NOTES

ON

MECHANICAL DRAWING

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MECHANICAL DRAWING

PREPARED FOR THE USE OF
STUDENTS IN

ELEMENTARY AND ADVANCED MECHANICAL DRAWING

BY

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SIXTH EDITION.

PREFACE.

Mechanical drawings are required in all constructive work and, as the name implies, are made with precision instruments. In making such drawings, strict adherence to the principles of projection, accuracy and neatness in execution remove all doubts as to what is intended and make a drawing perfectly clear to all accustomed to reading and working from them.

The student should realize that the user of a drawing constructs as the drawing shows, not as the one who made the drawing intended to show.

The matter contained in these Notes is not an exhaustive treatise on mechanical drawing, but is intended to supplement class instruction.

These Notes contain recognized standards, conventions and technic used in American practice, together with tables and other information valuable in drawing.

Questions are continually arising in a student's mind as to just how to represent certain conditions, and since he will remember longer that which he looks up for himself, it is his duty to answer these questions by referring to the standards, conventions and technic of practice before questioning his instructor.

The previous editions of the Notes were developed along lines suggested by students' questions.

The present edition has been enlarged along the same lines. Part of the subject-matter has been rewritten to increase its scope.

The numbering of the paragraphs under each topic provides a ready reference for the student's attention relative to errors in his work and for study or other assignment.

The topic headings and the more important features under each have been emphasized by **bold-face** type.

The lack of complete uniformity in all lines of work using mechanical drawings makes it impossible to include in these Notes anything except fundamentals.

PHILADELPHIA, PA.,
September, 1916.

HORACE P. FRY.

PREFACE TO SIXTH EDITION.

The present edition is practically the same as the previous one. A few paragraphs have been rewritten.

A Checking Index has been found most useful in correcting student's work, it has been added directly after the regular index.

January, 1919.

H. P. F.

CLASSIFICATION OF DRAWINGS.

1. **DRAWINGS** are divided into two classes—those made purely freehand and those made with instruments of precision.

2. **FREEHAND DRAWINGS** are made for artistic effects, historical records or the purpose of registering mental pictures. They show only that which is visible and are readily understood.

3. **FREEHAND SKETCHES** for constructive purposes are made with few or no instruments, but in other respects they are the same as a mechanical drawing.

4. **MECHANICAL DRAWINGS** are made with instruments of precision to convey, from one person to another, complete and accurate information of the visible and invisible structure of an object, not necessarily of a mechanical nature. They are made according to definite principles of projection and are fully understood only by those who have been trained in this so-called "graphic language."

5. **GEOMETRICAL DRAWINGS** are made with instruments and involve the principles of Geometry in solving problems. A knowledge of these principles is valuable and fundamental, but very few of them are used, since anyone making a Mechanical Drawing has at his command instruments for obtaining the same results by quicker means. For example, drawing lines parallel, erecting perpendiculars and drawing arcs (fillets) tangent to lines.

ESSENTIALS. 1. A designer, in any line of work, uses drawing as the means of expressing his ideas.

2. The aim in learning how to draw is to acquire the ability to express ideas graphically, so they may be put into concrete form for practical use.

3. In making a mechanical drawing the draftsman (meaning anyone making the drawing) should remember that **correctness in projection, accuracy, practical dimensioning, clearness, neatness, necessary notes and a proper title are all essential to the working value of the drawing,** since the object of such a drawing is to enable one to make that which has been pictured without recourse to any other information than that contained on the drawing. **The artisan constructs as the drawing shows, not as the draftsman may have intended to show.**

INSTRUMENT LIST.

1. THE MATERIALS SPECIFIED are standard and representative types used in good practice. A novice should consult his instructor before making any substitutions until he learns that the best are cheapest in the end.

2. THE COMPLETE EQUIPMENT should be at hand at all times, and contain the following items: [all consumed, broken and lost portions to be replaced at once].

A. One set of approved Drawing Instruments in a morocco-covered case having two metal hinges and clasps (see Fig. 1), the set to include

- $5\frac{1}{2}''$ compass, pen, pencil and lengthening bar, fixed needle point leg.
- $3\frac{1}{4}''$ bow spacer.
- $3\frac{1}{4}''$ bow pencil with needle point.
- $3\frac{1}{4}''$ bow pen with needle point.
- 5″ ruling pen.
- Nickel-plated lead case.
- [Set No. 2050, made by Theodore Altender & Sons, Philadelphia.]

FIG. 1.

B. Triangular box-wood scale having the following scales thereon: 12″, 9″, 6″, 4″, 3″, 2″, $1\frac{1}{2}''$ to the foot, and 50 parts to the inch divided the full length of the scale.

C. One 8″—45° celluloid triangle. Not less than $\frac{1}{16}''$ thick.

D. One 12″—60° celluloid triangle. Not less than $\frac{1}{16}''$ thick.

E. T-square, 30″ blade (not set in head). Blade to have celluloid edges tongued and grooved to wood.

F. One celluloid irregular curve, as shown in Fig. 2. (K. and E. No. 19.)

G. One Linograph (senior size) may be substituted for C. D. and F.

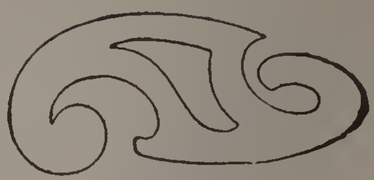


FIG. 2.

H. Two 6H and one H drawing pencils. (Kooh-i-noor, Eldorado or Castell.)

I. One bottle of black waterproof drawing ink. Higgins'.

J. One erasing shield. Polished on one side only.

K. One small ink eraser. (E. Faber's improved.)

L. One large pencil eraser. (E. Faber's ruby or emerald.)

M. One art gum cleaning rubber (large).

N. One dozen $\frac{3}{8}$″ thumb tacks. (Thin head, K. & E. Ideal.)

O. Two sheets 22″ x 30″ drawing paper. (K. & E. Normal.)

P. Drawing board, white pine, 23″ x 31″ with cleats on the back; face of board must not be shellacked. Each cleat to have a 3″ x $\frac{3}{16}$″ slot cut through next to board. Slots must be in line and about central of the cleats.

Q. One drawing kit containing paper wallet, freehand lettering paper, pencil file, Eagle 1928 penholder, 390 Gillott pens and 516F Leonard's ball pointed pens, ink-rag, Dennison paper clips and 4″ x 6″ scratch pad.

1. USE OF INSTRUMENTS. Every article itemized in the foregoing list is required and used for a specific purpose.

2. The uses of the instruments and ways of handling them are best explained by demonstrations and proficiency acquired by constant practice.

3. Triangles are used to obtain angles of 15°, 75° and any multitude of 15° as shown in Fig. 3.

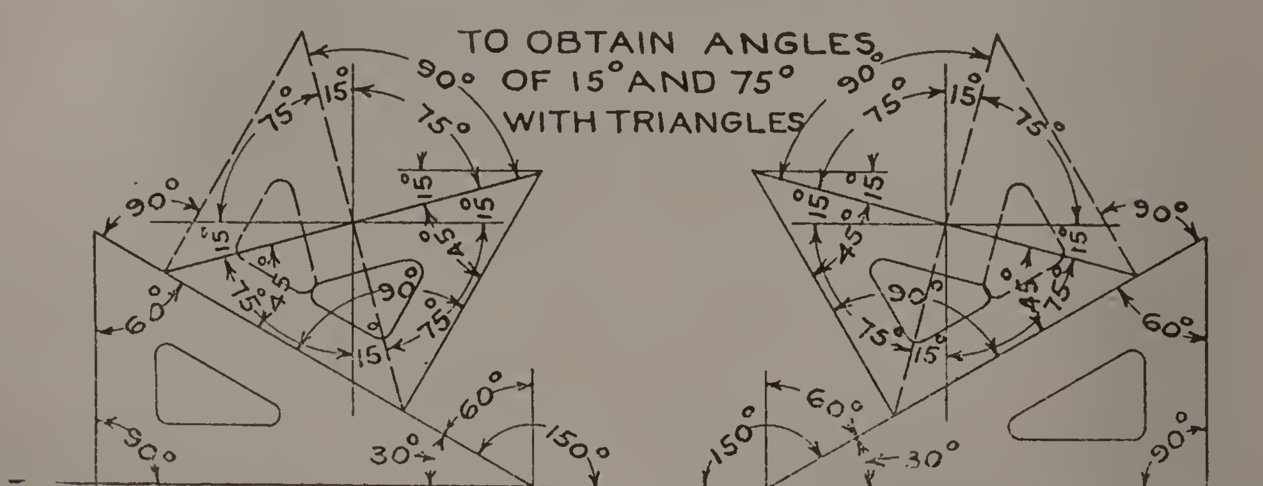


FIG. 3.

4. Chisel points must be used on all instrument leads and pencils. Cut the wood back for $1\frac{1}{4}''$, exposing the lead for $\frac{3}{8}''$, then flatten the lead by rubbing opposite sides on a file and bring to a knife edge by using a slight rocking motion. This point will have the appearance of the ruling pen point, but broader.

1. A NUMBER CIRCLE is placed in the lower left corner of each drawing and tracing. Its size, form and location are shown in Fig. 4.

2. The classification number of the drawing is to be placed in the central zone of the number circle.

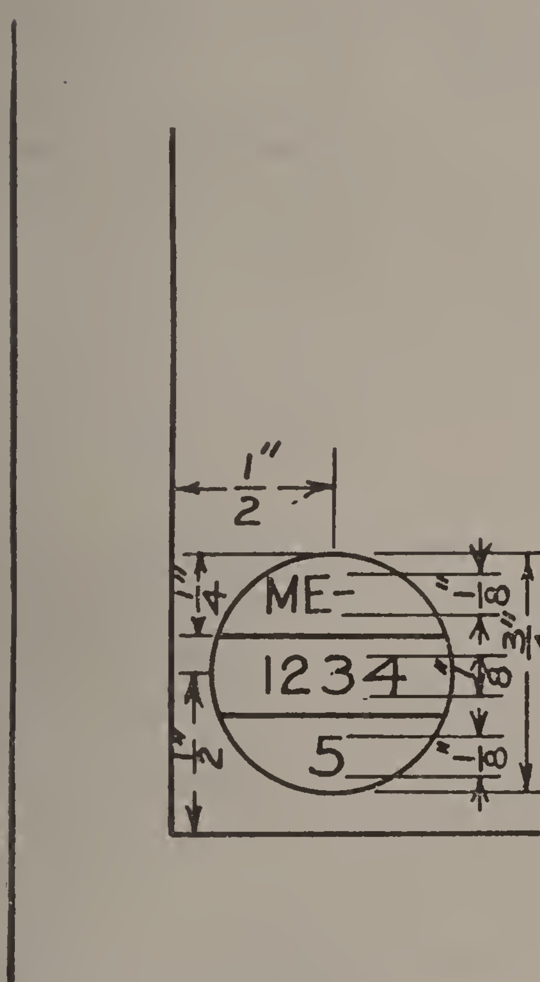


Fig. 4.

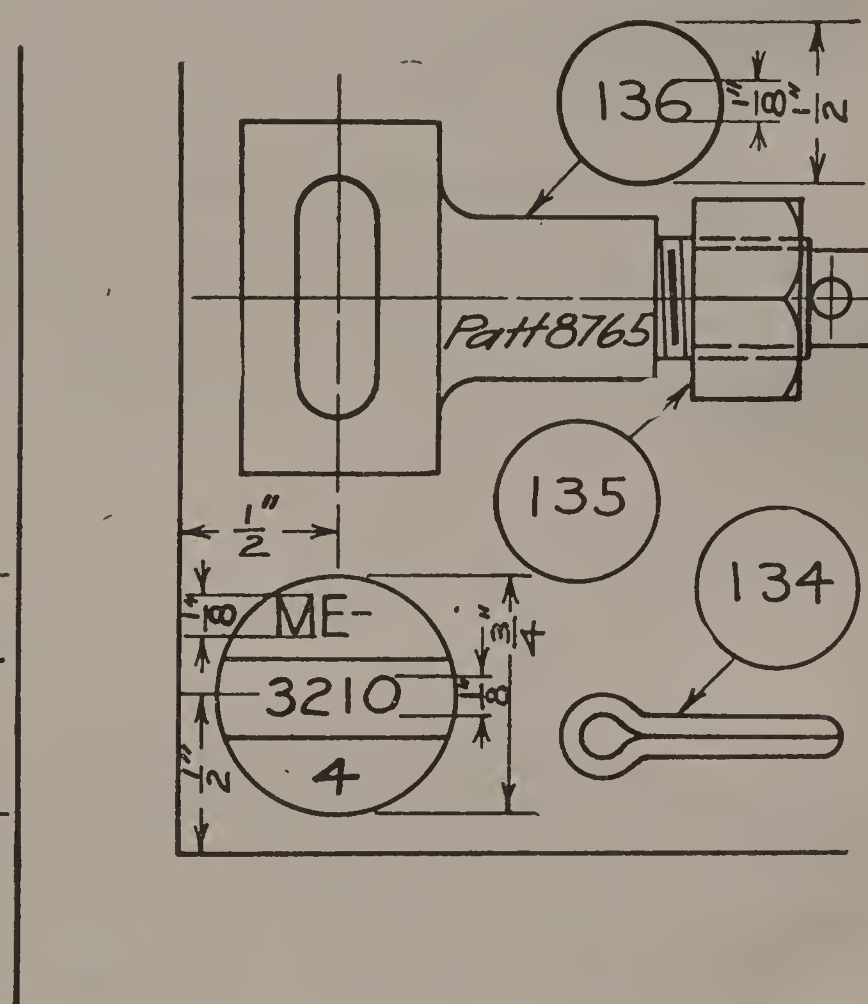


Fig. 5.

3. The course number is to be placed in the top segment of the number circle and the class section number in the bottom one.

4. A drawing showing more than one part, each having an individual part number, must have the part numbers in separate circles.

5. The part number circle is placed near the principle view of the part and connected to the view by a leader as shown in Fig. 5.

6. Pattern numbers are serial numbers entered thus: **Patt. 8765** on the principle view in a conspicuous place. See Fig. 5.

7. Tracing index number is a serial number assigned, for designating and filing purposes, from an index when a tracing is completed. Block letters and numbers $\frac{5}{8}''$ high as shown in Fig. 40 are suitable for this purpose. The letter designating the size of sheet and the serial number are placed on the lower right margin as shown in Fig. 8.

SIZE OF SHEETS. 1. Drawings are made on sheets, ruled and cut to standard forms. Use the forms shown in Figs. 6, 7 and 8, as specified for each type of work.

2. Form 1-E signifies a sheet cut exactly 10″ x 14″ and ruled with a $\frac{1}{2}''$ margin.

3. Sheets are to be trimmed to size after the drawing has been completed. (See reference on trimming.)

SIZE OF TRACINGS. 1. Tracings are to be ruled and trimmed to one of the sizes shown in Fig. 8 unless specific orders to the contrary are given.

2. A tracing is trimmed to size after it has been checked and all corrections have been made. (See reference on trimming.)

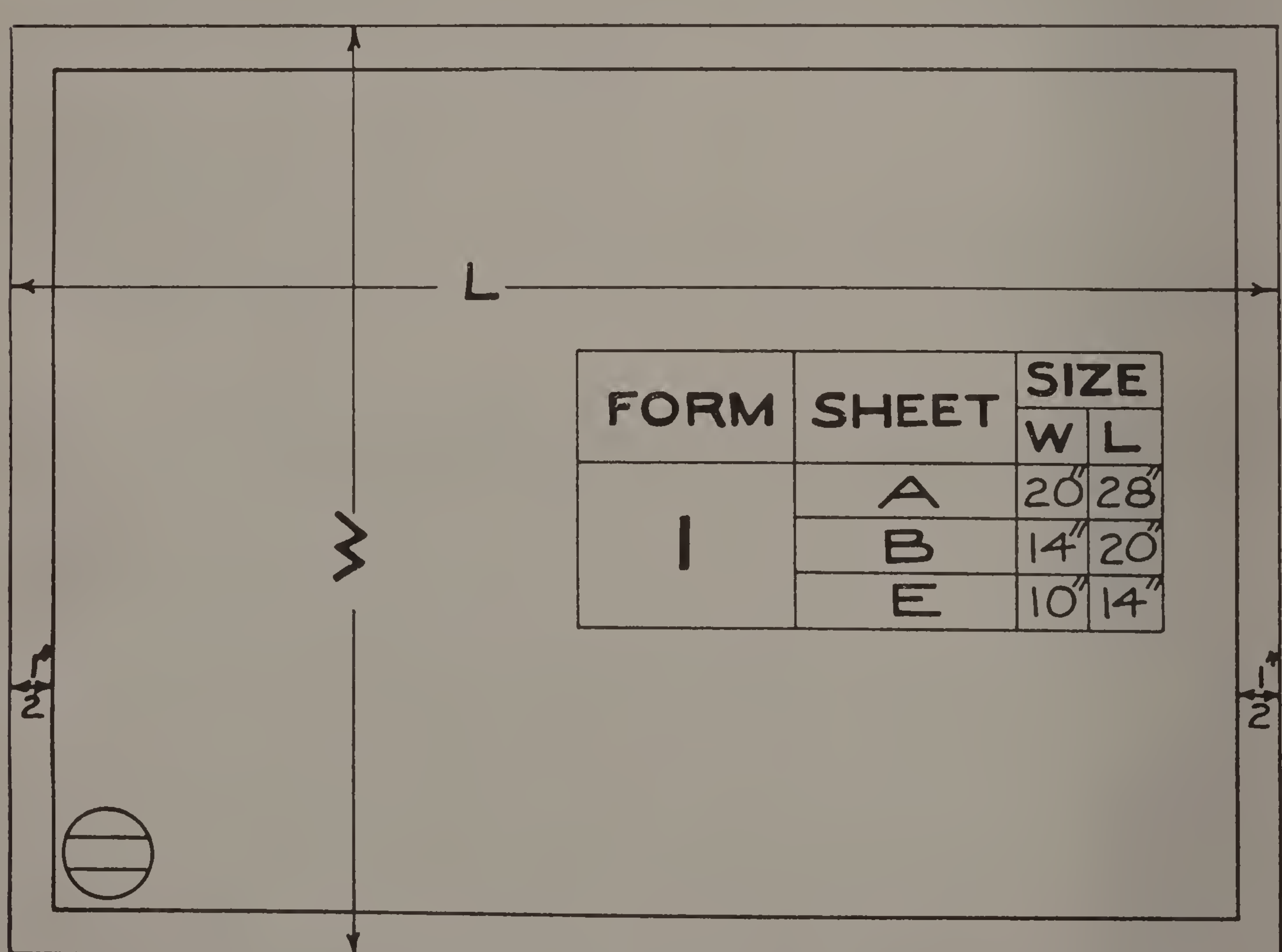
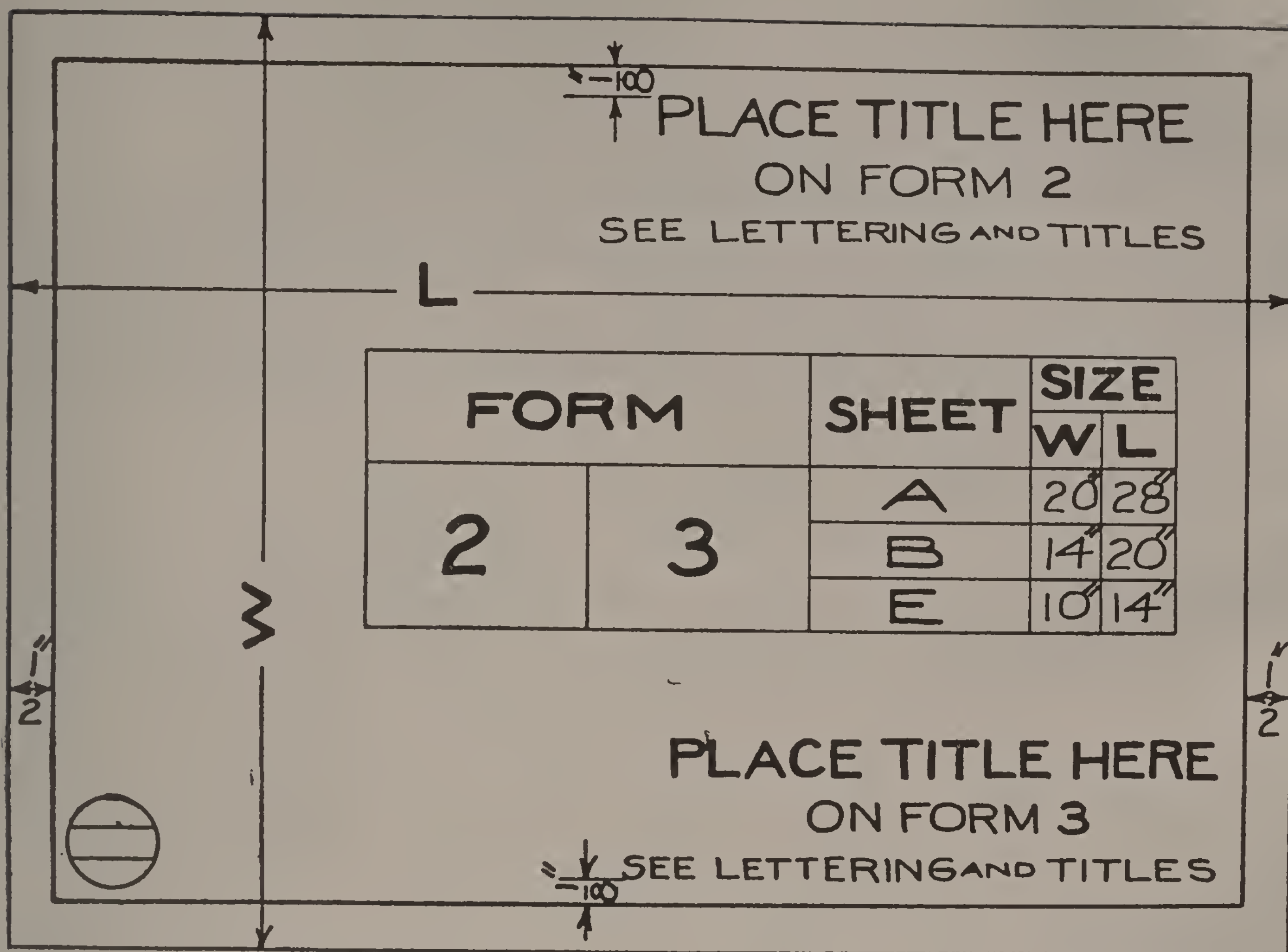


Fig. 6.


1/100
PLACE TITLE HERE
ON FORM 2
SEE LETTERING AND TITLES
L
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B
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ON FORM 3
SEE LETTERING AND TITLES
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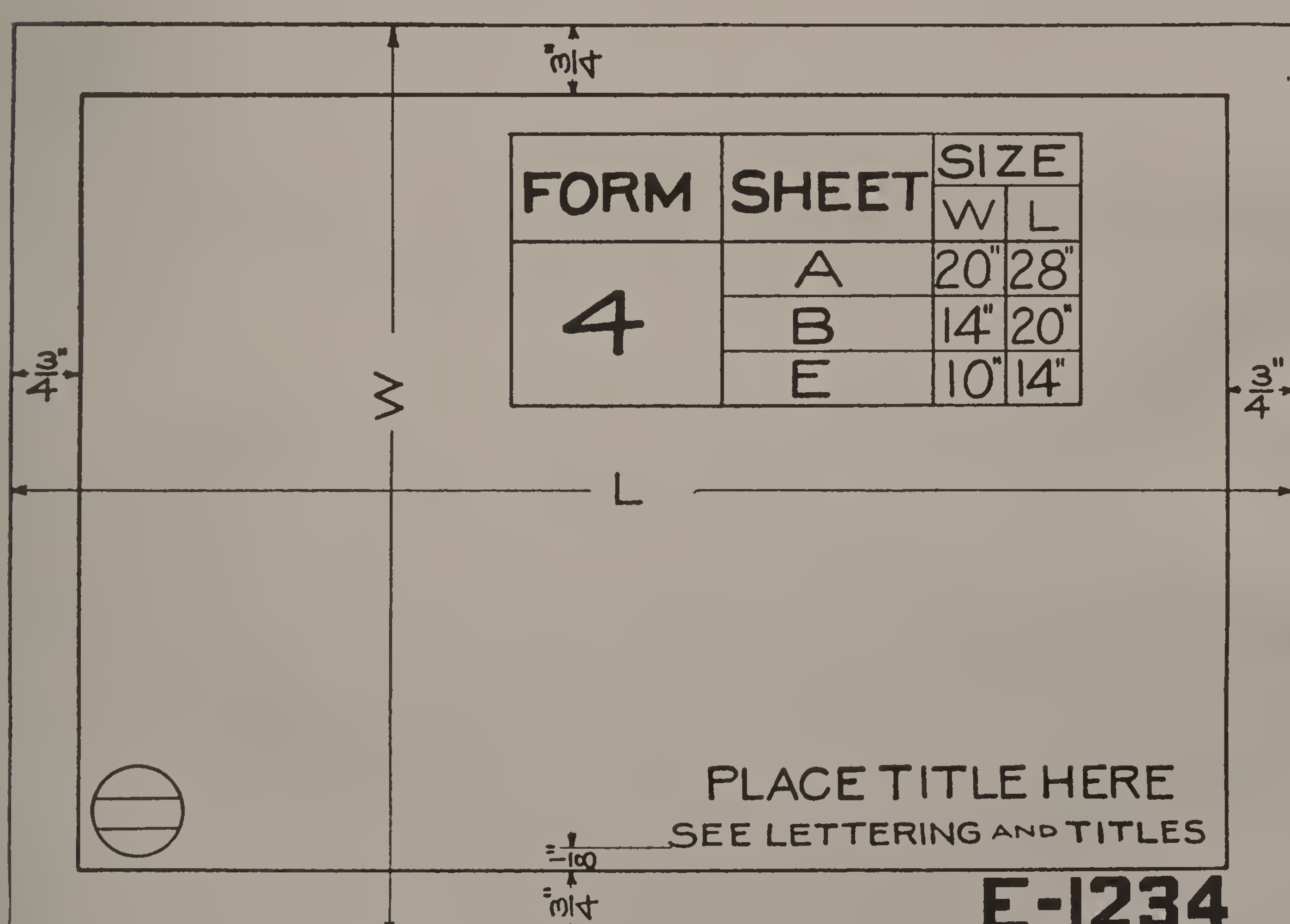
FIG. 7.


3/4"
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3/4"
E-1234

FIG. 8.

TRIMMING. **1. Trim drawing paper with a sharp penknife,** using the **lower edge** of your **T-square** as a guide and the **back** of your **drawing-board** to cut on. **Never use the face of board or table top. Trim drawings when completed.**

2. Trim tracing cloth with shears, leaving $\frac{1}{4}''$ outside of margin all around for thumb-tacks, **trim tracings to size after they have been checked and corrections made.**

3. Drawing and tracing sheets are to be neatly trimmed to exact size of form specified and have no thumb-tack holes in them.

PROJECTION. **1. Perspective projection** gives on one plane in one view an image of the object as the eye sees it. The image is formed on the plane of projection at the intersection with it of projection lines drawn from a point (the eye) to all points of the object. This method finds its greatest use in Architecture.

2. Axonimetric projection gives on one plane one view of an object that shows its three dimensional surfaces, length, height and width. The method is used to obtain pictorial effect, the illustration in Fig. 10 having been drawn by this method.

3. Isometric projection, a particular type of axonimetric projection, is used as a ready means of making a Mechanical or Freehand Isometric Drawing of an object. This method was used in drawing the illustration for Fig. 9. (See reference on Isometric Drawing.)

4. Orthographic projection gives on one plane as many views of an object as may be desired by revolving into that plane all planes of projection. A projection (view) on a plane of projection is formed on the plane at the intersection with it of parallel lines drawn perpendicular to the plane from all points of the object. See projection on horizontal plane in Fig. 10. (Read paragraph 11.)

5. Coordinate planes of projection are two planes, one vertical and one horizontal, intersecting at right angles and forming four dihedral angles known as first, second, third and fourth angle, as indicated in Fig. 9.

6. A profile plane of projection is one at right angles to the two coordinate planes; it is shown in Fig. 9.

7. Auxiliary planes of projection are planes other than the coordinate and profile planes and when used they **must be passed at right angles to a previous plane of projection.**

8. All planes of projection are considered indefinite in extent. An object may be placed anywhere in any one of the four angles and projected upon the planes.

9. Third angle projection gives the most logical and practical views; it is used universally in American practice and all drawings are to be made accordingly unless otherwise directed.

10. In third angle projection the planes of projection are between the observer and the object. Let it be assumed, as in Fig. 10, that the object is surrounded by transparent planes of projection and the object to be projected on all of the planes by drawing projection lines as shown on the horizontal plane.

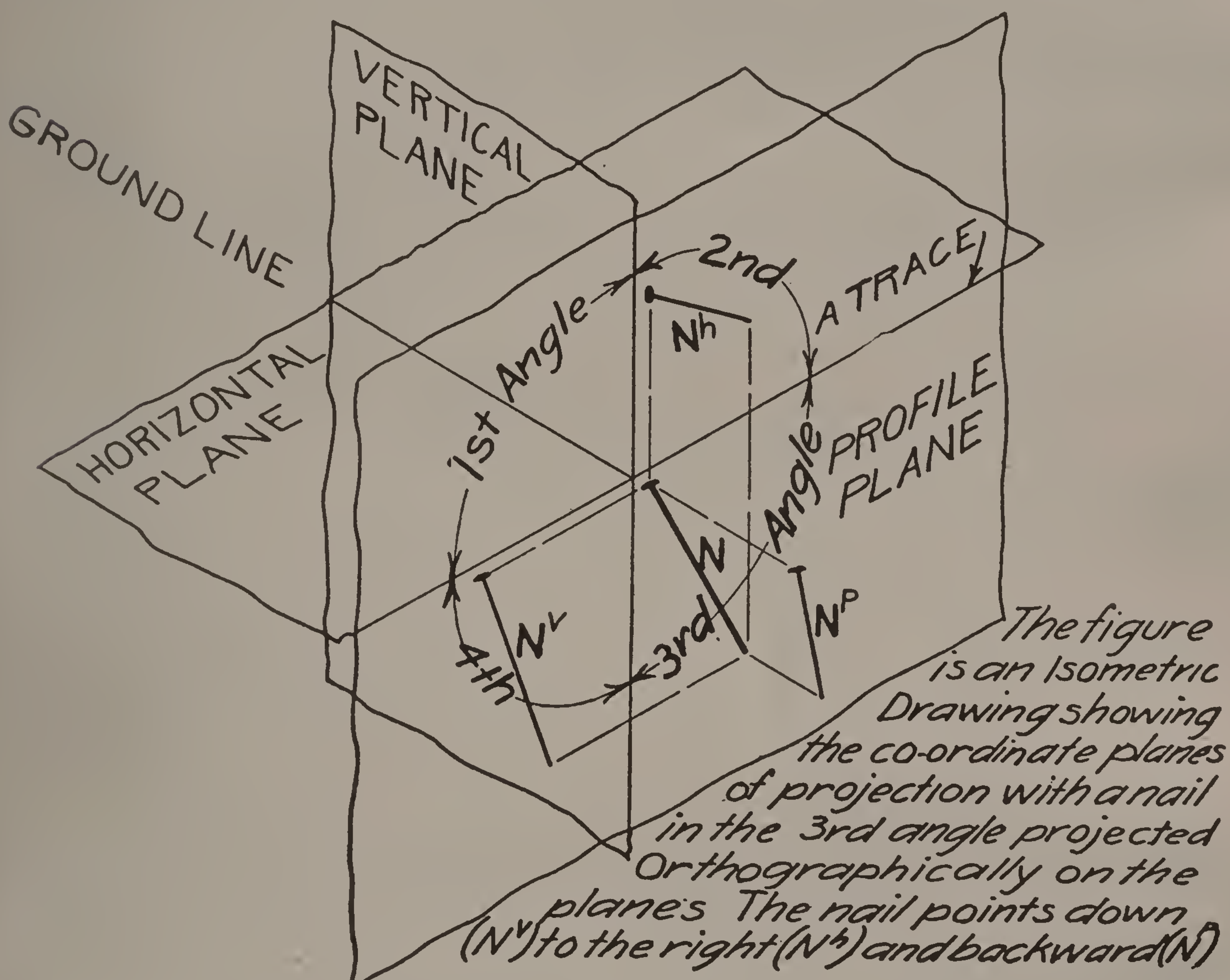


FIG. 9.

11. Projection lines are lines drawn perpendicular from points of the object to the planes of projection.

12. The trace of a line is a point where the line, prolonged if necessary, cuts a plane.

13. The trace of a plane is a line where the plane, extended if necessary, cuts another plane.

14. The true length of a line or the true size and shape of a plane surface will be the projection of the line or surface on a plane parallel to the line or surface.

15. A Descriptive Geometry should be consulted for a complete treatment of the subject.

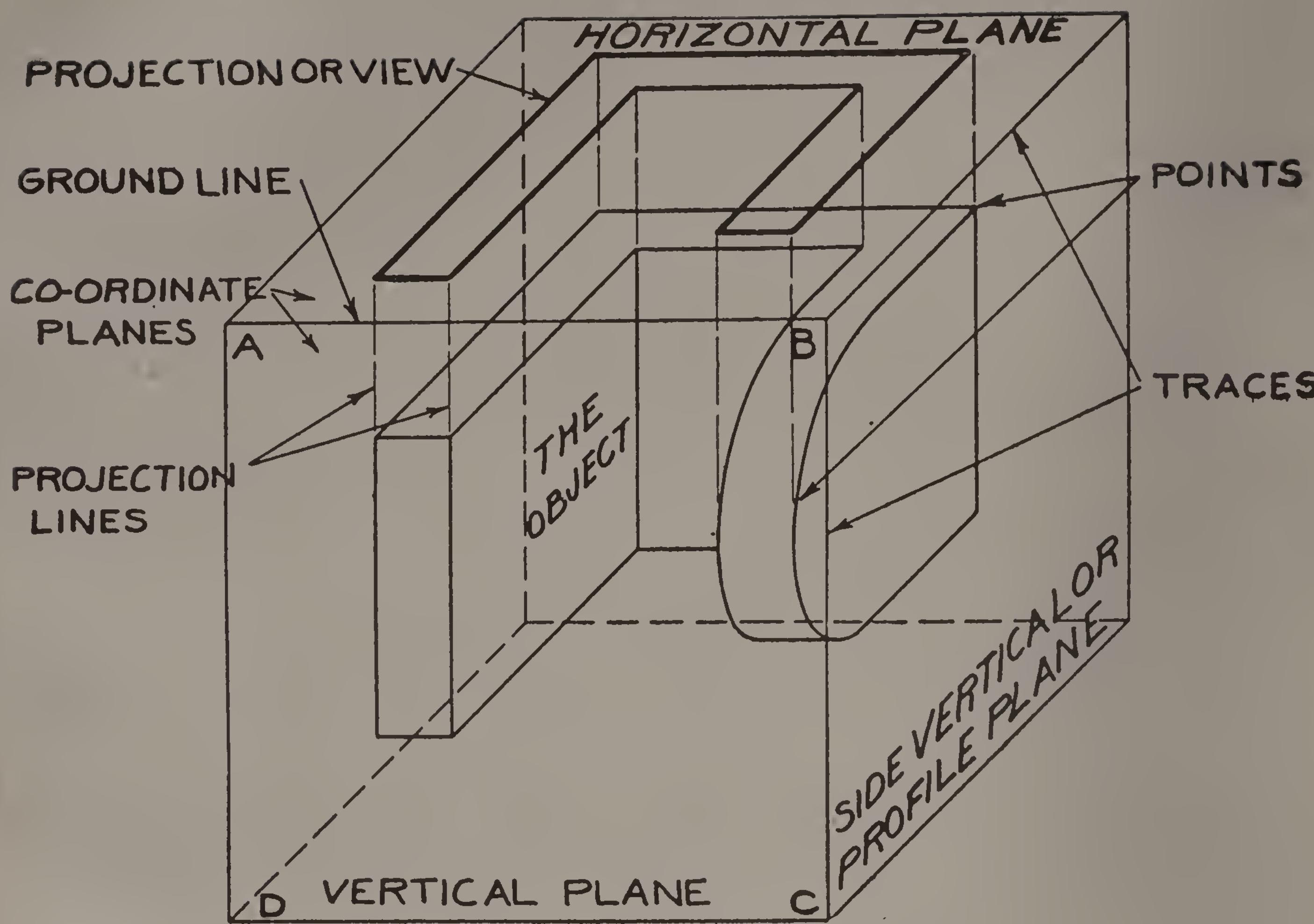

HORIZONTAL PLANE
PROJECTION OR VIEW
GROUND LINE
CO-ORDINATE PLANES
A
B
POINTS
TRACES
PROJECTION LINES
THE OBJECT
SIDE VERTICAL OR PROFILE PLANE
D
VERTICAL PLANE
C

FIG. 10.

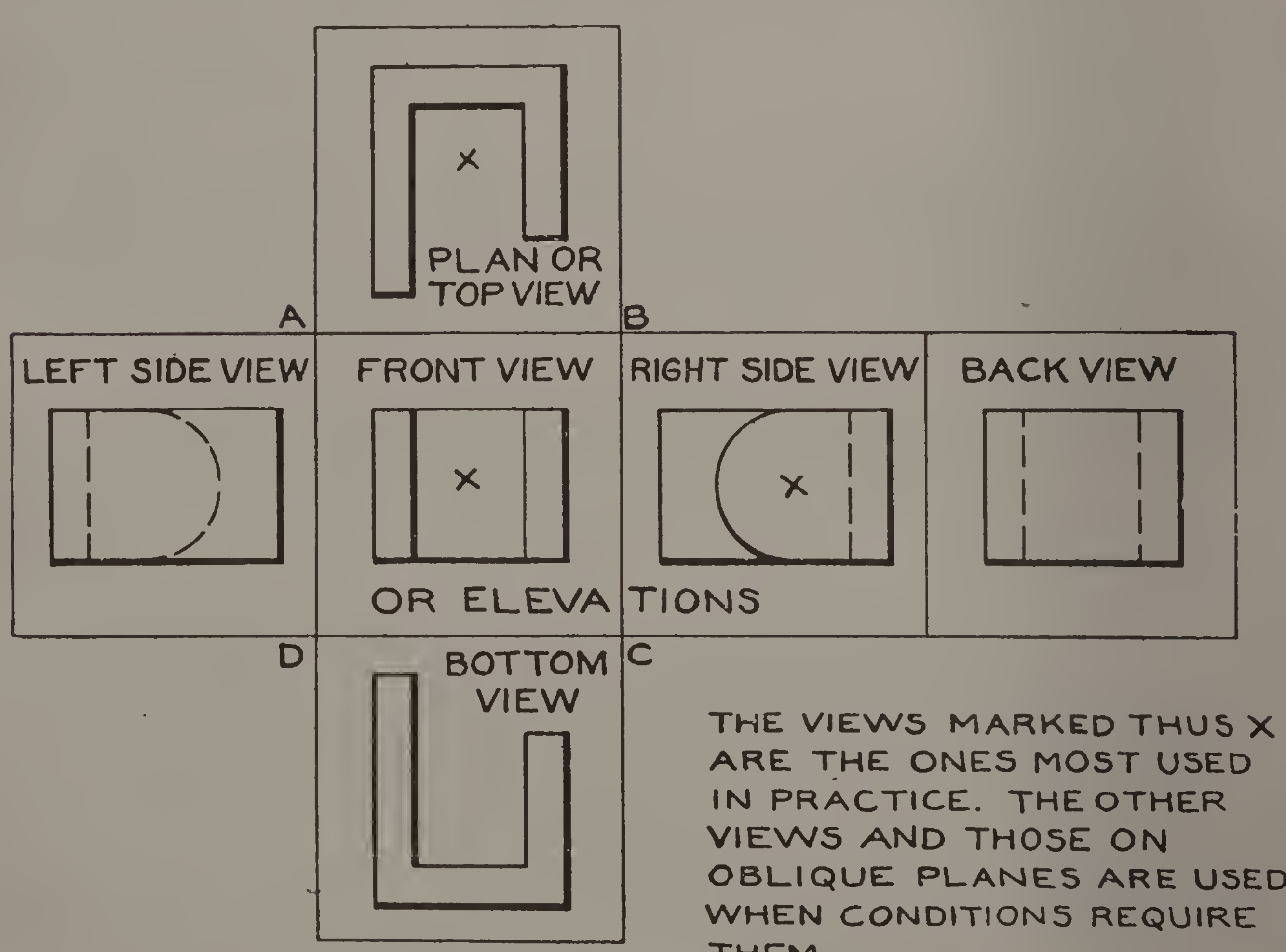

PLAN OR TOP VIEW
A
B
LEFT SIDE VIEW
FRONT VIEW
RIGHT SIDE VIEW
BACK VIEW
OR ELEVATIONS
D
C
BOTTOM VIEW
THE VIEWS MARKED THUS X ARE THE ONES MOST USED IN PRACTICE. THE OTHER VIEWS AND THOSE ON OBLIQUE PLANES ARE USED WHEN CONDITIONS REQUIRE THEM.

FIG. 11.

ARRANGEMENT OF VIEWS. **1.** Let one of the planes, A B C D, in Fig. 10, coincide with the plane of the paper and revolve each of the others about its intersection with that plane and toward the observer, until they are all in the plane of the paper, then the views will be in their proper relative positions.

2. The names and positions of the views when properly projected and revolved are shown in Fig. 11.

SCALES. **1. Full-size drawings** of objects are not always possible or practical, and in such cases they must be made one-half size or some other conventional size. A scale is used to make a drawing less than full size.

2. A scale is a fraction of the unit measure, one foot in U. S. practice, **subdivided into the same number of parts that the unit is divided** and is used in the same way as the full-size unit.

3. The standard scales used in Machine Drawing are 9″, 6″, 4″, 3″, 2″, $1\frac{1}{2}$″ and 1″ to the foot. Drawings should be made to one of these scales or full size (never larger).

4. Scales 3″, $1\frac{1}{2}$″, $\frac{3}{4}$″, $\frac{1}{2}$″, $\frac{3}{8}$″, $\frac{1}{4}$″, $\frac{3}{16}$″, $\frac{3}{32}$″ and $\frac{1}{8}$″ to the foot are used by Architects. Scales 10, 20, 30, 40, 50, and 100 feet to an inch are used in Civil Engineering work.

5. The words **size** and **scale** should not occur together. Either **Half size** or **Scale 6″=1′** is correct. **Scale half size** is incorrect. Scale 9″ to 1′ is $\frac{9}{12}$, or $\frac{3}{4}$ size. Scale 3″ to 1′ is $\frac{3}{12}$, or $\frac{1}{4}$ size.

6. To determine the scale for a drawing assume rectangles, as in Fig. 12, to represent the least areas which will contain the different views desired. The dimensions of the rectangles being the over-all dimensions of the object to be drawn. If $A+B$ is less than L_1, the length of the paper, the drawing can be made full size, provided $C+D<W_1$. If the paper is not large enough, multiply the dimensions (L_1 and W_1) of the paper by 12 divided by a scale; that is, either $\frac{4}{3}$, 2, 3, 4, 6 or 8, until the paper is increased enough to draw the object full size; the reciprocal of the multiplier will be the size the object can be drawn on the original paper size L_1+W_1. If, for example, a sheet should have to be made four times longer in order to draw the object full size, the object can be drawn $\frac{1}{4}$ size, or scale 3″ to 1′ on the original sheet.

7. Decide which views are required to properly and clearly show the object, before starting the drawing, and lay out the sheet so that the views, when properly placed, will leave room for the title also a bill of material when required. Move the views from the center of the paper rather than reduce the scale.

LAYING OUT VIEWS. 1. The distance between views should not be less than ½″ or more than 1½″ (F and J, Fig. 12), depending on the space required for dimensions.

The rectangles previously referred to in Fig. 12 are not to be used in the actual laying out of the views.

2. The distance between views and margins is determined graphically as follows: Lay off from the left margin a distance, to the scale that will be used, equal to the over-all lengths (A+B, Fig. 12), of the views and add on the full size distance allowed between views and measure to full size the remaining distance

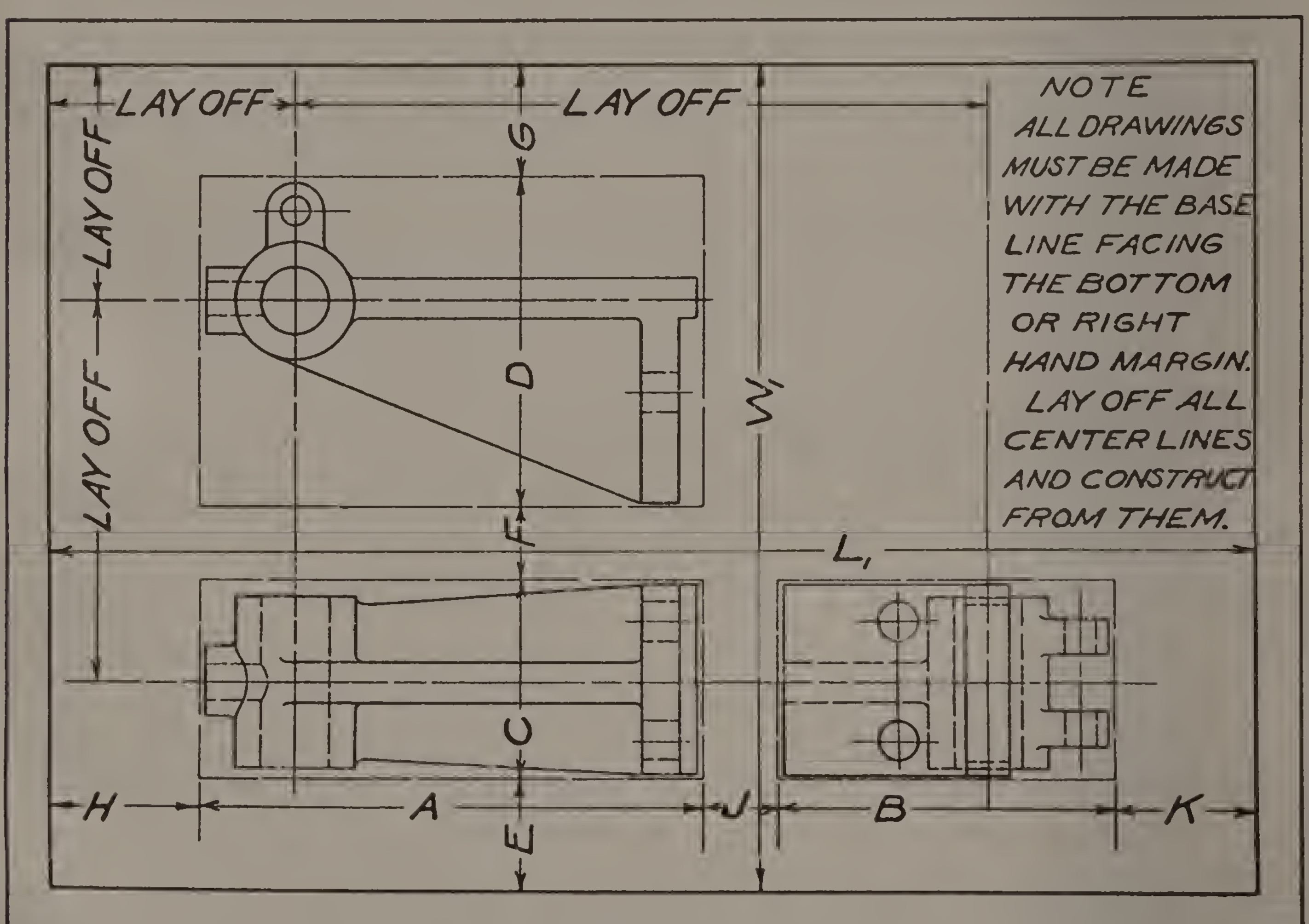


Fig. 12.

to the right-hand margin. This remainder is divided equally between the two sides (H and K), but is not figured closely.

3. To lay out a drawing the important center line or base line in each view is carefully located and from these the drawing is accurately constructed.

Begin at the left and (see Fig. 12) mark off the full-size distance (H) that the view will be from the left margin; add to this the scale distance to the center line, and so on to the successive center lines. The horizontal center lines are located by measuring from the top margin.

4. Accuracy in laying out a drawing is necessary, since the operation of drawing is that of building up on paper the views of an object, which in most cases does not exist; in other words, it is designing (building) by steps, and inaccuracies in the building are not permissible.

5. Draw the views simultaneously. There is no gain in completing one at a time. Observe the principles of projection and the practice of reading drawings from the bottom and the right margins of the sheet.

6. The base of an object as drawn should face the bottom or right margin to avoid having the object appear inverted.

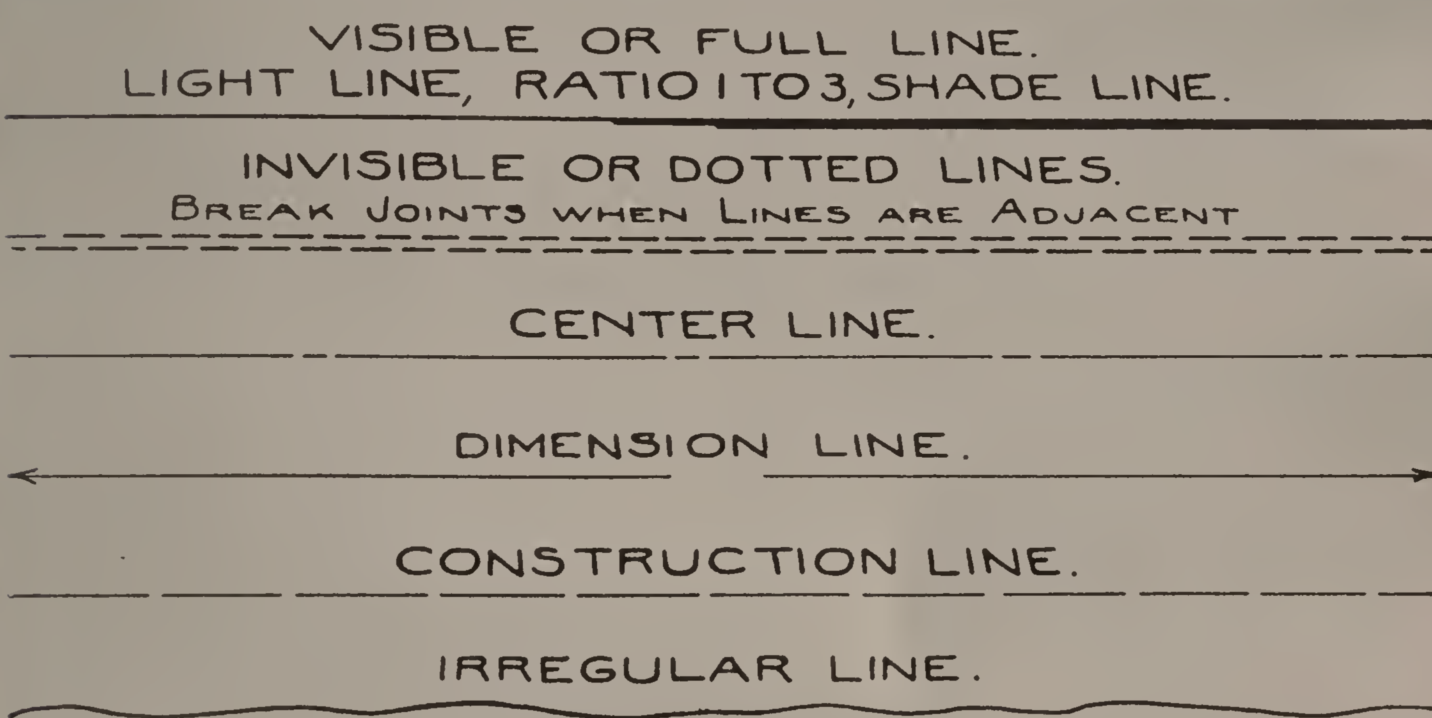


Fig. 13.

LINES. 1. All drawings are to be made with a 6H sharp chisel-pointed pencil. (See Par. 4, page 7.) **The pencil work is to be clear and distinct and have a finished appearance before any inking is done.** It is not necessary to pencil cross-hatching or dimensions on a drawing that is to be inked. Cross-hatching may be done lightly freehand to indicate the areas to be sectioned.

2. Full lines are drawn for all visible edges. (See Fig. 13 for width of line.)

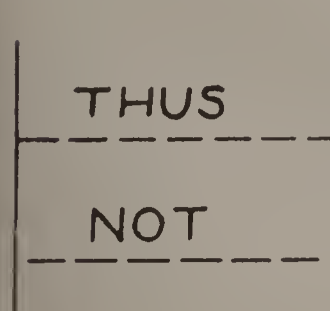


Fig. 14.

3. Dotted lines are used to show hidden edges, and should be drawn as the clearness of the drawing is thereby furthered. Dotted lines are in reality short dashes with spaces about $\frac{1}{4}$ the length of the dash. (See Fig. 13.). **The first and last dash of a dotted line should touch the lines at which the hidden edge actually terminates.** (See Fig. 14.)

4. Parallel dotted lines that lie close together, should have the dashes and spaces staggered as shown in Fig. 13. The eye can more readily follow broken lines with spaces staggered.

5. The full lines in the two views, Fig. 15, represent lines in full view, and the dotted lines hidden ones. If the drawing is too much complicated by showing all the hidden edges, some may be omitted, provided the clearness of the drawing is not impaired.

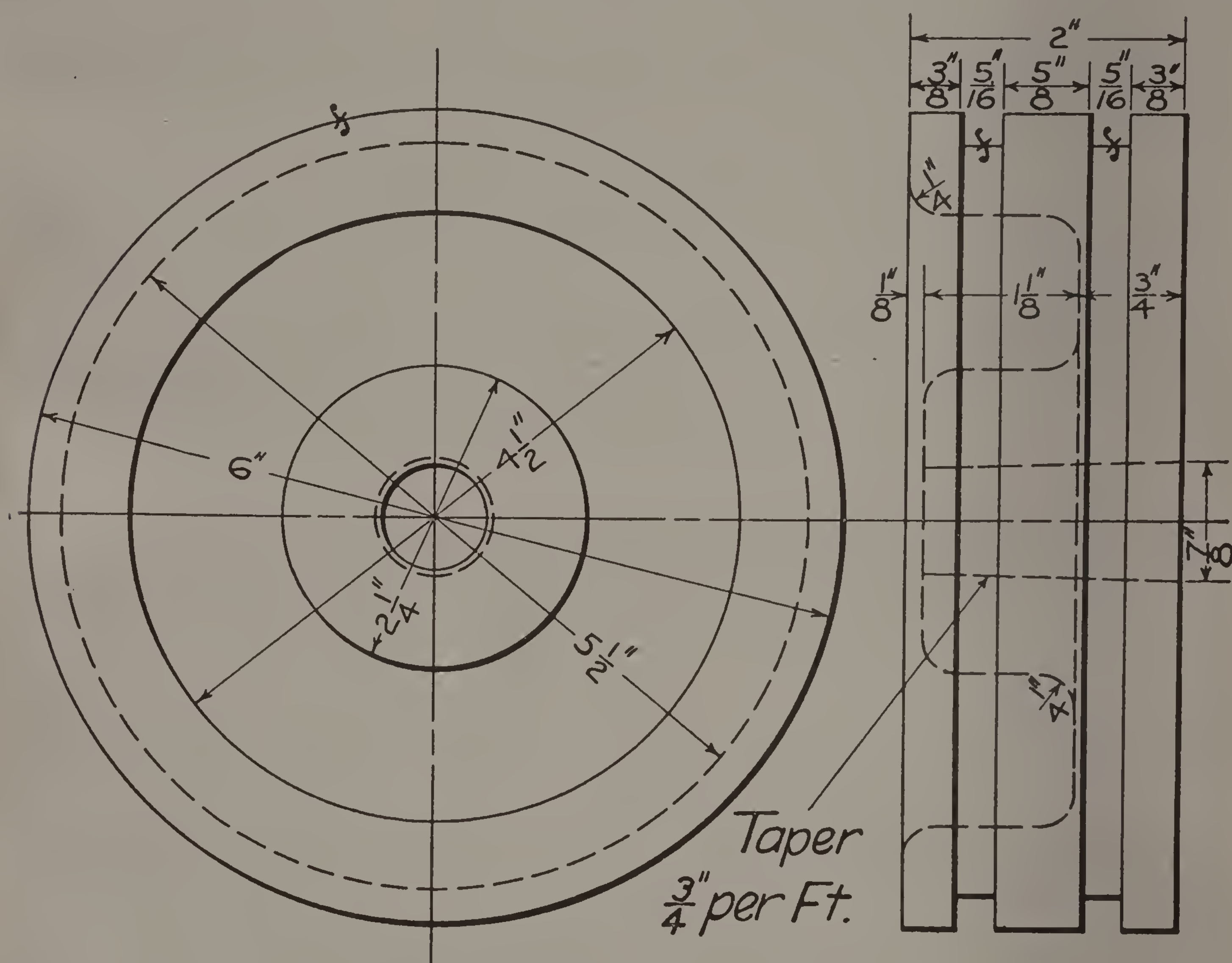


Fig. 15.

6. Center lines are long dash and dot black lines somewhat lighter than the outline. (See Fig. 13.) They are drawn through all axes of symmetry, the centers of all holes, bolts and rivets and where dimensions are to be given from some fixed line. **The breaks on each side of the dots should be short and should be in open spaces, not where lines are crossed.** (See Fig. 15.)

7. Center lines may be drawn continuous between different views of the same object; they must be offset for clearness when views of different objects are adjacent. (See Figs. 15 and 16.)

8. Irregular lines are used to denote a break when a portion of a view is shown in section. (See Figs. 13 and 16.)

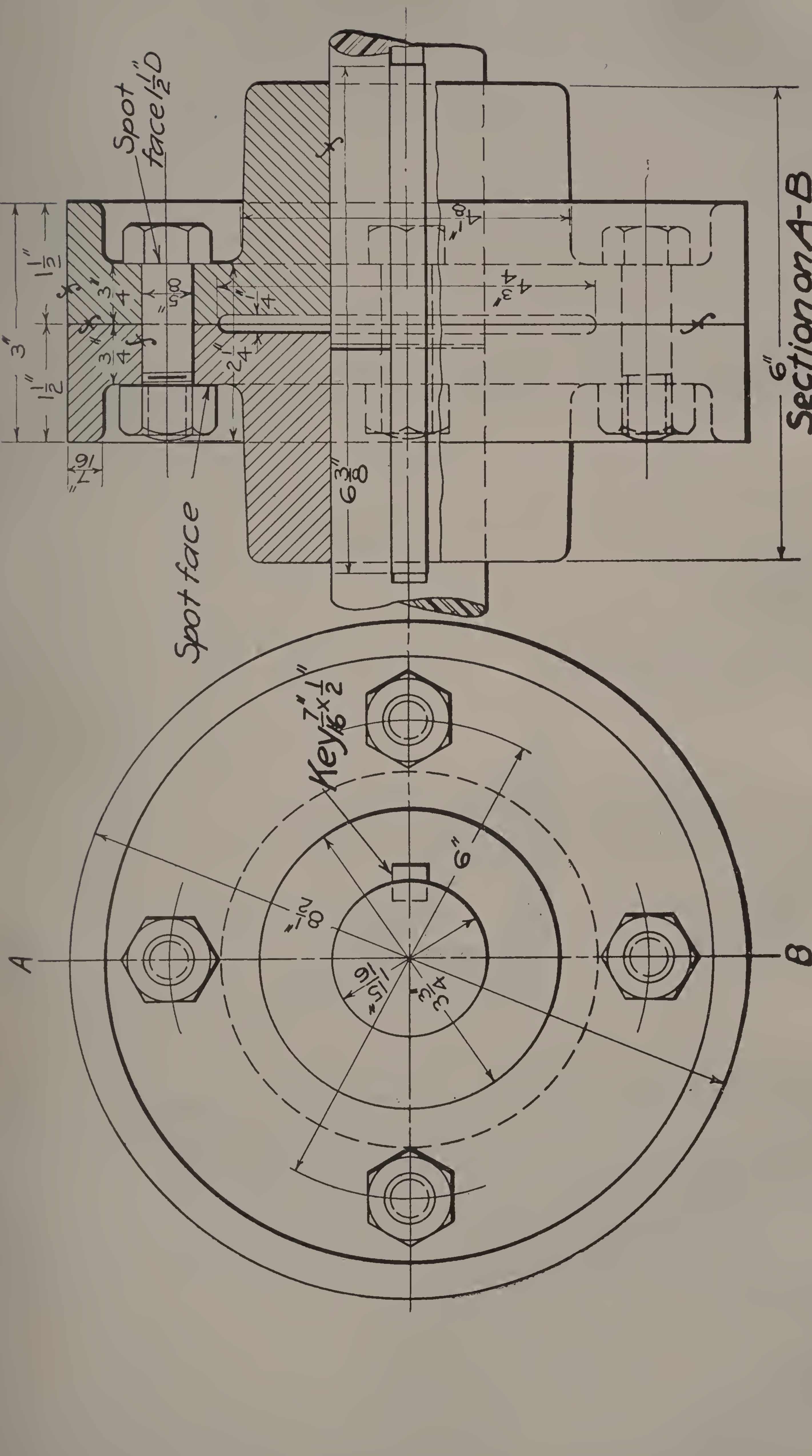


FIG. 16.

9. Construction lines are fine dash lines (see Fig. 13). They are used largely in elementary work to connect the projections on two adjacent planes. These lines should not touch the points between which they are drawn. (See Figs. 9 and 10.)

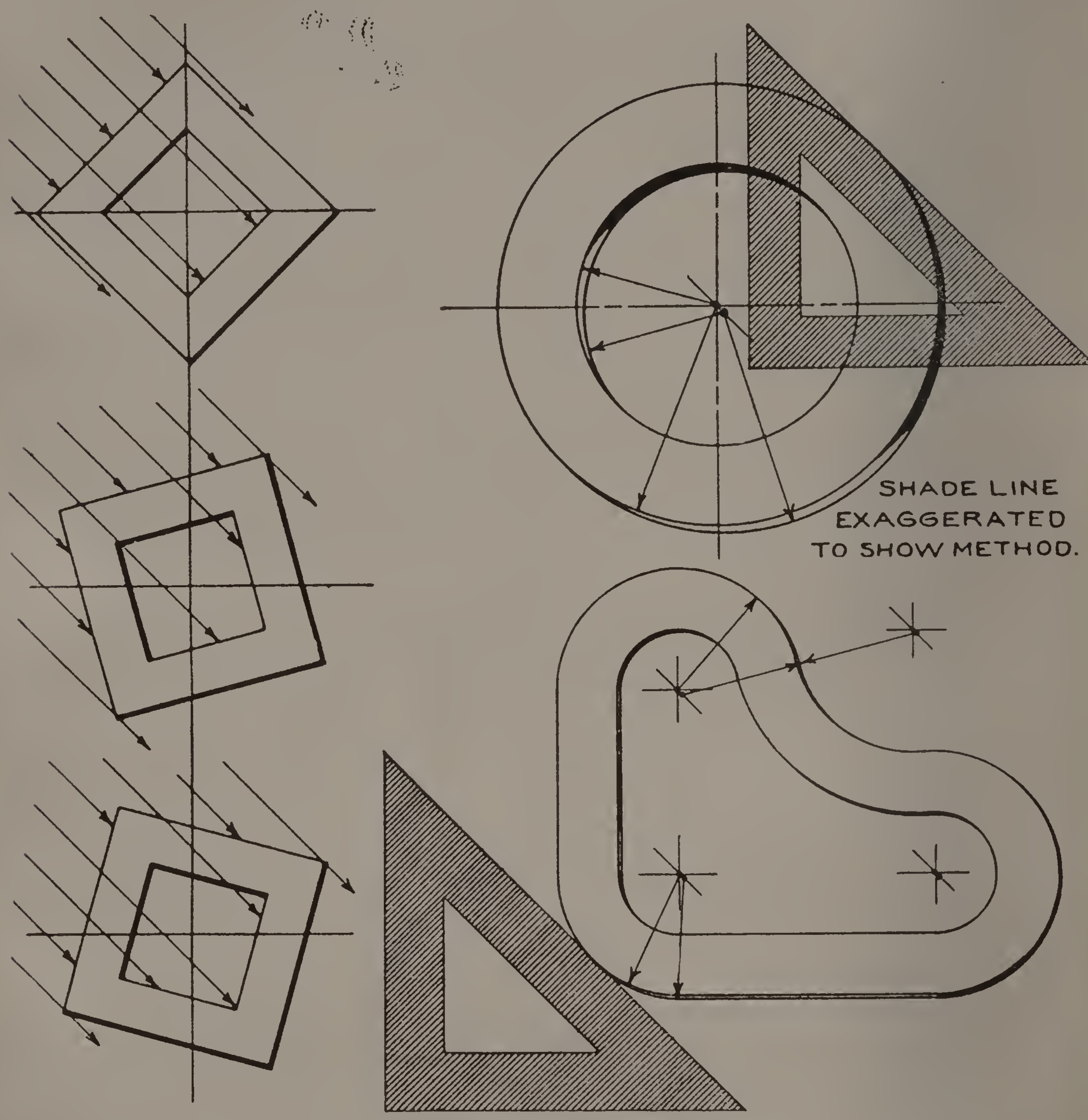


Fig. 17.

10. Adjacent part lines are drawn like construction lines. They are used to show a part that is adjacent to the piece drawn.

11. Extension or reference lines are full light lines used to prolong the lines of a drawing in order to place a dimension away from the view or at a more readable place; they should not quite touch the view so that they may not be taken for part of it. (See Figs. 15 and 16.)

SHADE LINES. 1. Shade lines are heavy black lines about three times as wide as the outline. (See Fig. 13.) They are drawn to distinguish readily the raised and depressed portions of an object and make the views stand out. (See Fig. 15.) The light is supposed to fall on all views of the object from the upper left-hand corner of the drawing, in parallel rays, at an angle of 45° with the plane of the paper as shown by the arrows to the left in Fig. 17. **No account is taken of the shadows cast by one portion of the object upon another.** The position of shade lines is conventional; for example, in Fig. 15 the lower lines of the right-hand view do not, strictly speaking, represent the divisions between a light and a dark surface, yet it is the custom to shade them as shown.

2. Draw all shade lines outside of the outlines.

3. A line common to two surfaces is not shaded when both surfaces are visible.

4. Shade the views independently of each other. By sliding a 45° triangle on the T-square and assuming the hypotenuse to be the ray of light, it is easy to determine, on just which surfaces the light does not impinge. (See Fig. 17.)

5. Make all shade lines on a drawing of uniform width and equal to the widest part of a shaded arc.

6. To shade a circle or arc always move the needle point of the instrument, without changing the radius, down to the right at an angle of 45° and a distance equal to the desired thickness of the shade line. Do this by eye. (See Fig. 17.) This will make the shade line blend into the outline at the proper place, *i. e.*, where the light ray is tangent to the curve. By placing the needle point in the original center and springing the pen slightly outward, the space between the original and eccentric curve can be filled in easily.

7. To shade an arc that joins a shade line at each end, change the radius without moving the needle from the original center, draw a concentric arc and fill in the intervening space.

8. Pencil lines are not shaded.

9. Shade lines are not used on tracings. All lines are heavy.

INKING IN. 1. Beginners make the mistake of drawing very fine ink lines that look neat but are not practical. If the nibs of the pen are forced close together the ink will not flow readily and the result is a fine gray line. **A fairly heavy black line is correct** (see Fig. 13); this may be obtained by opening the nibs of the pen so that the ink flows freely.

2. The outside of the pen must be kept free of ink. Never allow ink to harden in a pen; wipe frequently, and when through using see that the pen is quite clean. Do not scrape with a knife.

3. When inking a drawing, first draw all circles and arcs, shading them as you go; after that draw the light straight lines, and finally the shaded straight lines. Dotted lines are not shaded.

4. Lines, letters and figures must be black. If they have been lightened by erasure go over them until they are black.

5. The surface of the paper that has been roughened by erasures can be restored by rubbing it with a piece of hard-surfaced paper, the finger nail, a piece of polished bone, ivory or celluloid. This will prevent the ink from spreading.

6. Keep your paper and materials free from dust and particles of eraser to avoid blots and errors. Dust the drawing frequently.

DIMENSIONING. 1. Dimension lines are full light lines drawn to connect the points between which a dimension is given. The lines are terminated by arrow heads, and the dimension is

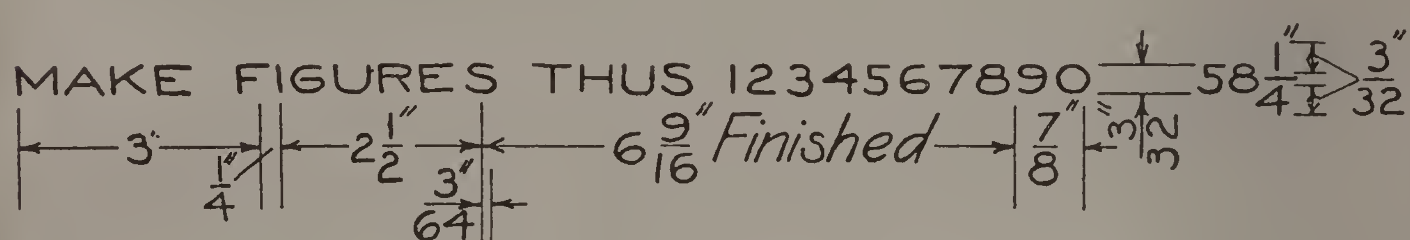


Fig. 18.

written in a break provided for that purpose, usually, but not necessarily, in the center of the line, as in Figs. 13 and 16. **Dimensions should be kept in line.** (See Fig. 15 at top and Fig. 18.)

2. Arrow heads are made with a fine writing pen. They should be small, neat and sharp, and touch the line to which they refer. (See Figs. 18 and 19.)

3. Dimension figures on a drawing should all be as near the same size as possible and not in proportion to the size of the dimension or drawing. Figures $\frac{3}{32}''$ high, made as shown in Fig. 18, are large enough for all practical purposes. (See Fractions.)

4. Figures printed in a line with lettering, as in a note or title, are made as high as the capital letters.

5. Figures must be placed in open spaces, where they can be read distinctly, and not on top of lines. (See Fig. 19.)

6. When the space is too small to contain a dimension, the arrow heads may be reversed and placed with the dimension outside the space as shown in Fig. 19.

7. For lack of room a dimension or note may be written in a convenient place and connected to the required point by a straight leader. Such a leader should always have an arrow head to indicate the point to which the dimension or note refers. (See Fig. 19.)

8. Fractions must always have the dividing line at right angles to the figures, thus: $\frac{3}{8}''$, never 3/8″, each figure in the numerator and denominator should, for clearness, be $\frac{3}{32}''$ high the same as the whole number and should not touch the line. (See Fig. 18.)

9. Inch and foot marks should be made neat and distinct (see sample under abbreviations) and accompany every dimension. (See Figs. 16 and 19.)

10. Dimensions may be placed directly on the views but this frequently crowds the drawing too much. Dimensions should

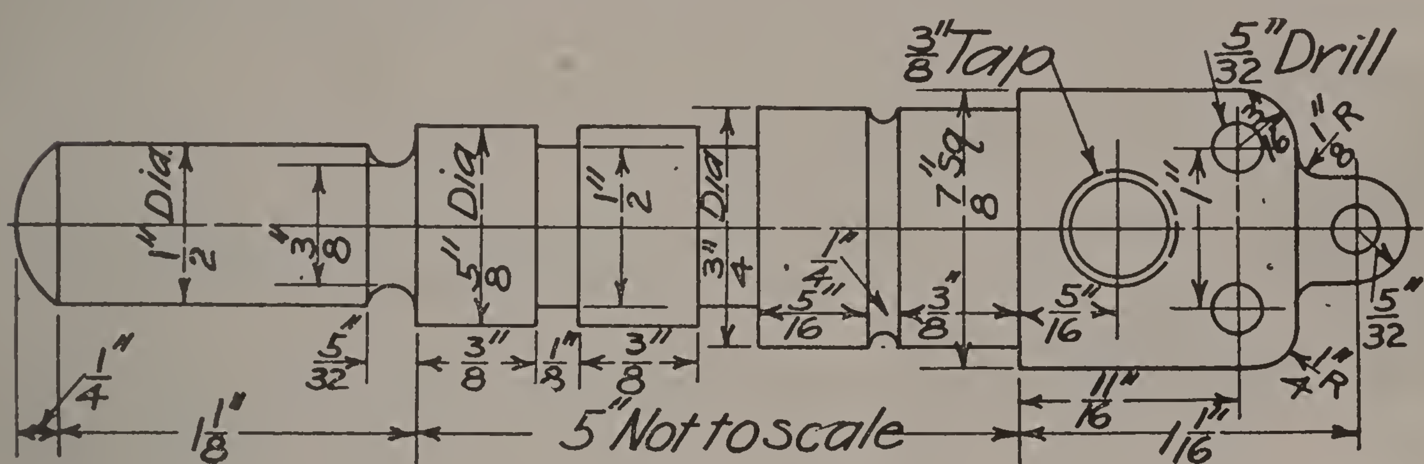


Fig. 19.

be placed outside the views wherever clearness is gained thereby, using extension lines between which the dimensions are given. **Dimension the views in blank before entering the dimension figures;** that is, first draw all extension lines and dimension lines, then make all arrow heads. **Dimensions must be kept in line** as shown at the top of Fig. 15 and in Figs. 18 and 19.

11. Dimensions may be placed on a section but not on top of cross-hatching. Dimension a drawing before cross-hatching it.

12. Dimension figures must always be placed at right angles to the dimension line and read only from the bottom or right-hand side of a drawing. (See Fig. 19.)

13. Dimensions of machine parts are usually given in inches, thus: $2\frac{1}{2}''$, 27″, the inch mark being placed after the figure. **In large works, dimensions over two feet are given in feet and inches,** thus: 4′—0″, 20′—$8\frac{1}{2}''$, 3′—$0\frac{7}{8}''$. A dash between feet and inches and a zero for no inches are essential to avoid errors.

14. Necessary dimensions, for a piece and every feature of it, are length, width, thickness and location. They must be given on a drawing and care taken to avoid repetition. Give dimensions from finished surfaces wherever possible, from center lines, and from one center line to another. Center lines are not used as dimension lines.

15. The size and location of holes must be given on the circular view. Locate holes from center lines or from center to center. Give cord distances and pitch circle diameter for holes on an arc; angular distances are undesirable.

16. Give dimensions to full lines, in preference to dotted ones.

17. Useful dimensions are those which are of most service to the user of the drawing who should never be required to do any calculating. A little thought as to the process the material must undergo in the construction of the object, will quickly determine what dimensions to give.

18. Over-all dimensions are useful in getting out material and should be given where needed.

19. Distribute the dimensions among all the views and do not crowd too many into one. Select dimensions that are the best for each view.

20. A circular arc is dimensioned by a radial line, which need not extend to the center, with an arrow head only at the arc as shown for the $\frac{1}{4}''$ fillet and round corner in Fig. 15.

21. Circular pieces and bores are dimensioned by diameters, whether the complete circle or only a part of it is drawn; in the latter case **Diam.** must be printed after the dimension figure and the dimension line extended beyond the center as shown in the semicircular view, Fig. 38.

22. Distances that are not to scale, as on a foreshortened view of a long piece, must have **Not to Scale** printed after the dimension figure. (See Fig. 19.)

23. Omitted dimensions give trouble. To determine if a dimension is missing, scan for arrow heads the line in all views to which a dimension is desired. If no arrow head touches the line that dimension is missing.

24. Tabulated dimensions are used for parts that are similar in shape but different in size. Only one of the parts is drawn and the dimensions of all parts tabulated as shown in Plate I. Dimensions that are common to all of the parts may remain on the views.

ABBREVIATIONS. The abbreviations and symbols most commonly used in practice are shown in Fig. 20.

ANGLE	∠	HEXAGONAL	Hex.
CENTER LINE	℄	INCHES	Ins. or "
CENTER TO CENTER	℄ to ℄	INSIDE	I. S.
CHAIN	═══	LEFT HAND	L. H.
CIRCULAR PITCH	C. P.	OUTSIDE	O. S.
CIRCUMFERENCE	Circum.	PITCH CIRCLE DIAM.	P.C.D.
DEGREES	°	RADIUS	Rad. or R.
DIAMETRAL PITCH	D. P.	RIGHT HAND	R. H.
DIAMETER	Diam.	SQUARE	Sq.
FEET	Ft. or '	THREADS	Thds.
FINISH MARK	ʃ	THREADS PER INCH	Thds. per In.

FIG. 20.

FINISH MARKS. Finish marks indicate that the surfaces marked must be machined to the exact dimension given, not necessarily polished. They are made with a writing pen (see Fig. 21) and should read from the bottom of the drawing only. (See Fig. 16.) The casting or forging is made full, where indicated by a finish mark, to allow for machining. When a piece is to be finished all over, omit these marks and print **"finished"** in the general title. (See Titles.)

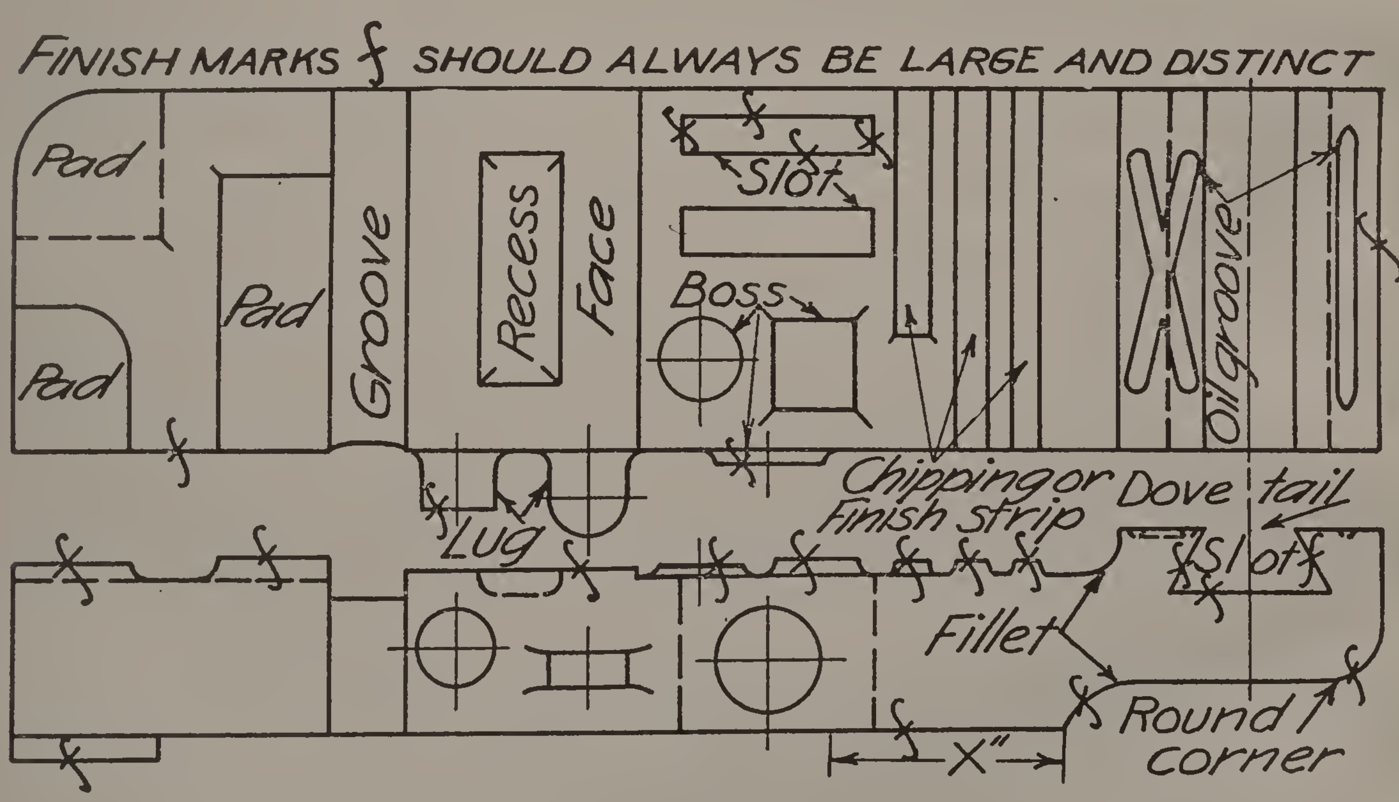


FIG. 21.

FINISHED SURFACES. The mechanical operations that are required to finish a surface are Boring, Broaching, Chipping, Drilling, Filing, Milling, Planing, Reaming, Scraping, Shaping and Turning.

The operation may be specified on the drawing for any given surface as a guide to the artisan.

FITTING SYMBOLS. Parts that fit together, as a wheel on a shaft and a shaft in a bearing, must have an allowance made for tight or loose fitting of the parts. Conventional Fitting Symbols and their uses are shown in Fig. 22.

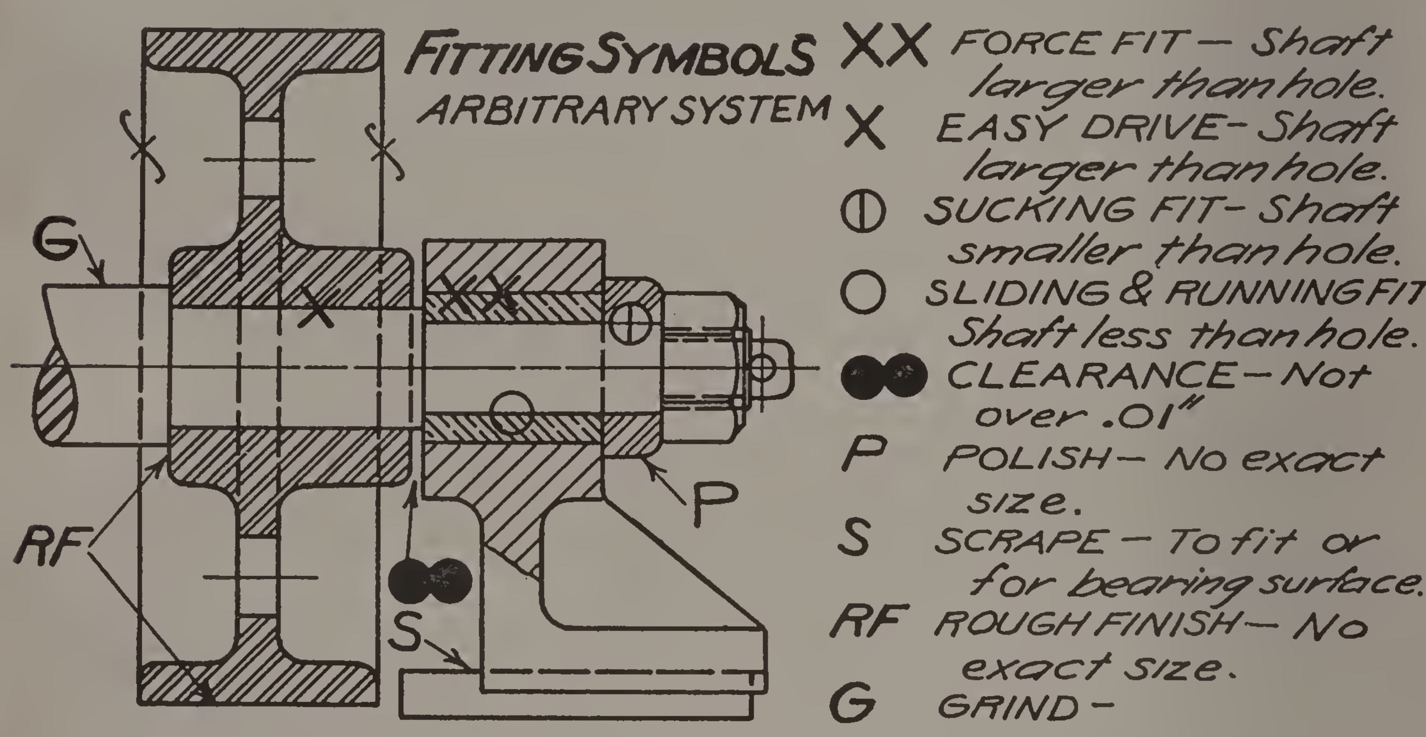


FIG. 22.

SECTIONS. 1. As the object of a drawing is to represent the exact construction of the machine or part drawn, it is often convenient for clearness to draw some of the views or parts of them as sections through the object. Thus, in Fig. 16, the upper half of the right-hand view represents a section on a plane A—B that is normal to the vertical plane of projection. That is, we assume the near portion of the upper half of the object (as shown in the right-hand view only) to be cut away, back to the section plane, showing the construction of the object as it appears at that section.

2. The trace of a section plane must be lettered, in one of the views, and a note placed directly under the view stating where the section is taken; thus, **Section on A—B, Section on X—Y—Z.** Inclined lower case letters are used for this notation. (See Fig. 23.)

3. A section plane may be offset, as shown at A—B—C—D in Fig. 23, to include portions of an object that are not in a straight line.

4. When the surface of a section stops at a plane through the center line, the center line is made a full line as far as the section extends, and shaded if the conditions require it.

5. When the surface of a section extends a little beyond the center line an irregular line (Fig. 13) is drawn to show a fractured surface. The latter method is frequently necessary to more clearly show the detail of the interior; for example, the key and keyway in the illustration, Fig. 16.

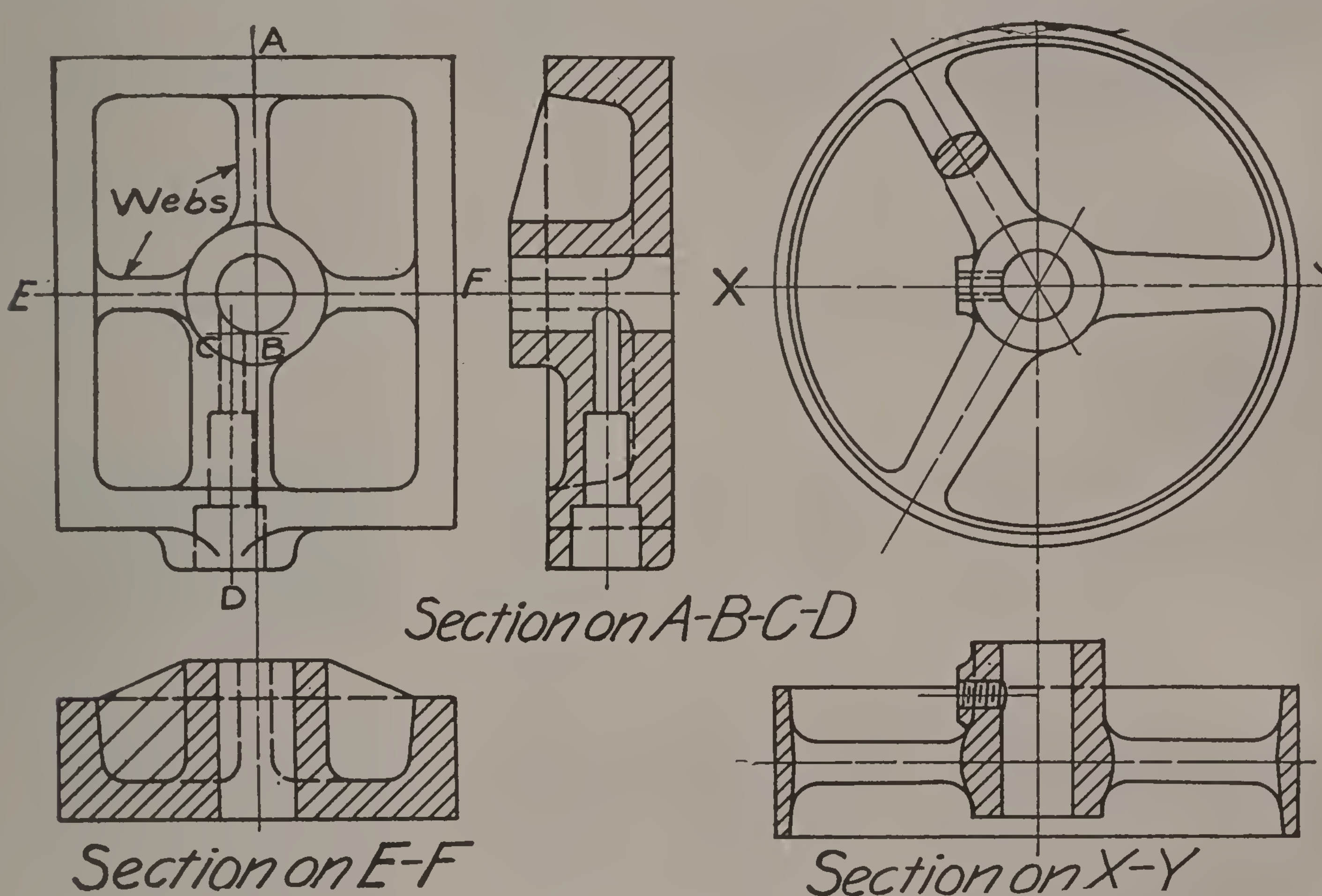


Fig. 23.

CROSS-HATCHING. 1. All portions of the object cut by a section plane are cross-hatched by lines making an angle of 45°, except where otherwise shown in the "Conventional Standard Cross-hatchings" Plate A. **Cross-hatching is done after a drawing is fully dimensioned, omitting it where the dimension is placed.**

2. All sections of the same piece, in the same plane, are cross-hatched in the same direction. Cross-hatching lines are never drawn across a full line.

3. When two or more pieces, of the same or different material, show in a section adjacent to each other, the cross-hatching must be drawn in opposite directions. (See Figs. 16, 22 and 44.)

CONVENTIONAL STANDARD CROSS-HATCHINGS

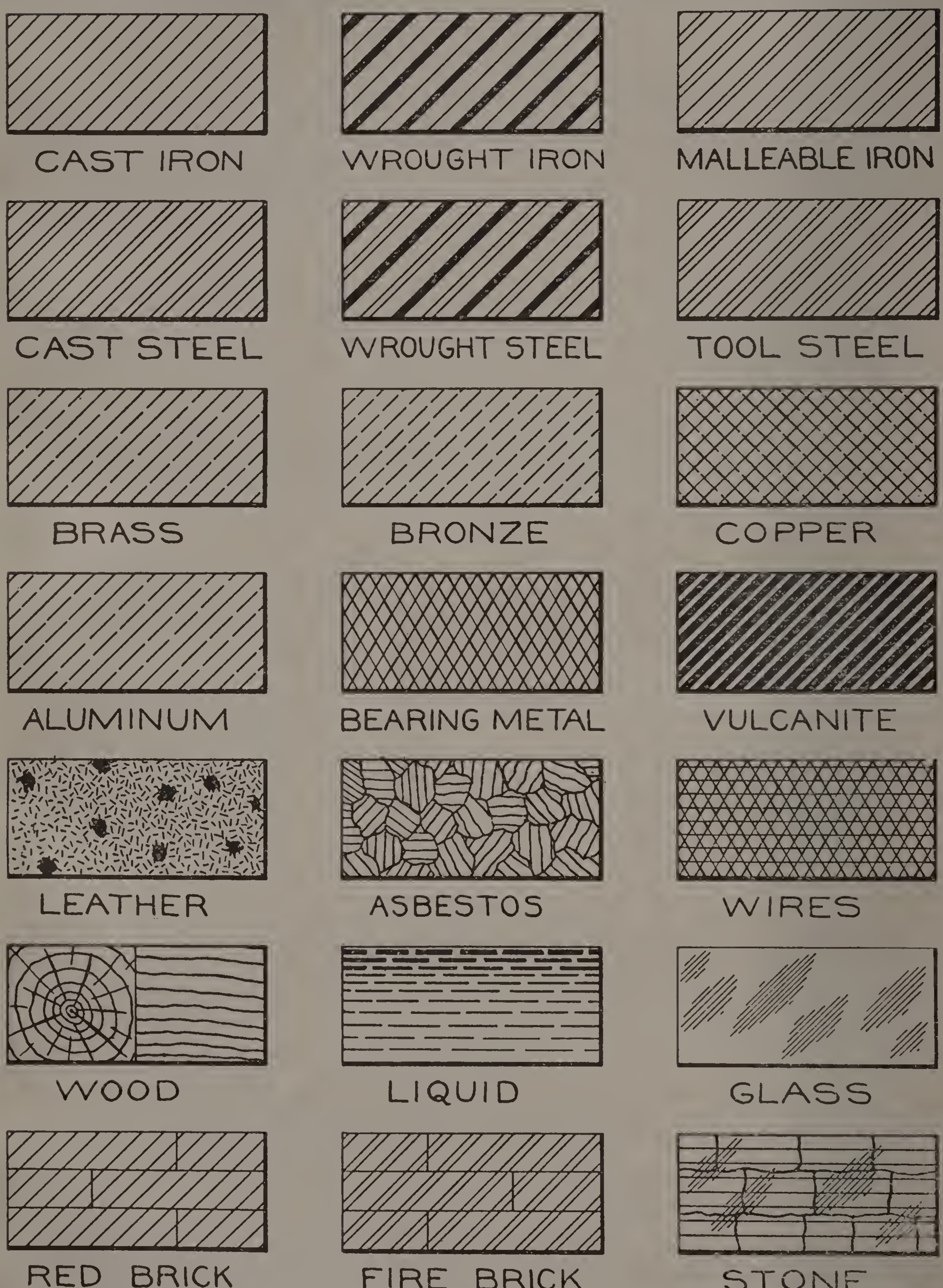


Plate A.

4. Care should be taken to space the cross-hatching uniformly. This is readily done by eye, after a little practice on a separate sheet of paper. The appearance of a drawing, which is otherwise faultless, is often spoiled by poor cross-hatching.

5. Cross-hatching lines should be somewhat finer than the outline and not too close. Use about a $\frac{1}{16}''$ space. They may be drawn across center lines.

6. The system of conventional standard cross-hatchings to be used in sectioning is shown on Plate A. Note the spacing and width of line.

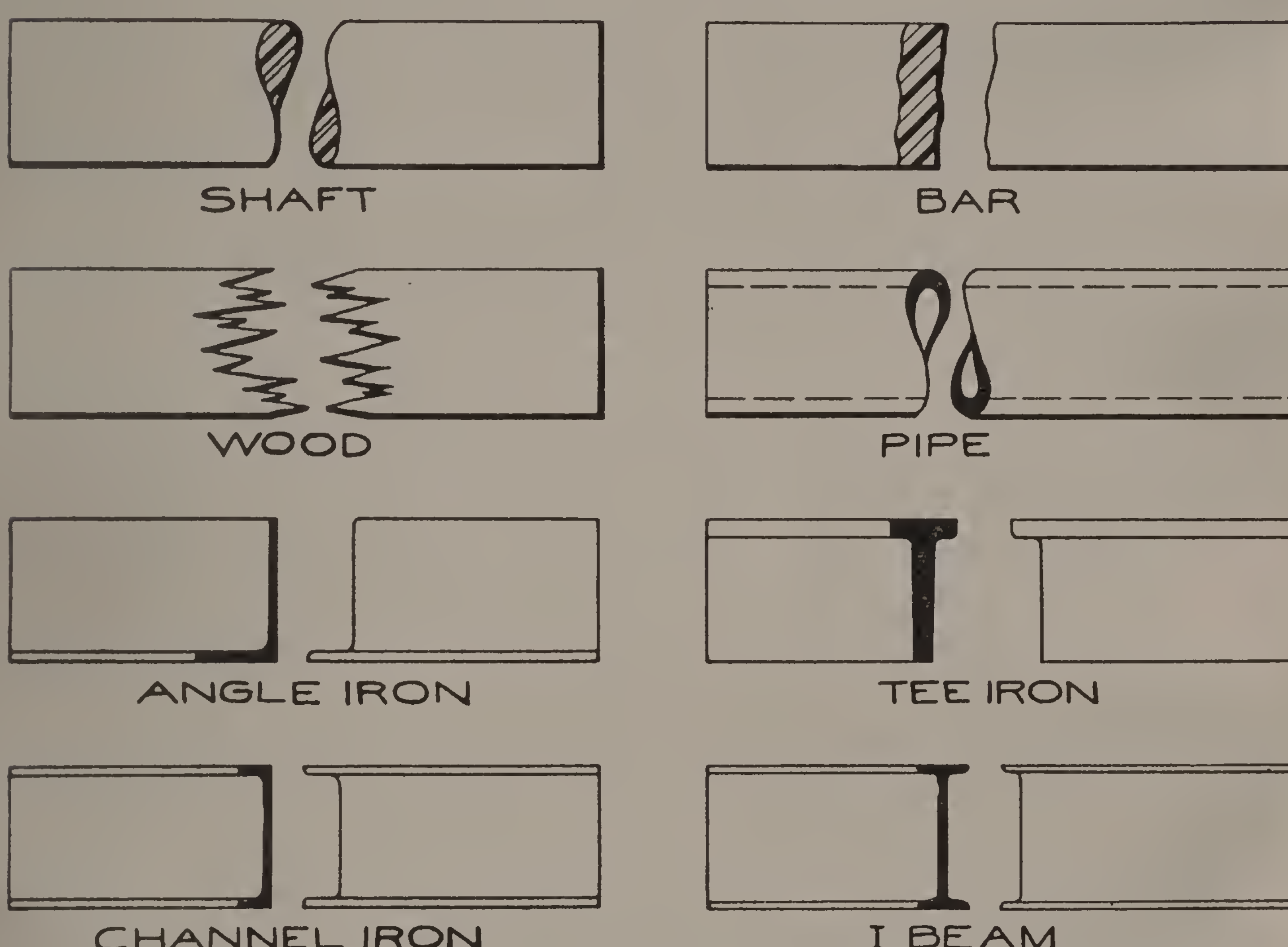


Fig. 24.

7. Axles, Balls, Bolts, Cotters, Keys, Nuts, Screws, Shafts, Spokes of Wheels, Valve Stems, etc., are not cross-hatched when a section is taken longitudinally through them, but are drawn full as though the cutting plane did not pass through them in order to make a drawing clearer. (See Figs. 16, 22 and 23.)

8. Ribs, Webs and similar thin parts are not cross-hatched when a section is taken lengthwise through them. An alternative method used to some extent shows every other section line drawn across the rib or web. (See Fig. 23 for both methods.)

9. A shaft, bar, or other long piece is represented as broken, as shown in Fig. 24, when its full length cannot be drawn to a practical scale. The break should show roughly the outline of the cross-section of the piece.

10. Long structural details are always drawn foreshortened (other pieces may be if advisable) without a break showing and the dimension marked **Not to Scale.** (See Structural Drawing and Elementary Design by Conklin.)

TINTING. 1. When a large area of a drawing on paper or cloth is in section it is often more convenient to color the section than to cross-hatch it. This method is used in Architectural and Civil Engineering practice.

2. A drawing should be fully inked in with water-proof ink, freed from pencil marks and well cleaned **before the color is applied,** as the color is readily removed with a pencil eraser. If it is too dark a cleaning eraser will tone it down.

3. A section on paper or the dull side of tracing cloth may be colored by rubbing a soft black lead pencil over it. For producing distinctive colors the ordinary colored crayon may be applied generously and then blended to a uniform tint by rubbing the surface with a piece of cloth dipped in gasoline. Any color outside of the section is readily erased with an art gum eraser.

4. Colored inks, standardized, and moist water colors are also used for tinting sections. These liquid colors may be used sparingly on the dull side of tracing cloth. The cloth will wrinkle if too moist.

5. For tinting sections with moist water colors use the ones named for the materials given in the list below.

The color mentioned first, for a given material, should predominate in mixing the tint representing that material. In any case, a very small quantity of color will suffice.

Cast iron.......Paynes gray.
Wrought iron...Prussian blue.
Wrought steel...Prussian blue and crimson lake.
Cast steel.......Crimson lake and Prussian blue.
Brass...........Gamboge.
Bronze.........Gamboge and crimson lake.
Copper.........Crimson lake and gamboge.
Babbitt.........Water-thinned India ink.
Leather.........Water-thinned India ink and burnt sienna.
Wood..........Burnt sienna.
Glass...........Prussian blue and gamboge.

6. Go over the portions to be tinted with a brush, using clear water, just before applying the tint; this will prevent the tint from drying too rapidly. Make the tint light, then, by going over it again, if necessary, the proper shade may be obtained. Mix the tint in a saucer and stir with every dipping of the brush. **Remember that the process is that of tinting and not painting.**

7. A smooth tint will result if it is done quickly, working from left to right and downward. Keep a drop of tint on the paper just ahead of the brush and leave the part tinted practically dry. An excess of moisture remaining will cause the tint to dry blotchy. If the tint runs over a line, brush back quickly with the finger.

8. When the area to be tinted is quite large, the paper should be stretched. This is done by thoroughly wetting the entire paper and pasting it, along the edges, to the drawing board, allowing it to become thoroughly dry before starting the drawing.

9. Lines and dimensions may be placed directly on any tinted surface if necessary, but cannot be erased without removing the tint.

LINE SHADING

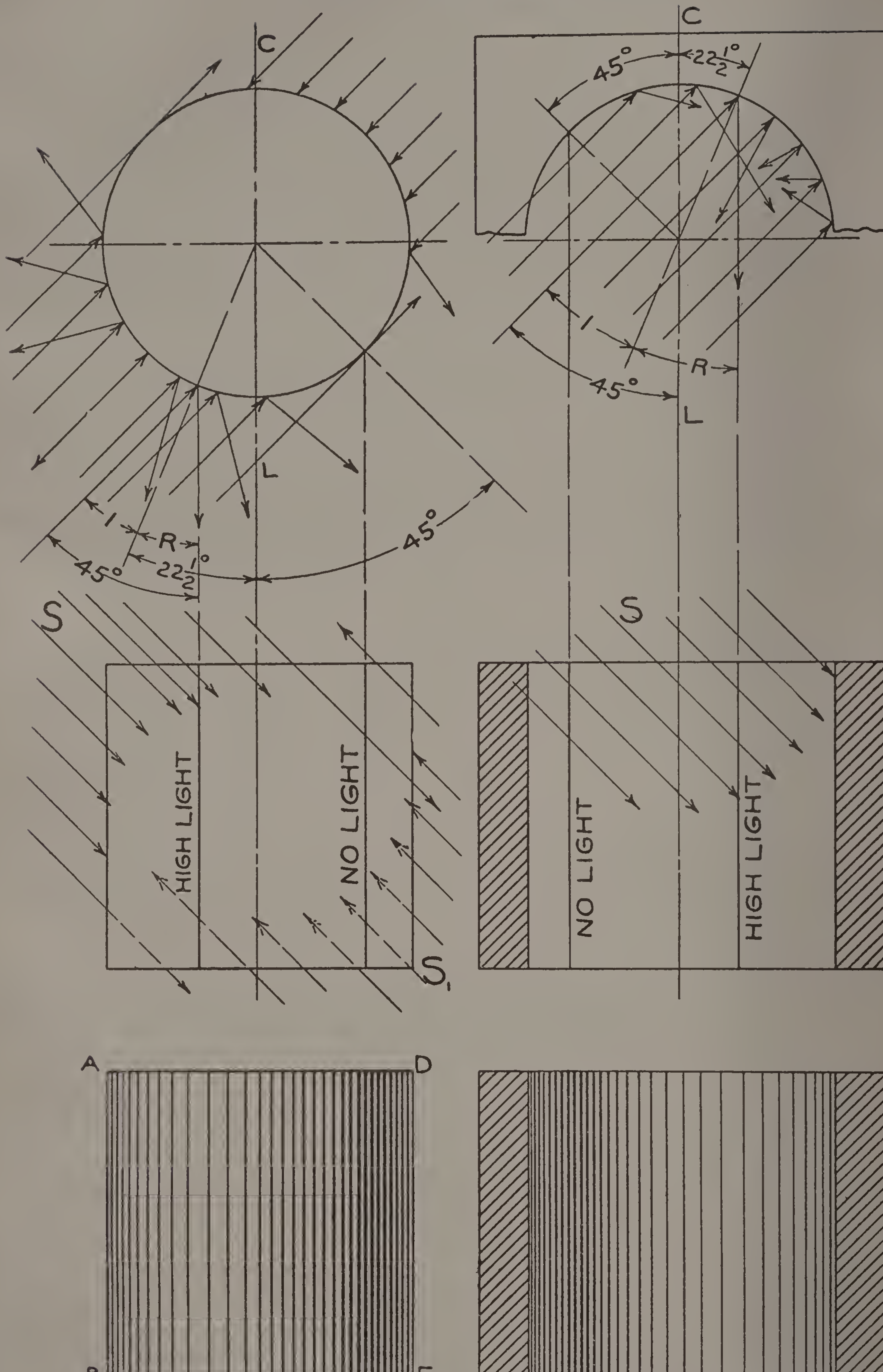


FIG. 25.

LINE SHADING. 1. Line shading is used to represent more clearly or more quickly the contour of the surfaces of which the piece is composed.

2. This method is used where the number of views is limited or where it is desired to represent to those who are not familiar with the principles of mechanical drawing, the construction of a machine or some part it is desired to emphasize.

3. Book and magazine illustrations and Patent Office drawings are examples in the use of line shading.

4. The distribution of light and shade found in current practice in the case of a circular cylinder can be produced by assuming the illumination to come from the opposite sources S and S_1 (Fig. 25) in parallel rays, their vertical projections making 45° with the horizontal plane of projection and their horizontal projections at 45° with the ground line. Source S is to the left and back of the observer.

5. The brightest part of an illuminated object is that which reflects the rays of light directly into the eye of the observer. Assuming the light to fall as above described, and knowing the angle of reflection R must equal the angle of incidence I, reference to Fig. 25 will show that the high light element must be $22\frac{1}{2}°$ around from the center line C L. At this element only, the rays of light would be reflected normal to the plane of projection and to the eye of the observer.

6. The dark element, or no light, is 45° around on the opposite side of the center line C L, for at this point the light rays are tangent and there is no reflected light. Beyond this element the surface is slightly illuminated by the rays S_1 from below.

7. The limiting elements A B and D E (Fig. 25) are of the same shade. The shades received by all surfaces of revolution are shown by lines which represent the generatrix in various positions, the intensity of the shade being effected by the thickness of the lines.

8. First, ink the outline of the drawing with a uniform line; omit dimensions, dotted lines, shade lines and center lines, although the latter are always penciled for construction. **Second, ink the shading, the straight lines first, and then the curved ones.** Avoid making lines fine or too close.

9. Practice line shading different surfaces on a separate sheet of paper before line shading a drawing.

10. Examples of line shading will be found on Plates B, C, and D, which cover most shapes met with. Study them and apply to your special case.

11. Do not use a knife on line shading; use a rubber to erase errors and restore the surface by rubbing it with a piece of paper.

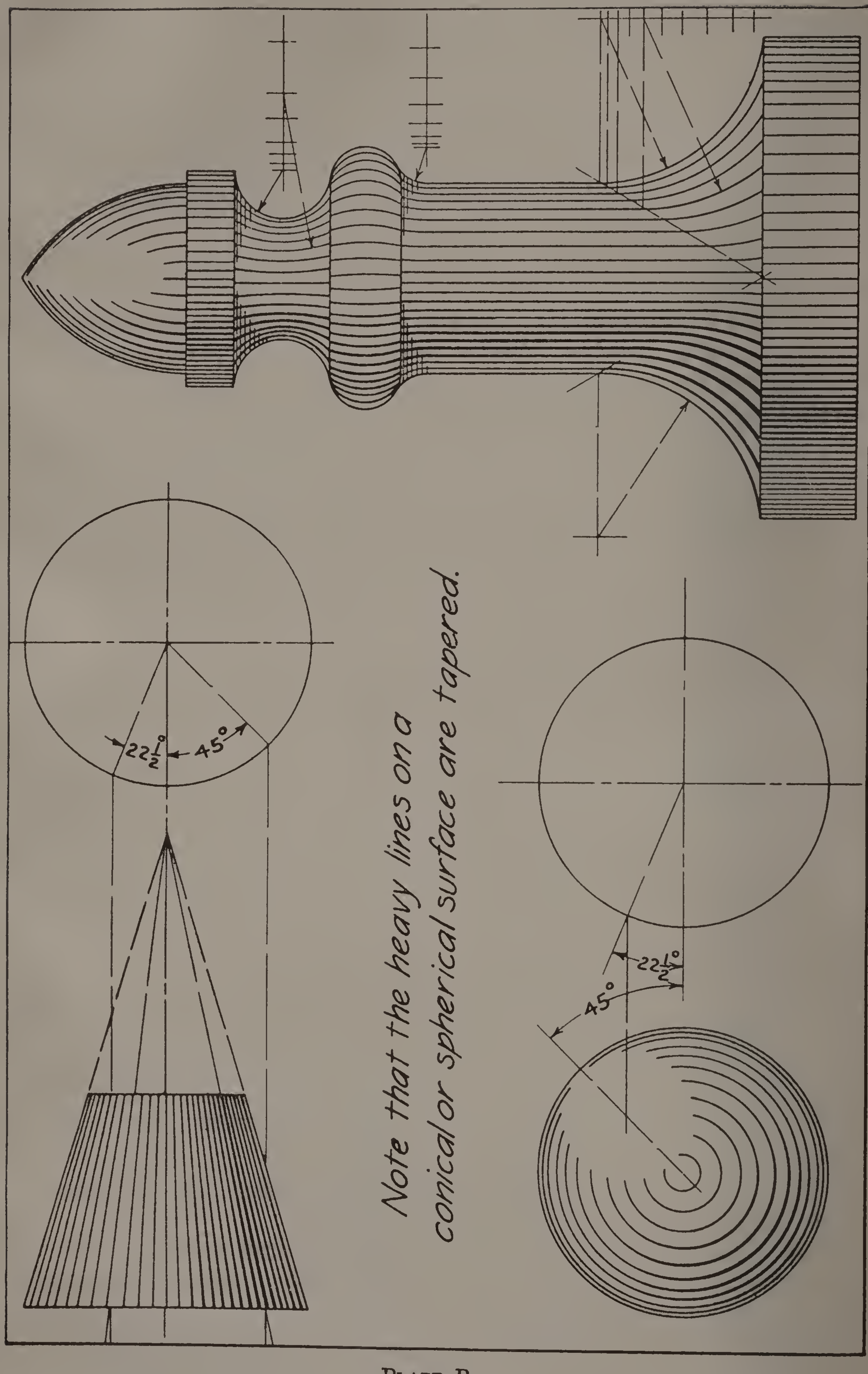
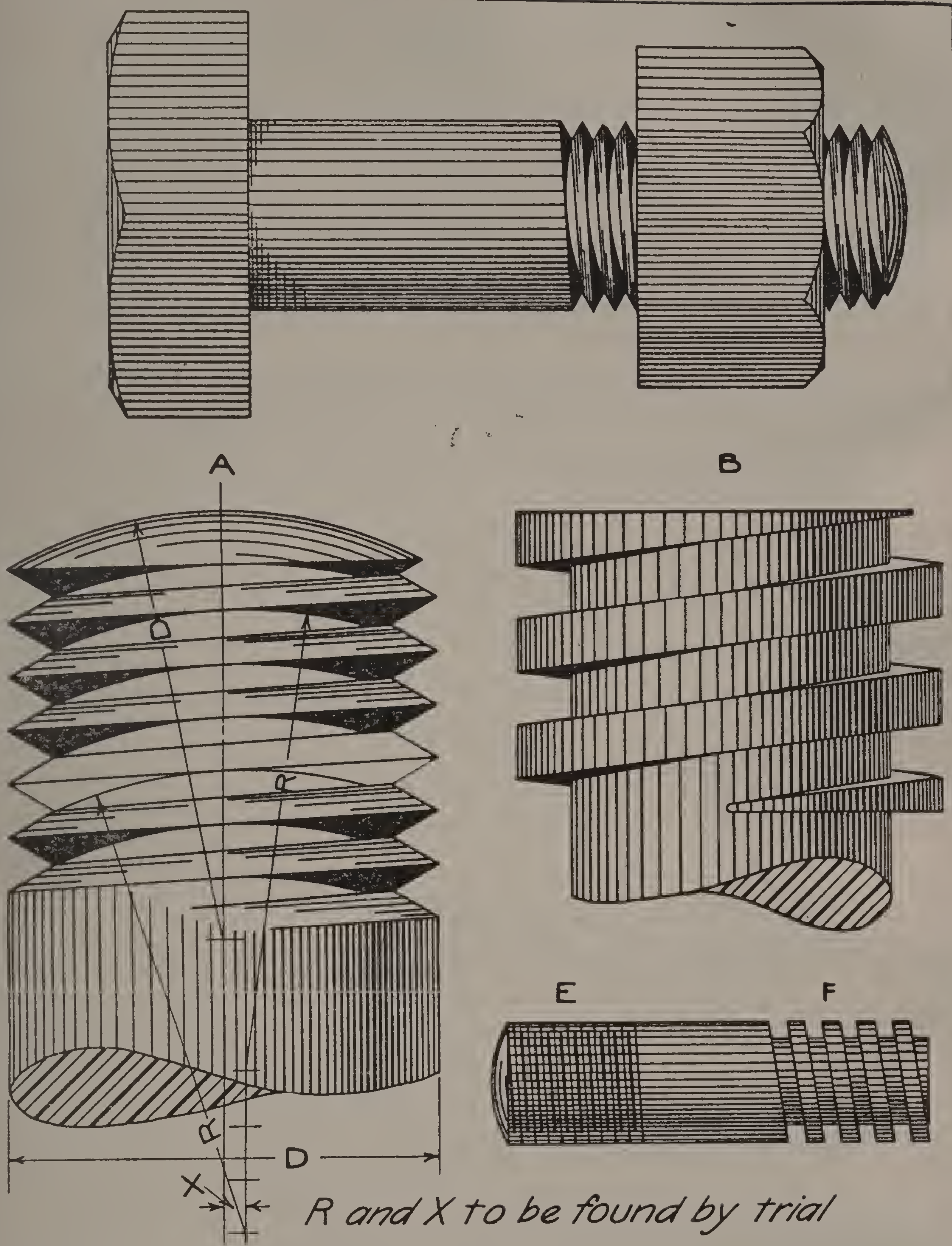
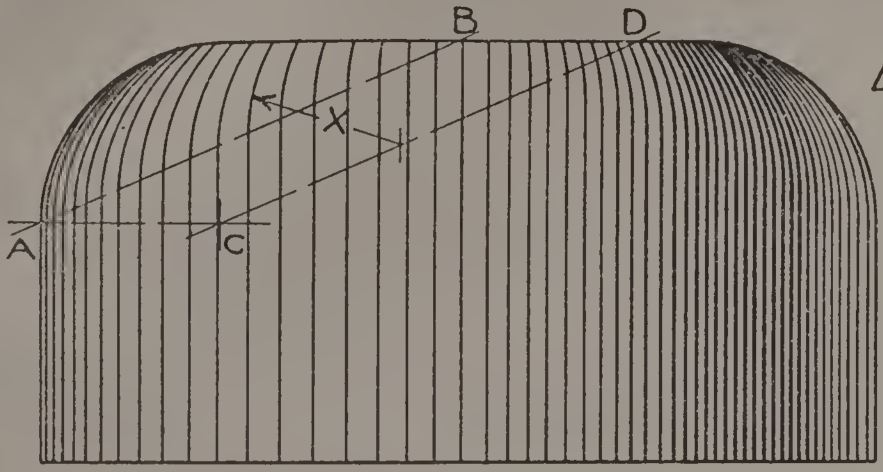

Note that the heavy lines on a
conical or spherical surface are tapered.
22½°
45°
22½°
45°

PLATE B.

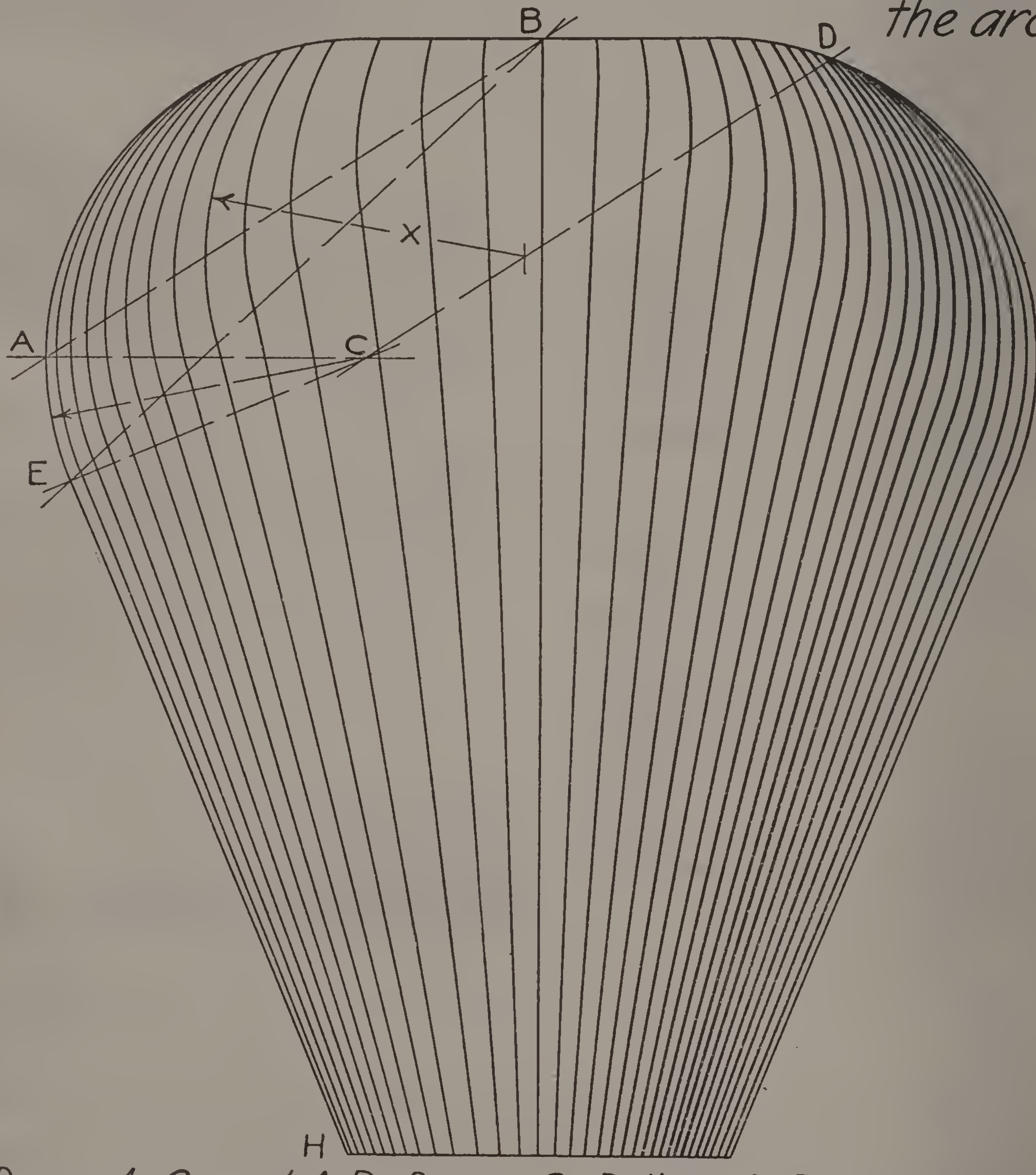


Screw threads that are $\frac{5}{8}''$ or over in diameter, when drawn to scale, should be drawn to the exact shape and pitch, the curve of the helix being neglected, and shade as shown at A and B. When under $\frac{5}{8}''$ Diam. use the conventional methods E and F

Plate C.



Draw A–C and A–B
" C–D ll to A–B
Prolong straight lines to meet A–B
With radii X= A–C and ¢ on C–D draw the arcs.



Draw A–C and A–B Draw C–D ll to A–B. Draw C–E ⊥ to E–H. Draw E–B. Prolong straight lines to E–B. With radii X=C–E and ¢ on C–D draw the arcs.

Plate D.

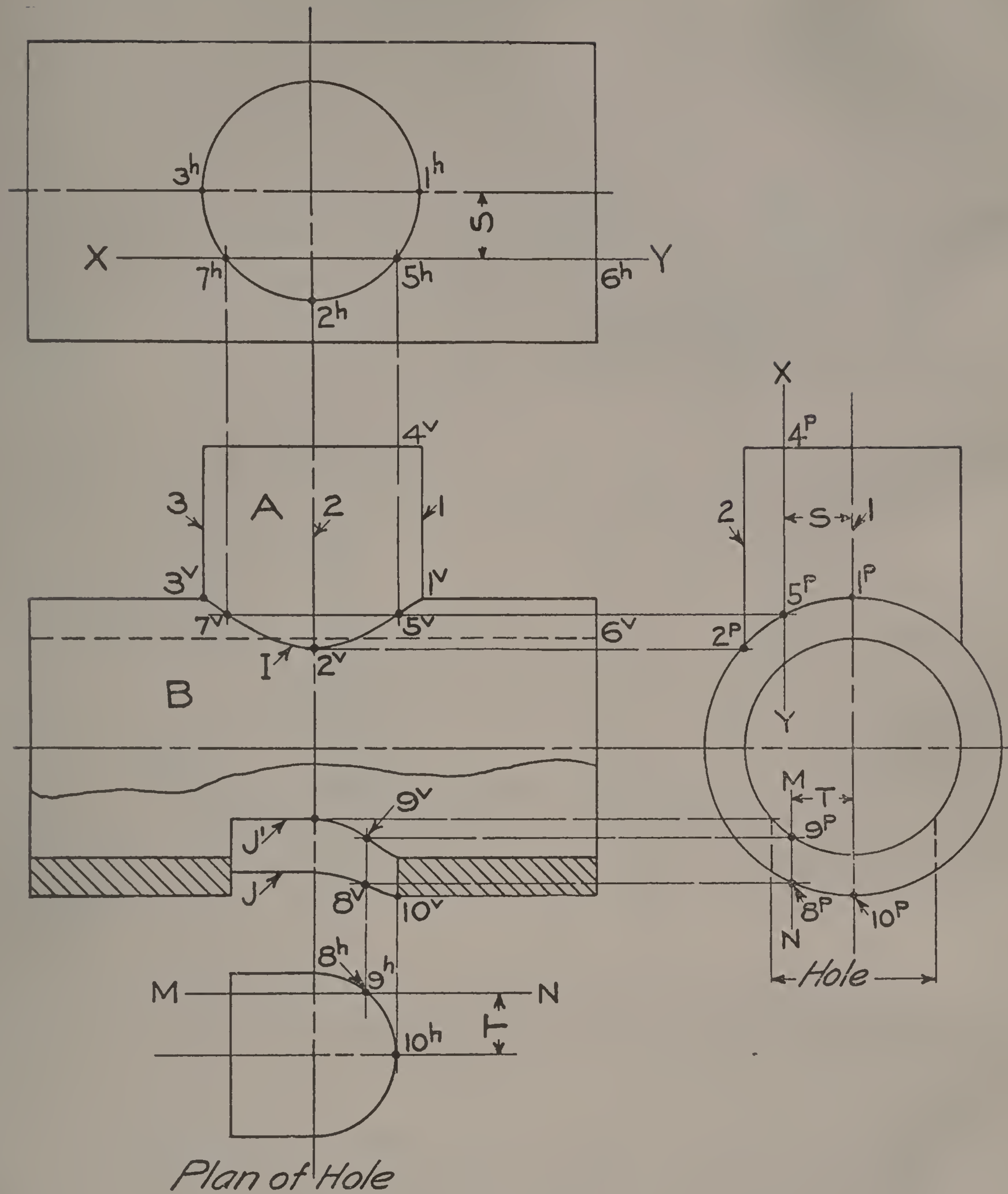


FIG. 26.

INTERSECTIONS. 1. The intersections of curved surfaces should be drawn as an aid to the understanding of a drawing. The line of intersection of two pieces must be carefully plotted when it is required that one or both pieces be cut to fit together at the line of intersection. (See Developments.)

2. Descriptive Geometry treats of the methods employed in finding intersections, but the student unfamiliar with this subject can plot most of the simpler ones met with in practice if he observes the following instructions.

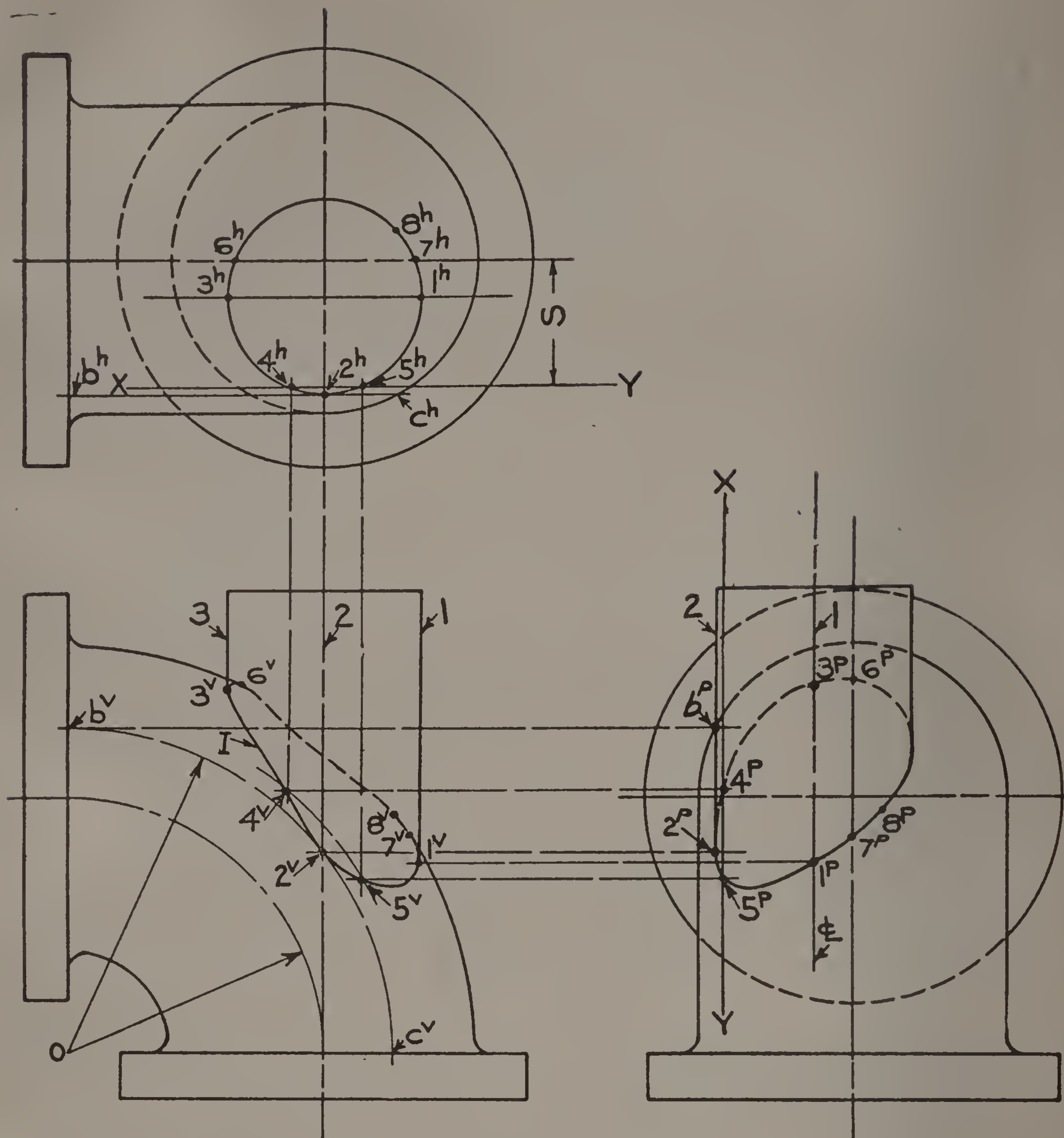


Fig. 27.

3. To determine a point on the line of intersection of two surfaces, pass a plane through both in a way that its trace on each surface will be an element or other known line, these elements will intersect at a point on the line of intersection of the surfaces.

4. A sufficient number of points should be plotted to determine the shape of a curve of intersection. Approximate the curve by drawing a light freehand line through the points plotted, as a guide for applying the Irregular (French) Curve. With the aid of the Irregular Curve a smooth curving line is drawn through the points.

5. Two intersecting cylinders, A and B, with axes at right angles and in the same plane are shown in Fig. 26. I is their line of intersection, its shape being determined by plotting points.

These points are the intersections of elements in the cylindrical surface A with elements in the cylindrical surface B. Element 1 of A intersects element 1 of B at 1^v and element 3 of A intersects it at 3^v. Element 2 of A (see end view) intersects element 2 of B at 2^p; 2^v, the projection of this point on the vertical, plane is the lowest point on the curve of intersection I. **Intermediate points are found by passing planes in such a way that they cut elements from each surface, the intersection of the elements in any one plane being a point on the curve.** For example, the plane X—Y at any distance S from the center line (see end view) cuts element 4^p5^p from A and 6^h5^h (see top view) from B. From 5^p and 5^h the projection 5^v on the vertical plane is determined. This point, 5^v, being the intersection of two elements, is a point on the curve of intersection. Another point, 7^v, is determined by projection from 7^h.

6. Cylinder B (Fig. 26) is hollow and has been broken away to show a hole cut through its lower portion. This case is similar to the previous one, the difference being that the thickness of the cylinder is shown and the surface of the hole therefore intersects the inside as well as the outside surface of the cylinder B.

7. The plane M—N (see end view) cuts on the cylindrical surfaces elements that pass through the points 8^p and 9^p and cuts the element 8^p9^p on the semi-cylindrical surface of the hole. The points 8^p9^p in which the elements meet, if projected on the vertical plane, determine 8^v and 9^v, which are points on the lines of intersections J and J′.

8. A pipe elbow with its center at O, intersected by an offset cylindrical outlet, is shown in Fig. 27. In this case points in the line of intersection I are found by passing planes containing elements of the cylindrical surface and arcs on the surface of the elbow. Element 2 appears to intersect the elbow at b^p, end view, but a plane passed through 2 cuts from the elbow, front view, the arc $b^v2^vc^v$. This arc is found by projecting the point b^p to b^v on the center line through O, thus determining a point in the plane through which to draw an arc with O as its center. The element 2 lies in the plane of this arc and intersects it at 2^v, which is a point on the line of intersection $1^v2^v3^v$. The point 2^v projected to the end view determines 2^p, a point on the intersection that appears in that view. Pass any other plane, as X—Y, at any distance S from the center line. The points of the lines of intersection that lie in this plane are 4^v and 5^v in the front view and 4^p and 5^p in the end view. A sufficient number of points are to be found through which smooth curves of intersection may be drawn.

9. Note that between 6^v and 7^v, front view, the line of intersection replaces a portion of the arc of the elbow in this view. This is due to a portion of the cylindrical piece, $6^h8^h7^h$ top view, $6^p8^p7^p$ end view, overlapping the center of the elbow.

10. A bell-shaped surface of revolution (B) intersected by a plane surface (S) and a cylindrical surface (C) is shown in Fig. 28. (Heavy lines given light ones to be found.) Any cutting plane, as X—X, passed perpendicular to the axis of revolution will cut an arc of radius or_2^h on the surface of revolution and a straight line

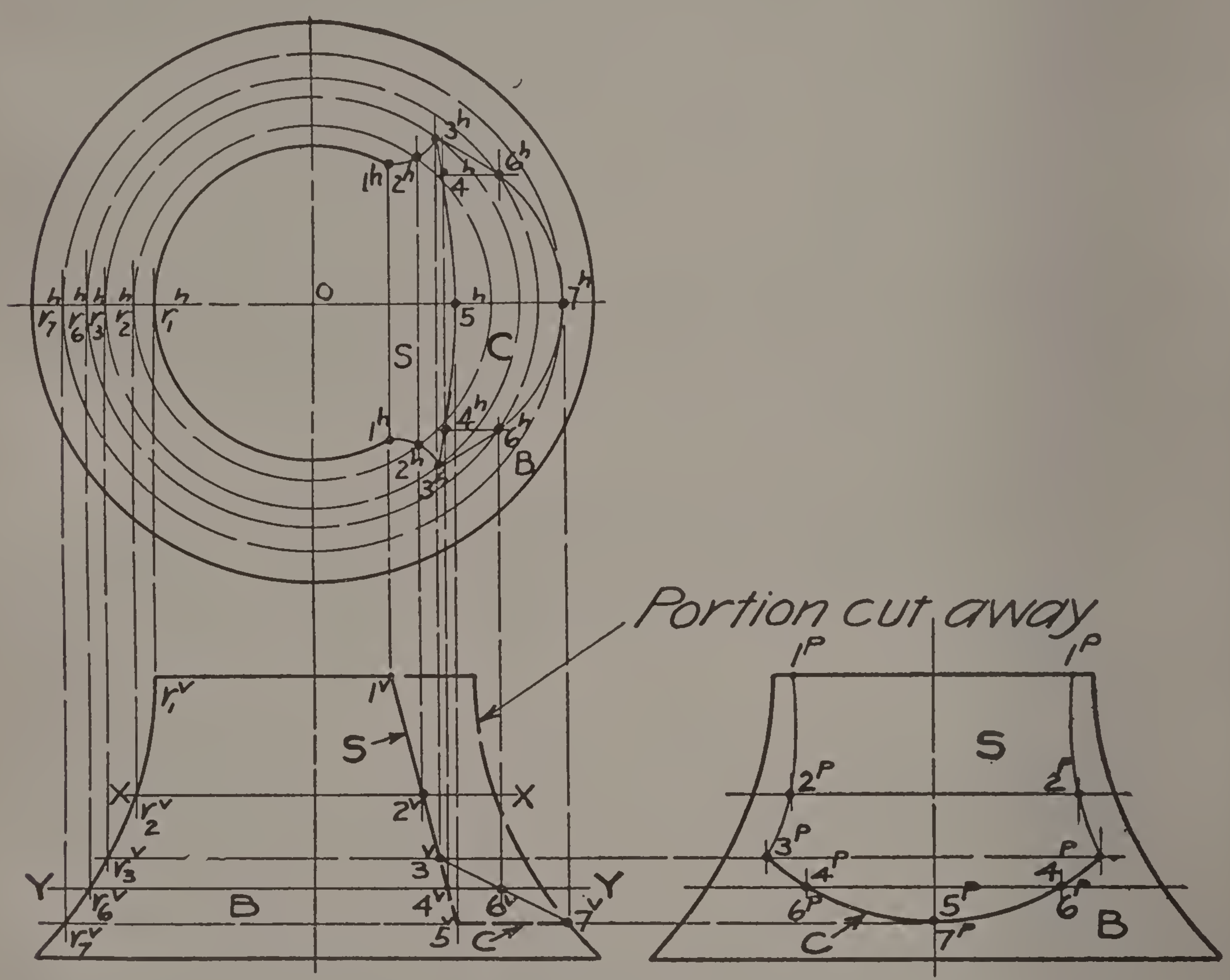


FIG. 28.

element 2^p2^p on the plane surface; this arc and element lie in the same plane and intersect at points 2^h and 2^h (projected from 2^v) which are points on the line of intersection of the two surfaces (B and S). 1^h and 3^h are the limit points of this line and its shape on the profile plane will be given by the points 1^p, 2^p, 3^p found by projection. Any cutting plane, as Y—Y, cuts an arc of radius or_6^h on the bell surface and elements 6^p4^p at 6^p (side view) on the cylindrical surface, also an element at 4^v on the plane surface. Project 4^h4^h from 4^v and 6^h4^h from 6^p. The elements 6^h4^h and 4^h4^h lie in the same plane and intersect at 4^h, which is a point on the line of intersection of the cylindrical surface (C) and plane surface (S); 3^h, 5^h and 3^h are the limit points of this line. The element 6^h4^h and arc of radius $or_6{}^h$ lie in the same plane and intersect at 6^h, which is a point on the line of intersection of the bell surface (B) and the cylindrical surface (C); 3^h, 7^h and 3^h are the limit points of this line and its shape on the vertical projection will be given by the points 3^v, 6^v, 7^v found by projection. Read paragraph 4.

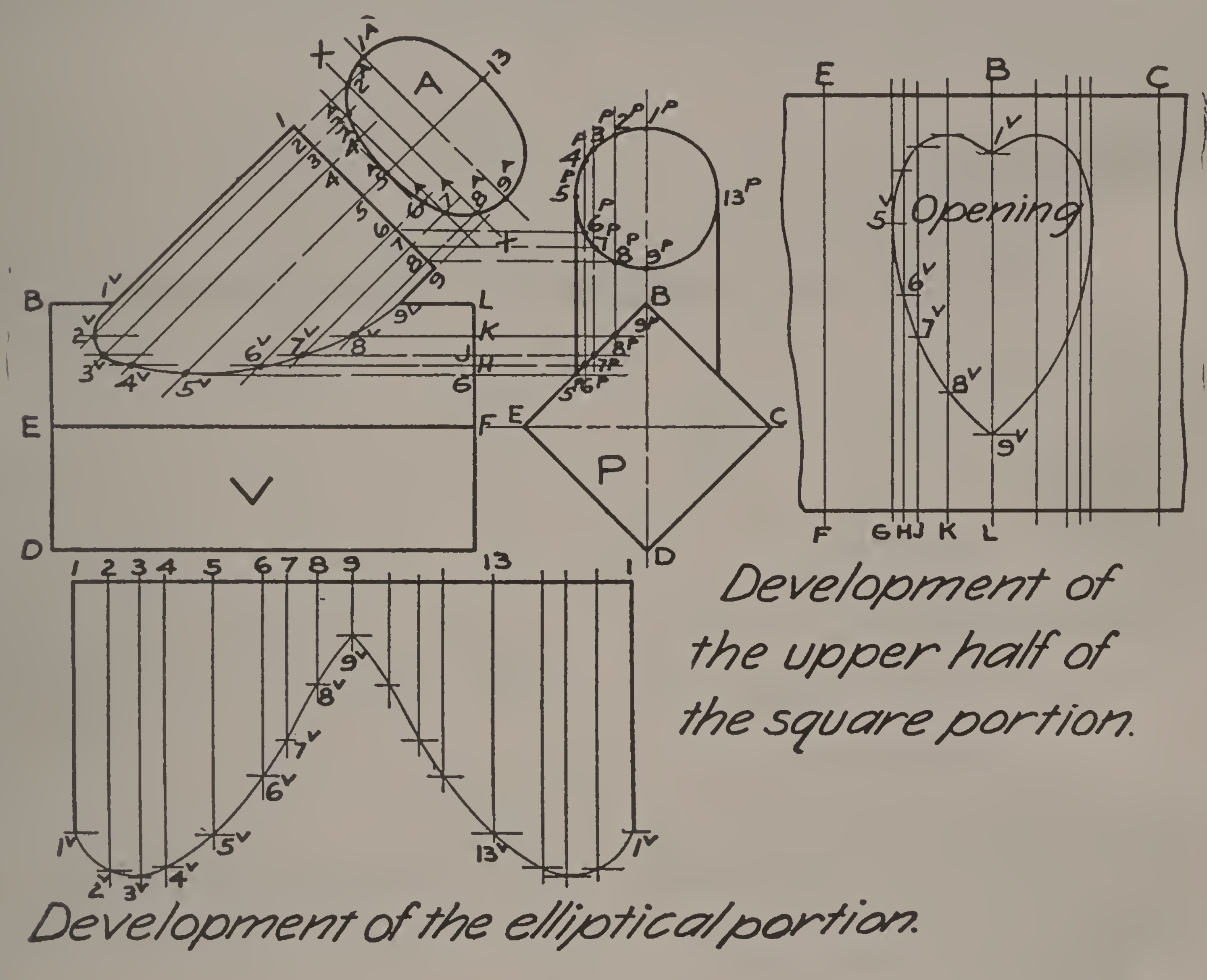
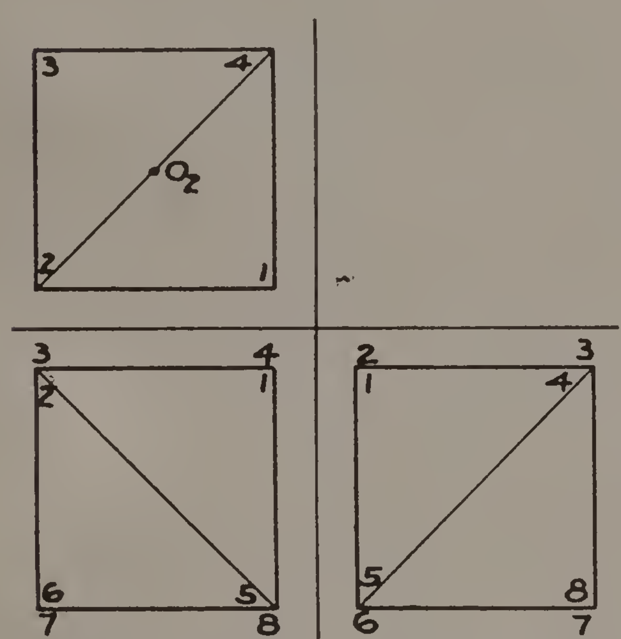


FIG. 29.

DEVELOPMENTS. 1. The development of surfaces is necessary when sheet material is required to be cut to fit together. The line of intersection of the surfaces must first be determined and from it the development plotted.

2. An elliptical shaped piece intersecting one of square section is shown in Fig. 29. In this case an auxiliary view A is required to show the true size and shape of the elliptical piece. The line of intersection 1^v, 2^v, 3^v, 4^v, etc., was determined by planes, as X—X, passed parallel to the axis of the oval piece. These gave elements as 6–6^v intersecting elements as H–6.

3. To plot the development of the elliptical piece draws a base line 1, 2, 3, 4, ... 13, ... 1 and make 1,2 equal to 1^A2^A measured on the arc by stepping off carefully with a bow spacer, make 2,3 = 2^A3^A, etc. Draw the elements $1,1^v$, $2,2^v$, etc., perpendicular to the base line and equal in length to the corresponding element on the vertical projection. A smooth curve drawn through the points $1^v,2^v,3^v$, etc., plotted on the developed surface of the elliptical piece will give the shape the piece must be cut to fit the opening in the square piece. The opening is plotted in a similar manner.



ORTHOGRAPHIC PROJECTION

FIG. 30.

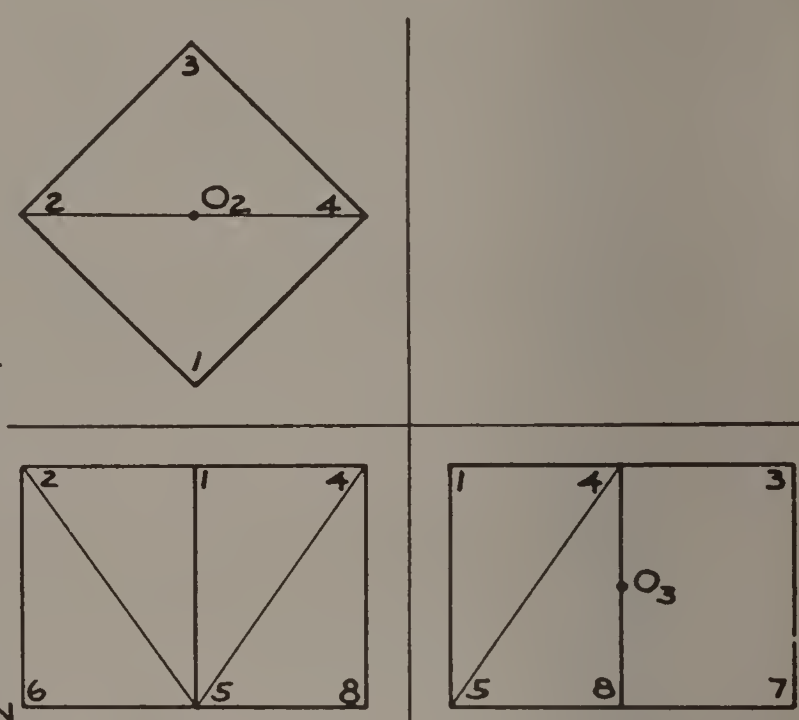


FIG. 31.

ISOMETRIC DRAWING. 1. An Isometric Projection of a cube is one in which all lines of the cube are of equal length, (isos equal + metron, measure).

2. Orthographic Projections, 3d angle, of a cube in three positions are shown: first, in Fig. 30, with all faces parallel to the planes of projection; second, in Fig. 31, rotated through 45° about a vertical axis 0_2; third, in Fig. 32, rotated about a horizontal axis 0_3 until its diagonal (1–7) is perpendicular to the vertical plane. The vertical projection of the cube in this position is an isometric projection, since all edges of the cube are equal in length. The edges are shorter than the true length on the cube.

3. Isometric Planes are the three dimension planes of the cube visible in its isometric projection. (See Fig. 33.)

4. Isometric Axes are the lines of intersection of the isometric planes and are at 120° with each other. (See Fig. 33.)

5. Isometric Lines are lines that are perpendicular to either isometric plane H, V or P, Fig. 33; they are measured in their true length parallel to the axes. **Non-Isometric Lines** must be plotted by the Orthographic Coordinates of points in the lines.

6. Isometric Projections of Circles that are parallel to the Isometric Planes will be ellipses. The lengths of the major and minor axes are not known, as they are in the ellipse which is the oblique projection of a cylinder or cone. (See Geometric Drawing, Plate V, for drawing an ellipse with axes given.)

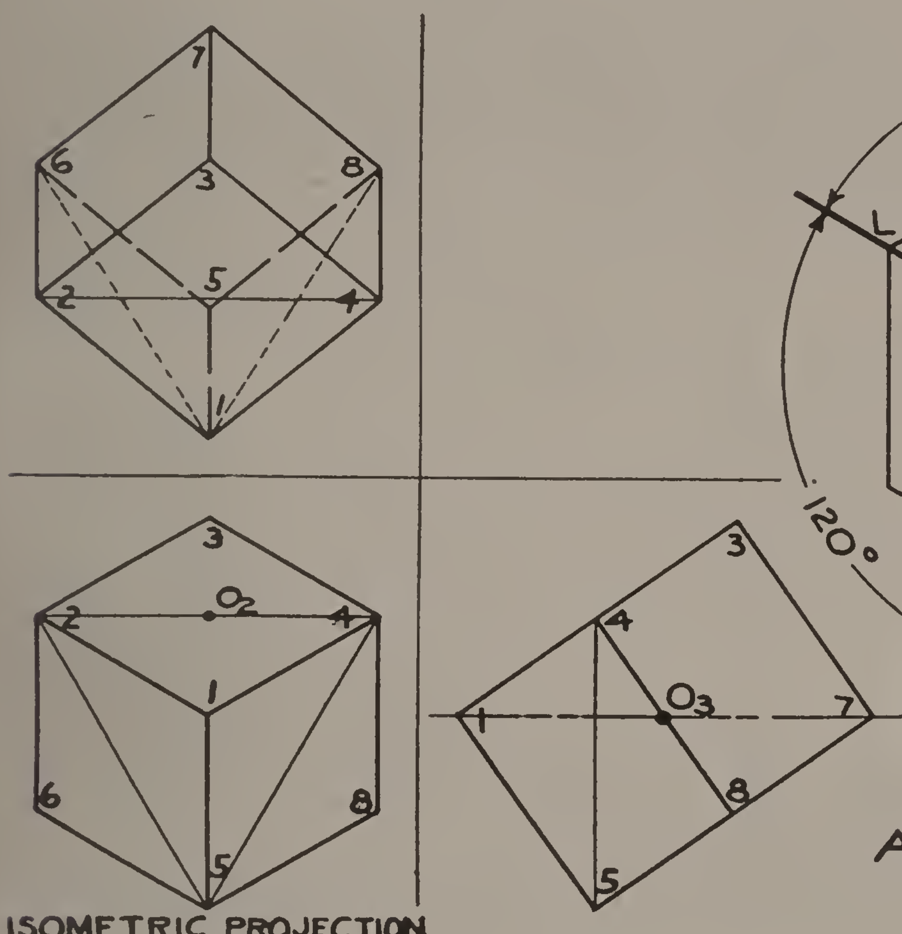


FIG. 32.

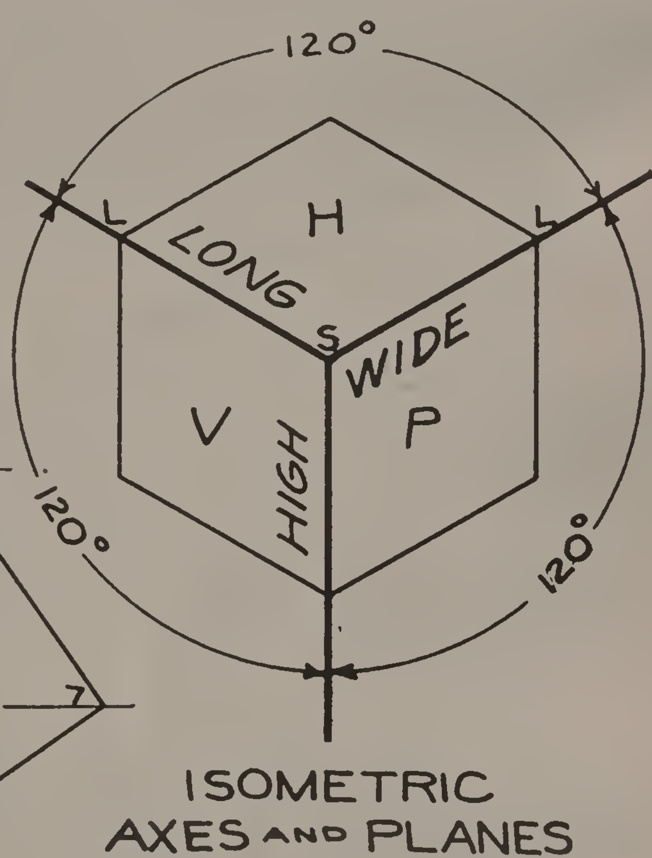


FIG. 33.

7. A circle inscribed in the face of a cube will touch at the four diameter points D (Fig. 35). Any points in the circle, as A, B, E, M, N, can be projected on an Isometric Plane by laying off the coordinate distances for each point parallel to the Isometric Axes of the circle plane, as X_1—A and Y_1—A for point A in Fig. 34. If the circle had a dip in it at B to B′ perpendicular to its plane and then slanted up to E (a situation impossible to show in the one view of Fig. 35) the point B′ would have to be determined by a third dimension, as B—B′, Fig. 34, laid off downward parallel to the vertical axis. The slant line will be the one drawn from B′ to E. B—B′ is an Isometric Line and B′—E a Non-Isometric Line plotted by the Orthographic Coordinates of its points. It should be noted that the four 45° points F, of the circle, always fall on the major and minor axes of the ellipse. (See Fig. 34.)

8. To draw the Isometric of a circle plot its center on the drawing and draw through it the two diameter lines D—D parallel to the isometric axes in the plane of the circle. Draw lines through

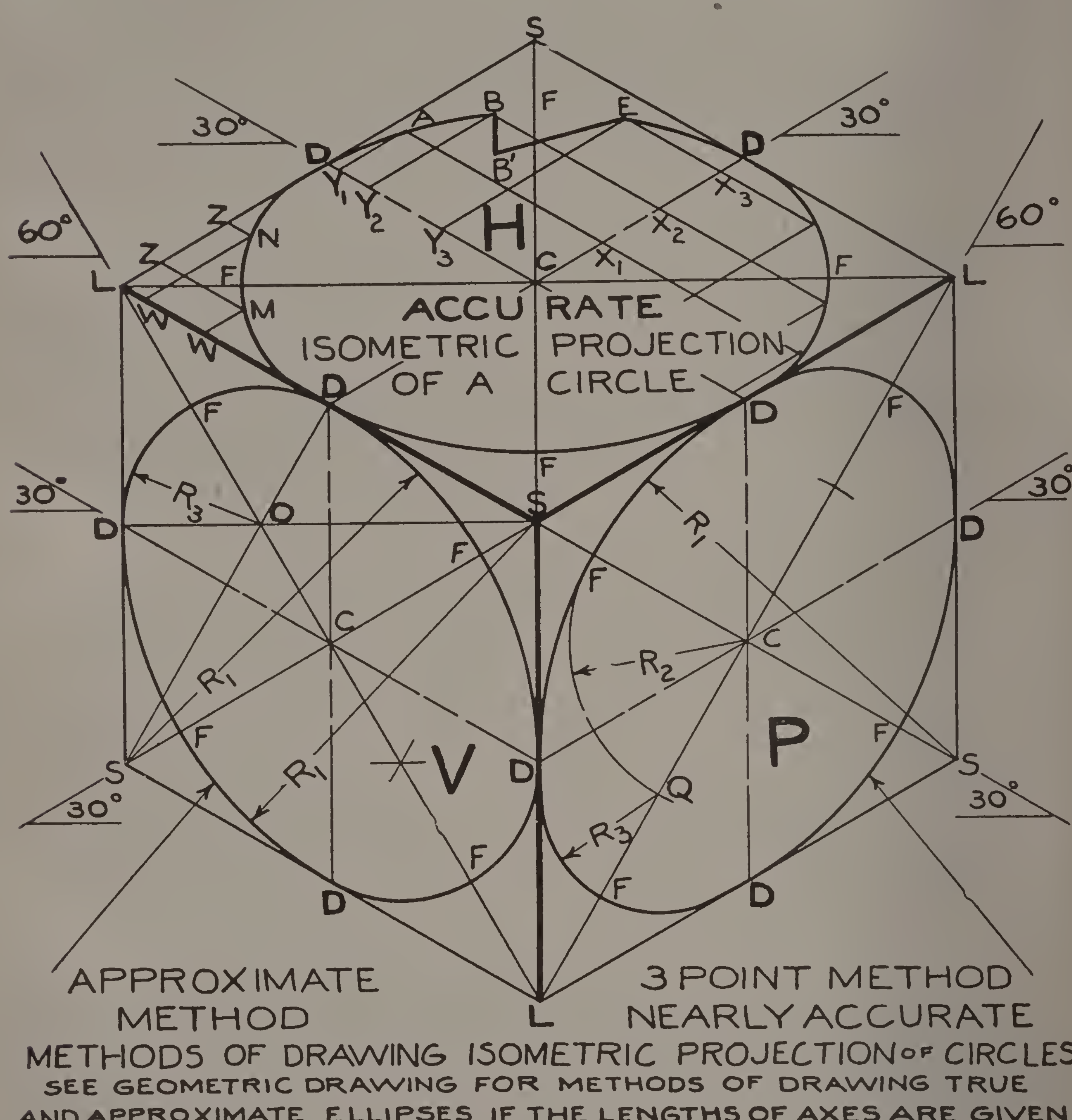


Fig. 34.

the diameter points D parallel to the diameter lines, a line through their intersections L and L will determine the direction of the major axis of the ellipse and one through S and S the direction of the minor axis. The ellipse may be drawn by one of the three methods shown in Fig. 34, the three-point method, being easiest, is preferred. The arcs in this method are drawn in the order of the radii R_1, R_2, R_3. See paragraph 9 for details of this method.

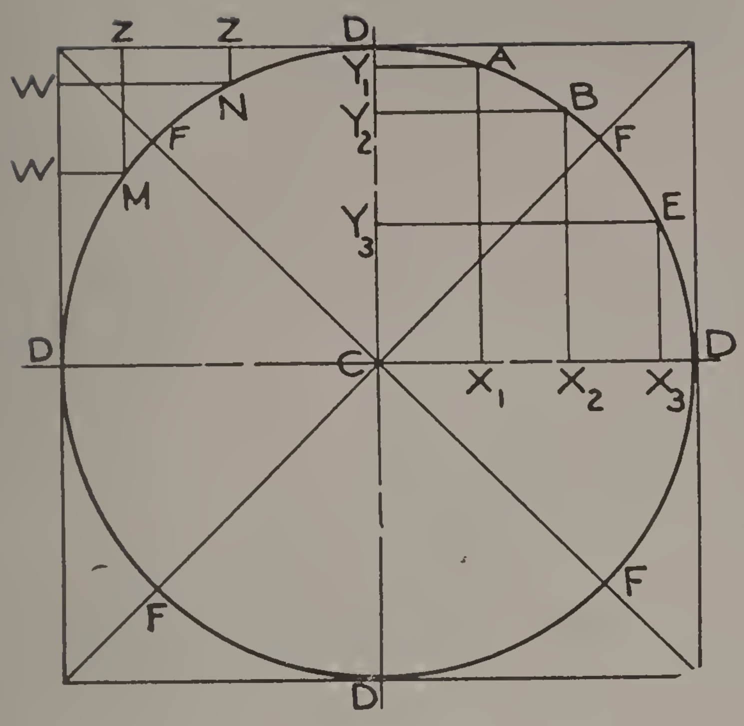


FIG. 35.

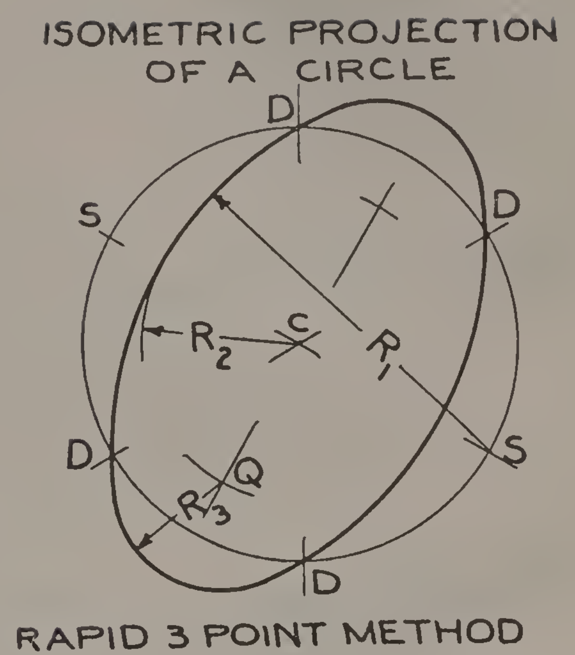


FIG. 36.

9. The Isometric three-point ellipse may be constructed quickly by drawing lightly, with C as the center, a circle whose diameter D—D is equal to the circle to be projected. The four diameter points D and the two S points will fall on this circle and, as shown in Fig. 36, they can be readily located with a triangle and are the points required to construct the ellipse. Point Q is R_2 from C.

10. An Isometric Drawing of a portion of a drawer is shown in Fig. 37. This illustrates the application of the isometric circle in each of the planes and the method of centering a drawing.

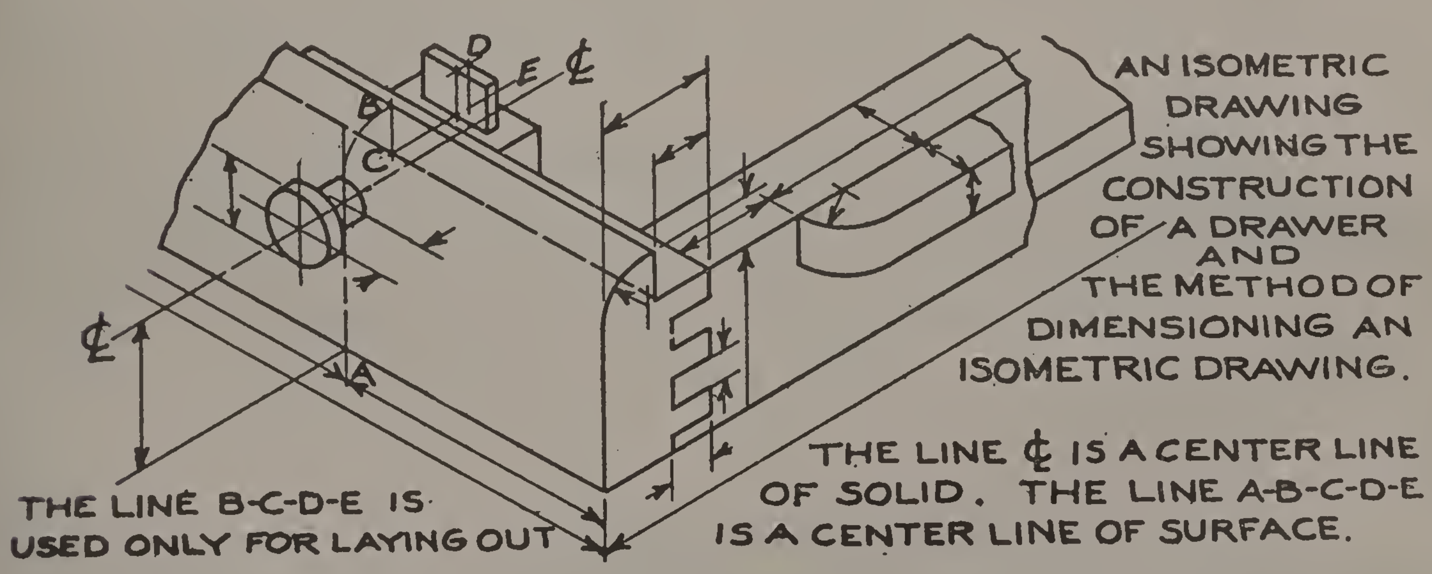


FIG. 37.

SKETCHING. 1. For Freehand Machine Sketching the following materials are required:

Sketching outfit:

Sketch board, 14″ x 9″ x $\frac{1}{8}$″ fiber.
Steel clip, 2$\frac{1}{2}$″ Bull Dog type.
Pad cross-section paper, $\frac{1}{10}$ x $\frac{1}{10}$″ ruling.
H lead pencil, Mongol or Venus.
Pencil eraser, E. Faber No. 111 Emerald.
2-ft. boxwood rule, Stanley No. 59.
Pair 6″ firm joint inside calipers, B. & S. make.

2. The object of a sketch is to give, in as few views as are necessary, sufficient information as to the shape and size of the machine or the part represented to enable a draftsman to make complete working drawings. Sketches are made freehand on cross-section paper; unruled paper is used when the sketcher is an adept.

3. Each sketch sheet must contain the name of the machine, the name of the piece, quantity required, material, finish, and the part number. (See Figs. 38 and 39.)

4. Each sketch sheet should contain sketcher's name, date sketch was completed and total time consumed in sketching all views of each piece placed as shown on Figs. 38 and 39.

5. The size of the sketch need not be in proportion to the size of the object, but should be large enough to contain all dimensions without being crowded. Clearness is essential in sketching.

6. Parts are to be sketched separately, not assembled.

7. The piece should first be sketched by eye, endeavoring to maintain its relative proportions before taking any measurements.

8. The dimension lines with arrow heads are then placed where the dimension figures will show to the best advantage. Finally the piece is measured and the dimensions placed in the spaces previously provided.

9. Sketch the views of one piece only on a sheet, until otherwise instructed. When the piece is large or complicated, each view should be placed on a separate sheet.

10. In sketching large pieces one view may extend over two or more sheets of the sketch paper. The portion of the view on each sheet must begin and end at a center line or other fixed line on the object.

11. If more than one sheet is required, to properly portray the piece, **page the sheets in the lower left corner** as shown in Fig. 38.

12. In general, the same views, sections, etc., which would be used in making working drawings are used in sketching, except that in sketching many abbreviations are used to simplify the

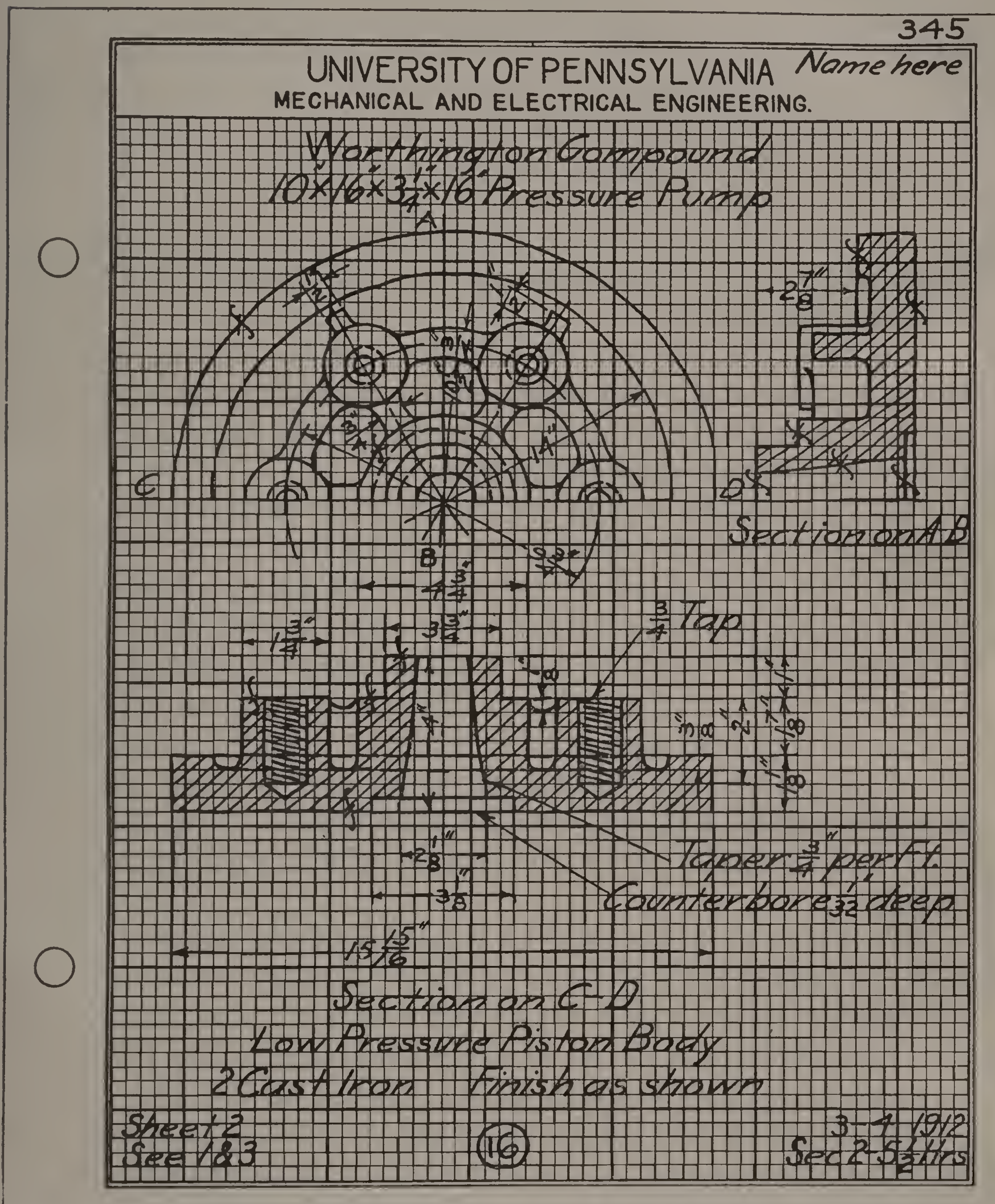


FIG. 38.

work. For example, in Fig. 39 only one view of each detail is shown, the plan being omitted, and the abbreviations **Diam.** and **Hex.** added after the dimensions to indicate that those portions are round and hexagonal. In the same way **Sq.** for square, **Oct.** for octagonal, and other abbreviations are used. (See Abbreviations, Fig. 20.)

13. When a piece is symmetrical about an axis, a view of one-half of it is sufficient. (See Fig. 38.) By taking advantage of these and similar points, both time and labor are saved.

14. Directions given for dimensioning drawings are applicable to sketches, although it is better to give too many dimensions than too few, as one does not always have access to the object when he makes the working drawings from the sketches.

15. Rough castings should be measured to the nearest sixteenth and allowance made for draft, when this affects the required measurement.

16. Judgment should be exercised when making measurements, especially of rough work, as an apparently odd dimension may be due to the irregularities of casting or forging. **On finished work, measure as closely as possible.**

17. Dimensions should be referred to center lines and to finished surfaces rather than to rough ones.

18. The radii of all curves should be given. To ascertain these, take a piece of paper and with a pencil mark the outline of the curve upon it, and then with a pair of calipers, used as dividers, obtain the correct radius. When this cannot be done, take a wire or thin strip of lead and bend it around the curve, and with the aid of this mark the outline on paper and proceed as before. Irregular curves and non-circular arcs should have their ordinates and abscissas given for use in plotting the curves on a drawing.

19. Holes should always be located by their centers. Where there are several holes of the same size, similarly located in a piece, it is not necessary to give the diameter of more than one of them. When measuring the depth of drilled holes, give the distance to the point where they begin to taper. (See H on Fig. 45.)

20. Tapering and tapped holes should always be noted. The number of threads will be understood to be standard unless otherwise noted.

21. To dimension a cavity from which the open calipers can not be extracted, scratch a cross on each leg of the caliper and, measuring the distance between their centers, extract the calipers and adjust the crosses to this same distance. The measurement across the caliper points is the one desired.

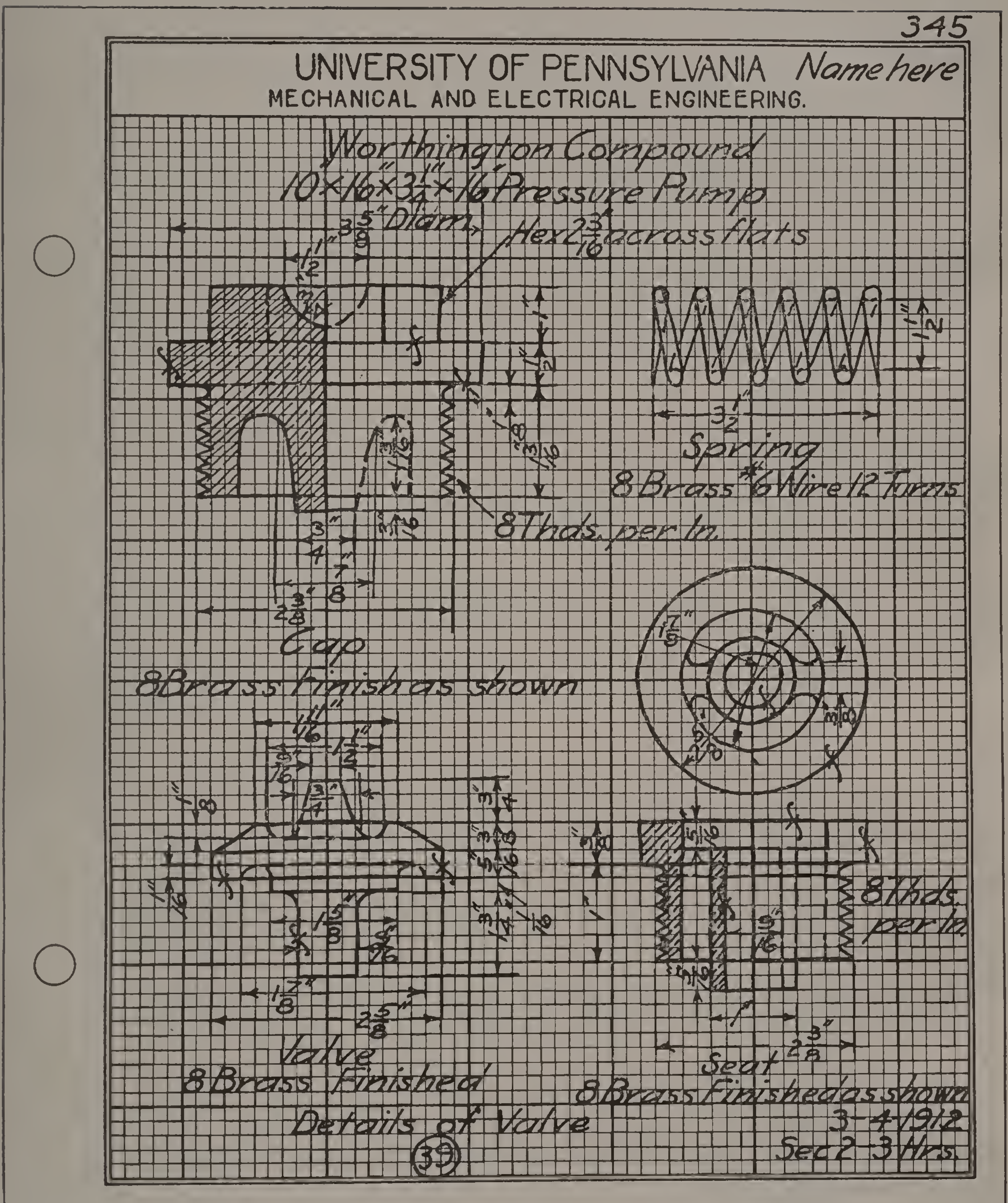

345
UNIVERSITY OF PENNSYLVANIA Name here
MECHANICAL AND ELECTRICAL ENGINEERING.
Worthington Compound
10"×16"×3¼"×16" Pressure Pump
Hex 2 3/16" across flats
Spring
8 Brass #16 Wire 12 Turns
8 Thds. per In.
Cap
8 Brass Finish as shown
Valve
8 Brass Finished
Seat
8 Brass Finished as shown
Details of Valve
3-4-1912
Sec 2 3 Hrs.
39

Fig. 39.

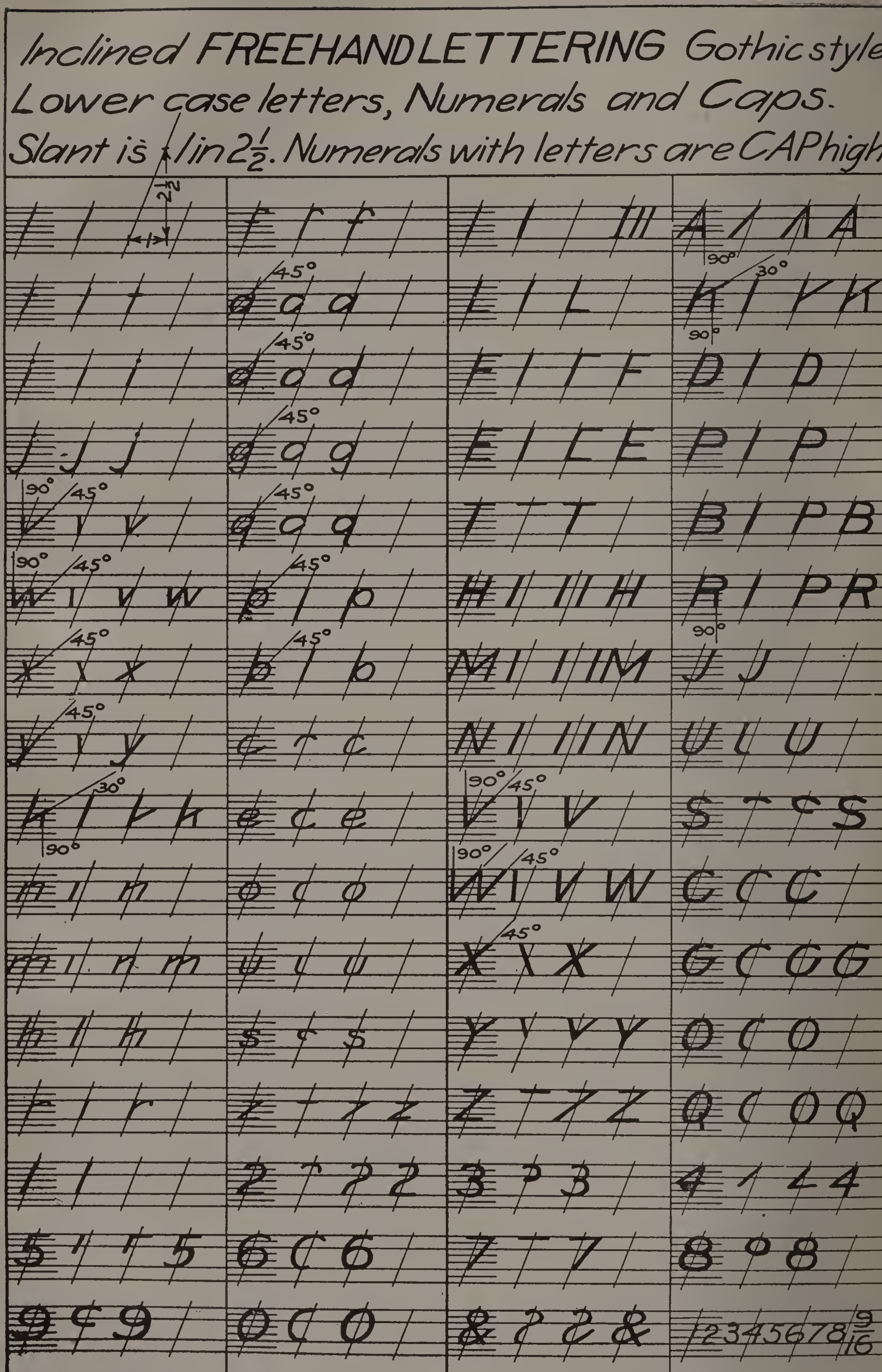

Inclined FREEHAND LETTERING Gothic style
Lower case letters, Numerals and Caps.
Slant is 1 in 2½. Numerals with letters are CAP high

Plate E.

LETTERING. 1. Special attention should be given to lettering, as, when well executed, it adds greatly to the working value of a drawing. With care and constant practice one can do satisfactory lettering.

2. Bold single-stroke letters are desirable. They are easily made, look well and are appropriate on mechanical drawings.

3. The lettering on all drawings, unless otherwise directed, is to be done according to the system described in Reinhardt's "Freehand Lettering" (see Plate E), using inclined and upright letters of the "Gothic" type in the three heights shown on Plate F.

4. For the small lettering in descriptive matter, notes, dimensions and arrow heads a "Gillott No. 390" pen should be used.

5. For the main title, large letters and when filling in, a "Hewitt's Patent Ball Pointed Pen," Leonard's No. 516F, is most suitable.

6. Notes and descriptive matter should read from the Lower or Right-hand edge of a drawing and not in a diagonal direction.

7. Index numbers on tracings are of the block type shown in Fig. 40.

8. Ruled letters and figures are shown in Fig. 41.

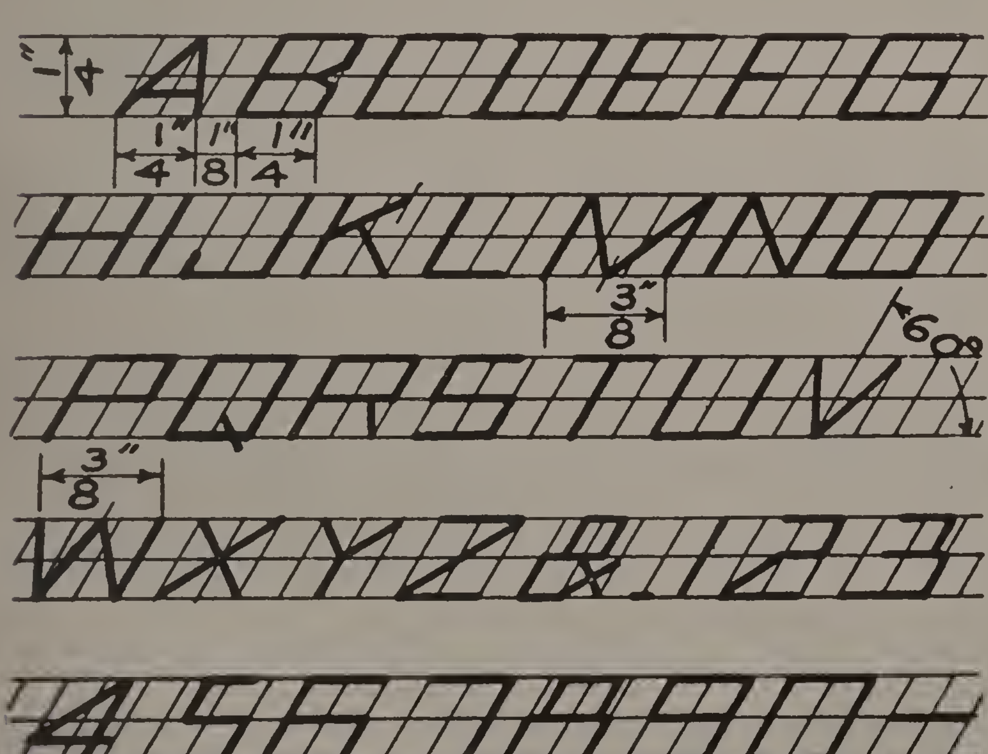


FIG. 41.

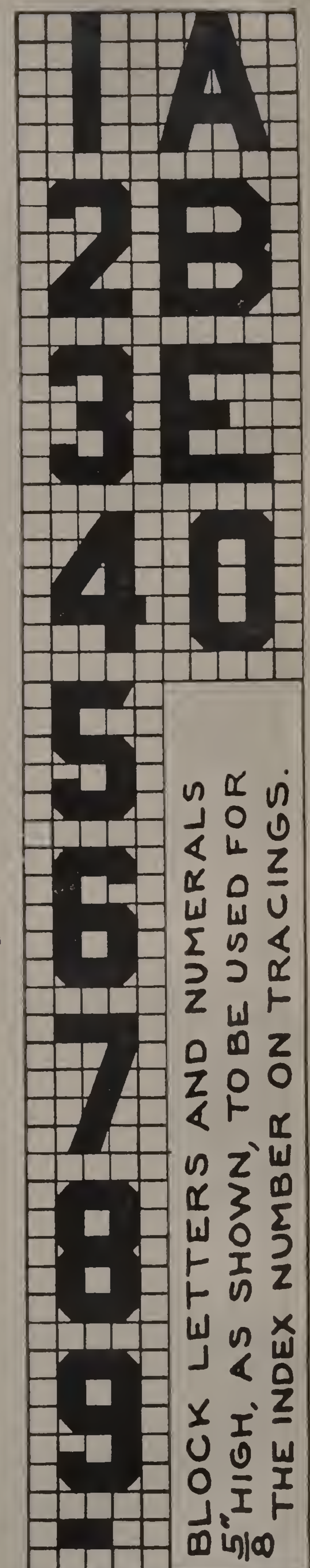


FIG. 40.

7/32" *Small slanting lower case Gothic letters, Reinhardt's*
3/32" *System, to be used for descriptive matter. Notes to read from BOTTOM or RIGHT HAND SIDE of drawing, not diagonally. All lettering, on a drawing, should be made with a firm black line. Fine lines are to be avoided.*

1/8" SMALL UPRIGHT CAPS TO BE USED FOR SUB-CAPTIONS, SUCH AS NAMES OF SEPARATE PIECES ON A DETAIL SHEET. ALSO USED FOR THE PART OF SECONDARY IMPORTANCE IN THE TITLE.

3/16" EXTENDED, COMPRESSED, OR SQUARE UPRIGHT CAPITAL LETTERS TO BE USED FOR THE PART OF FIRST IMPORTANCE IN THE TITLE. NO LARGER.

3/32" LETTERS OF THIS SIZE TO BE USED FOR SCALE, NAME, DATE, ETC.

Plate F.

TITLES. **1. Every drawing should have a general title** (see Plate G) containing the following essential information:

NAME OF THE PIECE.
NAME OF THE MACHINE OF WHICH IT IS A PART.
QUANTITY REQUIRED, MATERIAL, FINISH.
SCALE, NAME OF DRAFTSMAN, DATE COMPLETED.
TRACED—(NAME) CHECKED—(NAME)
APPROVED—(NAME) DATE—(NUMERALS)

2. Any one piece of a machine is a detail of that machine, strictly speaking, but should not be designated as such in the title. **Name it in the title when no other parts are drawn.** When several pieces of a machine are drawn separately on a sheet, it then becomes a detail drawing and should have a general title as follows:

DETAILS OF
NAME OF THE MACHINE OF WHICH THEY ARE PARTS.
SCALES. NAME OF DRAFTSMAN. DATE COMPLETED.
TRACED—(NAME) CHECKED—(NAME)
APPROVED—(NAME) DATE—(NUMERALS)

3. Part numbers are frequently used as a substitute for names of pieces on a detail sheet. These numbers are necessary when the pieces are difficult to name concisely or are numerous and similar. "PART NUMBER—" replaces "NAME OF PIECE" in the sub-captions. On the assembly drawing the numbers must appear in circles with leaders to the parts designated. (See Fig. 5.)

4. The Location of the Title on Drawings is shown on Forms 2, 3 and 4, under size of sheets, and on Plates G, J and K.

5. Titles should have a symmetrical appearance, and each line of words should vary in height according to their importance.

SUB-CAPTIONS. **1. A sub-caption is to be placed under each piece on a detail sheet** (see Plate H); it should contain the following essentials:

NAME OF PIECE.
QUANTITY REQUIRED, MATERIAL, FINISH.
SCALE.

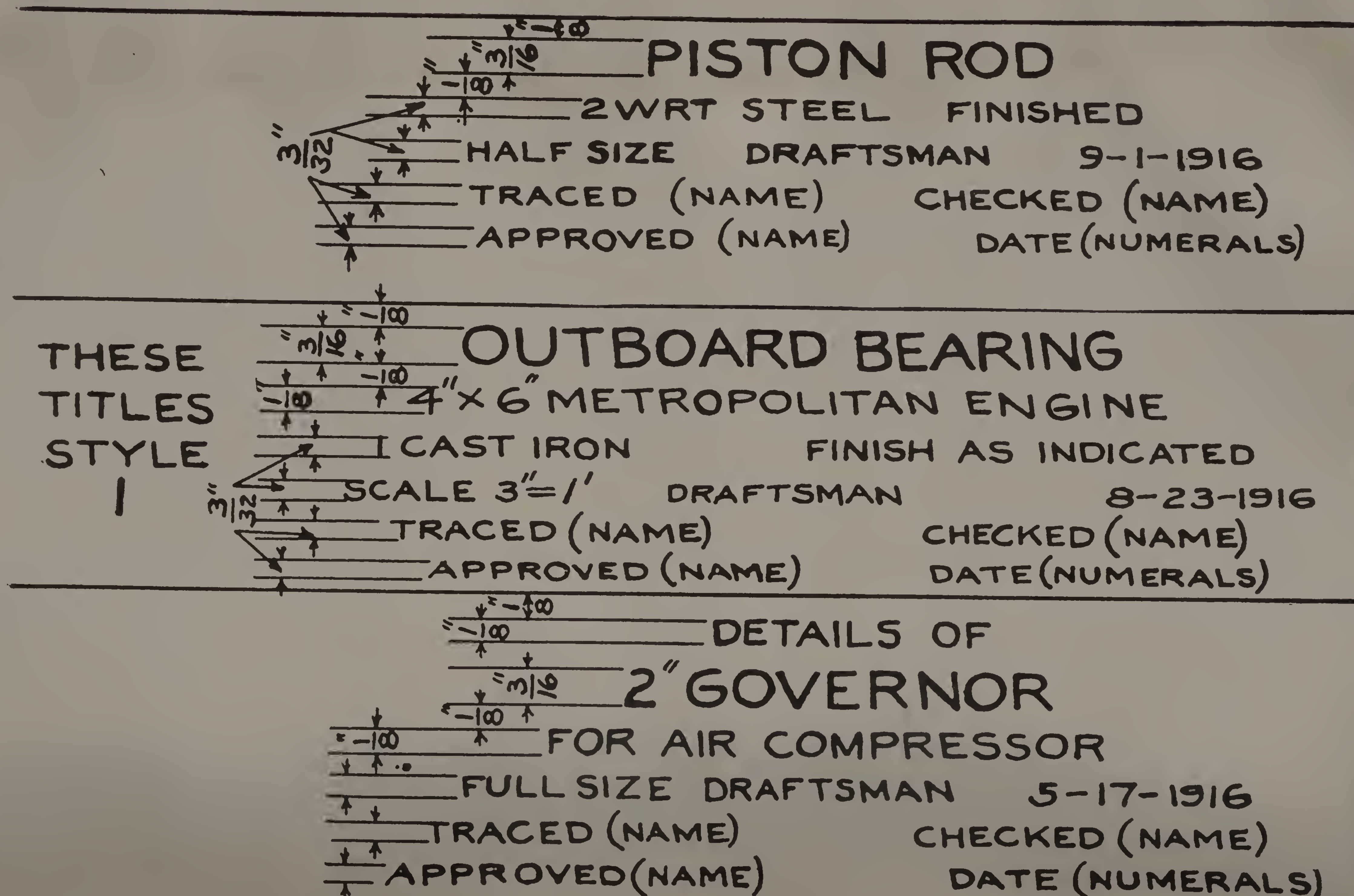
2. If the scale is the same for all the details it should be omitted from the sub-captions. Avoid using more than three scales.

BILL OF MATERIALS. **1. A list should be placed on drawings that show several pieces assembled.** Its form should be as shown on Plate H or J and contain the following essentials:

BILL OF MATERIALS.
PART NO., PRINCIPAL PIECE, QUANTITY REQUIRED, MATERIAL, FINISH.
PART NO., SECONDARY PIECE, QUANTITY REQUIRED, MATERIAL, FINISH.
PART NO., SMALLEST PIECE, QUANTITY REQUIRED, MATERIAL, FINISH.

2. The words "QUANTITY REQUIRED" in the TITLE on an assembly drawing mean the number of units wanted. A unit being an assemblage of all the pieces specified in the BILL OF MATERIALS.

3. When a BILL OF MATERIALS is given substitute the words "AS SHOWN" for "MATERIAL, FINISH" in the TITLE.



3/16"
1/8"
PISTON ROD
2 WRT STEEL FINISHED
3/32"
HALF SIZE DRAFTSMAN 9-1-1916
TRACED (NAME) CHECKED (NAME)
APPROVED (NAME) DATE (NUMERALS)
THESE TITLES STYLE I
OUTBOARD BEARING
4"×6" METROPOLITAN ENGINE
I CAST IRON FINISH AS INDICATED
SCALE 3"=1' DRAFTSMAN 8-23-1916
TRACED (NAME) CHECKED (NAME)
APPROVED (NAME) DATE (NUMERALS)
DETAILS OF
2" GOVERNOR
FOR AIR COMPRESSOR
FULL SIZE DRAFTSMAN 5-17-1916
TRACED (NAME) CHECKED (NAME)
APPROVED (NAME) DATE (NUMERALS)

PLATE G.

FORMS FOR SUB-CAPTIONS

SUB-CAPTIONS TO BE PLACED CENTRALLY UNDER THE VIEWS OF EACH PART ON A SHEET OF DETAILS. OMIT SCALE IF ALL PARTS ON THE SHEET ARE TO THE SAME SCALE. THE SCALE OR SCALES MUST ALWAYS APPEAR IN THE MAIN TITLE.

PISTON RING
4 CAST IRON FINISHED
SCALE 3" = 1'

JIB CHANNEL
2 CAMBRIA 15" - 35# CHANNELS
SCALE 2" = 1'

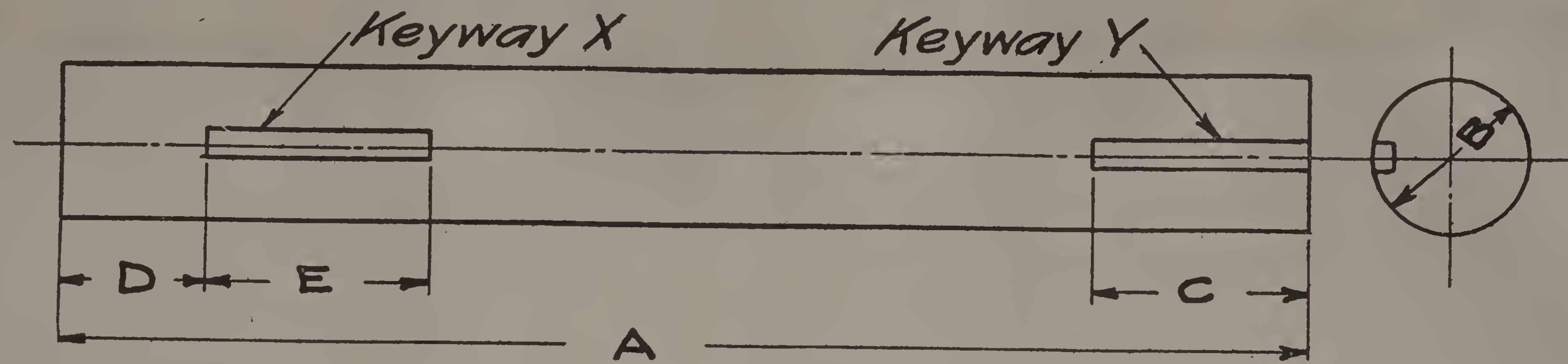
FORM FOR BILL OF MATERIALS

The bill to be independent of the title. Place it in a conspicuous place on the drawing. Enter the items in the order of their importance.

BILL OF MATERIALS

Piston Body	*1 Cast Iron*	*Finish as shown*
Piston Follower	*1 Cast Iron*	*Finished*
Bull Ring	*1 Cast Iron*	*Finished*
Piston Ring	*2 Cast Iron*	*Finished*
Stud	*4 Steel*	———
Nuts	*4 Wrt. Iron*	———

PLATE H.



SHAFTS

Part Number	Quantity Required	Material	Finish	A	B	C	D	E	X	Y
1	1	Steel	Finish	37"	$2\frac{1}{2}$"	—	4"	10"	$\frac{5}{8}$" × $\frac{5}{16}$"	——
3	1	Wrt. Iron	Finish	18"	1"	6"	—	—	——	$\frac{1}{4}$" × $\frac{1}{8}$"

FORM FOR TABULATING DIMENSIONS

Parts that are similar in shape but different in size are to have their Sub-captions and dimensions tabulated as shown above.

Plate I.

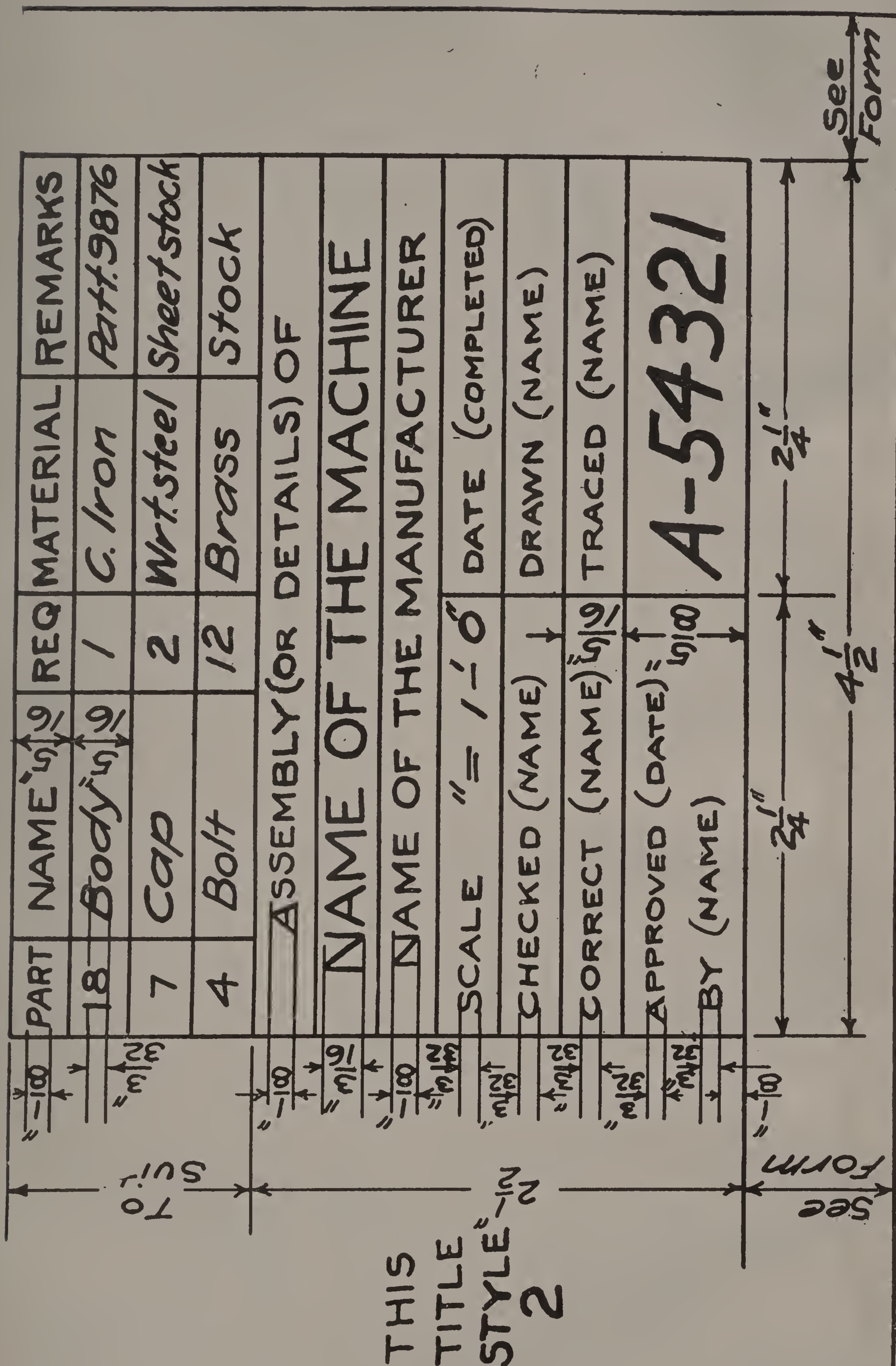

PART
NAME
REQ
MATERIAL
REMARKS
18
Body
1
C. Iron
Patt. 9876
7
Cap
2
Wrt. steel
Sheet stock
4
Bolt
12
Brass
Stock
ASSEMBLY (OR DETAILS) OF
NAME OF THE MACHINE
NAME OF THE MANUFACTURER
SCALE " = 1'-0"
DATE (COMPLETED)
CHECKED (NAME)
DRAWN (NAME)
CORRECT (NAME)
TRACED (NAME)
APPROVED (DATE)
BY (NAME)
A-54321
See Form
To suit
THIS TITLE STYLE 2

PLATE J.

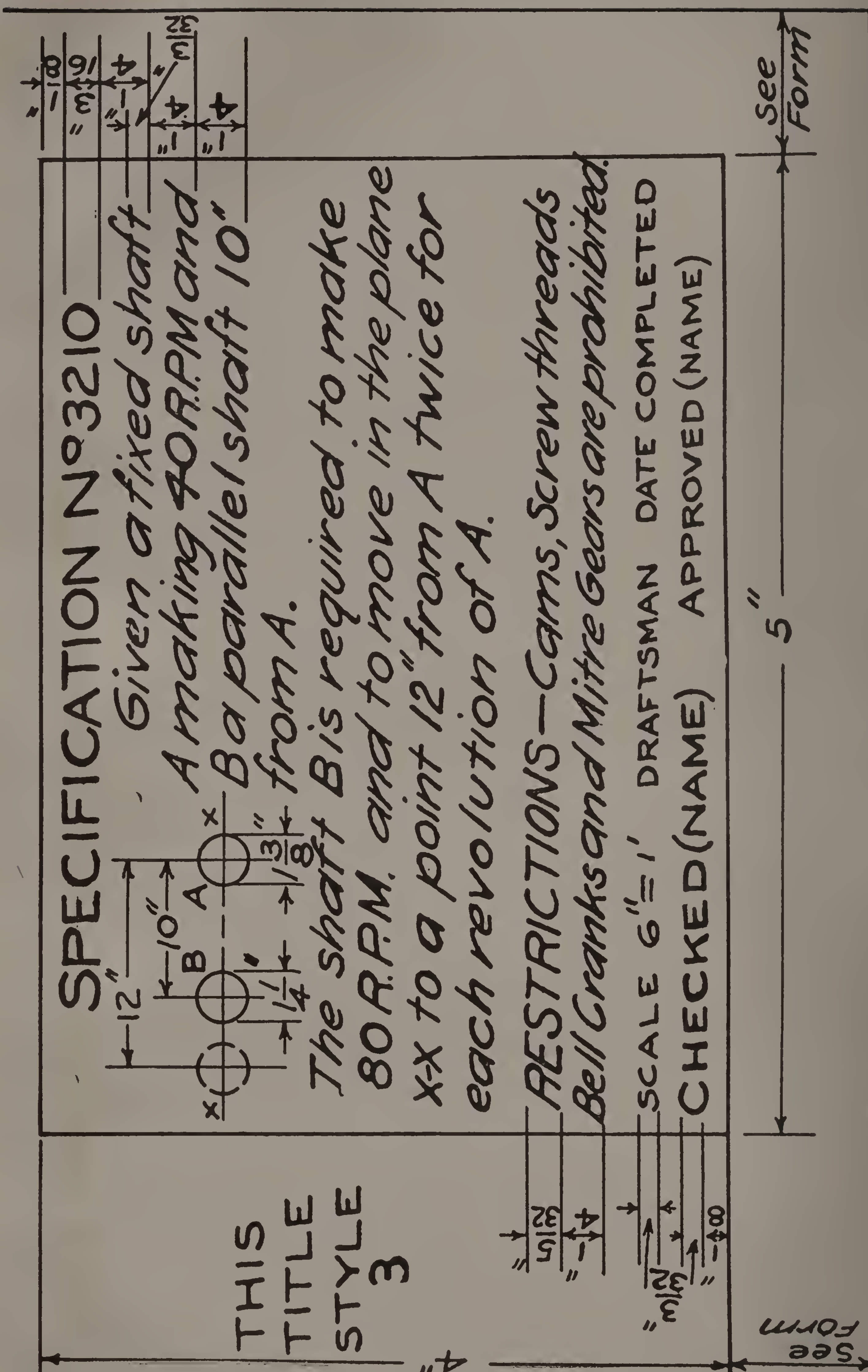

SPECIFICATION No 3210
Given a fixed shaft
A making 40 R.P.M. and
B a parallel shaft 10"
from A.
The shaft B is required to make
80 R.P.M. and to move in the plane
X-X to a point 12" from A twice for
each revolution of A.
RESTRICTIONS—Cams, Screw threads
Bell Cranks and Mitre Gears are prohibited.
SCALE 6"=1'
DRAFTSMAN
DATE COMPLETED
CHECKED (NAME)
APPROVED (NAME)
12"
10"
B
A
X
X
THIS TITLE STYLE 3
5"
4"
See Form
See Form

PLATE K.

ASSEMBLY DRAWINGS. **1.** When a portion or the whole of a machine is drawn showing the various parts joined together in their relative positions, it is known as an assembly drawing.

2. In laying out the drawing of a machine the designer makes the assembly drawing first, the details being drawn out to larger scales afterwards. On assembly drawings it is often well to show sections on different parallel planes in the same view.

ERECTING DRAWINGS. **1. Erecting drawings are those which show all the parts of the machine in place,** but neglect the unnecessary and minute details of construction. They are frequently drawn to a scale smaller than that of the original design. They are use to assemble the fabricated parts and are sent with a machine to be used in setting it up at its destination.

2. Erecting Drawings should have sufficient dimensions to enable the erectors to distinguish and place the various parts in their proper relation to each other.

TRACINGS. **1. For reproducing drawings,** without injury to the original, tracings of them are made upon tracing paper or cloth.

2. Tracing cloth or linen is used almost exclusively, owing to its wearing qualities. It is a specially sized and calendered fabric, having one side glazed and the other rough, the former being known as the smooth side, the latter the dull side. Tracings can be made on either side of the cloth, but the side used should be thoroughly rubbed with powdered chalk or soapstone to remove greasiness and permit the ink to "take" more readily, the excess chalk must be thoroughly cleaned off before starting to trace. Tracings partly inked may be rubbed with powder, if the ink fails to take, without injury to the lines.

3. The dull side of the cloth is to be used for all tracings unless otherwise directed. It is easier to draw pencil lines on the dull side when making additions to views or checker's corrections. Drawings traced in ink on the dull side will make the tracing lie flat after removing from the board and not roll up, an objectionable feature caused by drawing on the smooth side.

4. Heavy black lines are required on tracing cloth. (See thickness at middle of full line, Fig. 13.) Light, in printing, will burn through fine thin lines, causing a blue-print to appear blurred and indistinct. (Read "Inking In," paragraph 3.)

5. Lines on tracings are not shaded. All lines are drawn heavy.

6. When lettering a tracing rule pencil guide lines and print all lettering without any attempt at tracing it.

7. Ink may be erased from tracing cloth, the pencil eraser usually being sufficient. The ink eraser should be used with care to avoid cutting the fabric. Place a triangle or other hard-surfaced article under the cloth when erasing. Wherever an erasure has been made, the place should be rubbed with a soapstone pencil or powdered chalk before re-inking to prevent the ink from passing through the cloth. The powder must be removed before the ink is applied.

8. Ink dropped upon tracing cloth should never be blotted, but should be smeared as quickly as possible with the thumb, using a scooping-up motion. When the smear has dried it is readily erased with the pencil eraser.

9. Pencil and crayon marks can be removed from tracing cloth with the Art Gum cleaner without affecting the ink lines.

10. Trim tracings as directed in "Trimming" instructions.

BLUE-PRINTS. 1. Original drawings are seldom sent into the shop. Duplicates in the shape of either blue-prints (white lines on a blue ground) or white prints (blue or black lines on a white ground) are used in place of them.

2. Blue prints are moderate in cost and can be produced in endless numbers. They are obtained by exposing a sensitized paper or cloth to light rays. A positive tracing of the original drawing on a translucent medium, such as tracing cloth or paper, is interposed between a light and the sensitized paper and in direct contact with the latter, the time of exposure depending upon the intensity of the light and the composition of the sensitizing emulsion.

3. The age, or length of time the paper has been sensitized, modifies the time of exposure. The fresher the paper, the less exposure required. The prints are fixed by immersing for about ten minutes in clear water. Special papers require the addition of chemicals to the fixing bath. Instructions for the treatment of such papers generally accompany them.

4. Blue-Print Paper, and other sensitized papers, are obtainable in different grades of stock and different weights. Light weight paper is used for prints that will require very little usage or for prints to be mailed. Heavy weight tough papers are used for prints requiring rough or frequent handling.

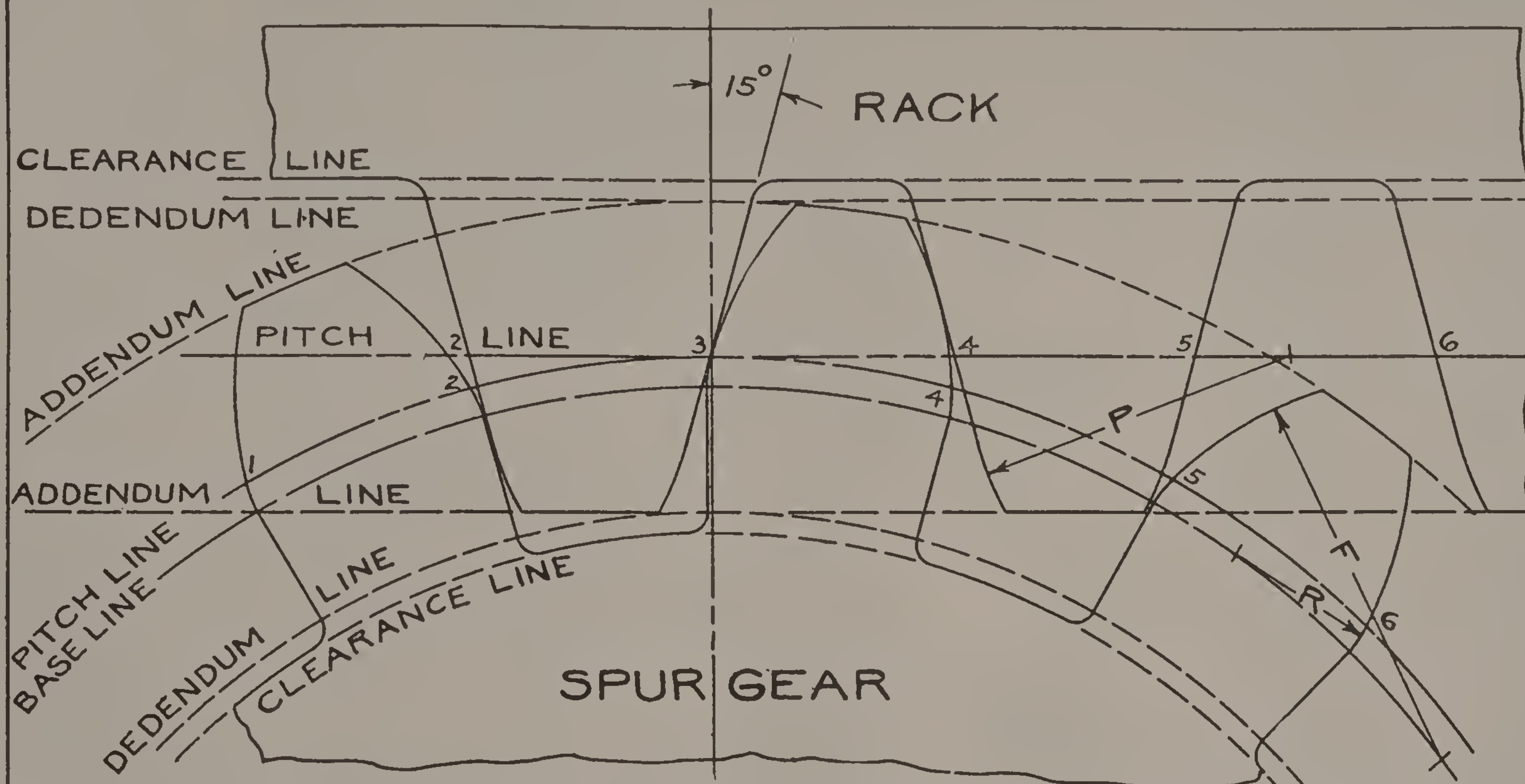
GEARS. 1. Conventional lines and notations for spur and bevel gears will be found on Plates L and M.

22. For the theory of gearing and method of drawing various types of gear wheels, refer to one of the many text-books on the

DRAWING THE STANDARD INVOLUTE TOOTH

USING GRANT'S INVOLUTE ODONTOGRAPH

STANDARD INTERCHANGEABLE TOOTH, CENTERS ON BASE LINE

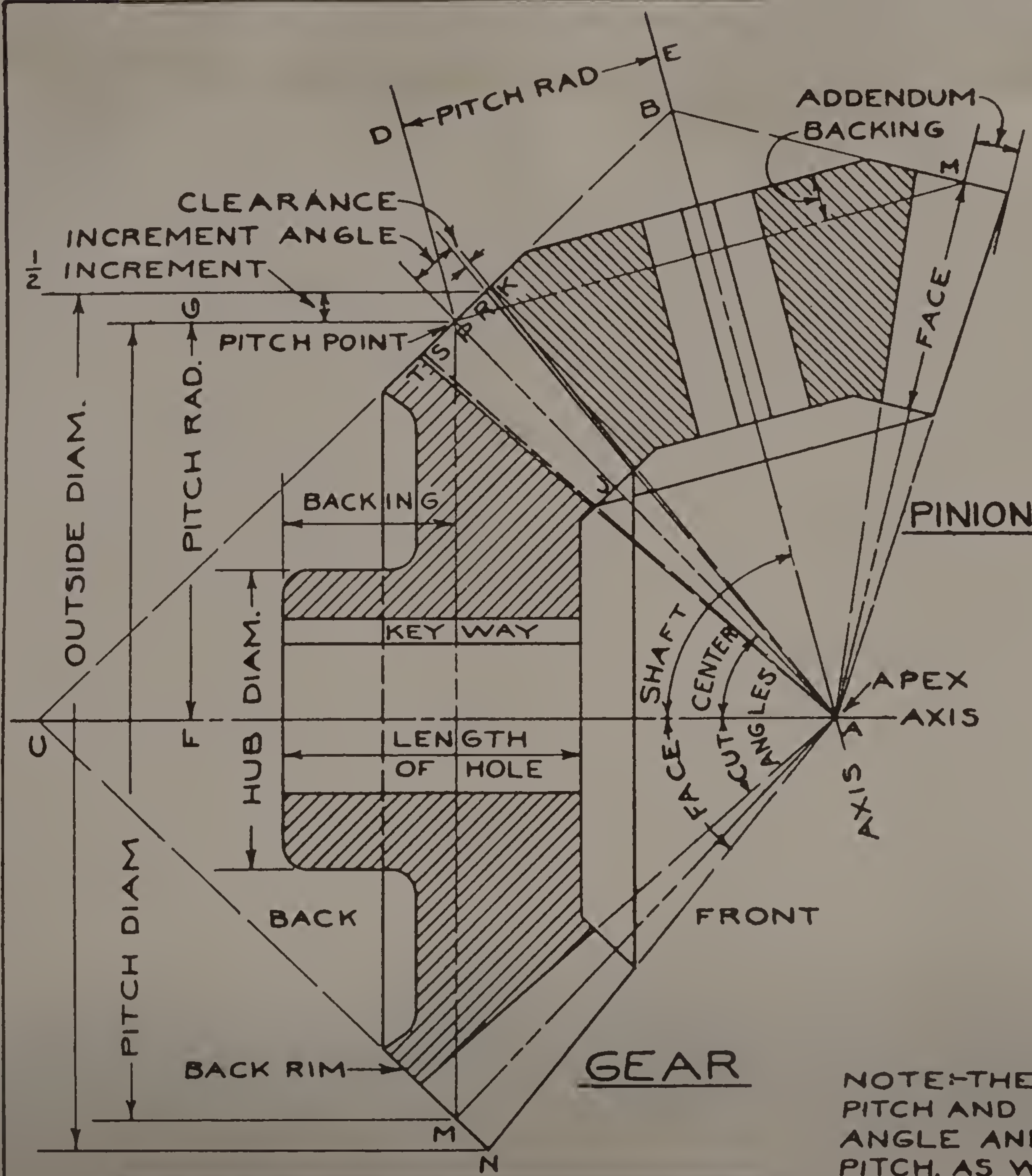


DRAW THE PITCH LINE, SPACE OFF THE PITCH POINTS 1-2-3 ETC. BY DIVIDING THE CIRCLE INTO 2X NO OF TEETH SPACES OR $\frac{1}{2}$ CIRCULAR PITCH DISTANCES.
DRAW ADDENDUM LINE OUTSIDE PITCH LINE A DISTANCE = 1 ÷ DIAMETRAL PITCH OR $\frac{1}{3}$ CIR. PITCH. DRAW DEDENDUM LINE THE SAME DISTANCE INSIDE OF PITCH LINE AND CLEARANCE LINE INSIDE DEDENDUM LINE $\frac{1}{8}$ THIS DISTANCE.
DRAW BASE LINE INSIDE OF PITCH LINE A DISTANC = $\frac{1}{60}$ PITCH DIAMETER.
WITH RAD. F AND CEN. ON BASE LINE DRAW FACE FROM PITCH TO ADDENDUM.
WITH RAD. R AND CEN. ON BASE LINE DRAW FLANK FROM PITCH TO BASE LINE.
DRAW RADIAL LINES FROM BASE TO DEDENDUM AND ROUND OFF INTO CLEARANCE.
RACK:— DRAW STRAIGHT LINES THROUGH PITCH POINTS 15° WITH NORMAL, ROUND INTO CLEARANCE. P = 2.1 ÷ DIAM. PITCH OR .67 X CIR. PITCH, ₵ ON PITCH LINE.

NUMBER OF TEETH	DIVIDE THE NUMBER BY DIAMETRAL PITCH FOR		MULTIPLY NUMBER BY CIRCULAR PITCH FOR	
	FACE RADIUS	FLANK RADIUS	FACE RADIUS	FLANK RADIUS
10	2.28	69	73	.22
11	2.40	83	76	.27
12	2.51	96	.80	31
13	2.62	1.09	.83	34
14	2.72	1.22	.87	.39
15	2.82	1.34	.90	43
16	2.92	1.46	93	47
17	3.02	1.58	96	50
18	3.12	1.69	99	.54
19	3.22	1.79	1.03	57
20	3.32	1.89	1.06	60
21	3.41	1.98	1.09	63
22	3.49	2.06	1 1 1	66
23	3.57	2.15	1.13	.69
24	3.64	2.24	1.16	.71
25	3.71	2.33	1.18	.74
26	3.78	2.42	1.20	.77
27	3 85	2.50	1.23	80
28	3.92	2.59	1.25	82
29	3.99	2.67	1.27	.85
30	4.06	2.76	1.29	88
31	4.13	2.85	1.31	.91
32	4.20	2.93	1.34	93
33	4.27	3.01	1.36	.96
34	4.33	3.09	1.38	.99
35	4.39	3.16	1.39	1.01
36	4.45	3.23	1.41	1.03
37–40	4.20		1.34	
41–45	4.63		1.48	
46–51	5.06		1.61	
52–60	5.74		1.83	
61–70	6.52		2.07	
71–90	7.72		2.46	
91–120	9.78		3.11	
121–180	13.38		4.26	
181–360	21.62		6.88	

PLATE L.

DRAWING BEVEL GEARS



A pair of GEARS having Axes meeting at an angle are BEVEL GEARS. MITER GEARS are Bevel Gears of equal diameter with Axes at 90°.

Method of drawing gear blanks.

Draw the Axes EA and FA.

Draw DP and GP parallel to the Axes at a distance = pitch radii of gears.

Draw PA, Lay off PJ = given face.

Draw CPB at right angles to PA.

Make PR = PS = known Addendum.

Make RK = ST = known Clearance.

Draw KA, RA, SA and TA.

PM is the working PITCH DIAM.

RN is the Outside Diameter.

All lines on the Teeth meet at the Apex.

NOTE:—THE INCREMENT, OR DIFFERENCE BETWEEN THE PITCH AND OUTSIDE DIAMETERS, VARIES WITH THE SHAFT ANGLE AND IS NOT THE SAME FOR ALL GEARS OF THE SAME PITCH, AS WITH SPUR GEARS.

PLATE M.

subject. George B. Grant's "Treatise on Gears," and Brown & Sharpe's "Practical Treatise on Gearing" and "Formulæ in Gearing," are published by the manufacturers.

SCREW THREADS. 1. A helix or screw curve is the path of a point moving on the surface of a circular cylinder, the motion of the point around the axis and parallel to the axis being uniform.

2. The method of drawing the helix is shown in Fig. 42, the true shape of a V and a square thread being shown. When drawing screw threads, except for very large diameters, it is not necessary to lay down the curve of the helices of which they are comprised. Straight lines properly drawn from point to point and root to root answer all practical purposes. (See Fig. 43.)

3. To draw a screw thread, lay off the pitch of the points accurately on one side. Draw shape of threads on that side. Locate any one point on opposite side. Draw the point line across, then draw all point lines parallel to this one. Draw shape of threads on opposite side. Draw root lines across. This is the quickest, most accurate and practical method of drawing threads.

4. A right-hand thread is one that will cause a threaded piece to advance into a tapped hole when the piece is turned clockwise. (See Fig. 43.)

5. A left-hand thread is one that will cause a threaded piece to advance into a tapped hole when the piece is turned counter-clockwise. (See Fig. 43.)

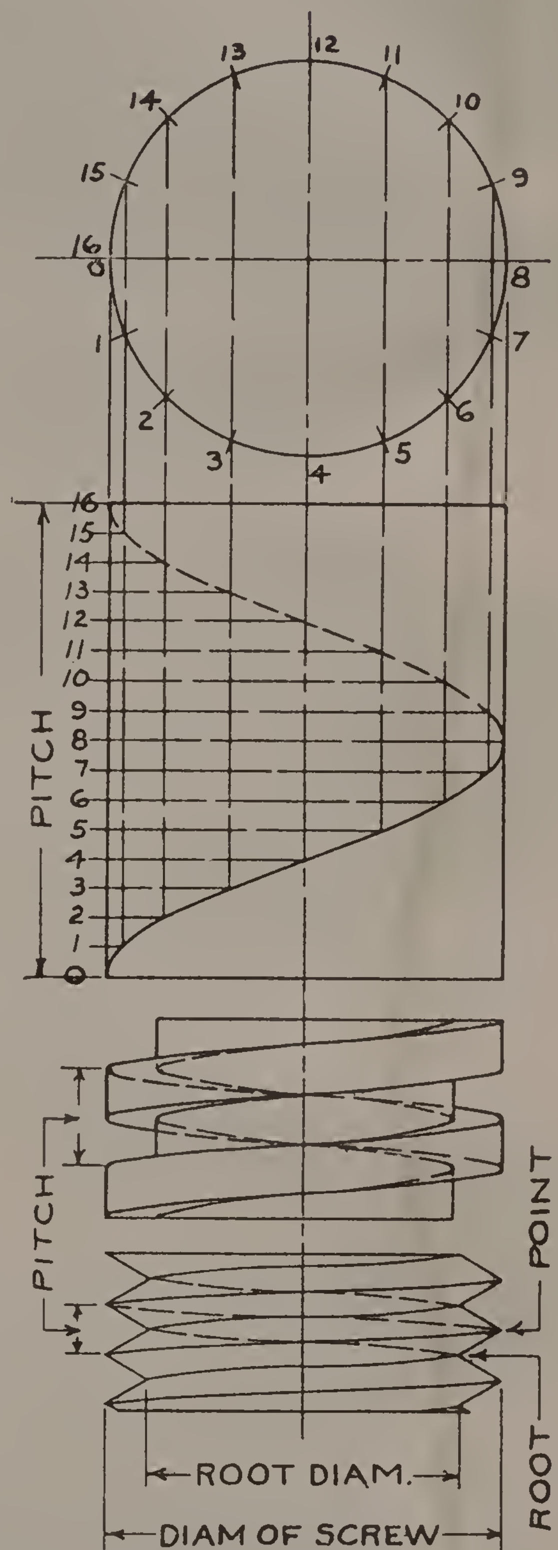


FIG. 42.

6. To determine a thread let the threaded piece be held horizontally with the axis at right angles to the body, the threads seen will incline away from the body from left to right for a right-hand thread and from right to left for a left-hand thread. Threads seen in a section are the reverse of this. (See Fig. 43.)

7. Threads are understood to be U. S. standard, single and right-hand unless otherwise specified. Standard shapes are shown in Plates N and O.

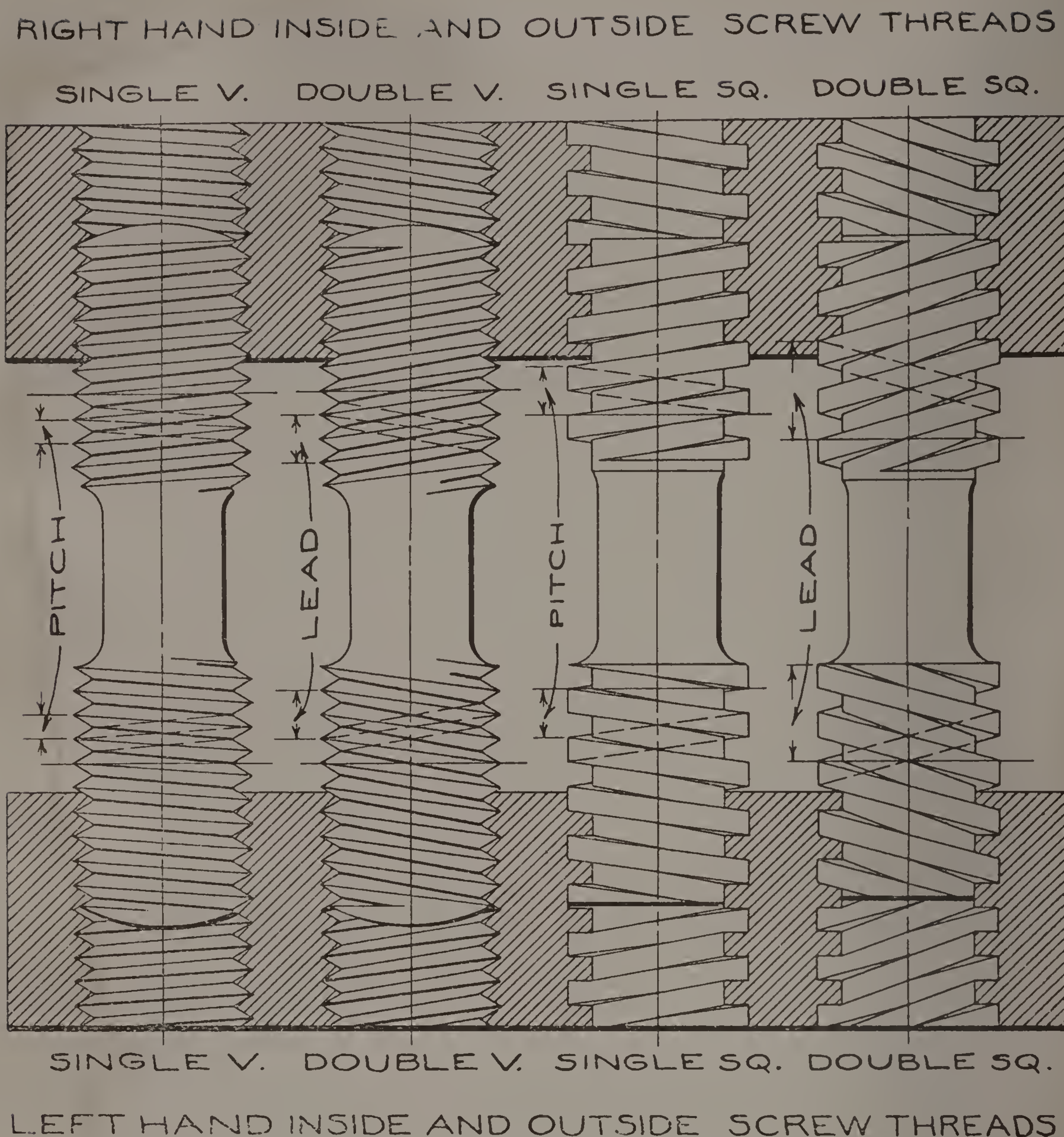


Fig. 43.

8. The pitch of a single thread is the distance between two adjacent points. It is the distance a point would advance parallel to the axis in one revolution of the thread (Fig. 42); *e. g.*, single thread $\frac{1}{4}''$ pitch, 4 pitch, or 4 threads per inch are the same.

9. The lead of a double, triple or other multiple thread is the distance from one point to the next point of the same thread. (See Fig. 43.) The distance between two adjacent multiple threads is sometimes called the divided pitch. The lead is more generally specified.

10. Multiple threads are noted thus: Double thread $\frac{1}{2}''$ lead, or Double thread 2 pitch; Triple thread $\frac{3}{4}''$ lead, or Triple thread $1\frac{1}{3}$ pitch. Triple thread 3 pitch, means three threads each making three revolutions per inch.

11. The diameter of a thread is the extreme outside diameter of the threaded portion of a piece. (See Fig. 42.)

12. Screw threads in a section are drawn as shown in Fig. 44. Note that at B the point and root lines are not drawn across the section, and that those drawn at C and A are in back of the section.

13. Hidden threads are always represented by parallel dotted lines. (See nuts, Fig. 16, hole, Fig. 45, and bolt in Fig. 46.)

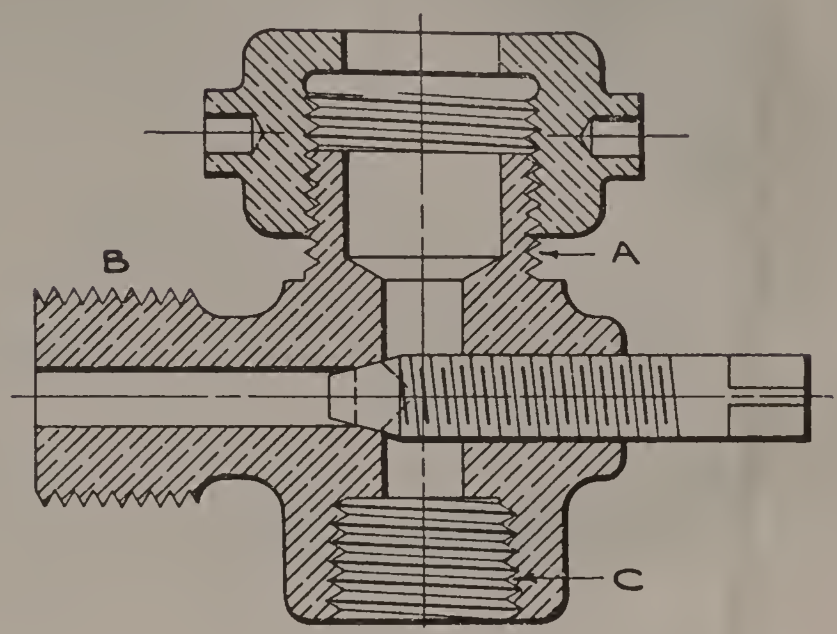


FIG. 44.

TAPPED HOLES. 1. The diameter of a tapped (threaded) hole is the outside diameter of the threaded piece that would fit that hole, not **R** the apparent diameter of the hole. (See Fig. 45.)

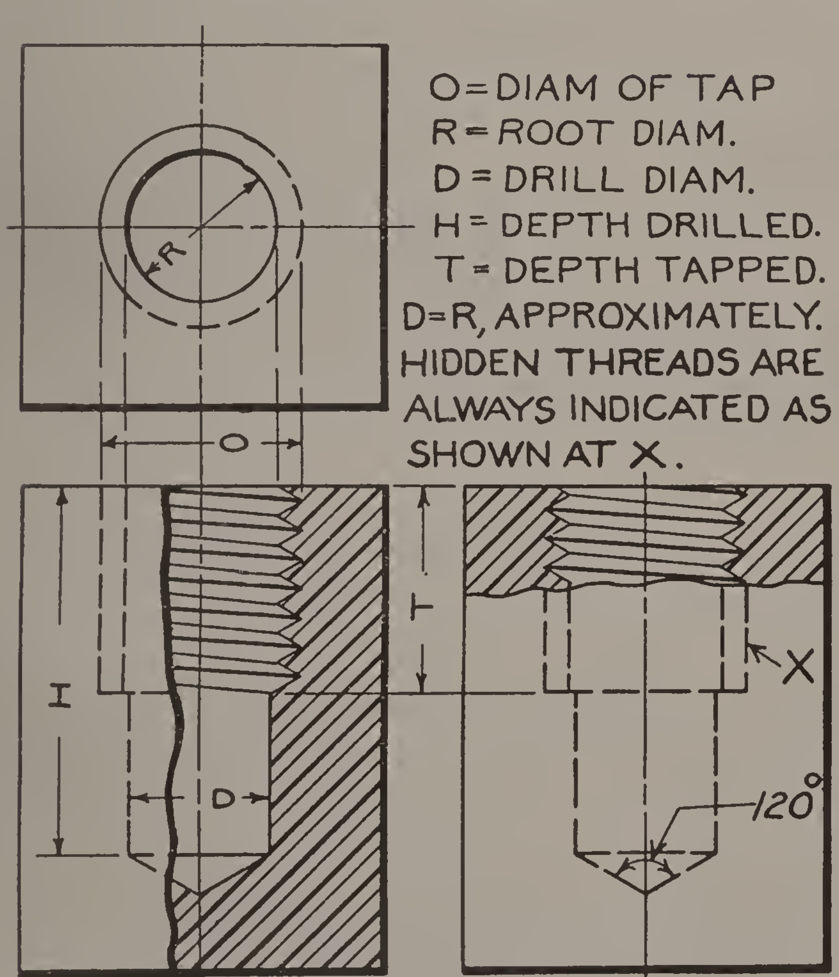


FIG. 45.

2. Drill size for tap is the diameter of the hole which is drilled to prepare it for the tap and which leaves the proper amount of stock for threads. Drills have a conical point which is 118° or, for all practical purposes on a drawing, 120°. Fig. 45 shows the shape of the bottom of a hole which has been drilled. The hole in this case has not been tapped to its full depth.

3. A section through a threaded hole shows the threads at the back of the hole inclined in the opposite direction to those in the portion cut away. A little thought with reference to Figs. 42, 43, 44 and 45 will make this clear.

4. Tapped holes are shown by two circles, the inner one full and the outer one half full and half dotted. (Figs. 45 and 46.)

5. All threaded holes should be designated by a note stating the diameter or size of tap and number of threads per inch. $\frac{3}{4}''$ Tap means that the hole is to be tapped to take a screw $\frac{3}{4}''$ in diameter.

CONVENTIONAL THREADS. 1. This method of showing screw threads is to be used, for clearness and economy, **when the diameter of a thread, as drawn, measures less than $\frac{5}{8}''$** on straight threads (see Fig. 46) and less than 1″ on pipe threads (see Plate S).

2. Conventional threads are used to indicate threads of all types. It is not necessary that the number of conventional threads should correspond with the actual number of threads

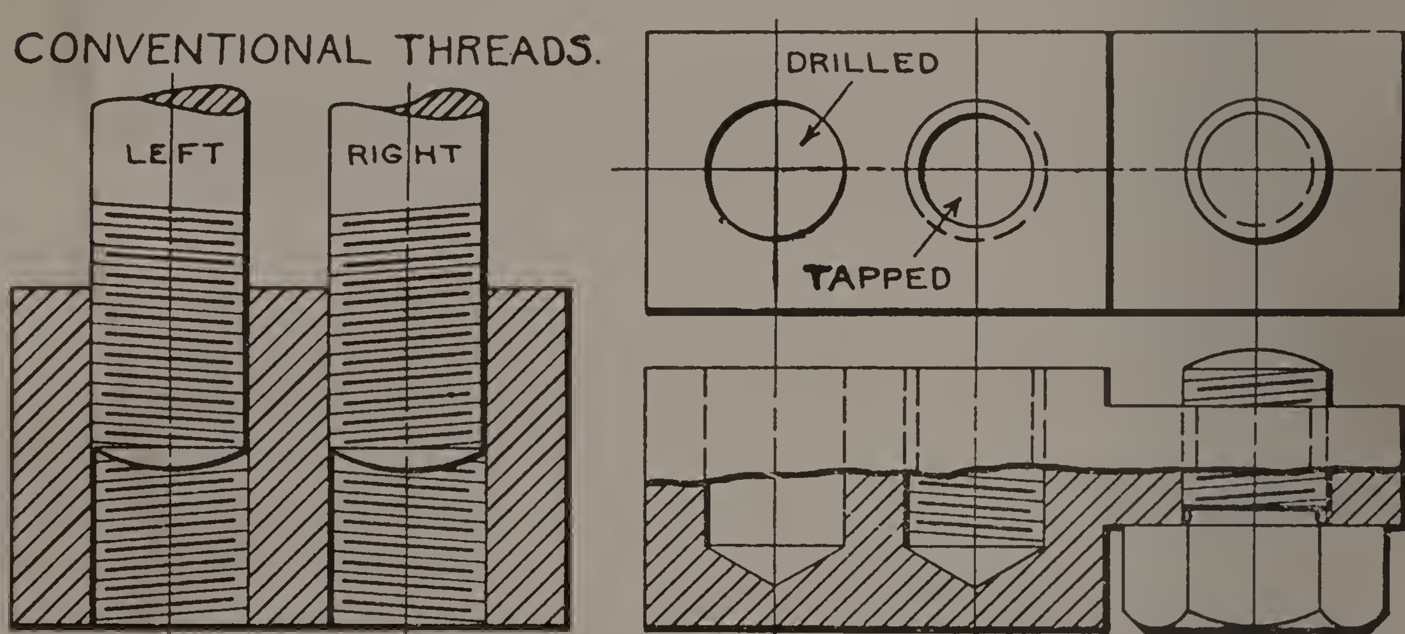


Fig. 46.

on the piece. If the thread is other than the U. S. Standard, or if the number of threads does not correspond with the standard number for the given diameter, there should be a note to that effect, thus: **"13thds per inch," "Square Threads 4 per inch," "Double Square Thread 2 pitch," "Triple V Thread $\frac{1}{2}''$ Lead," "$\frac{3}{4}''$ Pipe Thread," "Taper Thread 14 per inch, taper x in. per ft.," "Acme Thread 4 per inch."**

3. The spacing of conventional thread lines should be done by eye; pencil lines may be drawn to limit the length of the heavy root lines. The inclination of the lines should be practically the same as though the thread were drawn out to its actual shape. That is, for a single thread a point on one side should be diametrically opposite the adjoining root. For a double thread the point on one side should be diametrically opposite the point of the next thread. For triple threads the point on one side is diametrically opposite the next root but one. Fig 43 will make this clear.

4. **Conventional threads are not to be used on a section showing two pieces screwed together and both cross-hatched,** as A, Fig. 44, or on a section showing an isolated outside thread, as B, Fig. 44. Isolated inside threads, as C, Fig 44, may be drawn conventionally as stated in Paragraph 1.

CORED HOLES. 1. Cored, bored, counter-bored, countersunk and spot face holes must be so noted, the method and the required dimensions for each case are shown in Fig. 47.

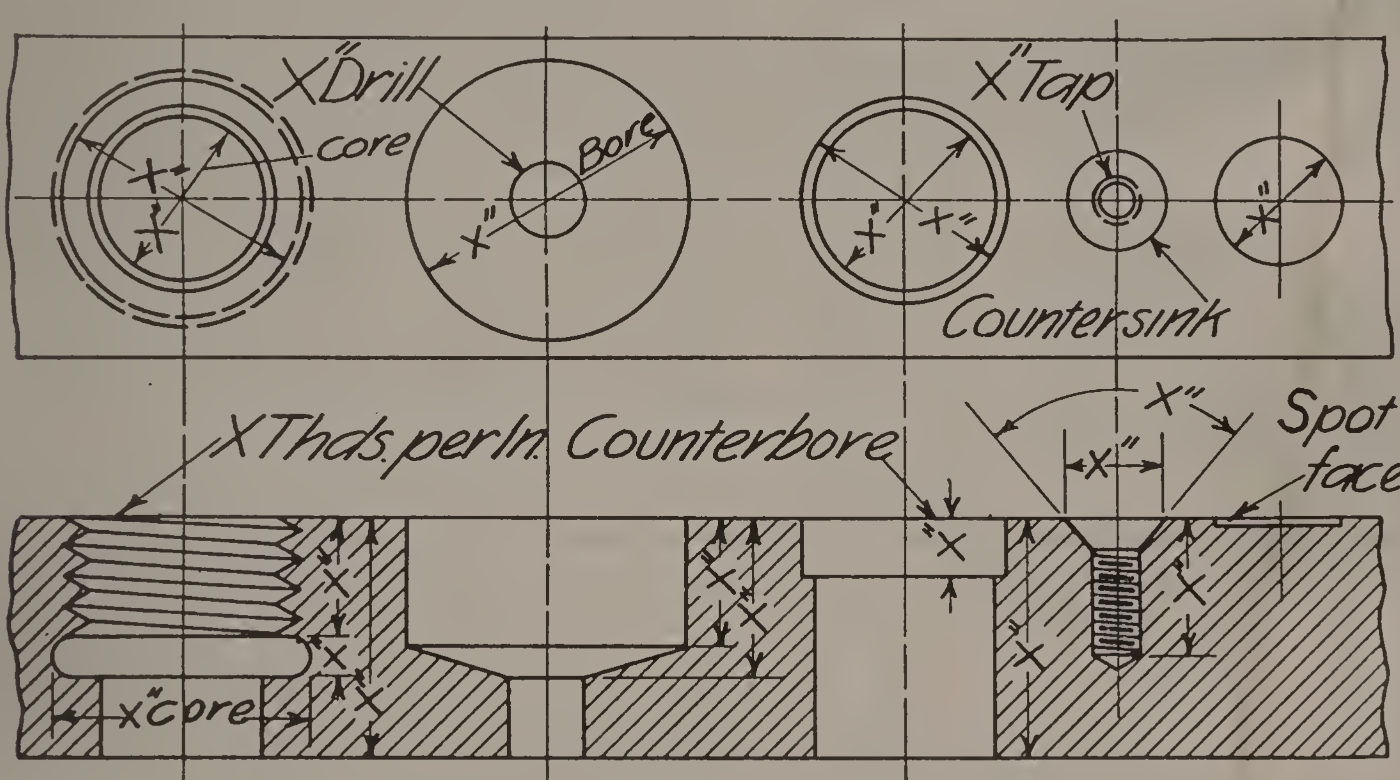


Fig. 47.

SCREW THREAD PROPORTIONS AND TABLES. The standard forms and proportions of screw threads in practical use in the United States will be found on Plates N and O.

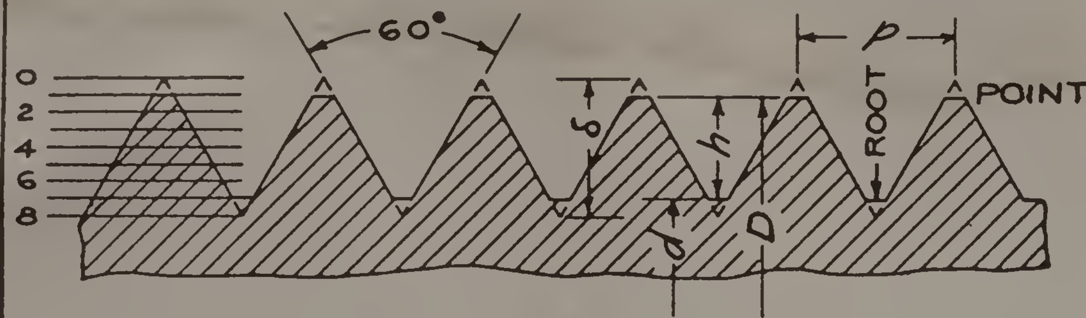
BOLTS. 1. The standard proportions for Bolt Threads, Heads and Nuts shown on Plate P and tabulated on Plate Q, were adopted by the Franklin Institute, December, 1864. The sizes for bolt heads in Plate Q are a manufacturer's.

2. **Manufacturers have deviated slightly from these proportions,** owing to the materials used in their manufacture not being commercial sizes.

3. **When drawing bolts and nuts,** take dimensions from table on Plate Q and use the method shown on Plate P for approximating the curves which are, in reality, portions of hyperbolas, the results of chamfering.

U.S. STANDARD SCREW THREAD

SELLERS OR FRANKLIN INSTITUTE STANDARD

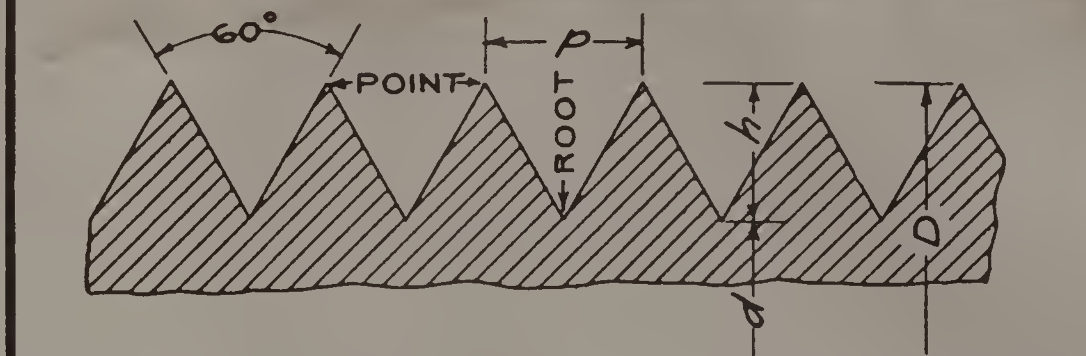


p = PITCH OF THREAD = 1 ÷ NO. OF THDS. PER IN.
δ = DEPTH OF THREAD = $p \cos 30°$
POINT IS CUT OFF $\frac{1}{8}\delta$, ROOT IS FILLED IN $\frac{1}{8}\delta$
$h = \frac{3}{4}\delta = \frac{3}{4} p \cos 30° = .65p$
D = OUTSIDE DIAM. d = EFFECTIVE DIAM. AT ROOT
$d = D - 2h = D - 2 \times .65p = D - 1.3p$

TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS	TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS	TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS
$\frac{1}{4}$	$\frac{3}{16}$	20	$\frac{7}{8}$	$\frac{47}{64}$	9	2	$1\frac{23}{32}$	$4\frac{1}{2}$
$\frac{5}{16}$	$\frac{1}{4}$	18	1	$\frac{27}{32}$	8	$2\frac{1}{4}$	$1\frac{31}{32}$	$4\frac{1}{2}$
$\frac{3}{8}$	$\frac{19}{64}$	16	$1\frac{1}{8}$	$\frac{15}{16}$	7	$2\frac{1}{2}$	$2\frac{3}{16}$	4
$\frac{7}{16}$	$\frac{11}{32}$	14	$1\frac{1}{4}$	$1\frac{5}{64}$	7	$2\frac{3}{4}$	$2\frac{7}{16}$	4
$\frac{1}{2}$	$\frac{27}{64}$	13	$1\frac{3}{8}$	$1\frac{11}{64}$	6	3	$2\frac{41}{64}$	$3\frac{1}{2}$
$\frac{9}{16}$	$\frac{15}{32}$	12	$1\frac{1}{2}$	$1\frac{19}{64}$	6	$3\frac{1}{4}$	$2\frac{15}{16}$	$3\frac{1}{2}$
$\frac{5}{8}$	$\frac{33}{64}$	11	$1\frac{5}{8}$	$1\frac{13}{32}$	$5\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{3}{32}$	$3\frac{1}{4}$
$\frac{11}{16}$	$\frac{37}{64}$	11	$1\frac{3}{4}$	$1\frac{1}{2}$	5	$3\frac{3}{4}$	$3\frac{5}{16}$	3
$\frac{3}{4}$	$\frac{5}{8}$	10	$1\frac{7}{8}$	$1\frac{5}{8}$	5	4	$3\frac{9}{16}$	3

V-STANDARD SCREW THREAD

TABLE GIVES ACCEPTED PITCH FOR SAME

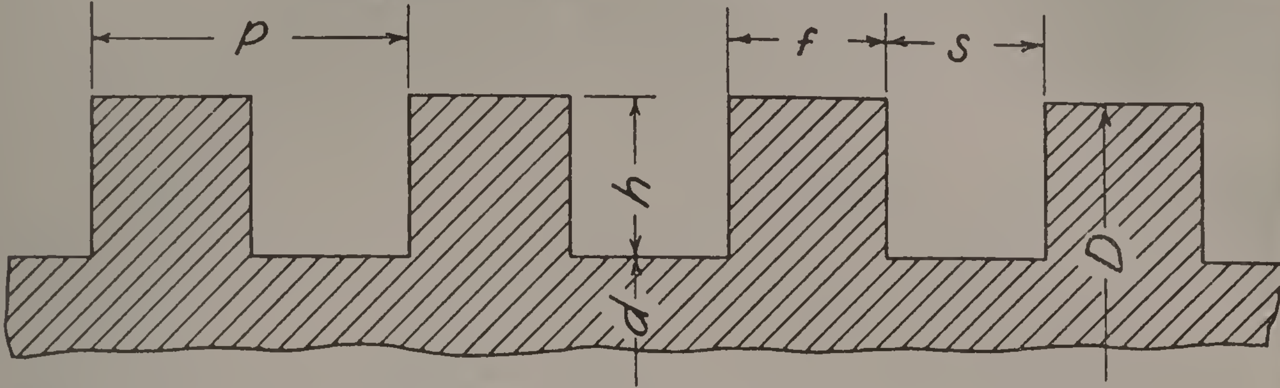


p = PITCH OF THREAD = 1 ÷ NO. OF THDS. PER INCH
h = DEPTH OF THREAD = $p \cos 30° = .866p$
D = OUTSIDE DIAM. d = EFFECTIVE DIAM. AT ROOT
$d = D - 2h = D - 2 \times .866p = D - 1.732p$

TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS	TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS	TAP DIAM	DRILL HOLE FOR TAP	NO OF THDS
$\frac{1}{4}$	$\frac{3}{16}$	20	$\frac{7}{8}$	$\frac{47}{64}$	9	2	$1\frac{11}{16}$	$4\frac{1}{2}$
$\frac{5}{16}$	$\frac{15}{64}$	18	1	$\frac{13}{16}$	8	$2\frac{1}{4}$	$1\frac{7}{8}$	$4\frac{1}{2}$
$\frac{3}{8}$	$\frac{9}{32}$	16	$1\frac{1}{8}$	$\frac{59}{64}$	7	$2\frac{1}{2}$	$2\frac{1}{16}$	4
$\frac{7}{16}$	$\frac{21}{64}$	14	$1\frac{1}{4}$	$1\frac{3}{16}$	7	$2\frac{3}{4}$	$2\frac{5}{16}$	4
$\frac{1}{2}$	$\frac{25}{64}$	12	$1\frac{3}{8}$	$1\frac{1}{8}$	6	3	$2\frac{1}{2}$	$3\frac{1}{2}$
$\frac{9}{16}$	$\frac{29}{64}$	12	$1\frac{1}{2}$	$1\frac{17}{64}$	6	$3\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{2}$
$\frac{5}{8}$	$\frac{1}{2}$	11	$1\frac{5}{8}$	$1\frac{11}{32}$	5	$3\frac{1}{2}$	$2\frac{31}{32}$	$3\frac{1}{4}$
$\frac{11}{16}$	$\frac{9}{16}$	11	$1\frac{3}{4}$	$1\frac{15}{32}$	5	$3\frac{3}{4}$	$3\frac{3}{16}$	3
$\frac{3}{4}$	$\frac{39}{64}$	10	$1\frac{7}{8}$	$1\frac{19}{32}$	$4\frac{1}{2}$	4	$3\frac{27}{64}$	3

PLATE N.

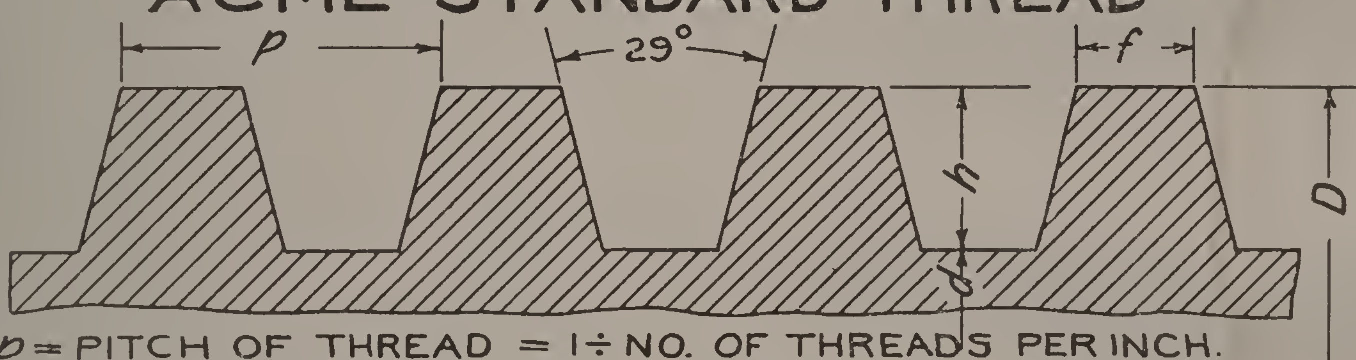
SQUARE THREAD



p = PITCH OF THREAD = 1 ÷ NO. OF THREADS PER INCH.
h = DEPTH OF THREAD = $\frac{p}{2}$, $f = s = \frac{p}{2}$
D = OUTSIDE DIAM.
d = EFFECTIVE DIAM. AT ROOT = $D-2h = D-p$

DIAM OF SCREW	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$"	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
THREADS PER INCH	10	9	8	7	6	$5\frac{1}{2}$	5	$4\frac{1}{2}$	4	$3\frac{1}{2}$	$3\frac{1}{2}$	3	3
DIAM OF SCREW	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	
THREADS PER INCH	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{4}$	2	2	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	

ACME STANDARD THREAD



p = PITCH OF THREAD = 1 ÷ NO. OF THREADS PER INCH.
D = OUTSIDE DIAM. OF SCREW. d = DIAM. OF SCREW AT ROOT.

NUMBER OF THREADS PER INCH	h DEPTH OF THREAD	f WIDTH AT POINT
1	.5100	.3707
1⅓	.3850	.2780
2	.2600	.1853
3	.1767	.1235
4	.1350	.0927
5	.1100	.0741
6	.0933	.0618
7	.0814	.0529
8	.0725	.0463
9	.0655	.0413
10	.0600	.0371

h = DEPTH OF THREAD = $\frac{1}{2 \times \text{NO. THDS. PER IN.}} + .01$

$d = D - 2h = D - \frac{1}{\text{NO. OF THDS PER IN}} + .02$

f = WIDTH AT POINT = $\frac{.3707}{\text{NO. OF THDS. PER IN.}}$

TO DRAW THE ACME THREAD, FIRST LAYOFF THE SUCCESSIVE PITCHES, FROM THESE POINTS MARK OFF THE POINT WIDTHS f. THROUGH THE TWO SETS OF POINTS THUS FOUND DRAW LINES AT 30 AS SHOWN. THIS IS SUFFICIENTLY CLOSE FOR A DRAWING.

Plate O.

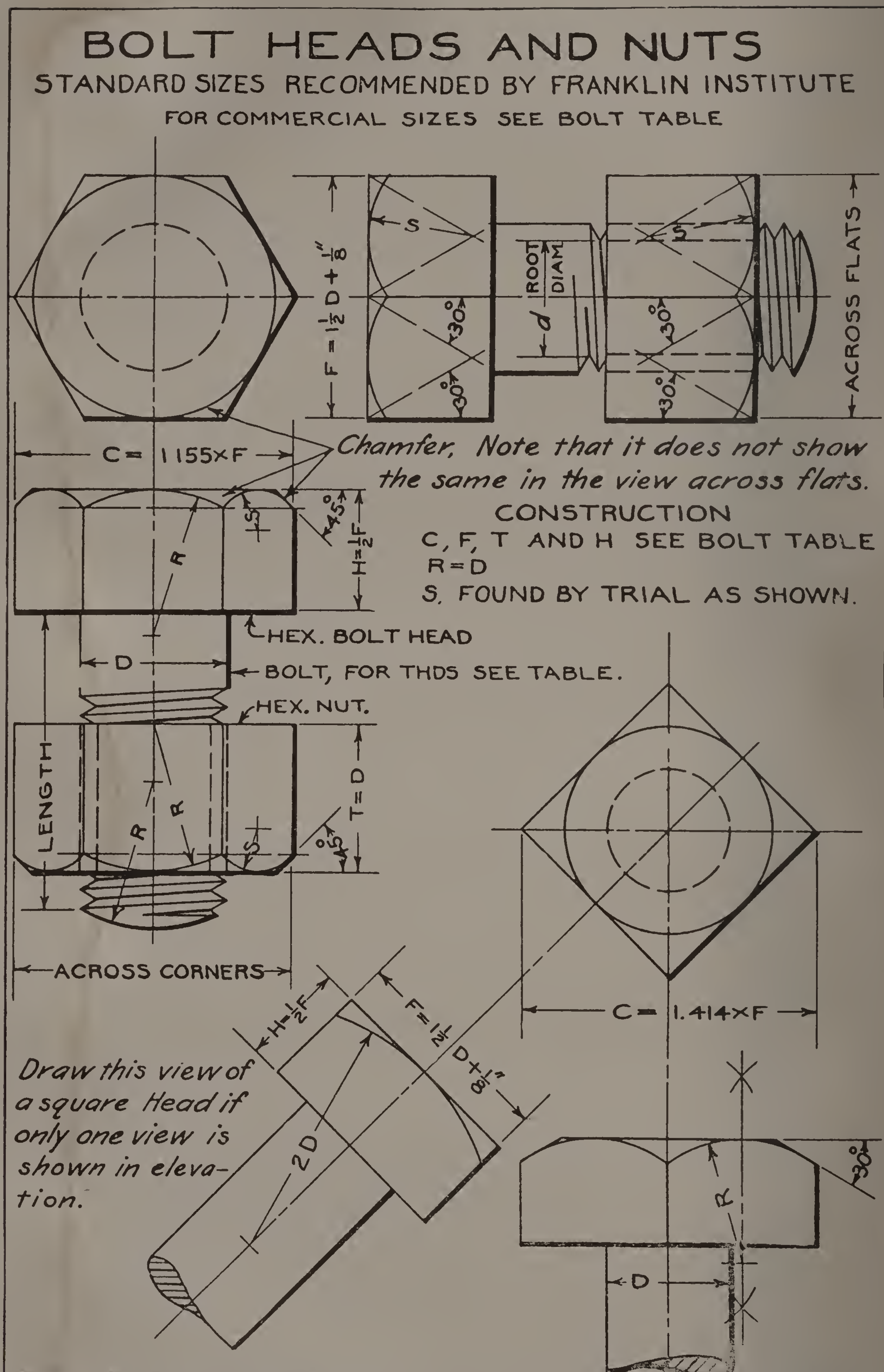
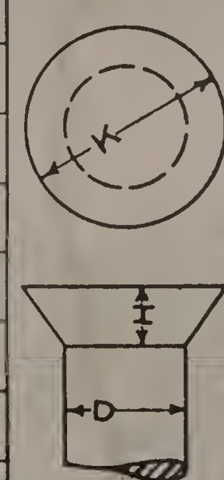

BOLT HEADS AND NUTS
STANDARD SIZES RECOMMENDED BY FRANKLIN INSTITUTE
FOR COMMERCIAL SIZES SEE BOLT TABLE
S
F = 1½ D + ⅛"
ROOT DIAM
d
30°
30°
ACROSS FLATS
C = 1.155×F
Chamfer, Note that it does not show the same in the view across flats.
45°
H=½F
R
CONSTRUCTION
C, F, T AND H SEE BOLT TABLE
R=D
S. FOUND BY TRIAL AS SHOWN.
HEX. BOLT HEAD
D
BOLT, FOR THDS SEE TABLE.
HEX. NUT.
LENGTH
T=D
ACROSS CORNERS
H=½F
F=1½D+⅛"
2D
Draw this view of a square Head if only one view is shown in elevation.
C = 1.414×F
D

Plate P.

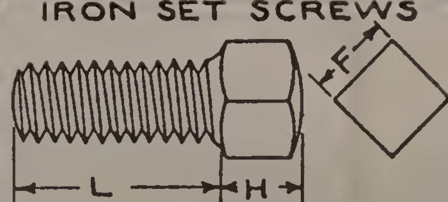
PROPORTIONS FOR U.S. STANDARD SCREW THREADS AND NUTS

HOOPES AND TOWNSEND'S STANDARD SIZES FOR BOLT HEADS

DIAM OF BOLT D	BOLT THREADS: THDS. PER INCH N	BOLT THREADS: DIAM. AT ROOT d	BOLT THREADS: AREA AT ROOT A	NUTS: THICK HEX. OR SQ. T	NUTS: HEX. LONG DIAM. C	NUTS: SQ. LONG DIAM. C	NUTS: HEX, SQ. SHORT DIAM. F	HEADS: HEX. OR SQ. SHORT DIAM. F	HEADS: HEX. OR SQ. THICK H	HEADS: COUNTERSUNK DIAM. K	HEADS: COUNTERSUNK THICK H
$\frac{1}{4}$	20	.185	.026	$\frac{1}{4}$	$\frac{37}{64}$	$\frac{45}{64}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{1}{8}$
$\frac{5}{16}$	18	.240	.045	$\frac{5}{16}$	$\frac{11}{16}$	$\frac{27}{32}$	$\frac{19}{32}$	$\frac{15}{32}$	$\frac{15}{64}$	$\frac{9}{16}$	$\frac{3}{16}$
$\frac{3}{8}$	16	.294	.067	$\frac{3}{8}$	$\frac{51}{64}$	$\frac{63}{64}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{11}{16}$	$\frac{3}{16}$
$\frac{7}{16}$	14	.344	.092	$\frac{7}{16}$	$\frac{7}{8}$	$1\frac{7}{64}$	$\frac{25}{32}$	$\frac{21}{32}$	$\frac{21}{64}$	$\frac{3}{4}$	$\frac{7}{16}$
$\frac{1}{2}$	13	400	.125	$\frac{1}{2}$	1	$1\frac{15}{64}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{7}{8}$	$\frac{1}{4}$
$\frac{9}{16}$	12	.454	.161	$\frac{9}{16}$	$1\frac{1}{8}$	$1\frac{23}{64}$	$\frac{31}{32}$	$\frac{27}{32}$	$\frac{27}{64}$	$\frac{15}{16}$	$\frac{1}{4}$
$\frac{5}{8}$	11	.507	.201	$\frac{5}{8}$	$1\frac{7}{32}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{15}{32}$	$1\frac{1}{8}$	$\frac{1}{4}$
$\frac{3}{4}$	10	.620	.301	$\frac{3}{4}$	$1\frac{7}{16}$	$1\frac{49}{64}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{9}{16}$	$1\frac{1}{4}$	$\frac{3}{8}$
$\frac{7}{8}$	9	731	.419	$\frac{7}{8}$	$1\frac{21}{32}$	$2\frac{1}{32}$	$1\frac{7}{16}$	$1\frac{5}{16}$	$\frac{21}{32}$	$1\frac{3}{8}$	$\frac{7}{16}$
1	8	837	.550	1	$1\frac{7}{8}$	$2\frac{19}{64}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{5}{8}$	$\frac{1}{2}$
$1\frac{1}{8}$	7	.940	.693	$1\frac{1}{8}$	$2\frac{3}{32}$	$2\frac{9}{16}$	$1\frac{13}{16}$	$1\frac{11}{16}$	$\frac{27}{32}$		
$1\frac{1}{4}$	7	1.065	.890	$1\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{53}{64}$	2	$1\frac{7}{8}$	$\frac{15}{16}$		
$1\frac{3}{8}$	6	1.160	1.056	$1\frac{3}{8}$	$2\frac{17}{32}$	$3\frac{3}{32}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$1\frac{1}{32}$		
$1\frac{1}{2}$	6	1.284	1.294	$1\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{23}{64}$	$2\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{1}{8}$		
$1\frac{5}{8}$	$5\frac{1}{2}$	1.389	1.515	$1\frac{5}{8}$	$2\frac{31}{32}$	$3\frac{5}{8}$	$2\frac{9}{16}$	$2\frac{7}{16}$	$1\frac{7}{32}$		
$1\frac{3}{4}$	5	1.491	1.746	$1\frac{3}{4}$	$3\frac{3}{16}$	$3\frac{57}{64}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{5}{16}$		
$1\frac{7}{8}$	5	1.616	2.051	$1\frac{7}{8}$	$3\frac{13}{32}$	$4\frac{5}{32}$	$2\frac{15}{16}$	$2\frac{13}{16}$	$1\frac{13}{32}$		
2	$4\frac{1}{2}$	1.712	2.301	2	$3\frac{5}{8}$	$4\frac{27}{64}$	$3\frac{1}{8}$	3	$1\frac{1}{2}$		
$2\frac{1}{4}$	$4\frac{1}{2}$	1.962	3.023	$2\frac{1}{4}$	$4\frac{1}{16}$	$4\frac{61}{64}$	$3\frac{1}{2}$				
$2\frac{1}{2}$	4	2.176	3.718	$2\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{31}{64}$	$3\frac{7}{8}$				
$2\frac{3}{4}$	4	2.426	4.622	$2\frac{3}{4}$	$4\frac{29}{32}$	6	$4\frac{1}{4}$				
3	$3\frac{1}{2}$	2.629	5.428	3	$5\frac{3}{8}$	$6\frac{17}{32}$	$4\frac{5}{8}$				
$3\frac{1}{4}$	$3\frac{1}{2}$	2.879	6.509	$3\frac{1}{4}$	$5\frac{13}{16}$	$7\frac{1}{16}$	5				
$3\frac{1}{2}$	$3\frac{1}{4}$	3.100	7.547	$3\frac{1}{2}$	$6\frac{7}{64}$	$7\frac{39}{64}$	$5\frac{3}{8}$				
$3\frac{3}{4}$	3	3.318	8.641	$3\frac{3}{4}$	$6\frac{21}{32}$	$8\frac{1}{8}$	$5\frac{3}{4}$				
4	3	3.567	9.993	4	$7\frac{3}{32}$	$8\frac{41}{64}$	$6\frac{1}{8}$				



IRON SET SCREWS



REGULAR SQ. HEAD
CUP OR ROUND POINT
THREADS U.S. STANDARD
F=H, SAME AS DIAM. OF SCREW.
DIAMETERS FROM $\frac{1}{4}$" TO $1\frac{1}{4}$"
LENGTH UNDER HEAD = L
VARIES FROM $\frac{3}{4}$" TO 5"

PLATE Q.

MACHINE SCREWS. 1. Standard machine screws are shown on Plate R. The values in the table are very close to the A. S. M. E. Standard.

TAPERS. 1. When it is desired that two or more pieces shall fit tightly and at the same time be readily removable or adjustable for taking up wear, one or more of the pieces are made tapering.

2. The necessary dimensions are those of the larger end, the length of the tapered portion and the taper per foot or fraction of an inch in a whole number of inches, *i. e.*, $\frac{1}{4}''$ in 5″. (See Fig. 48.)

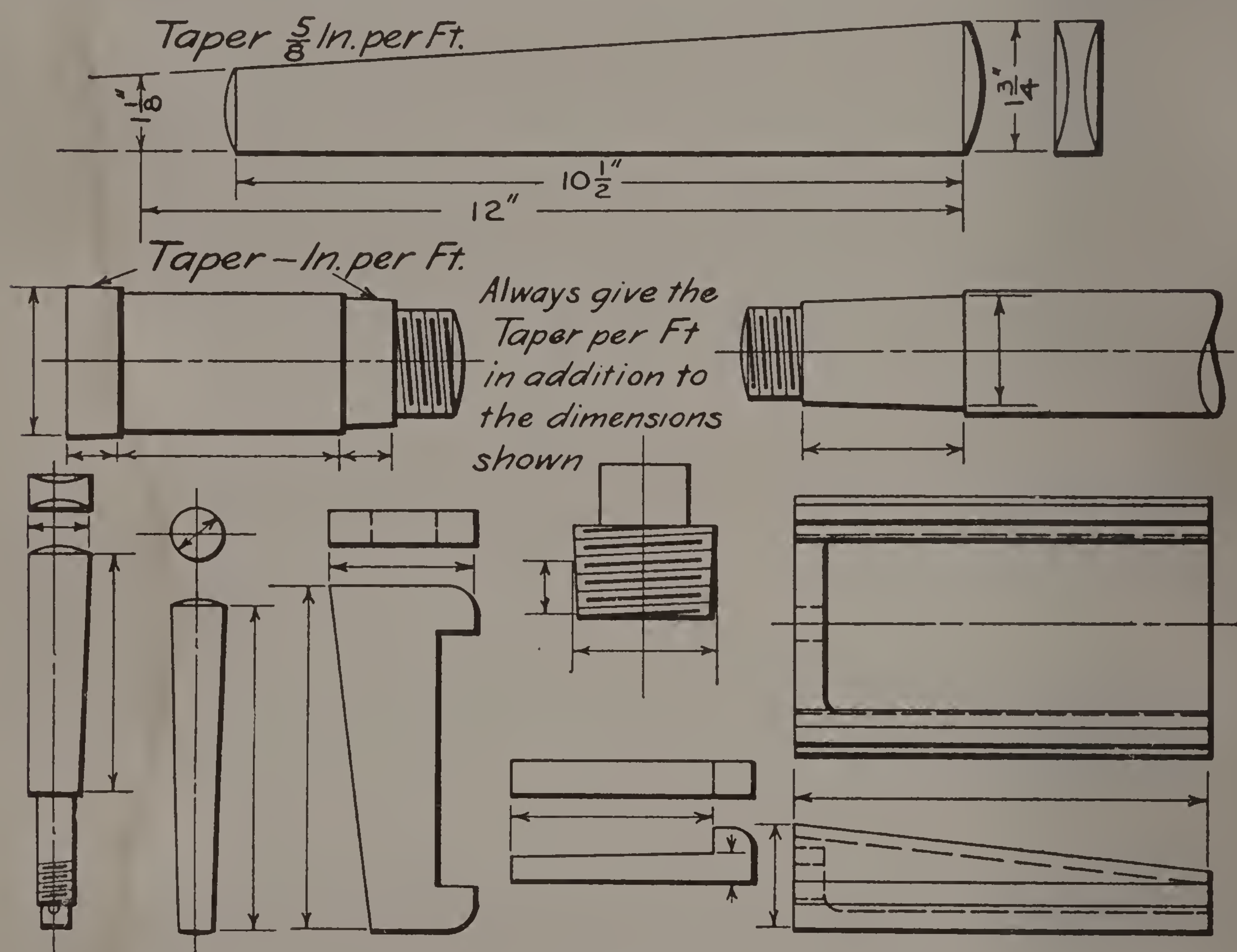


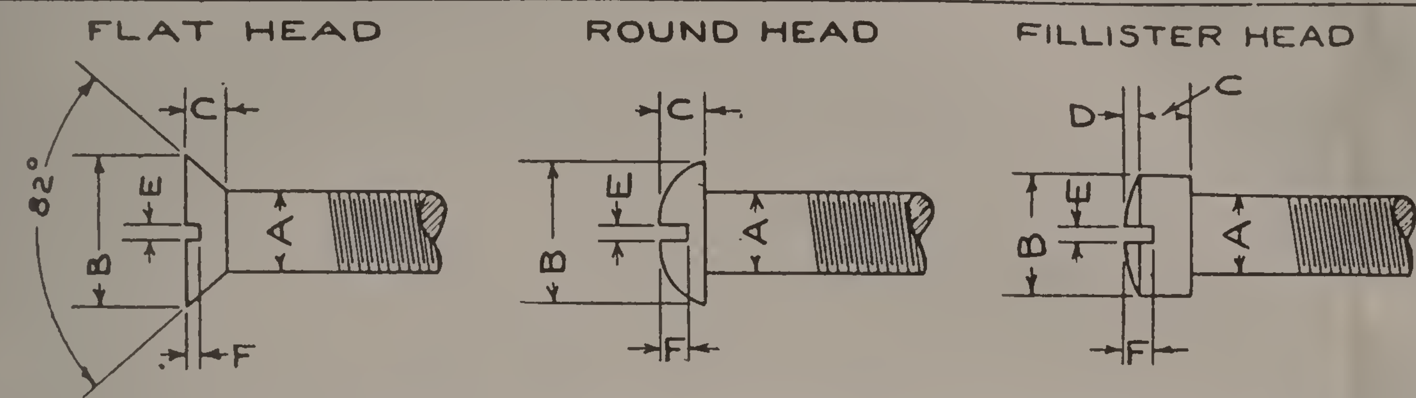
Fig. 48.

3. On a tapered piece that does not fit anything, give the size at each end and its length. The rate of taper must not be given.

4. There is no universal standard for tapers, different lines of work and different shops adopt tapers suitable to their requirements. The following, used in locomotive practice, is a fair sample:
Bolt Taper $\frac{1}{16}''$ in 12″. Boiler Taps 1″ in 12″.
Cross-head Pins $\frac{1}{4}''$ in 5″. Brass Cock Plug $2\frac{1}{4}''$ in 12″.
Cross-head Key $\frac{3}{4}''$ in 8″. Cross-head End of Piston Rod $\frac{1}{4}''$ in 5″.
Connecting Rod, Stub Keys and Cotters $\frac{3}{4}''$ in 12″.

STANDARD MACHINE SCREWS

AMERICAN SCREW COMPANY



NO	A	FLAT HEAD				ROUND HEAD				FILLISTER HEAD				
		B	C	E	F	B	C	E	F	B	C	D	E	F
2	.0842	.1631	.0454	.030	.0151	.1544	.0672	.030	.0403	.1350	.0549	.0126	.030	.0338
3	.0973	.1894	.0530	.032	.0177	.1786	.0746	.032	.0448	.1561	.0634	.0146	.032	.0390
4	.1105	.2158	.0605	.034	.0202	.2028	.0820	.034	.0492	.1772	.0720	.0166	.034	.0443
5	.1236	.2421	.0681	.036	.0227	.2270	.0894	.036	.0536	.1984	.0806	.0186	.036	.0496
6	.1368	.2684	.0757	.039	.0252	.2512	.0968	.039	.0580	.2195	.0892	.0205	.039	.0549
7	.1500	.2947	.0832	.041	.0277	.2754	.1042	.041	.0625	.2406	.0978	.0225	.041	.0602
8	.1631	.3210	.0908	.043	.0303	.2996	.1116	.043	.0670	.2617	.1063	.0245	.043	.0654
9	.1763	.3474	.0984	.045	.0328	.3238	.1190	.045	.0714	.2828	.1149	.0265	.045	.0707
10	.1894	.3737	.1059	.048	.0353	.3480	.1264	.048	.0758	.3040	.1235	.0285	.048	.0760
12	.2158	.4263	.1210	.052	.0403	.3922	.1412	.052	.0847	.3462	.1407	.0324	.052	.0866
14	.2421	.4790	.1362	.057	.0454	.4364	.1560	.057	.0936	.3884	.1578	.0364	.057	.0971
16	.2684	.5316	.1513	.061	.0504	.4806	.1708	.061	.1024	.4307	.1750	.0403	.061	.1077
18	.2947	.5842	.1665	.066	.0555	.5248	.1856	.066	.1114	.4729	.1921	.0443	.066	.1182
20	.3210	.6368	.1816	.070	.0605	.5690	.2004	.070	.1202	.5152	.2093	.0483	.070	.1288
22	.3474	.6895	.1967	.075	.0656	.6106	.2152	.075	.1291	.5574	.2267	.0520	.075	.1384
24	.3737	.7421	.2118	.079	.0706	.6522	.2300	.079	.1380	.5996	.2436	.0562	.079	.1499
26	.4000	.7421	.1967	.084	.0656	.6938	.2448	.084	.1469	.6419	.2608	.0601	.084	.1605
28	.4263	.7948	.2118	.088	.0706	.7354	.2596	.088	.1558	.6841	.2779	.0641	.088	.1710
30	.4526	.8474	.2270	.093	.0757	.7770	.2744	.093	.1646	.7264	.2951	.0681	.093	.1816

MACHINE SCREWS ARE DESIGNATED THUS—"#12×20 FILLISTER HEAD MACHINE SCREWS" WHICH MEANS SIZE (GAUGE) #12 HAVING 20 THREADS PER INCH THEREON. SEE LAST COLUMN IN THE TABLE OF STANDARDS FOR WIRE GAUGES.
THE NUMBER OF THREADS PER INCH FOR THE VARIOUS SIZES WILL BE FOUND IN THE FOLLOWING TABLE.

NO	THREADS PER INCH								NO	THREADS PER INCH							
2	64	56	48	..	..	..	..	..	12	24	20	..	..	..			
3	..	56	48	..	..	..	..	..	14	24	20	18	..	..			
4	..	..	..	40	36	32	..	..	16	..	20	18	16	..			
5	..	..	..	40	36	32	..	..	18	..	20	18	16	..			
6	..	..	..	..	36	32	30	..	20	..	..	18	16	..			
7	..	..	..	..	..	32	30	..	22	..	..	18	16	..			
8	..	..	..	..	36	32	30	..	24	..	..	18	16	14			
9	..	..	..	..	..	32	30	24	26	..	..	..	16	14			
10	..	..	..	..	..	32	30	24	28	..	..	..	16	14			
									30	..	..	..	16	14			

Plate R.

STANDARD STEEL TAPER PINS. 1. These pins, made by Pratt and Whitney Co., taper $\frac{1}{4}''$ per foot, and lengths vary by $\frac{1}{4}''$.

Size No.	0	1	2	3	4	5	6	7	8	9	10
Large Diam.	0.156	0.172	0.193	0.219	0.250	0.289	0.341	0.409	0.492	0.591	0.706
Length	$\frac{3}{4}$–1	$\frac{3}{4}$–$1\frac{1}{4}$	$\frac{3}{4}$–$1\frac{1}{2}$	$\frac{3}{4}$–$1\frac{3}{4}$	$\frac{3}{4}$–2	$\frac{3}{4}$–$2\frac{1}{4}$	$\frac{3}{4}$–$3\frac{1}{4}$	1–$3\frac{3}{4}$	$1\frac{1}{4}$–$4\frac{1}{2}$	$1\frac{1}{2}$–$5\frac{1}{4}$	$1\frac{1}{2}$–6

PIPE. 1. Iron pipe is always specified by its nominal internal diameter. The pipe table, Plate S, shows that the actual sizes differ from the nominal. Use actual sizes on drawings.

2. A pipe tapped hole is indicated by two circles, the inner one being full and equal to the drill size, the outer one half full and half dotted and equal to the outside diameter of the pipe. (See illustration on Plate S.)

3. Tubes of iron, steel, brass, copper, etc., are specified by their outside diameter and a gauge number for the thickness of the material, thus: 2″ brass tube, 12 B. & S. gauge.

STANDARD GAUGES. 1. Standard gauges for Wire, Plate Tubes and Screws are given in Plate T.

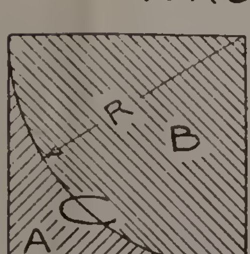
WEIGHTS OF CASTINGS AND FORGINGS. 1. The approximate weight of a piece is often required, especially for making estimates of cost from drawings. This is done by finding the volume and multiplying by the specific weight of the material of which it is to be made. As results within 10 per cent of actual weight are considered satisfactory in practice, it is not necessary to consider small fillets and other minute details.

2. Assume the piece divided into a number of parts, the volumes of which are readily obtainable. From these the total volume and weight may be found.

3. If close estimating is required and there are numerous fillets of some size, the fillets and round edges should be taken into account. See Fig. 49 for the method of finding areas of fillets, round edges and corners.

WEIGHTS OF METALS

ALUMINUM	WEIGHS	.094#	PER	CU. IN.
BRASS	"	.30#	"	"
BRONZE AND COPPER	"	.31#	"	"
CAST IRON	"	.26#	"	"
CAST STEEL	"	.28#	"	"
LEAD	"	.41#	"	"
WROUGHT IRON AND STEEL	"	.28#	"	"



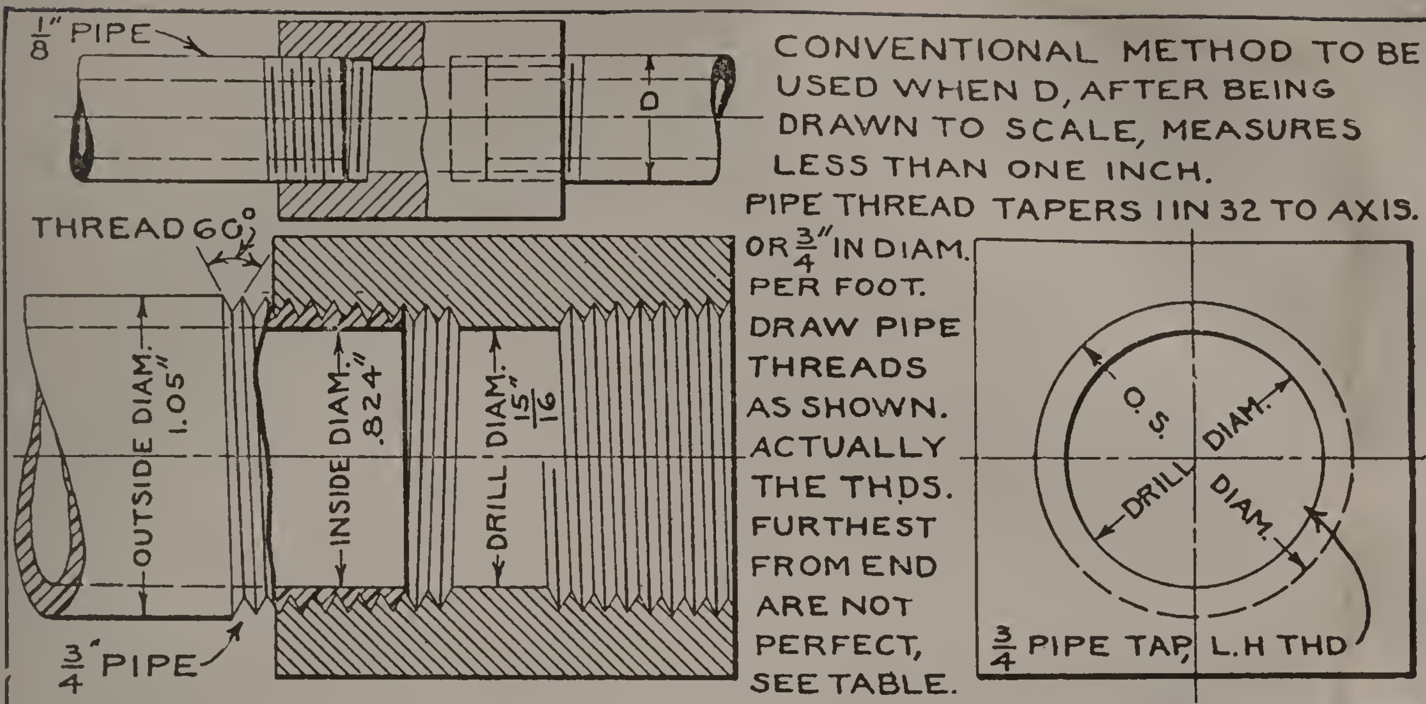
LET A = AREA OF CROSS SECTION OF A FILLET

$A = C - B \qquad C = R^2 \qquad B = \frac{\pi R^2}{4}$

$A = C - B = R^2 - \frac{\pi R^2}{4} = R^2 - .7854R^2 = R^2(1 - .7854)$

THEREFORE $A = .2146R^2 = .2R^2$ APPROXIMATELY

Fig. 49.



WROUGHT IRON STEAM, GAS AND WATER PIPE

NATIONAL TUBE COMPANY — STANDARD DIMENSIONS

DIAMETERS				TRANSVERSE INTERNAL AREAS		THREADS			DRILL HOLE FOR TAP
NOMINAL INTERNAL	ACTUAL INTERNAL STANDARD	ACTUAL INTERNAL EXTRA HEAVY	ACTUAL EXTERNAL	STANDARD	EXTRA HEAVY	NO PER INCH	LENGTH THREADED	LENGTH PERFECT AT ROOT	
1/8	270	.205	.405	.057	.033	27	9/32	3/16	21/64
1/4	.364	294	.540	.104	.068	18	3/8	9/32	29/64
3/8	.494	.421	.675	.191	.139	18	7/16	19/64	19/32
1/2	.623	.542	.840	.304	.231	14	1/2	3/8	23/32
3/4	.824	.736	1.050	.533	.425	14	9/16	13/32	15/16
1	1.048	.951	1.315	861	.710	11 1/2	5/8	1/2	1 3/16
1 1/4	1.380	1.272	1.660	1.496	1.271	11 1/2	11/16	35/64	1 15/32
1 1/2	1.611	1.494	1.900	2.036	1.753	11 1/2	13/16	9/16	1 23/32
2	2.067	1.933	2.375	3.356	2.935	11 1/2	7/8	37/64	2 3/16
2 1/2	2.468	2.315	2.875	4.780	4.209	8	1	7/8	2 11/16
3	3.067	2.892	3.500	7.383	6.569	8	1	15/16	3 5/16
3 1/2	3.548	3.358	4.000	9.887	8.856	8	1 1/16	1	3 13/16
4	4.026	3.818	4.500	12.730	11.449	8	1 1/8	1 3/64	4 5/16
4 1/2	4.508	4.280	5.000	15.961	14.387	8	1 1/4	1 7/64	4 13/16
5	5.045	4.813	5.563	19.985	18.193	8	1 1/4	1 5/32	5 3/8
6	6.065	5.751	6.625	28.886	25.976	8	1 3/8	1 1/4	6 3/8
7	7.023	6.625	7.625	38.743	34.472	8	1 1/2	1 3/8	7 7/16
8	7.982	7.625	8.625	50.021	45.664	8	1 5/8	1 7/16	8 7/16
9	8.937	8.625	9.625	62.722	58.426	8	1 5/8	1 9/16	9 3/8
10	10.019	9.750	10.750	78.822	74.662	8	1 3/4	1 11/16	10 15/32
11	11.000	....	11.750	95.034	....	8	1 7/8	1 3/4	11 7/16
12	12.000	11.750	12.750	113.090	108.430	8	1 7/8	1 3/4	12 7/16

Plate S.

STANDARDS FOR WIRE GAUGES
IN USE IN THE UNITED STATES
DIMENSIONS ARE IN DECIMAL PARTS OF AN INCH

NUMBER OF WIRE GAUGE	AMERICAN OR BROWN AND SHARPE	BIRMINGHAM OR STUBS ENGLISH	STUBS STEEL WIRE	U.S. STANDARD FOR PLATE	NUMBER OF SCREW OR WIRE GAUGE	MACHINE AND WOOD SCREW GAUGE
000000	....	....	....	.4688	000000	....
00000	....	....	....	.4375	00000	....
0000	.46	.454	....	.4063	0000	....
000	.4096	.425	....	.3750	000	.0315
00	.3648	.38	....	.3438	00	.0447
0	.3249	.34	....	.3125	0	.0578
1	.2893	.3	.227	.2813	1	.0710
2	.2576	.284	.219	.2656	2	.0842
3	.2294	.259	.212	.25	3	.0973
4	.2043	.238	.207	.2344	4	.1105
5	.1819	.22	.204	.2188	5	.1236
6	.1620	.203	.201	.2031	6	.1368
7	.1443	.18	.199	.1875	7	.1500
8	.1285	.165	.197	.1719	8	.1631
9	.1144	.148	.194	.1563	9	.1763
10	.1019	.134	191	.1406	10	.1894
11	.0907	.12	.188	.125	11	.2026
12	.0808	.109	.185	.1094	12	.2158
13	.0720	.095	.182	.0938	13	.2289
14	.0641	.083	.180	.0781	14	.2421
15	.0571	.072	.178	.0703	15	.2552
16	.0508	.065	.175	.0625	16	.2684
17	.0453	.058	.172	.0563	17	.2816
18	.0403	.049	.168	.05	18	.2947
19	.0359	.042	.164	.0438	19	.3079
20	.0320	.035	.161	.0375	20	.3210
21	.0285	.032	.157	.0344	21	.3342
22	.0253	.028	.155	.0313	22	.3474
23	.0226	.025	.153	.0281	23	.3605
24	.0201	.022	.151	.025	24	.3737
25	.0179	.02	.148	.0219	25	.3868
26	.0159	.018	.146	.0188	26	.4000
27	.0142	.016	.143	.0172	27	.4132
28	.0126	.014	.139	.0156	28	.4263
29	.0113	.013	.134	.0140	29	.4395
30	.0100	.012	.127	.0125	30	.4526
31	.0089	.01	.120	.0109	31	.4658
32	.0080	.009	.115	.0102	32	.4790
33	.0071	.008	.112	.0094	33	.4921
34	.0063	.007	.110	.0086	34	.5053
35	.0056	.005	.108	.0078	35	.5184
36	.005	.004	.106	.0070	36	.5316
37	.0045	....	.103	.0066	37	.5448
38	.0040	....	.101	.0063	38	.5579
39	.0035	....	.099	....	39	.5711
40	.0031	....	.097	....	40	.5842

PLATE T.

DECIMALS OF AN INCH FOR EACH 64TH

32NDS.	64THS.	DECIMAL	FRACTION	32NDS.	64THS.	DECIMAL	FRACTION
	1	.015625			33	515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1-16	18	36	.5625	9-16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1-8	20	40	.625	5-8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3-16	22	44	.6875	11-16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1-4	24	48	.75	3-4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5-16	26	52	.8125	13-16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3-8	28	56	.875	7-8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7-16	30	60	.9375	15-16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1-2	32	64	1.	1

PLATE U.

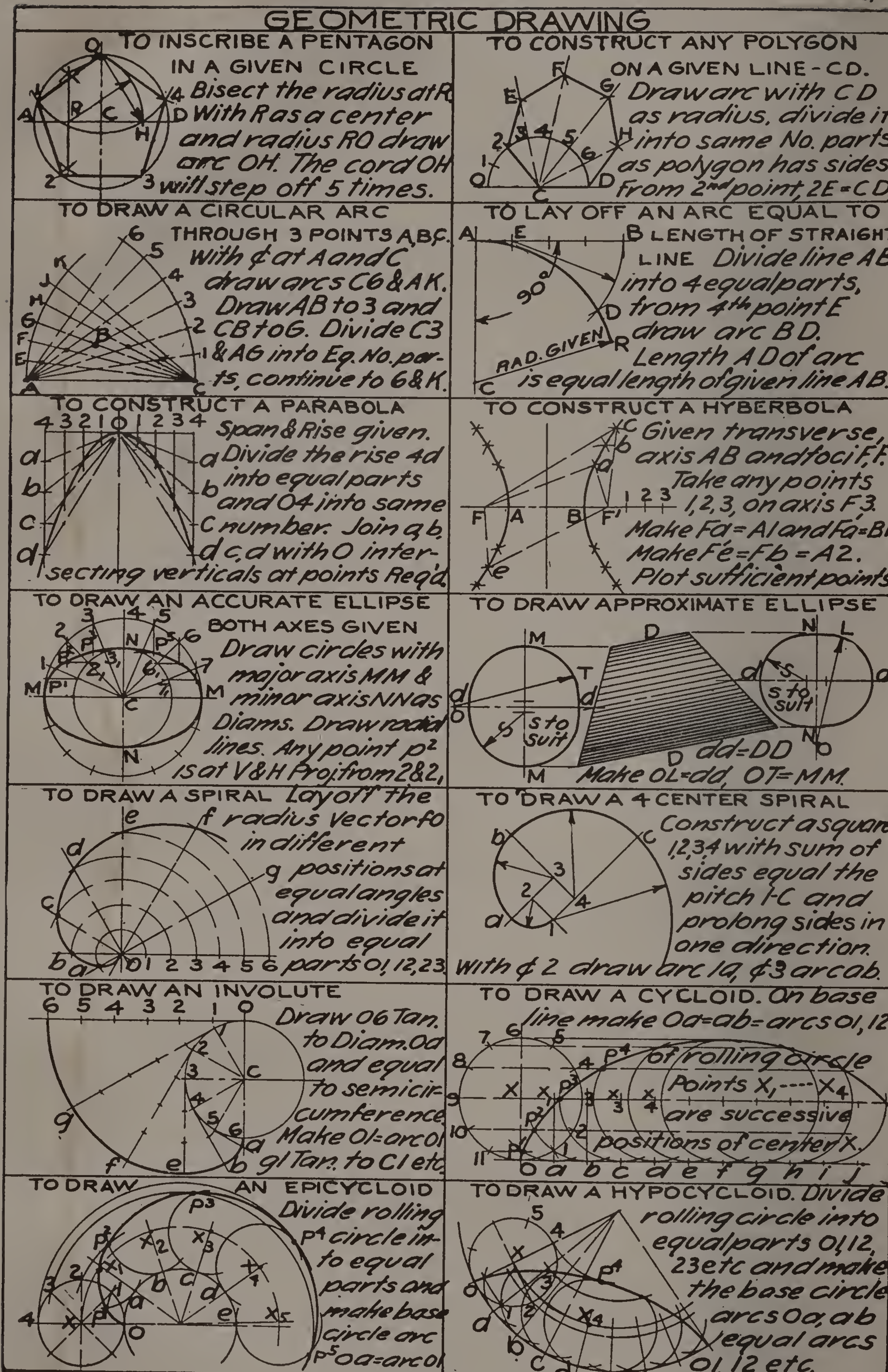

GEOMETRIC DRAWING
TO INSCRIBE A PENTAGON IN A GIVEN CIRCLE
Bisect the radius at R. With R as a center and radius RO draw arc OH. The cord OH will step off 5 times.
TO CONSTRUCT ANY POLYGON ON A GIVEN LINE - CD.
Draw arc with CD as radius, divide it into same No. parts as polygon has sides. From 2nd point, 2E = CD.
TO DRAW A CIRCULAR ARC THROUGH 3 POINTS A,B,C.
With ¢ at A and C draw arcs C6 & AK. Draw AB to 3 and CB to G. Divide C3 & AG into Eq. No. parts, continue to 6 & K.
TO LAY OFF AN ARC EQUAL TO LENGTH OF STRAIGHT LINE
Divide line AB into 4 equal parts, from 4th point E draw arc BD. Length AD of arc is equal length of given line AB.
90°
RAD. GIVEN
TO CONSTRUCT A PARABOLA
Span & Rise given. Divide the rise 4d into equal parts and O4 into same number. Join a,b,c,d with O intersecting verticals at points Req'd.
TO CONSTRUCT A HYBERBOLA
Given transverse, axis AB and foci F,F'. Take any points 1,2,3, on axis F3. Make Fa = A1 and F'a = B1. Make Fe = F'b = A2. Plot sufficient points.
TO DRAW AN ACCURATE ELLIPSE BOTH AXES GIVEN
Draw circles with major axis MM & minor axis NN as Diams. Draw radial lines. Any point p2 is at V&H Proj. from 2 & 2,
TO DRAW APPROXIMATE ELLIPSE
S to suit
Make OL = dd, OT = MM.
dd = DD
TO DRAW A SPIRAL
Lay off the radius vector fo in different positions at equal angles and divide it into equal parts 01, 12, 23
TO DRAW A 4 CENTER SPIRAL
Construct a square 1,2,3,4 with sum of sides equal the pitch 1-C and prolong sides in one direction. With ¢ 2 draw arc 1a, ¢ 3 arc ab.
TO DRAW AN INVOLUTE
Draw 06 Tan. to Diam. Oa and equal to semicircumference. Make 01 = arc 01 g1 Tan. to C1 etc.
TO DRAW A CYCLOID.
On base line make Oa = ab = arcs 01, 12 of rolling circle. Points X1 ---- X4 are successive positions of center X.
TO DRAW AN EPICYCLOID
Divide rolling circle into equal parts and make base circle arc P5 Oa = arc 01
TO DRAW A HYPOCYCLOID.
Divide rolling circle into equal parts 01, 12, 23 etc and make the base circle arcs Oa, ab equal arcs 01, 12 etc.

PLATE V.

CHECKING. 1. A Mechanical Drawing is always checked for errors, omissions and correctness in representation before it reaches the artisan.

2. The designer and draftsman should each check their work for their own satisfaction and protection. This should be done as the work progresses.

3. A drawing should be checked by some one familiar with the requirements other than the draftsman that made it, to avoid costly mistakes, doubtful meaning and impractical construction.

4. Drawings are corrected to make them right and explicit.

5. Erasing and making corrections on a drawing is easier and cheaper than making alterations on a piece in the shops—it keeps things from going to the scrap pile.

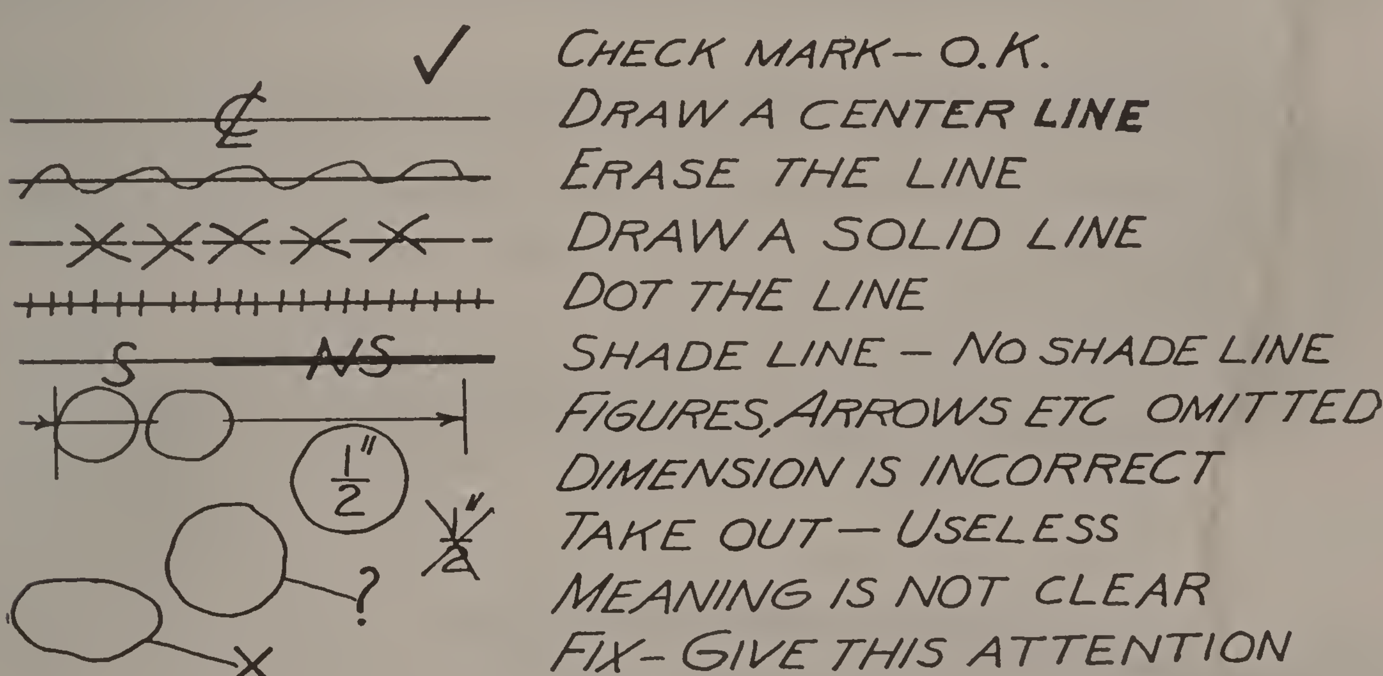


FIG. 50.

6. Check a drawing for the following features and make the required changes. (See Checker's Symbols, Fig. 50.)

Clearness.—Is the drawing easy to read and understand?
Are the lines correct in weight and punctuation?

Views.—Are they correctly projected from each other?
Do they show the object completely?
Would others show the object to better advantage?

Sections.—Are they drawn correctly and their locations indicated?
Are others needed to show the construction?

Dimensions.—Are the values correct by scale or calculations?
Are enough given for complete information and no repetitions?
Are necessary ones given without resort to addition and subtraction?
Are they the ones wanted and properly placed for usefulness?

Lettering.—Are all symbols for Finish, Fit and Identification given?
Has all material been correctly specified?
Have all parts been tabulated in the Bill of Materials?
Are all necessary notes given?
Does the title contain the necessary and correct information?
Is the index number, for filing and identification correct?

Design.—Is the design practical and of pleasing appearance?
See Practical Points in Mechanical Design Drawing, Page 79.

Motions.—Do moving parts have proper clearance?

Fastenings.—Can they be readily put in place and removed?

DESIGNING. **1.** A mechanical scheme may originate in the mind without a demand for it, or the idea may have to be evolved by the pressure of necessity; in the latter case considerable designing is required.

2. A design is developed by analytical and empirical methods augmented by the designer's mechanical sense of proportions.

3. Analytical design involves the determination of dimensions by mathematical formulas, deducted from scientific theories and tests which the designer should understand.

4. Empirical design is determining size by formulas and proportions based on experience, observation and good practice.

5. Mechanical sense of proportion is that ability which enables one to design the thing required, using previously determined sizes or quantities to build around.

6. The procedure in Mechanical Design should be about as indicated in the following typical schedule:

TYPICAL DESIGN SCHEDULE

Main Features

1. The thing required.
2. Specifications to be met.
3. General scheme of layout—scheme sketches.
4. Analysis and calculations involving forces, velocities, friction, etc.
5. Memorandum sketches for dimensions and quantities calculated.
6. Empirical proportioning of parts.
7. Standard proportions of parts.
8. Mechanical sense of proportions.
9. Layout of main center lines, base lines, clearance and reference lines.
10. Drawing the design accurately and in logical order.

Order of Procedure

Subject
Given
Required
Scheme
Mechanism
Assumptions
Analysis
Procedure
Formulate
Calculate
Result
Deductions
Conclusions
Drawing

7. Mechanical design drawing requires a full knowledge of Mechanical Drawing, the Theory of Design and Shop Methods of Construction.

8. Practical points to observe in designing:

Keep notes, in loose-leaf form, in a neat and logical order, including all sketches, calculations and memoranda.

Be systematic in designing and drawing; it is the shortest and best way to get results.

Freehand sketches make good memoranda as the work progresses.

Views showing sections make a drawing clear and more workable.

Cost of construction and ease of operation are controlled by the designer.

Take no risks in proportioning parts where their safe size can be calculated.

Make reasonable assumptions and test their fitness by calculation or graphical trial.

Think of the construction, fabricating and machining of the parts as the drawing progresses—impractical and impossible design must be avoided.

The general appearance should be harmonious in design, not ugly.

Things that are right look right—is true.

Erecting must be done with the least effort.

Dismantling for cleaning or replacements should be the least possible.

Take a machine apart mentally while drawing it.

Adjustment for wear must be provided and accessible for take-up.

Adjustment for centering should be provided when necessary.

Centering and lining up must be provided for by pins or projections in recesses.

Parts should be few in number, especially those to be replaced.

Moving parts must not foul anything; leave plenty of clearance.

Right and left-hand parts should be avoided; they are not interchangeable.

Minor details omitted cause delay, inconvenience and expense.

Non-essentials should be omitted from the design—aim for simplicity.

Thin ribs will crack if adjoining wall is quite thick.

Fillets must be shown; sharp corners are weak and undesirable.

Round edges must be shown where required.

Oil holes and grooves must be provided and be easy to reach.

Standard fastenings, fittings and parts should be used to reduce costs.

Through bolts are preferred to studs and studs to cap bolts.

Bolts should have room for inserting and forced removal.

Nuts and cap bolts must be free to turn when near fillets, ribs or walls.

Check nuts or cotter pins should be specified where needed.

Machine screws are preferable to bolts on small work.

Set screws should be used for holding parts in place, not for transmitting any considerable force.

Keys are fastenings used to transmit appreciable force.

Keys should have room for inserting and be easy to remove.

Tapering cotters are fastenings used where adjustment and quick release are required.

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