drawn. The bolt hole may likewise be drawn in the plan view by laying off on the line *m n* its diameter central with the line *e f*, and by projecting its foreshortened width from the side view (*a*). The elliptical curve *r s* may be described on locating the points *r*, *s*, and *s* by projecting these points from the side view at (*a*), and the rib, which is $\frac{3}{8}''$ in thickness, may be drawn to finish view (*c*) after the $\frac{1}{8}''$ fillets at *e* and *g* have been made. Similar fillets are made at the other corners of the washer. View (*b*) may readily be projected, its center line *e f* being located $3\frac{5}{8}''$ from the face of the boss *g f* in view (*a*).

View (*d*) is equally as simple and may be projected from view (*a*) in the same manner as view (*c*). It should be noticed that in views (*b*) and (*d*) the sides of the boss at *m* and *n* are connected with the flange *j h*. A side view of this feature is seen at (*a*), where its front edge is indicated by the letter *v*. Add this line to view (*a*) by drawing a line parallel with line *g f* from the axis *n o* to the flange, rounding it off with a $\frac{1}{8}''$ fillet at the top. In views (*b*) and (*d*) the connection of the boss with the flange is indicated by lines drawn from points *n* and *m* at right angles to the flange. The lines of projection may be omitted or they may be designated on the drawing by very light or, preferably, dotted lines.

Block out the title and ink in the plate carefully, placing on the drawing all notes of reference and notes designating the scale, etc., leaving out, as is usual, all the reference letters, and if so desired the construction lines, though the projection lines in Fig. 8 may be put in.

DRAWING PLATE, TITLE: BEAM CONNECTIONS

35. This plate shows the details for **I-beam connections** of the several sizes usual in building construction. These connections are the ones usually employed in steel construction by the mills and construction companies. They are so designed as to be sufficiently strong to resist the downward pressure at the ends due to the safe load supported

BEAM CO

Sca

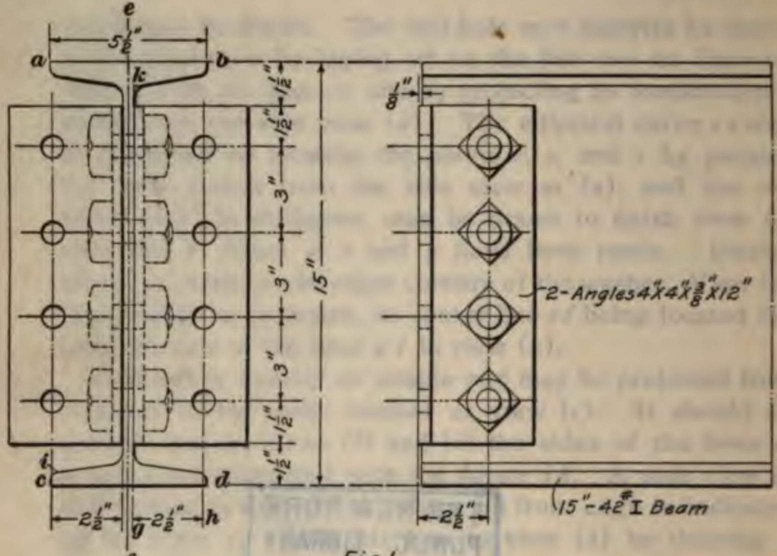


Fig. 1.

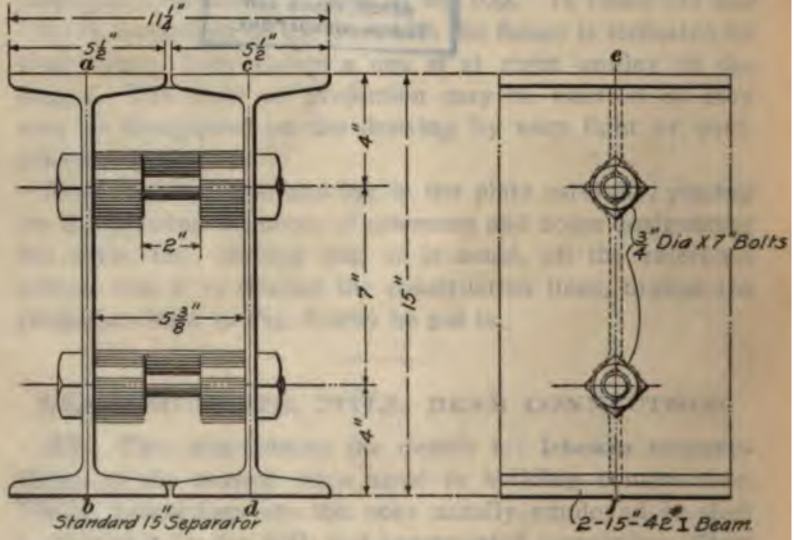


Fig. 3.

ECTIONS

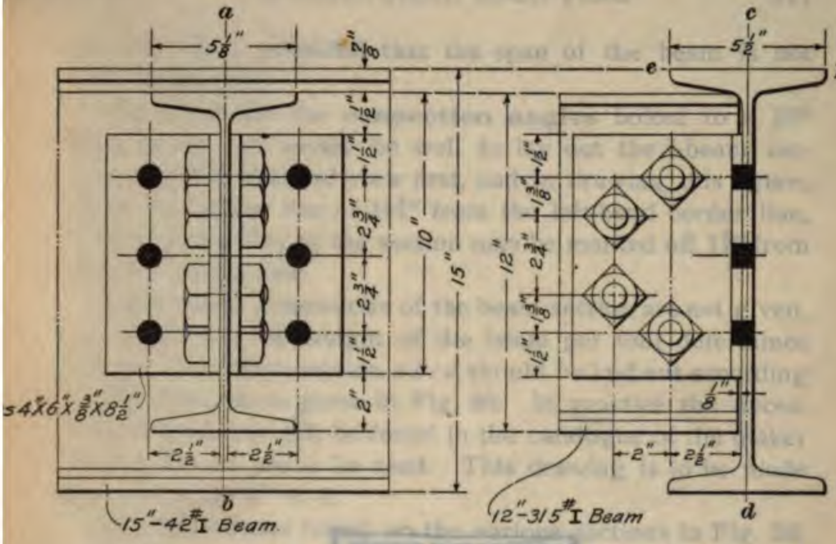


Fig. 2.

lts 3/4" Diam

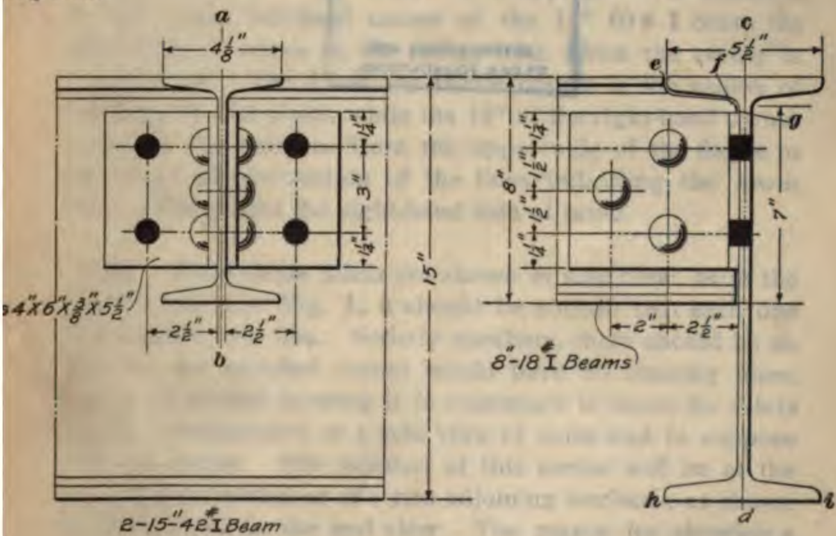
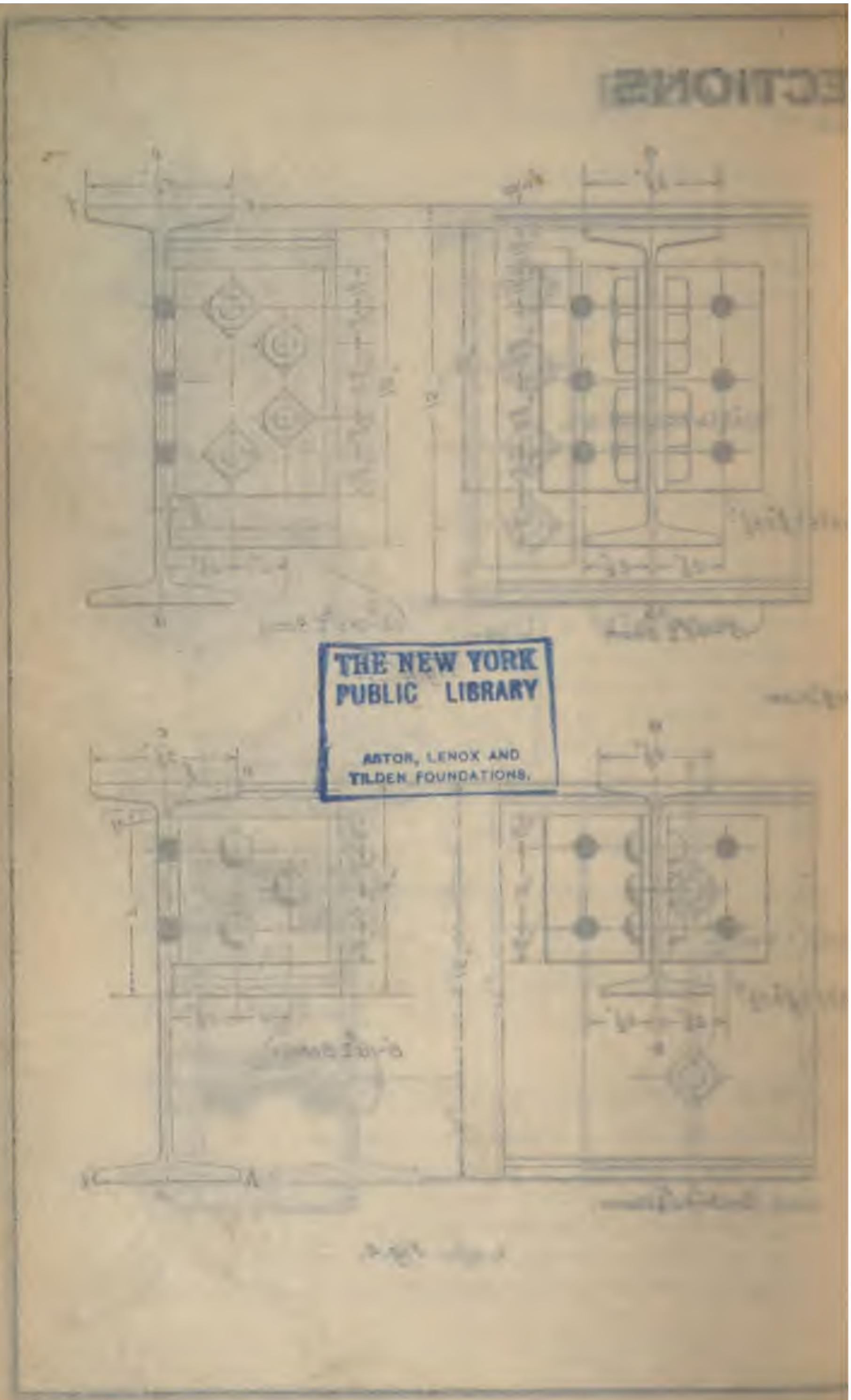


Fig. 4.

INTERNATIONAL TEXTBOOK COMPANY
L. LONDON



by the beam, provided that the span of the beam is not unusually short.

Fig. **1** shows the **connection angles** bolted to a 15″ 42 # beam. It would be well to lay out the I-beam section *a b c d* in the end view first, and in drawing this figure, draw the center line *e f* $1\frac{13}{16}''$ from the left-hand border line, while the top line of the section may be marked off $1\frac{3}{4}''$ from the top border line.

The several dimensions of the beam section are not given, for practically the weight of the beam per foot determines them. The beam section *a b c d* should be laid out according to the dimensions given in Fig. 26. In practice the necessary dimensions will be found in the catalogue of the maker whose beams are to be used. This drawing is to be made to a scale of 3″ = 1′.

The dimensions found, on the various sections in Fig. 26, near the corners and fillets, together with a small arrow, indicate the radius of the curve at that place. For instance, at the upper left-hand corner of the 15″ 60 # **I** beam the dimension $\frac{1}{4}''$ refers to the radius with which the corner is rounded off. The $\frac{5}{8}''$ at the inside corner is the radius of the fillet at that place, while the $\frac{11}{16}''$ at the right-hand corner indicates the distance from the upper side of the flange to the point of intersection of the lines indicating the lower side of flange and the right-hand side of same.

36. When these fillets are shown in side view, as in the side elevation in Fig. **1**, it should be noticed that each one is indicated by a line. Strictly speaking, there should be no line, as the rounded corner would have no limiting lines, but in structural drawing it is customary to leave the fillets out of consideration in a side view of same and to suppose a sharp corner. The location of this corner will be at the line of intersection of the two adjoining surfaces, as shown at the point *k* in the end view. The reason for showing a fillet in this manner is the necessity of having a definite point from which to measure distances, when beams are connected with other structural parts that occupy positions in or near the fillets. The several dimensions of the connections when the size and weight of the beam or rolled shape are known can be obtained from the handbooks of the various rolling mills, as they usually contain dimensioned sections of the standard shapes. The dimensioned sections for the different rolled shapes shown on these plates are given in Fig. 26.

The section of the **I** beam in the left-hand view of Fig. **1** having been completed, the connecting angles, which are 4″ in width, should be marked off and drawn and the center lines for the bolt holes laid out and the holes described. In all structural work the dimensions, wherever possible, should be given from center lines, and rivet and bolt holes should always be located by center lines. The distance gh locating the vertical center lines of the rivet holes from the back of the angles, is the standard distance employed by most steel mills for this size angle.

The right-hand view in Fig. **1**, which is a side elevation, may be drawn by projecting the edges of the beam from the sectional view, the back of the angle, or the extreme left-hand line, being $4\frac{3}{8}$″ from the left-hand border line. It will be noticed that the connection angles are extended forward from the end of the beam $\frac{1}{8}$″ so that when the angles are bolted against the supporting beam they will fit against it square and not be kept away by the projecting end of the beam, which may be cut somewhat roughly.

All nuts and bolt heads are square in this class of construction, and after the angles have been laid out in this view the bolts may be designated, as shown, and dimensioned. It is not usual to show the one row of bolts in the end view, as done here, but in order to make the construction clear they should be designated on the plate in this particular figure.

37. Fig. **2** shows the **connection** of a 12″ **I** beam to one 15″ in depth. This type of joint is the one that is always used in the construction of steel-beam floor systems and is the standard connection for the sizes of beams shown.

In drawing Fig. **2**, mark off the vertical center line *c d* $1\frac{7}{16}''$ from the right-hand border line and the center line *a b* $6\frac{1}{16}''$ from the same border line, while the top line *e f* of the 15″ beam is located $1\frac{3}{4}''$ from the top border line.

After having drawn the beams and connecting angles in position, the bolts and bolt holes may be located according to the dimensions given, working, as before, from center lines. It will be noticed that the bolt holes in the 15″ beam are shown solid black; this is done to show that the bolts and rivets are put in place or driven when the work is erected, in which case they are called *field bolts* or *rivets.*

38. Fig. **3** shows a **sheet-steel separator** bolted between two 15″ I beams. These separators are used where it is necessary to employ two beams side by side, and they cause the beams to act in unison under the load. In this figure, the vertical center line *a b* of the left-hand beam section is located $1\frac{13}{16}''$ from the left-hand border line, while the lower line of the flanges of the beams is 2″ from the lower border line. The beams have the same section as the one shown in Fig. **1** and when placed side by side measure across the flanges $11\frac{1}{4}''$, when a $\frac{1}{4}''$ space is left between them. The side view of the right-hand portion of the figure shows the separator dotted, the center line *e f* of the bolt holes being located $6\frac{1}{2}''$ from the left-hand border line. This dotting in of the separator would not usually be done in a working drawing, as the separators are all made in standard sizes, and a note on the drawing to this effect is sufficient. The separator was shown in this case, however, in order to make this detail of construction clear. The figure may be finished without difficulty and, if so desired, the shade lines introduced as shown. In order that a correct idea of the appearance of the separator may be obtained, a perspective view of one is given in Fig. 28.

FIG. 28

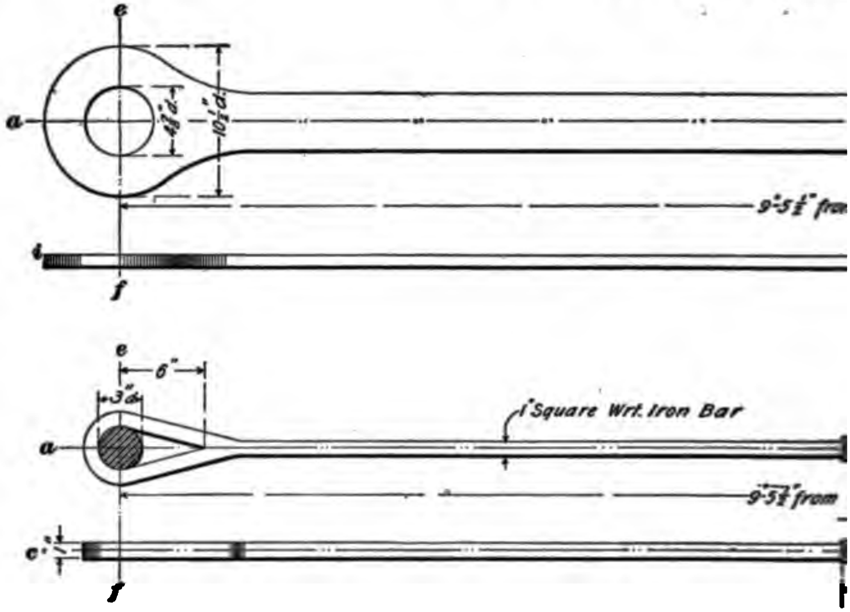
39. Fig. **4** shows the **connection** of an 8″ beam to one 15″ in depth. This connection differs somewhat from the construction shown in Fig. **2** in that the beams are flush on top and the connection is riveted and not bolted. When a beam connection has the flanges of the two beams flush, it is necessary to cut the auxiliary beam, as shown at *e f g*, so that its web will fit under the flange of the principal beam, and the angle connection can be made rigid. In drawing this figure, lay out the vertical center line *c d* of the 15″ beam $1\frac{7}{16}''$ from the right-hand border line and the vertical center line *a b* of the 8″ beam $6\frac{1}{16}''$ from the same border line; the bottom line *h i* of the 15″ beam should be made 2″ from the bottom border line. The figure may then be completed from the dimensions given and the lines laid down on the plate. The plate having been finished in pencil, the lines may be inked and the dimensions and notes placed on the sheet, thus completing the drawing.

DRAWING PLATE, TITLE: TENSION MEMBERS AND PINS

40. This plate shows, in detail, the **tension bars and rods** commonly used in both steel and wooden structures. These bars are used for resisting tension alone and are nearly always connected to the other members of the structure by bolts or pins. The form of pin used is shown in Figs. **6** and **7**.

41. Fig. **1** is known as a **tension bar** and is so designed that the bar around the *pinholes*, as the hole at either end is called, will have at least 40 per cent. more strength than the bar. Commence the drawing of the side view of the bar in Fig. **1** by laying out the center line *a b* 2″ from the top border line and draw the vertical center line *e f* of the left-hand pinhole $1\frac{13}{32}''$ from the left-hand border line, laying out the center line *g h* 9′ $5\frac{1}{2}''$ to scale from *e f*. Having thus obtained the centers for the pinholes, draw, to scale, the $4\frac{7}{8}''$ circles that represent these holes, and from the same centers draw the outline of the bar; the outer circle should have a diameter of $10\frac{1}{2}''$. Now draw the lines representing the width of the bar and connect these lines

TENSION ME



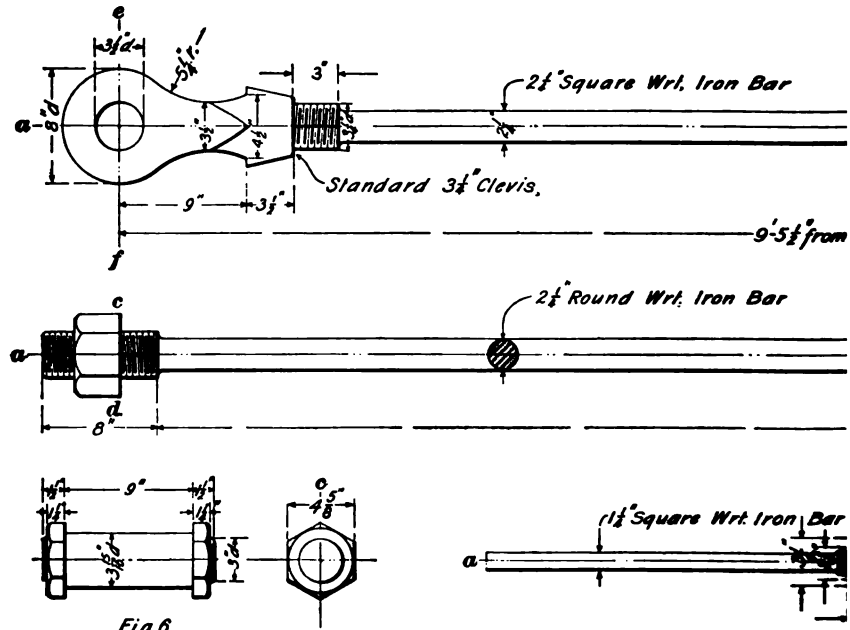


Fig. 6.

RS AND PINS.

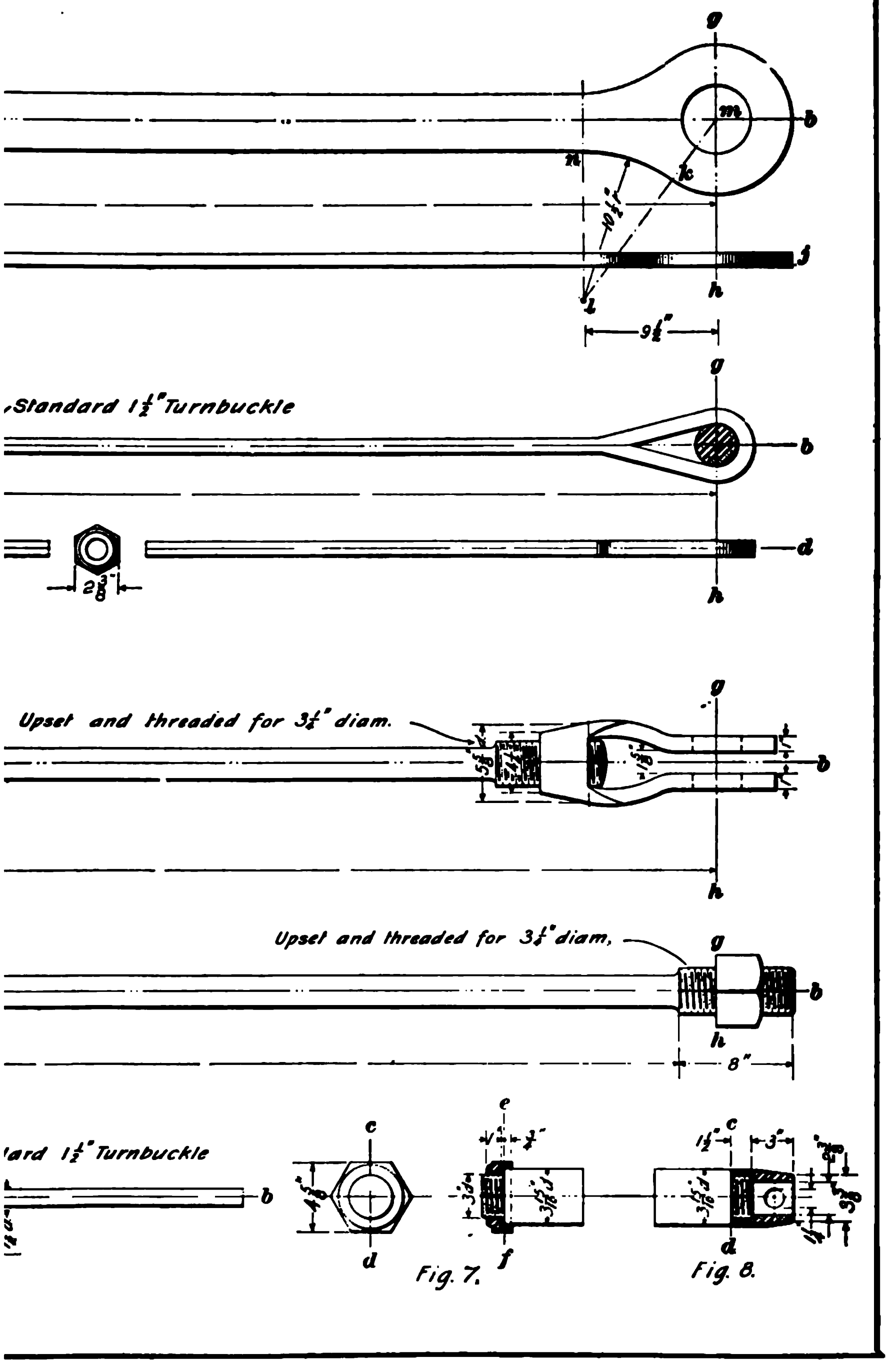


Fig. 7.

Fig. 8.

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and the circle forming the end of the bar with a curve having a radius of $10\frac{1}{2}''$. Whenever two curves or a curve and a straight line join in this manner, their point of juncture is found as follows: unite the centers *l* and *m* with a straight line, then the junction of the curves *k n* and *k b g* must be on this line at point *k*. Each curve is therefore continued up to this line and, if drawn correctly, they should intersect line *k l* at the same point. Curve *k n* is joined to the underside of the tension rod at the point where the perpendicular *l n* intersects the latter. None of these construction lines need be shown on the plate. The edge view of the bar is quite simple and requires no explanation. The top line *i j* is located $3\frac{3}{16}''$ from the top border line.

42. Fig. 2 shows a type of tension bar that is used for lighter work. It is provided with a turnbuckle at the center so that after the member is in place in the structure, the turnbuckle can be tightened and the distance between the centers of the eyes at the end of the bar reduced. By this means the bar may be drawn taut, or given an initial tension, and kept so. In laying out this figure, draw the horizontal center lines *a b* and *c d* of the views $4\frac{7}{8}''$ and $5\frac{13}{16}''$, respectively, from the top border line. The vertical center line *e f* is drawn $1\frac{13}{32}''$ from the left-hand border line. Having the center of the pin thus located, the circle representing it may be drawn with a $1\frac{1}{2}''$ radius and section-lined to designate wrought steel, as shown. The bar, which is 1″ square, and the loop at either end may now be laid out in the upper portion of the figure.

The side view of Fig. 2 shows an outside view of the **turnbuckle** while the lower, or edge, view shows a section through the turnbuckle. Turnbuckles are made in standard sizes so that the dimensions of this detail on such a drawing are not important for the reason that when the note "standard $1\frac{1}{4}''$ turnbuckle" appears, it is understood that it will be of the usual dimensions as manufactured. The principal dimensions are, however, given in Fig. 2 and no difficulty should be experienced in laying out the turnbuckle in both views and showing the swelled, or upset, ends on the rods engaging with the turnbuckle, as shown on the plate.

43. Fig. **3** shows a heavy $2\frac{1}{4}''$ **square tension rod** that is upset on either end to a $3\frac{1}{4}''$ round, and threaded. It will be noted that the right- and left-hand ends are threaded right- and left-handed, respectively, so that as the bar is turned, the distance between the centers of the pin-holes in the forgings can be increased or diminished as may be desired. These forgings are *clevises*, and the arrangement of the bar is to accomplish the same purpose as the turn-buckle shown in Fig. **2.** The clevis, however, is provided so that a tension bar can be connected to the same pin between the prongs of the clevis. Commence the figure by laying off the horizontal line *a b* $7\frac{11}{16}''$ from the upper border line, and lay out the vertical center lines *e f* and *g h* in the same manner as in the other figures. These clevises, like the turnbuckles, are standard forgings and are usually manufactured to the same dimensions for the same size rod. The several dimensions give all the data required to lay out the detail at the end of the rod. Only one view of the tension rod is given, because the clevis at one end is shown turned at right angles with that at the other end, thus showing both sides of this detail.

44. Fig. **4** shows a **round tension bar** simply upset at the end to $3\frac{1}{4}''$ in diameter and provided with hexagon nuts. This bar would usually be employed in a framed timber structure, or occasion might arise where it would be used in steel construction. The horizontal center line *a b* is located $9\frac{3}{4}''$ from the upper border line. In dimensioning this rod the distance is usually given from the inside face of the nuts; consequently, locate the rod so that the lines *c d* and *g h* to the left and right of the figure are, according to scale, 9′ $5\frac{1}{2}''$ apart with *c d* located $1\frac{13}{32}''$ from the left-hand border line.

Before laying out the hexagon nuts at either end, it would be well to construct the view shown at the center where the rod has been broken to admit it. This view is laid out so that the center line *e f* is coincident with the long diagonal of the hexagon nut. This being the case, the hexagon nut at the left can be projected from this view, but the one at the right must be laid out by taking the short diameter of the hexagon, which is 5″.

45. Fig. **5** shows an **open turnbuckle,** which is much used in building construction. This type of turnbuckle has the advantage that it may be tightened up by turning with a rod inserted through it for a lever, and does not require a wrench, which would be necessary in tightening the turnbuckle shown in Fig. **2.** The horizontal center line *a b* is located $1\frac{7}{16}''$ from the lower border line. In laying out the figure, follow the dimensions given.

46. Figs. **6, 7,** and **8** can be drawn on coincident center lines. Fig. **6** represents a **pin** with a shallow hexagon nut at either end. This drawing can readily be made from the dimensions given. It will be noted that the end of the pin is $\frac{3}{4}''$ from the left-hand border line, while the center line *c d* in the end view is $3\frac{3}{16}''$ from the same line. The longitudinal center line is a continuation of *a b*, Fig. **5.**

47. Fig. **7** shows a detail of the **hexagon nuts** used in Fig. **6.** Where a number of compression and tension members are held by a pin, it is difficult, on account of the variation in the thickness of the metal used in their construction, to dimension the pin so that the ordinary form of nuts, when screwed up in place, will hold the members tightly. Consequently, a nut has been devised that is countersunk on the face so that a variation of $\frac{1}{8}''$ or $\frac{1}{4}''$ will not prevent the nuts from being turned up and holding the members snugly on the pin. The section of the nut shown in Fig. **7** gives all the detail on the end of the pin and shows clearly the construction. The center line *c d*, showing the end view of the nut and pin in Fig. **7,** is located $4\frac{1}{2}''$ from the right-hand border line, while the shoulder *e f* of the pin is $3\frac{5}{16}''$ from the same line.

48. Fig. **8** shows, in section, a **pilot nut** that is screwed on the end of a pin so as to protect the screw threads when the pin is being inserted through the pinholes of the members to be connected. As its name implies, it pilots the pin to place, and when the pin is in place it is removed and the nut screwed on, as shown in Figs. **6** and **7**. The shoulder *cd* of the pin is, in this instance, $1\frac{5}{16}''$ from the right-hand border line. All the figures having been laid out in pencil, they should be carefully inked in and the dimension lines and notes inserted as usual. The title and subscription are then placed on the plate, as shown.

DRAWING PLATE, TITLE: RIVET WORK

49. On this plate is shown the method of drawing a **rivet** and various forms of **riveted joints**. Fig. **1** represents a $\frac{3}{4}''$ rivet, drawn full size. The various dimensions of the rivet are given in the figure. *G* is the *grip* of the rivet; this is equal to the thickness of the material through which it passes. In the drawing, this dimension is assumed to be $1\frac{5}{16}''$. The upper head of the rivet is of the usual hemispherical form, while the lower head has the form of the frustum of a cone. The former is called a *round head*, or *full head*, and the latter a *countersunk head*, it being countersunk into the surrounding material. The portion of a rivet included between the two heads, and which is approximately cylindrical in form, is called the *stem* of the rivet.

DIMENSIONS OF RIVET HEADS

50. The relative dimensions of **rivet heads** vary somewhat in the practice of different shops, but the round head is almost invariably a spherical segment, slightly less than a hemisphere. For the rivet heads on this plate, the following relative dimensions will be used, taking the results to the nearest $\frac{1}{32}''$.

For round heads:

$$\text{Diameter of head} = 1\tfrac{1}{2} \times \text{diameter of rivet} + \tfrac{1}{8}'' = D$$

$$\text{Depth of head} = .45\,D$$

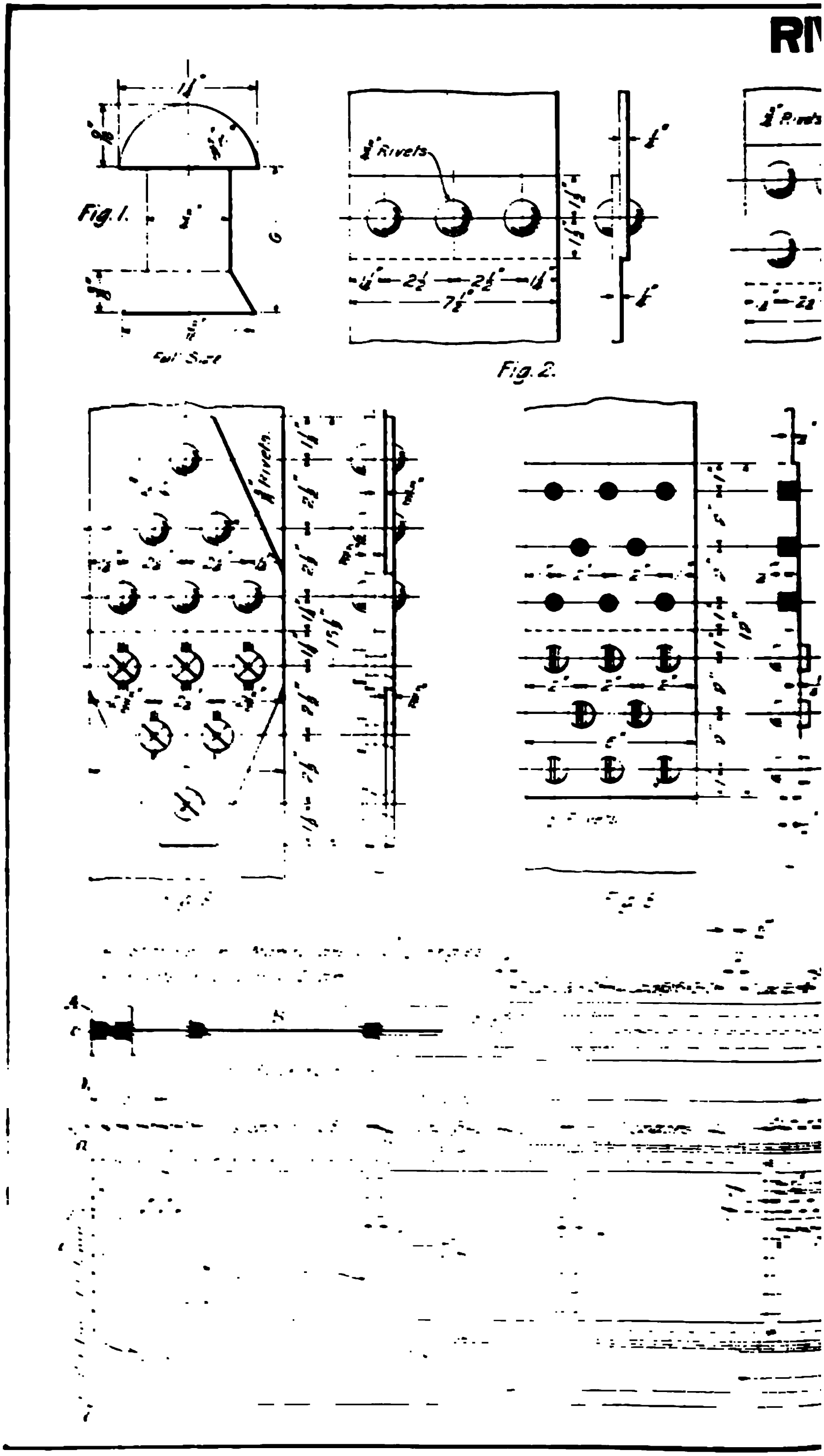


Fig. 1.
Full Size
Rivets
Fig. 2.
Rivets

K.

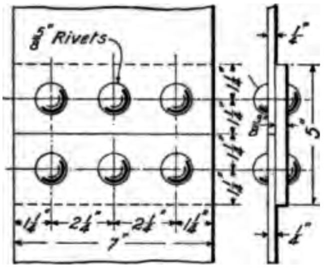


Fig. 4.

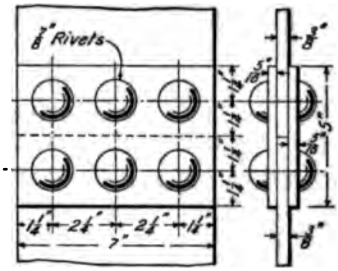


Fig. 5.

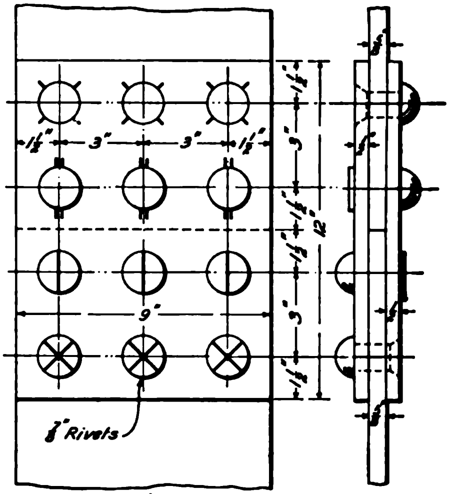
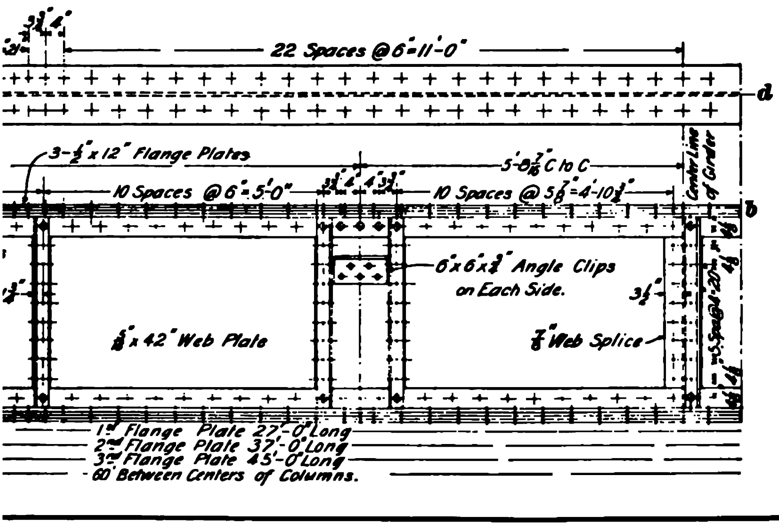


Fig. 6.



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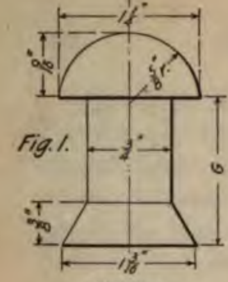


Full Size

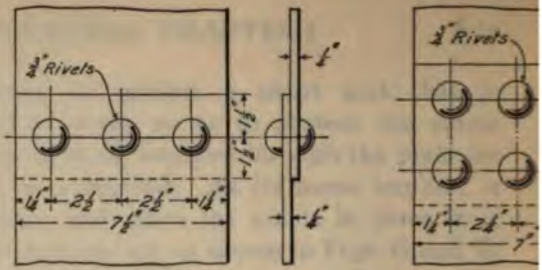


Fig. 2.

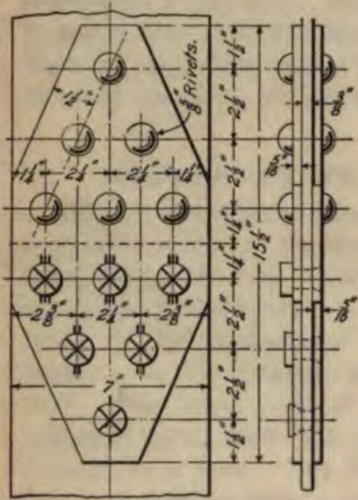


Fig. 9.

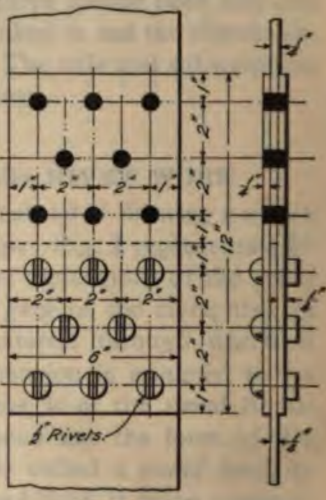
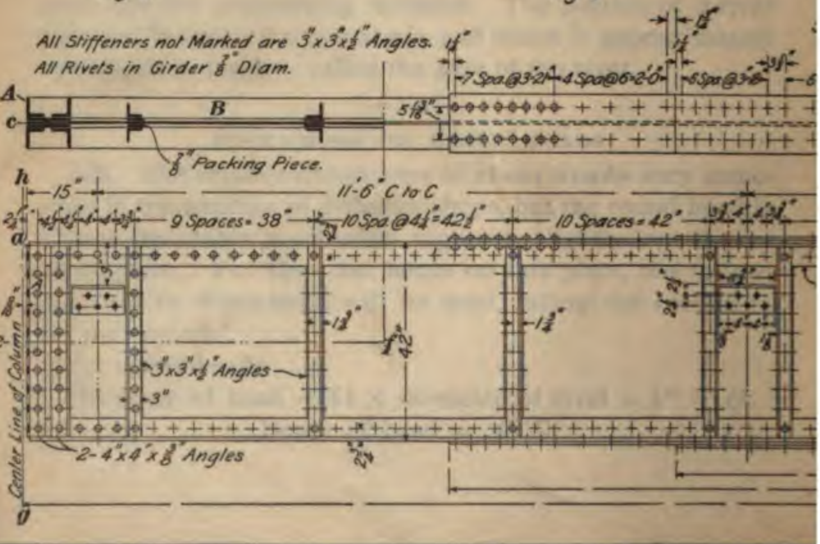


Fig. 8



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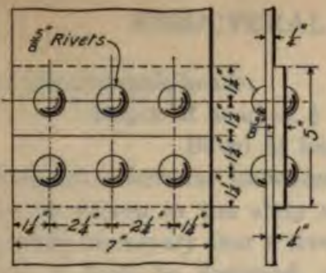


Fig. 4.

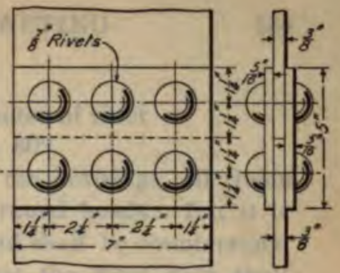


Fig. 5.

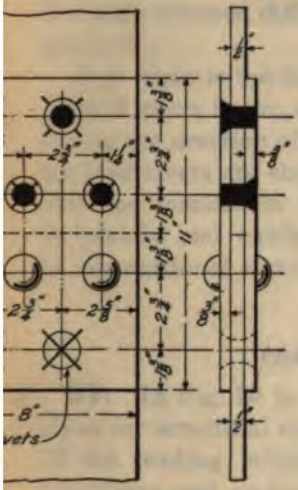


Fig. 7.

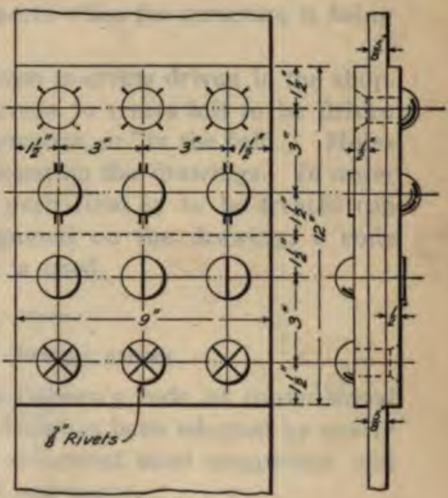
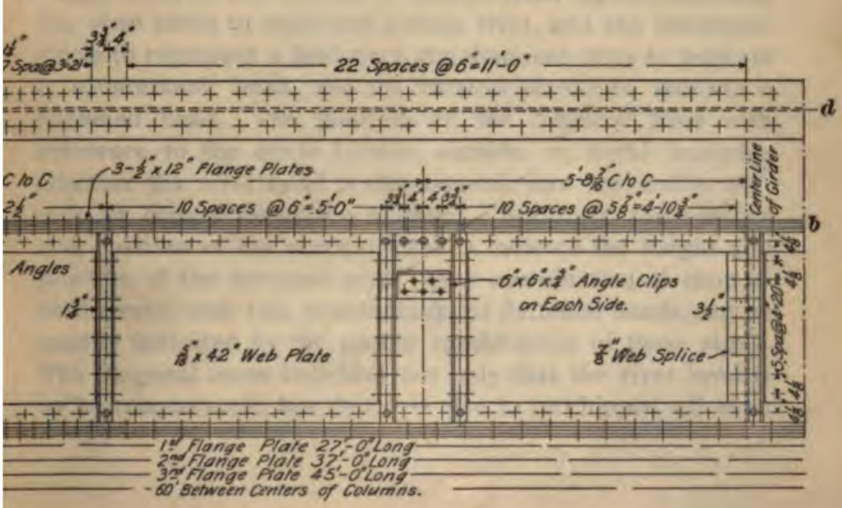


Fig. 6.



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For countersunk heads:

Depth of head = ½ diameter of rivet

Bevel of head = 60°

When not otherwise indicated on the drawings, all rivets are to be driven in the shop with round heads. But it is sometimes necessary that a rivet head shall be countersunk, or that it shall be flattened, or that the rivet hole shall be left vacant in the shop in order that some connection can be made between different parts when the structure is being erected.

Shop rivets is the name given to rivets driven in the shop.

Field rivets is the name given to rivets left to be driven during the erection of the structure, or "in the field." Holes for field rivets are shown vacant on the drawings. In order that the manner in which each rivet is to be treated can be plainly and easily designated on the drawing, a code of conventional rivet signs is used.

CODE OF RIVET SIGNS

51. In Fig. 29 is shown Osborn's code of conventional signs for structural rivets, which has been adopted by nearly all the leading bridge and structural steel companies, and consulting and architectural engineers.

The basis of this system of conventional signs consists of the open circle to represent a shop rivet, and the blackened circle to represent a field rivet, the diagonal cross to indicate a countersunk head, and the vertical stroke to indicate a flattened head. The position of the diagonal lines with reference to the circle (inside, outside, or both) indicates whether the rivet head is countersunk into the inside, outside, or both sides of the material. Similarly, the number and position of the vertical strokes indicate the height and position of the flattened head. Any combination of shop or field rivets, with full, countersunk, or flattened heads, can be readily indicated by the proper combination of these signs. The diagonal cross indicates not only that the rivet head is to be countersunk, but that it is also to be chipped off even

with the surrounding material; if the rivet is to be countersunk but not chipped, the sign to countersink may be combined with the sign to flatten to $\frac{1}{8}''$.

CONVENTIONAL SIGNS FOR STRUCTURAL RIVETS

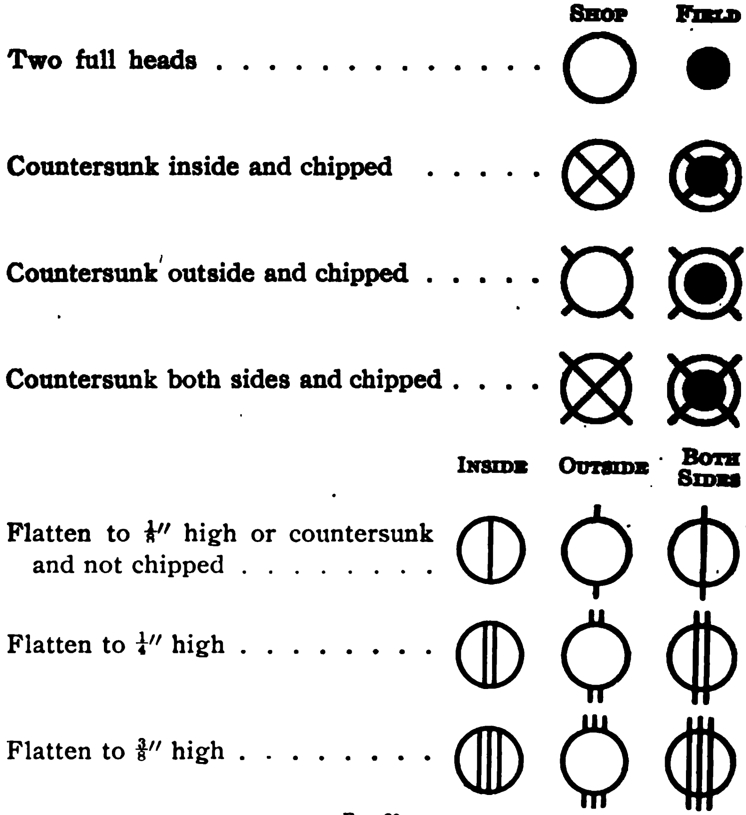


FIG. 29

52. Figs. **2** to **9**, inclusive, show different forms of riveted joints. Figs. **2** to **5**, inclusive, represent shop rivets with full heads, while Figs. **6** to **9**, inclusive, represent different combinations of shop and field rivets, with full, flattened, and countersunk heads. In the case of simple flat joints, like the joints shown in these figures, the *front side*, or the side that is seen, is considered as the *outside*, while the *rear side*, or the side that is invisible, is considered as the *inside*. It will be noticed that when the side view of a rivet having a countersunk head is shown, the stem of the rivet and the countersunk head are shown dotted, thus distinguishing the form of the rivet through the material that it connects. If neither head of the rivet is countersunk, the stem is not represented, as the positions of rivets having full or flattened heads are indicated sufficiently by the positions of the heads. The side views of vacant rivet holes are shown blackened.

When rivet heads are shaded, which is seldom done in practice, they are usually shaded in the manner shown in these figures, the outer arc of the shading being rather heavy and about a semicircumference in length, while the inner arc is lighter and less than a semicircumference in length. When a rivet is shown with a full head on the outside, but countersunk or flattened on the inside, the usual shading for the full head cannot be shown without detracting from the clearness of the countersunk or flattening signs. In such cases the head may be shaded as though it were a flattened head.

Fig. 2 is a **single-riveted lap joint** and Fig. 3 is a **double-riveted lap joint.** Fig. 4 is a **single-riveted butt joint** with a single connecting plate. The 7″ × $\frac{3}{8}$″ × 5″ plate that connects the two main plates is called a **butt strap, splice plate,** or **cover-plate.** Fig. 5 is a single-riveted butt joint, having double butt straps. Figs. 6 and 7 are **double-riveted** butt joints having double butt straps. The general arrangement of the rivets in regular and continuous rows shown in Fig. 6 is called **chain riveting,** and the alternating arrangement shown in each main plate of Figs. 7, 8, and 9 is designated as **zigzag riveting,** or **staggered riveting.** Fig. 8 is a **triple-riveted** butt joint, having double butt straps with staggered rivets. Fig. 9 is a somewhat similar form of joint that gives greater economy of material in certain cases. In this joint, the lower rivet is shown countersunk on both sides, but chipped off even on one side only; that is, it is shown countersunk on both sides and is also shown flattened to $\frac{1}{8}''$ on the outside and chipped on the inside.

Before proceeding to draw Fig. **10**, which is the plan and elevation of a plate girder, the student should familiarize himself with the names and purposes of the several parts, as given in the following description.

53. Definitions.—Referring to Fig. 30, which is a perspective view of the girder, the angles *a*, *a* are the **flange angles**, the upper pair forming the **top chords**, and the lower pair the **bottom chords** of the girder. Connecting these chords is the **web-plate** *b*, while the vertical angles *c*, *d*, *e* are known as **stiffeners**. The latter are required at

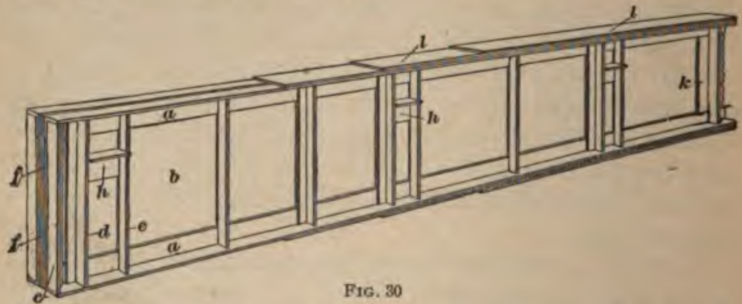


FIG. 30

the ends of the girders at *c* and *e* for the purpose of strengthening the web at the points where the girder is supported. The **packing pieces** *f*, *f* are commonly called **fillers**, from the fact that they are used to fill a space otherwise open, which is undesirable where a compactly built-up part is required. A flat surface is thus afforded for the angle stiffeners, so that they will ride over the flange angles and still be rigidly secured, by rivets, to the web-plate. The angle-iron **clips** *h*, *h* are for the support of the wooden floorbeams that extend from girder to girder. These clips are shown connected with field rivets in order that the beam may be put in place with greater ease and the clips then either bolted or riveted. As the web-plate shown in the plate is not usually manufactured in lengths greater than 45 ft., it is necessary to splice the web; the most convenient point at which the **splice** can be located is at the center, the vertical shear being zero at this point. Since the bending moment increases toward the center, **flange plates** *l* are added to afford sufficient strength, and enough rivets are placed at the end of each flange plate to equal in resistance their net strength.

54. The **girder** shown in Fig. 10 is for a span of 60 ft. The upper edge *a b* of the flange angles is laid off $2\frac{11}{16}''$ from the lower border line and the center line *c d* of the plan view is $3\frac{3}{4}''$ from the same line. The outer face of the angle *A*, forming one end of the end stiffeners, is laid off $\frac{3}{4}''$ from the left-hand border line, while the broken line to the right of the view is laid off $\frac{3}{4}''$ from the right-hand border line.

As this girder is to be attached to columns whose centers are 60 ft. apart, due allowance must be made for the thickness of the columns, web-plate, and angles. In this case, the web-plate of the column and the angles riveted to the web-plate are both $\frac{3}{8}''$ thick, and, consequently, the back of the stiffening angles at the end of the girder should be $\frac{9}{16}''$ from the center line of the column. The given distances of the center lines of the rivet holes from the backs of the angles are the standard distances recommended by the steel mills.

The view shown at *B* is a section of the girder along the line *e f*. It is customary in structural work to blacken the section of rolled shapes and plates, leaving a narrow light line so that the separate pieces may be distinguished; $\frac{1}{4}''$ clearance is usually allowed between the edges of the web-plate and the back of the flange angles and end stiffeners in order to allow for the unevenness incident to the shearing of the plate. All dimensions being given, no difficulty should be experienced in completing the plate.

DRAWING PLATE, TITLE: FOUNDATION AND DETAILS FOR CAST-IRON COLUMNS

55. Fig. 1 of this plate shows the elevation and partial plan of a **brick foundation pier** having a concrete footing and supporting, on a granite capstone, a cast-iron column base sustaining the lower end of the superimposed column. Fig. 2 shows a type of cast-iron column that may be used in the better class of mill, warehouse, or storehouse construction. The base supporting this column differs considerably in form from that shown in Fig. 1. The column is neatly molded at the foot and has at the top a filleted abacus *C* and crown mold *D*. The top of the column is arranged to support 20″ steel I-beam girders and, perpendicular to the direction of the girders, heavy wooden beams.

56. In proceeding with the plate, commence Fig. 1 by drawing the center lines *a b* and *c d* $1\frac{3}{16}''$ and $4\frac{5}{16}''$ from the top and left-hand border lines, respectively. Draw all horizontal lines representing the thickness of the concrete, the courses of the brickwork, together with the granite capstone and the height of the cast-iron base, commencing with the bottom horizontal line *e f* of the concrete footing $1\frac{1}{8}''$ from the bottom border line. The several dimensions in the width of the concrete footing, the courses of brick, and the granite capstone should be laid off central with the vertical center line, and the outline of the pier thus determined. The plan of the concrete and the brick pier should now be drawn, and since the pier is square the dimensions given in the elevation can be used in laying out the half plan. The plan of the cast-iron column and base is clearly shown, and in drawing it the dimensions given in the elevation should be followed. When the plan has been drawn, the ribs, or webs, which are triangular in shape and on the diagonal, can be projected from the plan. The projection lines, however, need not be shown on the drawing. It will be observed, from the detail of the cast-iron base, that the top flange is circular, while the bottom flange is square

FOUNDATION AND DET

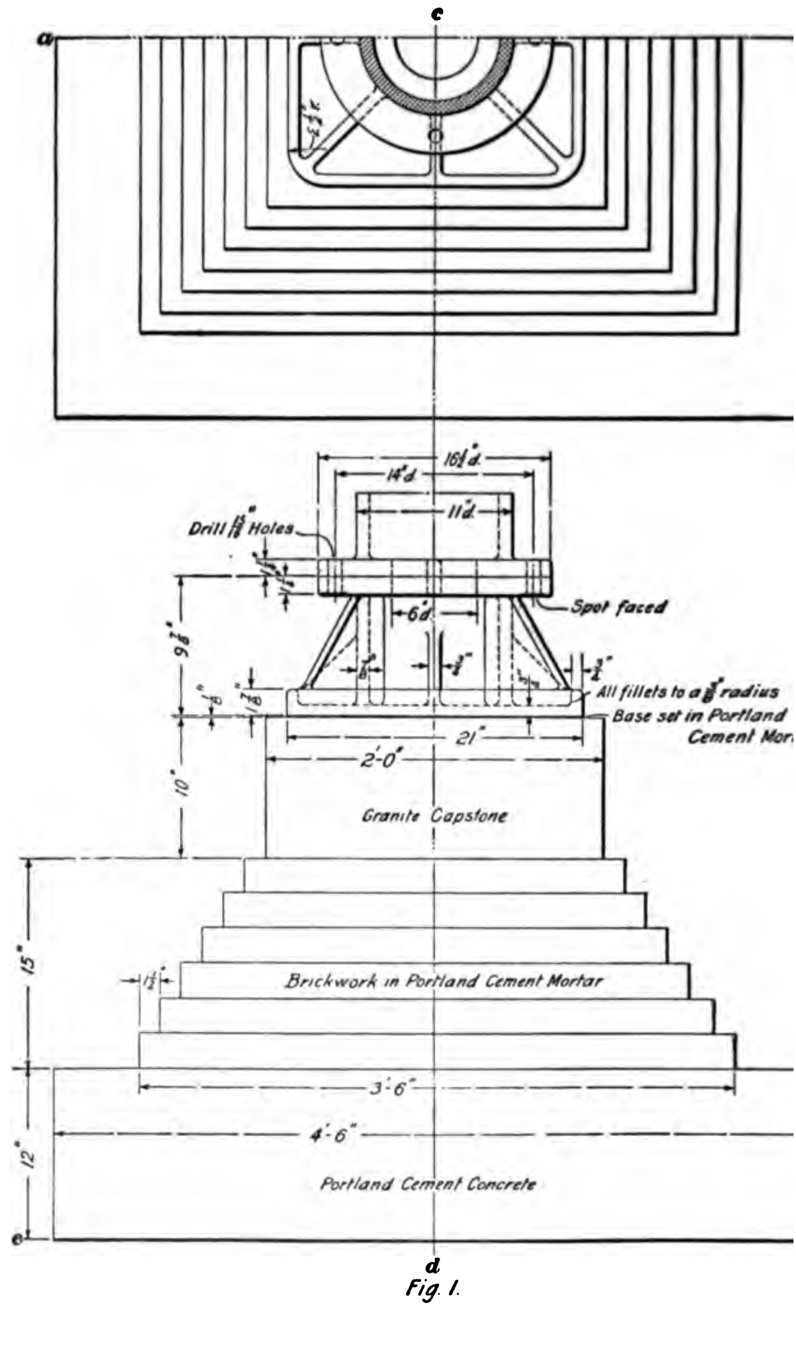
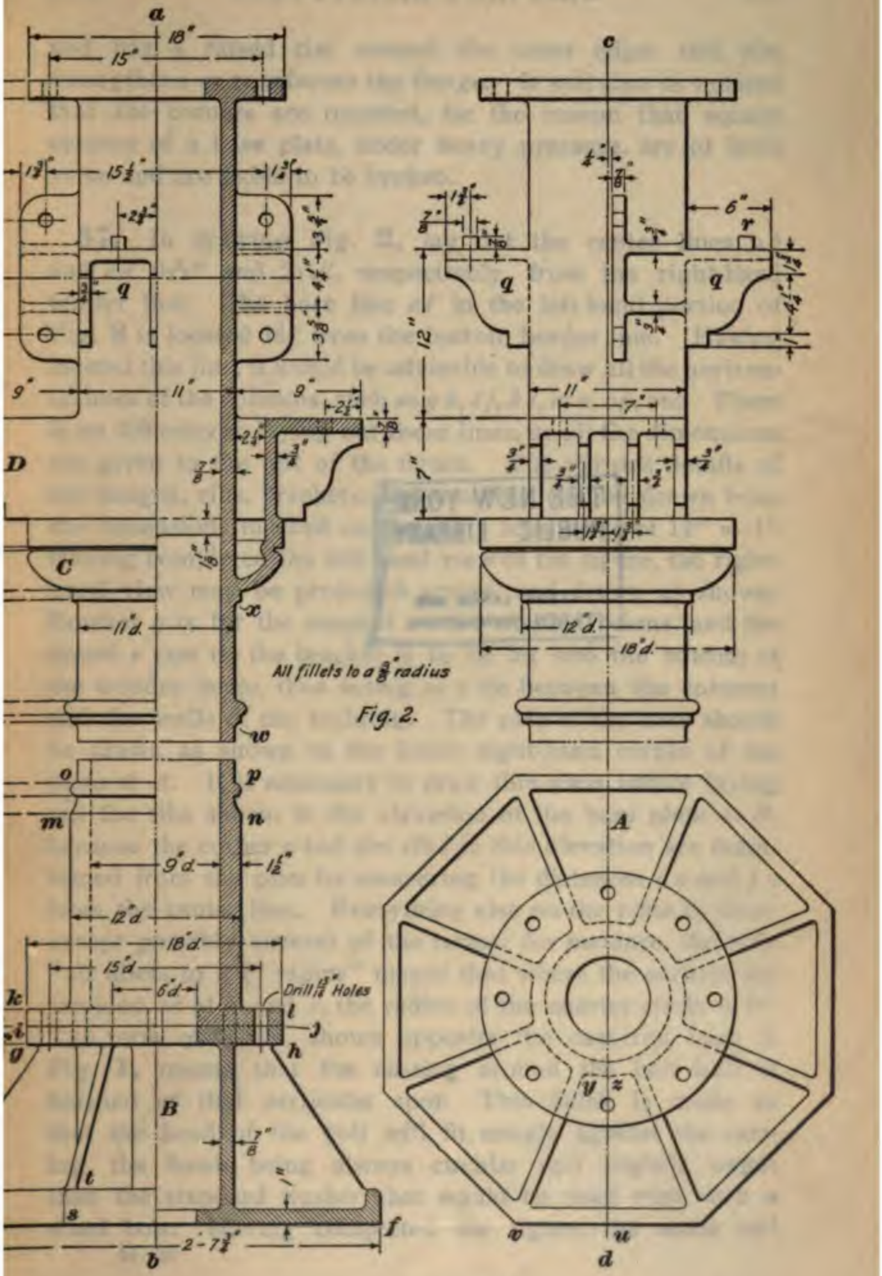
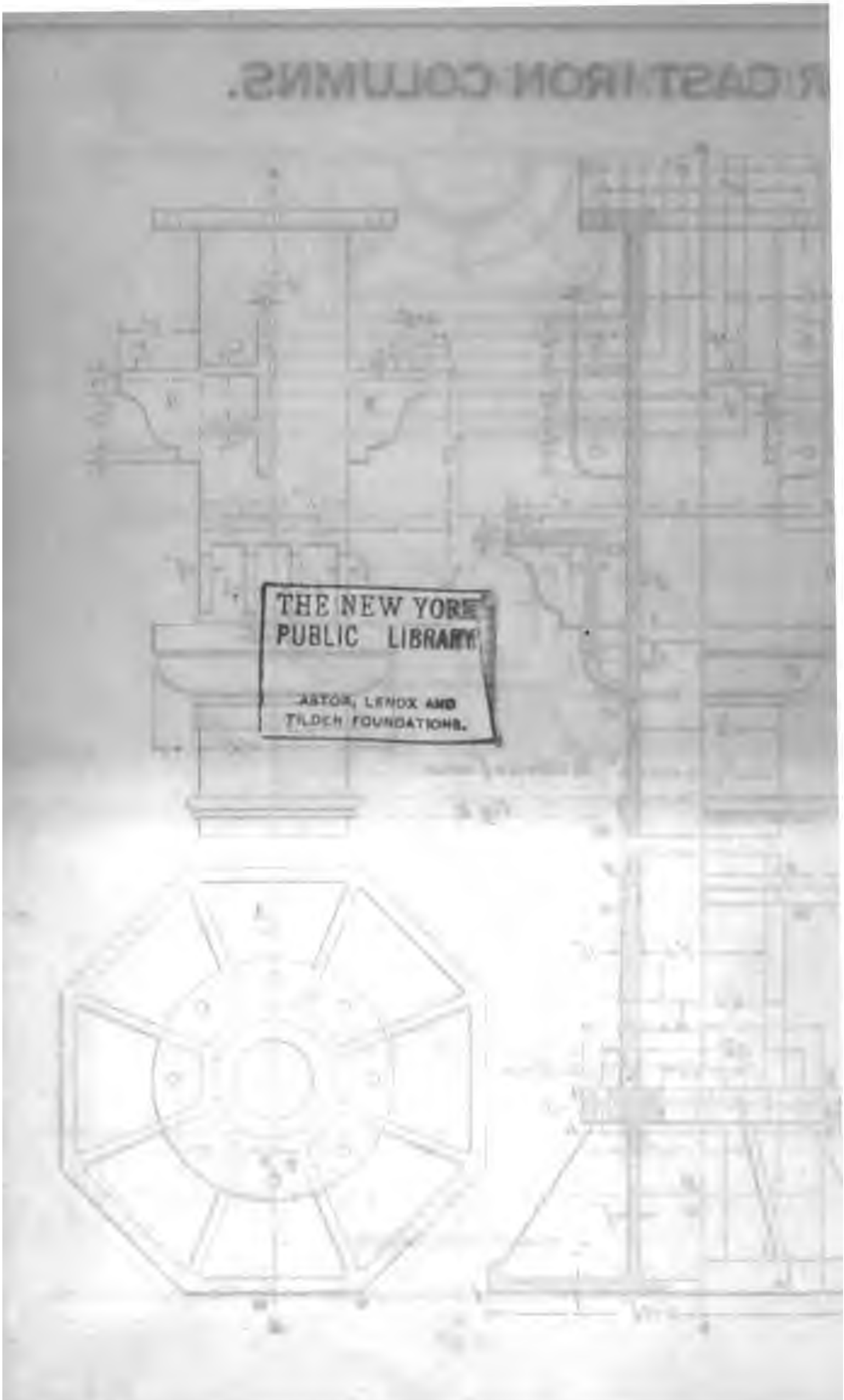


Fig. 1.

...OR CAST IRON COLUMNS.





and has a raised rim around the outer edge; this rim strengthens or reenforces the flange. It will also be noticed that the corners are rounded, for the reason that square corners of a base plate, under heavy pressure, are of little value and are liable to be broken.

57. In drawing Fig. **2**, lay out the center lines *a b* and *c d* $6\frac{9}{16}''$ and $2\frac{9}{16}''$, respectively, from the right-hand border line. The base line *e f* in the left-hand portion of Fig. **2** is located $1\frac{1}{8}''$ from the bottom border line. Having located this line, it would be advisable to draw all the horizontal lines of the columns, such as *g h*, *i j*, *k l*, *m n*, *o p*, etc. There is no difficulty in laying out these lines, as all the dimensions are given to the left of the figure. The various details of the flanges, ribs, brackets, and molding can be drawn from the dimensions marked on the plate to a scale of $1\frac{1}{2}'' = 1'$. Having completed the left-hand view of the figure, the right-hand view may be projected across, and drawn as shown. Bracket *q* is for the support of the wooden beams, and the dowel *r* cast on the bracket is to be let into the bottom of the wooden beam, thus acting as a tie between the columns and the walls of the building. The plan of the base should be drawn as shown in the lower right-hand corner of the plate at *A*. It is necessary to draw this view before laying out the ribs shown in the elevation of the base plate at *B*, because the corner *s* and the rib *t* in this elevation are determined from the plan by measuring the distances *u v* and *y z* from the center line. Everything else on the plate is clear, except possibly several of the terms; for instance, the note "all fillets to a $\frac{3}{8}''$ radius" means that where the corners are rounded, as at *w* and *x*, the radius of the quarter circle is $\frac{3}{8}''$. The term *spot-faced*, shown opposite the cast-iron base in Fig. **1**, means that the casting around the bolt hole is finished at that particular spot. This finish is made so that the head of the bolt will fit snugly against the casting, the finish being always circular and slightly larger than the standard washer that would be used with such a sized bolt. Having completed the figure, the notes and dimensions should be placed on the drawing and the entire plate finished by carefully inking in the lines. Much benefit may be derived from a careful inspection of the details on this plate.

DRAWING PLATE, TITLE: MILL CONSTRUCTION

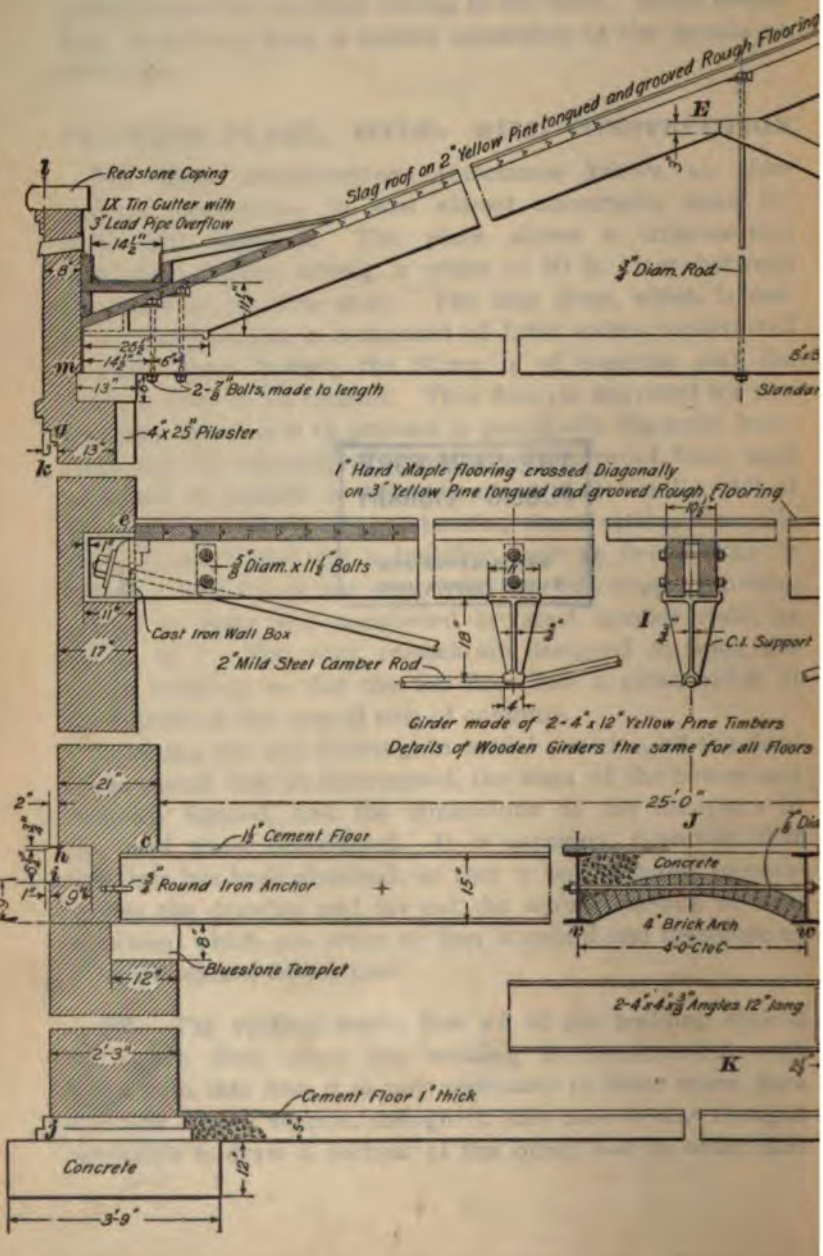
58. Mill construction, sometimes known as *slow-burning construction*, is now almost universally used for mills and factories. The plate shows a cross-section through a factory having a width of 50 ft. clear between the walls of the first story. The first floor, which is fire-proof construction, is composed of brick arches constructed between steel beams; the filling is of concrete and the finished floor is of cement. This floor is provided for two reasons: the desire to procure a practically fireproof basement and the necessity of securing a waterproof floor, such as would be needed in a dye house or paper mill. All of the upper stories are of slow-burning construction, the walls being proportioned for a building four or five stories in height. The floors are supported by yellow-pine girders, placed in pairs and reenforced by steel camber rods, as shown at *I*. The roof trusses are designed to span the entire building so that the top floor has a clear width of 50 ft. without the central row of columns.

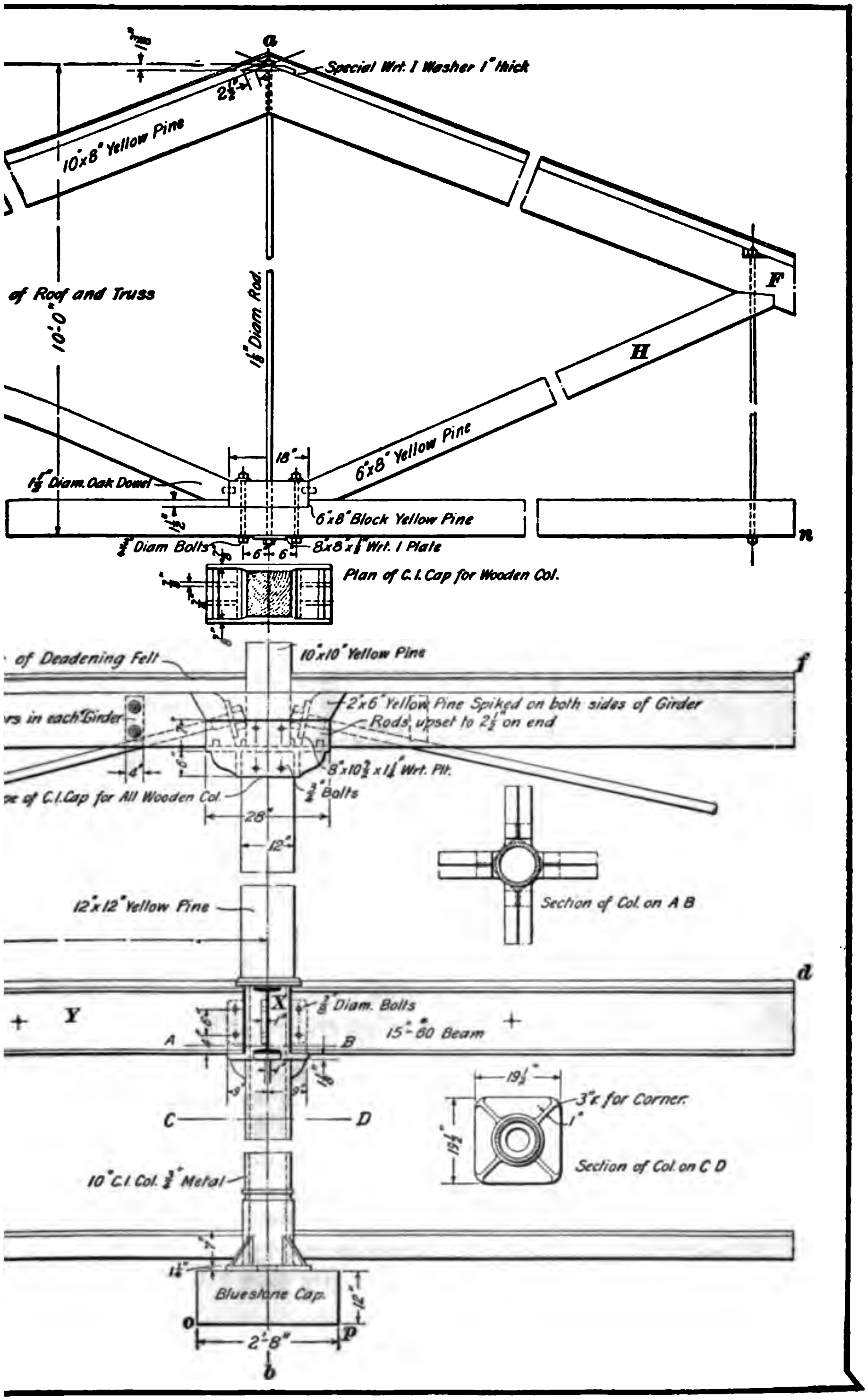
In laying out this drawing, in actual practice, all the floor loads should first be determined, the sizes of the beams and columns figured, and the dimensions of the members in the roof truss determined. It is assumed, however, that this data has been obtained, so that it only remains to commence the drawing and lay out the several details of construction, which are more or less standard and therefore to a certain extent determined.

59. The vertical center line *a b* of the building should be drawn first; since the building is symmetrical with respect to this line it is not necessary to draw more than one half of the section, though in this case it was thought advisable to draw a portion of the other half in order that

MILL CONSTRUCTION.

Scale ½" = 1 ft.




Special Wrt. I Washer 1" thick
10"x8" Yellow Pine
of Roof and Truss
10'-0"
1⅛" Diam. Rod.
F
H
6"x8" Yellow Pine
18"
1⅛" Diam. Oak Dowel
6"x8" Block Yellow Pine
¾" Diam Bolts
8"x8"x⅜" Wrt. I Plate
Plan of C.I. Cap for Wooden Col.
of Deadening Felt
10"x10" Yellow Pine
f
2"x6" Yellow Pine Spiked on both sides of Girder
Rods upset to 2½" on end
rs in each Girder
8"x10½"x1¼" Wrt. Plt.
¾" Bolts
of C.I. Cap for All Wooden Col.
28"
12"
12"x12" Yellow Pine
Section of Col. on A B
d
Y
X
⅞" Diam. Bolts
15"-80 Beam
A
B
19½"
3"R. for Corner.
C
D
Section of Col. on C D
10" C.I. Col. ¾" Metal
Bluestone Cap.
12"
2'-8"
b

the details of the central columns and posts could be more thoroughly studied. The vertical line may then be located $5\frac{7}{16}''$ from the right-hand border line and the horizontal lines *c d* and *e f*, representing the tops of the finished floors, may be laid off $3\frac{7}{8}''$ and $6\frac{3}{4}''$, respectively, from the lower border line. From the fact that the paper is limited in size, it is necessary to show broken lengths of the beams and columns, and consequently the principal horizontal and vertical dimensions, while figured correctly, are not true to scale. Where it is necessary to break the drawing in this way it is customary to place the end views or the sections between the broken ends of the members as shown at *I* and *J*. Since the dimension of 25 ft., given from the center of the column on the first floor to the inside of the wall, is not to scale, the vertical lines of the wall may be located to suit the size of the paper. The outside line of the main wall *g h* is consequently located 1″ from the left-hand border line. The lines *i j* and *k l* of the basement and parapet walls may be laid off from the main-wall line 2″ and 3″, respectively, to scale. From these lines, the section of the wall may be laid out from the dimensions given and by scaling the drawing plate.

60. The bottom line *m n* of the tie-member of the roof truss may now be drawn $8\frac{1}{16}''$ from the lower border line. Since the direction of the rafters *E*, *F* and of the struts *G*, *H* may be determined either from the plate or from a skeleton diagram laid out on a separate sheet from the dimensions given, the outlines and details of the roof truss may be completed. The rods and bolts should be clearly shown and the details around the parapet and the gutter carefully drawn.

61. The wooden girder composed of the two 4″ × 12″ yellow-pine timbers, and the rough flooring and the finished floor may be laid off from the top line *e f* of the finished floor that has been drawn. The details of the camber rod and the cast-iron supports, together with the column cap and beam connections, are clearly shown and may be drawn without difficulty. Two cast-iron supports, or bolsters, *I*, divide the span or length of each girder into three equal parts.

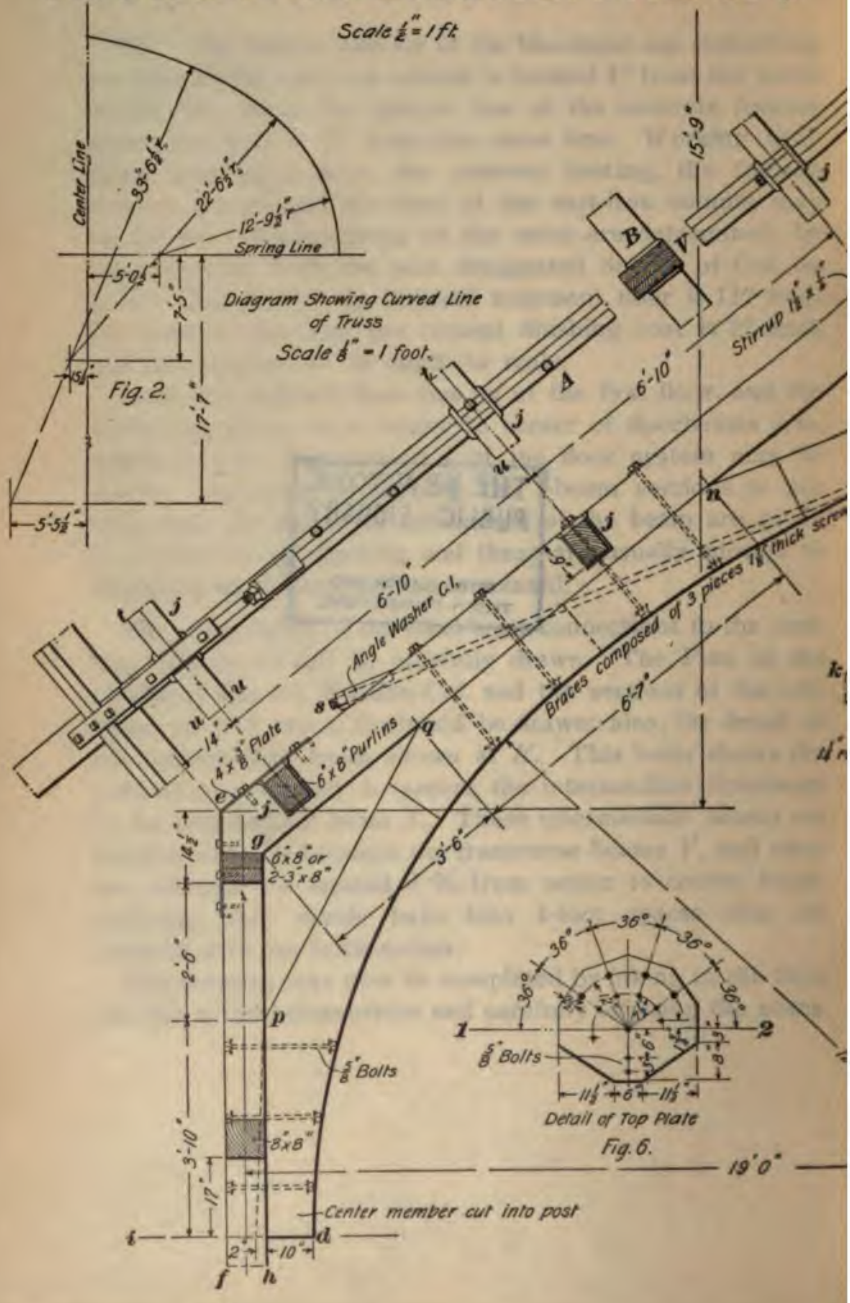
62. The bottom line *op* of the bluestone cap supporting the base of the cast-iron column is located $\frac{5}{8}''$ from the lower border line, while the bottom line of the concrete footing under the wall is $\frac{3}{4}''$ from the same line. Working from these lines as a base, the concrete footing, the footing courses above, and the base of the cast-iron column may be drawn. The positions of the webs are determined, by measurement, from the plan designated Section of Col. on C. D. The line of the finished basement floor is $1\frac{1}{2}''$ from the lower border line; the cement finishing coat is 1″ thick and the concrete 5″ in depth to scale.

From the finished floor line *cd* of the first floor, and the dimension given from center to center of floorbeams *v*, *w*, which is 4 ft., the section *J* of the floor system may be drawn. Accuracy in drawing the **I**-beam sections is not important, for the depth and weight of the beam are given in a note on the drawing and these are usually enough to designate what beam section is wanted.

63. The detail of the steel-beam connections to the cast-iron column should be carefully drawn. The Plan of the Cast-Iron Cap for Wooden Col. and the sections of the columns on *AB* and *CD* should be drawn; also, the detail of the intermediate beam shown at *K*. This latter shows the connection necessary to secure the intermediate floorbeam to the longitudinal beam *X*. These intermediate beams are located centrally between the transverse beams *Y*, and since the columns are located 8 ft. from center to center, longitudinally, they divide bays into 4-foot spaces that are spanned with the brick arches.

The drawing may now be completed by inking in the lines and the several dimensions and carefully lettering the notes.

TRUSS FOR CHURCH ROOF.



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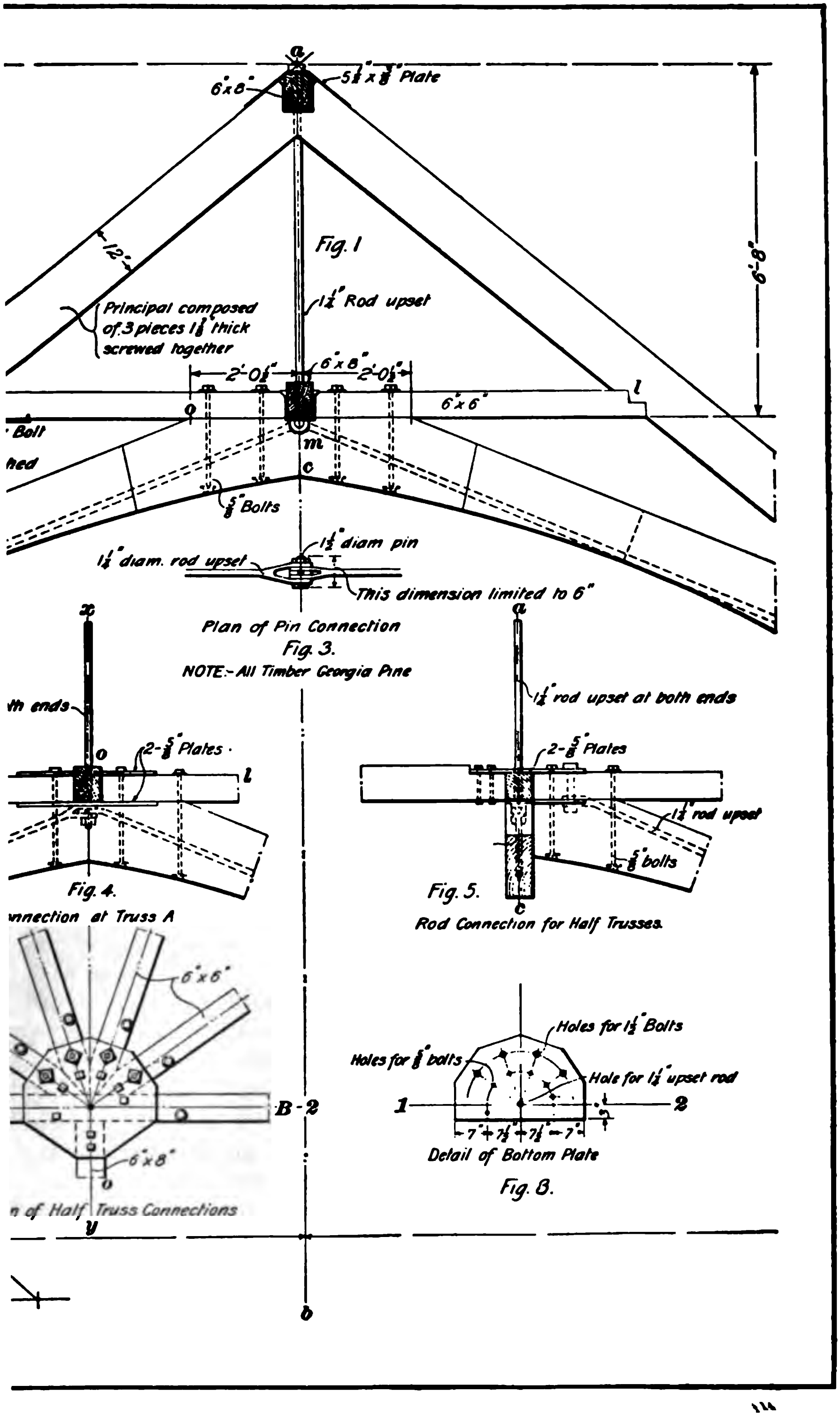

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DRAWING PLATE, TITLE: TRUSS FOR CHURCH ROOF

64. This type of **roof truss** is much used in church construction on account of its having no visible tie-rods and because by this means the vaulted effect of the Tudor or Gothic style can be obtained. The *normal roof truss* is the principal truss that spans the building and gives the roof its predominant slope, as shown in Fig. **1.** This figure may be commenced by drawing the vertical line *a b* $4\frac{15}{16}''$ from the right-hand border line. The inside profile of the truss is in the form of a Tudor or low Gothic arch. The extreme top of this curve *c* should be started $4\frac{7}{16}''$ from the upper border line. The outline of the curve is composed of a series of arcs of circles laid out from the radii given in the diagram, Fig. **2.** This diagram should be laid out before any attempt is made to draw the curve in Fig. **1.** The location of the center line of the diagram is $1\frac{3}{16}''$ from the left-hand border line and the *spring line* $3\frac{9}{16}''$ from the upper border line. The several curves and radii to the three centers are clearly shown and the location of the centers given.

65. The arcs of the large curves in Fig. **1** may be drawn by means of a string or strip of cardboard. Use a pin for the center and put the pencil either through the knot of the string or through a hole in the cardboard. The outline may be inked in by using the irregular curve, which will be found, by careful maneuvering, to approximate closely the desired curve. Having drawn the curved outline of the truss, lay off 10″ and 18″ from the point *d*, thus locating the vertical lines *g h* and *e f* of the upright. According to the dimension, the point *e* is located 7′ $6\frac{1}{2}''$, by scale, from the line *i d*, which is located $\frac{3}{4}''$ above the lower border line. From *e*, the outside sloping line of the rafter may be drawn to its intersection with the vertical center line at *a*, which is 15′ 9″, to scale, vertically from the point *e* already determined. The inside line of the rafter member is laid off 12″, to scale, from the line *a e*. The purlins *j*, *j* can now be located from the point *e* according to the dimensions given; the first one is 14″ from *e*, while the other two are located 6′ 10″ from center to center. The purlin at the apex of the truss is located on the vertical center line. The line *kl* of the collar beam should now be drawn 1′ 7″, to scale, from the point *c*, while the center of the pin connecting the wrought-iron tie-rods at *m* is located 12″, to scale, from *c*. The points *p*, *q*, *n*, and *o*, which are the extremities of the straightedges of the curved pieces, may be located from the points *g* and *r*. The distance of the point *p* from *g* is 3′, while from *q* to *g* is 3′ 8″, both measurements being laid out to scale. The points *o* and *n* are located 4′ 6″ and 5′ 5″, respectively, from the point *r*. The center line *sm* of the tie-rod intersects the outside line of the rafter *ae* 3′ 6″ from the point *e*. These several measurements are not shown on the drawing, because they would be determined, by scaling, in laying out the work. The various details of the joints and connections in this figure, together with the necessary straps and bolts, can now be laid out and the figure finished, the notes on the drawing, if followed closely, being sufficient information for the student.

66. The plan shown at *A* is a view looking perpendicular to the roof slope, and all lines, such as *tu*, can be projected from the elevation. The rafter member is broken at *V* in order to show its section, which is composed of three pieces of $1\frac{7}{8}''$ material fastened together with screws. The purlins are held to the truss by wrought-iron straps, or supports, *B*; these are often known as *stirrups*, or *beam anchors*. It will be observed that the purlins, as well as being supported by the wrought-iron straps, are let into the outside pieces of the rafter member about $\frac{1}{2}''$. A perspective view of a stirrup is given in Fig. 31.

FIG. 31

67. Figs. **3**, **4**, **5**, **6**, **7**, and **8** show the details of the construction that would be employed in this type of roof truss.

Figs. **4, 5, 6, 7,** and **8** relate to the end truss and the connecting half trusses that would be employed in the construction of the decagon end; the arrangement of the trusses in this end is clearly shown in plan in Fig. 32.

In Fig. **7** is shown a detail plan at the center of the principal end truss that is similar in elevation to the normal truss in Fig. **1,** though it is usually made somewhat heavier. The half trusses shown by the plan in Fig. **7** are connected to the principal truss at the apex of the Tudor arch forming

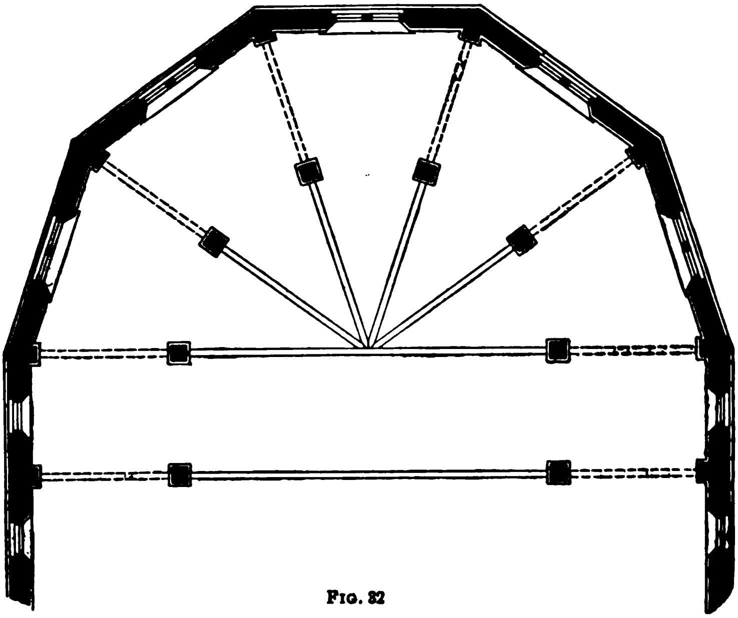


FIG. 32

the inside profile and at the apex of the truss itself. The connection of the half trusses to the principal truss is made by means of steel plates and wrought-iron bolts, as shown in Figs. **4, 5, 6, 7,** and **8.** Each half truss is a duplicate of one half of the normal truss and forms a roof covering for the plan shown in Fig. 32. Fig. **4** is an elevation and, with Fig. **5,** which is a side elevation, shows the details of the somewhat complex connection. Figs. **6** and **8** are merely details of the wrought-iron or steel plates that form the principal ties for the connection.

68. To locate these several views on the drawing in the same position as shown on the plate, draw the vertical center line *x y* of Figs. **4** and **7,** 7″ from the right-hand border line. The upper line *k l* of the collar beam in Fig. **4** is located $5\frac{3}{4}''$ from the lower border line. Fig. **4** is an elevation of the connection of the end trusses with the principal truss *B B*, Fig. **7,** viewed from the front. The

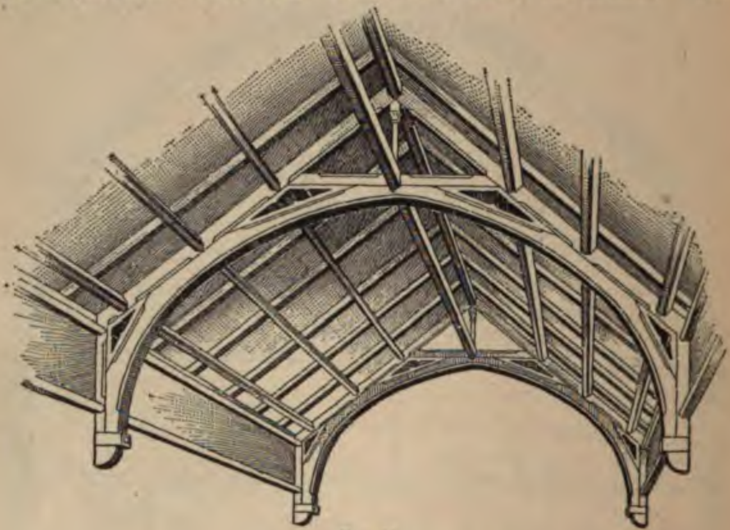


FIG. 33

section at *o*, in Fig. **4,** represents the 6″ × 8″ pieces shown at *o* in Fig. **7.** All the horizontal lines in Fig. **5** can be projected from Fig. **4.** At *c* in Fig. **5** is shown a section through the curved member of the principal truss *B B* in Fig. **7.** Fig. **4** is not a complete detail, as many of the dotted lines that could be projected from Fig. **7** are omitted. This is permissible in construction work, where the clearness of the drawing many times depends on the use of as few lines as possible. The side elevation, Fig. **5,** makes up for all the deficiencies of the drawing shown in Fig. **4.** The vertical center line *a c* of Fig. **5** may be drawn $2\frac{13}{16}''$

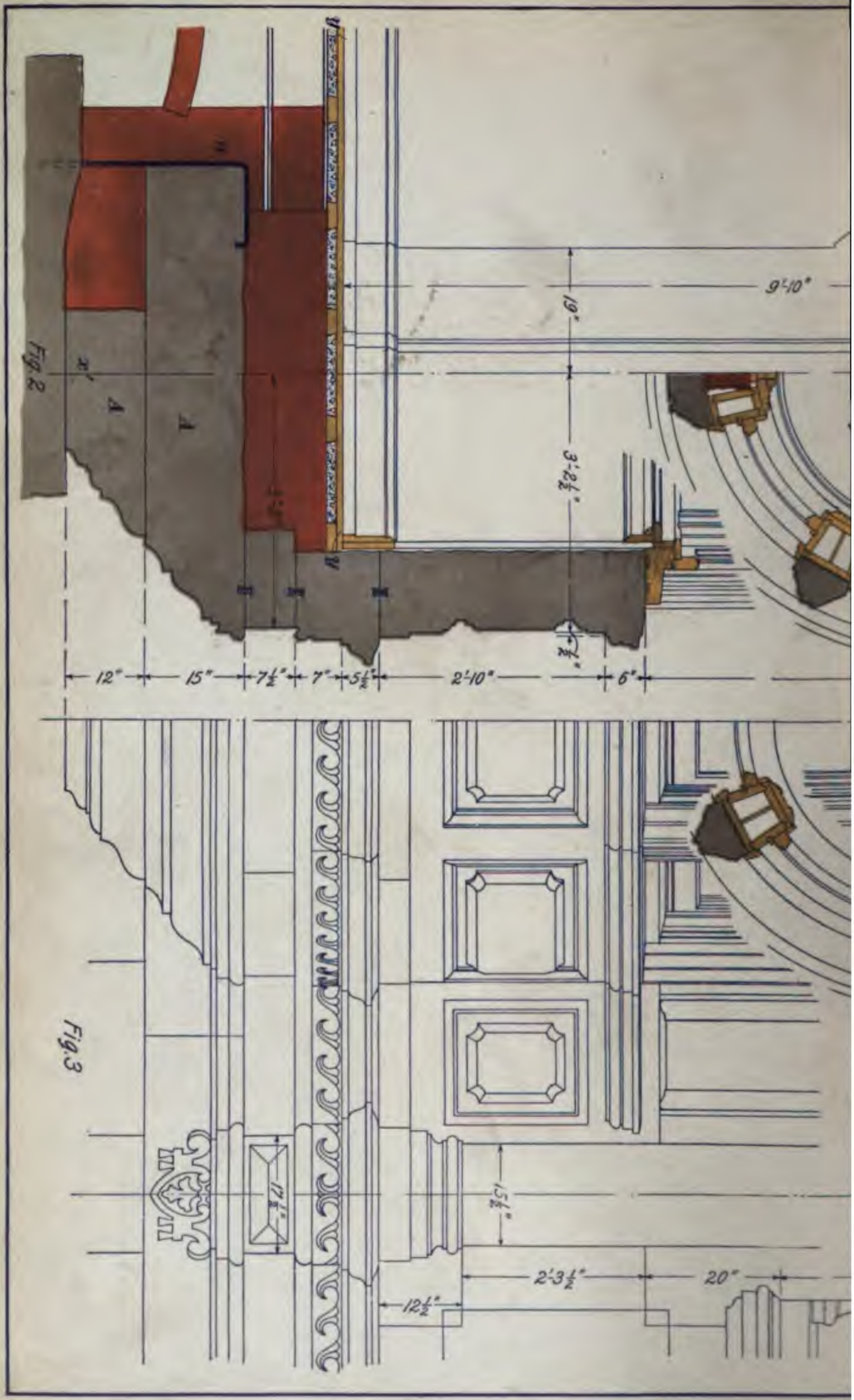
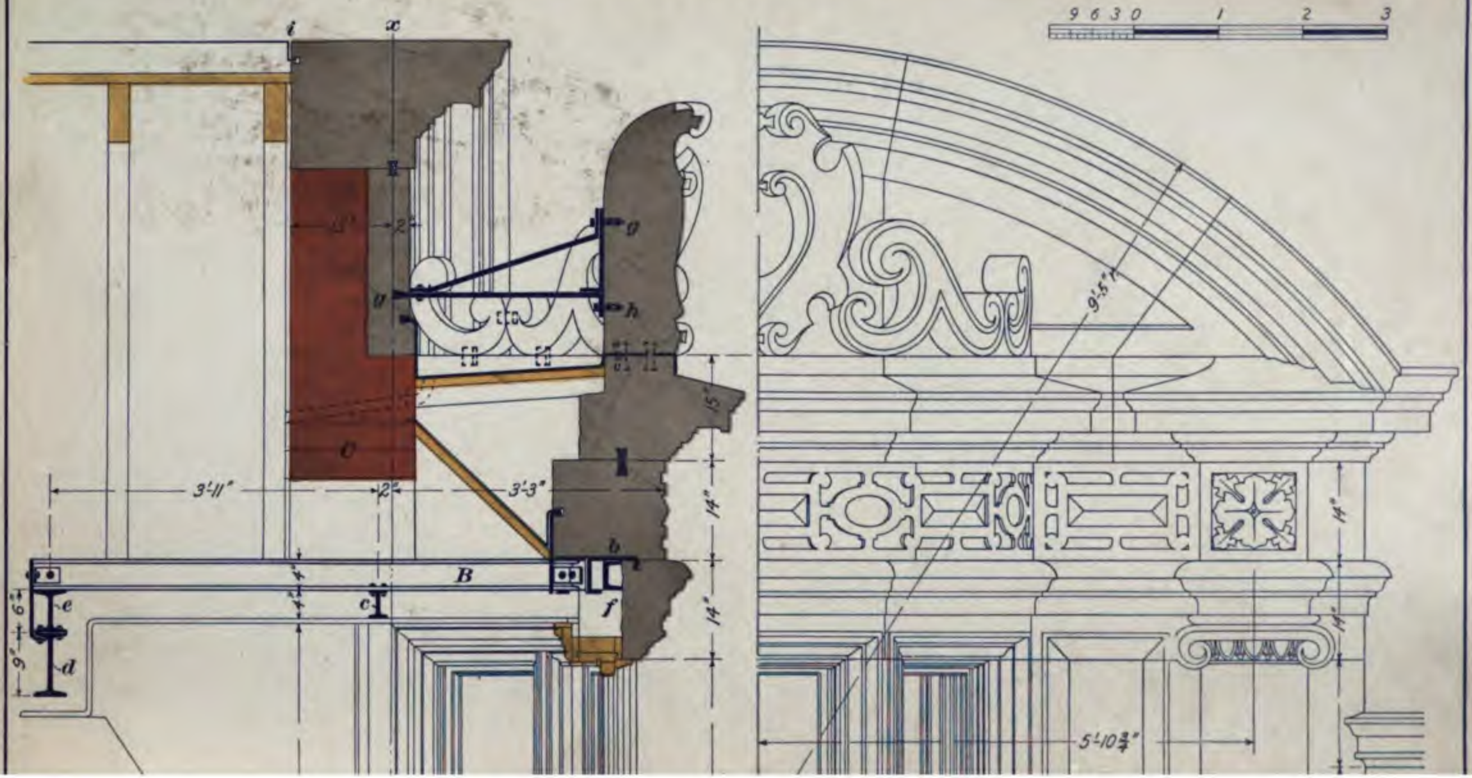


Fig. 2
Fig. 3
9'-10"
19"
3'-2½"
12"
15"
7½"
7"
5½"
2'-10"
6"
17½"
15½"
2'-3½"
20"
12½"

STONE CONSTRUCTION.



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from the right-hand border line, while the vertical center lines of the details in Figs. **6** and **8** may be drawn $11\frac{1}{16}''$ and $2\frac{15}{16}''$, respectively, from the right-hand border line. The horizontal center lines *1, 2* in Figs. **6, 7,** and **8** are located $2\frac{5}{8}''$ from the lower border line. After having completed these several views, the small details shown in Fig. **3,** which designate the manner in which the three tension members at *m*, Fig. **1,** are secured by a pin, should be drawn. The drawing is now practically finished and may be dimensioned and lettered, the title being placed as designated on the plate.

The work shown on the plate gives simply the constructive features, but Fig. 33 shows how such a truss may be treated architecturally so as to produce a finished appearance.

DRAWING PLATE, TITLE: STONE CONSTRUCTION

69. This plate shows the details, in plan, section, and elevation, of an **oriel** surmounted by a segmental pediment. It is usual for the architect to accompany $\frac{1}{8}''$ or $\frac{1}{4}''$ scale drawings with detail sheets of the more important features, such as columns, base and band courses, entrance doorways, oriel or bay windows, general door and window architraves, entablatures, dormer windows, roofs and towers, drawn to a $\frac{3}{4}''$ scale and sometimes larger. The main object, as in this case, is to show the conjunction of stone and metal work, on which the structure relies chiefly for support and balance.

Fig. **1** shows one half of the plan, which is to be drawn first (as from it the elevation and section are to be projected), taken at an imaginary line just above the sill course. Fig. **2** shows a section taken on the center line, omitting a portion to show plan of metal work, Fig. **4,** from which same is to be projected. Fig. **3** shows one half of the elevation, also omitting an important part to admit Fig. **1,** as economy of space is advisable in all detail drawings. Beginning at the corbel stones *A, A* in Fig. **2,** observe that the upper stone is counterbalanced by two iron anchor rods *a* built into the wall below. This is necessary because the outer portion of this stone carries most of the weight up to the cantilever beam *B*, which supports the work above. This beam is constructed of two 4″ steel I beams, with a 4″ channel *b* bent to a semicircle and secured to their outer ends, resting on and riveted to a 4″ I beam *c* stretched across the wall opening, with its ends built into the piers on either side. On this beam the cantilever is balanced and its inner ends extend back and are secured to the 9″ steel beam *d* of the main structure with two short pieces *e* of 6″ I beam used as blocking, all securely strapped and riveted together. A brick arch *C* is sprung over the opening in the main wall to carry the masonry of the pediment. All the coursed stones are anchored together on the top beds at the vertical joints and the lintel stones are secured by strap anchors bent over the 4″ channel, as shown at *f*. The ornamental cresting is secured by iron dowels and tie-rod, as shown at *g*, *g*.

The ridge of the main roof and the roof over the oriel are covered with copper, slots being cut in the stone work to admit the flashing, as shown at *i*.

In the plan Fig. **1**, all the jamb lines of stone architraves, wood frame, and sash, radiate from a common center *l*, 3″ back of the front line of the building, which is coincident with the line *k m*.

Start the drawing by locating the center *l* $8\frac{11}{16}$″ above the lower border line and $6\frac{5}{16}$″ from the right-hand border line, the distance between margin lines being 13″ × 17″. Having located the center line $x x'$ of the section, Fig. **2**, $3\frac{7}{16}$″ from the left-hand border line, and the floor line *y y* $3\frac{3}{16}$″ from the lower border line, little difficulty should be experienced in completing the drawing with the additional dimensions given on the plate. The scale to be used is $\frac{3}{4}$″ = 1′.

COLORING THE PLATE

70. In drawing architectural details, color is used in preference to the conventional section lining, as it is labor-saving and gives a clearer conception of the materials required.

When a drawing is to be traced for blueprinting, heavy section lining is preferable, as the prints may then be colored over the white section lines in accordance with the original drawing. Sometimes tracings are "blackened in" with India ink or an opaque color, on the reverse side, thus leaving a white space on the blueprint for coloring. In large details, only the extreme outer edge of each individual piece of stone, wood, or metal is colored.

TABLE I

Materials	Colors
Earth	Raw umber.
Rock	Neutral tint or blue wash streaked with sepia.
Concrete	Sepia or neutral tint with darker dots spread over.
Foundation stone	Light Prussian blue and sepia mixed.
Bluestone	Prussian blue and Payne's gray mixed.
Brownstone	Burnt umber.
Graystone	Light sepia.
Brickwork	Venetian red or crimson lake and burnt sienna mixed.
Terra cotta	Burnt sienna.
Steel	Neutral tint, or purple mixture of Prussian blue and crimson lake, or green mixture of Prussian blue and gamboge.
Wrought iron	Prussian blue.
Cast iron	Payne's gray.
Brass	Gamboge, with very little sienna or red mixed.
Copper	Burnt sienna, or crimson lake and gamboge mixed.
Tin	A line of light Prussian blue or Payne's gray.
Lead	Sepia and Prussian blue mixed.
Slate	Neutral tint or green.
Wood	For hardwood, sienna wash; other woods, gamboge, or any other yellow.

As this plate introduces the use of color in drafting, it is supplemented by a list of materials in common use and the colors and shades by which they may be represented on the drawing as given in Table I. While there may be a difference of opinion existing among architects as to the colors representing the respective materials, the main object is to show distinction and avoid confliction, in massing the colors. This is easily arranged by adding to or lessening the density of one of the colors in a mixture.

Of the many manufactured forms of color, those produced in small china pans, known as *moist colors*, are preferable, although cake color may be used, but this requires grinding in the same manner as stick India ink, and often straining through a wet piece of linen to remove the small undissolved particles. Colored inks in bottle form are often used and may be reduced in density by adding a drop of liquid ammonia to a small quantity of the ink mixed with a little water in a saucer.

Color should never be laid on thick but always in a light wash, using plenty of water in the mixing.

In coloring on tracing linen, it is better to apply the color to the reverse side to that on which the lines are. When the surface of the cloth, or tracing paper, appears oily and refuses to take the color, touch the tip of the brush, while wet, to a piece of soap occasionally and the color will run smooth.

71. Brushes.—A sable's-hair brush is preferable to a camel's-hair, as the latter becomes limp with use. A large brush with a fine point is better than a small one, as it holds more color and will make a narrow line as well as a broad wash under a slight pressure causing the tip to spread. Brushes should be washed out clean after using and drawn over a slip of paper to their natural point, keeping the hair together, and in this state allowed to dry.

72. Paper.—In order to obtain the best results, this plate should be drawn on cold-pressed water-color paper, Whatman's preferred. Although this is slightly rougher than ordinary paper, more satisfactory results may be obtained by its use. The paper should be *strained* on the drawing board in order to prevent its wrinkling, as the color dries and pulls on its outlines. This is done by turning the paper wrong side up, the right side being determined by holding the sheet up to the light so that the name of the maker, in water marks, will read correctly and not backwards. To strain the paper, dampen the back of the sheet with sponge and water, preserving a dry margin of about ½″, sponging first downwards, then across. Gum this ½″ margin, reverse the sheet on the board and press the edges down flat, slightly drawing them outwards with the fingers of both hands, stretching it both ways, as far as it will go, easily and without forcing. The dampened center will appear very rough, but this will dry out perfectly smooth. If the center shows signs of drying before the gummed edges, slightly dampen it on the right side, as the edges must be held down tight to the board, or the center while drying will draw it away, thus causing permanent wrinkles. It being easier to lay colored washes on paper than on tracing cloth, the student will, in this instance, ink in and color the pencil drawing and forward the same to us in place of the customary tracing.

73. Inking In.—If one desires, a very effective plate may be produced by grinding stick India ink with water in a small saucer until it becomes quite thick, yet not pasty. With this, carefully ink in the entire drawing, including free-hand work, dimension lines, and figures, omitting only the title and scale at head of plate. Avoid, if possible, making erasures. When the ink is thoroughly dry, gently wash over the entire surface of the plate inside the margin lines with a small soft sponge and clean water, removing all surplus ink, which may dry and blur the drawing.

If properly executed, sufficient ink will remain over the lines to hold the drawing. When the sheet is dry, the lines will appear gray and but little heavier than pencil. Now proceed to color, using only a light wash as previously described. After the color is dry, the drawing may be shade-lined, if desired, by going over the bottom lines and right-hand vertical lines of all projecting members casting a shadow on work below, as in previous plates, using a solution of the same ink mixed to a heavy gray color, not black.

All erasures and corrections may now be made and the title printed in black, as on preceding plates, also, the scale and margin lines, name, class letter and number, and date, thus completing the plate.

DRAWING PLATE, TITLE: STEEL COLUMNS AND CONNECTIONS

84. In this plate are shown two designs of **steel columns** used in the construction of modern office buildings, and also a common method of connecting the floorbeams to the columns. A side view and a front view of each design is given, and as it would manifestly be impossible to draw the columns in their full length, and since it would not serve any useful purpose to do so, a part of the column between the base and the floorbeam connection is broken away. When this is done, it is understood that the part broken away is similar to the ends of the column next to the break, which, in this case, is indicated by drawing a line consisting of a long dash and two dots across the column.

FIG. 37

The plate is practically a shop drawing for two structural steel columns of different sections. The column shown in Fig. 1 is made up of two 15″ channels, riveted through the flanges to two $\frac{7}{16}''\times 12''$ cover-plates. A cross-section through the column is shown in Fig. 37. The column in Fig. 2 is composed of four rolled sections, known as **Z** *bars*, and one web-plate $\frac{5}{8}''\times 8\frac{1}{2}''$ wide. The section of this column is constructed as shown in Fig. 38, and the dimensions of the several rolled shapes of which both column sections are composed and also the I beams for the support of the floor are shown in Fig. 26. In structural steel columns, the details of design requiring special attention are the base of the column, the

FIG. 38

STEEL COLUMNS

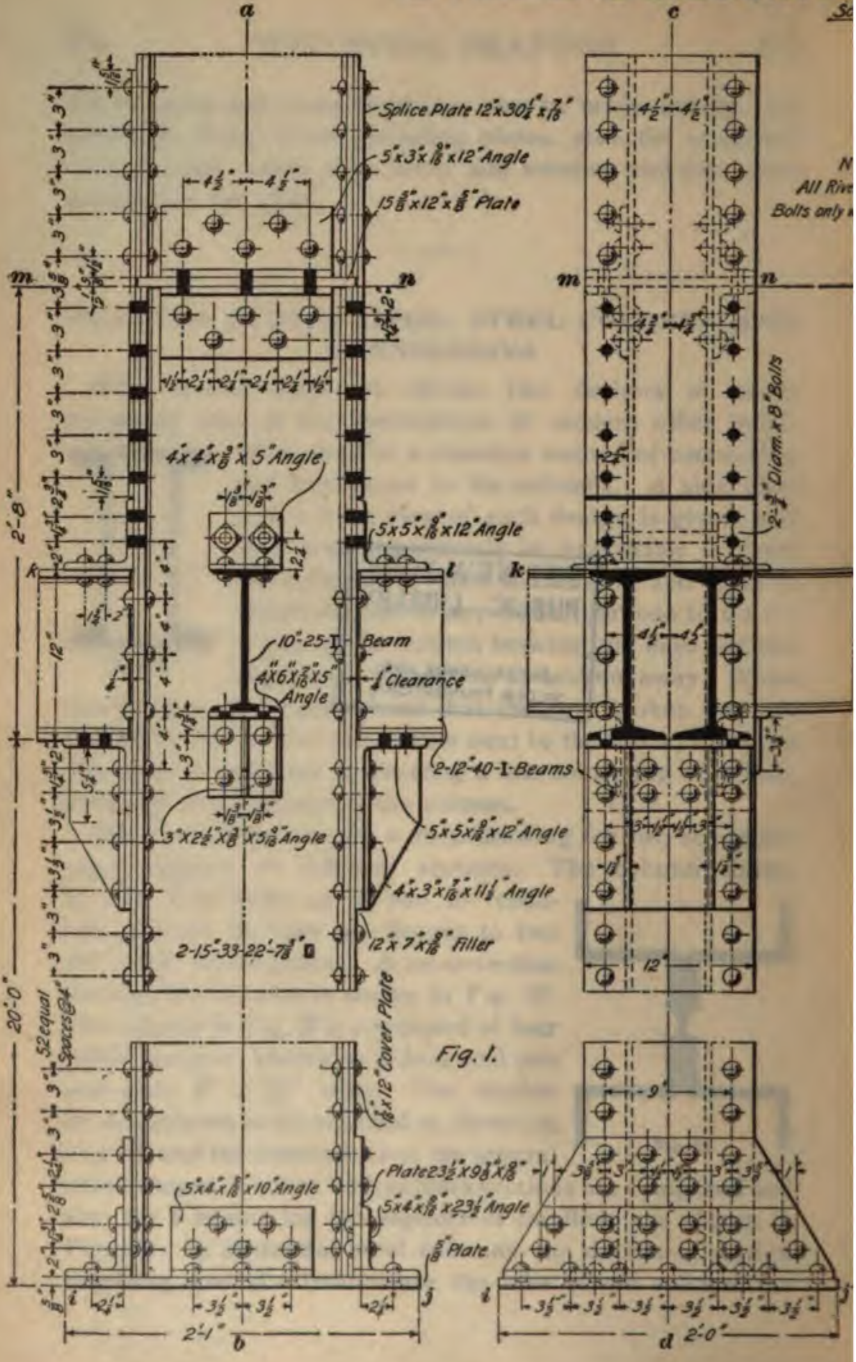


Fig. 1.

CONNECTIONS.

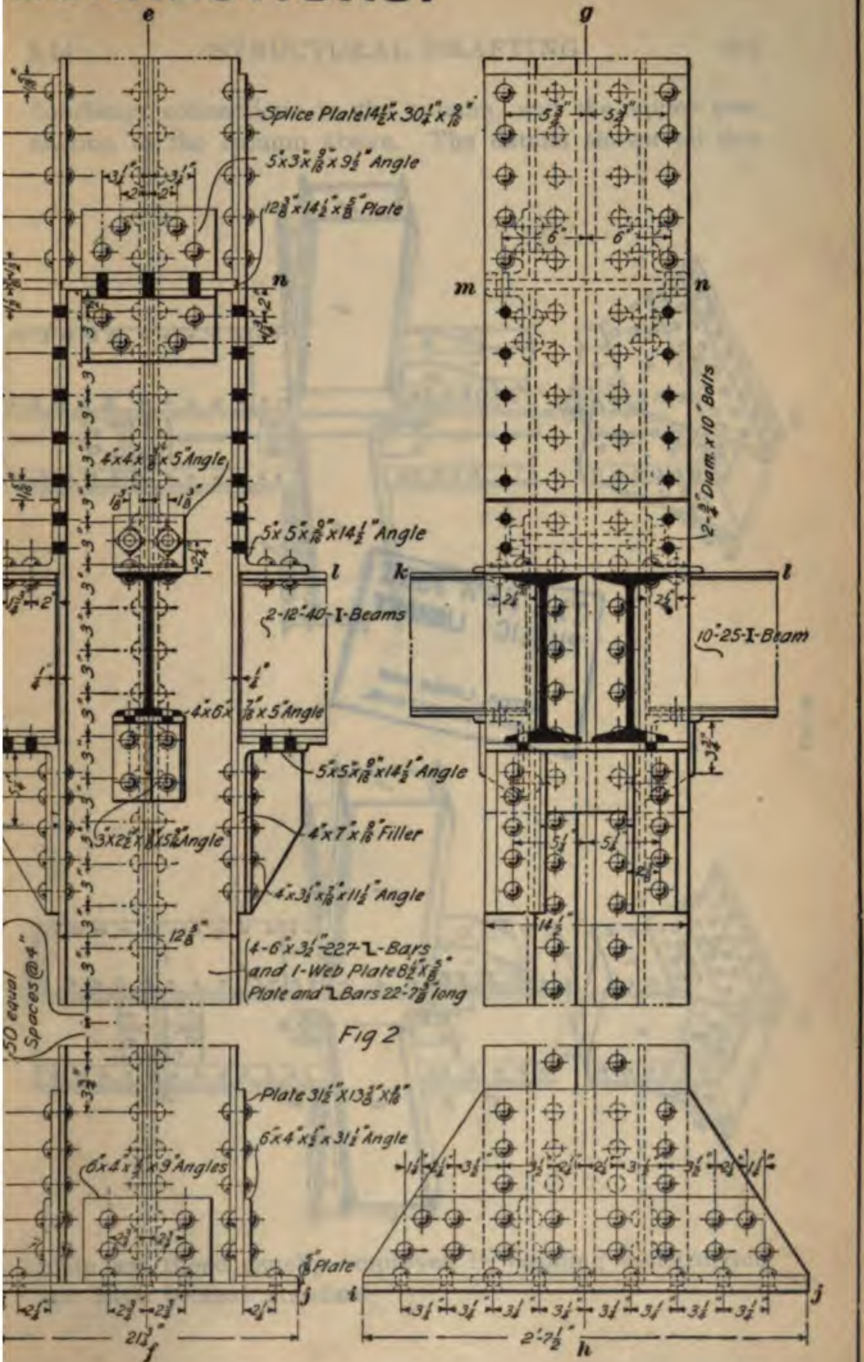
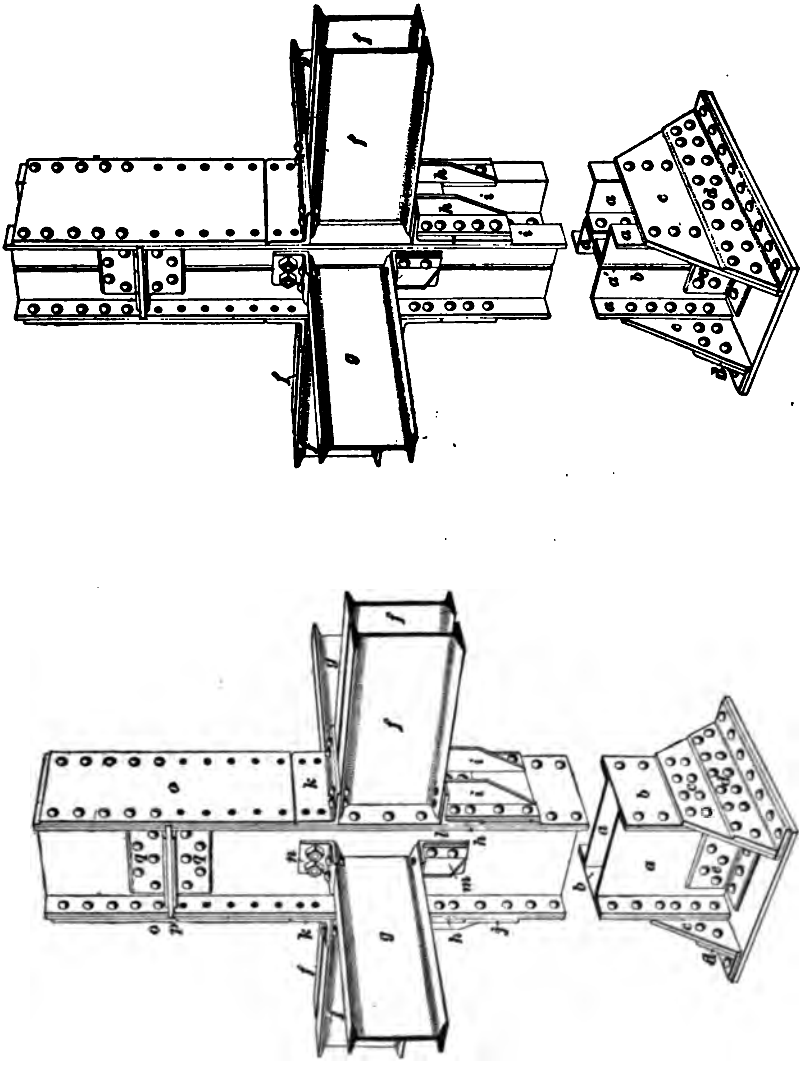


Fig 2

floorbeam connections to the column, and the upper connection to the column above. The details shown on this



(b)

(a)

FIG. 33

plate are those usually employed in building construction and have become standard.

85. In the design shown in Fig. **1**, and in perspective in Fig. 39 (*a*), the column consists of the two 15″ channels *a*, *a* placed back to back and tied together by cover-plates *b*, *b*, 12″ wide. The column is supported on a steel bedplate 24″ × 25″ × ⅝″, to which it is attached by side plates *c*, *c* and angle irons *d*, *d* riveted securely to the bedplate. Each channel, for further security, is tied to the bedplate by an angle iron, as *e*. The column supports two pairs of longitudinal floorbeams *f*, *f*, *f*, *f* and two transverse floorbeams *g*, *g*. Each pair of longitudinal floorbeams is supported on a horizontal bracket made from a 5″ × 5″ angle iron *h*, and stiffened by two 4″ × 3″ angle irons *i*, *i* placed back towards back. A filling piece *j* is placed between the cover-plate and the lower part of the angles *i*, *i*. The longitudinal floorbeams are tied on top to the column by a 5″ × 5″ angle iron *k*. Each transverse floorbeam rests on a bracket made from a 4″ × 6″ angle iron *l*, stiffened by a 3″ × 2½″ angle iron *m*, placed as shown. A 4″ × 4″ angle iron, as *n*, ties the top of these floorbeams to the column by means of two ¾″ bolts. The column is made in sections, the lower section being 22′ 8″ high. The upper section is spliced to the lower section by the vertical splice plates *o*, *o*, a horizontal plinth plate *p*, and 5″ × 3″ angle irons *q*, *q*.

The column shown in Fig. **2**, and in perspective in Fig. 39 (*b*), is built up from four **Z** bars *a*, *a*, *a*, *a* securely riveted to a web-plate *b*. Since the edge *a*′ is the dark edge of a recess, it should be shaded, according to the rules of shading. On referring to Fig. **2** it will be found that the line corresponding to *a*′, Fig. 39 (*b*), is made a light line instead of a shade line, as it should be. This is a conventionalism adopted frequently by experienced draftsmen, who will omit a shade line when its presence will render the drawing, or part of it, indistinct instead of clearer. It is readily seen that if the line mentioned is shaded on Fig. **2**, it will not be possible to show correctly the thickness of the web of the **I** beam; hence, the line is left light. The column, as shown in Fig. 39 (*b*), is supported on a steel bedplate 21¾″ × 31½″ × ⅝″, to which it is attached by the side plates *c*, *c* and angle irons *d*, *d*. For further security, each pair of **Z** bars is tied to the bedplate by an angle iron *e*. Two pairs of longitudinal floorbeams *f*, *f*, *f*, *f* and two transverse floorbeams *g*, *g* are connected to the column in practically the same manner as those shown in Fig. 39 (*a*). A slight difference in the construction of the brackets supporting the longitudinal floorbeams will be noticed. Instead of using a single filling piece under the two stiffeners *h*, *h*, a separate filling piece, as at *i*, *i*, is used under each stiffener. Each transverse floorbeam is supported on a bracket made from a $4'' \times 6''$ angle iron stiffened by a $3'' \times 2\frac{1}{2}''$ angle iron, and is tied on top by a $4'' \times 4''$ angle iron riveted to it and bolted to the column. This column, like the other, is built in sections, the upper section being spliced to the lower section by two vertical splice plates, one horizontal plinth plate, and angle irons. It will be noticed that the manner in which the splice is made is identical with that used to splice the sections of the column shown in Fig. 39 (*a*).

86. Commence the drawing by laying out the vertical center lines *a b* and *c d* $2\frac{15}{32}''$ and $6\frac{1}{4}''$, respectively, from the left-hand border line, and *g h* and *e f* $2\frac{7}{16}''$ and $6\frac{5}{16}''$ from the right-hand border line. The horizontal base lines *i j* of the columns are drawn $\frac{15}{16}''$ from the bottom border line and the top lines $1\frac{1}{8}''$ below the top border line. From the vertical center lines of the several views of the columns, the widths of the columns in both figures may be laid out and the vertical lines representing the thickness of the rolled shapes and the cover-plates drawn.

From the base line *i j*, the thickness of the base plate in each view, which is drawn to a scale of $1\frac{1}{2}'' = 1'$, may be marked off and the angle plates for reenforcing and securing this plate to the column designed as shown on the plate. It will be noticed that the rivets holding the base plate to the angles that are riveted to the column are countersunk so that the column will take a full bearing on the capstone. The **I** beams, which are the main support of the floor construction and are secured to the columns, are on the same level at the top flange, as shown on the lines *k l* in the several views. These lines are $7\frac{5}{16}''$ from the lower border line, though they would have been located from the base lines *i j* by the vertical dimension given but for the fact that a section has been broken from the column between the base and brackets supporting the floorbeams, so that the views could be included between the upper and lower border lines. From the lines *k l*, the details of the several beam connections can be designed after laying off the depth of the floorbeams and working out the sections shown in black, from the information given for these sizes of beams in Fig. 26, by laying out the angle brackets with their stiffening angles and fillers, and putting in the necessary rivets and bolts to make a rigid connection.

87. The positions of the several views having been located with reference to the border lines, and the angles and plates having been arranged and drawn from the dimensions and notes given, all center lines for the bolts and rivets that have not been needed in the design of the connections should be laid out and the rivets and bolts shown. The rivets are designated by their conventional signs, as explained in connection with Drawing Plate, Title: Rivet Work. The work of drawing the details will be greatly facilitated by finishing one view of the column and then projecting to the other view all of the necessary horizontal lines. All rivets in these two designs are $\frac{3}{4}''$ in diameter, having a head $1\frac{1}{4}''$ in diameter and $\frac{9}{16}''$ high, the rivet holes being punched $\frac{13}{16}''$ in diameter. Particular attention should be paid to the spacing of rivets and an effort made to make the drawing accurate. Each detail should be carefully analyzed and no attempt to lay it out should be made until the construction is thoroughly understood. The plates should be finished as usual and the notes and dimensions carefully executed. The lines *m n* that designate the top of the first-floor columns are readily located from either the top or bottom flanges of the steel **I** beams supporting the floor and would probably be determined by the dimension from the base of the column, which, as

marked to the right of Fig. **1**, is 22′ 8″. When this line has been determined, the packing, or plinth, plate separating the upper and lower columns may be drawn 15$\frac{5}{8}$″ × 12″ × $\frac{5}{8}$″ in Fig. **1** and 12$\frac{5}{8}$″ × 14$\frac{1}{2}$″ × $\frac{5}{8}$″ in Fig. **2**, as designated by the note. The angles and splice plates in connection with the junction of the upper with the lower column, may likewise be drawn from the notes and dimensions on the plate. The reference letters printed in bold-face Italics are to be omitted.

DRAWING PLATE, TITLE: ROOF TRUSS FOR TRAIN SHED—I

STRESS DIAGRAMS

88. This plate and the two following ones represent the necessary construction drawings for the skeleton framework of a **train shed**. The elements of the design consist of steel columns at either side of the shed supporting the roof trusses, which are braced against lateral motion across the building by means of knee braces to the columns, and longitudinally by means of diagonal bracing between the columns and between the only upright members in the roof trusses. The roof truss must provide for the support of a lantern, or skylight, at the apex. By extending the rafter member and bracing it to the column, an outside shed, or projection over the pavement, is secured.

Fig. **1** shows the frame diagram for the roof truss subjected to the dead load, while Fig. **2** shows the diagram of stresses due to the dead load. Fig. **3** shows, to a larger scale than Fig. **1**, the frame diagram for the wind load, considering the wind as acting on the left-hand side of the truss and the vertical side of the lantern or skylight. The **stress diagrams** drawn in connection with this figure are shown in Figs. **4**, **5**, and **6**, Figs. **4** and **5** being the reaction diagrams, while Fig. **6** is the complete diagram of stresses due to the wind load. In drawing this plate, the student should not attempt merely to locate and scale the diagrams and thus reproduce them on his drawing; the purpose of the plate is to give practice in the application of graphical statics to structural design. It is assumed that the vertical panel loads in the frame diagram for the dead load have been carefully calculated and include the weight of the roof covering, the principal, and the snow load. The dimensions for the frame diagram in Fig. **1** are given in Fig. **3.** In this figure the span of the truss, or the distance from center to center of columns, is 80 ft., while the height of the columns is 25 ft. The height of the roof truss from apex to lower chord at the center is 13 ft. and the lower chord has a camber, or rise above the top of the column, of 3 ft. A better understanding of this plate may be obtained by occasionally consulting the succeeding one, which shows the general design of the truss. The distances between panel points on the rafter members are equal to 10′ 9″ throughout the truss. These measurements having been decided on, the frame diagram, Fig. **1,** may readily be drawn, the center line $a\ a'$ being drawn $3\frac{3}{4}''$ from the left-hand border line while the joint $B\ C\ M\ L\ K$ is located $1\frac{1}{4}''$ from the lower border line. Extreme accuracy should be employed in drawing this figure and the vertical loads and reactions should be designated as shown; also, the notation by which the members are known should be placed on the drawing.

89. It will be noticed that on all these figures capital letters are used for the frame diagrams and small letters for the stress diagrams, numerals being used if the diagrams are so complex as to require a greater scope in the notation than the alphabet affords. After the frame diagram for the dead load has been drawn, proceed with the corresponding stress diagram shown in Fig. **2.** In this diagram, a distance of 1″ equals 8,000 pounds, as designated in the scale. Proceed by drawing the load line $a\,b$, $b\,c$, $c\,d$, $d\,e$, etc., which need not be drawn in full, since the roof truss is symmetrically loaded and one half of the diagram will give all of the stresses. In locating the load line, it should be drawn $1\frac{1}{16}''$ from the right-hand border line, as shown on the plate, and the point *a* located $5\frac{3}{4}''$ above the lower border line. The distances *a b*, *b c*, *c d*, etc. are laid off equal, respectively, to the loads *A B*, *B C*, *C D*, etc. in the frame diagram. In this way the point *j* can be located, for *i j* is the force at the apex of the skylight roof and the point *z* will be located midway between *i* and *j*, for this is the central point of the diagram, and *a z* will measure, by scale, 25,000 pounds, which is the amount of the vertical reaction transmitted through the column at either end of the truss. When the load line has been measured off in this way, draw from the point *b* an indefinite line *b k* parallel with the projecting portion of the rafter member *B K* in the frame diagram. From *a*, draw an intersecting line *a k* parallel with the member similarly marked in the frame diagram; thus the point *k* will be located. From *k*, draw *k l* downwards and *l* will be found by drawing from *z* a line parallel with *L Z*. By working around the polygon of forces at any joint, as *A B K* in the frame diagram, the direction of the arrowheads may be obtained from the stress diagram; these arrows point in the direction in which it is necessary to draw the lines in the stress diagram. For instance, consider the joint *A B K*; the polygon of forces around this joint, referring to the stress diagram, is from *a* to *b* downwards, from *b* to *k* upwards, and from *k* to *a* upwards. As will be noticed, these lines have the same direction as the arrows about this joint. Similarly, the polygon of forces about the joint *K L Z A* is drawn in the stress diagram from *k* to *l* downwards, from *l* to *z* downwards, from *z* to *a* upwards, and from *a* to *k* downwards, all of the forces at this joint acting toward the joint, as will be seen in Fig. **1**. Next proceed with the joint *B C M L K* and then with *C D N M*. There are a number of unknown forces around the joint *M N O Z L*, but by drawing the stress diagram for the two preceding joints, *Z L*, *L M*, and *M N* will have been obtained, so that but two unknown forces, *N O* and *O Z*, will be left. No difficulty will be encountered with the joint *D E P O N*, but before proceeding with either *E R Q P* or *O P Q T Z*, it will be necessary to analyze the joints *I J S* and *I S R E*, on the completion of which *E R Q P* may be shown in the stress diagram, and the joints $OPQTZ$ and $TQRSWV$ finally drawn, completing the stress diagram. In laying out the stresses around this last joint, it will be noticed that WV is not represented in the stress diagram, for it is merely a repetition of QR, while VT is a line similar to TQ.

90. To proceed with the more difficult diagram on the plate, that is, the stress diagram for the wind load, it is necessary to draw the frame diagram shown in Fig. **3.** This diagram is located on the plate in such a position that the left-hand column, or the member UZ, is $5\frac{1}{8}''$ from the left-hand border line, while the right-hand column, or the member XZ, is situated $1\frac{7}{8}''$ from the right-hand border line. The feet of the columns are $7\frac{1}{2}''$ from the upper border line. The resultant wind pressures acting at each joint and normal to the slope of the roof are designated by the forces AB, $B'C$, CD, DE, FG, HI, and IJ. Besides these several forces there is a horizontal wind resultant against the vertical side of the lantern, or skylight, half of this pressure being represented by the force EF and the other half by GH. These forces should be shown on the diagram. Before proceeding, however, it is necessary to lay out the reaction diagrams shown in Figs. **4** and **5**, the origins o of which are located $2\frac{1}{8}''$ and $2''$, respectively, from the upper border line; the origin o of Fig. **4** is located $4\frac{3}{4}''$ from the left-hand border line, while the same point in Fig. **5** is $1\frac{3}{4}''$ from the right-hand border line. The purpose of these diagrams is to determine some of the unknown external forces that are necessary to produce equilibrium in the framed structure.

Having located the point o in each diagram, the force op should be calculated. In order to determine this force in Fig. **5**, it is necessary to consider the moments of all of the normal forces about the foot of the left-hand column, or at R_1, and divide the sum of these moments by the distance between the feet of the columns, on a line parallel to the slope of the roof. This distance is found to be 74.279 ft., as marked on the plate. The force op in Fig. **5** is found, by calculation, to equal, approximately, 5,100 pounds. The same force in Fig. **4** is the difference between the amount of op in Fig. **5** and the sum of the normal loads on the truss. As the sum of the normal loads is 15,000 pounds, op in Fig. **4** is 15,000 − 5,100 = 9,900 pounds.

When these oblique forces are laid off to scale they should be resolved into their horizontal and vertical components, which, in each diagram, are represented by up and ou, respectively. From p in each figure, lay off a distance pr, to scale, equal to 1,900 pounds; for this equals the reaction necessary at the foot of each column acting in opposition to the horizontal wind stresses EF and GH. Before these diagrams can be completed, it is necessary to calculate the upward pull on the left-hand column and the corresponding downward pressure on the right-hand column created by these two horizontal forces EF and GH; this is accomplished by calculating their moments about the foot of the right-hand column, or X', and dividing the sum of these moments by the span of the truss or the distance from center to center of columns. The result of this calculation gives, in this instance, 1,947.5 pounds, which amount should be laid off, in each diagram, from r to s, when os may be drawn. The lines os represent the amount and direction of the reactions at the feet of the columns.

To complete Figs. **4** and **5**, draw st, which is the vertical component of the oblique reaction and by which ot, an imaginary horizontal reaction at the feet of the columns, is determined. The horizontal reaction at R_1 equals 5,500 pounds, while at R_2 it equals 3,850 pounds. These reactions are supplied in order to counteract the oblique reactions so that all bending stress on the columns at a, a' will be eliminated. The imaginary forces UA and BB', which must be supplied, are determined by calculating the moment of R_1U and of BB' about a; UA is equal to the sum of R_1U and BB'. The forces JG and XG' are obtained from $X'X$, which was determined in the diagram, Fig. **5**, to equal 3,850 pounds.

91. All the forces having been obtained and the necessary calculations having been made, proceed with the stress diagram for the wind load, Fig. **6.** Locate the point z $5\frac{5}{8}''$ from both the right-hand border line and the lower border line. In commencing this figure, as with all graphical solutions, it is necessary to lay out the polygon of external forces, which, in this instance, extends from z to r_1 to u to a to b to b' to c to d to e to f to g to h to i to j to 6 to x to x' and back to z, the starting point. When this has been completed, the stresses for each joint in the truss can be laid out and the diagram completed as shown. The stresses in each diagram may then be measured, after which the table shown in the upper left-hand corner should be compiled. From this table, the maximum tensile or compressive stress in each member may readily be determined.

DRAWING PLATE, TITLE: ROOF TRUSS FOR TRAIN SHED—II

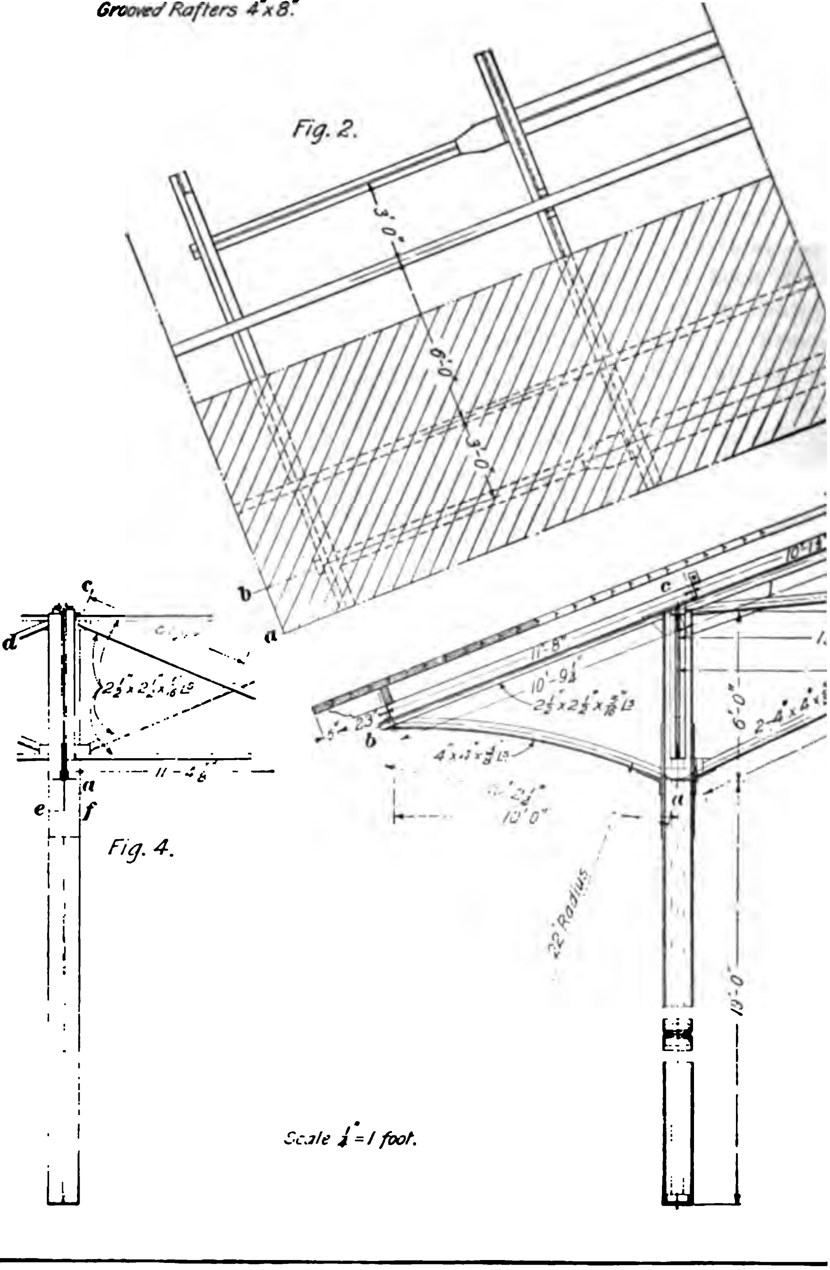
GENERAL DESIGN

92. This plate, showing the **general design** of the shed, must be drawn subsequent to the stress diagram, for this is the general drawing that gives, as well as the size of the shed, the dimensions of the several rolled shapes composing the members. Fig. **1** shows to a scale of $\frac{1}{4}'' = 1'$, one half of the truss with the purlins, rafters, and roof covering. The principal information given in this figure is the character of the structure and the general details of the shed. The important dimensions of the assembled structure are likewise given, and the sizes of the members and their lengths are denominated. Figs. **2** and **3** are not of much importance; their principal purpose is to show that the roof sheathing runs diagonally and that the siding of the skylight is divided into three panels, the central panel being a fixed glazed sash, while the side panels are filled with louvers. Fig. **4** illustrates the diagonal or portal bracing extending longitudinally of the building between the several

ROOF TRUSS

GENE

Note — Purlins Z Bars 6"x3/8" at 15.6 lbs. per foot.
Gusset Plates 5/16" Thick.
Roof 3x6 Spruce Plank – Tongue and Grooved Rafters 4"x8".



RAIN SHED - II

IGN.

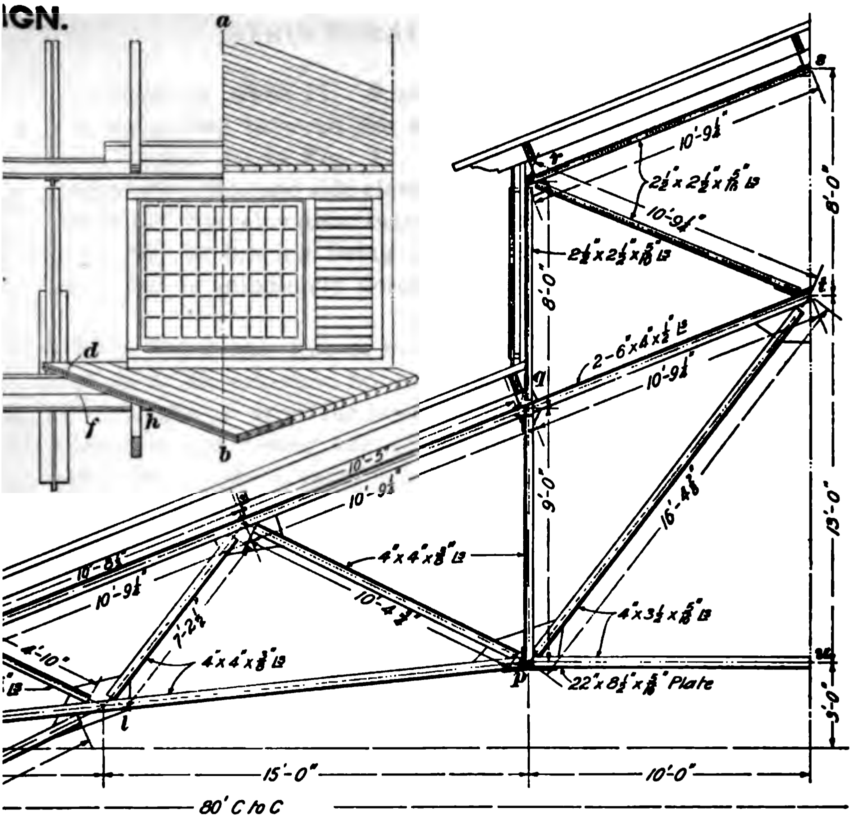
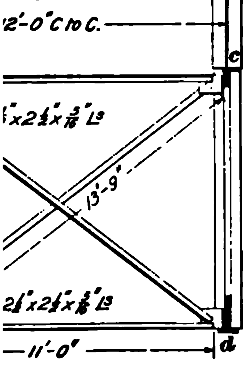


Fig. 1.

Fig. 5.



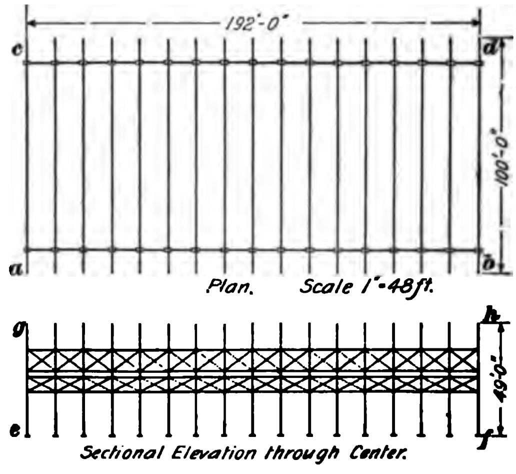


Fig. 6.

steel columns, while Fig. 5 shows a similar system of bracing, extending between the upright members of the roof truss marked *pq* in Fig. 1. Fig. 6 shows merely a diagrammatical plan and side elevation of the shed, the principal feature of the elevation being the diagonal bracing, the upper tier of bracing being detailed in Fig. 5, while the lower tier is completely described in Fig. 4.

93. The center line of the column in Fig. 1 is located $6\frac{5}{16}''$ from the left-hand border line, the foot of the column being located $\frac{1}{2}''$ from the lower border line, while the intersection of the center line of the rafter member and the center line of the column is $5\frac{3}{4}''$ from the lower border line. From the dimensions given, the center lines of the several members may readily be laid out and the members drawn to the size designated. The dimensions of the gusset plates can only be obtained from a detailed drawing, such as is shown in the next plate. Such details must usually be worked in conjunction with the general design.

Having laid out each connection and completed the skeleton framework, finish this figure by drawing in the Z bar purlins, wooden rafters, and sheathing as designated, placing on the drawing all of the dimensions called for by the plate. Figs. 2 and 3 require little explanation, though it will be observed that the Z bar purlins in Fig. 2 are projected from Fig. 1. Carefully study these figures and determine conclusively the appearance and position of the steel work before attempting the drawing. Locate the line *ac*, Fig. 2, $\frac{1}{8}''$ from the roof surface in Fig. 1. The center line *ab* in Fig. 3 may be drawn $5\frac{7}{8}''$ from the right-hand border line, while *cd*, *ef*, *gh* and all similar horizontal lines are projected from Fig. 1. Fig. 4 offers no difficulty and the bottom of this figure is in line with the bottom of the column in Fig. 1, while the center line of the column is $\frac{7}{8}''$ from the left-hand border line. Fig. 5 can be conveniently located $1\frac{1}{4}''$ and $5\frac{3}{4}''$ from the lower and right-hand border lines, respectively.

In drawing both of these figures, dependence must be placed on the details shown in the subsequent plate. It is customary for the draftsman, in laying out the general drawing, to decide on the details at the junction, and in designing these he must often roughly draw them full size, so as to determine whether there is sufficient room for bolting and riveting. Fig. **6** needs little explanation and may be drawn on the plate $\frac{3}{4}''$ from the right-hand border line and $1''$ from the lower border line, leaving a space of $\frac{7}{16}''$ between the two views. All notes and dimensions having been placed on the plate, it may be titled and inked in. This plate gives only the general design, and is such a drawing as is frequently furnished by the architect or consulting engineer to the steel company.

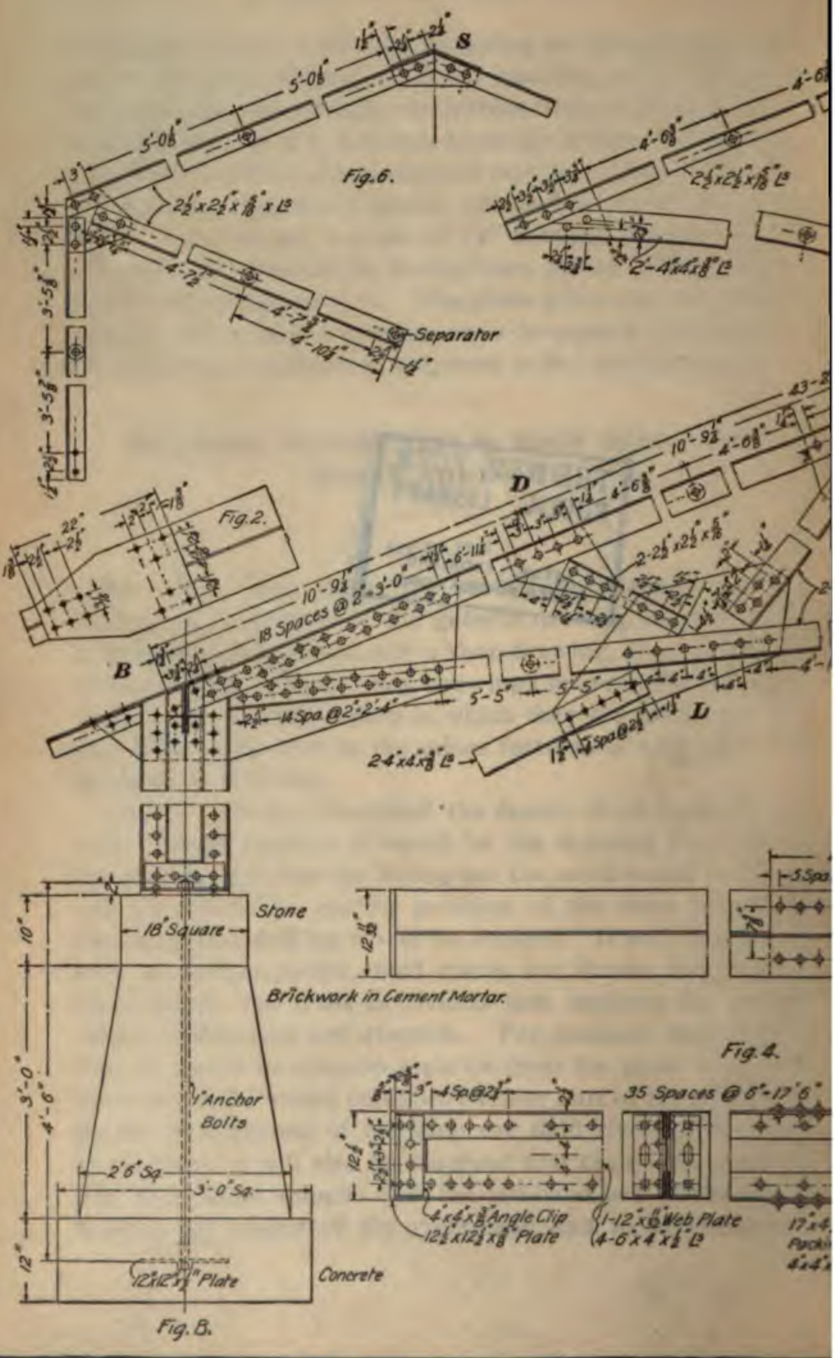
DRAWING PLATE, TITLE: ROOF TRUSS FOR TRAIN SHED—III

DETAILS

94. This plate shows the **structural details** for the train shed designated in the general drawing on the preceding plate. It is practically a shop drawing, though it must be understood that all shop drawings possess the individuality of the particular shop in which they are made, so that they differ somewhat in the minor features of execution and methods of detailing.

On this plate are illustrated the details of all joints in the truss, and in practice it would be the drawing from which the wooden templets for laying out the work would be made and by which the correct position of the rivet holes for punching and drilling would be located. It will be noticed that, at certain points, field rivets are shown and that at these points the truss is divided into sections for convenience in shipment and erection. For example, the column, Fig. **4**, would be shipped separate from the truss, while the half truss *T B P* would compose another part of the shipment. By the arrangement of the shop and field rivets at the apex of the truss, it will also be observed that the gusset plate *T*, Fig. **1**, is to be shipped with the left-hand half of the truss, leaving the angles of the right-hand half to be connected

ROOF TRUSS



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TRAIN SHED - III
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Scale 3/4" = 1 Ft.

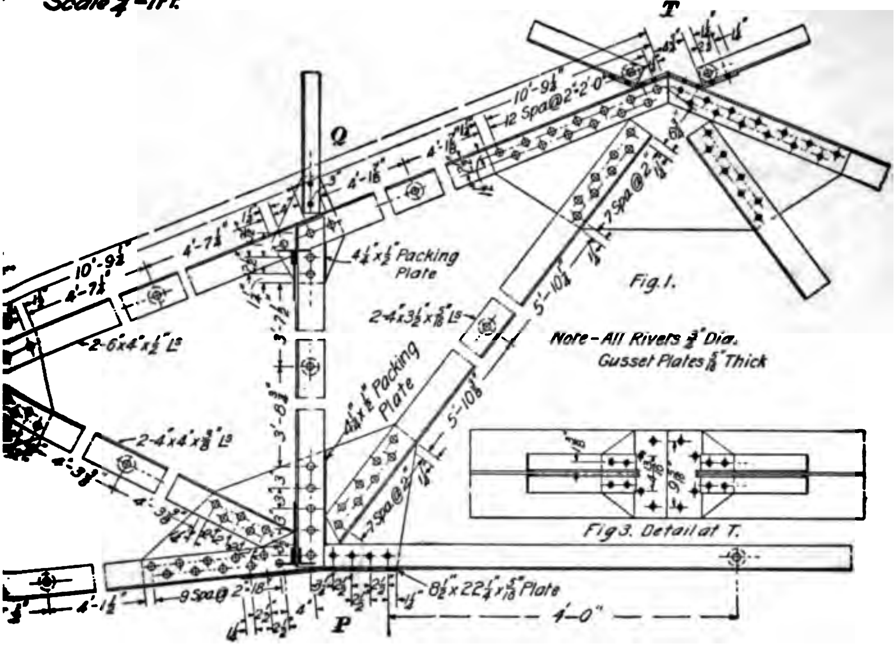
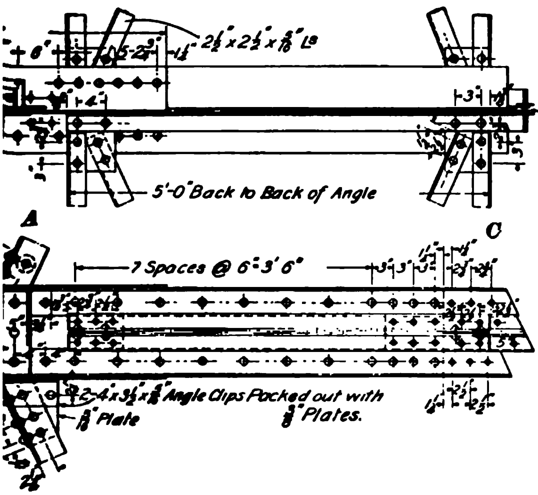


Fig. 1.

Fig 3. Detail at T.



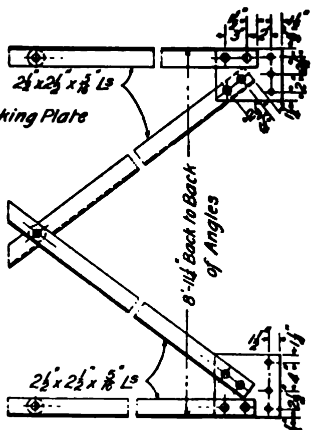


Fig. 7.

when the truss is erected. It is hardly necessary to locate the several views, for the student should be competent to lay out the work with little explanation, especially as all of the dimensions are given.

In Fig. **1** are shown the details for the junction of the several members of the roof truss. In Fig. **2** is shown a normal view of the top flange of the rafter member at its junction with the structural steel column, while Fig. **3** shows a plan view looking down on the top of the truss at its apex. Fig. **4** is the necessary drawing for the steel columns, and in conjunction with this are shown the connections for the knee braces at *A* and the diagonal wind bracing at *C*. In Fig. **5** is shown the detail for the canopy supported over the sidewalk, which is considered as a portion of the roof truss. Fig. **6** shows, in detail, the construction for the support of the lantern or skylight, while in Figs. **7** and **8** are shown, respectively, the diagonal wind bracing between the upright members in the roof truss and the foundation pier and footing for the support of the steel columns.

In drawing this plate, observe extreme accuracy and be careful in laying out the oblique members of the roof truss to draw them at the correct angle, which may be obtained from the general drawing.

DRAWING PLATE, TITLE: DETAILS OF GYMNASIUM TRUSS

95. This plate deals only with some parts of the truss, but a clear understanding of the complete truss may be obtained by studying the elevation given in Fig. 40. The truss is an arched steel truss with an outside span of 90′ 8″, and the parts selected for detailed treatment on the plate are the lower portion, or what might be called the *heel* connection, and the upper portion, or *peak* connection. The former is shown in Fig. **1**, the latter in Fig. **2**.

Owing to the fact that this truss is of such size that it cannot be shipped in one piece, it is necessary to divide it into pieces of suitable size. The points where it is disconnected, which constitute field connections, are *A A′* at the center of the truss; $B B'$ near the outside left-hand bend; at the intermediate points C, D, E; and at other similarly located

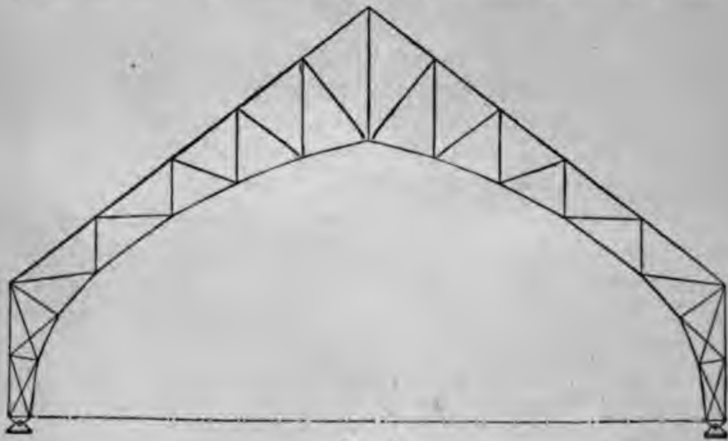


FIG. 40

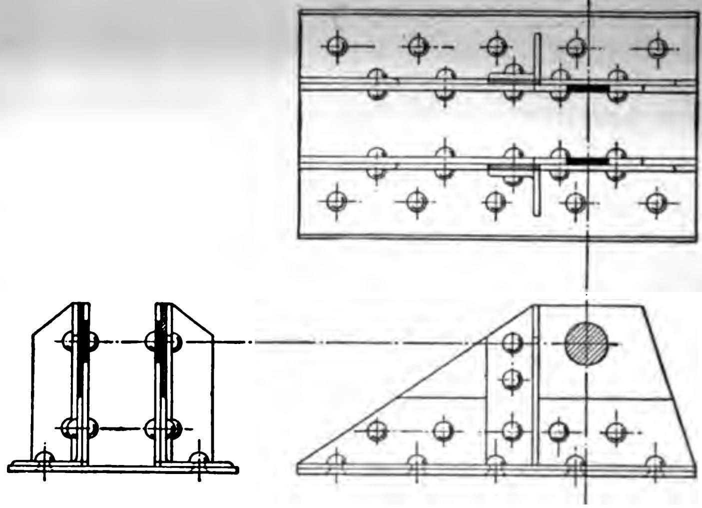


FIG. 41

points, not shown on the plate. The great length of the members *e*, *f*, *g*, and *h* made it necessary for them to be detached and riveted in place during erection. For similar

DETAILS OF
SH

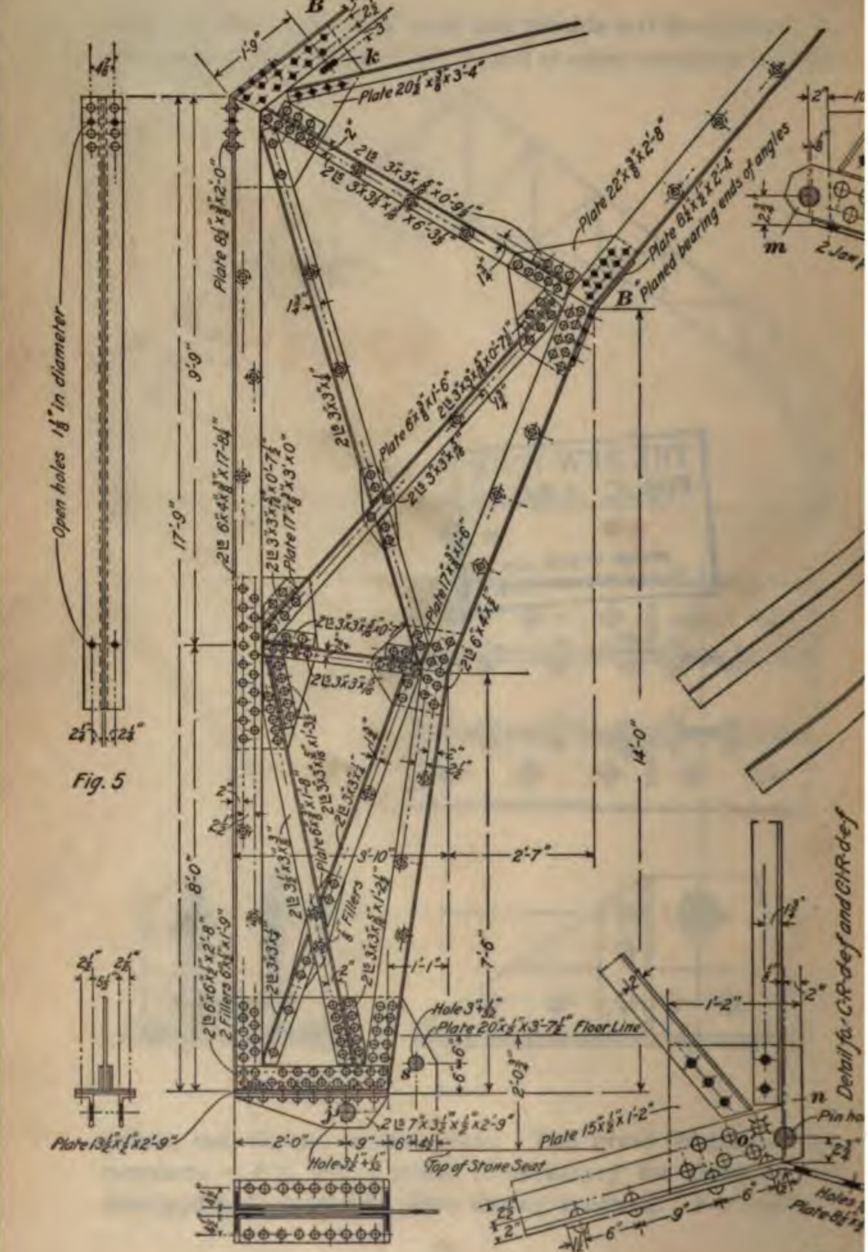
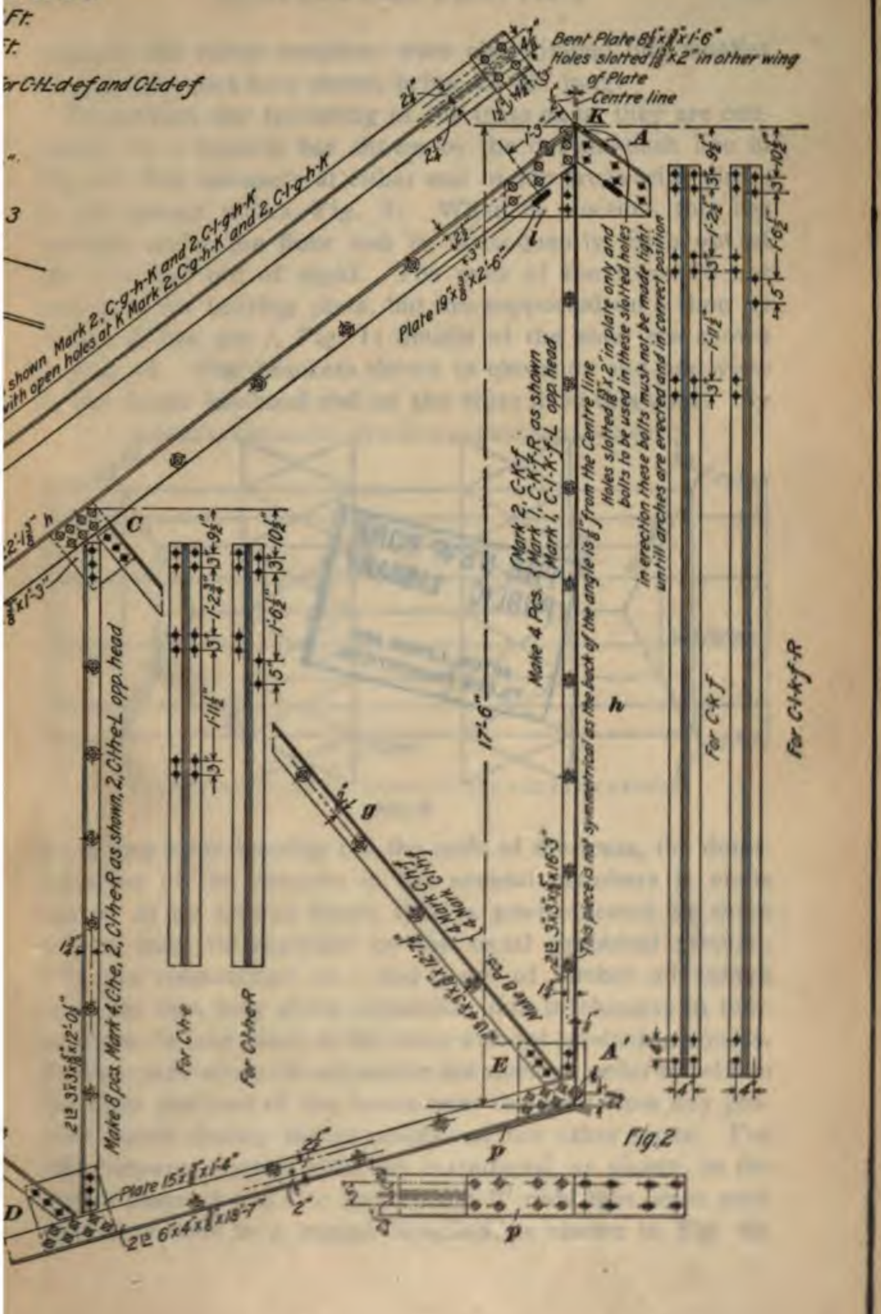


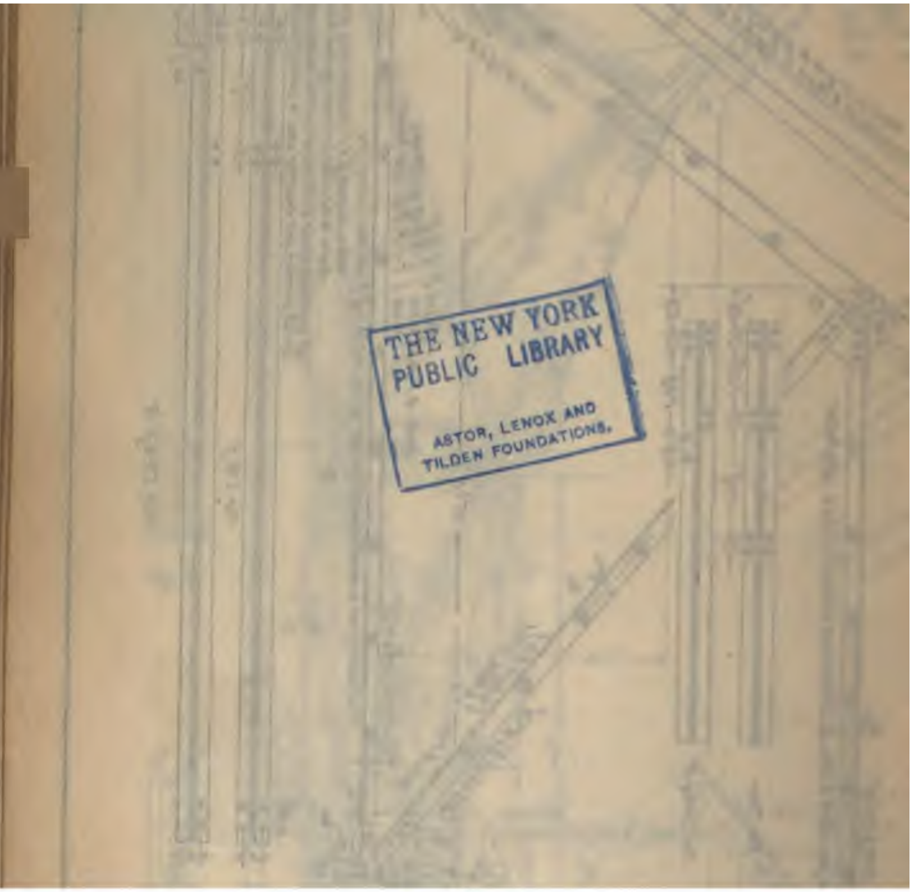
Fig. 5

Fig. 1

Fig. 4

ASIUM TRUSS
WING





reasons, the rafter members were also divided into smaller lengths, the part here shown being 22′ 1⅜″ long.

To prevent any spreading of the truss ends, they are connected by a tension bar shown by the dot-and-dash line in Fig. 40, that connects at either end of the truss with pins *s* in the gusset plates, Fig. **1.** When in position, this bar extends under the floor and is, consequently, both out of the way and out of sight. The ends of the truss do not rest on a flat bearing plate, but are supported on a shoe by means of the pin *j*, Fig. **1**; details of the shoe are shown in Fig. 41. The brackets shown in elevation and end view at the lower left-hand end of the truss fit in this shoe. By

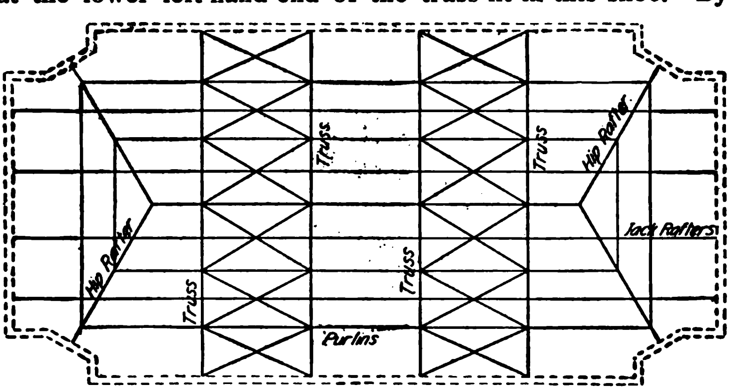


FIG. 42

providing a pin bearing for the ends of the truss, the determination of the stresses in the several members is made easier, as an arched frame that is pin-connected at three points, may be analyzed by the usual graphical method. The pin connections at *i* and *j* are of further advantage in so far that they allow expansion, due to changes in temperature, to take place in the truss without producing strains. Further provisions for expansion are made in order to relieve the light portions of the frame near the apex from any possible strain during the expansion of the other parts. For this purpose, slotted holes are introduced, as shown, in the gusset plates *k* and *l* to receive the 1″ rods that brace each pair of trusses in a lateral direction, as shown in Fig. 42.

As the brace rods pass obliquely through these holes, they require a special tapered washer in order that the nut at the end may get a firm bearing. When any expansion occurs, the slotted holes permit the brace rods to have a certain amount of motion.

96. It will be noticed that all the members are made up of two angles riveted side by side with a series of separators interposed between them, the rivets passing through the latter, one of which is shown more fully in Fig. 43. These separators prevent the angles in the tension members from striking each other in case of vibration, while in the strut members the separators prevent any spreading of the angles and thus insure a maximum reaction under compression.

The jaw plate *m*, Fig. **3**, overlaps the connection at *n*, Fig. **4**, to a considerable extent; it is therefore necessary to countersink the rivet at *o*, as shown. The joint shown in Fig. **4** is stiffened laterally by the splice plate *p*, which has its right-hand half provided with slotted holes, thus allowing for movement in case of expansion.

97. The main views on the plate are drawn to a scale of $\frac{1}{2}'' = 1'$, and those of the enlarged views to a scale of $1'' = 1'$. In the notes placed near some of the truss members, mention is made of certain letters. These are shop marks and are not intended to refer to the reference letters used in some of the views. The separate views found near some of the members represent side views of the same, as, for instance, Fig. **5**, which is a side view of the adjacent vertical member of the truss; beside members *f* and *h* are found similar views. Below the end containing the pin *j* is shown a sectional plan taken through the center of pin *s*; under the center of the truss is a bottom plan of the lower member showing the splice plate *p*.

FIG. 43

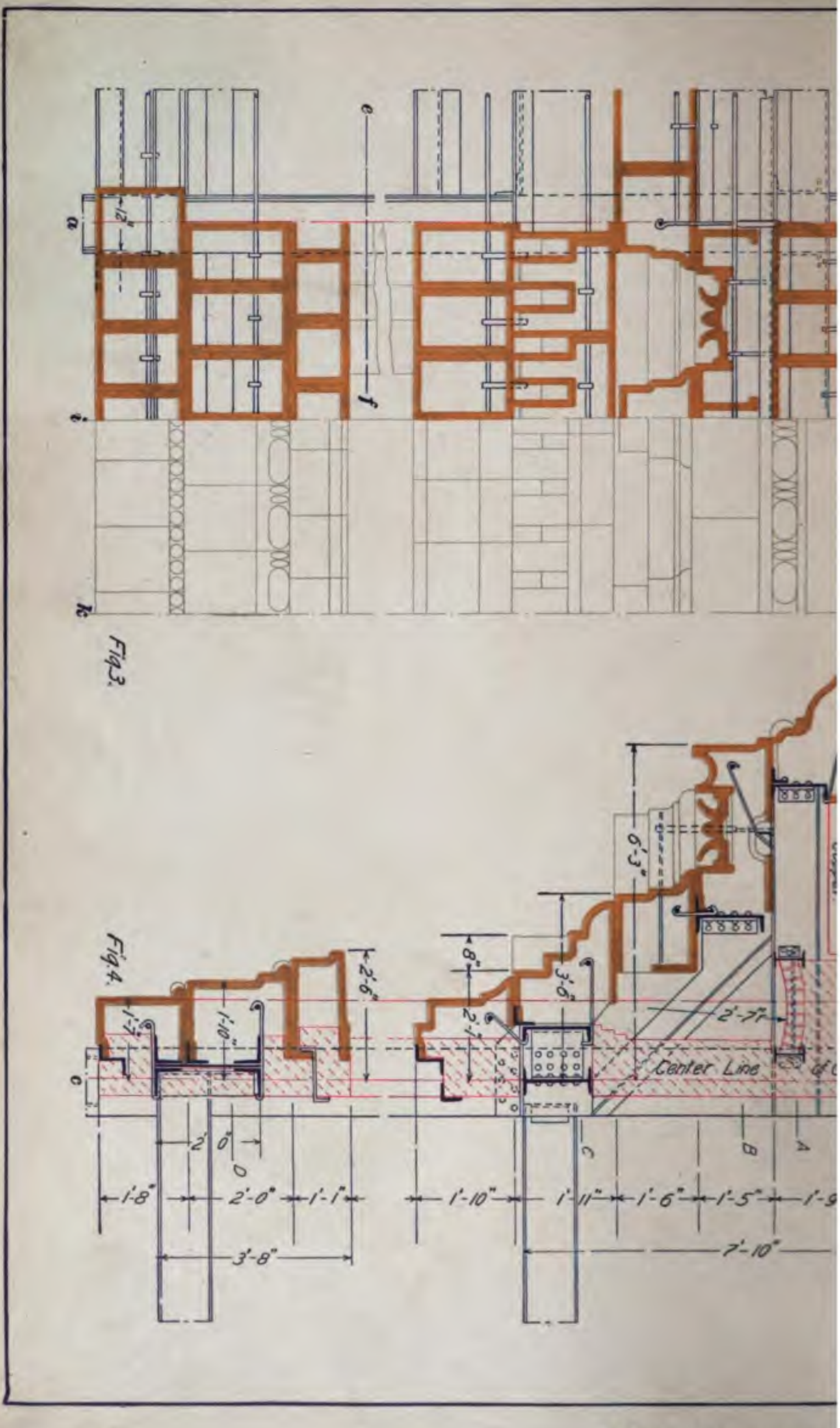


Fig. 3.

Fig. 4.

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SPANDREL SECTIONS.

DETAILS.

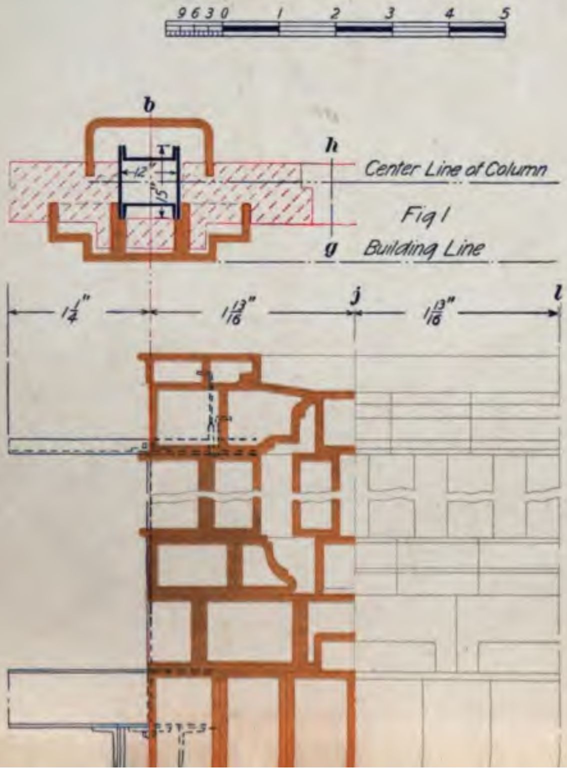


Fig 1

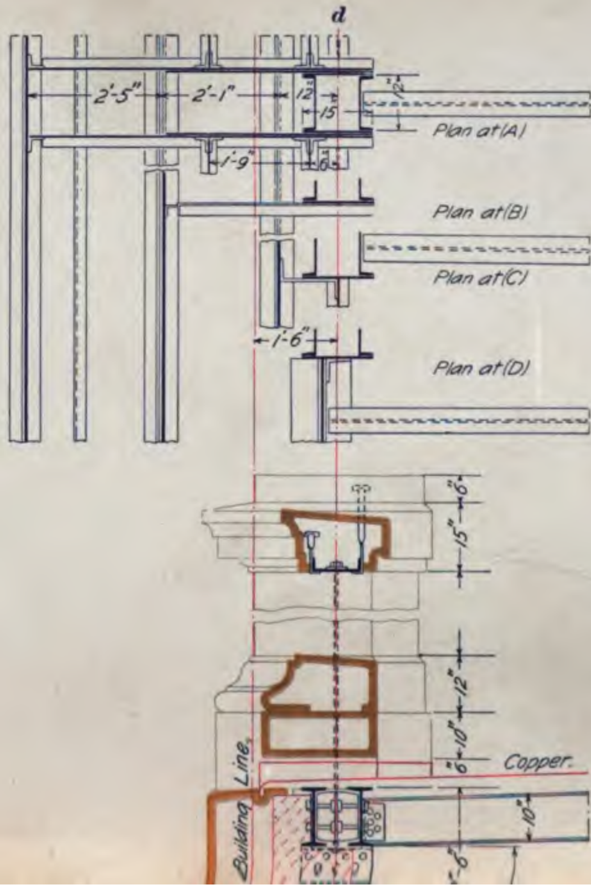


Fig 2

DRAWING PLATE, TITLE: SPANDREL SECTIONS

98. The exterior walls in skeleton construction are necessarily mere shells, or casings, covering the steel frame, on which they rely for support. They may be divided into panels, including the space between the vertical supports and a height sufficient to embrace one distinct architectural feature and type of construction. These panels are called **spandrel sections** and are usually drawn to a $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{2}$, or any convenient large scale by which the construction may be clearly shown. This plate gives, in detail, the entablature of a high building consisting of the architrave, frieze, and cornice, and the parapet to be drawn to a scale of $\frac{1}{2}'' = 1'$. It will readily be seen that the extreme height calls for heroic proportions and the distortion of many classic lines in the several members in order to obtain the perspective effect desired. In this case, a height of nearly three stories is required for this prominent feature of the design.

The importance of accurately drawn and scaled spandrel sections will be readily understood when it is known that from these sections the exaggerated proportion and projection of the moldings may be determined; the location of and required allowance for joints ascertained; the position and size of tie-rods, hangers, straps, and anchors, as well as the most economic construction of the plate girders, the size, weight, and position of beams, channels, cantilevers, etc. and the general massing of materials determined.

Fig. **1** is a sectional plan of a pier and window jamb, which shows the building to be of brick with terra-cotta trimming; from it, a portion of the lines in the elevation, Fig. **3**, may be projected. Fig. **2** shows a plan of the steel construction taken through the column at four given altitudes. From this plan and Fig. **3**, the sectional elevation, Fig. **4**, is to be projected. Fig. **3** is divided into three vertical parts: (E) showing the steel frame and connections in elevation; (F) a vertical section through the terra cotta, showing the width and varying thickness of blocks, the vertical joints, also, the location of tie-rods, hangers, straps, and anchors; (*G*) the front elevation of the completed work with the position of the face joints. Fig. **4** shows a section through the wall taken at *g h*, Fig. **1**. This section should be carefully and accurately drawn, as it is the key to the massing of the parts, and in actual practice an error in this might cause serious trouble.

Having the border lines at 13″ × 17″ apart, draw, in light pencil lines, a similar parallelogram inside of this, at $\frac{3}{4}$″ from bottom and sides, and 1″ from top. The drawing is, in no instance, to project beyond this enclosure. Next draw the vertical line *a b* $1\frac{1}{4}$″ inside of this and *c d* $2\frac{1}{4}$″ from the opposite side; likewise, lines *i j* and *k l* according to the distances given. Then take the $\frac{1}{2}$″ scale and proceed with Fig. **1** followed by Fig. **2**. Then lay off the horizontal lines of Fig. **3**, according to the vertical line of figures found on Fig. **4**. Project these across in drawing in the terracotta details. The principal lines of the steel frame should be drawn next, procuring the dimensions from the plan, Fig. **2**, and the line of height given in Fig. **4**.

The bearing angles, hangers, and ties are to be located after the terra cotta has been detailed, as they are subservient to it. Next follows the brick backing, the parallel dotted section lines being spaced $\frac{3}{32}$″ apart before lining with the pen.

99. This being a general drawing from which the necessary full-size details are made and also the shop drawings for the steel work, it is not necessary to show the riveting or other detail that does not directly affect the exterior design. When the entire drawing has been completed in pencil and all superfluous lines erased, it may be cleaned up and prepared for inking in and coloring by going over it lightly with a velvet or sponge rubber.

For the purpose of inking in and laying on washes of color, proceed as follows:

1. First mix up a light wash of burnt sienna and water. Then with a small brush capable of spreading $\frac{1}{16}$″ at the

tip, color in between the pencil lines representing terra cotta. Next mix up in a saucer a small quantity of Prussian blue and water sufficiently strong to give a clear and distinct blue line when applied. Fill the drawing pen with this up to about $\frac{1}{4}''$ from the point and proceed to ink in all the ironwork, as shown on the copy.

2. If bottled India ink, not water-proof, is used, dip out a small quantity in a saucer and dilute with a drop or two of ammonia and water to deprive it of its glossy blackness; but stick ink, ground in water to a blackness little heavier than a pencil line, is preferable. Filling the pen as previously described, proceed to line up all the work except those lines that are in color, being careful not to go over the blue again nor encroach on the position reserved for the red lines, nor extend outside of these and leave a ragged edge too wide to be covered by the black lines that follow.

3. For the red lines, mix up either vermilion or crimson lake with a little yellow and proceed to line up in the usual manner.

The lettering and figures may be of the dense black, as on previous plates.

SKETCHING

INTRODUCTION

1. In practice, the draftsman is required in most cases to draw from rough freehand sketches, made by himself or by some one else, either from an actual object or an imaginary one. For instance, suppose that a machine is in operation somewhere, of which the drawings never existed or were lost. For the purpose, say, of rebuilding or regularly manufacturing this machine, a set of working drawings is required. Suppose, as is most generally the case, that the machine is so located that it is not readily accessible to the draftsman at all times, so that he cannot take measurements while making the drawing, even if this were commendable. In such cases he must make **sketches,** that is, rough mechanical drawings freehand, from which later on he executes the regular drawings.

Again, suppose a certain change or modification is to be made in a machine, machine part, or mechanism, or a new one is to be made, and a working drawing is required. The idea is then made clear to the draftsman by means of sketches more or less complete, from which the regular drawings are subsequently elaborated.

2. A sketch must have all the essentials of a working drawing except that it is not made to scale, although the relative proportions of the object represented are maintained as near as this is possible by mere eyesight. As in a mechanical drawing, the sketch must clearly contain all the dimensions and explanatory notes necessary to enable the object to be made from it. To all intents and purposes, then, a working sketch could be immediately used as a working drawing, and is sometimes so used in cases of emergency. A regular working drawing is, however, generally more elaborate; not only is it drawn to scale, but generally a smaller number of views of the object are shown than are required in a sketch. In both, one endeavors to get along with as few views as are necessary to clearly represent the object, although in a sketch a multiplicity of lines is avoided by additional views and sections, which can be quickly drawn; also, various notes, short cuts, and conventional marks may be used more freely on a sketch than would be tolerated on a regular drawing.

3. Method of Procedure.—In sketching an object, it is first fully represented in as many views as are necessary to bring out all the details; the measurements are taken afterwards and written in. This is by far the best plan, as much time may be wasted by trying to take measurements and write dimensions as one sketches. Furthermore, by first fully completing the sketch a better general knowledge of the object is gained, which will help in distinguishing between dimensions that are essential and those that are not. Of this more will be said later.

SKETCHING MACHINE DETAILS

GENERAL REMARKS ON SKETCHING

4. Materials for Sketching.—All that is needed for making a sketch are a lead pencil, paper, and a soft rubber. It is convenient to have the rubber attached to the end of the pencil. Various rubber-tipped pencils are in the market and are readily obtainable from stationers. The paper is best used in letter size, 8″ × 10″ done up in pads, from which the single sheets can be detached one by one. The paper should be heavy, so that it will stand considerable abuse; Manila paper is very good for the purpose. Cross-section paper is well adapted to sketching; the little squares are a great aid in enabling the piece to be sketched in proper proportion and assist materially in producing rapidity. The kind that is divided into $\frac{1}{16}$″ squares is to be preferred. The student, however, is advised not to use it until he has become proficient in making sketches on plain paper, since in actual practice he will frequently be obliged to make sketches on plain paper, and he will find it very difficult to do this if he has learned to depend on cross-section paper. The student should not use it in the work done in connection with this paper. It must be kept in mind that the sketch is not a correct drawing to scale, and the student should be guided by the eye entirely, except when making various views of the same object correspond, of which more will be said presently.

5. Sketch of a Single Object Requiring But One View.—As previously stated, one should get along with as few views as possible; in some cases a single view will be sufficient for the sketch, while perhaps two might be called for in the working drawing made from it. Thus, the object illustrated in Fig. 1 can be fully represented by a side view, as shown in the sketch, Fig. 2; nor would the working drawing subsequently made from it require any more, since the view cannot be mistaken for anything else than a stud bolt with a hexagonal head. If the bolt had a square head, only one side would be shown; the fact that two sides are shown in the sketch indicates that the head is hexagonal.

FIG. 1

6. Fig. 3 illustrates an object—a bushing—that might be sketched in a single view, but would probably in a working drawing be represented by

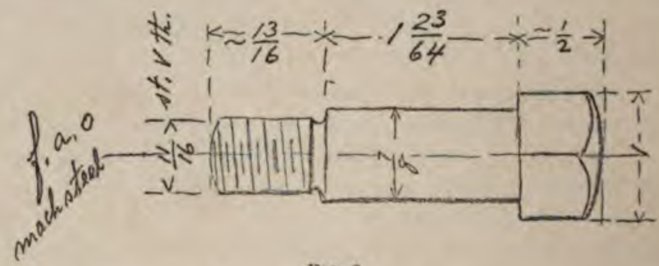


FIG. 2

both a section and an end view, to show that the two rectangles represent cylinders and that there are only two holes in the flange. In the sketch, Fig. 4, the end view may be dispensed with and a note substituted giving the information about the holes. That the body is cylindrical may be indicated conveniently by adding to some of the measurements the letter D, meaning diameter. While such a view is sufficient, an end view alone would clearly not be, as it would not disclose

FIG. 3

the length of the two cylinders, and would, even with the necessary information to that effect, be wholly inadequate to form at once a mental picture of the shape

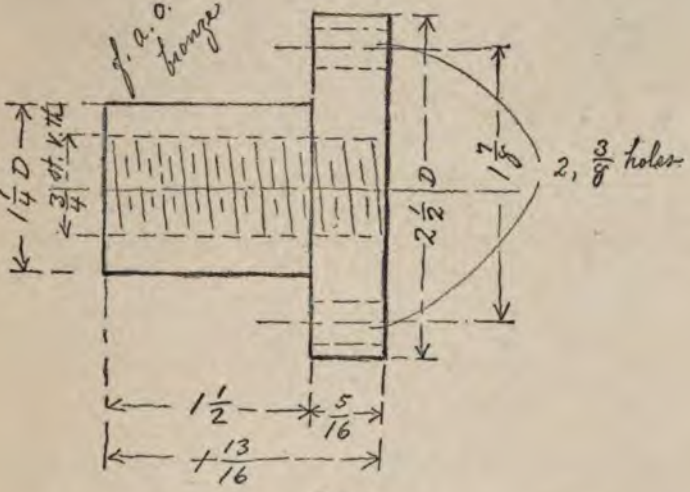


FIG. 4

of the body. It is thus seen that judgment must be used as to what view to sketch. Rather than leave any doubts, two views should be made.

7. Sketch of a Single Object Requiring Two Views.—Fig. 5 is an illustration of an object—a gripper from a printing press—that requires two views: a front view giving the peculiar outline of the piece, and an end view, or a bottom view, to show the width. See Fig. 6. While either the front view and the end view, or the front view

FIG. 5

and the bottom view, would suffice, an end view and bottom view would not. The bottom view is shown in dotted lines, and it is at once evident that this view

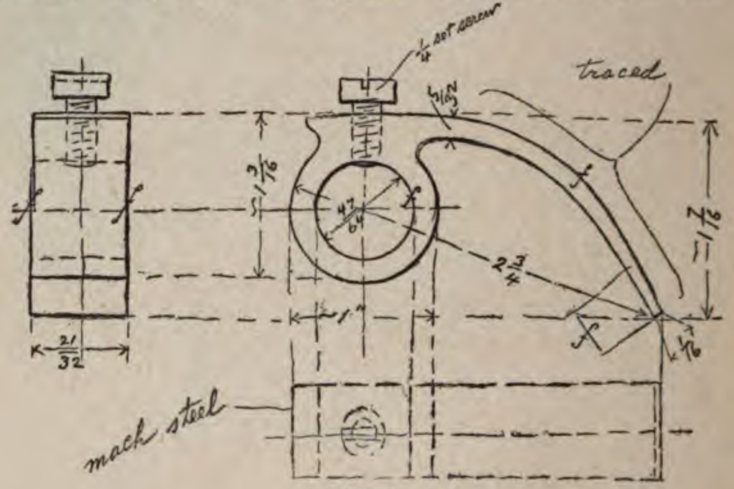


FIG. 6

and the end view would not show the shape of the object in this instance.

8. Sketch of a Single Object Requiring Three Views.—An object is represented in Fig. 7 that is simple in appearance. However, it is necessary to show three views in order that the drawing may clearly bring out its shape. The front view, Fig. 8, is the main view; the side view and plan give the depth of the uprights and base, and they also show, respectively, that the uprights and ends of the base terminate in semicircles. These are features the front view does not show.

FIG. 7

9. Sketch of a Single Object Requiring a Section. Three outside views will, as a general rule, be sufficient to

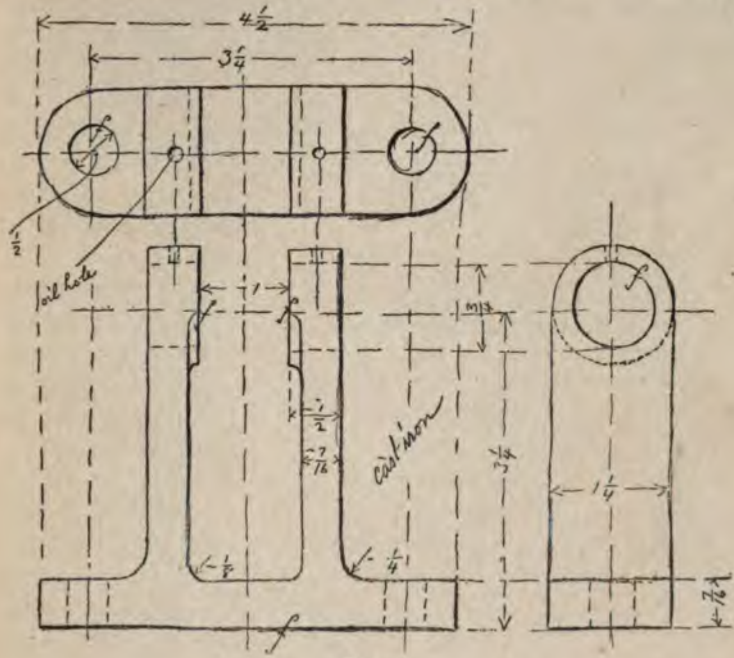


FIG. 8

clearly bring out the details of any object, even if the object is hollow and outlines are thus hidden from sight. In many cases, as, for instance, in the case of the bushing shown in Figs. 3 and 4, dotted lines may be employed to point out such hidden features. Often, however, many dotted lines become confusing, and it is then much better to make a section, that is,

FIG. 9

to imagine the object cut along a certain plane and one of the parts removed, a sketch being made of the remaining part. Fig. 9 is an example of such an object—a safety collar. A side view and front view, Fig. 10, give all the outside features. To show everything of the inside in a single section, a so-called conventional section has been taken along the broken line *a b c* of the front view. This enables the draftsman to show both the hemispherical cavities—in one of which the setscrew is placed with its head below the outside circumference, so it cannot catch on the clothing—and the holes with rectangular cross-sections cored in the casting to secure lightness. The section further shows the offset in the middle of the shaft hole, leaving only a comparatively small surface at each side to be finished and fitted to the shaft. It also shows that the end surfaces are not planes but concave surfaces. A section along a line *c d*, equivalent to the dotted lines in the front view, would not

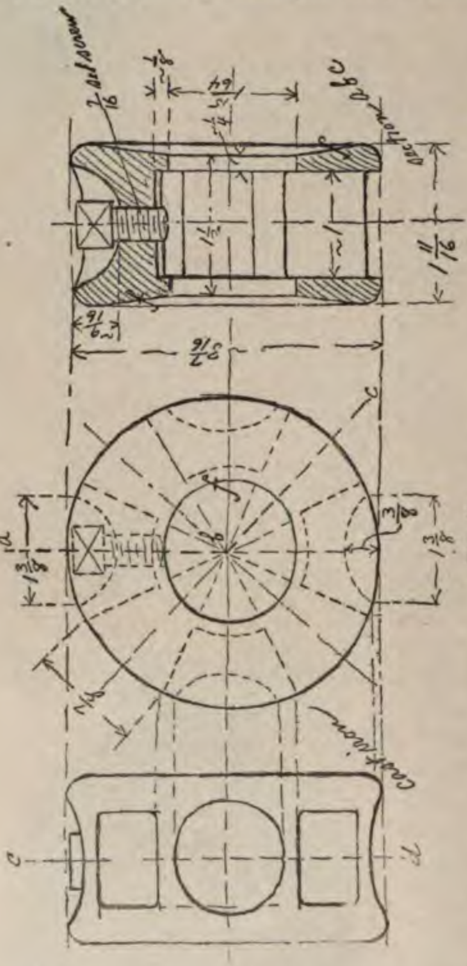


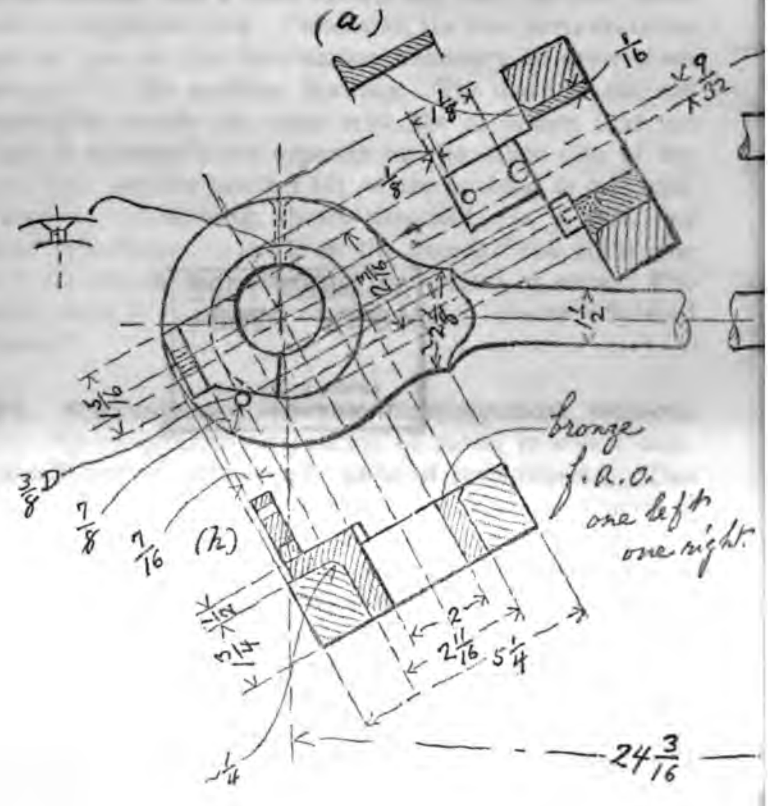
FIG. 10

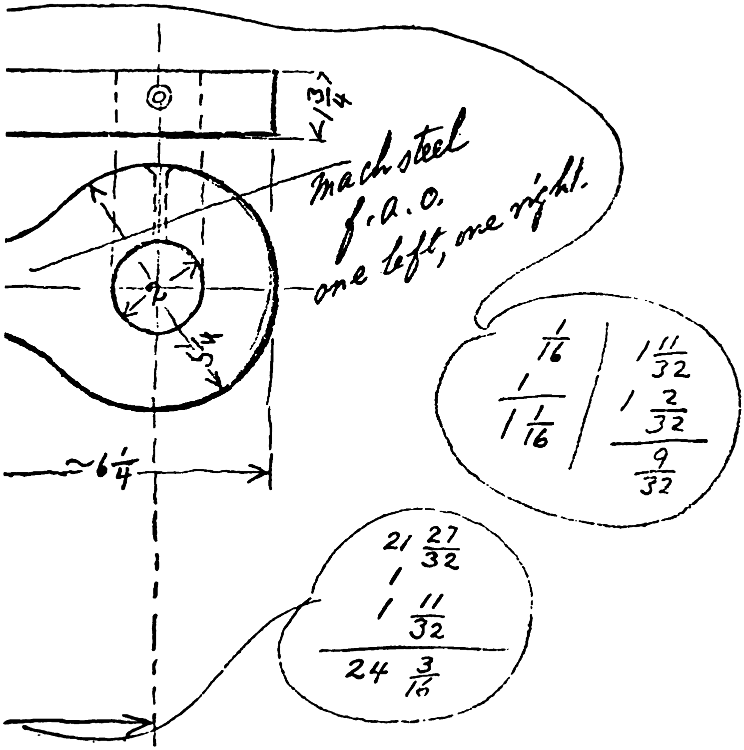
FIG. 11

show these latter features clearly and would therefore not be sufficient.

10. Sketch of Two or More Objects Fitted Together.—When a combination of parts is to be sketched, such as an entire mechanism, it is advantageous in several respects to sketch them as a whole first. The following is gained thereby: a clear idea is acquired of how the various parts fit and work together; many dimensions will have to be taken but once. After having gained all the information possible without taking the mechanism apart, each piece is removed one by one, sketching while doing so any additional features that may present themselves, which may even call for additional figures. Fig. 11, which shows one of a pair of connecting-rods from a printing press, is an illustration. The two parts fitted together are the rod proper, having two eyes, one of which is provided with an eccentric bushing having a bracket of peculiar shape. In taking the view of the combination as a whole, the bushing was observed to have a larger outside diameter in the front than in the back. To find out how far into the eye the larger part extended, the bushing had to be slipped out, when it was seen that the larger diameter was due simply to a slender shoulder following the rounding of the edge of the eye of the rod proper, and a little sketch (*a*), Fig. 12, was jotted down to emphasize this. Otherwise, the two parts sketched together give all the information necessary to draw them separately on the working drawing. The mate of the rod sketched is exactly the same with the exception that the $\frac{3}{8}''$ pin is symmetrically opposite on the other side of the center line, and the bracket (*h*) of the bushing is reversed, as seen on the bushing, shown detached. In a case like this it is sufficient to mark on the sketch "one right, one left," the sketch thus covering four pieces at once. The abbreviation *f. a. o.* found on this sketch means "finished all over."

11. Fragmentary Views: Symmetrical Objects. Many objects present a repetition of parts, in which case, it is sufficient to sketch only parts of such objects. This is particularly the case in objects that are symmetrical with reference to certain lines so that the sketch will also be symmetrical to such lines, which are called axes of symmetry. An **axis of symmetry** is any line so drawn, that if the part of the figure on one side of the line be folded on this line, it will coincide exactly with the other part, point for point and line for line. The use of fragmentary sketches must not, however, be carried too far, using the expedient only when it is of real help—when it saves time and it does not make the sketch clearer, to draw the view in full. Thus, it would not help much to show only half of the bolt (Fig. 1), the bushing (Fig. 3), the gripper (Fig. 5), the bracket (Fig. 7), or the collar (Fig. 9), as these pieces, though they are symmetrical to a certain center line, are as easily sketched in full. Cases in which fragmentary sketches may be made are


(a)
bronze
f.a.o.
one left
one right.
3/8 D
7/8
7/16
2
2 11/16
5 1/4
24 3/16


3/4
mach steel
f.a.o.
one left, one right.
2
5 1/4
~6 1/4
1/16
1
1 1/16
1 11/32
1 2/32
9/32
21 27/32
1
1 11/32
24 3/16

symmetrical machine frames, as shown in Fig. 13 and sketched in Fig. 14, or pulleys and other wheels, as shown in Fig. 15 and sketched in Fig. 16.

FIG. 13

12. Center Lines and Proportions.—In starting a sketch, decide on a view that seems to disclose most of the features of the object. Select one of the most striking dimensions,—as, for instance, the total length or total height of the piece to be sketched,—and mark

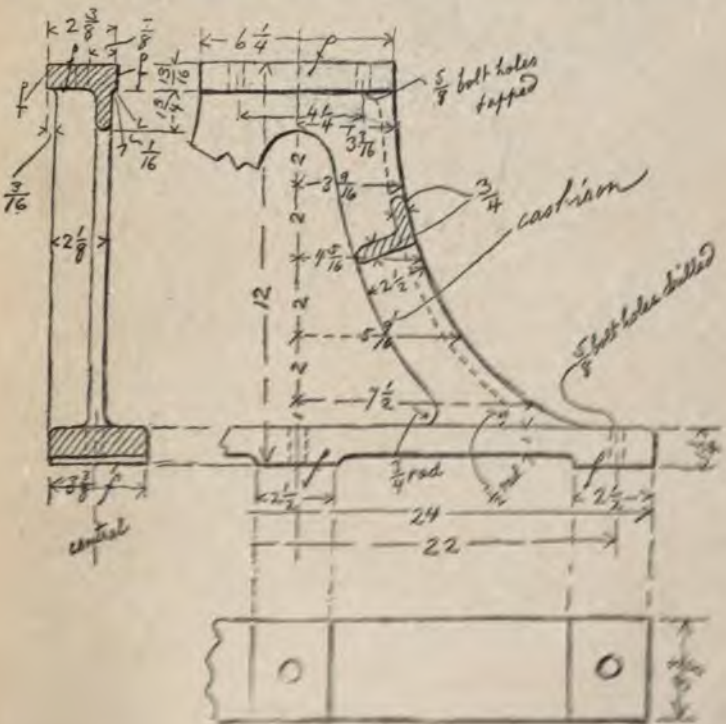


FIG. 14

down a distance on the paper that represents the dimension. Then, until the sketch is completed, this forms the basis to proportion the other dimensions, by comparing them mentally with it. If the object is symmetrical to certain axes, draw these axes first. Thus, in round pieces like those shown in Figs. 1 and 3, draw the center line. Although measurements are not taken from these imaginary lines, they are of great help in guiding the eye while making the sketch. This is especially true in the case of circles. When more than one view is sketched of an object, the center lines at once serve to bring various views in proper relation to one another. Thus, in sketching

FIG. 15

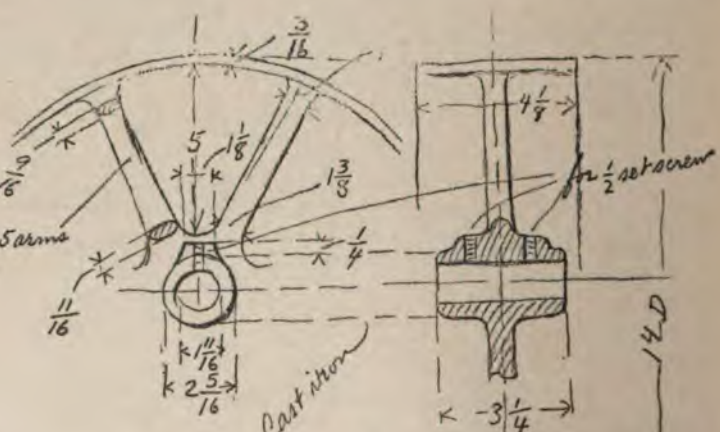


FIG. 16

the object, Figs. 7 and 8, the front view is drawn first, starting with the center line, dividing the figure vertically into symmetrical halves. Next draw the base line, and then the center lines of the bolt holes in the base at equal distances right and left of the main center line; draw the center line of the shaft holes in uprights parallel to and at the proper distance (judging by the eye only, of course) from the base line, and around this skeleton of center lines, draw the outlines of the object. When the front view is finished, start the plan. To do this, prolong the main center line, also the center lines of the holes in the base. Draw a horizontal axis of symmetry parallel to the base and the axis of the shaft, thus obtaining a skeleton of center lines for the plan around which to draw it. Proceed similarly with the side view, carrying over the center line of shaft holes and drawing a new axis of symmetry parallel to the main center line of the first view.

13. Projection Lines.—In sketching various views of an object, use will be made of the principles of geometrical drawing, and projection lines will be drawn from one view to the other. Such lines should be traced on the sketch very faintly, and many of them only mentally, as they will make the sketch confused if used too freely or made too heavy.

14. Shade Lines.—It is not customary, as a rule, to employ shade lines on a working drawing. They are, however, recommended on sketches, as they tend to make the sketch clearer, without entailing much expenditure of time, and no artifice should be spared that will effect this, especially as a sketch may be laid aside a long time before the finished drawing is made.

15. Sections and Cutting Plane Lines.—Sections must be placed in the sketch in proper position toward the lines of section along which they are taken. The proper position alone will indicate in most cases along which line the section is taken, but in so-called conventional sections it is necessary to make the cutting plane line very plain and to note near the sectional view the line of section, as done, for instance, in Fig. 10. There are two sections in Fig. 12; one is taken on the center line passing through the center of both the eccentric hole of the bushing and the center of the eye of the rod; the other section is really a conventional section, the section of the eye being taken on the center line passing through the center of the eye, and the section of the bushing being taken on the center line passing through its own center. There is no need of mentioning this on the sketch, however, as no one will suppose that a measurement is taken of the dimension of the eye along the line passing through the center of the eccentric bushing.

16. Cross-Sectioning Material.—No distinction is made on a sketch between materials by means of cross-section lines—the name of the material should be written on the sketch.

17. Finish Marks.—Finish marks should be placed in the sketch wherever lines represent finished surfaces, except in those cases where it is evident from the nature of the pieces that the surfaces must be finished, such as surfaces fitted together. The principle to be followed in making a sketch is in general: Give all the data necessary, but avoid unnecessary marks and lines.

MEASUREMENTS

MEASURING INSTRUMENTS

18. The instruments to be used in measuring the dimensions of an object for the purpose of making a sketch and subsequently a working drawing depend to a certain extent on the accuracy required. To explain more fully, suppose one of the eccentric bushings on the connecting-rod for a printing press, Fig. 11, to be so worn as to need replacing, but that the press is to be kept running while a new piece is being made. A very accurate measuring of the dimensions is then necessary, as the piece must fit exactly. On the other hand, suppose a whole machine is to be rebuilt from an existing pattern, and that for this purpose drawings are to be made which henceforth shall be considered standard. The dimensions need not necessarily be as accurate as in the first case, as the various pieces of the new machine will be fitted together when assembling. In the former case, it may be necessary to employ much more delicate instruments than in the latter case, so that in general it may be said that a draftsman may in the long run make good use of any measuring instrument to be found in the market. For ordinary cases, however, the tools here enumerated and described will be found amply sufficient.

19. The Two-Foot Rule.—The best-known tool for measuring linear dimensions is the two-foot rule, which is

(a)

(b)

FIG. 17

usually made up of four leaves, hinged together, to allow it to be folded for convenience in carrying, as shown in Fig. 17. The rule is usually made of boxwood, with brass joints and edges. It is divided into inches and fractions of an inch. Divisions smaller, however, than $\frac{1}{16}''$ are rarely marked on them, so that the smallest fraction that can be directly measured is $\frac{1}{16}''$, but with a little practice it is possible to locate the middle and quarter points between the sixteenth-inch marks with a fair degree of accuracy, thus making it possible to measure distances as small as

$\frac{1}{32}''$ and $\frac{1}{64}''$. The two-foot rule is well adapted to comparatively rough work, where accuracy of measurement is not particularly essential.

20. The Standard Steel Rule.—For more accurate measurements, steel rules are used. These rules are always graduated on both edges of each side, and a large choice of different kinds of graduations is offered by the makers. For use in sketching, two kinds of rules, both 12 inches long, will be found very essential. One has divisions of the inch into 8 parts on one edge of the one side, into 16 parts on the other edge of the same side, and into 32 and 64 parts on the two edges, respectively, of the other side. The other rule has divisions of the inch into 10, 20, 50, and 100 parts on the four edges, respectively.

21. Steel Tapes.—In measuring distances greater than a few feet, steel tapes are very convenient. They are made in lengths varying from 2 feet to 100 feet for shop use. The graduations are not very fine; hence, tapes are only suitable for approximate measurements. For a special use of a pocket steel tape, see Art. **33.**

22. The Straightedge.—It is very convenient to have a straightedge among the tools, although any straight piece of metal or wood, the blade of a square (see Fig. 18), may be used instead in an emergency.

23. The Square.—An instrument that comes into frequent use is the square. It is best to have one with an adjustable blade, called an *adjustable square*, and shown in Fig. 18. The blade *a* is held in the stock *b* by means of a hook clamp that enters the groove *c* in the blade, and is tightened by means of the nut *d*. The stock can be set at any point throughout the length of the blade, and also, of course, flush with the end of it, and thus serves also as a *solid square*. A special bevel blade *e* for testing angles of 45° and 30° is generally furnished with this square.

The stock is also usually provided with a level at *f* that may be used in testing either a vertical or a horizontal surface.

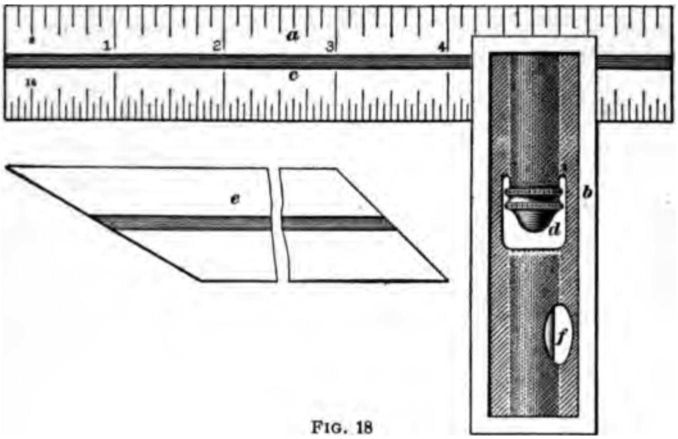


FIG. 18

It should be borne in mind that a square is perfect only when the blade and stock are exactly at right angles to each other, and that a fall or any careless use is liable to destroy its accuracy.

24. Calipers.—Calipers are of almost endless shapes and sizes. They are used to measure either the diameters or lengths, from a small fraction of an inch to several feet. The simplest forms of calipers are shown in Fig. 19. Fig. 19 (*a*) illustrates *outside calipers*, used for taking outside measurements of shafts, wheels, and similar articles, and Fig. 19(*b*) shows a companion tool, the *inside calipers*, which, as the name implies, is used to measure the

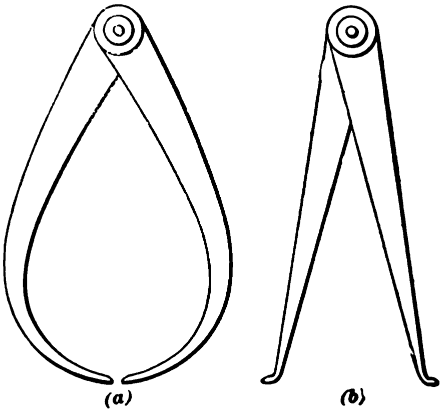


FIG. 19

diameter of holes, or the distance between two objects. Another class of calipers is provided with an adjusting screw, as shown in Fig. 20 (*a*) and (*b*). Calipers are often used to measure the outside diameter of screws, and when so used are made as in Fig. 20 (*a*), except that the contact surfaces *a* and *b* are made wide enough to reach across two or more threads. Similar calipers are used to measure the bottom of screw threads, in which case the points are beveled and thin, like a knife blade.

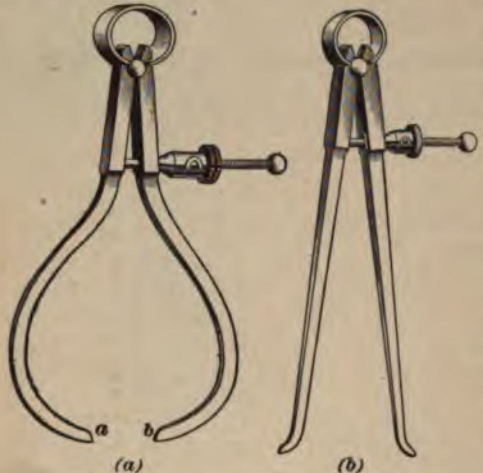


FIG. 20

25. The Plumb-Bob.—The **plumb-bob** is often very convenient to have among the tools used in sketching, although any small piece of metal, as a nut, a penknife, or other small, heavy object tied to a thread does equally well in most instances, since it does not often happen in sketching that a plumb-line must be established over a certain point; in this latter case, a regular plumb-bob having a sharp point would be required, as shown in Fig. 21.

FIG. 21

FIG. 22

26. Surface Gauge.—A **surface gauge** consists of a flat base to which is attached a vertical standard that carries an adjustable scriber. Fig. 22 shows a simple form of this instrument. Its use in sketching, as well as that of the other tools described, will be more fully treated in the following pages.

TAKING MEASUREMENTS

27. Writing Measurements on the Sketch.—After the sketch itself is completed,—or when in a combination of objects fitted together, as a whole machine, the sketch has been completed as far as that is possible without taking the combination apart,—the taking of measurements is begun. *Each measurement must be put down on the sketch as soon as it has been taken.* The student should never take several measurements one after another with the intention of writing them down on the sketch together. He is certain to make mistakes, causing himself and others considerable annoyance in using the sketch afterwards.

The ascertaining of dimensions of an object by measuring often calls for considerable ingenuity, and sometimes methods of the draftsman's own devising will be resorted to that are not found described in the following pages, which contain, however, those in most frequent use.

28. Distance Between Two Points on a Plane Surface.—This is the simplest measurement; it is taken by means of the rule, and needs no explanation. Most frequently the points between which the dimension is wanted are located on the edge of a flat surface, that is, in the corner of two flat surfaces meeting as, for instance, in Fig. 14, the top and bottom measurements ($6\frac{1}{4}''$ and $24''$) of the stand.

29. Length of Cylindrical Surfaces.—A measurement equally simple is to find the length of cylindrical surfaces by means of the rule, as, for instance, the lengths ($1\frac{1}{2}''$ and $\frac{5}{16}''$) of the two cylinders in Fig. 4, or the length of the shank of the tap bolt ($1\frac{23}{64}''$) of Fig. 2.

30. Round and Otherwise Undefined Corners: Distance Between Parallel Planes.—Often one of the points, or even both, the distance between which is to be ascertained, is imaginary, as, for instance, when there are round corners. In such cases the adjoining surface must be prolonged so that a sharp corner is established. For instance, the length ($1\frac{11}{16}''$) of the safety collar, Fig. 10, could not be measured directly with the rule, but the collar had to be placed between two flat surfaces, and the distance between the latter measured. This was most conveniently done by laying the collar on a plane surface and using the adjustable square, as shown in Fig. 23.

FIG. 23

In the same manner, the square must be used to get the over-all dimension ($1\frac{3}{16}''$) of the bushing, shown in Fig. 4. See Fig. 24. As will readily be observed, this method is really equivalent to taking the shortest, that is, perpendicular, distance between two parallel planes.

31. Thickness.—It is not always convenient or possible to measure distances between parallel planes, real or imaginary, by means of the plane surface and adjustable square, as shown in Figs. 23 and 24. In such cases, the outside calipers are used; thus, while the distance across flats of the hexagonal head of the bolt, Fig. 1, may be measured with the plane and square, it is more convenient

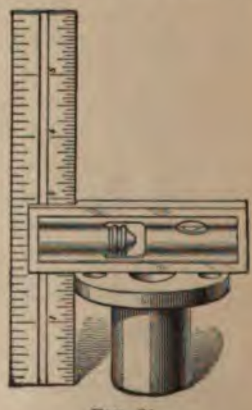


FIG. 24

to use the calipers, while the thicknesses ($\frac{3}{8}''$) of the webs in the cast-iron stand, Figs. 13 and 14, must be measured with the outside calipers, if the measurement is to be accurate, the corners being round. Such dimensions are called *thicknesses.*

32. Distances Between Curved Surfaces: Outside Diameters.—The outside calipers are also used to ascertain dimensions of curved surfaces. Thus, the dimension ($1\frac{3}{16}''$) between the top of the piece, Fig. 6, and the bottom is measured with the outside calipers. Logically, all outside diameters are measured with the same instrument. The procedure is as follows: Open the calipers approximately wide enough to let the body to be measured pass freely between the points. Then, by gently tapping the calipers against some convenient object, a frame near by, for instance,

FIG. 25

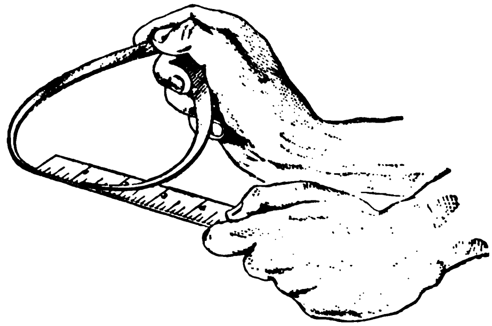


FIG. 26

gradually close (or open) the legs until the points just touch the body measured. See Fig. 25. There should be no play, nor should the points pinch too hard. It requires a little practice to get the proper touch by tapping the calipers. The process is easier with spring calipers, having screw adjustment, shown in Fig. 20.

After the calipers are properly adjusted, the distance between the points is measured with the steel rule in the manner shown in Fig. 26.

33. It often happens that very large diameters are to be measured, for which the calipers available are too small, as in the case of pulleys, wheels, and similar objects. Often in such cases one can measure near enough across the side of such objects, as a pulley, for instance, with a long rule or a stick, but equally as often this cannot be done on account of other parts being in the way; for instance, when a pulley is keyed to a shaft, perhaps near to a hanger besides. In most cases the steel tape furnishes excellent means for getting at the diameter, by measuring the circumference of the wheel or pulley and dividing the same by 3.1416. Thus, if the circumference as measured with the tape is 7 ft. $\frac{1}{16}''$, the diameter is 7 ft. $\frac{1}{16}'' \div 3.1416 = 7.0052$ ft. $\div 3.1416 = 2\frac{1}{4}$ ft., very nearly = 2 ft. 3″.

34. Inside Dimensions: Holes.—To measure inside dimensions, such as the diameters of holes, for instance,

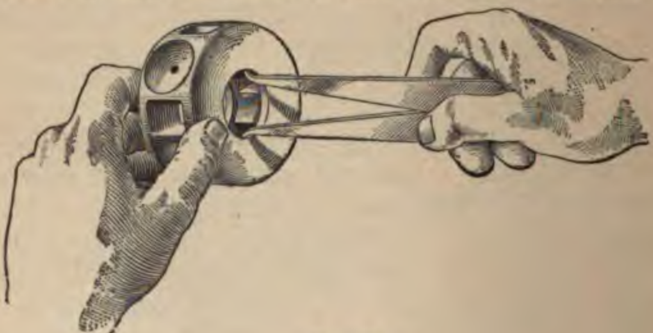


FIG. 27

the inside calipers are used, as in Fig. 27. The procedure is identically the same as with outside calipers, but care must be taken in tapping the instrument not to strike on the points, as these will be easily injured thereby. After the instrument is adjusted, the distance between the points is again measured with the rule, as shown in Fig. 28.

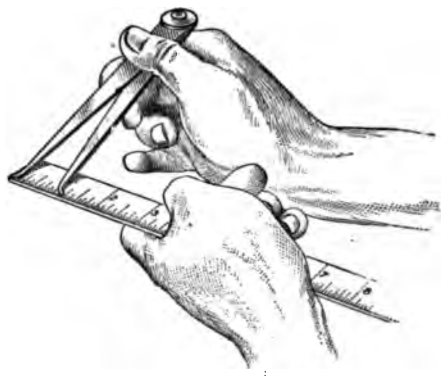


FIG. 28

35. Over-All Dimensions.—When the length of an object is measured in successive steps, as, for instance, the bushing, Fig. 4, it is best also to measure the whole length, which then serves as a check on the measurements previously taken.

36. Exact and Approximate Dimensions.—In the case of most objects some dimensions must be exact, while others may be approximate. Thus, in Fig. 2, the length ($1\frac{23}{64}$") of the shank of the bolt must be measured exactly, as the bolt is to be fitted into the eye of a lever that must move freely, without undue play between the shoulder of the head and the piece into which the bolt is screwed. Suppose that the bolt had been broken off at the screw and a new one was to be made; then it is evident that the shank of the old bolt must be very carefully measured so that the new one will exactly fit the length of the lever eye. The other lengths, that is, the extreme height of the head ($\frac{1}{2}$") and the length of the screw to the top of its rounded end ($\frac{13}{16}$") are clearly not so important. It is permissible to round off such unimportant dimensions to the nearest $\frac{1}{32}$" or even $\frac{1}{16}$", as the case may be. Thus, suppose the length of the screw, Fig. 2, actually measured $\frac{51}{64}$", it would be perfectly correct enough to mark this dimension $\frac{13}{16}$" on the sketch. Other examples are the width and thickness of the base and uprights of the object shown in Figs. 7 and 8. The piece is a casting finished only at the surfaces marked *f, f*. The actual measurements showed the thickness of the base to be between $\frac{13}{32}''$ and $\frac{15}{32}''$ and the thickness of the upright varied between about the same figures. This was evidently due to the shaking of the pattern in the mold, and the thickness intended was no doubt $\frac{7}{16}''$, so this measurement was marked on the sketch. Likewise, the radii of the fillets joining the uprights and base were "guessed at" more or less (see Art. **43**) to be $\frac{1}{4}''$ and $\frac{1}{8}''$, respectively. In the various sketches a number of such dimensions that have been rounded off, averaged, or more or less arbitrarily fixed are marked with a little wavy line preceding the figures. See Figs. 8, 12, etc.

37. Establishing Centers.—Distances between two centers, as of two shafts, two holes, or distances between a center and a surface, etc., cannot in the majority of cases be measured directly with any of the instruments, and it requires considerable ingenuity and care at times to establish such dimensions. The following are a few examples.

A case very frequently occurring is the establishing of the distance between centers of two holes, as, for instance, in the connecting-rod, Figs. 11 and 12. This dimension ($24\frac{3}{16}''$) is here obtained by measuring the distance between the inside edges of the holes ($21\frac{27}{32}''$), and adding to this measurement half of the diameter of each hole, measured with the calipers, the result being $21\frac{27}{32}'' + \frac{2}{2}'' + \frac{2\frac{11}{16}''}{2} = 21\frac{27}{32}'' + 1'' + 1\frac{11}{32}'' = 24\frac{3}{16}''$. Fig. 11 also furnishes another illustration: the distance between the center of the outside circle of the eccentric bushing and the center of the inside circle, that is, the eccentricity of the two circles. To find this, measure the thickness of the bushing at the thinnest part ($\frac{1}{16}''$), add to it half of the diameter of the inner circle, and deduct this sum from half of the diameter of the outside circle; thus, $\frac{2\frac{11}{16}''}{2} - (\frac{1}{16}'' + \frac{2}{2}'') = 1\frac{11}{32}'' - (\frac{1}{16}'' + 1'') = 1\frac{11}{32}'' - 1\frac{1}{16}'' = \frac{9}{32}.''$

38. If the holes are of the same size, the distance between centers is at once obtained by measuring from the outside edge of one hole to the inside edge of the other, as, for instance, the distance $3\frac{1}{4}''$ between centers of bolt holes in Fig. 8, and $4\frac{1}{4}''$ and $22''$ in Fig. 14. Similarly, the distance between the center of the shaft holes in the object, Fig. 7, and the bottom of the base is obtained by measuring the distance from the bottom of the hole to the bottom of the base and adding to this the radius of the hole. The first dimension is, however, not directly measurable with a rule, but must be gotten by prolonging the bottom line of the hole by means of some convenient straight piece and the square, as shown in Fig. 29. This straight piece must, moreover, be round in section, as its under edge would not otherwise represent the prolongation of the bottom line of the hole. At first sight it might seem as if this dimension might have been taken more easily by measuring the total height of the piece and deducting therefrom the thickness of the metal on top of the hole and the radius of the latter; but this would not give a reliable measurement, as the piece is not finished on top, while the bottom is, and as the dimension sought is an essential one,

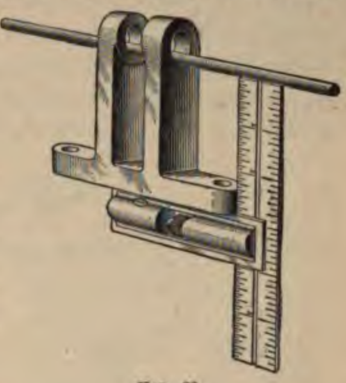


FIG. 29

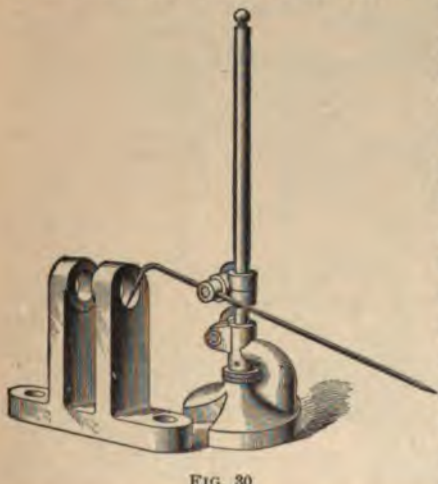


FIG. 30

it must be accurate. An easier way to get the measurement, however, is by the use of the surface gauge. The gauge is adjusted so that the point of the scriber lightly touches the bottom of the hole; the scriber is then removed and the distance from the plane to the point measured. See Figs. 30 and 31.

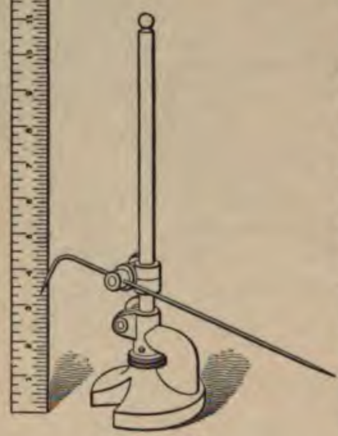


FIG. 31

Another example of finding the distance of a center from a plane surface is shown in Fig. 32. The adjustable square is used to find the distance from the top of the frame of the machine, which is finished, to the top of the collar below. To this is added half of the diameter of the collar, ascertained by means of the outside calipers.

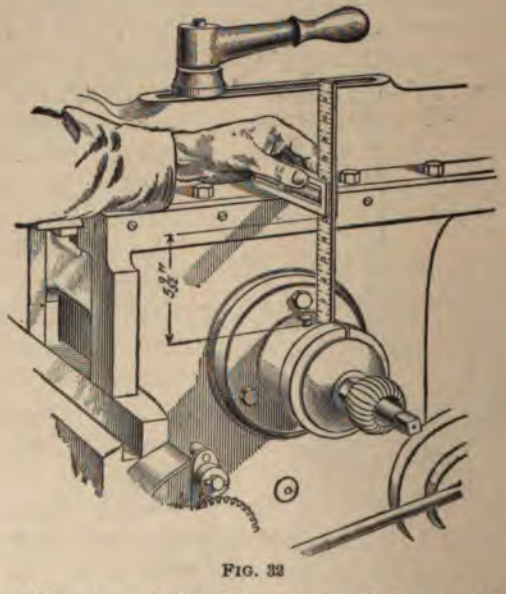


FIG. 32

A further example is given in Fig. 33. It was required to measure the horizontal distance of the center of the shaft from the vertical finished front of the machine. The square could not be used in the same manner as in Fig. 32, as the sliding carriage, already in its lowest position, was in the way. The dimension had thus to be transferred higher up, as it were. The plumb-bob was conveniently suspended, so that the plumb-line just touched the left side of the disk.

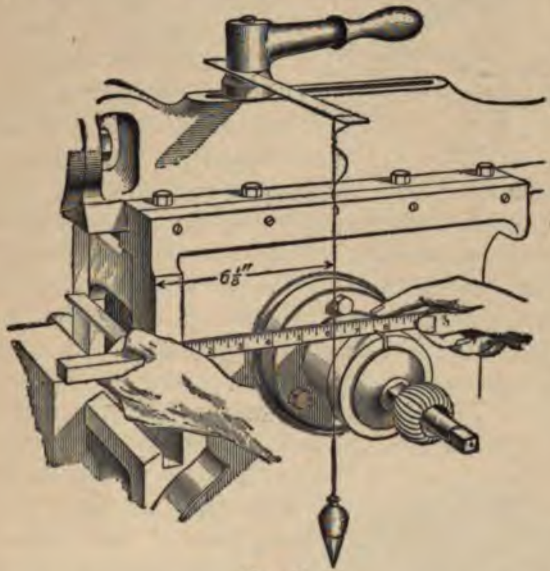


FIG. 33

Next, the distance between this line and the front of the machine was measured and one-half of the diameter of the disk added thereto. Before this method could be employed, however, it had to be ascertained whether the machine so stood on the floor that the front surface of the frame were vertical. It was found not to be the case, and had to be wedged up on one side to make it so.

39. Centers of Gear-Wheels: Pitch of Gears.—The distance between centers of two gear-wheels in mesh must be measured with particular accuracy, as it furnishes the only clue to accurately ascertain the pitch of the gears. If the shafts are accessible, either in front or back of the gears, the distance between centers is easily established by measuring the distance between the shafts by means of inside calipers if the distance is short, or by means of two steel rules slid one upon the other, if the distance is greater. See Fig. 34. To this measurement the radii of the shafts are added. If the shafts are flush with the wheels, so that the distance between centers cannot be measured in the above way, and if there are no hubs to make use of, the distance may be obtained by measuring across the wheels themselves and deducting their outside radii. This method will be absolutely exact only, however, if the number of teeth in both wheels is even, because, if the number is odd, the outside diameter cannot be measured accurately with the calipers; there is a tooth on one end of the diameter and a space on the opposite end, the measurement being between the point of the tooth on the one end of a diameter and the point of the tooth next to the space at the other end of the diameter. The difference between the dimensions so obtained is, however, but very slight in ordinary cases.

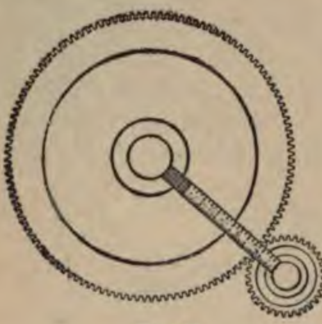


FIG. 34

40. Having by some means ascertained the distance between centers, the diametral pitch* is found by dividing the sum of the teeth of both wheels by double the distance from center to center, and the circular pitch† by multiplying

* The diametral pitch is a number indicating the ratio between the number of teeth and the pitch diameter; thus, 4 (diametral) pitch means that there are four teeth to each inch of the diameter, so that a wheel that has this pitch and has a pitch diameter of 5 inches has $5 \times 4 = 20$ teeth, or a wheel that has 4 pitch and 20 teeth has a pitch diameter of 5 inches.

† The circular pitch is the linear measure on the pitch circle from a point on one tooth to the corresponding point on the next tooth.

double the distance from center to center by 3.1416 and dividing the product by the sum of the teeth of both wheels, or by formulas:

$$\text{diametral pitch} = \frac{N+n}{2c},$$

$$\text{circular pitch} = \frac{6.2832c}{N+n},$$

in which N = number of teeth of large wheel;
n = number of teeth of small wheel;
c = distance from center to center.

By calculating both pitches it is generally recognized by what system they are constructed. Thus, if the calculation yields, for instance, a whole number, or a whole number and a half, or a whole number and a quarter, for the diametral pitch, but an awkward decimal number for the circular pitch, it is fair to assume that the gears are cut to the diametral pitch indicated by that number. If the calculation yields an awkward decimal number for the diametral pitch, but a whole number, or a whole number and simple fraction for the circular pitch, it is fair to assume that the gears are cut to circular pitch.

Thus, the distance between the gears, Figs. 35 and 36, is by measurement $11\frac{37}{64}''$ $(= 11.578''+)$ from center to center. There are 15 teeth in the pinion, or small gear, and 124 teeth in the large gear. The diametral pitch is thus

$$\frac{124+15}{2 \times 11.578} = \frac{139}{23.156} = 6.003,$$

or 6, very nearly.

The circular pitch is

$$\frac{6.2832 \times 11.578''}{124+15} = .5233'',$$

that is, between $\frac{33}{64}''$ and $\frac{17}{32}''$.

FIG. 36

It is thus very evident that the gears are cut to 6 diametral pitch. As a proof, using 6 for the diametral pitch, the distance from center to center is:

Pitch radius of large wheel + pitch radius of pinion $= \frac{1}{2}\left(\frac{124}{6}+\frac{15}{6}\right) = \frac{139}{12} = 11\frac{7}{12}'' = 11\frac{37\frac{1}{3}}{64}''$, as against $11\frac{37}{64}''$ from actual measurement, the difference being only $\frac{1}{3}$ of $\frac{1}{64}''$, or $\frac{1}{192}''$.

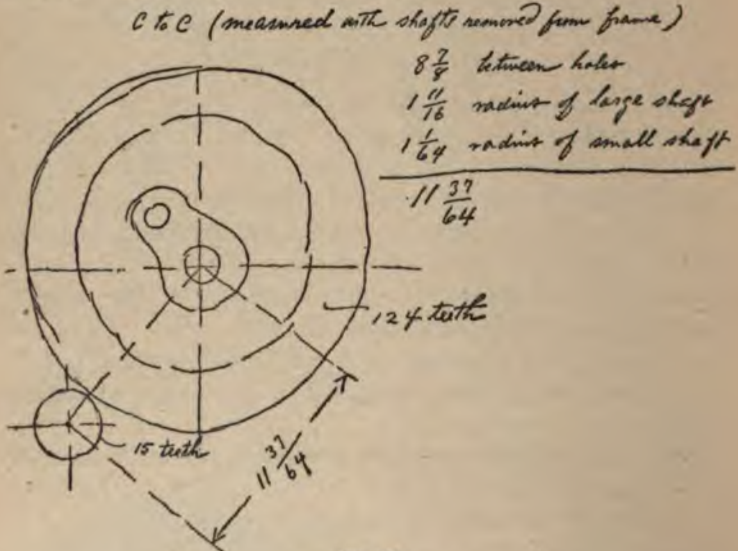


FIG. 36

In taking dimensions of gear-wheels, it is generally more exact to measure with a rule having inches divided into 100 parts.

41. The method of finding the pitch from the distances between centers is the only exact one, but cannot always be employed; in many cases, the circular pitch must be measured directly at the point where the two wheels are in mesh, guessing more or less at the location of the pitch line; this will be quite close, however, since the teeth touch at the pitch line when passing through the line connecting the centers of the wheels. This method must be employed invariably with miter and other bevel gears; it should always be employed as a check.

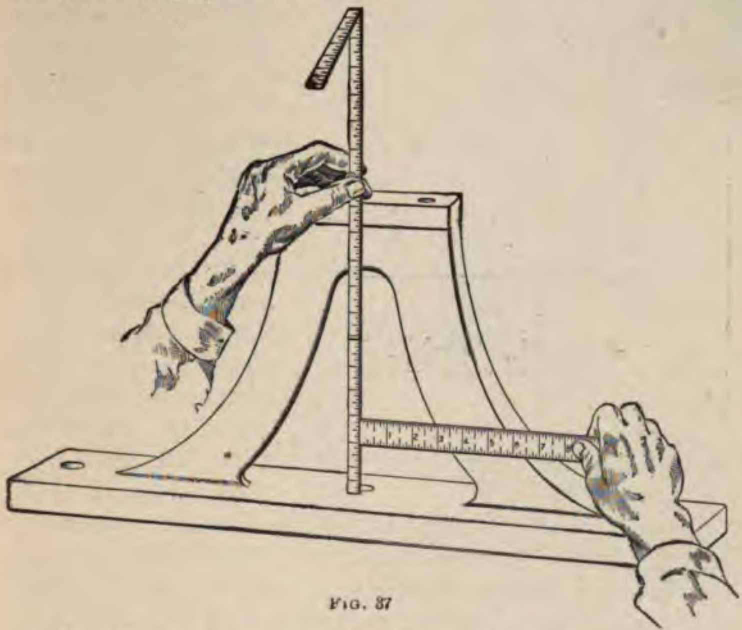


Fig. 37

42. Curved Outlines: Fillets.—Curved outlines, such as occur in machinery frames, sometimes give considerable trouble in sketching. Fortunately, the dimensions are in such cases seldom required to be exact, and the measurements can be rounded off. The frame, Fig. 13, is an example. To get the curved outline of the stand, the two-foot rule was held vertically in the center and horizontal measurements taken at various points of the rule, as illustrated in Fig. 37.

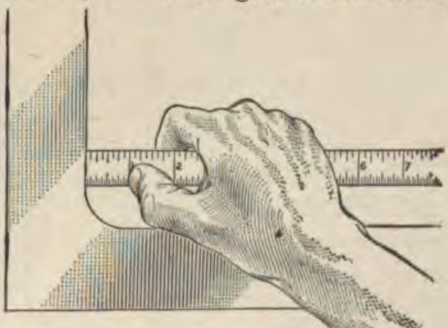


Fig. 38

43. Sharp corners are avoided in machine frames whenever possible, and rounded off by fillets. It is generally sufficient to measure the radius of such fillets approximately. Small ones may be judged entirely by eyesight, placing the rule against the surface of the object where the curve begins and reading off a length equal to the distance of the rule from the other surface. See Fig. 38. Large fillets are best measured by means of the

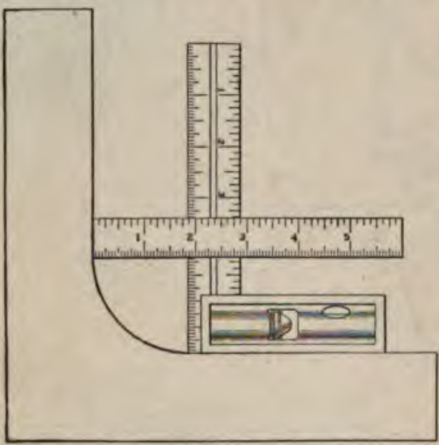


FIG. 39

rule and square, placing, as before, the rule against one surface of the object where the curve begins and the square on the other surface, sliding it against the rule until both indicate the same distance, as illustrated in Fig. 39.

There are cases, however, in which it is essential to get a curved outline very exactly. In such cases it is best, if possible, to trace the outline by placing the object on the sketching pad and run the pencil point along the curves, as was done with the curved piece, Figs. 5 and 6. Evidently this method cannot always be resorted to, as, for instance, when the object is large or when the curve is so located on the object that it cannot be traced. The cam shown

FIG. 40

in Fig. 40 is an example. In such cases nothing short of a templet will suffice, made of either stiff paper or even tin

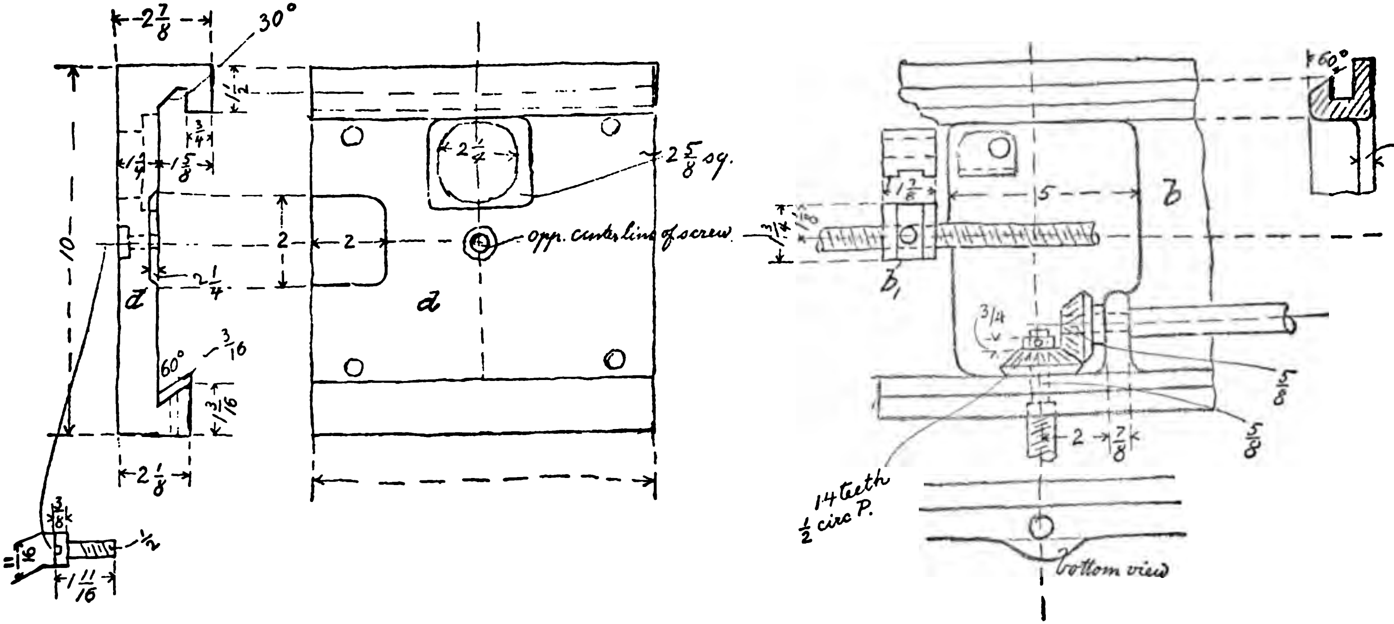


FIG. 41

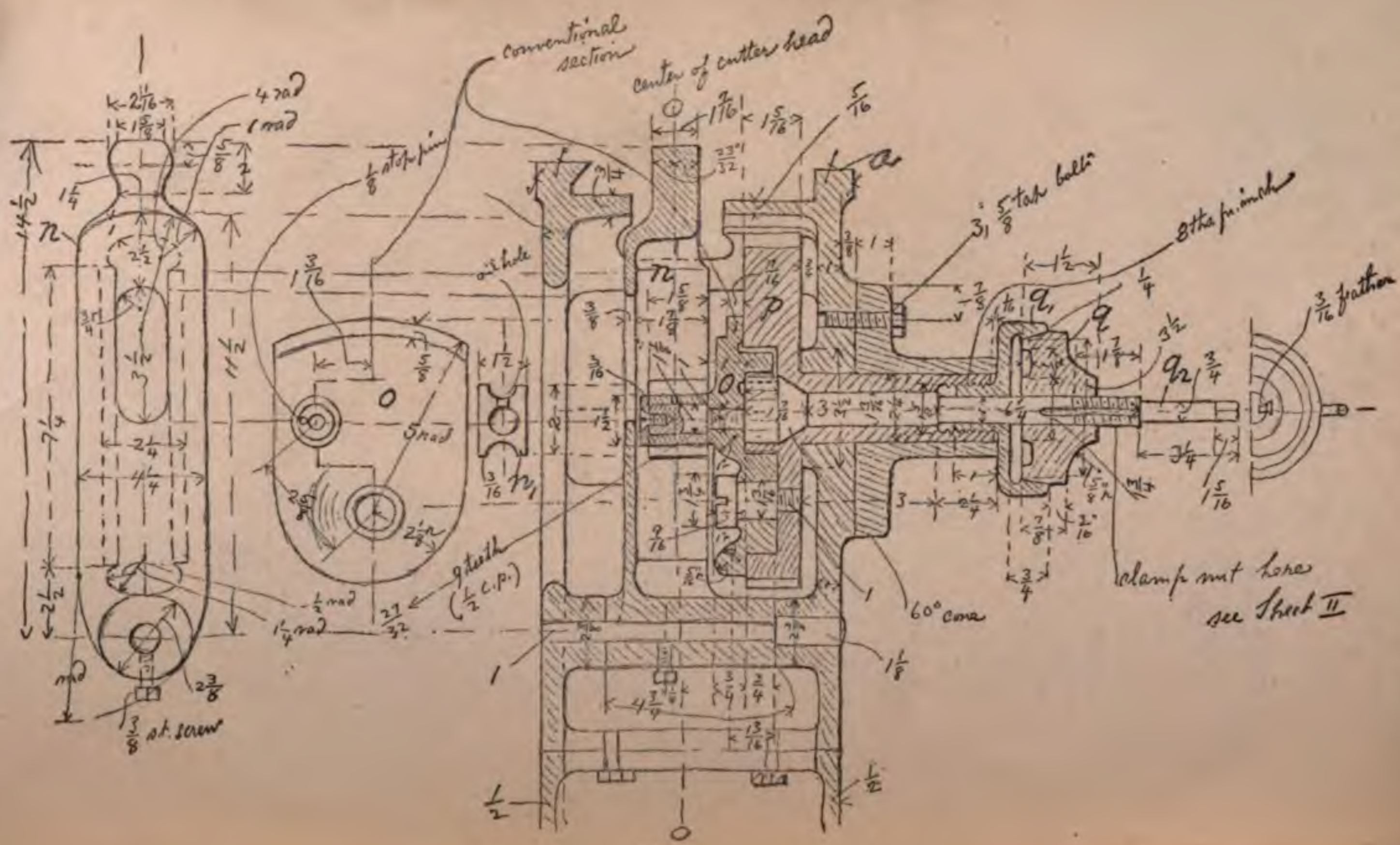

conventional section
center of cutter head
oil hole
9 teeth (1/2 c.p.)
3/8 st. screw
4 rad
1 rad
5 rad
1/2 rad
1 1/4 rad
3, 5/8 tap bolts
8 ths per inch
3/16 feather
60° cone
clamp nut here
see Sheet II
n
n₁
o
p
q
q₁
q₂
a
1/8 stop pin

plate. The sheet is placed over the curve and by gentle taps with the hand or a peen hammer the outline is transferred.

SKETCHING COMPLETE MACHINES

NOTE.—The student is requested to read the following pages with great care, and he is invited to ask questions concerning anything he does not understand. The sketches are exact reproductions of the original sketches, which were made by an experienced draftsman. While the student would not be expected to make sketches of such a complicated machine as this until he had had considerable experience, yet he can derive great benefit from a careful study of these sketches and their description.

44. In order to further illustrate what has been said in the foregoing articles, a complete set of sketches as actually taken from a machine are here added. The machine is a shaping machine, or, as it is called, a **crank-shaper,** illustrated in Figs. 43 and 44. The function of this machine is to cut into or plane the surfaces of any work fastened to the table seen in front; the cutting operation is performed by a tool held by a reciprocating slide, while the work is moved at right angles to the direction of motion of the tool (or vertically) a certain amount called the *feed* after every stroke, either automatically or by hand.

The five accompanying illustrations are large folders, and to distinguish between these and the other cuts, they have been designated as plates and numbered according to the Roman notation.

45. In accordance with the principle laid down in Art. **3,** the machine was first sketched in its entirety, in four views: a front view (Plate I), a plan (Plate II), a right-side view (Plate III), and a partial left-side view (Plate IV). Each of these views requires a whole sheet of the sketching paper; then various details were sketched and also a sectional elevation of the frame (Figs. 41 and 42 and Plate V).

The side view was started and finished first; next the front view, and lastly the plan. After these views were completed, the various measurements were taken, those being taken first which could be ascertained without removing any of the parts. Most of the outside dimensions, either of the frame or of the parts fastened to it, were obtained at this time; likewise, the distances between shaft centers, by the methods shown in Figs. 32 and 33.

After obtaining as many dimensions as possible without dismantling the machine, and especially such dimensions as are common to pieces fitted together, one part after another was taken off to get at other dimensions. The dismantling must be done very cautiously, so as not to miss a single point of importance. Wherever necessary, separate sketches should be made of parts that would be represented on too small a scale in the main view to be clearly seen. In such cases it is advisable to draw a line from these separate details to the main view, indicating the places where they belong, as shown on Plates I–V, and Figs. 41 and 42.

46. It should be remembered that the various dimensions are rarely found more than once in the sketches, and that dimensions of one and the same part may often be found in entirely different places, perhaps in connection with the part to which it is to be fitted. It is therefore necessary that the draftsman clearly understand the construction and function of the machine before he attempts to lay out a drawing from the sketches.

The reference letters used in the following description are to be found on the sketches, Plates I to V and Figs. 41 and 42, and the sketches should be studied in conjunction with the text illustrations, as the student, by means of the latter, will get a better understanding of the shape and location of the parts.

47. The fundamental part of the machine, as seen in Figs. 43 and 44, is the *frame*, or *column*, *a* (Plates I and III), provided on its face with vertical rails a_1, along which the *cross-rails* *b* may be made to move up or down, by means of the vertical screw visible below it. This screw may be turned by the pair of bevel gears, shown in Fig. 45, one of

which is keyed to the shaft having a crank at one end. The *saddle d* is moved along the cross-rail *b* by means of a

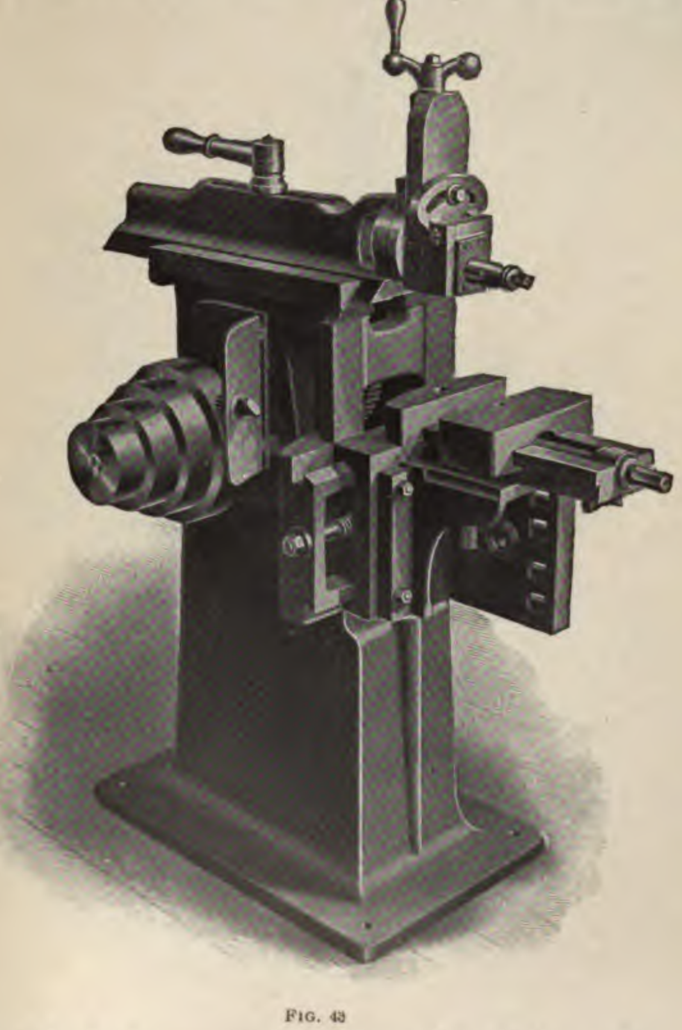


FIG. 43

nut on the feed-screw; see Figs. 44 and 45, the latter showing the nut detached from the saddle. When the feed-screw is turned by hand or automatically by the mechanism to be described farther on, the saddle may be made to move either to the left or right, according to the direction in which the screw is turning.

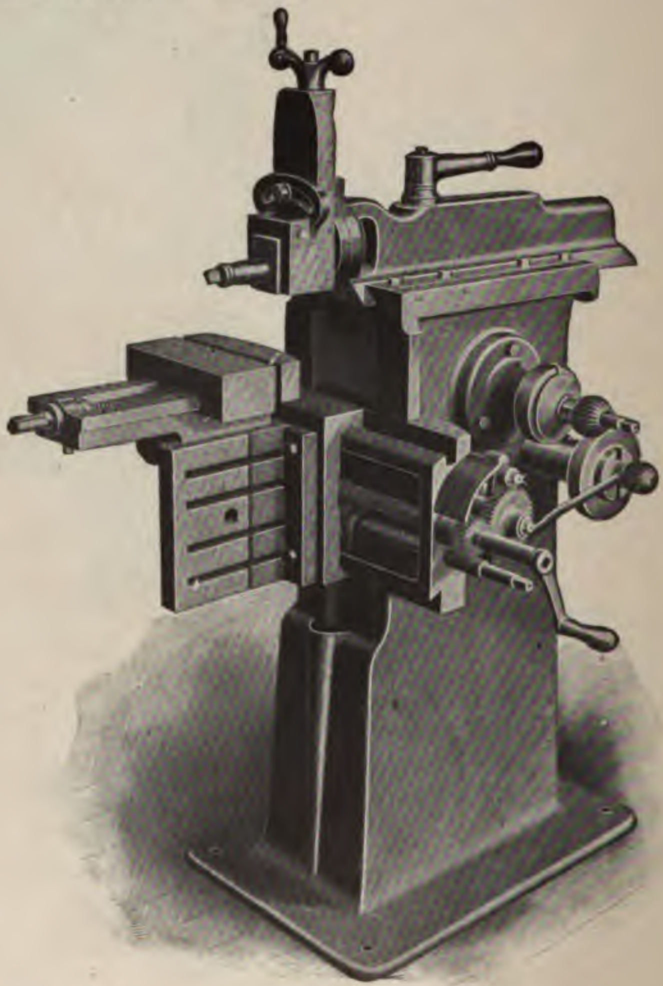
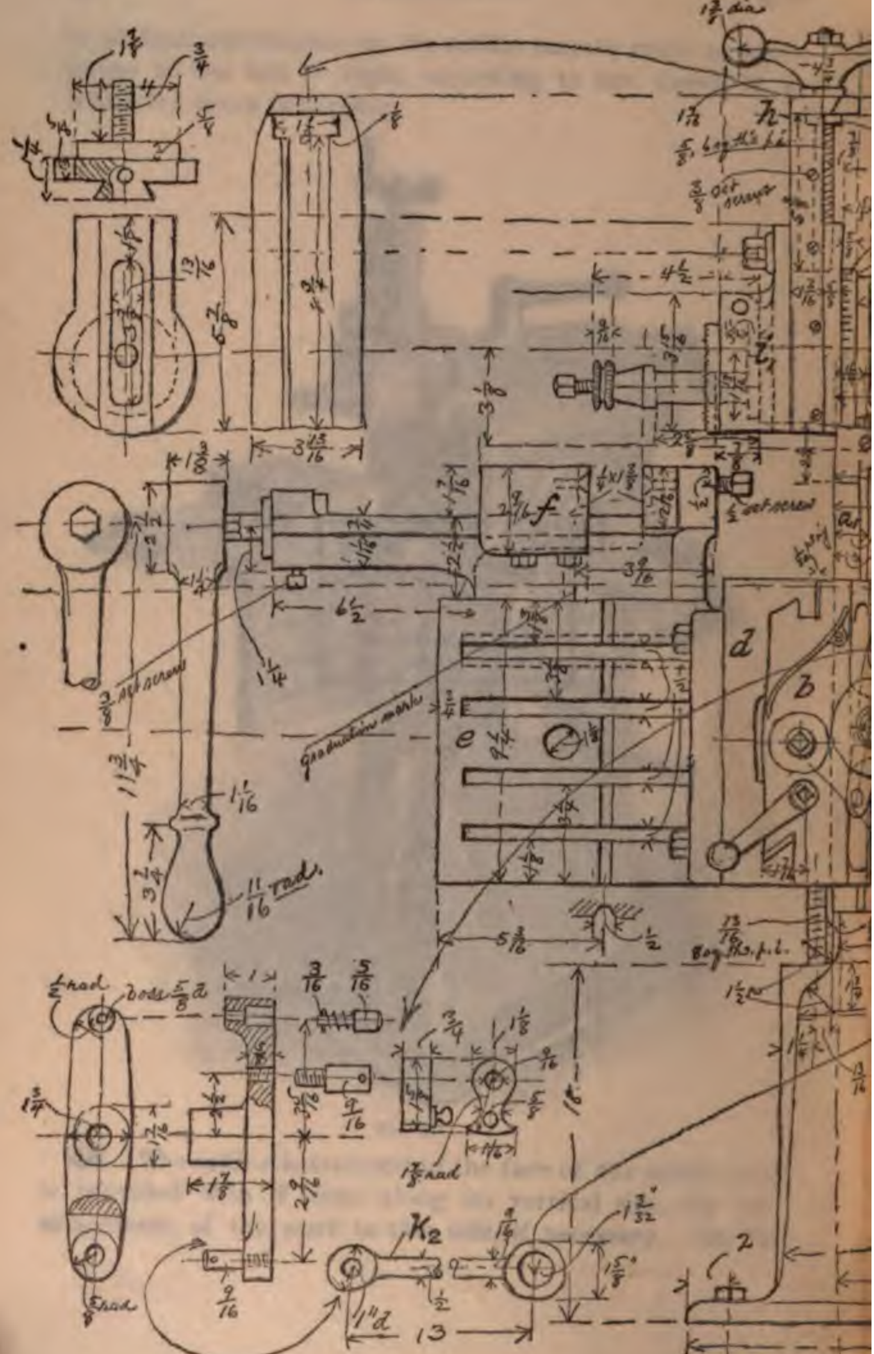
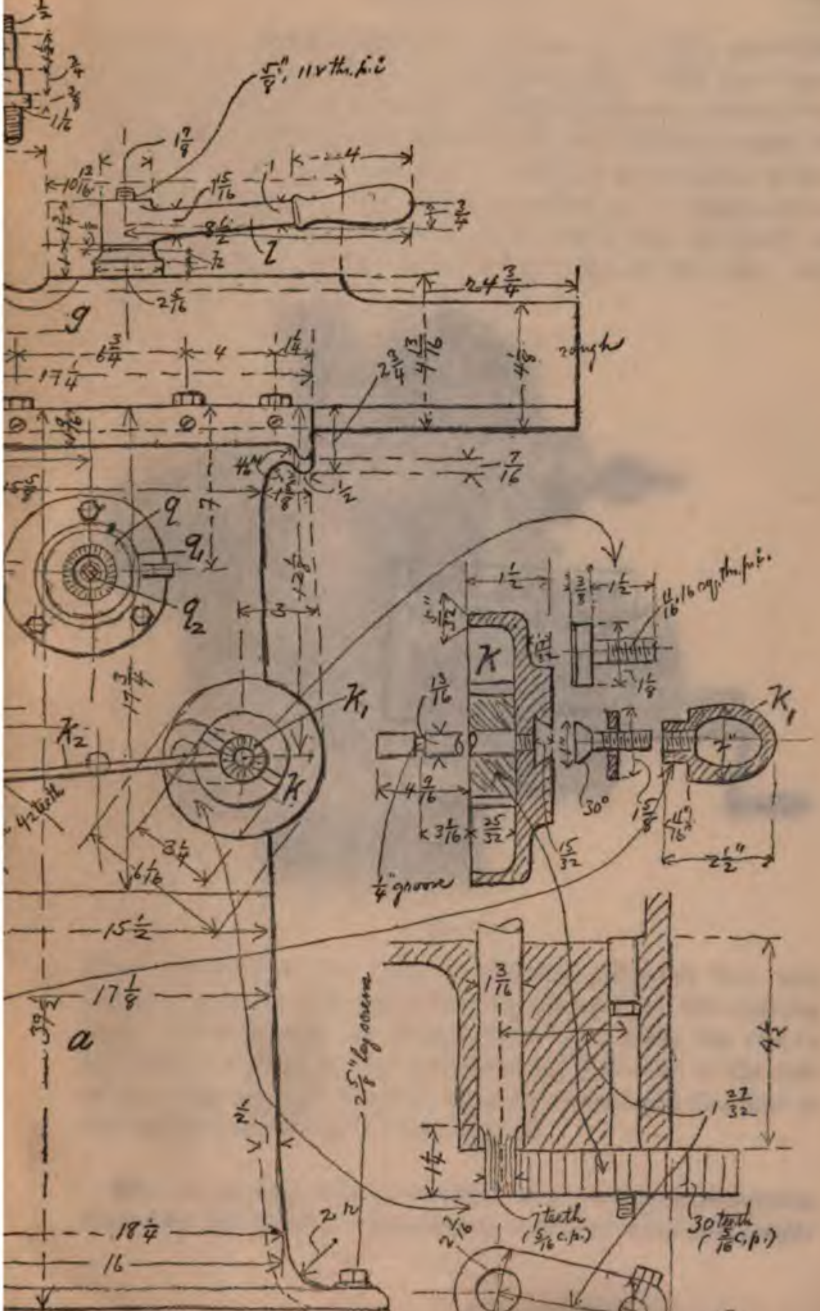


FIG. 44

48. The *table e* is fastened to the face of the saddle and is provided with **T** slots along its vertical side, for the attachment of the work to this side, if necessary. On its



graduation marks
set screw
11/16 rad.
K2
1"d
13
16"
d
b
e
f



g
q
q_1
q_2
K
K_1
K_2
l
rough
a
¼" groove
30°
7 teeth (5/16 c.p.)
30 teeth (3/16 c.p.)

top side it supports the *vise f* (Plates I, II, III), provided with one stationary and one movable jaw. The front jaw may be moved in and out by turning the screw (Plate II) to adjust the distance between the jaws for different sizes of work, and to hold it securely. The vise is swiveled on the table, and may be held in any position by a clamp screw underneath. Graduations on the table are intended to register with a mark on the lower edge of the vise. By

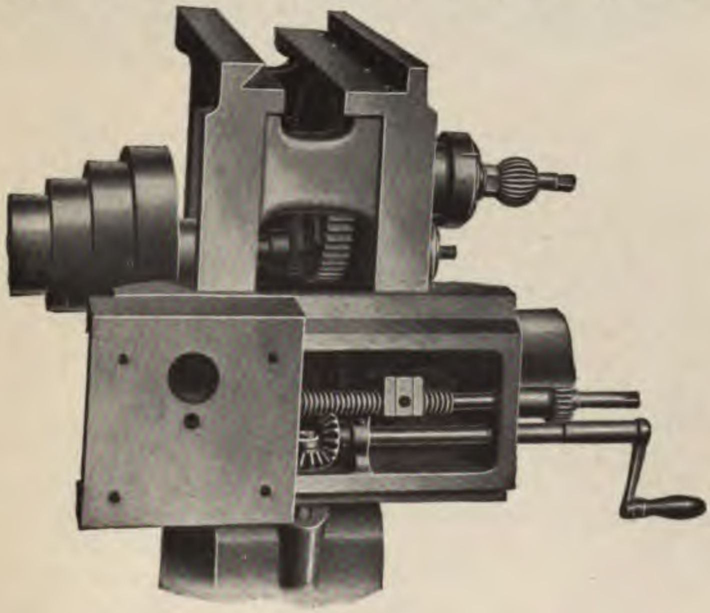


FIG. 45

these means the vise may be quickly adjusted into any angular position with reference to the path of the cutting tool. By loosening the clamp screw that holds the vise to the table, the vise may be detached and fastened to the side of the table by inserting the clamp bolt through the hole in the center; see Plate III and Fig. 44.

49. A cutting tool is inserted in the tool post projecting from the *tool block i*. The latter, together with the *shaper* *head h*, is fastened to the *ram g* and can be adjusted. The ram moves forwards and backwards in a longitudinal direction, between beveled guides, carrying the tool over the work. It should be noted that the tool block *i* is not rigidly attached to the shaper head *h*, but that it is able to swing

FIG. 46

on a pin in its upper end. This may be better understood by studying Fig. 46, a bottom view of the ram, in which the tool block is seen swung out in a position perpendicular to the face of the shaper head. By being swiveled in this manner, the tool is relieved from any unnecessary pressure against the work during the backward motion of the ram. This is not the only way in which the tool block may be moved relative to the ram. As indicated in the upper right-hand corner of Plate I, in the detail view of the shaper head *h*, the base plate i_1 of the tool block is able to swing in a plane at right angles to the ram around a central screw passing into the shaper head. The curved slot in the upper part of the plate indicates the extent of this angular motion. The purpose of this adjustment is to enable the tool to cut at the proper angle. Whenever such adjustment is to be made, the bolt, projecting through the curved slot, is loosened that the tool block may be swung into the desired position. The whole shaper head is also capable of moving up or down along the beveled guide in the front end of the ram (see Plate II). The handle, visible above the latter in Figs. 43 and 44, is attached to a screw that engages with the ram head. This screw supports the shaper head *h*, and the latter may therefore be lowered or raised by turning the screw in the proper direction (see Plate III). The purpose of this adjustment is to bring the tool down to the work and to regulate the depth to which the tool will cut.

50. The various adjustments mentioned are not sufficient for all purposes; provision must also be made for cases in which the tool has to cut along a plane that is at an angle with the horizontal plane of the machine. In this case the forward motion of the tool after each cut must be in a direction parallel with the plane along which the tool is cutting. For this purpose the head *h* of the ram (see Plates II and III), to which the shaper head is attached, may be swung around a stationary bolt in the ram until the desired angle is obtained. Various angles are marked off on the movable ram head, which, in conjunction with an index on the ram itself, will indicate the angular inclination. The nut engaging with the bolt just mentioned is seen in the recess in the front end of the ram (Plate III).

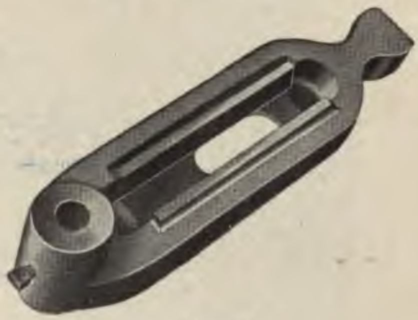


FIG. 47

51. The reciprocating motion is imparted to the ram by means of the oscillating lever *n*, Fig 42, shown detached in Fig. 47 and in position in Fig. 49. The upper end of this lever engages with a fork g_1 (Plate IV and Fig. 46) fastened in a slot in the upper part of the ram, while its lower end is fulcrumed on a rod the end of which is seen in Fig. 49. The point where the stroke of the ram begins and ends, relative to the work, may be determined by the position of the fork in the ram. It may be shifted along the slot, seen in Fig. 46, and held in any desired position by means of the handle *l* engaging with a screw in the fork (see Plate III, Figs. 43 and 44). It should be noticed that the length of the stroke is unaffected by any position the

FIG. 48

fork may occupy. To alter this length, other means are required to be pointed out farther on.

If the jib *m* (Plates II and IV), which is fastened to the frame by the four bolts, visible in Fig. 44, is detached, the

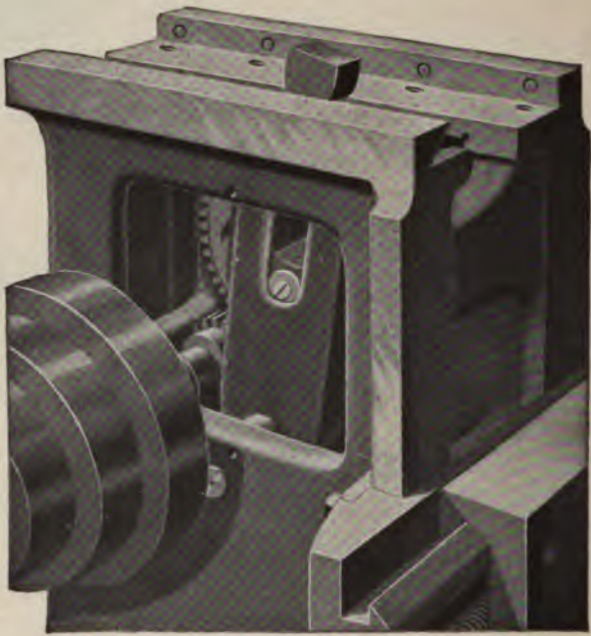
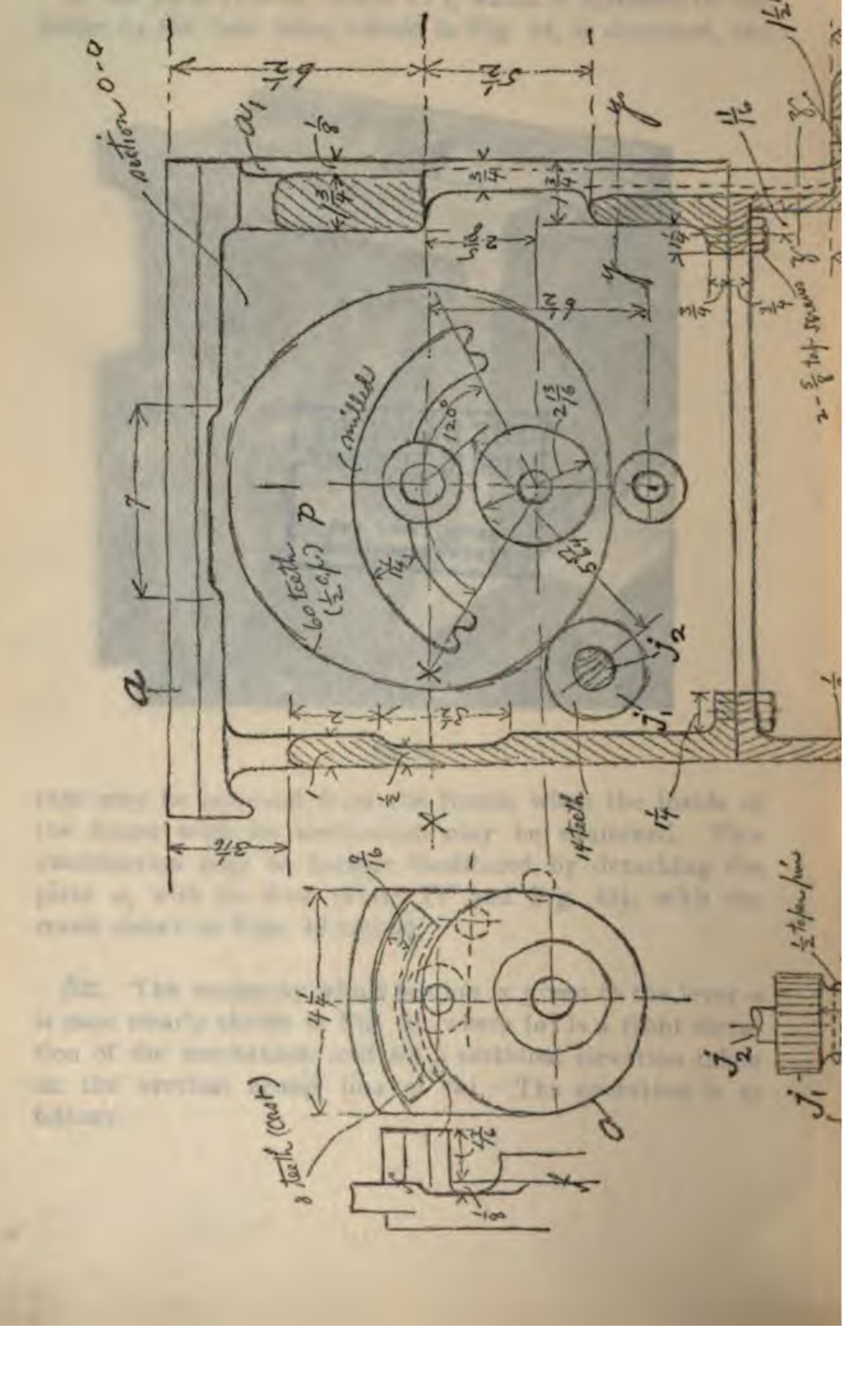


FIG. 49

ram may be removed from the frame, when the inside of the frame with its mechanism may be examined. This examination may be further facilitated by detaching the plate a_2 with its door (Plate IV and Fig. 43), with the result shown in Figs. 49 and 50.

52. The means by which motion is given to the lever *n* is most clearly shown in Fig. 51, where (*a*) is a front elevation of the mechanism and (*b*) a sectional elevation taken on the vertical center line of (*a*). The operation is as follows:



section o-o
60 teeth
(milled)
120°
14 teeth
8 teeth (cast)
2-5/8 tap screws
1/2 taper pin

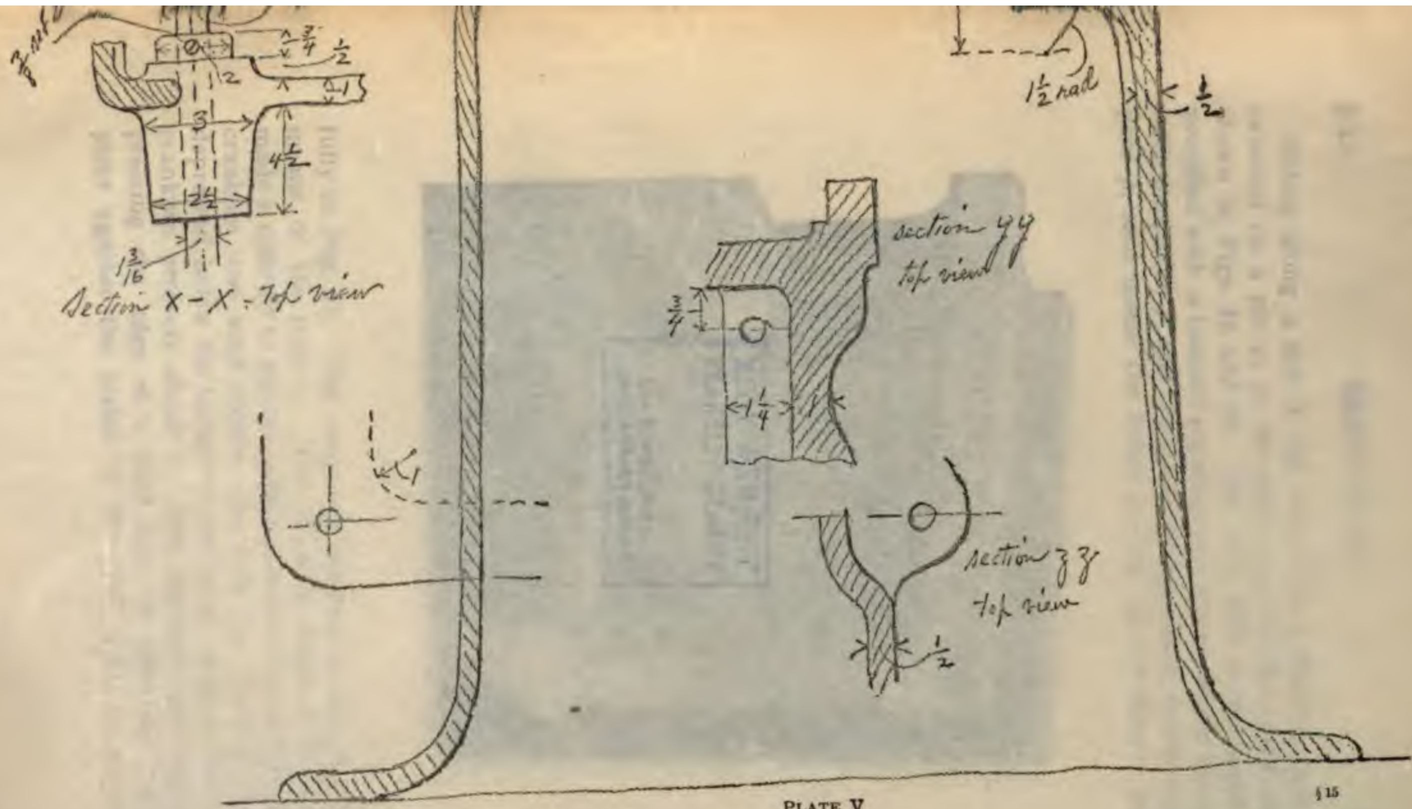
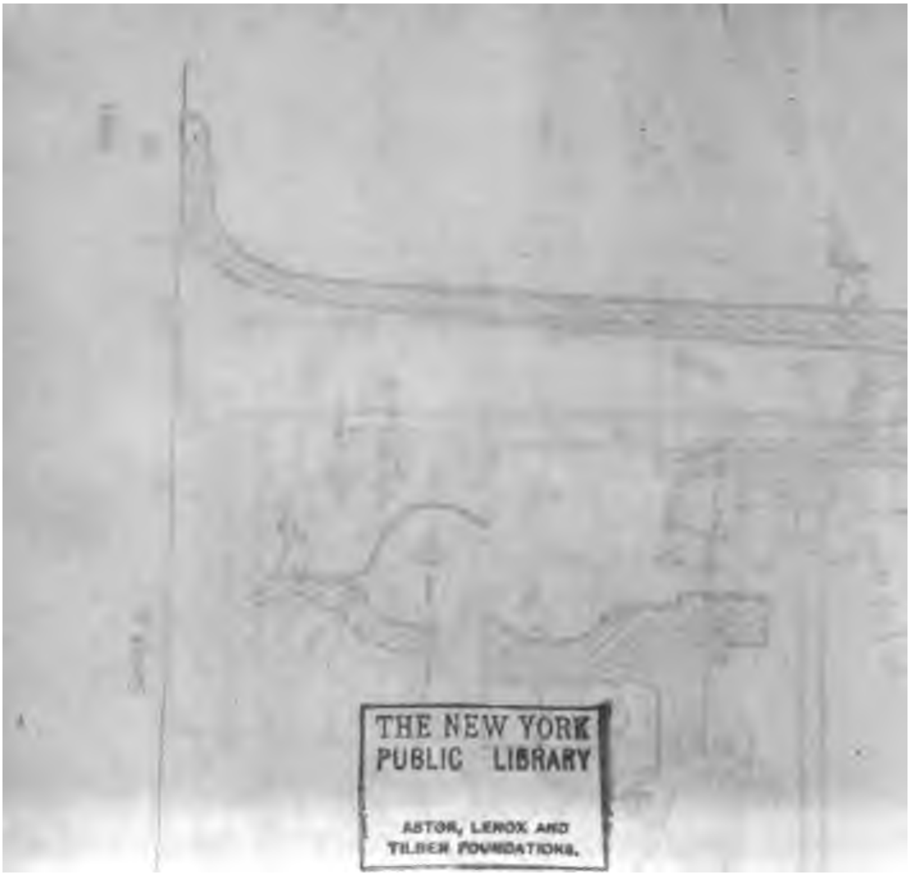

Section X-X - Top view
section y-y
top view
section z-z
top view
1½ rad

PLATE V



Sliding along a slot in the lever *n* is a block n_1 that is swiveled on a pin o_2 in the plate *o*, called the *crank*, also shown in Figs. 48 and 52. The rear side of the crank is provided with a toothed segment and a boss, which engage with the pinion p_1 and the recess, respectively, on the large gear *p*, seen inside the frame in Fig. 50, but shown more

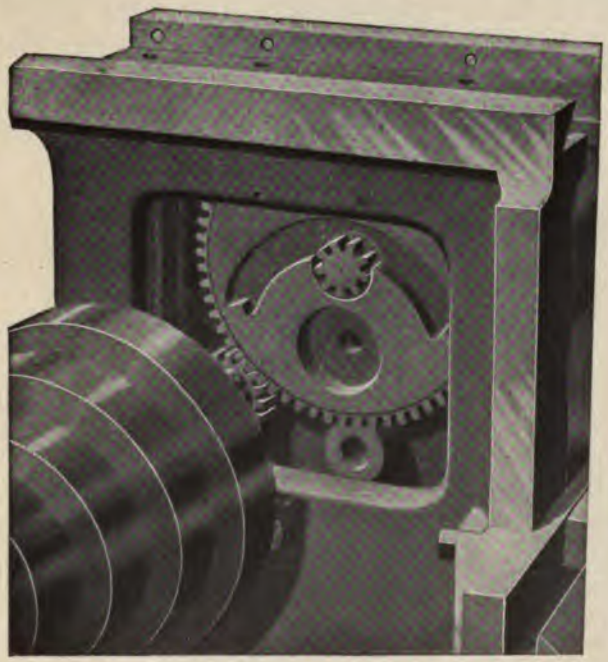


FIG. 50

fully in Fig. 51. The crank *o* is fastened to the gear *p* by means of the stud o_1. The peculiar shape of the crank made it difficult to get the center-to-center distance between crankpin and stud center, the hole for the stud being depressed below the surface of the crank proper, while the crankpin projects above it. The distance was found by pressing the edge of a steel rule or other flat straight piece against the inside of the stud hole, as shown in

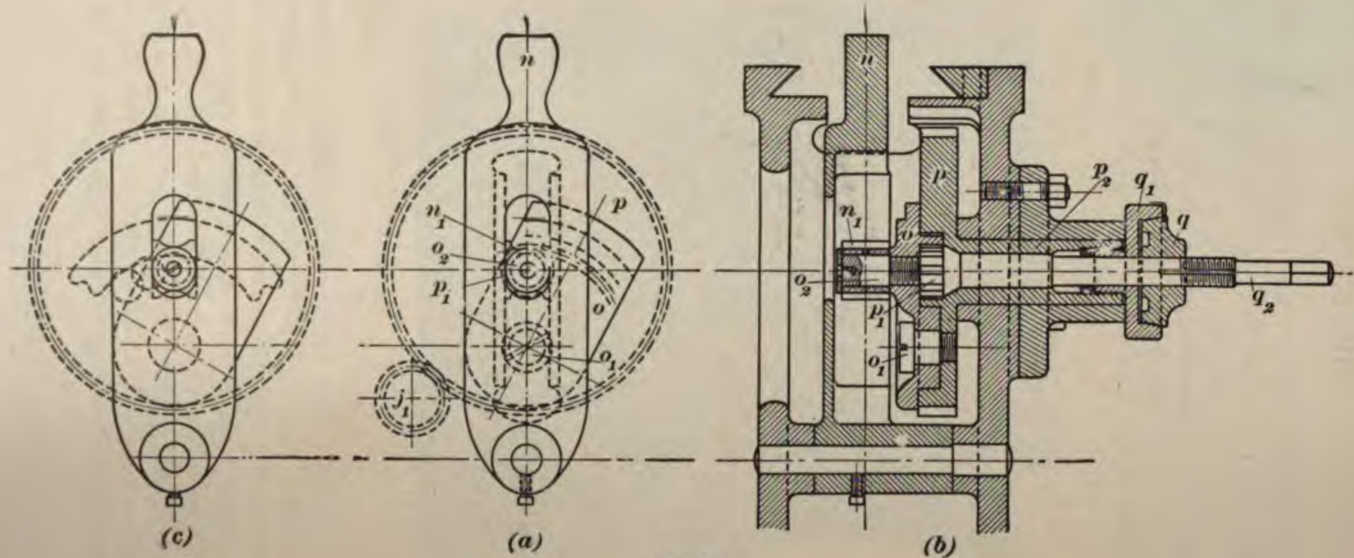


FIG. 51

Fig. 52, and calipering carefully between the edge of the hole and the pin. To this distance is added one-half the diameters of pin and hole. For the present it will be assumed that the pinion p_1 is in one piece with the gear p. When, therefore, the gear p is revolving, the crank will revolve with it, and also the block n_1, giving an oscillating motion to the lever n. The extent of this motion will depend on the distance between the centers of the block n and the gear p. Motion is imparted to the gear p by means

FIG. 52

of the pinion j_1, Fig. 51 (a), on the driving shaft j_2 (Plates IV and V, Figs. 49 and 50), which also carries the cone pulley j (Plates II and IV). The latter may be driven by a belt from a countershaft conveniently situated above the shaper.

53. Automatic Cross-Feed.—The previous description refers to the main functions of the machine; attention will now be called to the possible modifications and extensions of these various functions. When the work is to be moved in a horizontal direction while undergoing a planing process, it is generally desirable that this motion shall be performed automatically. In that case the screw shown in the cross-rail in Fig. 44, with a handle attached, must be given a fraction of a turn during the return stroke of the ram. This is the purpose of the two gears, seen in Fig. 44, at the right-hand side of the cross-rail. The smaller gear is pinned to the screw, while the larger revolves loosely on a stud on the cross-rail. On the same stud is a rocking lever, seen in Fig. 44 and on Plate III. The upper end of this lever has a pawl, which, when the cross-feed is to be made by hand, is held out of mesh by a little spring-actuated pin. When the feed is required to be automatic, the pawl is let down either to the left or right of its supporting stud, depending on whether the gear is to be driven to the right or left, respectively. The lower end of the lever has a pin inserted in one eye of the connecting-rod k_2, whose other eye fits over the shoulder of the hollow nut k_1 on the cross-feed disk k. This disk has a dovetail slot, seen more clearly in Fig. 44, in which is a block having a screw with a washer and the hollow nut k_1. By means of the latter the dovetail block can be clamped in any position in the slot of the disk. It follows that when k revolves it will impart an oscillating motion to the rocking lever, and that the extent of this motion will depend on the distance between the center of the nut k_1, and that of the disk k. The disk is fastened to a stud that revolves in the boss, seen in Figs. 44 and 53, and the detail sketch on Plate III. It receives its motion from the little pinion, partly visible in Fig. 45, which engages with the gear seen on the inside of the disk k (Plate III). Fig. 53 represents the disk moved out of gear with the pinion to better show the inside of the disk. This pinion consists of teeth cut directly in the end of the driving shaft j_2 (Plate IV).

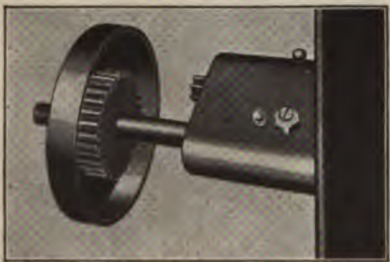


FIG. 53

54. Adjustment of the Stroke.—The adjustment of the ram stroke will now be explained in detail. On the right-hand side of the frame and above the feed-disk k is a collar, fastened to the frame, as seen in Figs. 44

and 54. Outside of this collar there is a revolving pulley q_1, Plate III, with a clamp disk q, Fig. 51 (*b*) and Fig. 44. This disk carries a little pointer that indicates, by means of marks on the pulley, the length of the stroke. By loosening the spherical nut outside the disk q, it is possible to adjust the latter relative to the pulley q_1 until the pointer indicates the desired stroke. How this adjustment affects the stroke will be explained by means of Fig. 51 (*a*). The clamp disk q is feathered to the shaft q_2, and will therefore turn with the latter, but can be moved in and out longitudinally.

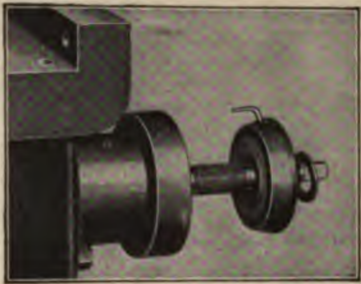


FIG. 54

It has already been explained that the pinion p_1 engages with the segmental gear on the crank o and that the latter may swing around the stud o_1. Fig. 51 (*a*) is a front elevation of these parts, in which the center of the crankpin o_2 is shown in line with the center of the pinion p_1. If adjusted in this position, the effect will be that while the gear p is revolving with the pinion and the crank, the pin will simply revolve around its own center, letting the block n_1, lever n, and the ram remain stationary. To impart motion to the latter, the shaft q_2 with its pinion is turned by means of a crank that may be placed on the end of the shaft q_2 and the crank o moved to the left until the pin o_2 occupies any position between the central and the extreme left-hand position, indicated by means of dotted lines in Fig. 51 (*c*). After the crank has been adjusted, the spherical nut is screwed up against the clamp disk q; this draws the conical surface of the clamp disk, as well as the conical surface on the back of the pinion p_1, down on their seats, making a solid frictional connection between the parts. As the hollow shaft p_2 supports all these parts, the whole mechanism will revolve with the gear p.

55. Some explanations will here be added to facilitate the understanding of the various sketches, each plate being considered in succession.

Plate I. — The main view is a front elevation of the assembled machine, some parts being shown in section and some broken away so as to expose hidden parts. The left half of the shaper head h has been removed in order to show the circular head of the ram. Likewise, part of the right-hand side of the vise is broken off to obtain a free view of the upper part of the frame, it being understood that both halves of the vise are symmetrical. The lower side of the table is shown in section better to show the **T** slots and central hole through which to insert the clamp screw, when the vise is fastened to the side of the table. In all cases where parts are sketched separate from the places where they belong, connecting lines indicate their true positions. For instance, the little screw sketched on the right-hand side has a line connecting it with the hole in the tool block. The long piece in the upper left-hand corner is a side view of the gib that holds the ram in place, and a line is seen leading from this piece to the place where the front end of the gib is seen in the main view.

Plate II.—The graduated circle shown above the main view is a constructive detail enabling the student to space the graduations on the ram in a correct manner. The set-screw shown to the right and below the ram is one of four screws that serve to adjust the gib with reference to the ram. These screws may also be seen in Fig. 44.

Plate III.—The two views in the lower right-hand corner represent a sectional plan view and end view, respectively, of the boss that supports the end of the driving shaft j_2 and the stud for the cross-feed disk k. Above these views is found a sectional view of the cross-feed disk with its dove-tail block and hollow nut k_1. In the lower left-hand corner is the connecting-rod k_2 with some details for the rocking lever.

Plate IV.—In the upper right-hand corner is a plan view of the table e on which are indicated the graduations by which the vise may be adjusted. In the upper left-hand corner is a rear view of the frame with the ram in position. At the bottom of the plate is a longitudinal section of the ram with the fork g_1, also various sections taken across the ram at the places indicated by the vertical lines. The detail in the lower right-hand corner is the screw in the top of the fork.

Fig. 41.—The views taken from left to right are: An end view of the saddle, a rear elevation of the same, and, lastly, a front elevation of the central part of the cross-rail. There is also shown part of the screw that supports the cross-rail and the bevel gears by which it is raised and lowered; also, details of the nut engaging the cross-feed screw, a sectional detail of the upper part of the rail, and a partial bottom view of the rail.

Fig. 42.—The views on this sheet should be easily understood in conjunction with Fig. 51, and require no additional information.

Plate V.—The main view is a sectional side elevation of the frame taken along line *o o*, Fig. 42, with the lever and crank removed. Sections are also taken along lines *x x*, *y y*, and *z z*, and shown at various places on the sheet. Section *x x* gives a plan view of the driving pinion j_1, together with the driving shaft j, and the supporting boss. Above is found a detail view of the crank and below a plan view of one corner of the base.

CONCLUSION

56. The student is advised to practice sketching at every opportunity. He may sketch any convenient object, as, for example, a monkeywrench, a table, a vise, etc. The kitchen stove, or a wagon will present considerable difficulty. No matter what the object may be that is sketched, it must always be kept in mind that every sketch must be so made and dimensioned that a working or finished drawing can be made from it without the necessity of seeing the

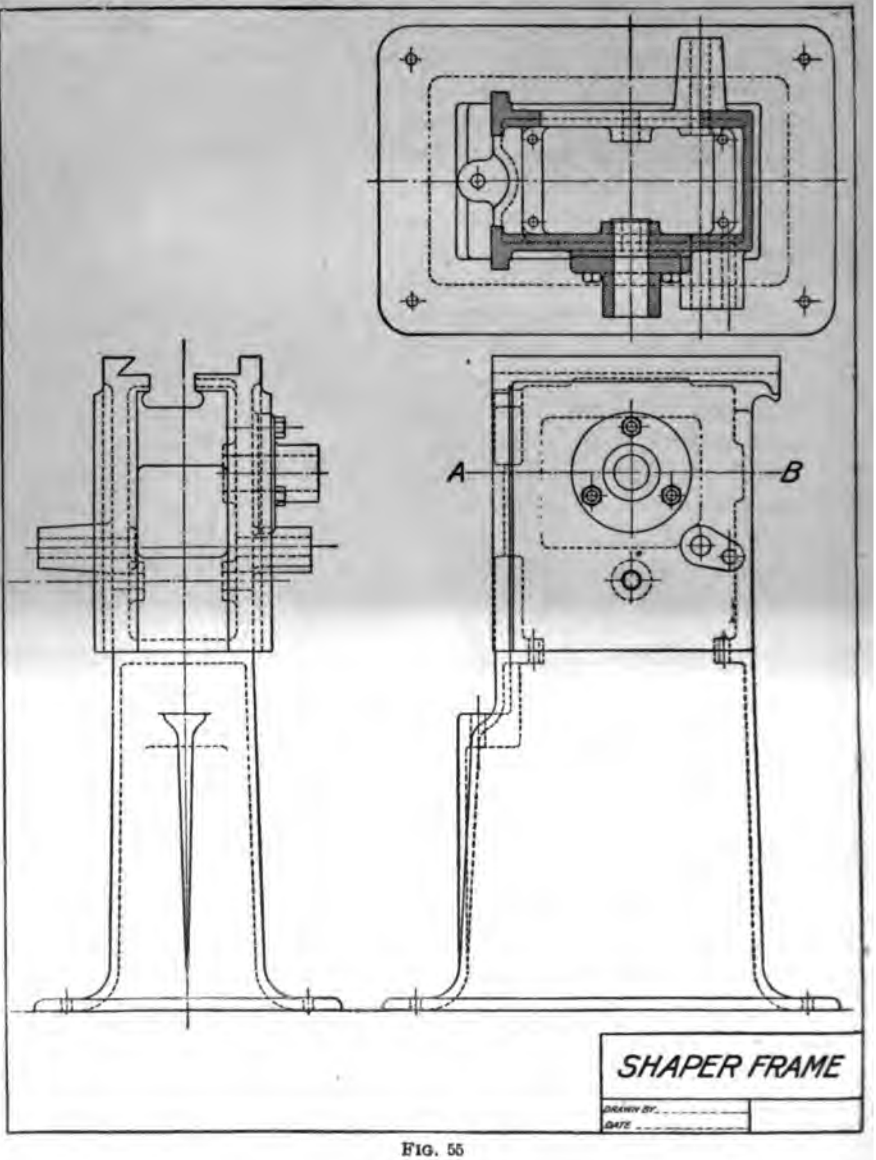


FIG. 55

object again. Hence, the student is advised not only to make sketches of convenient objects, but also make at least pencil drawings from these sketches. The making of the drawing will reveal any omissions or defects in the sketches, and will afford him the best kind of practice.

After the student has attained a certain degree of proficiency and gained confidence in himself, he is advised to go to some machine shop or other establishment where mechanical work is being done and sketch some of the smaller objects to be found there. Then, when he gets employment as a draftsmen, he will find the work comparatively easy and his advancement will be more rapid.

INDEX

NOTE.—All items in this index refer first to the section and then to the page of the section. Thus, "Addendum, §14, p109" means that addendum will be found on page 109 of section 14.

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