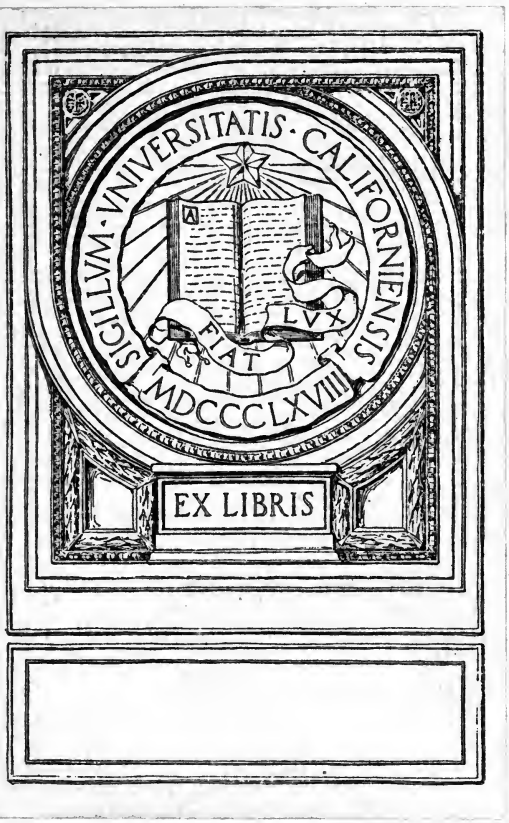
MECHANICAL DRAWING

PHILLIPS AND ORTH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THE UNIVERSITY OF WISCONSIN

MECHANICAL DRAWING
FOR
COLLEGES AND UNIVERSITIES

BY

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PUBLISHERS' NOTE

The present volume is for use in University classes and is complete in itself. It is to be followed, however, by a book for high schools by Professors Crawshaw and Phillips; and the two books will form a complete course in Mechanical Drawing for High School and University work. In this connection the publishers wish to announce their Vocational Series for Schools and Colleges under the editorial supervision of Professor F. D. Crawshaw of the University of Wisconsin. This series is intended to supply an increasing demand for textbooks for use in the vocational courses that are now being so widely adopted as a part of public education.

PREFACE

A drawing is a plan, and sometimes also a specification, for construction work or the assembly of constructed parts. From the beginning of time drawing has been a means of expression and consequently is a form of language. Only within recent years, however, has the art of graphical expression been an important element in the process of developing machinery and structural work. Today a drawing is one of the first steps in the production of practically all machines and structures. Mechanical drawing is the particular form of drawing used for this purpose. The commercial value of mechanical drawing is therefore quite evident.

Drawing has educational as well as commercial value if it is properly taught. It is recognized as one of the best known means of training for habits of observation and perception. As a means of strengthening the imagination and developing coordination between the hand and eye, it has few, if any, equals.

It has been the aim of the authors to arrange a course in drawing which will develop these powers, and which at the same time will give the student an appreciation of the best commercial drafting room practice while making complete, accurate, and well-finished drawings of industrial projects. The course presented in this book is designed for college students who have not had, necessarily, previous experience in drawing. Both the plan and the details of the course have been carefully worked out and repeatedly tested under practical conditions. The present form and content of the course represent the result of years of experience in teaching drawing. The course has fulfilled the educational and commercial requirements as set forth herein.

As an example, each element in drawing is treated separately before the elements are combined. By concentration of thought and effort and by means of repeated performance of similar

operations, the student is enabled to comprehend the theory involved and to develop technique and skill in a minimum of time.

The elements or general divisions in drawing are introduced in the order in which they would naturally occur in a commercial drafting room, as follows: Perspective Sketching, Orthographic Sketching, Pencil Mechanical Drawing, Tracing and Blueprinting. Within these divisions the ideas of progression and concentration are again carried out by introducing lines and conventions in the following progressive order: Straight Vertical and Horizontal Lines, Straight Oblique Lines, Large Circles and Arcs of Circles, Small Circles and Arcs of Circles Tangent to Straight Lines, Arcs of Circles Tangent to One Another, Irregular Curves. It will be noticed that the drawing of tangencies is deferred until the end of Chapter IV. This is done to prepare the student for the necessary conventions used in section views and to give him considerable skill in the handling of instruments in all fundamental operations.

Special attention is called to the subject of Perspective Sketching, as treated in Chapter I. The authors have endeavored to reduce this subject to its lowest terms for use in mechanical drawing where it serves principally to interpret orthographic drawing. In commercial practice the representation of objects by perspective is increasing and hence it would seem that every student of mechanical drawing should become familiar with at least a simple treatment of 45° perspective, the form emphasized in this text. It is assumed that the time devoted to this part of the course will not exceed one-fifth the total time for the work of the first four chapters—approximately one hundred hours.

Every problem given in this course requires thought on the part of the student to reach a solution. The various methods of presenting problems and the solutions required are exemplified in Plates 2, 7, 13, 18, 26, 29, 32, and 35. The problems of the course have been carefully chosen to illustrate principles of representation, dimensioning, etc., and are arranged in accordance with the principle that the more advanced the position of the problem in the course, the more difficult its solution from the standpoint of both the theory and the technique. Groups of

problems are presented for most of the plates, from which problems may be assigned, thus affording a means of suiting the problem to the ability of the student and of lessening the tendency of students to copy from others.

With each orthographic problem a *type problem* is given. This type problem consists of the given data and the solution of a problem similar to that assigned to the student. Example: Figs. 65, 68, and 69 show the given views, constructive stage of pencil mechanical drawing, and the completed drawing. By this method suggestions are given as to methods of representation and dimensioning, while, at the same time, a high standard of technique is set for the student.

It has been the aim in arranging the material and selecting the problems of the course, to distribute the introduction of theory and the use of the various instruments in such a way that the student will comprehend both the theory and its application. The means used to this end is A COURSE IN WORKING DRAWINGS, supplemented by lectures and demonstrations. By applying theory in a well graded, practical problem, immediately after the theory is presented the student should develop a full comprehension of drawing as it is used in commercial practice.

To aid the instructor in securing the viewpoint of the authors in the teaching of the course, Chapter X, The Instructor's Guide, was prepared. It attempts only to emphasize the principal points which the authors have found important. It should reinforce rather than limit the instructor's individual method.

The authors wish to express their appreciation of the cooperation of Professor Crawshaw from the very beginning to the end of the book. He has been a co-author in its production.

THE AUTHORS.

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CHAPTER I

PERSPECTIVE SKETCHING

General Principles

A freehand drawing in outline, which represents an object as it appears when viewed from any given position, is called a perspective sketch.

Fig. 1 is a perspective drawing of a try-square. In this case the try-square is placed with the blade and beam making equal angles with the horizontal line marked *horizon*. The try-square is shown as an observer would see it when standing directly in front of A B, with his eye on the same level as S.

In Fig. 1 the line marked *horizon* represents a line in space at an infinite distance in front of the observer. The eye of the observer is on a level with this line and is, consequently, above the level of the try-square, which rests on a horizontal plane.

The *horizon* or *horizon line* is therefore an imaginary horizontal line on a level with the eye of the observer and at an infinite distance in front of him. The apparent meeting of sky and water when one looks over a large body of water is an example of an *horizon*.

Since the horizon is always on a level with the eye of the observer, it follows that, as the eye is raised or lowered to secure a different view of the object, the horizon will be raised or lowered the same distance.

Direction of Lines in Perspective. Referring again to Fig. 1, we note that:

1. The vertical edges of the try-square are represented by vertical lines in perspective. Example: A B and C D.

2. The horizontal edges of the try-square receding to the right and left converge to points *on the horizon* to the right and left of the observer. These points are called *vanishing points.* Since the beam and blade of the try-square make equal angles with the horizon, the vanishing points are at *equal distances* to the right and left of the point S, which is vertically above A and directly in front of the observer.

A vanishing point is the common intersection of two or more converging lines which represent parallel receding edges of an object.

All parallel horizontal receding lines must converge to the *same point* on the horizon. Example: The horizontal lines of

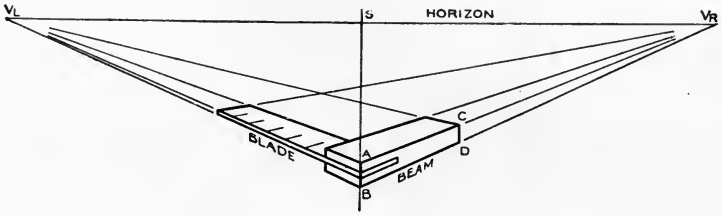


FIG. 1. PERSPECTIVE OF TRY-SQUARE

the try-square converging to the right in its perspective meet in VR. Likewise all the horizontal lines converging to the left meet in VL.

Measurements in Perspective. Equal distances on the front *vertical* edge of an object are represented by equal lengths in perspective. Example: In Fig. 1 the blade of the try-square divides the front vertical edge of the beam of the try-square into two equal parts which are shown by lines of equal length.

Foreshortening is the process of shortening parts of a perspective of an object so as to give the impression of true form and proportion.

Since the parallel receding lines in perspective converge, equal *vertical* distances included between two such lines will be

shorter as their distance from the observer increases. Example: The edges A B and C D of the try-square are equal while in the perspective of the try-square, C D is shorter than A B. Fig. 1.

On *horizontal* receding edges equal distances are, also, represented by shorter lengths as the distance from the observer increases. Example: In Fig. 1 the spaces between the lines representing the one-inch marks grow shorter as they are farther away from the observer.

The Cube in Perspective. Thus far only a general consideration of perspective has been given. The following is an application of the principles thus far developed to the representation of a one-inch cube.

In this course the cube will be regarded as the *basic form* for all perspective drawing. In Fig. 2 the eye of the observer is directly in front of the point S. The vertical faces of the cube make 45° with the horizon and, also, with the direction in which the observer is looking. This is sometimes referred to as 45° perspective, and is the kind emphasized in this course. In 45° perspective the distance from the point directly above A (S in Fig. 2) to the vanishing points and to the eye *must be equal.* In this course 14″ is used.

The edges of the cube are one inch long. Therefore the front vertical edge of the cube is drawn in its true length.

The principles already developed will be recognized in the following analysis of the perspective of the cube.

Since the side faces are *equally inclined* to the direction in which the observer is looking:

1. Angle D A E = Angle D′ A E′.
2. Angle F B H = Angle F′ B H′.

These angles will hereafter be referred to as the *angles of inclination.*

3. The perspective of the corner G is directly above A.

Due to the *convergence* of A D with B F and A D′ with B F′:

1. Angles F B H and F′ B H′ are greater than angles D A E and D′ A E′.
2. Lines D F and D F′ are shorter than A B. D F = D′ F′.

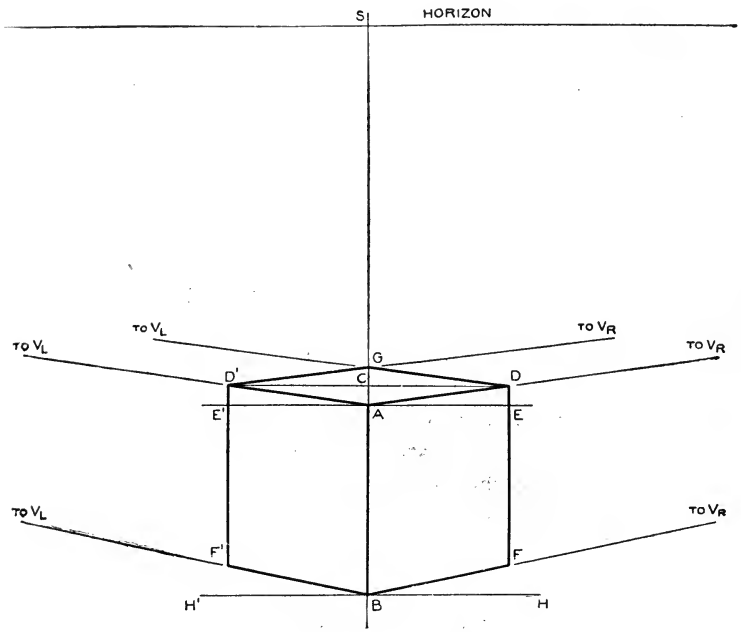


FIG. 2. PERSPECTIVE OF A ONE-INCH CUBE

Due to the *convergence* of A D with D′ G and A D′ with D G:

1. G D and G D′ are shorter than A D and A D′.
2. G C is shorter than C A.

Due to *foreshortening:*

1. A D and A D′ are shorter than A B.

Rectangular Objects

PREPARATORY INSTRUCTIONS FOR PLATE 1

The following is a list of the materials needed to make the perspective sketches. Chapter V gives a description of each.

1. Drawing board.
2. High grade drawing paper similar to Universal—9″ x 12″ sheets.
3. High grade pencils { 3H / 5H
4. Pencil pointer.
5. Erasers—Ruby and Flexible gray.
6. Thumb tacks.

In preparing to make a freehand perspective sketch the steps should be taken in the order given below:

The *drawing board* should be placed on the desk with the longer edges parallel to the front edge of the drawing table. It may be tilted to any convenient angle.

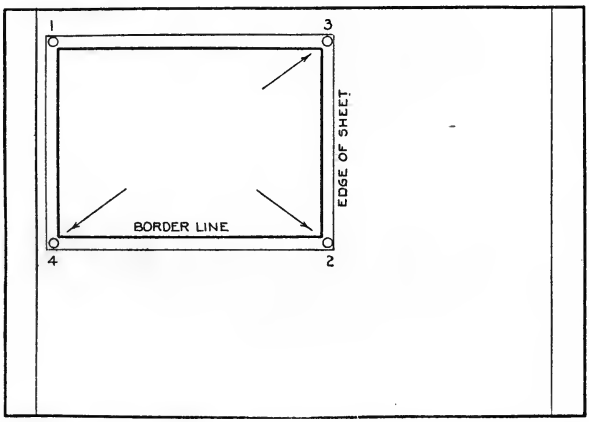


Fig. 3. Position of the Sheet on the Drawing Board

A *sheet of paper* may now be tacked near the upper left hand corner of the board with the longer edges parallel to the longer edges of the board. Fig. 3. To fasten the sheet insert

a tack in the upper left hand corner; square the paper with the board and, stretching it diagonally, insert a tack in the lower right hand corner. Insert a tack in the upper right hand corner. Stretch the sheet in the direction of the lower left hand corner and insert a fourth tack.

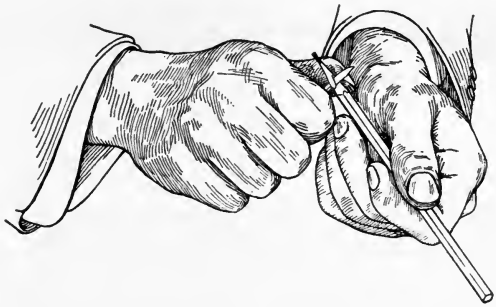


FIG. 4. SHARPENING THE PENCIL. WHITTLING AWAY THE WOOD

To *sharpen the pencil* grasp it in the left hand as illustrated in Fig. 4 and, with the knife in the right hand, cut the shavings by drawing the knife toward the body and through the *wood*

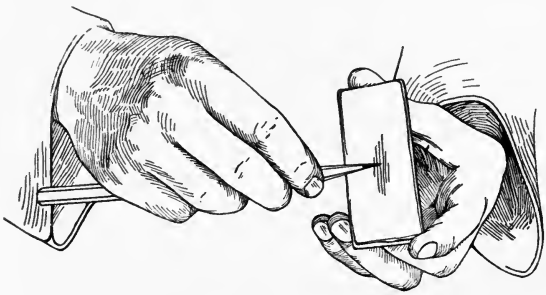


FIG. 5. SHARPENING THE PENCIL. POINTING THE LEAD

only. About one-quarter inch of lead should be exposed and the wood tapered back about one inch from the lead. Sharpen the lead on the surface of a piece of sand paper or a file, rotating the pencil so as to produce a conical point. Fig. 5. The sharpened lead should be slightly rounded on the end in order that

soft lines as shown in Fig. 6 may be produced. This figure also shows the sketching pencils properly sharpened.

The Position of the Hand and Pencil in Sketching. In drawing a line the pencil is held firmly, but not rigidly, between the first two fingers and the thumb, as in writing.

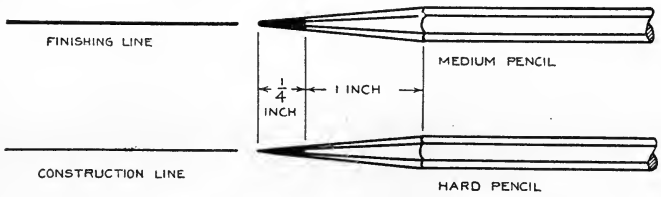


FIG. 6. SKETCHING PENCILS PROPERLY SHARPENED

In sketching a horizontal line the ends of the third and fourth fingers should rest upon the board to help support and steady the hand. Fig. 7. With the forearm resting on the drawing board, the hand should be moved from left to right,

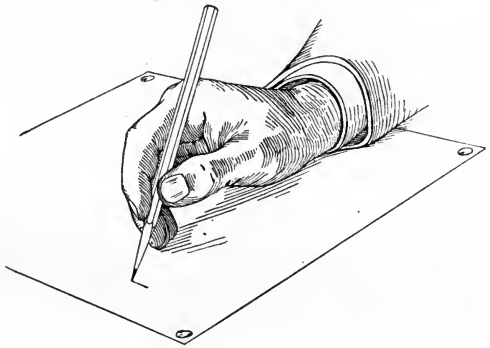


FIG. 7. SKETCHING A HORIZONTAL LINE

hinging at the wrist. This will permit only short strokes, about one inch long, to be taken. To sketch a long line, therefore, one must join together a series of one-inch lines. The position for each stroke should be obtained by moving the hand and forearm in the direction of the line. Each section should be

joined to the preceding one, but not lapped upon it, as the lapping of sections produces an undesirable sketchy effect.

In sketching a vertical line the hand is placed in the position shown in Fig. 8. The hand rests upon its side instead of upon the ends of the third and fourth fingers, as in Fig. 7. The pencil is moved downward. The strokes are made with a *finger movement* while the hand remains stationary. Each stroke should be about one inch long and succeeding strokes should be joined as previously described for horizontal lines.

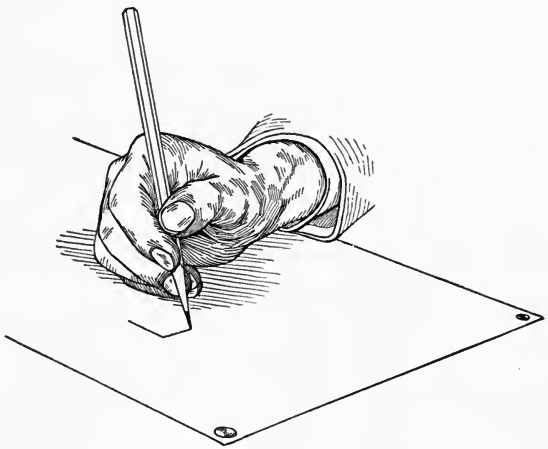


Fig. 8. Sketching a Vertical Line

Do not allow the forearm to assume a considerable angle with the vertical.

The Border Rectangle. Before starting a sketch draw a freehand border line one-half inch from each edge of the sheet.

The Constructive Stage. In making a freehand sketch first draw all lines very lightly with the 5H pencil. The general direction of a long line can be determined by first running the hand freely from one end to the other. In doing this the pencil should not touch the paper. The line may then be drawn in sections as described above. To test the straightness of a line place the edge of the drawing pencil near it. The outline

thus secured is known as the *constructive stage,* Fig. 9.

The Finishing Stage. When the constructive stage of the sketch has been completed all lines except those forming the

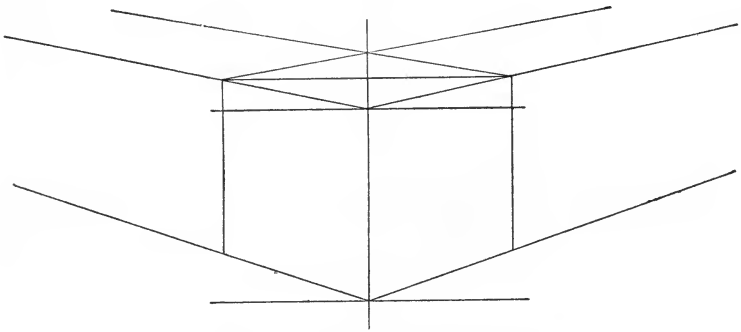


FIG. 9. CONSTRUCTIVE STAGE

outline of the object should be erased. The 3H pencil should then be properly sharpened and the lines of the object traced over to make them true and uniform in width and grayness of tone. Fig. 10.

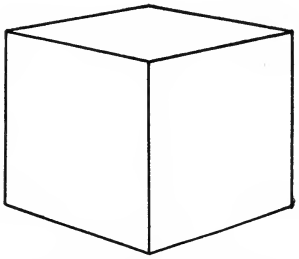


FIG. 10. FINISHING STAGE

*** DATA FOR PLATE 1**

Given: The perspective of a cube. Fig. 11.

Required: To copy the drawing shown in Fig. 11 to an enlarged scale, omitting the reference letters.

* Each drawing plate should be followed by the lettering plate of the same number. See Chapter VII.

Instructions:

1. Draw the border rectangle.
2. To locate the perspective of a cube:
   a. Draw two very light horizontal lines X V_R and Y Z, dividing the space between upper and lower border lines into three equal parts.

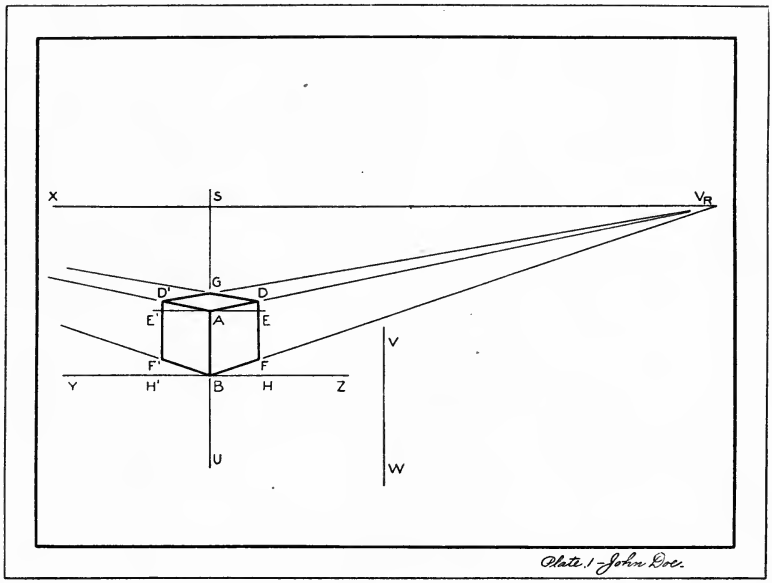


FIG. 11. PERSPECTIVE OF A CUBE—PLATE 1

   b. Draw a vertical line V W through the center of the sheet and S U midway between V W and the left border line.
   c. From B estimate one inch up on S U, thus locating A, the upper front corner of the cube.
3. V_R is about $\frac{1}{4}''$ from the right border line.
4. Sketch lightly a horizontal line through A and connect A with V_R.

5. Get the direction of A D′ by drawing the angle of inclination D′ A E′ equal to angle D A E. More than one trial may be necessary to make these angles equal as illustrated by A D′ and A D‴. Fig. 12.

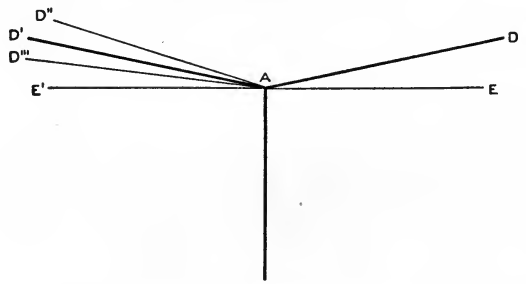


Fig. 12. Sketching the Angles of Inclination

Erase each trial line before drawing another, until the angle is correct. Draw lines B V_R and B F′ in the same manner.

6. To obtain the width of a vertical face of the cube draw D F so that the figure A D F B appears as a square.

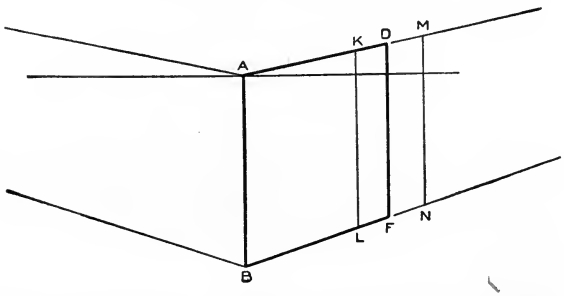


Fig. 13. Determining the Width of the Face of the Cube

Fig. 13 shows the process of getting D F located by trial. Erase each trial line before drawing the next one. Lines representing vertical edges may be tested for direction by placing a pencil along the line.

7. Draw D′ F′, making A E′ = A E. Complete the perspective of the cube by drawing D′ V_R and D G. Fig. 11.

This completes the constructive stage.

8. After erasing unnecessary lines the outline of the cube should be traced over with a well sharpened pencil to produce a line of even weight and uniform shade. Fig. 10 shows the cube, actual size, as it should appear on the student's drawing.

9. Write the plate number and name in the lower right hand corner of the sheet as in Fig. 11. Remove the sheet from the board, turn it over, and press the paper back into the thumb tack holes.

PREPARATORY INSTRUCTIONS FOR PLATE 2

A Scale of Levels. The size of the figure representing a horizontal square and the angle of inclination increase with the distance of the square below the level of the eye. Fig. 14. On

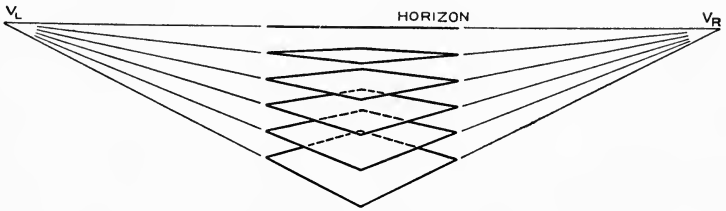


Fig. 14. Variation of Area with Level

the left in Fig. 15 is a scale of levels in which the top face of a one-inch cube is represented at levels one-half inch apart. The numerals indicate the distance in inches of the front corner of each square below the horizon. In this course this scale will be used in drawing objects at different levels.

The three cubes at the right in Fig. 15 show an application of the scale in representing an object at different levels.

Vertical Measurements. All vertical distances on an object should be measured on the perspective of the *front vertical edge* for the following reasons:

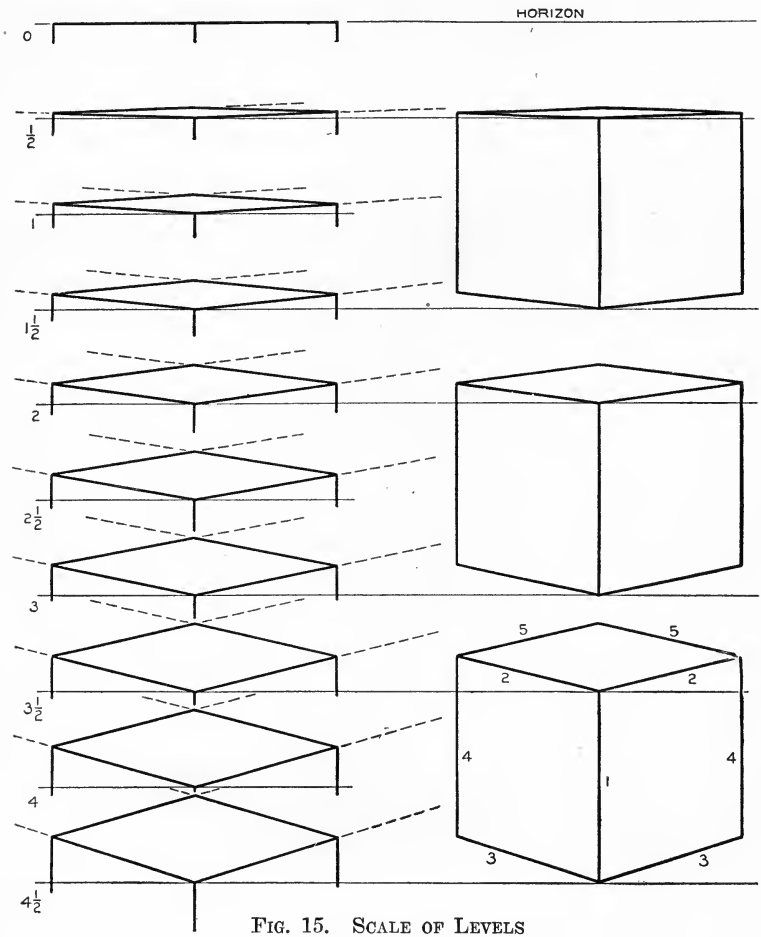


FIG. 15. SCALE OF LEVELS

1. The front vertical edge is drawn full length.

2. In general, equal vertical distances are equal in perspective only when measured on the *same* vertical edge. Example: A B = B K = K L. Fig. 16.

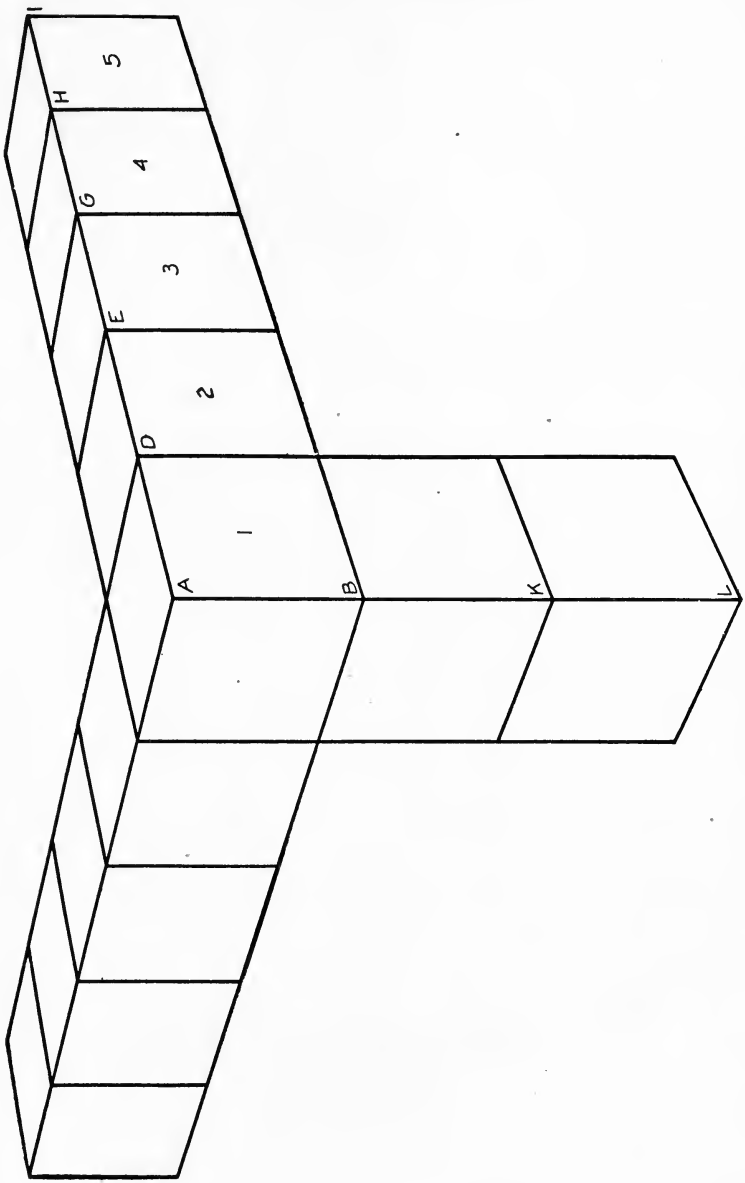


FIG. 16. FORESHORTENING SCALE

Horizontal Measurements. All horizontal lengths should be estimated by drawing the faces of one-inch cubes so that they appear to be squares.

In Fig. 16 lengths A D, D E, E G, G H, and H I, representing equal horizontal distances, are measured by making faces 1, 2, 3, 4, and 5 appear as squares.

The Enclosing Solid. An imaginary solid, which for purposes of construction is made to circumscribe an object, is called *an enclosing solid.* Fig. 17.

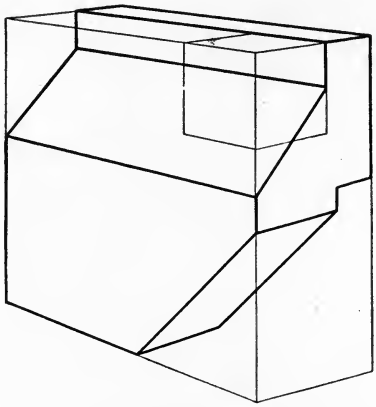


FIG. 17. ENCLOSING SOLID

The Measure Cube. The first step in making a perspective sketch is to draw a one-inch cube with its upper front corner coincident with the corresponding corner of the object or its enclosing solid. The level of the upper face of the cube is determined by the level of the top of the object. The front vertical edge of the cube serves as the vertical unit of measure and the width of the side faces as the horizontal unit of measure. This cube is therefore called *the measure cube.*

The Table Line. When an object rests on a horizontal surface its position with reference to that surface is shown by a horizontal line called *the table line.* The position of this line is shown in Fig. 20. It should be drawn freehand.

DATA FOR PLATE 2

Given: The dimensioned perspective sketch of a plate washer. Fig. 20.

Required: To make a sketch of the plate washer, full size, omitting all dimensions and lettering.

Instructions:

1. Draw the border rectangle as in Plate 1. Here and throughout the constructive stage use the 5H pencil.

2. To locate the center of the sheet proceed as follows: Place the edge of the pencil in the position of one of the diagonals of the border line rectangle. Lift the pencil and draw a part of the diagonal near the center of the sheet. In like manner draw a part of the other diagonal. The intersecting lines will locate the center of the sheet.

3. Draw the measure cube with its upper front corner A at the center of the sheet and $3\frac{1}{2}''$ below the level of the eye. Fig. 18. Refer to the angle of inclination in Fig. 15 for the required level. Reproduce this angle as illustrated in Fig. 12.

4. Complete the enclosing solid by drawing the lines in the order indicated by the numerals. Fig. 18. Measure vertically and to the right and left as previously described under *vertical* and *horizontal measurements,* respectively, pages 25 and 27.

5. To sketch the groove through the plate washer locate B, $\frac{1}{2}''$ below A, and draw line 10, converging with line 3, Fig. 19. Lay off from A on line 3 a distance representing $\frac{1}{2}''$. The principle of foreshortening applied here will make this distance slightly greater than one-half of A D′. Draw line 11. In the same manner locate and draw line 12. Draw line 13 converging with line 2. This completes the constructive stage.

6. Erase all lines except the outline of the figure and retrace the sketch with a carefully sharpened 3H pencil. Draw a table line as in Fig. 20.

7. Write the plate number and name in the lower right hand corner of the sheet and press the paper back into the thumb tack holes as directed in Plate 1.

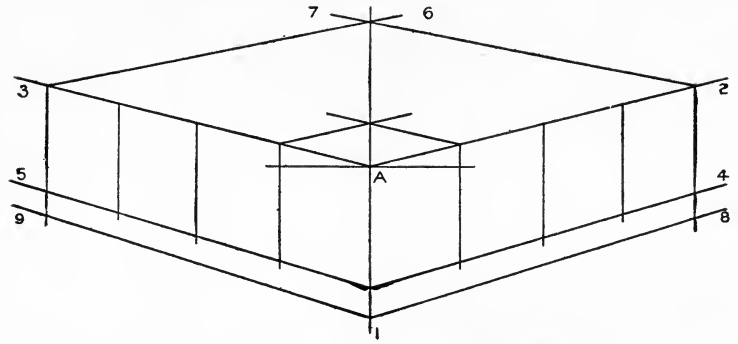


FIG. 18. CONSTRUCTIVE STAGE. ENCLOSING SOLID

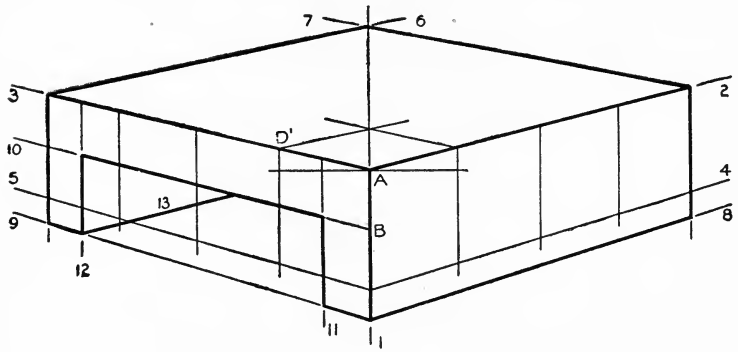


FIG. 19. CONSTRUCTIVE STAGE COMPLETE

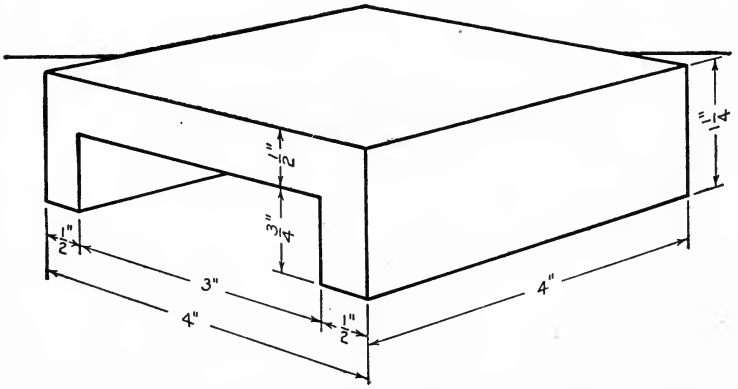


FIG. 20. PLATE WASHER. FINISHED SKETCH

DATA FOR EXTRA PLATE

Given: A dimensioned perspective sketch of an Equalizer Safety Block. Fig. 21.

Required: To make a sketch of the Equalizer Safety Block, full size, omitting all dimensions.

The upper front corner of the enclosing solid is in the center of the sheet and $3\frac{1}{2}''$ below the level of the eye.

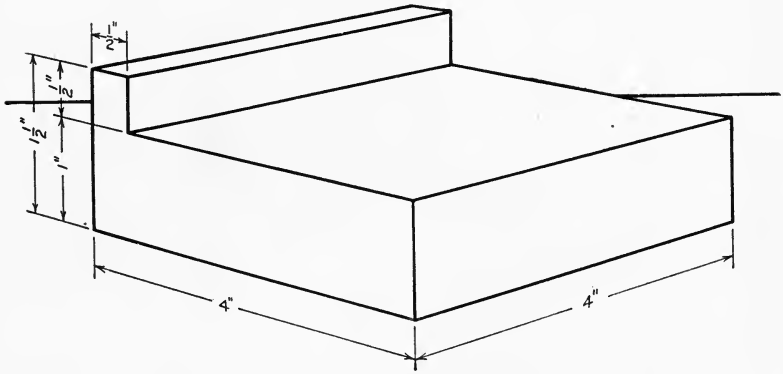


FIG. 21. EQUALIZER SAFETY BLOCK

ANGULAR OBJECTS

PREPARATORY INSTRUCTIONS FOR PLATE 3

To Center a Perspective Sketch. It is essential that the finished sketch be centrally located on the sheet. To accomplish this the student should use considerable care in locating the upper front corner of the measure cube. Some idea of the position of this point may be had by comparing the dimensions of the object which are to be laid off to the right and left, and by taking into account the height of the object and the level at which it is drawn. If at any time during the constructive stage it becomes evident that the sketch is not centrally located determine the correct position of the measure cube, erase all lines, and proceed as before.

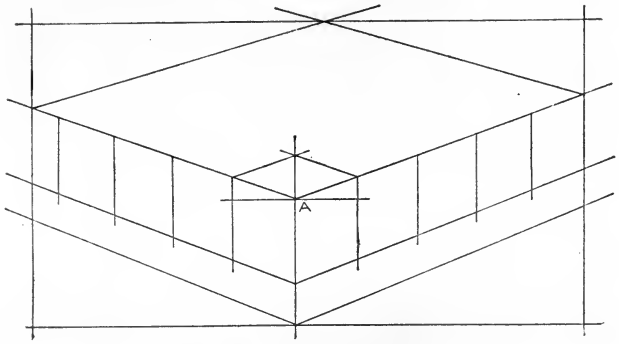


FIG. 22. ENCLOSING SOLID

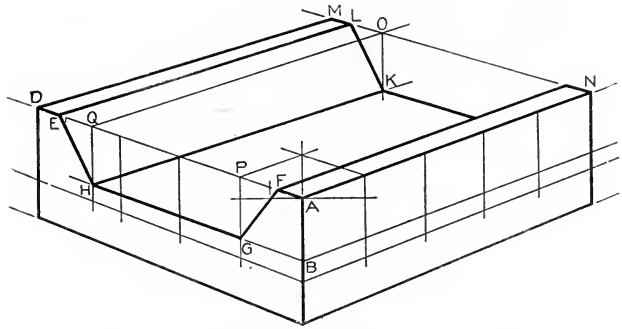


FIG. 23. CONSTRUCTIVE STAGE COMPLETE

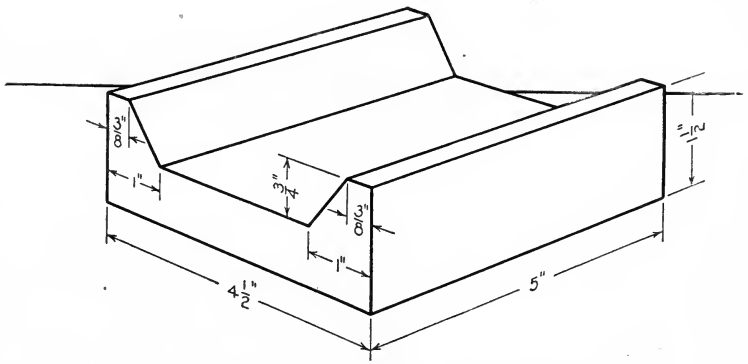


FIG. 24. JOURNAL BOX WEDGE. FINISHED SKETCH

DATA FOR PLATE 3

Given: The dimensioned perspective sketch of a Journal Box Wedge with the upper surfaces 5″ below the level of the eye. Fig. 24.

Required: To draw the Journal Box Wedge, full size, with the upper surfaces $3\frac{1}{2}$″ below the level of the eye. This object introduces inclined surfaces.

Instructions:

1. Locate the upper front corner of the measure cube A, Fig. 22, a short distance above and to the left of the center of the sheet.

2. Complete the enclosing solid as in Plate 2, taking care to secure the necessary convergence.

3. To sketch the groove in the Journal Box Wedge, locate a point $\frac{3}{4}$″ below A, Fig. 23, and draw B H. A P is the edge of the measure cube and therefore represents one inch. Make D Q represent one inch and draw vertical lines through P and Q to intercept the line through B in G and H. Lay off A F and D E to represent three-eighths of an inch and join E H and F G. To locate point K on the farther end of the wedge draw Q O, meeting M N in O. The vertical line through O strikes the line, vanishing from H in K.

4. Draw the horizontal line through K vanishing to the left.

5. Sketch in all remaining lines necessary to complete the drawing. This completes the constructive stage.

6. Finish the sketch in the usual manner.

DATA FOR EXTRA PLATE

Given: The dimensioned sketch of a Bracket, Fig. 25, with the upper surface of the enclosing solid $2\frac{1}{2}$″ below the level of the eye.

Required: To draw the Bracket, full size, with the top surface of the enclosing solid $3\frac{1}{2}''$ below the level of the eye.

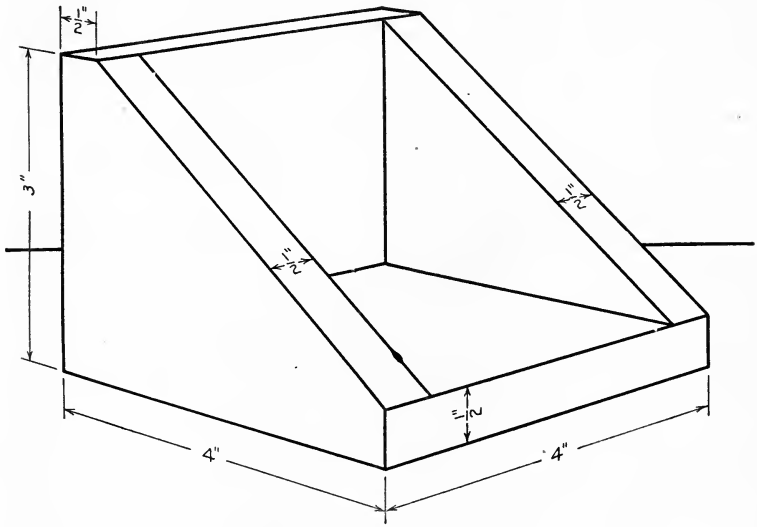


Fig. 25. Bracket

Cylindrical Objects

PREPARATORY INSTRUCTIONS FOR PLATE 4

The Vertical Measure Cylinder. As stated before, the cube is the basic form for the perspective sketching in this course. Fig. 26 shows a cylinder inscribed in a measure cube. The cylinder is therefore one inch in diameter and one inch long. The principle of foreshortening makes the axis of the cylinder and the major axis of each of the ellipses representing its bases slightly less than one inch. In sketching, these differences may be ignored. In Fig. 27 these distances are one inch in length.

The following is an analysis of a cylinder which will be referred to as the *vertical measure cylinder:*

1. The distance between the center of the ellipses is equal to their major axes or one inch. A B = C C′ = D D′.

2. The major axes C C′ and D D′ of the ellipses are at right angles with the axis of the cylinder.

3. The minor axes E E′ and F F′ are coincident with the axis of the cylinder.

4. Due to the difference in level the minor axis F F′ of the lower ellipse is greater than the minor axis E E′ of the upper ellipse. Having given the upper ellipse, the half length of the minor axis of the lower ellipse may be determined by drawing F H′ through D′, converging with E H.

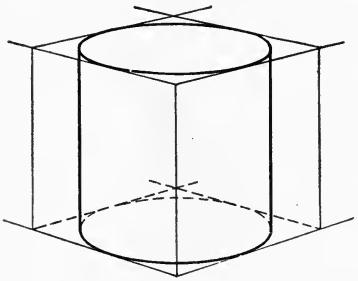


FIG. 26. VERTICAL CYLINDER INSCRIBED IN A MEASURE CUBE

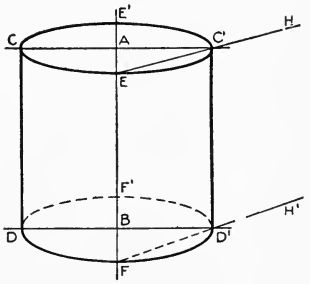


FIG. 27. VERTICAL MEASURE CYLINDER

A Scale of Levels. The left half of Fig. 28 is a *scale of levels* showing the upper base of a measure cube at levels one-half inch apart. It is evident that the area and minor axis of the ellipse increase with the distance of the ellipse below the level of the eye. The numerals indicate the distance of the center of each circle below the horizon.

The three cylinders in Fig. 28 show an application of the scale to the sketching of vertical cylinders at different levels.

To Draw and Test an Ellipse Representing a One-inch Circle:

1. Draw light indefinite lines at right angles to each other to represent the axes of the ellipse.

2. On the line representing the major axis lay off on either side of the intersection of the axes one-half the diameter of the circle.

3. Refer to the *scale of levels;* estimate and lay off the minor axis.

4. Sketch the ellipse lightly, comparing the form with the corresponding ellipse in the scale of levels. Care should be taken to avoid sharp or blunt ends.

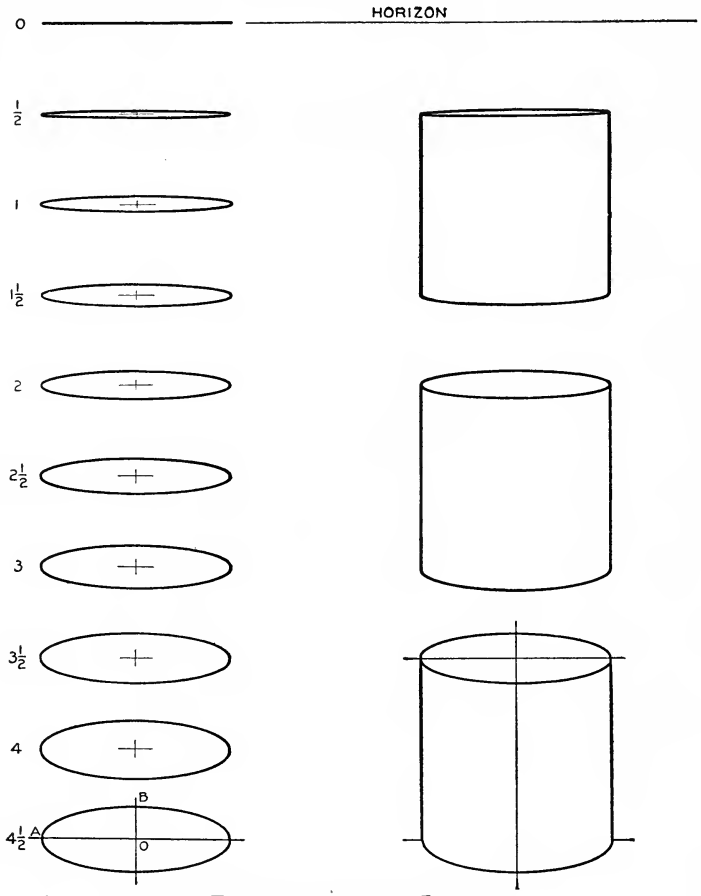


FIG. 28. SCALE OF LEVELS

5. Ordinary defects in the form of the ellipse will be evident if the sheet is turned to the right, to the left, and upside down. A further test recommended is as follows: Locate A and B on the axis equidistant from O. Fig. 29. The vertical distances from these points to the ellipse should be equal. Compare these distances and make the necessary corrections. Likewise locate

C and D equidistant from O and compare the vertical distances from these points to the ellipse. Make the necessary corrections as before.

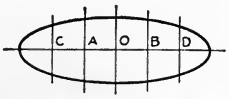


Fig. 29. Testing an Ellipse

Concentric Circles in Perspective. Fig. 30 shows two ellipses inscribed in concentric squares. The ellipses therefore represent circles. On account of foreshortening, the axes of the ellipses do not coincide with the line representing the diameter of the

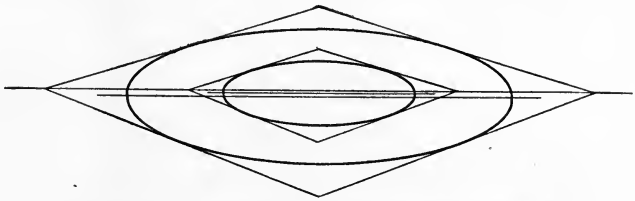


Fig. 30. Concentric Circles in Perspective

circles or with each other. In most cases the difference is so slight that it may be ignored. In this course when ellipses representing concentric circles are to be drawn their major axes will be made coincident unless attention is called to conditions

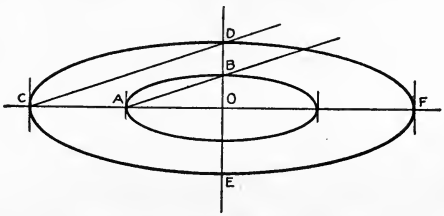


Fig. 31. Concentric Circles in Horizontal Plane

which require the construction shown in Fig. 30. In Figs. 31 and 32 the major axis C F is laid off equal to the diameter of the circle as in the case of the ellipse representing the one-inch circle. Fig. 27. A one-inch ellipse should be drawn first and

tested. The half length of the minor axis of a larger or smaller ellipse may be drawn as shown in Figs. 31 and 32. C D is drawn through C parallel to A B.

DATA FOR PLATE 4

Given: The dimensions of a Bushing, which consists of a hollow cylinder, outside diameter 2″, inside diameter 1″, length 3″.

Required: A perspective sketch of the Bushing with its axis vertical and the upper base $2\frac{1}{2}$″ below the level of the eye.

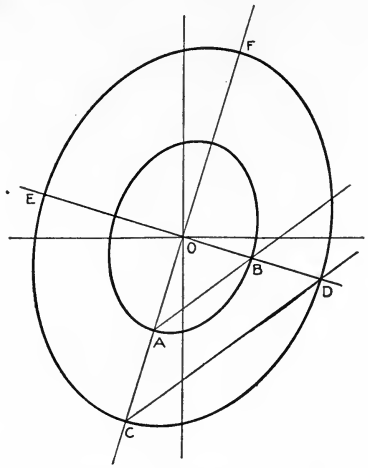


FIG. 32. CONCENTRIC CIRCLES IN A VERTICAL PLANE

Instructions:

1. Draw through the center of the sheet a vertical line to represent the axis of the cylinder.

2. Through points $1\frac{1}{2}$″ above and below the center of the sheet draw horizontal lines as the major axes of the ellipses representing the ends of the bushing. The minor axes will coincide with the axis of the cylinder. Care should be taken to make the angle between these axes a right angle.

3. Draw the ellipse representing the smaller circle in the upper end of the bushing at the required level. Refer to the

scale of levels to estimate the major and minor axes of the ellipse. Draw the ellipse with these axes and test it as described under, "To Draw and Test an Ellipse," page 34.

4. Lay off the major axis and determine the length of the minor axis of the large ellipse as described under, "Concentric Circles in Perspective," page 36.

5. Only one-half of the larger ellipse representing the lower end of the bushing will be seen. The length of the minor axis of this ellipse may be found by the method illustrated in Fig. 27. While only the lower half of the ellipse will be needed, the complete ellipse should be drawn as construction.

6. Complete the constructive stage of the sketch by drawing the vertical contour elements of the cylinder, joining the ends of the major axes of the large ellipses.

7. Erase all construction lines and complete the sketch in the usual manner.

DATA FOR EXTRA PLATE

Given: The dimensions of a washer which in form is a disc with a round hole through it. Outside diameter 4″, inside diameter 2″, thickness ⅜″.

Required: To draw the washer with its axis vertical, and its upper surface four inches below the level of the eye. At this level a portion of the bottom of the hole will be visible.

PREPARATORY INSTRUCTIONS FOR PLATE 5

The Horizontal Measure Cylinder. Fig. 33 shows a horizontal cylinder inscribed in a measure cube. This cylinder is therefore one inch in diameter and one inch long. Due to foreshortening, the major axis of the nearer base is slightly less than one inch, and the axis of the cylinder is shorter than the line representing the horizontal edge of the measure cube.

These differences are so slight that they will be disregarded in the following analysis of the cylinder, which will hereafter be referred to as the *horizontal measure cylinder.* Fig. 34.

Figs. 35 and 36 are similar to Figs. 33 and 34, respectively, and show a horizontal cylinder at a different level with its axis receding to the right instead of to the left.

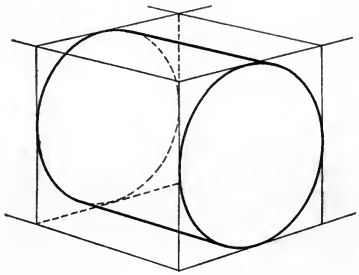


FIG. 33. HORIZONTAL CYLINDER INSCRIBED IN A MEASURE CUBE

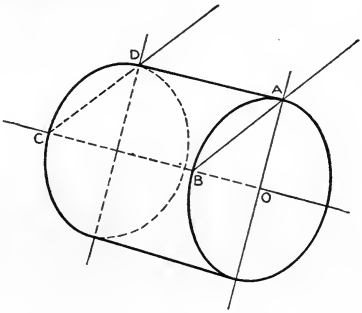


FIG. 34. HORIZONTAL MEASURE CYLINDER

1. The distance between the centers of the bases is equal to the horizontal receding edge of the measure cube. For sketching purposes this may be made three-fourths the length of the major axis of the nearer base.

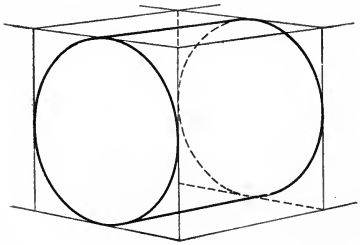


FIG. 35. HORIZONTAL CYLINDER INSCRIBED IN A MEASURE CUBE

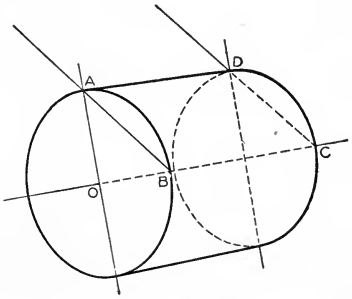


FIG. 36. HORIZONTAL MEASURE CYLINDER

2. The major axes of the bases are perpendicular to, and the minor axes coincident with, the axis of the cylinder as in the vertical measure cylinder.

3. The major axis of the nearer base is equal in length to the diameter of the cylinder, or one inch. The major axis of the

farther base is shorter, on account of the convergence of the contour elements of the cylinder.

4. When the nearer ellipse is drawn, the half length of the minor axis of the farther ellipse may be determined by drawing a line C D through D, converging with A B. Fig. 34.

5. Since the axis of a horizontal cylinder always extends toward a vanishing point, the inclination of the axis determines the level at which a cylinder is drawn. Figs. 34 and 36.

DATA FOR PLATE 5

Given: The Bushing represented in Plate 4.

Required: To draw the Bushing in a horizontal position with its axis $4\frac{1}{2}''$ below the level of the eye.

Instructions:

1. Draw through the center of the sheet a line in the direction of one of the vanishing points, to represent the axis of the cylinder at the required level. The angle of inclination may be obtained from Fig. 15.

2. From any point on this line lay off three foreshortened inches referring to Fig. 16. Mark off one-half of this length on each side of the center of the sheet.

3. Draw through the points thus determined the major axes of the bases at right angles to the axis of the cylinder.

4. Draw the ellipses representing the nearer end of the Bushing, as shown in Fig. 32. Test each ellipse as described under "To Draw and Test an Ellipse," page 34.

5. From the ends of the major axis of the larger ellipse draw contour elements converging with the axis of the cylinder to determine the ends of the major axis of the farther base.

6. The half length of the minor axis of the farther base may be determined as shown in Figs. 34 and 36. While only one-half of the farther ellipse will show in the finished drawing, a better result will be obtained by drawing the complete ellipse as construction.

7. Erase all construction lines, and finish the sketch in the usual manner.

DATA FOR EXTRA PLATE

Given: The dimensions of a washer, which consists of a disc with a round hole through it. Outside diameter, 4″; inside diameter, 2″; thickness, $\frac{3}{8}$″.

Required: To draw the washer with the axes of the cylinders horizontal and 3″ below the level of the eye. Attention is called to the fact that a portion of the farther end of the hole will be visible.

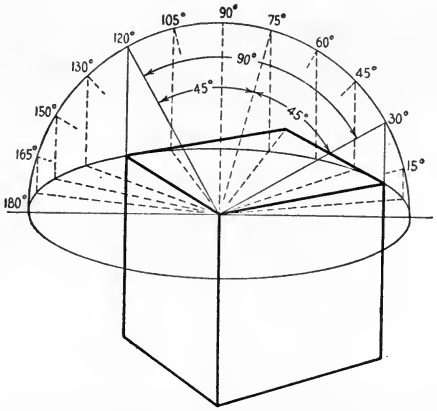


FIG. 37. DRAWING A CUBE AT ANY ANGLE

EXTENSION OF PERSPECTIVE THEORY

PREPARATORY INSTRUCTIONS FOR EXTRA PLATES

The Measure Cube in New Positions. In the preceding plates the measure cube was drawn at different levels, but always with its side faces at 45° with the horizon.

If the measure cube is turned with its side faces making other angles with the horizon, the number of positions in which an object may be drawn will be increased.

Fig. 37 shows a method of constructing a measure cube at any level and with its side faces at any desired angle. The steps in the construction are as follows:

1. Draw an ellipse representing a two-inch circle at the required level.

2. Draw a semi-circle of the same diameter as the circle represented by the ellipse with its center at the center of the ellipse.

3. Mark off on the semi-circle the angles which the faces of the cube are to make with the horizon. These angles should be 90° apart.

4. Vertical lines through these points intercept the ellipse in the ends of the nearer edges of the upper face of the cube. These edges meet at the center of the ellipse which is the upper front corner of the cube.

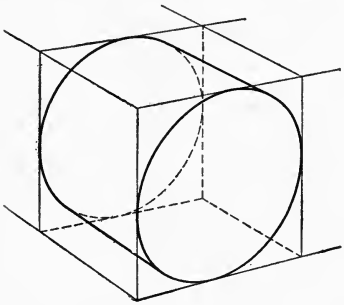


FIG. 38. CYLINDER INSCRIBED IN A MEASURE CUBE

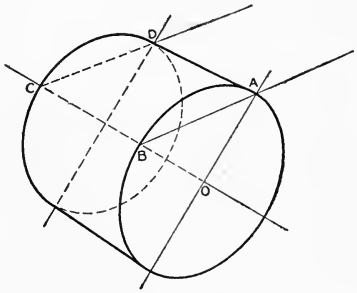


FIG. 39. MEASURE CYLINDER

5. Make the front vertical edge one inch long as in 45° perspective.

6. Complete the cube by drawing the remaining edges converging so as to give the faces of the cube the appearance of squares. It will be noted that the farther edges of the upper face intersect on the line making 45° with each of the side faces.

The Measure Cylinder in New Positions. Fig. 38 shows a horizontal cylinder inscribed in a measure cube with its side faces at other than 45° to the horizon. This cylinder is therefore one inch in diameter and one inch long. Due to foreshortening, the major axis of the nearer base is slightly less than one inch and the axis of the cylinder is shorter than the line representing the horizontal edge of the measure cube. These differ-

ences are so slight that they will be disregarded in the following analysis of the measure cylinder. Fig. 39.

1. The distance between the centers of the bases is equal to the horizontal receding edge of the measure cube. This distance will be shorter as the angle of the axis of the cylinder to the horizon increases.

2. The major axis of the bases are perpendicular to, and the minor axis coincident with, the axis of the cylinder.

3. The major axis of the nearer base is equal in length to the diameter of the cylinder, or one inch. The major axis of

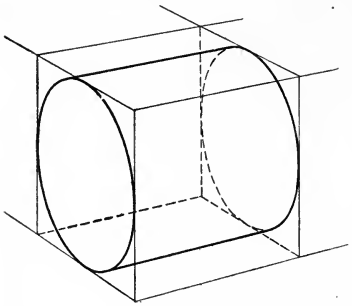


FIG. 40. CYLINDER INSCRIBED IN A MEASURE CUBE

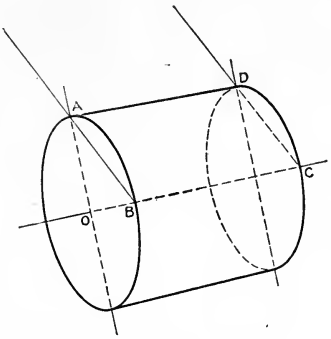


FIG. 41. MEASURE CYLINDER

the farther base is shorter on account of the convergence of the contour elements of the cylinder.

4. The length of the minor axis of the nearer base will depend upon the angle that the axis of the cylinder makes with the horizon. Fig. 39 illustrates the case in which the minor axis is lengthened, due to the axis of the cylinder making an angle greater than 45° with the horizon. Fig. 41 illustrates the case in which the minor axis is shortened, due to the axis of the cylinder making an angle less than 45° with the horizon. The length of the minor axis for other positions may be estimated by using Figs. 39 and 41 as guides. For any angle the axis of the cylinder makes with the horizon the length of the minor

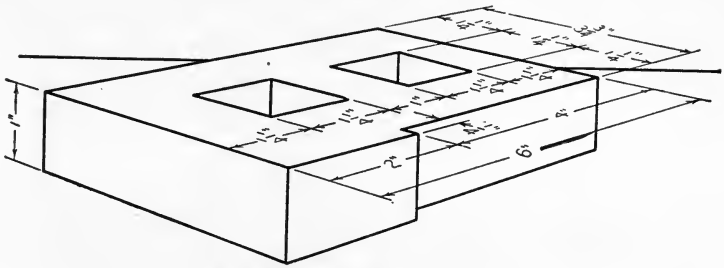


FIG. 42. SILL FILLING PIECE

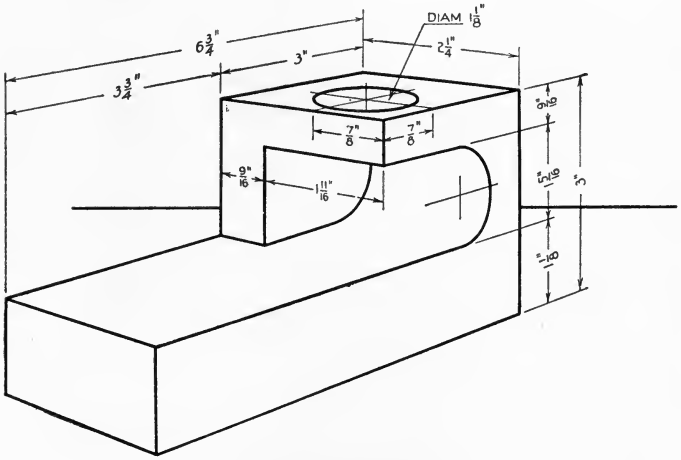


FIG. 43. DRILL JIG

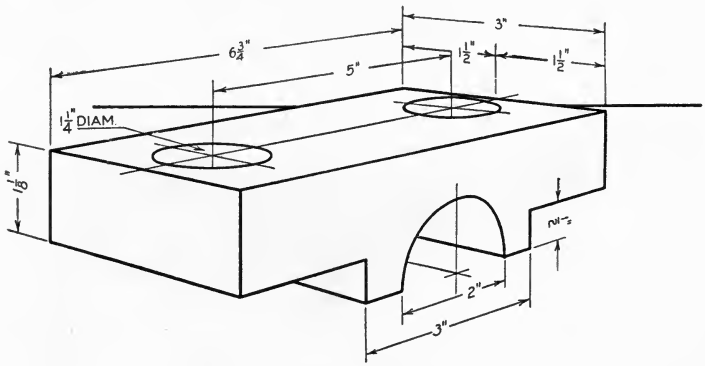


FIG. 44. SCREW BEARING CAP

axis will remain the same for all levels. When the nearer ellipse is drawn, the half length of the minor axis of the farther base may be determined by drawing a line C D through D, converging with A B. Figs. 39 and 41.

DATA FOR EXTRA PLATE

Given: The objects shown in Figs. 42, 43, 44, and 45.

Required: To draw one or more of the above objects in positions selected from the following table by the instructor. The level at which the object is drawn may be assumed by the student.

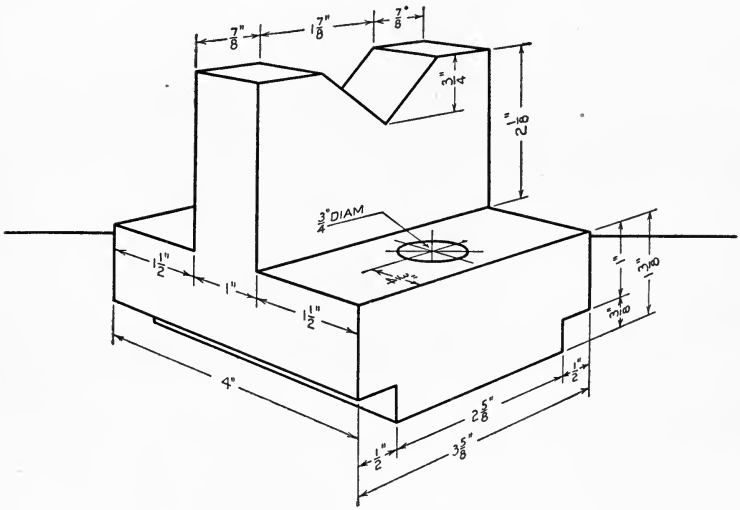


Fig. 45. Drill Jig

The right vertical face of the enclosing solid makes one of the following angles with the horizon:

1. 15°.
2. 30°.
3. 60°.
4. 75°.

The objects should be centered on the sheet as in previous problems.

Summary

It has been the aim of this chapter to develop in a condensed but thorough manner the essential principles upon which perspective sketching is based. Furthermore, the presentation is intended to assist the student to develop a fair degree of skill in drawing perspectives of rectangular, angular, and cylindrical objects. He should now be able to draw objects composed of a combination of these elementary forms. It is hoped that the student will have gained confidence in his ability to visualize and represent an object pictorially. If this has been accomplished he will find a use for perspective as an interpretation of orthographic drawing which will be treated in the succeeding chapters.

As a means of reviewing Chapter I the following questions and problems are given:

Review Questions

1. (a) What is the horizon? (b) How is it represented? (c) What is its relation to the eye?

2. (a) What is a vanishing point? (b) Where is it located?

3. Where do parallel horizontal lines appear to meet in perspective?

4. Do vertical lines appear to converge in perspective?

5. (a) What is meant by foreshortening? (b) Are the perspectives of equal lengths on the same vertical edge equal? (c) On the same horizontal edge? (d) Are the perspectives of equal vertical lengths at different distances from the observer equal?

6. (a) What is the angle of inclination? (b) How does it vary?

7. (a) The paper is fastened in what position on the drawing board? (b) How is it fastened?

8. Describe in detail how the pencil should be sharpened for sketching.

9. (a) What is the position of the hand and pencil in sketching horizontal lines? (b) Vertical lines? (c) What is the

essential difference? (d) What movements are made to produce the line?

10. (a) What is meant by constructive stage? (b) Finishing stage?

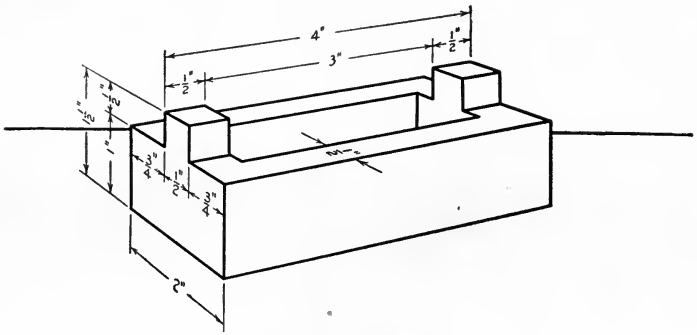


FIG. 46. FRAME

11. In what way does a scale of levels assist in making a perspective of a rectangular object?

12. (a) Where are all vertical measurements laid off in perspective? (b) Why?

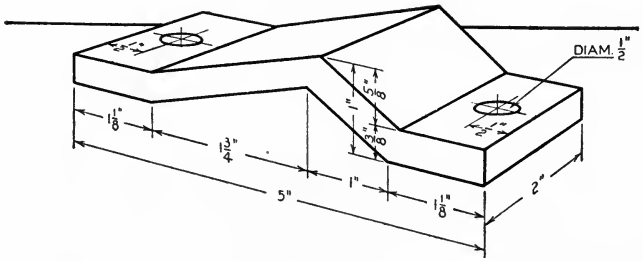


FIG. 47. BRACE

13. How are horizontal measurements made?

14. Explain what is meant by enclosing solid.

15. (a) What is a measure cube? (b) Why is it called a measure cube?

16. Of what use is the table line?

17. (a) How do you proceed to locate the drawing centrally on the sheet?

18. How are the perspectives of the inclined lines located?

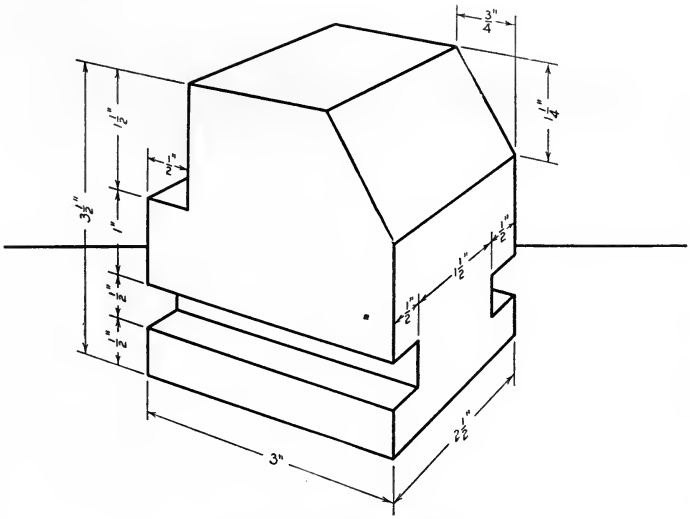


FIG. 48. CLUTCH JAW

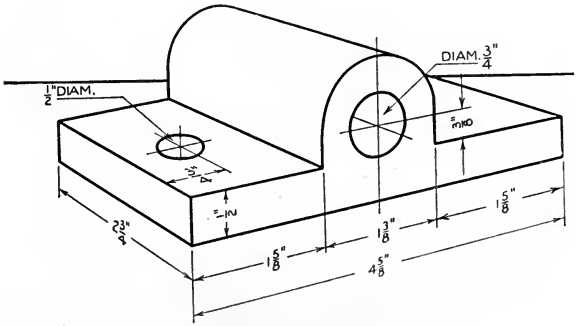


FIG. 49. SOLID BOX

19. (a) Give the proportions of the vertical measure cylinder. (b) The major axes of the bases are at what angle with the axis of the cylinder?

20. How does the difference in level affect the appearance of a horizontal circle in perspective?

21. Of what assistance is a scale of levels in drawing a vertical cylinder?

22. How is the ratio of the minor axes of two ellipses representing concentric circles determined?

23. (a) Give the proportions of a horizontal measure cylinder. (b) The major axes of the bases are at what angle with the axis of the cylinder? (c) What is the relative length of the major and minor axes of the nearer base?

DATA FOR REVIEW PROBLEMS

Given: The object shown in Figs. 46, 47, 48, 49.

Required: To draw one or more of the above objects in 45° perspective. The level at which the object is drawn may be assumed by the student.

CHAPTER II

ORTHOGRAPHIC SKETCHING

PREPARATORY INSTRUCTIONS FOR PLATE 6

Views. In perspective sketching the object was viewed from one position, so chosen as to show its three general dimensions in one view. Such a sketch does not show the principal edges of the object in their true lengths.

In order to represent the principal edges of an object in their true lengths, it is usually viewed in two or more directions, viz.; from directly in front, directly above, or directly from the right or left. Views thus secured are known as orthographic. In engineering drawing orthographic views are generally used.

Fig. 52 shows two views of a Chafing Plate. The view marked top represents orthographically what is seen from directly above the object and the view marked front represents what is seen from directly in front of the object. The top view shows two general dimensions in horizontal directions, viz.; from left to right and from front to back. The front view shows the horizontal dimension from left to right and the vertical dimension. Thus the three dimensions are given in the two views and the proportions of the object are determined.

Relation of Top and Front Views. For convenience in making and interpreting the drawing it is essential that the top view always be placed directly above the front view. Under this condition all distances from left to right may be projected from one view to the other.

"Reading" the Drawing. To form a mental image of an object the relation of its surfaces, edges, and corners as represented must be studied. This process is called *reading the drawing* and is illustrated under the four following headings:

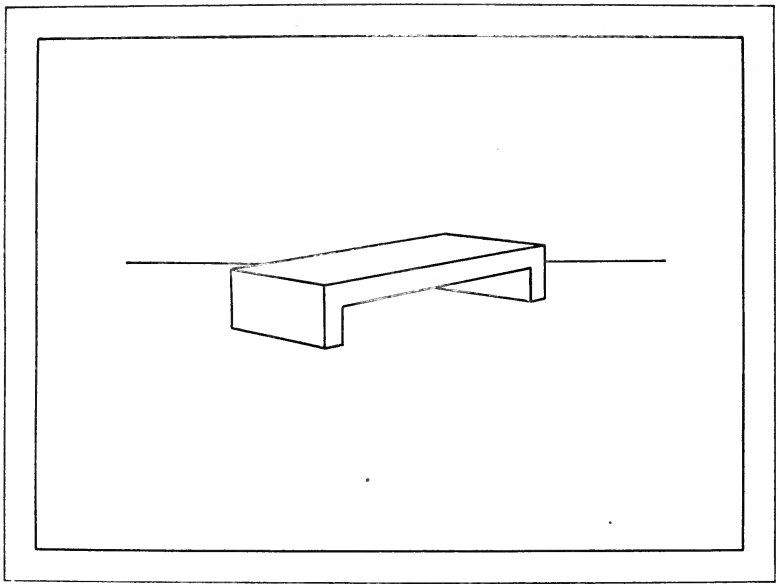


FIG. 50. TYPE PROBLEM—PERSPECTIVE OF CHAFING PLATE

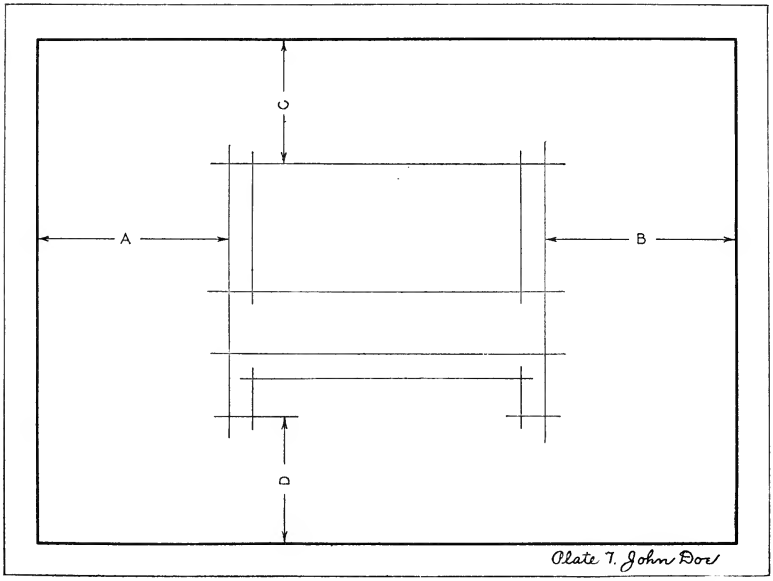


FIG. 51. TYPE PROBLEM
CONSTRUCTIVE STAGE OF THE ORTHOGRAPHIC SKETCH

Plane Surfaces. Fig. 52 represents an object having plane surfaces.

1. When the observer is looking perpendicularly at a surface it shows in its true form and size. Example: The rectangular top surface A B C D of the Chafing Plate, Fig. 52, is represented in its true form and size in the top view.

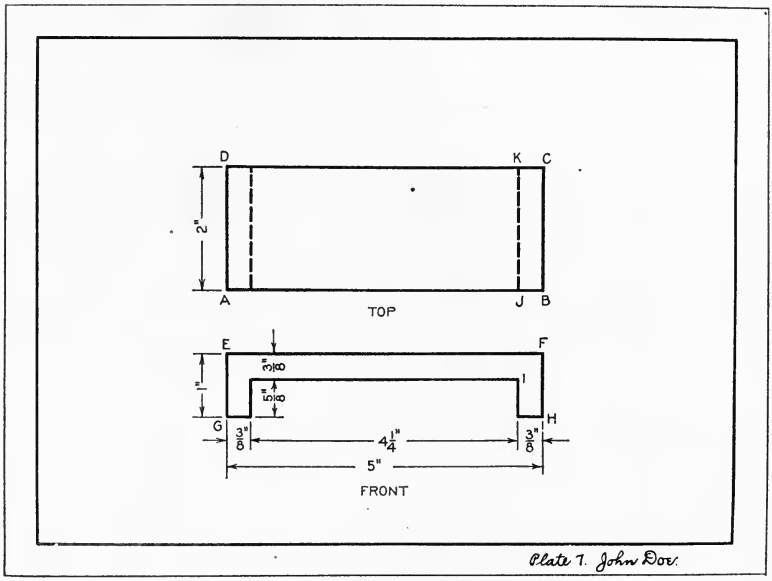


Fig. 52. Type Problem—Finished Sketch of Chafing Plate

2. When the observer is looking edgewise at a surface it appears as a straight line. Example: Line E F is the front view of the top surface A B C D, Fig. 52.

Straight Edges. 1. A straight edge viewed at right angles to its length shows as a line in its true length. Example: The front edge of the top surface of the Chafing Plate shows in its true length in the top view and in the front view in lines A B and E F respectively.

2. A straight edge viewed endwise appears as a point. Example: Point F is the front view of the edge B C. Fig. 52.

Corners. 1. A corner shows as a point when viewed from any direction. Example: The upper front corner at the right of the Chafing Plate is represented by B in the top view and F in the front view.

Invisible Edges. Hidden edges or surfaces are represented by dotted lines to distinguish them from visible edges, or surfaces. Example: K J in the top view, Fig. 52.

Problems and Questions on Orthographic Principles

The student should test his knowledge of the orthographic principles just stated by answering the following questions: See Fig. 53.

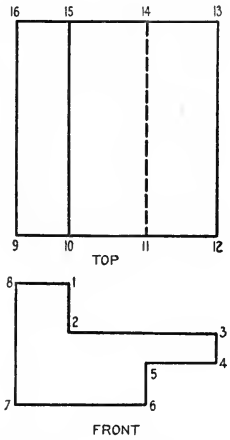


Fig. 53. Review Problem

1. (a) Where is the front view of the horizontal surface 9, 10, 15, 16? (b) Of 10, 12, 13, 15? (c) Of 9, 11, 14, 16?

2. (a) Where is the top view of the horizontal surface 5, 4? (b) Of 8, 1?

3. (a) Where is the top view of the front vertical surface 1, 2, 3, 4, 5, 6, 7, 8? (b) Of the rear vertical surface 1, 2, 3, 4, 5, 6, 7, 8?

4. (a) Where is the top view of the vertical surface 7, 8? (b) Of 3, 4? (c) Of 5, 6?

5. (a) Where is the top view of the front horizontal edge 2, 3? (b) Of 7, 6?

6. (a) Where is the front view of the rear horizontal edge 15, 13? (b) Of 16, 14?

7. (a) Where is the front view of the upper horizontal edge 10, 15? (b) Of 12, 13?

8. (a) Where is the top view of the edge 5? (b) Of 6?

9. (a) Where is the front view of the upper front corner 12? (b) Of 9? (c) Of the upper back corner 15?

10. (a) Where is the top view of the front corner 2? (b) Of 5?

The Type Problem. In each of the following problems presented for solution the methods to be employed and the results to be obtained will be illustrated by a type problem. This type problem will consist of two parts:

1. A drawing of an object similar to, and represented in the same manner as, the one given for solution.
2. A solution of the problem corresponding to that required.

Example: Fig. 52 is the type problem for the first orthographic sketch. Fig. 50 is the perspective made from Fig. 52 corresponding to the one the student will make from Fig. 54 or 55.

Materials. The materials used for the plates in this chapter are the same as those used in perspective sketching (see page 17) except that in this case the 5H pencil will be used for both the constructive and finishing stages.

Perspective Sketches. In this chapter perspective sketches will be drawn preceding the orthographic sketches as a means of interpreting the orthographic views and at the same time to continue the practice necessary to develop skill in representing objects in perspective.

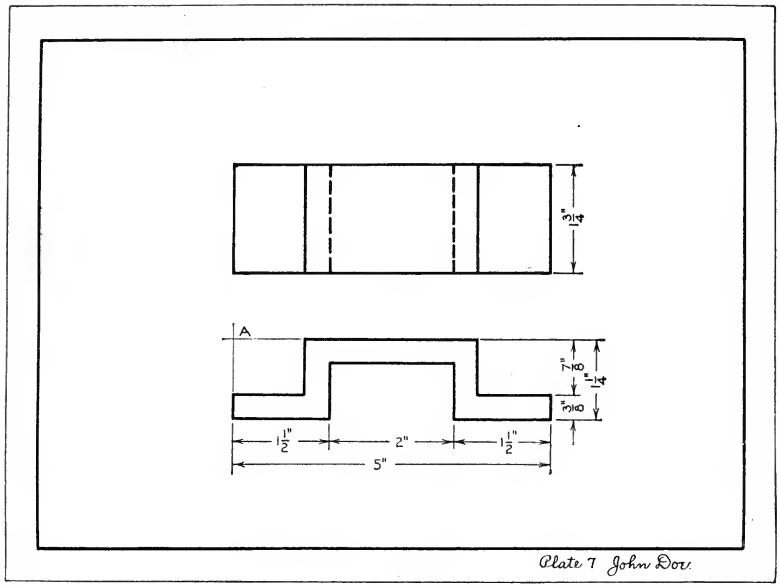


FIG. 54. SPRING STEM GUIDE

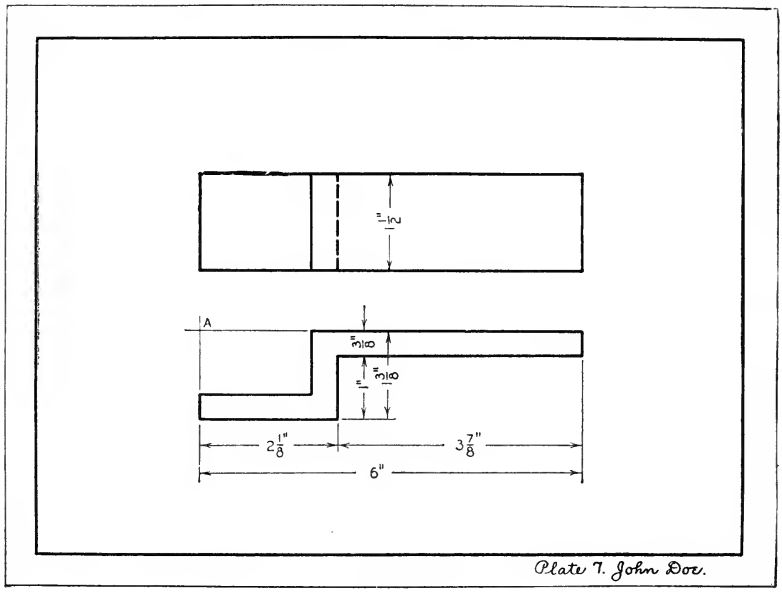


FIG. 55. BRACE

DATA FOR PLATE 6

Given: An orthographic sketch, Fig. 54 or 55.

Required: To draw a 45° perspective sketch of the object shown in Fig. 54 or 55 as assigned by the instructor, with the upper front corner of the enclosing solid $3\frac{1}{2}''$ below the level of the eye. Use the corner marked A as the upper front corner of the object. Omit all dimensions.

PREPARATORY INSTRUCTIONS FOR PLATE 7

Constructive Stage. In this stage all lines should be drawn light and full. In laying out the views of an orthographic sketch on the sheet proceed in the following manner:

1. Referring to Fig. 51, mark off tentatively the position of the extreme right and left of each view. Shift both marks to the right or to the left, if necessary, to make A equal B.

2. In like manner mark off the vertical dimension of each view, leaving a space between the two views proportional to that which is shown in the figure. This distance should be from $\frac{3}{4}''$ to $1''$. Shift all marks up or down, if necessary, to make C equal D.

3. Make any necessary adjustments in the general proportion of the views.

4. In proportioning the details of the views a comparison of the dimensions of each detail with the dimensions of the views in which it appears will aid in securing good results. Example: In the front view, Fig. 52, the height of the opening is five-eighths of the total height of the view, and its length is slightly more than four-fifths of the length of the view.

Finishing Stage. 1. All construction lines should be erased and the lines of the drawing retraced, using the 5H pencil.

2. Invisible edges should now be represented by dotted lines, which are composed of $\frac{1}{8}''$ dashes with $\frac{1}{32}''$ spaces between them.

Fig. 56 shows the correct method of joining dotted lines to full lines.

Arrangement of Dimensions. When detail dimensions and a dimension representing their sum are given, they should be grouped in parallel lines. The shorter dimensions should be near the outline of the object to avoid confusion arising from the crossing of extension and dimension lines. Example: Those below the front view, Fig. 52, are properly arranged.

The Dimension Form. The dimension form consists of the *numerals* designating feet and inches, the *foot and inch marks,* the *dash,* the *dimension* and *extension lines,* and the *arrowheads* as arranged in Fig. 193.

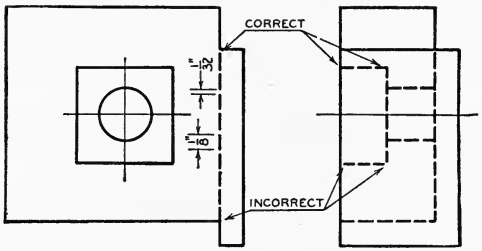


Fig. 56. Dotted Lines

It will be seen that the arrowheads are placed on the dimension lines with their points touching the extension lines. They are composed of two slightly curved lines symmetrical with respect to the dimension line. The length of the arrowhead should be about $\frac{1}{8}''$ and the width $\frac{1}{16}''$. Fig. 193. The strokes for arrowheads pointing in different directions are shown in Fig. 194.

Horizontal dimensions should be read with the observer at the bottom of the sheet. Vertical dimensions should be read with the observer at the right of the sheet.

Whole Numbers and Fractions. The whole number in a dimension will be made one-eighth inch high.

The total height of the fraction should be twice the height of the whole number with a clear space between each numeral

and the division line. Fig. 196. To check these heights mark off an eighth-inch and a quarter-inch space on the edge of a card and use it as a scale.

Extension lines should begin about $\frac{1}{32}''$ from the outline of the object and should continue to about $\frac{1}{8}''$ beyond the arrowhead.

The space between the outline of the object and the nearest dimension line or between two parallel consecutive dimension lines should be about $\frac{1}{4}''$.

DATA FOR PLATE 7

Given: Orthographic sketches, Figs. 54 and 55.

Required: To make the orthographic sketch shown in Fig. 54 or 55 to an enlarged scale.

Instructions: 1. Draw a border line as in perspective sketching.

2. Proportion the views and locate them centrally on the sheet as previously explained.

3. Draw in the details and finish the drawing as usual.

4. Arrange the dimensions as shown, keeping in mind the points mentioned under "Dimensioning," page 57.

PREPARATORY INSTRUCTIONS FOR PLATE 8

Relation of Front and Side Views. As previously explained, an observer sees all vertical dimensions and the horizontal dimensions from right to left in the front view. All vertical dimensions and the horizontal dimension from front to back are seen in the side view. For convenience in making and reading the drawing the right side view is placed to the right of the front view, when only these two are drawn. In like manner the left side view is placed to the left of the front view. In either case all vertical distances may be projected from one view to the other. Fig. 57 shows the front and two side views of an object in their proper relative positions.

Since the two side views convey the same information, if one is given the other may be drawn. The essential difference between the side views is that in one, parts of the object may be concealed while in the other they are visible. Example: In Fig. 57, A B is invisible from the left and visible from the right. When this is the case usually the better solution is to draw the view in which as few hidden lines as possible are represented.

Inclined Surface. A plane surface of an object which is neither horizontal nor vertical is called an *inclined surface.* Fig. 57 represents an object having inclined surfaces. If the surface is rectangular and two of its edges are at right angles to the direction in which it is viewed, as C D E F in Fig. 57,

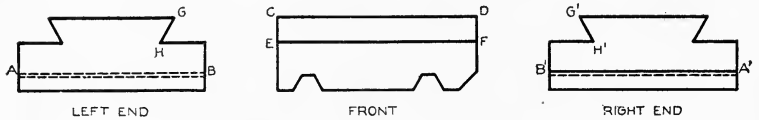


Fig. 57. Relation of Front and Side Views

the vertical dimension of the rectangle representing the surface in the front view is less than the actual width of the surface.

The inclined surface C D E F is represented by the inclined line G H in the left side view. G H is equal to the true width of the surface. G′ H′, representing the same surface in the right side view, is also equal to the true width of the surface. It is evident that the front view of the object shows the true length of the inclined surface and the side view its true width.

Inclined Edges. A straight edge which is not at right angles to the direction in which it is viewed is represented by a line shorter than the actual length of the edge.

Example: The line E C in Fig. 57 is shorter than the edge of the inclined surface which it represents.

In the side view this line is viewed in a direction at right angles to it and therefore shows in its true length in G H.

The student should test his knowledge of the orthographic principles just stated by answering the following questions:

Problems and Questions in Orthographic Principles

Refer to Fig. 58.

1. Where is the side view of the inclined surface 1, 2, 7, 8?

2. (a) Is line 1, 2 equal to the true width of the inclined surface? (b) Where is its true length shown? (c) Why?

3. Where is the inclined edge 1, 8 shown in its true length? Why?

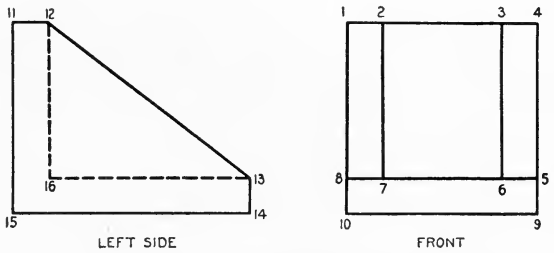


Fig. 58. Review Problem

4. (a) Is the vertical surface 11, 15 on the front or back of the object? (b) Why? (c) Where is it shown in the front view?

5. Where is the vertical surface 14, 13 shown in the front view?

6. Where is the horizontal surface 13, 16 shown in the front view?

7. Where is the horizontal surface 6, 7 shown in the side view?

8. Where is the vertical surface 4, 9 shown in the side view?

In sketching an angle where the dimension is given in degrees the ends of the inclined line should be located by estimating the length of the legs of the right triangle of which the inclined line is the hypotenuse. Example: See Fig. 59.

In determining the position of a line passing through an

invisible corner make a construction for the invisible corner as shown in Fig. 59.

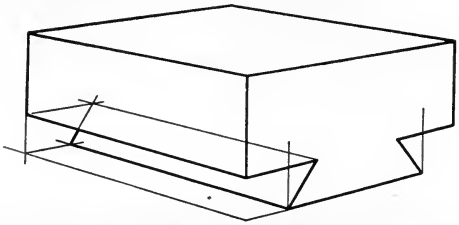


FIG. 59. CONSTRUCTION FOR ANGLES AND HIDDEN CORNERS

DATA FOR PLATE 8

Given: Orthographic sketches, Figs. 63 and 64.

Required: To draw a 45° perspective sketch of the object shown in Fig. 63 or 64 as assigned by the instructor. The

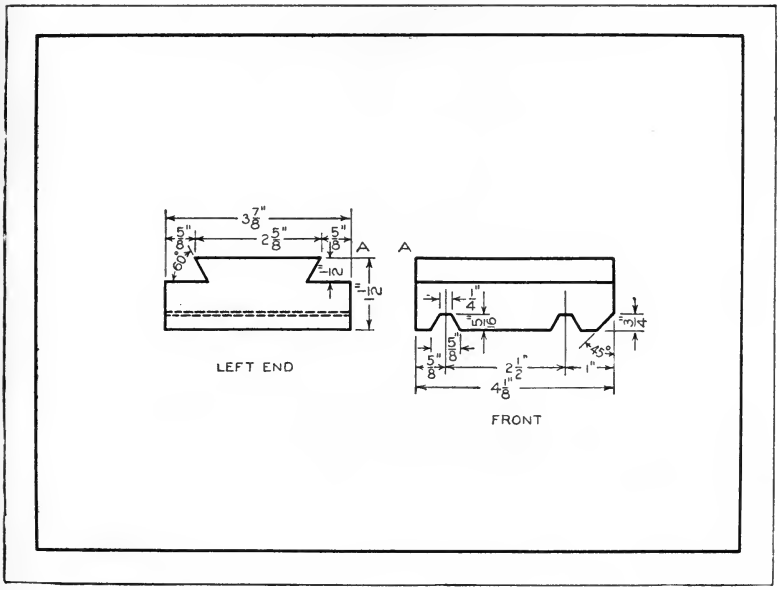


FIG. 60. TYPE PROBLEM—GIVEN VIEWS

upper front corner of the enclosing solid is $3\frac{1}{2}''$ below the level of the eye. Use the point marked A as the upper corner of the measure cube. Omit all dimensions.

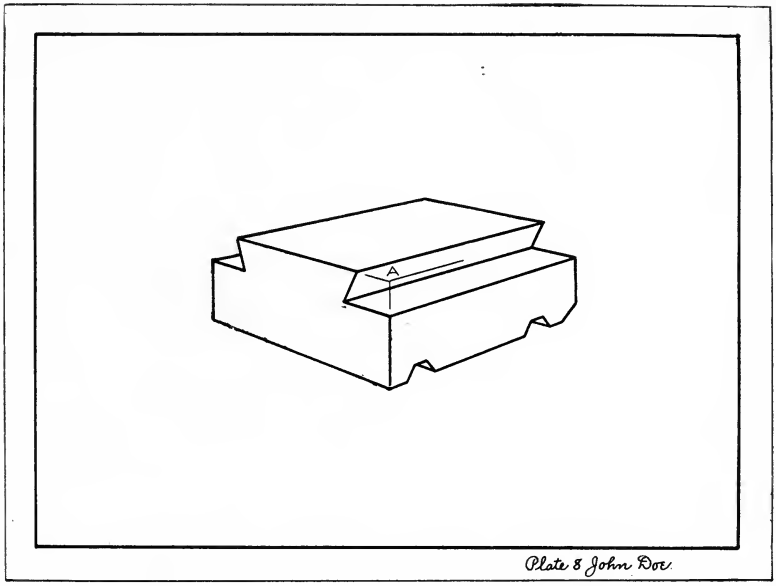


FIG. 61. TYPE PROBLEM—PERSPECTIVE SKETCH

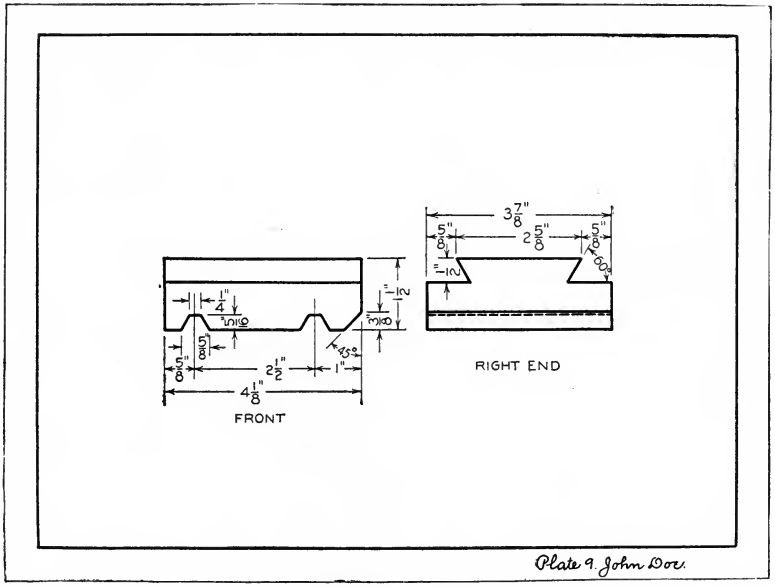


FIG. 62. TYPE PROBLEM—REQUIRED VIEWS

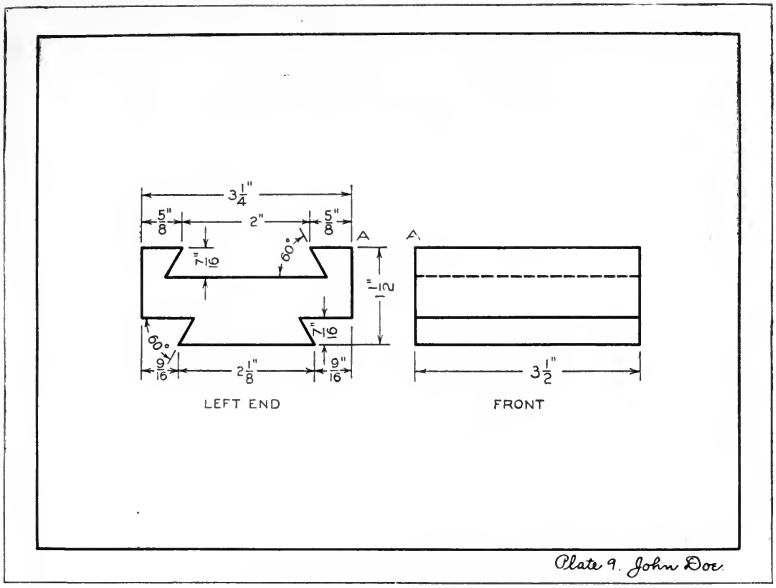


FIG. 63. DOVETAIL CROSS SLIDE

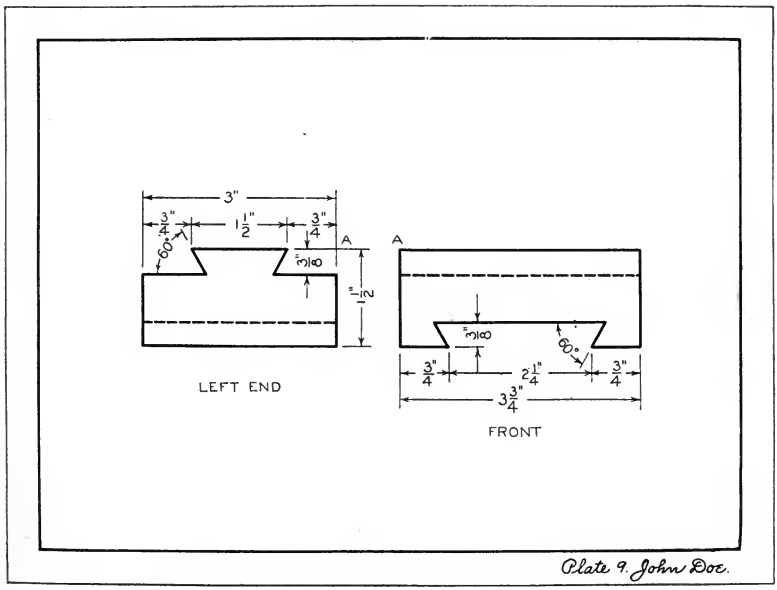


FIG. 64. DOUBLE DOVETAIL

PREPARATORY INSTRUCTIONS FOR PLATE 9

Dimensioning Angles. An angle may be dimensioned in degrees as in Fig. 62. In this case the dimension line is an arc with its center at the intersection of the two lines forming the angle. An angle is sometimes dimensioned, as in the case of the grooves through the object in Fig. 62, where the widths at the top and bottom of the groove are given.

DATA FOR PLATE 9

Given: Orthographic sketches, Figs. 63 and 64, showing the front and left side of each of the objects.

Required: To draw the front and right side views of the object shown in Fig. 63 or 64 as assigned by the instructor.

Instructions: 1. Block in the views of the object as in Plate 7 so that they are in the center of the sheet.

2. Complete the details of the views in light line.

3. Trace over the lines, making them the proper weight.

4. Draw the dimension lines and put in the arrowheads and figures. The dimensions on this plate should be placed in positions similar to those in the type problem, Fig. 62.

5. Write in the plate number and name as usual. Press the paper back into the tack holes.

PREPARATORY INSTRUCTIONS FOR PLATE 10

Cylindrical Surfaces. Fig. 65 represents an object having cylindrical surfaces. When viewed in a direction at right angles to the axis of the cylinder a cylindrical surface appears as a rectangle. Two of the sides of the rectangle represent the circular bases of the cylinder and are therefore equal in length to its diameter. They represent the bases of the cylinder viewed edgewise. Example: A B and C D, Fig. 65. The other two sides of the rectangle represent the contour elements, or the elements which divide the visible part of the surface from that which is invisible. Example: A C and B D, Fig. 65.

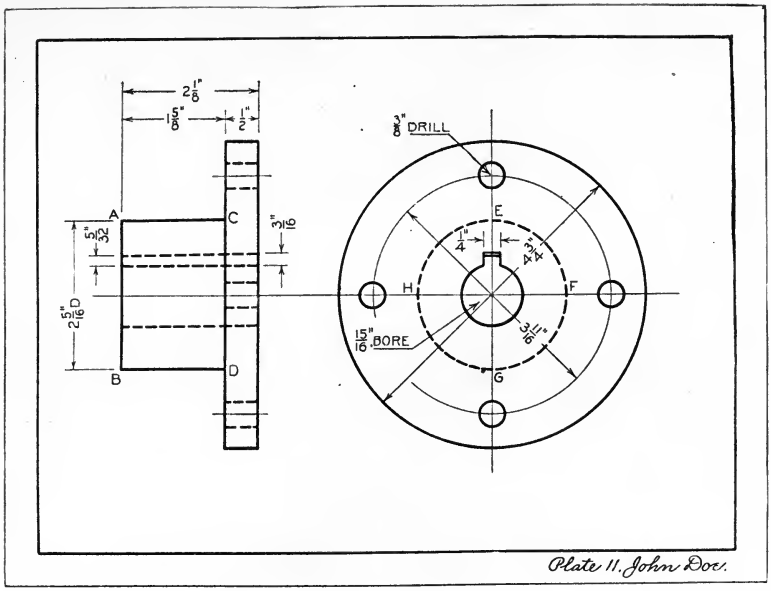


FIG. 65. TYPE PROBLEM—GIVEN VIEWS OF SHAFT COUPLING

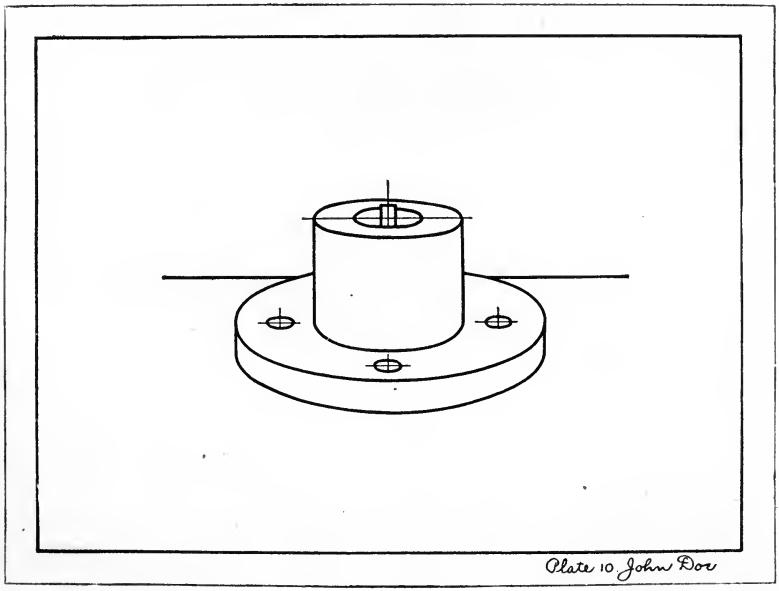


FIG. 66. TYPE PROBLEM—PERSPECTIVE OF SHAFT COUPLING

When the observer is looking in the direction of the axis of a cylinder the cylindrical surface is seen edgewise and appears as a circle. Example: E F G H, Fig. 65.

Circular Edges. A circular edge viewed in a direction at right angles to its plane shows as a true circle. Example: E F G H in Fig. 65.

A circular edge viewed in the direction of its plane shows as a straight line equal in length to the diameter of the circle. Example: A B and C D in Fig. 65.

The student should test his knowledge of the orthographic principles just mentioned by answering the following questions: See Fig. 70.

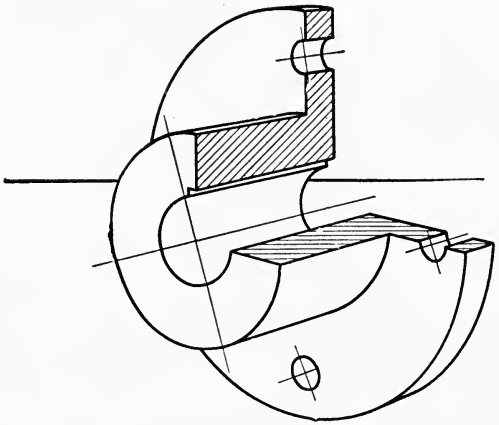


Fig. 67. Quarter Section Illustrated in Perspective

1. (a) Where is the left end view of the cylindrical surface 3, 4, 11, 12? (b) Of 1, 2, 13, 14?

2. Where is the front view of the cylindrical surface 25, 26, 27, 28?

3. (a) Where is the circular surface 1, 16, 14, 15, shown in the end view? (b) Where is the surface 2, 3, 12, 13 shown in the end view?

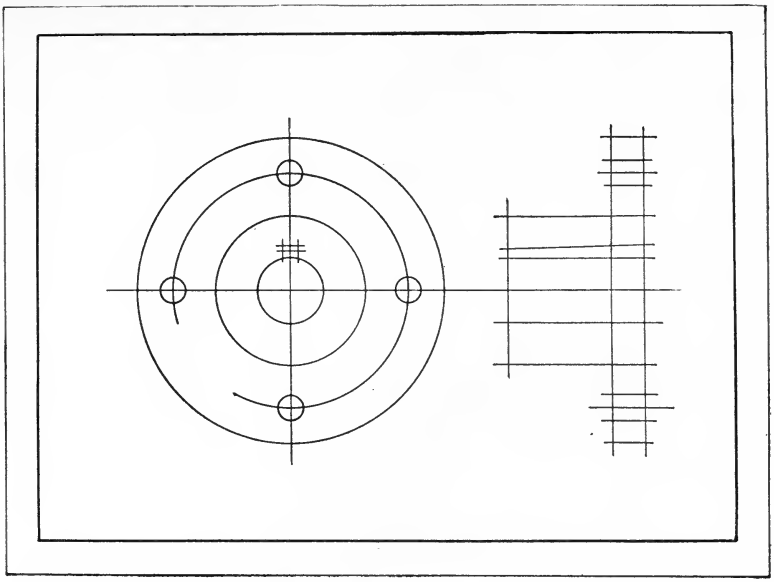


FIG. 68. TYPE PROBLEM—CONSTRUCTIVE STAGE OF THE ORTHOGRAPHIC SKETCH

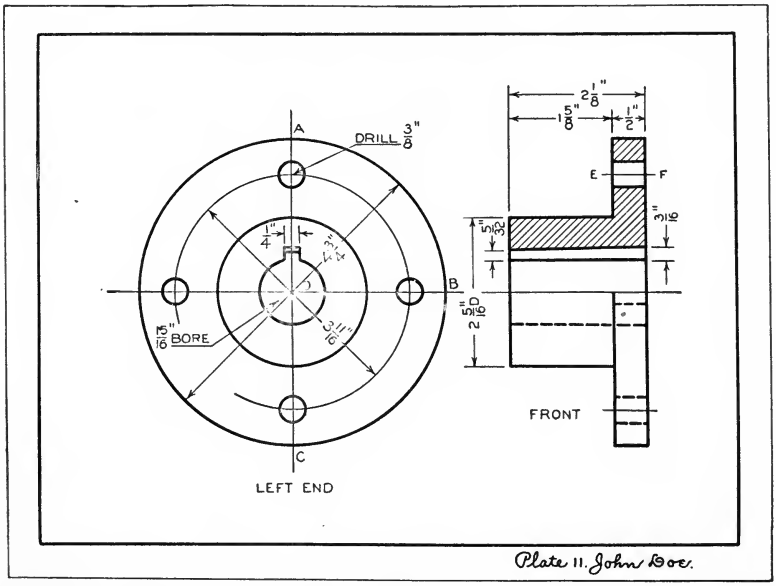


FIG. 69. TYPE PROBLEM—FINISHED SKETCH OF THE SHAFT COUPLING (67)

4. (a) Where is the circular edge 6, 9 shown in the end view? (b) Where is the circular edge 4, 11 shown in the end view?

5. What surface would be crosshatched if a quarter section were made cutting on the lines 0, 17 and 0, 18?

DATA FOR PLATE 10

Given: Orthographic sketches, Figs. 71 and 72.

Required: To draw a perspective of the object shown in Fig. 71 or 72 as assigned by the instructor, with its axis vertical. The upper end of the object is $2\frac{1}{2}''$ below the level of the eye.

PREPARATORY INSTRUCTIONS FOR PLATE 11

Quarter Sections. A drawing can often be made much clearer by representing the object with a portion of it removed.

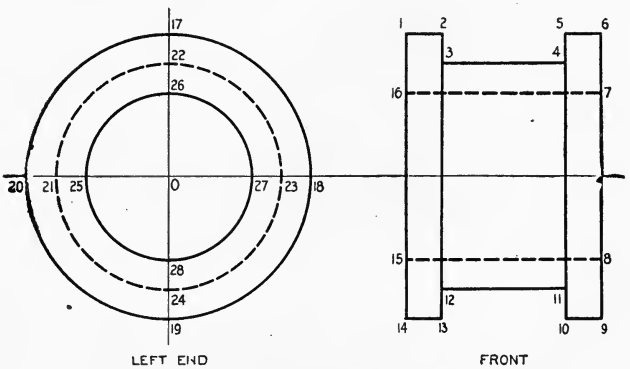


FIG. 70. REVIEW PROBLEM

One of the chief advantages is the reduction of dotted lines. Sections are usually taken by considering the object cut through an axis of symmetry. A view which shows the object cut into the center on two planes at right angles to each other is called a *quarter section.* Example: In Fig. 69 the front view is shown in quarter section. In drawing the front view the quarter

A O B (end view) is supposed to be removed. It should be noted that the end view represents the complete object.

Crosshatching. The cut surface in the section view is represented conventionally by *crosshatching* which consists of very fine parallel lines, equally spaced. In this problem the lines should be drawn $\frac{1}{16}''$ apart and at an angle of 45° with the horizontal.

Center Lines. A line which represents an axis of symmetry is called a *center line.* Center lines may be straight or curved. Of the straight lines there are two classes, principal and secondary. A principal center line is one about which the entire view is symmetrical. Example: A C in Fig. 69. The principal center lines should extend about $\frac{1}{2}''$ beyond the outline of the view. A secondary center line is one about which only part of the view is symmetrical. Example: E F, Fig. 69, is the center line for the hole only. Secondary center lines should extend about $\frac{1}{4}''$ beyond the outline of the part of which they represent the axes.

A circular center line usually passes through the centers of a number of holes grouped at a certain distance from a central point. It is not quite a complete circle. Example: See left end view. Fig. 69.

In general, every circle must have two center lines at right angles to each other. When one of the center lines is circular the other is therefore radial. Example: See Fig. 71.

Dimensioning Cylindrical Surfaces and Circles. The diameter of the cylinder may be given by placing the dimension on a diameter of the circle representing the cylindrical surface. Example: See Fig. 69. It may be given between extension lines drawn from the rectangular view. Example: See Fig. 69. In this case the dimension figures should be followed by a **D** or **Diam** to indicate that the dimension is a diameter. A hole to be drilled, cored, or bored may be indicated by printing the word, showing how it is to be obtained or finished, together with the dimension and arrow pointing to the hole. The word and the dimension should be placed in an open area near the hole represented. The line drawn under the word should be about $\frac{1}{32}''$ below the letters. Example: See Fig. 69.

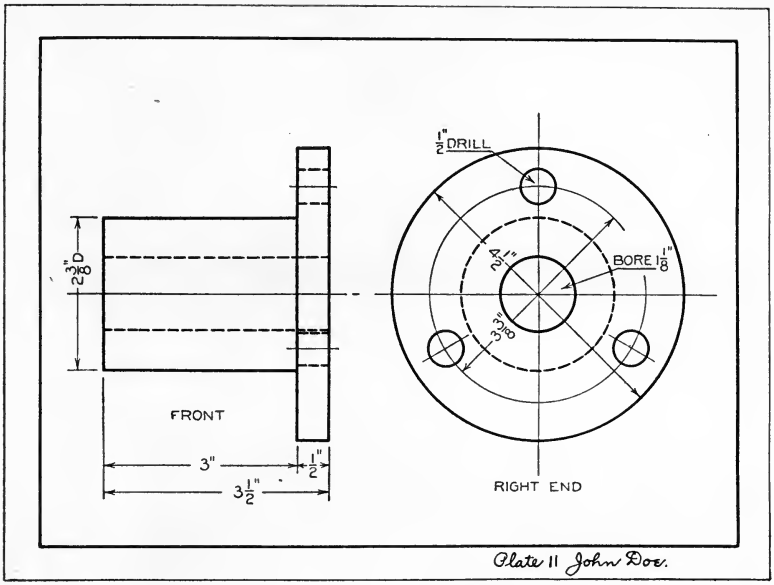


FIG. 71. TRUNNION BEARING

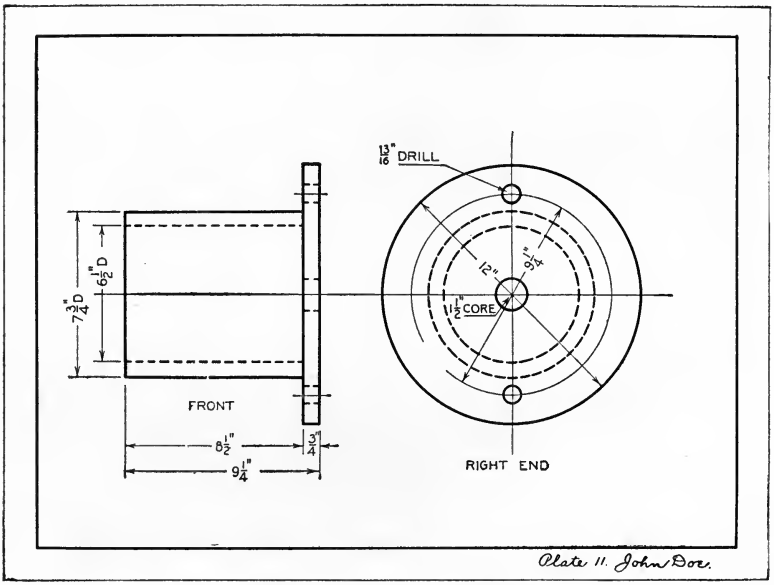


FIG. 72. SPRING CASING BASE

To Sketch a Circle. Draw two light lines at right angles and lay off a length equal to the radius on each, measuring out from their intersection. Sketch in the circle through the four points thus located. If the circle is large, draw radial lines at 45° with those previously drawn and lay off points as before.

DATA FOR PLATE 11

Given: Orthographic sketches, Figs. 71 and 72 showing the front and right end views.

Required: To draw the front quarter section and left end views of the objects. Fig. 71 or 72 as assigned by the instructor.

Instructions:

1. Proportion the views on the plate.
2. Draw the principal center lines for the circular view. Draw the circles in the following order: (1) The larger circles. (2) Circular center line. (3) The circles representing the small holes.
3. To draw the rectangular view, first determine its vertical dimension by projecting from the end view. Complete the view.
4. Retrace the lines as in the finishing stage, giving particular attention to those affected by the quarter section.
5. Draw in extension and dimension lines and put in the dimensions. Finish the sketch by crosshatching the cut surfaces. Care should be taken to make the section lines parallel to each other and at 45° to the horizontal.

Summary

In this chapter the work of the preceding chapter has been continued in order that the value of the perspective sketch as an aid in interpreting orthographic views might be apparent. At the same time more general application has been made of perspective principles and additional skill has been acquired in representing objects pictorially.

It has been the chief aim of this chapter to familiarize the

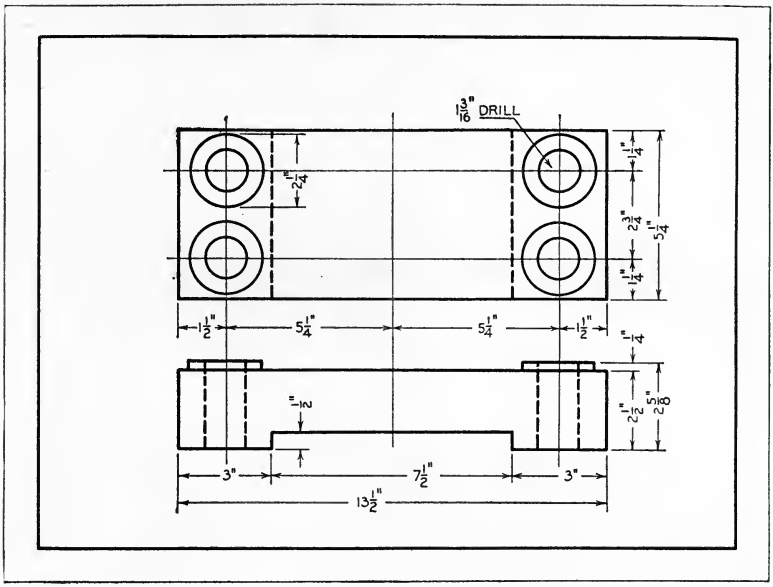


FIG. 73. BEARING CAP

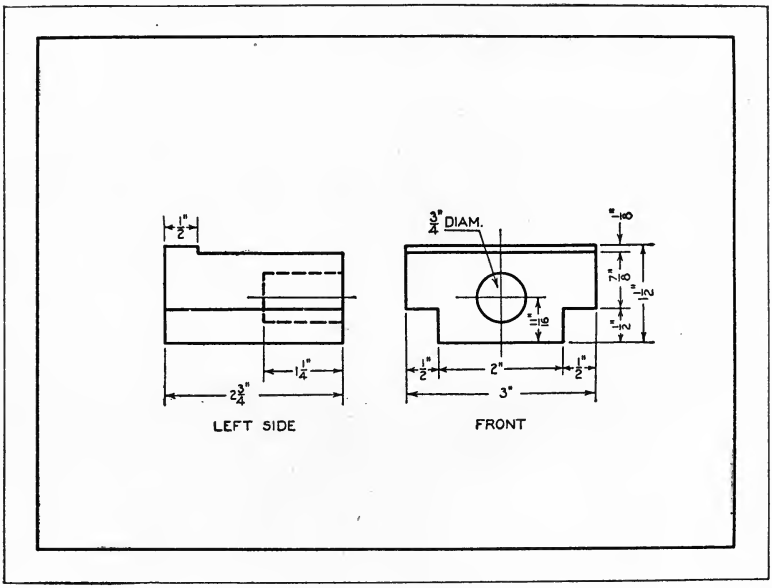


FIG. 74. VISE JAW

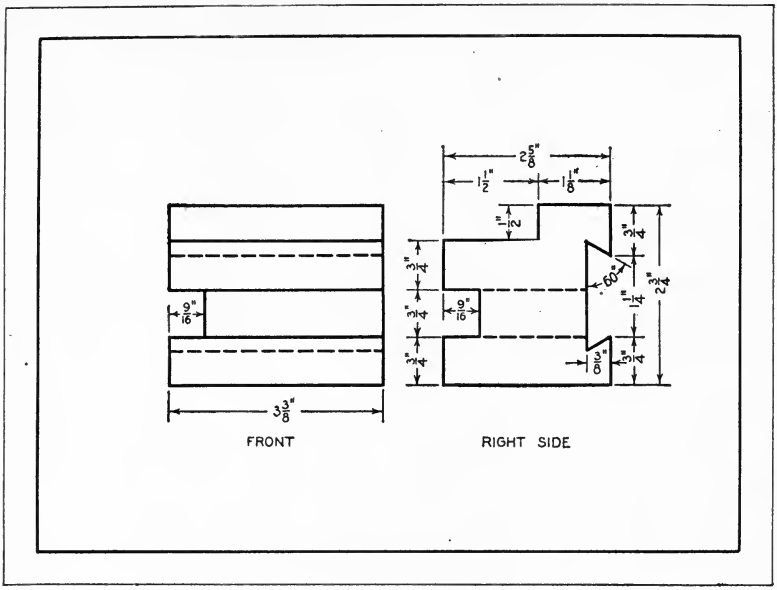


FIG. 75. TURNING TOOL HOLDER

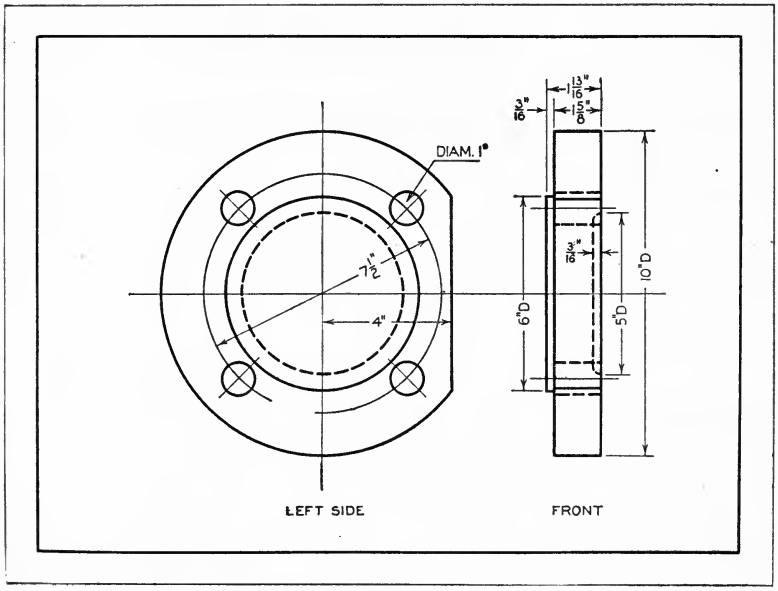


FIG. 76. VALVE BONNET

student with the method of representation generally used in engineering drawing. By this time the student should be able to read drawings of ordinary complexity as well as to make freehand orthographic sketches with a considerable degree of skill and confidence.

As a means of reviewing Chapter II the following questions and problems are given:

Review Questions

1. (a) In what direction does one look at an object in making its orthographic views? (b) How does this differ from the way it is viewed in making a perspective of it?

2. (a) How many general dimensions does each orthographic view show? (b) How many orthographic views are necessary to show three general dimensions?

3. (a) What is the position of the top with reference to the front view? (b) Why? (c) Which general dimension is common in the top and front views?

4. What is meant by "Reading" a drawing?

5. (a) Under what condition does a surface appear as a line in a view? (b) When a hidden surface is viewed edgewise how is it represented?

6. (a) When is a plane surface shown in its true form in one view and as a straight line in the other? (b) When is a plane surface shown in less than its true size in one view and as a straight line in the other?

7. (a) When is a cylindrical surface represented as a rectangle in one view and as a circle in the other? (b) When is a circular surface represented as a straight line in one view and as a circle in the other?

8. (a) When is a straight edge of an object shown in its true length in two views? (b) When in its true length in one view and as a point in the other? (c) When in its true length in one view and in less than its true length in the other?

9. How are the corners of an object represented?

10. Describe the process of proportioning the views of an object and locating them centrally on the sheet.

11. What are the lengths of dashes and spaces in dotted lines?

12. (a) Illustrate by a sketch how detail and overall dimensions are grouped. (b) What space is allowed between the outline of the object and the nearest dimension line? (c) Between dimension lines?

13. (a) Where is the right side view placed with respect to the front view? (b) Where is the left side view placed with respect to the front view?

14. (a) What general dimensions of an object are shown in the right side view? (b) In the left side view?

15. What determines the choice between a right and left side view?

16. (a) Why is an object sometimes shown with a part removed? (b) Define quarter section. (c) Is the part cut by the section planes shown as removed in both views?

17. (a) What is the purpose of crosshatching? (b) At what angles are the crosshatching lines drawn? (c) What is the usual distance between crosshatching lines?

18. (a) What is a principal center line? (b) A secondary center line?

19. (a) When is a straight center line used? (b) Circular center line?

20. (a) How many center lines must be drawn for each circle? (b) At what angle to each other?

21. Illustrate how the two views of a cylinder may be dimensioned.

DATA FOR REVIEW PROBLEMS

Given: An orthographic sketch, Fig. 73.

Required: To make the orthographic sketch shown in Fig. 73 to an enlarged scale.

Given: An orthographic sketch, Fig. 74, showing the front and left side views of the object.

Required: To draw the front and right side views of the object shown in Fig. 74.

Given: An orthographic sketch, Fig. 75, showing the front and right side views of the object.

Required: To draw the front and left side views of the object shown in Fig. 75.

Given: An orthographic sketch, Fig. 76, showing the front and left side views of the object.

Required: To draw the front quarter section and right side views of the object shown in Fig. 76.

CHAPTER III

PENCIL MECHANICAL DRAWING

PREPARATORY INSTRUCTIONS FOR PLATE 12

Three View Problems. While in most cases two views are sufficient to show the form of an object, some objects require three views. Example: The front and side views of the Drill Jig Base in Fig. 77A do not show the form of the vertical groove. Hence a top view is necessary. Also, the front view is required to show the V groove and the left side to show the T slot.

As stated under Plate 8, the right and left side views convey the same information and therefore either may be drawn. The one is usually selected which requires the fewer dotted lines. Example: Comparing Fig. 77, A and B, the left side view is preferable for this reason. Ordinarily the right or left side view is drawn opposite the front view. In some cases, however, a better arrangement will be secured by placing the side view opposite the top view instead of opposite the front view. Fig. 77, C and D. In this case the views are so related that horizontal distances from front to back, which are common to the top and side views, may be projected from one view to the other. To relate properly the side view to the front view of an object, attention should be given to the following condition. In all cases the side views of the front surface are adjacent to the front view of the object. Example: M N and O P in Fig. 77 represent the side views of the front surface.

The student should test his knowledge of the orthographic principles just stated by answering the following questions: See Fig. 78.

1. (a) Why is the top view of the object necessary? (b) The front view? (c) The right side view?

2. (a) Is the right side view preferable to the left side view? (b) Why?

3. (a) Where is the near horizontal edge 5 6 shown in the top view? (b) In the front view?

4. (a) Where is the vertical surface 5, 8 shown in the front view? (b) In the top view?

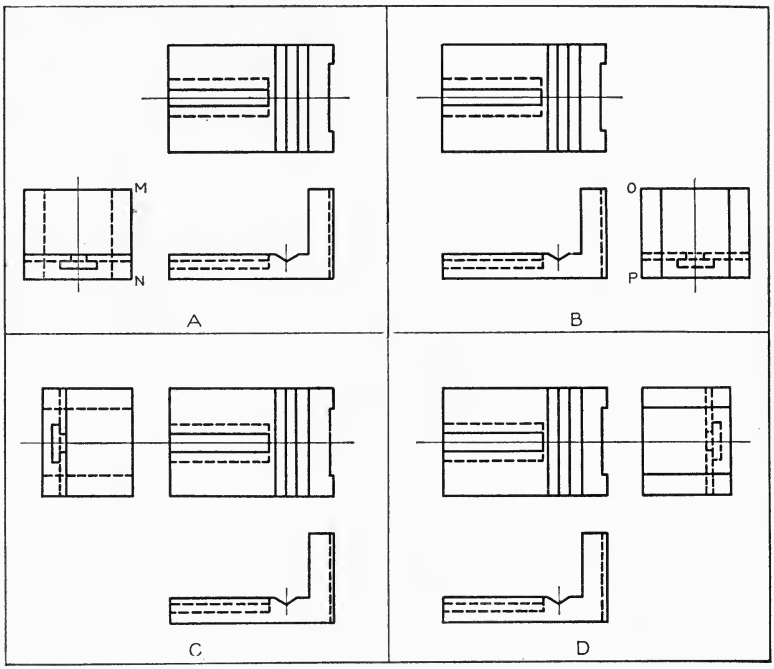


Fig. 77. Relation of Front, Top, and Side Views

5. (a) Where is the back vertical surface 1, 2, 3, 4 shown in the side view? (b) In the top view?

6. Draw the right side view opposite the top view.

7. Draw the left side view opposite the front view.

8. Draw the left side view opposite the top view.

In this chapter an orthographic sketch will precede each mechanical drawing. This will develop further skill in ortho-

graphic sketching and will make the student familiar with the problem. As a result, time will be saved in making the mechanical drawing.

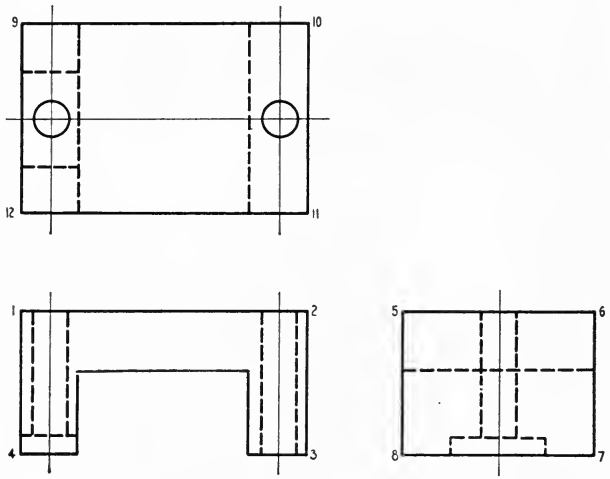


Fig. 78. Review Problem

DATA FOR PLATE 12

Given: Perspective sketches, Figs. 82, 83, and 84.

Required: To draw a three view orthographic sketch of the object shown in Fig. 82, 83, or 84 with dimensions, as assigned by the instructor.

Proceed as in the orthographic sketching in Chapter II.

PREPARATORY INSTRUCTIONS FOR PLATE 13

The following is a list of materials needed in making the pencil mechanical drawings in this chapter. See Chapter V for complete description of each.

1. Drawing board.
2. High grade paper similar to Duplex or Cream, 11″ x 15″ sheets.
3. T-square.

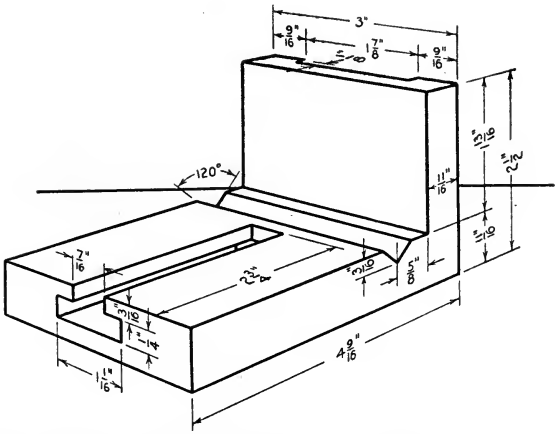


FIG. 79. TYPE PROBLEM—PERSPECTIVE OF DRILL JIG BASE

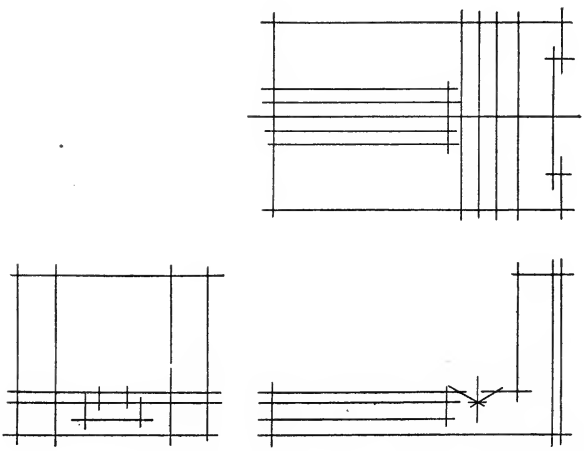


FIG. 80. TYPE PROBLEM—CONSTRUCTIVE STAGE OF THE PENCIL MECHANICAL DRAWING

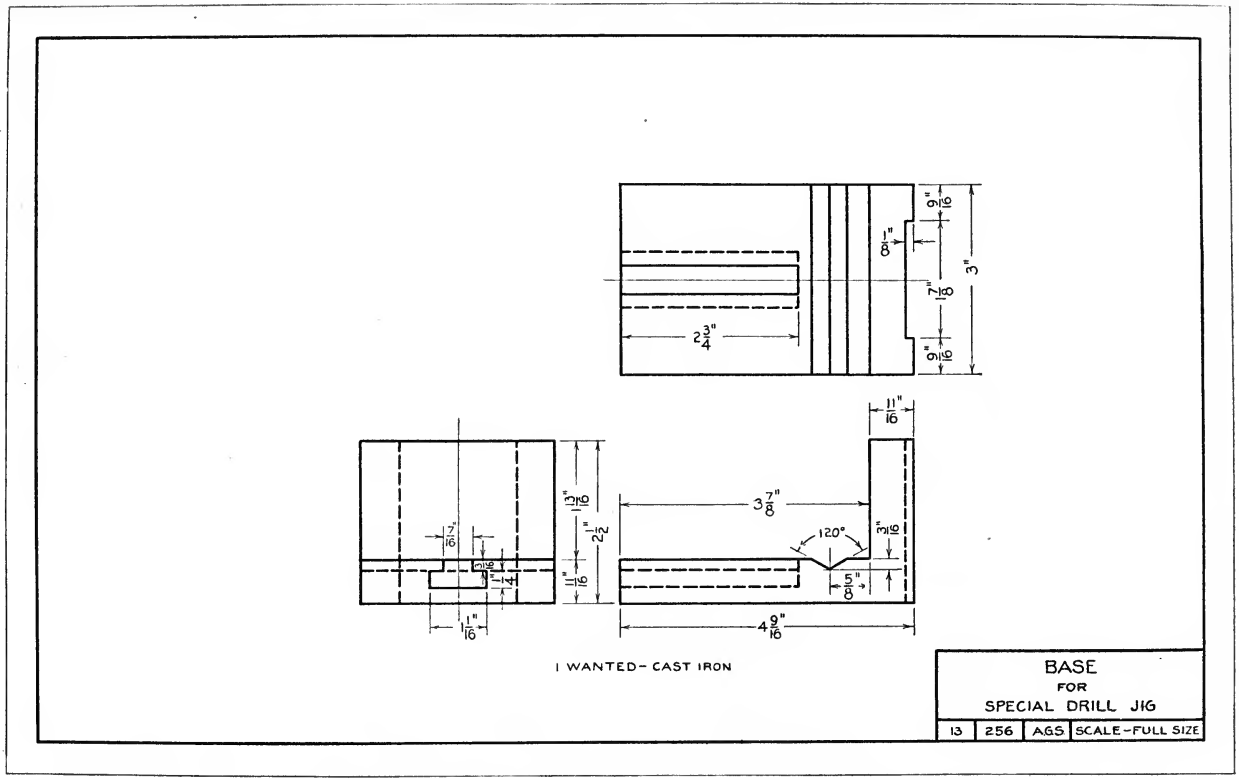


FIG. 81. TYPE PROBLEM—FINISHED DRAWING OF THE DRILL JIG BASE (81)

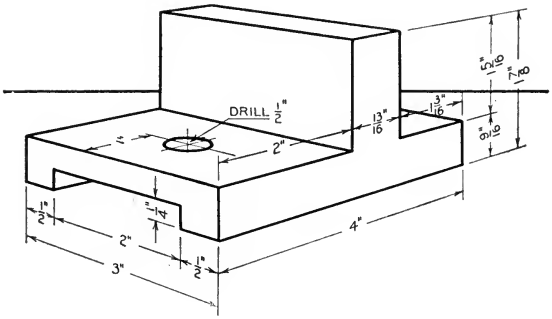


FIG. 82. CLAMP FOR TENSION WEIGHING FIXTURE
ONE WANTED—CAST IRON

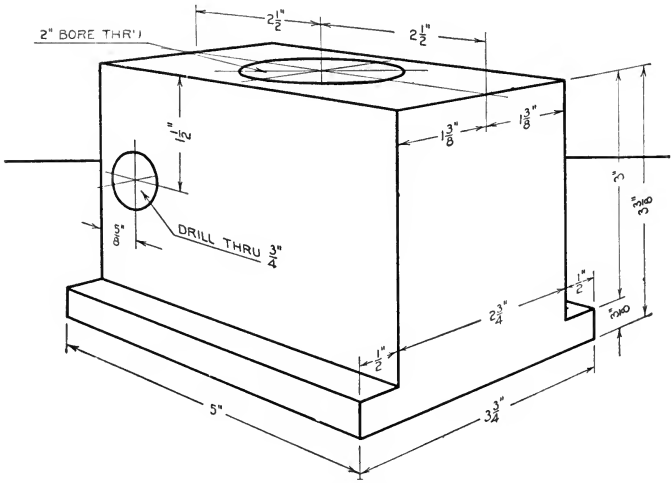


FIG. 83. YOKE BLOCK FOR LOCOMOTIVE VALVE MOTION
ONE WANTED—CAST IRON

4. 30°-60° and 45° triangles.
5. High grade 5H pencil.
6. Scale.
7. Bow compass.
8. 4H compass lead.
9. Pencil pointer.
10. Eraser.
11. Erasing shield.

The T-square should be placed with the head against the left edge of the drawing board and held firmly in place with the

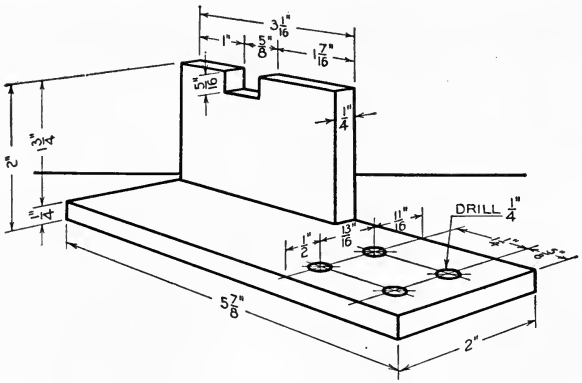


Fig. 84. Angle for Tension Weighing Fixture
One Wanted—Cast Iron

left hand as shown in Fig. 86. All horizontal lines are ruled along its upper edge.

The Drawing Paper should be fastened to the board in the same position as for sketching. After inserting the first tack make the upper edge of the sheet horizontal by means of the T-square; stretch the sheet and insert the remaining thumb tacks in the usual manner.

The 5H pencil should be sharpened at both ends. One end is used for ruling lines and the other for laying off measurements. The ruling point is obtained by cutting away the wood to expose about $\frac{1}{4}''$ of lead and by rubbing opposite sides of the lead on a sandpaper pad or file to produce a wedge-shaped

point. Fig. 85. This point is used for ruling continuous lines. The measuring point is similar to the conical point used in sketching except that the point is sharper in order that very accurate measurements may be laid off with it. It is used

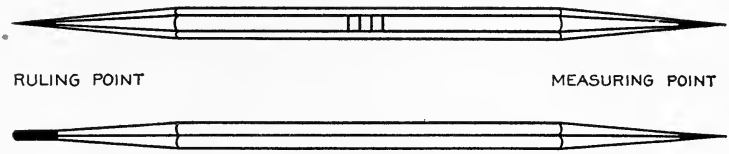


FIG. 85. RULING AND MEASURING POINTS OF THE MECHANICAL DRAWING PENCIL

both for measuring and making dotted lines. All measurements on this plate should be laid off from the edge of the scale, graduated to inches and sixteenths. To insure accuracy the eye should be directly above the division on the scale from which

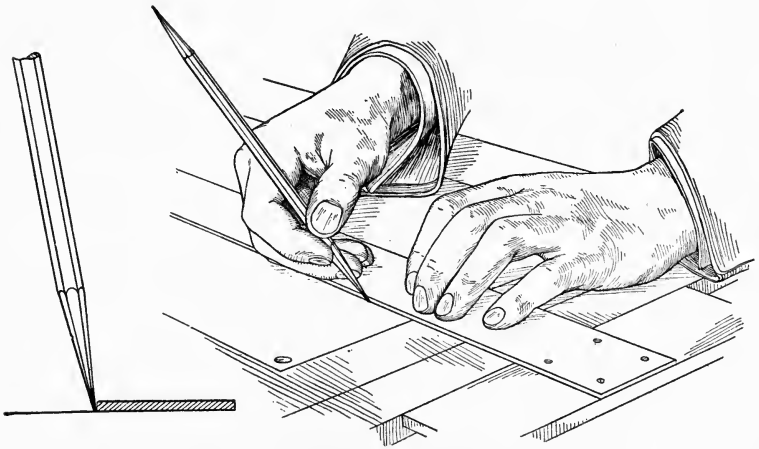


FIG. 86. RULING A HORIZONTAL LINE

the dimension is to be laid off. Care should be taken to place the point of the pencil on the paper exactly opposite the mark on the scale. The pencil should be revolved upon its axis while

in this position without pressing the lead into the paper. The mark left by the pencil should be a small, round dot just visible to the eye.

Ruling Horizontal Lines. In ruling horizontal lines the position of the hand is the same as for sketching horizontal lines. In this case, however, the pencil is held leaning slightly forward with the point in the position shown in Fig. 86. The line is drawn with a continuous motion to the right with the tip of the fourth finger touching the T-square to steady the hand. Fig. 86. The forearm should always be at right angles with the line being drawn.

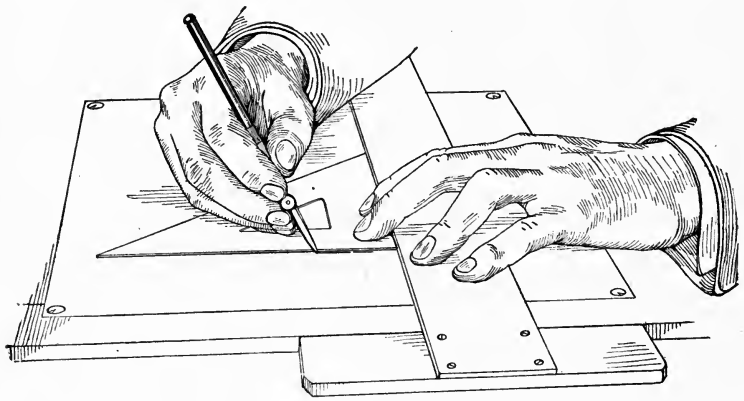


Fig. 87. Ruling a Vertical Line

Vertical Lines are drawn along the edge of a triangle which is set against the T-square as shown in Fig. 87. Note that the triangle is to the right of the line. The line should be drawn away from the T-square with the hand and arm in the same relative position to the line being drawn as for horizontal lines.

In using the bow compass proceed in the following manner:

1. Sharpen the lead to a narrow wedge in width about one-half the diameter of the lead.

2. Set the lead so that it projects about one-half the length of the needle point beyond the shoulder.

3. Draw the center lines of the circle to be drawn at right angles and lay off the radius on one of them.

4. Grasp the compass by the handle between the thumb and first finger of the right hand. Care should be taken to place the needle point exactly at the intersection of the center lines.

5. Adjust the lead to the exact radius and draw the circle, rolling the handle of the compass between the thumb and finger. Fig. 88.

When erasing lines which are very close to or joining required lines, the erasing shield should be used. The shield pro-

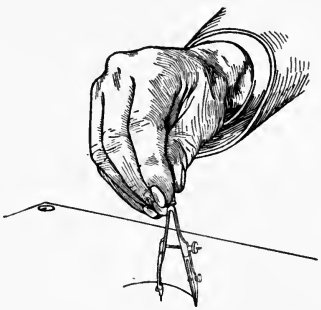


FIG. 88. DRAWING A CIRCLE WITH THE BOW COMPASS

tects the required lines and thus the time lost in retracing them is avoided.

The Border Rectangle. To draw the border rectangle proceed as follows:

1. Lay off $\frac{1}{2}''$ from the upper and left-hand edges of the sheet.

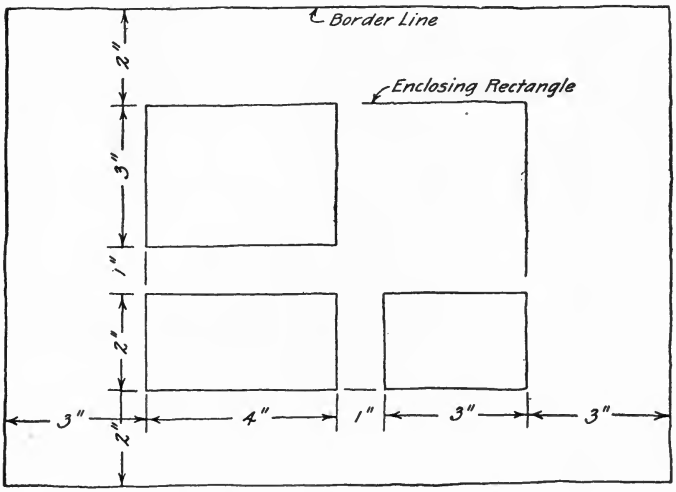
2. Through the points thus located draw the upper and left-hand sides of the border rectangle.

3. On these lines and from their intersection lay off 14″ to the right and 10″ downward.

4. Through the points thus found draw the remaining sides of the border rectangle.

The Enclosing Rectangle. In mechanical drawing the views are located centrally by calculating the position of a rectangle

in which they may be inscribed. In this course the distance between views should not be less than $\frac{3}{4}''$ or more than $1''$. The student's calculation should be made as indicated in Fig. 89.



Scale of Drawing = Full size.
Border rectangle = 10" × 14"
4" = width of front view
3" = width of side view
1" = space between views
8" = width of enclosing rectangle
14" = length of border rectangle
8" = length of enclosing rectangle
2)6"
3" = distance between the views and the borderline at the right and left
2" = height of front view
3" = height of top view
1" = space between views
6" = height of enclosing rectangle
10" = height of border rectangle
6"
2)4"
2" = distance between the views and the border line at the top and bottom

FIG. 89. CALCULATION FOR THE SIZE AND POSITION OF THE ENCLOSING RECTANGLE

Accuracy. It is of prime importance that a mechanical drawing be accurate. Accuracy depends both upon the quality and condition of the instruments and materials and upon the

skill of the draftsman. All straight edges, angles, etc., should be tested as described in Chapter V. When the tools are found to be in good condition the draftsman should then take great care to lay off measurements accurately, and draw the lines exactly through the points located.

Errors multiply with the number of operations involved, hence, other things being equal, the most direct construction is the most accurate one.

Constructive Stage. In this stage all measurements are laid off and lines drawn lightly and of indefinite length. As many measurements as possible should be made while the scale is being used. Whenever practicable, consecutive measurements should be laid off with the scale in one position. The lines should be drawn long enough so that there will be no need to extend them.

No distinction is made between visible and invisible edges in this stage.

Finishing Stage. The lines not needed in the finished drawing are now erased and the required lines retraced with a carefully sharpened pencil, care being taken to make them of uniform width and shade and to end them at the proper points. The lines should be drawn in the following order: (1) Horizontal lines beginning at the top of the sheet. (2) Vertical lines beginning at the left of the sheet. The hidden edges should now be represented by dotted lines. They are composed of $\frac{1}{8}''$ dashes and $\frac{1}{32}''$ spaces. Fig. 56. The end of each dash can be made distinct by keeping the end of the pencil in contact with the paper until the end of the line is reached.

Extension and Dimension Lines. As in orthographic sketching the extension lines should begin about $\frac{1}{32}''$ from the outline of the object and continue about $\frac{1}{8}''$ beyond the arrowheads. The space between the outline of the object and the nearest dimension line, or between two parallel consecutive dimension lines, should be about $\frac{1}{4}''$. The extension and dimension lines should be of the same width and shade as the object lines. Center lines may be used as extension lines, but not as dimension lines.

The Dimension Figures should be of the same height as those used in orthographic sketching, Fig. 196.

Notes are used to explain points which the drawing does not make clear. They usually relate to materials, finish, number of parts needed, etc. Example: See note below the view, Fig. 81.

The Title. The views of an object with their dimensions and notes do not convey all of the necessary information. A *title* which supplies the deficiency is therefore added. The title is usually placed in the lower right-hand corner of the sheet so that it will be easily accessible when the drawing is filed. The titles in this chapter will contain the *name of the object,* the *name of the machine* for which it is to be made, the *scale* to which it is to be drawn, the *plate number,* the *student's initials,* and the *filing number.* For a more general discussion of the contents of a title see page 147. The relative importance of the items in the title is shown by varying the heights of the letters. The more important items are printed in larger letters. The words for each title in this chapter will be given below the figure from which the drawing is made.

The Title Block. The title for each mechanical drawing plate in this course will be placed in a *title block.* The dimensions of this block with the height of each line of letters and the positions of the items are shown in Fig. 90.

Balancing a Title. It is essential to the appearance of a title that the lines be symmetrical with respect to a vertical center line. Example: Fig. 90 shows a title properly balanced.

To balance the title proceed as follows:

1. Tack a piece of drawing paper to the board opposite the lower right-hand corner of the sheet. Fig. 90. This will be referred to as the *trial sheet.*

2. Draw a line as a continuation of the lower border line on the trial sheet. This is a base line for measurements.

3. Lay off on the trial sheet the space for the letters as given in Fig. 90. Extreme accuracy in making these measurements is necessary as the width of the letters varies with their

height. A small error in height makes the letter appear much too large or too small.

4. Rule each guide line on the trial sheet and the drawing sheet with one setting of the T-square. Care should be taken to draw exactly through the points located. Check the heights of the spaces with the scale.

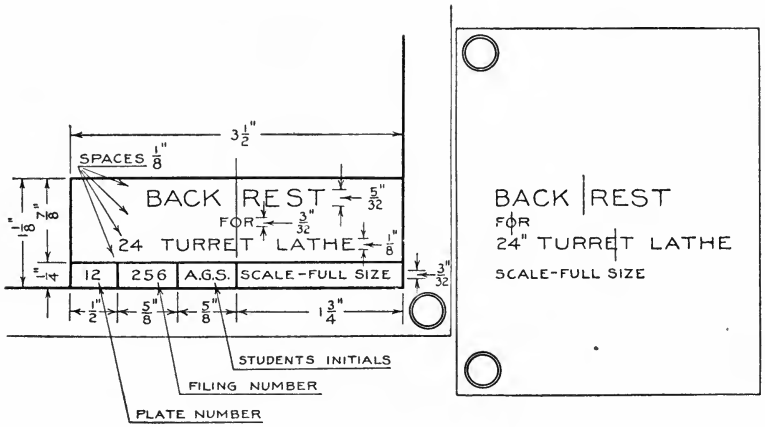


FIG. 90. TITLE BLOCK—SHOWING A METHOD OF BALANCING THE LINES OF THE TITLE

5. Letter each line of the title on the trial sheet, giving attention to the proportion of the letters and to spacing. Do not try to balance the lines on this sheet.

6. Locate the middle point of each line on the trial sheet.

7. Draw the vertical center line of the title through the center of the title rectangle.

8. Cut out each line of letters from the trial sheet and place it above the space in which it is to be lettered on the drawing sheet, with its middle point on the center line of the title.

9. Letter each line, following the spacing on the trial line. The result should be a perfectly balanced title.

DATA FOR PLATE 13

Given: The orthographic sketch, Plate 12.

Required: To make a pencil mechanical drawing from Plate 12.

Instructions: 1. Test the drawing board, T-square, and triangles as explained in Chapter V.

2. Draw the border line as previously explained.

3. Calculate the size of the enclosing rectangle.

4. Lay off as many of the dimensions of the object as possible at one time. Draw the lines lightly.

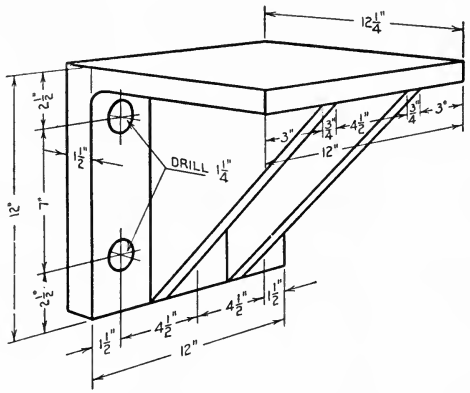


FIG. 91. TYPE PROBLEM—PERSPECTIVE OF CHAIN SUPPORT

5. Check the drawing for accuracy.

6. Erase unnecessary lines and retrace the drawing, taking care to end the lines exactly at their intersections. Dot the lines representing hidden edges.

7. Draw extension and dimension lines and put in dimensions.

8. Letter a note, giving the number of parts required and the material from which they are to be made.

9. Letter the title, using the name of the object given below the figure from which the drawing was made.

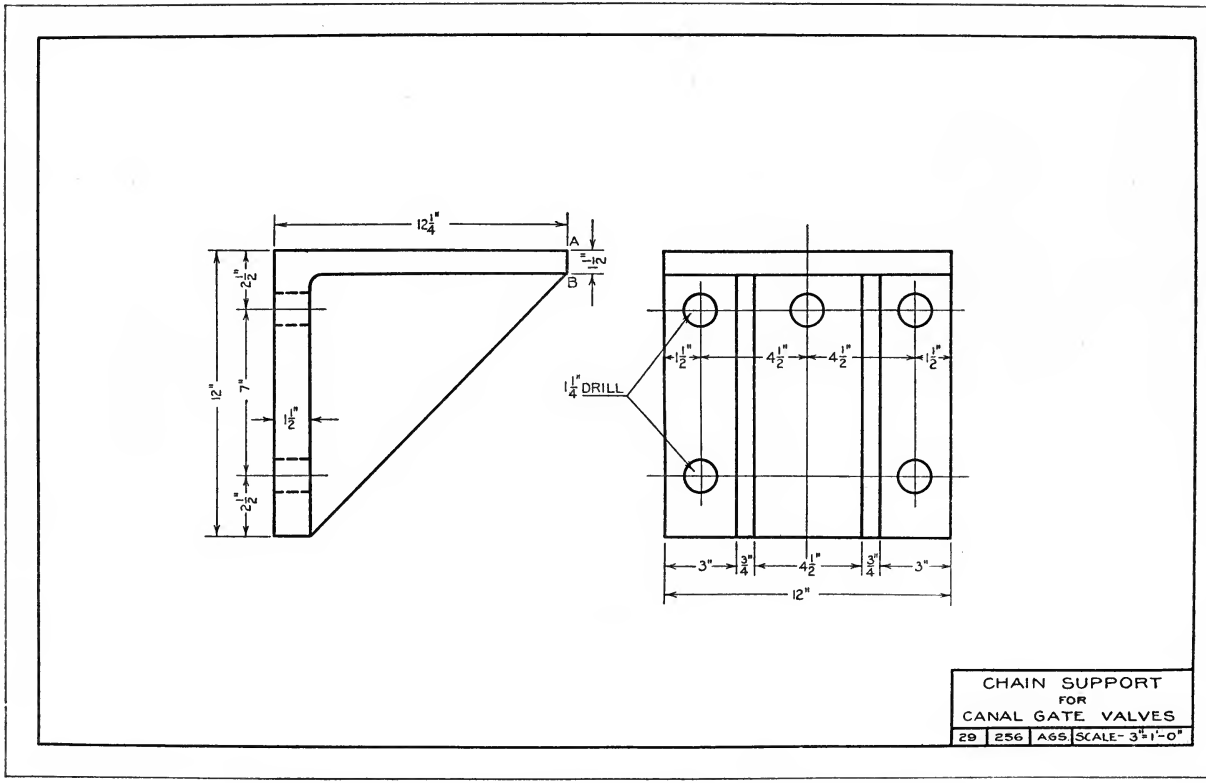


FIG. 92. TYPE PROBLEM—FINISHED DRAWING OF THE CHAIN SUPPORT

PREPARATORY INSTRUCTIONS FOR PLATE 14

Relation of Front and Side Views. In all cases the side views of the front surface are *adjacent* to the front view of the object. Example: A B, Fig. 92, represents the side view of the front surface of the chain support.

Dimensioning Angles. The direction of inclined lines is given in two ways. The more common method is by coördinates as shown in Fig. 92. Another method less frequently used is shown in Fig. 62. When an angle is dimensioned in degrees the dimension line is an arc with its center at the intersection of the lines forming the angle.

DATA FOR PLATE 14

Given: Perspective sketches, Figs. 93, 94, and 95.

Required: To draw a two view orthographic sketch of the object shown in Fig. 93, 94, or 95 with dimensions, as assigned by the instructor.

Instructions: Proceed as in orthographic sketching, Chapter II.

PREPARATORY INSTRUCTIONS FOR PLATE 15

Inclined Lines. When inclined lines make an angle of 30°, 45°, or 60° they may be drawn along the edge of one of the triangles in combination with the T-square. Angles of 15° and 75° may be obtained by a combination of the two triangles and the T-square. See Chapter V for detailed discussion.

Scale. When an object is too large to be drawn full size on the sheet it may be drawn to some fraction of its actual size. Half and quarter size are common scales for drawing machine parts. The edge of the scale, graduated to read half or quarter size, should be used instead of dividing the dimensions by 2 or 4.

DATA FOR PLATE 15

Given: The orthographic sketch, Plate 14.

Required: To make a pencil mechanical drawing from Plate 14. (Draw the Journal Bearing, Fig. 95, half size.)

Instructions: 1. Draw the border line and calculate the size of the enclosing rectangle as in Plate 13.

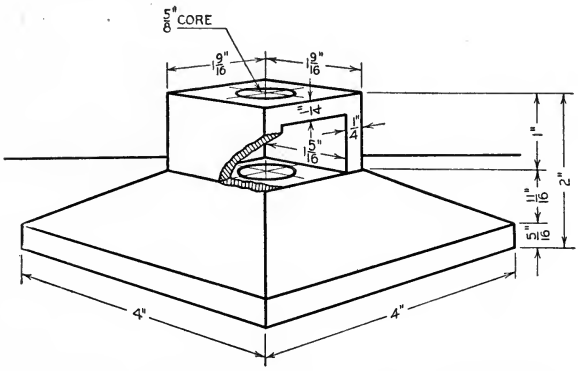


Fig. 93. Foundation Washer for Corliss Engine Bed
Twelve Wanted—Cast Iron

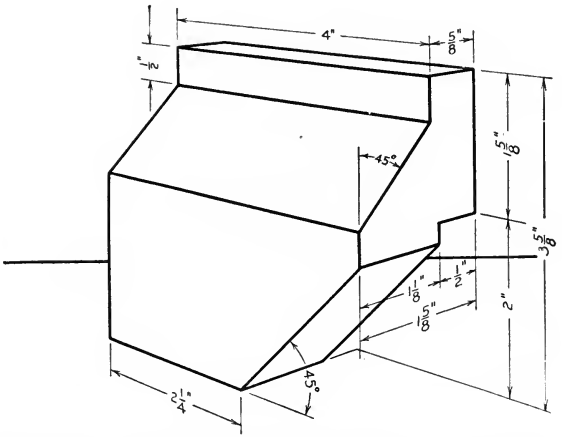


Fig. 94. Back Rest for Twenty-Four-Inch Turret Lathe
Four Wanted—Cast Iron

2. Lay off the dimensions of the object and complete the constructive stage.

3. Check carefully each dimension for accuracy.

4. Retrace the object lines, drawing: (1) horizontal lines, beginning at the top; (2) vertical lines, beginning at the left; (3) inclined lines.

5. Draw extension and dimension lines and put in dimensions.

6. Letter a note, giving the number of parts required and the material from which they are to be made.

7. Letter the title, using the name of the object given below the figure from which the drawing was made.

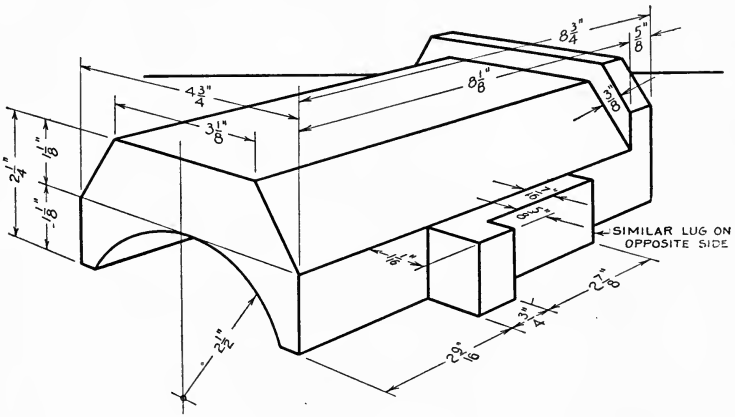


Fig. 95. Journal Bearing for Electric Railway Motor Car Eight Wanted—Brass

PREPARATORY INSTRUCTIONS FOR PLATE 16

Tangencies. In either freehand or mechanical drawing where a straight line is tangent to an arc, the arc should be drawn first. In the constructive stage the arc should be drawn long enough so that it will extend beyond the point of tangency. Fig. 97. The straight line may then be drawn tangent to the arc. Before finishing the drawing the unnecessary part of the arc is erased.

Radius Dimensions. The dimension forms for radius dimensions are shown in Fig. 98. When the distance between the arc and its center is great enough to admit the figures and arrowheads the form is as shown in Fig. 98. Note the circle about

the center in place of an arrowhead. This circle should be made freehand and about $\frac{1}{16}''$ in diameter. When the distance between the arc and its center is short the center is not indicated as shown by $\frac{1}{8}''$ radius, Fig. 99.

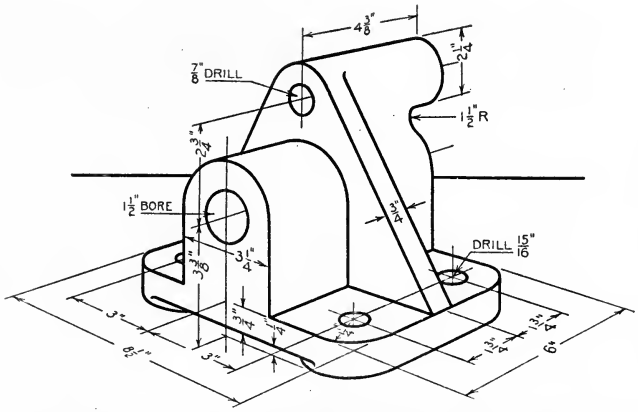


FIG. 96. TYPE PROBLEM—PERSPECTIVE OF BRAKE LEVER BRACKET

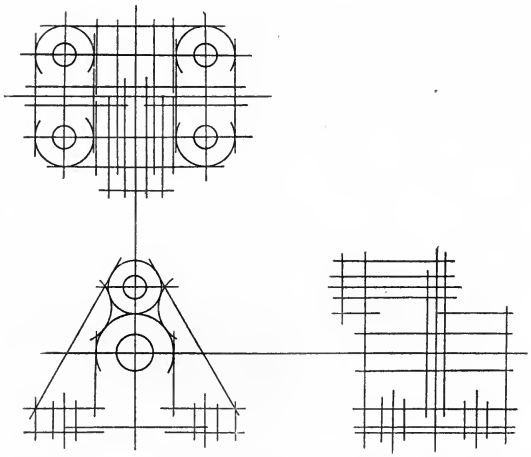


FIG. 97. TYPE PROBLEM—CONSTRUCTIVE STAGE OF MECHANICAL DRAWING

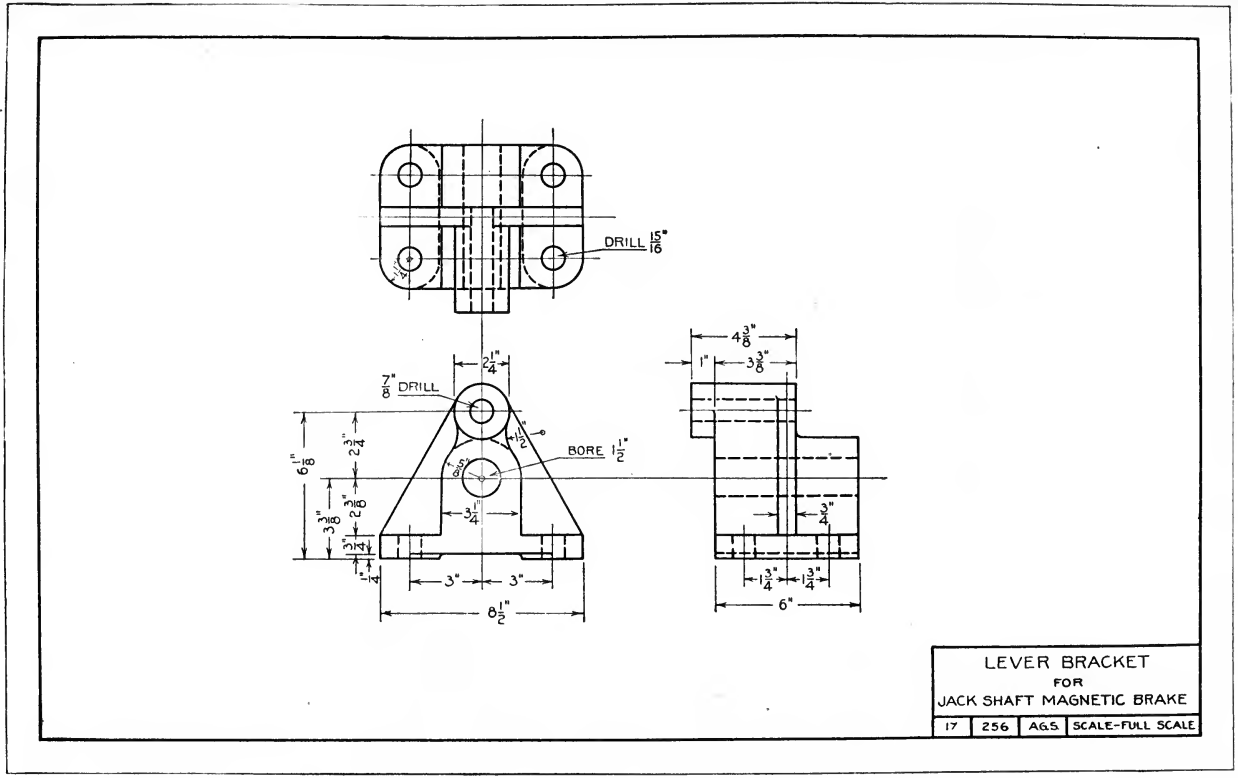


FIG. 98. TYPE PROBLEM—FINISHED DRAWING

DATA FOR PLATE 16

Given: Perspective sketches, Figs. 99, 100, and 101.

Required: To draw an orthographic sketch of the object shown in Fig. 99, 100, or 101 with dimensions, as assigned

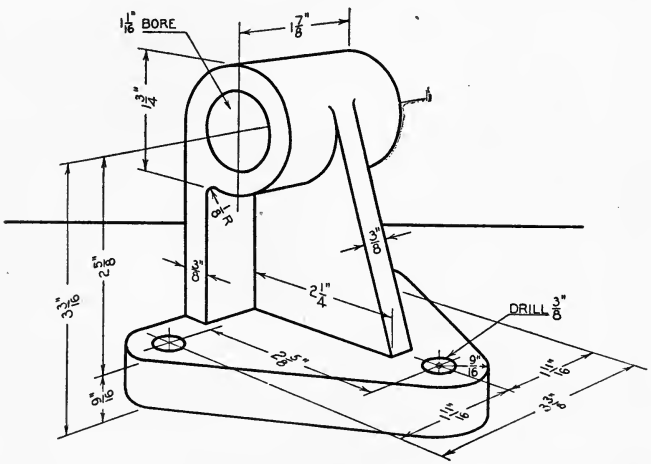


FIG. 99. BRUSH HOLDER BRACKET FOR PRESSURE TUNNEL CABLE REEL
TWO WANTED—CAST IRON

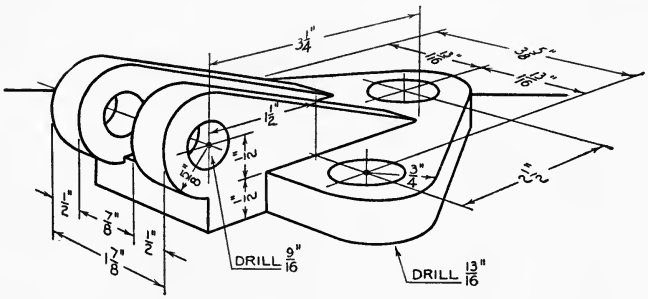


FIG. 100. HINGE BRACKET FOR GEAR CASING OIL COVER
TWO WANTED—CAST IRON

by the instructor. The student should decide what views are necessary to show the form of the object.

Instructions: In drawing the circles and arcs sketch in the center lines and lay off the radii on each, as in Plate 10.

PREPARATORY INSTRUCTIONS FOR PLATE 17

Given: The orthographic sketch, Plate 16.

Required: To make a pencil mechanical drawing from Plate 16.

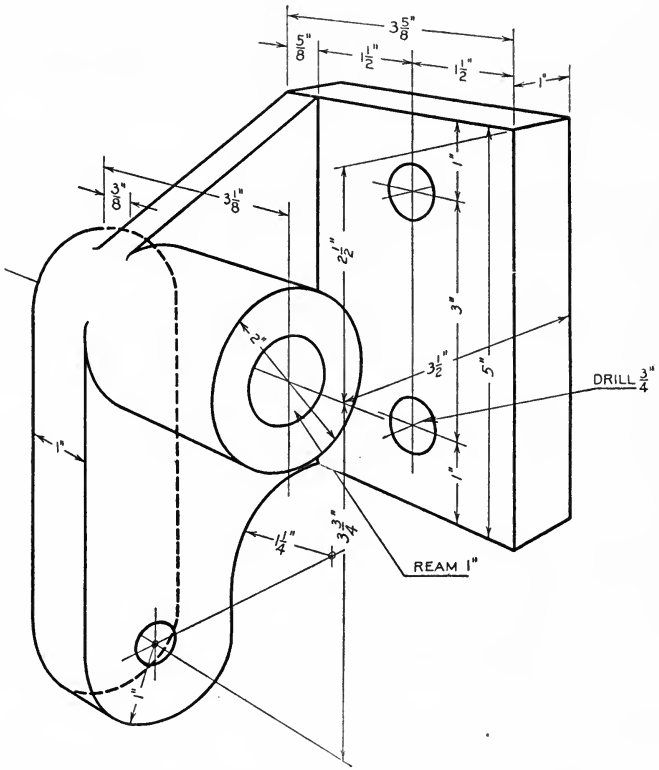


FIG. 101. CLUTCH LEVER BRACKET FOR VALVE OPERATING MECHANISM ONE WANTED—CAST IRON

Instructions: 1. Draw the border line and enclosing rectangle.

2. Locate and draw two center lines at right angles to each other for each arc or circle.

3. Draw the arcs of indefinite length so that they extend beyond the points of tangency.

4. Draw the straight lines tangent to the arcs.

5. When the constructive stage is complete retrace the lines in the following order: (1) circles and arcs; (2) horizontal lines, beginning at the top of the sheet; (3) vertical lines, beginning at the left of the sheet; (4) inclined lines.

6. The center lines may be produced and used as extension lines where appropriate.

7. Letter a note, giving the number of parts required and the materials from which they are to be made.

8. Letter the title.

Summary

In this chapter orthographic sketching has been continued. A more general application of the principles of orthographic drawing has been made. This has been done principally by introducing problems requiring three views from perspective sketches. It has been the chief aim of this chapter to give considerable practice with some of the common instruments and materials used in making mechanical drawings and to fix a standard of technique. The student should now be able to make neat, accurate mechanical drawings of simple objects. The technique of the lettering, arrowheads, and figures should be of a standard comparable with that secured in the mechanical line work.

As a means of reviewing Chapter III the following questions and problems are given:

Review Questions

1. (a) What determines the number of views of an object? (b) When are more than two views necessary?

2. Where is the front surface of an object represented in the side view?

3. (a) What dimension is common to the top and side views? (b) If only the top and side views were drawn how should they be related?

4. (a) Describe the position of the T-square for drawing horizontal lines. (b) How is it held? (c) Illustrate by a sketch the position of the pencil in ruling a line along the T-square.

5. Describe the process of squaring and fastening the paper on the board for a mechanical drawing.

6. (a) What is the shape of the ruling point of the pencil? (b) How is it obtained? (c) How does the measuring point of the mechanical drawing pencil differ from the point of the sketching pencil?

7. (a) Describe the positions of the T-square and triangle for drawing a vertical line. (b) In which direction is the line always drawn?

8. (a) What is the shape of the point of the lead used in the bow compass? (b) How should it be set with reference to the needle point?

9. Illustrate by a sketch and show calculations for determining the size of an enclosing rectangle.

10. Describe the process of drawing the border rectangle for a mechanical drawing sheet.

11. (a) Define the constructive stage of the mechanical drawing. (b) How are hidden edges shown in this stage?

12. In what order are the lines drawn in the finishing stage?

13. (a) What space is left between the outline of the object and the end of the extension line? (b) How far should the extension line run beyond the arrowhead? (c) How far should the nearest dimension line be from the outline of the object? (d) How far apart should dimension lines be placed?

14. (a) What is the height of the whole number in a dimension? (b) The total height of the fraction?

15. What is the purpose of notes on a drawing?

16. What information does the title contain?

17. What is the title block?

18. Describe the steps taken in balancing two or more lines in a title.

19. What dimension forms are used in showing the inclination of a line?

20. (a) What angles can be obtained with each triangle used in combination with the T-square? (b) With both triangles used in combination with the T-square?

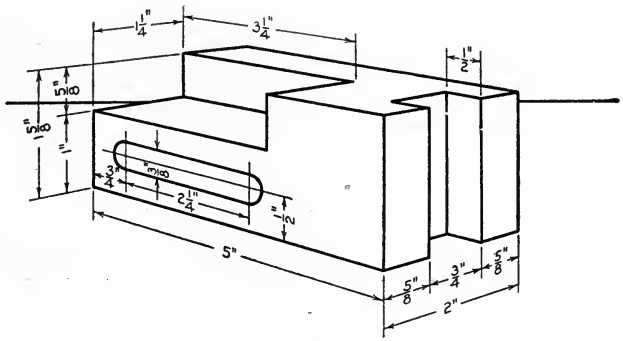


Fig. 102. Tool Holder for 24" Turret Lathe—Six Wanted—Cast Iron

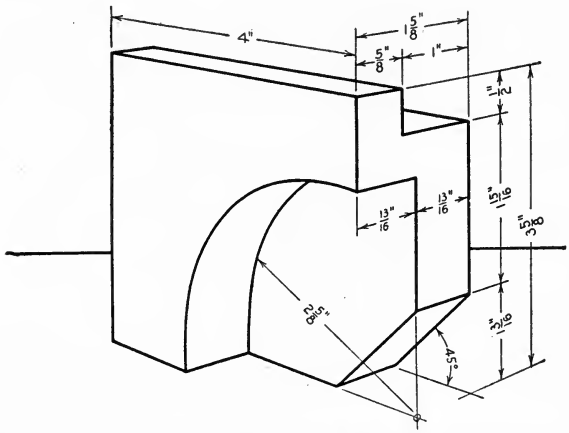


Fig 103. Back Rest for Turret Lathe—Four Wanted—Cast Iron

21. In what order are the lines drawn when an arc and a straight line are tangent to each other?

22. (a) Show two ways of dimensioning a radius. (b) Under what condition is each used?

DATA FOR REVIEW PROBLEMS

Given: A perspective sketch, Fig. 102.

Required:

1. To make an orthographic sketch of the object shown in Fig. 102.

2. To make a pencil mechanical drawing from the orthographic sketch.

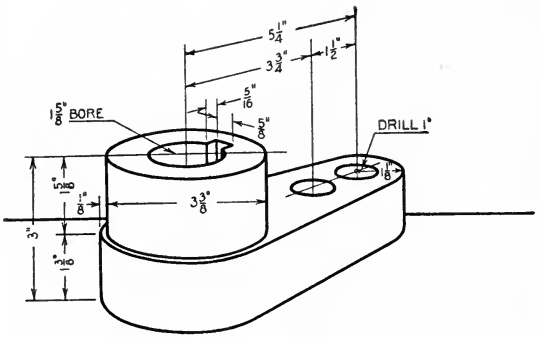


FIG. 104. DASH POT ARM FOR 22"X42" CORLISS ENGINE
TWO WANTED—CAST IRON

Given: A perspective sketch, Fig. 103.

Required:

1. To make an orthographic sketch of the object shown in Fig. 103.

2. To make a pencil mechanical drawing from the orthographic sketch.

Given: A perspective sketch, Fig. 104.

Required:

1. To make an orthographic sketch of the object shown in Fig. 104.

2. To make a pencil mechanical drawing from the orthographic sketch.

CHAPTER IV

TRACING AND BLUEPRINTING

PREPARATORY INSTRUCTIONS FOR PLATE 18

The Half Section. As explained under Instructions for Plate 11, a drawing may often be made much clearer by representing the object with a portion removed. An object is fre-

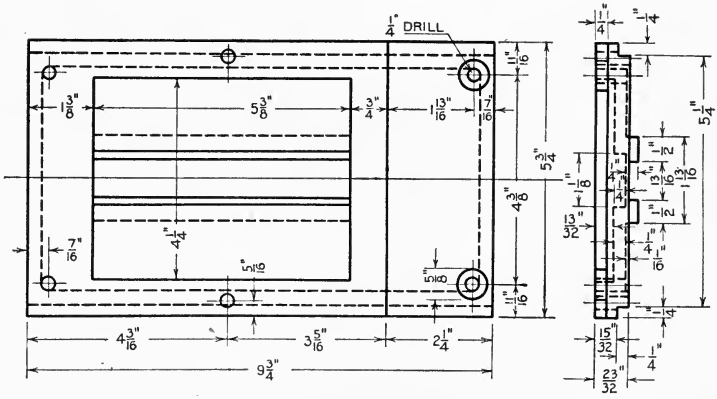


FIG. 105. TYPE PROBLEM—COVER FOR LIMIT SWITCH BOX

quently imagined cut through an axis of symmetry into two similar parts. The view of the object obtained by looking in a direction at right angles to the cut surface is called a half section. In Fig. 106 the areas representing the cut surface are crosshatched, as in the case of the quarter section, with parallel lines about $\frac{1}{16}''$ apart. The angle of the lines is usually 45°.

The student should test his knowledge of the orthographic principles involved in making half section views by answering the following questions. See Fig. 107.

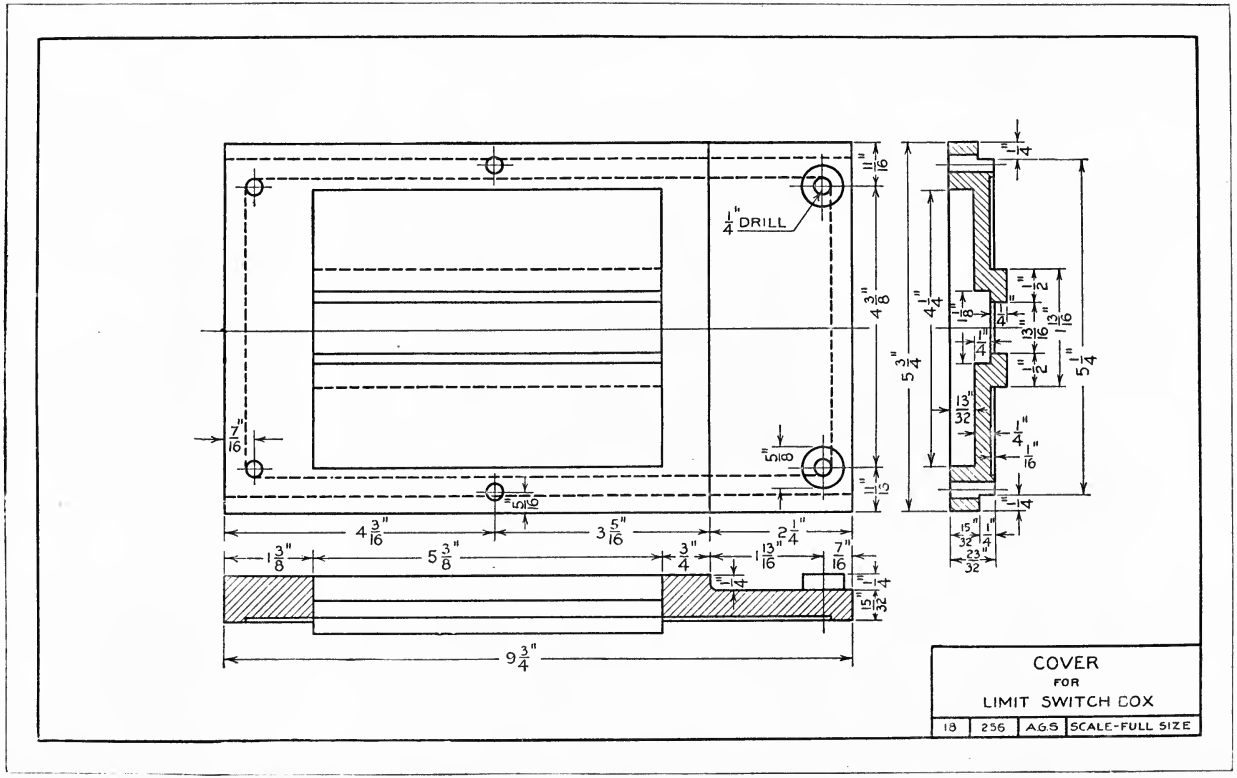


FIG. 106. TYPE PROBLEM—COVER FOR LIMIT SWITCH BOX—HALF SECTION

1. Where is the surface 1, 6, shown in the side view?

2. (a) Does the rectangle 20, 21, 22, 23 in the side view represent an opening or a solid part of the object? (b) Why?

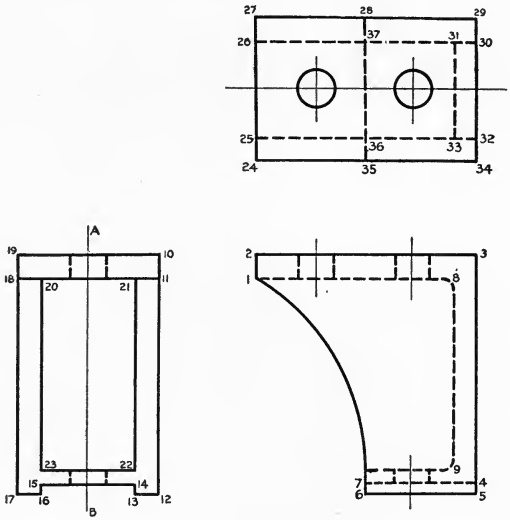


FIG. 107. REVIEW PROBLEM

3. Where is the surface 7, 4 shown in the side and top views?

4. Make a front view of the object when cut on AB.

5. (a) Is the side view affected by the section? (b) Top view?

Each tracing in this chapter will be preceded by a pencil mechanical drawing. The pencil drawing is made to give the student additional practice in the handling of the instruments already used, to introduce the use of new instruments, and to provide drawings for the tracings.

DATA FOR PLATE 18

Given: Orthographic sketches, Figs. 108, 109, and 110.

Required: To make a pencil mechanical drawing of the object shown in Fig. 108, 109, or 110, as assigned by the

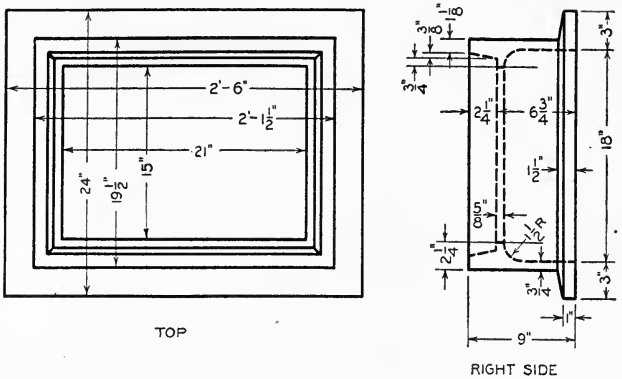


FIG. 108. MANHOLE HEAD FOR CATSKILL AQUEDUCT CONDUIT TWENTY-SEVEN WANTED—CAST IRON

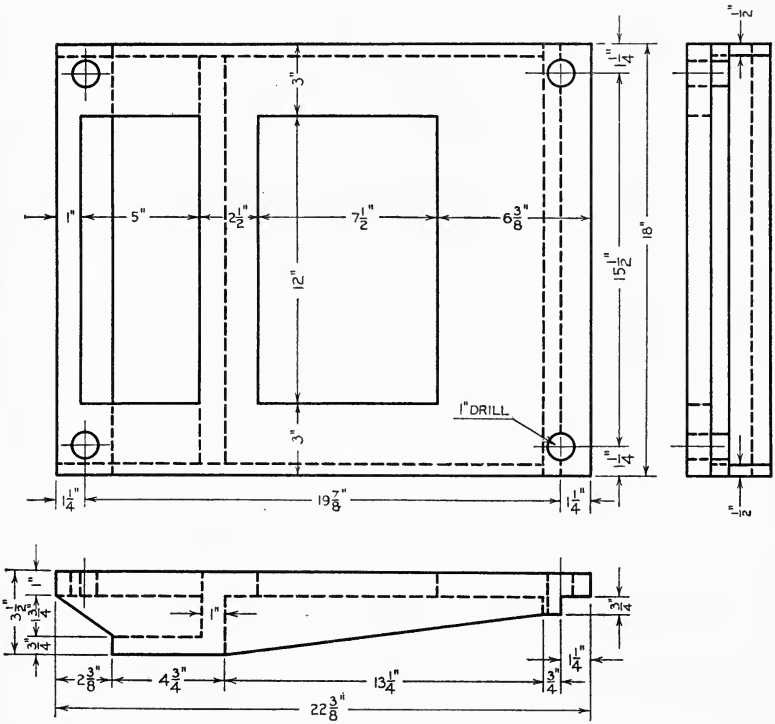


FIG. 109. AIR PUMP BRACKET FOR ATLANTIC TYPE LOCOMOTIVE ONE WANTED—CAST IRON

instructor. The views given and required may be obtained from the following table:

Given		
Fig. 108.	Top and right side views.	
Fig. 109.	Top, right side, and front views.	
Fig. 110.	Top, right side, and front views.	
Required		**Scale**
Top and front half section views.		Quarter size
Top, left side, and front half section views.		Quarter size
Top, right side, and front half section views.		Half size

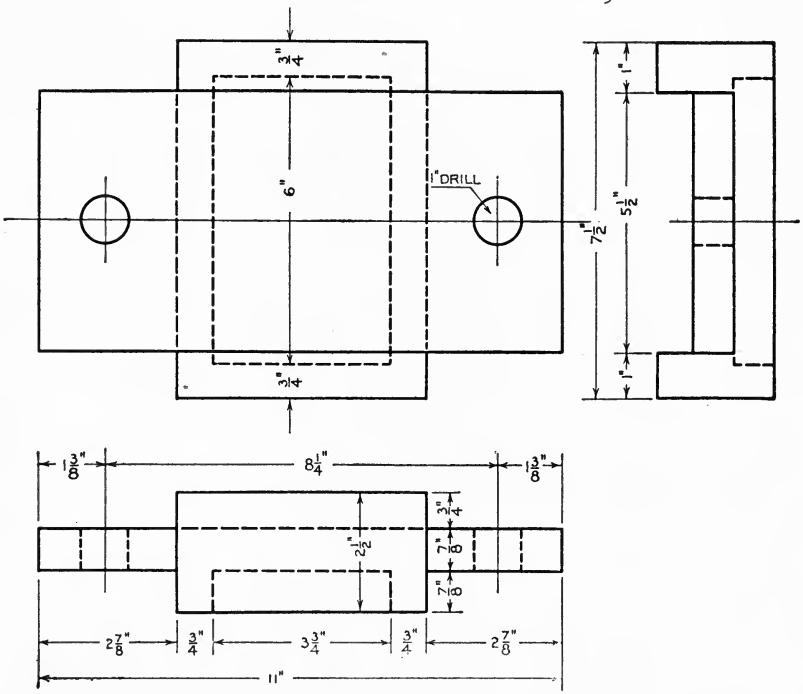


FIG. 110. TRUCK SPRING SEAT FOR ATLANTIC TYPE LOCOMOTIVE
EIGHT WANTED—CAST IRON

Instructions: Proceed as for the mechanical drawing plates of Chapter III.

PREPARATORY INSTRUCTIONS FOR PLATE 19

The following is a list of the instruments and materials needed to make tracings of mechanical drawings. See Chapter V for complete description of each:

1. Tracing cloth.
2. Black waterproof ink.
3. Ruling pen.
4. Compass.
5. Bow pen.

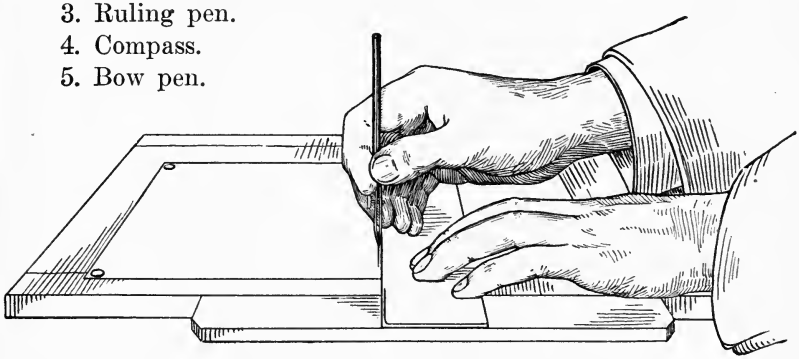


FIG. 111. RULING A HORIZONTAL LINE

Tracing Cloth. It will be noticed that one side of the tracing cloth has a glazed surface and the other a dull surface. Either side may be used under conditions described in Chapter V. For the tracings of this chapter use the dull side.

The cloth is fastened to the board with the same thumb tacks used to hold the paper. In order to avoid shifting the paper the cloth should be spread over the sheet and one tack at a time removed and inserted through the cloth into the hole from which it came.

To prepare the cloth so that it will take ink readily dust the surface lightly with powdered chalk. Rub thoroughly and remove all superfluous chalk.

Black Ink. Black ink will be used for all lines on the plates of this chapter. Replace the cork in the bottle.

The Ruling Pen should be held in the hand as shown in Fig. 111. Note that the first finger rests above the thumb screw with the second finger against the right side of the pen. The

pen should be held in a vertical plane, but it may lean slightly to the right. In this position both nibs will touch the cloth with equal pressure, which is essential to the production of smooth, sharply defined lines. Before using the pen it should be tested as described in Chapter V. The pen should be filled to the height shown in Fig. 111, about $\frac{1}{4}''$, by inserting the ink between the nibs with the quill which is attached to the stopper of the bottle. Care should be taken to avoid getting ink on the outside surfaces of the nibs. The pen should be adjusted to approximately the width of line required, before being filled.

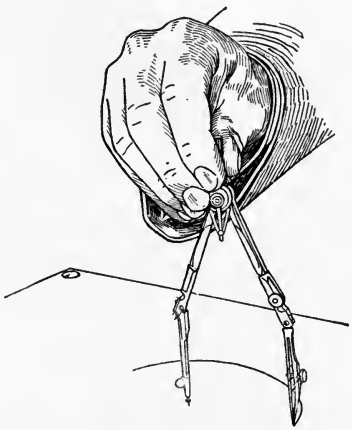


FIG. 112. DRAWING A CIRCLE WITH THE COMPASS

After it is filled it may be adjusted to the exact width of line. Clean the pen frequently by pulling a cloth downward between the nibs.

The center of the ink line should be directly over the pencil line in tracing. Care must be taken to set the pen exactly at the beginning of a line. At the end of a line the pen should be lifted vertically in order that the ink may not draw out and cause the line to overrun. In drawing dotted lines the pen must be set down vertically, the dash drawn and the pen then lifted vertically so as to make both ends of the dash square.

The spacing of section lines is done entirely by eye. In order to avoid varying the spaces the pen should be placed

against the ruling edge and the distance from the point of the pen to the last line drawn made equal to the perpendicular distance between any two sequential preceding lines.

When starting the crosshatching in a corner there is a tendency to space the lines too closely, the spaces increasing as the lines become longer. The student should practice crosshatching rectangular areas on a scrap of tracing cloth before attempting the work on the drawing.

The Compass. When using the compass for either penciling or inking, the legs should be adjusted so that the pen or pencil part and the needle point are *perpendicular* to the drawing board. With the legs in this position the compass revolves about the needle point as an axis and the two nibs of the pen bear with equal pressure, thus producing sharply defined lines. The compass is held by the handle, between the thumb and first finger of the right hand. It is rotated by rolling the handle between the thumb and finger. Fig. 112. The compass should be filled, adjusted, and cared for in the same manner as the ruling pen.

The Bow Pen is used for all circles and arcs of $\frac{3}{4}''$ radius or *less.* The pen should be filled and the nibs adjusted in the same manner as the ruling pen.

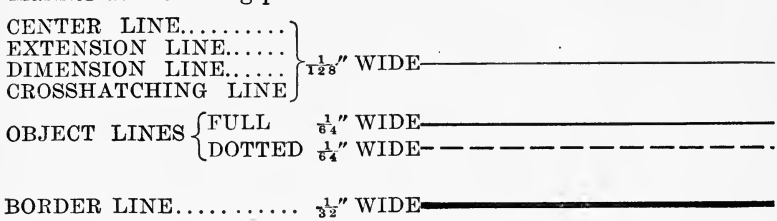


Fig. 113. Line Notation for Ink Drawings

Line Notation. In inking, the object lines are drawn noticeably heavier than all other lines except the border line. The difference in width thus secured produces a sharp contrast between classes of lines, which makes the drawing easy to read and gives it a good appearance. In small drawings or those containing intricate detail the width of the object lines is slightly reduced. In this course the standard widths of lines are as follows. See Fig. 113:

1. Object lines (full and dotted), $\frac{1}{64}''$ wide.

2. Center, extension, dimension, and crosshatching lines, $\frac{1}{128}''$ (estimated one-half the width of the object lines).
3. Border line, $\frac{1}{32}''$ wide.

Where lines of the same width are to be made with two different instruments, sample lines should be drawn on a scrap of tracing cloth and the pens adjusted until the lines are of exactly the same width.

The dotted lines should be composed of alternate $\frac{1}{8}''$ dashes and $\frac{1}{32}''$ spaces. A $\frac{1}{32}''$ space should also be left between the end of the extension line and the outline of the object. Correct and incorrect methods in line notation are shown in Fig. 56.

Order of Inking the Drawing. The drawing should be inked in the order given below to secure economy of time and effort.

1. Object lines.
   a. Circles and arcs of circles.
   b. Horizontal lines (beginning at the top).
   c. Vertical lines (beginning at the left).
   d. Inclined lines.
2. Center lines (same order as object lines).
3. Extension and dimension lines (same order as object lines).
4. Arrowheads.
5. Dimension figures and notes.
6. Crosshatching lines.
7. Title.
8. Border line.

In inking the title and notes, pencil guide lines on the tracing cloth will be found of great assistance in keeping the letters uniform in height.

Erasure. When it is found necessary to erase a line the shield should be used as in the pencil drawing. A ruby pencil eraser will remove the ink with the least injury to the cloth. The line can then be re-inked if necessary with little danger of the ink's spreading. When a blot occurs in an open area as much of the wet ink should be removed at once as possible and the spot allowed to dry before attempting to erase.

Trimming the Tracing Cloth. When the tracing is finished

lay off $\frac{1}{2}''$ from each corner of the border rectangle to make a one-half inch margin. Place the tracing on the back of the drawing board. With a sharp knife running along the edge of the T-square blade not used for ruling, trim the sheet to the rectangle determined by the eight pencil points. The T-square blade should be placed over the finished sheet. The drawing will then be held firmly and will be protected from the knife in case it should slip.

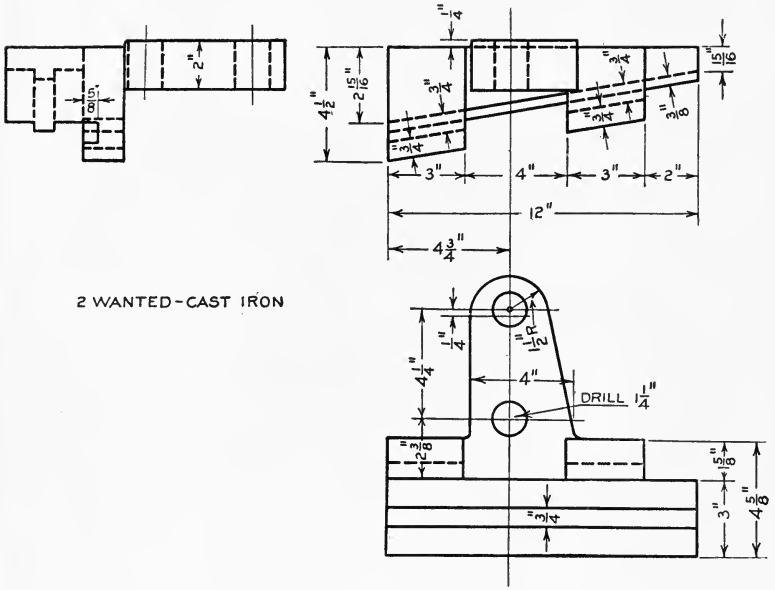


FIG. 114. TYPE PROBLEM—CLUTCH SHOE—GIVEN VIEWS

DATA FOR PLATE 19

Given: The pencil mechanical drawing, Plate 18.

Required: To make a tracing of Plate 18.

Instructions:

1. Fasten the tracing cloth over the mechanical drawing and prepare the surface for inking as previously described.

2. Ink the drawing following the steps outlined under, "Order of Inking the Drawing," page 112.

3. Trim the sheet to 11″x15″.

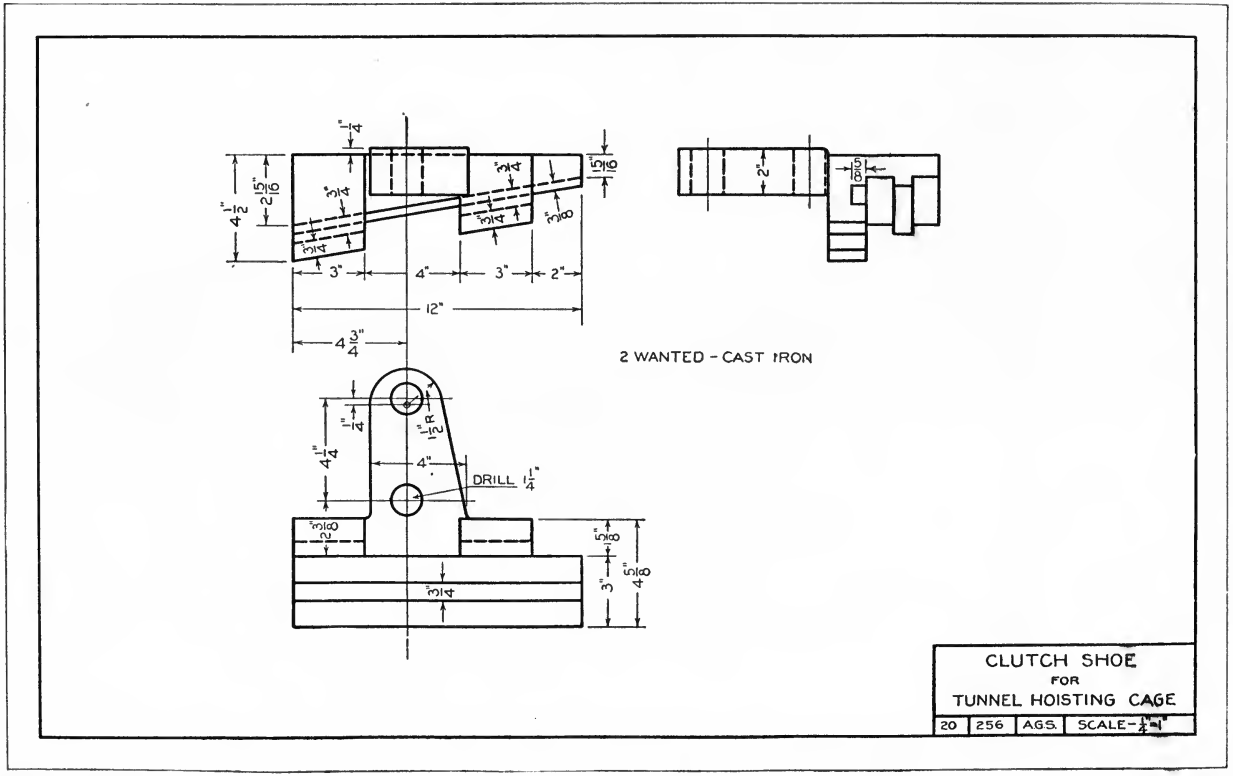


FIG. 115. TYPE PROBLEM—CLUTCH SHOE—FINISHED DRAWING

DATA FOR PLATE 20

Given: Orthographic sketches, Figs. 116, 117, and 118.

Required: To make a pencil mechanical drawing of the object shown in Fig. 116, 117, or 118, as assigned by the instructor. The views given and required may be obtained from the following table:

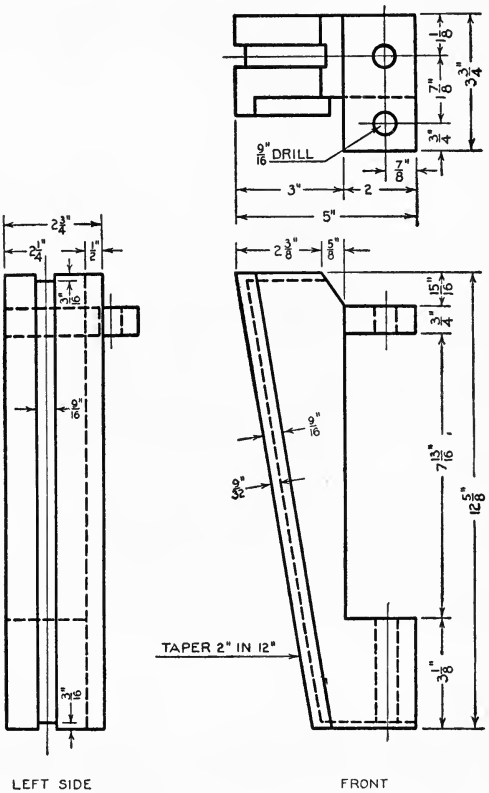


FIG. 116. CLUTCH BRACKET FOR PRESSURE TUNNEL HOISTING CAGE TWO WANTED—CAST IRON

Given

Fig. 116. Top, left side, and front views.
Fig. 117. Front and left side views.
Fig. 118. Front and right side views.

Required	Scale
Top, front, and right side views.	Half size
Front and right side views.	Quarter size
Front and left side views.	Half size

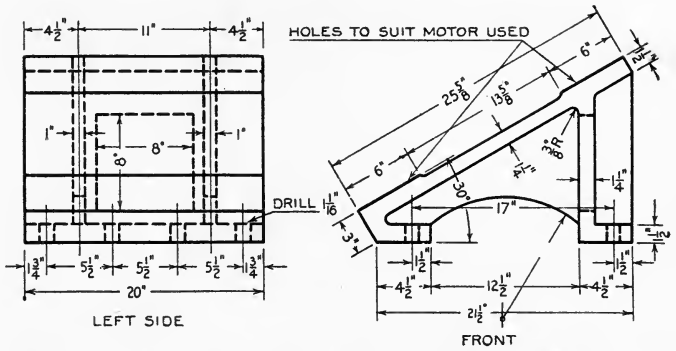


FIG. 117. MOTOR BRACKET FOR VALVE OPERATING MECHANISM
ONE WANTED—CAST IRON

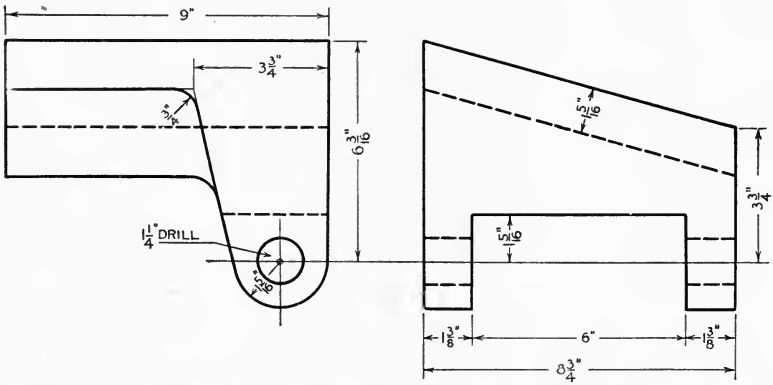


FIG. 118. THROTTLE LEVER FULCRUM FOR ATLANTIC TYPE LOCOMOTIVE
ONE WANTED—CAST IRON

PREPARATORY INSTRUCTIONS FOR PLATE 21

Blueprints should be made from the following tracings in order that the student may see that the lines on his tracing produce lines of the proper width on the blueprint.

Blueprinting. The most common method of reproducing drawings is by *blueprinting.* Blueprints are made on a white paper, one side of which has been coated with a solution sensitive to light. To make the prints, the inked side of the tracing is placed against the glass of a printing frame. The sensitized side of the blueprint paper is then placed against the tracing cloth and held firmly in contact with it.

The length of exposure to the light depends on the intensity of the sunlight or electric light and upon the "speed" of the blueprint paper. After removing the paper from the frame it should be washed by turning it over several times in a basin of water. This removes the chemical on the sensitized side of the paper which was covered by the lines of the drawing on the tracing cloth and leaves the white paper exposed, forming the outline of the blueprint drawing. The result is a reproduction of the drawing in white lines with a blue background.

DATA FOR PLATE 21

Given: The pencil mechanical drawing, Plate 20.

Required: To make a tracing of Plate 20.

Instructions:

1. Fasten the tracing cloth over the mechanical drawing and prepare the surface for inking.

2. Ink the drawing, following the steps outlined under, "Order of Inking the Drawing," page 112.

3. Trim the sheet and press the cloth back into the tack holes.

PREPARATORY INSTRUCTIONS FOR PLATE 22

Tangencies. In mechanical drawing where a straight line is tangent to an arc, the arc should be drawn first. In the constructive stage the arc should be drawn long so that it will extend beyond the point of tangency. A straight edge may then be laid tangent to the arc and the straight line drawn in.

Before the drawing is finished the unnecessary part of the arc is erased.

Centers for rounded corners, fillets and other arcs of circles, which do not have their centers on any line of the drawing,

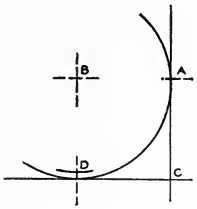


FIG. 119. "TRIAL AND ERROR" METHOD OF LOCATING CENTERS

are located by what is called the "trial and error" method. The compass should be first adjusted to the proper radius. To locate the center of the arc, set the lead on the tangent line at A, Fig. 119, estimating A C as nearly as possible equal to

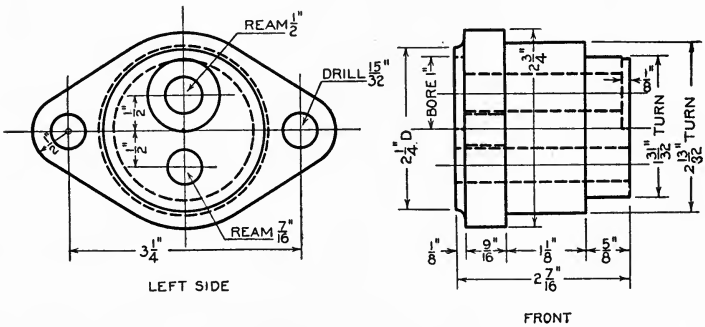
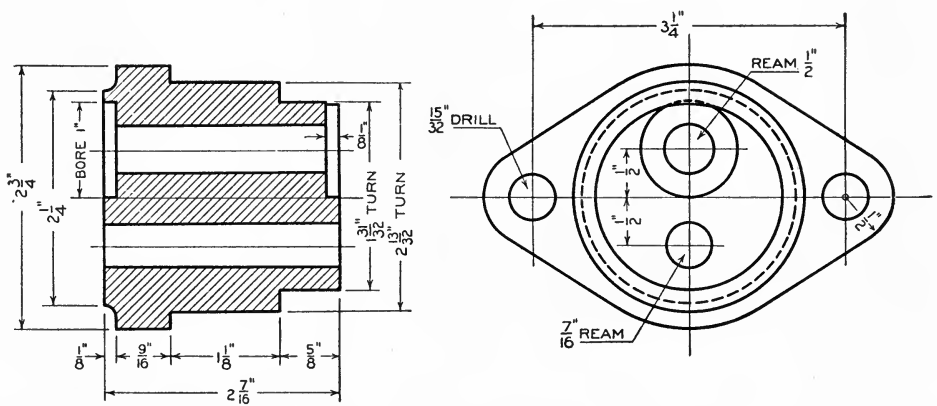


FIG. 120. TYPE PROBLEM—IGNITOR BODY—GIVEN VIEWS

the radius of the arc. Set the needle point at B opposite A and bring the lead around to D. Move the needle point parallel to A C an amount equal to the error. Then the compass should be again rotated back to A to test for accuracy, and if necessary further adjustment should be made before drawing the arc.



IGNITOR BODY FOR 6 H.P. GASOLINE ENGINE			
22	256	A65	SCALE-FULL SIZE

FIG. 121. TYPE PROBLEM—IGNITOR BODY—FINISHED DRAWING

DATA FOR PLATE 22

Given: Orthographic sketches, Figs. 122, 123, and 124.

Required: To draw the views of the object shown in Fig. 122, 123, or 124, as assigned by the instructor. See table below.

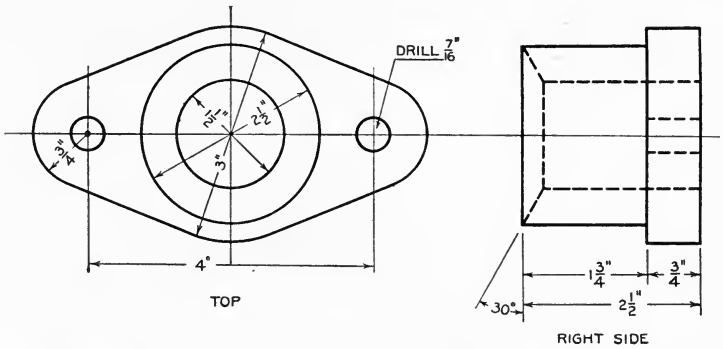


FIG. 122. STUFFING BOX GLAND FOR 22"x42" CORLISS ENGINE ONE WANTED—CAST IRON

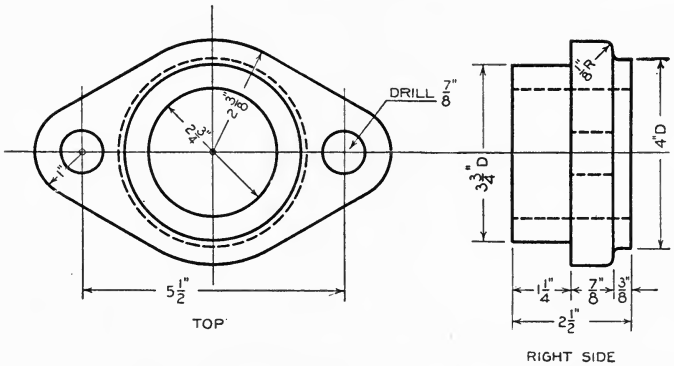


FIG. 123. BEARING FOR 2¾" SHAFT—ONE WANTED—CAST IRON

Given

Fig. 122. Top and right side views.
Fig. 123. Top and right side views.
Fig. 124. Top and right side views.

Required	Scale
Top and front half section views.	Full size
Top and front half section views.	Full size
Top and front half section views.	Half size

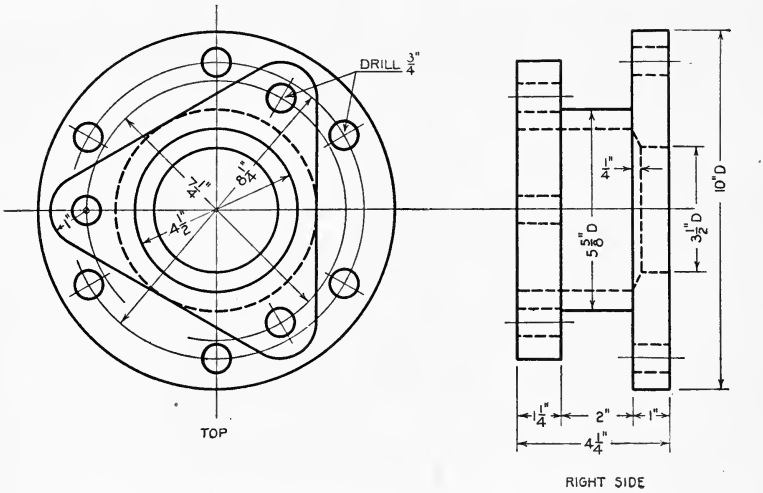


FIG. 124. STUFFING BOX FOR 36" GATE VALVE—ONE WANTED—CAST IRON

PREPARATORY INSTRUCTIONS FOR PLATE 23

Locating Points of Tangency. To secure perfect joints where lines are tangent in the tracings the exact points of tangency should be located and marked in pencil on the tracing cloth. The method of locating the tangent points depends upon the geometrical principle, that a line perpendicular to a tangent at its point of contact passes through the center of the circle.

To locate a point of tangency place the hypotenuse of either triangle against any edge of the other triangle, as shown in Fig. 125. Move them as one tool until a side of the triangle A is coincident with the tangent line. With triangle B held firmly in place, slide triangle A into the position marked A′ where the side at right angles to the tangent line passes through

the center of the arc. A short dash should be drawn across the tangent line to mark the point of tangency.

The point of tangency between two arcs may be located by drawing the straight line joining their centers. This line passes through their point of contact.

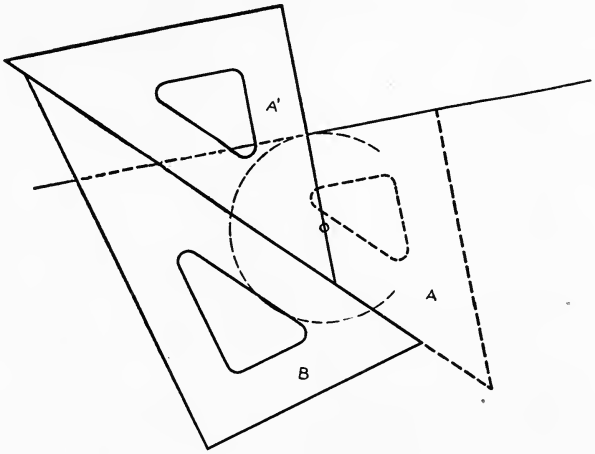


Fig. 125. Method of Locating Points of Tangency

DATA FOR PLATE 23

Given: The pencil mechanical drawing, Plate 22.

Required: To make a tracing from Plate 22.

Instructions:

1. Fasten the tracing cloth and prepare it for inking.
2. Locate the points of tangency.
3. Ink the drawing in the usual order.
4. Trim the sheet and press the cloth back into the tack holes.

Summary

The pencil mechanical drawing of Chapter III has been continued in this chapter to develop further skill in the use of instruments and to improve the technique in both the mechanical and freehand elements of the drawing. It has been the chief

aim of this chapter to familiarize the student with the instruments, materials, and methods used and to fix a standard of technique in inking. The student should now be able to make neat tracings with proper width of lines, good joints, and uniform spacing in crosshatching. The technique of the lettering, arrowheads, and figures should be comparable with that secured in the mechanical line work.

Review Questions

1. (a) Define half section. (b) How does a half section differ from a quarter section?

2. (a) What is the difference between the two sides of the tracing cloth? (b) Which side is used in this course?

3. (a) Describe the process of fastening the cloth over the pencil drawing. (b) How is the cloth prepared for inking?

4. (a) How is the ruling pen held for ruling lines? (b) How is it adjusted to the proper width of line? (c) How is it filled? (d) How cleaned?

5. (a) What precautions are taken in beginning and ending a line? (b) How does the pen approach and leave the paper in drawing dotted lines?

6. How are the spaces between crosshatching lines estimated?

7. (a) Why are the needle point and the pen and pencil points of the compass set at right angles to the plane of the drawing paper? (b) How is the compass held when drawing a circle? (c) How is it rotated?

8. (a) In inking why are the object lines made wider than the other lines? (b) Give the standard width of inked object, extension, dimension, and center lines, and the border line.

9. In what order are the different kinds of lines inked?

10. (a) In what order are the object lines inked? (b) Center lines? (c) Extension and dimension lines?

11. How is ink removed from a drawing?

12. How is the tracing trimmed to the required size?

13. (a) Upon what geometrical principle does the method of finding the point of tangency between an arc and a straight line depend? (b) Give the steps in the construction necessary to locate a point of tangency.

DATA FOR REVIEW PROBLEMS

Given: The top, front, and right side views of an object. Fig. 126.

Required: To draw the top, front half section, and right side views of the object shown in Fig. 126. Scale, full size.

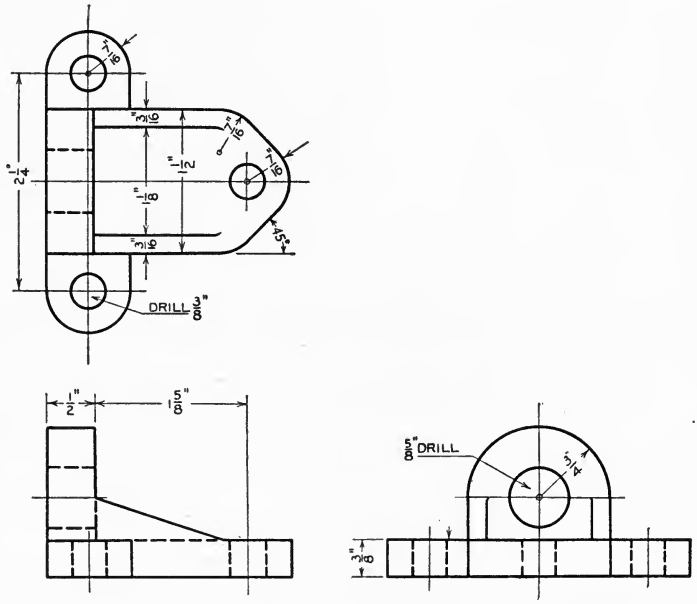


FIG 126. SAND BOX BRACKET FOR ATLANTIC TYPE LOCOMOTIVE ONE WANTED—CAST IRON

Given: The top, front, and right side views of an object. Fig. 127.

Required: To draw the top, front, and left side views of the object shown in Fig. 127. Scale, half size.

Given: The top and right side views of an object. Fig. 128.

Required: To draw the top and front half section views of the object shown in Fig. 128. Scale, half size.

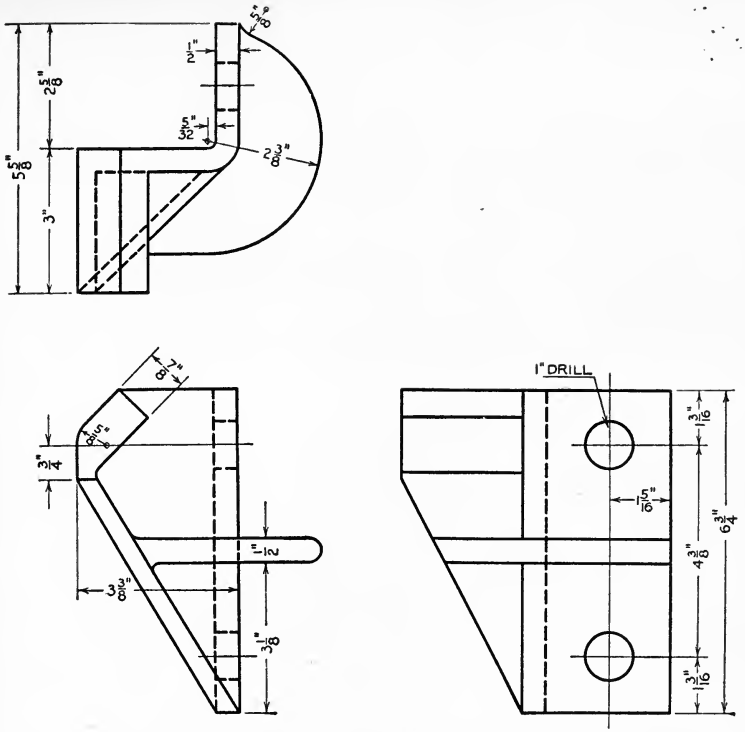


FIG. 127. DEAD LEVER FULCRUM FOR ATLANTIC TYPE LOCOMOTIVE
ONE WANTED—CAST IRON

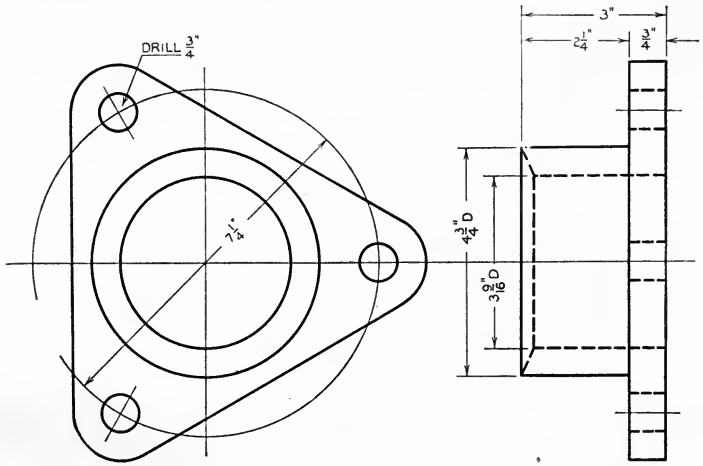


FIG. 128. STUFFING BOX GLAND FOR 36" GATE VALVE
ONE WANTED—CAST IRON

CHAPTER V

INSTRUMENTS AND MATERIALS

Drawing Paper. In selecting a drawing paper the draftsman should have in mind the purpose for which it is to be used. The quality of the paper required depends upon such elements as the following: The nature of the drawing, whether freehand or mechanical; whether it is to be a rough sketch or a fine line drawing; whether or not the drawing is to be inked; the amount of erasing necessary, etc. For whatever purpose it is to be used the paper should be strong and have a uniform surface and thickness.

For *freehand drawing,* where it is desired to produce a porous, uniform line with a soft pencil, a slightly grained surface is satisfactory. It should stand erasing without injury. These qualities are essential for the paper used in the perspective and orthographic sketching in this course.

Under some conditions in orthographic sketching it is convenient to use cross-section paper. Fig. 276. By its use the views of a complicated object are more easily related and their details are more readily proportioned. It will be found of special value in sketching the machine parts described in Chapter VIII.

For *mechanical drawing,* where a sharp, fine line is to be produced with a hard pencil, a tough, hard paper should be used. It should stand considerable erasing without injury to the surface. It should not become brittle or discolored from reasonable exposure or age. If freehand lettering is to be done the surface must be reasonably smooth to secure the best results. If considerable time is to be spent on a drawing, a paper should be selected which has an agreeable tint and which will not soil easily with handling. The paper used for the mechanical drawings of this course must fulfil these requirements.

The more common brands of drawing paper may be purchased either in sheets or rolls. The standard names and sizes of sheets are as follows:

Cap	13″ x 17″	Imperial	22″ x 30″
Demy	15″ x 20″	Atlas	26″ x 34″
Medium	17″ x 22″	Double Elephant	27″ x 40″
Royal	19″ x 24″	Antiquarian	31″ x 53″
Super Royal	19″ x 27″		

In rolls the same brand of paper is usually less expensive than in sheets. Rolls vary in width from twenty-seven to seventy-two inches. Small rolls are sold by the linear yard and large rolls by weight.

Tracing Paper. For temporary drawings, especially where some part of a machine or structure is to be duplicated, a thin transparent paper called *tracing paper* may be used with a considerable saving of time. It should not be used for a permanent drawing or one which will require much handling.

Tracing Cloth is a thin, firm cloth sized to hold ink and to make the cloth transparent. It is generally used when drawings are to be reproduced by the blue, black, or brown printing process. Drawings made on tracing cloth may be kept indefinitely if the cloth is kept dry and handled carefully. The drawings may be changed and new prints made from time to time.

One side of the cloth is glazed and the other is dull. Either side may be used for inking. The glazed side will admit of more erasing, but when inking is done on this side the cloth will curl. For work where penciling is to be done on the cloth, for drawings to be used for photographic reproduction, and for tinting, the dull side should be used.

Sometimes the ink does not adhere to the surface of the cloth, particularly when the glazed side is used. To overcome this difficulty powdered chalk may be rubbed into the surface with a soft cloth. The chalk should be thoroughly removed before inking.

Blueprint Paper. Instead of sending the tracing into the shop where it would soon be injured or worn out, prints are

made, usually on *blueprint* paper. This is a white paper covered with a solution which, after being exposed to light, turns blue when washed in water. The result is white lines on a blue background. The method of making blueprints is described in detail on page 117.

Van Dyke Paper is similar to blueprint paper except that it gives a white line on a brown background. It is usually used

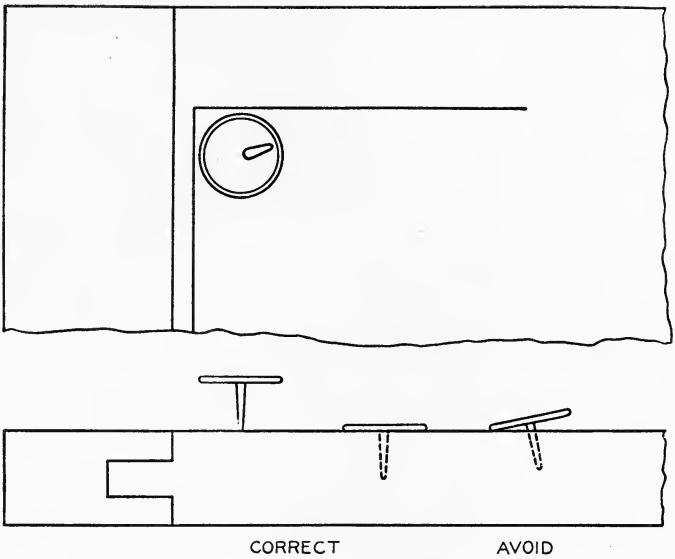


FIG. 129. POSITION OF THUMB TACKS

for making negatives from which positive blueprints are made—*i. e.*, prints having blue lines on a white background.

Thumb Tacks. Drawing paper and tracing cloth are fastened to the drawing board by means of thumb tacks. In order that the thumb tacks may hold the paper or cloth firmly and not be an obstruction to the T-square and triangles, they should be pressed down vertically until the heads are flush with the paper. Fig. 129.

Pencils. The lead of the drawing pencil should be of firm, even grain. To secure the desired effect in the drawing the

hardness of the pencil must be considered in connection with the surface of the paper. For freehand drawing a soft pencil should be used on a slightly grained surface. A soft pencil is easily controlled and consequently there is more freedom in drawing lines with it than can be secured with a hard pencil. The soft sketching pencil should be sharpened to a blunt conical point, as described on page 18.

For mechanical drawing, where it is desired to produce fine sharp lines, a hard pencil should be used on a comparatively smooth, hard surfaced paper. One end of the mechanical drawing pencil should be sharpened to a wedge point for ruling full lines and the other end to a fine conical point for laying off measurements and making dotted lines. The method of sharpening the pencil is described on page 84.

Drawing pencils are graded as to hardness as follows:

Soft: 6B, 5B, 4B, 3B, BB, B.
Medium: F, H, HH, 3H, 4H.
Hard: 5H, 6H, 7H, 8H, 9H.

Manipulation of the Pencil. In sketching, the pencil is held as in writing. Horizontal lines are drawn in short sections with a wrist movement. The hand is moved into a new position for each section. In drawing vertical lines the strokes are made downward with a finger movement. See page 20.

For the short strokes in lettering the finger movement is used since the muscles of the fingers are more sensitive than those of the wrist or arm. The vertical strokes are made with a finger movement and the horizontal, inclined, and curved strokes with a combined finger and wrist movement.

In ruling lines the pencil is inclined slightly forward and the line is drawn with a movement of the hand and forearm. See page 85.

The Eraser. Ordinarily a medium hard eraser, such as the ruby, is used for removing pencil lines from a drawing. A soft flexible eraser is very satisfactory for cleaning a pencil drawing without erasing the lines. When erasing lines the paper near the lines to be erased should be held down with the thumb and first finger of the left hand to prevent it from crum-

bling or tearing. On ink drawings erasures must be carefully made, especially if inking is to be done over the erased areas. It will be found that if the ruby eraser is used for removing ink lines the drawing surface will be left in good condition for re-inking. In case a blot occurs the ink should not be allowed to soak into the tracing cloth. As much of the ink as possible should be taken up with a blotter or cloth and the remainder allowed to dry before erasing.

The Erasing Shield is used to protect the parts of the drawing which are not to be erased. The opening best suited to expose only the part to be erased is selected The shield is held

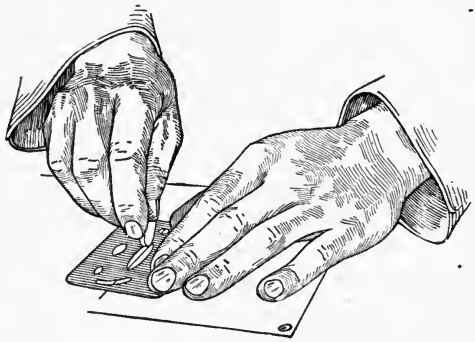


FIG. 130. USING THE ERASER AND SHIELD

in position on the drawing with the thumb and first finger of the left hand, while the eraser is applied with the right. Fig. 130. Where the openings are not of a suitable form a shield may be made by cutting a hole in a piece of celluloid or thin stiff paper. Stock erasing shields are made of brass or celluloid.

The Drawing Board should be made of well seasoned, straight grained, soft wood, free from knots and cracks. The best boards are designed to prevent warping, various means being used to accomplish this end. Some are built up of narrow strips glued together; others have a series of saw cuts in the back running lengthwise with the grain to reduce the transverse strength Such boards are made rigid by cleats of hard wood screwed through oblong slots fitted with metal bushings to the

back of the board. This construction allows the board to expand and contract, the screws sliding in the slots. The board is also equipped with side ledges or strips of hardwood set into the end edges to allow the T-square to move easily. Fig. 131.

For accurate work it is necessary that the edge of the board, against which the head of the T-square is placed, be perfectly straight and that the face of the board be a perfect plane. To *test the edges* of the board place on each a standard straight

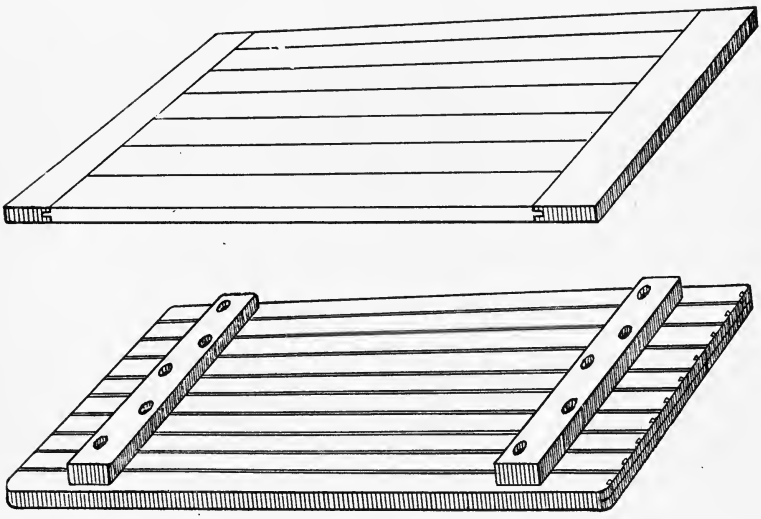


Fig. 131. Drawing Boards

edge or the edge of a T-square blade which is known to be straight. An edge of the board is straight if, when held up to the light, the straight edge is in contact at all points.

The surface of the board may be tested in like manner by placing the straight edge upon it in various positions.

The edges and surface of the board should be kept free from cuts, scratches, and bruises. The board should not be subjected to extremes of temperature or moisture.

The T-Square is used to draw horizontal lines and to provide an edge against which the triangles are placed. It consists

of a rule called the blade attached to one end, which is a cross-piece called the head. Fig. 132. The head is sometimes fastened to the blade by means of a swivel, so that the blade may be set at any desired angle.

T-squares are made of steel, hard rubber, and wood. The steel blade is the most accurate but tends to soil the drawing. For ordinary work wooden blades are used. They are usually made of maple, mahogany, or pear wood and their edges are often lined with hardwood or celluloid,

The celluloid edges make it possible to see lines near the one to be drawn and are therefore quite convenient when joining lines at corners, etc.

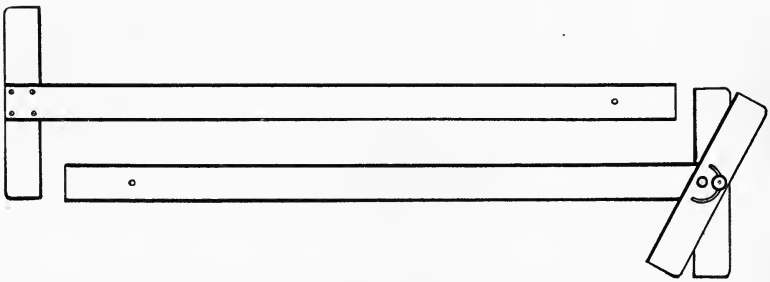


FIG. 132. T-SQUARE—PLAIN AND SWIVEL HEAD

The upper or working edge of the T-square and the edge of the head which rests against the drawing should be perfectly straight. The edge of the blade may be tested as follows: (1) Draw a long line along the edge of the blade. (2) Reverse the ends of the blade with respect to the ruled line, keeping the *same side up* and bringing the *same edge* against the ruled line. (3) Draw a second line along this edge of the blade. If the edge of the blade is straight the two lines will coincide. Both the head and the blade of the T-square may also be tested by means of a straight edge. Since the T-square is used only for ruling parallel lines, and as lines at other angles are drawn with the triangles in combination with the T-square, it is evident that the edge of the head and blade need not be exactly at an angle of 90° to each other.

Care should be taken to preserve the upper edge of the blade of the T-square from injury. It should never be used as a guide for the knife in cutting paper.

When using the T-square the head is pressed firmly against the edge of the board with the left hand as shown in Fig. 86. The lines are always drawn along its upper edge.

The Triangles are used in combination with the T-square for drawing lines at certain angles to the horizontal. They are used in combination with the T-square for drawing lines at various angles with lines which are not horizontal.

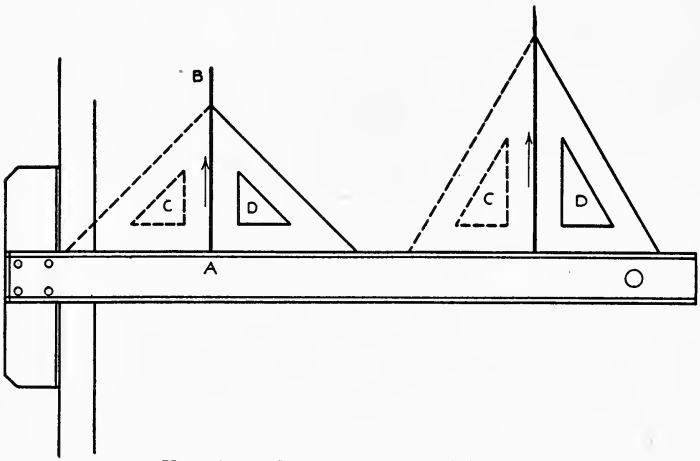


FIG. 133. TESTING THE 90° ANGLE

They are made of steel, wood, hard rubber, or celluloid. Steel triangles are used for the most accurate work. Triangles made of wood are easily injured and are likely to change their shape. Those made of celluloid have the advantage of being transparent and are most generally used.

For accurate work it is necessary that the edges of the triangles be straight and that the angles be true. The edges may be tested by the method given for testing the T-square.

Assuming that the edge of the T-square has been found to be straight, the 90° angle of a triangle may be tested as follows: Place the triangle in position D, as shown in Fig. 133, and

draw the line A B. If, when the triangle is turned over into position C, the vertical edge coincides with the line A B, the angle is 90°. When the 90° angle of the 45° triangle has been found true, the 45° angles are true if equal.

Compare the two 45° angles as follows, Fig. 134: (1) Place the triangle against the T-square and draw a 45° line. (2) Turn the triangle over so that the other 45° angle comes into the position previously occupied by the first. If the edge of the triangle coincides with the line drawn, the 45° angles are equal.

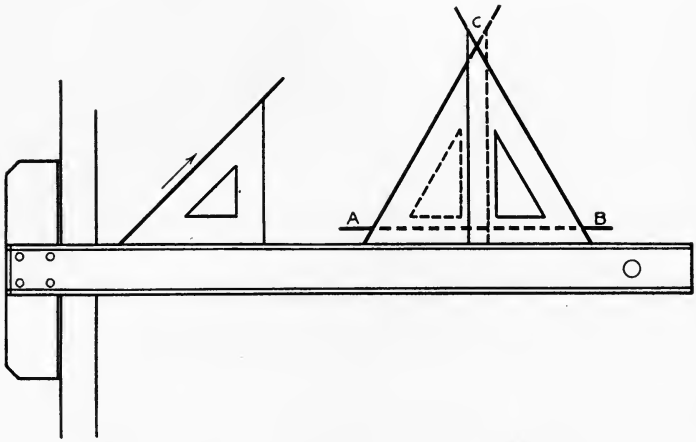


FIG. 134.
TESTING THE 45° ANGLE

FIG. 135.
TESTING THE 30° AND 60° ANGLES

The 60° angle of a 30°–60° triangle may be tested as follows: (1) Draw a horizontal line, A B, along the T-square. Fig. 135. (2) Draw a 60° line, B C, along the edge of the triangle crossing the horizontal line. (3) Turn the triangle over and draw a second 60° line, A C, completing a triangle. If the triangle formed is equilateral the 60° angle is true.

The lengths of the sides of the triangle may be compared by means of the dividers. When the edges are straight and the 90° and 60° angles are found to be true, the remaining angle, 30°, will also be true.

With the 30°–60° triangle, lines may be drawn at 90° to the horizontal and at 30° or 60° with the horizontal to the right and to the left. Fig. 136.

With the 45° triangle, lines may be drawn at 90° to the horizontal and at 45° with the horizontal to the right and to the left. Fig. 137.

By combining the two triangles, lines may be drawn at 15° or 75° with the horizontal to the right and to the left. Fig. 138.

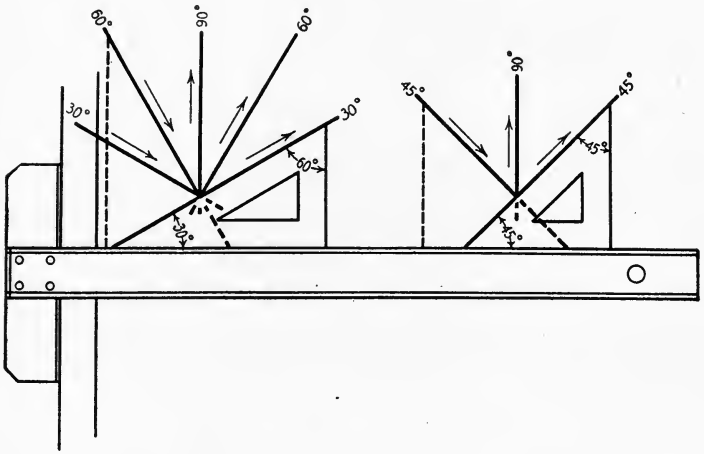


FIG. 136. LINES DRAWN WITH THE 30°-60° TRIANGLE

FIG. 137. LINES DRAWN WITH THE 45° TRIANGLE

Lines parallel to any given line may be drawn by placing the two triangles in contact and sliding them as one tool until an edge of one of them coincides with the given line. Fig. 139. With the triangle A held firmly in place, triangle B may be moved along it and lines drawn parallel to the given line.

Lines perpendicular to the given line may be drawn along the edge of triangle B, which is at 90° to the given line.

The direction in which the lines should be drawn along the triangles is shown in Figs. 136 and 137. The forearm should always make a right angle with the line being drawn.

The edges of the triangles should not be cut or bruised. If they are allowed to fall on the floor a corner may be blunted and

as a result the angle will not be true. The celluloid triangles should not be allowed to remain bent for any length of time, as they will remain permanently so.

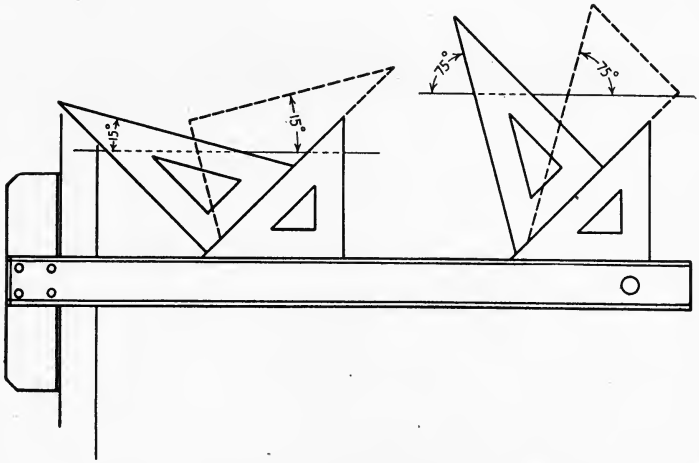


FIG. 138. LINES DRAWN WITH A COMBINATION OF THE 30°-60° AND 45° TRIANGLES

The Irregular Curve is used for drawing a smooth curve through a series of points. It is made from the same materials as the triangles. Various sizes and forms may be had to fit different curves.

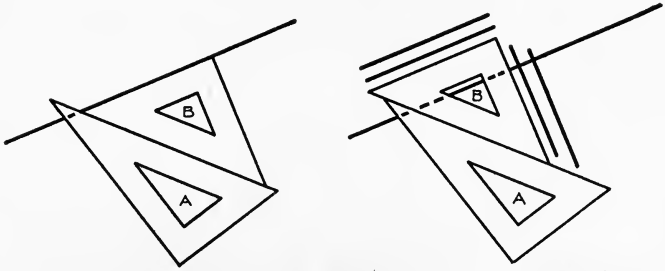


FIG. 139. LINES DRAWN PARALLEL OR PERPENDICULAR TO ANY GIVEN LINE

The line is drawn in sections obtained by selecting portions of the irregular curve which will pass through a number of given points. Fig. 259. It is seldom advisable to draw through

all of the points of the section of the line to which the curve is fitted, since the direction of the line at the end of the section is apt to be such that the succeeding section cannot be joined to it to produce a smooth curve. To make sure of a good joint the curve for each section should *fit back* a short distance on the preceding section.

Scales are used for taking measurements and laying off distances. They are made of paper, steel, and wood. Ordinarily scales are made of boxwood. There are two general forms, the flat and the triangular. The flat scale may have from one to four graduated faces and the triangular scale from four to six graduated faces. The graduations are placed directly on the wooden face of the scale or the face is coated with a white compound which makes the graduations easier to read.

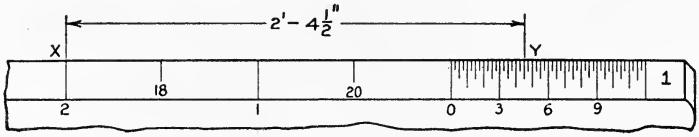


FIG. 140. READING THE ARCHITECT'S SCALE

The faces of the scales are graduated as follows:

The Engineer's Scale is divided to 10, 20, 30, 40, 50, and 60 parts to the inch. It is full divided, *i.e.,* the small divisions are marked off for the full length of a face.

The Architect's Scale is divided to $\frac{3}{32}$, $\frac{3}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$ and 3 inches to the foot. The edges on this scale are open divided, *i.e.,* only the portion of a face representing one foot is subdivided to read in smaller units. One face of the scale is usually divided to $\frac{1}{16}''$ for its full length.

To illustrate the reading of the architect's scale consider the edge designated by a figure 1 at the end. Fig. 140. This indicates that one inch on this scale represents one foot. The inch to the right of the 0 at the right end of the scale is divided into forty-eight equal parts so that each of the smaller divisions represents $\frac{1}{4}''$ and the spaces between the 0, 3, 6 and 9 represent 3″ each. To the left of the 0 the readings 1, 2, etc., are inches and therefore represent feet. To measure off 2′, $4\frac{1}{2}''$

to the right of point X, place the 2 opposite the point and read four and one-half inches to the right past the 0. In case it is desired to lay off this distance to the left of Y, place the four and one-half inch mark opposite Y and read past the 0 to the 2.

The Proportional Inch Scale is divided to read one-half or one-fourth inch to the inch and has one face divided to $\frac{1}{16}''$ for its full length. The open divided edges are read in the same manner as is the architect's scale. The difference is that in this case the large division represents inches instead of feet. One of the large divisions is subdivided to read sixteenths.

Drawing Instruments. In beginning drawing it is important that the student have a good set of instruments. It is difficult to define a "good" set of instruments, for the better grades are extensively imitated. The student should be guided in his selection either by some experienced draftsman or by the trade mark and the price charged by a reliable dealer.

A good set of instruments differs from a poor one, mainly, in the quality of materials used, correct tempering, and good workmanship. The steel of the pens must be properly tempered so that when once sharpened the points will remain in good condition for a reasonable time. The compass and dividers must be so made that they will retain their alignment and adjustment when handled with ordinary care. These qualities can only be definitely determined after the instruments have been given a fair trial.

To secure uniformly satisfactory results in drawing it is necessary to start with a good set of instruments and to keep them in good condition. In the following discussion the selection, use, and care of each of the drawing instruments is considered.

The Compass is used for drawing circles and arcs of circles. Fig. 112. The better grades are made of German silver. It is important that a compass be light, yet rigid. The most important part of the compass is the head which, in the modern instruments, consists of two discs held in contact in a fork by means of pivot screws. By adjusting these screws the pressure between the discs is regulated. This pressure should be such that the legs of the compass may be opened or closed without springing them.

On the other hand, the joint should be tight enough to retain its setting when the instrument is in use.

The thing of next importance is the socket joint of the removable pen and pencil parts. These are made in various forms. They usually consist of a shank on the pen and pencil parts which fits into a corresponding socket in the compass leg. The proper position of the shank in the socket is insured by some device such as a feather or sharp corner on the shank

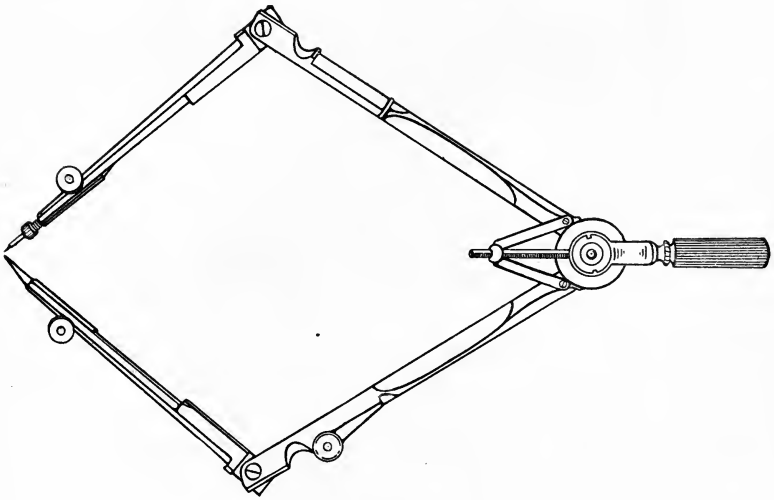


FIG. 141. TESTING THE COMPASS

which is matched by a corresponding slit or groove in the socket. These parts are made to clamp together with a thumb screw or else a bayonet fitting is used.

The legs of the compass and its parts should move in the same plane. To test the compass for alignment place the parts in the sockets, bend the legs out at the head, and then bring the joints together, as shown in Fig. 141. If the points come exactly together the joints are true.

Before using a compass the needle point and lead should be adjusted as follows: Place the pen in the compass and adjust the needle point so that it projects slightly beyond the nibs of the pen. Remove the pen; replace the pencil and adjust the

lead so that it is slightly shorter than the needle point. The pen and pencil parts are now interchangeable without adjusting the needle point.

The compass lead should be sharpened to a wedge point similar to the ruling point of the pencil. The width of the wedge in this case should be about one-half the diameter of the lead.

In describing a circle the lower portion of the legs should be bent so that they are perpendicular to the plane of the paper. Fig. 112. The compass will then revolve about the needle as an axis and, when inking, the nibs of the pen will bear upon the paper with equal pressure, which is a condition that must be fulfilled in order that the ink line will not be ragged.

Before drawing a circle in pencil the radius should be marked off on a center line. The needle point should then be set exactly at the intersection of the center lines and the compass adjusted to the proper radius. The circle or arc is drawn by rotating the compass, the handle being rolled between the thumb and first finger of the right hand. The lead or pen should stop exactly at the starting point without lapping the line.

The large compass should not be used for circles of less than $\frac{3}{4}''$ radius. For very large circles the lengthening bar should be inserted between the leg of the compass and the pen or pencil part. Where this does not suffice a beam compass should be used.

Dividers are similar to compasses in general appearance. The legs terminate in sharp steel points. The dividers are used for laying off distances from the scale, for transferring lengths, or for dividing straight or curved lines into any number of equal parts.

To divide a line into any number of equal parts with the dividers proceed as follows: Assume that the line is to be divided into three equal parts. (1) Open the dividers to what is estimated to be one-third the length of the line. (2) Step off the estimated distance three times on the line. (3) Adjust the dividers to one-third the error, making the distance between the points larger or smaller as the case may require. (4) Repeat the process until the third step ends exactly at the end of the

line. In taking the steps the dividers are held by the handle between the thumb and first finger and swung alternately first to one side of the line and then to the other, as shown in Fig. 142. This avoids rolling the handle into an awkward position between the thumb and finger.

The Bow Pen, Bow Pencil, and Bow Dividers. The bow pen and bow pencil are used to describe small circles, and the

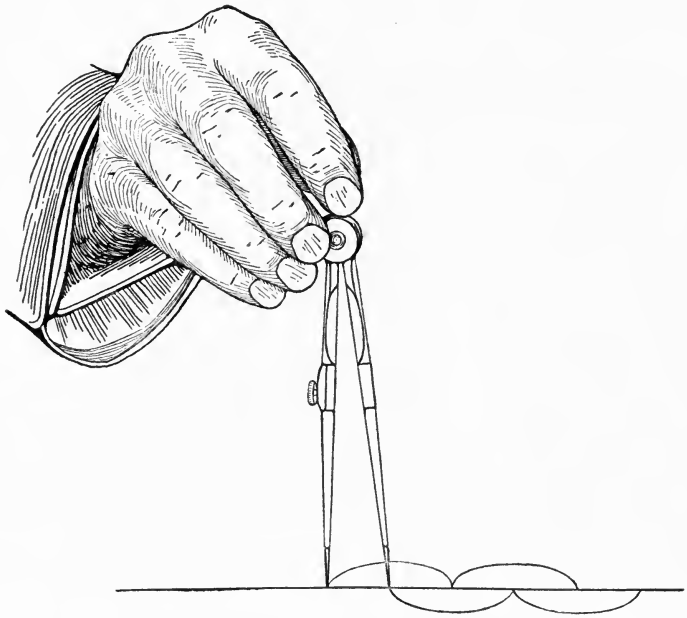


FIG. 142. STEPPING OFF WITH THE DIVIDERS

bow dividers to lay off small distances. They have the advantage that they retain their adjustment. There are two forms of adjusting devices, as shown in Fig. 143. To make large adjustments in the instruments having side screws the pressure on the nut should be relieved by pressing the legs together with the left hand while the nut is made to spin with the first finger of the right hand.

The Ruling Pen is used more than any other instrument in the draftsman's outfit and should therefore be carefully selected.

The steel of which the pen is made should be properly tempered and of such quality as to retain a smooth, sharp edge. The blades should be of the same length, the inner one sufficiently stiff to resist a light pressure against the ruling edge. The nibs should be of the same width, equally rounded and directly opposite each other. The ends of the nibs should be narrow enough to give control in starting and ending lines but broad enough to hold a reasonable amount of ink. When the nibs are too narrow the ink is drawn from the points by capillary attraction, making it difficult to start the ink at the beginning of a line.

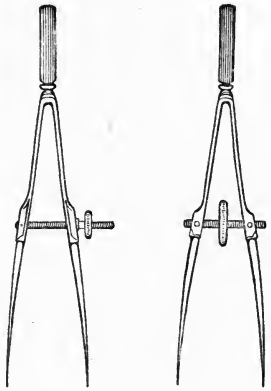


FIG. 143. CENTER AND SIDE SCREW ADJUSTMENT OF BOW INSTRUMENTS

For very long or heavy lines a Swedish pen will be found convenient, as it will hold more ink than the ordinary pen.

The ruling pen should be adjusted, filled, and used in the following manner: (1) Adjust the pen by turning the thumb screw to approximately the proper width of line. (2) Fill the pen by inserting the quill, attached to the stopper of the ink bottle, between the nibs of the pen. Be sure there is no ink on the outside of the nibs. (3) Set the pen to give the exact width of the line required, testing it on the margin of the drawing or on a separate sheet. It should be tested on the same kind of surface as that on which it is to be used. (4) Hold the pen in the hand, as shown in Fig. 111, with the first finger

above the thumb screw and the second finger against the right side of the pen. It should be held in a vertical plane, but may be allowed to lean slightly in the direction of motion. (5) Draw rather slowly with a movement of the hand and arm, the forearm remaining perpendicular to the line being drawn. There should be no wrist movement as the pen must not be rotated upon its axis. The tips of the third and fourth fingers should slide on the surface of the T-square or triangle to steady the hand. As the end of the line is approached the motion of the hand and arm should cease and the line should be completed with a finger movement.

The pen should be cleaned frequently by inserting a cloth at the side and pulling it out between the nibs. This should be done while the pen is in use. The pen should not be laid away until the surfaces are thoroughly cleaned as ink will corrode steel. If the ink does not start readily at the beginning of a line squeeze the nibs of the pen together slightly to draw the ink down to the point. If the ink has been allowed to stand for some time the pen should be cleaned and refilled. Do not touch the pen to the hand or a cloth to start the ink. Various devices are on the market for making it possible to open a pen for cleaning without changing the adjustment. The best of them must be handled with care to avoid changing the setting.

The pen of the compass should be filled, adjusted, and cared for in the same manner as the ruling pen.

The nibs of the pen should be as sharp as they can be made without producing the sensation of cutting when the pen is in use. They should not scratch the paper when drawing a line. This occurs if they are sharpened to a point instead of a rounded edge, or if the point is rough or notched. The length and condition of the points may be tested by holding the pen up to the light and bringing the nibs together slowly.

In case the pen becomes broken or dull from use it should be sharpened as follows: (1) Provide a close-grained oil stone. (2) Close the nibs until they just touch each other. (3) Hold the pen on the stone as in drawing a line and move it back and forth, revolving it slowly in the plane of motion until the nibs are evenly rounded and of the same length.

Fig. 144. This will dull the nibs. (4) Separate the nibs and sharpen them by rubbing the *outside* on the oil stone, giving at the same time a slight rotary motion to the handle, which is held

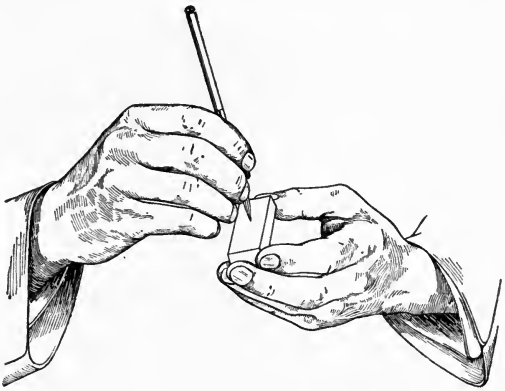


FIG. 144. SHARPENING THE PEN—EVENING THE NIBS

at a small angle with the face of the stone. Fig. 145. The point of the pen should be examined frequently and the process continued until the nibs are sharp. If a burr is produced on the inside of a nib it may be removed by placing the inside surface flat against the oil stone and rubbing it lightly.

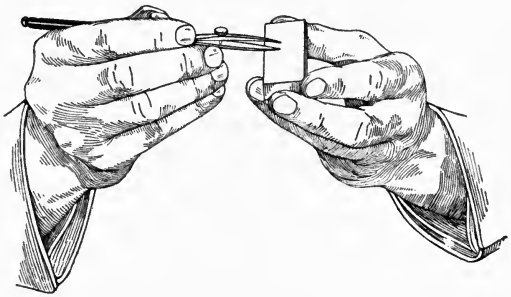


FIG. 145. SHARPENING THE PEN—GRINDING THE NIBS

The Protractor is an instrument used for laying off degrees. It usually consists of a semicircular disc of cardboard, brass, celluloid, or steel, graduated to read to one or one-half degrees. For more accurate work it may be had with an arm and a vernier, reading to one minute.

CHAPTER VI

CONVENTIONS

Line Notation. Through the medium of lines a working drawing conveys information as to the form of an object. A line notation is therefore necessary. The distinction between the lines is usually made by varying their width or color, or by using discontinuous lines with certain combinations of dashes and spaces.

In a pencil drawing the lines must be heavy enough to be easily seen through the tracing cloth, but their widths must be approximately the same. In a tracing, however, which is used in making a print for the workman, a variation in width is possible and assists in conveying the necessary information.

While the object lines should be noticeably heavier than the auxiliary lines of a drawing, the draftsman should use his judgment as to the width of each in any particular case. In general the lines will be narrower the more intricate the detail of the drawing. The line notation given in Fig. 113 shows the weights of lines suitable for most of the tracings in this course.

The following references will give definitions and uses of the different kinds of lines in a drawing:

Object line. Page 111
Dotted line. Pages 53, 56, 112
Center line. Pages 69, 112
Extension line. Pages 57, 58, 112, 184
Dimension line. Pages 57, 58, 112, 184
Crosshatch or Section line. Pages 69, 104, 112
Broken line. Page 154

All of the above lines except the broken line are made mechanically. It is made with a writing pen.

Dimensioning. The draftsman's judgment is used more in dimensioning than in making any other part of the drawing. To avoid mistakes and to facilitate the work of the mechanic, only necessary dimensions should be given. They should be placed in such a way as to make the drawing easily read. Cases are rare where it is advisable to repeat the same dimensions on different views. Repeating dimensions adds to the difficulty in checking them and when changes are made there is a possibility of making a change in one place and not in another. This leads to confusion. Placing dimensions in obscure and out-of-the-way places should be avoided. Whenever possible dimensions should be grouped in such a way as to make their relation obvious. It should not be necessary for the mechanic to do any calculating to obtain necessary dimensions.

No doubt the best guide to follow is for the draftsman to imagine himself in the mechanic's place and to consider the operations through which the object must go to become a finished product. With this idea in mind and with a working knowledge of shop methods, which every draftsman should possess, most problems in dimensioning will be solved without difficulty. For example, when a machinist drills a hole he sets the point of the drill at its center; hence the hole should be dimensioned by referring its center to some surface, line, or point easily accessible.

In machine drawings dimensions are usually given in inches *up to* twenty-four inches. *Above* twenty-four inches they should be given in feet and inches. Examples: $23\frac{1}{2}''$, $2'—4\frac{1}{2}''$.

In structural drawings all dimensions *above* twelve inches read in feet and inches. Examples: $11\frac{1}{2}''$, $1'—3\frac{3}{4}''$.

For all ordinary work fractions in dimensions containing mixed numbers have the following denominators: 2, 4, 8, 16, 32, 64; such denominators as 6 or 19 are not used. When very small fractions of an inch are necessary, as in the case of special fits, etc., the fractional part of an inch may be expressed in decimals of three or four places. Example: 5.006″ bore.

The following references will give examples of dimensioning in detail:

The dimension form. Page 184
Linear dimensions. Page 81
Angular dimensions. Page 62
Diametrical dimensions. Page 70
Radial dimensions. Page 97

Figures and Notes. If a drawing is to present a neat appearance a suitable type of letter and figure should be used for all notes and dimensions. A very plain letter should be selected; one that can be drawn with reasonable rapidity and that will be in harmony with the remainder of the drawing. It is essential that a standard height be adopted and adhered to for all notes and figures on the drawing. For this course the standard height for the whole number is $\frac{1}{8}''$ and the total height of the fraction $\frac{1}{4}''$ as shown in Fig. 196. Whenever possible notes should be lettered on horizontal guide lines. The letters should be $\frac{3}{32}''$ high. To insure uniform heights for all notes the distance between the ruled guide lines should be accurately laid off with the scale or stepped off with the dividers.

For the plates of this course, up to and including those of Chapter IV, the vertical Gothic letters and vertical Arabic numerals will be used for all dimensions and notes. For all succeeding plates the inclined lower case Gothic and inclined Arabic numerals will be used. As a rule inclined letters are used for notes in office practice.

The Title is usually placed in a rectangle in the lower right-hand corner of the sheet. Various elements may enter into the title, depending upon the character of the drawing and the use to be made of it. The following items are usually found in the titles of commercial drawings of machines or structures.

1. Name of part or parts of machine or structure.
2. Name of complete machine or structure.
3. Manufacturer's firm name and address.
4. Drawing number.
5. Date of finishing drawings.
6. Scale to which drawing is made.
7. Initials of draftsman, tracers, and checker.

The relative importance of the items of a title is shown by varying the heights or weight, or both, of the letters. In some drafting offices a rubber stamp is used on the pencil drawing to obtain the words and lines that are common to all drawings. The same words and lines are often printed on the tracing cloth in type. Example: Fig. 146. The style of letter used should be plain and dignified, whether printed in type or drawn free-

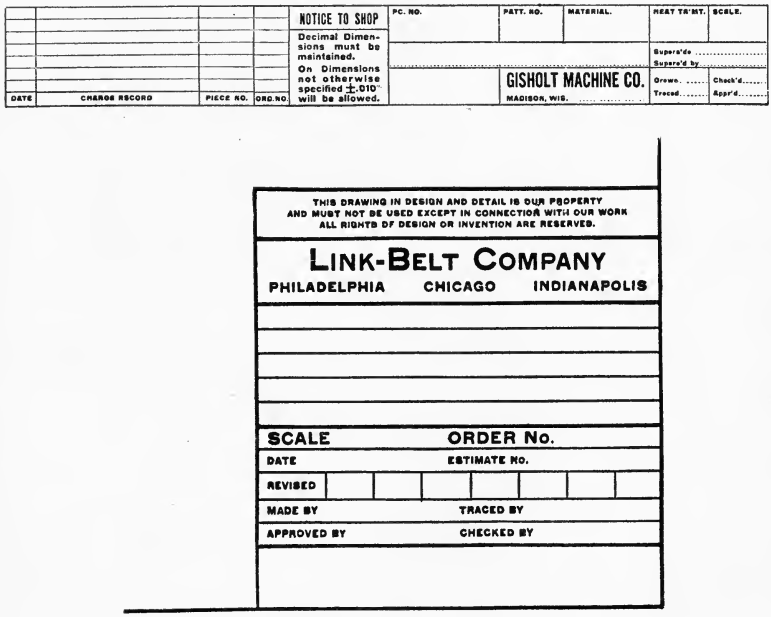


FIG. 146. COMMERCIAL TITLES

hand. For all titles in this course the vertical capital letters should be used.

A Bill of Material may be given on the drawing or on a separate sheet. It is a tabulated form in which such information as the following is given:

1. Number of each part required on one complete machine or structure.

2. Description or name of piece.

3. Mark or number by which a piece is designated on the drawing.
4. General drawing number.
5. Shop drawing number.
6. Erection drawing number.
7. Material from which each piece is made.
8. Pattern number, if cast.
9. Where used.
10. Estimated weight.
11. Order number.

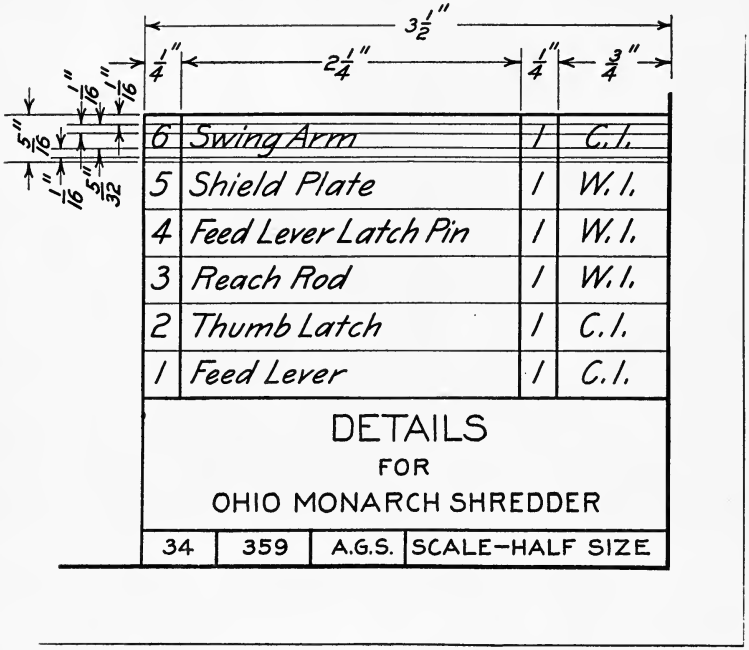


FIG. 147. BILL OF MATERIAL

The bill of material includes standard parts such as bolts and screws which are not detailed on the drawings. A simple bill of material is shown in Fig. 147.

Sectional Views. Very often a drawing is not clear because the interior of the object is complex or because a part of it is obscured by other lines. In such cases the object may be represented more clearly if a portion of it is imagined cut away to expose the hidden part. The most common exam-

ples of this method of representation are: (1) half-section in which the object is cut into two similar parts through an axis of symmetry, and (2) quarter-section in which the object is cut

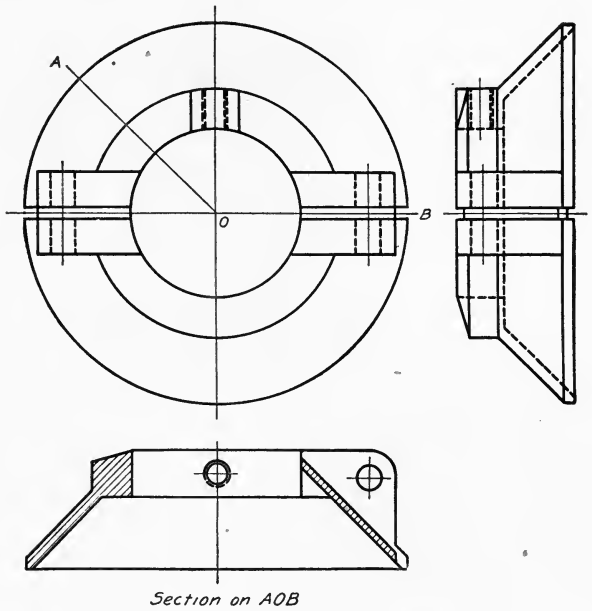


FIG. 148. BROKEN LINE SECTION

into the center on two planes at right angles. These sections are described in detail and illustrated on pages 68 and 104.

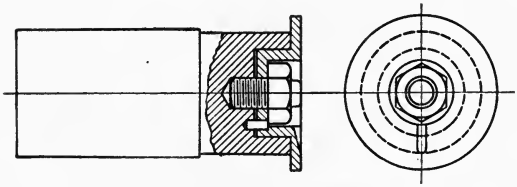


FIG. 149. PARTIAL SECTION

Other methods of sectioning may be used, depending upon the form of the object or part which it is desired to make clear. Fig. 148 illustrates a case where the section is taken on a broken line, AOB. In drawing the section view, the cut surface OA is considered revolved into the same plane with OB. Fig. 149

illustrates what is called a partial section. The ragged line indicates that a part of the shaft has been broken away.

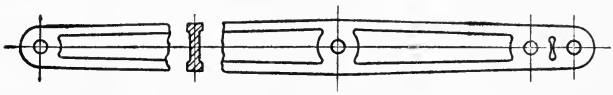


FIG. 150. REVOLVED SECTION

The cross-section of an object is often given by showing a revolved section in one of the views, Fig. 150 or 151. Where

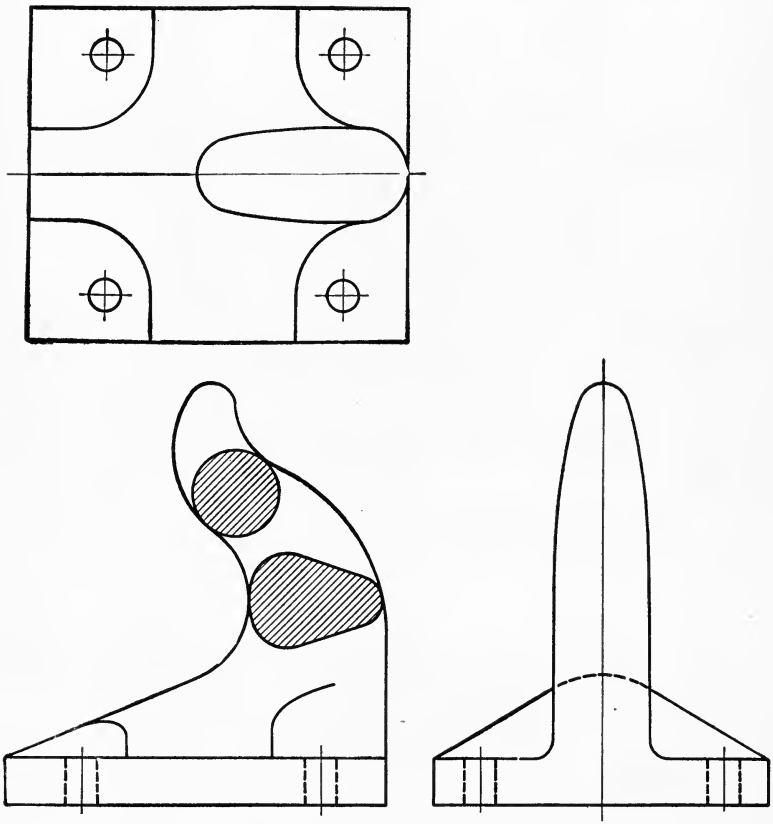


FIG. 151. REVOLVED SECTION

the section cannot well be revolved a line may be drawn across the view of the part at the place where the section is taken and

the section drawn in an open space near the view. Reference should be made to the line on which the section is taken. Fig. 152. Such parts as spokes or arms of wheels, solid shafts or

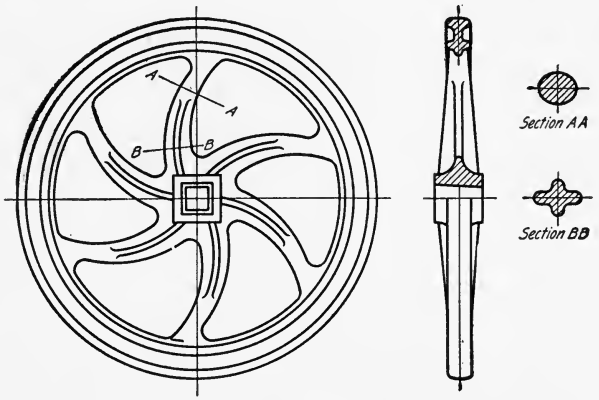


FIG. 152. SEPARATE SECTIONS

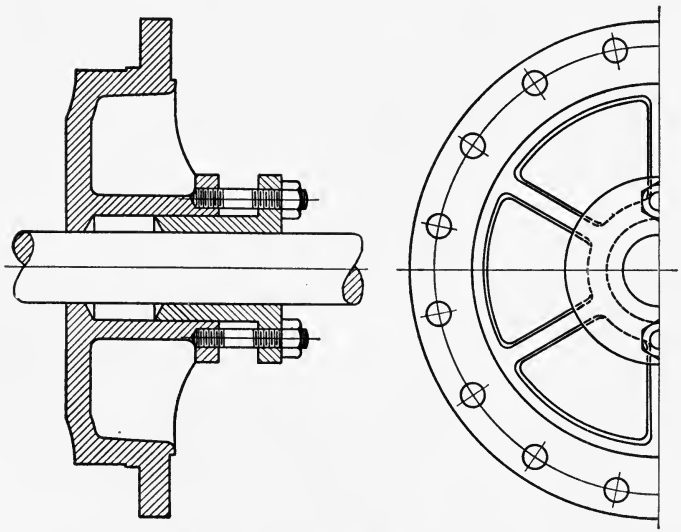


FIG. 153. SECTION THROUGH RIBS, SHAFTS, BOLTS, ETC.

rods, screws, bolts, studs, and nuts are not represented as cut when the section plane passes through their axes. Fig. 153.

Ribs and webs are not sectioned when the section plane is parallel to their lateral faces.

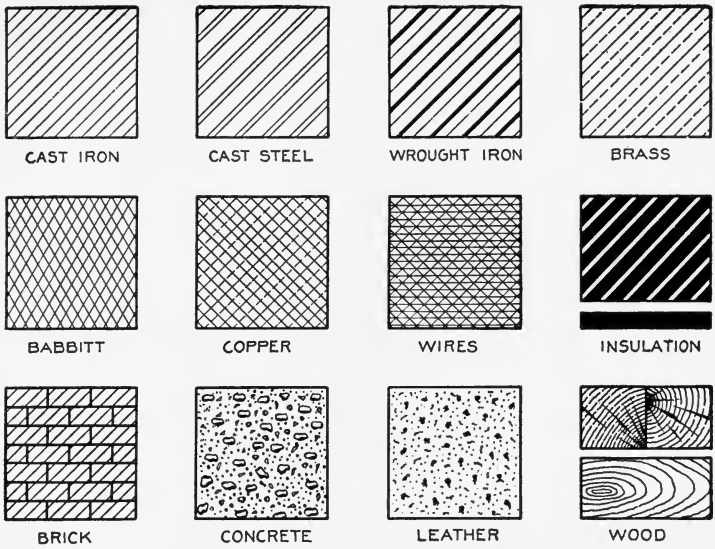


FIG. 154. CONVENTIONAL CROSS-SECTIONING

When a section is taken through an assembly, adjacent parts are crosshatched in different directions to aid in distinguishing one from another.

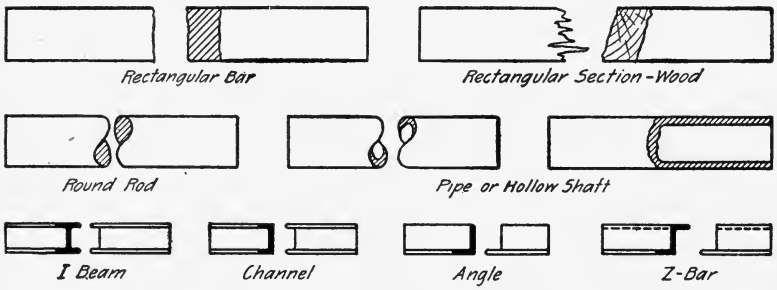


FIG. 155. CONVENTIONAL BREAKS

Various combinations of lines are used to represent sections of different materials. No standard section notation has ever been universally adopted. It is customary to add a note giving the name of the material unless a local section notation is in

use. Except for a few cases where it is desirable to distinguish between the metals in adjacent parts, such as the babbit and the casting of a bearing, nothing is gained by using characteristic section lines since, in general, a note must be added to insure proper interpretation.

Fig. 154 shows a few sections in common use.

Breaks. Where it is desirable to omit part of a shaft or rod either may be broken and the break indicated as shown in Fig. 155. The ragged line representing the break is drawn freehand in both the pencil and the ink drawing.

Screw Threads. The curve of the screw thread is the helix. It is generated by a point which moves on the surface of a

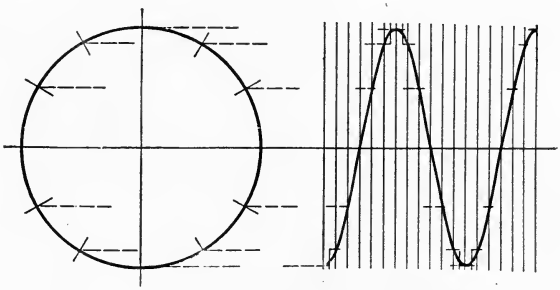


Fig. 156. Construction of the Helix

cylinder and which advances uniformly in the direction of the axis of the cylinder and at the same time has a uniform motion around its axis. Fig. 156 shows the construction for the helix. The distance in the direction of the axis traversed by a point in one revolution is called the *pitch*. Pitch in the case of a thread is its advance in the direction of the axis in one revolution.

In Fig. 157 the proportions of the several common thread forms are shown to a large scale.

The V-thread is shown in Fig. 158 as it would actually appear with the edges drawn as helices. On account of the difficulty of constructing and drawing these curves they are usually conventionalized into straight lines as shown in Fig. 159. The method commonly used for representing screws up to about one inch in diameter, as measured on the drawing, is still further

simplified by omitting the short inclined lines forming the "saw teeth." Fig. 160. On the pencil drawing no distinction is made in the weight of the two sets of parallel lines drawn across the screw, but on the tracing it is customary to make a striking contrast between the longer and shorter lines as shown.

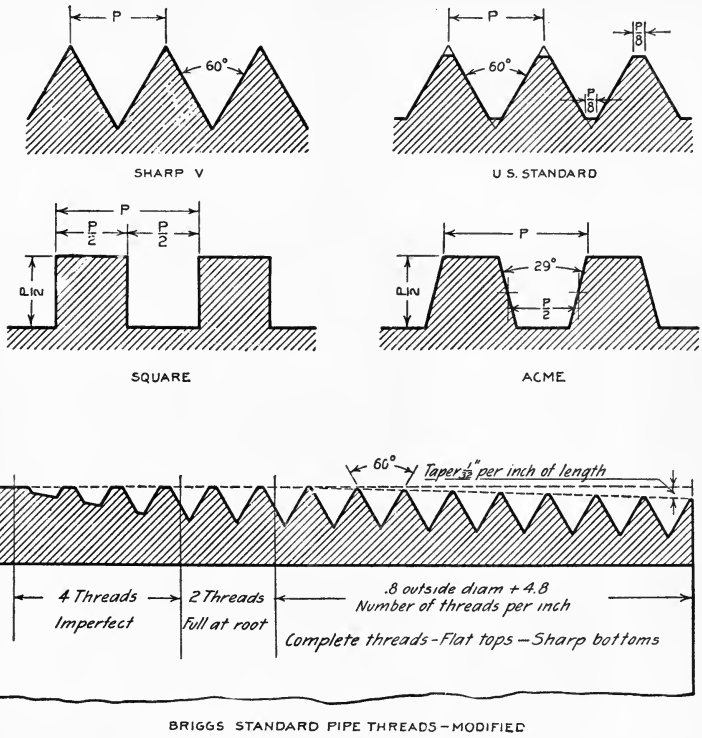


Fig. 157. Proportions of Common Thread Forms

In this course the shorter lines will be made object-line width and the longer lines center-line width. The angle at which these lines are drawn is estimated. It remains practically constant for all sizes of standard screws as the pitch of the thread increases with the diameter of the screw. It will be noted that the lines in the section view of the nut make the opposite angle to the horizontal that those on the screw make because of the fact that

the part of the nut shown matches the *invisible* half of the screw. The lines are usually spaced by eye. Guide lines should be drawn to limit the length of the shorter lines.

In the conventional end view of the bolt, the circle representing the outer edges of the thread is a full line, while one-

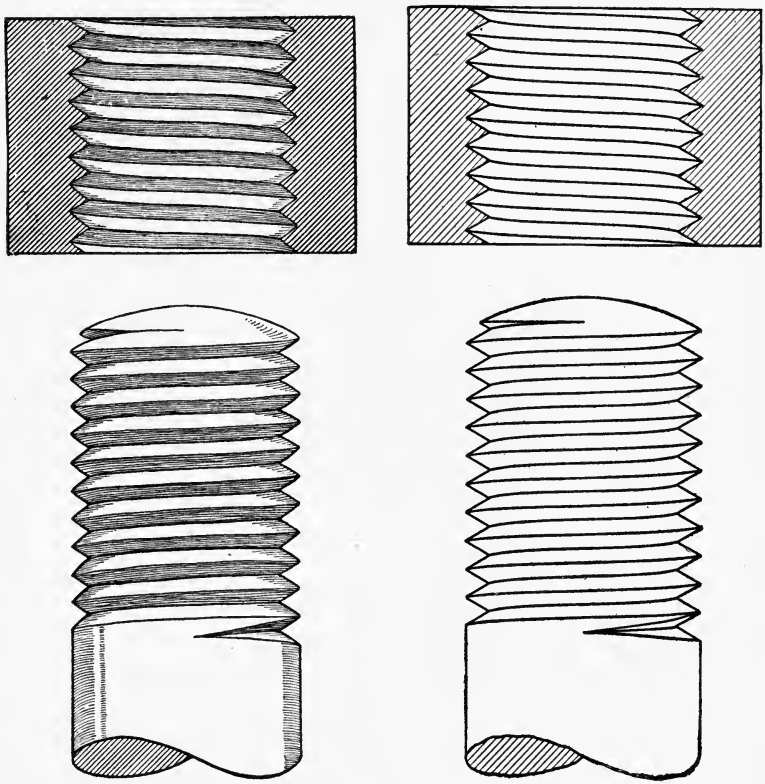


FIG. 158. V-THREAD—SHOWING HELICES

half of the circle representing the inner edges of the thread is a dotted line and the other half is a full line.

In the conventional end view of the nut, the circle representing the inner edges of thread is a full line, while one-half of the circle representing the outer edges of the thread is a dotted line and the other half is a full line.

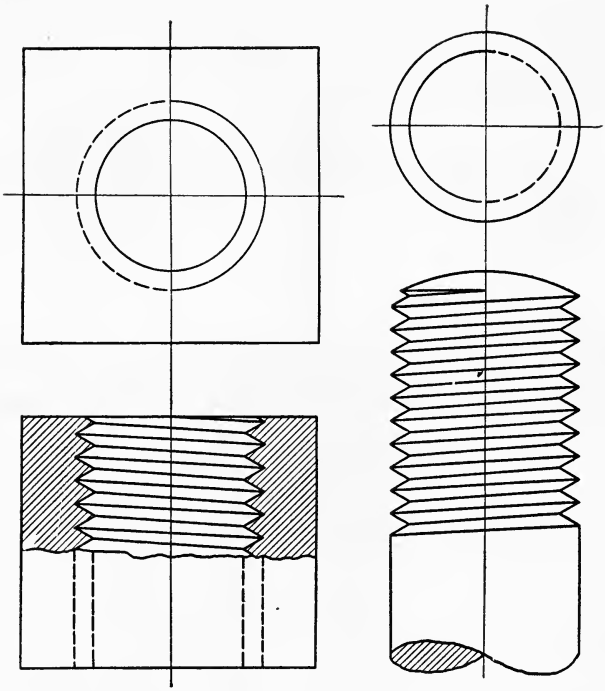


FIG. 159. V-THREAD—CONVENTIONAL REPRESENTATION FOR LARGE SIZES

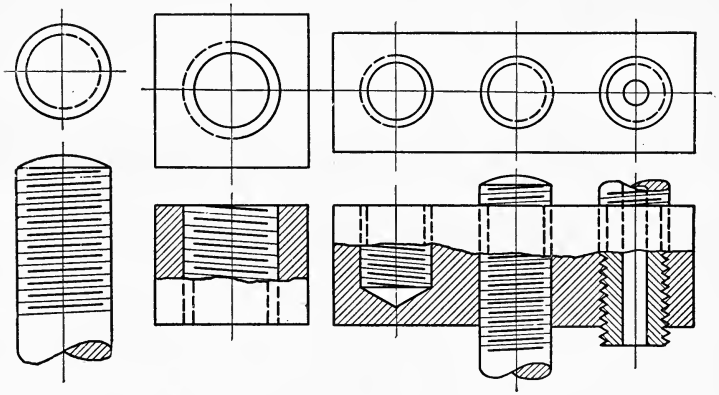


FIG. 160. V-THREAD—CONVENTIONAL REPRESENTATION FOR SMALL SIZES

A study of the relation of these conventions to the form of the object should enable the student to fix in mind the principles on which they are based. With this relation in mind it

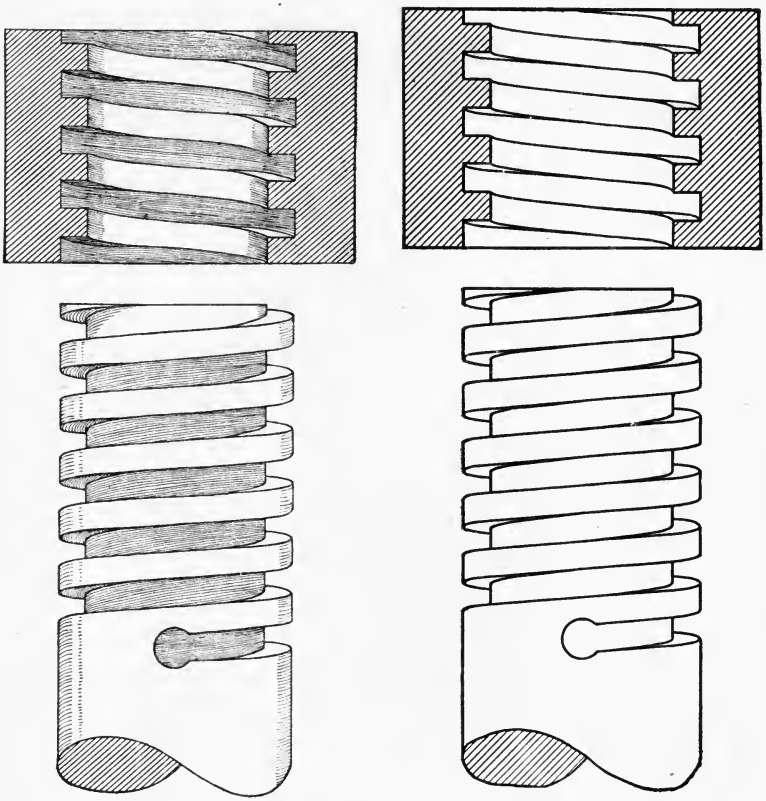


FIG. 161. SQUARE THREAD—EDGES DRAWN AS HELICES

will be unnecessary for him to refer to the figures in rendering the convention.

The United States Standard (U. S. S.) or Sellers thread, Fig. 157, differs from the sharp V-thread in that the outer and inner edges of the thread are flattened. The same convention is used for representing it that is used for the sharp V-thread.

The Square Thread is shown in Fig. 161 with the edges drawn as helices. Fig. 162 is a conventional representation of the

screw and nut in which the helices have been replaced by straight lines.

For small sizes the method shown in Fig. 163 is generally used because of its simplicity. The Acme screw thread is rep-

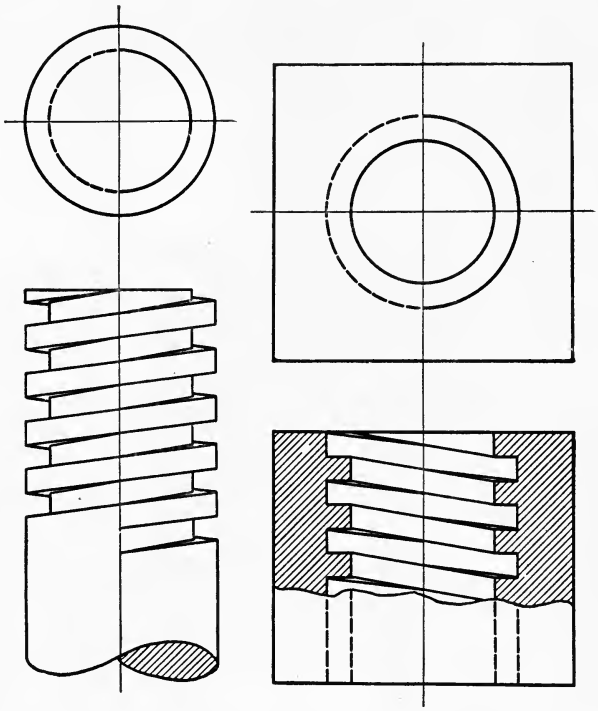


FIG. 162. SQUARE THREAD—CONVENTIONAL REPRESENTATION FOR LARGE SIZES

resented conventionally as shown in Fig. 164. It is convenient in drawing to make the angle between the faces of the thread 30° instead of 29°.

Pipe Thread. The basic form of the Briggs standard pipe thread is that of the V-thread. This thread is rounded slightly at the outer and inner edges. A modified form in which the threads have flat outer edges and sharp inner edges is shown in Fig. 157. This form is used by manufacturers because of

the comparative ease with which taps and dies are made for cutting the threads.

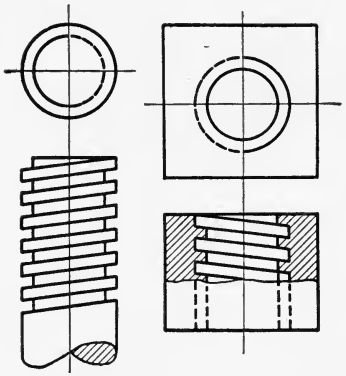


Fig. 163.
Square Thread — Conventional Representation for Small Sizes.

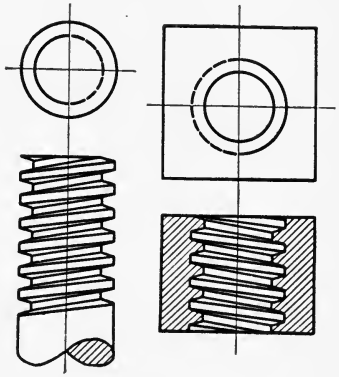


Fig. 164.
Acme Thread — Conventional Representation

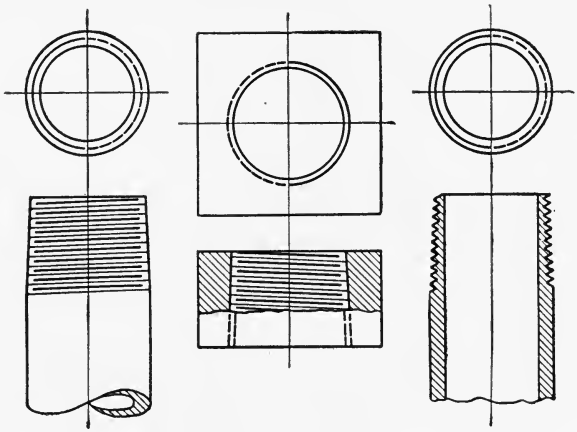


Fig. 165. Pipe Threads—Conventional Representations

The threaded portion of the pipes tapers one thirty-second of an inch in radius for each inch of length. A table of pipe sizes is given on page 265.

Pipe threads are represented conventionally as shown in Fig. 165.

Springs. The curve of the coil spring is the helix. Fig. 166 shows a spring in which the curves are drawn and also the conventional representation which shows the curves replaced by straight lines.

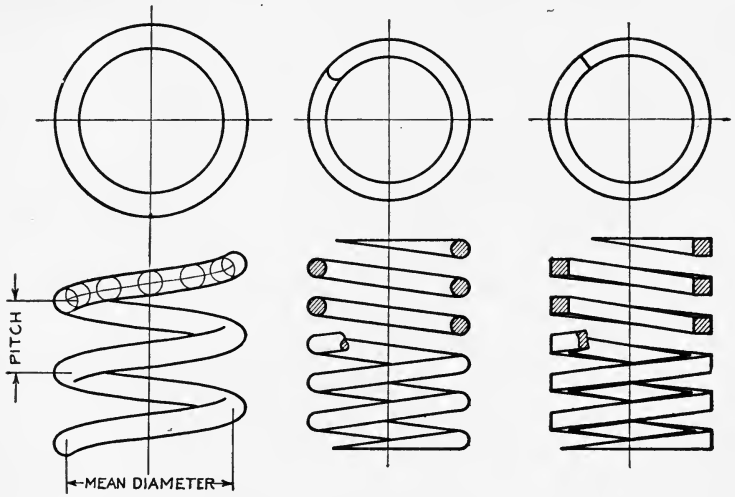


FIG. 166. COIL SPRING—SHOWING ACTUAL AND CONVENTIONAL REPRESENTATION

Bolts and Nuts. A bolt consists of a rod with a head on one end and a screw on the other to receive a nut. Fig. 167. What are known as United States Standard bolts and nuts are shown

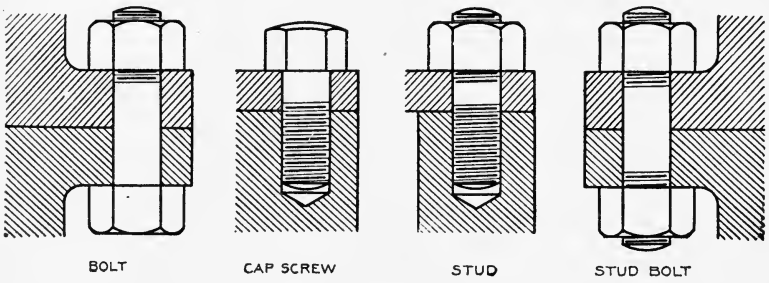


FIG. 167. COMMON SCREW FASTENINGS

in Figs. 168 and 170. The proportions given by the formulae are those adopted for rough bolts and nuts. The finished nuts are

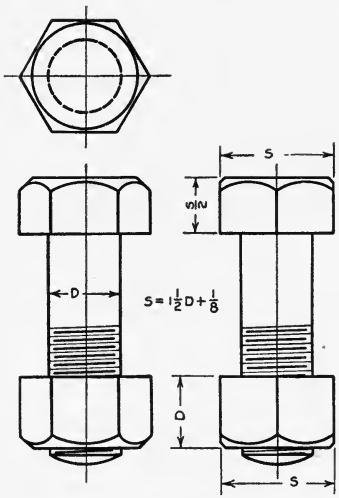


FIG. 168. ACTUAL PROPORTIONS

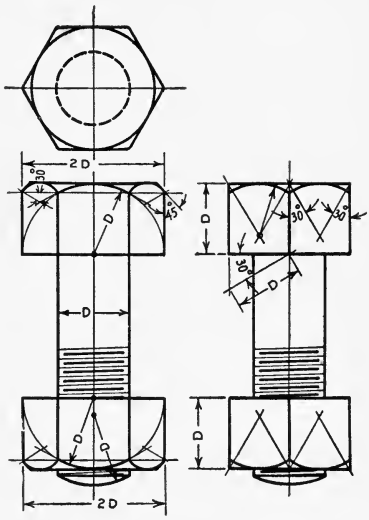


FIG. 169. CONVENTIONAL REPRESENTATION

HEXAGONAL HEAD—U. S. STANDARD BOLTS AND NUTS

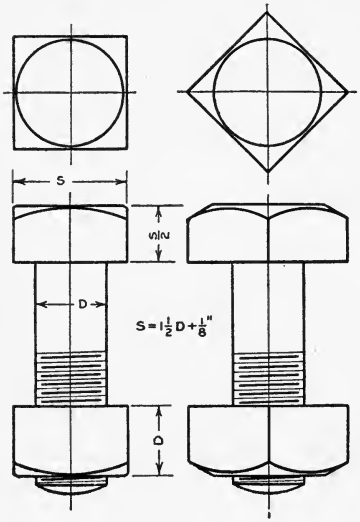


FIG. 170. ACTUAL PROPORTIONS

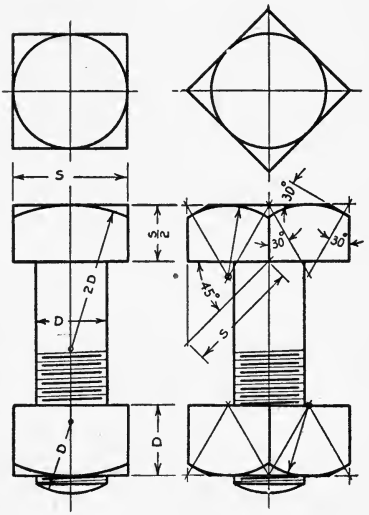


FIG. 171. CONVENTIONAL REPRESENTATION

SQUARE HEAD—U. S. STANDARD BOLTS AND NUTS

$\frac{1}{16}''$ less in width and thickness than the rough nuts. The finished heads have the same sizes as the finished nuts. A table of standard sizes is given on page 263. United States Standard threads are used on these bolts.

Figs. 169 and 171 show the conventional methods of representing hexagonal and square bolt heads and nuts. Hexagonal heads and nuts are usually drawn to show three faces, whereas square heads and nuts are drawn to show two faces. When this is done the hexagonal forms are easily distinguished from the square forms.

Since the proportions of the head and nut of standard bolts are fixed it is only necessary to give three dimensions, viz., the length of the bolt under the head, the length of the threaded portion, and the diameter.

A Stud is a rod threaded at both ends. One end is screwed into a threaded hole. The other end receives a nut. In Fig. 167 a standard nut is used.

A stud placed through two unthreaded holes with a nut at each end is called a *stud bolt.* Fig. 167.

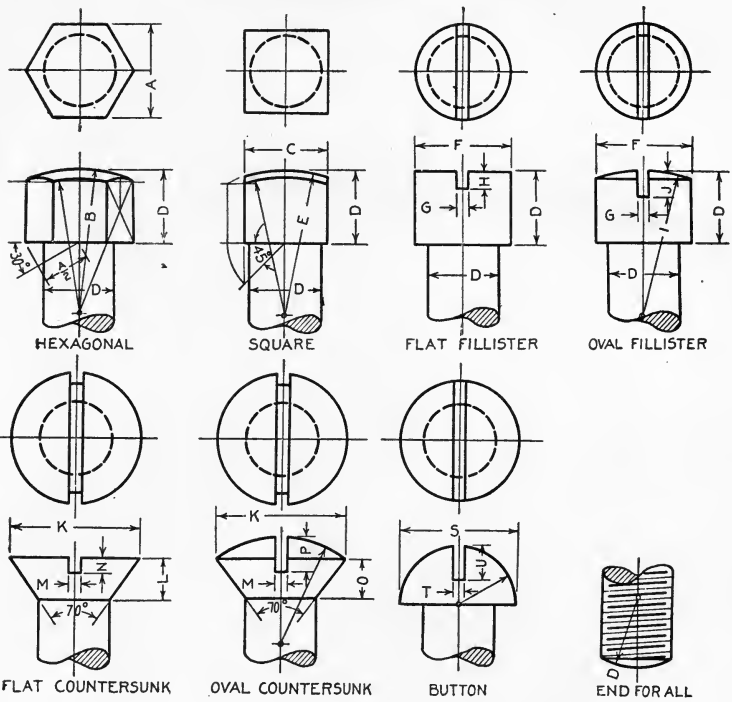
Cap Screws are similar in form to bolts. They hold two parts together by passing through an unthreaded hole in one and a threaded hole in the other. Fig. 167. Heads of various forms are used as shown in Fig. 172.

Machine Screws are similar to cap screws in form. They differ from them by being measured in decimals instead of even fractions of an inch.

Tap Bolts have the same form as cap screws except that they are not finished before threading, are threaded for their full length, and are used for rough work.

Set Screws are used ordinarily to prevent relative motion of two parts such as a pulley and shaft. The screw is passed through a threaded hole in one part and the point is forced against another part. The proportions of the set screws and the shapes of the different points are shown in Fig. 173.

Multiple Threads. It is sometimes necessary to increase the distance traversed by a nut in one revolution. If a coarse



D	A	B	C	E	F	G	H	I	J	K	L	M	N	P	O	R	S	T	U
1/8	...	...	...	...	3/16	.032	1/16	1/4	5/64	1/4	3/32	.040	3/64	5/64	9/64	3/16	7/32	.035	1/16
3/16	...	...	...	...	1/4	.040	1/16	5/16	3/32	3/8	9/64	.064	3/64	3/32	13/64	9/32	5/16	.051	3/32
1/4	7/16	21/32	3/8	9/16	3/8	.064	1/16	1/2	3/32	15/32	5/32	.072	1/16	1/8	17/64	3/8	7/16	.072	1/8
5/16	1/2	3/4	7/16	21/32	7/16	.072	5/64	5/8	1/4	5/8	7/32	.102	5/64	5/32	11/32	15/32	9/16	.091	5/32
3/8	9/16	27/32	1/2	3/4	9/16	.091	3/32	3/4	9/64	3/4	17/64	.114	3/32	3/16	13/32	9/16	5/8	.102	3/16
7/16	5/8	15/16	9/16	27/32	5/8	.102	7/64	7/8	11/64	13/16	17/64	.114	3/32	7/32	13/32	21/32	3/4	.114	7/32
1/2	3/4	1 1/8	5/8	15/16	3/4	.114	1/8	1 1/16	3/16	7/8	17/64	.128	3/32	1/4	13/32	3/4	13/16	.114	1/4
9/16	13/16	1 7/32	11/16	1 1/32	13/16	.114	9/64	1 1/8	7/32	1	5/16	.133	7/64	9/32	15/32	27/32	15/16	.114	9/32
5/8	7/8	1 5/16	3/4	1 1/8	7/8	.128	5/32	1 1/4	15/64	1 1/8	23/64	.133	1/8	5/16	35/64	15/16	1	.133	5/16
3/4	1	1 1/2	7/8	1 5/16	1	.132	3/16	1 1/2	9/32	1 3/8	7/16	.133	5/32	3/8	21/32	1 1/8	1 1/4	.133	3/8
7/8	1 1/8	1 11/16	1 1/8	1 11/16	1 1/8	.133	7/32	1 5/8	21/64	...	...	...	...	...	...	...	...	...	...
1	1 1/4	1 7/8	1 1/4	1 7/8	1 1/4	.165	1/4	1 3/4	3/8	...	...	...	...	...	...	...	...	...	...
1 1/8	1 3/8	2 1/16	1 3/8	2 1/16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1 1/4	1 1/2	2 1/4	1 1/2	2 1/4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

FIG. 172. VARIOUS FORMS OF CAP SCREW HEADS

enough single thread is used to give the advance required the strength of the bolt may be considerably diminished. To obvi-

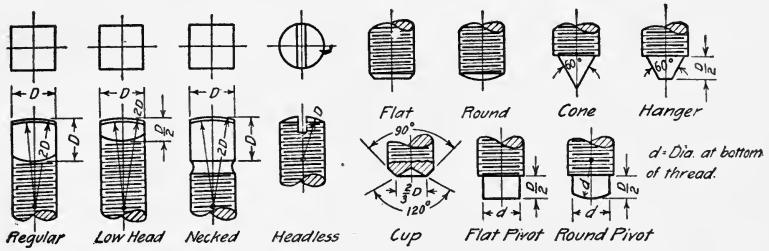


FIG. 173. SET SCREW HEADS AND POINTS

ate this difficulty more than one thread may be cut side by side. The advance for one revolution of a multiple thread is com-

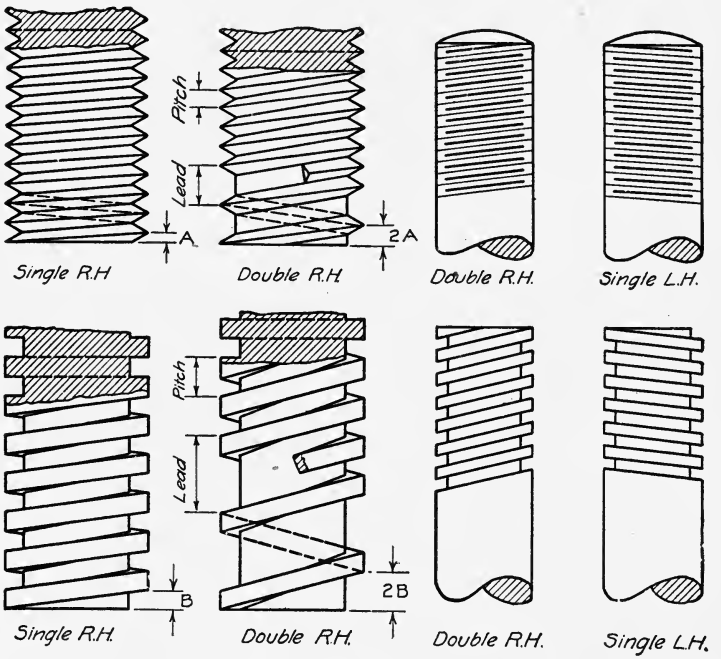


FIG. 174. CONVENTIONAL REPRESENTATION OF MULTIPLE THREADS

monly called the "lead," and the pitch is the distance between corresponding points on two successive threads. Fig. 174. The

conventions for multiple threads are distinguished from those for single threads by increasing the angle of the cross lines and by a note indicating the kind of threads as double, triple, quadruple, etc.

Method of Indicating Finish. Where and how a part is to be finished may be shown by symbols or notes, or both. In case a hole is to be bored, drilled, reamed, cored, etc., a note is usually made in connection with the dimension figure. Fig. 175. A cylindrical surface to be turned, ground, polished, rough

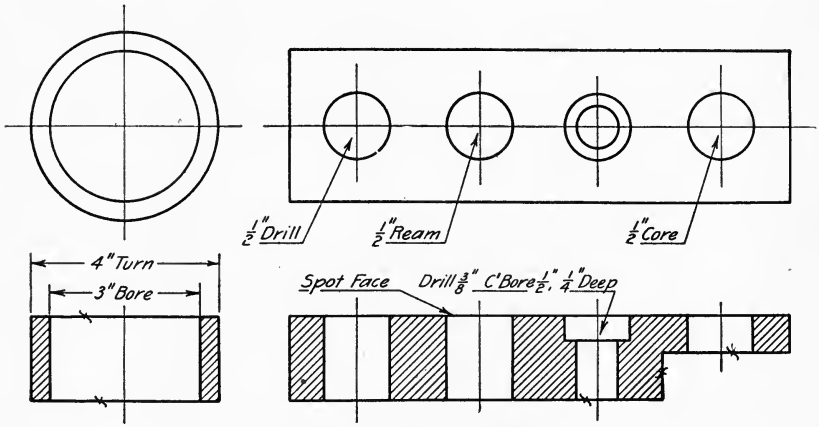


Fig. 175. Methods of Indicating Finish

finished, etc., may have the method of finishing indicated in the same way. In case all surfaces of the object are to be finished and the method can be left to the workman's judgment a note may be made: FINISH ALL OVER. Where only certain surfaces are to be finished the character **f** may be placed across the lines which represent these surfaces viewed edgewise. Fig. 175.

While the indication of finish is a very small part of a drawing, it is nevertheless a very important detail. The omission of a finish mark may mean the making of a large number of castings from a pattern on which no stock has been allowed for finish.

Spur Gears. Fig. 176 represents a spur gear and pinion. Each is diminished as it would be in a working drawing. They are here drawn in mesh to show the relation between the tooth circles. The pitch circles, indicated by P. D. (pitch diameter) following the dimensions, are tangent to each other and form the basis for all calculations as to speed. The widths of the teeth are measured on these circles, the width being equal

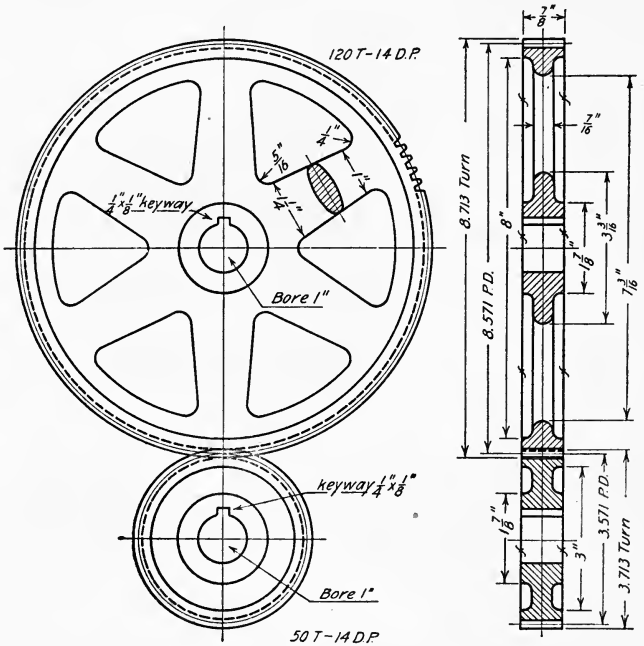


Fig. 176. Spur Gear and Pinion

to the space between teeth for cut gears. The distance measured on the pitch circle between corresponding points on two successive teeth is called the *circular* pitch. Another common method of determining the spacing of the teeth is to give the number of teeth for each inch of the pitch diameter. The *diametral pitch* for the gears shown in Fig. 176 is indicated by the note 14 D. P.

The distance that the tooth projects beyond the pitch circle, called the addendum, is expressed by the fraction $\frac{1}{\text{diametral pitch}}$ or $\frac{\text{circular pitch}}{3.141}$. The working part of the tooth inside the pitch circle, called the dedendum, is equal to the addendum.

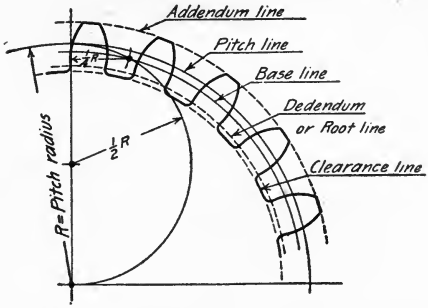


FIG. 177. CONVENTIONAL METHOD OF DRAWING SPUR GEAR TEETH

The teeth extend one-tenth to one-eighth of the addendum below the dedendum line to allow clearance for the teeth of the mating gear.

For machine cut gears the teeth may or may not be drawn as in Fig. 176. This method is usually considered an unneces-

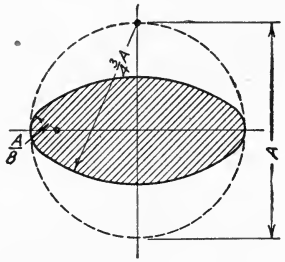


FIG. 178. A METHOD OF DRAWING ACTIONS OF ARMS OF GEARS AND PULLEYS

sary waste of time. For cast gears the teeth are laid out full size to assist the patternmaker.

When it is necessary or desirable to have the teeth accurately constructed Grant's Odontograph table is recommended.

A conventional method, Fig. 177, may be used for representation where accuracy of the tooth curves is not essential. Here the tooth curve is a single arc with a radius equal to one-fourth of the radius of the pitch circle. After one center is located as shown, all others are located on a circle drawn through the first center.

The sections of the arms of gears or pulleys may be drawn as indicated in Fig. 178.

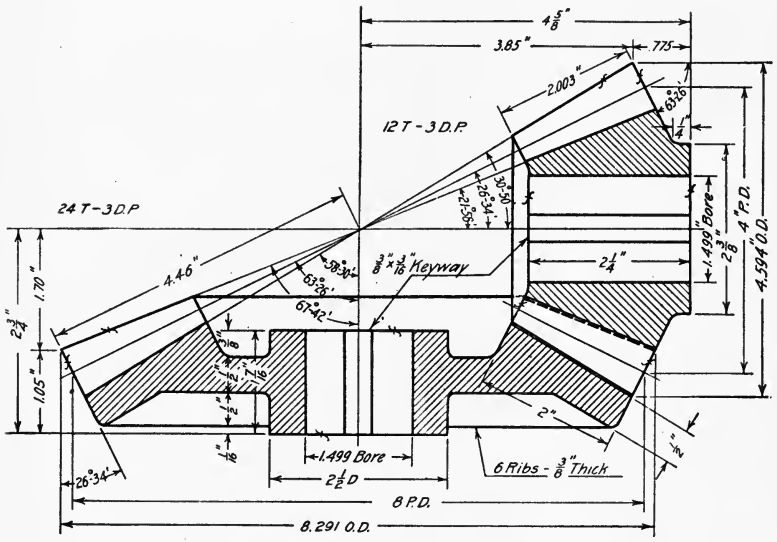


FIG. 179. BEVEL GEAR AND PINION

Bevel Gears. Fig. 179 is a working drawing of a pair of bevel gears. This form of gears does not admit of conventional representation. The drawing of bevel gears is so intimately connected with their design that they are not considered in this course.

Worm Gears. As in the case of bevel gears the drawing of worm wheels and worms involves machine design. The method of representing them is shown in Fig. 180.

Structural Details

The framework of bridges, roof trusses, etc., is a combination of plates and rolled structural shapes held together by rivets. The conventions used in machine drawing must be modified for use in structural drawings on account of the

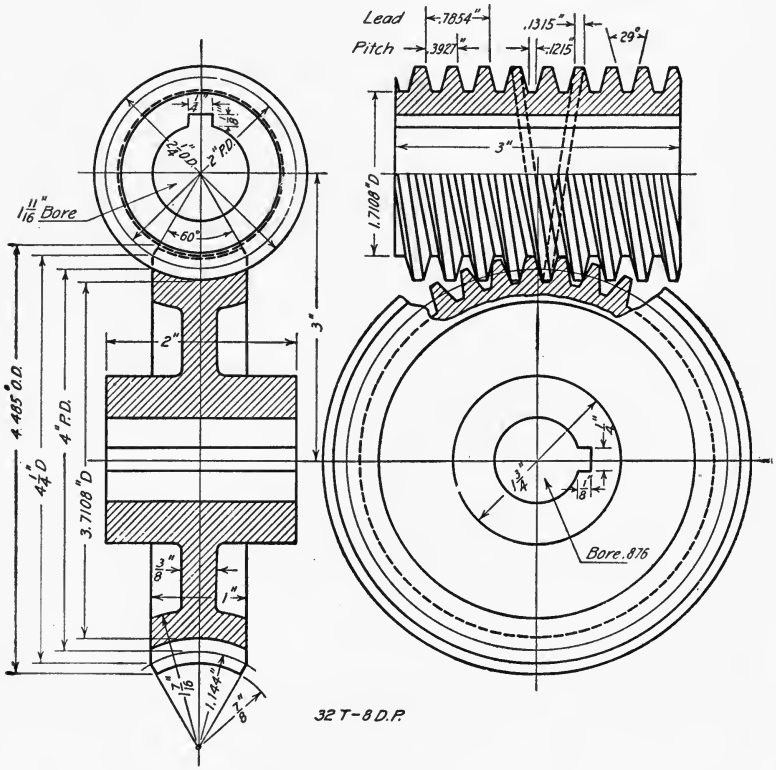
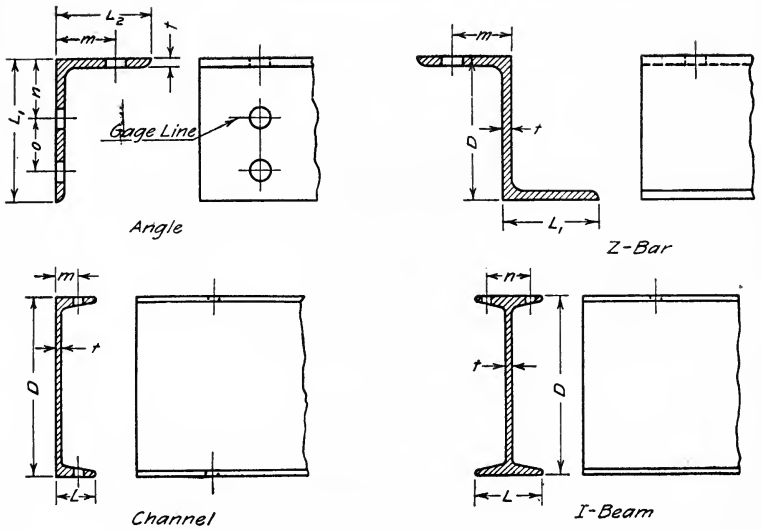


Fig. 180. Worm Wheel and Worm

peculiarities of these structural elements. As the dimensions in structural details are often crowded it is customary to draw full dimension lines and place the figures above or below such lines. The object lines are drawn lighter than in the average



(All dimensions in inches.)

I-BEAMS		CHANNELS		ANGLES				Z-BARS	
Depth of Beam	n	Depth of Channel	m	Length of Leg	m	n	o	Depth of Bar	m
3	$1\frac{7}{16}$	3	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	...	...	3 to $3\frac{1}{2}$	$1\frac{5}{8}$
4	$1\frac{1}{2}$	4	1	1	$\frac{5}{8}$	...	...	4 to $4\frac{1}{2}$	$1\frac{3}{4}$
5	$1\frac{3}{4}$	5	1 to $1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$	...	...	5 to $5\frac{1}{2}$	$1\frac{7}{8}$
6	2	6	$1\frac{1}{16}$ to $1\frac{7}{16}$	..	..	...	...	6 to $6\frac{1}{2}$	2
7	$2\frac{1}{4}$	7	$1\frac{3}{16}$ to $1\frac{5}{8}$	$1\frac{3}{8}$	$\frac{7}{8}$	...	...	.....	...
8	$2\frac{1}{4}$	8	$1\frac{1}{4}$ to $1\frac{9}{16}$	$1\frac{1}{2}$	$\frac{7}{8}$	...	...	.....	...
9	$2\frac{1}{2}$	9	$1\frac{3}{8}$ to $1\frac{3}{4}$	$1\frac{3}{4}$	1	...	...	.....	...
10	$2\frac{5}{8}$	10	$1\frac{1}{2}$ to $2\frac{1}{16}$	2	$1\frac{1}{8}$	...	...	.....	...
12	$2\frac{3}{4}$ to 3	12	$1\frac{3}{4}$ to $2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{4}$	...	...	.....	...
15	3 to $3\frac{3}{4}$	15	$1\frac{7}{8}$ to $2\frac{5}{16}$	..	..	...	...	.....	...
18	$3\frac{1}{4}$	..	.....	$2\frac{1}{2}$	$1\frac{3}{8}$	...	...	.....	...
20	$3\frac{1}{2}$ to 4	..	.....	$2\frac{3}{4}$	$1\frac{5}{8}$	...	...	.....	...
24	4	..	.....	3	$1\frac{3}{4}$	...	...	.....	...
..	.....	..	.....	$3\frac{1}{2}$	2	...	...	.....	...
..	.....	..	.....	4	$2\frac{1}{2}$	...	...	.....	...
..	.....	..	.....	$4\frac{1}{2}$	$2\frac{1}{2}$	2	$1\frac{1}{4}$	.....	...
..	.....	..	.....	5	3	2	$1\frac{3}{4}$	.....	...
..	.....	..	.....	6	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{4}$	.....	...
..	.....	..	.....	7	4	$2\frac{1}{2}$	3	.....	...
..	.....	..	.....	8	$4\frac{1}{2}$	3	3	.....	...

FIG. 181. DIMENSIONS FOR STRUCTURAL SHAPES

machine drawing because the space between them is often very small.

The dimensions and other information for angles, bars, channels, beams, and plates should be given for each in the order indicated below, referring to Fig. 181:

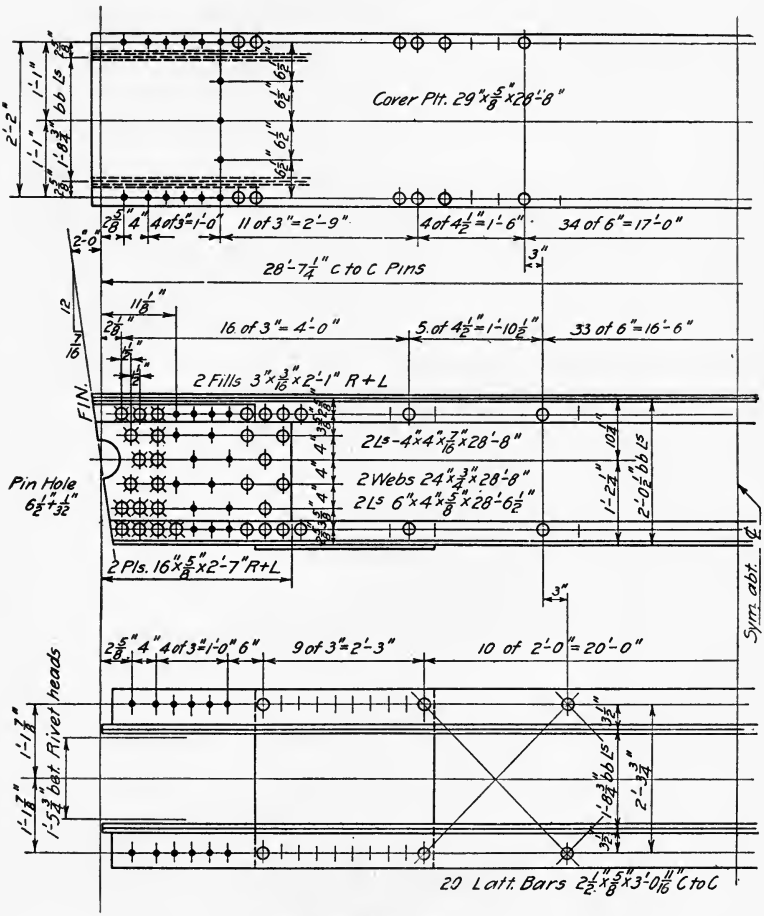


FIG. 182. TYPE PROBLEM—STRUCTURAL DRAWING

Angles—No Req.—$L_1 \times L_2 \times t \times$ length, example $= 2L_8$—$2\frac{1}{2}'' \times 1\frac{1}{4}'' \times \frac{5}{16}''$, 2'—$3\frac{1}{2}''$ long.

Z-bars—No. Req. D × L_1 × t × length, example 2 z_s—$5\frac{1}{16}''$ × $3\frac{5}{16}''$ × $\frac{3}{4}''$, 9′—$8\frac{1}{2}'$ long.

Channels—No. Req. D × wt. per ft. × length, example = 3 [s —8″—11.25#, 8′—$7\frac{1}{2}''$ long.

I-beams—No. Req. D × wt. per ft. × length, example 2 Is—9″—21#, 20′—$3\frac{1}{4}''$ long.

Plates—No Req. Width (inches) × thickness × length (ft. and in.), 2 Pls—72″ × $\frac{3}{8}''$ × 14′—$10\frac{3}{4}''$.

The dimensions m, n, and o, Fig. 181, locate the line of rivet centers, or gage line.

A table of standard gages is given on page 171. Angles are dimensioned by giving the length of the horizontal and vertical legs of a right triangle of which the inclined line is the hypotenuse. The longer leg is always taken as 12″. Fig. 182.

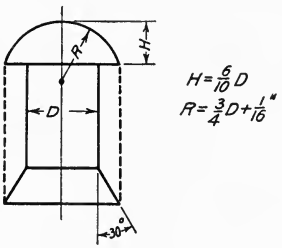


Fig. 183. Proportions of Rivets

The rivets used in structural work are, as a rule, either buttonhead or countersunk, having the proportions shown in Fig. 183. Where occasion demands it the buttonhead may be flattened to allow for clearance.

Structural work is usually assembled in the shop into convenient shipping units and these units are then put together in the field. Fig. 184 shows the Osborn rivet code for distinguishing shop and field rivets. The form of the head and its position are also indicated.

Shade Lines. An ordinary working drawing is made easier to read by the use of shade lines which make certain parts stand out in relief. Fig. 185.

The selection of lines to be shaded is based on the theory that light comes over the draftsman's left shoulder, the rays taking the direction of the diagonal of a cube with its faces in the simplest position with reference to the observer. In accordance

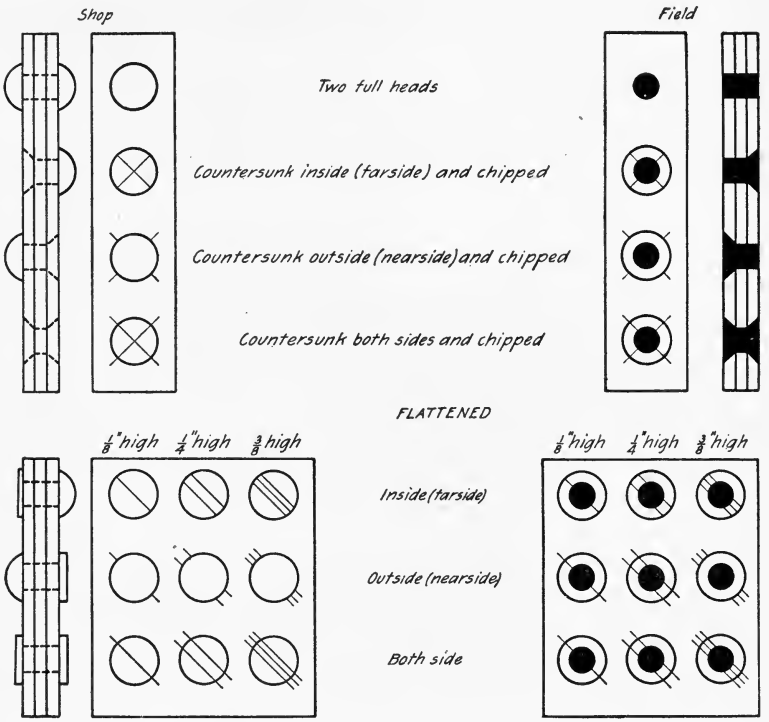


Fig. 184. Osborne Rivet Code

with this theory the lines representing edges which separate a lighted from an unlighted surface should be shaded. The theory holds for the front view only. The following rule gives concisely the conventional method for all views. *Shade the right-hand and lower edges of all surfaces.*

Other minor rules are: (1) Do not shade the line of intersection between visible surfaces. (2) The extreme element of a

cylindrical surface should not be shaded. (3) The shade line is drawn outside the surface which it bounds. When a drawing is to be shaded the complete drawing is first inked in light lines and the shade lines added. A circle is shaded by shifting

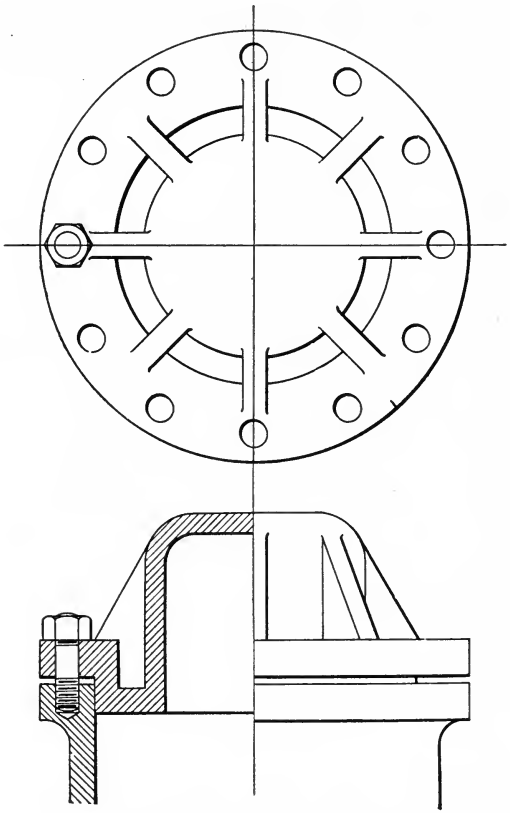


FIG. 185. SHADED DRAWING

the center on a 45° line through the center of the circle a distance equal to the width of the shade line, retaining a fixed radius. Small circles may be shaded by springing the bow instrument.

CHAPTER VII

LETTERING

Modern practice demands that the lettering done on engineering drawings be simple, legible, and capable of easy and rapid rendition. The simple Gothic style fulfils these requirements and is therefore quite generally used.

Form and Proportion. A careful study of the form and proportion of each letter must be made before the student can hope to make any considerable progress in lettering. Practice in drawing the letters will add something to his control of the media with which he works, but first of all he must have a distinct knowledge of what he is trying to accomplish.

Strokes. For convenience in forming letters they are divided into strokes. In most cases the strokes are natural divisions of the outline of the letter. Three things should be remembered about the strokes for each letter: (1) the number of strokes, (2) the order in which they are made, (3) the direction in which each stroke is drawn. The advantage in knowing and using a system of strokes lies in the fact that drawing the letters repeatedly in the same manner makes the forming of each letter more nearly automatic. Hence it adds to the ease with which letters can be produced and aids in securing uniform results.

Spacing. Second only in importance to the forms of the letters is their relation to each other. The best effect is obtained when the areas included between the letters in a word *appear* equal. For the capital letters the area of these spaces should be equal to the area of a rectangle one-half the normal width of the H. The space between words should be about three times that between letters. Words set off by a comma should be spaced from one to one-half times the usual distance. The space between sentences should be about twice the space between words.

The final test of good spacing is legibility. The letters must be far enough apart to avoid a crowded effect and yet the spaces must not be so great that the letters appear scattered. In like manner words must be separated enough to stand out individually, but not enough apart to make reading difficult.

Lettering in Pencil. The pencil used for the freehand work on a drawing should be softer than the pencil used for the mechanical work. It should be of such a grade that when properly sharpened a clear gray line can be produced with a single stroke. It should not be hard enough to cut into the surface of the paper as difficulty is then experienced in controlling the direction of the line.

The lead should be sharpened to a long taper, conical in form and rather blunt at the end. With one-quarter inch of lead exposed, and this tapered back to the wood, the section of the lead will be so nearly uniform near the end that it will stand considerable use without resharpening. The pencil should be held in the hand in the same position as the pen shown in Fig. 186, with the forearm nearly in the direction of the vertical stems of letters or, in the case of the inclined letters, nearly in the direction of the slant. The strokes should be drawn with a finger movement. The pencil should be turned about its axis frequently to keep the point round so as to produce a line of uniform weight. All strokes should be made with the hand held in the same position. Shifting the arm to obtain advantageous positions for drawing strokes in different directions is a habit which will prevent the acquirement of commercial speed and at the same time will prevent the development of the professional type of lettering as distinct from the labored effect produced by the average novice.

Lettering in Ink. The beginner will find it more difficult to produce satisfactory results with pen and ink than with the pencil because of the complications which arise from the nature of the media. To secure a black line of uniform weight with a quick drying fluid such as India ink, and with an ordinary writing pen, presents a problem which usually requires a careful study of the methods of using these materials and considerable intelligent practice.

The pen should be held in the hand as shown in Fig. 186. In drawing a line the points of the pen should be side by side so that the width of the line can be controlled by the pressure applied to spread the nibs. The position of the pen in the hand should not be changed for strokes of different direction, but rather the weight of line should be kept uniform by varying the pressure on the pen. In lettering in ink as in lettering with the pencil, the hand should be held in the same position for all strokes. This will give a better general effect and will make it easier to develop commercial speed in forming the letters.

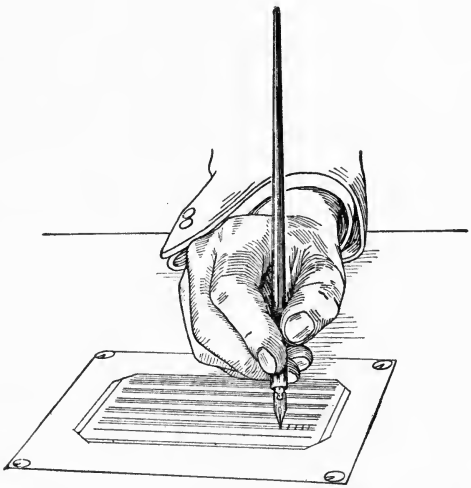


FIG. 186. CORRECT POSITION OF THE HAND AND PEN FOR LETTERING

The pen should be filled by applying the quill attached to the stopper ot the ink bottle to the under side of the pen. Enough ink should be put on the pen to last a reasonable length of time and to produce a wet line so that when it is dry, enough carbon will have been deposited to make it black. Overloading the pen, on the other hand, will cause the corners to fill at intersecting lines. The pen should be wiped frequently to remove the dry ink from the surfaces of the pen and between the nibs. Fresh ink and a clean pen are necessary to produce sharp clean-cut lines.

Titles. The title contains information by which the drawing can be identified, such as the name of the part or parts of the machine or structure, name of the complete machine or structure, manufacturer's firm name and address, drawing number, date, scale, and initials of draftsman, tracer, and checker.

The usual position of the title is in the lower right-hand corner of the sheet where it does not interfere with the drawing and at the same time may be read without taking the sheet from its place in a drawer or file. The relative importance of the items in the title is shown by varying the heights and widths of the letters or the weight of their stems, or both.

The lines should be balanced, *i. e.*, the middle point of each line should fall on the same vertical line. To give the best

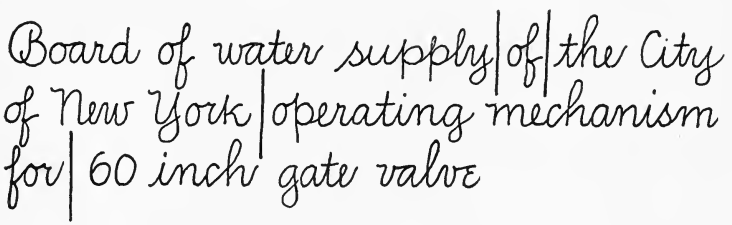


Fig. 187. Title Material Divided Into Groups of Words

effect the lines should vary in length. The general contour of the title is very commonly oval or pyramidal in form.

The arrangement of the lines of the title and the determination of the height of each line presents a problem in design for the solution of which the contour of the title should be kept in mind.

The space between the lines of letters for the single stroke capitals should be from three-fourths to one and three-fourths the height of the smallest adjacent letters.

The style of letter used for the title should be dignified. For this reason the capital letters are generally used.

The steps in designing a title should be taken in about the following order: (1) Assuming that the wording or at least the substance of the title is stated, write out the complete title and divide the words into logical groups for the different lines. Fig. 187. (2) Rewrite, tentatively arranging the lines as they

will be in the printed title. Fig. 188. (3) Decide upon the relative importance of the lines and select heights of letters accordingly. It may now appear that a rearrangement of the lines will give a better outline without affecting the meaning. (4) The title may be balanced by printing each line lightly in

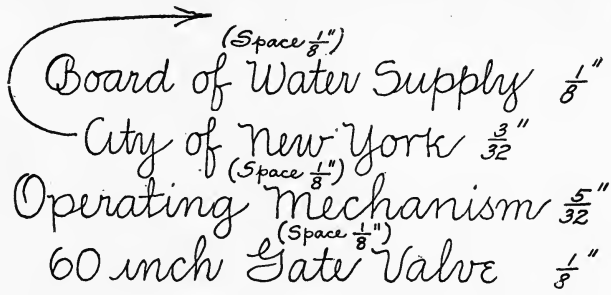


Fig. 188. Tentative Arrangement of the Lines of the Title

its proper space to obtain the spacing of the letters. Any adjustment necessary to make the middle point of each line fall on the center line of the title should be made. The letters should then be drawn in full weight. This method may be used with success by those who have had considerable experi-

CITY OF NEW YORK
BOARD OF WATER SUPPLY
OPERATING MECHANISM
60 INCH GATE VALVE

Fig. 189. Finished Title

ence in lettering. The beginner will obtain better results with but little more work by lettering the lines first on a trial sheet to get the spacing and then by using these lines as a guide in balancing the lines and spacing the letters on the drawing, as described on page 89. Fig. 189 shows a balanced title.

In drafting offices or business firms where large numbers of drawings similar in general character are made, the items common to all titles are very often printed on the pencil drawing with a rubber stamp and on the tracing in type. Uniformity in treatment is thus secured and much time in lettering is saved. Fig. 146 illustrates commercial titles. These title forms are printed on the *under side* of the tracing cloth. Errors may thus be corrected and changes made in the lettering done by the draftsman without erasing the printed lines and letters.

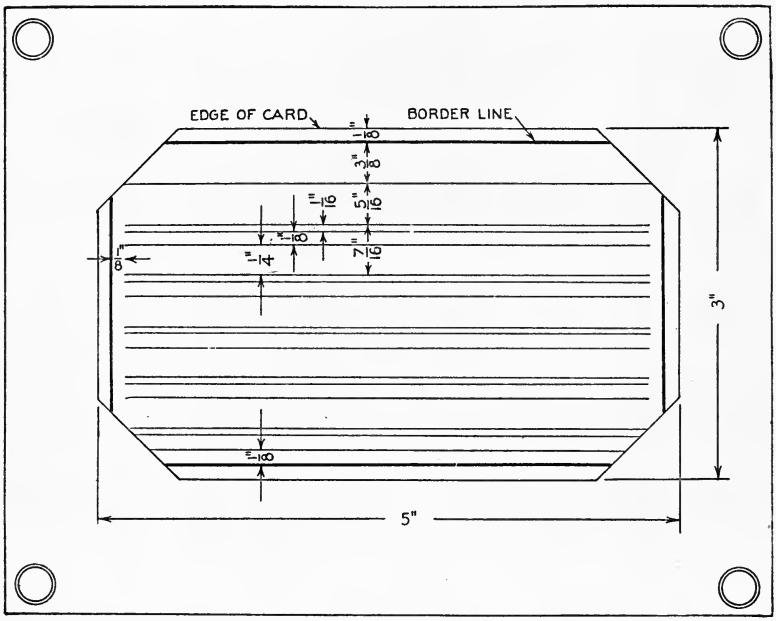


Fig. 190. Lettering Card

LETTERING PLATES

Vertical Freehand Gothic Capital Letters and Numerals

PREPARATORY INSTRUCTIONS FOR PLATE 1

The Plate. The first ten lettering plates will be in pencil. Three by five cards of the regular drawing paper, ruled as shown in Fig. 190, will be used.

The Lettering Pencil. Use the 3H pencil for lettering, sharpened to a conical point as for freehand sketching. Fig. 6.

Number, Order, and Direction of Strokes. Each letter or numeral is made by one or more strokes. In general, vertical

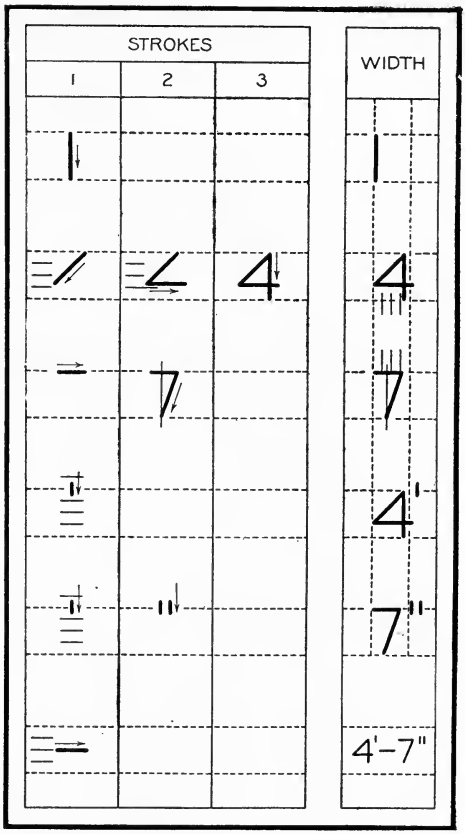


Fig. 191

and inclined strokes are made downward and horizontal strokes to the right. Fig. 191 shows the number, order, and direction of strokes for the numerals 1, 4, 7, and the symbols used for the foot, inch, and dash. The relative width of numerals is shown in column 4.

The Scale of Heights. For convenience in estimating vertical distances the space between the guide lines is divided into four equal parts. Fig. 191.

A Scale of Widths. The width of the H is taken as the unit of width. This distance is divided into four equal parts. Horizontal distances may be estimated by observing their relation to these divisions. Fig. 191.

Drawing the Strokes. Before starting a stroke carefully *plan its position and direction.* Make each line with *one move-*

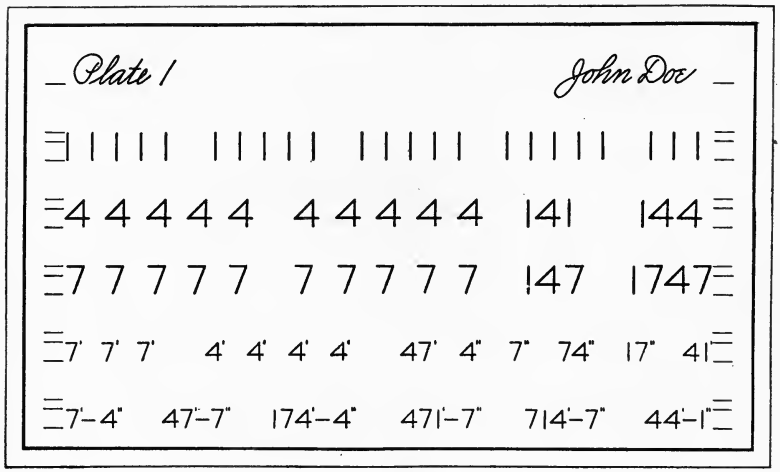


Fig. 192

ment of the pencil. A vertical stroke is made by drawing a line from one point to another *directly below it.* In case a stroke or letter is unsatisfactory it should be erased and redrawn.

Foot and Inch Marks. A short dash placed to the upper right of a numeral indicates feet. Two such dashes similarly placed indicate inches. A horizontal dash is placed between numerals representing feet and inches. See Fig. 191.

DATA FOR PLATE 1

Given: Plate 1 to reduced size, Fig. 192.

Required: To make the plate to an enlarged scale.

Instructions:

1. Fasten the card to the board either with thumb tacks or by inserting its corners in diagonal slits cut in a larger piece of paper which is tacked to the board. Fig. 190.

2. Draw the numerals and symbols, using the number, order, and direction of strokes shown in Fig. 191.

3. Write in the plate number, followed by the name at the top of the sheet as indicated in Fig. 192.

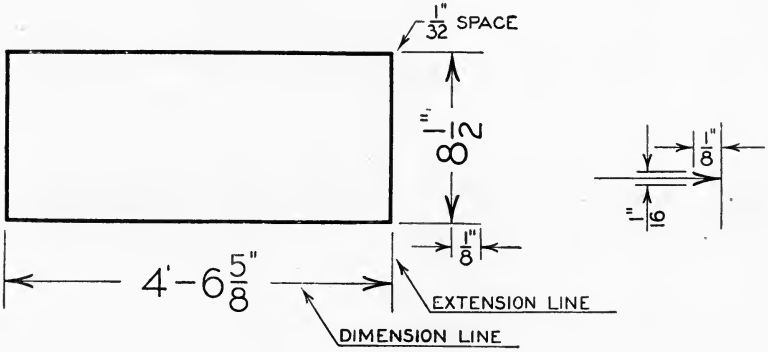


FIG. 193. DIMENSION FORM AND ARROWHEAD

PREPARATORY INSTRUCTIONS FOR PLATE 2

Curved Strokes. In making the curved strokes of the 5 and the 2 the student should have in mind the form of the *complete* oval.

The Dimension Form. The dimension form consists of the numerals designating feet and inches, the foot and inch marks, the dash, the dimension and extension lines, and the arrowheads as arranged in Fig. 193.

It will be seen that the arrowheads are placed on the dimension lines with their points touching the extension lines. They are composed of two slightly curved lines symmetrical with respect to the dimension line. The length of the arrowhead should be about $\frac{1}{8}''$ and the width $\frac{1}{16}''$. Fig. 193. Fig. 194 shows strokes for arrowheads pointing in different directions.

DATA FOR PLATE 2

Given: Plate 2 to reduced size, Fig. 195.

Required: To make the plate to an enlarged scale.

Instructions: Proceed as in Plate 1, following carefully the number, order, and direction of strokes.

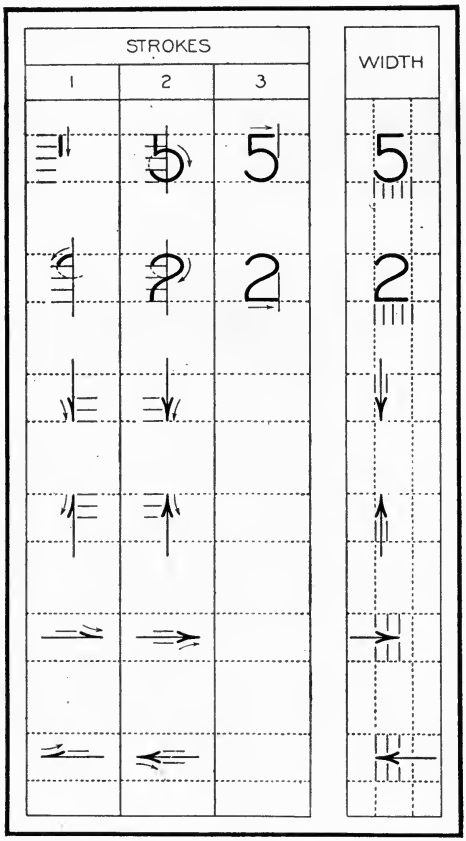


FIG. 194

PREPARATORY INSTRUCTIONS FOR PLATE 3

Curved Strokes. The oval of the numeral 0 is the basic form for the 6 and 9. In making the outline strokes of these numerals the student should have in mind the form of the *complete* oval.

Whole Numbers and Fractions. The whole number in a dimension will be made $\frac{1}{8}''$ high.

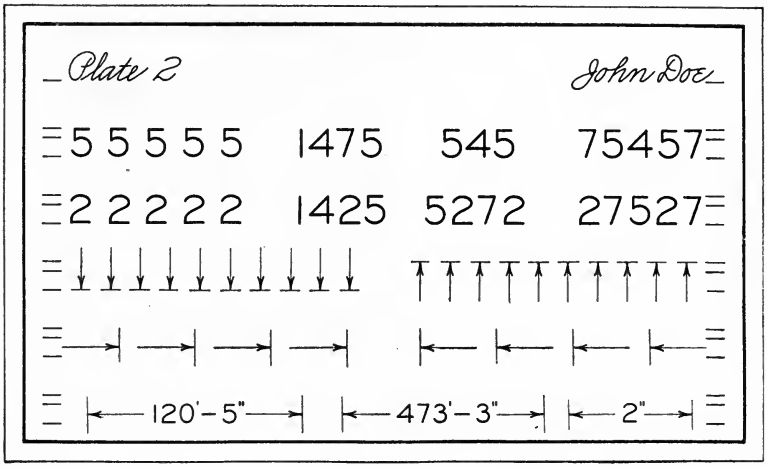


Fig. 195

The total height of the fraction should be twice the height of the whole number with a clear space between each numeral

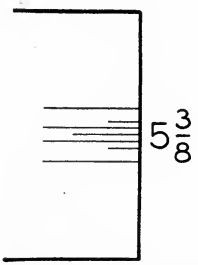


Fig. 196. Showing Actual Heights of Whole Number and Fractions

and the division line. Fig. 196. To check these heights mark off an eighth inch and a quarter inch space on the edge of a card and use it as a scale. Fig. 196.

DATA FOR PLATE 3

Given: Plate 3 to reduced size. Fig. 198.

Required: To make the plate to an enlarged scale.

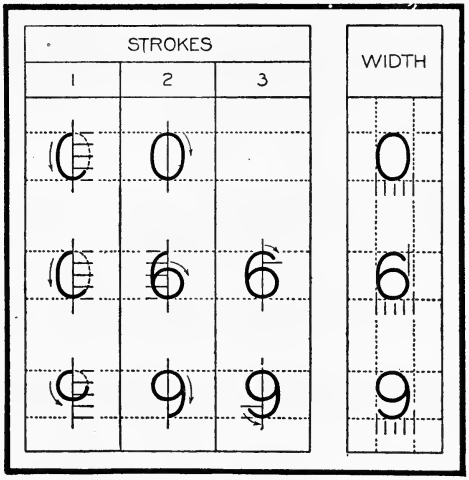


FIG. 197

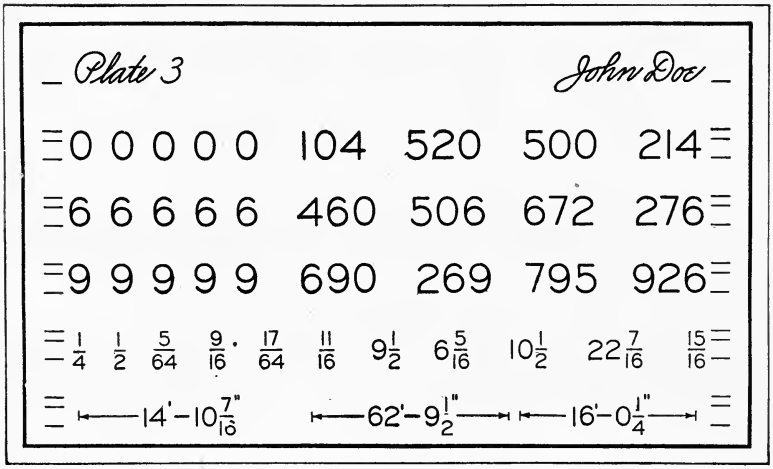


FIG. 198

PREPARATORY INSTRUCTIONS FOR PLATE 4

The combination of ovals in the 8 serves as a basic form for the 3. In making the curved strokes of these numerals the student should have in mind the form of the complete oval.

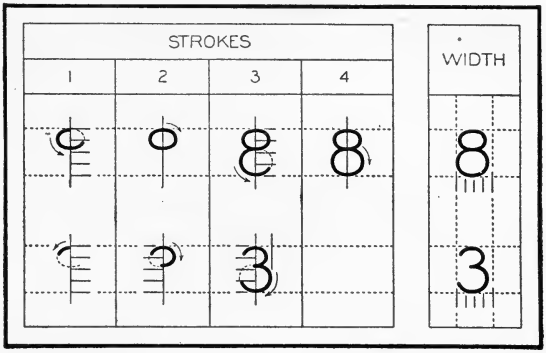


FIG. 199

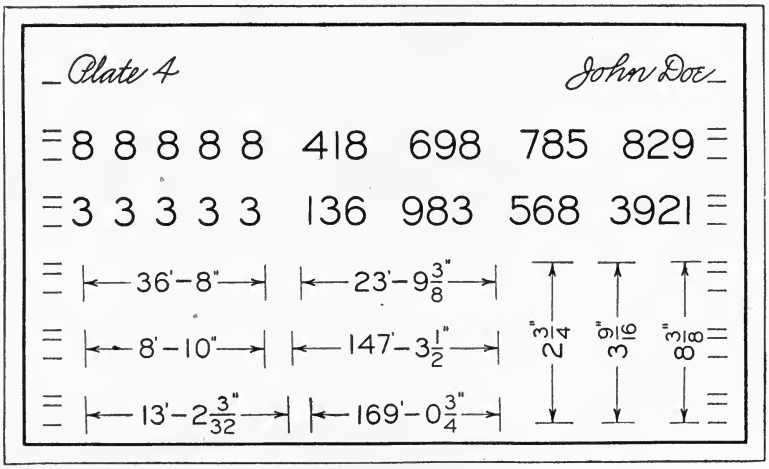


FIG. 200

DATA FOR PLATE 4

Given: Plate 4 to reduced size. Fig. 200.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS FOR PLATE 5

Horizontal and Vertical Strokes. As stated under Plate 1 vertical strokes are usually made downward and horizontal strokes to the right.

FIG. 201. SPACING OF ADJACENT VERTICAL STEMS

The direction of horizontal and vertical strokes must be exact.

The relative width of the letters is shown in column 4. Fig. 202.

Spacing. In this and the following plates the practice of individual letters will be followed by the practice of words. In order that the lettering may present a good appearance, it is as important that the letters be well spaced as that they be properly formed.

Correct spacing depends more on the judgment of the draftsman than on any rule which might be given. However, it may be said that as a rule the letters should *appear* to be equally spaced.

For this style of letters adjacent vertical strokes should be a distance apart equal to one-half the width of the H. Example: H and I, Fig. 201. Letters of irregular form should be placed at such a distance that the space appears equal to that between the H and I. Example: I and T, Fig. 201.

When spacing a letter the beginning of the first stroke should be carefully located.

DATA FOR PLATE 5

Given: Plate 5 to reduced size. Fig. 203.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS FOR PLATE 6

Inclined Strokes. Before starting an inclined stroke the student should sense its direction, moving the pencil between its two ends without touching the paper.

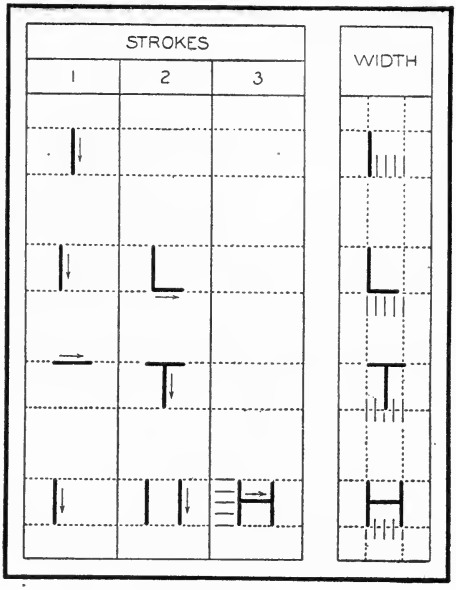


FIG. 202

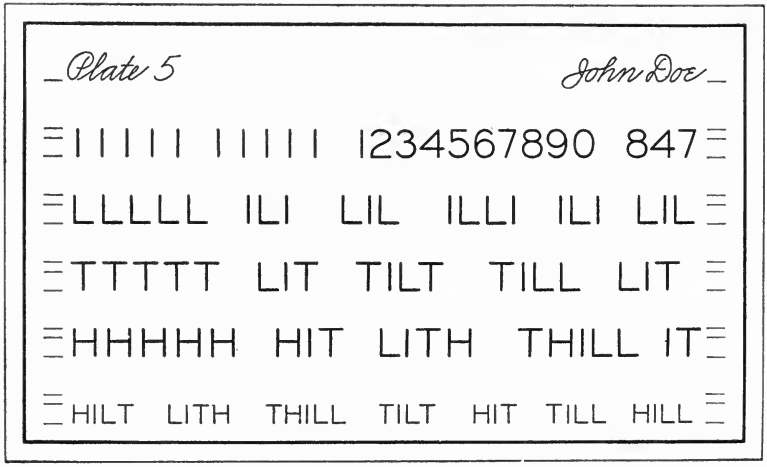


FIG. 203

DATA FOR PLATE 6

Given: Plate 6 to reduced size. Fig. 205.

Required: To make the plate to an enlarged scale.

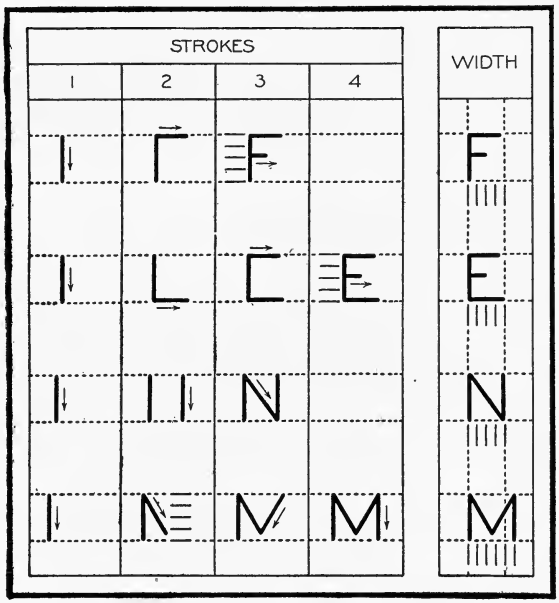


FIG. 204

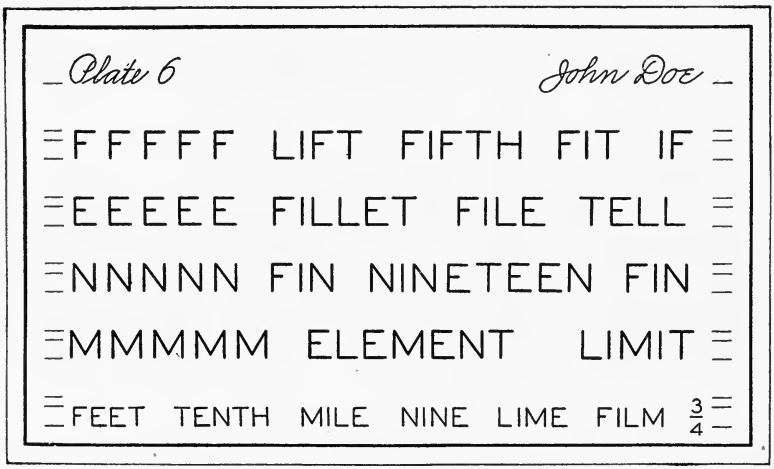


FIG. 205

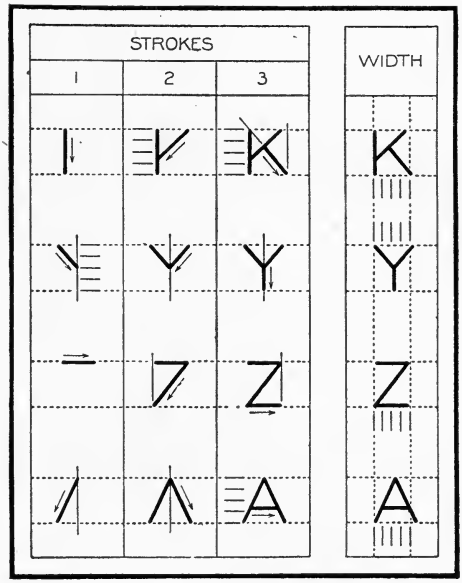


FIG. 206

FIG. 207

PREPARATORY INSTRUCTIONS FOR PLATE 7

As stated under Plate 6, the student should sense the direction of an inclined stroke before drawing it.

KEY

FIG. 208. SPACING OF IRREGULAR FORMS

The spacing between irregular letters should appear equal to the area of one-half the H. Fig. 208.

DATA FOR PLATE 7

Given. Plate 7 to reduced size. Fig. 207.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 8

Given: Plate 8 to a reduced size. Fig. 211.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS FOR PLATE 9

The letter O is wider than the numeral 0.

The forms of the Q, C, and G are based on the oval of the O.

Spacing Curved Stroke Letters. As stated in Plate 5, the area included between the contour of two adjacent letters should appear equal to the area of one-half of the H. When a vertical stroke and a curved stroke are properly spaced the clear distance between them is slightly less than one-half the width of the H. Example: The I and O, Fig. 209.

FIG. 209. SPACING OF CURVED FORMS

The clear distance between two curved strokes will be less than that between vertical and curved strokes. Example: The O O in Fig. 209.

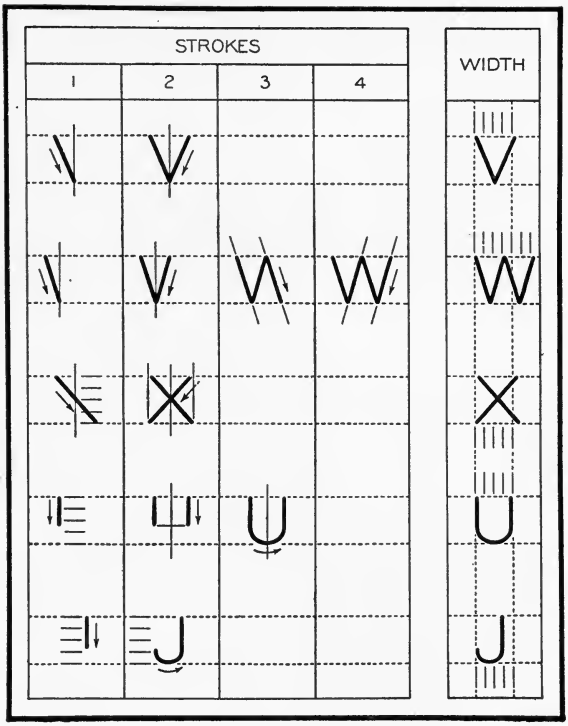


FIG. 210

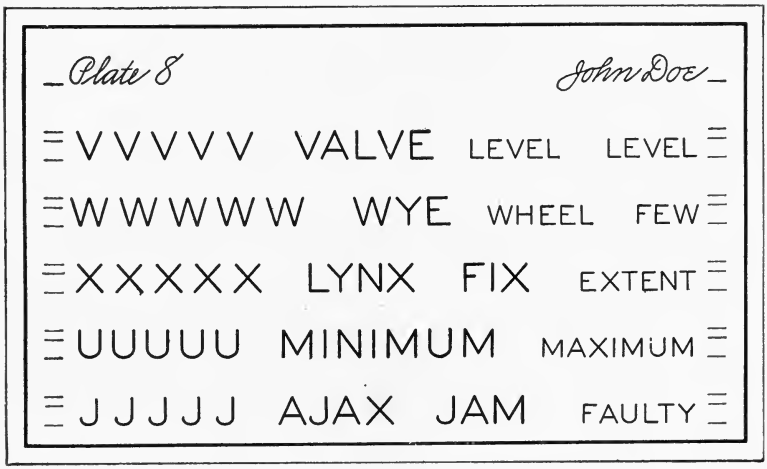


FIG. 211

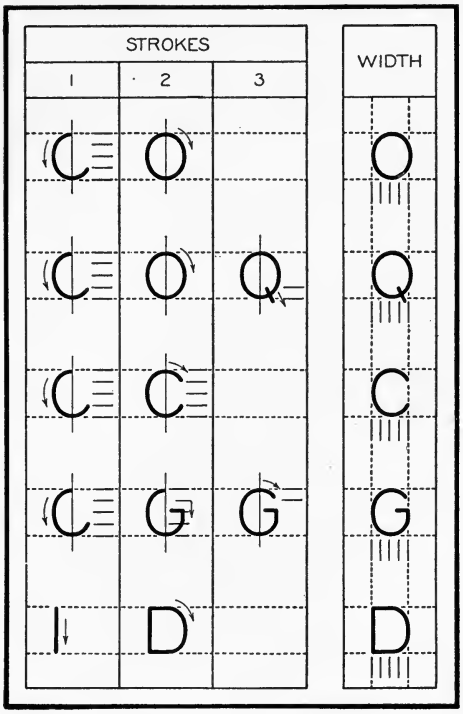


FIG. 212

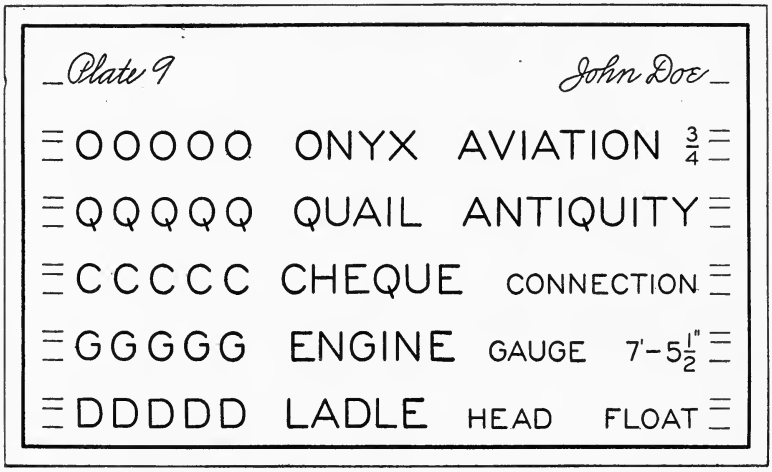


FIG. 213

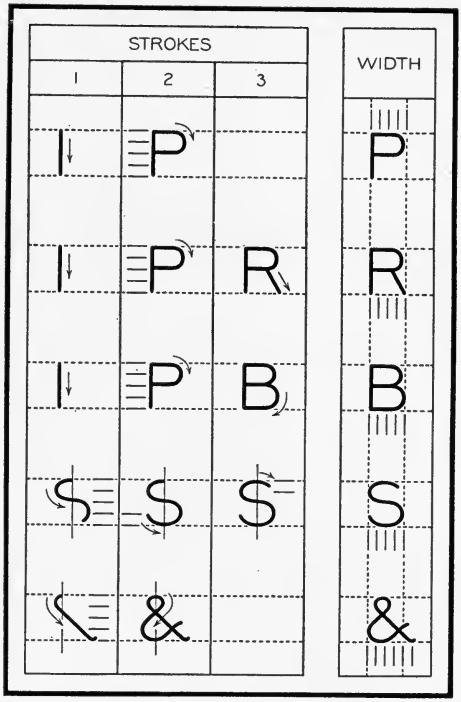


FIG. 214

Plate 10 *John Doe*

PPPPP PITCH DIAM PATCH

RRRRR ROD RULE ARMATURE

BBBBB BEARING BUILDER BIN

SSSSS SCREW PISTON FOR 4

&&&&& SCOTT & JONES

FIG. 215

When spacing a letter having a curved outline the beginning of the first stroke should be carefully located. In planning the letter the clear space between it and the previous letter should be held in mind.

DATA FOR PLATE 9

Given: Plate 9 to reduced size. Fig. 213.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS FOR PLATE 10

The first two strokes of the P, R, and B are exactly alike. The basic form of the S is a combination of two ovals. When drawing the strokes of the S these ovals should be held in mind.

DATA FOR PLATE 10

Given: Plate 10 to a reduced size. Fig. 215.

Required: To make the plate to an enlarged scale.

Lettering in Ink

PREPARATORY INSTRUCTIONS FOR PLATE 11

The following is a list of the materials used in making lettering plates in ink.

1. Tracing Cloth, 4″ × 6″ sheets.
2. One of the following or any similar pen which will give satisfactory results may be used:

303 Gillott's 404 Gillott's Spencerian No. 1 Lady Falcon	Three of each.

3. Penholder.
4. Black waterproof drawing ink.

Square one of the three by five inch cards on the board and stretch the tracing cloth over it with the dull side up. The surface of the cloth should be prepared for inking by being rubbed with chalk dust. All superfluous chalk must be removed

to prevent its clogging the pen. The guide lines for the letters should be drawn on the cloth in pencil. When the plate is finished a border rectangle should be drawn and the sheet trimmed to $3'' \times 5''$. Fig. 190. The space outside the cutting lines may be used to try the pen on during the process of lettering the plate. A pen should be selected which will give a width of line suited to the height of letters to be made. The proper width of line should be secured with but little spreading of the nibs of the pen. Fig. 186 illustrates the position of the pen in the hand while lettering. Note that the forearm is nearly parallel to the vertical strokes. Vertical strokes should be made with a finger movement. In making the horizontal and curved strokes this movement is combined with a turn of the wrist.

ROUGH ROUND RODS
OHIO CORLISS ENGINE

FIG. 216. EXAMPLES OF WORD SPACING

To fill the pen, place the ink on the under side by means of the quill attached to the stopper of the bottle. The stopper should be returned to the bottle since the ink dries rapidly.

Composition. In this and the following plates in lettering words will be combined into phrases and sentences. The spacing of words plays an important part in securing a good general effect in a line of letters. The space between words should appear equal to three times that between letters or one and one-half times the width of the H. Adjacent vertical strokes will therefore be separated by a space one and one-half times the width of the H. The clear distance between two words having vertical strokes adjacent to a curved stroke will be less than one and one-half times the width of the H. The clear distance between two words having adjacent curved strokes will be still less. Example: See Fig. 216.

DATA FOR PLATE 11

Given: Plate 11 to reduced size. Fig. 217.

Required: To make the plate to an enlarged scale. In this plate the wording of the titles for the first pencil mechanical drawing plates is used. The letters are approximately the height used in the title.

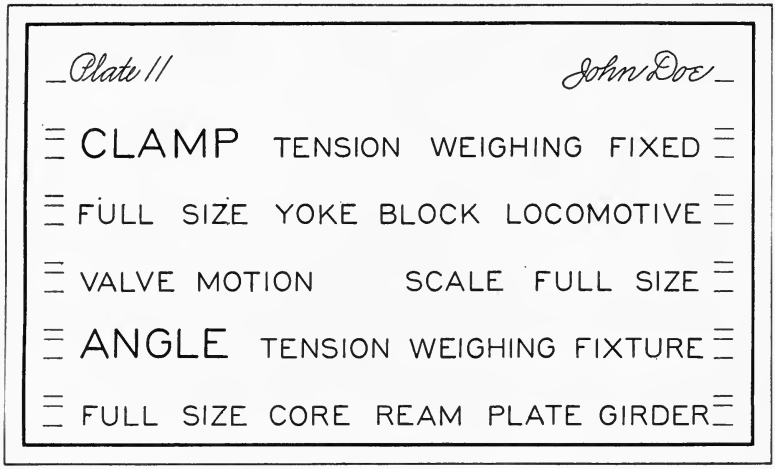


FIG. 217

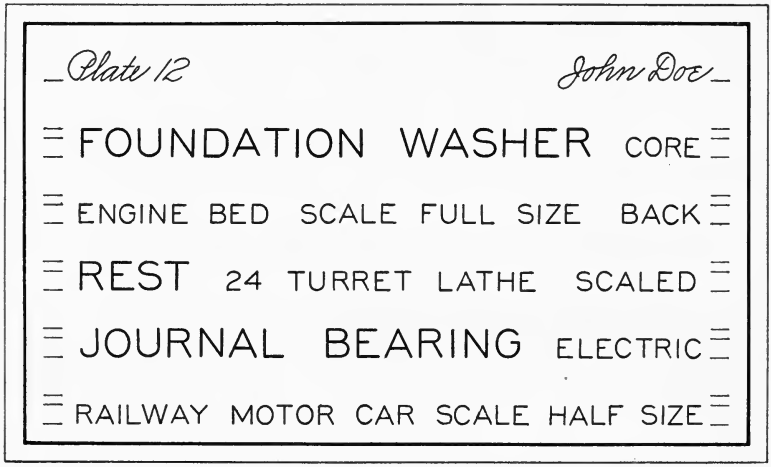


FIG. 218

DATA FOR PLATE 12

Given: Plate 12 to reduced size. Fig. 218.

Required: To make the plate to an enlarged scale. The words in this title are the same as those used in the second mechanical drawing, Plate 15.

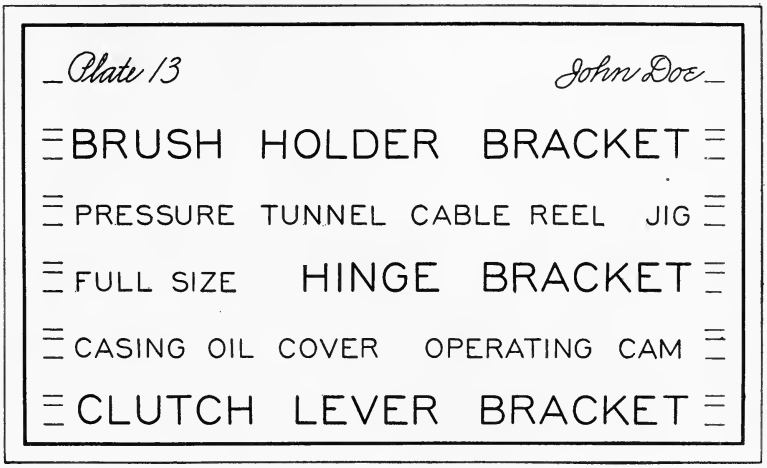


Fig. 219

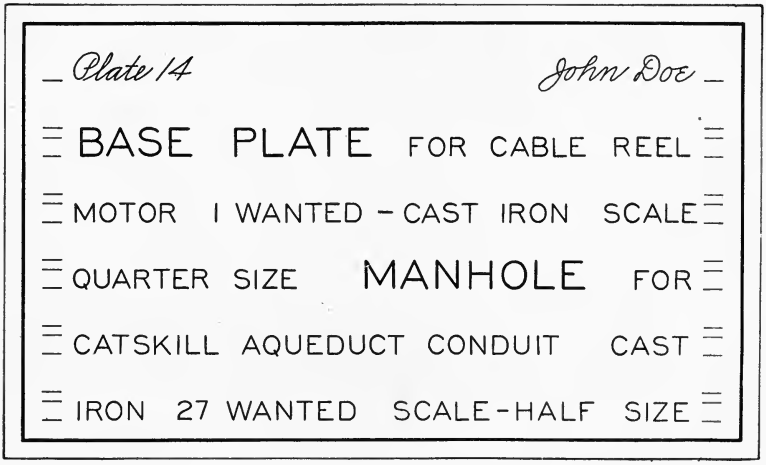


Fig. 220

DATA FOR PLATE 13

Given: Plate 13 to reduced size. Fig. 219.

Required: To make the plate in ink to an enlarged scale. The words in this title are the same as those used in the third mechanical drawing, Plate 17.

DATA FOR PLATE 14

Given: Plate 14 to reduced size. Fig. 220.

Required: To make the plate in ink to an enlarged scale. The words used in this title are the same as those used in the first tracing, Plate 19.

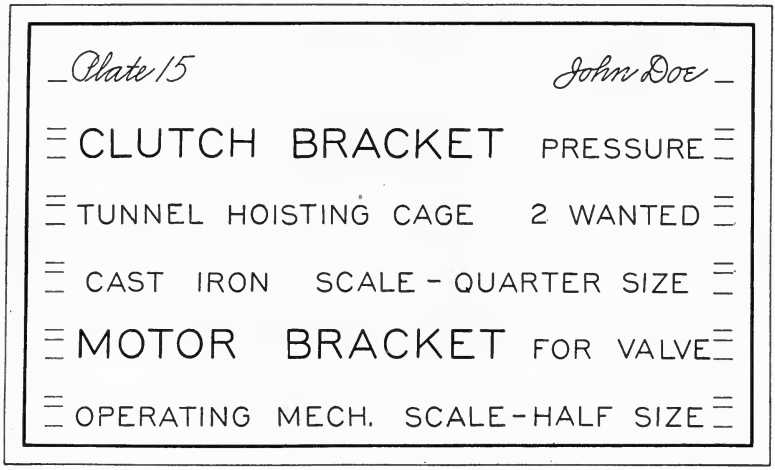


FIG. 221

DATA FOR PLATE 15

Given: Plate 15 to a reduced size. Fig. 221.

Required: To make the plate in ink to an enlarged scale. The words used in this title are the same as those used in the second tracing, Plate 21.

PREPARATORY INSTRUCTIONS FOR PLATE 16

Composition. This and the following plates will be devoted to the practice of notes which frequently appear on the drawing to give information not shown by the views.

DATA FOR PLATE 16

Given: Plate 16 to reduced size. Fig. 222.

Required: To make the plate in ink to an enlarged scale.

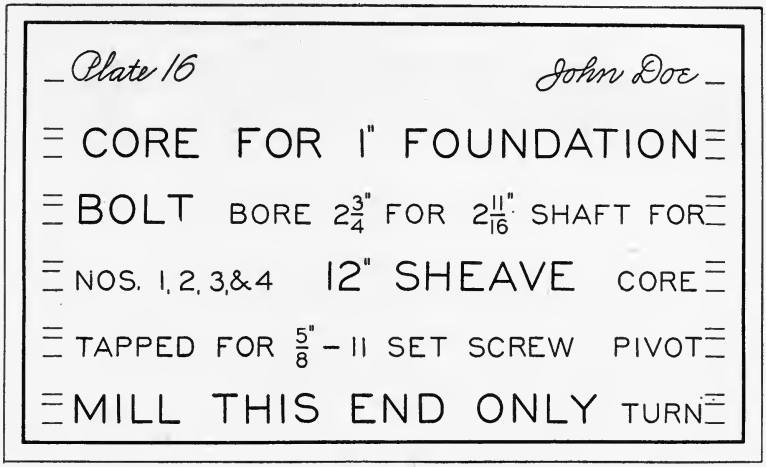


FIG. 222

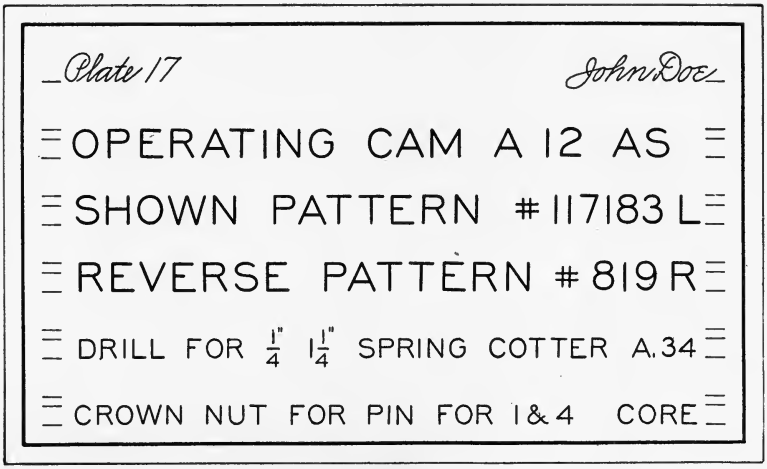


FIG. 223

DATA FOR PLATE 17

Given: Plate 17 to reduced size. Fig. 223.

Required: To make the plate in ink to an enlarged scale.

DATA FOR PLATE 18

Given: Plate 18 to reduced size. Fig. 224.
Required: To make the plate to an enlarged scale.

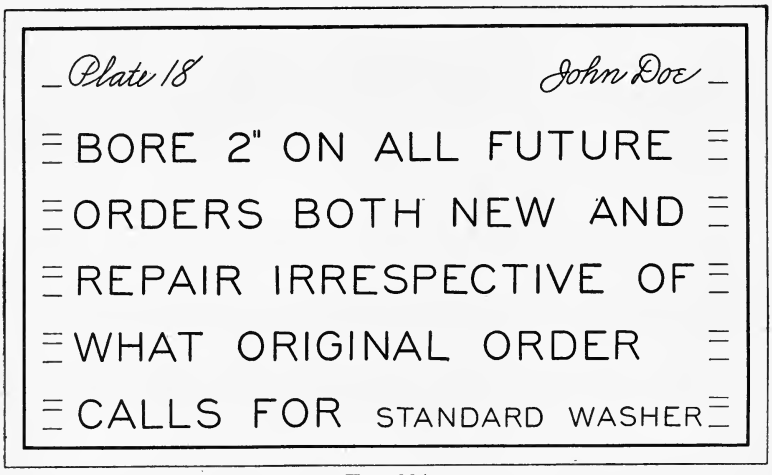


FIG. 224

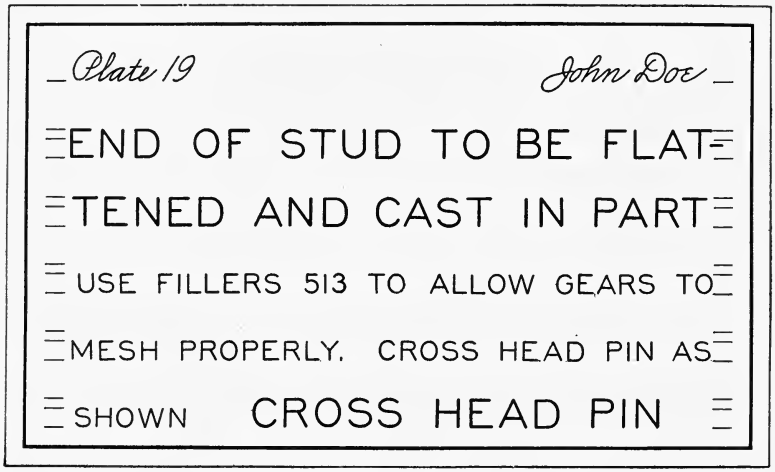


FIG. 225

DATA FOR PLATE 19

Given: Plate 19 to reduced size. Fig. 225.
Required: To make the plate to an enlarged scale.

DATA FOR PLATE 20

Given: Plate 20 to reduced size. Fig. 226.

Required: To make the plate to an enlarged scale.

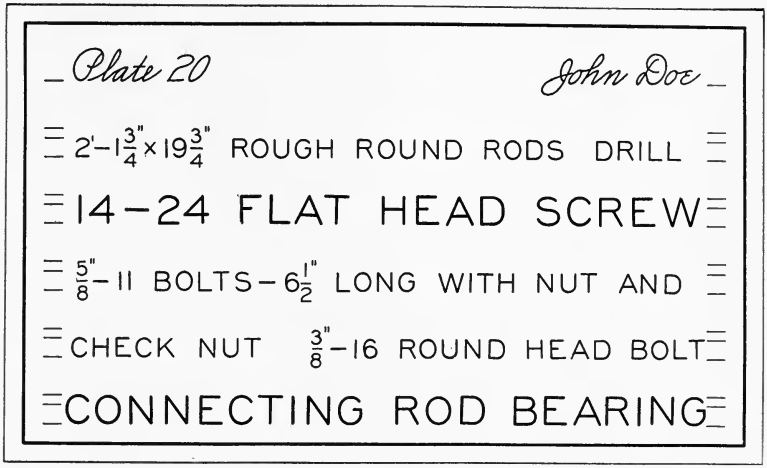


FIG. 226

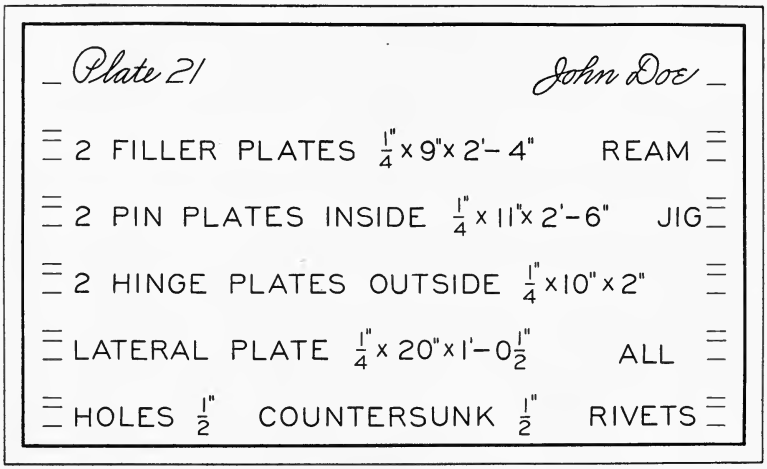


FIG. 227

DATA FOR PLATE 21

Given: Plate 21 to reduced size. Fig. 227.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 22

Given: Plate 22 to reduced size. Fig. 228.

Required: To make the plate to an enlarged scale.

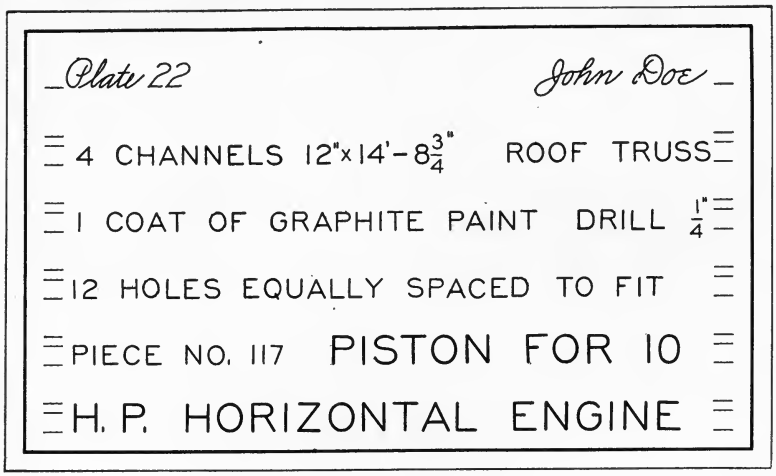


FIG. 228

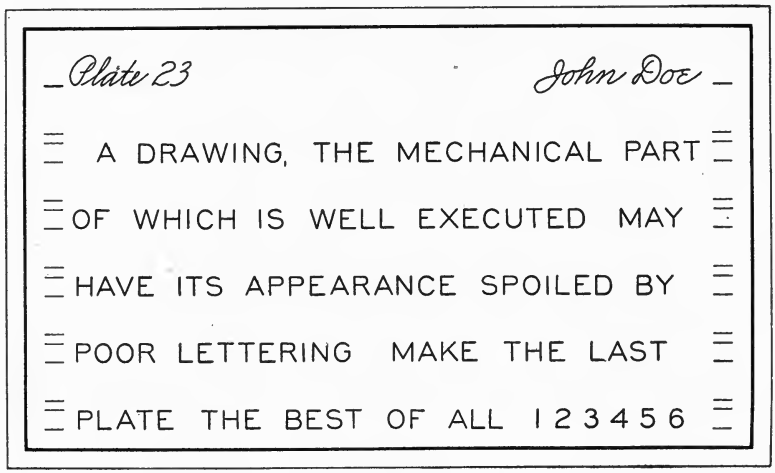
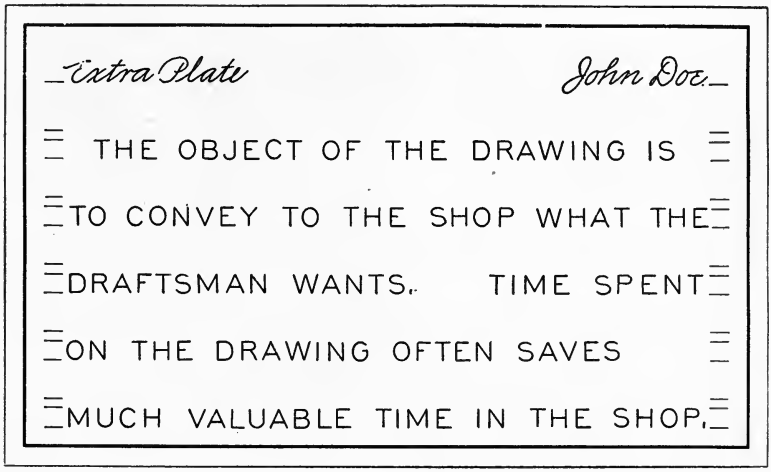


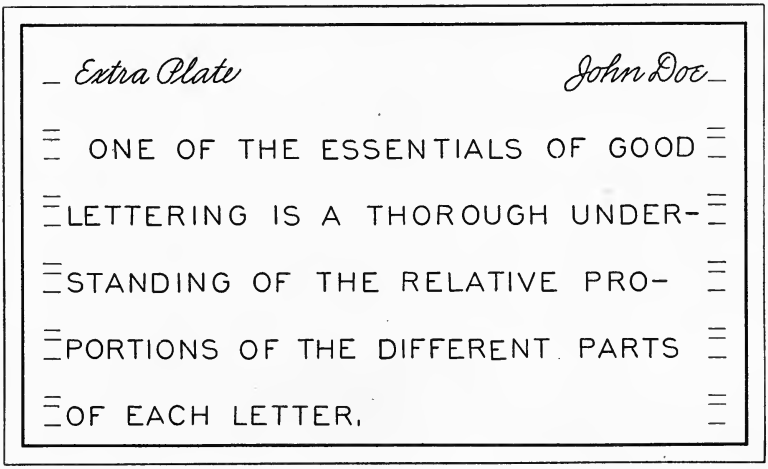
FIG. 229

DATA FOR PLATE 23

Given: Plate 23 to reduced size. Fig. 229.

Required: To make the plate to an enlarged scale.


Extra Plate
John Doe
THE OBJECT OF THE DRAWING IS
TO CONVEY TO THE SHOP WHAT THE
DRAFTSMAN WANTS. TIME SPENT
ON THE DRAWING OFTEN SAVES
MUCH VALUABLE TIME IN THE SHOP.


Extra Plate
John Doe
ONE OF THE ESSENTIALS OF GOOD
LETTERING IS A THOROUGH UNDER-
STANDING OF THE RELATIVE PRO-
PORTIONS OF THE DIFFERENT PARTS
OF EACH LETTER.

INCLINED FREEHAND LOWER CASE LETTERS AND NUMERALS

PREPARATORY INSTRUCTIONS FOR PLATE 1

The Slope of the inclined letters is equal to that of the hypotenuse of a right triangle, the vertical leg of which is two and one-half units long and the horizontal leg one unit long. Fig. 230.

Lettering in Ink. The following list of plates will be made in ink directly on tracing cloth. A list of materials needed and directions for lettering in ink are given for Plate 11 of the vertical Gothic letters.

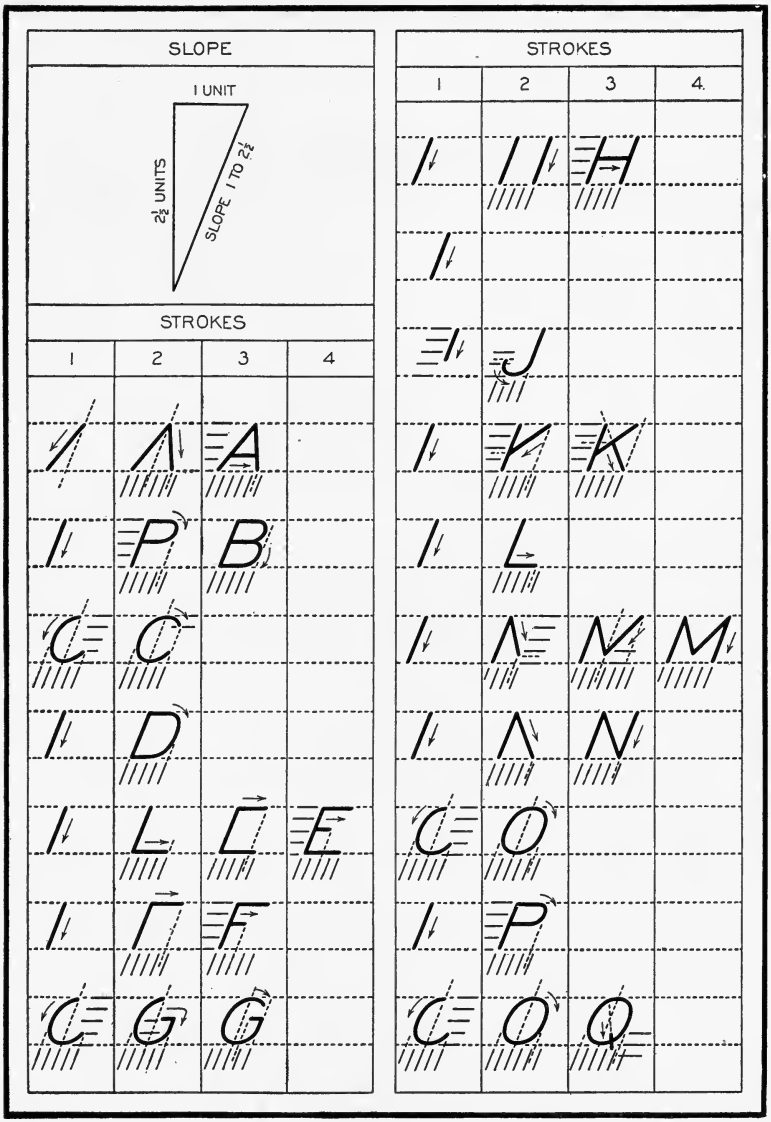


FIG. 230

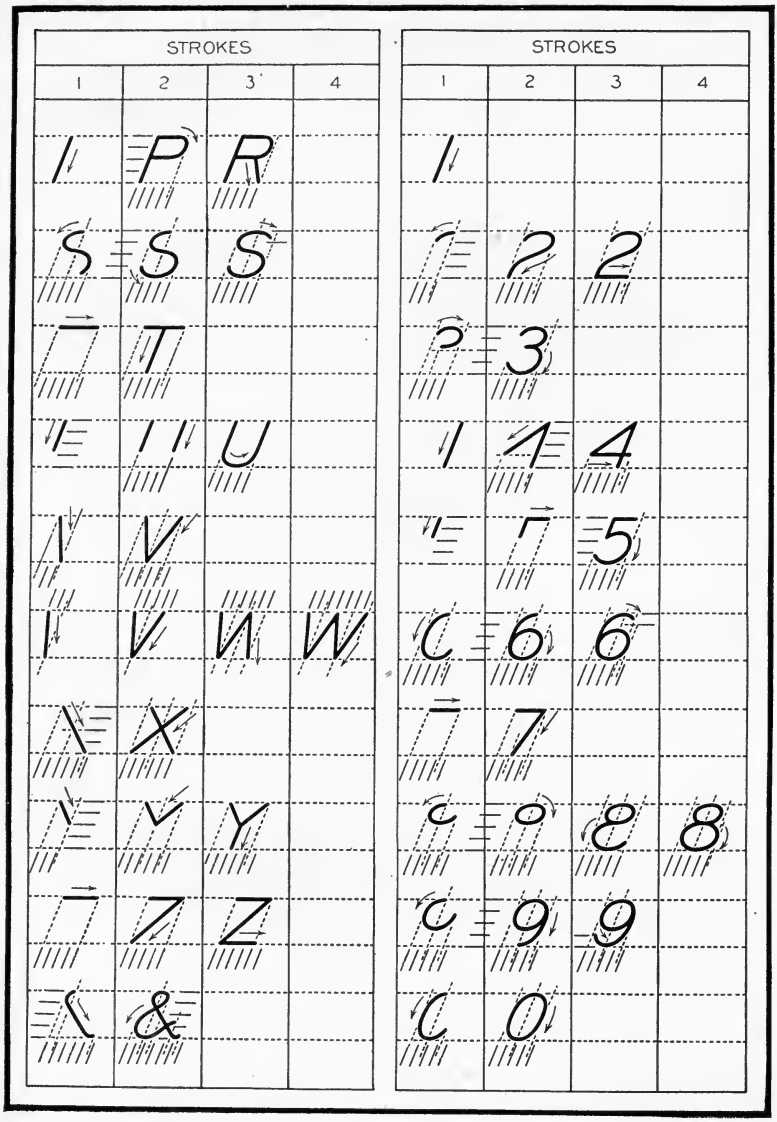


FIG. 231

DATA FOR PLATE 1

Given: Plate 1 to reduced size. Fig. 232.

Required: To make the plate to an enlarged scale.

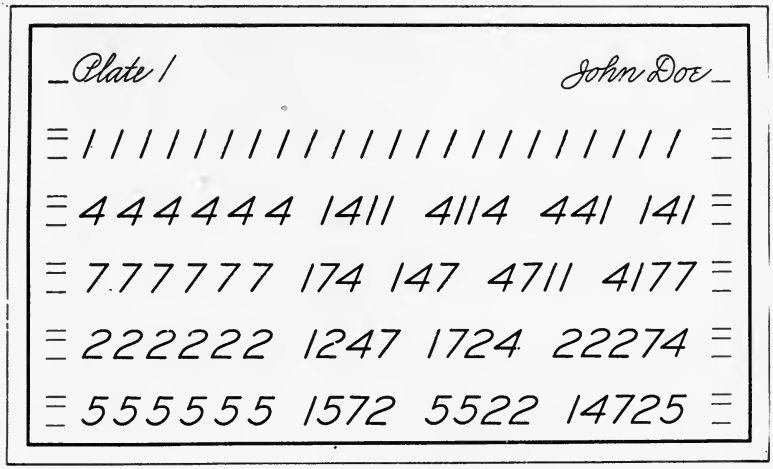


FIG. 232

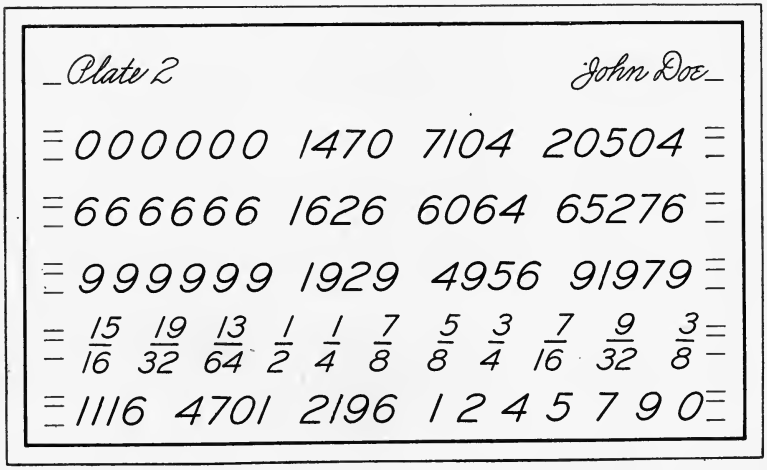


FIG. 233

PREPARATORY INSTRUCTIONS AND DATA FOR PLATE 2

Curved Strokes. The 6 and 9 have the same oval outline as the 0. This form should be kept in mind while drawing the 6 and 9.

Given: Plate 2 to reduced size. Fig. 233.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS AND DATA FOR PLATE 3

The two ovals of the 8 have their major axes at 45°. The same combination of ovals is the basic form for the 3.

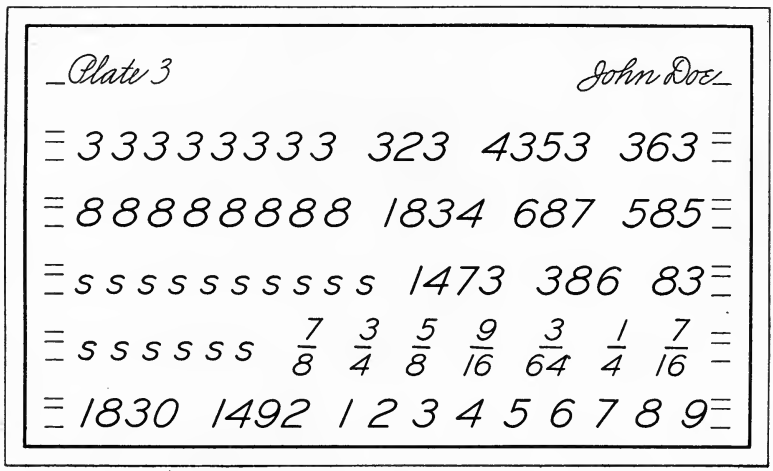


FIG. 234

Given: Plate 3 to reduced size. Fig. 234.

Required: To make the plate to an enlarged scale.

The strokes for the S are given in Fig. 243.

PREPARATORY INSTRUCTIONS AND DATA FOR PLATE 4

Spacing of Letters. Observe carefully the spacing of the letters in the words. Correct spacing is as essential as correct forms.

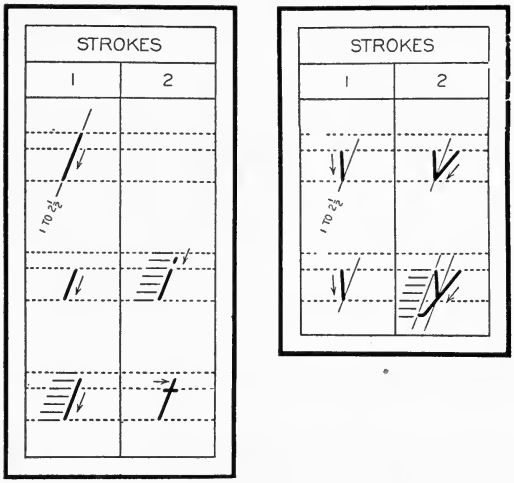


FIG. 235

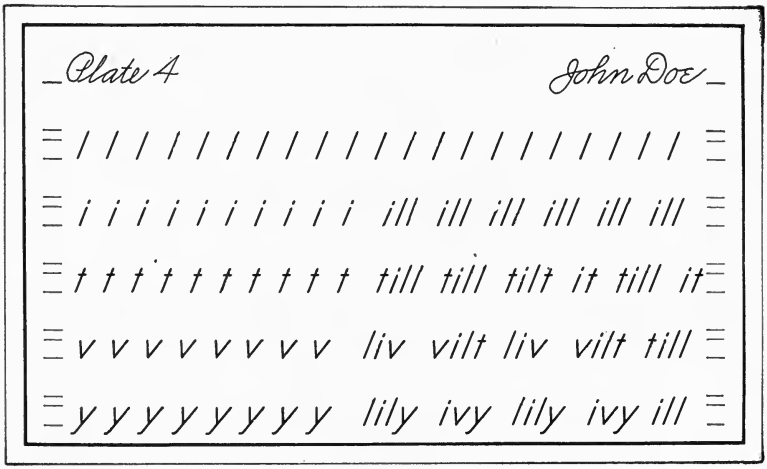


FIG. 236

Given: Plate 4 to reduced size. Fig. 236.

Required: To make the plate to an enlarged scale.

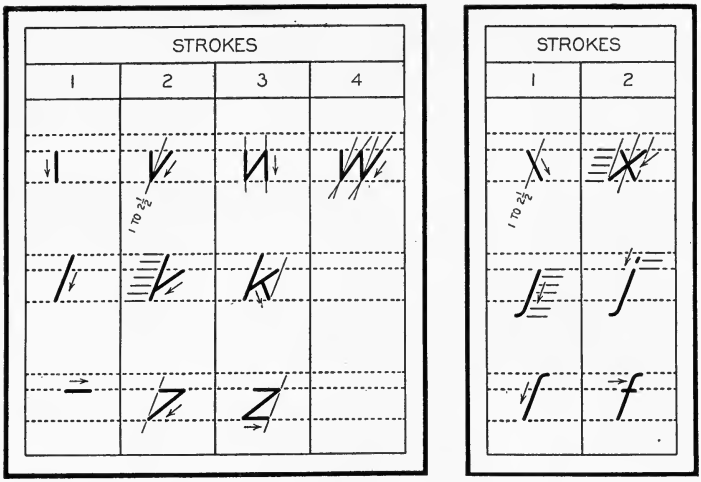


FIG. 237

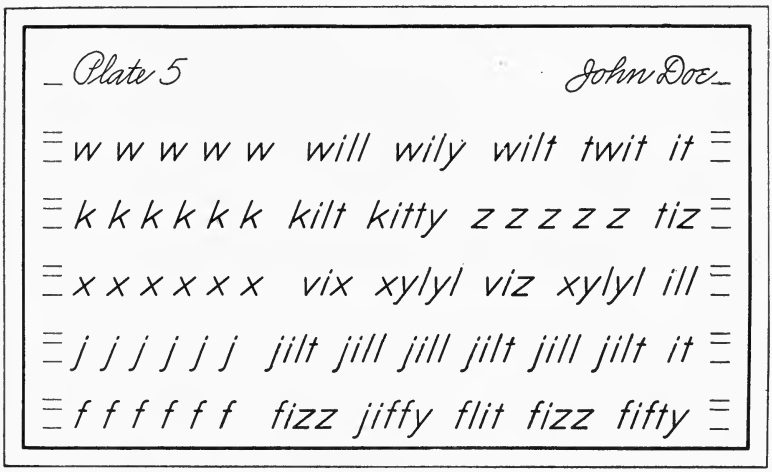


FIG. 238

DATA FOR PLATE 5

Given: Plate 5 to reduced size. Fig. 238.

Required: To make the plate to an enlarged scale.

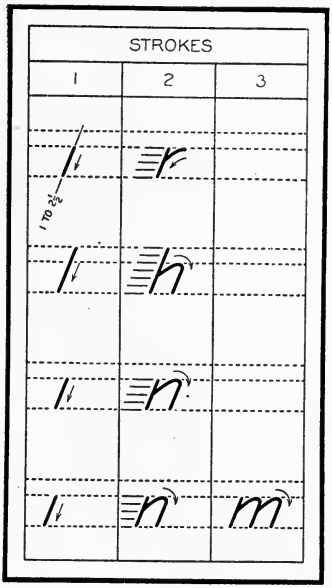


FIG. 239

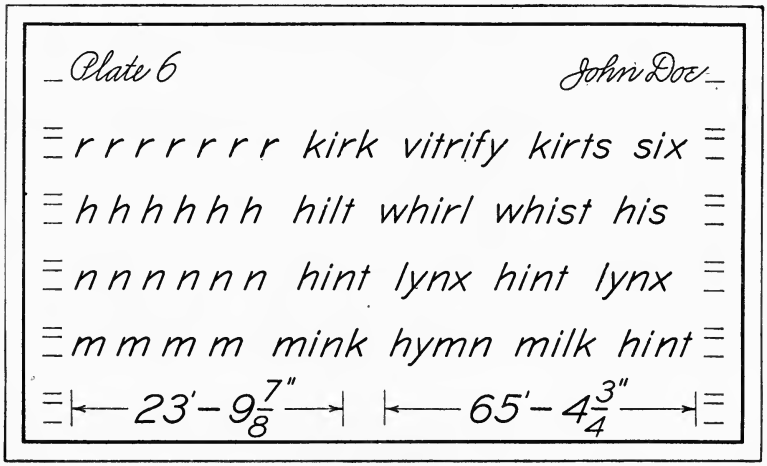


FIG. 240

DATA FOR PLATE 6

Given: Plate 6 to reduced size. Fig. 240.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS AND DATA FOR PLATE 7

Curved Strokes. The major axes of the oval letters of this plate are in the direction of the slope.

Given: Plate 7 to reduced size. Fig. 242.

Required: To make the plate to an enlarged scale.

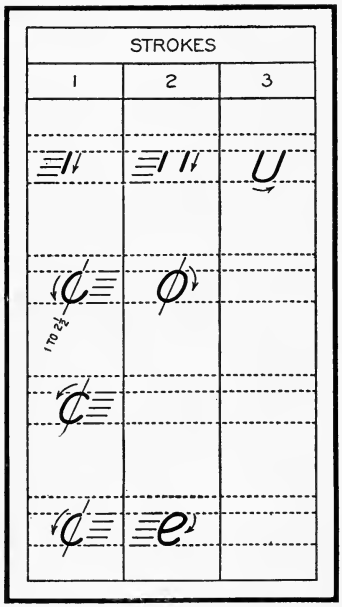


FIG. 241

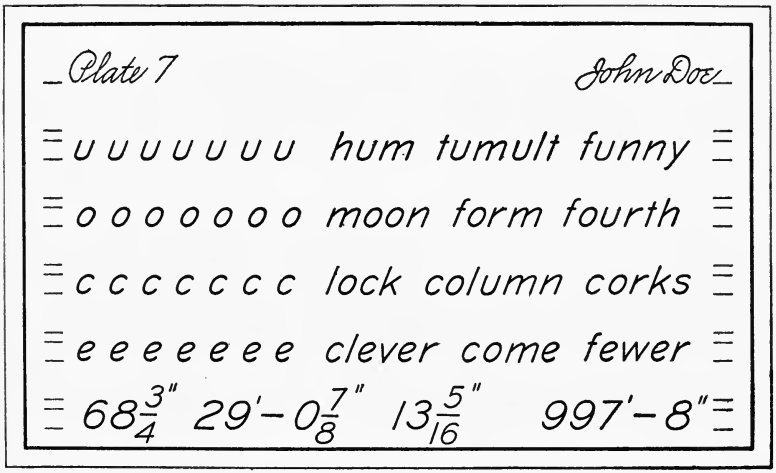


FIG. 242

PREPARATORY INSTRUCTIONS FOR PLATE 8

Curved Strokes. The major axes of the ovals of this plate make 45° with the horizontal.

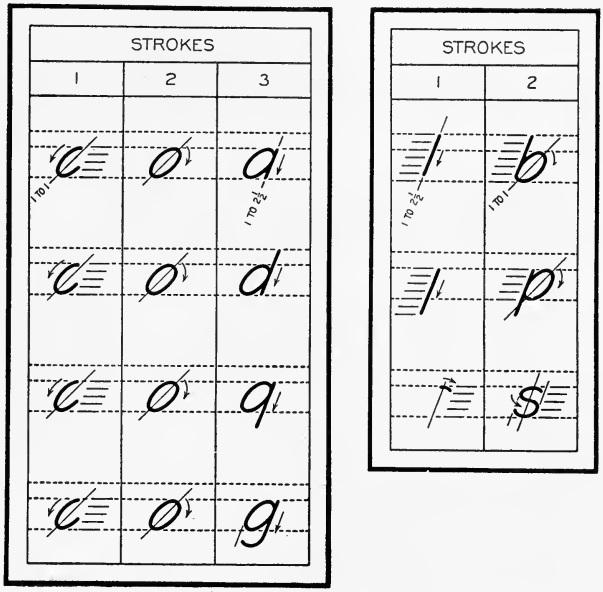


FIG. 243

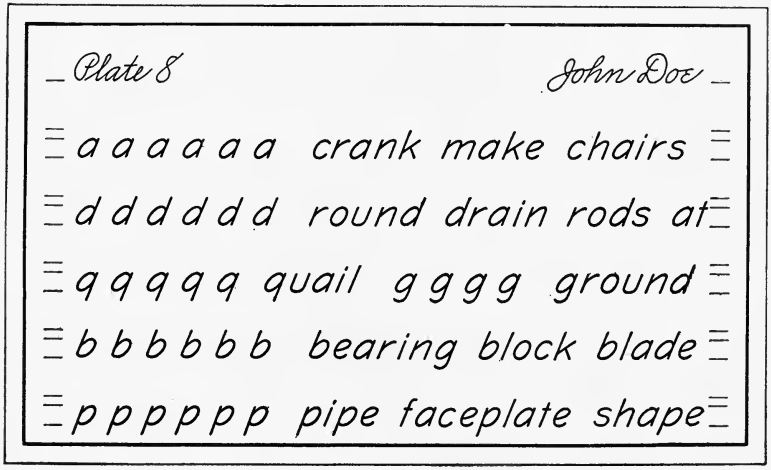


FIG. 244

DATA FOR PLATE 8

Given: Plate 8 to reduced size. Fig. 244.

Required: To make the plate to an enlarged scale.

PREPARATORY INSTRUCTIONS FOR PLATE 9

Composition. In the following composition plates the spacing of letters and words should be given as much consideration as the forms of the letters. The student should strive to produce a good general effect in the plate.

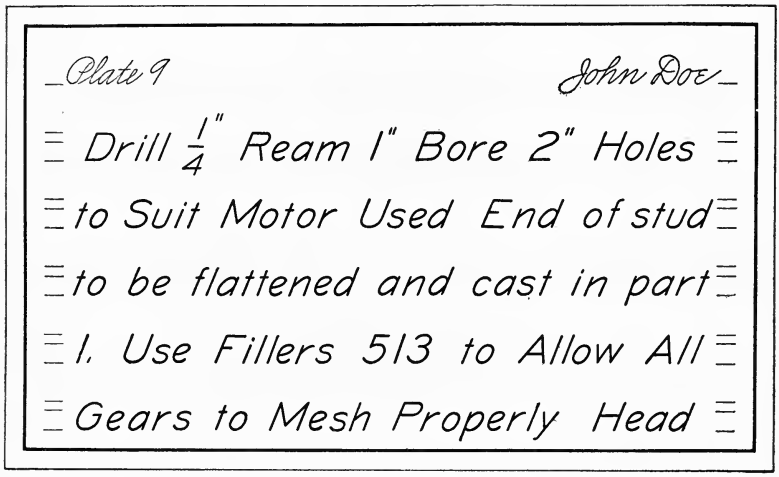


FIG. 245

DATA FOR PLATE 9

Given: Plate 9 to reduced size. Fig. 245.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 10

Given: Plate 10 to reduced size. Fig. 246.

Required: To make the plate to an enlarged scale.

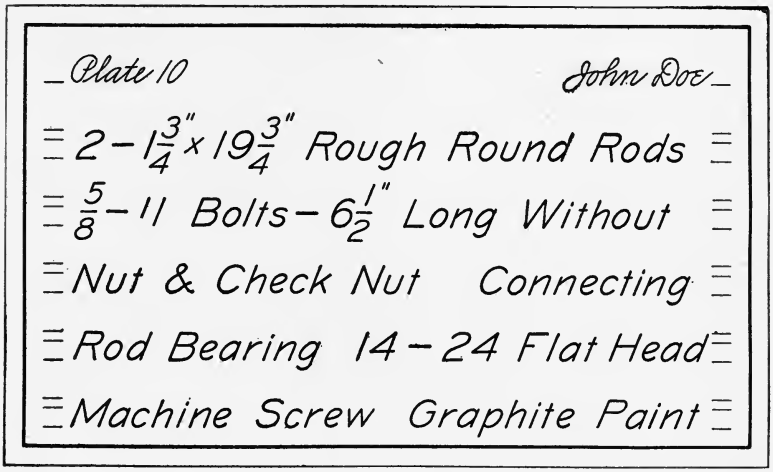


FIG. 246.

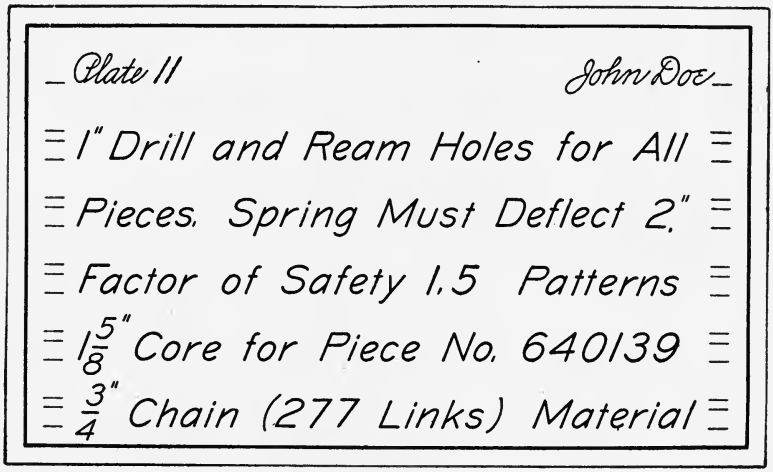


FIG. 247

DATA FOR PLATE 11

Given: Plate 11 to reduced size. Fig. 247.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 12

Given: Plate 12 to reduced size. Fig. 248.

Required: To make the plate to an enlarged scale.

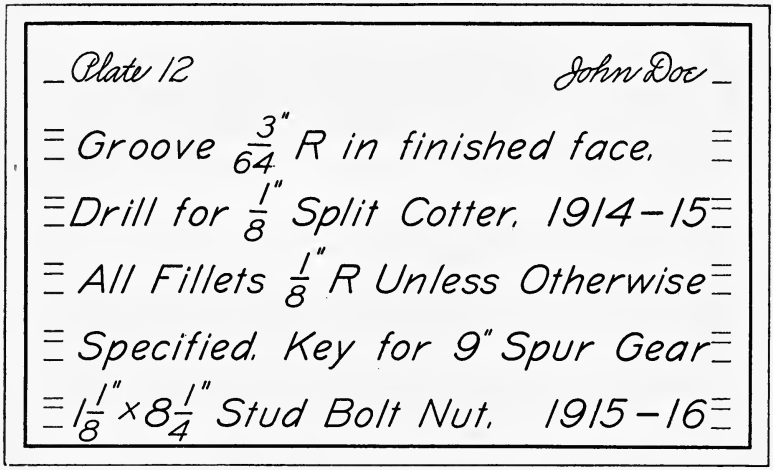


FIG. 248

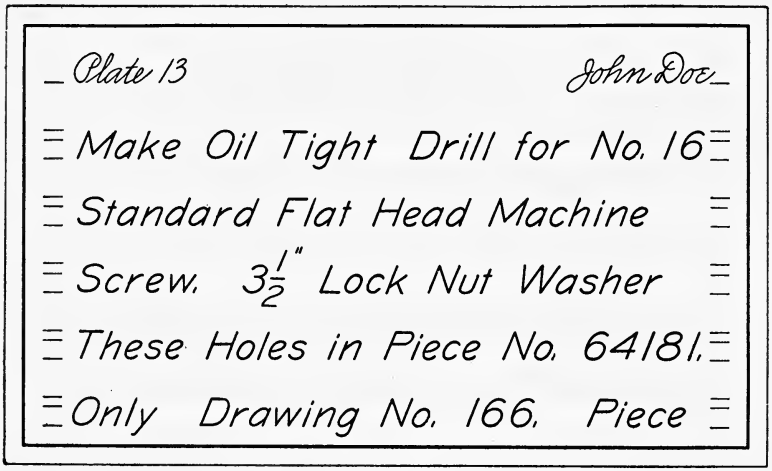


FIG. 249

DATA FOR PLATE 13

Given: Plate 13 to reduced size. Fig. 249.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 14

Given: Plate 14 to reduced size. Fig. 250.
Required: To make the plate to an enlarged scale.

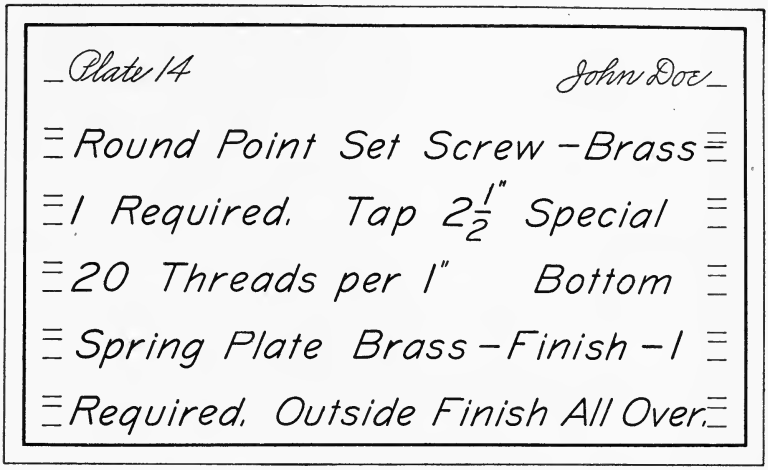


Fig. 250

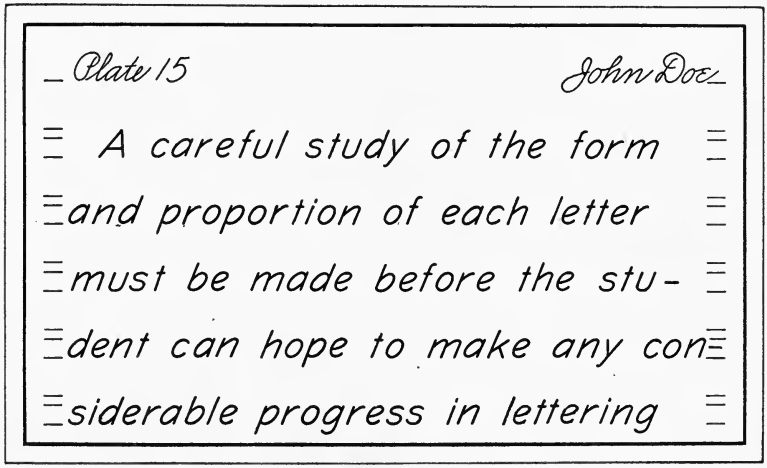


Fig. 251

DATA FOR PLATE 15

Given: Plate 15 to reduced size. Fig. 251.
Required: To make the plate to an enlarged scale.

DATA FOR PLATE 16

Given: Plate 16 to reduced size. Fig. 252.
Required: To make the plate to an enlarged scale.

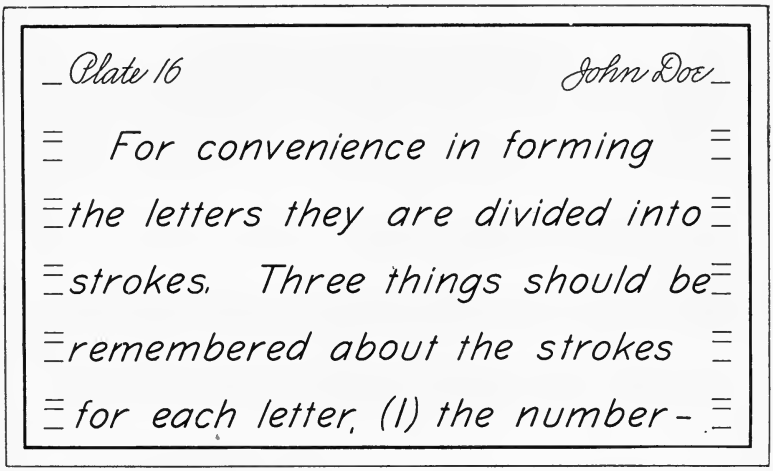


FIG. 252

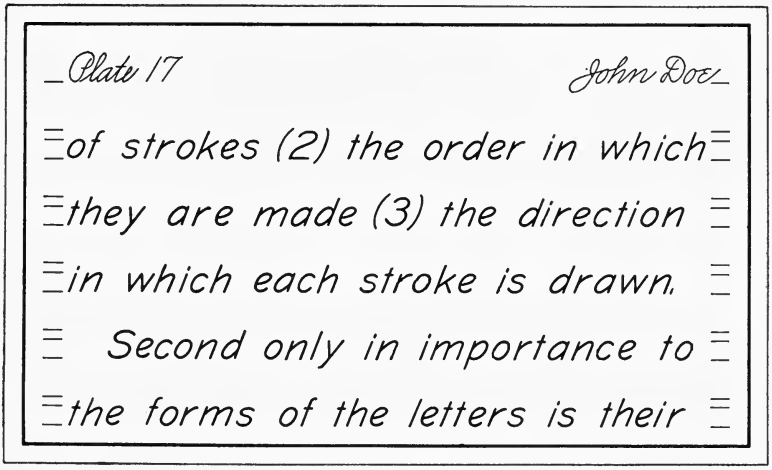


FIG. 253

DATA FOR PLATE 17

Given: Plate 17 to reduced size. Fig. 253.
Required: To make the plate to an enlarged scale.

DATA FOR PLATE 18

Given: Plate 18 to reduced size. Fig. 254.
Required: To make the plate to an enlarged scale.

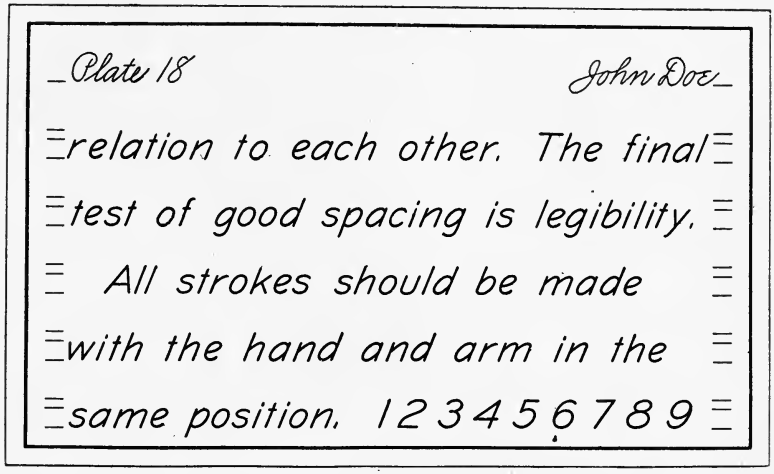


FIG. 254

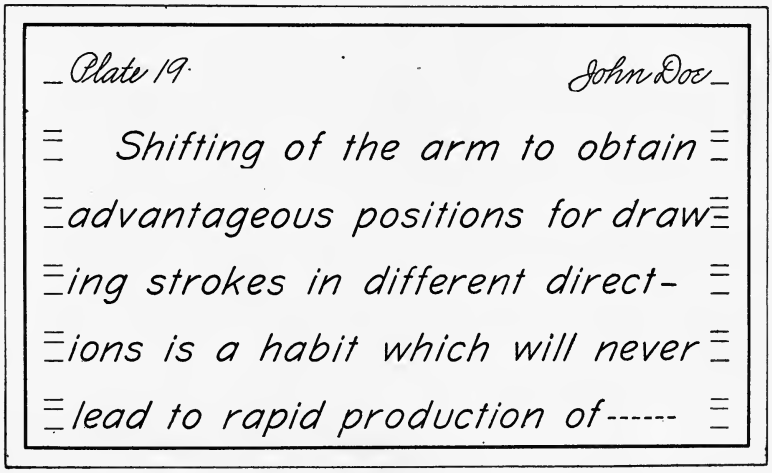


FIG. 255

DATA FOR PLATE 19

Given: Plate 19 to reduced size. Fig. 255.
Required: To make the plate to an enlarged scale.

DATA FOR PLATE 20

Given: Plate 20 to reduced size. Fig. 256.

Required: To make the plate to an enlarged scale.

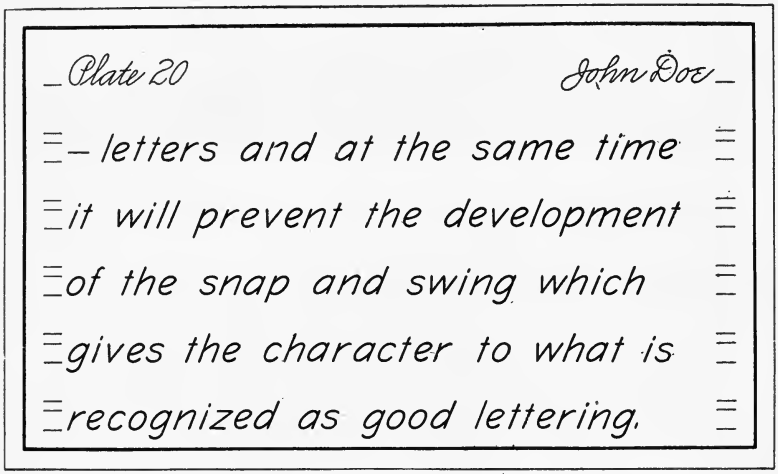


FIG. 256

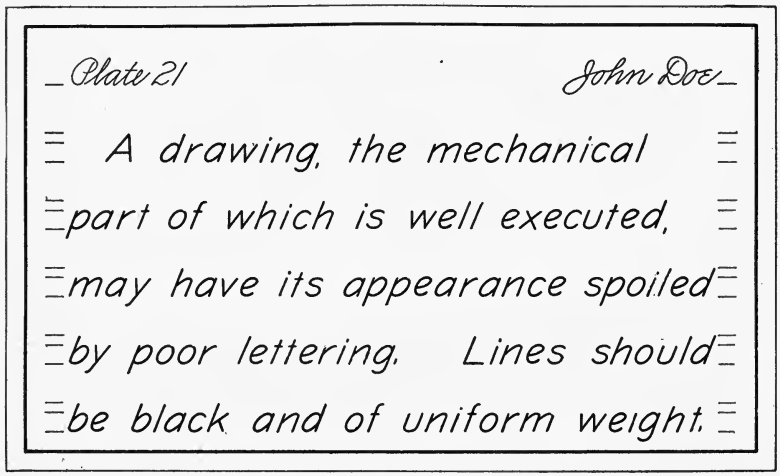


FIG. 257

DATA FOR PLATE 21

Given: Plate 21 to reduced size. Fig. 257.

Required: To make the plate to an enlarged scale.

DATA FOR PLATE 22

Given: Plate 22 to reduced size. Fig. 258.
Required: To make the plate to an enlarged scale.

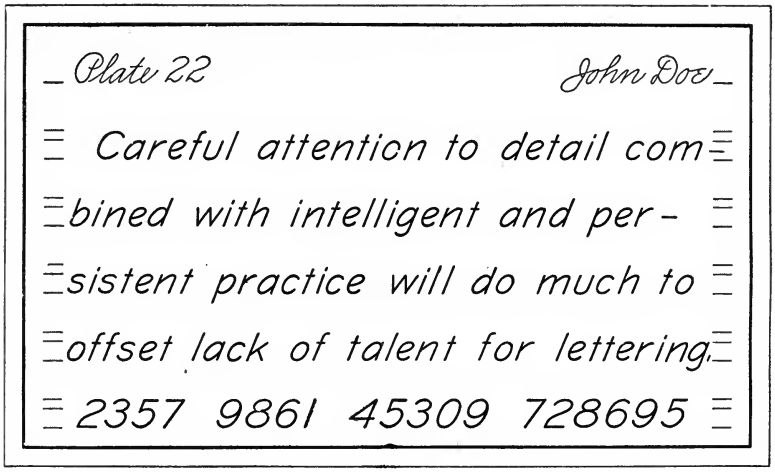


FIG. 258

CHAPTER VIII

ADVANCED DRAWING

Drawing from Models—Detail Drawing—Assembly Drawing

PREPARATORY INSTRUCTIONS FOR PLATE 24

Irregular Curve. A curved line which is determined by a series of points may be drawn with the irregular curve. When the points through which the line is to be drawn have been

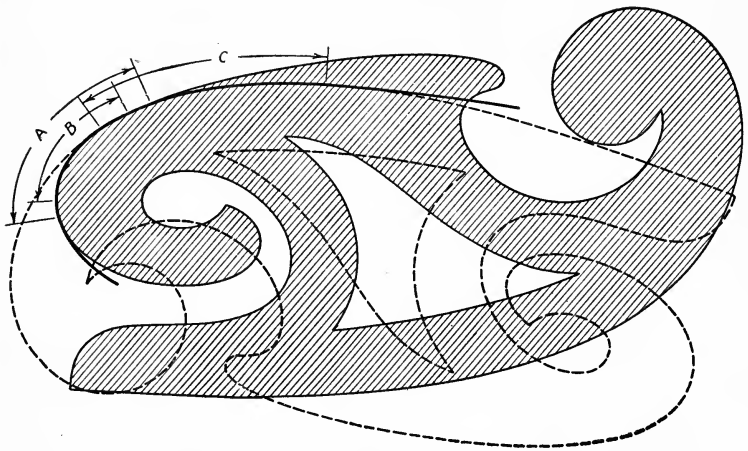


Fig. 259. Using the Irregular Curve

located, proceed to draw the line as follows, referring to Fig. 259 as an example. Beginning at the left end of the line, find by trial that portion of the irregular curve which will fit as

many consecutive points as possible. To secure a smooth curve the line drawn should not go through all of the points coincident with the irregular curve. Example, Fig. 259. If the irregular curve coincides with the line for the distance A only the distance B should be drawn with this setting of the curve. In setting the irregular curve after a section has been drawn care should be taken to fit it back on a portion of the line already drawn to insure a smooth joint. Example: C, the new setting, overlaps B, previously drawn. The irregular curve should always be between the draftsman and the line being drawn. The forearm should be nearly perpendicular to the tangent to the curve at any point.

When inking a curve the pen should be held vertically and rotated on its axis as the line is drawn to keep the nibs always in the direction of the edge of the irregular curve.

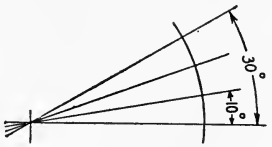


FIG. 260. CONSTRUCTING ANGLES OF 5°, 10°, ETC.

Constructing Angles in Multiples of 5°. Angles of 5° or 10° are easily constructed, as shown in Fig. 260. With the T-square and triangle two lines are drawn at 30° to each other. With their intersection as a center draw an arc of any convenient radius. With the dividers trisect the arc between the two lines. Radial lines through these points on the arc are 10° apart.

An angle of 5° may be obtained by trisecting an arc between two lines making an angle of 15° with each other, or bisecting an arc between two lines making an angle of 10° with each other.

The use of a protractor affords a more direct method of constructing angles.

DATA FOR PLATE 24

Given: A cam, Fig. 261; a swivel hook, Fig. 262; and a swing arm, Fig. 263.

Required: To make a pencil mechanical drawing of the object shown in Fig. 261, 262, or 263, as assigned by the instructor.

Instructions: Use the inclined lower case letters for notes and the inclined Arabic numerals for dimensions on this drawing. The title should be lettered in vertical capital letters.

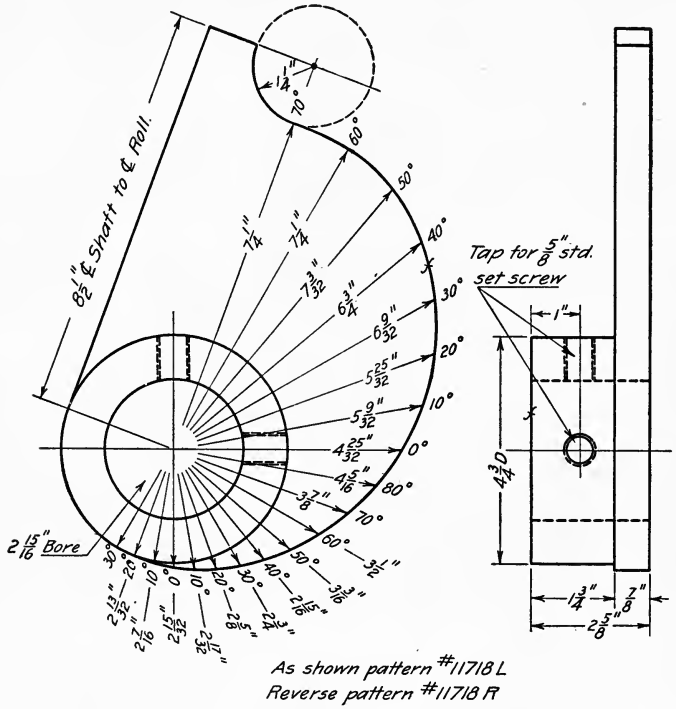


FIG. 261. OPERATING CAM FOR 24" PIVOTED BUCKET CONVEYOR EIGHT WANTED—CAST IRON

Cam. The points for the curve of the cam are determined by measuring from the center of the hub on radial lines 10° apart. To obtain dimensions for calculating the size of the enclosing rectangle, construct a few points of the curve and scale the layout.

Swivel Hook. The drawing of the swivel hook is peculiar in that only one view is given. A second view is made unneces-

sary in this case by the revolved section and the evident form of the swivel end.

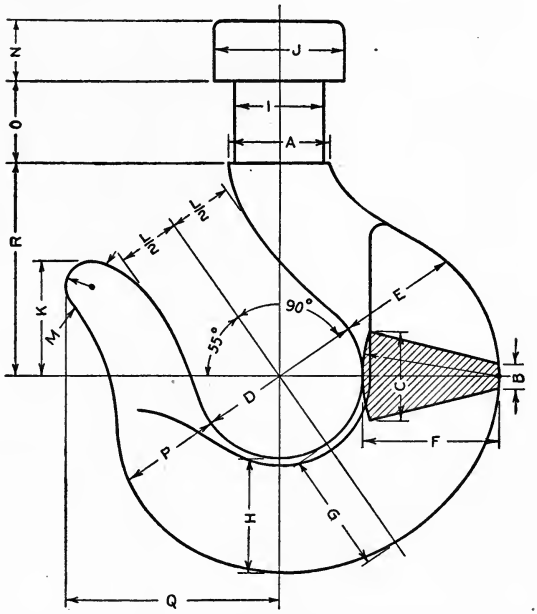


FIG. 262. SWIVEL HOOK FOR –TON ELECTRIC CRANE ONE WANTED—STEEL

(All dimensions in inches.)

Tons	Lbs.	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
$\frac{1}{8}$	250	$\frac{5}{8}$	$\frac{5}{32}$	$\frac{35}{64}$	$1\frac{5}{16}$	$\frac{11}{16}$	$\frac{27}{32}$	$\frac{3}{4}$	$\frac{23}{32}$	$\frac{9}{16}$	$\frac{13}{16}$	$\frac{15}{16}$	1	$\frac{5}{16}$	$\frac{21}{64}$	$\frac{9}{16}$	$\frac{21}{32}$	$1\frac{11}{16}$	$1\frac{11}{16}$
$\frac{1}{4}$	500	$\frac{11}{16}$	$\frac{11}{64}$	$\frac{5}{8}$	$1\frac{3}{8}$	$\frac{3}{4}$	$\frac{59}{64}$	$\frac{53}{64}$	$\frac{25}{32}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{31}{32}$	$1\frac{1}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{47}{64}$	$1\frac{3}{4}$	$1\frac{3}{4}$
$\frac{1}{2}$	1000	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{21}{32}$	$1\frac{1}{2}$	$\frac{13}{16}$	1	$\frac{29}{32}$	$\frac{55}{64}$	$\frac{11}{16}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{1}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{11}{16}$	$\frac{51}{64}$	$1\frac{15}{16}$	$1\frac{15}{16}$
1	2000	$1\frac{1}{16}$	$\frac{17}{64}$	$\frac{15}{16}$	$1\frac{3}{4}$	$1\frac{5}{32}$	$1\frac{27}{64}$	$1\frac{9}{32}$	$1\frac{13}{64}$	$\frac{15}{16}$	$1\frac{3}{8}$	$1\frac{7}{32}$	$1\frac{5}{16}$	$\frac{17}{32}$	$\frac{41}{64}$	$\frac{7}{8}$	$1\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{1}{4}$
$1\frac{1}{2}$	3000	$1\frac{1}{4}$	$\frac{5}{16}$	$1\frac{3}{32}$	2	$1\frac{23}{64}$	$1\frac{43}{64}$	$1\frac{1}{2}$	$1\frac{27}{64}$	$1\frac{1}{8}$	$1\frac{9}{16}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$\frac{5}{8}$	$\frac{51}{64}$	$1\frac{1}{16}$	$1\frac{5}{16}$	$2\frac{9}{16}$	$2\frac{9}{16}$
2	4000	$1\frac{3}{8}$	$\frac{11}{32}$	$1\frac{7}{32}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{27}{32}$	$1\frac{21}{32}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{9}{16}$	$1\frac{11}{16}$	$\frac{11}{16}$	$\frac{29}{32}$	$1\frac{1}{4}$	$1\frac{29}{64}$	$2\frac{15}{16}$	$2\frac{15}{16}$
3	6000	$1\frac{3}{4}$	$\frac{7}{16}$	$1\frac{17}{32}$	$2\frac{3}{4}$	$1\frac{57}{64}$	$2\frac{11}{32}$	$2\frac{7}{64}$	$1\frac{63}{64}$	$1\frac{9}{16}$	$2\frac{3}{16}$	$1\frac{7}{8}$	2	$\frac{7}{8}$	$1\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{27}{32}$	$3\frac{9}{16}$	$3\frac{9}{16}$
4	8000	2	$\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{4}$	$2\frac{11}{64}$	$2\frac{43}{64}$	$2\frac{13}{32}$	$2\frac{17}{64}$	$1\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{7}{16}$	1	$1\frac{21}{64}$	2	$2\frac{7}{64}$	$4\frac{3}{16}$	$4\frac{3}{16}$
5	10000	$2\frac{1}{4}$	$\frac{9}{16}$	$1\frac{31}{32}$	$3\frac{3}{4}$	$2\frac{7}{16}$	3	$2\frac{45}{64}$	$2\frac{35}{64}$	2	$2\frac{13}{16}$	$2\frac{9}{16}$	$2\frac{13}{16}$	$1\frac{1}{8}$	$1\frac{35}{64}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$4\frac{13}{16}$	$4\frac{13}{16}$
6	12000	$2\frac{1}{2}$	$\frac{5}{8}$	$2\frac{3}{16}$	$4\frac{1}{4}$	$2\frac{45}{64}$	$3\frac{11}{32}$	3	$2\frac{27}{32}$	$2\frac{3}{16}$	$3\frac{1}{8}$	$2\frac{5}{8}$	$3\frac{3}{16}$	$1\frac{1}{4}$	$1\frac{45}{64}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$5\frac{1}{2}$	$5\frac{1}{2}$
8	16000	$2\frac{7}{8}$	$\frac{23}{32}$	$2\frac{1}{2}$	$5\frac{1}{4}$	$3\frac{1}{8}$	$3\frac{27}{32}$	$3\frac{29}{64}$	$3\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{9}{16}$	$3\frac{15}{16}$	$1\frac{7}{16}$	$1\frac{31}{32}$	$3\frac{1}{2}$	$3\frac{1}{32}$	$6\frac{3}{4}$	$6\frac{3}{4}$
10	20000	$3\frac{1}{4}$	$\frac{13}{16}$	$2\frac{13}{16}$	$6\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{11}{32}$	$3\frac{29}{32}$	$3\frac{11}{16}$	$2\frac{7}{8}$	4	$4\frac{1}{4}$	$4\frac{11}{16}$	$1\frac{5}{8}$	$2\frac{9}{32}$	$4\frac{1}{4}$	$3\frac{7}{16}$	8	8

A table of values of the dimension symbols for various sizes of the hook is given with the view. This is called a *tabulated drawing.*

Swing Arm. Attention is called to the method of showing the detail of the fork by means of a partial auxiliary view; also to the method of relating centers by coordinate dimensions.

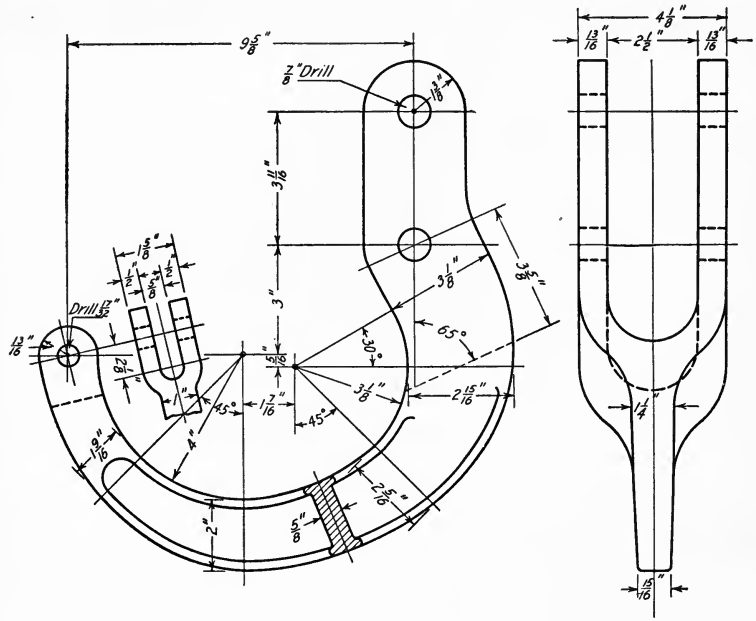


FIG. 263. SWING ARM FOR OHIO MONARCH SHREDDER ONE WANTED—CAST IRON

DATA FOR PLATE 25

Given: The pencil mechanical drawing, Plate 24.

Required: To make a tracing of Plate 24.

Instructions: The lines of the drawing should be inked in the following order:

1. Arcs and circles.
2. Irregular curves.
3. Horizontal lines.
4. Vertical lines.
5. Inclined lines.

Sketching from the Object

PREPARATORY INSTRUCTIONS FOR PLATE 26

Freehand sketches may be made by a designer to get an idea of the form of certain parts in working out his design. A designer or chief draftsman may use them as a means of conveying his ideas to a junior draftsman.

In case a machine is broken time may often be saved by sketching the broken parts in the shop and having parts made to replace them instead of sending to the manufacturer of the machine for repairs. When a change of design is contemplated and the original drawings are not to be had, sketches of the parts affected may be made from the existing machine and the desired changes incorporated in the mechanical drawing made from sketches. When time permits and it is desirable to have a permanent record of the drawing a mechanical drawing should be made from the sketch, but in an emergency the sketch if carefully drawn and checked may be used as a shop drawing.

In making the orthographic sketches of Chapter II, the fact that certain views of the object were shown in correct proportion and were dimensioned made the task of drawing the other views of the object to larger scale a simple process.

The drawing of orthographic sketches from dimensioned perspective sketches, Chapter III, increased the difficulty of selecting and arranging the views and to some extent the dimensions.

Compared to sketching from orthographic and perspective views the average beginner will find the making of an orthographic sketch from the object a rather intangible problem. He will find it difficult to represent in outline an object which to the eye stands out in relief in light and shadow. At the same time he must keep in mind the fact that only two dimensions can be represented in each view. He is, also, confronted with the necessity of establishing center lines, datum lines, etc., which are not edges of the object but are of prime importance in the drawing.

He must select dimensions to show the proper relation between the details of the object. These dimensions must also

be selected to show similar distances on parts which are fitted to the object. He must use his judgment as to the accuracy with which each measurement should be made, as to the allowance for inaccuracies of workmanship, inaccuracies inherent in the process of manufacture, etc.

Selecting Views. In selecting the views of an object to be drawn the principles developed in previous chapters should be used. In general only necessary views are drawn, but in the sketch additional views, partial views, sections, etc., may be drawn in preference to complicating the necessary views with lines.

Methods Used in Drawing. After an inspection of the object and after a decision has been reached as to what views are to be drawn, the student should place the object, if it is removable, so that he can obtain the required views without changing its position. Very often the shifting of the object leads to errors in the relative position of the views, such as placing the left side view to the right instead of to the left of the front view. With the object always in the same position and the principles as to relation of views, developed in former chapters, well in mind, such errors are not likely to occur. The views should show the object in as good proportion as can be obtained without scaling it. Time should not be wasted in taking dimensions at this stage and attempting to lay them out to scale.

The first step in the construction of the drawing is to locate center or other reference lines. Circles should be constructed by first drawing two center lines at right angles. The radii should then be estimated from the intersection on these lines, and the circle drawn through the four points located.

If the object is of cylindrical form it will usually be found advantageous to draw the circular view first because of the ease with which the other views may be drawn by projecting the diameters from the circular view. In some cases where the views of the details of the object are interdependent it will be necessary to construct two or more views simultaneously.

The use of the coordinate paper greatly facilitates the alignment and proportioning of the details in different views. The student should learn to use the ruled lines merely as a guide

in locating and proportioning the views. The use of the squares as units of measurement for the purpose of drawing the object to scale is not to be considered; for while it is admitted that their use will aid in proportioning the drawing, it is not one of the functions of a freehand sketch to show the object in accurate proportion, and the counting of the squares entails a serious waste of time.

Selection and Arrangement of Dimensions. When the views of the object are complete and have been checked carefully to make sure that they, together with necessary supplementary notes, fully represent the object, the question of dimensioning should next be considered.

To dimension an object properly the draftsman must have some knowledge of the process through which it must go in the shop to become a finished product. If it be a casting he must know what dimensions the patternmakers will use in making the pattern; if it has finished surfaces he must know with what machines each is finished and give the dimensions in such a way that the machinist may use them directly. Example: The diameter of a part to be turned in the lathe should be given rather than the radius, since the most convenient and accurate method of measuring a cylindrical surface is by means of the caliper or micrometer.

Enough dimensions should be given to determine completely the sizes and relation of the details of the object. When a sketch is made at some distance from the place at which it is to be used either to furnish information for a mechanical drawing or as a shop drawing, the draftsman must be sure that all necessary dimensions are given. However, he should guard against giving unnecessary or useless dimensions in an attempt to avoid omitting necessary dimensions. All finished surfaces, special fits, etc., should be marked in such a way that they cannot be misunderstood. The nature of the sketch admits of a freer use of explanatory notes than would be tolerated on the mechanical drawing.

Details which are required to be accurately located on the object should be referred by dimensions to center lines or finished surfaces. As the dimensions to be given are planned the

extension and dimension lines should be drawn, but the dimension figures should not be inserted until all such lines are drawn.

When the extension and dimension lines are drawn the arrowheads should be made.

MEASUREMENTS

Measuring Instruments

The following paragraphs contain a short description of the more common tools used in taking measurements from the object for the purpose of dimensioning a sketch:

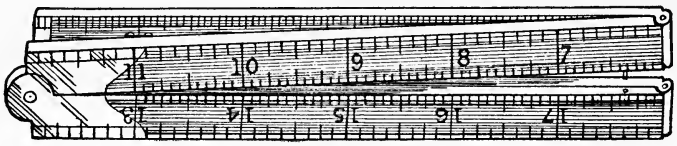


Fig. 264. Folding Rule

The Folding Rule. Rules are made of various lengths which may be folded and carried in the pocket. The smallest divisions are usually $\frac{1}{16}''$ and $\frac{1}{10}''$. Their construction makes the division into smaller fractions of an inch unwarrantable as these rules

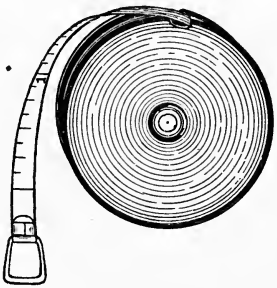


Fig. 265. Steel Tape

cannot be depended upon to read accurately to smaller units. A two-foot rule will be found very serviceable where accuracy is not required. While convenient in measuring long distances they are in general suitable only for rough work. Fig. 264.

The Steel Tape. Steel tape may be had in lengths of 3 feet to 200 feet or more. As in the case of the rules their divisions are coarse and cannot be used for accurate measurements. Fig. 265.

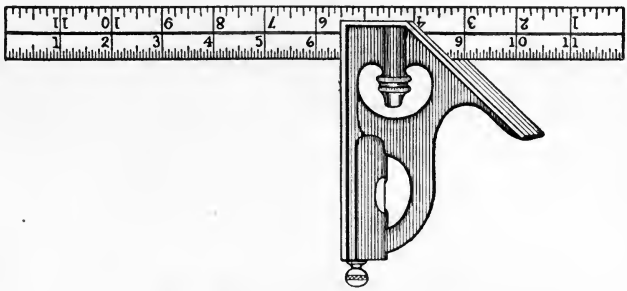


FIG. 266. ADJUSTABLE SQUARE

The Steel Scale. For accurate measurements steel scales are used. These scales may be had in lengths of 1″ to 72″, and with various combinations of graduations on the two edges of each

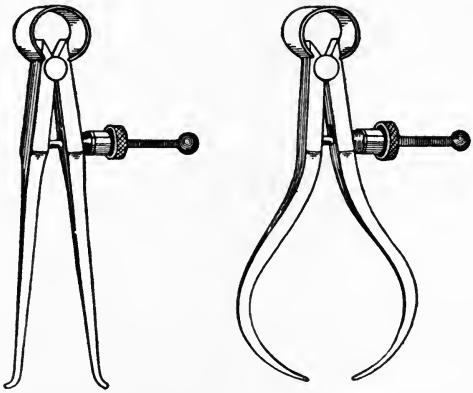


FIG. 267. OUTSIDE CALIPER. INSIDE CALIPER

side. The most common graduations are $\frac{1}{8}''$, $\frac{1}{16}''$, $\frac{1}{32}''$, $\frac{1}{64}''$, and $\frac{1}{100}''$. Fig. 266.

The Adjustable Square. Fig. 266 shows a square in which the blade is adjustable in the stock. The blade is an ordinary steel scale with a groove made to receive a hook which serves

to clamp the blade in the stock. The stock is furnished with a level. This instrument will be found useful in many ways.

Calipers. Calipers are used for obtaining measurements of length or diameter where the scale cannot be applied directly. After they are set to the distance which is to be measured they are placed upon a scale and the distance read. Fig. 267 shows two forms of calipers, one adapted to outside measurements, such as diameters of shafts, etc., while the other is best suited to inside measurements, such as the diameter of holes.

Other Devices, such as the plumb bob, straight edge, and surface gauge, may be of occasional use in taking measurements from the object.

Taking Measurements

Having drawn the dimension lines, extension lines, and arrowheads, there remains the taking of dimensions from the object and inserting them on the drawing. In doing this judgment must be exercised in determining with what degree of accuracy each measurement should be taken. Examples: Dimensions between rough surfaces usually need not be given closer than the nearest $\frac{1}{16}''$ or $\frac{1}{32}''$, while the inside diameter of the bushing in which a shaft is to run would probably be given .003″ or .004″ larger than the diameter of the shaft.

Judgment must also be exercised in determining whether irregularities such as the uneven thickness of castings, lack of symmetry, apparent discrepancies in spacing of holes, etc., are intentional and essential to the design and construction of the object, or whether they are non-essentials which have come about through natural causes in the process of manufacture or poor workmanship, and should be eliminated from the drawing.

The problems arising in the taking of measurements from the object are so varied that no attempt will be made here to discuss the subject fully. However, a few examples may be given which will illustrate the use of the measuring instruments and also the general principles involved in securing dimensions.

The distance between points on the same plane surface such as the distance between two parallel edges of the surface and

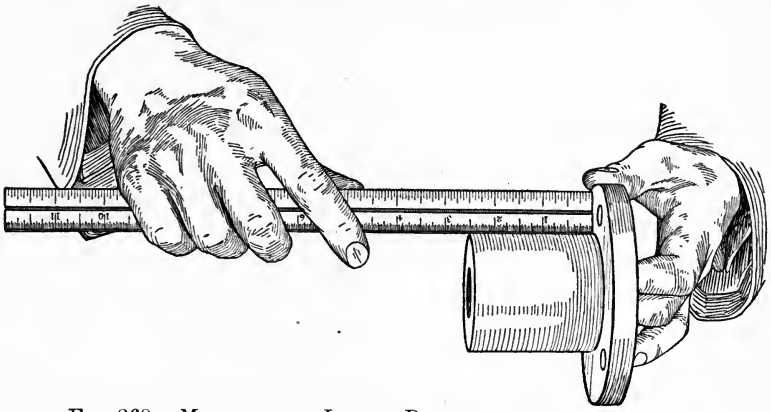


FIG. 268. MEASURING A LINEAR DISTANCE WITH THE SCALE

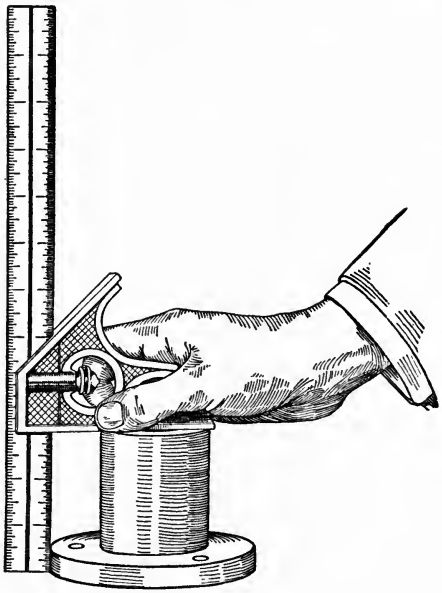


FIG. 269. MEASURING LINEAR DISTANCES WITH SQUARE

the length of cylinders may be measured directly with the rule or steel scale, as shown in Fig. 268. This method is only applicable for accurate measurement when the corners are sharp. When the corners are rounded the same dimension may be obtained by using the square or caliper, as shown in Fig. 269 or 270.

The use of the square here needs no explanation. The caliper must be set very carefully so that its points touch both surfaces between which the distance is to be measured, but not with enough pressure to spring the caliper. The proper adjustment

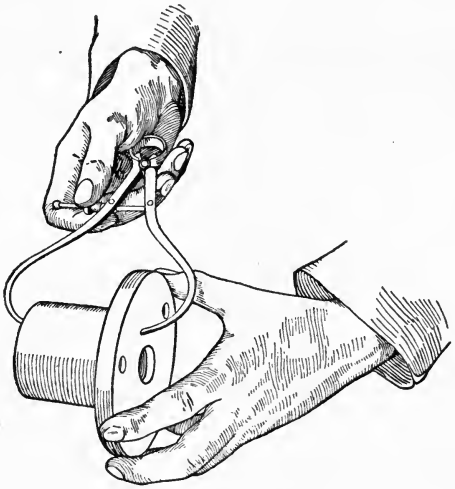


FIG. 270. MEASURING LINEAR DISTANCES WITH THE CALIPER

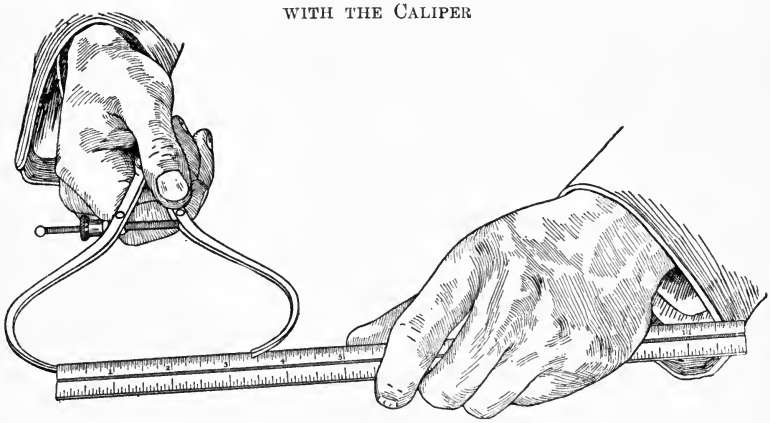


FIG. 271. READING THE CALIPER MEASUREMENT FROM THE SCALE

is obtained by means of the thumb screw on the adjustable caliper or by tapping the leg against a solid object in the case of the plain caliper. The distance between the points of the caliper

is measured with the steel scale, as shown in Fig. 271. Note that one point of the caliper rests against the end of the scale so that the operator's attention may be given entirely to reading the scale division at the other point.

The outside caliper is used in obtaining dimensions of curved surfaces. See Fig. 272. It is adjusted and the measurement

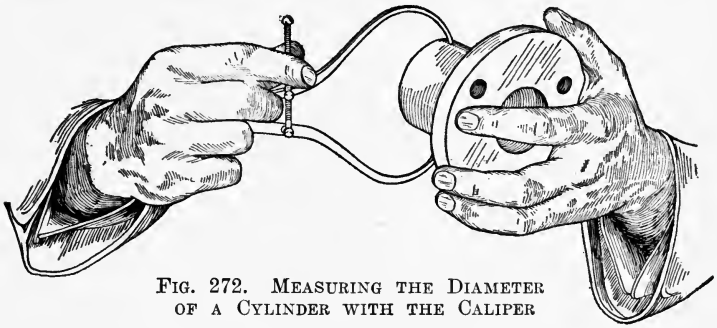


FIG. 272. MEASURING THE DIAMETER OF A CYLINDER WITH THE CALIPER

taken from the scale as previously described.

The inside caliper is used in measuring the diameters of holes and the openings between surfaces where the scale cannot be applied. Fig. 273. Measurements are obtained from the

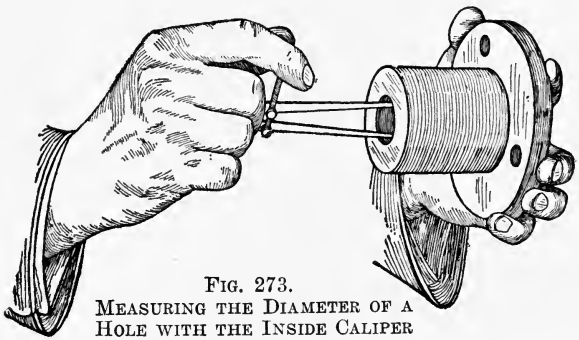


FIG. 273.
MEASURING THE DIAMETER OF A HOLE WITH THE INSIDE CALIPER

inside caliper by placing it over the scale, as shown in Fig. 274. Note that the scale is placed against a smooth surface and at right angles to it. One point of the inside caliper is placed against the smooth surface. By this method the scale division opposite the other point may be easily and accurately read.

When, as is very often the case, it is necessary to locate

centers of holes with reference to each other or with reference to some finished surface or datum line, a difficulty arises from

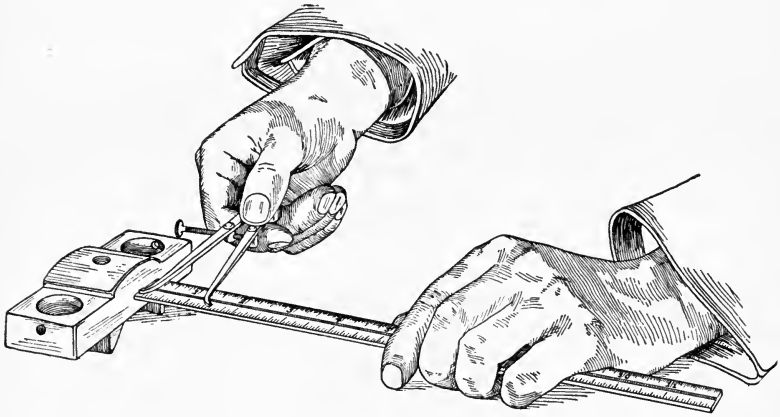


FIG. 274. READING MEASUREMENTS FROM THE INSIDE CALIPER

the fact that a center line does not exist on the object and must be established or the dimension obtained in a roundabout way.

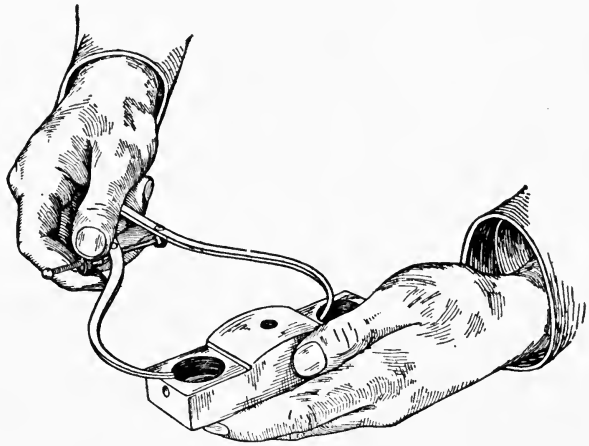


FIG. 275. MEASURING THE CENTER TO CENTER DISTANCE OF EQUAL HOLES

In the case of two holes of equal diameter the center-to-center distance may be obtained by measuring from the near edge of one to the far edge of the other. Fig. 275. The center-to-center distance of holes of unequal diameter may be obtained

by measuring from the near edge of one to the near edge of the other and adding one-half the diameter of each. The distance from an edge or surface to the center of a hole may be had by adding one-half the diameter of the hole to the distance from the edge or surface to the near edge of the hole.

Fig. 275 shows an object the form of which makes it necessary to use the caliper in measuring the distance between the centers of the two holes. The corners of cast parts are usually

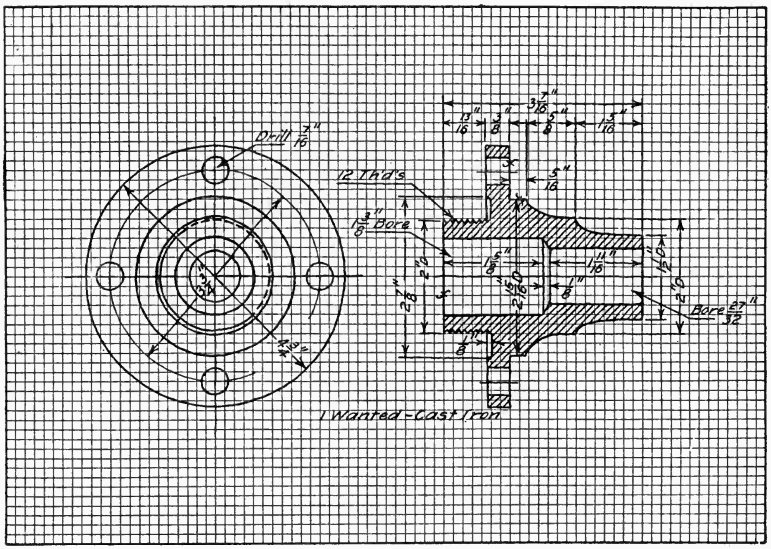


Fig. 276. Type Problem—Cylinder Head.—Freehand Sketch

rounded or filleted. The radii of these curves are not easily measured, but usually it is unnecessary to measure them accurately. The radii of small fillets may often be estimated entirely by eye or the scale held against the object at one point of tangency and the radius estimated by placing the thumb nail at the division on the scale opposite the other tangent point. A very satisfactory method applicable in some cases is to place the object over a sheet of paper and trace around the corner or fillet with a sharp pencil. The center of the arc thus obtained may be found by trial with the dividers and the radius measured.

Checking. Where a number of detail dimensions have been taken which make up the length of a larger detail or the whole length of the object, this over-all dimension should be checked by direct measurement as well as by addition of the detail dimensions.

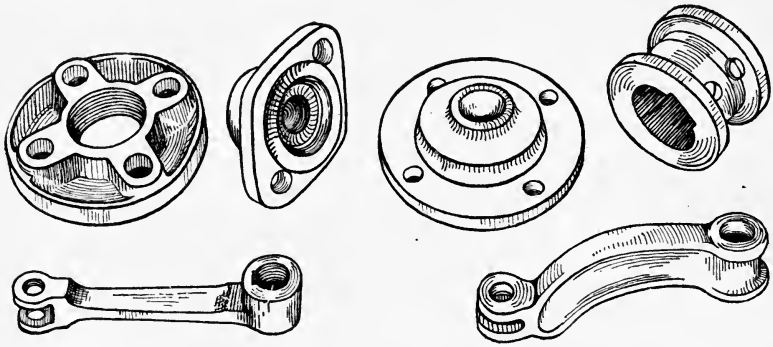


FIG. 277. TYPICAL OBJECTS FOR FIRST DRAWING FROM MODEL

DATA FOR PLATE 26

Given: A simple machine part or model preferably finished all over. Fig. 277 shows typical objects for this plate.

Required: To make a freehand orthographic sketch.

Instructions: The following is a brief summary of the steps arranged in sequential order to be taken in making a sketch from the object. It is believed that by carefully observing the steps of this outline the draftsman will be able to make the sketch complete and accurate with a minimum amount of effort, and to do the work in the least amount of time.

1. Select views.
2. Draw views (proportioning details by eye without taking dimensions).
3. Plan dimensions—draw dimension and extension lines.
4. Draw arrowheads.
5. Take dimensions from the object and place figures.
6. Mark finished surfaces.
7. Print all notes, including the name of the part drawn, the number required, and the material from which each part is to be made.

DATA FOR PLATE 27

Given: The orthographic sketch, Plate 26.
Required: To make a mechanical drawing from Plate 26.

DATA FOR PLATE 28

Given: The mechanical drawing, Plate 27.
Required: To make tracing from Plate 27.

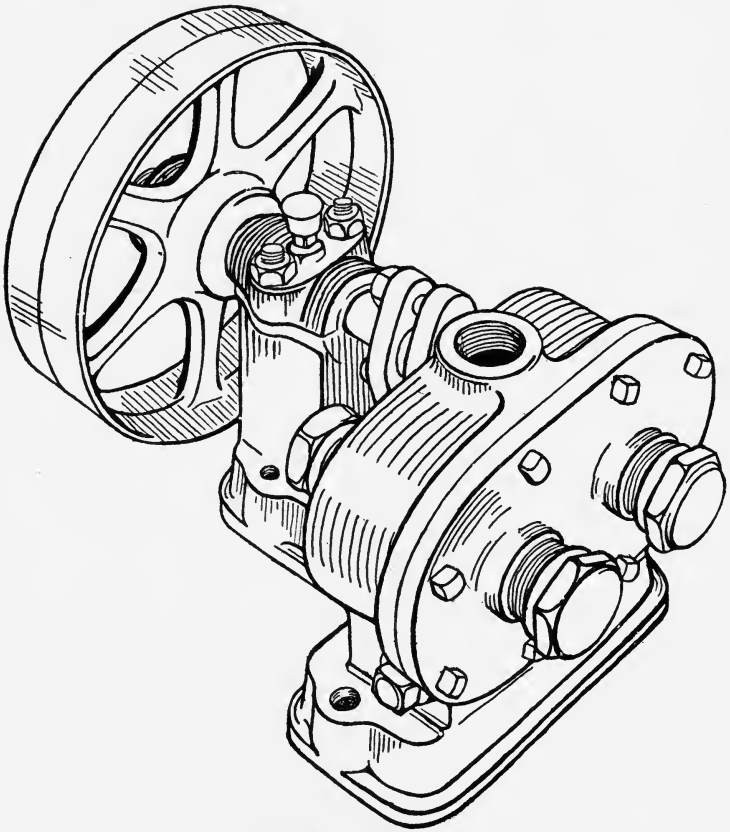


FIG. 278. TYPICAL MODEL OF COMPLETE MACHINE

PREPARATORY INSTRUCTIONS FOR PLATE 29

The model for this plate should be a complete machine or some unit of a machine which is composed of several parts. The

parts of the model then can be divided into several groups and each group assigned to a student.* Fig. 278 shows a typical model, the parts of which are divided into groups. Fig. 279. The detail drawings of this model will be used later (Plate 35) in making an assembly drawing.

DATA FOR PLATE 29

Given: A part or group of parts of a machine.

Required: To make an orthographic sketch of each part assigned by the instructor.

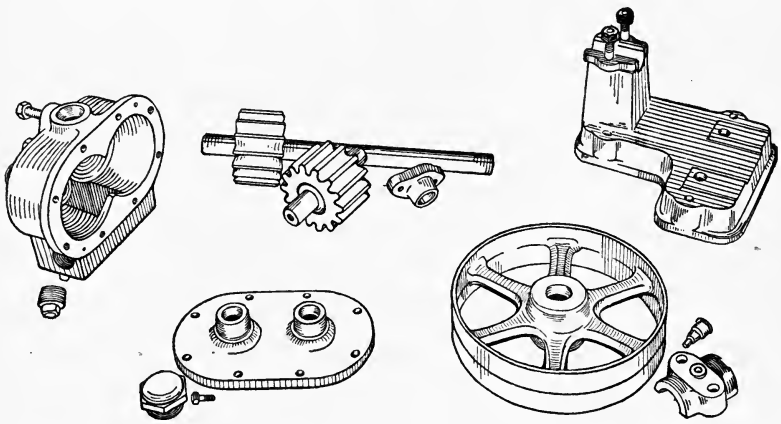


FIG. 279. SHOWING GROUPING OF PARTS OF MACHINE FOR ASSIGNMENT

Instructions: In making the sketches proceed according to the steps outlined for Plate 25.

More than one part may be drawn on each sheet, provided the views are not too small or crowded too closely together.

In drawing and dimensioning these objects the student should check each detail with the parts which are related to it or depend upon it in any way.

Note should be made of the name of each part, the number required, and the material from which it is made.

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* This plan gives best results when there are from 3 to 6 students working on each model.

PREPARATORY INSTRUCTIONS FOR PLATE 30

When making the mechanical drawing all of the parts in each group should be drawn on one sheet if possible. The arrangement of the views should be such as to make the best use of the space available, and at the same time produce a pleasing effect for the sheet as a whole. This will require careful study. The solution will depend largely on the draftsman's judgment. In general it may be said that the distance between views of different objects should be greater than that between views of the same object. The enclosing rectangles for each view may be drawn lightly to make sure that sufficient space has been allowed for the drawing of all parts before drawing the views, or better yet a rectangle equal in size to the enclosing rectangle for the views of each part may be cut from paper and moved about until the best possible arrangement is secured.

Before starting to plan the arrangement of the sheet the areas occupied by the bill of material and the title block should be laid out. The bill of material as shown in Fig. 282 contains the *reference figure* corresponding to the one placed near the views of the object, the *name of the object,* the *number required,* and the *materials from which it is made.* The width of the bill of material is equal to the width of the title block and the height depends upon the number of parts to be listed. See Fig. 147 for detail dimensions.

In some shops the information referred to above is given for each part near the views of that part and is called a sub-title.

The title for a sheet containing the drawings of several parts must be a general one in which the word "details" usually takes the place of the name of the part drawn. See Fig. 280. It is often convenient to use different scales for the various objects, in which case the scale for each should be printed with the views of that part and the words, "Scales as noted," printed in the usual place in the title.

DATA FOR PLATE 30

Given: The orthographic sketch, Plate 29.

Required: To make a mechanical drawing from Plate 29.

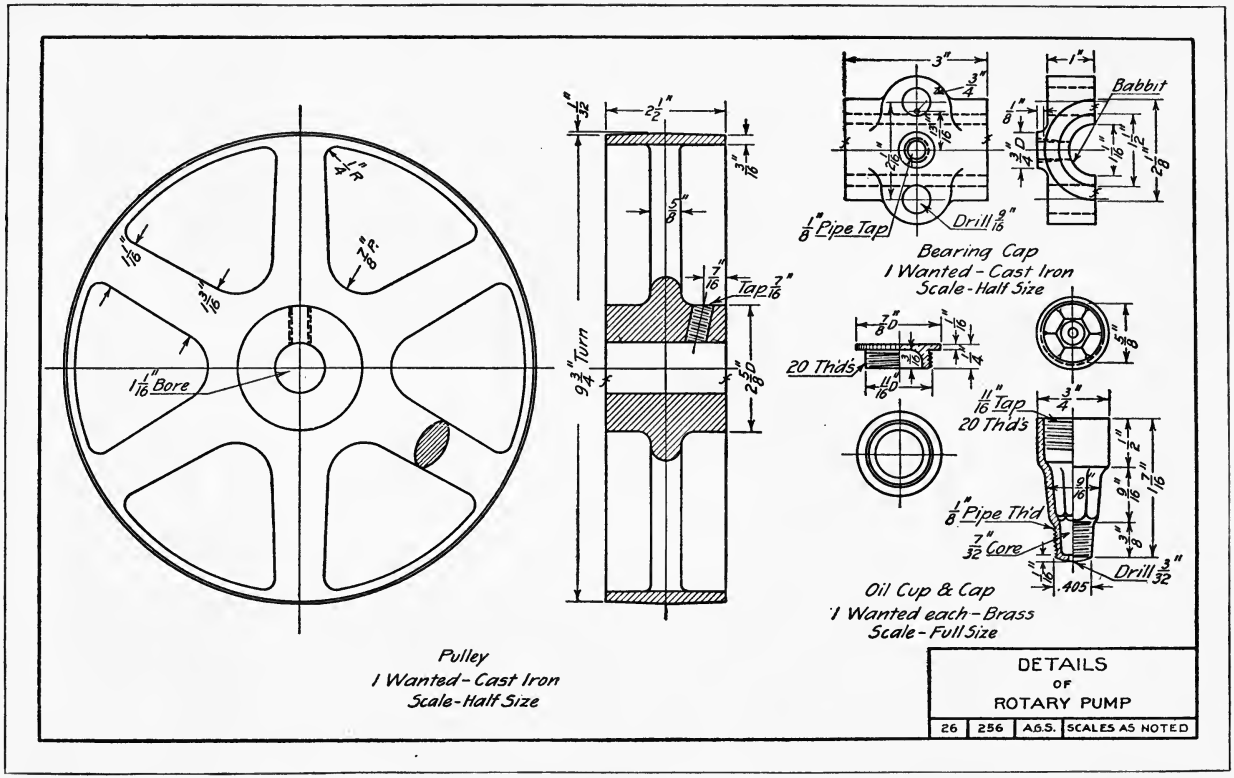


FIG. 280. TYPE PROBLEM—MECHANICAL DRAWING OF SEVERAL DETAILS ON THE SAME SHEET

DATA FOR PLATE 31

Given: The pencil mechanical drawing, Plate 30.

Required: To make a tracing of Plate 30.

Instructions: The width of the top and left sides of the rectangle enclosing the bill of material and the vertical division lines should be object line width ($\frac{1}{6}$ ″). The horizontal lines between lines of lettering should be center line width ($\frac{1}{128}$″).

PREPARATORY INSTRUCTIONS FOR PLATE 32

One of the problems of the draftsman is to make detail drawings from the original layout of a machine in which the parts are shown assembled. On this assembly drawing some important dimensions may be given, others may be scaled from the drawing, and the remainder must be supplied by the draftsman himself. Since this course does not presuppose a knowledge of design all necessary dimensions will be given on the assembly drawing from which the student draws this plate.

The reading of the assembly drawing to get the correct form for each detail will in most cases require careful study. The different parts may be distinguished when in section by various crosshatching for different metals and by the sectioning of adjacent parts at opposite angles. But even with this aid the different views must be compared carefully to check the first impression gained of the form of each part and to make sure that no detail has been overlooked. Each part of the object must be dimensioned completely. It is not sufficient to give a dimension on the views of one part and omit the same dimension on the views of another part, even though it is evident that the dimension is the same on both.

DATA FOR PLATE 32

Given: An assembly drawing of an adjustable step bearing, Fig. 283, a connecting rod end, Fig. 284, and a pipe union, Fig. 285.

Required: To make a freehand orthographic detail sketch of the object shown in Fig. 283, 284, or 285 as assigned by the instructor.

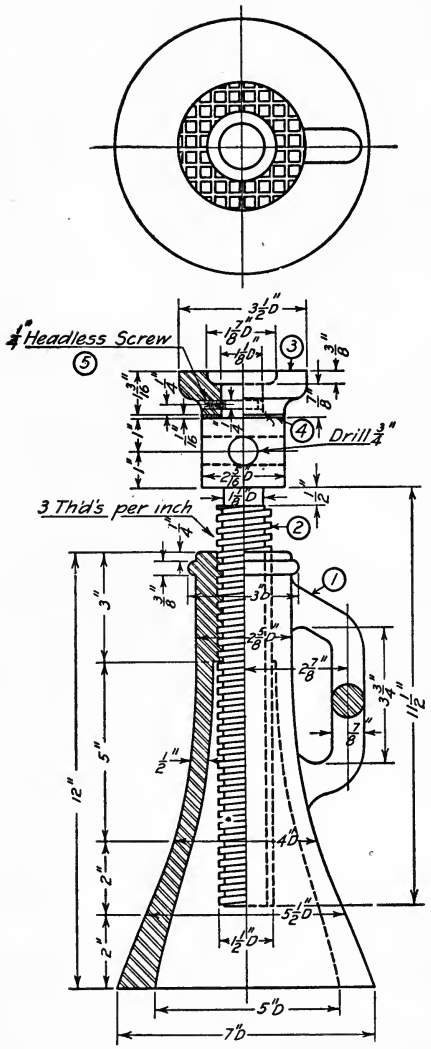


FIG. 281. TYPE PROBLEM—JACK SCREW.—ASSEMBLY DRAWING

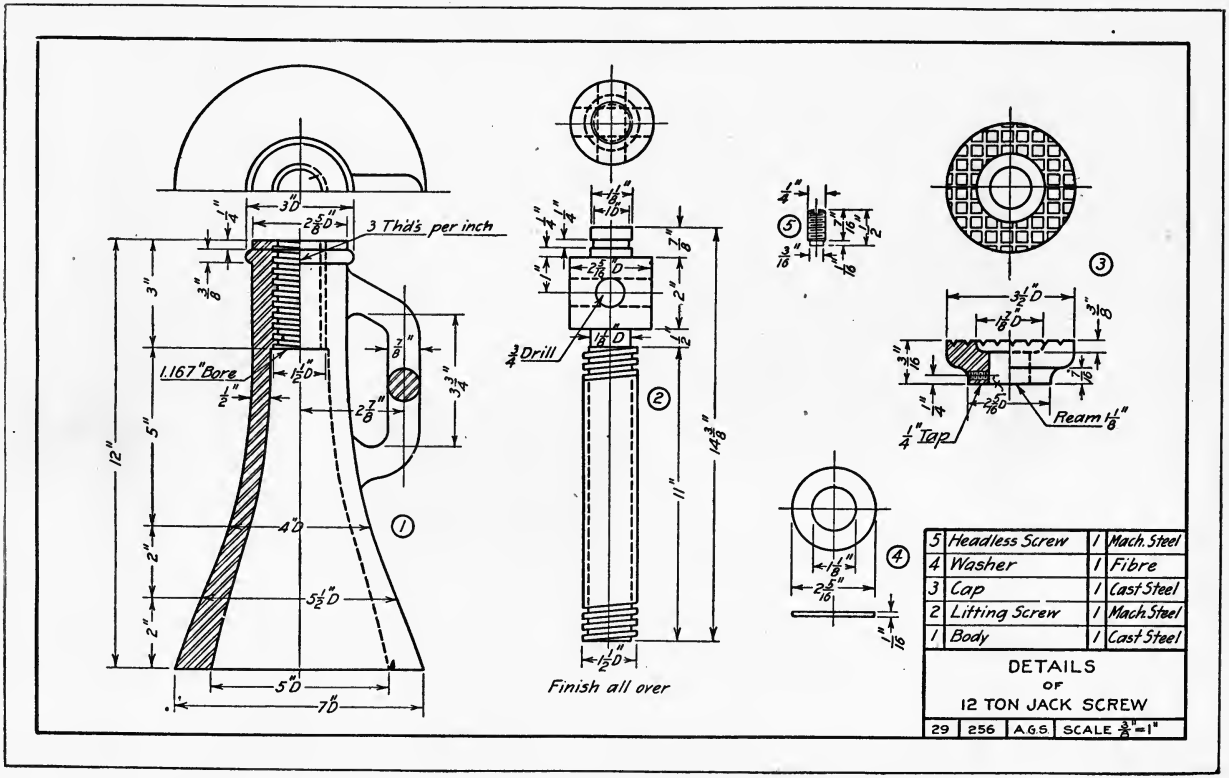


FIG. 282. TYPE PROBLEM—JACK SCREW.—DETAILS

Adjustable Step Bearing. The step bearing is used to support a vertical shaft. Its parts as designated by the figures in circles in Fig. 283 are named as follows:

1. Base.
2. Bearing cup.
3. Upper bearing disc.
4. Lower bearing disc.
5. Set screw.
6. Lock nut.
7. Bushing.

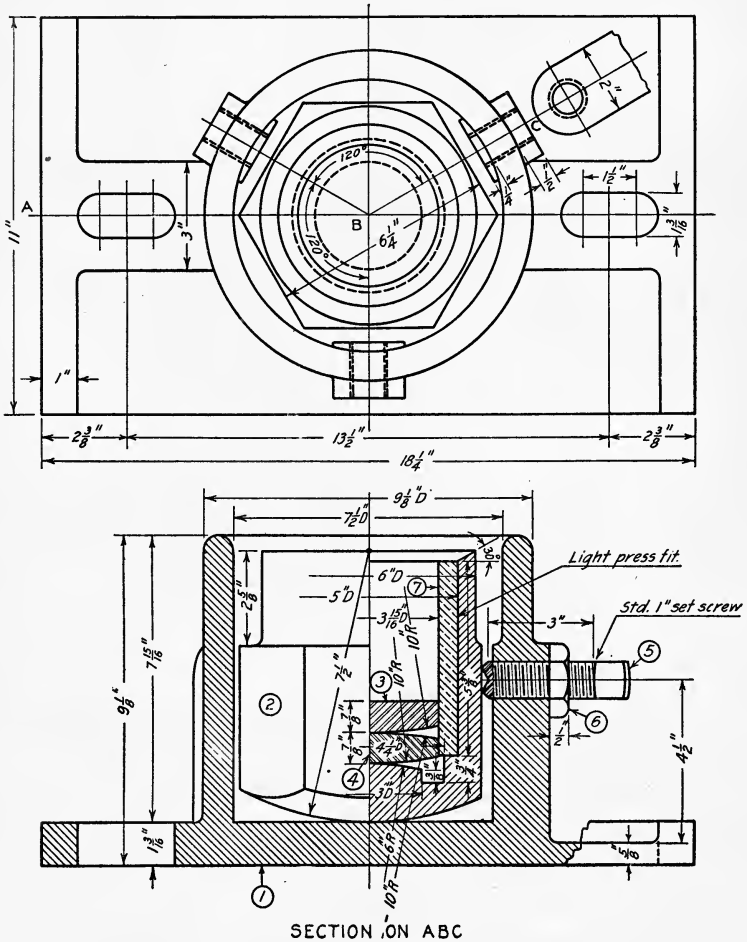


FIG. 283. ADJUSTABLE STEP BEARING

It should be noted that the lower end of (2) is spherical and that (2) is adjusted in (1) by means of set screws (5), acting against three of its faces. The intersections of the spherical surfaces with these faces result in curves corresponding to the chamfer curves of the hexagonal head cap screw.

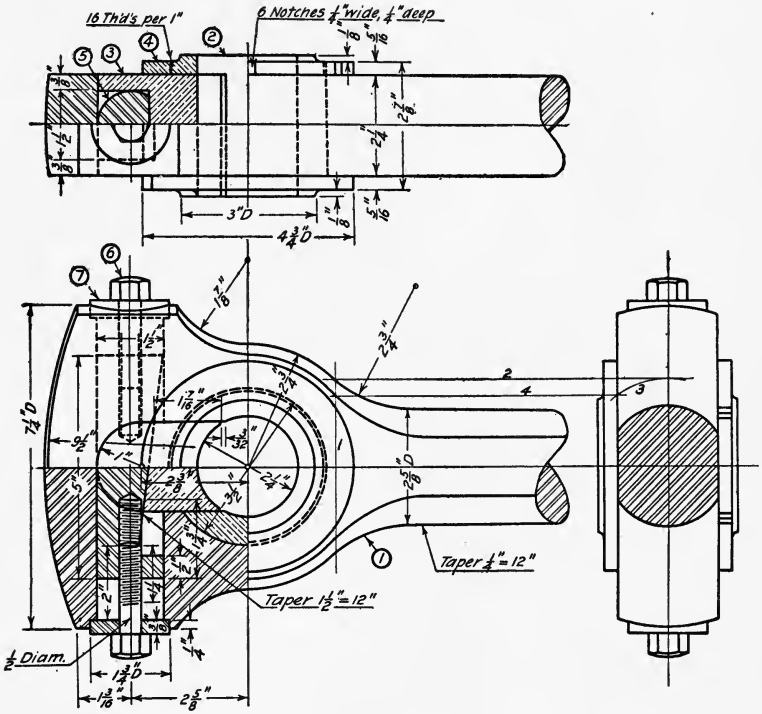
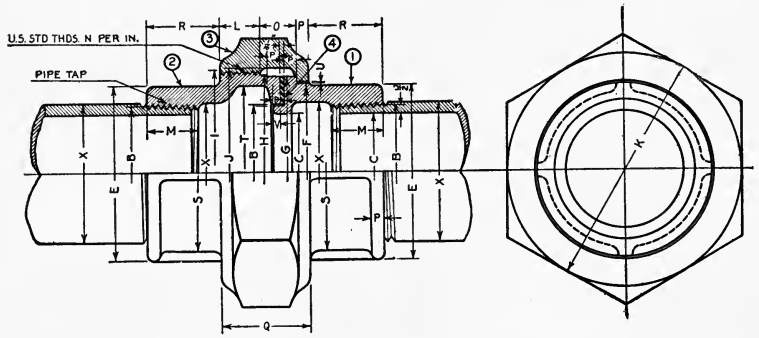


FIG. 284. CONNECTING ROD END FOR NORDBERG CORLISS ENGINE

Connecting Rod End. This is the crank end of a connecting rod for a compound Corliss engine. Its parts as designated by the figures in circles in Fig. 284 are named as follows:

1. Rod end.
2. Stationary box.
3. Adjustable box.
4. Retaining nut.
5. Adjusting wedge.
6. Cap screw.
7. Washer.

Provision is made for taking up wear on the box and crank pin by moving the adjustable box toward the center of the pin. This is accomplished by loosening the upper cap screw and



(All dimensions in inches.)

A	B	C	D	E	F	G	H	I	J	K
1	1.246	1.048	.198	1.74	1.79	1.98	2.01	2.13	2.19	2.49
$1\frac{1}{4}$	1.592	1.380	.212	2.12	2.18	2.37	2.40	2.52	2.58	2.90
$1\frac{1}{2}$	1.831	1.610	.221	2.40	2.46	2.66	2.69	2.81	2.87	3.20
2	2.301	2.067	.239	2.89	2.95	3.16	3.19	3.31	3.38	3.74
$2\frac{1}{2}$	2.775	2.468	.307	3.39	3.45	3.67	3.70	3.86	3.93	4.39

L	M	N	O	P	Q	R	S	T	U	V	X
.49	$\frac{9}{16}$	11	.3625	.15	1.003	$\frac{13}{16}$	1.565	1.76	.007	.10	1.315
.53	.6	11	.3825	.16	1.073	.9	1.91	2.15	.007	.11	1.66
.55	.7	11	.4025	.17	1.123	1.0	2.18	2.40	.007	.13	1.9
.60	.8	11	.4225	.18	1.2025	1.1	2.66	2.90	.008	.14	2.375
.77	.9	8	.5225	.23	1.5225	1.2	3.16	3.41	.008	.16	2.875

FIG. 285. PIPE UNION

tightening the lower one, thus drawing down the wedge, the inclined surface of which acts against a similar surface on the adjustable box, causing it to move toward the center of the bearing.

The rod is finished by turning in the lathe; consequently any section at right angles to the longitudinal axis is circular in outline. The front and back faces of the rod are plane. The intersection of the plane surfaces and the turned surfaces must be represented by a curve in the front view. Points on this curve may be found by taking sections at intervals and locating the points where the circular arcs, cut from the surface of the rod, pierce the flat faces. An example of the construction is shown in Fig. 284. The steps in the construction are taken in the order indicated by the numbers.

Pipe Union. Fig. 285 shows a union for joining two pieces of pipe to facilitate connection. Its parts as designated by the figures in circles are named as follows:

1. Swivel end.
2. Screw end.
3. Nut.
4. Gasket.

The dimensions for different sizes are shown in the table. The values of A are nominal inside diameters. It will be noted that the actual inside diameters, C, differ from the nominal diameters.

In making the drawing the decimals given in the table should be converted to the nearest one-thirty-second or one-sixty-fourth of an inch, as the occasion may require, by referring to a table of decimal equivalents.

DATA FOR PLATE 33

Given: The orthographic sketch, Plate 32.

Required: To make a pencil mechanical drawing from Plate 32.

DATA FOR PLATE 34

Given: The pencil mechanical drawing, Plate 33.

Required: To make a tracing of Plate 33.

PREPARATORY INSTRUCTIONS FOR PLATE 35

An Assembly or General Drawing is made for the purpose of showing the position and relation of parts of a machine or structure. Usually only the most important dimensions are given. Example: Fig. 286.

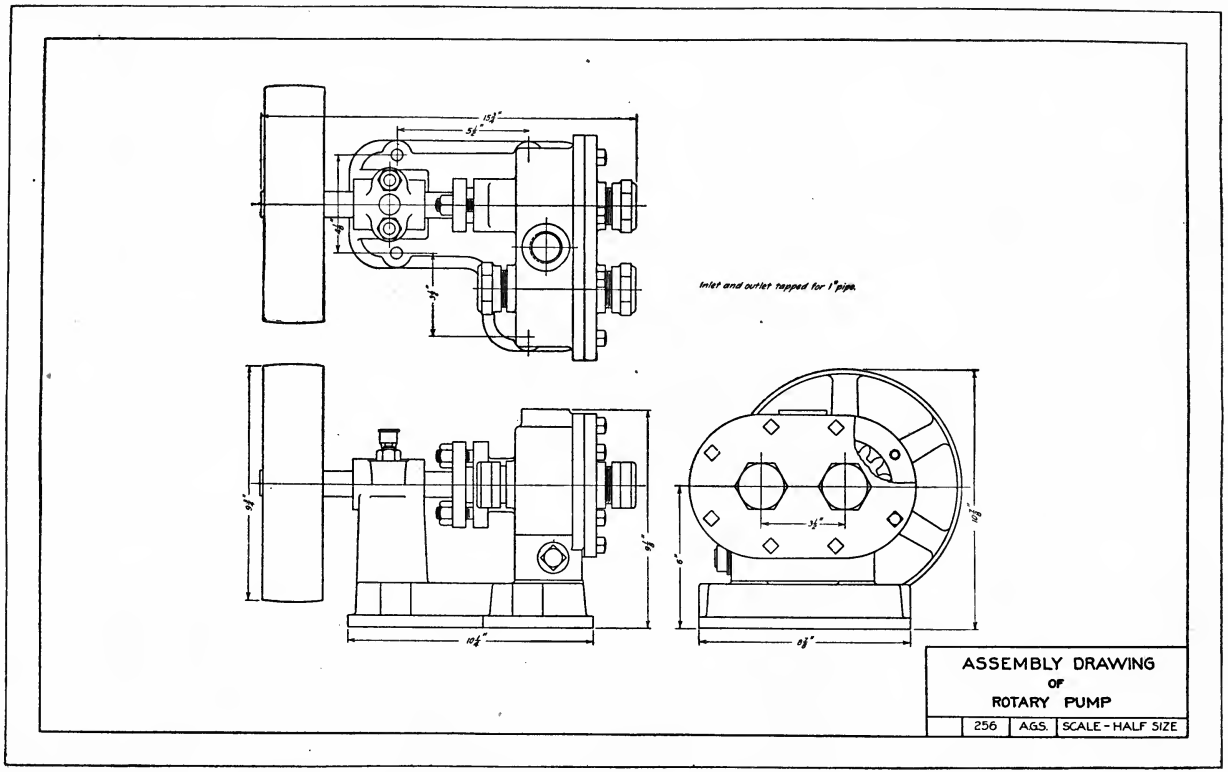


FIG. 286. TYPE PROBLEM—ASSEMBLY DRAWING

DATA FOR PLATE 35

Given: Blueprints for all of the parts of the object drawn in Plates 29, 30, and 31.

Required: To make a pencil mechanical drawing from the details.

DATA FOR PLATE 36

Given: The pencil mechanical drawing, Plate 35.

Required: To make a tracing of Plate 35.

CHAPTER IX

AUXILIARY VIEWS, ISOMETRIC AND CABINET DRAWING, TABLES, ETC.

Auxiliary Views. Views of an object other than those commonly used, such as the top, front, and side views, are sometimes desirable. Fig. 287 shows an object in which a part is

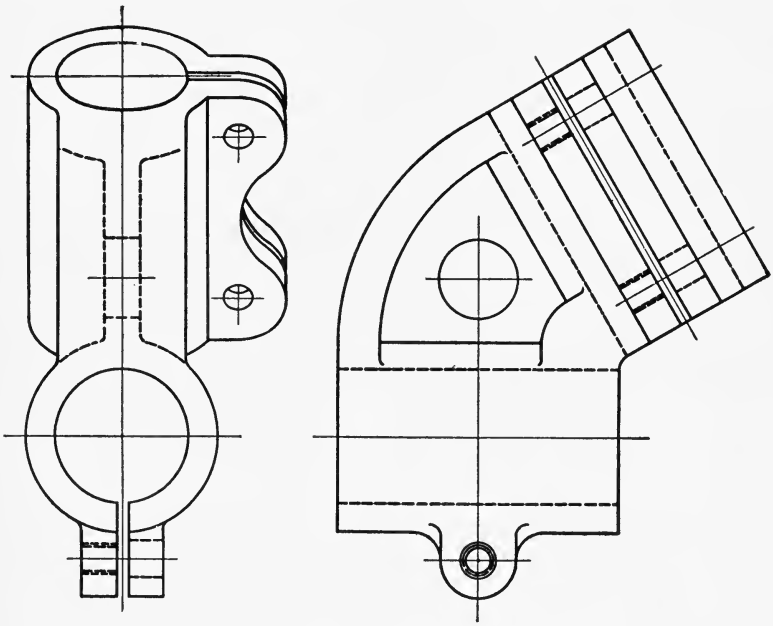


FIG. 287. FRONT AND SIDE VIEWS OF BRACKET

inclined to the horizontal. The side view is difficult to draw. Dimensions in the direction of the axis of the cylindrical part do not show in their true size in this view.

By drawing a partial view of the object looking in the direction of the axis of the inclined part and another partial view looking in a direction at right angles to the faces of the flange on this part, the drawing process is simplified as the circles and arcs show in these views in their true forms and sizes. Fig. 288.

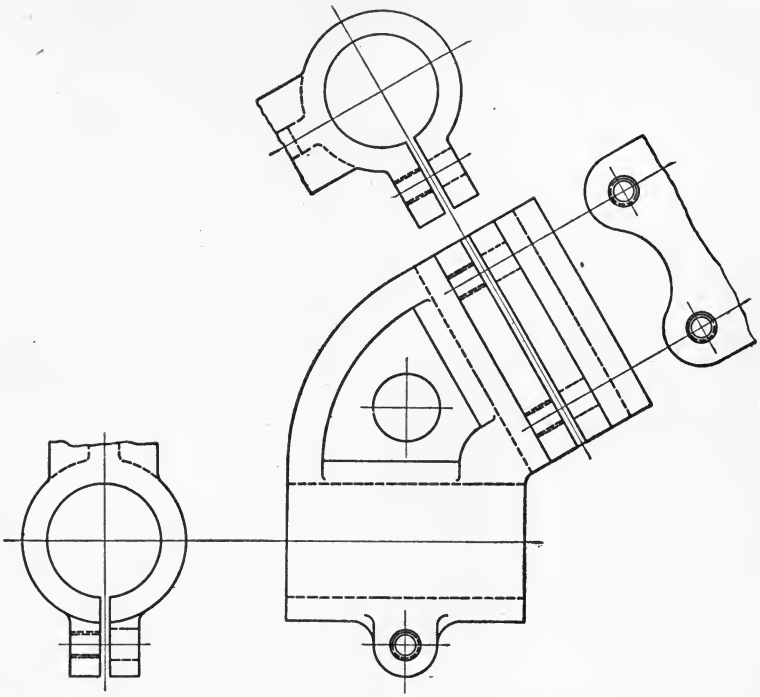


FIG. 288. REPRESENTATION OF BRACKET SIMPLIFIED BY USE OF AUXILIARY VIEWS

Isometric Drawing is a method of representing objects pictorially. While an isometric drawing does not give a true picture of the object, the fact that measurements are made and the construction laid out mechanically, recommends this method of representation where time is an important factor. It is used often in patent office drawings and frequently where it is necessary to show the form of an object to one who is not accustomed to reading orthographic drawing.

Derivation of the Axes. To get an understanding of the principles on which isometric drawing is based, consider a cube turned into a position so that one of its diagonals is viewed endwise. Fig. 289.

When in this position the three edges meeting in the near corner of the cube are represented by lines 120° apart. The 120° angles represent the three right angles around the corner of the cube. Since the three edges forming these angles all make the same angle with the diagonal of the cube the amount of foreshortening for each of the three edges is the same. To determine the amount of foreshortening to draw the cube full size would require a construction or a special scale. But, since the three edges are all foreshortened in the same ratio, the

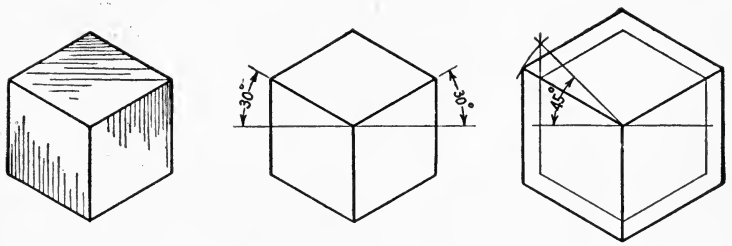


FIG. 289. THE CUBE IN ISOMETRIC.

actual length of the edges may be used in making the drawing. The only effect of this will be to increase slightly the size of the drawing. Fig. 289.

The three lines 120° apart are the axes parallel to which all measurements are made in isometric drawing.

Non-Isometric Lines. A line which is not parallel to one of the three axes is a *non-isometric* line. A non-isometric line is drawn by referring points on the line to the axes by means of coordinates. Fig. 290 shows a rectangular solid on the top face of which is a non-isometric line consisting of a curved and a straight portion. The position of the point D is determined in the isometric by transferring lengths AB and AC from the orthographic views with the dividers and drawing lines BD and CD parallel to the axes. In some cases where a figure containing non-isometric lines is to be drawn, it is convenient to enclose the figure in a rectangle. The hexagon in the side

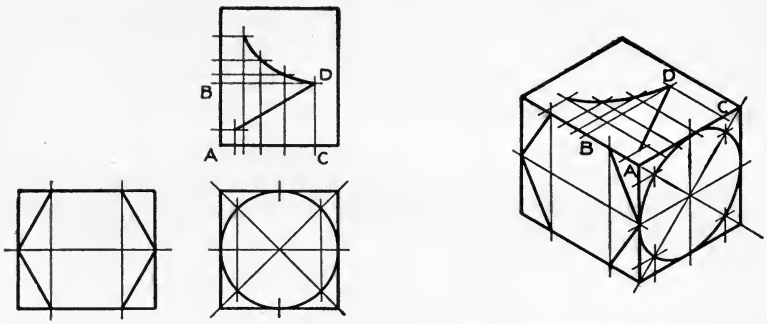


FIG. 290. LOCATING POINTS ON NON-ISOMETRIC LINES USING TWO COORDINATES

face of the rectangular solid, Fig. 290, and the circle enclosed in a square, Fig. 290, are illustrations of this point.

When non-isometric lines do not lie in a face of a rectangular solid three coordinates are necessary to locate points on each line. In drawing the isometric of the frustum of the hexagonal pyramid, Fig. 291, the base is first enclosed in a rectangle and

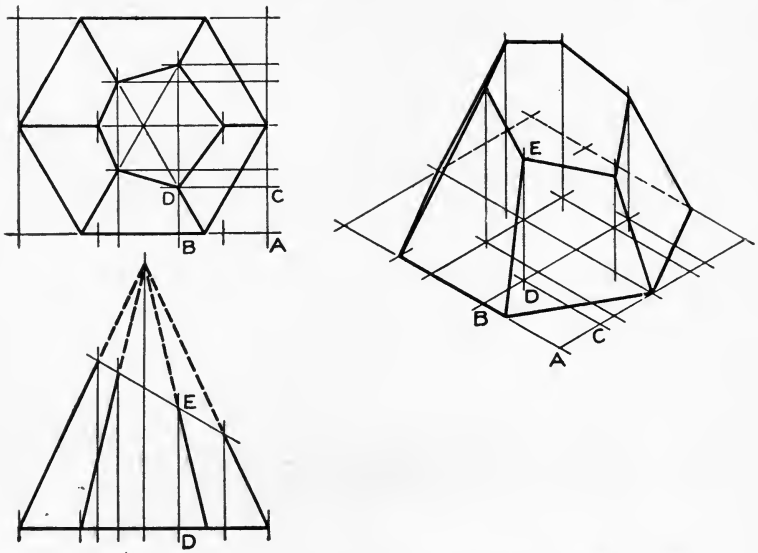


FIG. 291. LOCATING POINTS ON NON-ISOMETRIC LINES USING THREE COORDINATES

the points on the top face are located by three coordinates as shown. The lengths AB, BD, and DE are taken from the orthographic views and laid off on the isometric in the directions parallel to the three axes.

Isometric Circles. Circles may be drawn by locating points as described above or by the four-center method shown in Fig. 292. Point A, the center for the smaller arc, is located by lay-

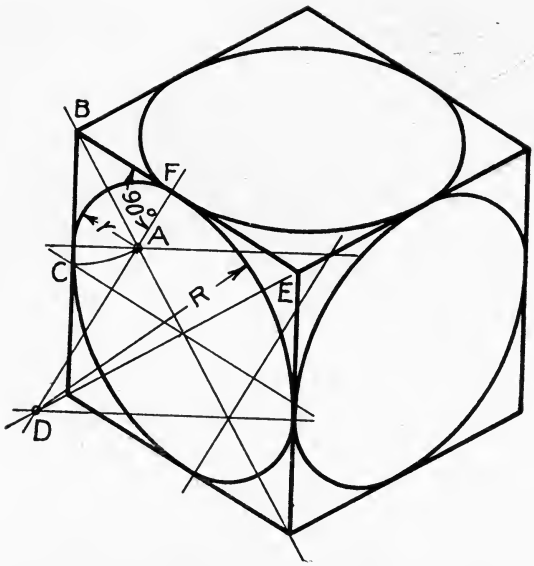


FIG. 292. A FOUR-CENTER METHOD FOR DRAWING CIRCLES IN ISOMETRIC

ing off AB = BC. The center D for the larger arc is located by drawing AD through A perpendicular to BE. The other centers are located in a similar manner. The arcs are tangent at the point F. The four-center method is an approximation and is usually suitable only for full circles. Where an arc is drawn which must pass through certain points the plotting method is preferable. Fig. 293.

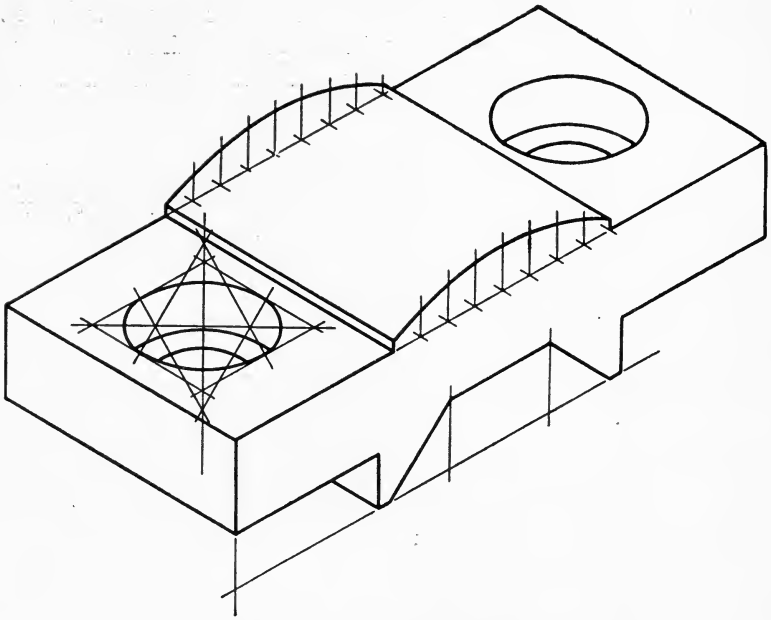


FIG. 293. METHODS OF DRAWING CIRCLES AND ARC

Cabinet Drawing is similar to isometric in that measurements are made parallel to three axes. One of the axes is horizontal, the second vertical, and the third 45° to the horizontal. Fig. 294. Actual lengths are measured parallel to the horizontal and vertical axes and one-half the actual lengths are measured parallel to the 45° axis. Any figure which lies in a plane parallel to the plane of the horizontal and vertical axes

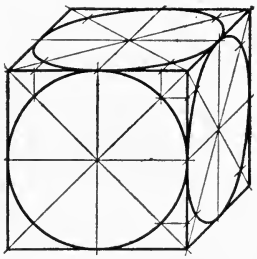


FIG. 294. CABINET DRAWING OF CUBE

is shown in its true size and shape. For example, an object which has a number of circles parallel to one plane is more easily represented in cabinet than in isometric drawing since

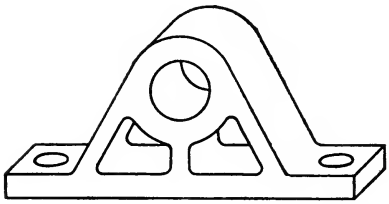


FIG. 295. EXAMPLE OF AN OBJECT WITH CIRCLES AND ARCS PARALLEL TO ONE PLANE

the circles can be drawn with the compass. Fig. 295. However, when a circle is to be drawn parallel to either of the planes determined by the 45° axis and the horizontal or vertical axis the points on the curve must be plotted.

TABLE OF DECIMAL EQUIVALENTS FROM $\frac{1}{64}$ TO 1 INCH

Fraction	Decimal Equivalent	Fraction	Decimal Equivalent
$\frac{1}{64}$	.015625	$\frac{33}{64}$	.515625
$\frac{1}{32}$	.03125	$\frac{17}{32}$	.53125
$\frac{3}{64}$	.046875	$\frac{35}{64}$	.546875
$\frac{1}{16}$	.0625	$\frac{9}{16}$	.5625
$\frac{5}{64}$	.078125	$\frac{37}{64}$	.578125
$\frac{3}{32}$	.09375	$\frac{19}{32}$	.59375
$\frac{7}{64}$	.109375	$\frac{39}{64}$	.609375
$\frac{1}{8}$	.125	$\frac{5}{8}$	.625
$\frac{9}{64}$	.140625	$\frac{41}{64}$	.640625
$\frac{5}{32}$	.15625	$\frac{21}{32}$	.65625
$\frac{11}{64}$	.171875	$\frac{43}{64}$	.671875
$\frac{3}{16}$	.1875	$\frac{11}{16}$	.6875
$\frac{13}{64}$	.203125	$\frac{45}{64}$	.703125
$\frac{7}{32}$	.21875	$\frac{23}{32}$	.71875
$\frac{15}{64}$	.234375	$\frac{47}{64}$	.734375
$\frac{1}{4}$	.25	$\frac{3}{4}$	.75
$\frac{17}{64}$	.265625	$\frac{49}{64}$	.765625
$\frac{9}{32}$	.28125	$\frac{25}{32}$	.78125
$\frac{19}{64}$	.296875	$\frac{51}{64}$	.796875
$\frac{5}{16}$	.3125	$\frac{13}{16}$	.8125
$\frac{21}{64}$	.328125	$\frac{53}{64}$	.828125
$\frac{11}{32}$	.34375	$\frac{27}{32}$	.84375
$\frac{23}{64}$	.359375	$\frac{55}{64}$	.859375
$\frac{3}{8}$	.375	$\frac{7}{8}$	.875
$\frac{25}{64}$	.390625	$\frac{57}{64}$	.890625
$\frac{13}{32}$	.40625	$\frac{29}{32}$	.90625
$\frac{27}{64}$	.421875	$\frac{59}{64}$	.921875
$\frac{7}{16}$	.4375	$\frac{15}{16}$	.9375
$\frac{29}{64}$	.453125	$\frac{61}{64}$	.953125
$\frac{15}{32}$	.46875	$\frac{31}{32}$	.96875
$\frac{31}{64}$	.484375	$\frac{63}{64}$	.984375
$\frac{1}{2}$	.5	1	1.00000

TABLE OF DIMENSIONS OF U. S. STANDARD BOLTS, HEADS AND NUTS, ROUGH

(All dimensions in inches.)

DIAM. OF BOLT	NO. OF THDS. PER INCH	SHORT DIAMETER OF HEXAGON OR SQUARE	LONG DIAMETER OF HEADS AND NUTS		THICKNESS HEXAGON AND SQUARE		DIAM. OF TAP DRILL NEAREST 64TH	ROOT DIAMETER
		Dist. across flats	Hexagon Dist. acr.	Square corners	Heads	Nuts		
$\frac{1}{4}$	20	$\frac{1}{2}$	$\frac{37}{64}$	$\frac{23}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{13}{64}$	.185
$\frac{5}{16}$	18	$\frac{19}{32}$	$\frac{11}{16}$	$\frac{27}{32}$	$\frac{19}{64}$	$\frac{5}{16}$	$\frac{1}{4}$	.240
$\frac{3}{8}$	16	$\frac{11}{16}$	$\frac{51}{64}$	$\frac{31}{32}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{5}{16}$	.294
$\frac{7}{16}$	14	$\frac{25}{32}$	$\frac{29}{32}$	$1\frac{7}{64}$	$\frac{25}{64}$	$\frac{7}{16}$	$\frac{23}{64}$	.344
$\frac{1}{2}$	13	$\frac{7}{8}$	$1\frac{1}{64}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{27}{64}$	.400
$\frac{9}{16}$	12	$\frac{31}{32}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{31}{64}$	$\frac{9}{16}$	$\frac{15}{32}$	.454
$\frac{5}{8}$	11	$1\frac{1}{16}$	$1\frac{15}{64}$	$1\frac{1}{2}$	$\frac{17}{32}$	$\frac{5}{8}$	$\frac{17}{32}$	.507
$\frac{3}{4}$	10	$1\frac{1}{4}$	$1\frac{29}{64}$	$1\frac{25}{32}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{41}{64}$	.620
$\frac{7}{8}$	9	$1\frac{7}{16}$	$1\frac{43}{64}$	$2\frac{1}{32}$	$\frac{23}{32}$	$\frac{7}{8}$	$\frac{3}{4}$	.731
1	8	$1\frac{5}{8}$	$1\frac{7}{8}$	$2\frac{19}{64}$	$\frac{13}{16}$	1	$\frac{55}{64}$	.837
$1\frac{1}{8}$	7	$1\frac{13}{16}$	$2\frac{3}{32}$	$2\frac{9}{16}$	$\frac{29}{32}$	$1\frac{1}{8}$	$\frac{31}{32}$	.940
$1\frac{1}{4}$	7	2	$2\frac{5}{16}$	$2\frac{53}{64}$	1	$1\frac{1}{4}$	$1\frac{3}{32}$	1.065
$1\frac{3}{8}$	6	$2\frac{3}{16}$	$2\frac{17}{32}$	$3\frac{3}{32}$	$1\frac{3}{32}$	$1\frac{3}{8}$	$1\frac{13}{64}$	1.160
$1\frac{1}{2}$	6	$2\frac{3}{8}$	$2\frac{3}{4}$	$3\frac{23}{64}$	$1\frac{1}{16}$	$1\frac{1}{2}$	$1\frac{21}{64}$	1.284
$1\frac{3}{4}$	5	$2\frac{3}{4}$	$3\frac{3}{16}$	$3\frac{57}{64}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{17}{32}$	1.491
2	$4\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{39}{64}$	$4\frac{27}{64}$	$1\frac{9}{16}$	2	$1\frac{3}{4}$	1.712
$2\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{3}{64}$	$4\frac{81}{64}$	$1\frac{3}{4}$	$2\frac{1}{4}$	2	1.962
$2\frac{1}{2}$	4	$3\frac{7}{8}$	$4\frac{31}{64}$	$5\frac{31}{64}$	$1\frac{15}{16}$	$2\frac{1}{2}$	$2\frac{7}{32}$	2.176
$2\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{29}{32}$	$6\frac{1}{64}$	$2\frac{1}{16}$	$2\frac{3}{4}$	$2\frac{15}{32}$	2.426
3	$3\frac{1}{2}$	$4\frac{5}{8}$	$5\frac{11}{32}$	$6\frac{17}{32}$	$2\frac{5}{16}$	3	$2\frac{11}{16}$	2.629

DIFFERENT STANDARDS OF WIRE GAUGES IN USE IN THE UNITED STATES

Dimensions in Decimal Parts of an Inch

NUMBER OF WIRE GAUGE	AMERICAN OR BROWN & SHARPE	BIRMINGHAM OR STUB'S WIRE	WASHBURN & MOEN MFG. CO. WORCESTER	IMPERIAL WIRE GAUGE	STUB'S STEEL WIRE	U. S. STANDARD FOR PLATE	MUSIC WIRE
00000000	.....	....	.....	.....	....	.....	.0083
0000000	.....	....	.....	.....	....	.....	.0087
000000	.....	....	.....	.464	....	.46875	.0095
00000	.....	....	.....	.432	....	.4375	.010
0000	.46	.454	.3938	.400	....	.40625	.011
000	.40964	.425	.3625	.372	....	.375	.012
00	.3648	.38	.3310	.348	....	.34375	.0133
0	.32486	.34	.3065	.324	....	.3125	.0144
1	.2893	.3	.2830	.300	.227	.28125	.0156
2	.25763	.284	.2625	.276	.219	.265625	.0166
3	.22942	.259	.2437	.252	.212	.25	.0178
4	.20431	.238	.2253	.232	.207	.234375	0188
5	.18194	.22	.2070	.212	.204	.21875	.0202
6	.16202	.203	.1920	.192	.201	.203125	.0215
7	.14428	.18	.1770	.176	.199	.1875	.023
8	.12849	.165	.1620	.160	.197	.171875	.024
9	.11443	.148	.1483	.144	.194	.15625	.0253
10	.10189	.134	.1350	.128	.191	.140625	.0276
11	.090742	.12	.1205	.116	.188	.125	.028
12	.080808	.109	.1055	.104	.185	.109375	.0294
13	.071961	.095	.0915	.092	182	.09375	.0316
14	.064084	.083	.0800	.080	.180	.078125	.0324
15	.057068	.072	.0720	.072	.178	.0703125	.0346
16	.05082	.065	.0625	.064	.175	.0625	.0365
17	.045257	.058	.0540	.056	.172	.05625	.037
18	.040303	.049	.0475	.048	.168	.05	.0397
19	.03589	.042	.0410	.040	.164	.04375	.0415
20	.031961	.035	.0348	.036	.161	.0375	.0434
21	.028462	.032	.03175	.032	.157	.034375	.0464
22	.025347	.028	.0286	.028	.155	.03125	.048
23	.022571	.025	.0258	.024	.153	.028125	.0513
24	.0201	.022	.0230	.022	.151	.025	.0555
25	.0179	.02	.0204	.020	.148	.021875	.058
26	.01594	.018	.0181	.018	.146	.01875	.0626
27	.014195	.016	.0173	.0164	.143	.0171875	.0656
28	.012641	.014	.0162	.0149	.139	.015625	.0728
29	.011257	.013	.0150	.0136	.134	.0140625	.076
30	.010025	.012	.0140	.0124	.127	.0125	.080
31	.008928	.01	.0132	.0116	.120	.0109375	.082
32	.00795	.009	.0128	.0108	.115	.01015625	.086
33	.00708	.008	.0118	.0100	.112	.009375	.090
34	.006304	.007	.0104	.0092	.110	.00859375	.095
35	.005614	.005	.0095	.0084	.108	.0078125	....
36	.005	.004	.0090	.0076	.106	.00703125	....
37	.004453	....	.....	.0068	.103	.006640625	....
38	.003965	....	.....	.0060	.101	.00625	....
39	.003531	....	.....	.0052	.099	.....	....
40	.003144	....	.....	.0048	.097	.....	....

TABLE OF PIPE SIZES

(All dimensions in inches.)

NOMINAL INSIDE DIAMETER	ACTUAL INSIDE DIAMETER	ACTUAL OUTSIDE DIAMETER	THICKNESS	NO. OF THREADS PER INCH	DIAMETER OF DRILL
$\frac{1}{8}$	.27	.405	.07	27	$\frac{21}{64}$
$\frac{1}{4}$	.36	.504	.08	18	$\frac{29}{64}$
$\frac{3}{8}$	.49	.675	.09	18	$\frac{19}{32}$
$\frac{1}{2}$	.62	.840	.10	14	$\frac{23}{32}$
$\frac{3}{4}$	.82	1.050	.11	14	$\frac{15}{16}$
1	1.04	1.315	.13	$11\frac{1}{2}$	$1\frac{3}{16}$
$1\frac{1}{4}$	1.38	1.660	.14	$11\frac{1}{2}$	$1\frac{15}{32}$
$1\frac{1}{2}$	1.61	1.900	.14	$11\frac{1}{2}$	$1\frac{23}{32}$
2	2.06	2.375	.15	$11\frac{1}{2}$	$2\frac{3}{16}$
$2\frac{1}{2}$	2.46	2.875	.20	8	$2\frac{11}{16}$
3	3.06	3.500	.21	8	$3\frac{5}{16}$
$3\frac{1}{2}$	3.56	4.000	.22	8	$3\frac{13}{16}$
4	4.02	4.500	.23	8	$4\frac{5}{16}$
$4\frac{1}{2}$	4.50	5.000	.24	8	...
5	5.04	5.560	.25	8	...
6	6.06	6.625	.28	8	...
7	7.02	7.625	.30	8	...
8	7.98	8.625	.32	8	...
9	9.00	9.625	.34	8	...
10	10.01	10.750	.36	8	...
11	11.00	11.750	.37	8	...
12	12.00	12.750	.37	8	...
13	13.25	14.000	.37	8	...
14	14.25	15.000	.37	8	...
15	15.40	16.000	.28	8	...
16	16.40	17.000	.30	8	...
17	17.30	18.000	.34	8	..

CHAPTER X

INSTRUCTOR'S GUIDE

Suggestions to Teachers

It is the aim of this chapter to give briefly the point-of-view of the authors on the results to be secured in this course together with their ideas on the administration of the course and the methods of securing results.

The course is the result of a development extending over a period of more than twenty years, during which time the problem of teaching drawing has been carefully studied. In every case the method herein presented has been repeatedly tested in the classroom. One of the fundamental ideas on which this course is based is that each division of the work requiring particular knowledge or skill must be given concentrated attention. Another idea of equal importance is that in drawing, work should be progressive from the standpoint of both theory and technique. A study of the outline given herewith will show how these two ideas of progression and concentration have been woven into the fabric of the course. The principles and methods presented in each division have been carried into the following division in such a way as to relieve the suddenness of the transition made and to give opportunity for further development.

The method of the course, viz., *to concentrate upon one element in drawing in each division of the course* and *to make use of this element in the succeeding divisions,* is exemplified in the development of the orthographic theory where the top and front views only are given in the first presentation, where the front and side views are given in the second presentation, and later where three views—front, top, and side—are given. On the side of technique the method is exemplified in Chapters I, II, III, and IV, where the emphasis falls successively on

perspective sketching, orthographic sketching, pencil mechanical drawing, and tracing. It should be noted, also, that the element in each division is continued in succeeding divisions.

Demonstrations. It is the belief of the authors that instruction on the manual part of the drawing course can be given most effectively by means of demonstrations. The instructor should present to the class the proper method of manipulating the instruments and materials by actually going through the process himself, calling attention to important points and explaining each step as he proceeds. The principle upon which each movement or process is based should be given in order that the student may not only know how a thing is done, but also why it is done in one way rather than another. For example, it is not sufficient to say that the paper should be fastened in the upper left hand corner of the drawing board. The reasons for so placing it should be given. First, it should be explained that the T-square is more easily manipulated when lines are drawn near the head. Second, that with the sheet in this position the arm may rest on the board while doing lettering or other freehand work in the lower part of the sheet.

The demonstrations may be given to the class as a whole or to groups of students as conditions may warrant. In general better results will be obtained when the demonstration is so timed that the student may make use of the information immediately.

There is a tendency on the part of instructors to give too much material in one demonstration or to spend *too much time on minute details* which the student with his limited knowledge of the subject cannot appreciate and which *tend to obscure* the really vital points. Demonstrations should not occupy more than *ten or fifteen minutes.* The material should be selected with a view to its immediate usefulness, leaving many minor details for individual instruction or for class or group demonstration after students have had some experience in carrying out the instructions of the first demonstration.

The following outline of a demonstration on the use of the ruling pen is given as an example:

DEMONSTRATION ON THE RULING PEN

I. Use.

A. Ruling lines in ink.

1. Guided by T-square.
2. Guided by triangles.
3. Guided by irregular curves.

II. Setting and Filling.

A. Set the pen by means of the thumb screw to the approximate width of the line desired.

B. Fill the pen by inserting between its nibs the quill which is attached to the stopper of the ink bottle. There should be about one-quarter of an inch of ink in the pen. There should be no ink on the outside of the nibs.

C. Adjust the pen to exact width of line by drawing trial lines on the margin of the sheet.

III. Manipulation.

A. Hold the pen with the first finger just above the thumb screw and with the second finger against the right edges of both blades.

B. Place the pen against the ruling edge with its axis in a vertical plane. The pen may lean slightly in the direction of motion.

C. The forearm should be at right angles to the line being drawn.

D. Draw slowly from left to right or from bottom to top. The tips of the third and fourth fingers should slide on the ruling edge.

IV. Cleaning.

A. Clean the pen frequently by inserting a cloth at the side and by drawing it out between the nibs.

B. Open the pen and clean it thoroughly before laying it away.

The following points which are not essential at first should be left for a later demonstration:

I. Sharpening the pen.
II. Drawing lines tangent to arcs.
III. Drawing irregular curves.
IV. The advantages of pens of different designs or makes.

Individual Instruction. As stated above, the instructor cannot anticipate all of the needs of the student when giving a

demonstration without going too much into detail, nor can he expect that every point made in the demonstration will be permanently fixed in the mind of the student. The demonstration should therefore be supplemented by individual instruction. The instructor should make a study of each individual's needs with a view to giving *just the instruction required.* This type of instruction must be carefully given, as too close attention to the work of a student may keep him from developing ability to do independent work. Under proper instruction the student will develop the power to take the data given him and with it reach the proper solution. The student's power to reason for himself can be developed by answering his questions with counter-questions and offering suggestions designed to lead him to think for himself. He should not be told to do a thing in a certain way without being given a reason for so doing it, unless it is a matter of arbitrary convention.

Recitations. In addition to the material which is given in the demonstration there is a considerable amount of information which may best be secured by a study of the text. An attempt on the part of the instructor to give all information verbally will lead his students to rely on him entirely and will take away the incentive for them to get needed information themselves.

The recitation is invaluable to test the student's knowledge of the principles and methods given in the text. It may also be used to advantage as a review of the demonstration and to ascertain the effectiveness of the instruction given by that method.

The recitation may be carried on by means of questions such as those given at the close of Chapters I, II, III, and IV. In answering some questions the student may be required to draw a sketch on the blackboard and explain it.

Quizzes. After the completion of each general division of the course, the student's knowledge of the subject matter in that division should be tested by requiring him to answer several questions or to make a drawing which will test his knowledge of the fundamentals. Questions should be answered, as far as possible, by means of sketches. Every opportunity should

be taken to have the student use drawing as a means of expression. Questions similar to those at the close of Chapters I, II, III, and IV may be used for the quizzes.

Problems. As previously stated, an attempt has been made to make the course progressive both in theory and technique. The problems of the course were selected and arranged with this in view. Except in the chapter on Perspective Sketching the problem for each plate may be selected from a group of problems. The group system makes it possible *to adapt the problem to the ability of the student.* The system also reduces the tendency for one student to copy from another. In all but a few problems the student finds it necessary to work out his own solution. As a rule he is required to read the given drawing and to understand the form of the object represented before he can proceed with his drawing. In many cases the choice of views is left entirely to the student. The dimensioning also presents a problem which the student must solve by using the general principles given him and from his knowledge of shop methods. Where this knowledge is limited the instructor must supply the necessary information.

What has been called a *type problem* is given with each student problem. The type problem serves to guide the student in the solution of his problem. The type problem shows a typical or standard arrangement of views, dimensions, etc., and a technique which serves as an ideal toward which the student should strive.

Perspective Sketching affords the most natural method of representing objects in outline. It gives a valuable training in *coordinating the hand and eye in drawing freehand lines* and estimating proportions. It serves as an intermediate step between observing an object and drawing its orthographic views. The student who first draws a perspective sketch of an object becomes so familiar with every detail of it that he cannot fail to have a clearer mental image of its form when he attempts to draw its orthographic views. By its use *he learns the more readily to interpret the orthographic drawing.* These considerations together with a growing use of this type of representation in drafting practice justifies its place in a drafting course.

The theory on which Perspective Sketching in this course is based is limited to a very simple treatment of 45° perspective. This treatment was adopted to make this division of the work in keeping with the elementary nature of the whole course and with the idea that the *perspective sketching should occupy but a small fraction of the total time given to the course.* The time allotted to this division of the work should be about one-fifth of the total time given to the work of the first four chapters. An extension of theory given at the end of Chapter I may be used to broaden the course if desired.

It is desirable that all members of a class be kept reasonably near together in each division of the course. To make this possible extra problems are given which may be assigned to those who forge ahead.

Orthographic Sketching. The work of this chapter offers opportunity for improvement in freehand technique and a considerable amount of drill in the fundamental principles of orthographic representation. The treatment of orthographic theory is made simple. *It is applicable to the requirements of drafting room practice.* It is essential to the success of the plan given that the student should consider the object to be placed in a *fixed* position. To obtain each of the required views he must imagine himself placed in the correct position with respect to the object. The practice of shifting the position of the object usually results in a confusion of the principles which relate to the position of views with reference to each other.

Another point of considerable importance is that *problems are simple and numerous.* A large number of problems gives drill in orthographic representation, and acquaints the student with a variety of forms and arrangements of views.

Technique. The authors believe that securing good technique, both freehand and mechanical, is as educative as an acquisition of a knowledge of the theory of drawing. The highest type of technique is not easy to obtain under any conditions. Proper instruction and classroom administration are necessary to secure good results.

A first requisite is to establish a satisfactory standard. This standard must be high and yet not unattainable. Often good

drawings from a previous term's work may be exhibited and will prove to be of great value in showing the student what has been accomplished by other students who have worked under similar conditions. *Individual instruction, in which the instructor draws a few sample lines, explains the proper sharpening of the pencil or the setting of the pen and its correct manipulation, cannot be overestimated as a means of establishing a good standard of technique.*

The beginner usually does not possess the necessary skill to make the minute detail of a drawing perfect. Neither has he an appreciation of the relation of these details to the general effect of the drawing. For example, he is not likely to notice slight imperfections, such as running by a corner or making the two barbs of an arrowhead non-symmetrical with respect to the dimension line. However, it is such imperfections which, taken in the aggregate, affect the general appearance of a drawing. Details of this kind must be given constant attention by the instructor. In most cases calling the student's attention to the defects in the drawing does not make a sufficient impression. He should be required to correct the defects by erasing and redrawing the lines.

Lettering. As a rule it is at first more difficult to obtain a satisfactory freehand technique than a satisfactory mechanical technique. To offset this tendency a number of plates of lettering have been designed. They are so arranged that if each *follows the drawing plate* of the same number, considerable practice will be had before it becomes necessary to do lettering on the regular drawing plates. Here again the ideas of progression and concentration are prominent features. *The letters of the alphabet are grouped according to characteristics of form, and are arranged in the order of the difficulty with which they are drawn.* Only four or five new letters are given on each plate. *Each letter is practiced individually* and then *in combination with those of previous plates.*

In the early stages in lettering the best results are obtained when the work is done in short periods of *fifteen or twenty minutes* each and following a demonstration. The instructor should draw each new letter on the board to large scale, and

call attention to the number, order, and direction of strokes, and to important points in the form and proportion of each letter. He should give suggestions concerning the making of strokes, the spacing of letters, etc.

The outline for a sample demonstration follows:

PLATE 6

I. The Capital Letter F.

1. First stroke vertical.

2. Second stroke horizontal on the upper guide line. Make slightly less in length than the width of the H, which is the standard of width.

3. Third stroke horizontal. Make it slightly above the middle of the space, on the same level with the horizontal stroke of the H. Make its length slightly more than half the length of the second stroke.

II. The Capital Letter E.

1. First stroke vertical.

2. Second stroke horizontal on the lower guide line. Make it equal in length to the width of the H.

3. Third and fourth strokes exactly like similar strokes of the F.

III. The Capital Letter N.

1. First stroke vertical.

2. Second stroke vertical. Space it a distance from the first stroke equal to the width of the H. This distance must be estimated by judging the horizontal distance from the first stroke to the beginning of the second stroke.

3. Third stroke. This is an inclined stroke drawn between two fixed points. The beginner should move the pencil in the direction of the stroke, to get a sense of its direction, before drawing the stroke.

IV. The Capital Letter M.

1. First stroke vertical.

2. Second stroke inclined. The angle at which this stroke is drawn determines the width of the letter. It must therefore be carefully estimated. The width of the letter is equal to its height. The stroke ends about one-fifth of the height of the letter above the lower guide line.

3. The third stroke makes the same angle to the vertical as does the second stroke. The starting point must be carefully located to get this angle correct and to make the end of the second stroke fall half way between the two vertical stems.

4. Fourth stroke vertical.

OUTLINE

OF

COURSE IN MECHANICAL DRAWING FOR COLLEGES

Group	Object	Fig.	Plate	Data Given	Required to Draw
				I. PERSPECTIVE	
A.	Rectangular Objects				
	1. Cube	11.	1	Perspective of cube	Cube to larger scale
	2. Plate Washer	20.	2	Perspective of object	Object to larger scale
	3. Equalizer Safety Block	21.	Extra.	Perspective of object	Object to larger scale
B.	Angular Objects				
	1. Journal Box Wedge	24.	3	Perspective of object	Object at different level
	2. Bracket	25.	Extra.	Perspective of object	Object at different level
C.	Cylindrical Objects				
	1. Bushing (axis vertical)		4	Description with dimensions	Perspective with axis vertical
	2. Washer (axis vertical)		Extra.	Description with dimensions	Perspective with axis vertical
	3. Bushing (axis horizontal)		5	Description with dimensions	Perspective with axis horizontal
	4. Washer (axis horizontal)		Extra.	Description with dimensions	Perspective with axis horizontal
D.	Extension of Perspective Theory				
	1. Sill Filling Piece	42.	Extra.	45° perspective of object	Object in other than 45° perspective
	2. Jig	43.	Extra.	45° perspective of object	Object in other than 45° perspective
	3. Bearing Cap	44.	Extra.	45° perspective of object	Object in other than 45° perspective
	4. Jig	45.	Extra.	45° perspective of object	Object in other than 45° perspective
E.	Review Problems				
	1. Frame	46.	Extra.	Object in other than 45° perspective.	Object in 45° perspective
	2. Brace	47.	Extra.	Object in other than 45° perspective.	Object in 45° perspective
	3. Clutch Jaw	48.	Extra.	Object in other than 45° perspective.	Object in 45° perspective
	4. Solid Box	49.	Extra.	Object in other than 45° perspective.	Object in 45° perspective

II. ORTHOGRAPHIC SKETCHING

A. Rectangular Objects

1. Spring Stem Guide	54..	6	..Orthographic sketch	..Perspective sketch
2. Spring Stem Guide	..	7	..Orthographic sketch	..Orthographic sketch
3. Brace	55..	6	..Orthographic sketch	..Perspective sketch
4. Brace	..	7	..Orthographic sketch	..Orthographic sketch

B. Angular Objects

1. Dovetail Cross Slide	63..	8	..Orthographic sketch	..Perspective sketch
2. Dovetail Cross Slide	..	9	..Orthographic sketch	..Different orthographic views
3. Double Dovetail	64..	8	..Orthographic sketch	..Perspective sketch
4. Double Dovetail	..	9	..Orthographic sketch	..Different orthographic views

C. Cylindrical Objects

1. Trunnion Bearing	71..	10	..Orthographic sketch	..Perspective sketch
2. Trunnion Bearing	..	11	..Orthographic sketch	..Different orthographic views
3. Spring Casing Base	72..	10	..Orthographic sketch	..Perspective sketch
4. Spring Casing Base	..	11	..Orthographic sketch	..Different orthographic views

D. Review Problems

1. Bearing Cap	73..	Extra.	.Orthographic sketch	..Different orthographic views
2. Vise Jaw	74..	Extra.	.Orthographic sketch	..Different orthographic views
3. Turning Tool Holder	75..	Extra.	.Orthographic sketch	..Different orthographic views
4. Valve Bonnet	76..	Extra.	.Orthographic sketch	..Different orthographic views

III. PENCIL MECHANICAL DRAWING

A.	RECTANGULAR OBJECTS					
	1. Clamp	82	12	Perspective sketch		Orthographic sketch
	2. Clamp		13	Orthographic sketch, plate 12		Pencil mechanical drawing
	3. Yoke Block	83	12			
	4. Yoke Block		13	(All plates 12 and 13 same as above)	(All plates 12 and 13 same as above)	
	5. Angle	84	12			
	6. Angle		13			
B.	ANGULAR OBJECTS					
	1. Foundation Washer	93	14	Perspective sketch		Orthographic sketch
	2. Foundation Washer		15	Orthographic sketch		Pencil mechanical drawing
	3. Back Rest	94	14			
	4. Back Rest		15	(All plates 14 and 15 same as above)	(All plates 14 and 15 same as above)	
	5. Journal Bearing	95	14			
	6. Journal Bearing		15			
C.	CYLINDRICAL OBJECTS					
	1. Brush Holder Bracket	99	16	Perspective sketch		Orthographic sketch
	2. Brush Holder Bracket		17	Orthographic sketch, plate 16		Pencil mechanical drawing
	3. Hinge Bracket	100	16			
	4. Hinge Bracket		17	(All plates 16 and 17 same as above)	(All plates 16 and 17 same as above)	
	5. Clutch Lever Bracket	101	16			
	6. Clutch Lever Bracket		17			
D.	REVIEW PROBLEMS					
	1. Tool Holder	102	Extra	Perspective sketch		Orthographic sketch
	2. Tool Holder		Extra	Orthographic sketch		Pencil mechanical drawing
	3. Back Rest	103	Extra			
	4. Back Rest		Extra	(All extra plates same as above)	(All extra plates same as above)	
	5. Rocker Arm	104	Extra			
	6. Rocker Arm		Extra			

IV. TRACING AND BLUEPRINTING

A. Rectangular Objects						[drawing
1. Manhole Head	108..	18	..Orthographic views	..Different views.	Mechanical pencil	
2. Manhole Head	..	19	..Mechanical pencil drawing, plate 18.	Tracing plate 18		
3. Air Pump Bracket	109..	18	..			
4. Air Pump Bracket	..	19	..(All plates 18 and 19 same as above).	(All plates 18 and 19 same as above)		
5. Truck Spring Seat	110..	18	..			
6. Truck Spring Seat	..	19	..			
B. Angular Objects						[drawing
1. Clutch Bracket	116..	20	..Orthographic views	..Different views.	Mechanical pencil	
2. Clutch Bracket	..	21	..Mechanical pencil drawing, plate 20.	Tracing plate 20		
3. Motor Bracket	117..	20	..			
4. Motor Bracket	..	21	..(All plates 20 and 21 same as above).	(All plates 20 and 21 same as above)		
5. Throttle Lever Fulcrum	118..	20	..			
6. Throttle Lever Fulcrum	..	21	..			
C. Cylindrical Objects						[drawing
1. Gland for Stuffing Box	122..	22	..Orthographic views	..Different views.	Mechanical pencil	
2. Gland for Stuffing Box	..	23	..Mechanical pencil drawing, plate 22.	Tracing plate 22		
3. Shaft Bearing	123..	22	..			
4. Shaft Bearing	..	23	..(All plates 22 and 23 same as above).	(All plates 22 and 23 same as above)		
5. Stuffing Box	124..	22	..			
6. Stuffing Box	..	23	..			
D. Review Problems						[drawing
1. Sand Box Bracket	126..	Extra..	Orthographic views	..Different views.	Mechanical pencil	
2. Sand Box Bracket	..	Extra..	Mechanical pencil drawing	..Tracing		
3. Dead Lever Fulcrum	127..	Extra..				
4. Dead Lever Fulcrum	..	Extra..	(All extra plates same as above)	....(All extra plates same as above)		
5. Stuffing Box Gland	128..	Extra..				
6. Stuffing Box Gland	..	Extra..				

VIII. ADVANCED DRAWING

A.	IRREGULAR CURVED OBJECTS				
	1. Operating Cam	261..	24	..Orthographic views	Pencil mechanical drawing
	2. Operating Cam	..	25	..Mechanical pencil drawing, plate 24.	Tracing plate 24.
	3. Swivel Hook	262..	24	..	
	4. Swivel Hook	..	25	..(All plates 24 and 25 same as above).	(All plates 24 and 25 same as above)
	5. Swing Arm	263..	24	..	
	6. Swing Arm	..	25	..	
B.	DRAWING FROM MODEL				
	1. Simple machine part.....	..	26	..Object	Freehand orthographic sketch
	2. Simple machine part.....	..	27	..Freehand orthographic sketch, pl. 26.	Pencil mechanical drawing
	3. Simple machine part.....	..	28	..Mechanical pencil drawing, plate 27.	Tracing plate 27
C.	DRAWING FROM MODEL				
	1. Part or parts of a machine	..	29	..Objects	Freehand orthographic sketch
	2. Part or parts of a machine	..	30	..Plate 29	Pencil mechanical drawing
	3. Part or parts of a machine	..	31	..Plate 30	Tracing of plate 30
D.	DETAILS FROM ASSEMBLY				
	1. Adjustable Step Bearing ..	283..	32	..Assembly drawing	Detail orthographic sketch
	2. Adjustable Step Bearing ..	..	33	..Plate 32	Pencil mechanical drawing
	3. Adjustable Step Bearing ..	..	34	..Plate 33	Tracing of plate 33
	4. Connecting Rod End.....	284..	32	..	
	5. Connecting Rod End.....	..	33	..	
	6. Connecting Rod End.....	..	34	..(All plates 32, 33, and 34 same as above)	(All plates 32, 33, and 34 same as above.)
	7. Pipe Union	285..	32	..	
	8. Pipe Union	..	33	..	
	9. Pipe Union	..	34	..	
E.	ASSEMBLY FROM DETAILS				
	1. Machine detailed in plate 31	..	35	..Prints of detail drawing, plate 31.	An assembly drawing
	3. Machine detailed in plate 31	..	36	..Plate 35	Tracing of plate 35

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