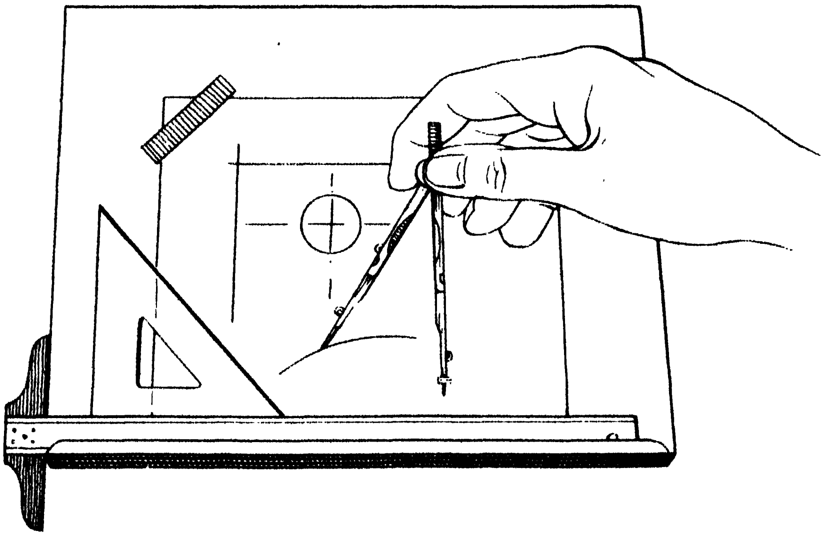
MODERN DRAFTING

Industrial Arts Education Series



MODERN DRAFTING

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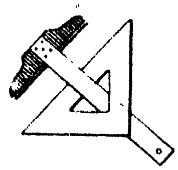

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FOREWORD

Drafting plays a highly significant part in our modern industrial world and is indispensable for our present and future civilization. The young people of today should learn drafting as a part of their general education and as a possible future vocation. The ability to read drawings and to make plans using drawing is of great value in many present-day activities. A clear understanding of the tools and techniques of drafting not only adds interest to living but also provides usable skills.

This volume, one of a series on industrial arts education, is a student text intended to introduce youth to the field of modern drafting. It has a wealth of problems adapted to different levels of ability. The text has been checked for reading level and supplemented with informative drawings and photographs.

The first six units deal with the fundamentals of drafting and will provide a year's course for the average beginning drafting class. The last six units of *Modern Drafting* take up specific industrial applications and will provide a full year's course for the average second-year drafting class. However, if a drafting class meets for five double periods a week, the students may be able to complete the major portion of this text in one year.

The authors have found it advantageous to have the two years of drafting instruction in one text. In the first year the fundamentals of drafting can be presented, and the field of applied drafting can be shown in a preliminary way. Then in the second year students find it convenient to be able to refer readily to the first year's work when they need to review the fundamentals of drafting while mastering the industrial applications.

The content of *Modern Drafting* is based on an extensive study of drafting courses from progressive schools, the American Vocational Association report on standards in industrial arts teaching, and studies of modern drafting practice in industry conducted under the direction of the authors during the past eleven years.

The authors wish to thank the many educators in the American public schools who have contributed directly or indirectly to this industrial arts series. While it is not possible to name all the leaders in industrial arts and vocational education who have influenced the authors' thinking during this present undertaking, the following deserve special mention: Earl L. Bedell, Director Vocational Education, Detroit, Michigan; Elmer Christy, Director Industrial Arts, Cincinnati, Ohio; H. H. Hargett, Supervisor Manual Training, St. Louis, Missouri; Coleman Hewitt, Industrial Arts Department, Chicago Teachers College, Chicago, Illinois; Melvin S. Lewis, Indiana University, Bloomington, Indiana; Arthur B. Mays, University of Illinois, Urbana, Illinois; John J. Metz, Editor *Industrial Arts and Vocational Education Magazine*, Milwaukee, Wisconsin; Frank C. Moore, Director Industrial Arts, Cleveland, Ohio; George E. Myers, University of Michigan, Ann Arbor, Michigan; C. E. Nihart, Supervisor Manual Arts, Los Angeles, California; Milo T. Oakland, Head

Industrial Arts, Northern Illinois State Teachers College, DeKalb, Illinois; Harold G. Palmer, Head Industrial Arts Department, State Teachers College, Cedar Falls, Iowa; Vern L. Pickens, Director Practical Arts, Kansas City, Missouri; Homer J. Smith, University of Minnesota, Minneapolis, Minnesota; Heber A. Sotzin, Head Industrial Arts Department, San Jose State Teachers College, San Jose, California; Roy R. Van Duzee, Director Vocational Education, West Allis, Wisconsin; and William E. Warner, Ohio State University, Columbus, Ohio.

The authors are indebted to the drafting teachers of the Chicago schools for suggestions on the content and organization of the text. Uda Koerner, Willey P. Klingensmith, George Jennings, and George Wilson have made outstanding contributions and valuable suggestions in the development of instructional materials for teaching drafting.

The authors wish to thank the following companies for their co-operation in furnishing photographs and materials from industry: Allis Chalmers Manufacturing Company, Milwaukee, Wisconsin; Pullman-Standard Car Manufacturing Company, Chicago, Illinois; General Motors Corporation, Detroit, Michigan; Link-Belt Company, Chicago, Illinois; Ross, Browne & Fleming, Chicago, Illinois; Illinois Central System, Chicago, Illinois; Bucyrus-Erie Company, South Milwaukee, Wisconsin; C. F. Pease Company, Chicago, Illinois; The American Society of Mechanical Engineers, New York, New York; American Bridge Company, Chicago, Illinois; Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York; A. B. Dick Company, Chicago, Illinois; and the Oriental Institute, University of Chicago, Chicago, Illinois. The authors also wish to thank the following individuals for pictures showing styles of architecture: Pearson and Dahlquist, Architects, Chicago; Rudolph P. Boehm, Architect, Chicago; Koerner and Gerhardt, Architects, Chicago; and J. E. Nagy, Director of Buildings and Maintenance, Nashville, Tennessee.

WILLIAM H. JOHNSON
LOUIS V. NEWKIRK

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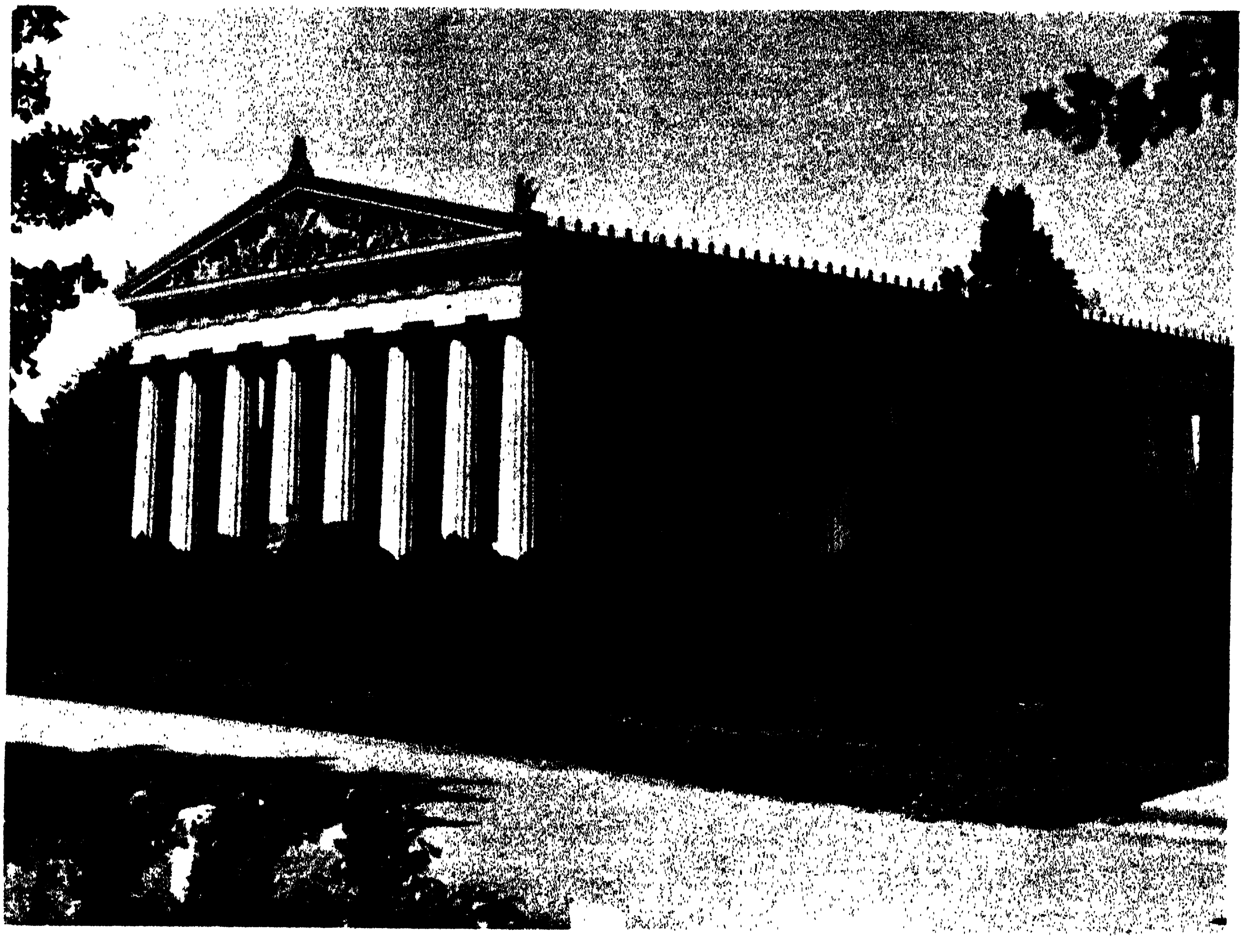

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Fig. 1—THE PARTHENON IN CENTENNIAL PARK, NASHVILLE

UNIT I

THE DRAFTSMAN'S LANGUAGE AND TOOLS

HISTORICAL BACKGROUND

Drawing is recognized as the oldest form of written expression. Primitive man first made use of drawing when he sketched on the walls of his cave rough pictures that told the stories of his prowess as a hunter and warrior. Although he drew many pictures, the cave man most often sketched what he had done rather than what he planned for the future.

The Egyptians early in their history used charts of the stars to serve as guides in their travels. Later they developed surveys to relocate their lands along the Nile after the floods. Records show that they also began the development of geometry and geometric drawing. Drawings or plans similar to those of today were used in the construction of the pyramids built by the Egyptian architect Imhotep about 5000 years ago.

The Egyptians, Greeks, and Romans contributed greatly to planning and drawing in the field of architecture, or the design and erection of buildings. Many of the ideas developed by them are still in use. This is especially true of the Greeks and Romans. The proportions and beauty of Grecian architecture as it was at the height of its development are often used today. The strength and mass of Roman and Grecian architecture are particularly suited to public buildings. Many of our larger buildings are developed from ideas and forms found in those built in Europe during the Greek, Roman, and Gothic periods. A reproduction of the famous Parthenon of Athens, which was built in Nashville, Tennessee, as a museum, is shown on the opposite page. Other examples of period architecture are the Museum of Science and Industry and the Rockefeller Memorial Chapel, in Chicago.

THE DRAFTSMAN'S LANGUAGE

It would be impossible to construct the many machines and buildings that are a necessary part of our modern civilization without the plans, sketches, and drawings used in designing and building them. In all fields of work planning and drawing are useful; in technical fields they are essential.

Technical drawing is recognized as the language of industry. The lines of the drawings may be made either with instruments or by freehand sketching. Instruments are used to give exactness of expression to the ideas of the technical expert or engineer. When instruments are used, the drawing is often said to be a *mechanical* drawing, to distinguish it from a *freehand* drawing.

The person who makes drawings for industry from the ideas of the engineer is called a *draftsman*. It is his job to place on paper a clear picture of the shape and exact dimensions of each object that is to be made. This graphic representation has to be clear enough so that it will give the mechanic who builds the object all the necessary information as to its size, shape, and material.

THE DRAFTSMAN'S TOOLS

A draftsman likes to have the best equipment that he can afford. He realizes that good tools are necessary to get exact results. The best advice that can be given drawing students also is to get the best

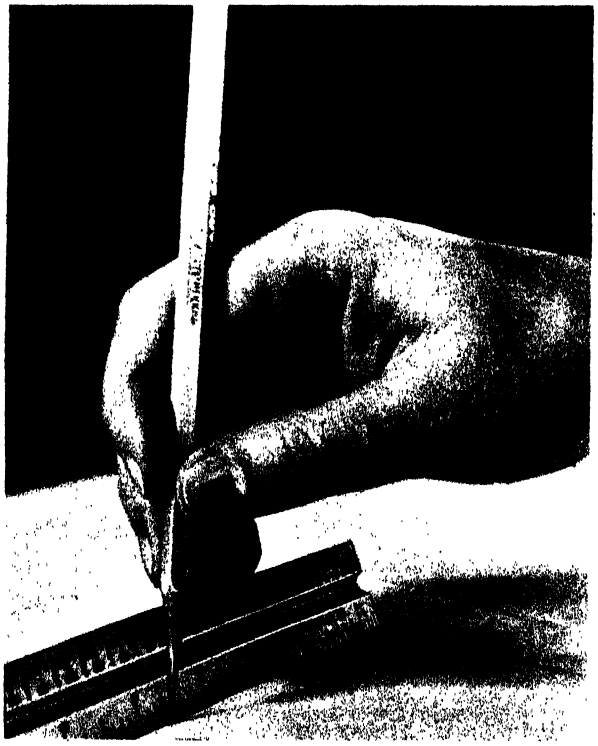

Fig. 2—HOLD YOUR PENCIL FREELY.

tools they can afford. Cheap tools will not last long, nor will they be accurate; good equipment will last indefinitely if given ordinary care.

Pencils

The drawing pencil is one of the draftsman's most important tools. Drawing pencils come in different grades of hardness, ranging from 6B, the softest grade, through 5B, 4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, 6H, 7H, and 8H to 9H, the hardest. A draftsman may have many of these grades if he is doing various types of drawing.

The number of the pencil to use depends upon the nature of the work being done and the kind of paper used. For general drawing only a few pencils are needed. These are usually HB, 2H, and 4H. An HB pencil is often used for lettering; a 2H pencil is good for linework; and a 4H pencil is used for general layout purposes.

The best results are usually obtained by

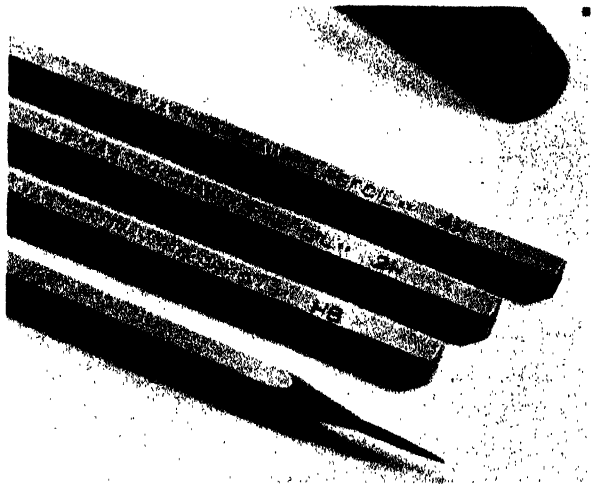

Fig. 3—PENCIL SHARPENED WITH CONICAL POINT

holding a pencil, as shown in Figure 2, freely and not too close to the point. The pencil should be held at right angles to the paper and inclined slightly in the direction of the stroke when drawing a line.

All drawing pencils have the grade of hardness stamped at one end. They should be sharpened at the other end. Thus it will be possible to identify the various pencils without trying them first. Most draftsmen find that best results are obtained when the pencil is sharpened in a certain manner. Figure 3 shows the conical point that is

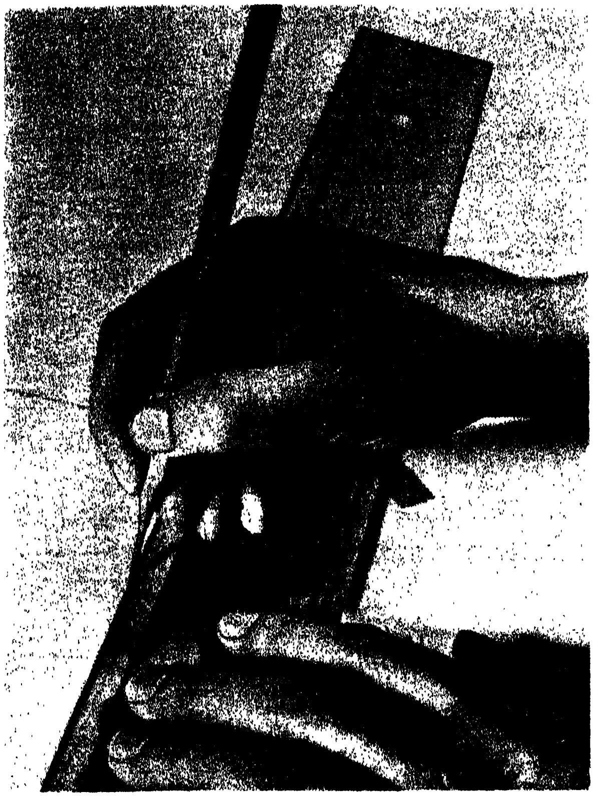

Fig. 4—USING THE T SQUARE

Fig. 5—USING THE TRIANGLE AND T SQUARE

used most frequently. When using this point it is best to rotate the pencil gradually.

Penknife and Sandpaper Block

When sharpening a pencil first remove the wood from the lead with a penknife and then rub the lead on a sandpaper block to shape the point. A good pencil sharpener may be used if it is set to give a long point. Pencils should be sharpened whenever they show signs of dullness.

The Drawing Board

The drawing board should be of softwood that is free from pitch; basswood or white pine is usually used. Either has a 2-inch strip of solid wood across the grain on each edge to prevent warping. Some drawing boards are made of plywood. Drawing boards come in various sizes; 20″ x 24″ is a suitable size for general purposes. The *working* edge of the board should be perfectly straight and its surface trim and smooth, as this is the edge along which the T square is moved. This edge will be to the left side of a right-handed draftsman.

The T Square

A T square is used for drawing horizontal lines. It also serves as a guide for the triangles.

The T square used most often has the head securely fastened to the blade at a right angle to it. There is also the *adjustable* T square, with one fixed and one adjustable head. Wood, steel, and celluloid are common materials used in making T squares. Transparent celluloid or plastic is often used on the edges of the better blades.

The head of the T square is placed at the left edge of the board and held firmly there

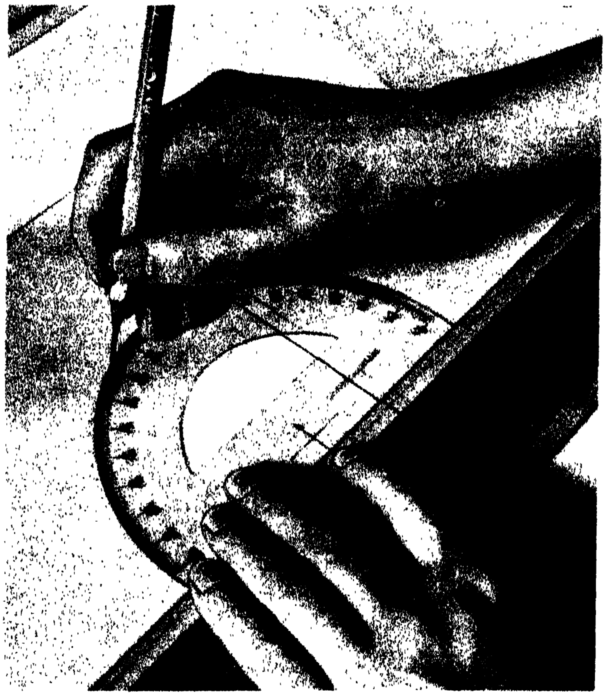

Fig. 6—MEASURING AN ANGLE WITH THE PROTRACTOR

while one is drawing. When the head of the T square is held firmly against the edge of the board, the blade lies horizontally. All horizontal lines are drawn along the upper edge of the blade and from left to right by a right-handed person.

Triangles

Triangles are usually made of celluloid, plastic, or wood. Celluloid or plastic triangles are better because they do not chip, warp, or break as easily as wooden ones. Two triangles are necessary, a 30°-60° triangle and a 45° triangle. While these may be secured in various sizes, an 8- or 10-inch 30°-60° triangle and an 8-inch 45° triangle are best for most uses.

Vertical and oblique lines are drawn with a triangle. The base of the triangle should rest on the blade of the T square and both should be held with the left hand, as shown in Figure 5. This leaves the right hand free to draw. Start the pencil at a point near the blade of the T square and proceed upward.

The Protractor

Sometimes it is necessary to measure and draw angles that cannot be measured with either the 45° or the 30°-60° triangle. Then the protractor is used. The protractor is a semicircular scale divided into 180 equal parts, each of which is called a degree (°). It is used for measuring arcs of a circle as well as angles. The protractor shown in Figure 6 is being used to measure an angle of $72\frac{1}{2}$°.

The Architects' Triangular Scales

The architects' triangular scale shown in Figure 7 is the one commonly used for general drawing. Another scale often used is the flat scale shown in Figure 17. As the triangular type is the more common, its use will be explained here.

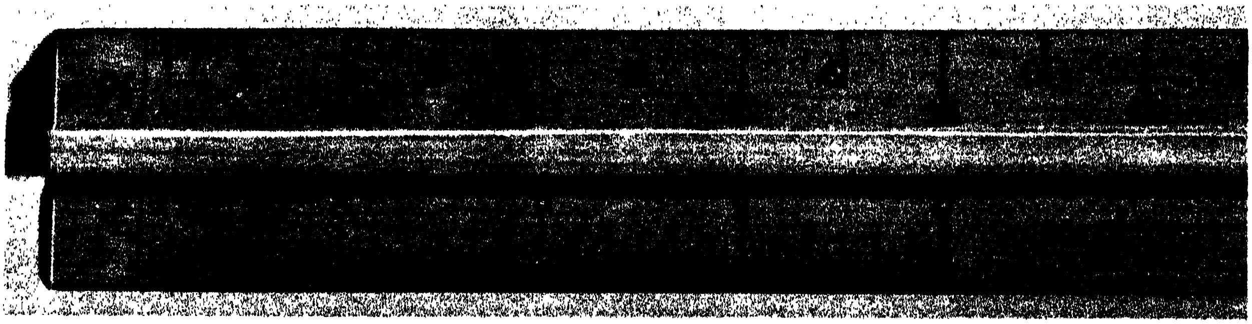

Fig. 7—THE ARCHITECTS' TRIANGULAR SCALE

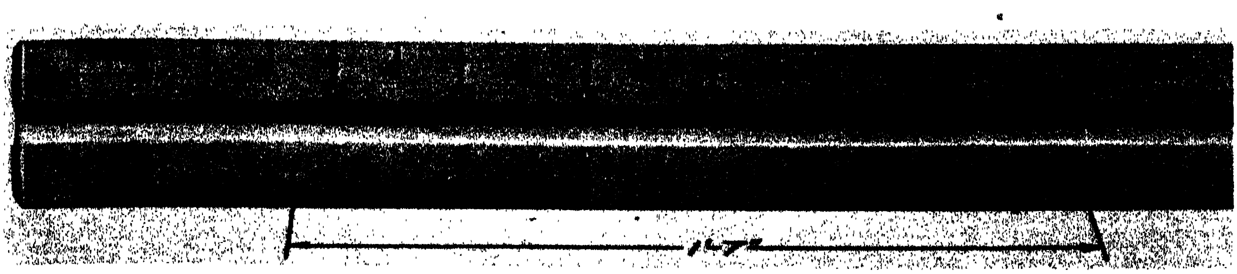

Fig. 8—1 FOOT, 7 INCHES ON THE 3-INCH SCALE

To protect the graduations, or markings, at the ends, the scale is made longer than the 12 inches that are graduated. The architects' triangular scale has various divisions, with eleven different scales in all. By means of these divisions the drawing of an object may be made either in actual size or larger or smaller according to the nature of the drawing and its use.

An examination of the scale reveals on one edge the common rule of 12 inches to the foot divided into $\frac{1}{16}''$ graduations. This scale, which is marked 16, is used for making drawings of objects in their actual size; or, by dividing the actual dimensions by 2, drawings one half the full size may be made. *The dimensions on the drawing are always marked the actual or full size of the object regardless of the scale used.*

The other scales range from $\frac{3}{32}'' = 1'\text{-}0''$ to $3'' = 1'\text{-}0''$. These are paired two to an edge and marked to show scale divisions of $\frac{3}{32}''$ and $\frac{3}{16}''$; $\frac{1}{8}''$ and $\frac{1}{4}''$; $\frac{1}{2}''$ and $1''$; $\frac{3}{8}''$ and $\frac{3}{4}''$; and $1\frac{1}{2}''$ and $3''$. Each unit on any of these scales represents a foot of actual measurement reduced to a particular length. All scales should be thought of in terms of feet. One of the units on each scale is marked in divisions that represent inches and fractions of an inch. The foot units lie to one side of the 0 mark and the inch units to the other.

Turn the scale until you find the face marked 3 and $1\frac{1}{2}$. These scales are used to make one-fourth size drawings, where $3'' = 1'\text{-}0''$, or one-eighth size drawings, where $1\frac{1}{2}'' = 1'\text{-}0''$. These are common scales for machine drawing. Figures 8 and 9 show two measurements; $1'\text{-}7''$ is shown on the $3'' = 1'\text{-}0''$ scale, and $1'\text{-}3''$ is shown on the $1\frac{1}{2}'' = 1'\text{-}0''$ scale.

The scale $\frac{1}{4}'' = 1'\text{-}0''$ is used to make still

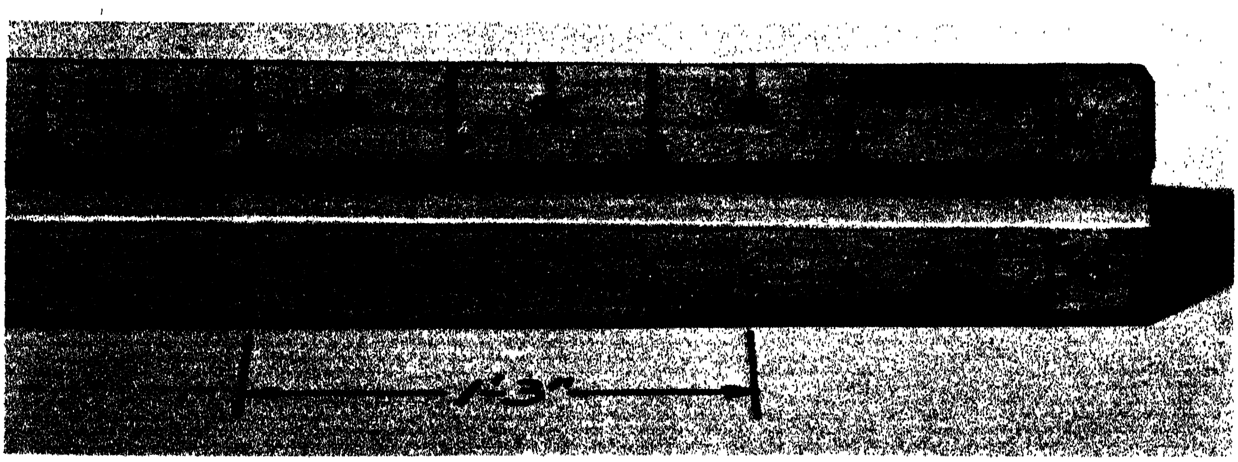

Fig. 9—1 FOOT, 3 INCHES ON THE 1½-INCH SCALE

Fig. 10—USING THE REGULAR DIVIDERS

Fig. 11—USING THE ERASING SHIELD

smaller drawings. This is the usual scale for architectural drawings. The small graduations represent inches, while the ¼″ graduations represent feet.

The other scales are used in the same manner. When laying off foot and inch measurements on a drawing, count the number of feet on one side of the 0 mark and the inches on the other side. Then lay off the required measurement on the drawing. Either light dots or small dashes may be used for the necessary marks.

The Dividers

Dividers are used for dividing a distance equally, transferring measurements, and spacing points or lines. The regular dividers shown in Figure 10 are used for these purposes. Accuracy is necessary in adjusting the divider points for the use to which they are to be put.

Erasers and Erasing Shield

The draftsman requires art gum and a good red or pink rubber eraser. The art gum is used to remove smears, the eraser to remove either pencil or ink lines. The *shield* is a useful tool, with irregular holes, that is used to protect the rest of the drawing when making an erasure. Figure 11 shows the shield in use.

French Curves

In addition to straight lines, curved lines are often necessary in drawing. All curves except circles and arcs may be drawn with the irregular, or French, curve shown in Figure 12. A freehand curved line is usually made first. A portion of the French curve is then fitted to this line, and the finished curve is drawn. Do not attempt to draw a long line without adjusting the curve to a new position.

Fig. 12—USING THE FRENCH CURVE

Fig. 13—USING THE BOW DIVIDERS TO STEP OFF SHORT EQUAL DISTANCES

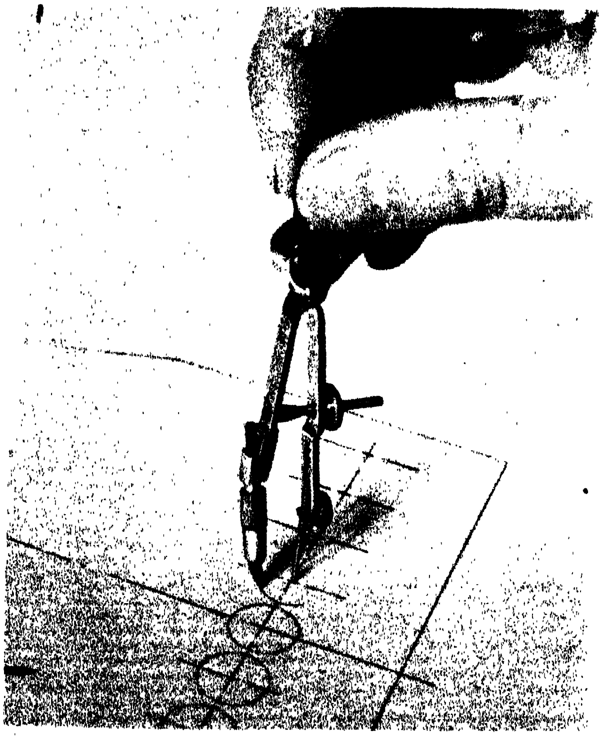

Fig. 14—DRAWING SMALL CIRCLES WITH THE BOW COMPASS

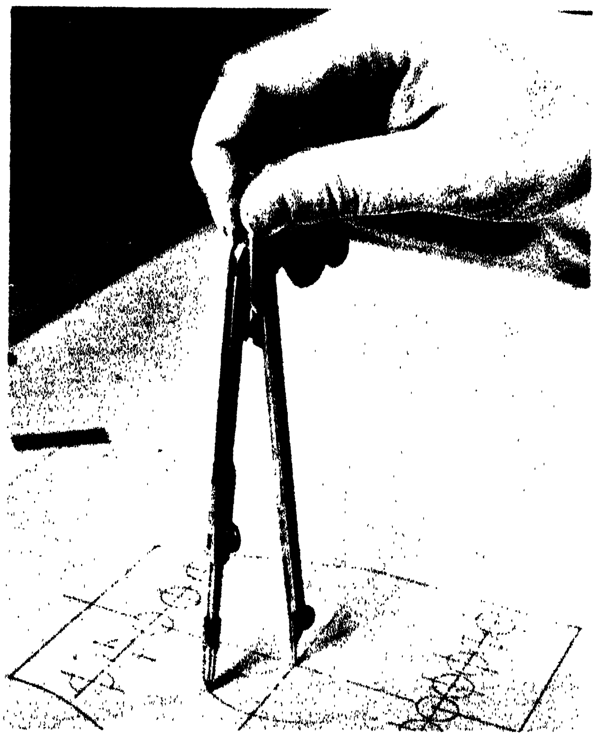

Fig. 15—USING THE REGULAR COMPASS

The Bow Instruments

Various small and exact adjustments may be made on the *bow instruments* by means of the adjusting screws.

The bow dividers, or points, can be adjusted to measure distances up to about $1\frac{1}{4}$ inches. Figure 13 shows a bow divider being used to "step off" equal distances along a center line.

There are two bow compasses in the usual set, one compass for pencil and one for ink. These vary as to size, but usually the radius may be made as large as one inch. They are used for drawing the smaller circles. A bow pencil compass in use is shown in Figure 14.

The Compass

For making most circles and arcs, the regular compass, held as shown in Figure 15, is used. The compass is rotated between the thumb and first finger. If a circle is to be made larger than 3 inches in radius, the legs of the compass should be bent so that they are nearly perpendicular to the paper. Some instrument sets contain an extension arm to be used when circles of large size are required. The compass usually has interchangeable legs, one for pencil and one for ink.

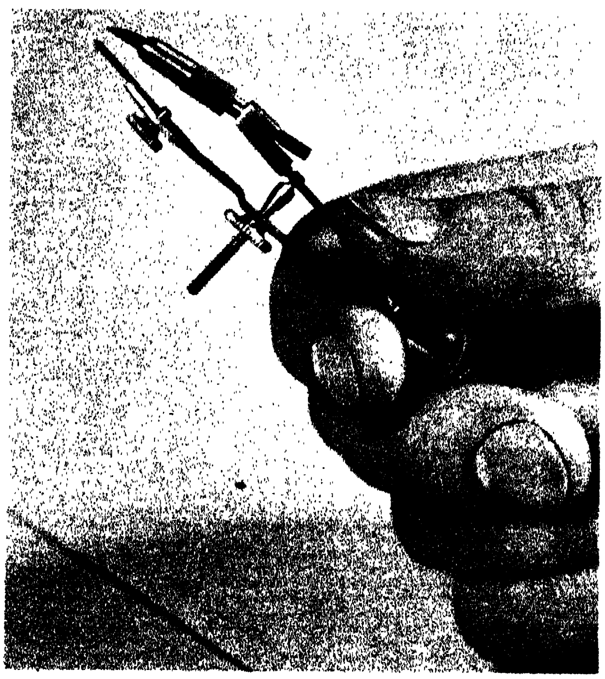

Fig. 16—SHARPEN THE LEAD TO A THIN CHISEL POINT.

The pencil compass should have a 3H or 4H lead, sharpened to a thin chisel point as shown in Figure 16. The lead must be placed in the compass in such a position that it will make a thin line.

The Ruling Pen

Drawings may be made more permanent by tracing them in ink. The ruling pen is used for inking straight lines and those curved lines that cannot be inked with a compass. The use of the ruling pen is discussed in Unit XII.

Buying Drawing Instruments

When buying a set of drawing instruments, get the best you can. If necessary, purchase a good set with fewer instruments rather than a poorly made one with more instruments. The common instruments in a set are a compass, a pair of dividers, a ruling pen, and the bow instruments—dividers, pencil compass, and pen compass. A regular drawing set is shown in Figure 17. Your instructor will be able to give suggestions that will be helpful in choosing drawing instruments.

SUMMARY

Drawing as a means of recording past experience is the oldest form of written expression. Very early man began to use crude forms of plans, and eventually the Egyptian developed geometry and drawing as parts of his skill in planning and erecting temples and other buildings.

Planning is essential to the production of the complex machines and structures of modern civilization. The necessary plans

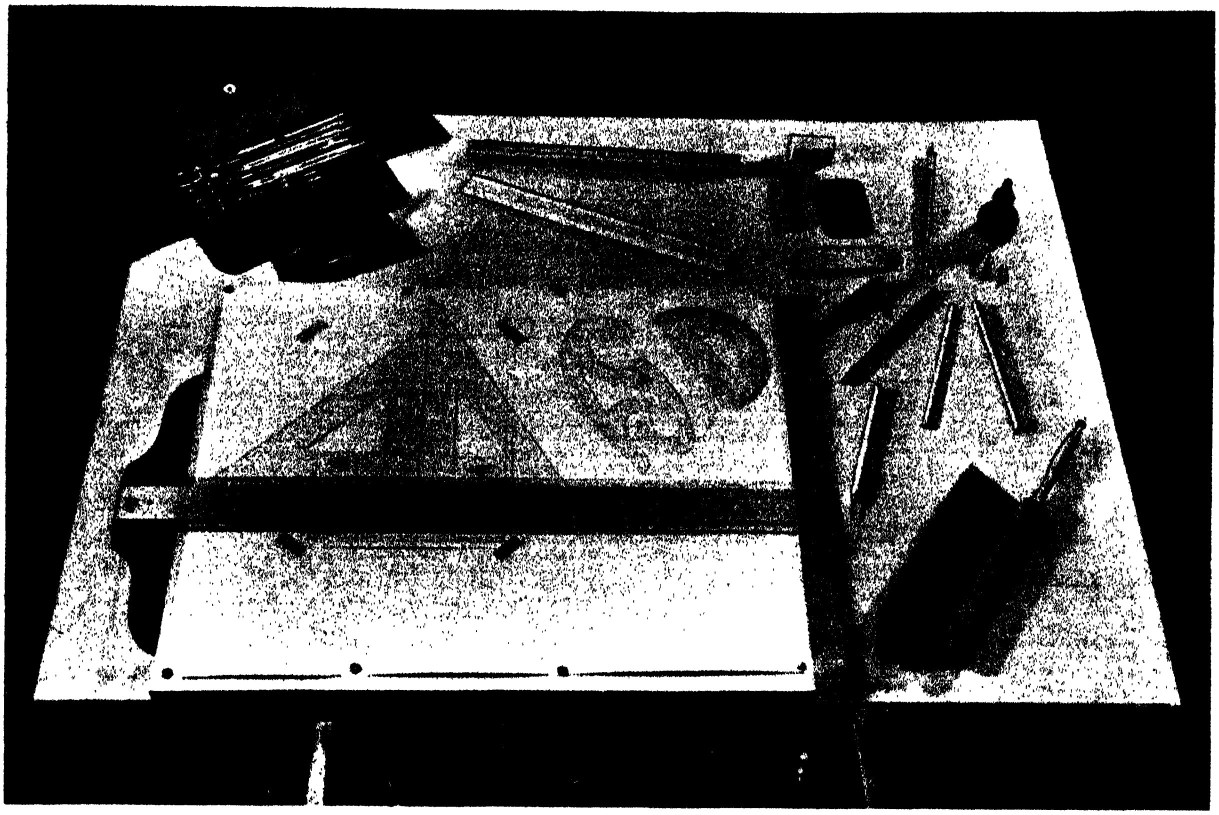

Fig. 17—DRAWING EQUIPMENT

are recorded in the language of industry, technical drawing.

When the draftsman uses instruments to give exactness to his drawings, these are called mechanical drawings, to distinguish them from freehand drawings. The tools used in mechanical drawing are the pencils, penknife, sandpaper block, erasers and erasing shield, drawing board, T square, triangles, protractor, architects' scale, French curves, compass, dividers, ruling pen, and bow instruments.

QUESTIONS

1. What did the ancient Greeks contribute to present-day architecture?
2. Why is technical drawing called the language of industry?
3. What is the difference between mechanical and freehand drawing?
4. On which end should a drawing pencil be sharpened?
5. Why should the working edges of the drawing board and T square be protected?
6. What instrument is used in drawing vertical lines?
7. When should the bow compass be used in preference to the large compass?

TOPICS FOR DISCUSSION

1. Compare drawing as a language with the English language.
2. Select several objects and show how planning was essential to the construction of each.

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UNIT II

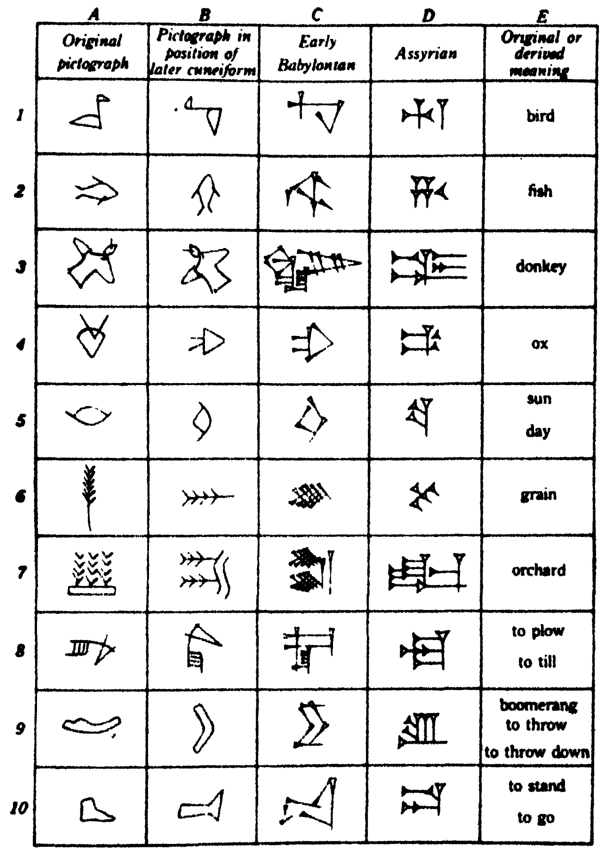
LETTERING AND TECHNIQUES

THE DEVELOPMENT OF THE ALPHABET

Writing gave to man a means of accurate communication over long distances and a method for storing the accumulated experiences and knowledge of the race. Its importance as a step in the development of mankind cannot be overestimated.

It is impossible to state when writing first came into use. But people who have made a study of the growth of written language say that it probably first appeared as symbols that represented pictures or objects. Early man used a very crude form of picture or symbol writing. Chinese writing still contains some characters of this kind. Examples of early forms of writing are shown in Figure 18.

The Egyptians developed picture writing to a high degree and later classified it to form *hieroglyphics,* in which each character represented an object or an idea associated with that object. About 5000 B.C., when it was discovered that certain pictures could represent particular sounds, hieroglyphics and symbols were combined to represent these sounds. From this step the Phoenicians are supposed to have developed a fixed symbol for each sound. Later the Greeks changed the positions and forms of the symbols to serve their own needs. Still later the Romans developed the Greek symbols into an alphabet of their own. Our present alphabet is taken almost directly from that of the Romans. A few of our letters, the U, V, Y, and W, were developed as late as the seventeenth century. The other letters have been a development over a period of 7000 years.



Courtesy Oriental Institute, University of Chicago

Fig. 18—EARLY FORMS OF WRITING

Drawings, the graphic language of shape, would not be complete without the necessary notes and dimensions to aid in completely understanding them. Lettering, which is used to give this essential information, is a fundamental part of drawing. Lettering is used rather than regular writing or script in order to give greater ease in reading and to make for more uniformity in the work of draftsmen.

THE STYLE OF LETTER

In industry the drafting department is often separated from other departments. When the blueprints from drawings are given to a workman, he often makes or builds the object shown without additional information. Drawings are sometimes used thousands of miles from the place where they were made. Therefore well formed letters that are easily and correctly read are required. Such letters have the same weight of line throughout, a proportion that is pleasing, and an even height.

Lettering is closely related to design. In some of the larger drafting plants, men may be employed to work only at lettering if the job is of a particular nature, such as the designing of inscriptions. Advertising agencies use men who have made a study of the designing of letters and have developed techniques in creating styles of lettering to fit particular needs. A sign painter is especially adept at his kind of lettering. Have you ever watched a man letter a sign on a wall or a large glass window? It seems almost impossible to do such an excellent job in such size, but it is apparently done easily. In some cases the letters are formed backwards, as when a sign is made on the inside of a window facing the street.

Each phase of drawing, such as architectural, engineering, or machine, has in general its own kind or style of lettering. The style is usually determined by the office where the drawing is done. It is also true that certain drafting styles vary with the individual. The letter used should always be appropriate for the particular drawing. The essential of all lettering, regardless of the style used, is ease in reading.

The Weight of the Letter

There are two kinds of letters, the *single-stroke* and the *built-up*, or outlined. These are shown in Figure 19. In the single-stroke letter the width of the lines that form the letter is the width of the stroke of the pencil or pen. This kind of letter is used in by far the greatest number of

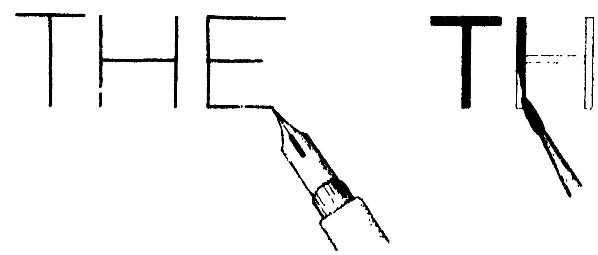


Fig. 19—SINGLE-STROKE AND BUILT-UP LETTERS

Fig. 20—EXTENDED AND COMPRESSED LETTERS

drawings. The outline of the built-up letter is drawn and the letter filled in solidly. The outline may be freehand or it may be mechanical.

The heaviness of the line, or the *weight* of the lettering, depends upon the type of pencil or pen used. For general lettering purposes, a 2H or H pencil may be used. When drawings are inked, different weights of letters require different types of pen points.

TYPE 1 ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 1/2 3/4 5/8
TITLES & DRAWING NUMBERS

TYPE 2
FOR SUB-TITLES OR MAIN TITLES
ON SMALL DRAWINGS

TYPE 3 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 1/2 3/4 5/8 9/32
FOR HEADINGS AND PROMINENT NOTES

TYPE 4 ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 1/2 3/4 5/8 23/64
FOR BILLS OF MATERIAL, DIMENSIONS & GENERAL NOTES

TYPE 5
Optional Type same as Type 4 but using Type 3 for First Letter of Principal Words. May be used for Sub-titles and Notes on the Body of Drawings.

Fig. 21—VERTICAL GOTHIC LETTERING

The Proportions of the Letter

There is a definite relationship of the width to the height for the letters in any specific alphabet. A letter may be varied in its appearance by either extending or compressing it. An *extended* letter is wider than usual in proportion to its height. The *compressed* letter is narrower than normal and is often used where space is limited. These two kinds of letters are shown in Figure 20.

Letters may be either light or heavy in proportion to the height and width. The *boldface* letter has a heavier line; the *lightface* letter has the normal weight of line.

Vertical Gothic Capitals

A good draftsman is required to letter well, using either inclined or vertical letters. Many instructors feel that the student should learn to make vertical Gothic letters first because this kind of letter is becoming more and more popular in the industrial world. This single-stroke letter is neat and easily read, and it can be made rapidly.

TYPE 1

ABCDEFGHIJKLMNOP
QRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{16}$
TO BE USED FOR MAIN TITLES
& DRAWING NUMBERS

TYPE 2

ABCDEFGHIJKLMNOPQR
STUVWXYZ&
1234567890 $\frac{13}{64}$ $\frac{5}{8}$ $\frac{1}{2}$
TO BE USED FOR SUB-TITLES

TYPE 3

ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{16}$
FOR HEADINGS AND PROMINENT NOTES

TYPE 4

ABCDEFGHIJKLMNOPQRSTUVWXYZ&
1234567890 $\frac{1}{2}$ $\frac{1}{4}$ $\frac{3}{8}$ $\frac{5}{16}$ $\frac{7}{32}$ $\frac{1}{8}$
FOR BILLS OF MATERIAL, DIMENSIONS & GENERAL NOTES

TYPE 5

OPTIONAL TYPE SAME AS TYPE 4 BUT USING TYPE 3 FOR FIRST LETTER OF PRINCIPAL WORDS. MAY BE USED FOR SUB-TITLES & NOTES ON THE BODY OF DRAWINGS.

TYPE 6

abcdefghijklmnopqrstuvwxyz
Type 6 may be used in place of
Type 4 with capitals of Type 3,
for Bills of Material and Notes
on Body of Drawing.

Fig. 22—INCLINED GOTHIC LETTERING

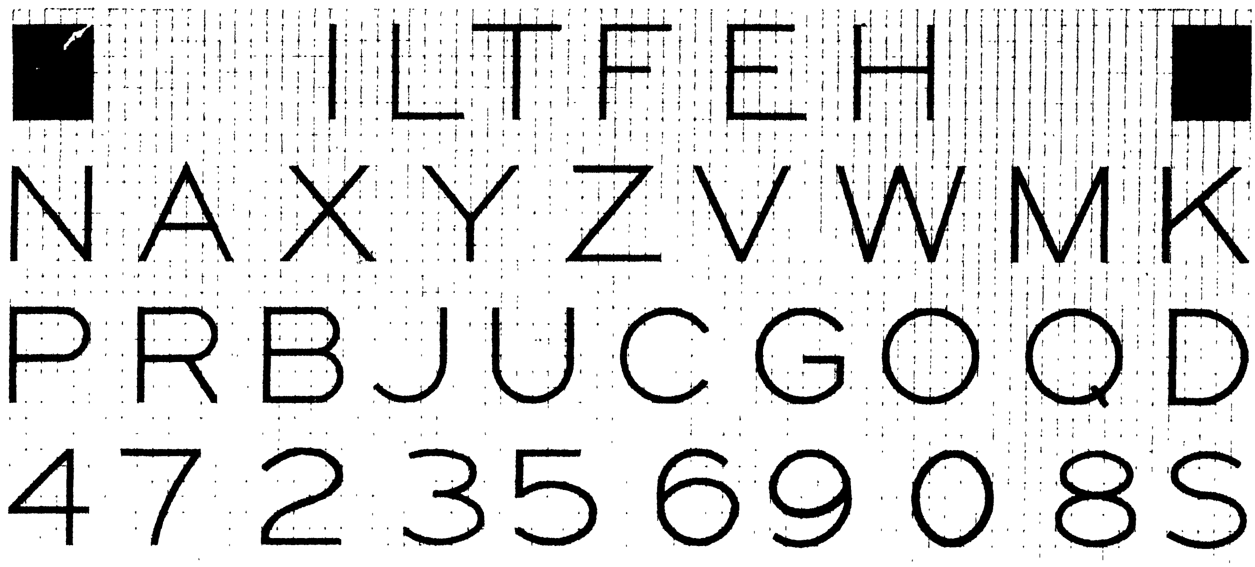


Fig. 23—VERTICAL GOTHIC LETTERING GROUPED ACCORDING TO CONSTRUCTION

The vertical Gothic lettering shown in Figure 21 is approved by the American Standards Association, which provides a code of standard practices for drafting in the United States. Shown in Figure 21 are the various sizes of lettering recommended for titles, notes, and subtitles. Notice that the lower case has been omitted. The accepted practice in the field is to use capitals only for the vertical Gothic letters.

Inclined Gothic Alphabet

The accepted types and sizes for the inclined Gothic lettering are shown in Figure 22. These are according to the recommendation of the American Standards Association. Notice that capitals are preferred.

MAKING THE LETTERS

Before you start to do any lettering, it would be well to study Figure 23. Here the characters of the vertical alphabet have been grouped, according to similar construction, on a cross-section background for analysis. The height of the letters is six units; it will be noticed that many of the letters are five units wide.

On the next pages vertical and inclined Gothic capitals are shown individually with each stroke of the letter accompanied by a small arrow and a number. The number signifies which part of the letter is made first, second, third, or fourth, and the arrow shows the direction of the stroke.

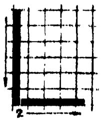
The slope of the inclined guide lines for the inclined Gothic capitals is an angle of $67\frac{1}{2}°$ with the horizontal. The inclined alphabet has the same heights and widths as the vertical. All strokes are made in the same order, and the shapes are the same except they have been inclined to the indicated slant. The numerator and denominator of a fraction are inclined so that they "line up" on the same slant guide line.

The directions that follow are given for the vertical letters. The same directions are to be used for the inclined letters. Study carefully every stroke in the drawing of each letter.

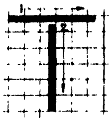
The first letters to study are I, L, T, F, E, and H. These letters are easiest to draw because the basic strokes are vertical and horizontal. You should practice making these letters according to the models.

is a true vertical line made with a downward stroke. Be sure that the stroke is uniform in width for its entire length.

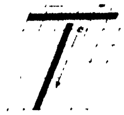
2

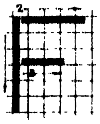


has a horizontal stroke added to the downward stroke of the I. Be sure that the bottom stroke does not slope either upward or downward.

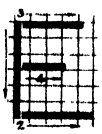


should be made straight. Start the vertical stroke at the center of the horizontal.

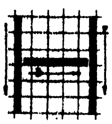




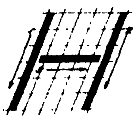
is made with the third stroke a bit above the middle of the vertical stroke to prevent a top-heavy appearance. The stroke is just over three units long.



is similar to the F, with the bottom stroke, however, made as the second stroke. This stroke is slightly longer than the top one.

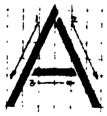


is made with the center or horizontal stroke slightly above the middle of the vertical strokes. This position prevents a top-heavy appearance.



The next group of letters includes N, A, X, Y, and Z. These introduce a slant line and are more difficult.

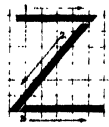
has the two vertical strokes made first in order to obtain the proper width of the letter.



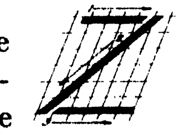
extends just past the top guide line; the horizontal stroke is located at about one third the height.

is not full width at the top. Notice that the two strokes cross at a point just above the center.

has the two inclined strokes meeting just below the middle of the height, and the angles of these with the third stroke are equal.

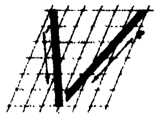


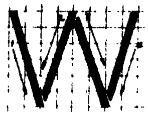
has the top stroke five units long centered over the bottom or third stroke. Be sure that the Z does not have a top-heavy appearance.



The group V, W, M, and K is studied next.

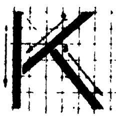
V is made with the two strokes meeting at the exact center of the width on the bottom guide line.



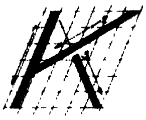


W is the widest letter in the alphabet, eight units wide. Make each V four units wide. Be sure that the strokes meet smoothly.

M is narrower than W; its width is six units. The two outside strokes are made first. The inclined strokes meet on the bottom guide line at the center of the width.

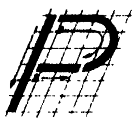


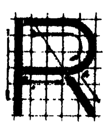
K does not have the full width at the top. Notice that the second stroke ends two units up from the bottom. The third stroke starts from the second stroke.



The group P, R, B, J, and U require closer study because of the introduction of the curved line.

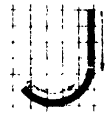
P must be made with the horizontal strokes at right angles to the vertical stroke. The second stroke begins slightly below the middle of the vertical stroke.



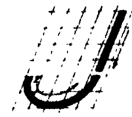


R is made in the same way as the P but with the fourth stroke added.

B starts with the vertical stroke. The second, third, and fourth strokes begin at right angles to the first stroke. The upper part of the B is less than five units wide.

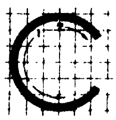


J begins with the vertical stroke. The curved second stroke should join the vertical stroke smoothly.

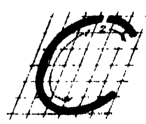


U has two parallel vertical strokes joined by the curved bottom stroke.

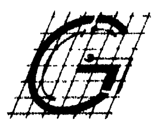
The last group, which contains C, G, O, Q, D, and S, is based on the circle.

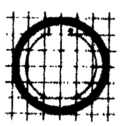


C is a circle cut less than one unit in width on the right side. Have the curve smooth. The opening is more than two units high.

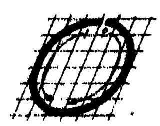


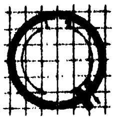
G is the same as the C but with the third angular stroke added. Be sure that the beginning of this stroke is horizontal.



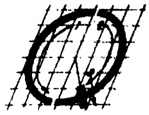


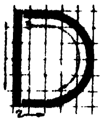
O is a perfect circle made in two strokes. The second stroke joins the first one at the bottom.



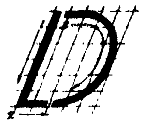


is formed in the same manner as the O except that it has the *kern*, the little third stroke, added.





is begun with a vertical stroke. The second stroke and the beginning of the third stroke are at right angles to the first.

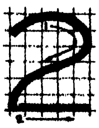


has the upper part smaller than the lower to avoid a top-heavy appearance. The curves join smoothly and gracefully.

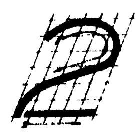
MAKING THE NUMERALS

The numerals should be studied closely for form because all mechanical drawing involves their use. Notice that the figures are all six units high and that all are five units wide except the figure 1. All figures are composed of the essential strokes that we find in the letters, namely, the straight and curved lines.

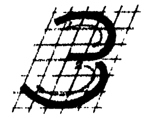
The figure 1, like the letter I, is merely a vertical line just six units high. Make it straight and true.

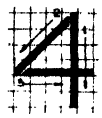


This figure is a combination of two strokes, one long curved stroke made first and the second a horizontal straight line. These strokes meet at right angles.



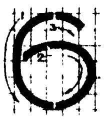
Two partial ellipses make up this figure. The first stroke ends at a point slightly above the center, where the second starts.



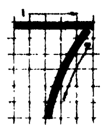


The vertical stroke is made first. Notice that the inclined stroke ends four full units to the left of this one. Be extremely careful to make the final stroke horizontal.

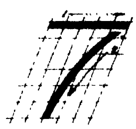
Be sure that the first and third strokes meet and that no space is left between them. The second stroke or lower portion is part of an ellipse; make this full and smooth.

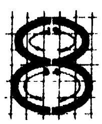


The first stroke is the left half of an ellipse. The other strokes should join this to form smooth curves without any bulges. The lower portion of the figure is a little more than four units high, leaving less than two units between this portion and the top.

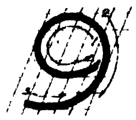


The second stroke ends just to the left of the center. This gives balance and stability to the figure.





Two ellipses are balanced one on top of the other to form this numeral. The upper ellipse touches the lower one, but the two do not intersect. Keep them well balanced; otherwise the figure lacks stability.

 This is almost the same as the figure 6 turned upside down  except that in the 9 the bottom has been made slightly longer than the top.

 The 0 is simply an ellipse one unit higher than it is wide.  It is not as wide as the letter O, but the curve should be quite full.

Fractions are made in the sizes shown in Figure 24. The space between the figures is divided by the bar in the fraction, which is always made horizontally even with inclined numerals. Notice in Figure 24 that the denominator is placed directly below the numerator, so that the fraction has a vertical appearance.

Mixed numbers are combinations of whole numbers and fractions. Keep the space between the whole number and the fraction about the same as that between two letters in the same word.

In making figures, you should be extremely careful to make the numerals the correct size, neither too large nor too small. Spacing between numerals should be about the same as that between letters in a word. It is well to use vertical guide lines in making all numerals.

GUIDE LINES

Horizontal guide lines should be used in lettering any part of a drawing. Top and bottom lines are used with capital letters. Three guide lines are needed if two sizes of letters are used. Figure 24 shows the use of guide lines.

Guide lines may be located with bow dividers. The dividers are set to the height of the required letters. After their location has been marked, the lines are drawn with a T square. When vertical guide lines are used, they are spaced at random. When lettering on tracing cloth or paper, it is always best to make new guide lines, reletter in pencil, and then ink the lettering.

There are several instruments on the market that are helpful in making guide lines, including the slant guide lines used with inclined letters.

SPACING AND COMPOSITION

When you have become proficient in making letters, you should begin composing words and sentences. Because of the sizes and shapes of letters, the spacing between them is not equal. The spacing should be such that the areas between the letters appear equal. The space between words should not be less than that required for the letter O. About twice this space between sentences is the usual practice.

Figure 25 shows a comparison of good and poor spacing between letters and words. Letters whose sides are curved should be closer to adjoining letters than those with straight sides. The desired appearance of the letters requires good judgment and much practice in making them. It is advisable to "block out" work in preliminary form and adjust the spacing before the final lettering is done.

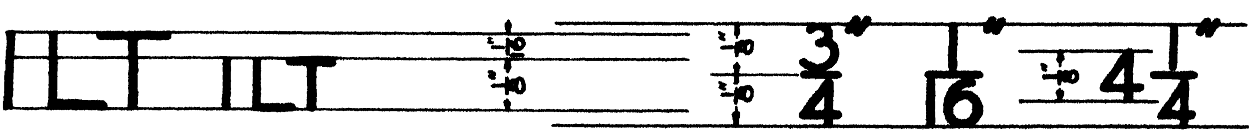


Fig. 24—GUIDE LINES

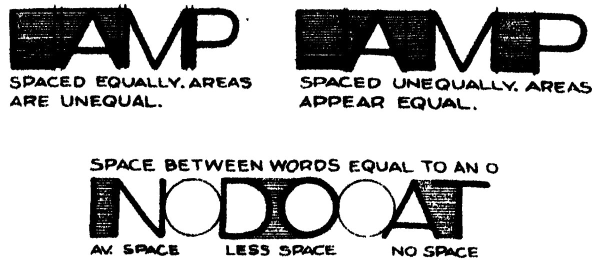


Fig. 25—EXAMPLES OF GOOD AND POOR SPACING

OTHER STYLES OF LETTER

There are many different types of lettering used in modern drawing practice. The architect uses a style of letter based on the Old Roman alphabet.

ABCDEFGHIJKL
MNOPQRSTUV
WXYZ

Fig. 26—OLD ROMAN STYLE

A modern vertical Roman alphabet is shown in Figure 27. Civil engineers use a letter of this style on their maps to show divisions, names of countries, and titles.

ABCDEFGHIJKL
MNOPQRSTUV
WXYZ

Fig. 27—MODERN ROMAN STYLE

An inclined modern Roman alphabet is used in nautical maps.

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ

Fig. 28—INCLINED MODERN ROMAN STYLE

DRAWING PAPER

Drawing paper comes in many varieties and finishes. Industry uses the kind particularly suited to its need. However, in most offices the draftsman draws directly on transparent tracing paper, such as vellum, or on tracing cloth. The advantage of using this kind of paper is that a blueprint of the drawing can be made at any time it is needed. The professional draftsman makes fewer mistakes than the beginning student and consequently fewer erasures. Therefore he is able to draw on a more delicate paper than the student. For the beginning student it is recommended that cream or buff detail paper be used. This paper is tough, stands up well under erasure, is easy on the eyes, and does not easily show dirt and line smears.

Sizes of Paper

Paper may be purchased either in sheets or rolls. Many drafting rooms have adopted standard sizes for convenience in filing. Their paper usually has printed on it the title block and the name of the company. The American Standards Association gives the following statement concerning paper sizes. "The recommended standard trimmed sheet sizes of drawing paper and cloth are as follows:

A	$8\frac{1}{2}$ x 11 in.	D	22 x 34 in.
B	11 x 17 in.	E	34 x 44 in."
C	17 x 22 in.		

Sizes B, C, D, and E can be folded into letter-size sheets $8\frac{1}{2}''$ x $11''$, so that they can be filed easily in the regular letter file. The problems in this book have been planned for the $8\frac{1}{2}''$ x $11''$ size; but, if desired, two drawings may be placed on one sheet $11''$ x $17''$. The smaller sheet is considered preferable for the beginner since it will fit into his notebook without being damaged on the outer edges.

Courtesy General Motors Corporation

Fig. 29—A DRAFTSMAN AT WORK

FASTENING PAPER TO THE DRAWING BOARD

Thumbtacks, Scotch drafting tape, staples, and rubber cement are all used to fasten drawing paper firmly on the board. Thumbtacks were used extensively until a few years ago. They can be used repeatedly, but their disadvantage is that the T square or triangles will not slide over them easily. Holes are made in the drawing paper and board when thumbtacks are used. Scotch drafting tape is rapidly replacing the thumbtack for most drawing purposes in industry. A good drafting tape may be used over again, it is reasonable in price, and a supply will last a long time.

It is recommended that a backing sheet of any kind of paper be used under the paper upon which the drawing is to be made. This backing sheet helps prevent the pencil point from punching through when it strikes an unevenness in the drawing board. The backing sheet should cover the entire surface of the board and should be replaced when it becomes dirty.

In fastening to the board the paper on which the drawing is to be made, the T square and either Scotch tape, thumb-

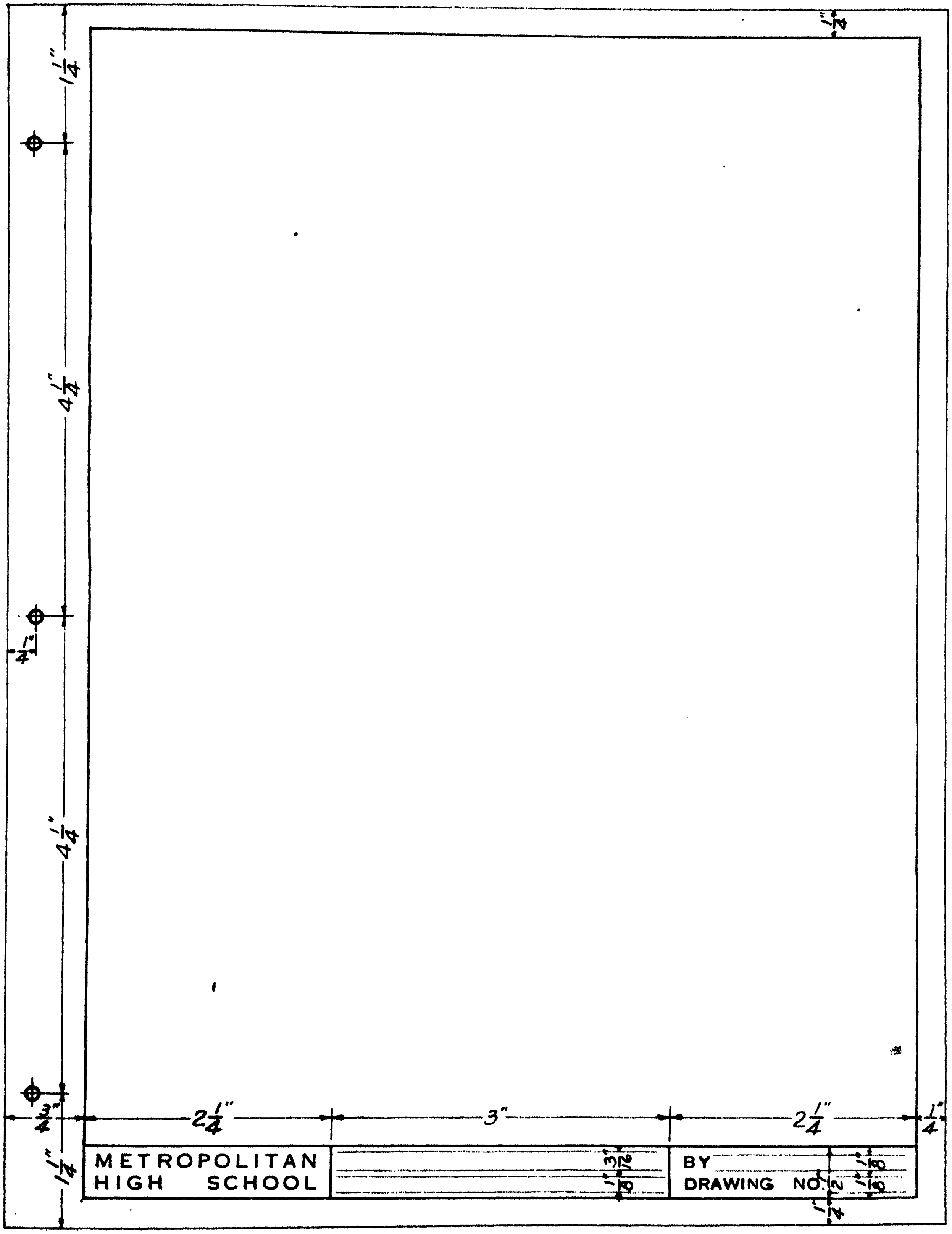


Fig. 30—BORDER LINE AND TITLE BLOCK FOR AN 8½″ x 11″ SHEET

tacks, rubber cement or staples are used. Place the sheet on the board near the left and top edges. Fasten the upper left corner of the paper with a fastener. The paper is then adjusted so that the top edge of the paper "lines up" with the top edge of the T square blade. Hold the head of the T square against the left edge of the board with the left hand. The lower right-hand corner of the paper is now fastened. The T square is removed, and the remaining two corners are fastened down. If the paper is very small, the bottom may be left free; on the other hand, if the paper is quite large, more than four fastenings may be required.

LAYING OUT THE SHEET

A suggested standard border line with title block for an $8\frac{1}{2}''$ x $11''$ sheet is shown in Figure 30. It will make for uniform appearance and conform to present practices in industry if the border line, title block, and punching indications can be printed on your sheets of drawing paper. You can then fill in the title of the drawing, the scale, your name, and the number of the drawing.

If a printed form is not used, lay out an $8\frac{1}{2}''$ x $11''$ sheet following the dimensions shown in Figure 30. When you lay out the sheet, the horizontal dimensions should be determined first and the vertical measurements next. After all distances have been measured, the border and title lines should be drawn in lightly. Guide lines for the lettering in the title space may be drawn at this time or after the drawing has been completed. Space these lines as shown in Figure 30. The border lines may be made heavier and the lettering done after the drawing has been completed.

The purpose of the wide margin at the left is to leave space for binding. The circles indicate the holes needed for the standard three-ring notebook.

In case $11''$ x $17''$ paper is used, a title block similar to that shown in Figure 30 should be designed. This may be printed insofar as border lines and standard portions of the title are concerned.

DIVIDING THE SHEET

Many of the problems in this book are grouped two or four to a drawing. Therefore it will often be necessary to divide the drawing sheet into either two or four parts. A horizontal line drawn through the center will divide the area inside the border lines into two equal parts. To divide the sheet into four equal areas, draw horizontal and vertical lines through the center point.

Finding the Center Point

The center of a rectangular area may be found by using one of the following methods. Connect the diagonally opposite corners of the panel with straight lines drawn with a triangle. These lines are called *diagonals*. The point where they cross, or *intersect*, is the center of the area.

A second method is to find half the height and half the width of the rectangle and with the T square and triangle to draw a horizontal and a vertical line through these points. The point of intersection of the two lines is the center of the rectangle.

SUMMARY

The importance of writing as a means of accurate communication is well illustrated in the lettering of the notes and dimensions necessary to complete understanding of drawings. Lettering is used rather than regular script to give greater ease in reading and more uniformity in the work of various draftsmen.

The style of letter, which is usually determined by the office where the drawing is done, will vary somewhat with the individual. The heaviness, or weight, of the lines that form the letters should depend upon the type of pen or pencil used, not upon the pressure of the stroke. The width of the letters may be varied to fit the demands of spacing in composing words and sentences. The American Standards Association recommends the vertical Gothic letter, and the accepted practice in the field is to use capitals only with these letters.

A cream or buff detail paper in an $8\frac{1}{2}''$ x $11''$ sheet is recommended for the problems in this book.

PROBLEMS

The drawing problems in this book have been devised to familiarize you with the proper drafting techniques and the proper handling of the tools used most frequently —the pencil, pen, T square, triangles, compass, and scale. Correct methods are illustrated, and simple exercises are planned so that all of these tools are used.

Do four lettering problems, choosing either the vertical or the inclined letters.

Vertical Lettering

If it is possible to obtain ruled lettering cards, they should be used in preference to regular drawing paper. However, the regular $8\frac{1}{2}''$ x $11''$ drawing sheet ruled with guide lines may be used.

Problem 1

The letters I, L, T, E, F, and H are made first. Notice that all the strokes are either vertical or horizontal. See Figure 31 for the location and spacing of the letters. Refer to pages 14-18 for the correct method of making letters and the proper proportions of each letter. An H or a 2H pencil sharpened to a conical point should be used.

Consider each letter well before attempting to make it and then draw it, using the utmost care. Do not hurry these first lettering problems as it is important to learn the proper methods and forms of good lettering. One can always do a rush job at the expense of neatness, but it is impossible to do a neat job of drawing if one has never learned how.

The letters N, A, X, Y, and Z are the next group. These letters are all composed of straight strokes, some of which are inclined. Make the strokes in the right direction and in the correct order.

Problem 2

The letters V, W, M, and K are to be lettered next. These are all made with straight strokes. Notice Figure 31 for the spacing between the letters. Try to make each letter definitely better than the preceding one; constantly strive to improve the quality of work done.

The first group of letters in which we have curved strokes is composed of P, R, B, J, and U. Pay particular attention to the curved strokes. Make them curve uniformly, with plenty of fullness.

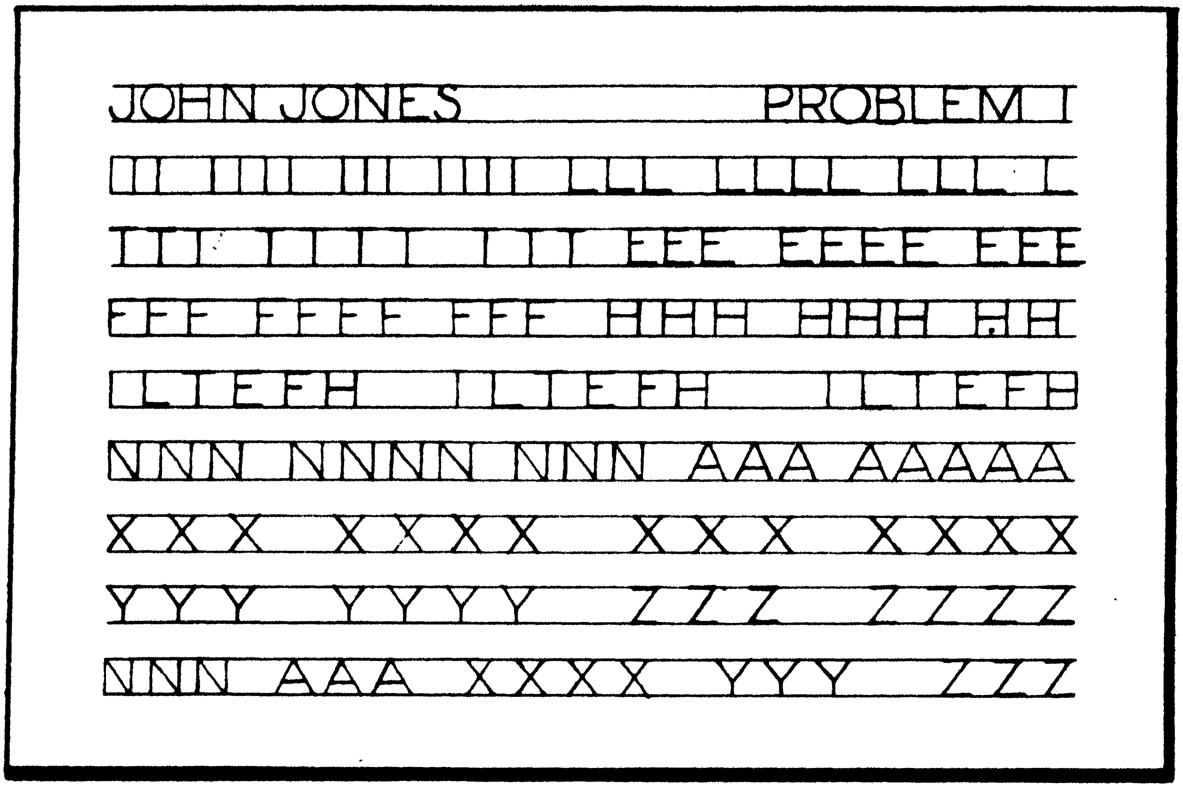
Problem 3

A final group of letters, consisting of C, G, O, Q, D, and S, is placed as shown in Figure 32.

These letters are followed by the numerals. Since neat figures are a necessary part of every good drawing, it is important that we learn how to make good ones. Refer to the problem illustration and study each numeral. Draw carefully the figures indicated in the lower part of the space.

Problem 4

Letters are fitted together into words, as shown, for example, in Figure 32. Pay particular attention to the areas between the letters of the word; these areas should be approximately equal. The space between two words should be about equal to the width of one letter six units wide.



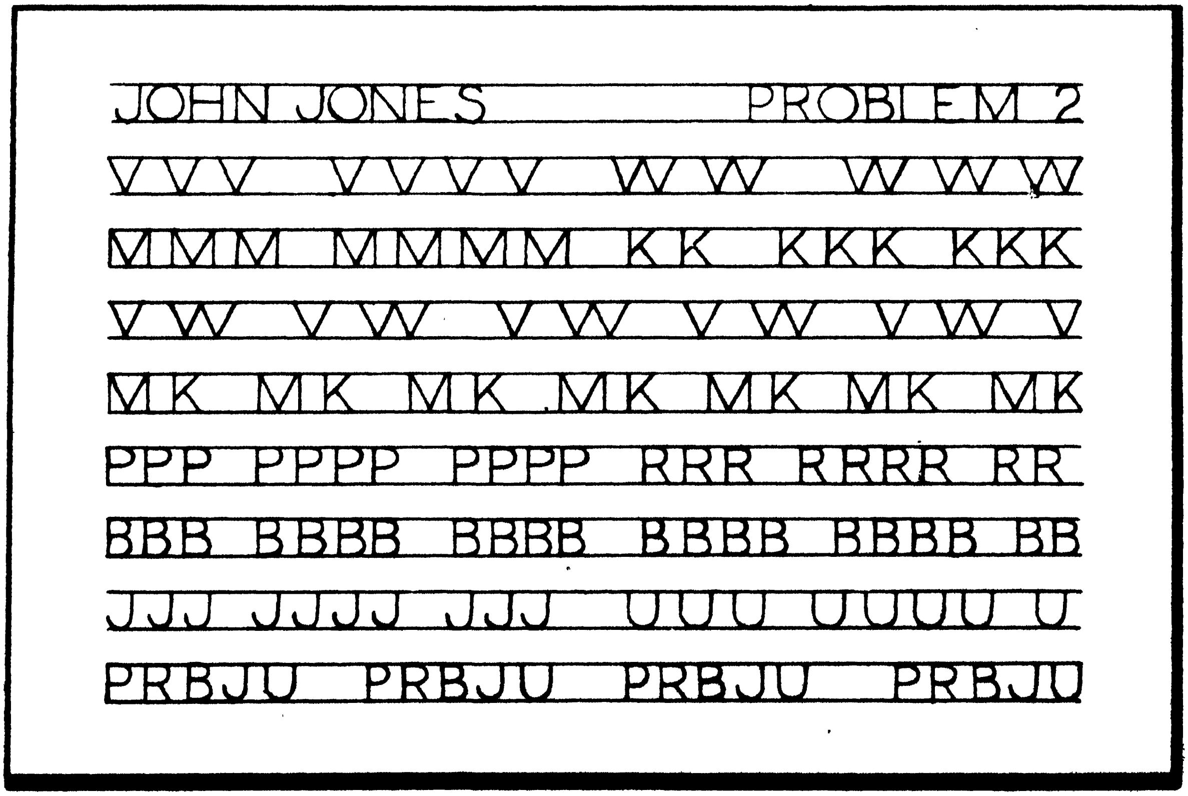


Fig. 31—VERTICAL LETTERING (PROBLEMS 1 AND 2)

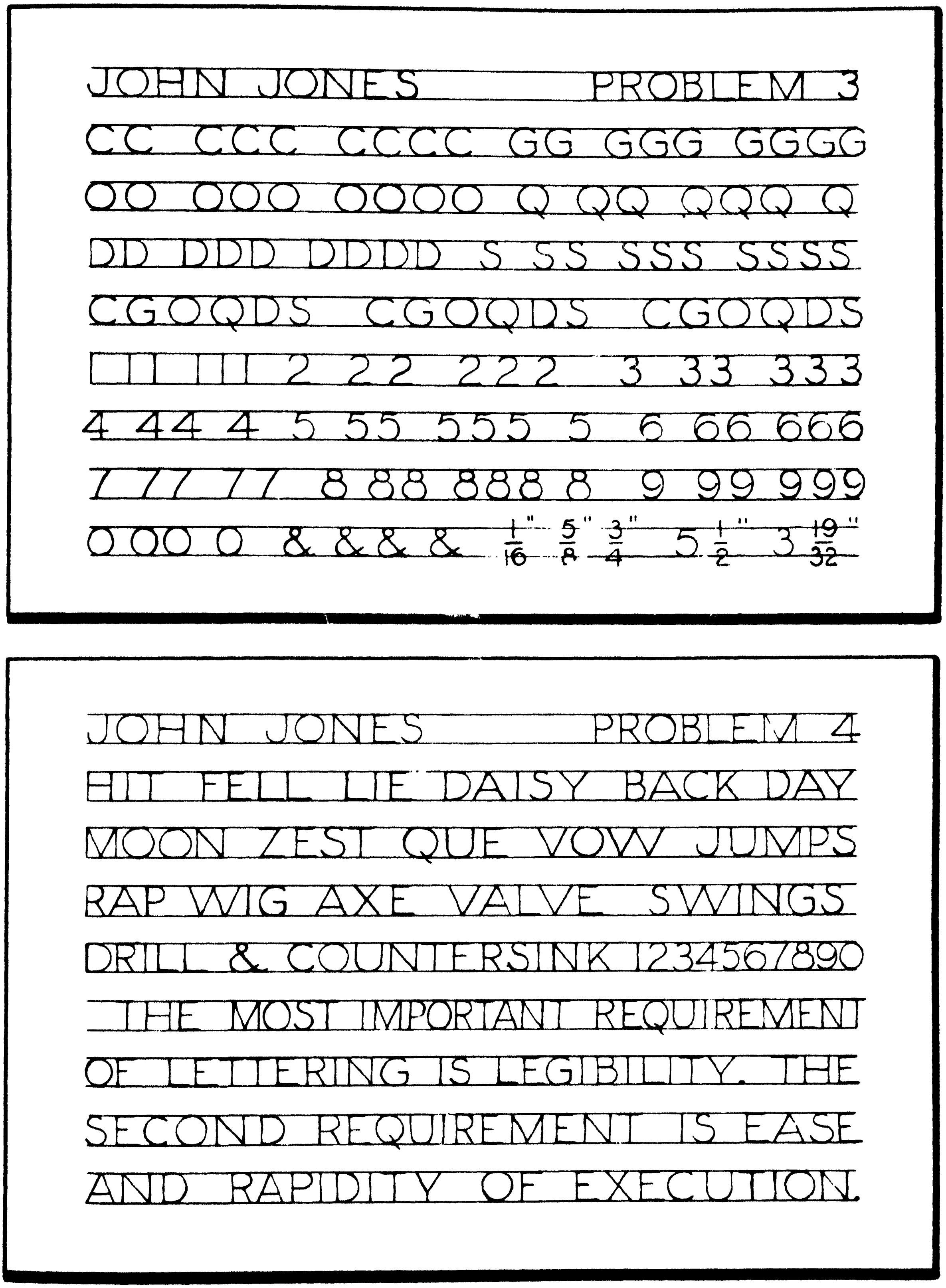


Fig. 32—VERTICAL LETTERING (PROBLEMS 3 AND 4)

Arrange words in sentences as shown. The space allowed between two sentences should be about equal to two letters six units wide.

Various words and sentences are also suggested. The space between two sentences should be approximately twice that between two words in a sentence.

INCLINED LETTERING

These problems are to be done by those who choose inclined lettering instead of the vertical. However, instructions for the problems in vertical lettering, on pages 14-18, should be read.

All inclined letters should be the same height as that for the vertical, six units; and the horizontal guide lines should be ruled at the same spacing. Slant guide lines should be lightly drawn at $67\frac{1}{2}°$ with the horizontal about every three fourths of an inch. These guide lines help in getting the correct slant for the letters. In making the letters study each letter for form and directions of strokes.

Problem 1

Make the letters I, L, T, E, F, and H, followed by the second group, N, A, X, Y, and Z, as shown in Figure 33.

Problem 2

Make the letters V, W, M, and K, followed by P, R, B, J, and U. These are illustrated in Figure 33.

Problem 3

Letters C, G, O, Q, D, and S are made next. Follow them with the numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, as shown in Figure 34.

Problem 4

Draw the letters grouped in various words as shown in Figure 34. The areas between letters should be approximately equal. The area between two words should be approximately equal to the amount taken by the letter O, or six units.

LINE TECHNIQUES

Divide the space inside the border lines into four equal areas as shown in Figure 35. Methods for doing this are given on page 22. Within each area leave a $\frac{1}{2}''$ margin on all sides. Lightly draw the margin lines.

The problem numbers of the drawings appear in the upper left-hand corner of each area of the sheet. These numbers are to be $\frac{1}{8}''$ high, and guide lines must be drawn for making them. Only on drawings where there are two or more problems are these numbers needed. There is a problem title lettered below the center of each problem. This title should be $\frac{1}{8}''$ high.

Problem 1—Horizontal Lines

Figure 35 shows a series of horizontal lines. These are drawn with the aid of the T square, pencil, and scale. Measure and locate on the left vertical margin line points at $\frac{1}{2}''$ intervals. Through each of the points draw a horizontal line across the page, giving attention to the following procedures.

Particular care should be given to holding the T square rigidly against the left edge of the drawing board while you are making the lines. Make the lines with a sharp 3H or 4H pencil and keep them uniform in width and parallel. Hold the pencil in a plane at right angles to the paper but inclined slightly in the direction in which the line is being made. This position is shown in Figure 4. Rotate the pencil slowly while drawing the lines.

Letter the problem title "Horizontal Lines" just below the lines and in the center of the panel.

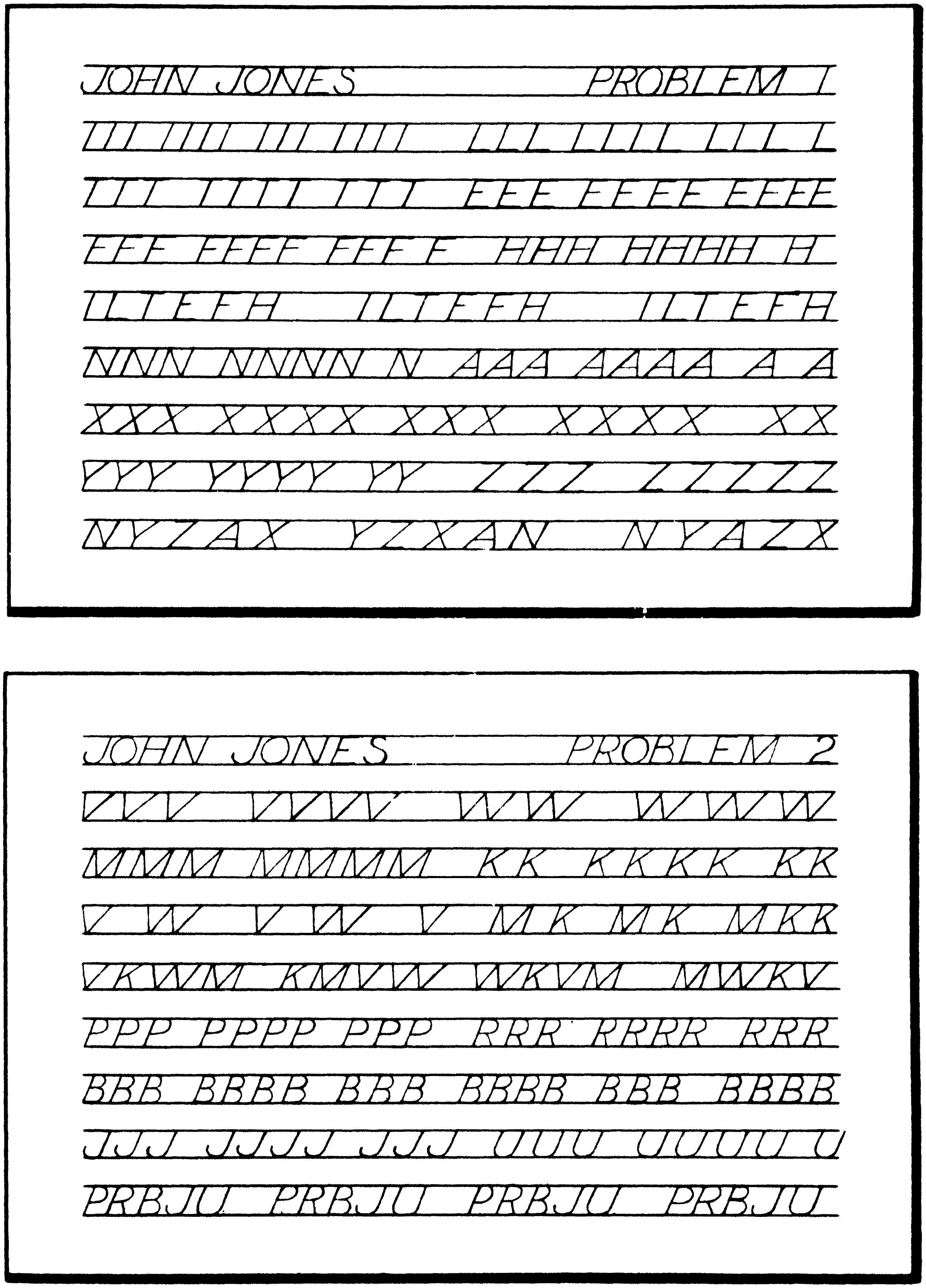


Fig. 33—INCLINED LETTERING (PROBLEMS 1 AND 2)

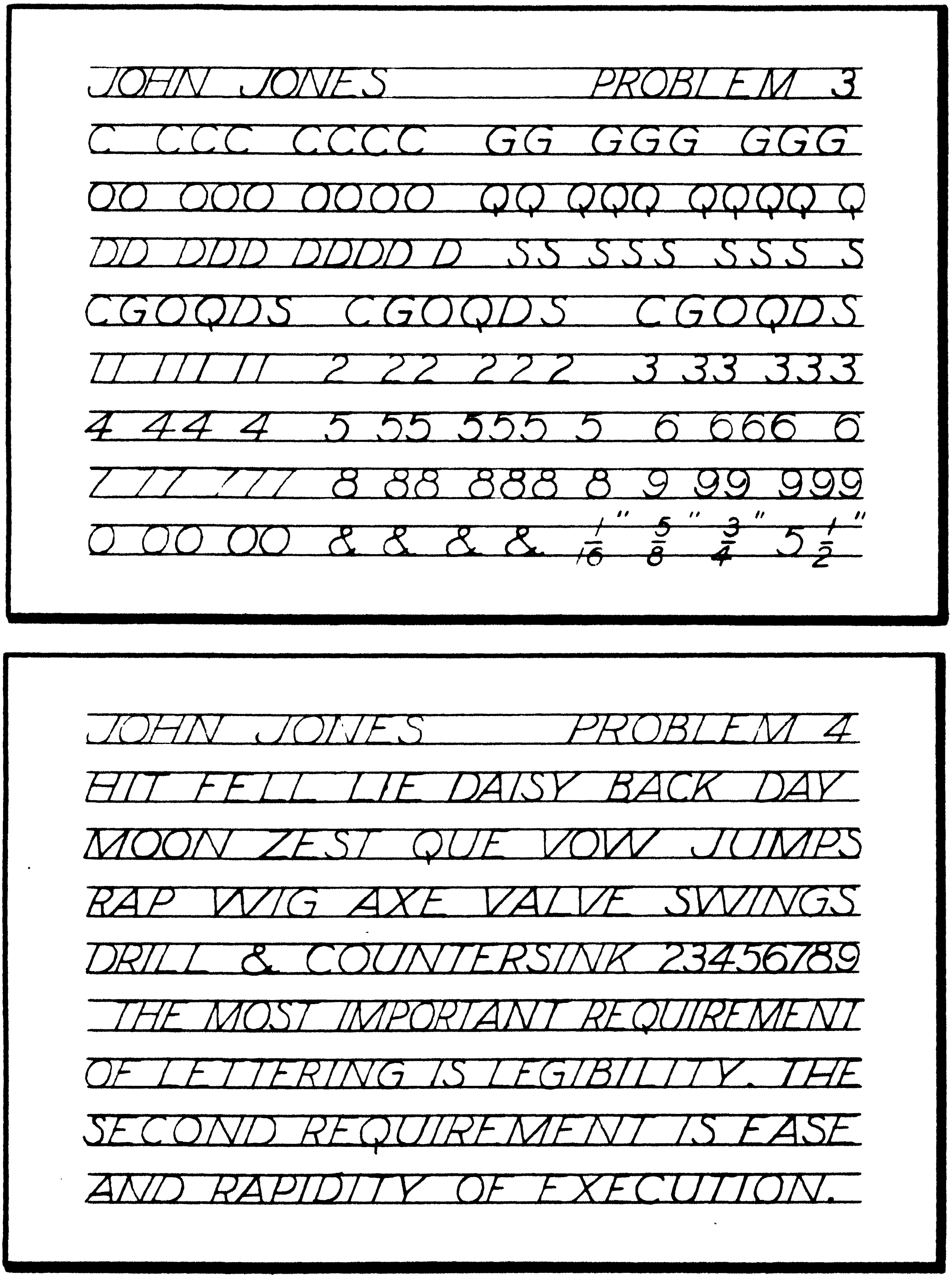


Fig. 34—INCLINED LETTERING (PROBLEMS 3 AND 4)

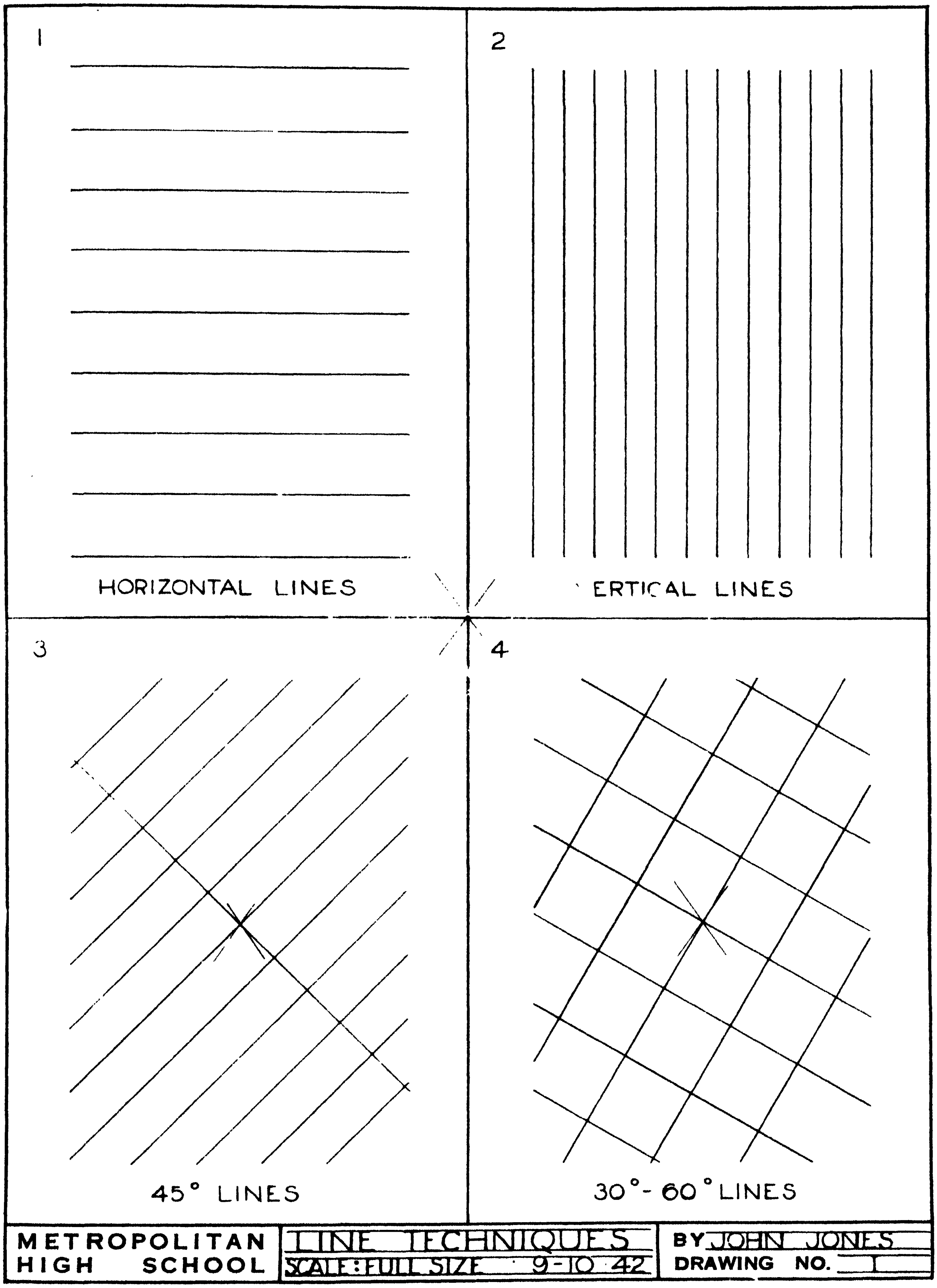


Fig. 35—LINE TECHNIQUES (PROBLEMS 1, 2, 3, AND 4)

Problem 2—Vertical Lines

Vertical lines may be drawn with either triangle. Have the 90° angle in the lower left-hand position; this means that the vertical edge of the triangle is toward the left.

Using the scale, measure $\frac{1}{4}''$ intervals along the bottom margin line. Hold the T square and triangle rigidly with the left hand and with the right draw the lines between the margins. These are spaced $\frac{1}{4}''$ apart and drawn away from the body.

Letter the problem title "Vertical Lines" as shown in Figure 35.

Problem 3—45° Lines

With the center of the panel as a point of location, rest the 45° triangle on the T square and draw a line from the left margin downward through the center and toward the right. On this line measure off $\frac{3}{8}''$ spaces on each side of the center point.

Turn the triangle over so that you can draw 45° lines upward and toward the right. Draw a line through each of the $\frac{3}{8}''$ points. Begin the 45° line on one of the margin lines and end it on another.

Letter the problem title.

Problem 4—30°-60° Lines

Draw a line 30° with the horizontal, using a downward stroke, toward the right and through the center of the panel. On this line measure $\frac{5}{8}''$ spaces on each side of the center point. With the 60° angle to the left, draw lines that are 60° with the horizontal through each of these points.

On the center 60° line measure $\frac{5}{8}''$ spaces on each side of the center point. Turn the triangle over and draw 30° lines through each of this second set of points. These lines are parallel to the first line drawn.

Letter the problem title and complete the title block.

LINE TECHNIQUES AND CIRCLES

Before starting the problems in Figure 36, sharpen the compass lead carefully. Notice the fine chisel-shaped point on the lead in Figure 16. Make all circles and parts of circles, or *arcs*, with clean, sharp lines. Hold the compass firmly so that the point does not jump off center, but take care not to make the hole too deep. Rotate the knurled top between the thumb and forefinger in a clockwise direction.

Problem 1—Overlapping Circles

Locate the center of the first panel shown in Figure 36. Use this point as a center and very lightly draw a circle with a radius of $\frac{3}{4}''$.

Using the same radius, $\frac{3}{4}''$, choose any point on the circumference and draw an arc that is about two thirds of a complete circle in length. Use the point where this arc intersects the circle as a center and draw another arc the same size. Draw a third, fourth, fifth, and sixth arc in the same manner. Erase the original circle and the excess portions of the arcs.

Problem 2—Circles within a Circle

Locate the center of the panel. Draw horizontal and vertical lines, each made up of a series of alternate long and short dashes, as shown in Figure 36. These are called *center* lines. Use their intersection as a center and construct a circle with a radius of $1\frac{1}{2}''$.

Draw the larger inside circles on the vertical center line. Their radius is $\frac{3}{4}''$, and the centers are the mid-points of the radii of the first circle. Make sure that these circles just touch the outer circle and just touch each other at the center. Locate the centers of the smaller circles so that they just touch the outer circle and the two inner circles; their radius is $\frac{1}{2}''$.

Letter the problem title.

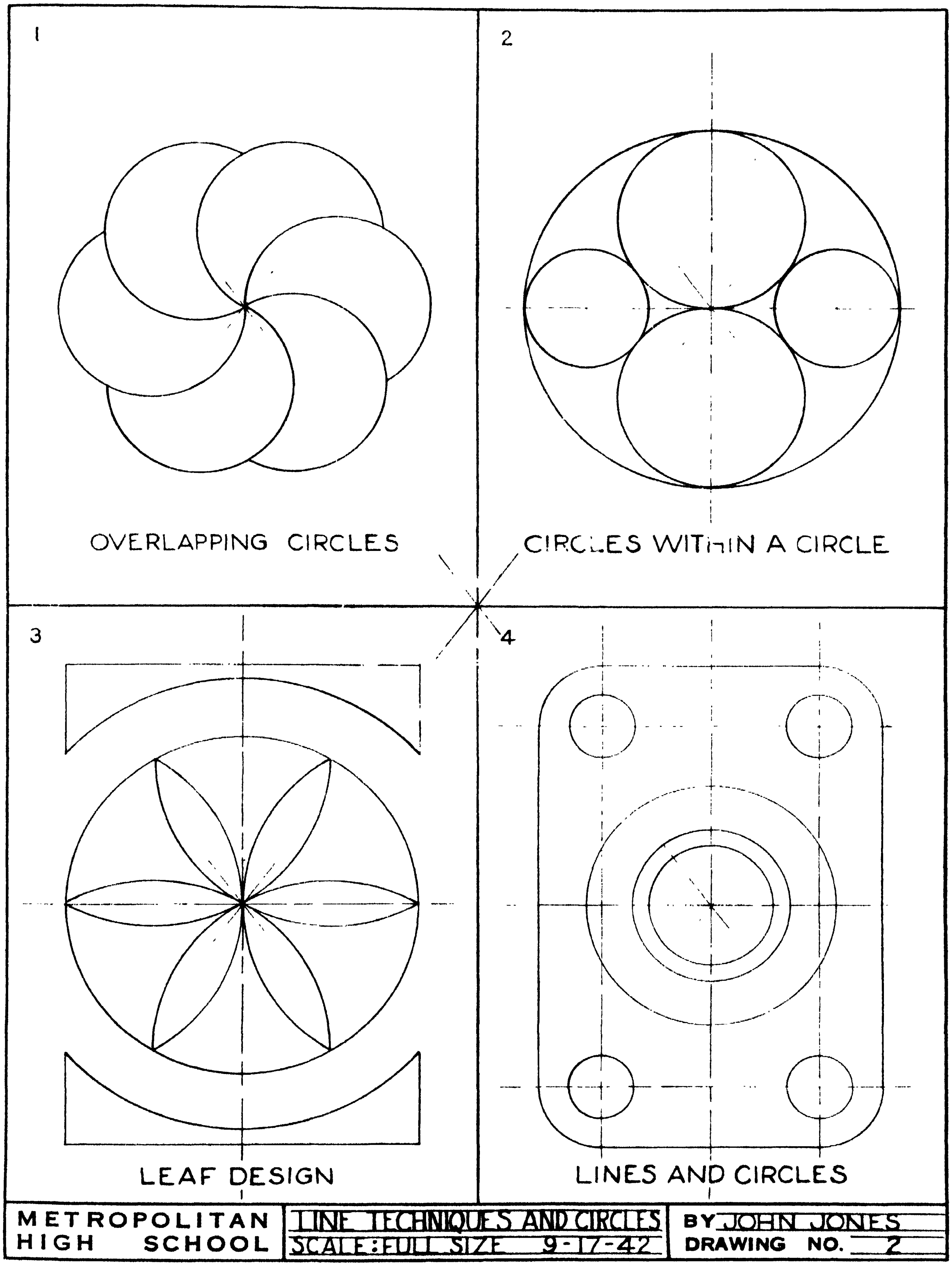


Fig. 36—LINE TECHNIQUES AND CIRCLES (PROBLEMS 1, 2, 3, AND 4)

Problem 3—Leaf Design

Locate the center of the area for the problem. Through this point draw horizontal and vertical center lines. Set your compass and draw a circle with a radius of $1\frac{3}{8}''$ about this center.

The leaf design is made by using the same radius, $1\frac{3}{8}''$, and drawing twelve arcs. The first arc is made with the compass point placed at a point where the horizontal center line crosses the circumference. This arc should pass through the center of the original circle and just meet the circumference at two points. Use these points as centers for additional arcs and continue until the leaf design is complete.

Measure 2″ each way from the horizontal center line and draw light horizontal lines. Set the compass at $1\frac{7}{8}''$. With the point of the compass at the center of the figure, make the two arcs shown in Figure 36. Using the T square and triangle, draw light vertical lines just touching the circle at the horizontal center line. These lines are *tangent* to the circle.

Complete the design by making the required lines heavier and letter the problem title, "Leaf Design."

Problem 4—Lines and Circles

Draw horizontal and vertical center lines through the center point of the panel.

Measure $1\frac{1}{2}''$ above and below the horizontal center line and draw two more horizontal center lines through these points. Measure $\frac{7}{8}''$ on each side of the vertical center line and draw two more vertical center lines through each of these two points.

Using the center of the panel as the center for a series of circles, draw one circle with a radius of $\frac{1}{2}''$, one with a radius of $\frac{5}{8}''$, and a third with a radius of 1″.

Using the intersection of the center lines as a center, draw in each of the corners a circle with a radius of $\frac{1}{4}''$. With the same centers but using a $\frac{1}{2}''$ radius, draw arcs each equal to one fourth of a circle. Draw with triangle and T square lines connecting the ends of the arcs.

Letter the problem title and complete the title block.

QUESTIONS

1. Our alphabet is developed from what?
2. What is meant by the style of a letter?
3. What is the difference between single-stroke and built-up letters?
4. When does a draftsman use a compressed type of lettering?
5. What are guide lines and when should they be used?
6. Approximately how much space should be left between words in a lettered sentence? How much between sentences?
7. The backing sheet serves what purpose?
8. The drawing paper should be placed near which edges of the drawing board?
9. Why is cream or buff drawing paper better for beginners to use?

TOPICS FOR DISCUSSION

1. Discuss the importance of the development of the alphabet.
2. Discuss the importance of lettering on a drawing.

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UNIT III

READING DRAWINGS

IMPORTANCE OF READING DRAWINGS

Drawing has been defined as the language of industry. Just as it is necessary to know the meaning of words when reading, it is necessary to understand the meaning of the "words" of a drawing. These words are the lines, symbols, and conventions by which the ideas of the engineer are conveyed to the mechanic, who must translate the original thought into the machine or structure that is to serve our industrial civilization. Much more time is spent in the reading of drawings than in the making of them.

The manufacturer makes the article shown in his catalogue more understandable to the reader by means of drawings or diagrams. The dentist sketches on a chart the particulars of the work he is to do. The lawyer draws a plan of the scene of an accident in order to give the jury an exact picture of what occurred. The architect shows sketches to the prospective home-owner to give him an idea of how a certain house will best serve his particular needs. The inventor checks the possibilities of actual construction of his proposed machine by means of sketches and detailed drawings. The motorist and the navigator both plan their journeys by means of charts and maps. The electrician uses a drawing to locate his wires, switches, and outlets when working out the most satisfactory installation. Regardless of the work a man

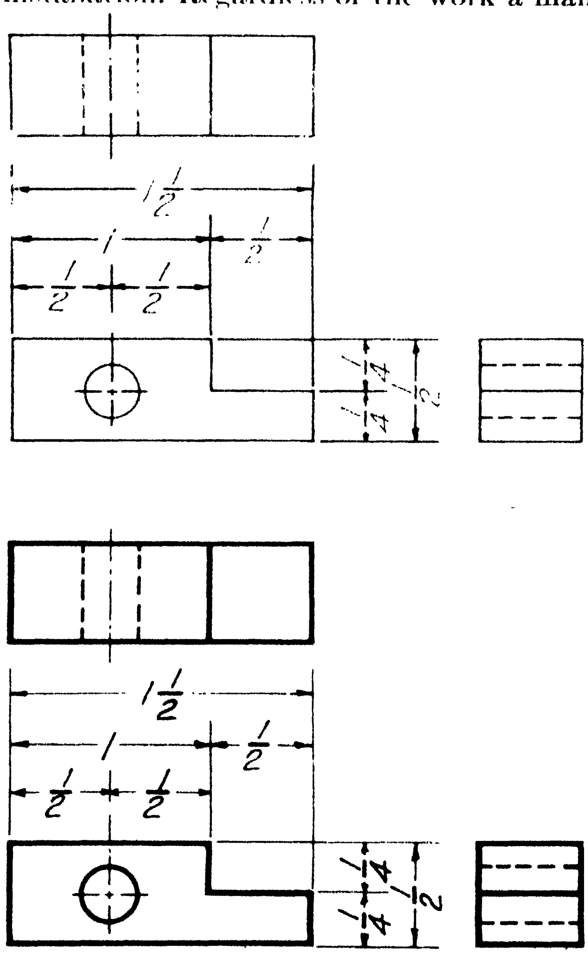


Fig. 37—COMPARISON OF THE WEIGHTS OF LINES

may do, there will be many times when the ability to "read" drawings with understanding will be required.

This ability can be gained only through familiarity with the lines, symbols, and conventions used in working drawings. Their meanings are given in following paragraphs, together with an explanation of how measurements are obtained and dimensions indicated to give exactness to a drawing.

LINES

The basis of all drawing is lines. A comparison of the drawings in Figure 37 shows how the different weights of lines give character to the drawing and make the more important parts stand out clearly. Many different lines are used even in simple drawings. All lines should be made so clearly that there will be no doubt of their meaning when the drawing is read. The weight of the line is determined by the degree of hardness of the pencil used, not by the amount of pressure exerted on the pencil.

The American Standards Association reports:

> Three weights of lines, heavy, medium, and light, are shown and are considered desirable on finished drawings in ink, both for legibility and appearance, although in rapid practice, and in particular on penciled drawings from which blueprints are to be made, this may be simplified to two weights, medium and light. For pencil drawings the lines should be in proportion to the ink lines, medium for outlines, hidden cutting plane, short break, adjacent part and alternate position lines, and light for section, center, dimension, long break, and ditto lines.

This report says briefly that two weights of lines are used in pencil drawings while three are used in ink drawings. Medium and light lines are used in pencil drawing; and heavy, medium, and light lines are found in ink drawings.

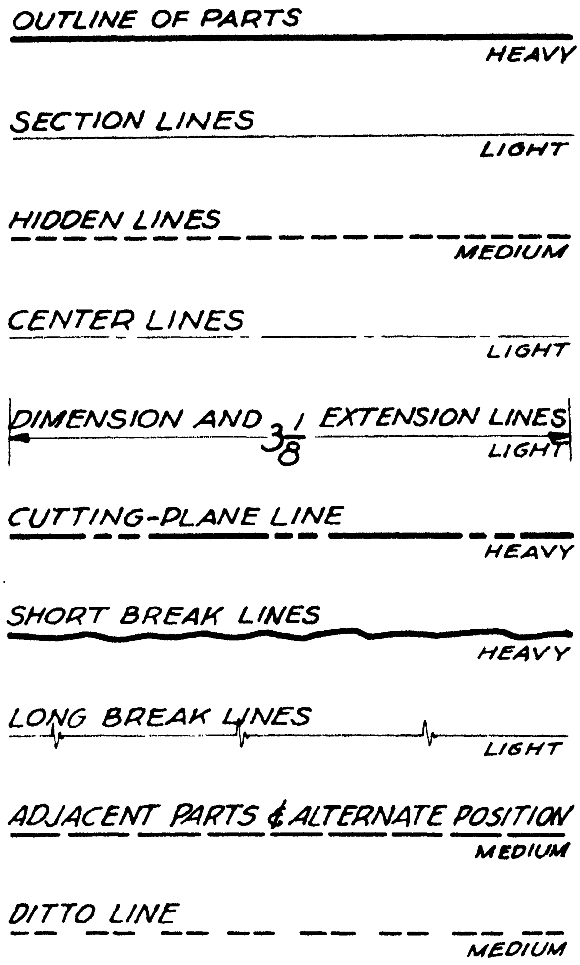


Fig. 38—THE ALPHABET OF LINES

The Alphabet of Lines

Certain conventional lines have been developed and standardized by long usage in industry. These are properly referred to as the *alphabet of lines*. They are shown in Figure 38.

The *center* line locates the centers of objects, circles, and arcs. It is shown by a series of lightweight alternate long and short dashes. The short dashes are about $\frac{1}{8}''$ long and the long dashes $\frac{3}{4}''$ in length; spaces between dashes are about $\frac{1}{16}''$.

The *visible outline* of an object is a heavy solid line in ink; medium weight in pencil. This line is sometimes called the

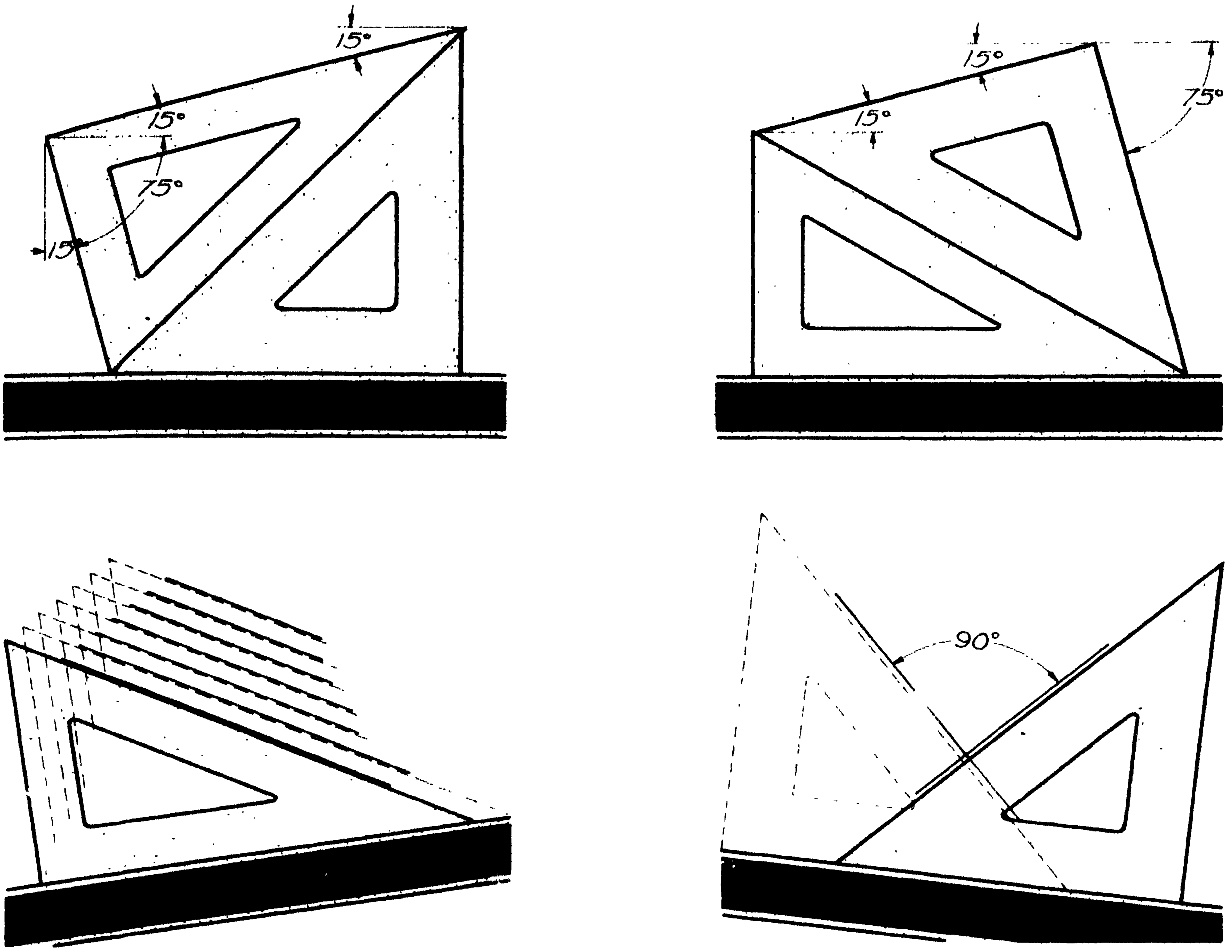


Fig. 39—DRAWING LINES AT VARIOUS ANGLES

object line. *Hidden* outlines are represented by a series of medium-weight dashes about $\frac{1}{8}''$ long and spaced $\frac{1}{16}''$ apart. These lines show surfaces or edges hidden from view by other parts of the object.

Dimension lines are light in weight and broken in the middle to provide space for dimensions. Arrowheads are placed at the ends of these lines to show the points where the dimensions end. *Extension* lines are used to show clearly the dimension limits.

Adjacent parts and *alternate* positions are shown by series of medium dashes slightly longer than those for the hidden outline.

A *cutting-plane* line is used to indicate an imaginary cut through an object along the line. It is made with long heavy dashes alternating with two small dashes. *Break* lines are used to designate the fact that a part has been cut off or broken out. Long break lines are light in weight with definite breaks. A short break is indicated with a heavy freehand line.

The *section* lines are light ones, used in making sectional views as explained on page 49. *Ditto*, or repeat, lines are used for the purpose suggested by their name.

Drawing lines at angles is shown in Figure 39. Here you see how angles of 15° and 75° may be drawn, how inclined parallel lines are drawn, and how a perpendicular may be drawn to an inclined line.

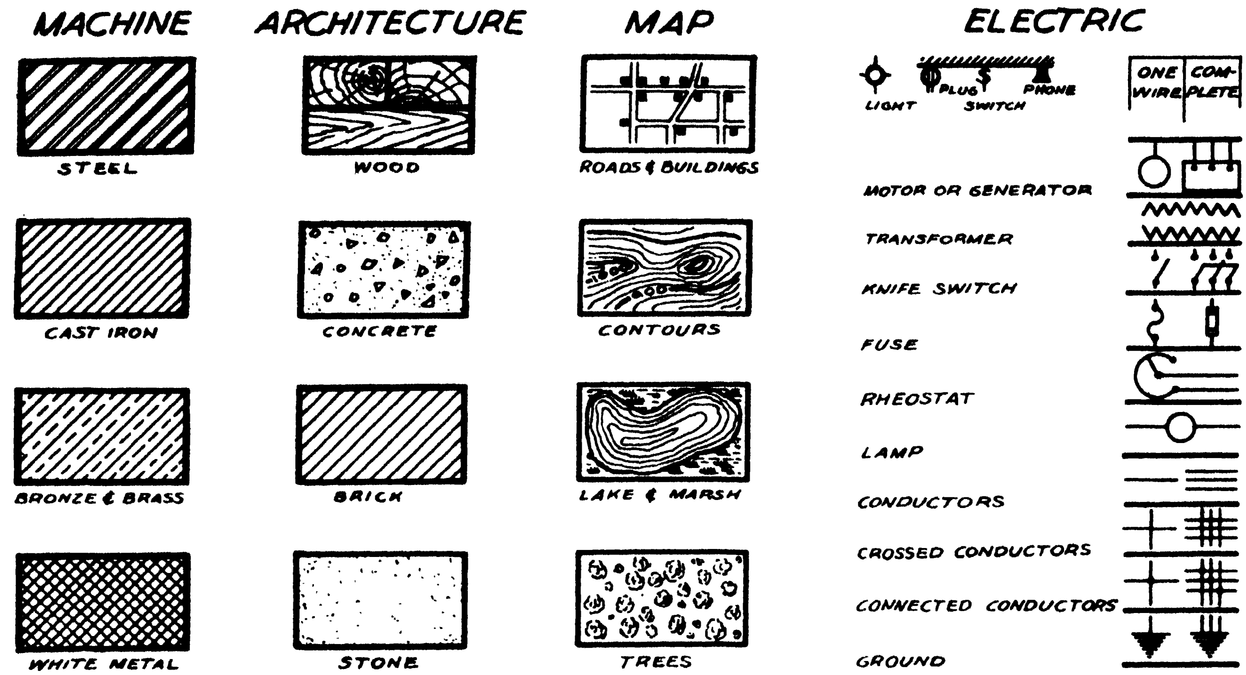


Fig. 40—SYMBOLS AND CONVENTIONS

SYMBOLS AND CONVENTIONS

Graphical representation by means of drawing is common throughout the world. Various symbols have developed in drawing practices, and from them the American Standards Association has adopted certain ones as standard. These are extremely helpful to the draftsman as well as the reader.

Materials, natural features, and items of equipment may all be represented by the use of symbols. Some of these symbols are shown in Figure 40. The metal symbols are widely used in machine and structural drawing. The building-material symbols are used in architectural and structural drafting. Some of the symbols will be recognized quite easily; the symbol representing wood might be recognized by a person not acquainted with drawing. Electrical symbols and map conventions are also shown.

Breaks in materials are represented as shown in Figure 41. Representing breaks is especially helpful when it is necessary to shorten a detail drawing. The true length is dimensioned, but the shortened section is shown.

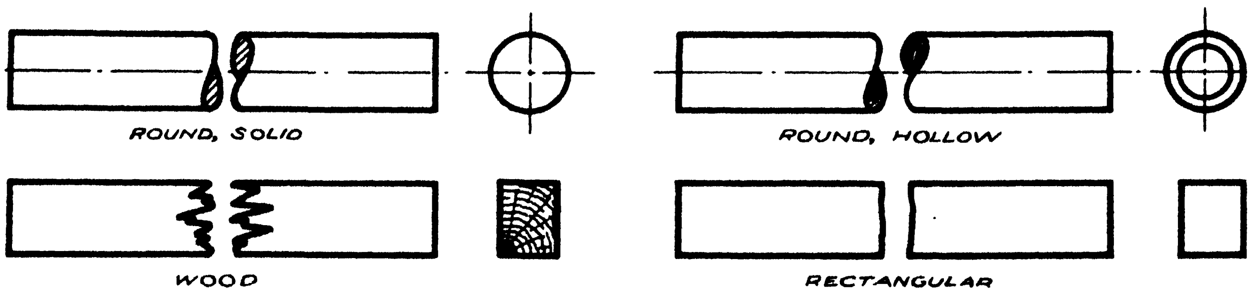
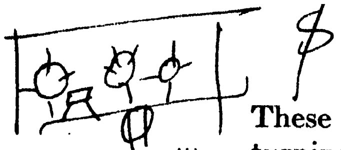


Fig. 41—INDICATING BREAKS IN MATERIALS



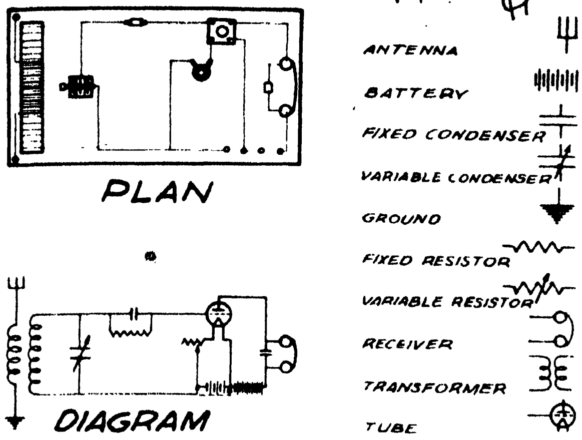


Fig. 42—RADIO SYMBOLS

Many radio companies place a wiring diagram in the radio instruction sheet so that a person may hook up the set properly. Symbols are used entirely on these diagrams, as shown in Figure 42. It can be readily seen that the use of symbols makes drawing easier to do and to read.

MEASURING THE OBJECT

Measurements enable us to find the size of an object and indicate the dimensions on the drawing. The three dimensions necessary for accurate measurement are length, width, and thickness—or, in other words, height, breadth, and depth.

The architects' scale is used only in making measurements on drawings. It should never be used as a ruler for measuring objects because it is made of boxwood, which is easily marred.

There are many different tools used to secure measurements of objects. The *folding rule* is used by carpenters, woodworkers, and cabinet makers. The *steel machinist's rule* is used in machine tool work and casting processes. This rule has graduations as small as $\frac{1}{64}$ inch.

Calipers are used to get accurate measurements of circular or cylindrical objects. These tools are used in wood and machine turning, where it is necessary to determine exact diameters. A *micrometer caliper* is used when accurate measurements in thousandths of an inch are required. This is used extensively in the automobile and aviation industries, where extreme accuracy is necessary. A *thickness gauge* also gives accurate measurements in thousandths of an inch. Each blade is numbered, and the thickness or space between two points or objects may be measured.

There is no regular prescribed manner in which measurements of an object should be made. It is advisable to take measurements directly whenever possible. It is well to get the over-all length and width first. Or one may make all the measurements on one side, beginning with the longest measurement and taking the shortest one last. The other sides are then measured in the same manner. The measurements between the centers of two holes, alike in size, may be made from edge to corresponding edge.

DIMENSIONING A DRAWING

The value of a working drawing lies in the clearness with which it tells the complete story of the shape and size of an object. The lines properly located and drawn give the shape; the size is told by proper dimensioning.

The dimensions placed on the drawing are those necessary for the workman to understand the drawing with the least effort. These dimensions should be shown in a certain manner. The dimension line should be a fine full line that contrasts well

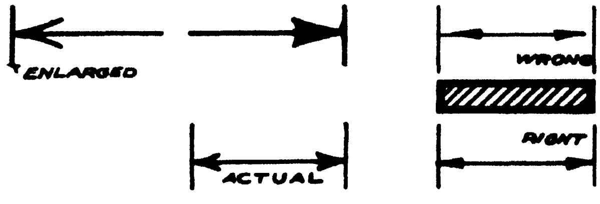


Fig. 43—ARROWHEADS

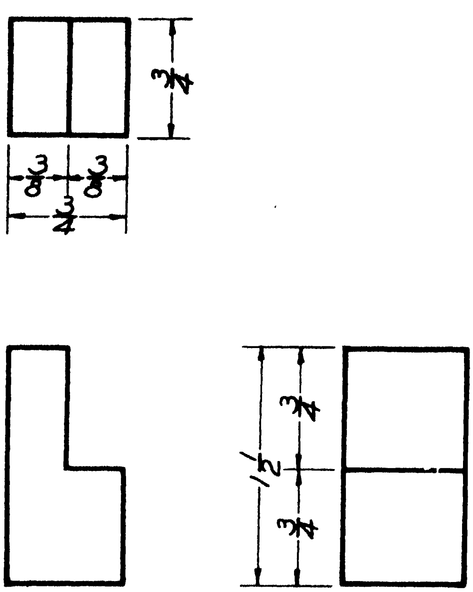


Fig. 44—DIMENSIONING A THREE-VIEW DRAWING

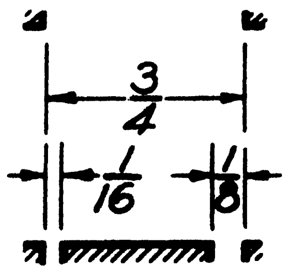


Fig. 45—SMALL DIMENSIONS

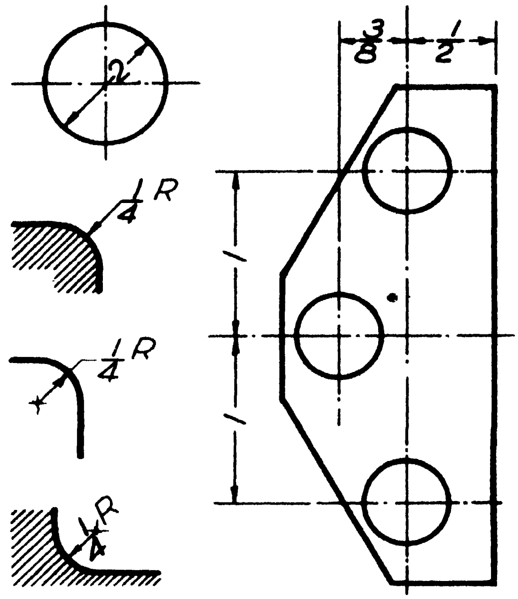


Fig. 46—DIMENSIONING CIRCLES AND ARCS

with the heavier outline of the object. The dimension lines contact the extension lines with long, slim arrowheads, shown in Figure 43, that indicate exactly the outside points of the dimension. Extension lines begin about $\frac{1}{16}''$ from the outline of the object and should extend about $\frac{1}{8}''$ beyond the dimension line. In machine drawing, space is left in the dimension line for figures. In architectural and structural drawing, it is common practice to place the figures above an unbroken line.

In general, a good height for dimension figures is $\frac{1}{8}''$. The total height of a fraction is $\frac{1}{4}''$. Fractions are always made with the division line horizontal. Dimensioning is done horizontally or vertically, with the figures usually read from the bottom or the right-hand side of the drawing.

Dimensions generally should be placed between views. Do not put dimensions on the face of a view if this can be avoided. The smaller or detail dimensions should be nearest the view; the large or over-all dimensions should be farthest away.

When several dimension lines are used they are parallel, $\frac{1}{4}''$ or $\frac{3}{8}''$ apart, and one $\frac{1}{4}''$ or $\frac{3}{8}''$ from the view. If necessary, the figures may be staggered to give added ease in reading. The proper method of dimensioning is shown in Figure 44. Very small dimensions are indicated as shown in Figure 45.

When dimensioning, use the symbol (″) for inches and (′) for feet. Feet and inches are indicated: 7′-4″. When there are no inches the fact should be shown: 7′-0″. The American Standards Association recommends that in machine drawing everything 72″ and under be dimensioned in inches. When all dimensions are in inches the inch mark may be omitted provided that a note on the drawing states that the dimensions are in inches. In this text all inch marks have been omitted. A dimension should not be repeated on a drawing unless for some special reason.

Circles are dimensioned by giving the diameter; arcs are dimensioned by giving the radius. The abbreviations *D* and *R* are used for *diameter* and *radius*. Although the *R* is always used, the *D* may be omitted when it is obvious that the dimension is a diameter. Holes should be dimensioned from center to center, not from edge to edge. (See Figure 46.)

Angles are dimensioned as shown in Figure 47.

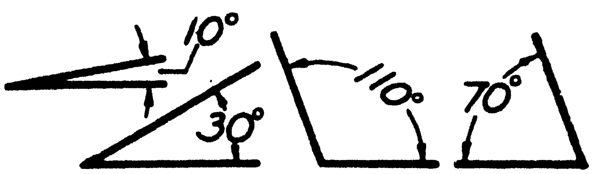


Fig. 47—DIMENSIONING ANGLES

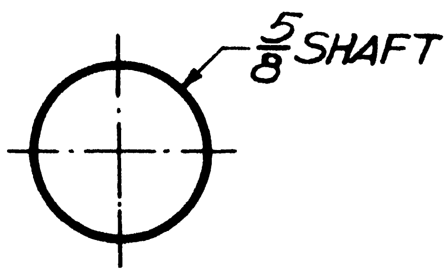


Fig. 48—NOTE AND LEADER

Necessary specific notes pertaining to particular parts of a drawing should be placed in a horizontal manner, as shown in Figure 48. The line leading from the note to the part to which it applies is called a *leader*. When the note applies to a circle the arrow must stop on the circumference and point toward the center.

The finished drawing should always be checked to make certain that all dimensions have been accurately placed and that none has been omitted.

DECIMAL DIMENSIONS

There are some large industrial plants that have adopted the decimal system for dimensions. All dimensions which are fractions, such as $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$, would be expressed as follows: .500, .250, and .125. A mixed number, such as $2\frac{3}{8}$, would be expressed as 2.375. The number of places to the right of the decimal point determines the accuracy with which the dimension should be laid out. If a distance is dimensioned as .5, it should be laid out to within $\frac{1}{16}$ inch; if the dimension is .500, it should be measured to within $\frac{1}{1000}$ inch. The use of decimal dimensions is shown in Figure 49.

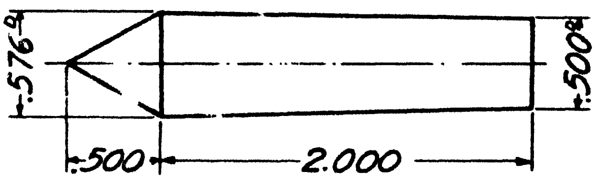


Fig. 49—DECIMAL DIMENSIONING

SUMMARY

The "words" through which meaning is given to a drawing are the lines, symbols, and conventions which have been developed and standardized by long usage in industry. The alphabet of lines includes the different kinds of lines used, with their various weights. These give character to the drawing and make it stand out clearly. Various symbols and conventions have also been standardized to indicate such materials and situations as are frequently shown in drawings.

Drawings would have little meaning unless they told accurately both the shape and size of an object. Lines properly located and drawn give the shape; the size is told by proper dimensioning shown in a conventional manner.

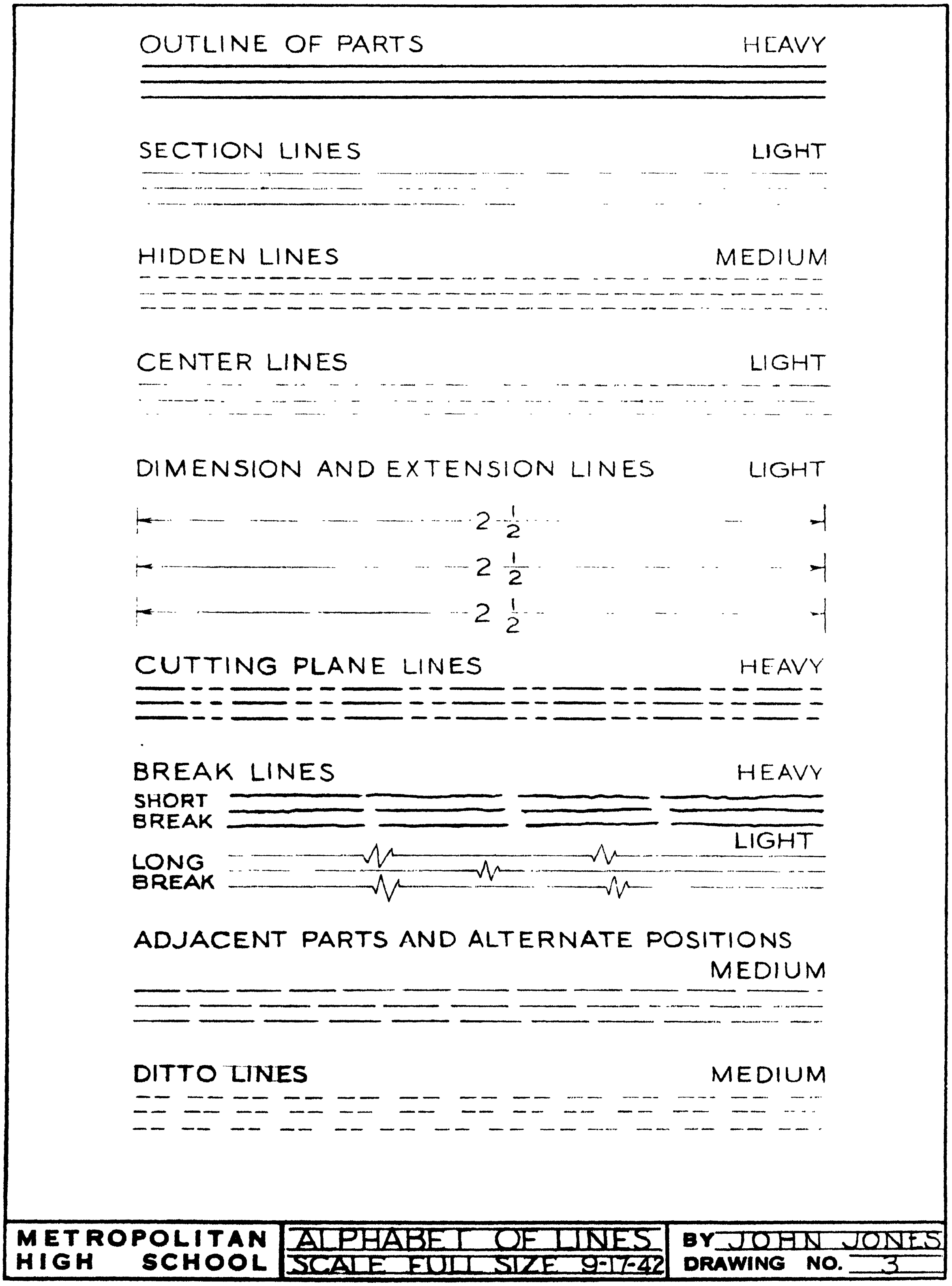


Fig. 50—THE ALPHABET OF LINES (PROBLEM)

PROBLEMS

Alphabet of lines

For Figure 50 leave a 1″ margin inside the customary border lines. Make all lettering $\frac{1}{8}''$ high. Space the lines as shown. Study the width of each kind of line and try to make your line the same width. Each successive line should be more nearly perfect than the previous one. For the hidden lines, the pencil should start and stop cleanly with each dash. Keep the dashes uniform and about $\frac{1}{8}''$ in length. The spaces between the dashes are uniform, about $\frac{1}{16}''$ in length. Draw each of the lines slowly and carefully.

Complete the title block to finish the drawing.

Indicating Dimensions

Problem 1—Detail and Over-all Dimensions

The dimensions given in the circles are to help you locate the problem in the space. *These dimensions and dimension lines are not to be placed on the drawing.*

Draw the pattern for Problem 1 in Figure 51. Make the lines that indicate the edges of the object heavy lines as shown. Place the detail dimensions $\frac{1}{4}''$ or $\frac{3}{8}''$ away from the object and then place the over-all dimensions $\frac{1}{4}''$ or $\frac{3}{8}''$ from the detail dimensions.

Notice that the extension lines do not quite touch the lines of the object; about $\frac{1}{16}''$ space is left, and the lines extend about $\frac{1}{8}''$ beyond the last dimension line. Be extremely careful when you are making the arrows; they should be sharp and not too large.

Make guide lines for the dimensions and problem title. The lettering of the figures and title of this problem may be left until later and the entire drawing lettered at one time. This will help to keep the drawing clean.

Problem 2—Small Dimensions

Make the visible, extension, and dimension lines the proper weights, as shown in Figure 51. Place the dimensions of the object as shown in the illustration.

Problem 3—Dimensions of Angles

Block out the area so that the space is well filled. Draw all dimension lines with a compass; use the same radius in each case.

Make guide lines for the figures. Notice that in the obtuse angle the guide lines point to the *vertex* of the angle.

Problem 4—Dimensions of Circles

Draw the center lines for each of the arcs or circles; space these well in the allotted area. Use the bow compass and draw each

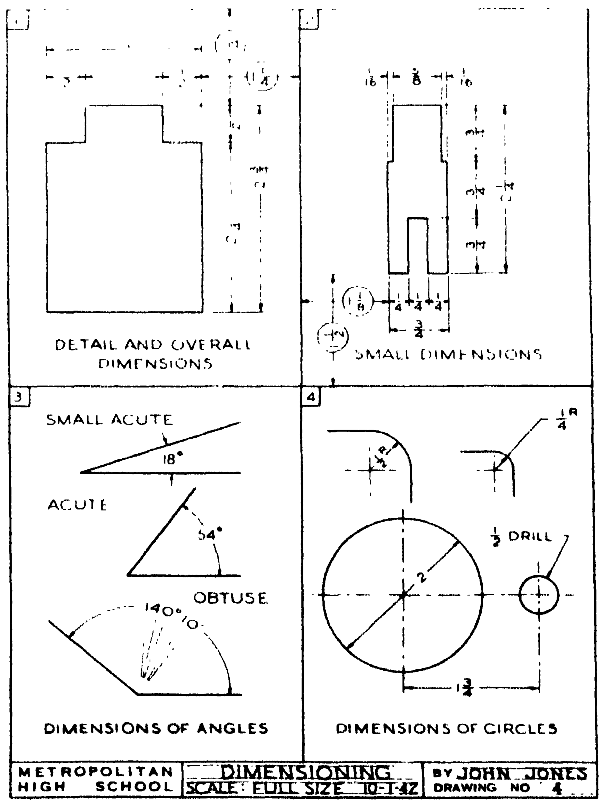


Fig. 51—INDICATING DIMENSIONS (PROBLEMS 1, 2, 3, AND 4)

arc or circle with the specified radius. Place the dimension lines and leaders. Use guide lines for all figures and letters.

Games

Problem 1—A Kite Frame

In Figure 52 the first drawing is a problem in the use of the scale. Find the scale marked 1, which is so divided that 1 inch on the scale or drawing represents 12 inches on the kite. Study the scale carefully and find the distances 12″, 24″, and 36″.

Lightly block in an area 3′-0″ x 3′-0″ in the position shown in the illustration. Draw the lines of the kite lightly. Then place all extension and dimension lines for the kite. Using an H or HB pencil, go over the lines forming the framework and make these heavier, as they are the most important part of the drawing.

The dimensions and lettering may be placed on the problem now or when the entire drawing is ready to be lettered. If the work is completed at once, the problem should be covered with a piece of paper so that the drawing will not become dirty while you are working on the second problem.

Problem 2—Checkerboard

This problem is to be drawn to a scale of 3″ = 12″.

Locate the upper right corner shown in Figure 52. From this point measure 12″ distances to the left and down, using a 3″ = 1′-0″ scale. Draw lines through the points indicated to make a 12″ square. Lay out a $\frac{1}{2}$″ chamfer and then a $\frac{1}{2}$″ border on each side, as shown in the illustration. The remainder of the square is to

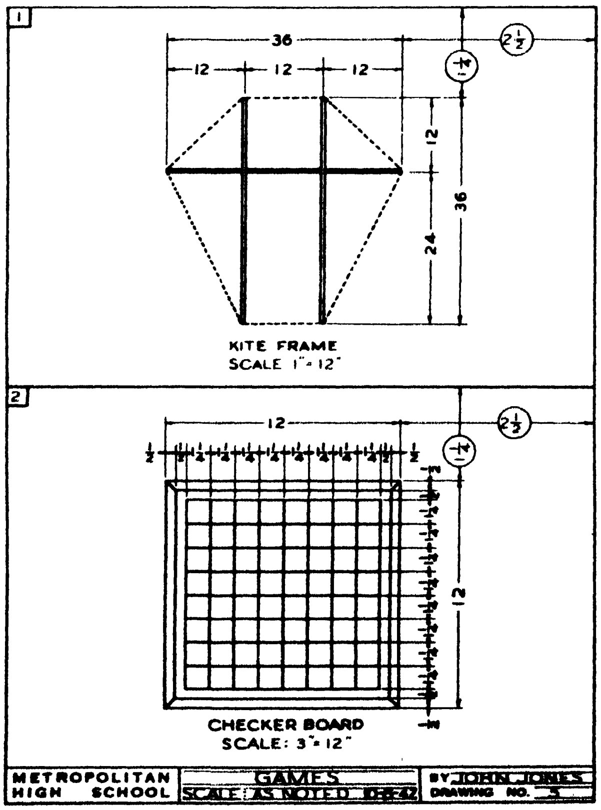


Fig. 52—GAMES (PROBLEMS 1 AND 2)

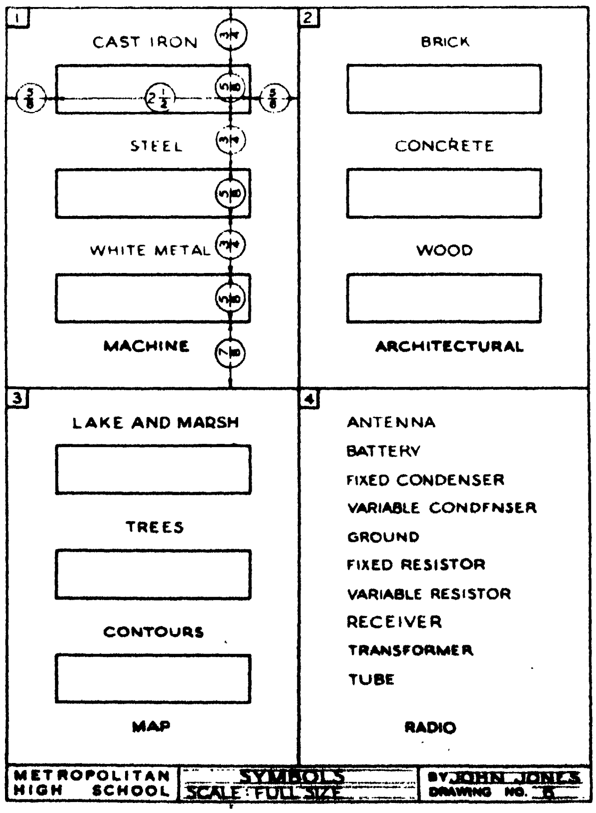


Fig. 53—SYMBOLS (PROBLEM)

be laid off in small $1\frac{1}{4}''$ squares. Draw the dimension and extension lines. Then the lines of the squares and the visible edges are made heavier.

Dimension and letter the titles and notes.

SYMBOLS

Divide the drawing sheet into four parts. Figure 53 shows the general layout for the four problems. Block in all the small areas for Problems 1, 2, and 3 at the same time, with a light line made with a sharp 3H or 4H pencil, and section each area with the correct symbol, or *lining*, as shown in Figures 40 and 42. Go over the outlines of all areas with an H pencil to get heavier outlines. Include the necessary radio symbols.

Rule the guide lines and letter the symbol identifications; then letter the problem and drawing titles.

GASKETS

The problems in Figure 54 are intended to give experience in laying out and dimensioning simple objects.

The illustration in the upper right corner of each problem space is for your information as to size and shape. *You should not copy these illustrations on your drawings.*

Problem 1—Engine Gasket

Since this is a symmetrical object, both horizontal and vertical center lines are drawn and distances are measured from these lines. The arcs on the inside corners have the same radius as that of the outside corners. After the drawing is completely blocked in, go over all visible edges and make them heavier. Then properly dimension the drawing and letter the title.

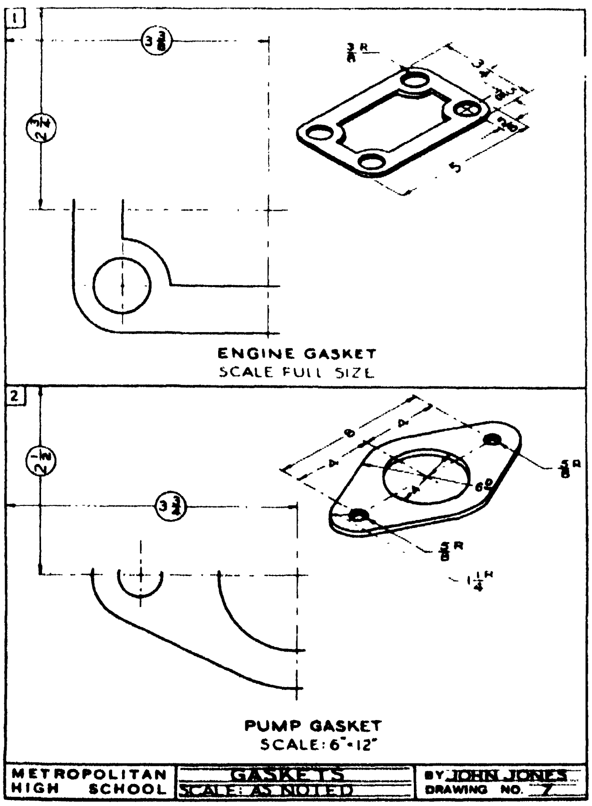


Fig. 54—GASKETS (PROBLEMS 1 AND 2)

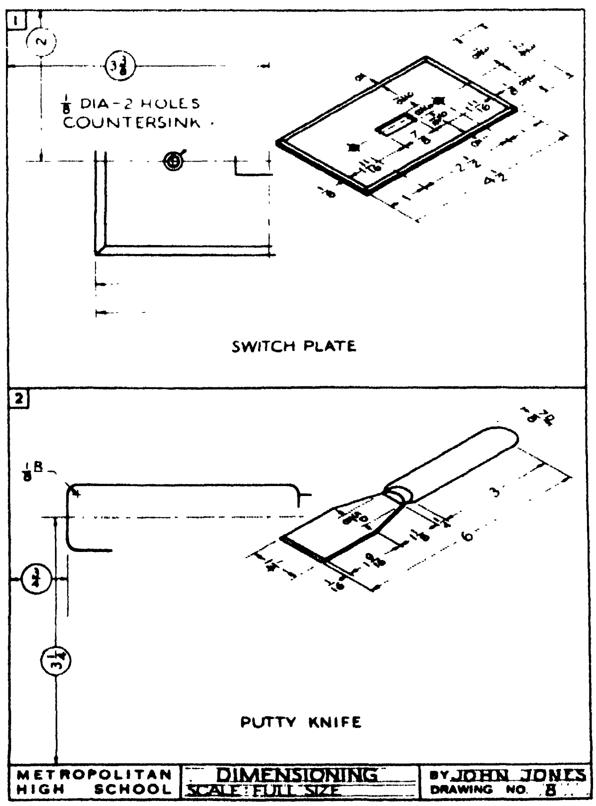


Fig. 55—DIMENSIONING (PROBLEMS 1 AND 2)

Problem 2—Pump Gasket

Lay out the principal horizontal and vertical center lines. Then locate and draw the vertical center lines for each of the small holes. Using these centers and the $\frac{5}{8}''$ radius, draw the small circles. With the same centers and the $1\frac{1}{4}''$ radius, draw the arcs indicating the ends of the gasket. Draw the 4″ diameter circle and the partial circle with the 6″ diameter. Complete the drawing, dimension it, and letter the problem title.

DIMENSIONING

Problem 1—Switch Plate

For the first problem in Figure 55 lay out the center lines, block in the view, and complete all line work. Draw guide lines before making any of the dimensions. Letter the note and title.

Problem 2—Putty Knife

Draw the horizontal center line and block in the view. The length is 6″. Dimension the problem and letter the title.

QUESTIONS

1. Why should the weight of the line be obtained by the degree of hardness of the pencil rather than the pressure on the pencil?
2. Why are different weights and kinds of lines used?
3. Why are symbols useful in making and reading drawings?
4. What kinds of objects are measured with calipers?
5. Why are dimensions placed on drawings?
6. Where and how should dimensions be placed?
7. When, if ever, should dimensions be staggered?
8. What dimensions are expressed in inches?
9. What is a leader?

TOPICS FOR DISCUSSION

1. The value of a code of standard drafting practices and symbols.
2. The alphabet of lines.
3. How to dimension a drawing.

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UNIT IV

WORKING DRAWINGS

THE NEED FOR MORE THAN ONE VIEW

In making the *working drawings*, from which the man in the shop will construct the article suggested by the engineer or designer, it is necessary for the draftsman to show the object so that all points are in their true relationships and all dimensions are given as they actually exist. When this has been done the design is correctly shown to any person who understands the reading of drawings.

In order to show an object in this manner, it must be presented from more than one point or position. This means that the object must be drawn in several views since each view can show only two dimensions; the third dimension will have to be obtained from one of the other views. Consequently we need two or more views — sometimes as many as six or seven — to describe an object completely in a working drawing. That is why this kind of drawing is sometimes called *multiview*, which means *many views*. Generally we draw the object as seen from three positions, top, front, and end.

ORTHOGRAPHIC DRAWING

Figure 56A shows a picture drawing of a rectangular block that we wish to describe in a working drawing. The three views that will be needed are shown pictorially in part B. It can be seen that any one of these views shows in itself only two of the three dimensions. Therefore we need to refer to at least two views for the full information needed as to the length, height, and depth of the block. The same three views appear in part C grouped in their proper relationships and drawn to show the true form and dimensions of the block. Part C is an *orthographic* drawing.

DIVIDED SURFACES

The same block, except that a portion of an end is cut away, is shown in Figure 57. This means that the object now has *two* top surfaces and *two* end surfaces. (Notice that the arrows in Figure 57 show these four surfaces.) Consequently the top and end views must be drawn to show these surfaces.

Orthographic drawings are made so that each view shows completely all the surfaces parallel to the view. These surfaces are shown in their true shapes and dimensions.

HIDDEN SURFACES

Figure 58 shows the same block but with the bottom of the other end cut away to form two additional surfaces, which are hidden in both the top and end views. Such surfaces are indicated by the use of the hidden lines at the proper locations in

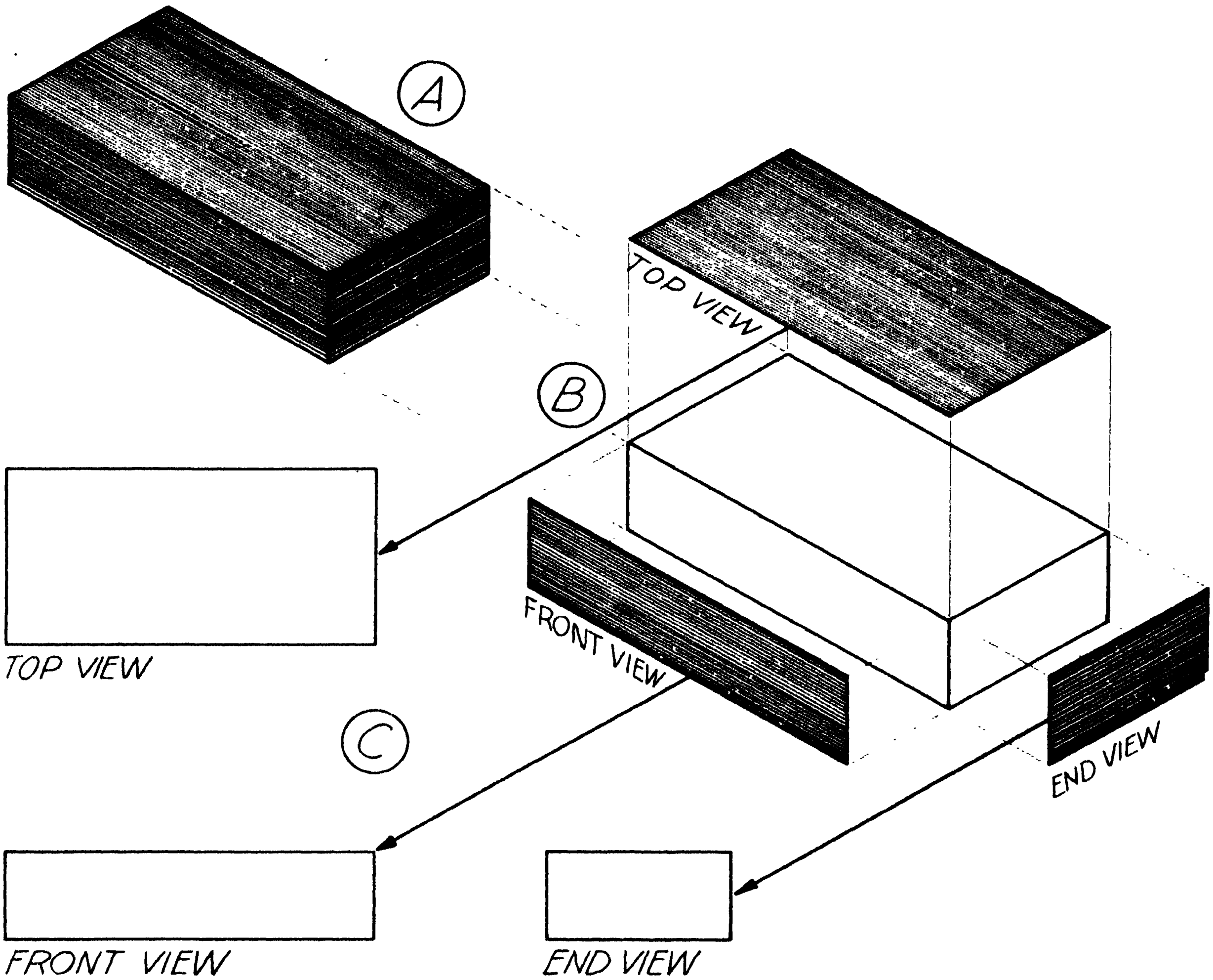

Fig. 56—ORTHOGRAPHIC DRAWING OF BLOCK

the top and end views. This is the way hidden portions are shown.

INCLINED SURFACES

As drawings become more complex, it is best to draw the views in a definite order and extend from one view to another as much information as possible as to length, width, or breadth. It is good procedure to draw that view first which will give the most information pertaining to the object.

Figure 59 shows a rectangular block with a bevel on one end. This bevel, or inclined surface, would be shown as a rectangle in all views except the one that shows the slope. In this case the front view would be most desirable because it will show the length and height of the object and the slope of the bevel in its true relationship and dimensions.

After the front view is completed, the top view is obtained from the lines in the front view that give the lengths; then the breadth of the top view is measured and shown. The top edge of the bevel is also extended as shown to divide the top view so as to indicate the horizontal surface and

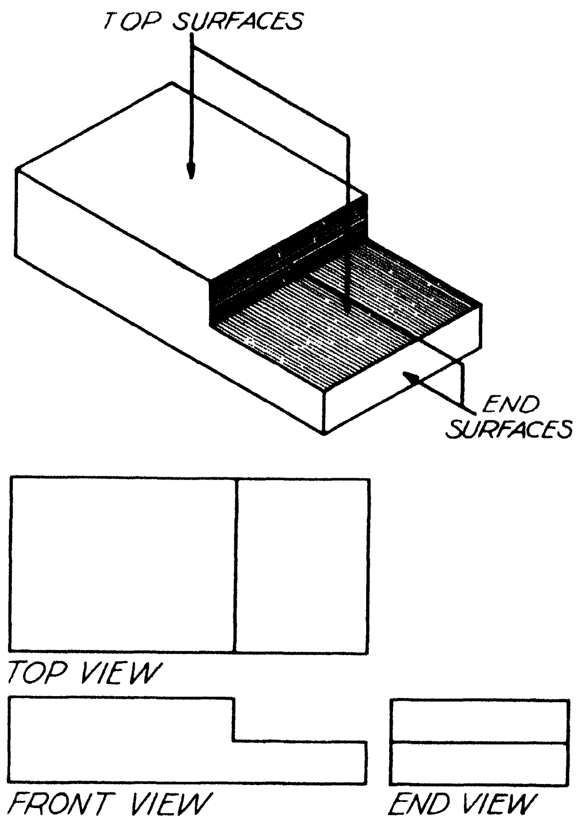

Fig. 57—ORTHOGRAPHIC DRAWING OF CUT BLOCK

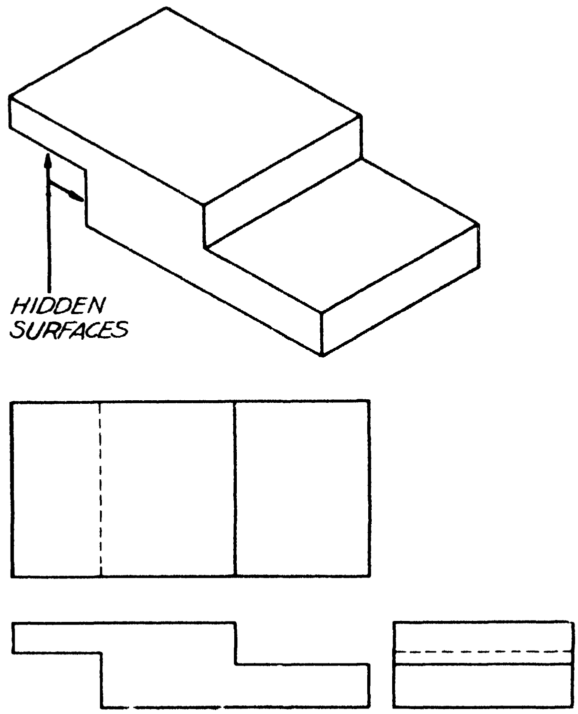

Fig. 58—HIDDEN SURFACES

the bevel surface. The extension of these lines is commonly called *projection.*

PROJECTION

Figure 56B shows shaded views of the top, front, and end of the block. Correctly speaking, we say that these are *projections* of the sides on planes parallel to them. The lines from the projections to the object in part B are called projectors. In a picture frame the lines meet on a diagonal line which runs across the corner. All the widths of the top member and side members are correspondingly equal. The diagonal line is at an angle of 45°. See the sketch of the picture frame in Figure 59.

If a 45° line is introduced in the drawing of the beveled block to the right of the top view, the width may be projected from the top view with horizontal lines to the 45° line and then vertical projection lines dropped to obtain the width of the end view. The height of the end view may be obtained by extending all heights from the front view with horizontal projection lines. This time the lower corner of the bevel is projected to divide the end view as shown to indicate the vertical and bevel surfaces.

The method of projection shown in Figure 59 is the general practical procedure in laying out the views of a working drawing.

AUXILIARY VIEWS

Notice that the bevel of the block represented in Figure 59 is not completely shown in any one of the three views. Therefore we must introduce an additional, or *auxiliary*, view. Figure 60 shows the front view of the same block with the additional view that is required to describe the beveled surface. This view is obtained by drawing the projection lines from each end of the

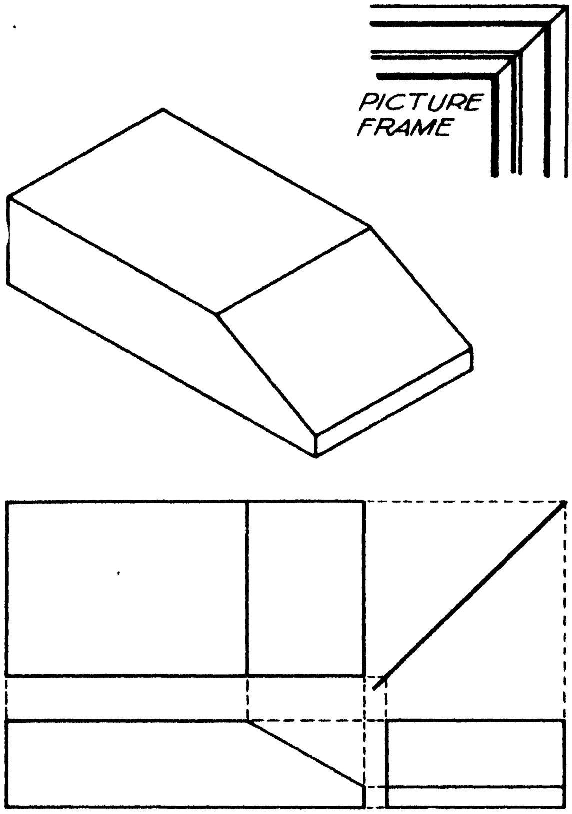

Fig. 59—BEVELED BLOCK

bevel at right angles, or 90°, to the beveled surface and making the other dimension equal to the depth of the block.

This is an auxiliary view of the inclined surface, but it is only a part of a complete auxiliary view of the entire block. Complete auxiliary views are seldom drawn.

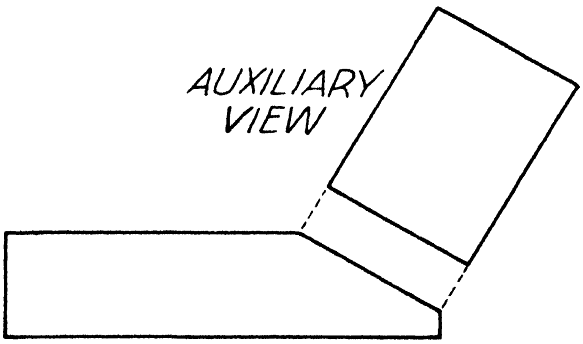

Fig. 60—AUXILIARY VIEW

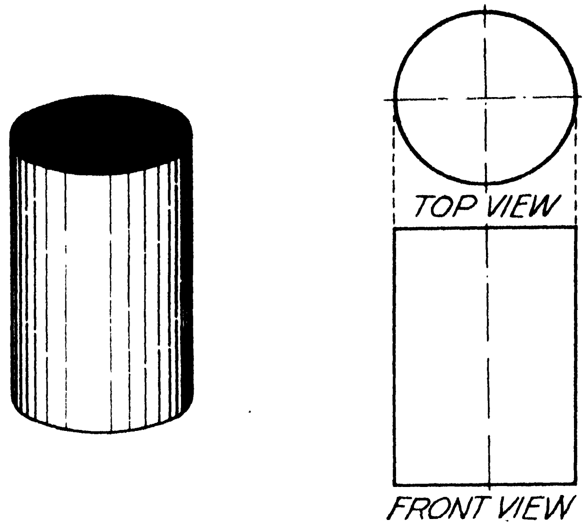

Fig. 61—CYLINDER

CURVED SURFACES

Some objects require only two views to describe them completely. This is the case of the cylinder shown in Figure 61. Cylindrical surfaces appear in their front view as flat rectangles. Study the two views of the cylinder and notice that all necessary information is given in these views.

Two views are all that are needed to describe a cone. One view completely describes a sphere.

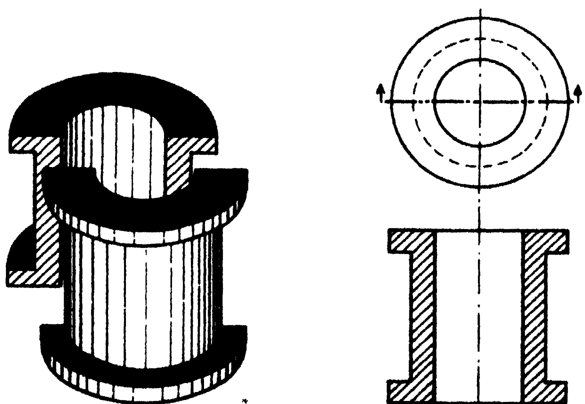

Fig. 62—FULL-SECTION DRAWING OF SPOOL

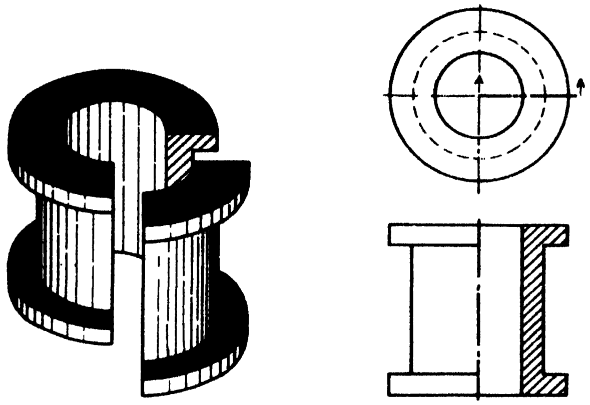

Fig. 63—HALF-SECTION DRAWING OF SPOOL

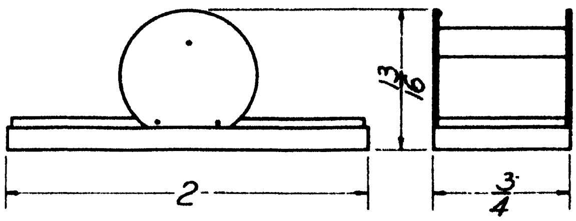

Fig. 64—ASSEMBLY DRAWING OF DESK TRAY

SECTIONAL VIEWS

In many cases the regular views of a working drawing become confused with hidden surfaces and conditions. To overcome this situation, we use the method of theoretically cutting out a section of the object and showing the resulting surfaces and conditions in full view. Figure 62 shows a spool in *full section;* that is, the front half is theoretically removed, as shown in the pictorial view.

Figure 63 shows a *half section* of the spool. The top view has been drawn as a regular view except that the *cutting-plane* lines are shown to indicate the theoretical portion that has been removed, as shown in the pictorial view. When a cutting-plane line coincides with a center line, either line may be shown. Arrows on the cutting-plane line show the direction from which the section is viewed.

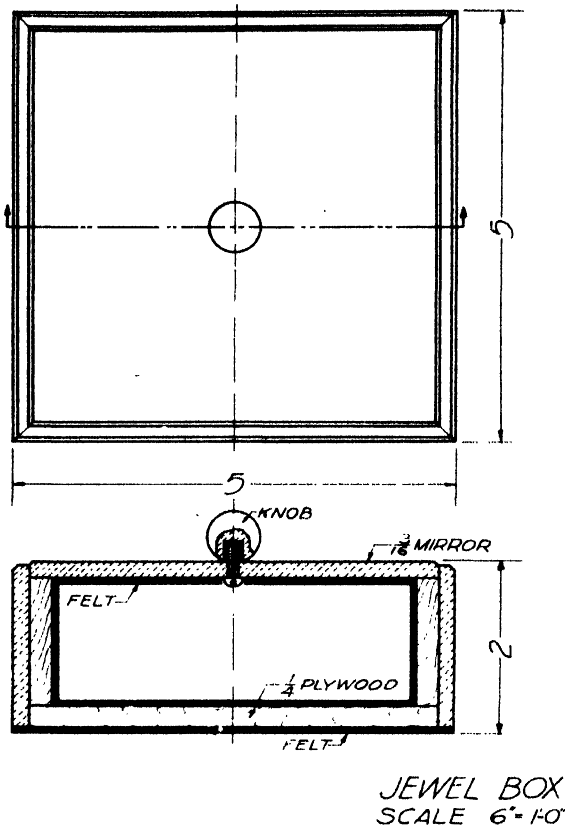

Fig. 65—ASSEMBLY SECTION DRAWING OF JEWEL BOX

The front view is drawn with the theoretical section removed and *only* that area of material that has been cut is cross-sectioned. Hidden lines are omitted in sectional views.

ASSEMBLY DRAWINGS

Figure 64 shows an assembly drawing of a desk tray. An *assembly drawing* is the drawing of a complete object with all the parts properly fitted together. Assembly views are drawn without the indication of hidden surfaces. Dimensioning of assembly views is limited to the general over-all dimensions.

An assembly *section* of a jewel box is shown in Figure 65. You will notice that the machine screw of the knob is not sectioned because, if it were, a false represen-

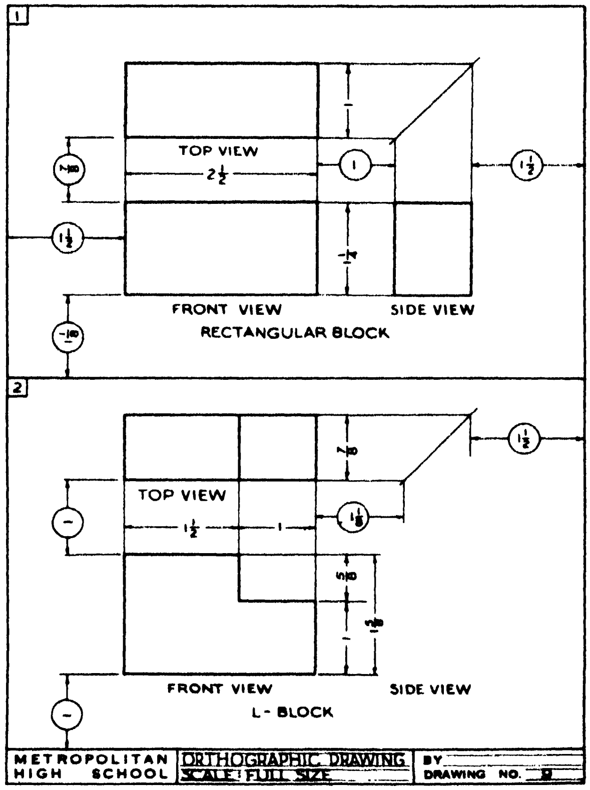

Fig. 66—ORTHOGRAPHIC DRAWING (PROBLEMS 1 AND 2)

tation of that particular part might be given. Different materials are sectioned with different kinds of section lines, or *crosshatching*, as shown. Crosshatchings should be drawn in reversed directions to distinguish between two adjoining parts of the same material.

SUMMARY

It is essential that working drawings show an object so that all parts are in their true relationships and all dimensions are shown as they actually exist. For this two or more views are necessary. It is this fact which gives to these drawings the name *multiview*. When the views are grouped in their proper relationships and drawn to show true form and dimensions an orthographic drawing is the result. These drawings are always made so that each view shows completely all the surfaces parallel to that view. Special problems are presented in the case of divided, hidden, or inclined surfaces. Projection, or extension, is the means used in transferring measurements from one view to another in working drawings.

Auxiliary views, sectional views, and assembly drawings are special working drawings used in certain circumstances.

ORTHOGRAPHIC DRAWINGS

Problem 1—Rectangular Block

Divide the drawing sheet into two parts. In all following drawings you will be expected to figure your own spacing. It may be done according to this plan, suggested for Figure 66. For the horizontal spacing add the length of the front view and the width of the side view, $2\frac{1}{2}'' + 1'' = 3\frac{1}{2}''$, and subtract this total from the width of the panel, $7\frac{1}{2}'' - 3\frac{1}{2}'' = 4''$. Since there is a space on each side of the two views and one between them, the 4″ must be divided into three parts. There should be a wider space on each side than in the middle; so the spacing shown in Figure 66 is advised. The vertical spacing is obtained in a similar manner.

After locating its corners, the front view should be drawn first. Using the triangle, project the ends up to form the ends of the top view. The width of the top view will have to be measured with a scale. Complete the top view.

Locate the 45° line as shown in the drawing. Project the width of the top view to this 45° line with the T square. Using the triangle, project vertical lines down through the points of intersection of the 45° line and the horizontal lines from the top view. These vertical lines form the sides of the side view. Project the height across from the front view. This gives the height of the side view.

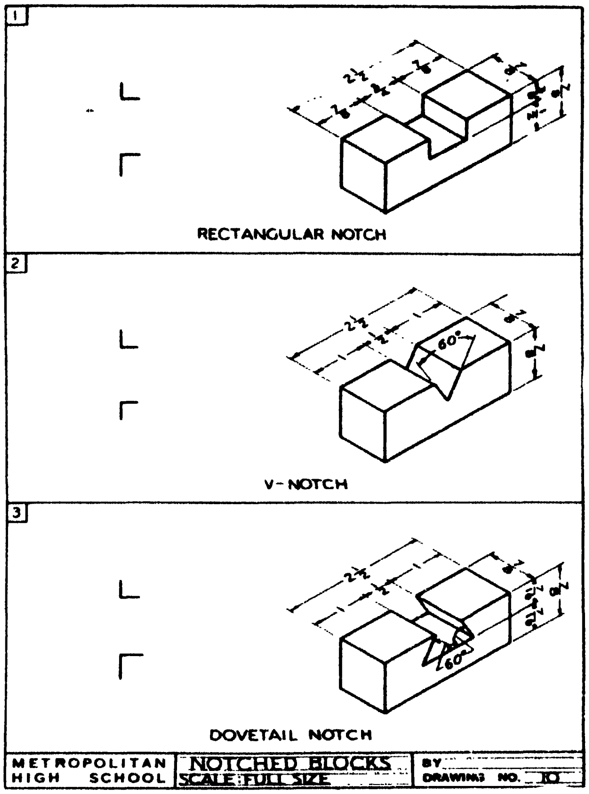

Fig. 67—NOTCHED BLOCKS (PROBLEMS 1, 2, AND 3)

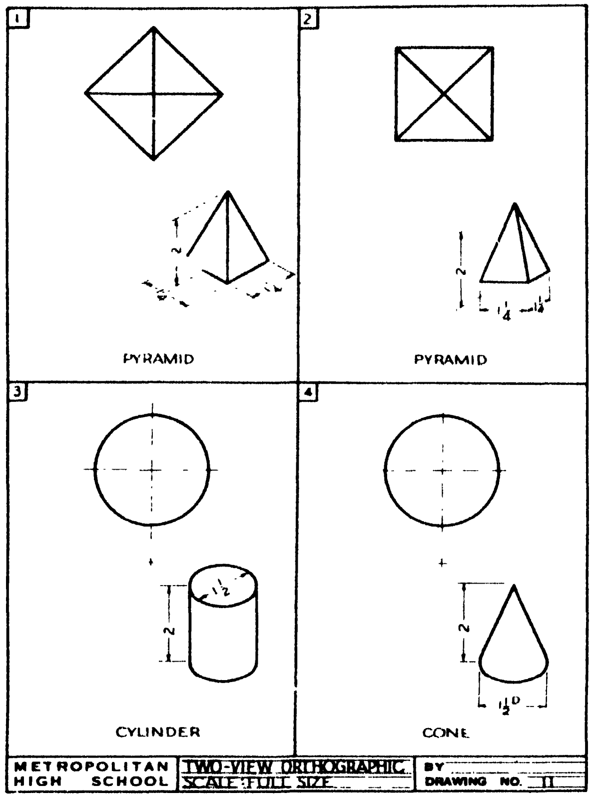

Fig. 68—TWO-VIEW ORTHOGRAPHIC DRAWING (PROBLEMS 1, 2, 3, AND 4)

Complete the three views for this problem and then dimension the drawing completely, omitting all dimensions shown in circles.

Problem 2—L-Block

Locate the front and top views. Using the 45° line, project the width from the top view and the heights from the front view to get the right-side view. Go over the visible edges to make them heavier. Dimension the block. Letter the view, problem, and drawing titles.

NOTCHED BLOCKS

The purpose of Figure 67 is to show the manner in which hidden lines are used. Divide the drawing space into three horizontal panels.

Problem 1—Rectangular Notch

Using as a guide the drawing shown, block out the views carefully so that they are well spaced in the panel. Locate the 45° line so that the right-side view will not be too close to the front view or the border lines. Watch for any hidden edges. Indicate all dimensions.

Problem 2—V-Notch

Lay out the views, paying special attention to their location. In locating the dimensions of the notch, make sure that the figures are placed properly. Check for hidden edges in the right-side view.

Problem 3—Dovetail Notch

In this problem there may be hidden edges or lines occurring in more than one view. Study this object carefully before beginning to draw.

Visible edges in all three problems should be made heavier with a soft pencil. Then letter all notes, dimensions, and titles, using guide lines.

TWO-VIEW ORTHOGRAPHIC DRAWINGS

Many objects have two of the three views alike when these are drawn. Therefore it is necessary to draw only two views if they give all the necessary information concerning the object.

In Figure 68 pay particular attention to the methods employed in dimensioning the problems.

Problem 1—Pyramid

You may sketch freehand on a sheet of scratch paper the three views of this object. Then you will discover that the right-side view is the same as the front view.

Draw the top view first and then complete the front view. The sides of the base as shown in the top view are to be drawn at 45° angles to the base. Dimension the drawing.

Problem 2—Pyramid from Another View

Note in this problem that the same pyramid as in Problem 1 is to be drawn, but here it is turned to a different position.

Problem 3—Cylinder

The side view of this object is the same as the front view, so that it is not necessary to draw the side view.

Problem 4—Cone

Notice that the top view of the cone and the cylinder are the same. This means that one view is not sufficient to give a complete picture of the object. But three views are not needed.

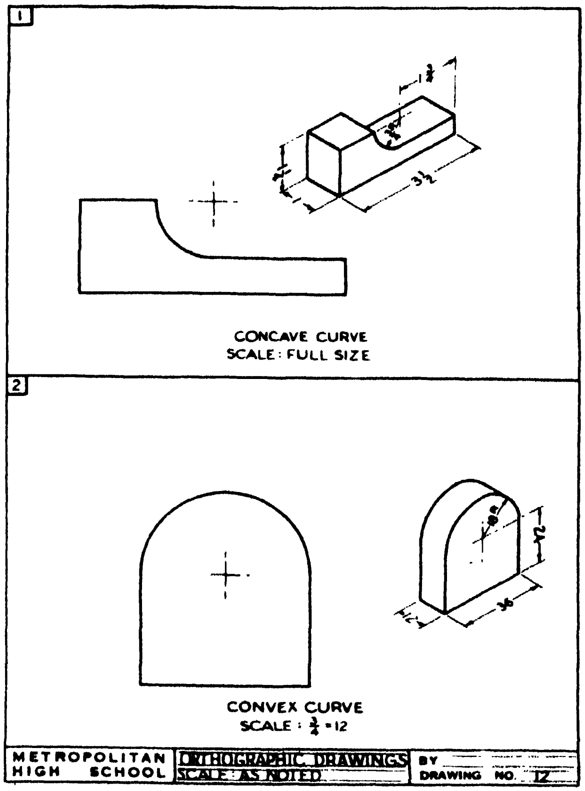

Fig. 69—THREE-VIEW ORTHOGRAPHIC DRAWING (PROBLEMS 1 AND 2)

THREE-VIEW ORTHOGRAPHIC DRAWINGS

Curved surfaces must be shown on many objects, and we must know how to project these surfaces in all views. See Figure 69.

Problem 1—Concave Curve

When the curve intersects the top surface there is a visible edge, but when it is tangent to the middle surface there is no horizontal edge. The curve projects true size in the front view, but not in either the top or the right-side views. Make a complete three-view drawing.

Problem 2—Convex Curve

This drawing is to be made to the scale of $\frac{3}{4}'' = 12''$, a scale frequently used by architects for drawing details. Here also

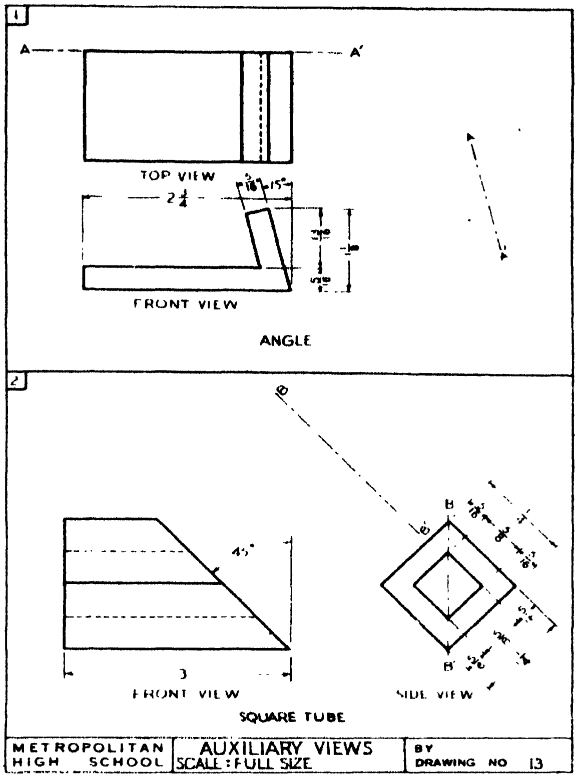

Fig. 70—AUXILIARY VIEWS (PROBLEMS 1 AND 2)

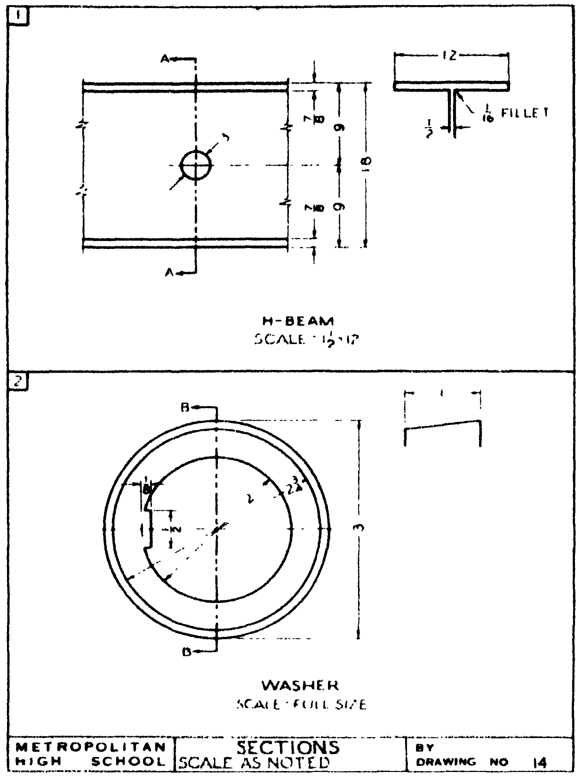

Fig. 71—SECTIONS (PROBLEMS 1 AND 2)

the curve shows as a true shape in only one view. Draw the three views needed.

AUXILIARY VIEWS

Auxiliary views are drawn to show surfaces which do not project as true size in any of the regular views. See Figure 70.

Problem 1—Angle

Draw the front and top views. Notice in the right part of the panel the location of the line *A-A'*; draw your auxiliary view to the left of this line. Show only the inclined face in the auxiliary view. This is called a *partial* auxiliary view. Such a view is all that is necessary in most cases.

Problem 2—Square Tube

Draw only the inclined face in the auxiliary view. Center the view about line *B-B'*.

SECTIONS

In making a section drawing we imagine that a portion of the object has been cut by a plane and then removed. We draw the section, showing the object as we would see it with the portion removed. See Figure 71.

Problem 1—H-Beam

An 18″ H-beam is shown with a 3″ hole in the front elevation. Section *A-A* is represented as going through the center of this hole. The beam in this problem is a steel beam; use the correct symbol for steel in making the section. The hole is not sectioned because there is no material there being cut.

Problem 2—Washer

Draw a full section of the cast iron washer. The location of the section is

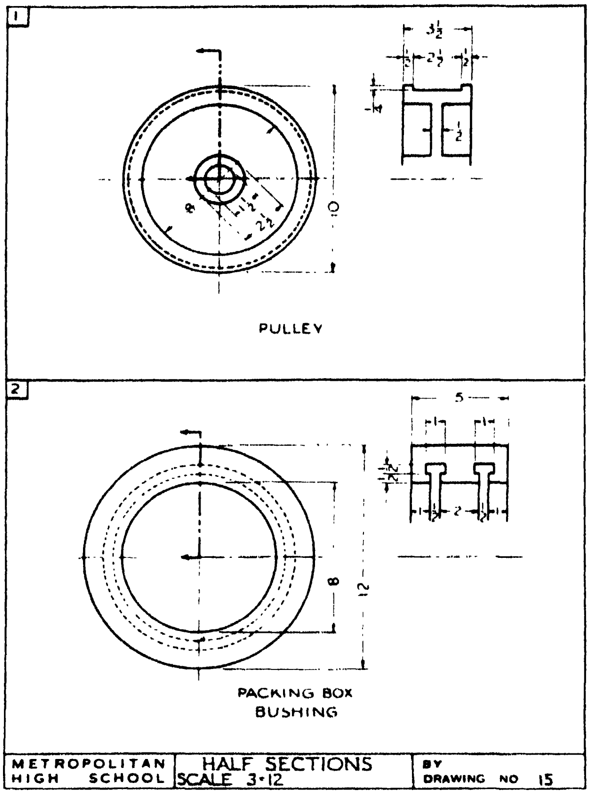

Fig. 72—HALF SECTIONS (PROBLEMS 1 AND 2)

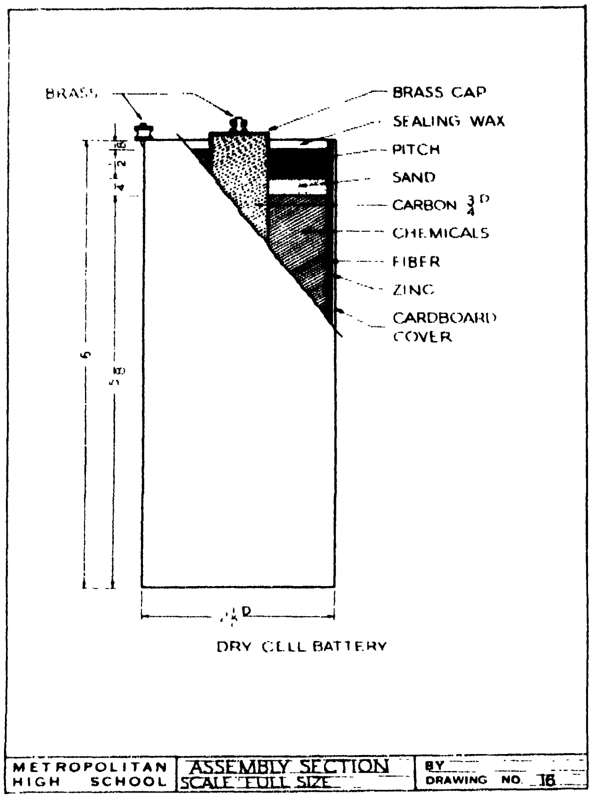

Fig. 73—ASSEMBLY SECTION (PROBLEM)

shown in the front elevation by the cutting plane *B-B*. Since the washer is made of cast iron, single lines uniformly spaced are the section lining to use.

HALF SECTIONS

Half sections may be used to show an object that is symmetrical about the center line. See Figure 72.

Problem 1—Pulley

Draw the front view and then outline the section view in the same location used for the right-side view. Section the upper half of the right-side view; make the lower half in elevation. The pulley is cast iron.

Problem 2—Packing Box Bushing

Draw the front view and the outline of the right-side view. This piece is also made of cast iron. Dimension and letter both problems.

ASSEMBLY SECTION

Figure 73 is a full section through a dry-cell battery showing how the various parts are fitted together. There are some materials sectioned here not shown in the regular symbols; use the section linings shown on the illustration.

QUESTIONS

1. What are working drawings? For what purpose are they used?
2. What is the name sometimes given to drawings having several views?
3. From which three positions do we normally draw an object?
4. What is meant by an orthographic drawing?
5. A draftsman takes distances from one view to another. What is the name for this procedure?

6. In what kind of view are inclined surfaces shown completely?

7. Some objects may be completely detailed in just two views. Name two such objects.

8. What kind of drawing is made to show the hidden or inside portions of an object?

9. What is the purpose of a cutting-plane line?

10. What is the purpose of an assembly drawing?

TOPICS FOR DISCUSSION

1. Make a study of the drawings in the books of your shop library and report the various kinds of drawings found.

2. Different explanations of projection are given in different texts on drawing. Find an explanation given in another drawing book.

3. Get an assembly drawing that is used in industry. Find all the various parts of the object and tell how they are identified.

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PICTORIAL DRAWING AND FREEHAND SKETCHING

PICTORIAL DRAWING

Although working drawings show the surfaces of an object in their true shape and dimensions, it takes an individual with the power of *visualization*, or the ability to form a mental image, to see in the different views the object as it actually exists in its entirety. There is, however, a type of drawing whose principal advantage is presenting the object *pictorially*, or more nearly as it appears to the eye.

There are several methods of drawing which present an object pictorially—that is, which show two or more surfaces of an object in a single view in such a manner as to give a picture. Probably the simplest method of showing it in this way is by oblique drawing, of which there are two common kinds, cavalier and cabinet. One-point perspective, isometric, and two-point perspective are other widely used kinds of pictorial presentation. These five methods are used to show the cross in Figure 74.

OBLIQUE DRAWING

An *oblique* drawing is one in which the front view of the object is shown in its true relation and dimensions just as it would be in a working drawing. The receding horizontal lines are drawn at any angle other than 90° from the front view. The horizontal lines are drawn in either their true length or anything less than that length. The vertical lines are always drawn truly vertical, and consequently they are parallel. The surfaces parallel to the front surface are drawn in true dimensions but are set back along the receding horizontal lines at either the true measurement or any proportional distance selected.

The object to be drawn should be placed so that circles or irregular surfaces are

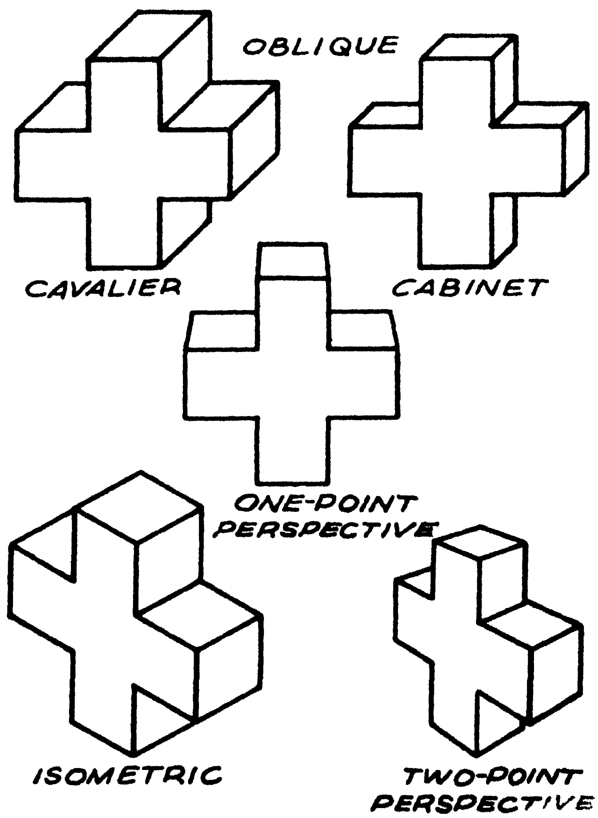

Fig. 74—FIVE TYPES OF PICTORIAL DRAWING

shown in the true view, that is, so that the curves will appear in the front surface or a surface parallel to it.

Cavalier Drawing

In *cavalier* drawing, a form of oblique drawing shown in Figure 75, the receding horizontal lines of the cube are drawn at an angle of 45° and are measured in their true dimensions. It can be seen that, while

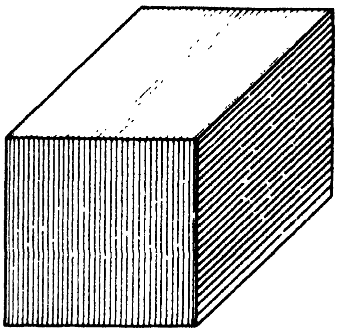

Fig. 75—CAVALIER DRAWING

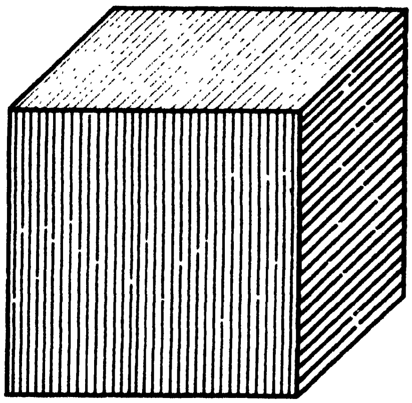

Fig. 76—CABINET DRAWING

this is a pictorial representation, the cube seems much longer or deeper than it should be. To overcome this illusion, we use another kind of oblique drawing.

Cabinet Drawing

The *cabinet* drawing in Figure 76 shows the same cube drawn with the receding horizontal lines still at an angle of 45° but measured in only one half of their actual dimensions. This method gives a much better appearance to the cube. However, we notice that at the top the back edge appears longer than the top front edge. This illusion can be corrected by using still another method of drawing.

ONE-POINT PERSPECTIVE DRAWING

The cube in Figure 77 is drawn in *one-point perspective.* One-point perspective drawing differs from either form of oblique drawing in that, while the front view is shown in its actual dimensions, the receding horizontal lines are drawn to meet at a point usually lying within the width of the object. This point may be either above, below, or within the object. In the illustration the point is above the cube. The depth of the cube is determined by *approximation.* This means that it is determined as correctly as possible without measurement. All vertical lines are truly vertical and parallel; but they are *foreshortened,* or made shorter in length as they recede, because the horizontal lines connecting their top points and bottom points meet. The result is a picture more nearly like that a camera would take if the camera were held in a position above and in front of the cube.

In cavalier, cabinet, and one-point perspective the front surface is shown as a true view just as in a working drawing.

ISOMETRIC DRAWING

A third method of pictorial drawing shows objects in a fashion more nearly like that in which we are accustomed to seeing them. In the *isometric* drawing, Figure 78, all dimensions are true dimensions and all vertical lines are truly vertical and parallel. All horizontal lines are drawn at an angle of 30° with the horizon. This method gives

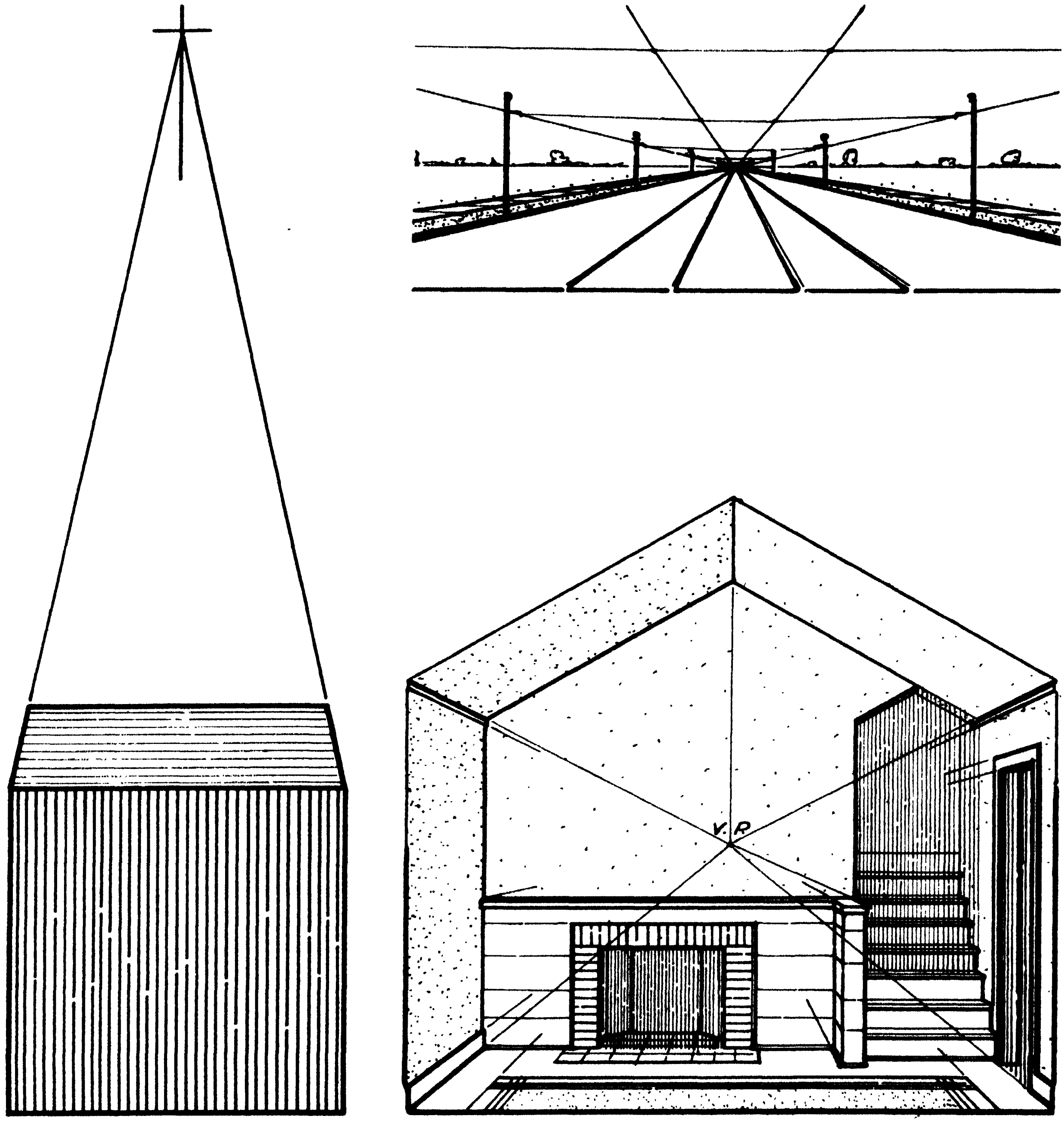

Fig. 77—ONE-POINT PERSPECTIVE DRAWING

a picture that shows the cube fairly well; but we still find that the object appears out of proportion.

Isometric Circles

In oblique drawing, circles, curves, and inclined surfaces can be shown in their true shapes and dimensions only in the front view. In isometric drawing, these cannot be shown in their true dimensions or relations.

Isometric circles, Figure 79, are made by drawing two lines from each *obtuse* corner, or large angle, of the isometric square to the mid-points of the opposite sides. The oval, or flattened circle, is drawn from four centers, two of which are at the obtuse corners and the other two at the intersections of the lines. Study Figure 79 to see how this is done.

Nonisometric Lines

Inclined lines and surfaces are always lengthened or shortened when shown in isometric drawing. This is shown in Figure 80. Any line not vertical or horizontal is a *nonisometric* line.

TWO-POINT PERSPECTIVE DRAWING

Figure 81 shows a cube drawn in *two-point perspective*. This kind of drawing is the most pleasing to the eye and shows the object in its most nearly true picture. The front corner of the cube is drawn in its true height, but all horizontal lines are drawn to meet in either a left- or right-hand vanishing point. These two vanishing points must be placed on a horizontal line at a distance that will give good proportional relationships to the angles made by the receding lines drawn from the front corner of the object. The width of the cube must be proportioned by approximation.

Perspective as presented in this unit is based entirely on approximation as to size, proportion, and the location of vanishing points. Where accurate and correct

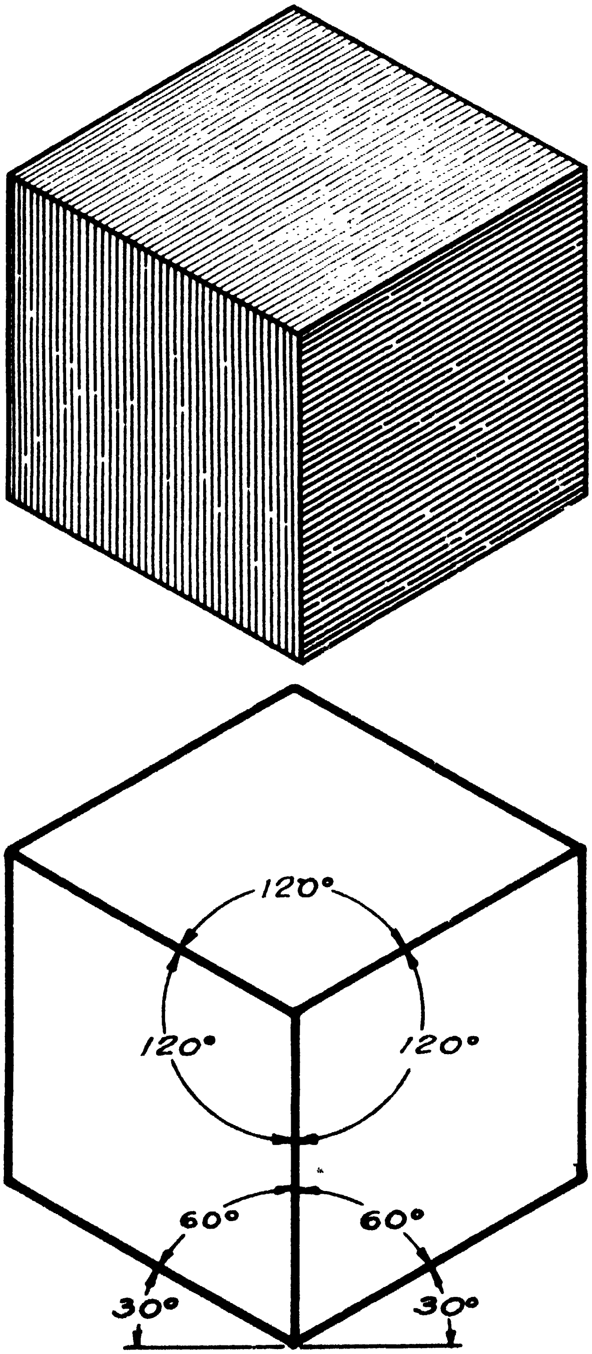

Fig. 78—ISOMETRIC CUBES

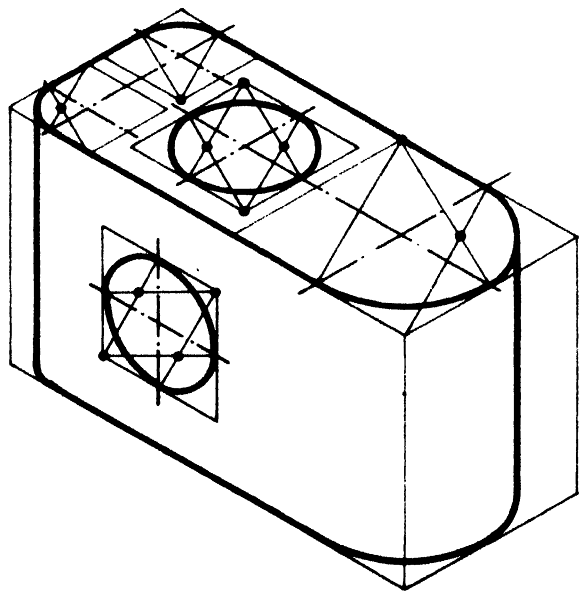

Fig. 79—ISOMETRIC CIRCLES

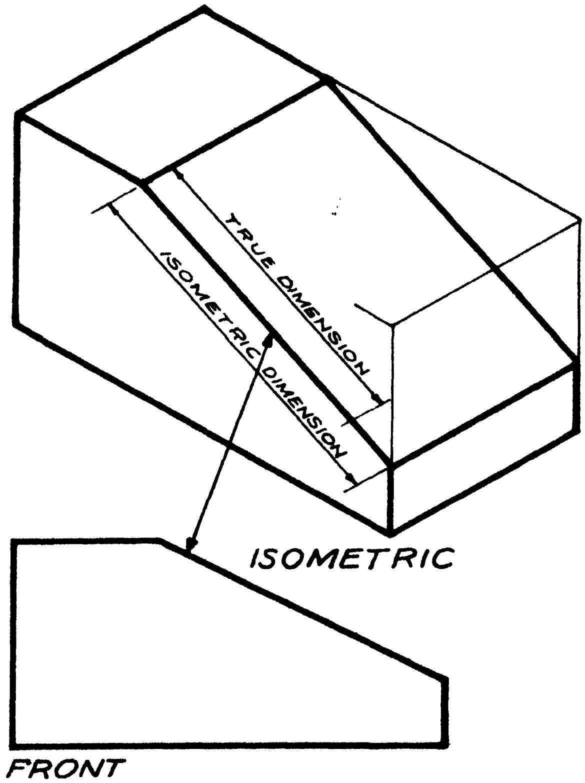

Fig. 80—NONISOMETRIC LINES

perspectives are required, the drawing is worked completely by mechanical projection. Since this projection involves considerable detail, it is not included here. Perspective is generally used in architectural drawing or freehand sketching.

BOX CONSTRUCTION

It is often necessary to draw an object that has inclined, stepped, or irregular surfaces. In these instances a rectangular block, or "box," having over-all dimensions the same as the over-all dimensions of the object must be constructed. The object is then located by measurements within this block, as shown in Figure 82. This means of locating points and proportioning lines may be used in either mechanical or freehand pictorial drawing.

FREEHAND SKETCHING

Freehand sketching is a necessary technique in any branch of the drafting field and a valuable asset for general use. It is desirable to be able both to present ideas graphically and to sketch objects that might be of interest.

Learning to draw requires the same patience as learning to walk. Both are a matter of training and practice. The only materials required for freehand sketching are paper and a soft pencil, probably HB, sharpened to a conical point. The pencil should be held lightly and comfortably in the hand and all strokes made with a full arm motion.

Good training in sketching can be gained by placing dots at various distances and

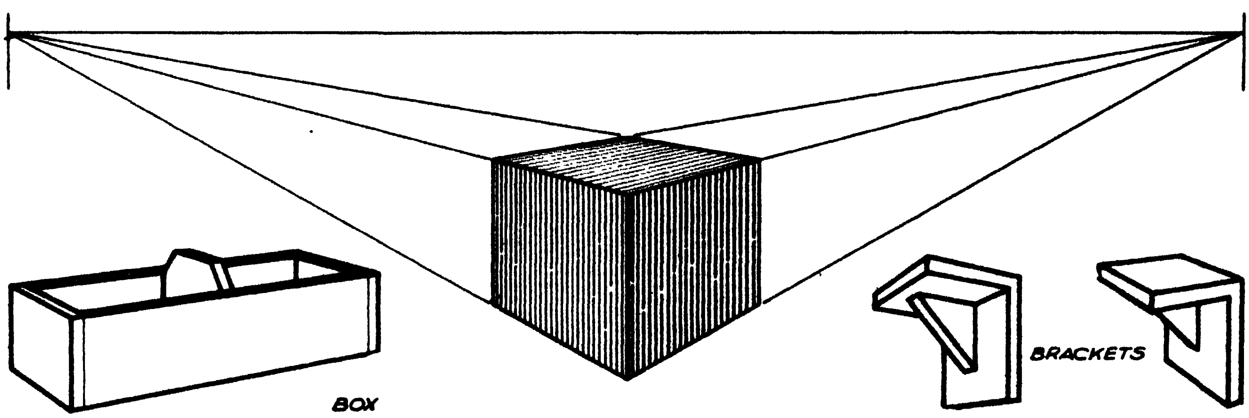

Fig. 81—TWO-POINT PERSPECTIVE DRAWING

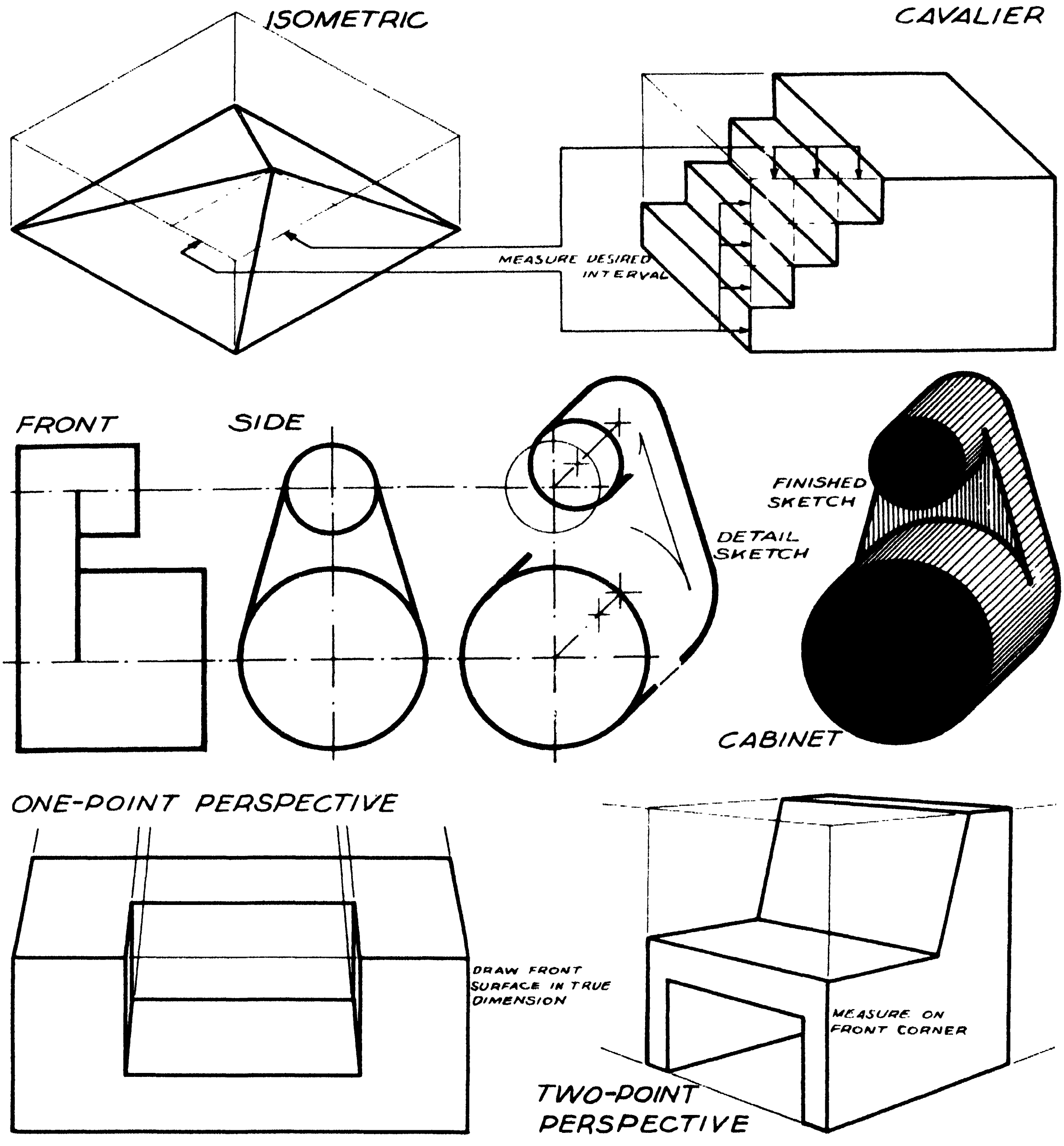

Fig. 82—BOX CONSTRUCTION

directions on the sheet and training the hand to connect them with direct strokes. Do not "brush in" or go over the lines. Try to make the first line the final line and eliminate mistakes by continued practice.

On complicated drawings the construction can be drawn in lightly and later the proper parts can be brought out to form the object. A few freehand sketches showing the construction lines are illustrated in Figure 83.

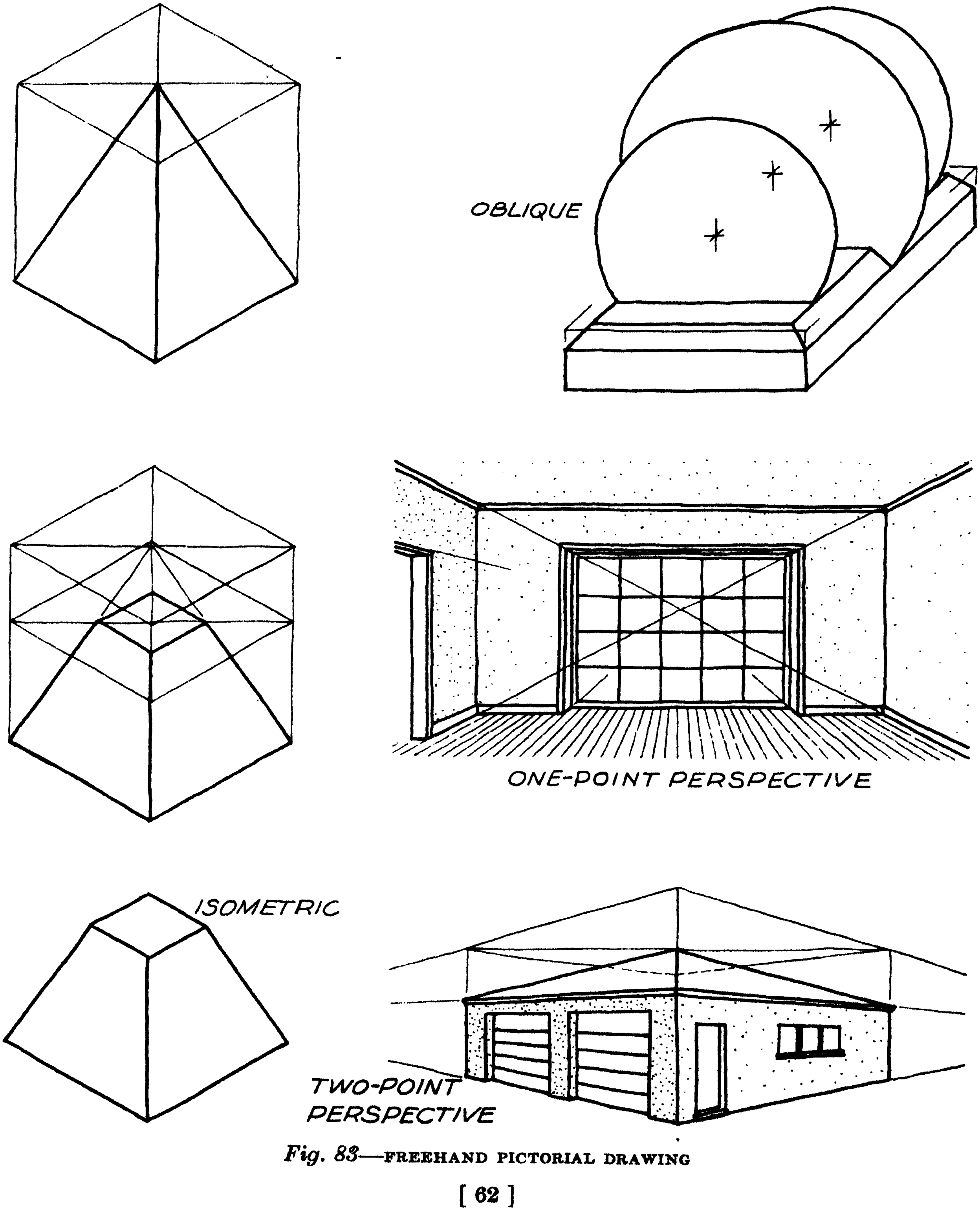

Fig. 83—FREEHAND PICTORIAL DRAWING

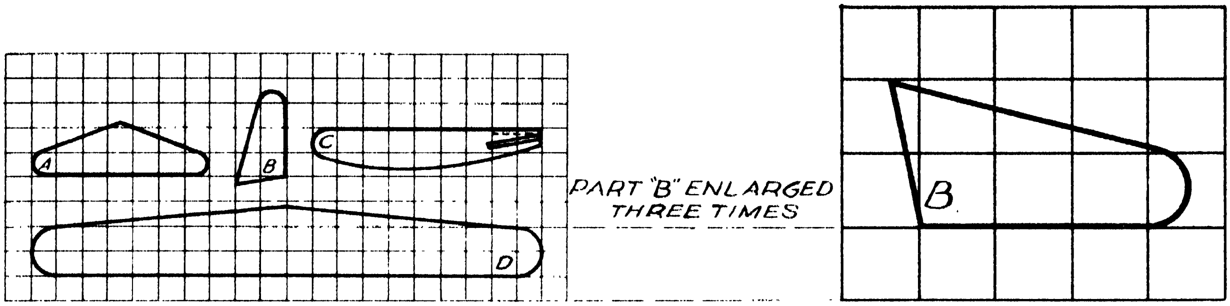

Fig. 84—ENLARGING BY THE "SQUARE-PAPER METHOD"

Orthographic drawings and any of the pictorial drawings may be made freehand. Orthographic and isometric drawings are those most generally used for shop sketches. Where fairly accurate sketches must be shown either cross-ruled or isometric paper may be used.

ENLARGING A DRAWING

Cross-ruled paper or regular-sized squares are sometimes used in designing or sketching patterns. It is necessary to know the size of the squares that are needed to give the proper dimensions to the object. A drawing may be enlarged to any size without measuring it if the "square-paper method" shown in Figure 84 is used.

SUMMARY

The advantage of pictorial drawing is that it presents the object more nearly as it actually appears to the eye and shows two or more surfaces in a single view. Five different methods of showing an object in this manner are discussed in this unit.

Two forms of oblique drawing, cavalier and cabinet, show the object in its true shape and dimensions in the front view, just as in working drawings. In cavalier drawing, the receding horizontal lines are drawn at an angle of 45° and measured in their true length. In cabinet drawing, the receding horizontal lines may be at any angle except 90° but they are measured in one half their actual dimensions. The front view of one-point perspective is the same as in oblique drawing, but the receding horizontal lines are drawn to meet at a point which is ordinarily within the width of the object. In isometric drawing, all dimensions are shown as true dimensions and all vertical lines are drawn vertically. The

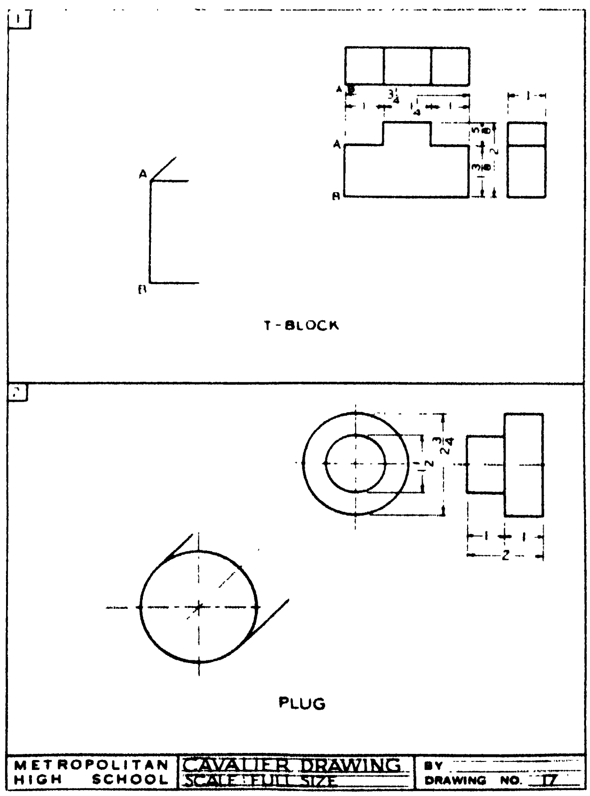

Fig. 85—CAVALIER DRAWING (PROBLEMS 1 AND 2)

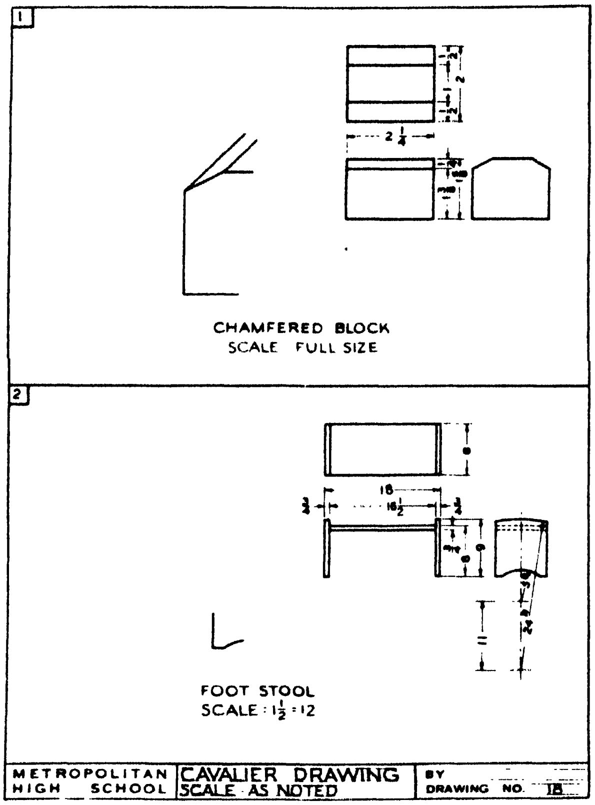

Fig. 86—CAVALIER DRAWING (PROBLEMS 1 AND 2)

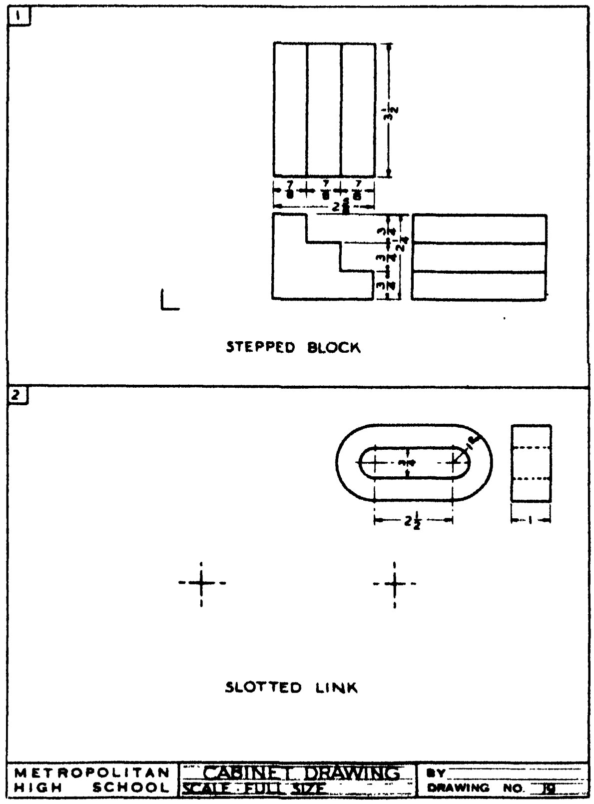

Fig. 87—CABINET DRAWING (PROBLEMS 1 AND 2)

horizontal lines are drawn at an angle of 30° with the horizon. In two-point perspective, all horizontal lines are drawn to meet in a right-hand or a left-hand vanishing point.

All these forms of pictorial drawing may be done as freehand sketches. A construction "box" is particularly useful in locating points and lines when the object has stepped or inclined surfaces. A helpful device for the sketching of objects and the enlarging of drawings is the use of cross-ruled paper or regular-sized squares.

CAVALIER DRAWING

Problem 1—T-Block

Locate line *AB* on your drawing sheet (see Figure 85) and draw the front of the object. Then draw the receding lines at 45° and for their true dimensions.

Problem 2—Plug

This problem involves circular surfaces. When an object has such a shape turn the view in cavalier drawing so that the circle projects as a true shape. The center lines for the plug are located by measuring back on a 45° line the thickness of the portion concerned.

CAVALIER DRAWING

Problem 1—Chamfered Block

The chamfered block in Figure 86 is to be made with the end of the block shown in the front view. The dimensions of the end must be obtained from the top and front views given in the illustration. Remember that the front view is the true projection in cavalier drawing. Do not show invisible lines in a cavalier or other pictorial drawing.

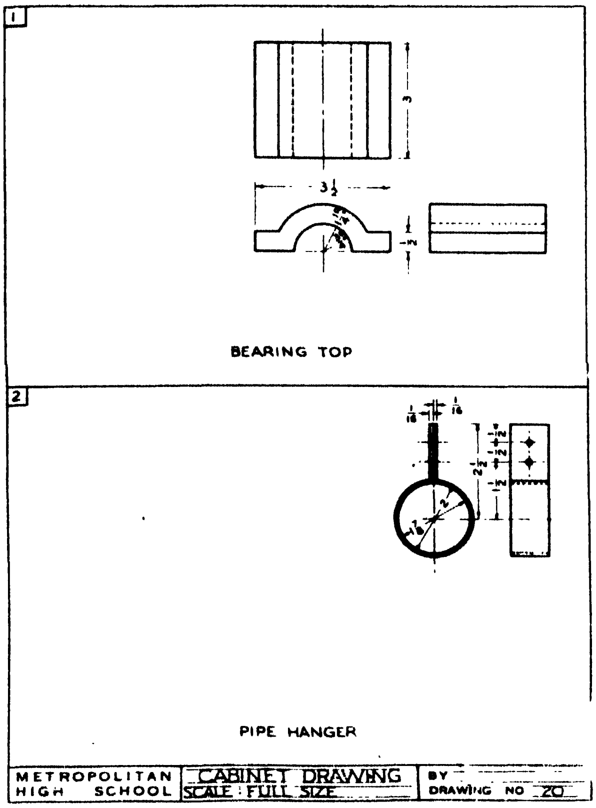

Fig. 88—CABINET DRAWING (PROBLEMS 1 AND 2)

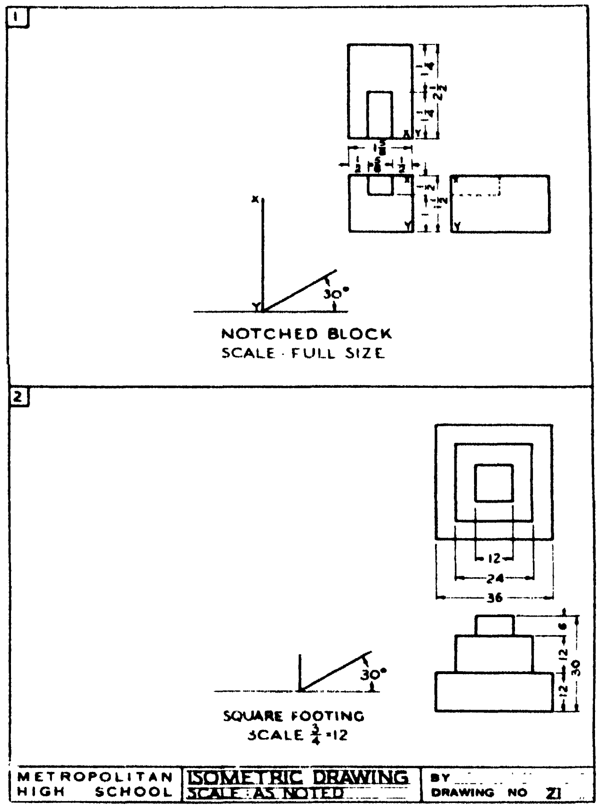

Fig. 89—ISOMETRIC DRAWING (PROBLEMS 1 AND 2)

Problem 2—Footstool

Make a cavalier drawing of the footstool. Notice the scale to use.

CABINET DRAWING

Make these cabinet drawings (see Figure 87) the same as cavalier but cut the receding lines to one half their actual length.

Problem 1—Stepped Block

Draw the front of the object so that the end of the step projects in its true shape. Then draw the receding lines and back outline.

Problem 2—Slotted Link

Draw the center lines. Then draw arcs to project in their true shapes and then draw receding center lines. Draw the circular portions for the back of the link. Then draw all the straight lines needed.

CABINET DRAWING

Problem 1—Bearing Top

Make a cabinet drawing of the bearing top as shown in Figure 88.

Problem 2—Pipe Hanger

In making the cabinet drawing of the pipe hanger, draw the $\frac{1}{4}''$ diameter holes freehand, constructed inside a square.

ISOMETRIC DRAWING

Problem 1—Notched Block

For Problem 1 in Figure 89 draw a rectangular box isometrically, using construction lines. Measure along the upper edge of this box to get the location of the notch and draw a small box inside the larger one. Go over all visible edges.

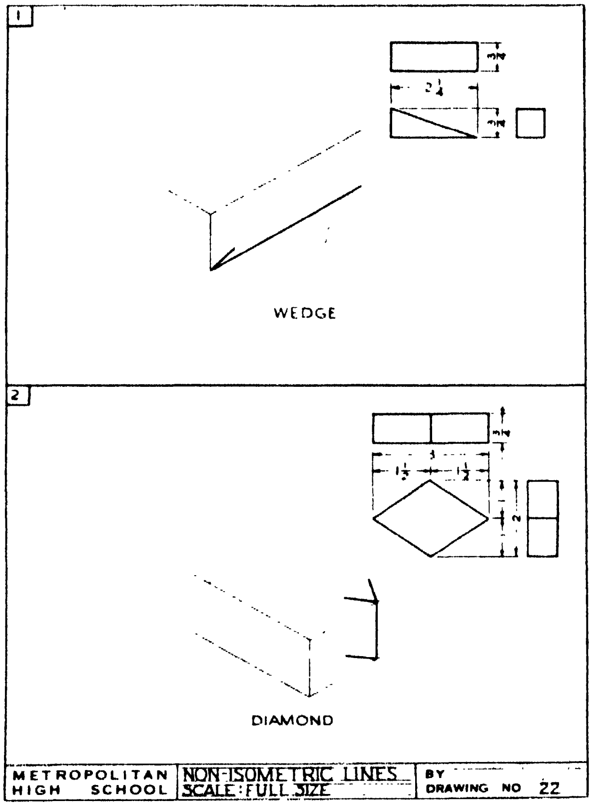

Fig. 90—NONISOMETRIC LINES (PROBLEMS 1 AND 2)

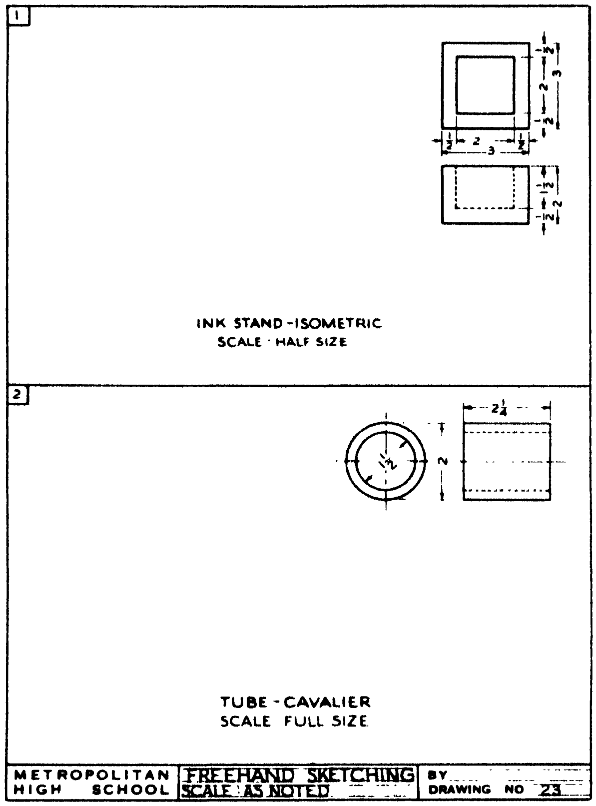

Fig. 91—FREEHAND SKETCHING (PROBLEMS 1 AND 2)

Problem 2—Footing

This problem can be drawn by making one large box and then measuring off the heights of the three different steps on the vertical edge. Compute and measure along the top edges to get the proper offsets for the two top blocks.

NONISOMETRIC LINES

Nonisometric lines are those which do not make the conventional angles with the regular surfaces, as discussed on page 59, and consequently cannot be measured directly from the drawing. See Figure 90.

Problem 1—Wedge

Draw a rectangular box to contain the wedge. Enclose within this box a wedge with the thin edge to the left.

Problem 2—Diamond

Draw a rectangular box having the same dimensions as the length, width, and thickness of the diamond. Use the mid-points of each one of the edges as the points of the diamond.

FREEHAND SKETCHING

These problems are to be sketched entirely freehand, using only pencil, paper, and eraser.

Problem 1—Inkstand

Sketch a freehand isometric drawing of the inkstand shown in Figure 91.

Problem 2—Tube

The tube should be sketched in cavalier drawing.

ONE-POINT PERSPECTIVE

In one-point perspective there is one point where all receding lines converge. This point, which is called a vanishing point, is usually located somewhere between the two sides of the object. The depth of the object is determined by approximation to make the drawing appear to have correct proportions. Both problems in Figure 92 are to be sketched freehand.

Problem 1—Cross

Draw center lines through point *O*. Using these center lines, draw the front face of the object. From each corner of this face draw a light construction line to the vanishing point *O*. On one of these lines approximate the depth of the object and through this point draw the horizontal and vertical lines. Continue until the entire back face of the object is completed.

Problem 2—Tent

Draw a vertical center line and a base line through point *O*. Draw the front face of the tent as dimensioned. Estimate the depth and draw the rear face.

FREEHAND SKETCHING

The purpose of Figure 93 is to show the comparison of three types of pictorial drawing of the same object. Notice that the only difference is in either the length or direction of the receding lines.

Problem 1—Cavalier Drawing
Problem 2—Cabinet Drawing
Problem 3—One-Point Perspective

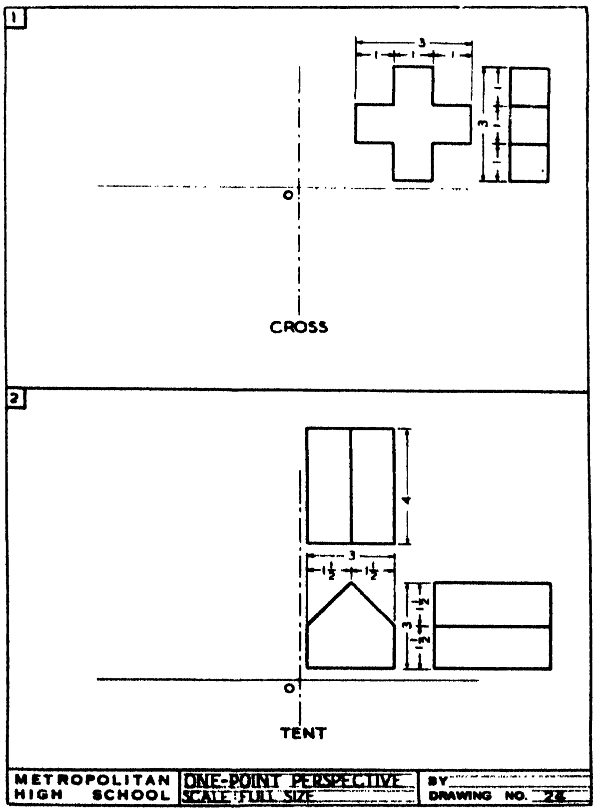

Fig. 92—ONE-POINT PERSPECTIVE (PROBLEMS 1 AND 2)

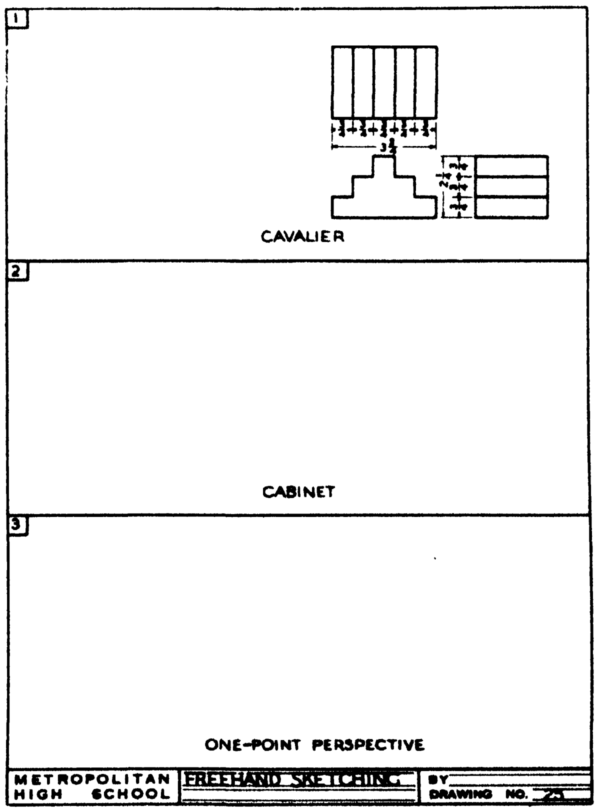

Fig. 93—FREEHAND SKETCHING (PROBLEMS 1, 2, AND 3)

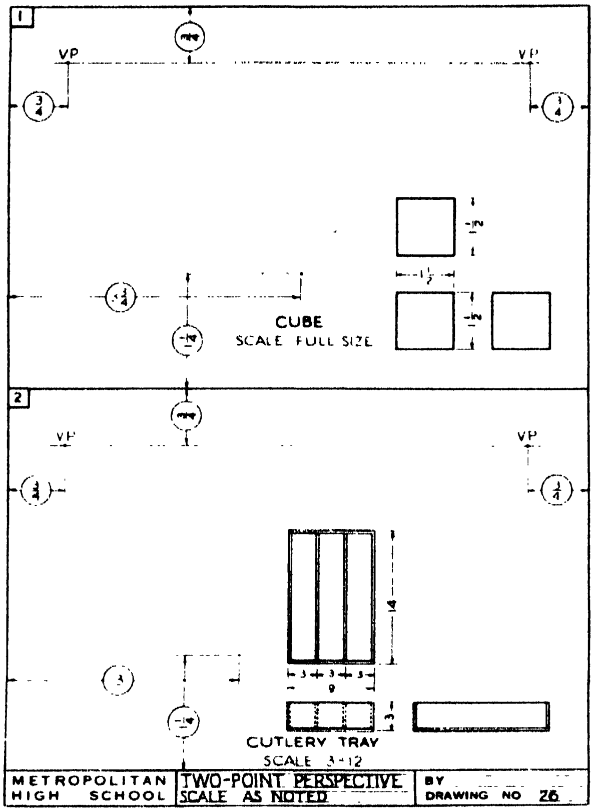

Fig. 94—TWO-POINT PERSPECTIVE (PROBLEMS 1 AND 2)

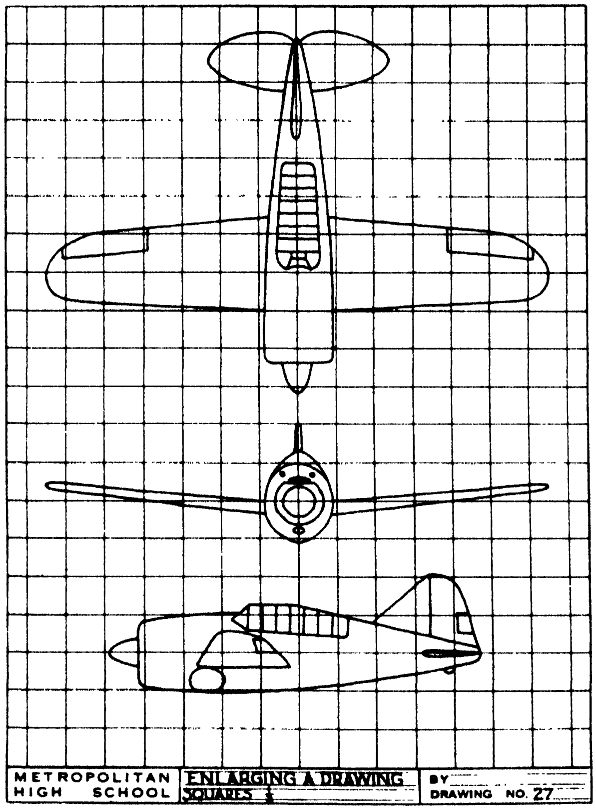

Fig. 95—ENLARGING A DRAWING (PROBLEM)

TWO-POINT PERSPECTIVE

Figure 94 is designed to give you an opportunity to do some freehand sketching. Notice the similarity between two-point perspective and isometric drawing.

Problem 1—Cube

Locate both vanishing points and the bottom corner of the object, using the given dimensions. Sketch the front edge of the cube. From both ends of this edge lightly draw lines to each vanishing point. On these lines estimate the length of the side and then complete the cube.

Problem 2—Cutlery Tray

Sketch freehand a two-point perspective of the cutlery tray. Use the dimensions given to locate points.

ENLARGING A DRAWING

Figure 95 shows the outline drawing of a small airplane. Cross-rule the drawing sheet in $\frac{1}{2}''$ squares. Locate a point where each line of the airplane intersects one of the $\frac{1}{2}''$-square lines. Connect the points with light lines to get the contour of the plane. Go over the outlines of the plane with an H or HB pencil.

QUESTIONS

1. What kind of drawing shows two or more surfaces of an object in one view?
2. Name some of the common types of pictorial drawings.
3. Distinguish between cavalier and cabinet drawing. To what general class of pictorial drawings do these two kinds of drawing belong?
4. What is the difference between the receding lines of a cabinet drawing and a one-point perspective?

5. Are any surfaces drawn in true shape in an isometric drawing?

6. What kind of pictorial drawing shows an object in its most nearly true picture?

7. What is "box" construction?

8. What kinds of paper are an aid when fairly accurate freehand sketches are to be made?

9. Which type of pictorial drawing does an architect frequently use?

10. If you are to draw an oblique projection of an object having one face circular, which way should the object be turned in the drawing that you make?

TOPICS FOR DISCUSSION

1. Obtain a piece of isometric ruled paper and explain how to use it.

2. There are many methods of drawing with mechanical perspective. Select one of the simpler methods and explain it to the class.

3. A pantograph is an instrument for enlarging drawings. Construct a simple one and demonstrate it to the class.

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UNIT VI

GEOMETRIC CONSTRUCTIONS

GEOMETRY IN DRAFTING

Since earliest times the designer, builder, engineer, and mathematician have had common interests and problems. The early architects and builders, such as the designers of the temples and pyramids of ancient Babylon and Egypt, were properly considered the leading mathematicians of their time.

Today it is equally true that there are many instances when the draftsman or engineer makes use of the principles of geometry and other branches of mathematics. Problems arise in the planning and erection of the necessary machines and buildings for our civilization; often geometric constructions aid in solving these problems. The truss, which is frequently

Courtesy Link-Belt Company, Chicago

Fig. 96—CONSULTATION ON AN ENGINEERING PROBLEM

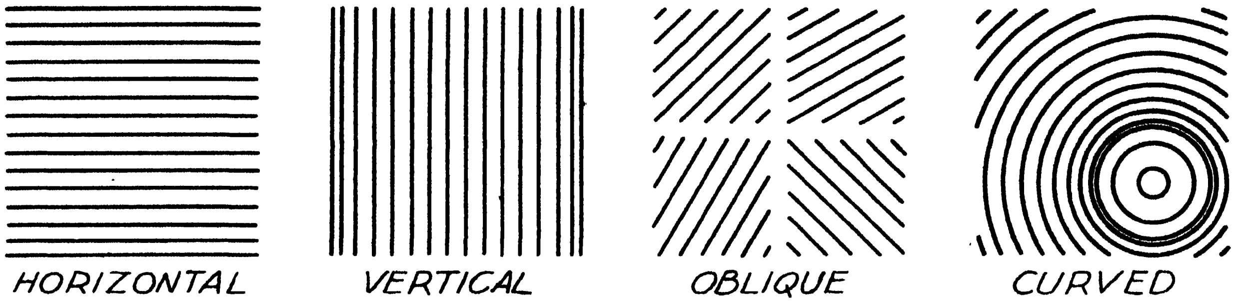

Fig. 97—KINDS OF LINES

used as a support in buildings and bridges, is made up of a combination of triangles, which are rigid geometrical shapes.

Some of the simpler operations in geometry, such as the drawing of lines in various directions, the construction of right angles, and the erection of perpendiculars, have been used in procedures in the previous units. We shall here study some additional ones.

LINES

Although the lines shown in Figure 97 have all been used in your previous work, their geometrical definitions are given here in a group. *Horizontal* lines are lines that are parallel to the horizon. *Vertical* lines are drawn perpendicular to the horizon and are always at right angles to horizontal lines. *Oblique* lines are those that slant and are neither horizontal nor vertical. *Curved* lines are lines no parts of which are straight. *Parallel* lines are lines that do not meet no matter how far they are extended. Parallel lines may be horizontal, vertical, oblique, or curved. The lines within each group in Figure 97 are parallel.

Bisecting a Line

It is often necessary to *bisect* a line when one is drawing, that is, to divide the line into two equal parts. A common method used to bisect a line is shown in Figure 98. The line *AB* is the line to be bisected. It may be drawn at any angle. The compass is set at a convenient radius greater than one half of the line *AB*. The ends of the line are used as centers and arcs are constructed that intersect at *X* and *Y*. The points of intersection of the arcs are connected with the line *XY*. This line cuts *AB* into two equal parts and is perpendicular to it.

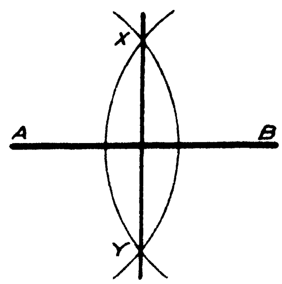

Fig. 98—BISECTING A LINE WITH A COMPASS

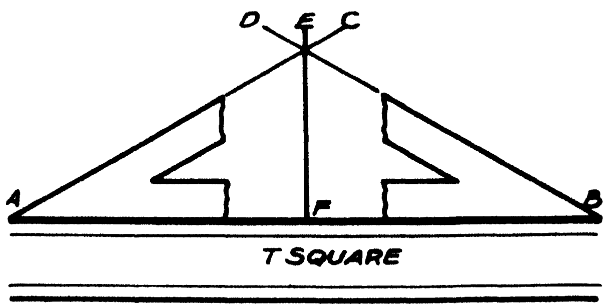

Fig. 99—BISECTING A LINE WITH TRIANGLE AND T SQUARE

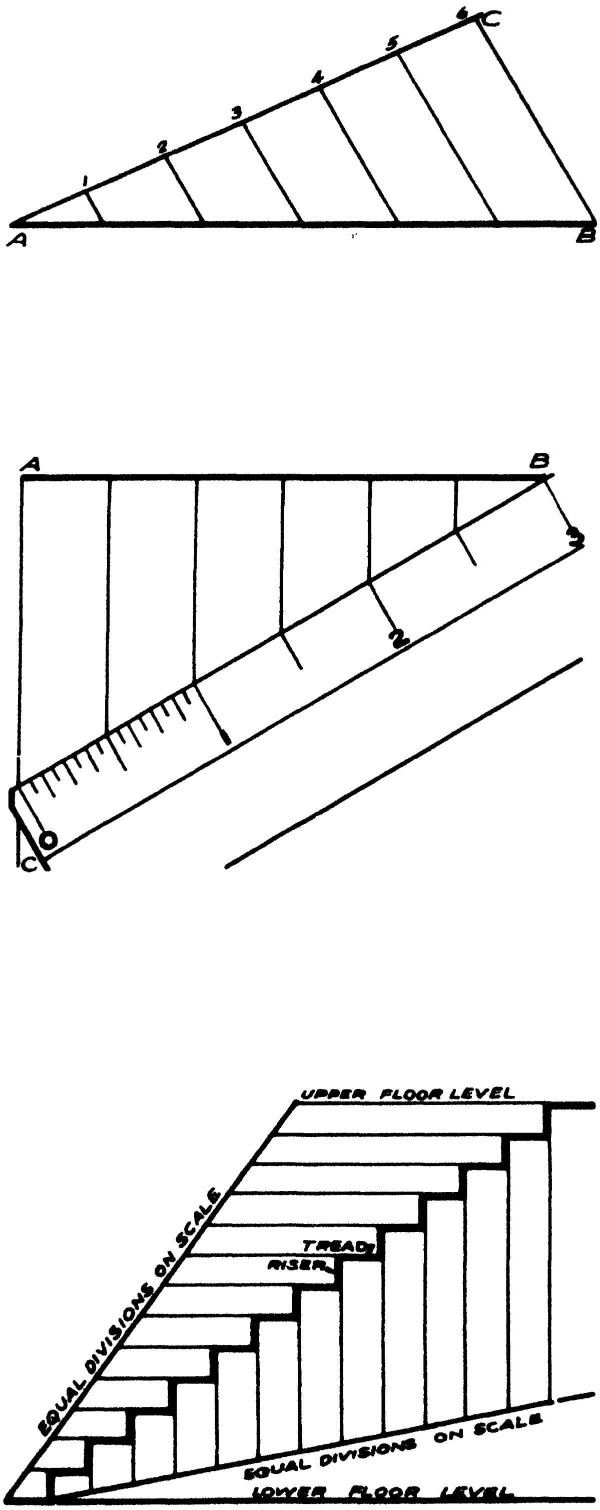

Fig. 100—A (TOP), DIVIDING A LINE INTO EQUAL PARTS; B (MIDDLE), ANOTHER METHOD OF DIVIDING A LINE INTO EQUAL PARTS; C (BOTTOM), LAYING OUT A FLIGHT OF STAIRS

Another method, while not strictly geometrical, is preferred by many draftsmen. Draw line *AB* (Figure 99) with the T square. With a 30°-60° triangle the line *AC* is drawn 30° with the horizontal. The triangle is reversed and line *BD* is drawn. From the intersection at *E* the vertical line *EF* is drawn. This line bisects the line *AB* and is perpendicular to it. Although the 30°-60° triangle is used in the illustration, the 45° triangle may be used instead.

Dividing a Line into Equal Parts

A line may be divided into equal parts in several different ways. One of the ways is shown in Figure 100A. The line *AB* is to be divided into six equal parts. The line *AC* is constructed at any convenient angle with *AB*. Six equal spaces are laid off on *AC* with a convenient setting of the dividers. The end of the last space, the point at 6, is connected to point *B*. Through the points 5, 4, 3, 2, and 1, lines are drawn parallel to *CB* intersecting the line *AB*. Line *AB* is now divided into six equal parts.

A draftsman frequently uses the method shown in Figure 100B. This method uses a scale. A perpendicular is constructed from *A* to make the line *AC*. The scale is placed so that one end of six equal divisions is at *B* and adjusted so that the other end is on line *AC*. The six divisions are marked, and with triangle and T square lines are drawn perpendicular to *AB* through each of the dividing points.

A practical application of dividing a line into equal parts is shown in Figure 100C.

ANGLES

An angle is formed by the meeting of two lines. The angles shown in Figure 101 are (A) a 90°, or *right*, angle; (B) an *obtuse* angle, which is an angle greater than 90° and less than 180°; and (C) an *acute* angle,

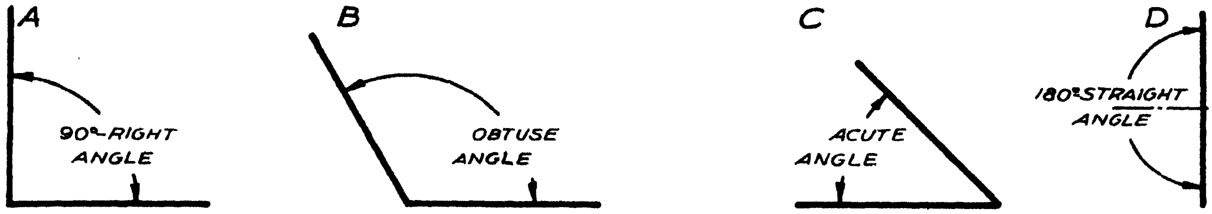

Fig. 101—KINDS OF ANGLES

or one less than 90°. A *straight*, or 180°, angle is a straight line, as shown in (D). Angles are measured in degrees. Arcs also are measured in degrees. A complete circle contains 360°.

Bisecting an Angle

Bisecting an angle requires the use of the compass. In Figure 102 is shown the angle *ABC*. With a compass and any convenient radius the arc *DE* is drawn. With *D* and *E*

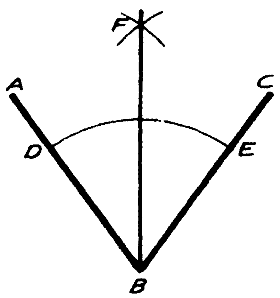

Fig. 102—BISECTING AN ANGLE

as centers, two arcs are constructed intersecting at *F*. The line *FB* from the intersection of the arcs bisects the angle *ABC*.

Transferring an Angle

Any angle may be *transferred* from one place to another by the method illustrated in Figure 103. *B′C′* is drawn in any desired position. With a convenient radius and *B* as a center, an arc is struck locating points *X* and *Y*. With the same radius and *B′* as a center, the arc to locate *X′* and *Y′* is drawn. With *YX* as a radius and *X′* as a center, another arc locating *Y′* is drawn. A line drawn through *Y′* to *B′* completes the angle *A′B′C′*.

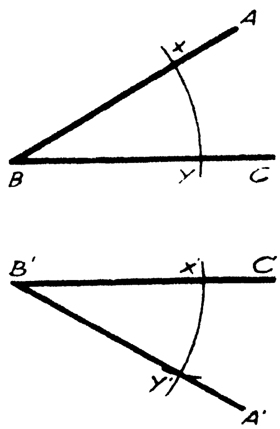

Fig. 103—TRANSFERRING AN ANGLE

TRIANGLES

Some of the common triangles are shown in Figure 104. The *right* triangle is so named because two of its sides form a right, or 90°, angle. The *equilateral* triangle has three equal sides and three equal angles of 60° each. The *isosceles* triangle has two equal sides and two equal angles. The *obtuse* triangle has an angle greater than 90°. A *scalene* triangle has no two sides equal.

Constructing a Triangle

Equilateral triangles may be constructed as shown in Figure 105. The length of *AB* is the length of the sides of the proposed triangle. Draw the line *AB* in the position desired. With *A* as a center and *AB* as the

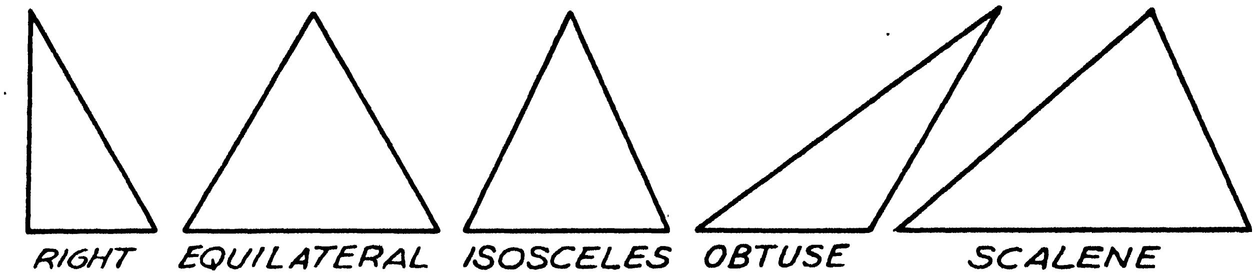

Fig. 104—KINDS OF TRIANGLES

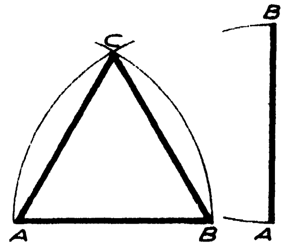

Fig. 105—CONSTRUCTING AN EQUILATERAL TRIANGLE

radius, construct the arc BC. With B as a center and the same radius, construct the arc AC. At the point of intersection of these arcs, draw the straight lines AC and BC to complete the equilateral triangle.

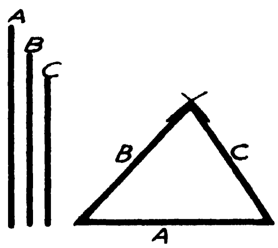

Fig. 106—CONSTRUCTING A TRIANGLE FROM THREE LINES

Sometimes it is necessary to construct a triangle when three sides are given but the angles are not given. Figure 106 shows three lines having different lengths, A, B, and C. The line A is drawn in the position desired. With B and C as radii and the ends of the line A as centers, two arcs are constructed intersecting as shown in the illustration. Lines drawn from this intersection to the ends of line A complete the triangle containing sides A, B, and C.

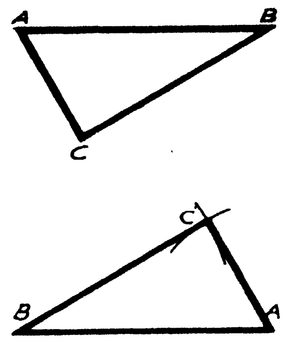

Fig. 107—TRANSFERRING A TRIANGLE

Transferring a Triangle

A triangle is constructed in a different position in the same manner that a triangle is constructed if three sides are given.

The triangle ABC in Figure 107 is to be transferred to a new position. The line $A'B'$ is constructed equal to AB. With A' as a center and AC as a radius, an arc is drawn that will pass through the *vertex*, or top point, of the triangle. With B' as the center and BC as a radius, a second arc intersecting the first is constructed. $A'C'$ and $B'C'$ are drawn to complete the transfer of the triangle.

TANGENTS

A straight line that touches a circle at only one point is said to be *tangent* to the circle. A radius of the circle drawn to this

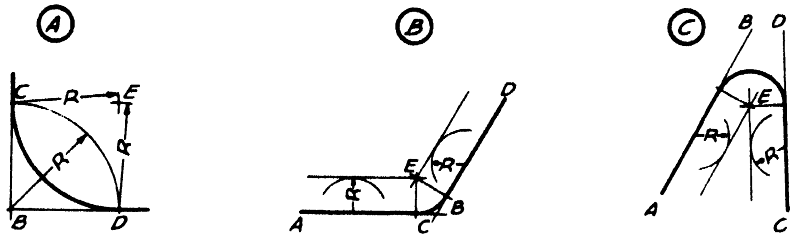

Fig. 108—ARCS TANGENT TO STRAIGHT LINES

line at the point of tangency is perpendicular to the tangent. The point of tangency between two tangent circles is on a line drawn through the centers of the two circles.

Arcs Tangent to Straight Lines

To construct an arc of the given radius *R* tangent to two lines at right angles (see Figure 108A), use the point of intersection of the two lines, *B*, as a center and the radius *R* and strike a preliminary arc *CD*. Using points *C* and *D* as centers and with the radius *R*, strike the arcs that intersect at point *E*. Use point *E* as a center and the radius *R* to draw the arc tangent to each of the two perpendicular lines.

To draw an arc of a given radius, *R*, tangent to two lines that are not perpendicular or parallel, use the procedures shown in Figure 108, parts B and C. With the radius *R*, strike two arcs with their centers on the line *AB* and also on line *CD* near the ends of each line parallel to *AB* and *CD*. Draw light lines tangent to these arcs. These lines intersect at *E*. Use *E* as a center and draw the tangent arc.

Arcs Tangent to Arcs and Lines

The construction of an arc tangent to the arc *AB* and the line *CD* is shown in Figure 109, parts A and B. Using *O* as a center, increase or decrease the radius *OJ* a distance equal to *R* and strike the arc *EF*. Construct *GH* parallel to *CD* at *R* distance away. The arc *EF* and the line *GH* intersect at *I*. Using *I* as a center and *R* as a radius, draw the arc tangent to the given arc and the straight line.

The construction of an arc tangent to arcs *AB* and *CD* is shown in Figure 109C. Increase radius *OJ* by the distance *R* and strike arc *EF*. Increase radius *PK* by *R* and strike arc *GH*. These two arcs intersect at point *I*. Use *I* as a center and *R* as a radius to draw arc *JK* tangent to the original arcs.

HEXAGONS

Hexagons are six-sided figures. It is often necessary in machine drafting to draw hexagonal heads for bolts. There are several methods that may be used to draw regular hexagons, that is, hexagons with six equal sides and six equal angles.

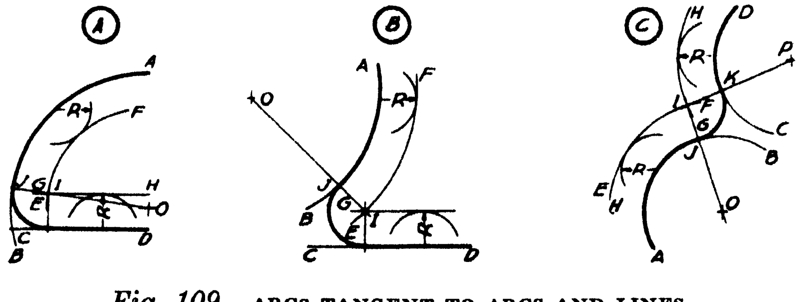

Fig. 109—ARCS TANGENT TO ARCS AND LINES

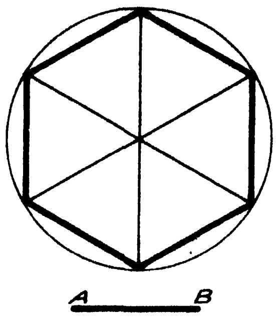

Fig. 110—CONSTRUCTING A HEXAGON WITH T SQUARE, TRIANGLE, AND COMPASS

Constructing a Regular Hexagon

Figure 110 shows a hexagon constructed with a T square, a 30°-60° triangle, and a compass. One side of the hexagon is equal in length to *AB*. With this length as a radius, construct a circle. Through the center of the circle, draw a vertical line and two 30° lines, using the T square and a 30°-60° triangle. These three lines divide the circumference into six equal parts. The points on the circumference are connected with straight lines to form a regular hexagon.

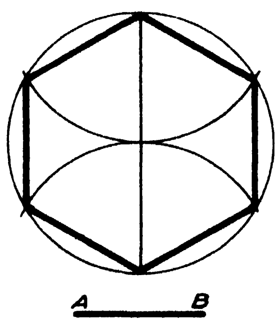

Fig. 111—CONSTRUCTING A HEXAGON WITH A COMPASS

A regular hexagon may be constructed with a compass as illustrated in Figure 111. With *AB*, the length of the side of the hexagon, as a radius, a circle is constructed. The vertical diameter of the circle is drawn. With the compass still set at the same radius and the ends of the diameter as centers, two arcs are drawn to locate four additional points on the circumference. When these six points are connected a regular hexagon is formed.

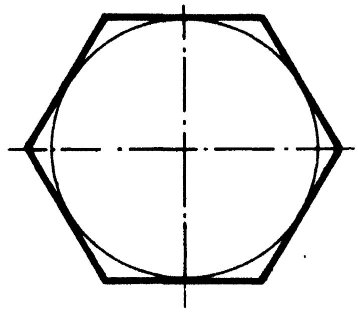

Fig. 112—CONSTRUCTING A HEXAGON OUTSIDE A CIRCLE

In the method of making a hexagon most commonly used in machine drafting the hexagon is constructed outside a circle. The diameter of a circle is used as the distance from the center of one side of the hexagon to the center of the opposite side. With the 30°-60° triangle the six sides are then drawn so that each side just touches the circle, as shown in Figure 112. Such a construction is used to make a drawing of a bolt head.

ELLIPSES

The construction of ellipses is necessary whenever oval shapes are required in drawing. Although there are several ways of making ellipses, two methods, in addition to the method given on page 58 for constructing circles isometrically, will serve most purposes.

The Concentric-Circle Method

The first method to be discussed for the drawing of ellipses is the two-circle or concentric-circle method shown in Figure 113. Two concentric circles are drawn with the diameters equal respectively to the major and minor, or long and short, axes of the proposed ellipse. The large circle is divided into a number of equal parts. In Figure 113 the circumference of the large circle is divided into twelve equal parts by using the 30°-60° triangle. The points of division are connected to the center of the proposed ellipse as shown. Vertical lines are then drawn inward from where the division lines intersect the large circle, and horizontal lines are drawn outward from the points where the division lines intersect the small circle. Where these horizontal and vertical lines intersect, points are determined which locate points for the ellipse. Through these points a smooth curve is drawn with the aid of a French curve.

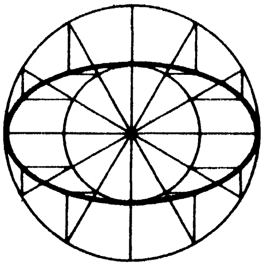

Fig. 113—THE CONCENTRIC-CIRCLE METHOD OF CONSTRUCTING AN ELLIPSE

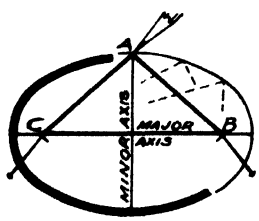

Fig. 114—A PIN-AND-STRING ELLIPSE

More points for the ellipse may be located if the circles are divided into a greater number of parts. However, it is advisable not to use too many points as the lines may become confusing.

The Pin-and-String Method

The second method of constructing an ellipse, known as the pin-and-string method, is often used in laying out arches. The major and minor axes are drawn as shown in Figure 114. With a radius of one half of the major axis and with *A*, one end of the minor axis, as a center, an arc is constructed cutting the major axis at points *B* and *C*. The points *B* and *C* are called the *foci* of the ellipse. Three pins are placed at points *A*, *B*, and *C*, and a string is tied around them. The pin at *A* is removed and replaced with a pencil. With the string kept taut, the pencil is moved around the pins to form the ellipse.

OBLIQUE CIRCLES

The concentric-circle and pin-and-string methods give exact ellipses. When it is necessary to draw circles in any oblique projection where all dimensions are shown as true dimensions, the circles may be drawn as approximate ellipses by erecting perpendicular bisectors to the sides of the square containing the circle. These bisectors will intersect in four points, which are the centers of the four arcs which form the ellipse.

This method is shown in Figure 115. In part A the points fall inside the area of

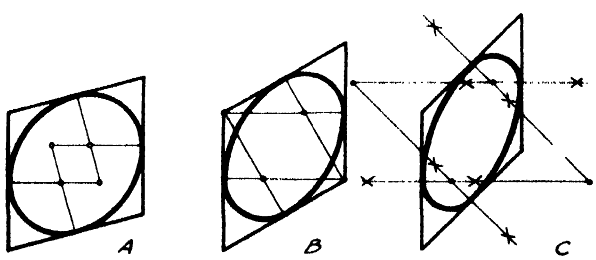

Fig. 115—OBLIQUE CIRCLES

the oblique square; in part B two of them fall on the obtuse corners; and in part C two fall outside the square.

SUMMARY

There has always existed a close relationship between mathematics and design and construction. There are many instances when the draftsman or engineer makes use of geometric constructions as an aid in solving his problems. The constructions explained and illustrated in this unit include bisecting a line, dividing a line into a number of equal parts, bisecting an angle, transferring an angle, constructing a triangle, transferring a triangle, constructing a regular hexagon, and constructing an ellipse.

Each of these constructions has practical application in the problems of the draftsman; and, since they will be frequently used, they should be thoroughly understood and the techniques mastered.

GEOMETRIC DIVISIONS

The following problems are not shown in separate illustrations; they are to be drawn following the methods illustrated in the text of this unit.

Divide the first drawing sheet into six equal areas, three down and two across.

Problem 1—Bisecting a Line

Draw a horizontal line in the center of this area, leaving a margin of 1″ from each border. Bisect this line, using the method illustrated in either Figure 98 or Figure 99.

Problem 2—A Ping-pong Table

In the space next to Problem 1, draw a ping-pong table 5′-0″ x 9′-0″, using the scale $\frac{1}{4}$″ = 1′-0″. Locate the position of the net by one of the methods of bisecting a line; use the other method to locate the line marking the two courts on each side.

Problem 3—Dividing a Line Equally

Draw a horizontal line to within $\frac{1}{2}$″ of each border of the area. This line should be two thirds of the way down in the space. Divide this line into six equal parts, using the method illustrated in Figure 100.

Problem 4—A Ladder

Draw the sides of the ladder 12′-0″ long and the space between the sides 1′-3″. Use the scale $\frac{1}{4}$″ = 1′-0″. Locate ten rungs in the ladder, using either method for dividing the side into equal spaces. Ten rungs will require eleven equal spaces.

Problem 5—Bisecting an Angle

Draw any convenient angle that fits well in the allotted space. Use the method described in Figure 102 to bisect the angle.

Problem 6—An Angle of $67\frac{1}{2}°$

An angle of $67\frac{1}{2}°$ is used for slant guide lines on inclined lettering. It may be constructed by drawing on a horizontal line a 45° angle to the left; this leaves an angle of 135° to the right. Bisect this 135° angle, using the method you used in Problem 5. You will then have a $67\frac{1}{2}°$ slant guide line.

GEOMETRIC CONSTRUCTION

Problems 1 and 2 require the upper half of the sheet divided in the center, and Problem 3 requires the lower half.

Problem 1—A Hexagon

Construct a regular hexagon with each side 1″ in length; use a T square, a 30°-60° triangle, and a compass. Notice that the radius of the circle is equal to one side of the hexagon. See Figure 110.

Problem 2—A Second Hexagon

Construct a hexagon having all sides equal to $1\frac{1}{2}$″. Use a compass and a triangle only, as shown in Figure 111.

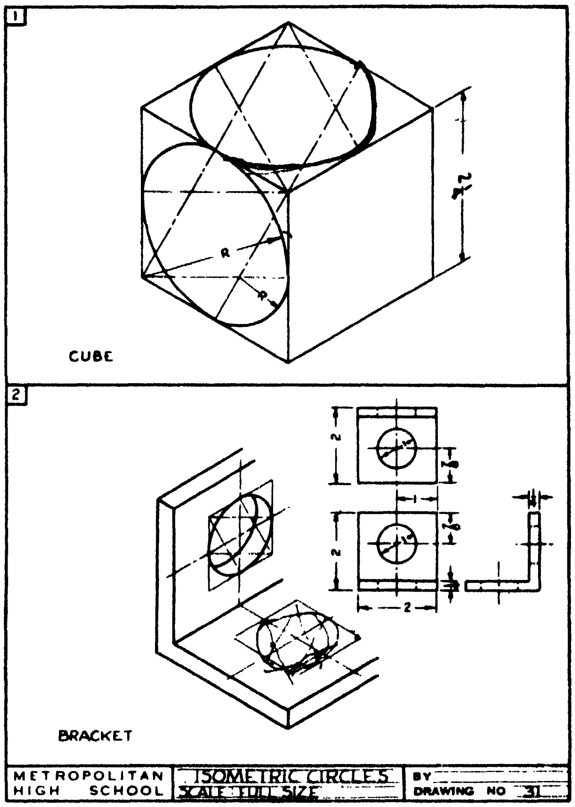

Fig. 116—ISOMETRIC CONSTRUCTIONS (PROBLEMS 1 AND 2)

Problem 3—Ellipse

For the ellipse to be constructed use the concentric-circle method illustrated in Figure 113. The major axis is 5″ and the minor axis 3″.

ELLIPSES

Problem 1—Pin-and-String Method

Using the pin-and-string method shown in Figure 114, make an ellipse with a major diameter of 4″ and a minor diameter of $2\frac{1}{2}$″. A more accurate ellipse may be obtained by using thread rather than string. Hold the pencil in a vertical position while you are drawing.

Problem 2—Circles in Oblique

In oblique projection a circle becomes an ellipse. To draw objects having circular faces in oblique it is essential to know how to make these ellipses. Draw a circle in oblique in a parallelogram with each of its four sides equal to 2″ and with angles of 45° and 135°. Use the method illustrated in Figure 115.

ISOMETRIC CONSTRUCTIONS

To draw a circle isometrically presents the problem of drawing an ellipse. Since exact methods of constructing an ellipse are long and require considerable time, an approximate method is generally used. This method is described and illustrated on pages 58 and 59. It results in an oval instead of an ellipse.

Problem 1—Isometric Circles

Draw a $2\frac{1}{4}$″ cube isometrically in the center of your upper panel (see Figure 116) and draw isometric circles in the three faces.

Problem 2—Bracket

Design an angle bracket with a circular hole in each leg. Make an isometric drawing of the bracket. The holes will be isometrically drawn as shown in Figure 116. A second oval indicates the thickness.

ANGLES AND TRIANGLES

Problem 1—Angles

Divide Problem 1 area into four equal parts with very light lines. In the first part construct a right angle, in the second an obtuse angle, in the third an acute angle, and in the fourth a straight angle. Letter the name of the angle under each.

Problem 2—Transferring an Angle

In the upper half of the area construct an angle of 37°, using your protractor as explained on page 4. Transfer this angle to the lower half of the area, using the method described for Figure 103.

Problem 3—Triangles

Plan Problem 3 area so that you can construct the following triangles: right, equilateral, isosceles, obtuse, and scalene.

Problem 4—Transferring a Triangle

In the upper half of the space construct a triangle having sides of $1\frac{1}{4}''$, $1\frac{3}{4}''$, and $2''$. In the lower half transfer this triangle by the method illustrated in Figure 107.

TANGENT ARCS

Problem 1—Constructing an Arc Tangent to Two Perpendicular Lines

Construct in the upper third of your sheet an arc with a $\frac{3}{4}''$ radius tangent to two perpendicular lines. See Figure 108A.

Problem 2—Constructing an Arc Tangent to Two Oblique Lines

In the center third of the sheet construct an arc with a $2''$ radius tangent to two lines which intersect at 135°. See Figure 108B.

Problem 3—Constructing an Arc Tangent to Two Arcs

Construct an arc with a radius of $\frac{1}{2}''$ tangent to an arc of $2''$ radius and a second arc of $1''$ radius.

QUESTIONS

1. Name some applications of mathematics to science or engineering.
2. What does the word *geometry* mean?
3. What is the name given to the process of dividing a line or an angle into two equal parts?
4. Define a right, an obtuse, an acute, and a straight angle.
5. Name four kinds of triangles.
6. Hexagons are drawn frequently in machine drafting to show what common object?
7. What name is given to the oblique projection of a circle?
8. What instrument is used to bisect a line or an angle?
9. Which method of constructing an ellipse requires the use of a French curve?
10. In drawing a hexagonal bolt head which method of constructing a hexagon should be used?
11. What is meant by the word *bisect?*
12. What is a tangent?
13. In constructing an arc tangent to two lines, how do you locate the center of the arc?
14. Name some of the common types of lines.
15. What relationship exists between a tangent to a circle and a radius of the circle drawn to the point of tangency?
16. Describe two methods of dividing a line into several equal parts.
17. Isometric circles and oblique circles are similar. Just what difference exists?
18. If you draw a circle and then use the radius to step off distances along the circumference equal to the radius, you have divided the circumference into a number of equal parts. What kind of figure do you get if you connect the adjoining points with straight lines?
19. Name two methods of drawing exact ellipses.
20. List several geometric divisions and several geometric constructions that are described in this unit.

TOPICS FOR DISCUSSION

1. Examine a truss of a bridge or one supporting the roof of a building to see the geometric shapes formed by the members. Describe to the class what you saw.

2. There are many geometric constructions other than those described in this unit. Find one of them and explain the construction.

3. A carpenter frequently has to lay out geometrical patterns. Describe one of these and show how the carpenter lays it out.

4. A surveyor in surveying land uses a transit to read angles and measure distances. A large portion of surveying is based on geometry and trigonometry. Can you give a few simple uses of the transit?

5. Geometry is one of the oldest branches of science. See what you can find out about the early history of geometry and about such men as Euclid and Archimedes.

6. The geometry used in this unit is commonly referred to as plane geometry. There is also another kind called solid or three-dimensional geometry. Explain to the class the nature of each kind.

7. There are geometric methods of constructing regular polygons of five, seven, eight, and nine

sides. These are very interesting but do not have many direct applications to industry. Can you demonstrate to the class one of these constructions?

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UNIT VII

SHEET-METAL DRAFTING AND SURFACE DEVELOPMENT

DRAWINGS AND PATTERNS

Each year millions of articles are made from thin sheets of metal. These include such familiar objects as toys, pails, funnels, cans, tin cups, baking tins, stovepipes, tanks, ventilators, gutters, and downspouts. The metals commonly used are steel, iron, brass, copper, aluminum, tin, lead, and zinc. The thin sheets of these metals are changed by the *sheet-metal worker* or *tinsmith* to the special forms needed by the consumer.

Shown in Figure 117 are three common articles—an elbow, a gutter, and a funnel—made from sheet metal. A drawing or pattern is necessary for the worker who is to make any of these. The drawing of the object represents a pattern laid out on a flat sheet in the true size and shape. Notice that the cube in Figure 118 is made by folding a series of six squares arranged in a definite order on a flat surface.

It is frequently helpful in understanding the problems of sheet-metal drawing to make heavy paper or cardboard patterns and fold them into the shapes desired. If you wish, the edges of the model may be held together with Scotch tape or airplane glue.

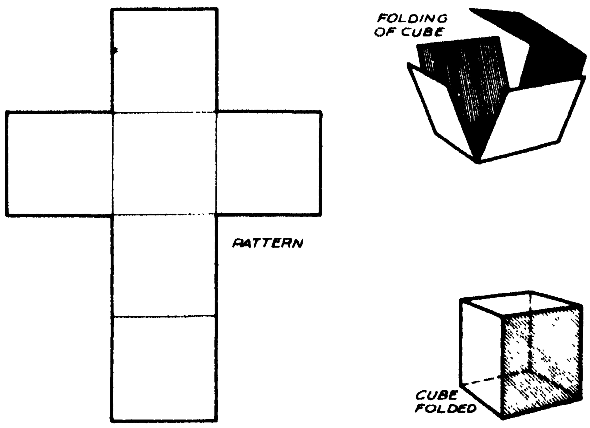

Fig. 118—CUBE DEVELOPMENT

Most companies making articles in large numbers find it cheaper to work with heavy paper in developing new patterns rather

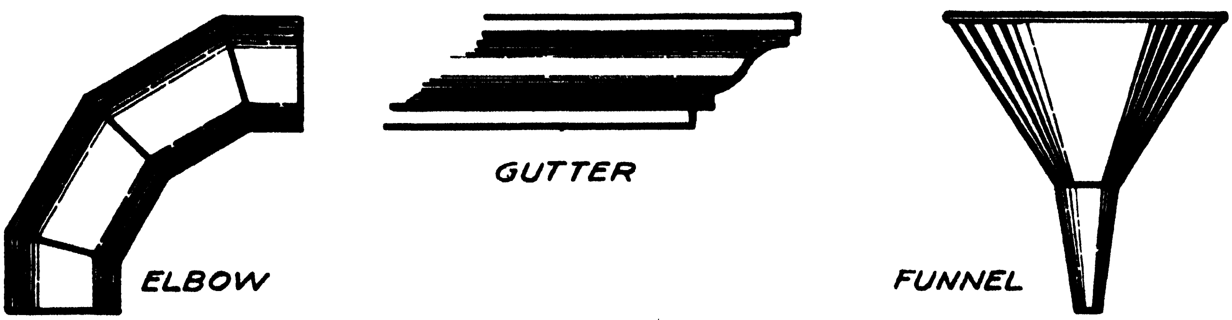

Fig. 117—SHEET-METAL ARTICLES

than to lay out the work directly on the sheet metal. Should the pattern be wrong or spoiled, a new one can be made without much loss. When the pattern has been developed correctly, production is started in metal.

The man who works with sheet metal must be able to understand a special form of drawing and must also have the ability to perform many hand and machine operations in shaping the metal to make the desired articles.

HEMS AND SEAMS

Articles of metal often have *hems*, formed by turning the edges to stiffen them and give smooth, rounded edges. Sometimes an edge is further strengthened by inserting a wire in the hem and bending the metal around it. Whenever metal is used, additional material is needed for forming the *seams* that close the joints; these seams may also strengthen the article. Figure 119 shows an allowance for the seams of a pyramid. Seam allowance is needed on only one of two meeting edges. Some of the

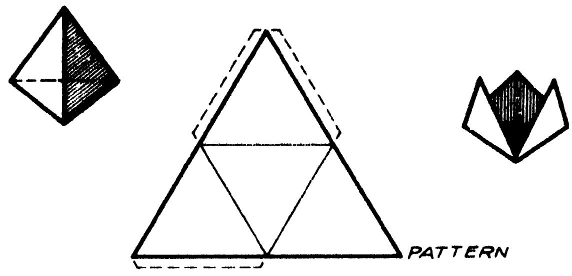

Fig. 119—SEAMS ON A PYRAMID

common hems, a wired edge, and seams used in metalwork are shown in Figure 120.

The amount of material required for seams depends upon the thickness of the metal used and the kind of joint. In industrial practice sheets range from $\frac{1}{160}''$ to $\frac{1}{4}''$ in thickness. Anything over $\frac{1}{4}''$ is considered *plate*. The thickness of galvanized iron is indicated by gauge number; the gauges commonly used are 24 and 26. Most articles of tin are 26- and 28-gauge. Copper is measured by the number of ounces to the square foot; a weight of 16 ounces is commonly used.

In laying out sheet-metal jobs, allowances must be made for laps and seams,

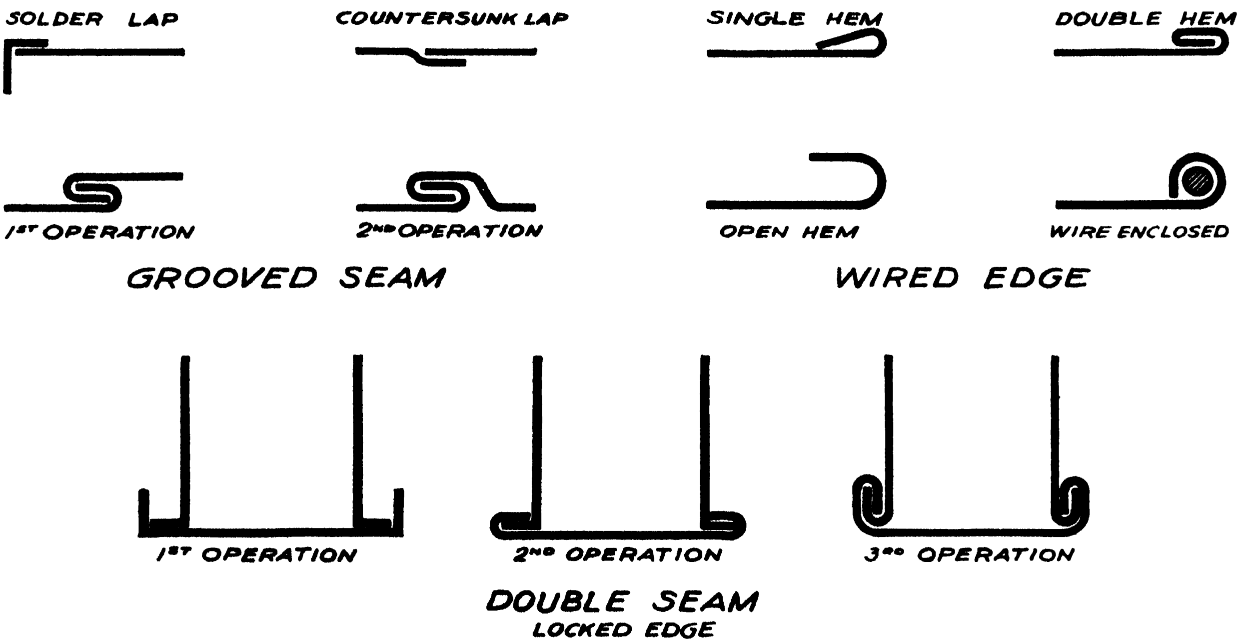

Fig. 120—METAL SEAMS AND EDGES

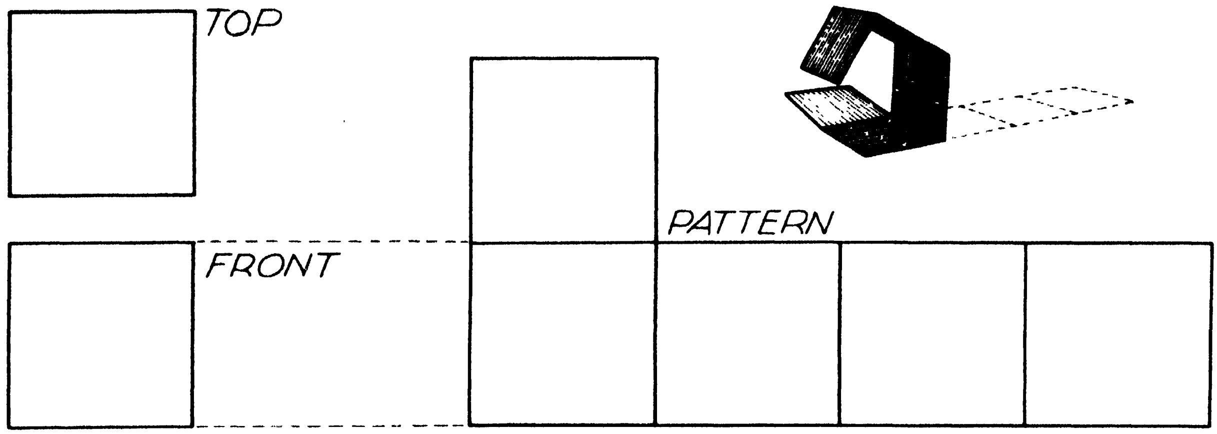

Fig. 121—DRAWING AND PATTERN FOR A SMALL BOX

thickness of material, commercial sizes of the sheets, and economy in cutting and using the material. The illustrations and problems in this unit do not include an allowance for hems and seams but show only the various surfaces of the object.

DEVELOPMENT OF PATTERNS

Because it is necessary for the sheet-metal worker to have a pattern of the combined surfaces of the object which he is to make, the draftsman must lay out these surfaces in such a manner that their true shapes and sizes are formed into a flat pattern. In this pattern the surfaces must be in their proper relationships to one another; and, wherever possible, the surfaces should be attached to one another so as to form a single sheet. A drawing of this kind of pattern, which is called *surface development*, is used in sheet-metal work to determine the pattern of the object.

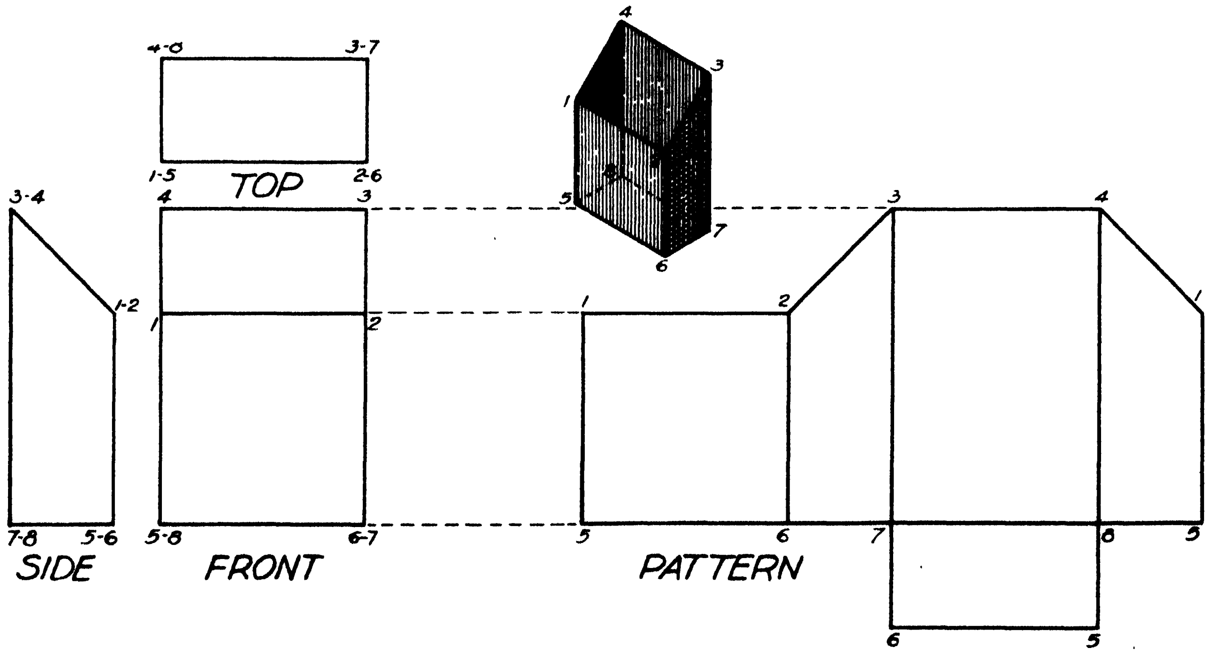

Fig. 122—DRAWING AND PATTERN FOR A MATCHBOX HOLDER

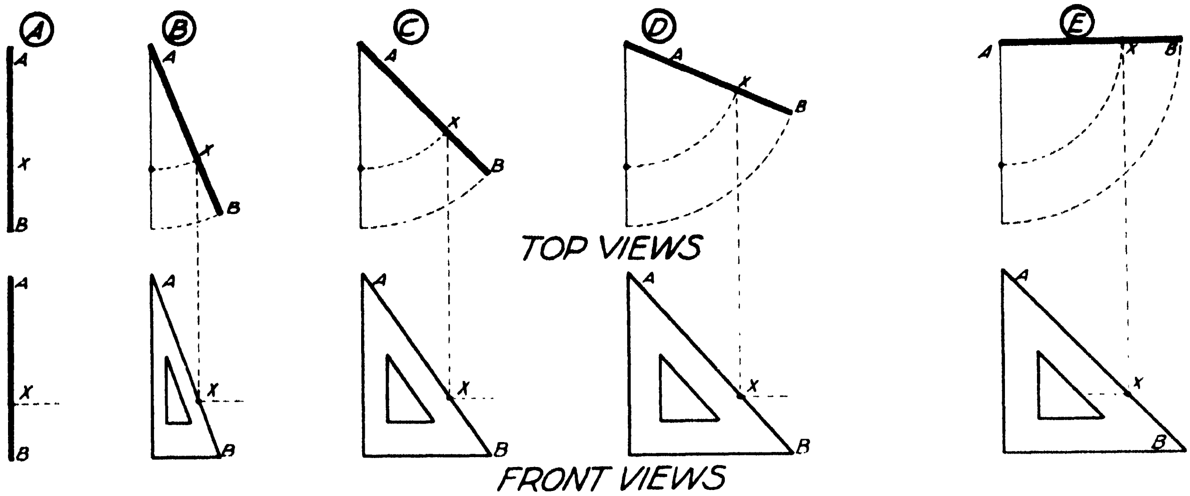

Fig. 123—THE TRUE LENGTHS OF LINES

There are three methods of making surface developments: by *parallel* lines, *radial* lines, and *triangulation*. A box or cubelike form can best be developed by the use of parallel lines.

DEVELOPMENT OF A CUBE

Figure 121 shows the drawing and pattern of a small box that is open at the top. The necessary two orthographic views, top and front, are drawn first. Project the *stretch-out line* from the base of the front view to form the base line of the development. The heights are projected from the front view to the pattern, and the widths of the sides are measured on the top view and laid off on the pattern. The bottom is measured in its true dimensions and added to one of the sides. The pictorial illustration shows how such a pattern actually folds.

Figure 122 shows a matchbox holder, the pattern of which is laid out in the same manner as for the box except that the shape and dimensions of the sides vary. To avoid confusing the surfaces, it is desirable to number each corner as shown in the pictorial illustration. Number each corner of the pattern and three-view drawing correspondingly. In this case the side view must be shown so that a true pattern of the side may be drawn. The left-side view is shown in place of the right in order to make the drawing less confusing. The heights are projected from either the front or side view. Care must be taken to project the height of each corner to the correspondingly numbered corner in the pattern.

THE TRUE LENGTHS OF LINES

In the previous examples all the surfaces were in true view and therefore could be measured directly because the corner lines on which measurements were indicated were true in length. However, we often have to lay out surfaces that are inclined, and consequently the lines that indicate the corners or edges are foreshortened and do not show the true lengths of the edges. Therefore we must alter the position of the object so that these foreshortened lines can be measured in their *true lengths*.

If we turn or revolve a 45° triangle as shown in Figure 123, we can easily see that the length of the line *AB* varies considerably in the front views. Observe the five different lengths of *AB*, which in each

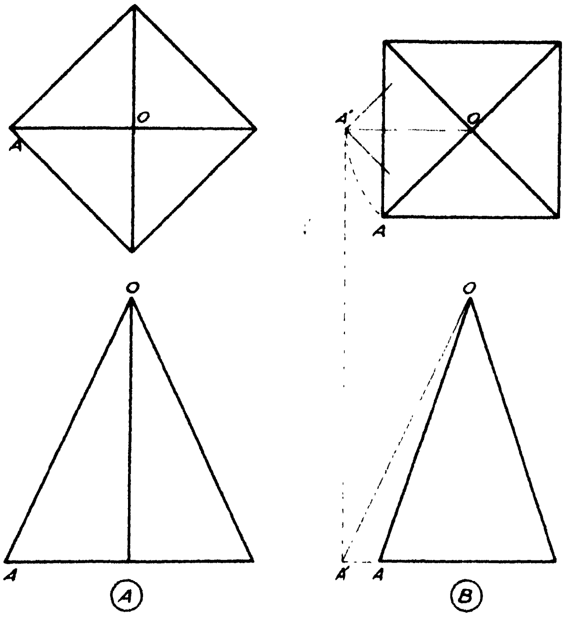

Fig. 124—THE TRUE LENGTHS OF EDGES ON A PYRAMID

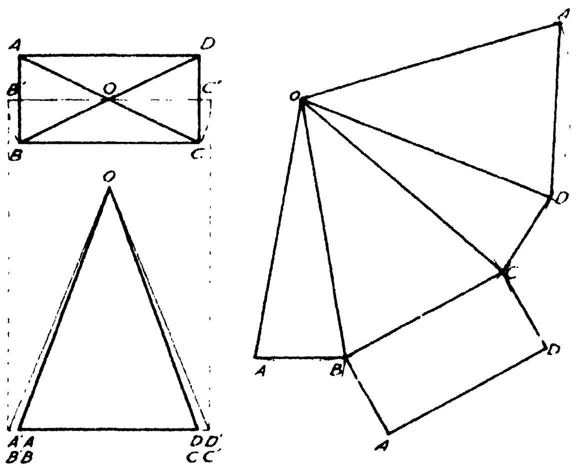

Fig. 125—DEVELOPMENT OF A PYRAMID

position represents the same edge of the triangle. Obviously the true length of AB is found only in the position E. Also notice that the true lengths from A to X and from B to X are found only in the last view.

True Lengths of Edges on a Pyramid

We encounter exactly the same situation with the pyramid in Figure 124. When the top view is drawn as shown in position A, line OA in the front view is the true length. But, if the view is drawn as shown in position B, we can easily see that line OA of position B is a little shorter than OA in position A. To overcome this difference, we do just what we did with the triangle: we theoretically revolve the pyramid so that OA takes the position of OA'. By measuring we find that OA' in position B is the same length as OA in position A.

DEVELOPMENT OF A PYRAMID

Development of a Regular Pyramid

To develop a pyramid (see Figure 125), the usual two views are first drawn and then the true lengths of OB and OC are obtained by constructing OB' and OC'. Since OA, OB, OC, and OD are all the same length, OB' is the true length for all four slanting edges of the pyramid. This fact can be verified by checking OB' with OC'. When all the slanting edges of a pyramid are the same length the pattern is laid out by drawing an arc whose radius is equal to the true length, measuring off the sides of the base around the arc, and draw-

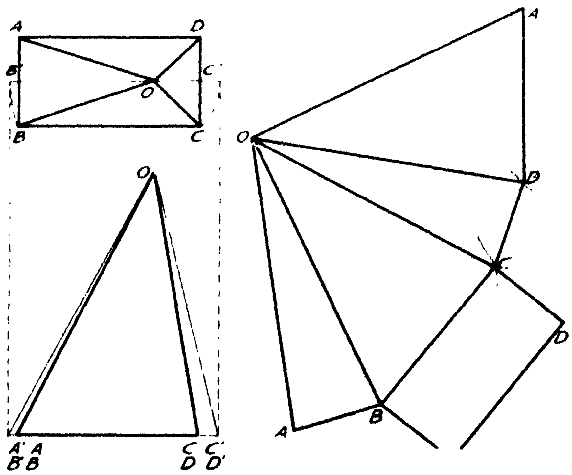

Fig. 126—DEVELOPMENT OF AN OBLIQUE PYRAMID

ing the folding edges to the center of the arc. Construct the base in its true shape and dimensions on the base line of any one of the triangular surfaces. This is the development of a regular pyramid

Development of an Oblique Pyramid

The pyramid in Figure 126 has corner lines of two different lengths; it is called an oblique pyramid. Consequently the true length must be found for each pair of corner lines. *OA* and *OB* are equal in length, and *OC* and *OD* are equal in length. Therefore *OB′* and *OC″* will give the required true lengths for each pair of edges.

In laying out the pattern, each triangular surface is constructed as a triangle with the three sides given. For example, construct line *AB* in the pattern equal to line *AB* in the top view. With the true lengths of *AO* and *BO* and with points *A* and *B* as centers, strike the intersecting arcs at *O*. Draw *AO* and *BO*, the true lengths. This process is explained on pages 73-74.

It is important in sheet-metal work to use as much continuous metal as possible and to have the least number of joints. Continue with the next triangular surface, using *BO* as the base. The triangles must be constructed so that each pair has a common side. Draw the pattern for the remaining triangular surfaces and attach the base in its true shape and dimensions.

Development of a Partial Pyramid

Figure 127 shows a pyramid the upper part of which has been cut off so that the lower part can form a *transition* piece. In geometry, when the top of a pyramid is cut off it is said to be *truncated.* Transition pieces are frequently used to join ducts and sheet-metal pipes of different sizes and shapes. The pattern is made by laying out the full pyramid and then laying out on the same pattern a second, partial pyramid at the top to show the part to be removed. This development is the same as for the pyramid shown in Figure 125.

It should be noted that the true length of lines *O1* and *O2*, as well as *O3* and *O4*, is obtained by projecting points 1-2 and 3-4 in the front view to the true-length lines at points 1′-2′ and 3′-4′. Therefore *O1′* and *O2′* equal the true length of all the edges of the part of the pyramid that is to be removed. The pattern is laid out using

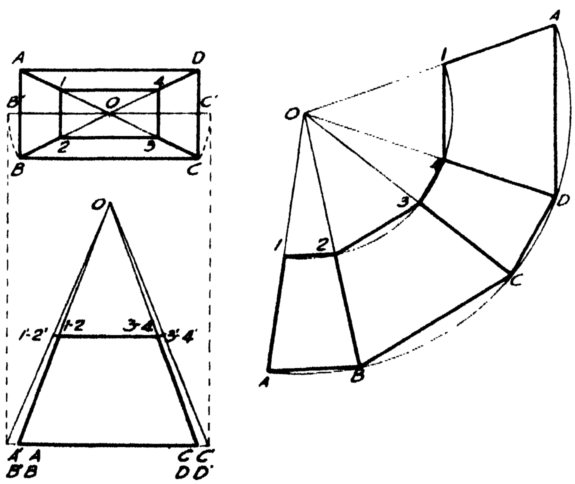

Fig. 127—DEVELOPMENT OF A PARTIAL PYRAMID

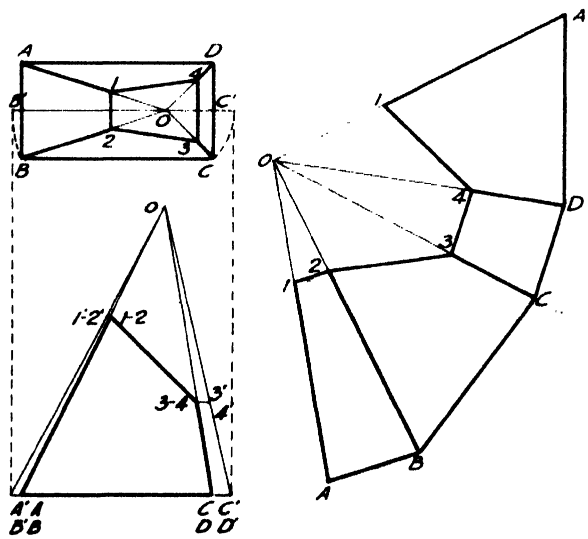

Fig. 128—IRREGULAR TRANSITION PIECE

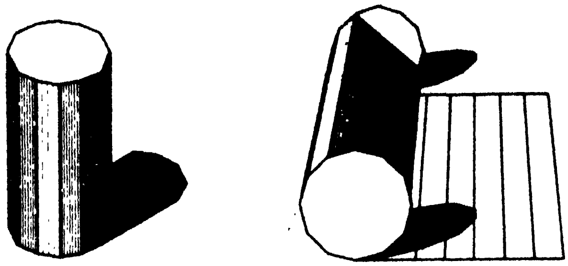

Fig. 129—CYLINDER REPRESENTED WITH FLAT SIDES

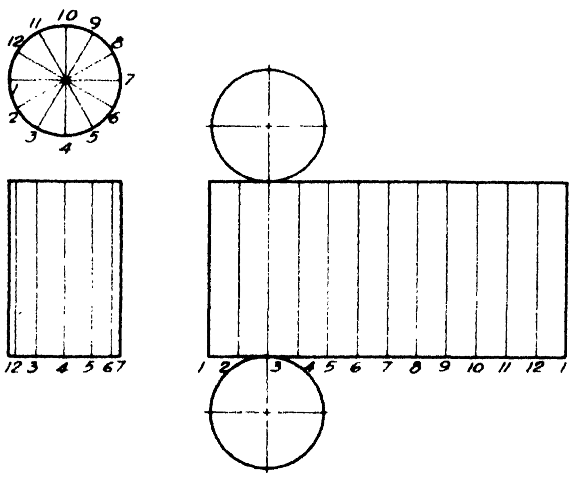

Fig. 130—DEVELOPMENT OF A CYLINDER

the long and short lengths as radii and then laying out the sides of the base on the base circle. After connecting the outside corners of the development with point *O*, connect points 1, 2, 3, 4, and 1.

The irregular transition piece shown in Figure 128 is first developed as a full pyramid as was the pyramid in Figure 126, and then the true lengths of the cut-off portion are determined as in Figure 127. These distances are indicated on the edges of the pattern, and the points are joined to show the portion of the pyramid that is to be removed. The remainder is the transition piece.

DEVELOPMENT OF A CYLINDER

The cylinder shown in Figure 129 is developed as having many flat sides. This is done because there is little difference between the length of a short straight line and the length of the arc which connects its end points.

Because an actual cylinder is not made up of flat surfaces and has no corners, *measuring lines*, or theoretical corners, must be added to the surface of the cylinder as shown in Figure 130. To show these, we draw the top and front views and then divide the top view into twelve equal parts by drawing horizontal and vertical lines and all possible 30° and 60° lines through the center. However, any convenient number of parts may be used; the more points used, the more accurate the pattern will be. Project the points located to the front view to construct the measuring lines of the cylinder. Proceed with the layout of the

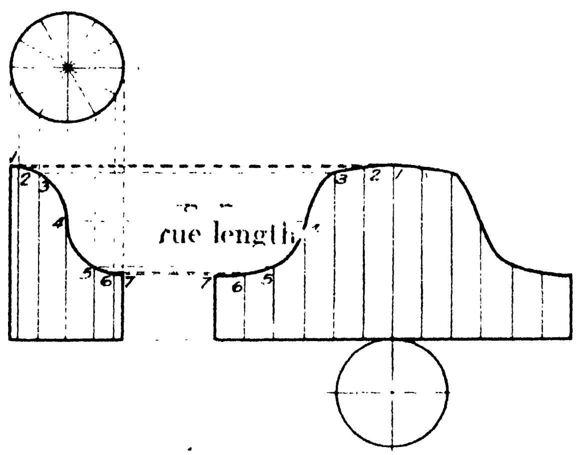

Fig. 131—DEVELOPMENT OF A SCOOP

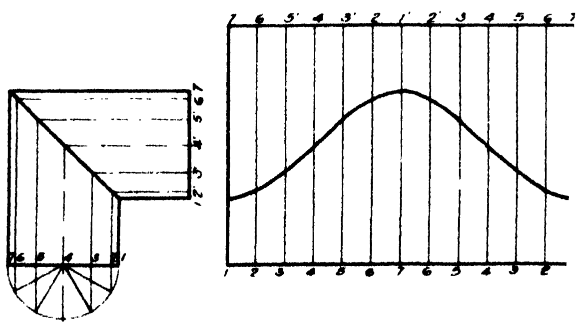

Fig. 132—DEVELOPMENT OF A TWO-PIECE ELBOW

pattern as for any prism, using the true distance between measuring lines as taken from the top view for the width of the theoretical flat surfaces. Then add the circular bases.

Development of a Partial Cylinder

Figure 131 illustrates a simple scoop. The procedure in the development of this pattern is the same as for the cylinder development except that the measuring lines are cut off by the curve of the scoop. The height of all measuring lines in the pattern must be the same as the corresponding lines in the front view. Therefore the heights are projected directly to the pattern provided that the stretch-out line is constructed as an extension of the base line of the scoop. Add the circular base at any convenient point along the stretch-out line.

A TWO-PIECE ELBOW

The two-piece elbow in Figure 132 is laid out in the same way as is the pattern for the scoop. You will notice that the pattern for both parts can be made from a single rectangular sheet because the curve on each piece is identical and the shallow part of one curve matches the deep curve of the other part. Construct a half plan of the base, which will be a semicircle, and divide it into six equal parts to give the location and spacing of the twelve measuring lines, or theoretical corners.

DEVELOPMENT OF A CONE

The cone in Figure 133 combines the principles of development of both the pyramid and the cylinder in that the pattern of the cone is made for a theoretical multisided pyramid. Lay out the pattern by using $O1$, which is in its true length, as the radius for the pattern. Lay off the distances for the twelve measuring lines and con-

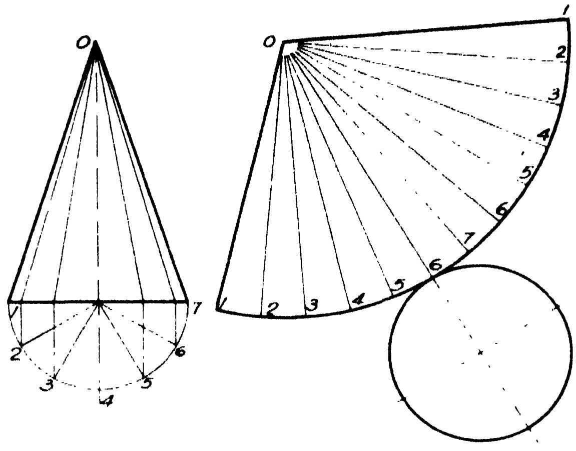

Fig. 133—DEVELOPMENT OF A CONE

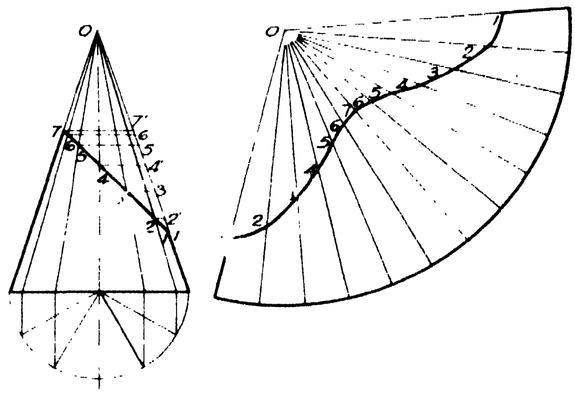

Fig. 134—DEVELOPMENT OF A PARTIAL CONE

nect the points to point O. The base is laid out by using the radius of the base of the cone as the radius for the pattern base. This is the second, or radial, method of development.

Development of a Partial Cone

The conical transition piece shown in Figure 134 is developed by laying out the pattern for the entire cone, obtaining the true lengths by projecting points 2 to 2′, 3 to 3′, etc., in the front view. Mark off the distances on the corresponding measuring lines of the pattern. Connect the indicated points to form the curve of the portion that is cut away from the original cone. Then improve the curve with a French curve.

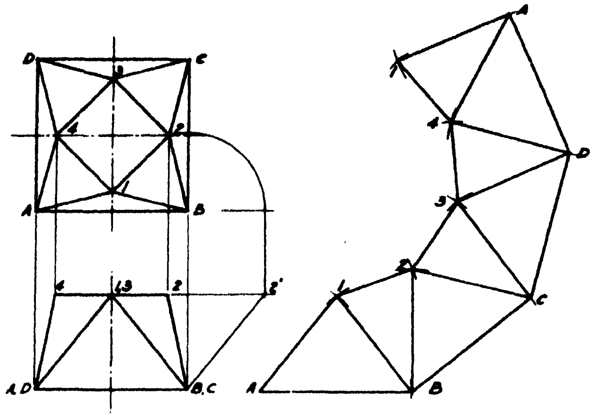

Fig. 135—A SQUARE-TO-SQUARE TRANSITION PIECE

TRIANGULATION

The square-to-square transition piece shown in Figure 135 is made up of triangular surfaces that can be laid out in pattern form after determining the true length of each side of each triangle. These true lengths can be obtained as shown on the front and top views. The triangles are laid out adjoining each other by use of the construction of a triangle with three sides given.

This method of development, triangulation, is also used to make patterns of curved surfaces that do not have the shape of a cylinder or a cone. The square-to-round transition piece shown in Figure 136 illustrates a curved surface that forms neither a cylinder nor a cone; nor is it made up of actual triangular surfaces, as is the transition piece that is shown in the preceding illustration.

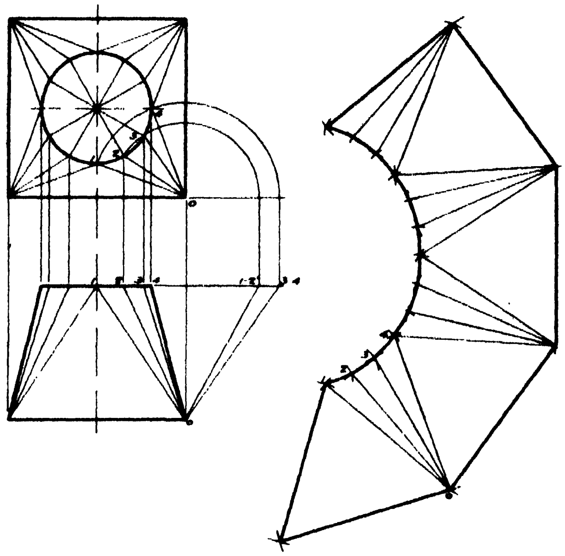

Fig. 136—A SQUARE-TO-ROUND TRANSITION PIECE

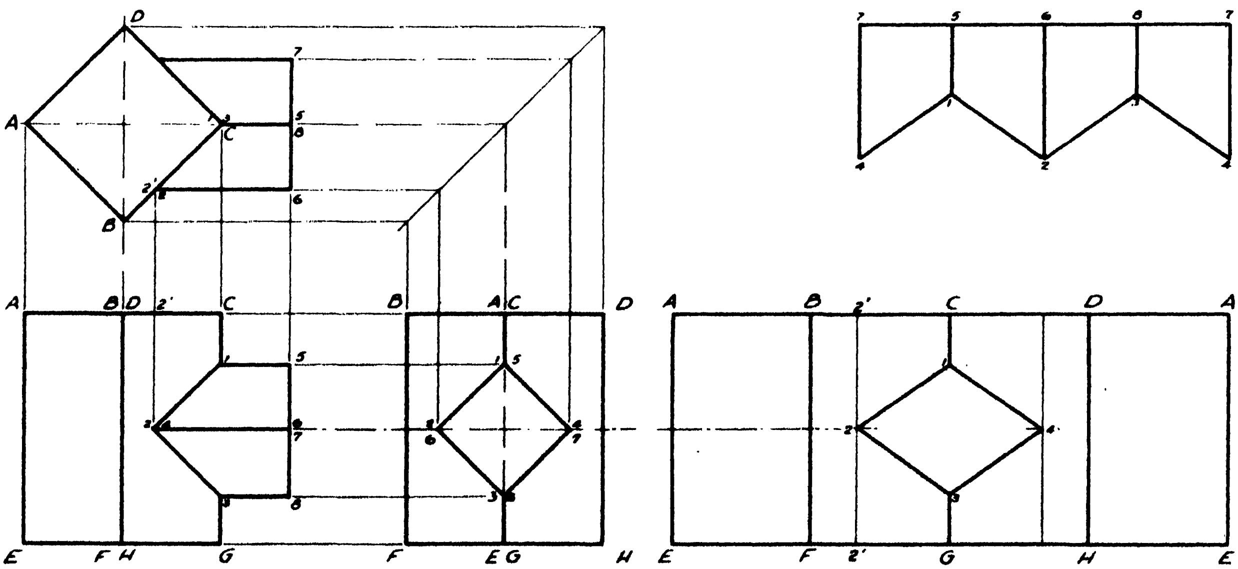

Fig. 137—INTERSECTION AND DEVELOPMENT OF TWO PRISMS

Therefore we must divide the surface into triangular areas. To do this, we must first divide the circular top into twelve equal parts. The points found are connected in groups of four to the nearest corner of the square base. The illustration shows the manner in which this is done. These lines divide the surface into sixteen triangles of three different shapes and sizes. By obtaining the true length of these measuring lines—*O*1 and *O*4, as well as *O*2 and *O*3—we now have the true dimensions of each of the sides of the triangles. The pattern is laid out by building up the triangles in the correct order, using the method explained for the square-to-square transition piece.

INTERSECTIONS

Many articles of sheet metal are made of more than one piece. When two or more pieces are used to make an article they must be joined. This line of junction between the two pieces of metal is called an *intersection.*

Intersection of Two Prisms

Figure 137 shows the intersection of two prisms. The top and side views are completely drawn first, and then a partial front view is laid out. Project point 2 from the side view and the top view so that the projections meet at point 2 in the front view. Connect points 1 and 2 and also 3 and 2 to complete the intersection and the front view.

In the development of the vertical prism, the points of intersection 1 and 3 on the corners are taken from either the front or side view and stepped off directly on the development. Step off the distance *B*-*2′* from the top view and transfer it to the development. Draw a vertical line through point *2′* on the development. Using your T square, project a horizontal line from point 2 in the front or side view until it intersects this vertical line in the development. This will locate point 2 on the intersection of the development. Point 4 is found in a similar manner.

In the development of the horizontal prism, the intersection is line 4-1, 1-2, 2-3, and 3-4. The necessary points are located by stepping off the true distances—7-4, 5-1, 6-2, and 8-3—from the front view.

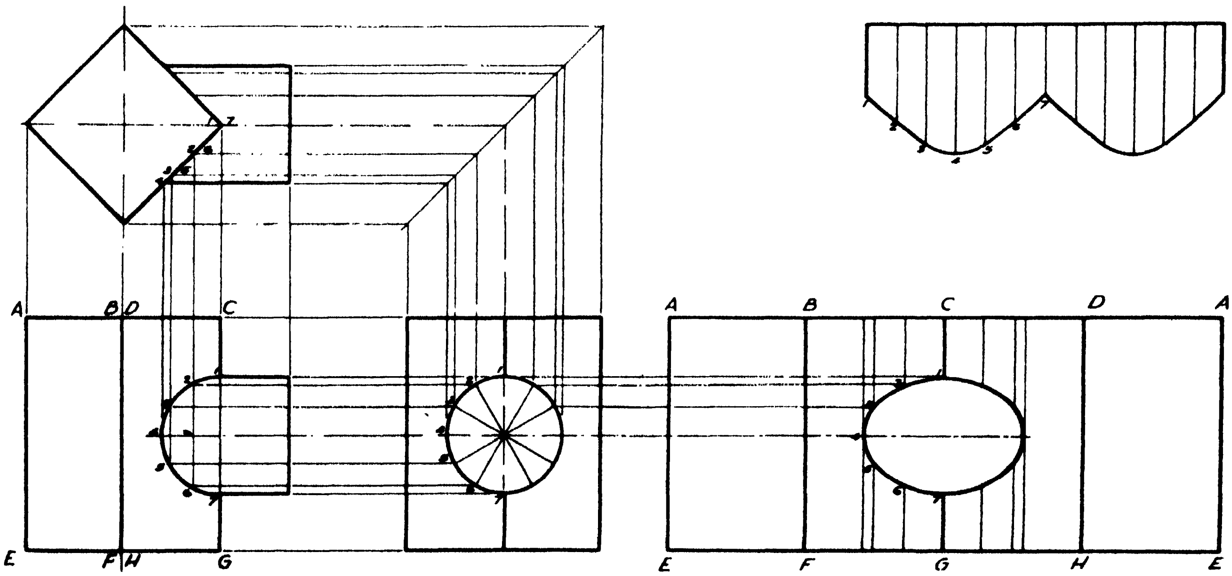

Fig. 138—INTERSECTION AND DEVELOPMENT OF A CYLINDER AND A PRISM

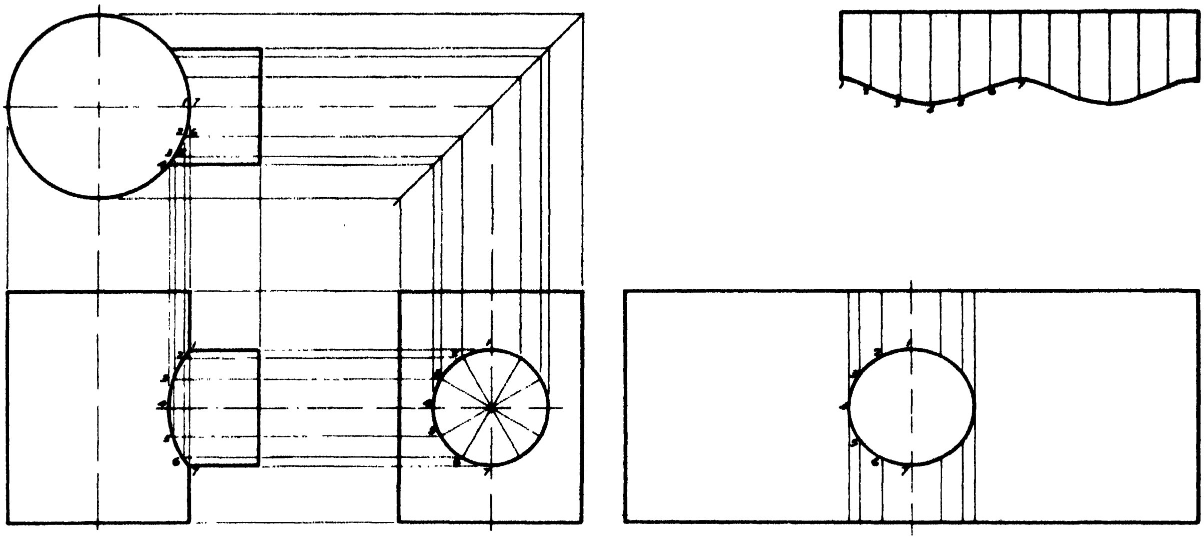

Fig. 139 — INTERSECTION AND DEVELOPMENT OF TWO CYLINDERS

Lines connecting points 4 and 1, 1 and 2, 2 and 3, and 3 and 4 are then drawn to complete the development.

Intersection of a Cylinder and a Prism

Figure 138 illustrates how the intersection of a cylinder and a prism is found and how the two pieces are developed. Draw the top, side, and partial front views. In the side view divide the circle into twelve equal parts. Project each of these elements to the front and top views. Then project the elements from the top view to the front view. The crossing of corresponding element lines locates points on the intersection. A line is sketched through points 1, 2, 3, 4, 5, 6, and 7 and then carefully drawn with the French or irregular curve.

Make the development of the prism by projecting the height from the side view and the length from the sum of the sides stepped off in the top view. The location of the intersection is determined by projecting horizontally points 1, 2, 3, 4, 5, 6, and 7 from the side view. The distances 1-2, 2-3, and 3-4 in the top view are stepped off on each side of vertical line *CG* in the development. Draw vertical lines through each of these points determined until they intersect the horizontal lines at points 1, 2, 3, 4, 5, 6, and 7 in the development. Draw the curve through each of these points and then complete the ellipse.

In the development of the cylindrical piece, the length is equal to the circumference of the circle. The length of the vertical elements in the development are stepped off from either the top or front view.

Intersection of Two Cylinders

Figure 139 illustrates the intersection of two cylinders. The procedure indicated is similar to that used for the intersection of the cylinder and the prism.

SUMMARY

Many articles are made of sheet metal by sheet-metal workers and tinsmiths. In order to make these objects, the workers must have patterns to use in cutting the metal. Allowances must be made for seams and hems. The amount of allowance depends upon the type of joint, the thickness, or gauge, of the metal, and other factors.

Fig. 140—UNUSUAL SHEET-METAL OBJECTS

Patterns, which are sometimes called surface developments, are made by the use of parallel lines, radial lines, or triangulation. In the parallel-lines method, the base of the development is commonly called the stretch-out line. All horizontal distances are measured from the top view and stepped off on this line. All vertical distances are measured on the front or side view and then located on the development.

The shapes of some objects require that true lengths of certain lines be found before a development can be made. This is done by revolving the line and projecting it to another view to obtain its true length.

Methods of making developments of pyramids, cones, cylinders, and elbows are presented here, for these forms occur frequently in practice.

When two ducts of sheet metal come together, the intersection formed must be worked out; this is done by making the developments and by using the edges or measuring lines to determine points of intersection on the development. From these the lines of intersection are made.

DEVELOPMENT OF A PRISM AND A CYLINDER

Problem 1—Rectangular Box

Draw the front and top views of the rectangular matchbox located as shown in Figure 141. Start the development at the

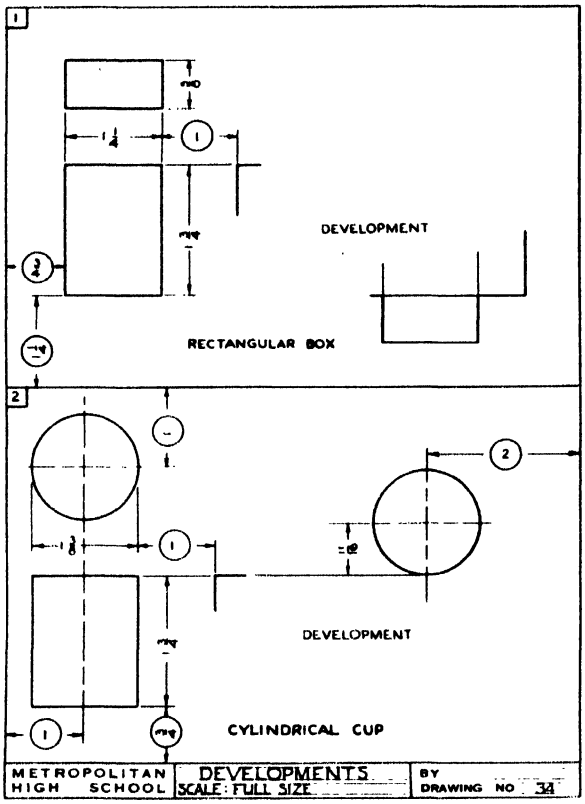

Fig. 141—DEVELOPMENT OF A BOX AND A CYLINDER (PROBLEMS 1 AND 2)

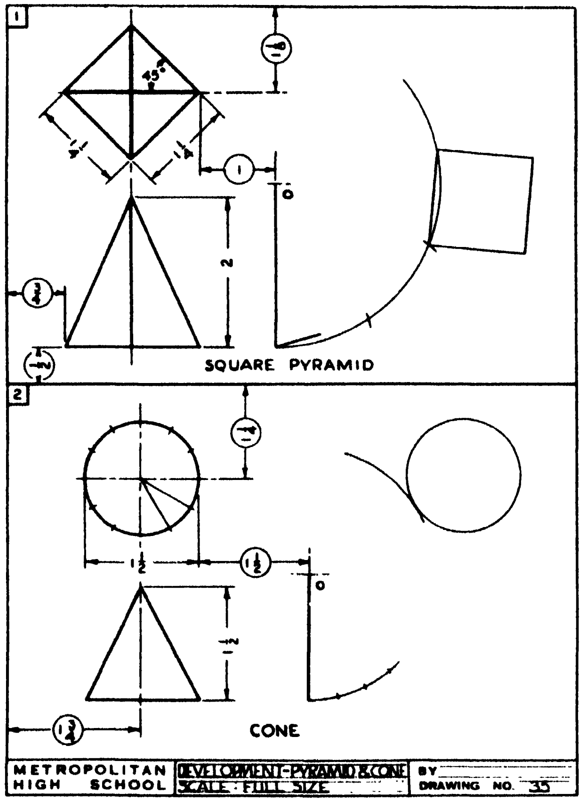

Fig. 142—DEVELOPMENT OF A PYRAMID AND A CONE (PROBLEMS 1 AND 2)

right of the front view and develop all six sides of the object. If difficulty is encountered in obtaining the ends of the lines, these points may be numbered. The length of each vertical line is projected from the front view. The other distances may be stepped off with the dividers from the top view.

Problem 2—Cylindrical Cup

Draw the front and top views in the left portion of the space as shown in the illustration. Project the development to the right of the front view. Notice that the base is shown on the top of the development. For the procedure refer to Figure 130 and its description. Divide the circumference in the top view into twelve equal parts.

DEVELOPMENT OF A PYRAMID AND A CONE

Problem 1—Pyramid

Draw the front and top views of the pyramid in Figure 142. Begin the development at point *O* and complete it, including the base. Make sure that the true length of the edge is used for the radius in making the layout. Refer to Figures 124 and 125 and the accompanying descriptions for the procedures in getting true lengths of lines and working out developments.

Problem 2—Cone

In making the development of the cone, use at least twelve equal divisions of the circumference. Draw the pattern of the base touching, or tangent to, the rest of the development.

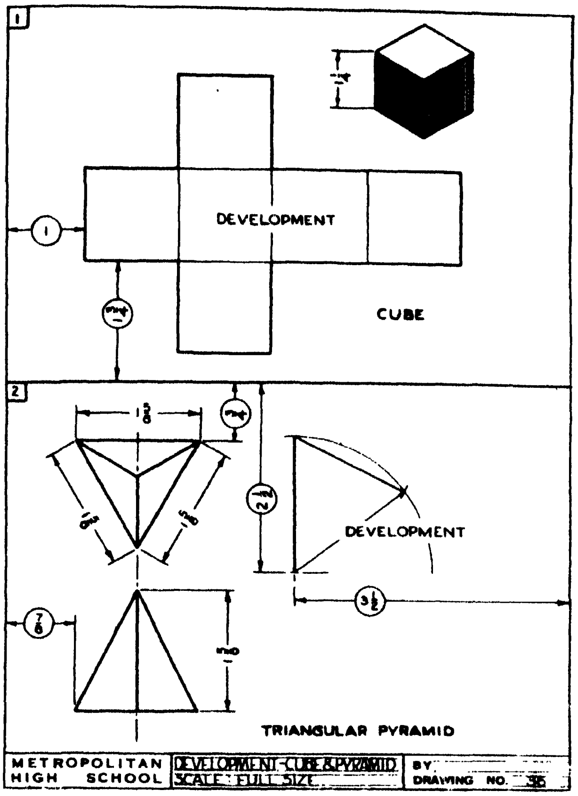

Fig. 143—DEVELOPMENT OF A CUBE AND A PYRAMID (PROBLEMS 1 AND 2)

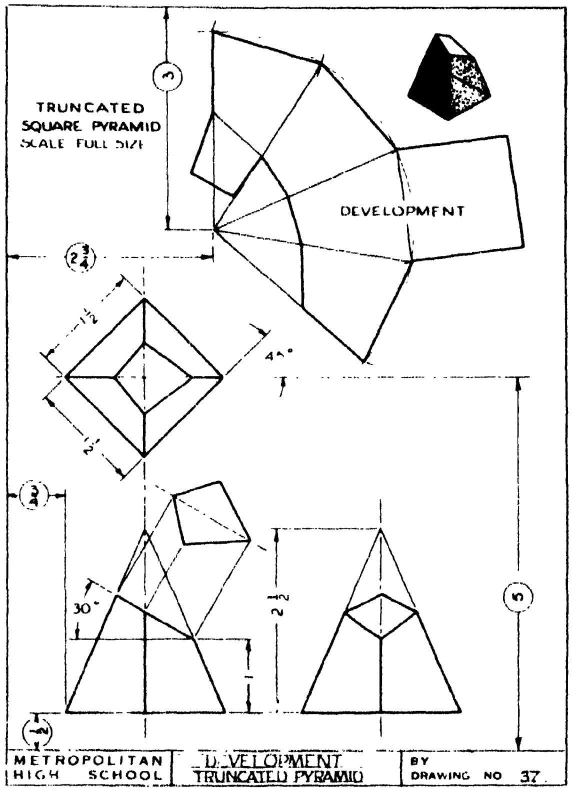

Fig. 144—DEVELOPMENT OF A TRUNCATED PYRAMID (PROBLEM)

DEVELOPMENT OF A CUBE AND A PYRAMID

Problem 1—Cube

Draw the pattern, or development, of a cube having each edge equal to $1\frac{1}{4}''$. See Figure 143.

Problem 2—Pyramid

Draw the front and top views of the pyramid. The true length of the slant height must be obtained before making the development. See Figure 124 for procedure. Make a complete development of the pyramid.

DEVELOPMENT OF A TRUNCATED PYRAMID

Draw the front, top, and side views and a development of the truncated pyramid. See Figure 144.

DEVELOPMENT OF A TRUNCATED CONE

Draw the front, top, side, and auxiliary views and make a development of the truncated cone. See Figure 145.

DEVELOPMENT OF A TWO-PIECE ELBOW

A two-piece elbow is nothing more than two cylinders which have been *mitered* together, that is, fitted on a 45° line. In Figure 146 the length of the development is obtained from the circumference of one of the cylinders. The width may be obtained by adding the longest element of piece A and the shortest element of B. Draw the front and top views and the developments.

DEVELOPMENT OF A SCOOP

The cylindrical portion of the scoop in Figure 147 is developed in the same manner as the cylinders in Figure 146 except

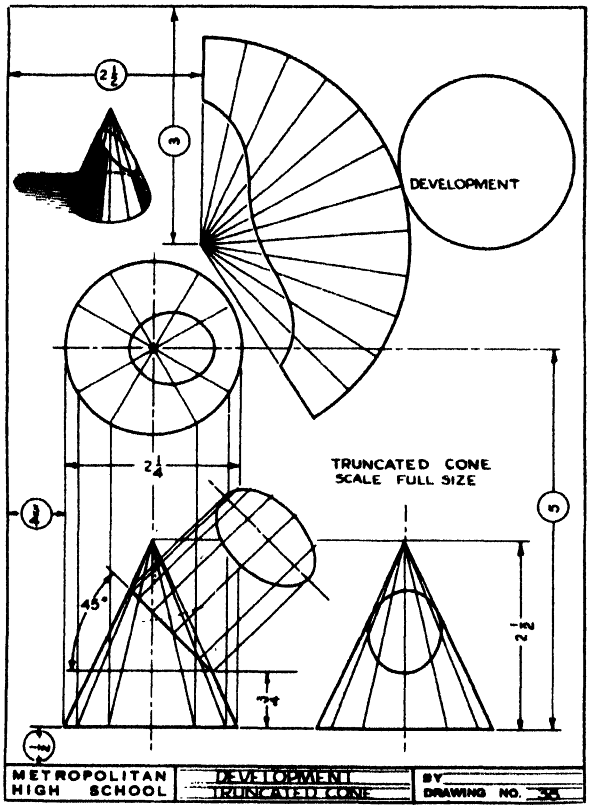

Fig. 145—A TRUNCATED CONE (PROBLEM)

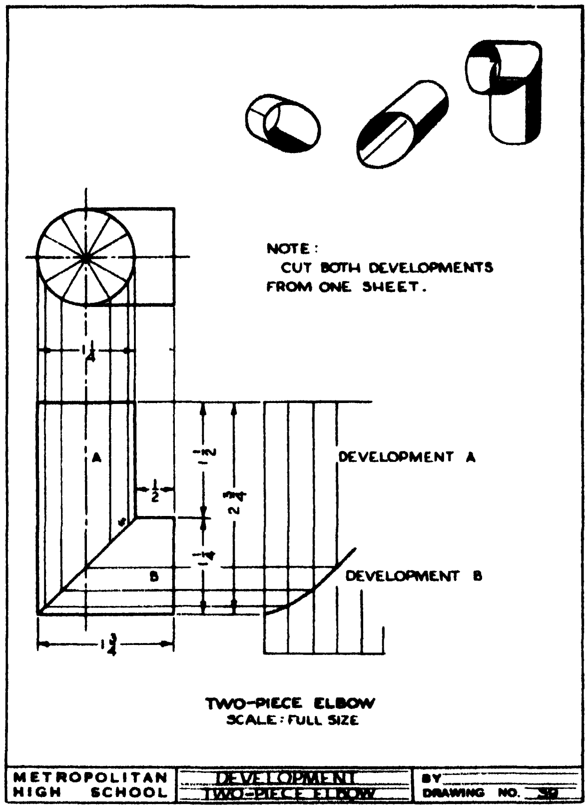

Fig. 146—A TWO-PIECE ELBOW (PROBLEM)

that one part of the scoop is only a half cylinder. The end of the scoop is a semicircle. The length of the handle may be stepped off from the side view.

INTERSECTIONS AND DEVELOPMENTS OF TWO PRISMS

Draw three views of the prisms in Figure 148 and project the lines of intersection in these views. Make developments of parts A and B.

INTERSECTION AND DEVELOPMENT OF A PRISM AND A CYLINDER

Draw intersections on the three views in Figure 149 by dividing the circle into twelve parts and projecting points to the two other views. Plot the intersections on the developments by stepping off the true lengths from the three views.

INTERSECTION AND DEVELOPMENT OF TWO CYLINDERS

Place the three views in Figure 150 in the lower portion of the sheet. Work out the intersection in the front view by dividing the upper circle into twelve parts and then projecting points of intersection to the side view and the front view. Draw developments of parts A and B, locating them in approximately the position shown in the figure.

A DUSTPAN

Draw the top and front views of the dustpan in Figure 151. Draw the development of the pan portion first, stepping off true-length distances from the two views. Start the development in the indicated corner. The handle is cylindrical in shape and fits at 30° against a right angle. Work

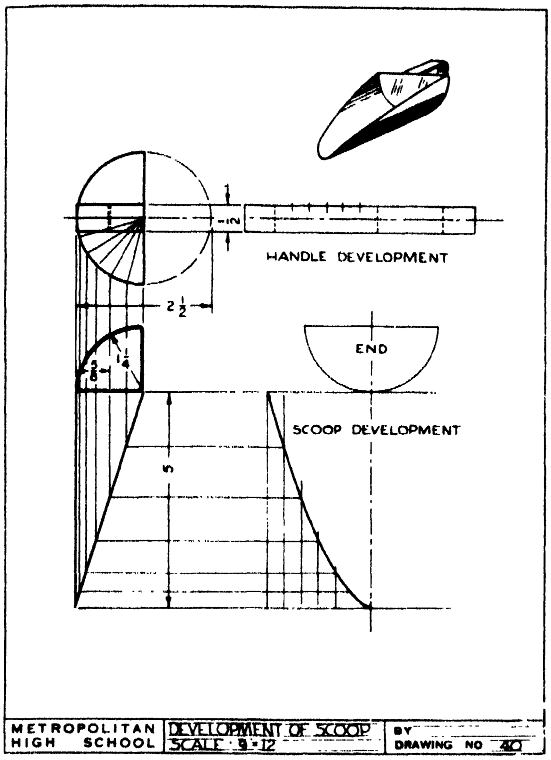

Fig. 147—A SCOOP (PROBLEM)

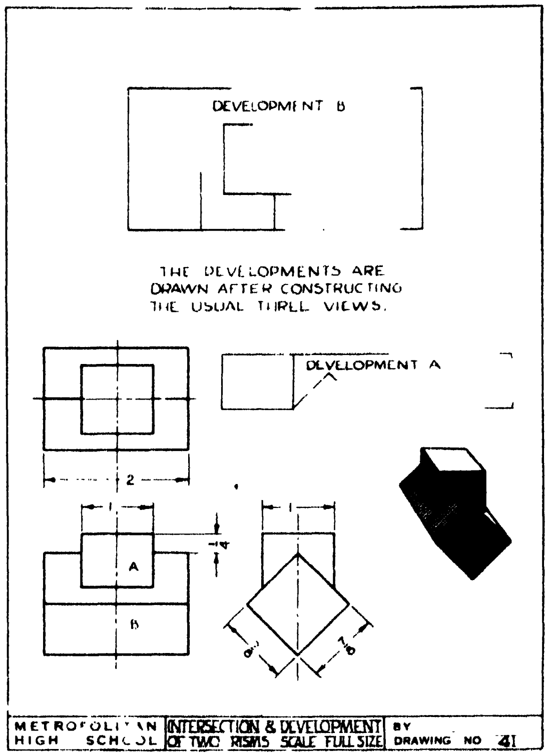

Fig. 148—TWO PRISMS (PROBLEM)

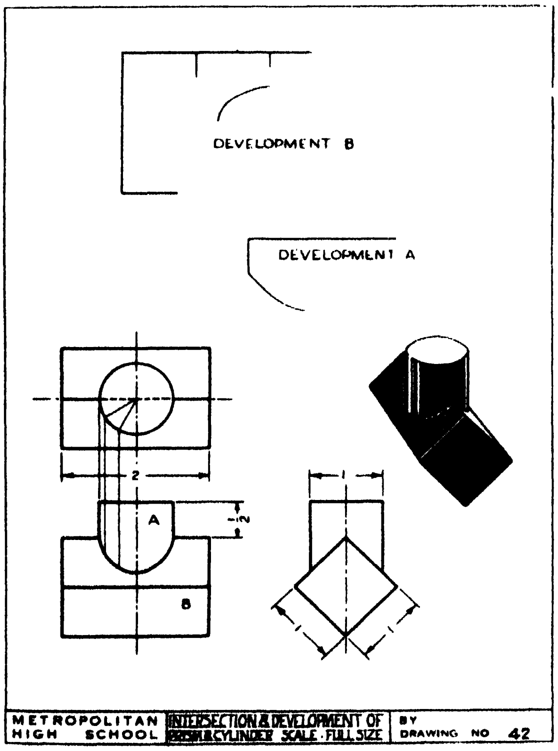

Fig. 149—A PRISM AND A CYLINDER (PROBLEM)

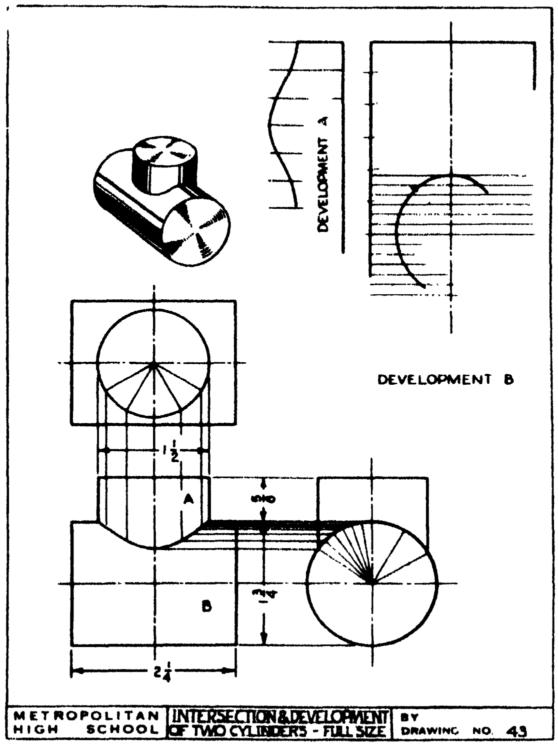

Fig. 150—TWO CYLINDERS (PROBLEM)

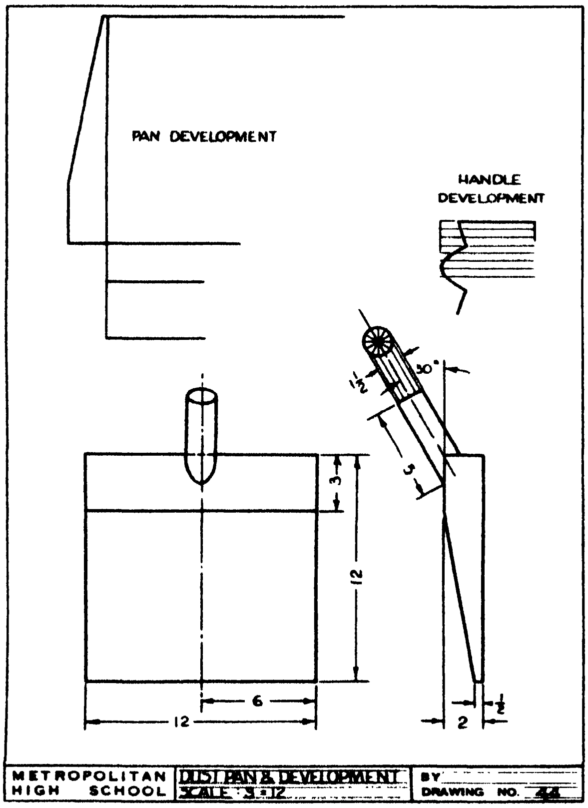

Fig. 151—A DUSTPAN (PROBLEM)

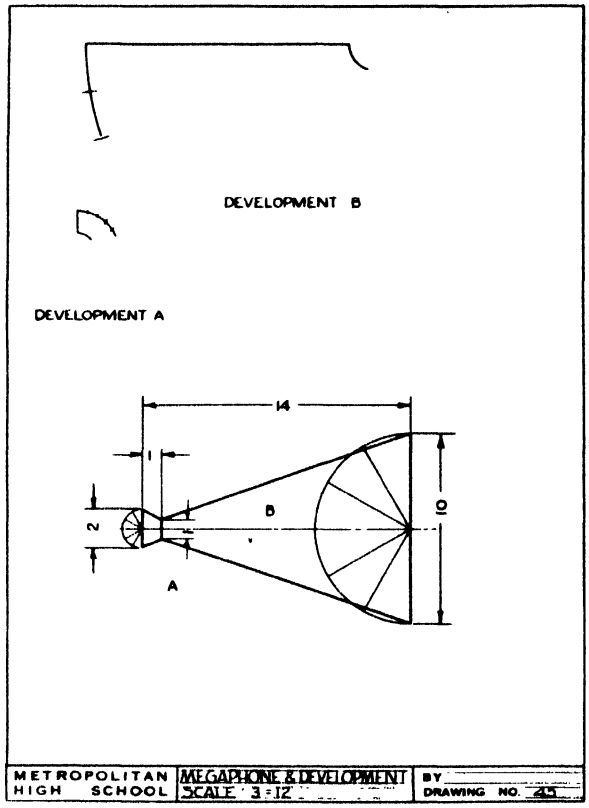

Fig. 152—A MEGAPHONE (PROBLEM)

out the intersection of these surfaces to get the shape of the end of the handle.

A MEGAPHONE

Draw the front view of the megaphone in Figure 152. The megaphone is formed by the intersection of two cones. Make developments of the two portions; start the developments at the indicated points.

QUESTIONS

1. What kind of work does a sheet-metal worker do?
2. What are the purposes of a hem on sheet-metal work?
3. Name the three methods of making surface developments, or patterns.
4. Why do we number or letter the corners of the object in the regular views before making a development?
5. What is meant by the true length of a line?
6. Where are measuring lines used?
7. What is an intersection? What other term is likely to be used in sheet-metal work?
8. What kind of sheet metal is usually used in duct work for warm-air furnaces?
9. How is the thickness of sheet metal designated?

TOPICS FOR DISCUSSION

1. Examine a warm-air heating system and carefully list the various shapes of pipes, ducts, elbows, and transition pieces.
2. Take a trip to a metal shop and notice the various kinds of machines, such as breaks, beaders, crimpers, and shears. Describe the operations performed by each of these machines.

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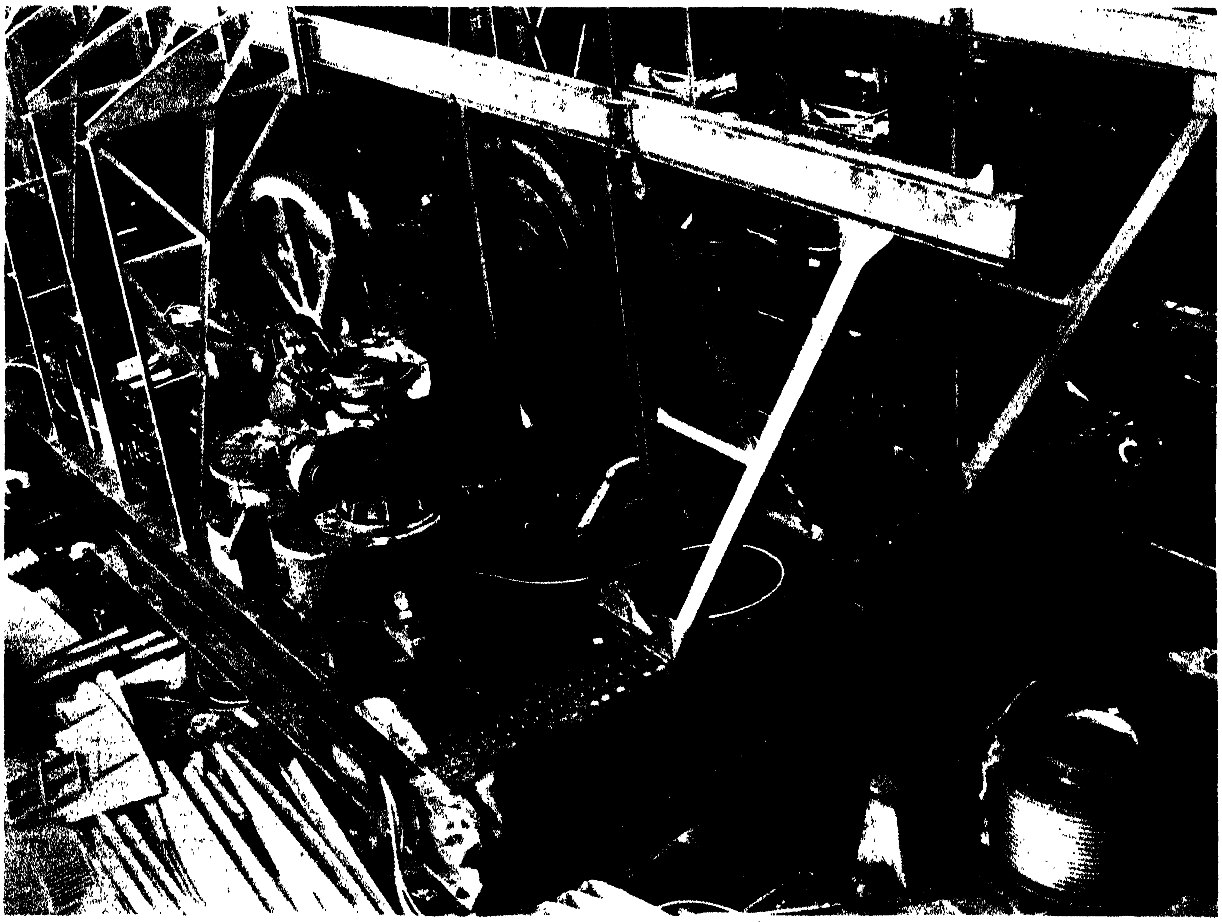
UNIT VIII

MACHINE DRAFTING

IMPORTANCE OF MACHINES

Man uses countless machines to do his work and perform the many different tasks that arise in an industrial civilization such as ours. Machines help to prepare and market the food we eat, weave the fabrics for our clothing, and shape the shoes we wear. They carry us to and from our work and aid in building and maintaining the offices, shops, and factories in which we earn our living with the help of still other machines. This is an era of mechanical inventions that do much to make possible the comfortable manner in which we live. The electric generator, mechanical refrigerator, power loom, airplane, automobile, train, radio, clock, typewriter, and printing press are but a few of these. It



Courtesy Bucyrus-Erie Company, South Milwaukee

Fig. 153—SWING MACHINERY UNIT FOR AN ELECTRIC SHOVEL

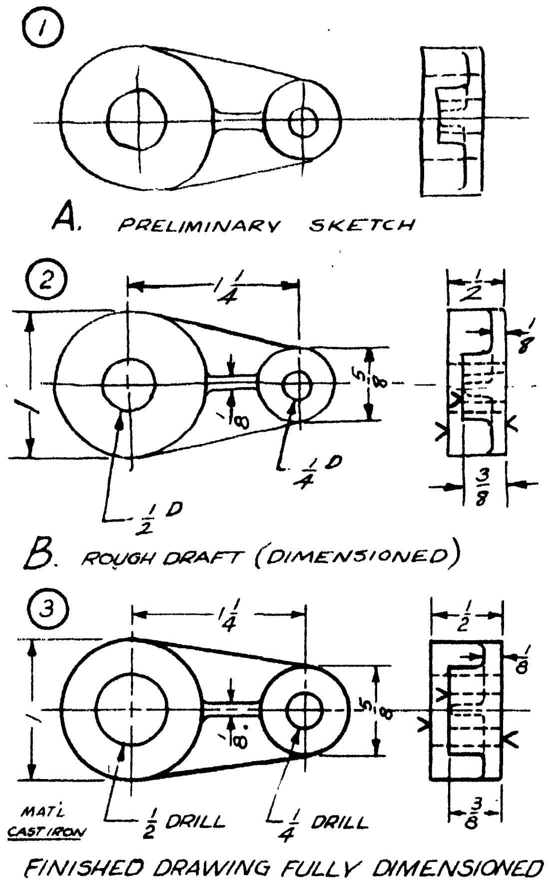


Fig. 154—PRELIMINARY SKETCH, ROUGH DRAFT, AND FINISHED DRAWING

was a most important step in the advancement of primitive man when early in his history he discovered the simple machines that made the forces of nature work to his advantage.

MECHANICAL ENGINEERING

Mechanical engineering is a broad term, which includes many different fields, such as aeronautical, automobile, hydraulic, steam, and marine engineering. All these fields include the design, construction, and operation of machines, from simple to very complex. Engineering also includes the design and construction of the tools with which to build and repair the machines.

There is always the desire on the part of man to plan new machines or improve those he already has so as to do his work more efficiently and with less effort and cost. A part of the problem is also to improve the appearance of the machine wherever possible. Whenever a new machine is designed or an old one improved, preliminary sketches are first made. Such a sketch is shown in Figure 154A.

The rough draft or tentative layout shown in Figure 154B is the next step. This shows all the parts in their relative sizes and positions so as to give true relationships. These first two drawings serve in checking the possibilities of the design.

A final drawing, such as the one shown in Figure 154C, is made after any suggested changes by the consulting engineers or designers are included in the plans. The final design is drawn by the draftsman to full size or to as large a scale as is necessary. It is from this drawing, usually penciled, that an experimental machine part or machine is made. If this proves successful, then quantity production is begun.

The task of producing a new machine is often a long process that involves many men, including the inventor or designer, the chief engineer, the consulting engineer, the draftsmen, and numerous assistants.

TRAINING THE ENGINEER

The highly skilled engineers and chief draftsmen are experienced men, with much training, knowledge, and imagination, who have the ability to work under their own direction. Technical education such as is given in universities and special schools is essential to the engineer. His profession is open only to carefully and exactly trained men. While a beginning may be made without technical education beyond the high school, eventually this training becomes necessary.

The engineer must have the ability to

Courtesy Illinois Central System, Chicago

Fig. 155—ERECTING BAY IN LOCOMOTIVE SHOP

read and make working drawings. He must know how mechanisms work, the properties of metals, and how tools and machines operate. A knowledge of mathematics is also required. He must know standard tools and their sizes, or he must know where to find and how to use handbooks, tables, and data sheets to acquire the necessary information.

Engineers have special duties and responsibilities that vary with the organizations in which they are employed. They are among the most experienced and highly trained of technical men. For their skill and imagination they may receive very large salaries.

When the untrained beginner starts work in an engineering office, he may make blueprints or file drawings. If he has had sufficient training, he might start making tracings from the drawings of the regular draftsmen. Further advancement will depend upon increased technical training and knowledge. The beginning draftsman should be able to make simple drawings. Increased skill in drafting and progress in technical knowledge about the particular work of the office should lead to advancement. In

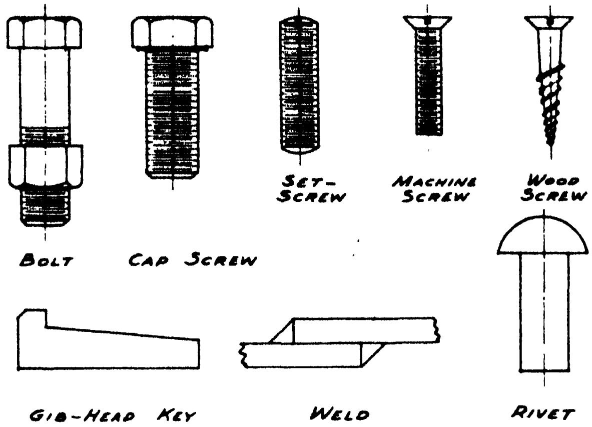


Fig. 156—FASTENERS

the drafting field, as in any other, ability to work with others helps one to obtain a more responsible position. Salaries vary widely, depending upon the capability of the worker and the demand for the kind of work he does.

FASTENERS

In earlier lessons in drafting the principles of drawing have been discussed. Now the drawing of machine parts will be explained. *Machine drawing* includes drawing the separate parts that make up a machine and drawing the complete or assembled machine. Since the parts are fastened together when the machine is assembled, many different means of fastening and support have been developed and standardized.

The common fastenings include screws, bolts, rivets, pins, keys, and welds. Some of these forms are shown in Figure 156.

Fastenings are of two general kinds. There are fasteners that may be removed readily in order to permit repairs. These are called removable fasteners. There are also those that are fixed or permanent, such as rivets and welds.

A fastening that will hold parts firmly together while the machine is in operation and yet will allow easy removal of a part for repair is very important. The most common of fastenings of this type are bolts and screws, made by cutting threads on rods. These are of different lengths and diameters, and they may have threads of different styles.

Screw Threads

A triangular piece of paper wrapped around a cylindrical object, such as a pencil, will give the actual path of the screw

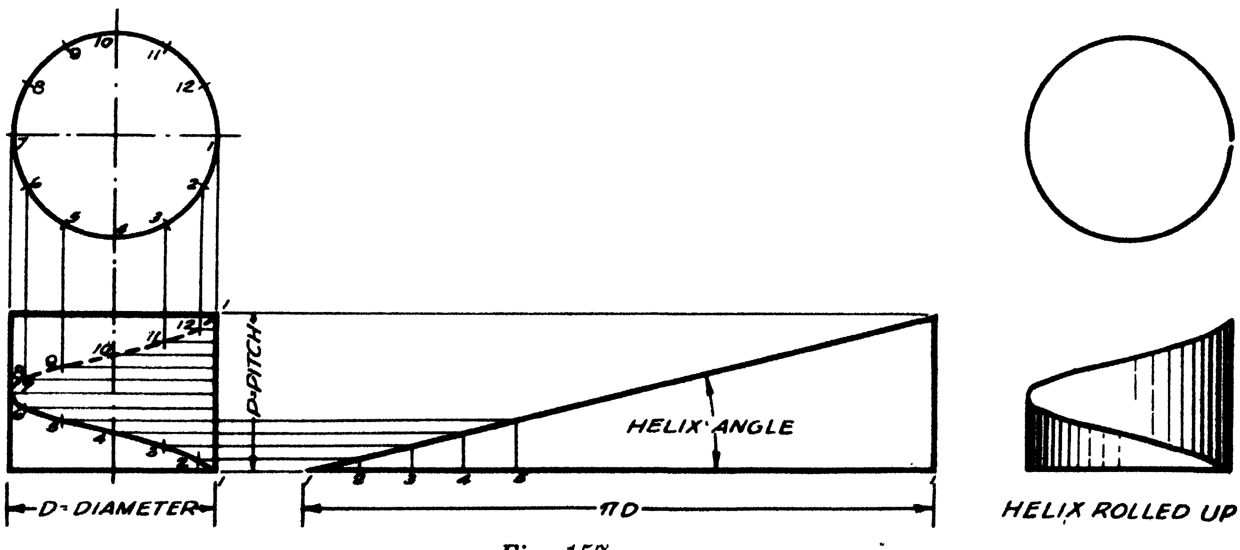


Fig. 157—A HELIX

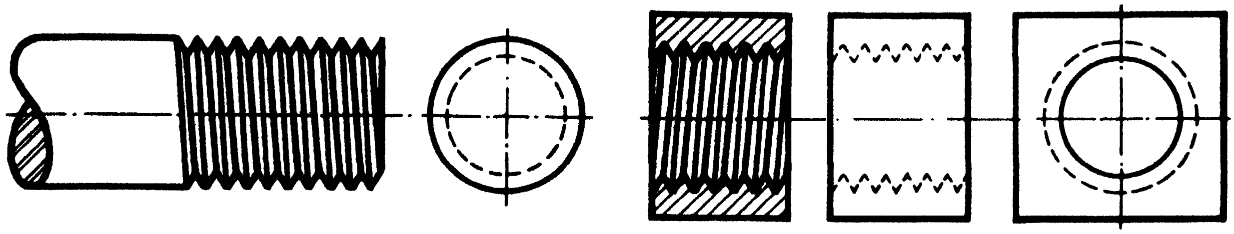


Fig. 158—THE AMERICAN STANDARD THREAD

thread around the bolt. This curve, which is called a *helix*, is shown in Figure 157. Since it would take too much time to draw a helix each time we draw a screw thread, certain conventions for drawing screw threads have been established. These conventions will be shown and discussed later in this unit.

In order to have uniformity in thread sizes and shapes, certain standards have been agreed upon. Figure 158 shows one of the shapes most commonly used, the American standard thread. An enlarged section showing the profile of this thread is shown in Figure 159. The top edge of the thread is called the *crest* and the bottom, or groove, the *root*. The diameter (*D*) is measured from the outside point of the thread, the crest, to the outside point on the other side. This diameter is also called the *outside* diameter. The distance from root to root is called the *inside* diameter. The distance from one crest to the next is the *pitch* (*P*); this is the same as the distance from root to root.

The American standard thread is V-shaped, as shown in Figure 159. The angle between the sides of the thread is 60°. The crest and root, or top and bottom, are flattened to one eighth the height of the thread.

There are five series of the American standard threads. They are the National Coarse Series, recommended for general use; the National Fine Series, which is used where a finer thread is needed; the 8-pitch Thread Series, used where there are eight threads to the inch regardless of the diameter, which may vary from 1″ to 6″; the 12-pitch Thread Series, with twelve threads to the inch regardless of the diameter, which may vary from $\frac{1}{2}$″ to 6″; and the 16-pitch Thread Series, with sixteen threads to the inch for all diameters from $\frac{3}{4}$″ to 4″. All these thread series have the same general shape; the only difference is that the number of threads per inch varies with each series.

There is another thread series, called the S.A.E. (Society of Automotive Engineers) Extra-fine Series, which has the same profile, or shape, as the American standard threads. Since these S.A.E. threads are used where thin metals are to be held together with machine screws, they are extremely fine threads.

The table on page 104 shows the number of screw threads for various diameters in the different series.

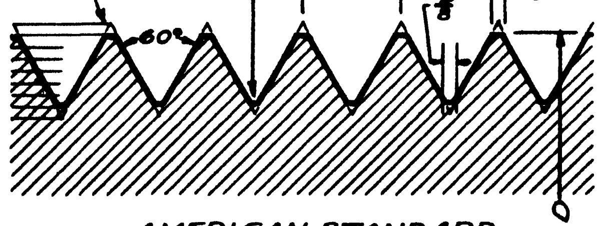


Fig. 159—THE AMERICAN STANDARD THREAD IS V-SHAPED.

THREADS PER INCH

Size of Diameter in Inches	Coarse (NC)	Fine (NF)	8-Pitch (N8)	12-Pitch (N12)	16-Pitch (N16)	S.A.E. Extra-fine (EF)	Size of Diameter in Inches
0	..	80	..	..	..	..	0
1	64	72	..	..	..	..	1
2	56	64	..	..	..	..	2
3	48	56	..	..	..	..	3
4	40	48	..	..	..	..	4
* 5	40	44	..	..	..	..	5 *
6	32	40	..	..	..	..	6
8	32	36	..	..	..	..	8
10	24	32	..	..	..	..	10
12	24	28	..	..	..	..	12
$\frac{1}{4}$	20	28	..	..	..	36	$\frac{1}{4}$
$\frac{5}{16}$	18	24	..	..	..	32	$\frac{5}{16}$
$\frac{3}{8}$	16	24	..	..	..	32	$\frac{3}{8}$
$\frac{7}{16}$	14	20	..	..	..	28	$\frac{7}{16}$
$\frac{1}{2}$	13	20	..	12	..	28	$\frac{1}{2}$
$\frac{9}{16}$	12	18	..	12	..	24	$\frac{9}{16}$
$\frac{5}{8}$	11	18	..	12	..	24	$\frac{5}{8}$
$\frac{3}{4}$	10	16	.	12	16	20	$\frac{3}{4}$
$\frac{7}{8}$	9	14	..	12	16	20	$\frac{7}{8}$
1	8	14	8	12	16	20	1
$1\frac{1}{8}$	7	12	8	12	16	18	$1\frac{1}{8}$
$1\frac{1}{4}$	7	12	8	12	16	18	$1\frac{1}{4}$
$1\frac{3}{8}$	6	12	8	12	16	18	$1\frac{3}{8}$
$1\frac{1}{2}$	6	12	8	12	16	18	$1\frac{1}{2}$
$1\frac{3}{4}$	5	12	8	12	16	16	$1\frac{3}{4}$
2	$4\frac{1}{2}$	12	8	12	16	16	2
$2\frac{1}{4}$	$4\frac{1}{2}$	12	8	12	16	16	$2\frac{1}{4}$
$2\frac{1}{2}$	4	12	8	12	16	16	$2\frac{1}{2}$
$2\frac{3}{4}$	4	12	8	12	16	16	$2\frac{3}{4}$
3	4	10	8	12	16	16	3

* Wire sizes.

Classes of Fit

Screw threads cut on the outside surface of a cylindrical object, such as those that are cut on bolts, are called *external* threads, because they are on the outside. Threads cut on the inside of an object, such as those that are cut in nuts, are called *internal* threads.

If a nut is to be screwed onto a bolt, the threads must be mating threads; that is, the threads must be of the same diameter and same series and must be tightened in the same direction. The amount of space or play between mating threads is called the *fit*. Fits have been grouped into four different classes, as follows:

Class 1. Loose fit—used where a large amount of play is immaterial

Class 2. Free fit—used on the ordinary thread work of interchangeable parts

Class 3. Medium fit—used in thread work where precision is essential

Class 4. Very close fit—used on selective work in unusual situations

Square and Acme Threads

Profiles of the square and acme types of screw threads are shown in Figure 160.

These threads are ordinarily used when the transfer of power is essential. They are found on jacks, wrenches, and lathes. There are other screw-thread forms, which are used in special situations; but the American standard thread is the one commonly used for general purposes.

Right- and Left-Hand Threads

A right-hand thread requires that either the bolthead or the nut be turned to the right, or in a clockwise direction, to tighten

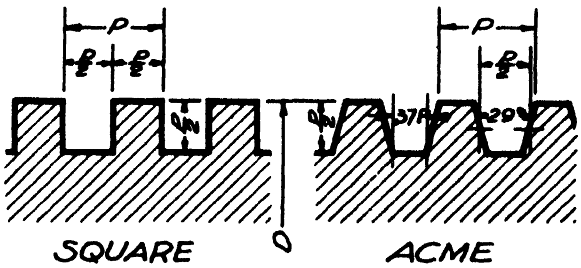


Fig. 160—SQUARE AND ACME TYPES OF THREADS

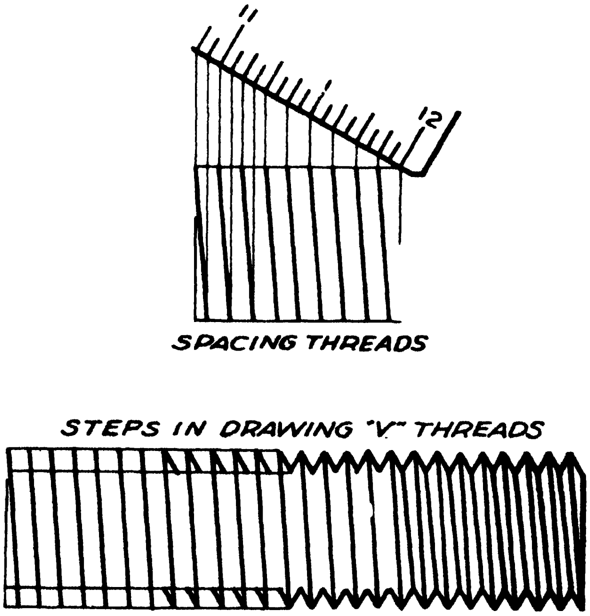


Fig. 161—LAYING OUT V THREADS

it. To unscrew it, the bolthead or nut should be turned to the left. In a left-hand thread, the bolthead or nut is turned to the left, or in a counterclockwise direction, to tighten it. All threads are assumed to be right-hand unless otherwise specified.

Drawing Screw Threads

As stated on page 103, the actual path of the screw thread is a helix, but in drawing threads certain conventions have been adopted. When threads must be shown 1″ or over in diameter on the drawing, they should be shown as nearly as possible as real threads. Figure 158 shows an American standard representation.

To lay out a thread, draw the diameter of the bolt with two horizontal lines. Then measure off with the scale the number of threads wanted per inch as shown at the top of Figure 161. The points indicated will give the location of the crests on the top side of the bolt. To locate the crests on the lower edge of the bolt, drop vertical lines from points halfway between the crest points on the top edge. Draw the slant line which represents the crest on the front face of the bolt. Draw the other crest lines parallel to this one through the crest points. From each of the crest points along the top and bottom, draw 60° lines both to the left and to the right. The points where these lines intersect are the points from which the root lines are drawn. These root points should all line up in straight horizontal lines.

When drawing internal threads in section, as shown in Figure 158, the crest lines slant in the opposite direction from that of the external threads because we see the rear half of the helix.

When drawing threads 1″ or less in diameter, the amount of drawing may be greatly reduced by using the conventions shown in Figure 162. Those on the left are regular or conventional threads; those on the right are simplified conventions.

In the regular conventions, the number of threads per inch is stepped off but all

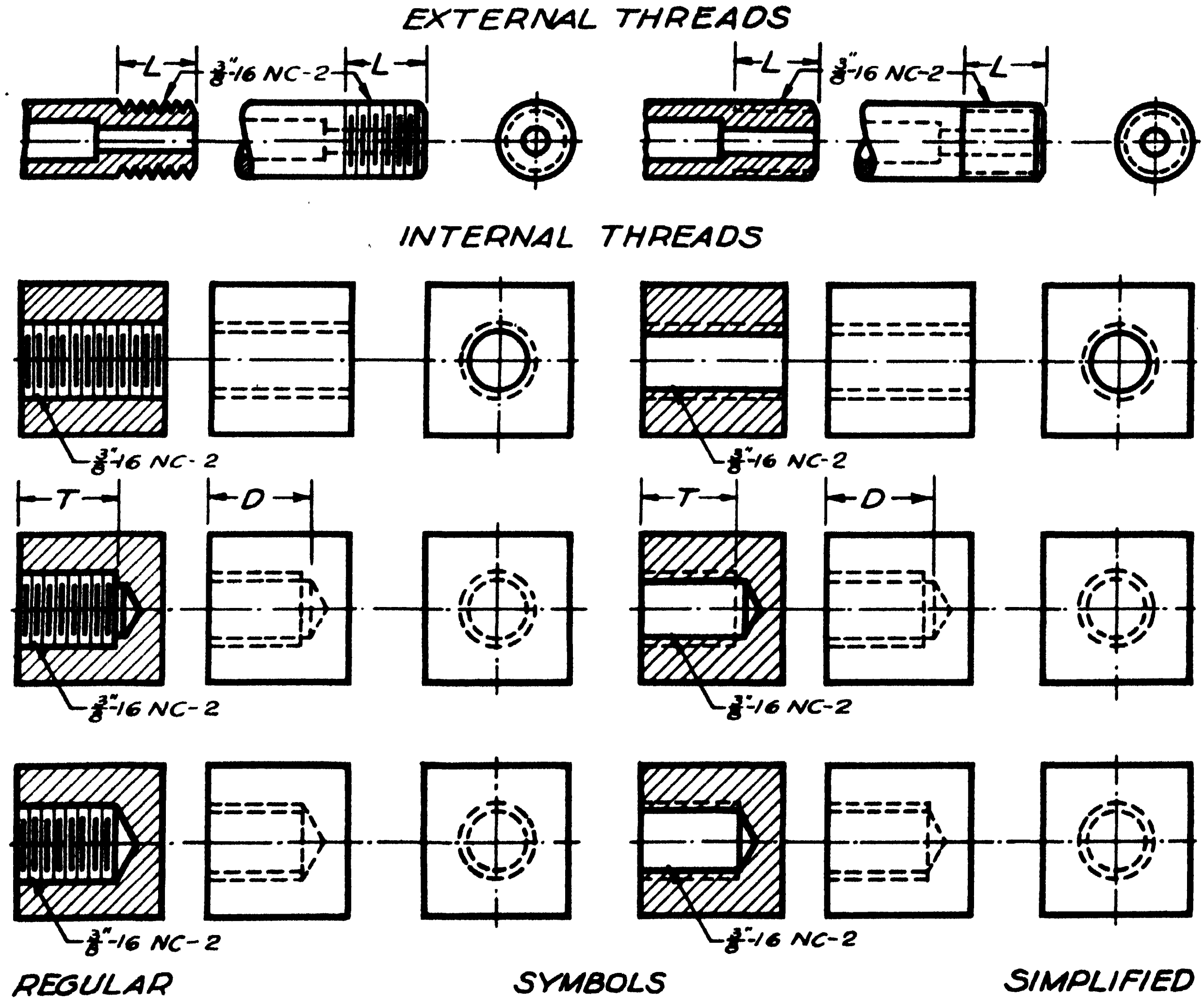


Fig. 162—THREAD CONVENTIONS

crest and root lines are drawn perpendicular to the center line of the bolt. The crest lines are drawn lightly and the root lines heavily. The length of the root lines is determined by the 60° lines from the crests. Internal threads are represented as are the external threads except that the surrounding area is sectioned.

In drawing the simplified conventions, hidden or invisible lines are used to represent the threaded portions.

Under "Internal Threads" above are shown holes drilled and tapped through, tapped but not for the depth of the hole, and tapped for the depth of the hole.

Thread Specifications

It is not possible to tell from looking at the drawing of a thread what its diameter or thread series is, which is its class of fit, or whether it has a left- or right-hand thread. This information must be given in the form of a note such as is shown in Figure 163. First the diameter of the bolt or hole is given, then the number of threads per inch, and then the thread series and the class of fit. A 1/4-20 NC-2 note would mean a shaft or hole 1/4" in diameter, 20 threads to the inch, National Coarse Series, and a class 2 fit. For a left-hand thread the note reads: 1/4-20 NC-2-LH. The *LH* means *left* *hand.* A thread note should always have a leader indicating the thread to which it applies, as shown in Figure 163.

American Standard Bolts and Nuts

There are three series of standard boltheads and nuts, as shown in Figure 164.

The *regular* boltheads and nuts are for all ordinary uses, and it is always under-

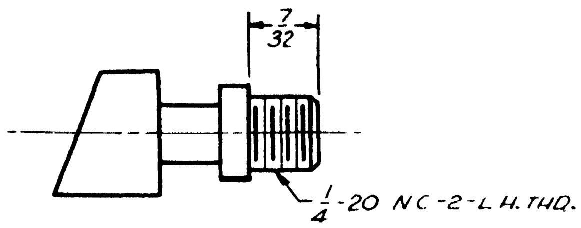


Fig. 163—THREAD SPECIFICATIONS

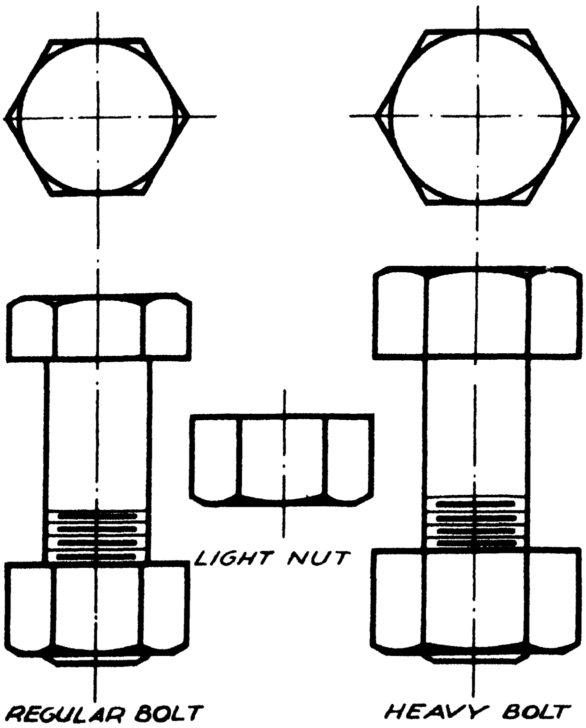


Fig. 164—STANDARD BOLTS AND NUTS

stood that they are to be used unless it is otherwise noted. *Heavy* boltheads and nuts are used where a larger and stronger bearing surface is required. There is a *light* series of nuts for use where saving in weight and material is desirable.

In the regular and the heavy series, the American Standards Association specifies three classes of finish: (1) unfinished, (2) semifinished, and (3) finished. Unfinished heads are not machined on any surface. Unfinished nuts are threaded but not machined on any other surface. Semifinished heads are machined under the head only and are either plain or washer-faced. Semifinished nuts are threaded and machined on the bearing surface only; they may be either plain, chamfered, cornered, or washer-faced. Finished heads are machined on all surfaces and have a washer face $\frac{1}{64}''$ thick. Finished nuts are machined on all surfaces and have a washer face on the bearing surface. Figure 165

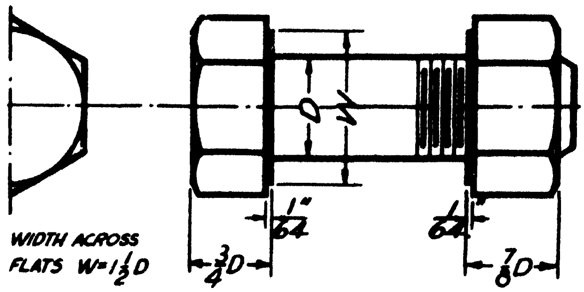


Fig. 165—A WASHER-FACED BOLT AND NUT

shows a finished and washer-faced bolt and nut. The unfinished and semifinished boltheads and nuts are made in both square and hexagonal shapes; finished heads and nuts are hexagonal only.

Drawing Bolts and Nuts

Boltheads and nuts are not dimensioned because they have been standardized, but distances relating to the diameter are used in drawing all bolts and nuts. See Figure 166 for detailed drawings of bolts and nuts. The distances from side to side of the hexagonal and square heads and nuts are called *flats.*

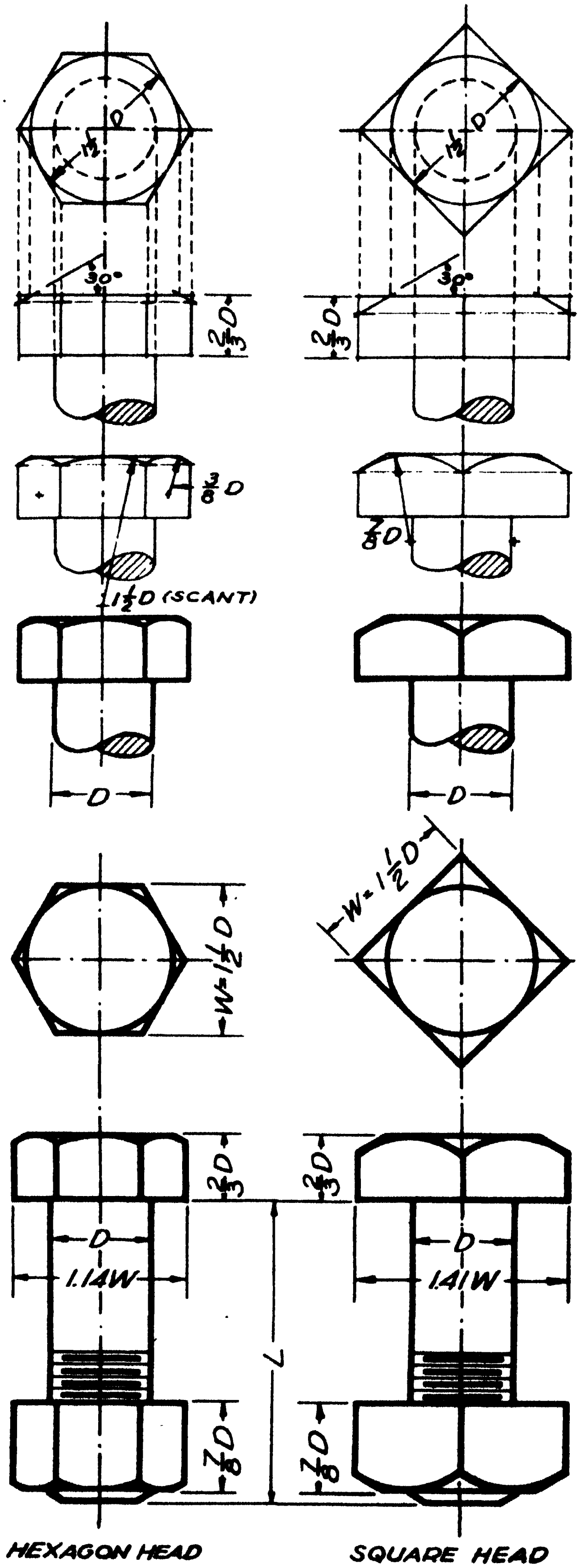


Fig. 166—STANDARD BOLT AND NUT PROPORTIONS

A designer frequently needs to know many exact dimensions regarding bolts and nuts. These exact dimensions are given in the various machinist's handbooks.

Specifying Bolts

In order that we may specify bolts completely, we should give the diameter, length, finish, shape of head, and thread specification. For example, $\frac{5}{8}''$ x $2''$ Semi-fin. Hex. Hd. Bolt; $\frac{5}{8}$-18 NF-2 would designate a bolt $\frac{5}{8}''$ in diameter, $2''$ long, semifinished, with hexagonal head, and with this thread specification: $\frac{5}{8}''$ diameter, 18 threads to the inch, National Fine Series, and a class 2 fit. With this information the correct bolt can be purchased.

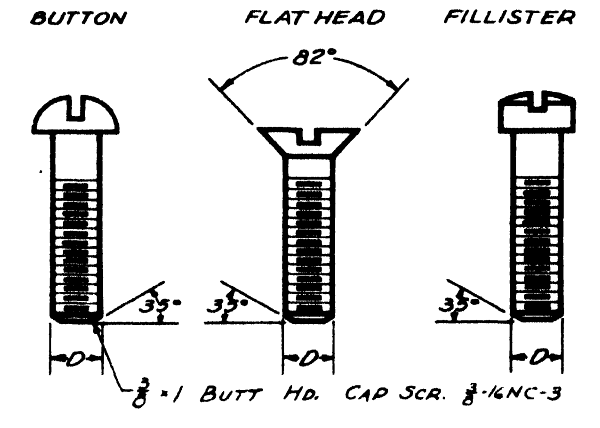


Fig. 167—AMERICAN STANDARD CAP SCREWS

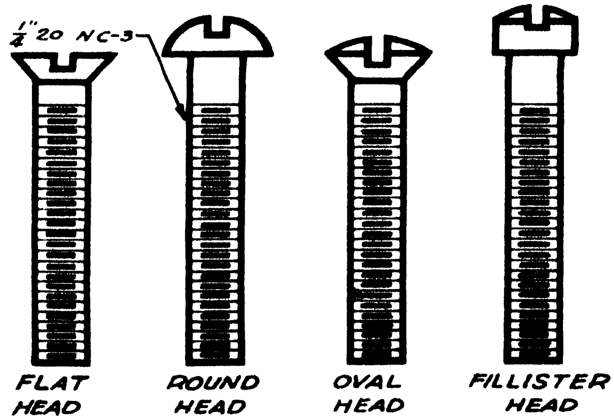


Fig. 168—MACHINE SCREWS

American Standard Screws

Three common American standard *cap screws* are shown in Figure 167. There are also square- and hexagonal-head cap screws. These differ from bolts in that they pass through a clear hole in one part and screw into a tapped hole in the other. They are used when a strong fastening is necessary.

Machine screws are shown in Figure 168. They are used in fastening small work, frequently in sheet metal. All machine screws have slotted heads.

Setscrews (see Figure 169) fasten two parts in relative positions by screwing through one part and bearing against the second. In industry one of the most common uses of a setscrew is to hold a pulley securely in place on a shaft. There are many different types of setscrews.

In all these screws, the American standard National Coarse and National Fine Series are used, as given in the table on page 104. There is only one class of fit, class 3, for the screws.

The regular and simplified conventions are used in drawings for representing the threads. Machine and cap screws should be specified in a manner similar to that for bolts. For example, $\frac{3}{8}''$ x $1''$ Flat Hd. Cap Screw; $\frac{3}{8}$-16 NC-3 would indicate a cap screw $\frac{3}{8}''$ in diameter, $1''$ long, with a flat head, and with this thread specification: $\frac{3}{8}''$ in diameter, 16 threads to the inch, National Coarse Series, and a class 3 fit. A similar specification is shown in Figure 168. Setscrews should be specified by giving the diameter, length, type of head, type of point, and thread specification. Dimensions are in terms of the diameter.

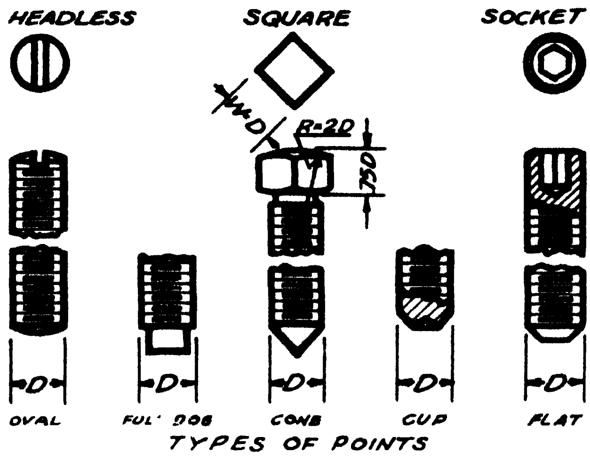


Fig. 169—SETSCREWS

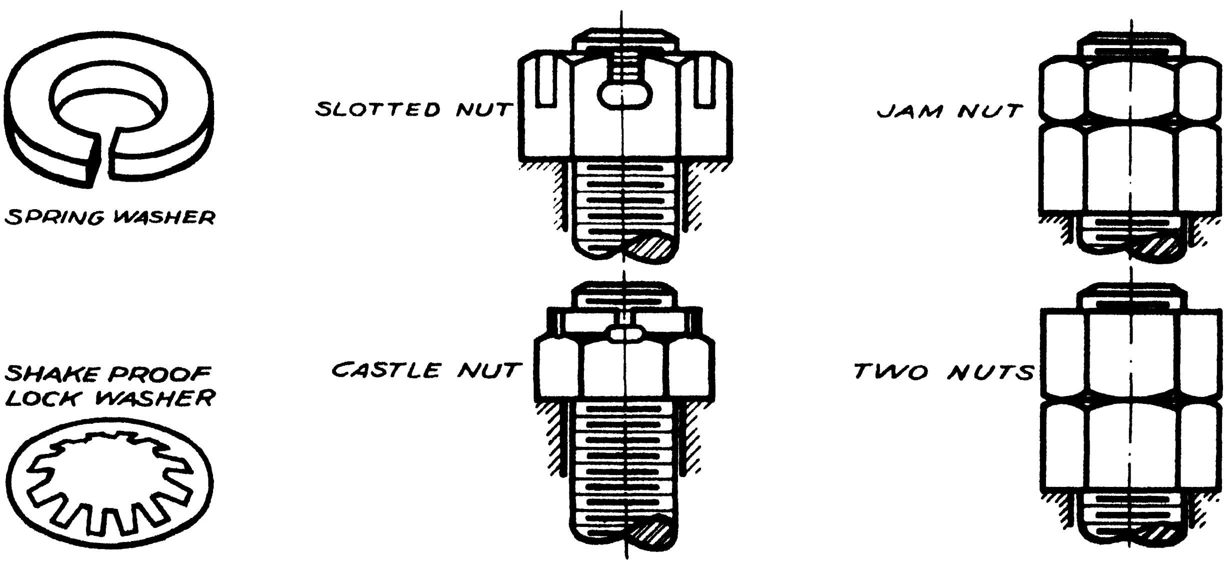


Fig. 170—LOCK NUTS AND WASHERS

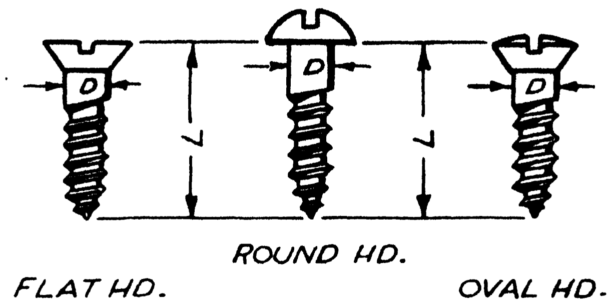
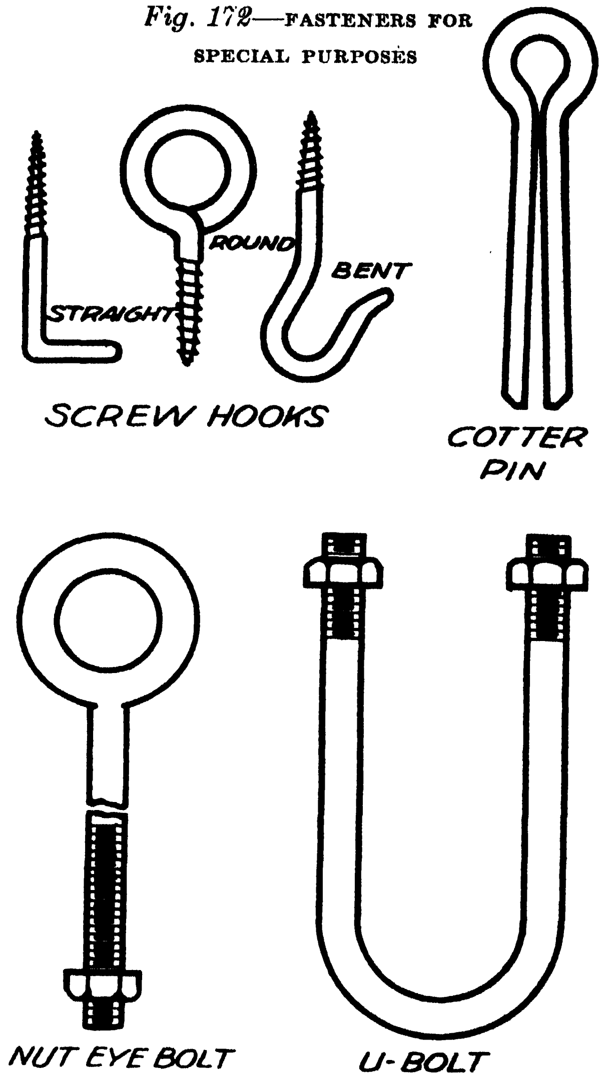


Fig. 171—COMMON WOOD SCREWS

Fig. 172—FASTENERS FOR SPECIAL PURPOSES



Locking Devices

Because of the vibration of moving machinery there is a tendency for fastenings to come loose. Consequently there have been developed several locking devices for holding bolts and nuts in place. Some of the more common are shown in Figure 170; these are the spring washer, shakeproof lock washer, slotted nut, castle nut, and jam nut. Another locking device may be made by using two nuts.

Other Fastenings

Wood screws are frequently used for fastening machines to wood surfaces. There are several types of wood screws, screws with flat, round, or oval heads, as shown in Figure 171. In addition, screws may be obtained in a variety of finishes, such as blued, bright, chromium, nickel-plated,

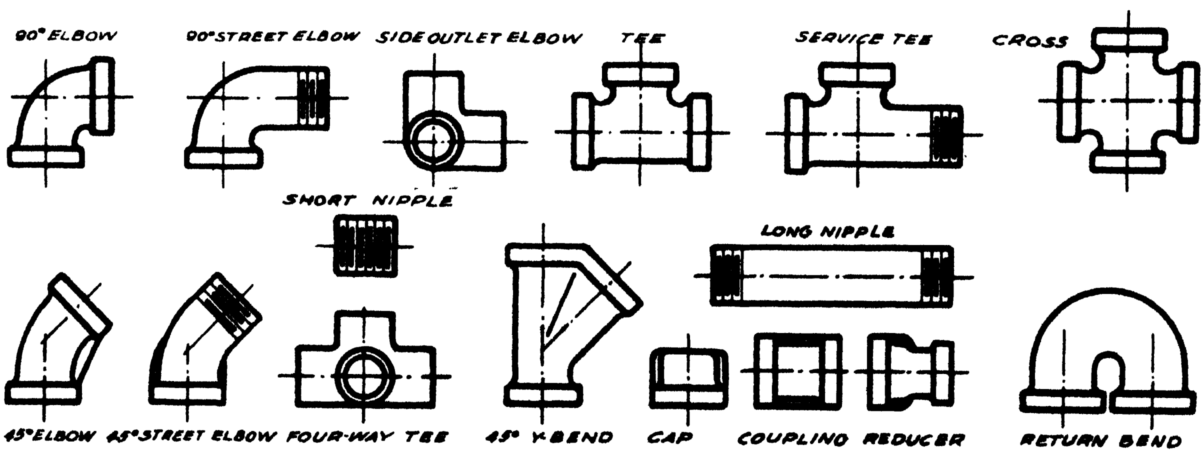


Fig. 173—COMMON PIPE FITTINGS

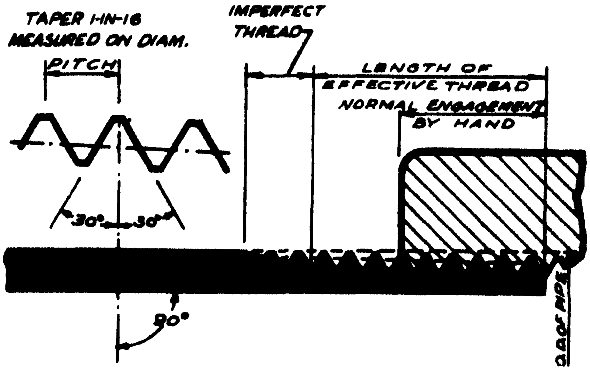


Fig. 174—AMERICAN STANDARD PIPE THREAD

brass, and copper. The size, or wire gauge, of a screw is given first; then are given the length, type of head, and kind of finish. The length of a screw with a flat or oval head is measured from the point to the top of the countersunk portion. The round-headed screw is measured from the point to the underside of the head.

Eyebolts, U-bolts, cotter pins, and screw hooks are illustrated in Figure 172. Each of these fasteners has a special use.

The American Standard Pipe Thread

Pipe is ordinarily threaded on the ends for the purpose of making a connection. The fittings commonly used to connect pipe are shown in Figure 173.

The American standard pipe thread is shown in Figure 174. Pipe threads are cut with an angle of 60° between the sides. The crest and root of the thread is truncated, making the depth of the thread eight tenths of the pitch. The taper in the thread is cut $\frac{1}{16}''$ per inch. If the taper of the thread is shown, it must be exaggerated to be seen; however, it is not necessary to draw it. It can be seen in Figure 174 that the distance a thread enters a fitting is fixed.

Pipe threads are represented by either the regular or simplified convention, as shown in Figure 175. The thread specification also is shown in this figure.

In making piping layouts for buildings, the layout may be made in either orthographic or isometric drawing. Figure 176 shows both ways. Pipe may be drawn with two lines, as shown on the left in the figure, or as a single line, as shown in the center and on the right.

Rivets

Rivets are used extensively to fasten sheets or plates of metal together permanently. Boilers and other structures of steel are fastened by rivets that are put into place while red-hot. On sheet-metal work, the rivets are made of soft steel and put into place without heating.

All rivets consist of a formed head and a shank made long enough to form a second head on the other side of the material.

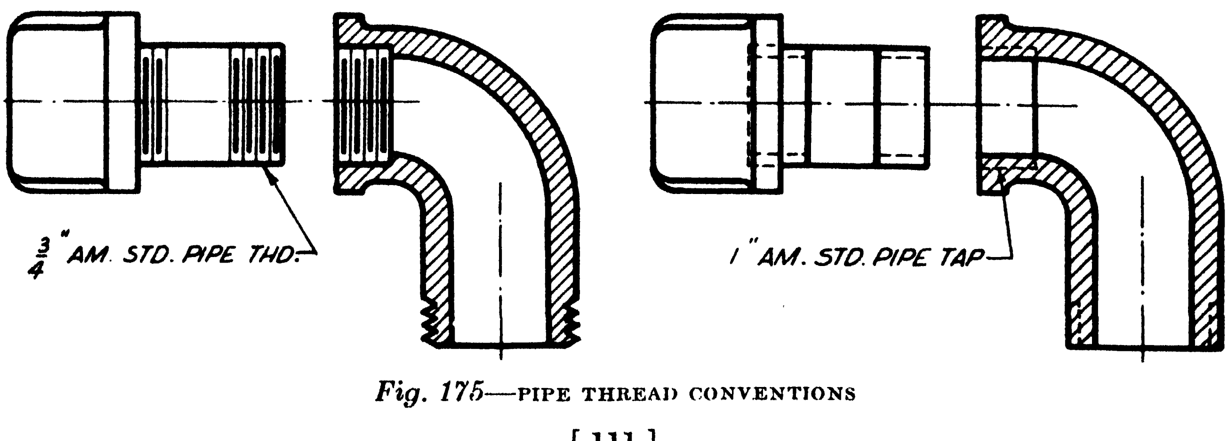


Fig. 175—PIPE THREAD CONVENTIONS

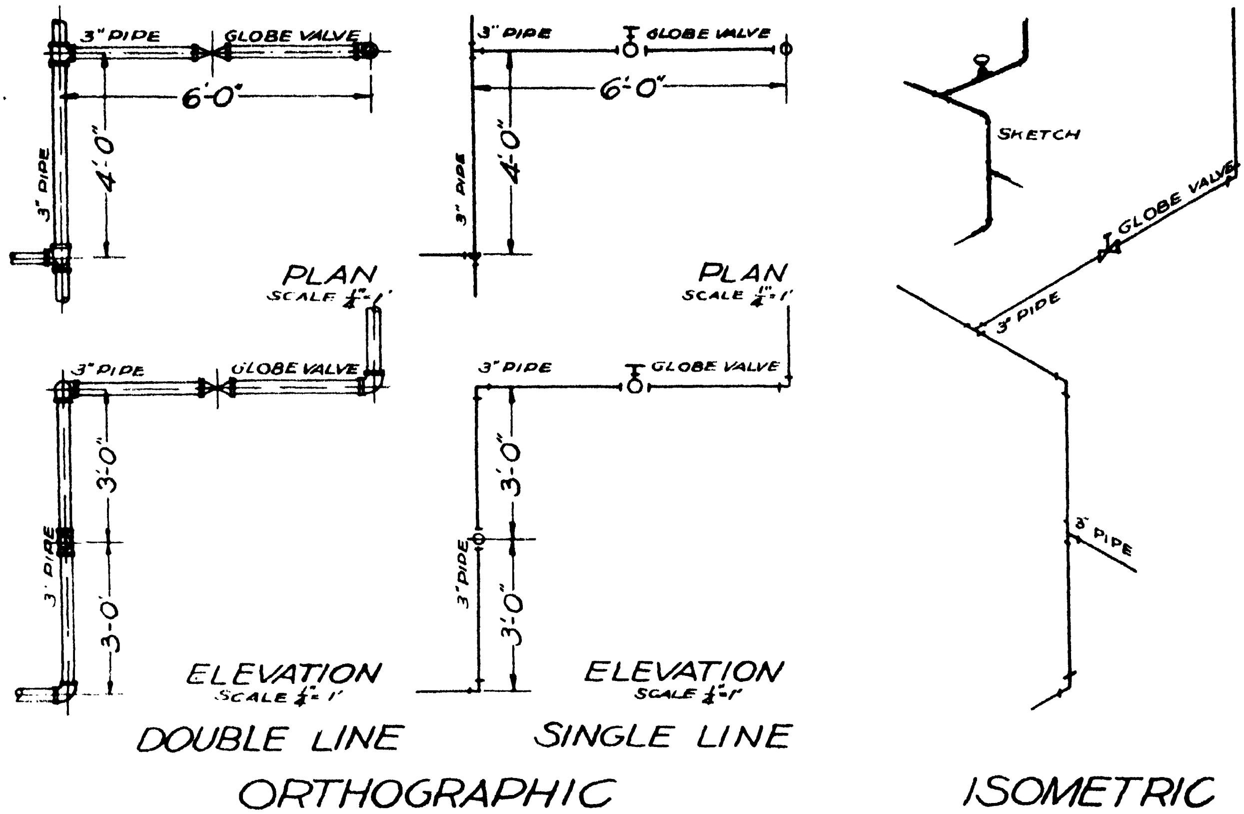


Fig. 176—PIPE LAYOUTS

Figure 177 shows some of the common rivet heads. The type of job determines the kind and size of rivet to be used.

Rivet holes are either punched or drilled. Drilled holes are better because they do not injure the metal, but they do require more time to make. In steel plates, large holes are made $\frac{1}{16}$″ larger than the rivets.

Figure 178 shows how rivets are used in fastening two sheets of metal together. When a single row of rivets is used, the joint is called a single-riveted lap joint. A double-riveted lap joint is also shown in Figure 178. Chain or staggered riveting is used when several rows of rivets are needed. A butt joint is still another type of joint.

As shown in Figure 178, the *pitch* (*P*) is the distance from the center of one rivet to the center of the next. This pitch depends upon the size of the rivet, the thickness of the sheets being joined, and the stresses the structure will have to withstand. The shank diameter of a rivet is indicated by *D*. The distance from the edge of the rivet hole to the edge of the plate should never be less than twice the rivet diameter. From the center of one rivet to the center of the next should not be less than 3*D*. These factors give the strength necessary for a strong joint.

Welded Joints

A most efficient means of making a permanent fastening or joint is *welding*. There are two general means of doing this, electricity and gas. The application of heat causes the two metals to flow together with or without other metal being added. Metals may also be joined in this manner by hammering or compressing them as heat is

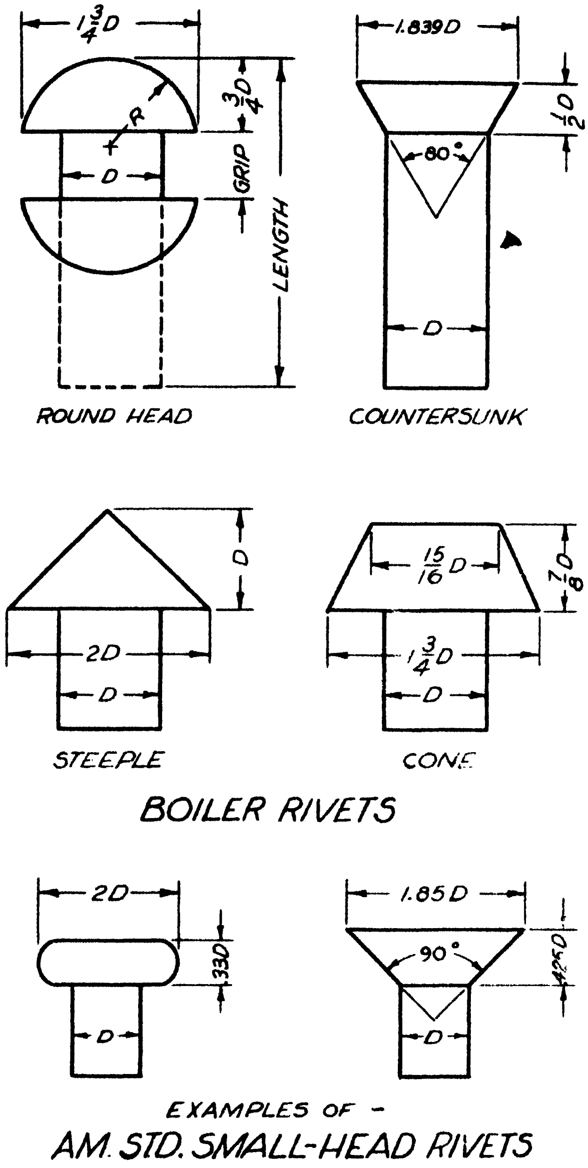


Fig. 177—RIVETS

applied. A few of the common welded joints are shown in Figure 179.

A thorough and comprehensive set of welding symbols for indicating various types of welds has been developed by the American Welding Society. In case drafting involving welding symbols is to be done, it is suggested that a copy of the booklet containing these symbols be secured.

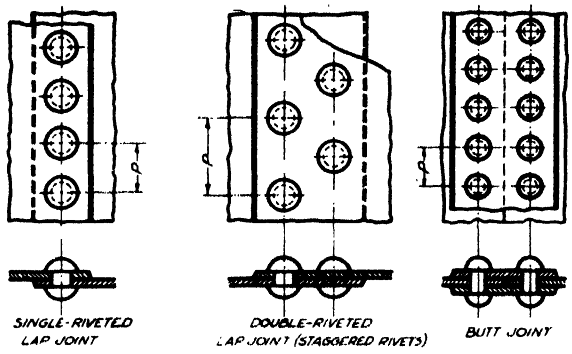


Fig. 178—RIVETED JOINTS

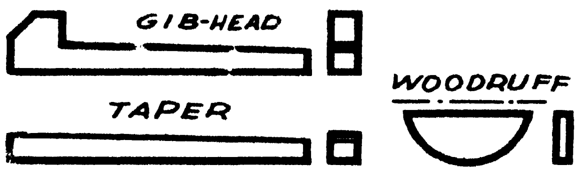


Fig. 180—KEYS

Keys

In order to transfer motion from a wheel to a shaft or vice versa, there must be some means of preventing any motion between the two parts. A common method of doing this is to use keys. A few of the common keys are shown in Figure 180. They are a gib-head key, a taper, and a Woodruff key. Figure 181 shows how a key can be fitted into a keyway to prevent motion between the wheel and shaft. The slot in the shaft and that in the wheel are aligned to receive the key.

Fig. 179—WELDED JOINTS

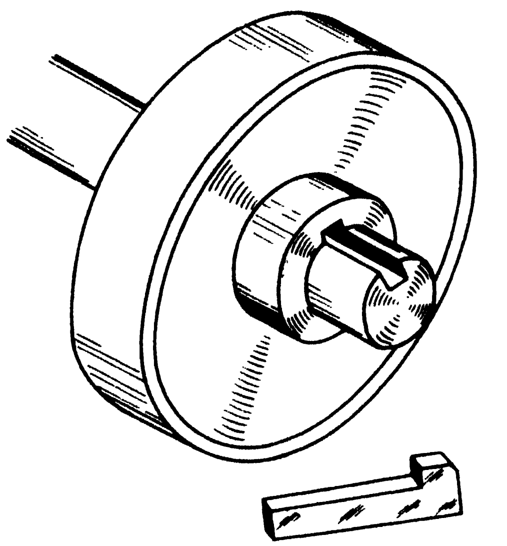


Fig. 181—USE OF KEY

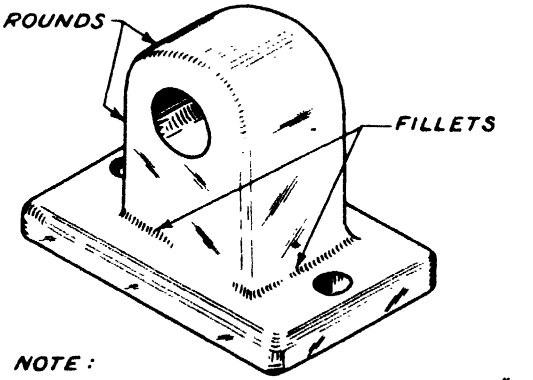


Fig. 182—FILLETS AND ROUNDS

FILLETS AND ROUNDS

In making castings, it has been found that sharp inside corners impair the strength of the casting. Therefore these corners are rounded to form what are called *fillets*. These are shown in Figure 182. In the same figure you will notice that the outside corners have been rounded to form what are called *rounds*. The radii of fillets and rounds are left to the patternmaker unless they are dimensioned directly on the drawing or unless a note is included, such as, "All fillets and rounds $\frac{1}{8}''$ R unless otherwise specified." Only the larger fillets and rounds are usually dimensioned directly on the drawing.

FINISHED SURFACES

Whenever two surfaces of a machine slide on each other or must fit together very closely, these surfaces must be finished. Therefore the rough surface of the casting or forging must be machined so that all the rough spots will be removed. A 60° *V* is used to designate the surface to be finished. The point of the *V* should just touch the surface to be finished, as shown in Figure 154. This symbol is used only on the views in which the finished surfaces project as edges.

In very technical work, the degree of roughness must be indicated. There are code numbers and letters recommended by the A.S.A. for the various degrees of roughness. These code numbers and letters are placed on the inside of the *V*.

Many objects must be finished on all surfaces. When all surfaces require finishing, a general note may be placed on the drawing, such as, "Finish all over."

The letter *f* has been used for many years, and is still used in many offices, to indicate a finished surface. It is used at a 60° angle to the finished edge.

ALLOWANCES AND TOLERANCES

Whenever two parts of a machine must fit together very closely extreme care has to be taken so that they are machined to exact sizes to give the desired fit. It is also necessary that the draftsman dimension the drawings to give the exact size of each part. When a shaft must fit into a hole as shown in Figure 183 there must be a certain amount of clearance between the parts. This clearance is called *allowance*. An allowance is intentional and is planned so

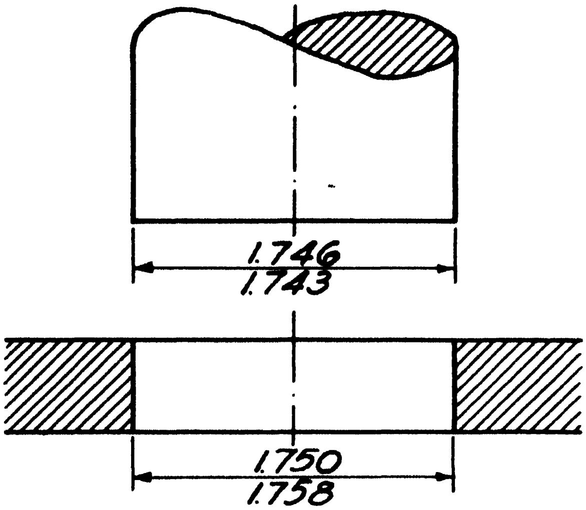


Fig. 183—ALLOWANCES AND TOLERANCES

that the parts will fit properly. When the machinist drills the hole for the part he must know how large to make the diameter. If the diameter is to be $1\frac{3}{4}''$, this diameter is called the *nominal* size; the *basic* size is 1.750″.

Since it is difficult to drill a hole exactly 1.750″ in diameter, permissible amounts of variation are indicated. The permissible amount is called *tolerance.* In order to express this tolerance in dimensioning, the maximum dimension of the part and the minimum dimension are both shown. These maximum and minimum dimensions are called *limits.* For example, in Figure 183, 1.758 is the maximum dimension, or permissible size, of the hole, and 1.750 is the minimum dimension, or permissible size, of the hole. The limits on the size of the shaft are 1.746 and 1.743; that is, a tolerance of .003″ is permitted on the shaft. The minimum allowance between the shaft and hole is 1.750 minus 1.746, or .004″, while the maximum allowance is 1.758 minus 1.743, or .015″.

The tolerances and allowances shown in this example are for a class 1, or loose fit, from A.S.A. standards for cylindrical fits.

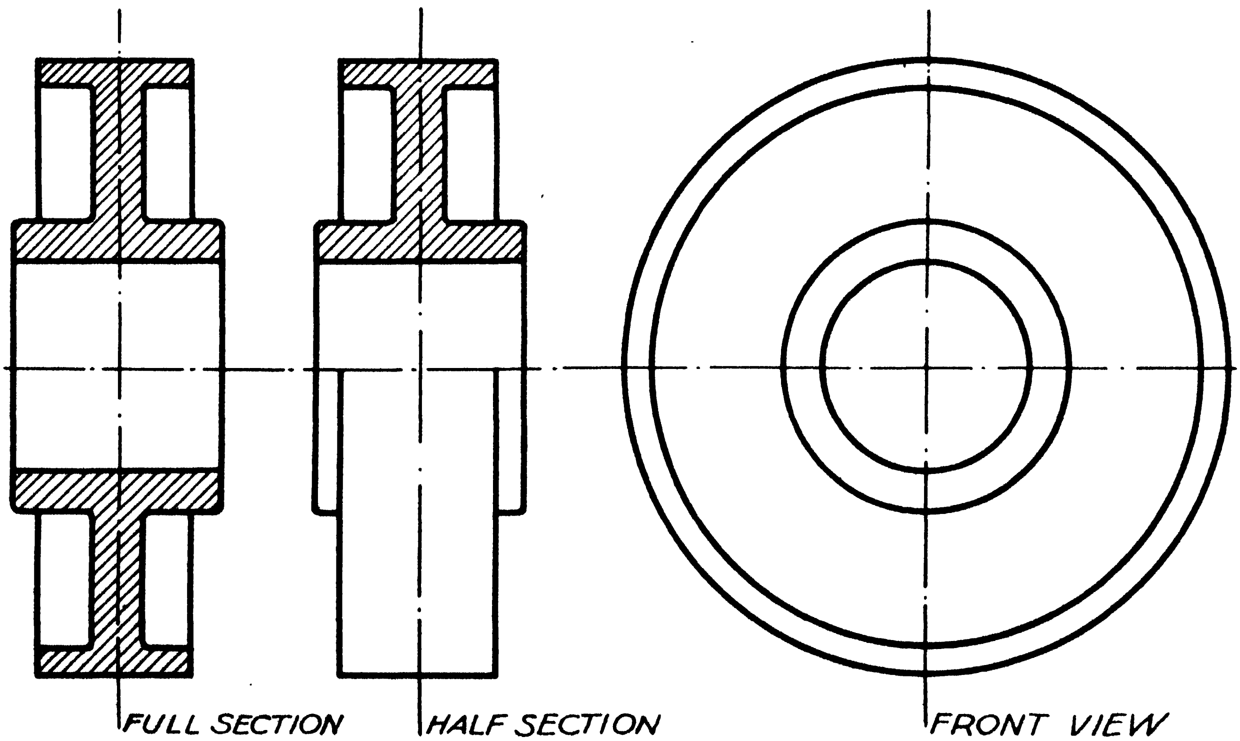


Fig. 184—A FULL AND A HALF SECTION

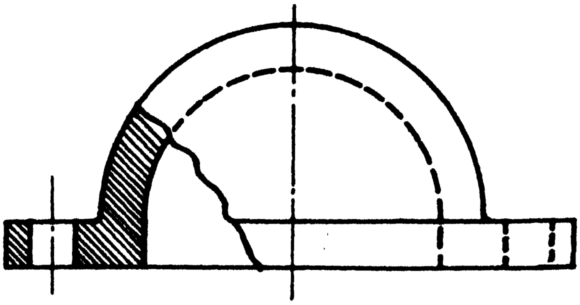


Fig. 185—A BROKEN, OR PARTIAL, SECTION

There are eight classes of fits, ranging from class 1—loose—to class 8—a heavy-force or shrink fit. If tolerances and allowances are needed for any of these fits, they may be found in a machinist's handbook.

There are other systems of expressing allowances and tolerances on drawings in industry, but the system explained here is recommended by the American Standards Association.

SECTIONS

Sections are common in machine drawing, both detail and assembly. In a sectional view an imaginary cut has been made and a part of the object removed so as to expose the interior to view. All interior edges that appear in the section are shown as visible lines. Figure 184 shows a full and a half section of a flanged wheel.

You have already learned the section-lining symbols for the more common materials. Only areas of material cut by the section plane should be section lined. Section lines are usually drawn about $\frac{1}{16}$''

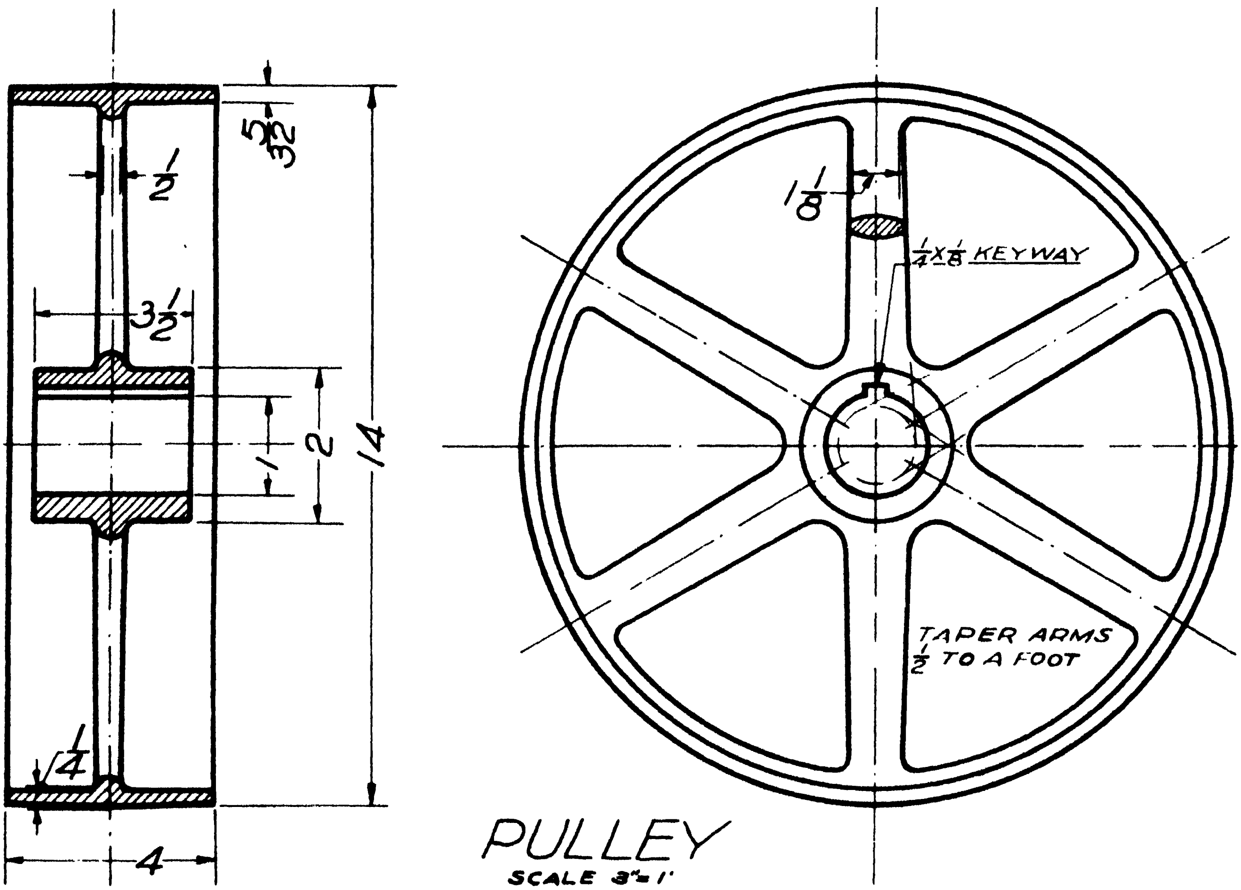


Fig. 186—A FULL SECTION AND A REVOLVED SECTION

apart. The spacing varies with the size of the area that is sectioned. Spacing must be uniform, but it is judged with the eye and not measured. The lines are generally at a 45° angle with the border line. Two adjacent parts are sectioned in opposite directions.

Broken or *partial* sections (Figure 185) are used when less than a half section is needed to give the desired information. *Revolved* sections are used when it is necessary to show the shape or cross section of a member at a particular point. Figure 186 shows a revolved section of the spoke in a pulley wheel.

A section may be made of any view. In a section view, however, the following objects are usually not sectioned: bolts, nuts, rivets, nails, screws, dowels, lugs, ball or roller bearings, shafts, spokes, keys, webs, ribs, cotter pins, and all other subjects of similar form that are solid. The full section in Figure 186 is taken on the vertical center line, but the spokes are not sectioned. The revolved section of a spoke is shown in the elevation.

CONVENTIONAL PROJECTION

Often true projections of certain objects in one or more views make rather awkward and confusing drawings. Certain conventional methods of representing these projections are therefore widely used. Figure 187 illustrates several of these, showing the true projections and the conventions that are preferred. In many cases the front view is revolved so that the side view or section will project as the conventional or preferred projection.

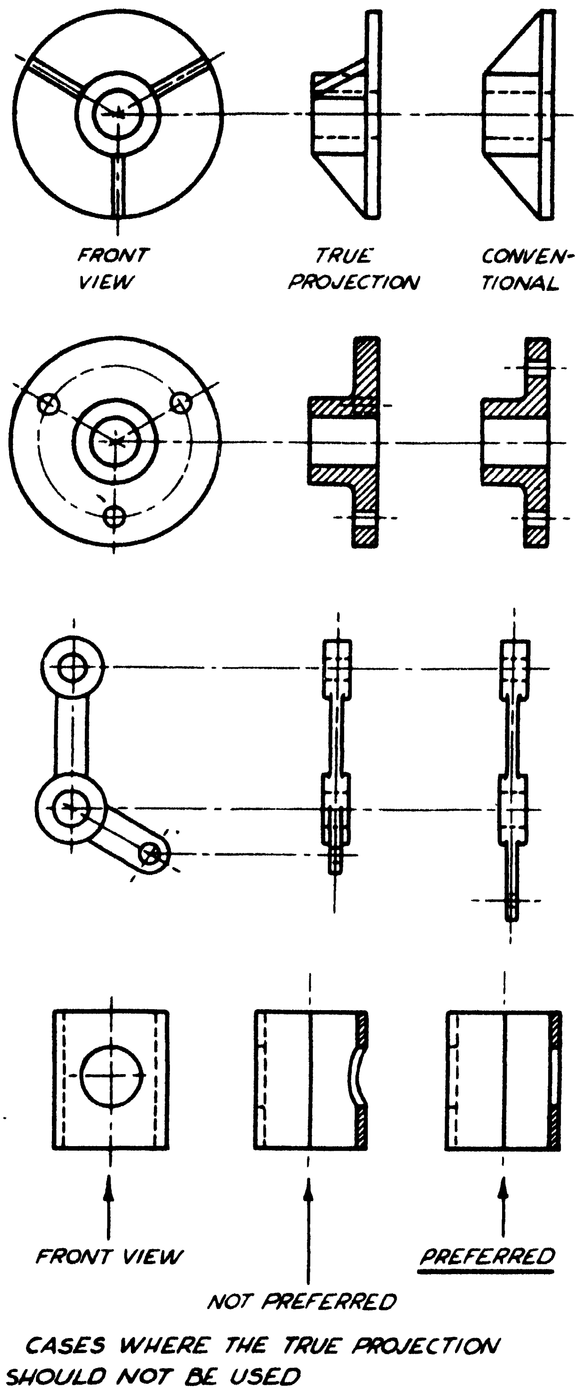


Fig. 187—CONVENTIONAL PROJECTION

DETAIL DRAWINGS

In machine work it is usually necessary to make two kinds of drawings, detail and assembly. A *detail* drawing shows an individual part of a larger structure, with the necessary views and dimensions to make that part. Such specifications are given on a detail drawing as are needed for the machinist to make the article without

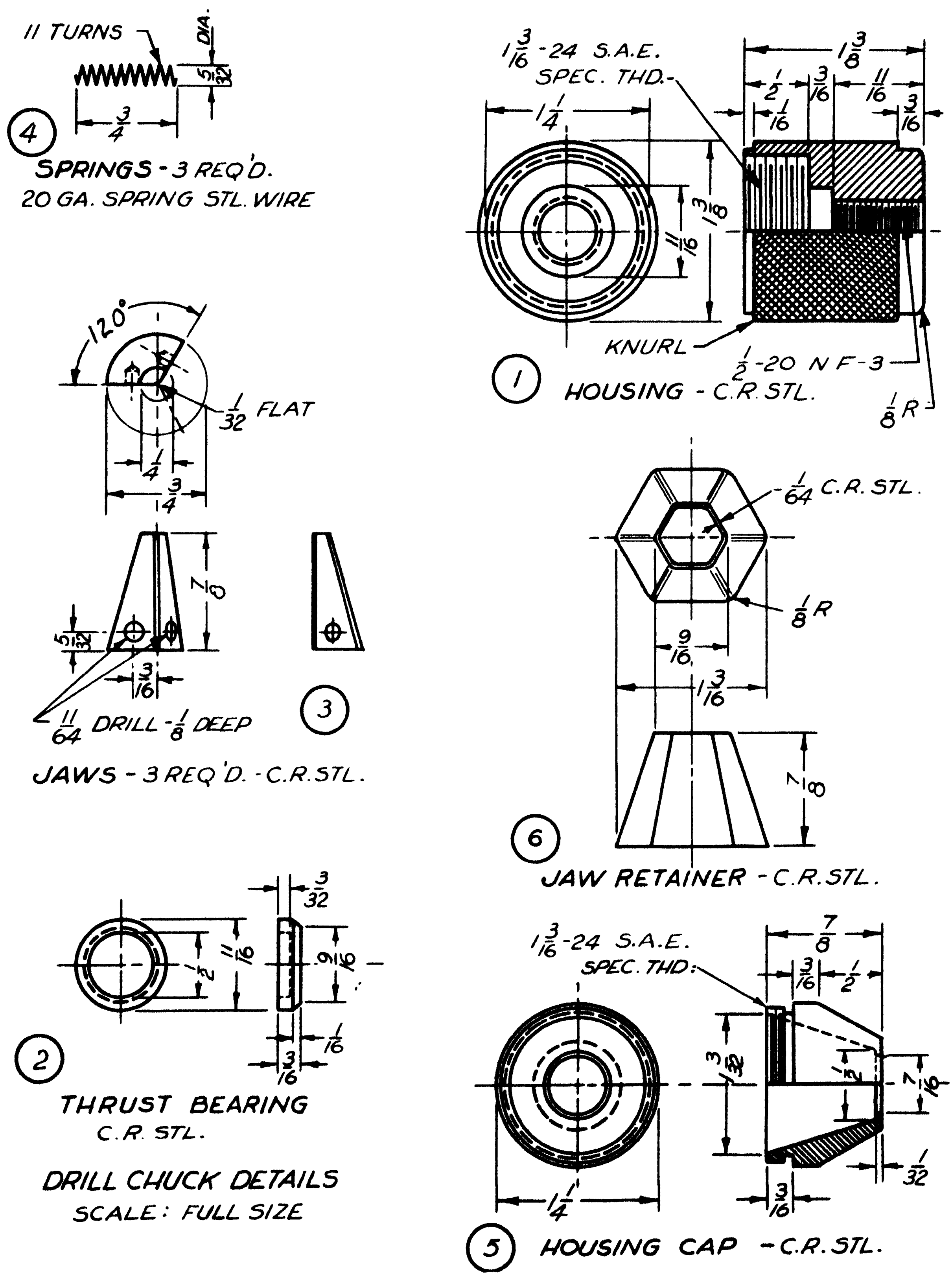
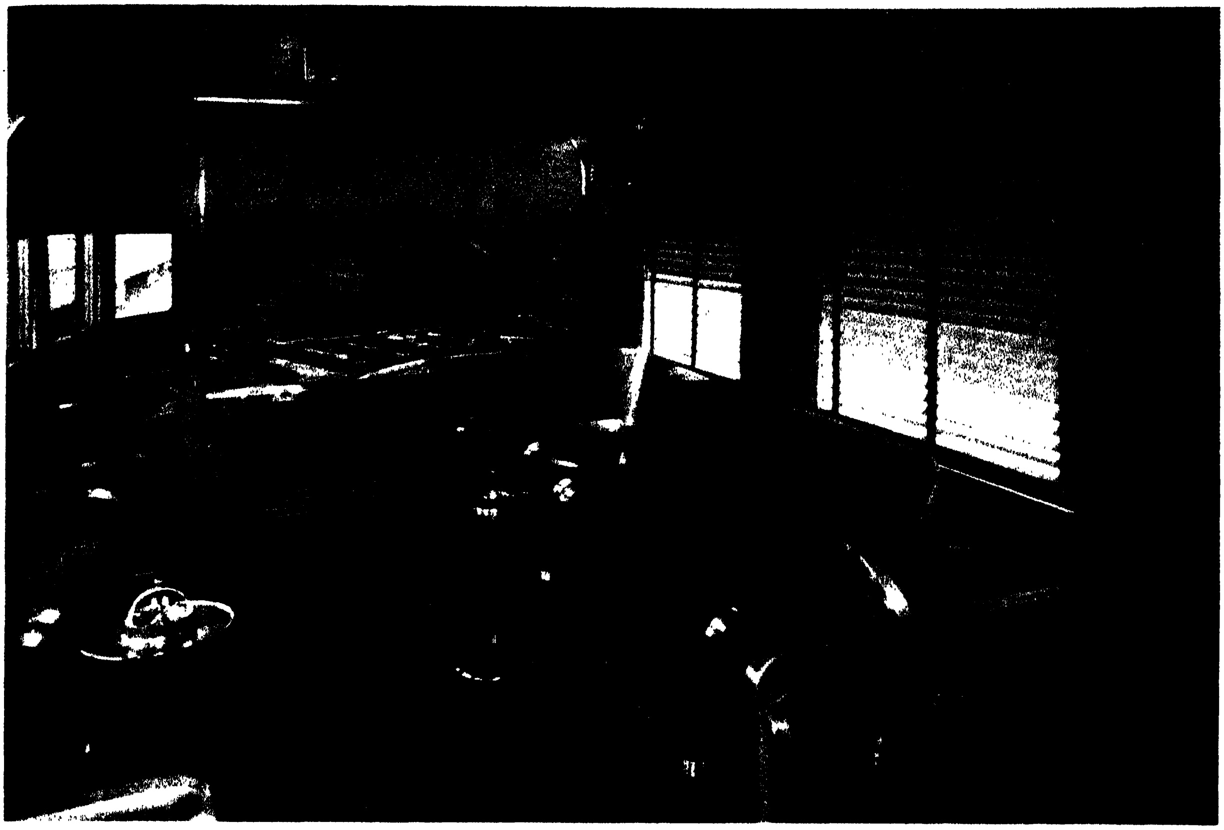


Fig. 188—DETAIL DRAWING OF DRILL CHUCK PARTS



Courtesy Pullman-Standard Car Manufacturing Company, Chicago

Fig. 189—INTERIOR OF A MODERN RAILWAY CAR

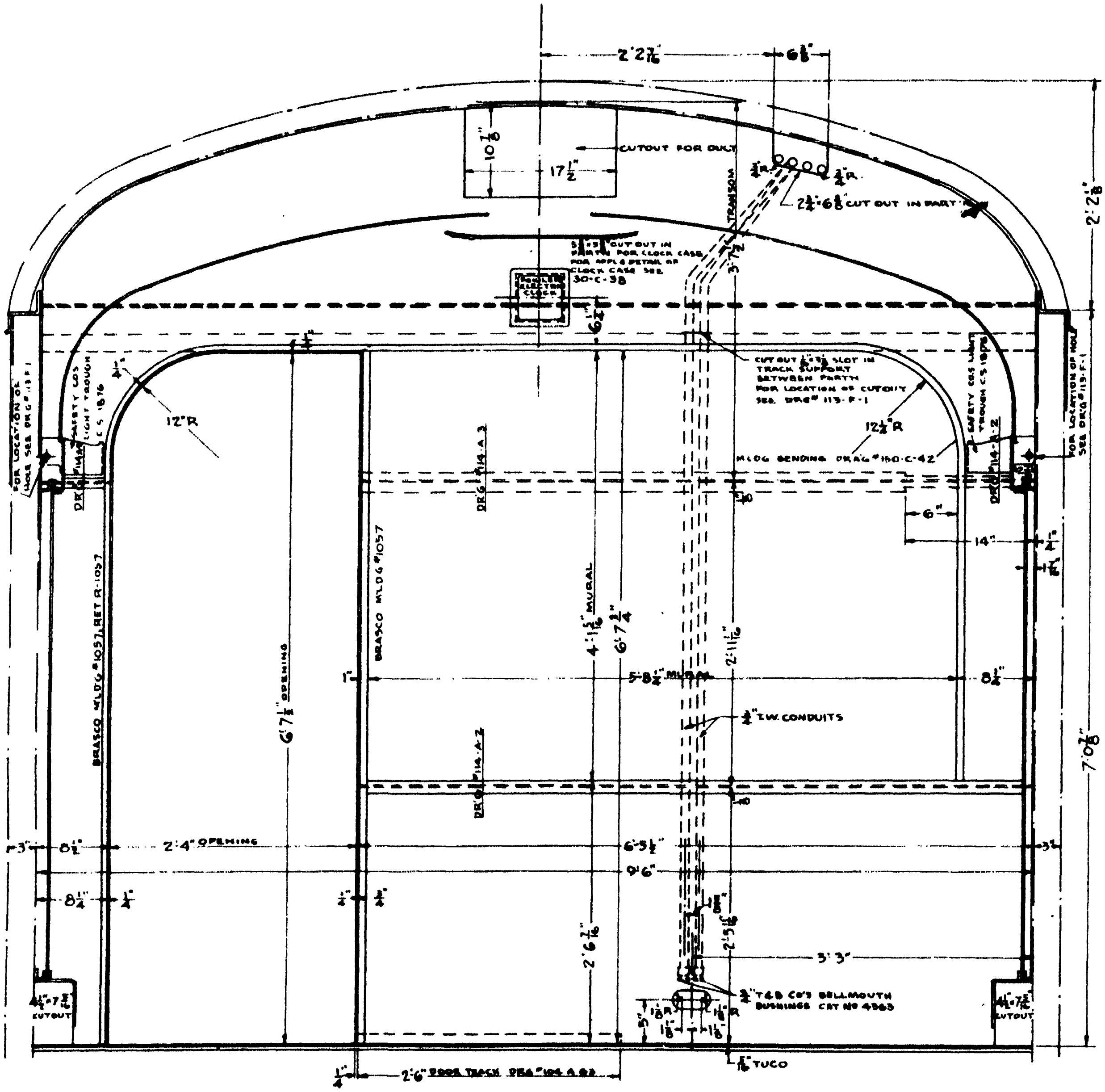
further instructions. Figure 188 shows a detail drawing for the various parts of a chuck. Some companies follow the procedure of showing only one part on each drawing. This is particularly true in the industries working on a mass production basis.

Detail drawings are usually made first and the assembly drawings made from them except for design assemblies, which are discussed on this page. Since large industries have become so specialized in the division of the various operations that go into making a complete whole, it is often convenient to make detail drawings for such special shops as the forge, foundry, and machine shops. These drawings contain only the information needed by the particular shop.

ASSEMBLY DRAWINGS

The *assembly* drawing shows the entire mechanism or a large section of it, with the various parts assembled or "put together" so that they may be seen in their proper relationships.

The designer of a new machine or structure is interested both in the relationships of all the various parts and in the requirements for each particular part. To help in determining what is necessary, the designer often makes use of a *design assembly.* This assembly is usually drawn full size except for large machines. It is often made with instruments, is generally not dimensioned, and is used when completed in the preparation of the detail and final assembly drawings. Often details have to be changed in the design assembly.



Courtesy Pullman-Standard Car Manufacturing Company, Chicago

Fig. 190—DRAWING OF PARTITION AT END OF CAR IN FIGURE 189

The details of simpler mechanisms are sometimes dimensioned completely in assembly drawings. These drawings are called *working-drawing assemblies* (see Figure 191).

For more complicated machines the assembly should contain only a few over-all dimensions if any dimensions are given. But each part should be numbered (or labeled) as shown in Figure 192. This drawing is an assembly section of the chuck shown in Figure 188. Sometimes an elevation and a section are both drawn. When the parts are numbered either a parts list or a bill of material should be placed on the drawing so that each part

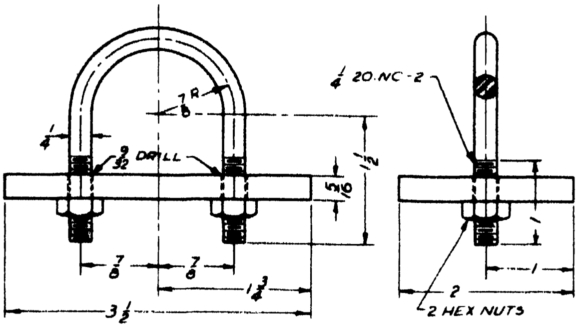
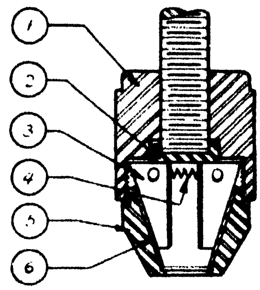


Fig. 191—WORKING-DRAWING ASSEMBLY



NO. PART	NAME	NO. REQ'D	MAT'L
1	HOUSING	1	STL
2	THRUST BEARING	1	STL
3	JAW	3	STL.
4	SPRING	3	SPRING STL
5	HOUSING CAP	1	STL
6	JAW RETAINER	1	STL.

ASSEMBLY OF DRILL CHUCK

Fig. 192—ASSEMBLY WITH LABELED PARTS

may be properly identified. A parts list and a bill of material are shown in Figure 193. On an assembly drawing the numbers are enclosed in circles and a leader is then drawn from each number to the particular part it identifies. As a matter of neatness all the numbers should line up in horizontal or vertical lines.

The purchaser of a machine often needs information as to the size, shape, and location of various parts in order to erect the machine. The *installation assembly drawing* (see Figure 195) provides this information for the pump shown in Figure 194. Such a drawing shows only the outlines of the exterior and the relationships between the exterior surfaces.

Complicated structures cannot be shown in a single assembly drawing. In such cases mechanisms are divided into units or groups of parts. The wiring system of an automobile (see Figure 196) is an example of such a *group assembly*.

Catalogues and other sales material often make use of *display assemblies*, which may include shade lines and surface shading as part of the effort to make articles attractive to prospective customers. Sometimes commercial artists make these drawings.

For individuals not skilled in reading orthographic projection, *pictorial assemblies* are sometimes prepared.

BEARINGS

The machines of today are more successful than those of earlier times because of the reduction of friction in the moving parts. Wherever a moving part is used, either roller or sliding bearings are found. If you have a bicycle, you will find ball bearings in the front and rear axles of the bicycle similar to those shown in Figure 197.

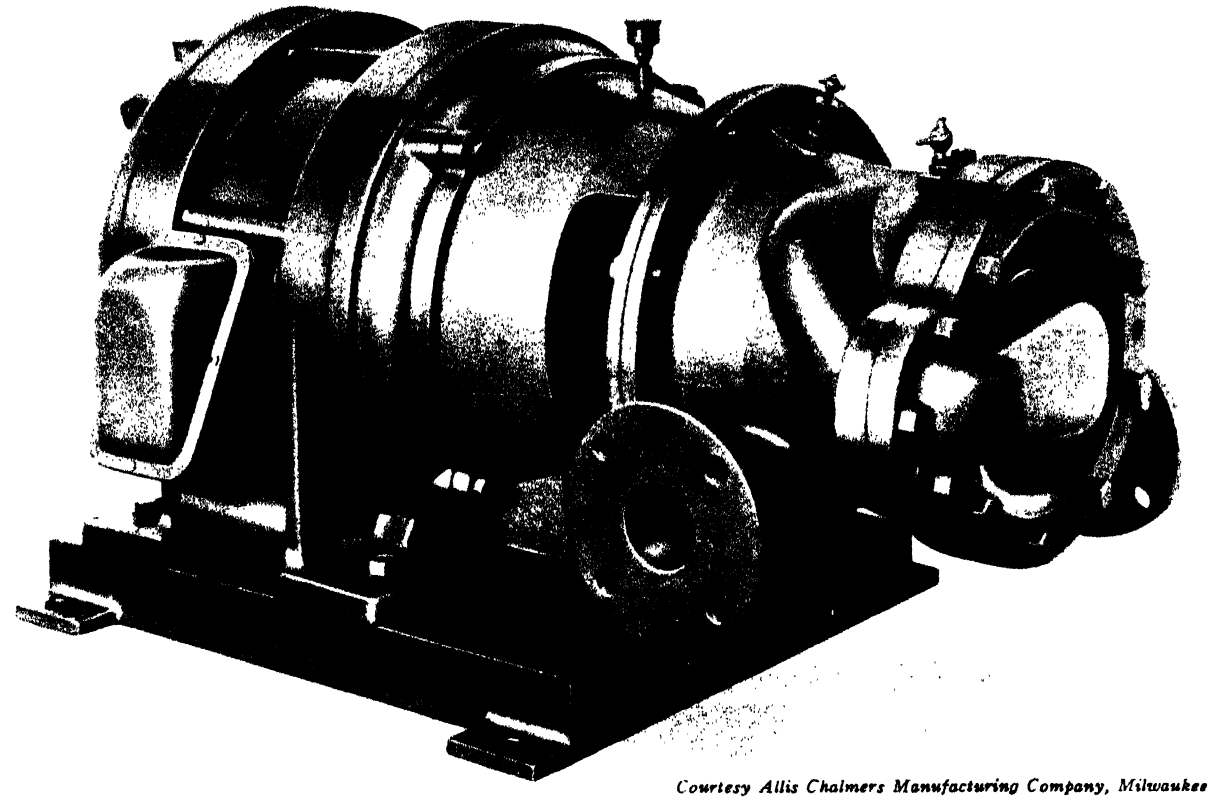
GEARS

The present-day automobile is the outstanding example of the use of modern gears. In the early days of the automobile the rear wheels were driven by a sprocket-chain drive similar to that used on a bi-

LIST OF PARTS	
PART NO.	NAME
1	BASE
2	BRACKET

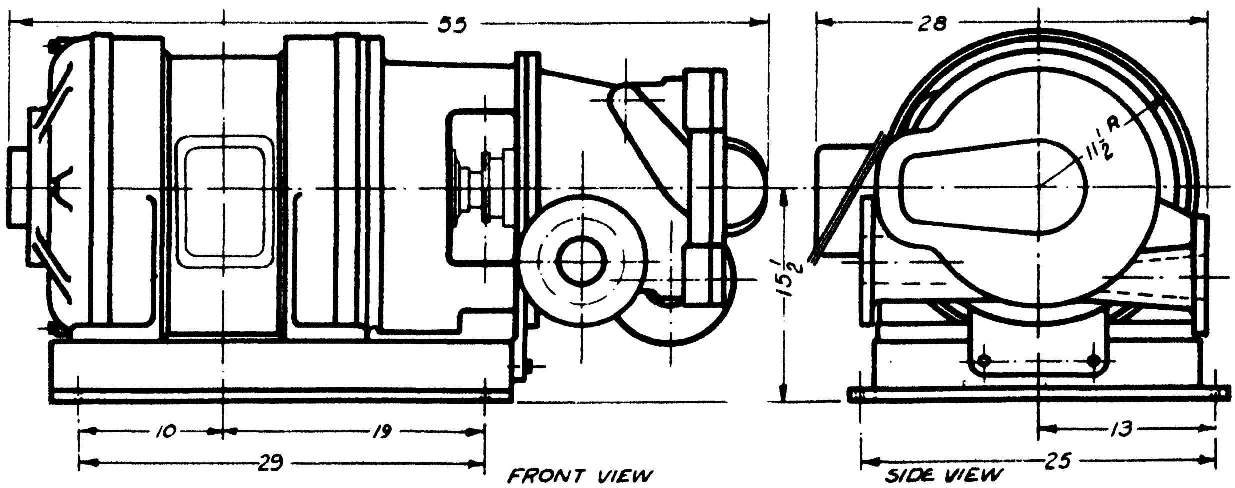
BILL OF MATERIAL			
PART NO.	NAME	MATERIAL	NO. REQ.
1	BASE	CAST IRON	1
2	BRACKET	CAST IRON	2

Fig. 193—PARTS LIST AND BILL OF MATERIAL



Courtesy Allis Chalmers Manufacturing Company, Milwaukee

Fig. 194—MULTIPUMP WITH 25-HORSEPOWER MOTOR



Courtesy Allis Chalmers Manufacturing Company, Milwaukee

Fig. 195—INSTALLATION ASSEMBLY

cycle. As improvements were made, the chain was eliminated in favor of gears. Figure 198 shows a typical gear used in industry today.

The material on gears in this book is designed to give you some knowledge of the common types of gears. Some engineers and designers in the industrial world devote their lives to the study and improvement of the design and workmanship of gears. It is impossible to include a detailed treatment of gears here; for further in-

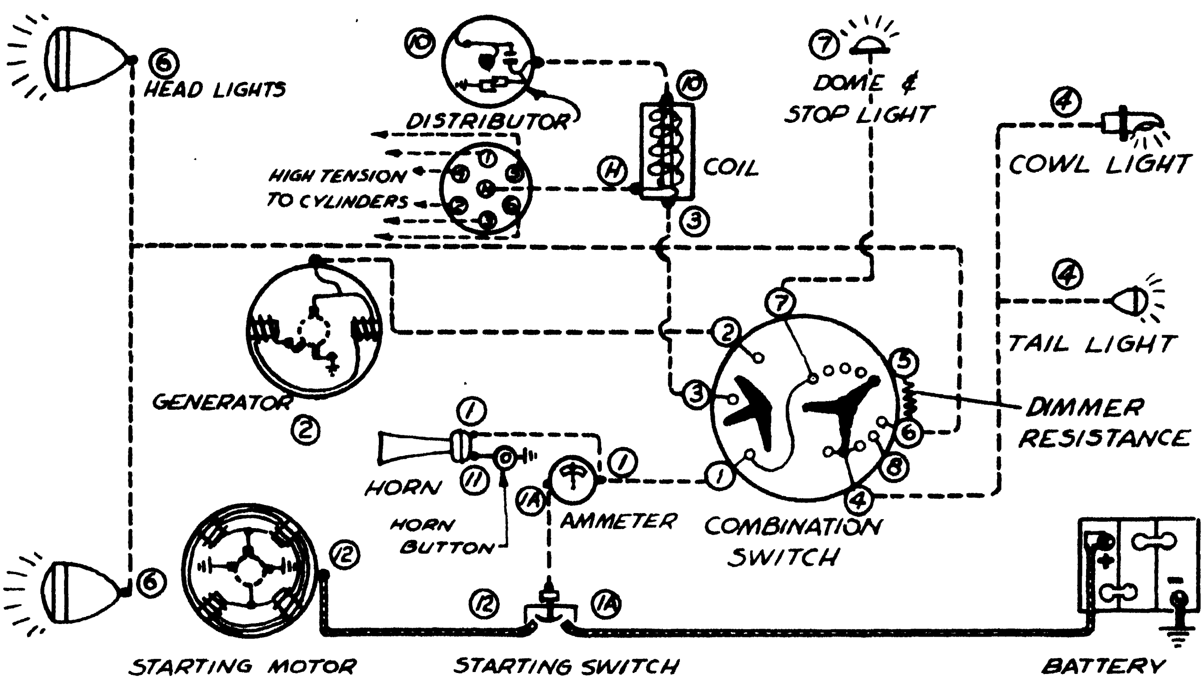


Fig. 196—GROUP ASSEMBLY

formation special books on gears may be studied.

All gears are really friction wheels, some with teeth, to prevent slipping. Figure 199 shows two types of friction wheels.

Figure 200 shows a spur gear, which is the common type used for power transmission between parallel shafts. If one of the pair of gears is much smaller than the other, it is called a *pinion* gear.

It is not necessary to draw the tooth outlines for gears, but certain specifications are needed to give the correct information. The specifications include the number of teeth and the diametrical pitch, which is the ratio of the number of teeth to the pitch diameter. Figure 201 is a detail drawing showing the names of the parts of a gear.

One of the largest *spur* gears ever made is shown in Figure 204. This gear, which weighs 54,000 pounds, was designed for use in a stone-crushing plant. Some idea of its height may be obtained by comparing its size with the height of the man standing next to it.

Another type of gear, the *bevel* gear, is shown in Figure 202. Bevel gears must be used in pairs. If bevel gears are put on shafts that are at right angles to each other, as shown, they are called *miter* gears. How-

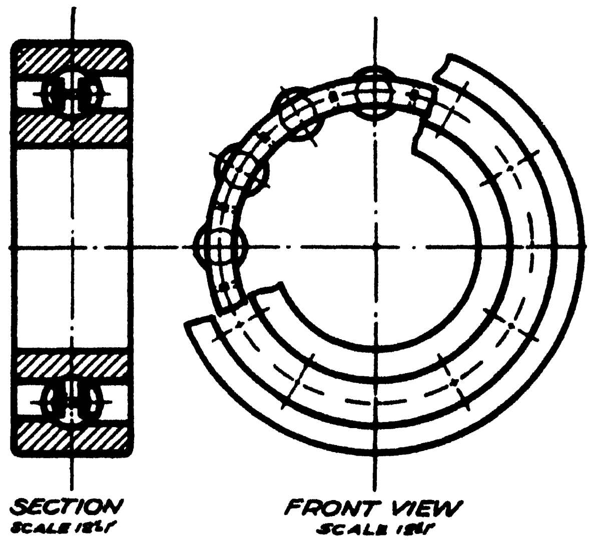


Fig. 197—BALL BEARINGS

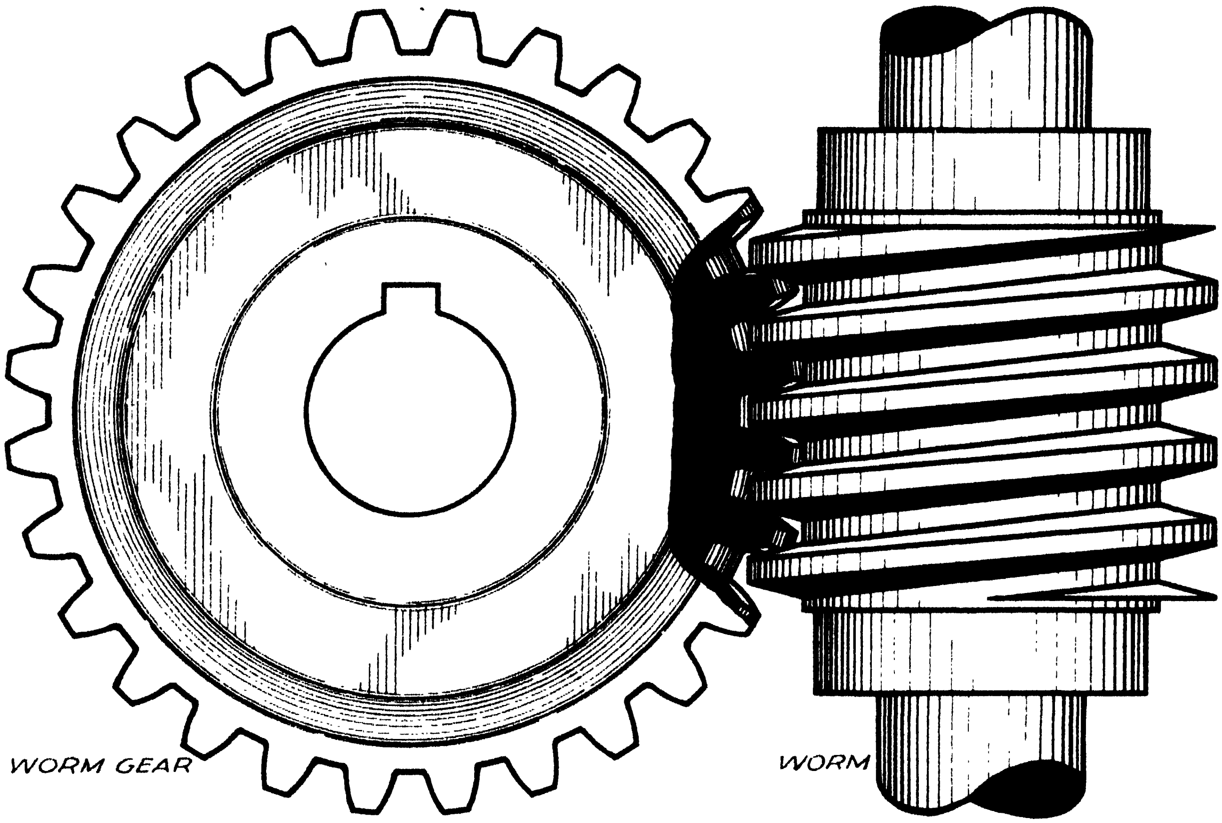


Fig. 198—A GEAR

ever, bevel gears may be designed for use on shafts that are at any angle with each other. The design of bevel gears involves the use of trigonometry and may present a difficult mathematical problem.

CAMS

Cams are plates or surfaces which are used to change or vary the motion of moving parts. Some of the common types of cams are shown in Figure 203. These are the *drum*, *heart*, and *plate*, or *disc*, cams.

SUMMARY

Machine drafting deals with drawing objects of many sizes, from the very small parts of machines up to and including assembled machines. Small but essential parts which must frequently be drawn are bolts, screws, and rivets; these are called fasteners. Bolts and screws have threads, which make them what we term removable fasteners, while rivets are called permanent fasteners. Among the more common thread forms are the American standard, square, and acme. There are several kinds of threads, to suit the various needs.

A most efficient means of making a permanent fastening is to weld the material. Several types of keys, such as a gib-head key, a taper, and a Woodruff key, are used to prevent motion between two parts, such as a wheel and shaft.

Corners of castings are rounded to add strength and to do away with sharp edges. The inside rounded corners are called fillets and the outside ones rounds. Parts of castings are sometimes machined to give a smooth finish. The area to be finished is indicated on the drawing with a 60° *V*,

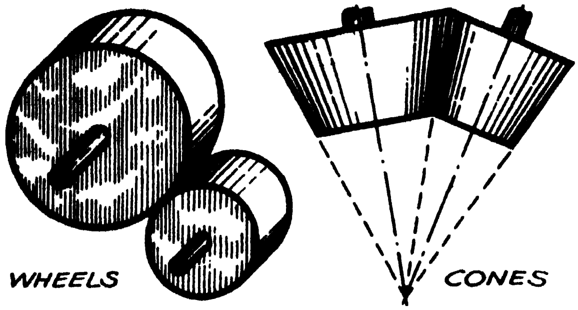


Fig. 199—FRICTION WHEELS

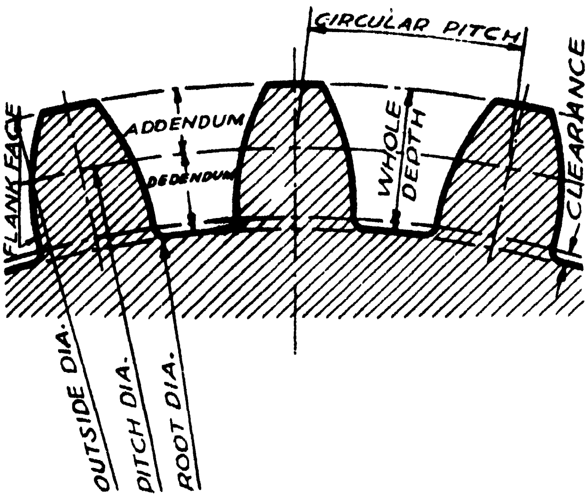


Fig. 201—NAMES OF GEAR PARTS

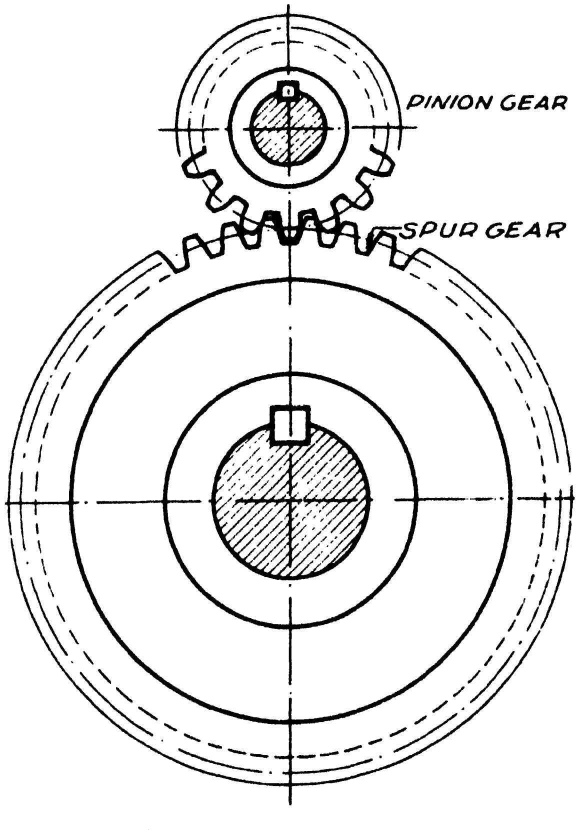


Fig. 200—A SPUR GEAR

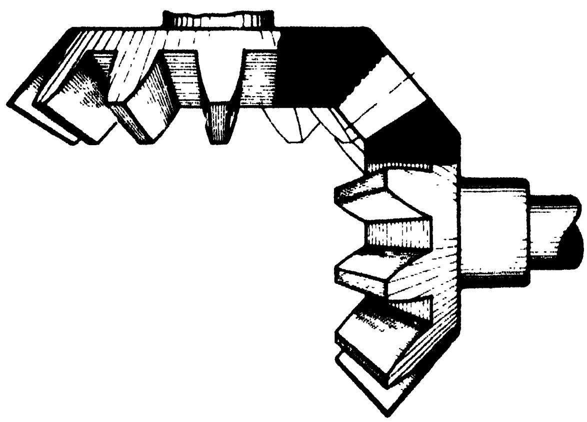


Fig. 202—A BEVEL GEAR

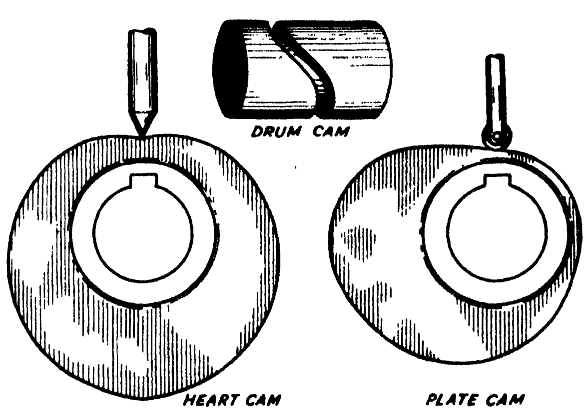
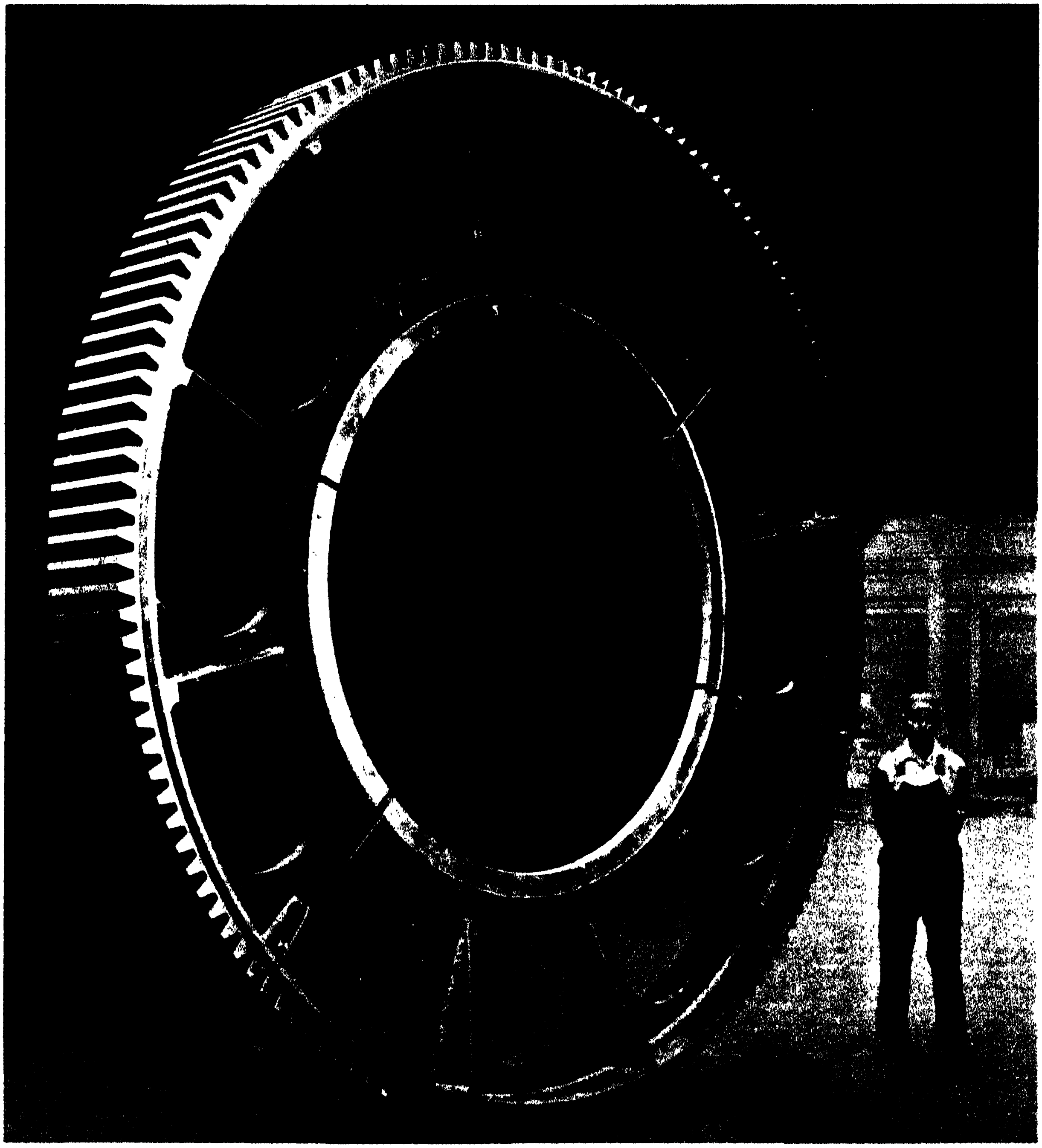


Fig. 203—CAMS

or in some cases the old finish mark *f* is used.

There are two main classes of machine drawings, detail and assembly. In detail drawing each part is drawn and completely dimensioned and all the necessary information is given for the making of that part. The assembly drawing shows all the parts fitted together in their proper working positions. In both kinds of drawings many



Courtesy Allis Chalmers Manufacturing Company, Milwaukee

Fig. 204—A LARGE SPUR GEAR

types of sections are usėd, such as full, half, broken, or partial, and revolved.

Among the commonly used parts in machine manufacture are bearings, gears, and cams. Each of these parts is used to accomplish a particular function. For example, gears are used to transmit power from one place to another. Bearings are used to reduce friction. Cams are used to vary the type of motion. .

THREAD FORMS

Problem 1—American Standard Threads

Make a section showing the shape of the American standard thread. Make the pitch equal to $\frac{3}{4}''$ on this drawing. Make the length of the threaded portion $5\frac{1}{4}''$. See Figure 205.

Problem 2—Square Threads

Draw along the top edge the profile of square threads. The pitch is $\frac{1}{2}''$; the length is $2''$.

Problem 3—Acme Threads

Using an area the same size as in Problem 2, draw the profile of an acme thread with a pitch equal to $\frac{1}{2}''$. Draw the angle between the faces of the profile 30° instead of 29°. Dimension it as 29°. We do this because a series of 29° angles requires too much time to construct with a protractor, and there is so little difference that it cannot be detected on the drawing.

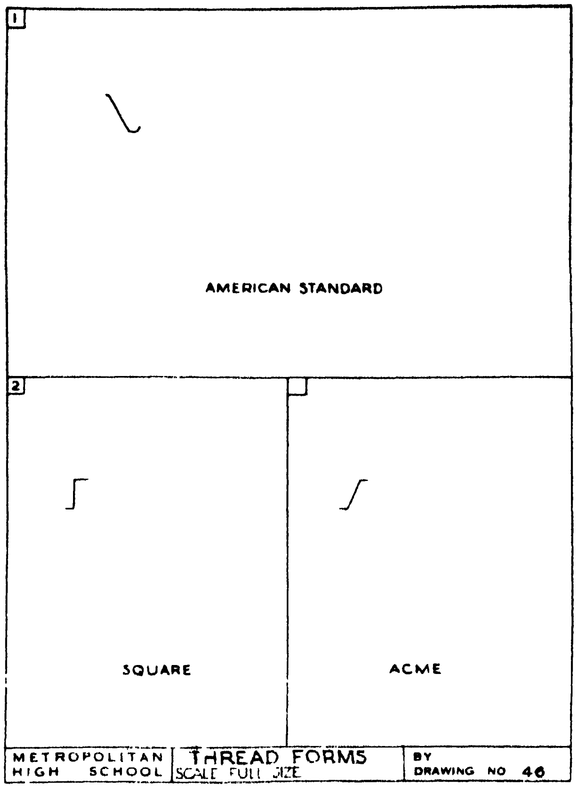


Fig. 205—THREAD FORMS (PROBLEMS 1, 2, AND 3)

LARGE THREADS

Problem 1—External Threads

Draw the American standard shaped thread on the end of a $2\frac{1}{2}''$ diameter bolt, four threads to the inch. This thread belongs to the NC (National Coarse) Series. Make the length of the threaded portion $3\frac{1}{2}''$. Put the following thread note on the drawing: $2\frac{1}{2}$-4 NC-2. The $2\frac{1}{2}$ is the diameter of the bolt, the 4 the number of threads per inch, *NC* the thread series, and 2 the class of fit. See Figure 206.

Problem 2—Internal Threads

The thread in this problem is a mate to the one drawn in Problem 1. The material is to be sectioned. Note the direction of the thread lines. The material is threaded all the way through. It is $2''$ thick.

REGULAR THREAD CONVENTIONS

The drawing for Figure 207 is the same as the left half of Figure 162 except that a $1''$ diameter is used for each of the threads. Choose your own thread series and class of fit and indicate each in a note. In the second column show these same threads in front views and in the third column show the threads in end views.

SIMPLIFIED THREAD CONVENTIONS

The threads on this drawing are the same as in Figure 207 except that they are shown in the simplified convention. See the right half of Figure 162. Make the diameters of the threads $1''$. Choose your own thread series and class of fit and indicate them in a thread note.

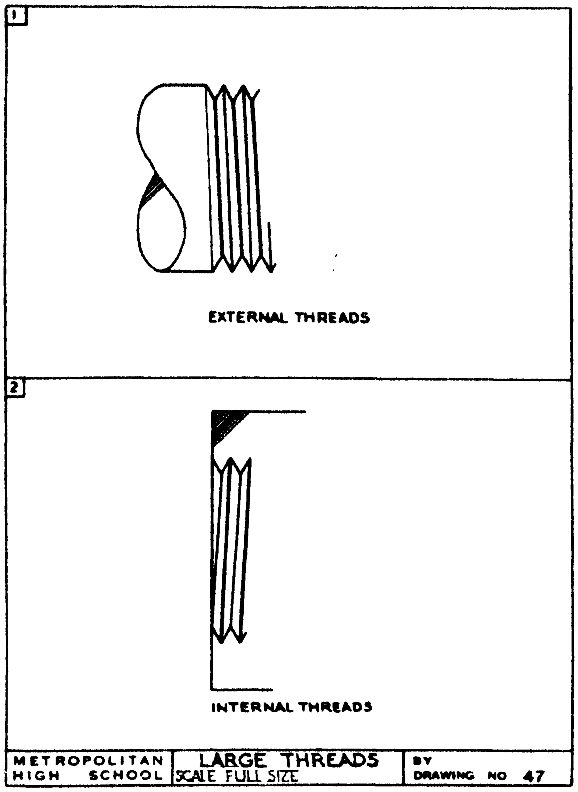


Fig. 206—LARGE THREADS (PROBLEMS 1 AND 2)

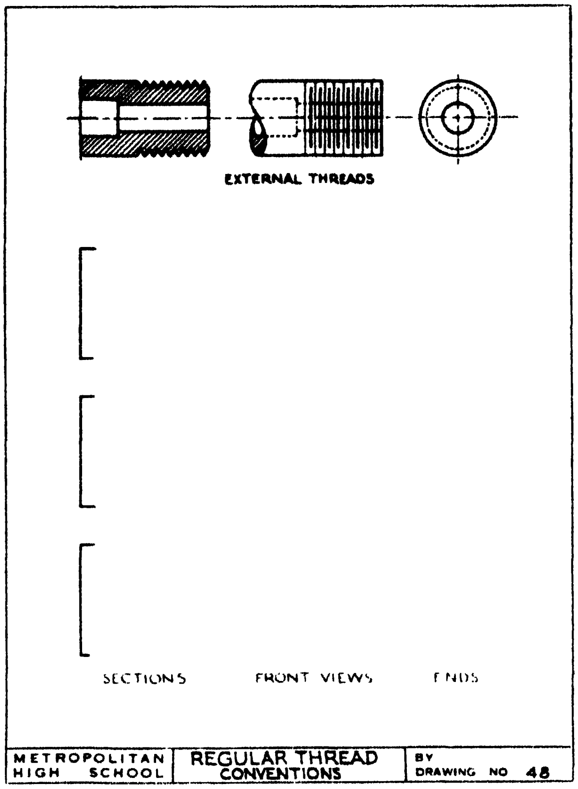


Fig. 207—REGULAR THREAD CONVENTIONS (PROBLEM)

BOLTS AND NUTS

Problem 1—Hexagonal Head

Refer to Figure 166 to get proportions for drawing the boltheads and nuts for Figure 209. Draw the bolthead and the side view of the bolt with the nut engaged on the bolt. In making your drawing use a 1″ diameter bolt and make the bolt 3″ long. Dimension your drawing in terms of *D*, however. Notice that the thickness of the bolthead is different from the thickness of the nut. Turn the bolthead so that two corners of the hexagon are located on the vertical center line.

Problem 2—Square Head

This problem is the same as Problem 1 except that the bolthead and nut are square.

SECTIONS

Problem 1—Flange

Make a full section of the cast-iron flange shown in Figure 210. The section is to be drawn in the location usually used for the side view. The side view is to be omitted. The section is to be taken on the vertical center line of the front view. Omit all invisible lines in sectional views. Pay particular attention to the location of the holes in the section since these are obtained by conventional projection instead of true projection. See page 117.

Problem 2—Column Support

A full section of the column support is to be drawn. Care should be taken when drawing the webs. Refer for help to Figure 187, page 117.

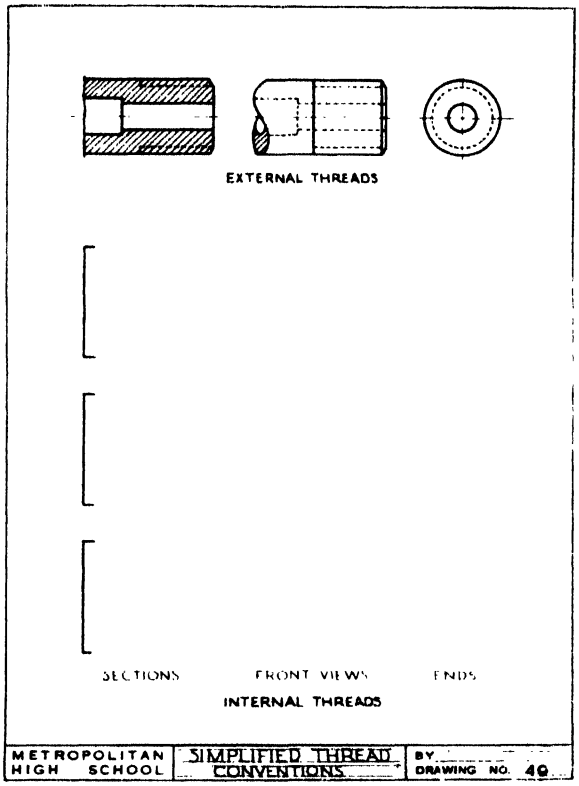


Fig. 208—SIMPLIFIED THREAD CONVENTIONS (PROBLEM)

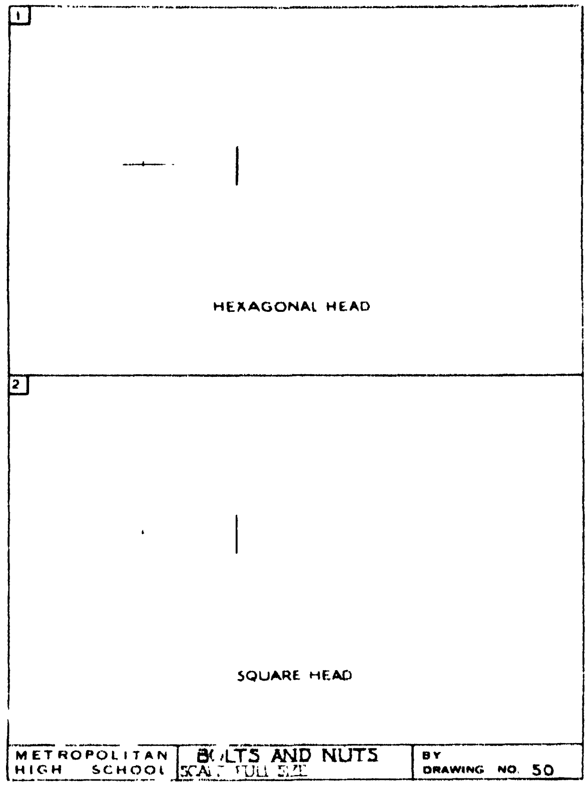


Fig. 209—BOLTS AND NUTS (PROBLEMS 1 AND 2)

RATCHET WHEEL

In Figure 211 the drawing shows a small piece used on many machines and a bit different from the usual ones. Make sure your dimensions are complete and correct. Draw front and top views of the ratchet wheel. The front view may be first blocked in a circle whose diameter is 4″. The points of the teeth may be located by drawing 45° lines in each direction through the intersection of the center lines. Dimension fully.

WRENCH

Draw the front view of the wrench and about the indicated center line show a revolved section of the handle. Extreme care must be exercised in laying out all the arcs and angles. See Figure 212.

HOLD-DOWN CLAMP DETAILS

Make a detail working drawing of each part of the hold-down clamp of the woodworking shaper. As in Figure 213, make as many views or sections as necessary to show each part completely. Pay particular attention to the location of each of the views on the drawing. Assign each part an identification number and place this number in a small circle just in front of the part title. On the line below the part title letter the name of the material from which the part is made. On the next line list the number required. Dimension completely.

HOLD-DOWN CLAMP ASSEMBLY

Make an assembly drawing of the hold-down clamp for the woodworking shaper shown in Figure 218. Turn your drawing

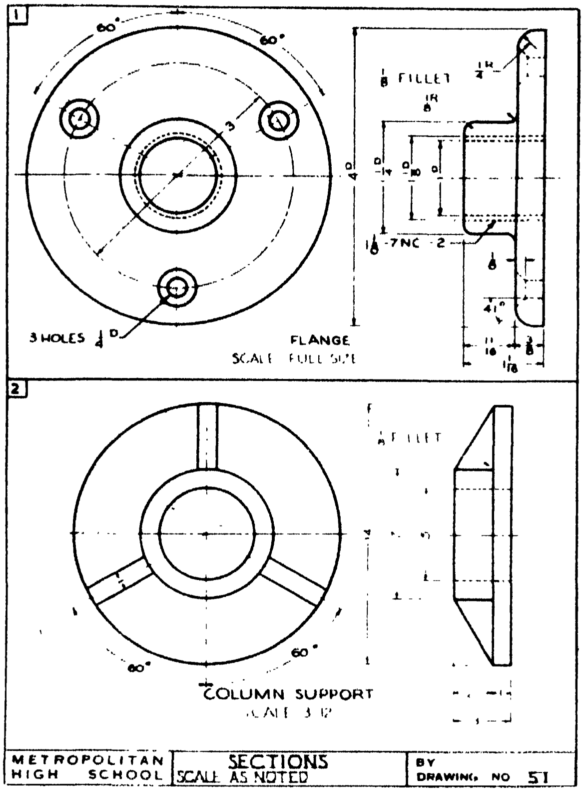


Fig. 210—SECTIONS (PROBLEMS 1 AND 2)

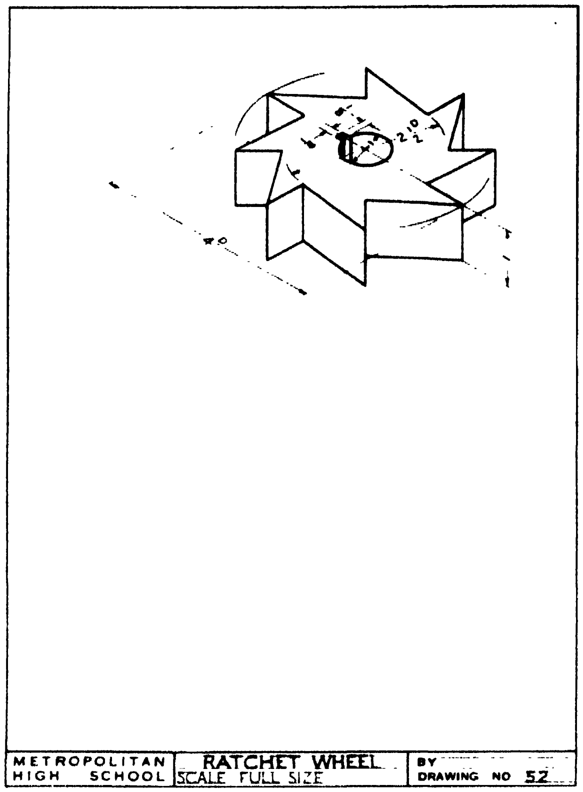


Fig. 211—RATCHET WHEEL (PROBLEM)

paper lengthwise and draw one elevation and one section of the clamp. Omit all dimensions. Number each part and make a parts list.

MONKEY WRENCH HANDLE

Make a detail working drawing of the handle of the monkey wrench shown in Figure 214. Show two views, front and side, with complete dimensions and notes.

MONKEY WRENCH PARTS

Draw all the necessary views of the remainder of the parts of the monkey wrench, shown in Figure 215. Use the regular or simplified convention for screw threads. Draw at least two views of each part and sections if necessary. Before laying out the sheet, sketch the necessary views lightly to get a good arrangement on the sheet.

ASSEMBLY OF MONKEY WRENCH

Make an assembly drawing, either section or elevation, of the monkey wrench shown in Figure 219, omitting all dimensions. Number each part and list it in a parts list.

POLISHING HEAD BASE

Make a detail drawing of the base of the polishing head shown in Figure 216. Give complete dimensions and notes. Draw three views, front, top, and right side. Study the spacing of the views on the sheet carefully before starting to draw. Lay out the center lines for each view; then block in each view. Locate center lines for the holes and draw the holes lightly. The inclined ends should be drawn in the front view and then projected to the two other views.

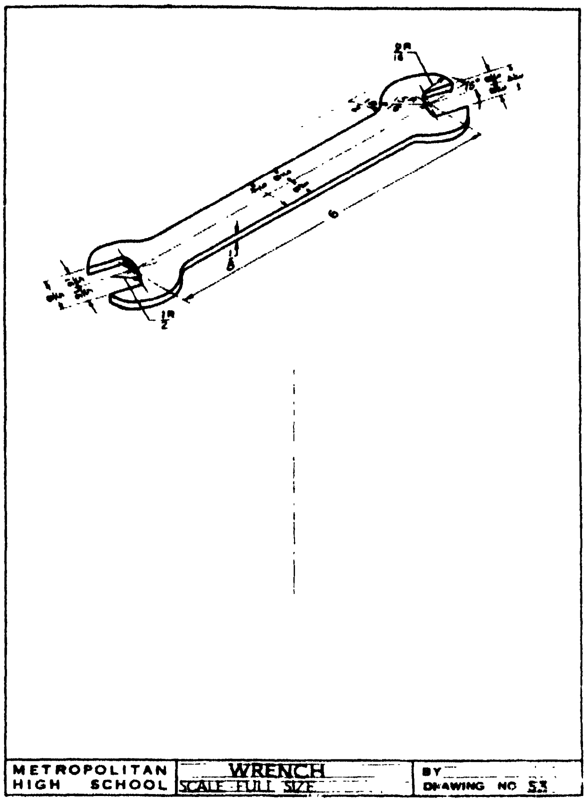


Fig. 212—WRENCH (PROBLEM)

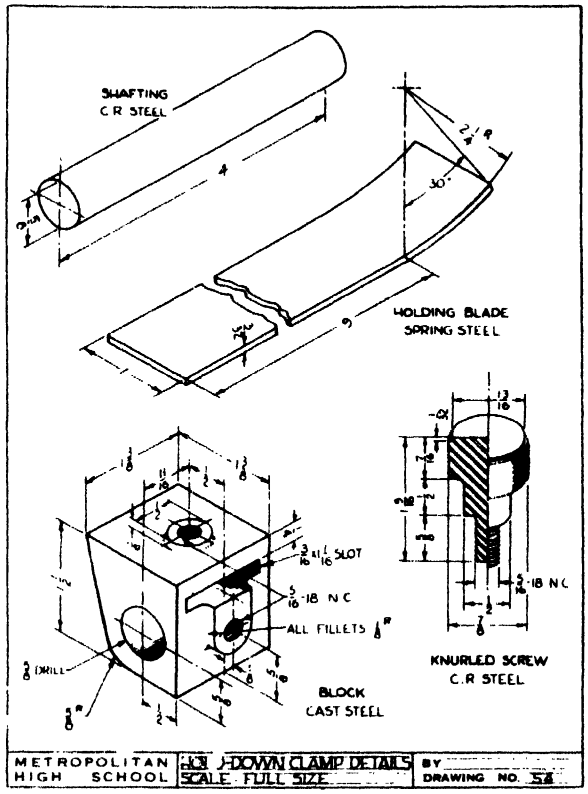


Fig. 213—HOLD-DOWN CLAMP DETAILS (PROBLEM)

POLISHING HEAD PARTS

Make complete working drawings of all the parts of a polishing head except the base. See Figure 217.

ASSEMBLY OF A POLISHING HEAD

Make an assembly drawing of a polishing head. Number each part and make a parts list.

QUESTIONS

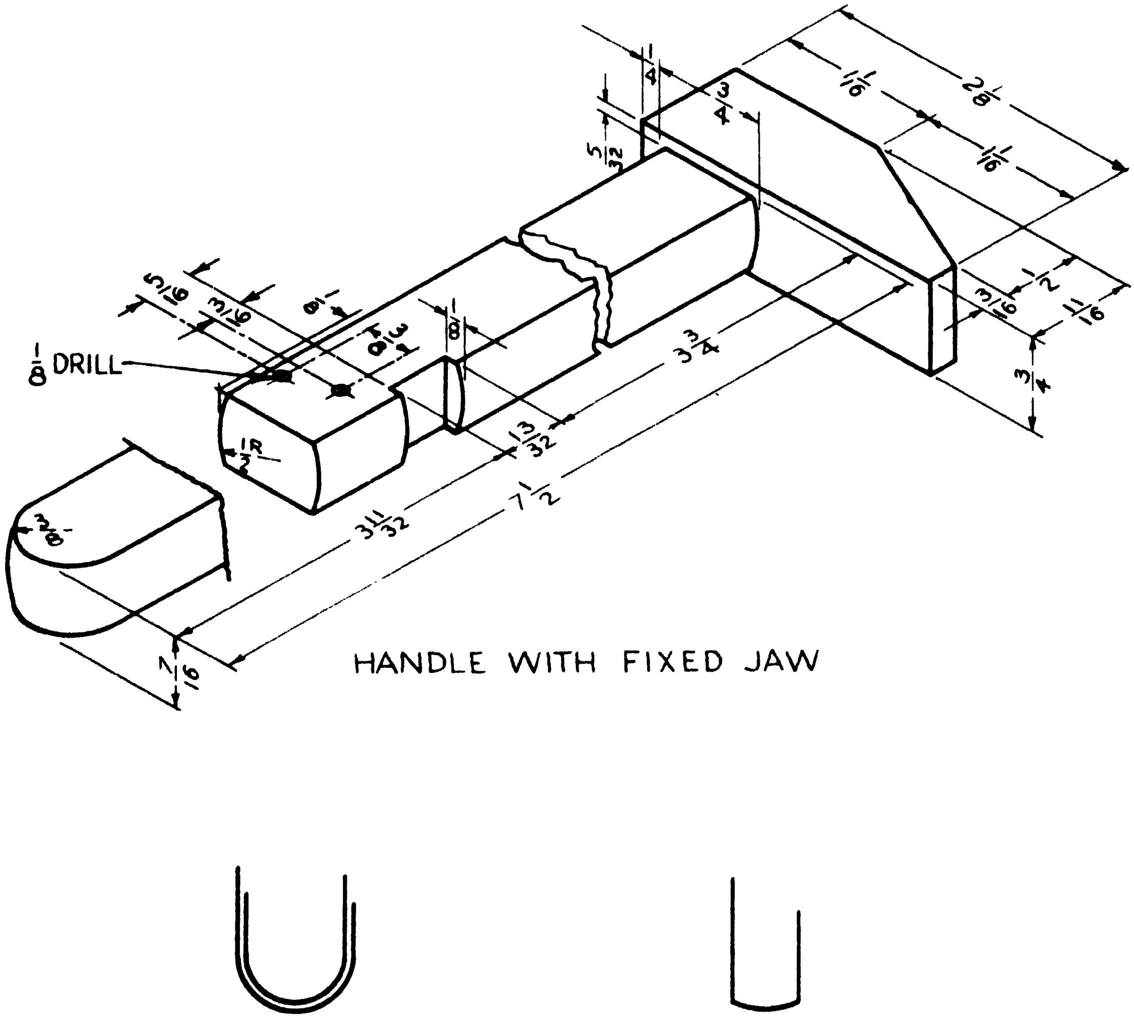
1. What two general types of fasteners are there?
2. What is one of the screw threads most commonly used?
3. What are the classes of screw fits?
4. Explain the following: 1-8 NC-3.
5. How do we indicate a finished surface on a drawing?
6. Distinguish between a detail drawing and an assembly drawing.
7. What are three common types of gears?
8. What is the difference between setscrews and machine screws?
9. Show by a sketch what is meant by a revolved section.
10. Tell how some common materials are represented in sections.

TOPICS FOR DISCUSSION

1. The amount of welding that is being done today in machine work has increased rapidly. A short paper on the history of this phase of machine work should prove very interesting.

2. Many machines have some portion that consists of a casting. In order to make a casting, a pattern has to be made first. Look up the procedure followed in patternmaking and write a short description of what happens in a pattern shop.

3. After the pattern has been completed the casting has to be made. The casting is made in a foundry. Consult some textbooks on foundry work and prepare a short paper on the procedures in this shop.



METROPOLITAN HIGH SCHOOL	MONKEY WRENCH DETAILS SCALE : FULL SIZE	BY DRAWING NO. 56

Fig. 214—MONKEY WRENCH HANDLE (PROBLEM)

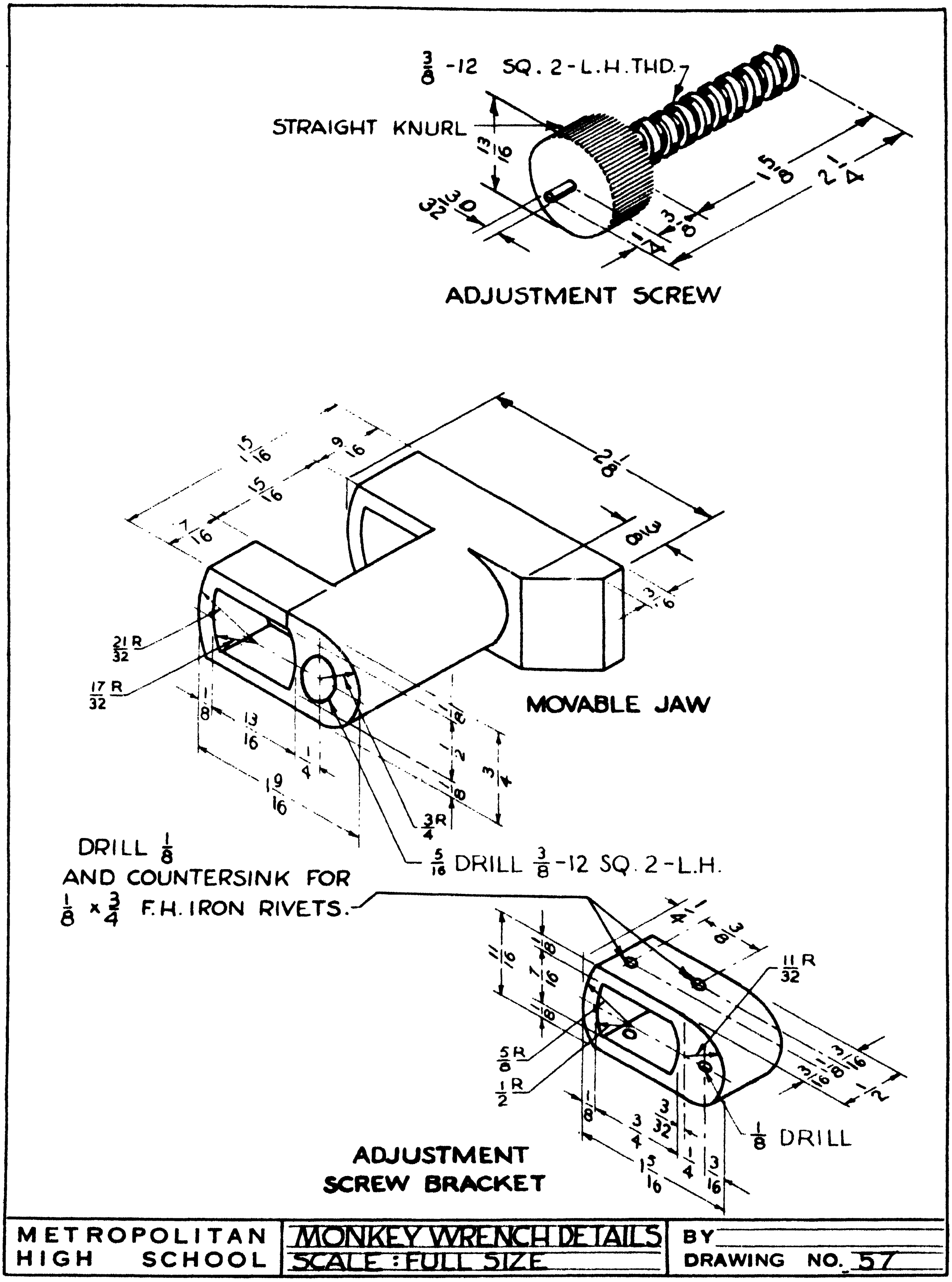


Fig. 215—MONKEY WRENCH PARTS (PROBLEM)

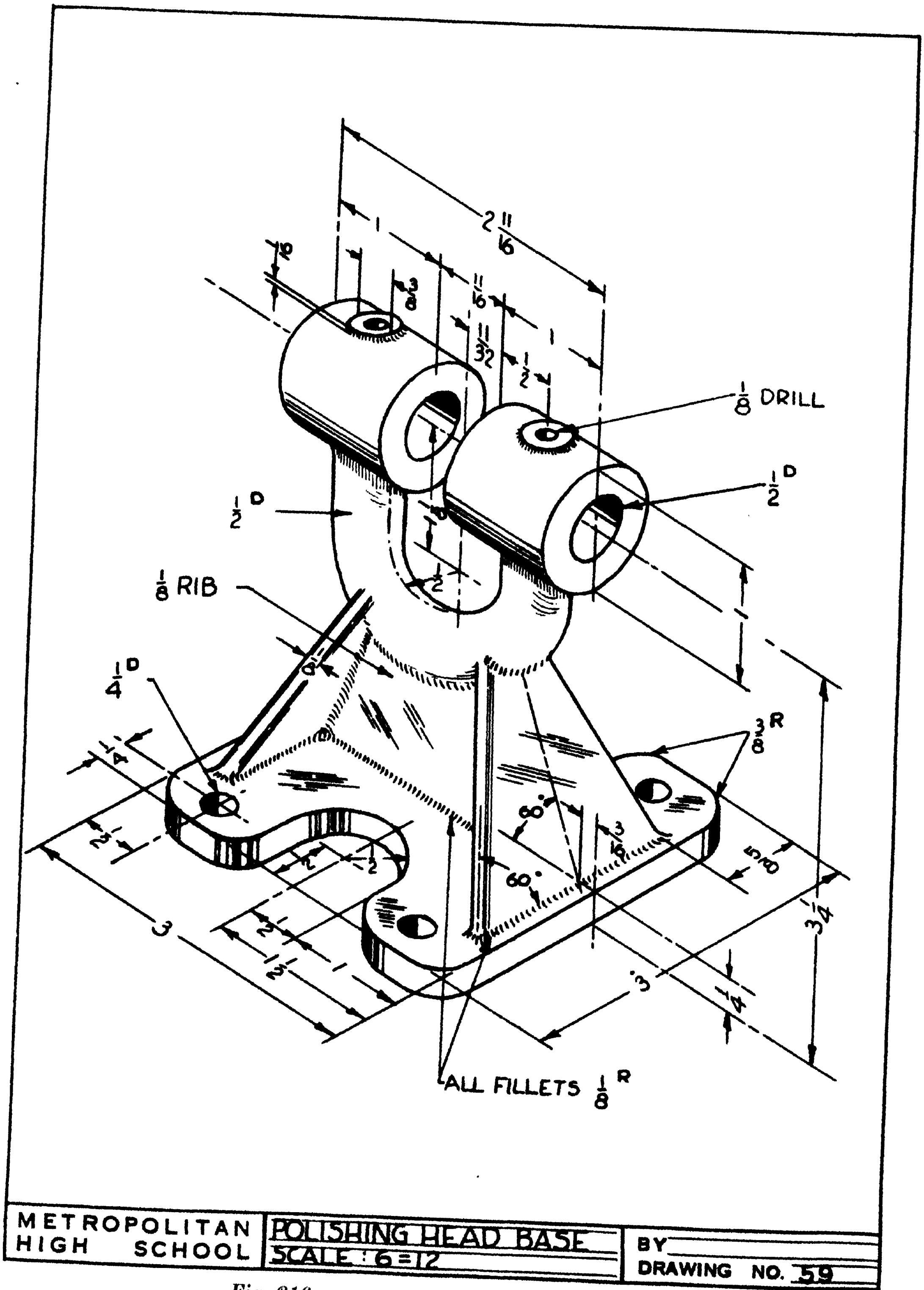


Fig. 216—POLISHING HEAD BASE (PROBLEM)

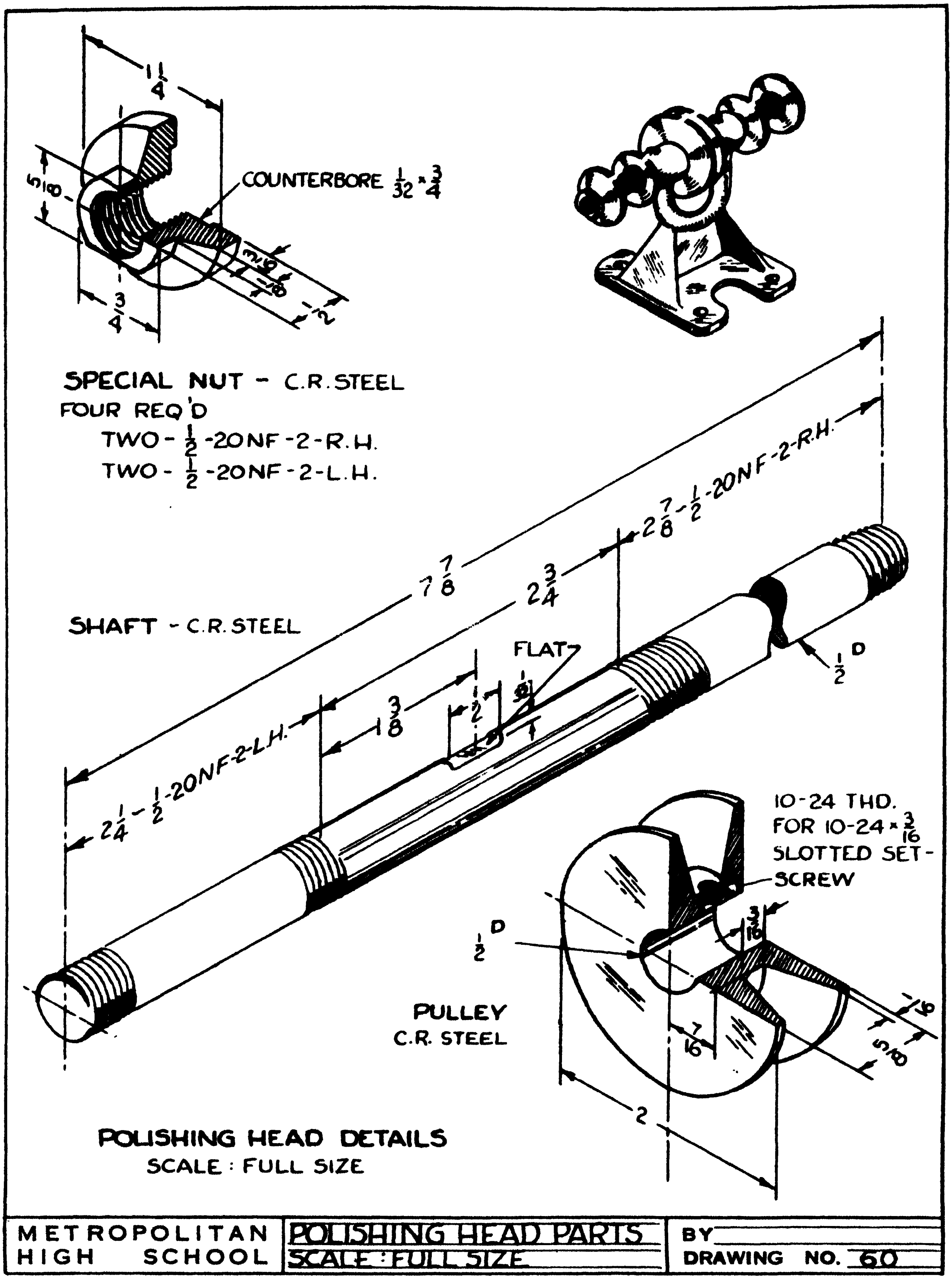


Fig. 217—POLISHING HEAD PARTS (PROBLEM)

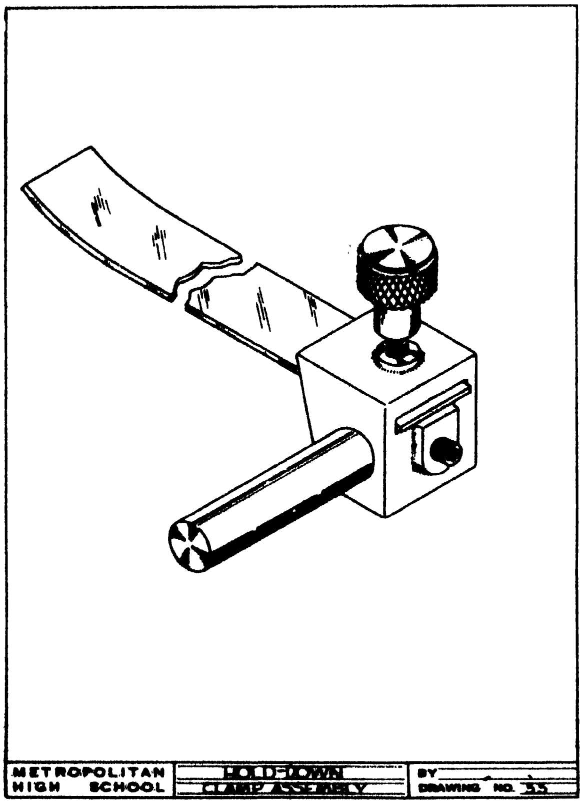


Fig. 218—HOLD-DOWN CLAMP ASSEMBLY (PROBLEM)

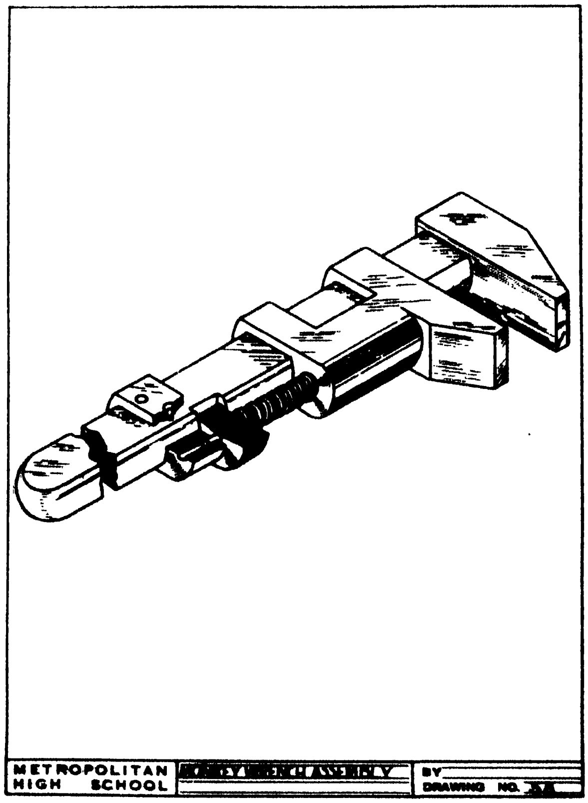


Fig. 219—ASSEMBLY OF MONKEY WRENCH (PROBLEM)

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UNIT IX

AIRCRAFT DRAFTING

PROGRESS OF AVIATION

For centuries man attempted to invent machines or devices that would enable him to fly. His earlier designs were patterned after the wings of birds, but none of his efforts proved successful until the Wright brothers designed and flew an airplane in 1903. Their flight was very short, about 120 feet, but it was enough to prove that heavier-than-air machines could be made to fly. Lighter-than-air craft, such as balloons, had been successfully flown as early as 1783.

Since 1903 much progress has been made in the flying of airplanes and in the design and construction of these planes. (See Figure 220.) The first twenty-five years of making and flying airplanes were a period of experimentation mainly, although tremendous advancement was made. The airplane was used somewhat during the First World War as a military weapon. After the war it was used experimentally for carrying mail, and many planes were used by sportsmen. The air-mail service grew rapidly, and by the early 'twenties passengers were carried on regularly scheduled airlines.

As airline business grew it created a demand for planes designed to carry heavier loads and with greater convenience for the passengers. New improvements were constantly added to make the planes safer and more comfortable. The airplane is now established as one of the principal means of travel and of shipping mail and express all over this country. In addition, transoceanic air routes have been developed between one continent and another.

In the Second World War the airplane has been of major importance. Many planes of different designs for numerous operations have been planned and built. These have been made in large numbers on a mass production basis. This has meant that many thousands of workers have had to be trained in the various phases of aircraft construction. In general, workers in the aircraft industry have to be highly skilled as their duties require exact workmanship. For example, since there is tremendous vibration between the parts of a plane, there can be very little tolerance, or play. This means that some of the work done must be within a few thousandths or ten-thousandths of an inch. Consequently airplane designers and draftsmen must be trained to be exceedingly accurate. The commercially operated airlines and the demand for military planes make the aircraft industry one of the major industries of this country.

AIRCRAFT MATERIALS

Various materials are used in airplane construction. The earlier plane had a wooden framework covered with a treated fabric. This made a very lightweight plane. Some of the smaller aircraft being built today are made of the same materials, al-

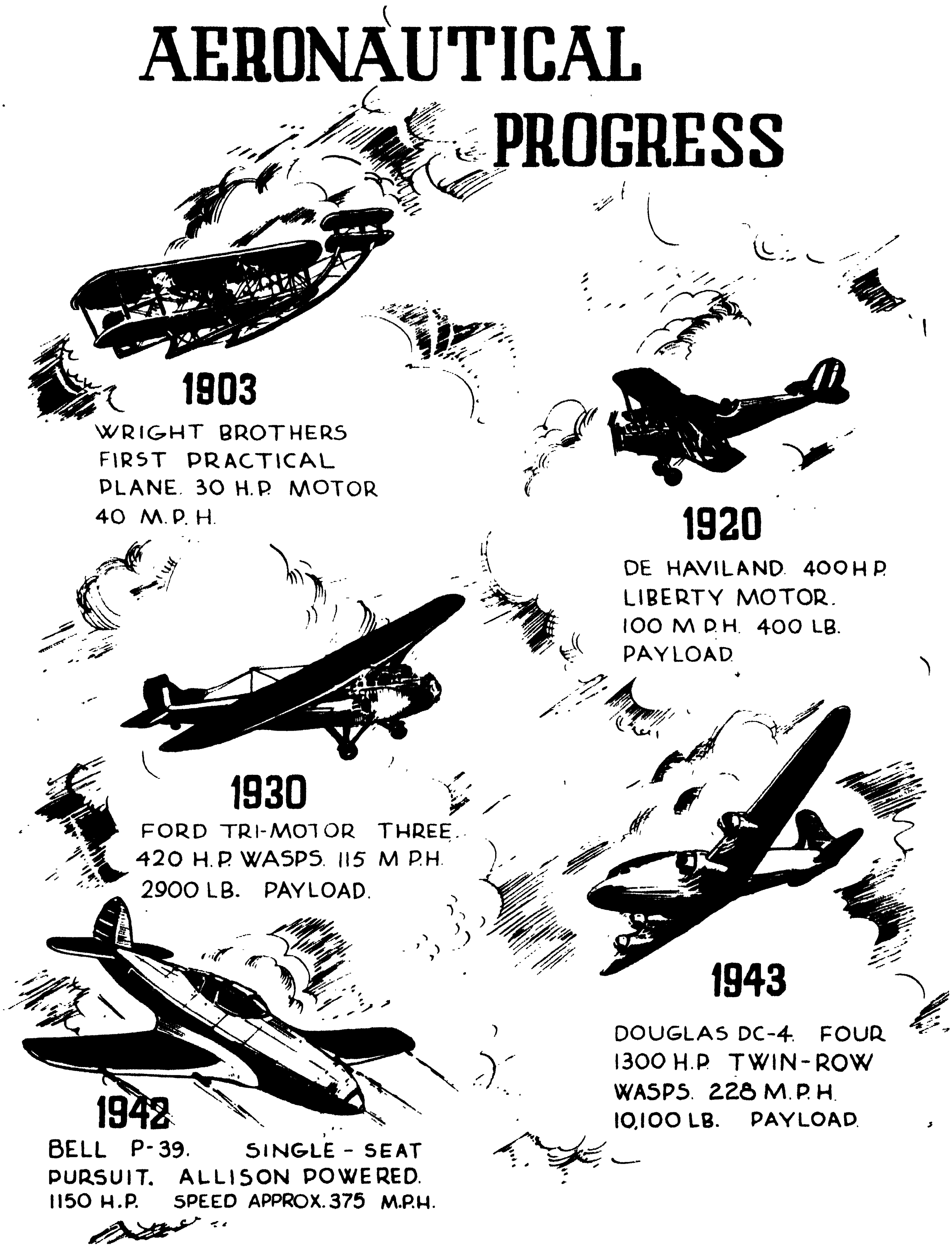
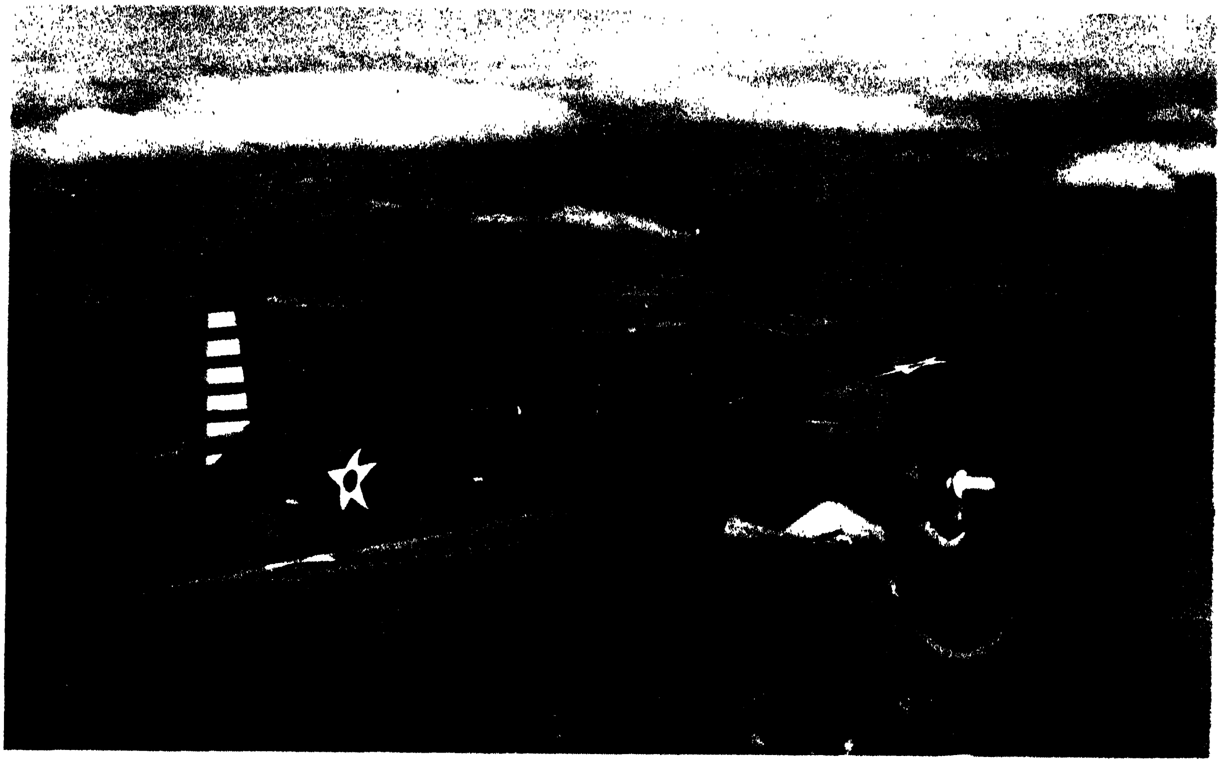


Fig. 220—EARLY AND RECENT TYPES OF AIRPLANES



Courtesy Grumman Aircraft Engineering Corporation

Fig. 221—A MODERN MILITARY PLANE

though lightweight metal tubes are used for the framework of the fuselage in most

Fig. 222—MODEL PLANES TO BE USED IN LEARNING TO IDENTIFY FLYING AIRCRAFT

of them. Aluminum alloy is widely used in most commercial and military craft. It is light in weight and very strong. Stainless steel is also being used in some planes. Wood and plastics are being used experimentally to form portions of the wings and fuselages of a few of the newer planes.

MODELS

Before airplanes can be built they must be planned, designed, and accurately drawn. Models are made and studied carefully, for gaining information as well as testing for results expected from new designs. Small-scale models are made and used in a wind tunnel to study the performance of planes. From an exact miniature model of the real plane the streamlining of each particular part can be carefully determined. Any changes needed in the design can be made and the model studied again to see its performance.

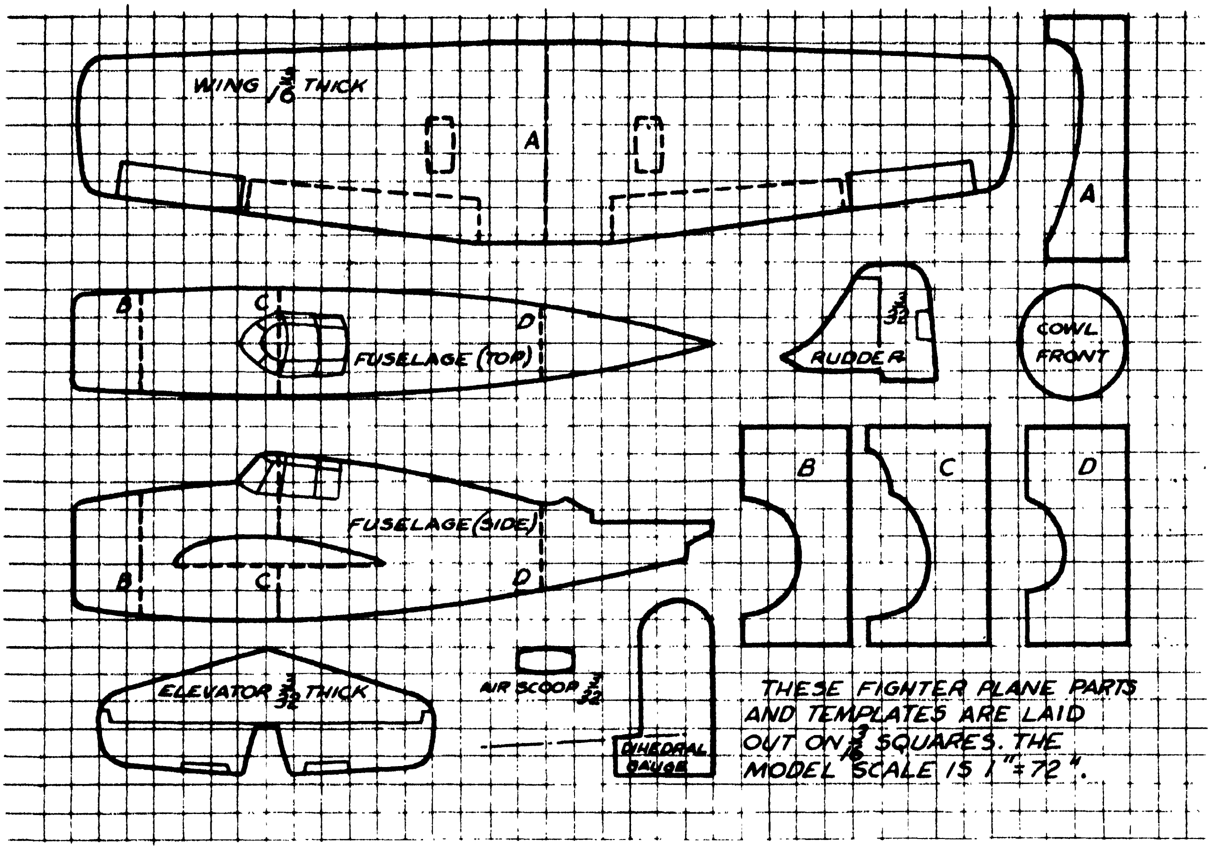


Fig. 223—TEMPLATE DRAWINGS FOR A MODEL PLANE

These preliminary design changes can be made with a minimum of expense, and the designers have accurate knowledge as to how the actual plane will perform in the air.

Solid Models

Solid models have been used in the military camps to teach observers to identify flying aircraft. Exact scale models of military planes, with propeller and retractable landing gear omitted, when studied in a sighting box give accurate pictures of planes in flight. Figure 222 shows models of planes made for such study.

Built-up Models

Nearly every boy has at one time made a built-up airplane model. The ribs of the wings, the framework of the fuselage, and all the structural members are made of a very lightweight wood. All the pieces are cut, fitted together, and held in place by airplane glue. Then the framework is covered with a thin paper and treated with dope, which makes the paper shrink and fit the frame snugly. Models of this type may be two- or three-piece gliders up to those constructed of hundreds of parts and even equipped with small gasoline motors. Many of these models will fly much farther than the airplane used by the Wrights in 1903. The better designed built-up models afford an opportunity to study the principles of aircraft construction and flight since some of these planes are constructed in the same manner as the larger planes.

Drawings of Models

Usually built-up and solid model planes, especially those included in commercial kits, have patterns of the members of the plane. For the built-up models the patterns are frequently stamped directly on the wood. The patterns, or templates as they are sometimes called, are used to lay out the exact shape of each of the members. Figure 223 shows patterns or templates for a solid model.

In addition to templates, an assembly drawing must be made to show how the various parts fit together. This may be a three-view drawing or a pictorial drawing; sometimes both kinds of drawings are used. Figure 224 shows the three views and the pictorial drawing of a solid model. The assembly drawing of a built-up model must show the location of each part of the airplane.

Full-Size Models

In actual aircraft production, after a plane has been designed but before production has begun, a life-size model of the plane or portions of it are built of cardboard or wood. This is called the *mock-up*. Its purpose is to aid in working out the positions for all the interior equipment, such as instruments, controls, and seats.

NOMENCLATURE

In aviation many new terms have been developed. A complete list would require several pages. The main portions of a plane are, however, relatively few. These are shown and named in Figure 224.

AIRCRAFT DRAFTING

Types of Drawings

In general, for aircraft construction there are detail drawings, which describe completely individual parts, and assembly drawings, which show all the various parts in their proper working relationships. Assembly drawings may be divided into subassembly drawings, which show all the parts of a portion, such as a wing or the fuselage, and installation drawings, showing how the subassemblies or details are to be fitted together. Large-scale detail layout drawings are also made, particularly for parts where close tolerances are required.

Conventions

The *position of a plane*, whether you are making a three-view drawing or a single side view, should show the nose pointed toward the left. (See Figure 224.)

All *dimensions* are placed on the drawing so that they may be read from the bottom of the sheet, unless extreme crowding would result from such placement. (See Figure 225.) Dimensions are all expressed in inches except for the wing span and total plane length. Both fractions and decimals are used. Decimals are used when exact measurements are necessary. Common fractions are seldom used to express divisions that are smaller than a thirty-second of an inch. Frequently dimensions are tied to a reference line.

The *scale* of most detail drawings is full size, although half and quarter sizes are also used. Occasionally it is necessary to make drawings twice or three times the actual size. These are for only the very small parts. For preliminary small-scale sketches the scale used may be one twentieth, one thirtieth, or one fortieth actual size.

Notes should always be lettered horizontally on the drawing in capitals. The lettering may be either inclined or vertical, depending on the office standard.

Large drawings have *zone marks* located every foot along the lower margin of the drawing. These zone marks are numbers,

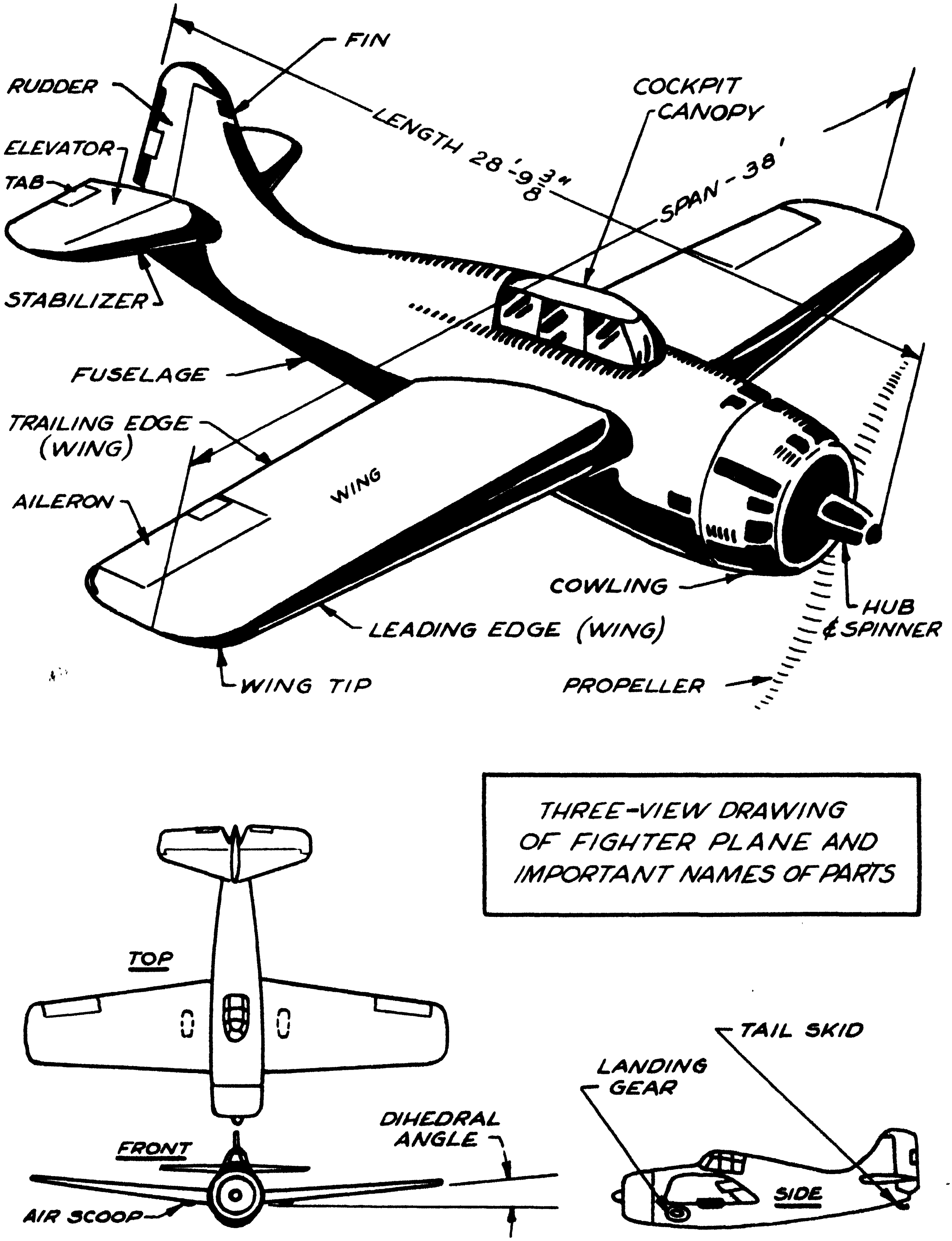


Fig. 224—A PICTORIAL AND A THREE-VIEW DRAWING OF A MODEL PLANE

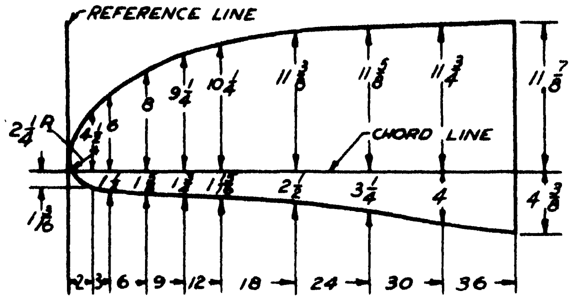


Fig. 225—DIMENSIONING AN AIRFOIL

reading from right to left. They are used to help locate parts on the drawing. The zone number of each part is given in the bill of material.

The *titles* of drawings are given with the basic word first, usually the noun, and then the descriptive portion of the title follows—for example: BRACKET—INSTRUMENT JUNCTION BOX.

The *dash numbering system* is used by some aircraft concerns. In this system each drawing is given a number and each part detailed on the drawing is given a number preceded by a dash. The part number is usually encased in a small circle on the drawing. When a particular part appears on some other drawing, such as an assembly, it bears its drawing number and the dash number. For example, a drawing has the number 19006 and the part has the number -2. On any other drawing this part is labeled 19006-2. The 19006 indicates the number of the drawing on which the part is detailed.

The titles on aircraft drawings usually have a great deal of information listed, such as the name of the company, the title, the scale, dates, the number, a parts list, a list of changes, a finish table, and in addition the names of the draftsman, tracer, and checker. Figure 226 shows a typical aircraft drawing title.

LOFTING

The lofting department, or mold loft, as it is frequently called, is usually a very large room where the various sheet-metal portions of the plane may be drawn full size. Most lofts have a smooth and level floor that is painted white. The floor is used as a drawing table, and the full-size drawing is made right on the floor. The drawing is very accurately done, with all curves carefully plotted. Long slender batten strips are then fitted to the lines on the floor and held in place by special tools. Thin white plywood or thin metal sheets are then slipped under these batten strips, and the drawing is transferred to the metal or plywood. From this, templates or patterns are made so that the sheet-metal worker can lay out the metal exactly.

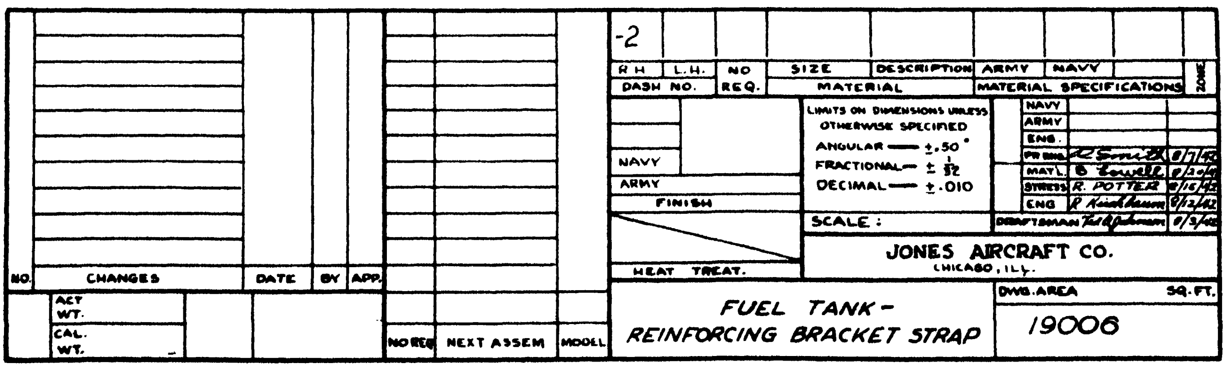


Fig. 226—TITLE BOX FOR AIRCRAFT DRAWING

For the full-size drawings, some aircraft companies use large sheets of plywood supported on trestles instead of the floor. The advantage here is that the plywood with the drawings may be filed away and kept. If made on the floor, they must be painted over when a new plane is to be laid out.

A T square is not used in the molding loft. Instead, the floor or plywood is accurately marked off in squares, which start from a given base line. All measurements are made from this line with special tools, such as tangent squares, trammels, battens, take-off rulers or ducks, and a bevel lifter.

Some lofting is also being done with special photographic equipment. The full-size drawings are photographed and then used on the pattern when needed.

Another method is to scribe the drawings on metal sheets. Each sheet is then moistened and put in a press, adjacent to another sheet of metal, and through an electrolytic process the drawing is transferred to the second sheet, which may be cut and used as a template.

FAIRING

The streamlining, or smoothing out, of rounded surfaces so that there are no humps or uneven lumps is called *fairing*. The fairing of the parts is carefully studied, and adjustments are made in the lofting department to provide the right allowances in the templates for the curves.

RIVETING

Inasmuch as there are from 75,000 to 400,000 rivets in each metal airplane, riveting is essential in its construction. There are several types of rivets used in aircraft work. Two types, small-head rivets, are shown in Figure 177. Flush-type rivets are used on the exterior, where air resistance

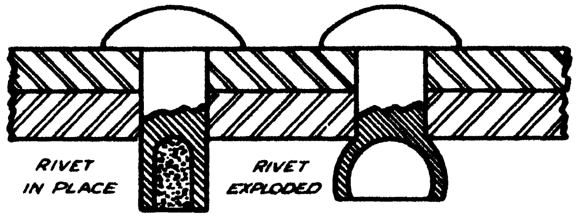


Fig. 227—AN EXPLOSIVE-TYPE RIVET

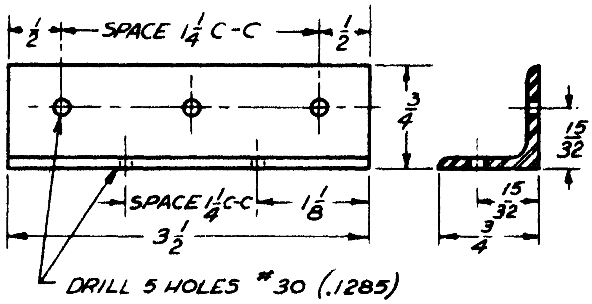


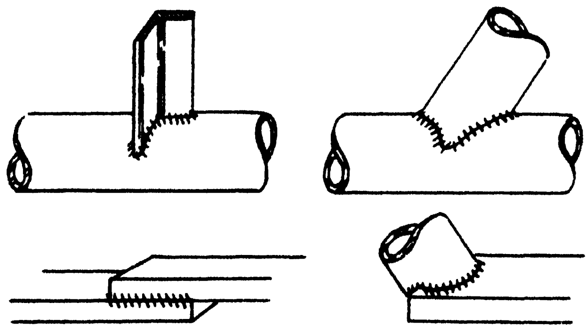
Fig. 228—RIVET DIMENSIONING

is a factor. A new explosive-type rivet is also being used where the regular rivets cannot be bucked with a bucking bar. This rivet is inserted in the hole, and a hot iron is applied to the head. The hot iron causes the explosive to ignite and form the head on the other side of the metal. (See Figure 227.) This type of rivet is well adapted to field repairing of metal portions of planes.

Rivet lengths vary from 1/8″ to 2″, and the diameters vary from 1/16″ to 1/2″. The length of a rivet is measured from the underside of the head to the end of the shank except for the flush rivets, which are measured from the top of the head to the end of the shank. As we have said, rivets should not be spaced closer than three times their diameter and should not be less than twice their diameter from the edge of the metal. Figure 228 shows how rivets are indicated and dimensioned on a drawing. The abbreviation *C-C* stands for "center to center" of rivet holes.

WELDING

Another method of fastening aircraft parts together is to weld them. The work connected with the tremendous number of rivets on a plane requires a huge amount of time, and the sheet metal on planes is so thin that it cannot be welded with gas welding equipment without burning the metal. Recently, however, electric spot



METHOD OF INDICATING A GAS WELD

Fig. 229—INDICATING FUSELAGE WELDING

welding has improved so much that many manufacturers are doing as much of this kind of welding as possible. It is frequently referred to as resistance welding.

Tubular fuselages are usually welded by oxyacetylene or gas welding. Figure 229 shows how this kind of weld is indicated on a drawing.

SUMMARY

Although aviation was in the experimental stage until a comparatively few years ago, tremendous progress in flying and aircraft construction has been made. Established airlines both domestic and intercontinental make regularly scheduled flights carrying passengers, mail, and express.

For the commercial and military planes aluminum and steel are used almost entirely, while wood and fabric are still used for private planes.

Small-scale models are used extensively in the wind tunnel for studying the reactions of planes. Built-up models are used by youngsters to give them an idea of plane construction and flight.

Assembly, detail, installation, and layout drawings are those most commonly used in the aircraft industry.

Conventions of aircraft drafting conform to those of general drawing except that in nearly all cases dimensions are read from the bottom of the sheet and are expressed in inches. The scale is full size ordinarily for detail drawings, drawings are zone marked, parts are dash numbered, and the title strip is elaborate.

Patterns or templates for the sheet-metal parts are drawn full size in the mold loft. However, some companies are using photographic or other duplicating processes to make these templates.

The two methods of fastening parts of airplanes together are riveting and welding. Gas or oxyacetylene welding is used on tubular fuselages, but resistance welding is used on sheet-metal parts.

TEMPLATES—FOR A SOLID-MODEL PLANE

Using the information in Figures 223 and 224, draw a set of templates for this plane. Use your dividers to step off distances. If you encounter difficulty, rule the drawing paper in $\frac{1}{2}''$ squares. Use a French curve to make the curved portions of your drawings.

MODEL PLANE—THREE-VIEW DRAWING

Make a three-view drawing showing the front, top, and side view of the plane in Figures 223 and 224. Make sure that the side view shows the plane in the correct position. Here again use your dividers and French curve. The problem should be placed lengthwise and the title lettered the long way of the sheet.

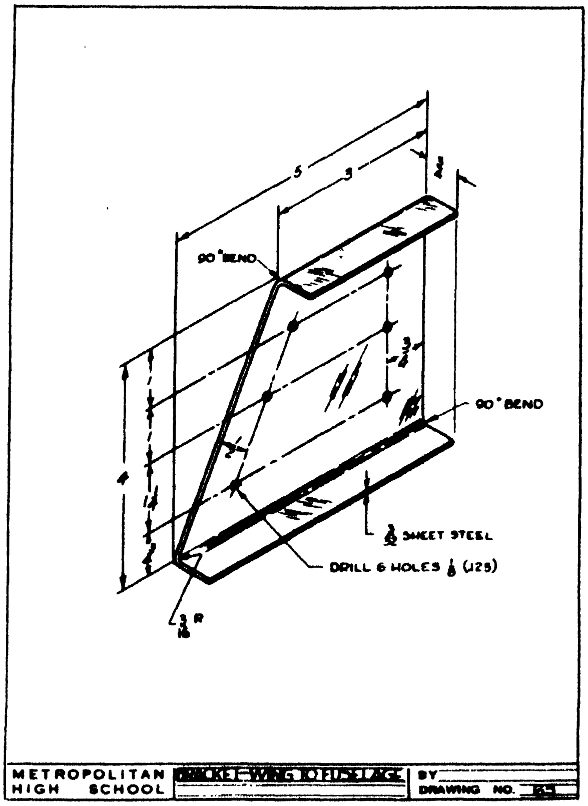


Fig. 230—BRACKET FOR FUSELAGE WING (PROBLEM)

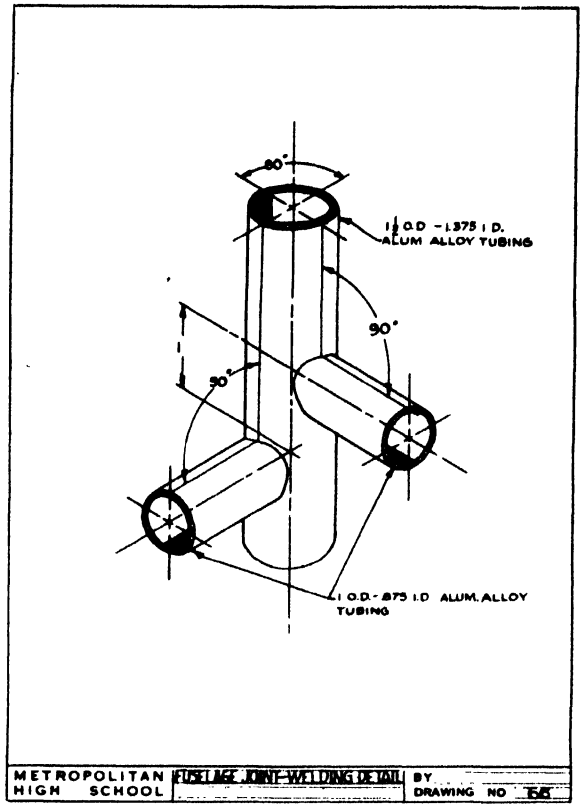


Fig. 231—WELDED JOINTS IN FUSELAGE (PROBLEM)

AIRFOIL

Figure 225 shows how an airfoil is laid out. Make your drawing one quarter size; that is, use the scale 3″ = 12″. Place the drawing lengthwise on the sheet.

BRACKET—WING TO FUSELAGE

Draw two views of the bracket shown in Figure 230. Dimension them completely.

WELDED JOINT—FUSELAGE

Make two views of the tubular members in Figure 231, showing the welded joints in each view and using the proper conventions. Refer to Figure 229 for the welding conventions.

PLANE—MODEL

Design and draw freehand or mechanically a model plane. Choose one that is not too difficult. Make only an outline drawing, omitting all dimensions.

QUESTIONS

1. By whom was the first successful airplane flight made? When?
2. When was the airplane first used as a military weapon?
3. Did the regular commercial airlines carry passengers or mail first?
4. What materials are commonly used to build airplanes?
5. Describe two kinds of airplane models.
6. What is a mock-up?
7. What are the zone marks on an airplane drawing?
8. Where are airplane templates laid out?
9. What kind of welding is used on the sheet-metal portions of a plane?
10. Describe an explosive-type rivet.
11. How are models of planes tested for wind resistance?

TOPICS FOR DISCUSSION

1. Before man was successful in making an airplane that would fly, many famous balloon ascensions were made. After referring to an encyclopedia or some other source, describe to the class one of these ascensions and discuss the underlying principle.

2. If someone in your group can bring to class a small gasoline motor for a model plane, draw a freehand sketch on the blackboard of an assembly section through the motor and show how it operates.

3. There are rules and regulations required for good flying. Discuss several of these rules in class and show the necessity of having them.

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UNIT X

ARCHITECTURAL DRAFTING

SHELTER

Shelter has always been one of man's most important needs. One of his first activities was, no doubt, the seeking of protection from the elements, from animals, and from the attacks of others. The easiest shelter for man to obtain and probably his first home was a natural cave with a stone to close the entrance for protection against intruders.

As man's requirements, knowledge, and skills increased he built more complicated homes, such as lake houses and tree houses. The lake house was built upon piles driven into the swampy shores of lakes; the tree house was built high in the branches of a tree. Such houses could be reached with difficulty. They were accessible only by ladders, which could be drawn up to prevent intrusion.

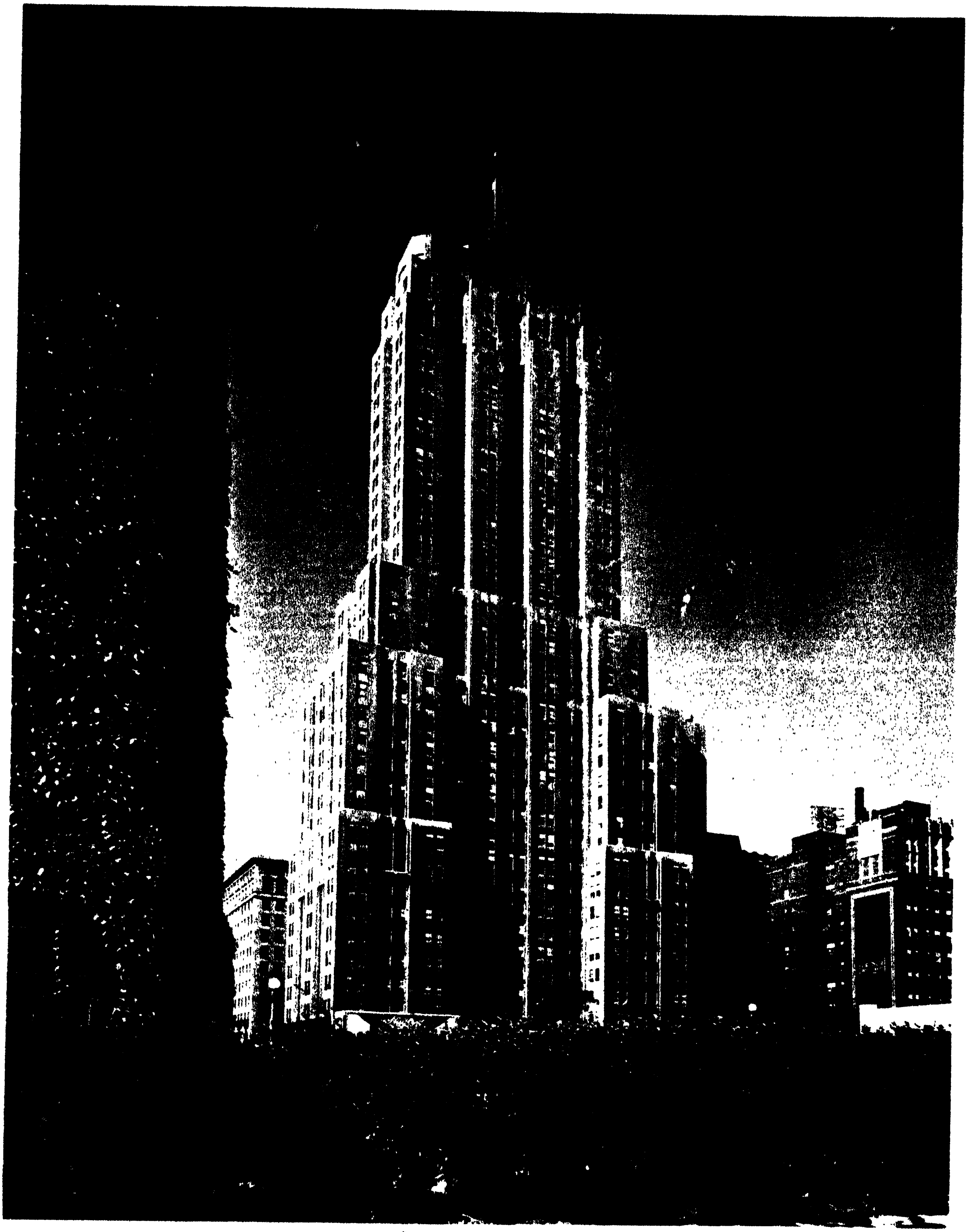
The kind of home man built was naturally dependent upon the materials available and the particular needs and requirements of the location. Man began early to build larger and more elaborate structures for various purposes. As the buildings became more complex, men who knew how to build came more and more into demand. Finally there was the architect, who made a profession of planning and supervising the erection of buildings.

Naturally many different kinds and styles of buildings developed to suit various needs and conditions. Factors such as the materials available for construction, the climate, the social and cultural conditions, and the purpose have always affected the design whether of huge public buildings or small private homes. Where wood or stone is plentiful the builder uses it; where little or no such material can be found dried mud or bricks serve for the walls. In a warm, dry climate houses are built so as to take every advantage of the out-of-doors—for example, the flat-roofed, enclosed garden or patio type of home, with little or no provision for heat, found in the Southwest. In a damp, cold region the walls will be solid, the roof will be steep, and some means of heating will be provided. Large dining rooms were usually planned for homes when families were large and many guests often entertained. Today, with smaller families and less entertaining in the home, the dining space frequently is small and may often be included in either the living room or the kitchen.

There is a great variety of style in the homes and public buildings in the United States, due largely to the influence of the many different localities from which our early settlers came. Figures 232 to 238 give an idea of some of the styles common to this country.

THE ARCHITECT

The training of the architect must be broad and must cover many fields. The necessary training for competence in these fields is so extensive that it requires most



Courtesy Ross, Browne and Fleming, Chicago; © Hedrich-Blessing Studio, Chicago

Fig. 232—A MODERN OFFICE BUILDING

Courtesy Koerner and Gerhardt, Architects

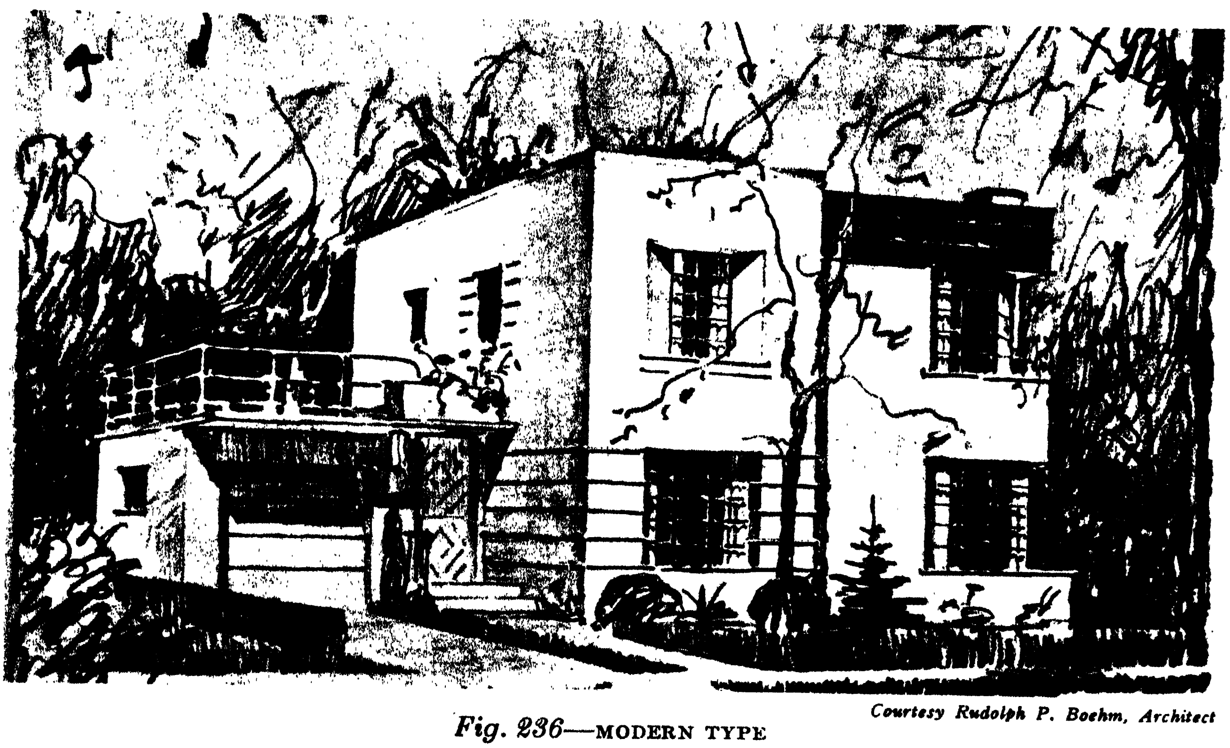
Fig. 233—CAPE COD TYPE OF HOUSE

Courtesy Rudolph P. Boehm, Architect

Fig. 234—RANCH HOUSE

Courtesy Pearson and Dahlquist, Architects

Fig. 235—MODERN COLONIAL TYPE



Courtesy Rudolph P. Boehm, Architect

Fig. 236—MODERN TYPE

Courtesy Pearson and Dahlquist, Architects

Fig. 237—FRENCH PROVINCIAL TYPE

Courtesy Pearson and Dahlquist, Architects

Fig. 238—GEORGIAN COLONIAL TYPE

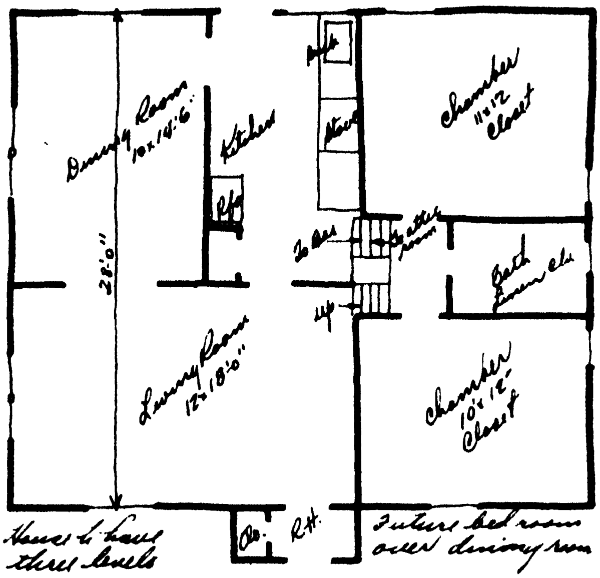


Fig. 239—CLIENT'S ROUGH SKETCH OF HOUSE

of the time that the average person is able to spend in formal training. Specifically the architectural field is made up of two main divisions, engineering and design. This division is so definitely marked and each branch requires such thorough training that some colleges divide their courses in architecture into architectural engineering and architectural design.

The architect, in addition to having his professional training, must be a good businessman, because his dealings are mainly with contractors and builders and his clients are often from the business world. The architect should also have a fundamental understanding of the needs and desires of his clients. The better he is able to understand their wants and needs, the easier it is for him to provide what is desired.

The architect is not entitled to practice in most states until he has been licensed. That is, the architect must prove to the state, by examination, that through his training and experience he is qualified to serve clients and protect their interests and also to protect the public from the standpoint of structural safety, sanitation, and fire prevention, as well as to make good designs.

The architect's duties begin with the interviewing of the client. As the result of the interview with the client, the architect formulates an idea of the client's requirements or the client may make a rough sketch of his needs. (See Figure 239.) The sketch in all probability must be modified to provide for further details and facilities to meet the requirements of the building ordinances or possibly a lending agency. Figure 241 shows the architect's development of the client's idea. It will be noticed that the plan has been refined to provide for closets, proper stairways, and other details.

After the sketches have been developed to the satisfaction of all concerned, the architect proceeds to correlate all the technical data pertaining to that particular building and then prepares the working drawings. Next he must write the specifications, which describe the materials to be used and the processes to be employed in the construction of the work. The finished plans and specifications are then submitted

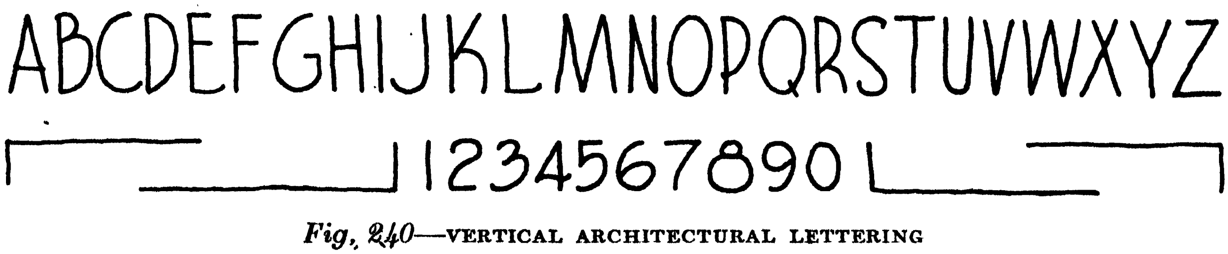


Fig. 240—VERTICAL ARCHITECTURAL LETTERING

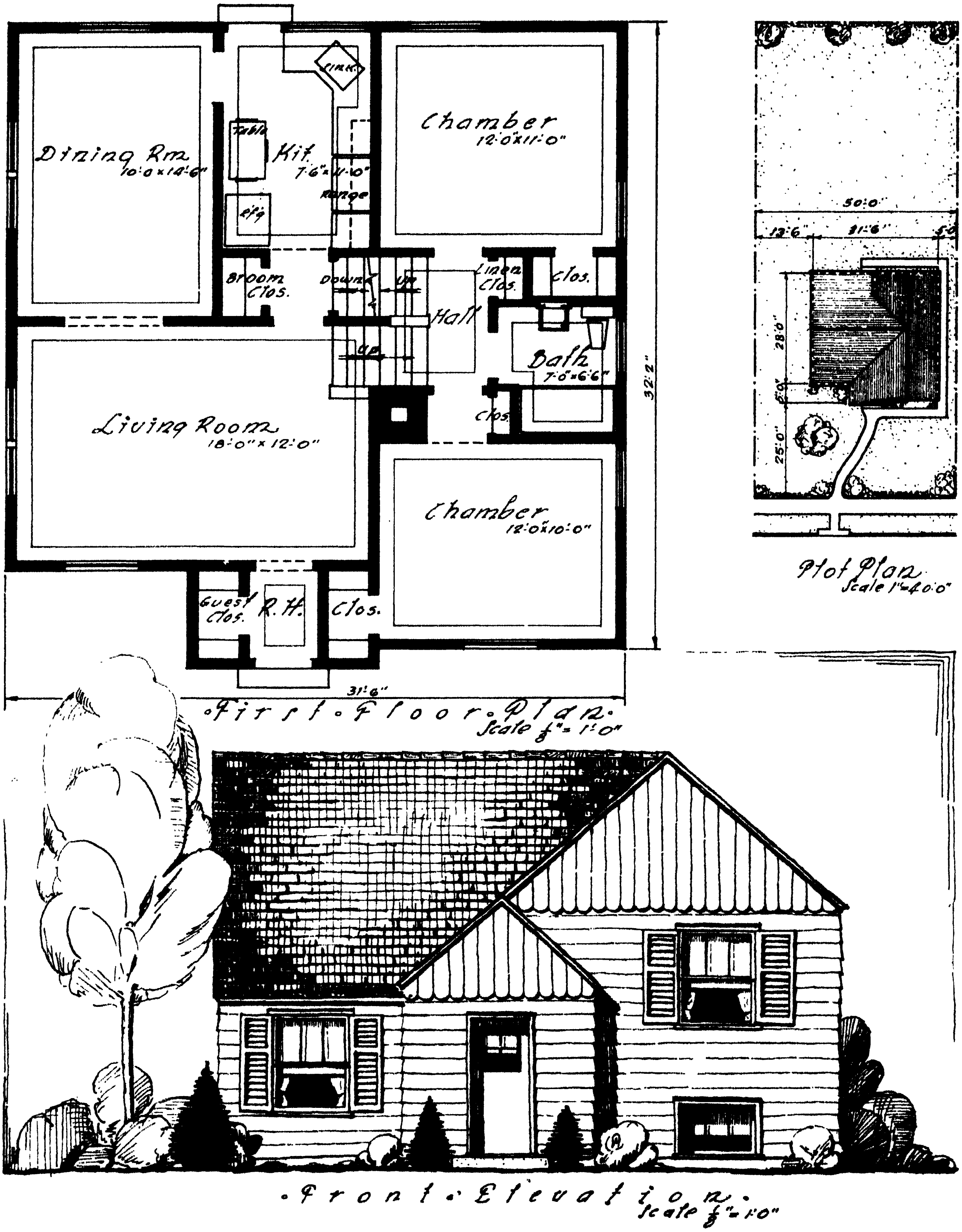


Fig. 241—ARCHITECT'S PRELIMINARY SKETCH OF THE HOUSE

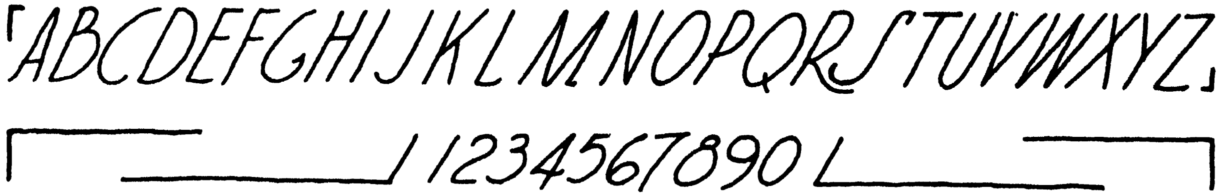


Fig. 242—INCLINED ARCHITECTURAL LETTERING

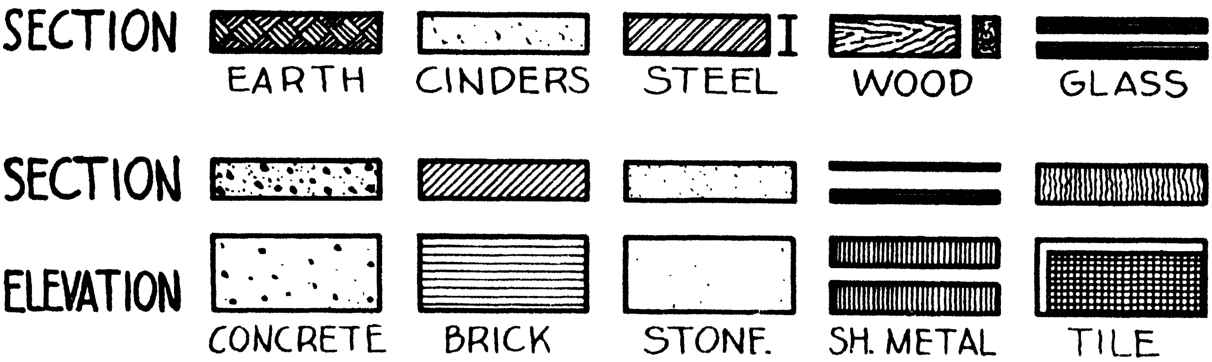


Fig. 243—ARCHITECTURAL SYMBOLS

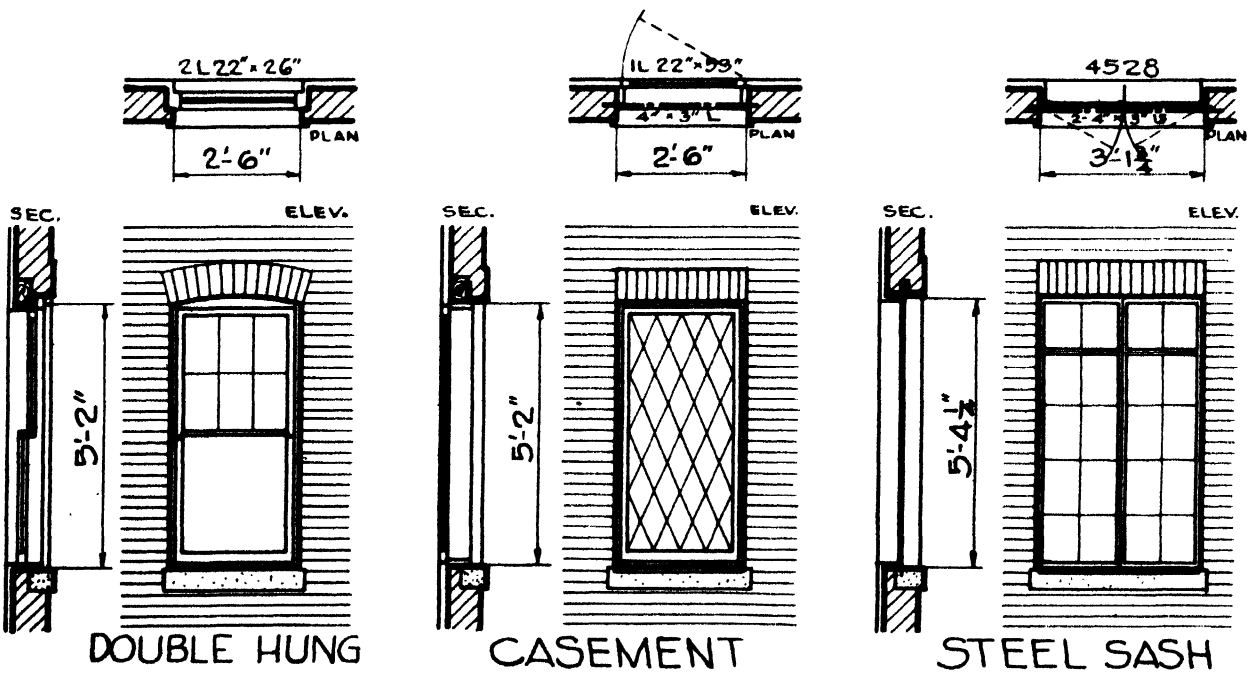


Fig. 244—WINDOWS IN MASONRY

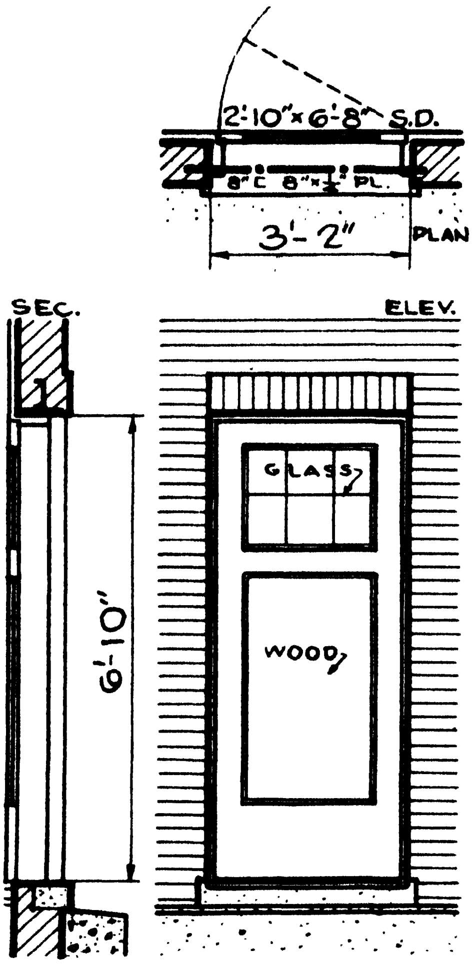


Fig. 245—DOOR IN MASONRY

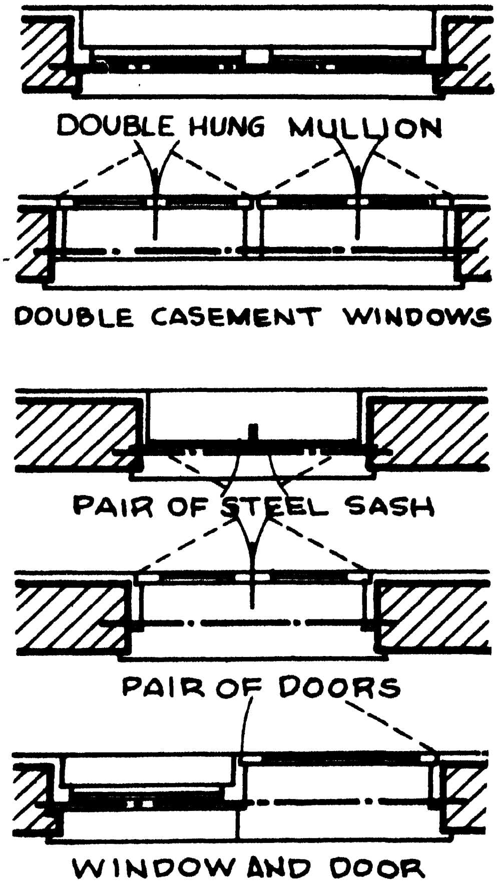


Fig. 246—PLANS OF DOORS AND WINDOWS IN MASONRY

to the contractors for estimates. The estimates are checked and compiled, and contracts are given to the successful bidders. The architect then supervises the construction of the building and handles the business and legal matters necessary for the completion of the building and the protection of the owner.

ARCHITECTURAL LETTERING

Either vertical or inclined lettering is used in architectural offices. Figure 240 shows a common style of vertical lettering, and Figure 242 shows the same style in inclined lettering. The vertical is preferred in most offices. In architectural lettering more freedom is permitted than in engineering drawings. This is also true as to weights of line, which may vary with individual architects. However, for students it is better to follow the recommended alphabets than to develop their own.

ARCHITECTURAL SYMBOLS

The architect uses a graphical language all his own. Naturally when a drawing must be reduced to such a small scale as $\frac{1}{4}'' = 1'\text{-}0''$ or $\frac{1}{8}'' = 1'\text{-}0''$ all conventions and symbols must be greatly simplified.

Figure 243 shows the symbols used to represent various common building materials.

Figures 244 and 245 show the conven-

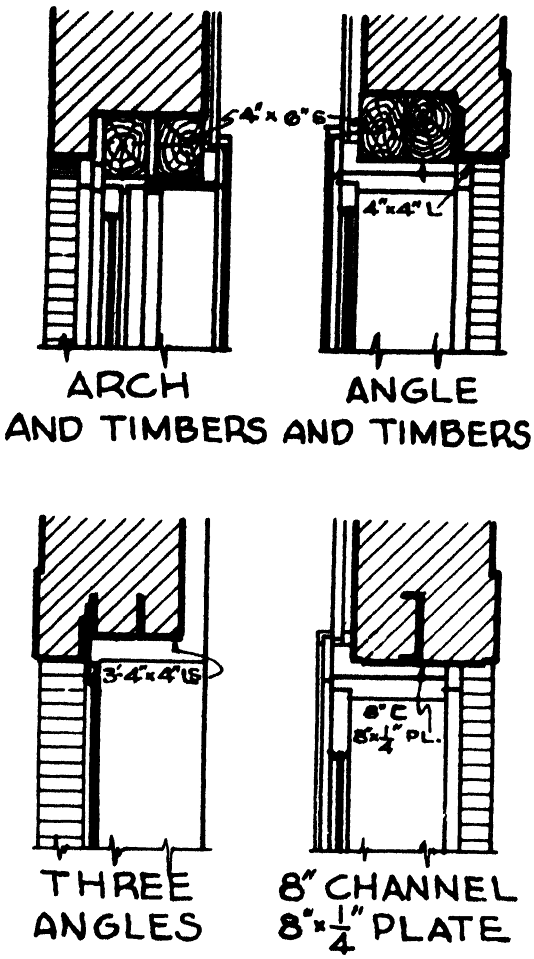


Fig. 247—LINTELS OF OPENINGS IN MASONRY

tions for indicating windows and doors in masonry construction, in plan, section, and elevation. The plans in Figure 246 show the conventions for various combinations of windows and doors. In all cases some method of construction must be devised to support the masonry over doors and windows. The sections in Figure 247 show methods of supporting the masonry above the opening. The beams or structural members are called *lintels*. They may be made entirely of wood or entirely of steel. Four types of lintels are shown here, but there are many other types. In one type of lintel shown, two pieces of wood 4″ x 6″ are used. The outside brick course is arched to support its own weight. Two pieces of wood 4″ x 6″ and a 4″ x 4″ angle are used in another type of lintel, in which the angle supports the outside brick course. The other lintels in Figure 247 are 4″ x 4″ angles, each of which supports a brick course, and a channel and plate lintel, in which the plate, stiffened by the channel, supports all the brickwork. Figures 248 and 249 show the door and window conventions for frame construction.

Plumbing symbols are shown in Figure 250. The layout of Figure 251 is used where one sewer system is installed. This requires that the waste be connected with a catch basin or a grease trap and the soil to run directly to the sewers. Downspouts leading from drains, laundry tubs, and roofs free from gravel can be connected to either the catch basin or the street sewer.

Figures 252 and 253 show the conventions for heating equipment. Figure 254 shows the electrical conventions.

Simplified details of various interior features are for the most part drawn at a scale of $\frac{1}{4}''=1'\text{-}0''$. This scale is sufficiently large to convey the general information for estimating. Details for actual construction are generally made at the time of construction and should be at a much larger scale and entirely complete as to material and design.

Stairs should have 9″ or 10″ treads and approximately $7\frac{1}{2}''$ risers. Twelve or thirteen risers are required for headroom either under or over the stairs. Figure 255 shows a plan and an elevation of stairs as they would be shown on an actual working drawing.

Kitchen cabinets can be made in any arrangement, using standard units for either metal or prefabricated wood cabinets. Mill-made cabinets can be designed in any size or detail. (See Figure 256.)

A fireplace can be made to any dimensions and details. The main consideration

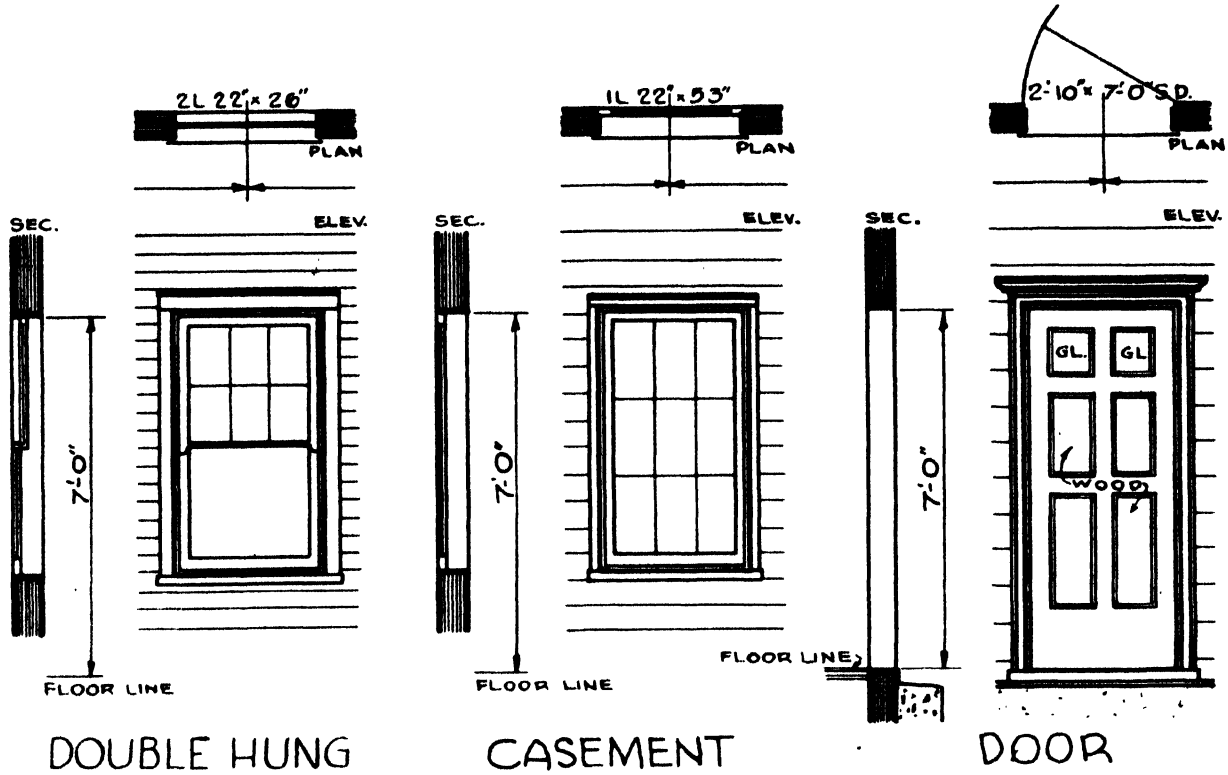


Fig. 248—DOORS AND WINDOWS IN EXTERIOR FRAME WALLS

is to include a throat and damper and to follow the manufacturer's recommendation as to proper opening and flue size. (See Figure 257.)

Conventions for interior doors and openings are shown in Figure 249. The difference between the plaster arch and the cased opening is that the plaster arch generally has a curved top and is finished with plaster while the cased opening is trimmed in wood.

Coves and cornices are used around the ceilings. The cornice is generally used in the main rooms and the cove in the halls and smaller rooms. (See Figure 258.)

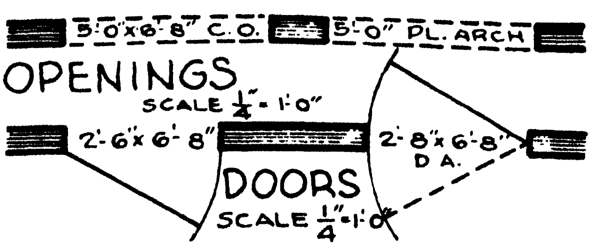


Fig. 249—DOORS AND WINDOWS IN INTERIOR FRAME WALLS

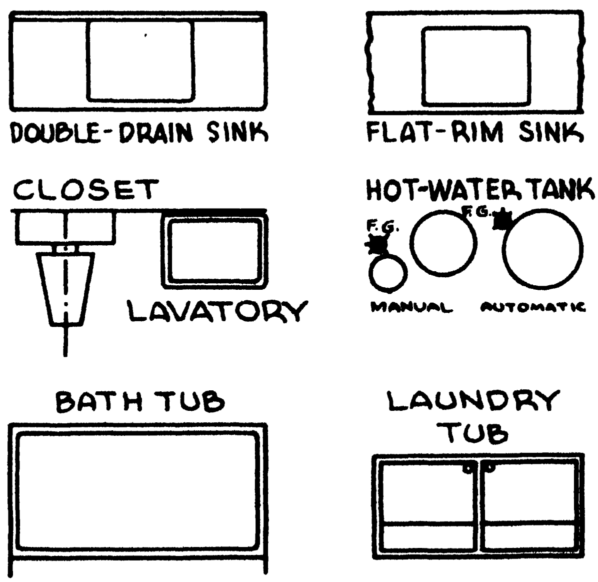


Fig. 250—PLUMBING FIXTURE SYMBOLS

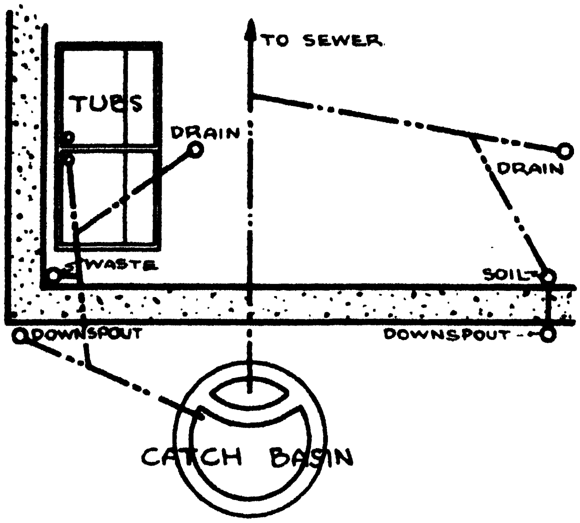


Fig. 251—SEWER LAYOUT FOR HOUSE

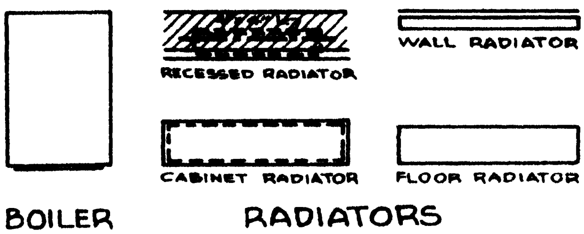


Fig. 252—STEAM HEATING CONVENTIONS

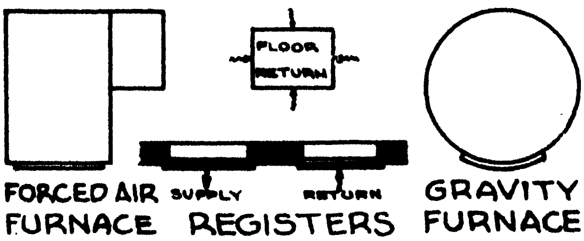


Fig. 253—WARM-AIR HEATING CONVENTIONS

MAKING WORKING DRAWINGS

The working drawings are made from the preliminary sketches. An architect usually makes a perspective of a building to give the owner a picture before working drawings are prepared. Figure 259 shows a perspective for the working drawings that follow. For convenience in drafting and duplicating, all drawings are made on tracing paper or cloth. By working with tracing paper or cloth the drawings can be traced from one floor to the other without the need for redrawing those parts of each

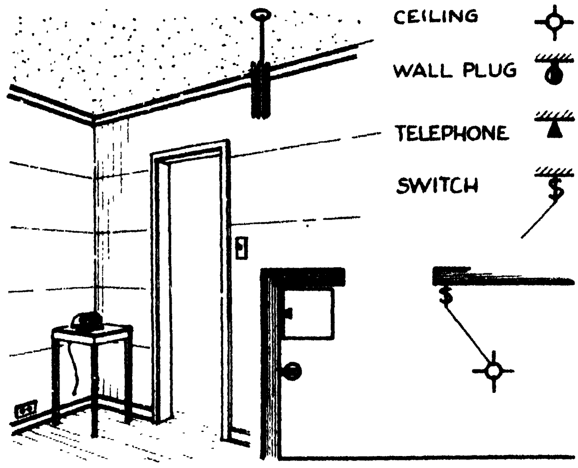


Fig. 254—COMMON ELECTRICAL CONVENTIONS

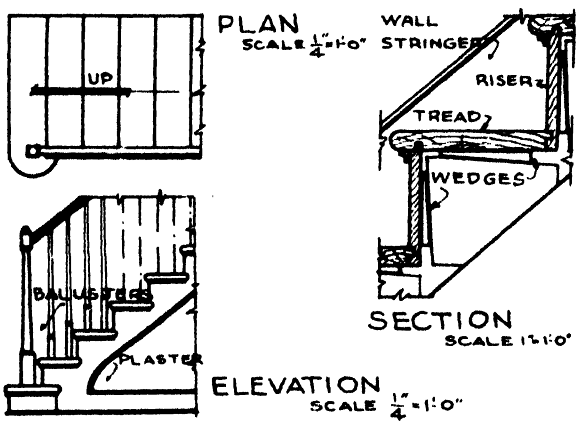


Fig. 255—DETAILS OF STAIRS

floor plan that are identical or related. Working drawings show the correct conventions and symbols; they are completely dimensioned and structurally designed; and they indicate the location of heating units, plumbing fixtures, electrical outlets, and all other features and equipment.

PLANS AND ELEVATIONS

The general practice in dimensioning a plan varies considerably. All plans should provide a complete dimensioning method that is absolutely correct and readily checked. A good method is shown in Figure 260. The dimensioning should be given in such a way that any group of dimensions

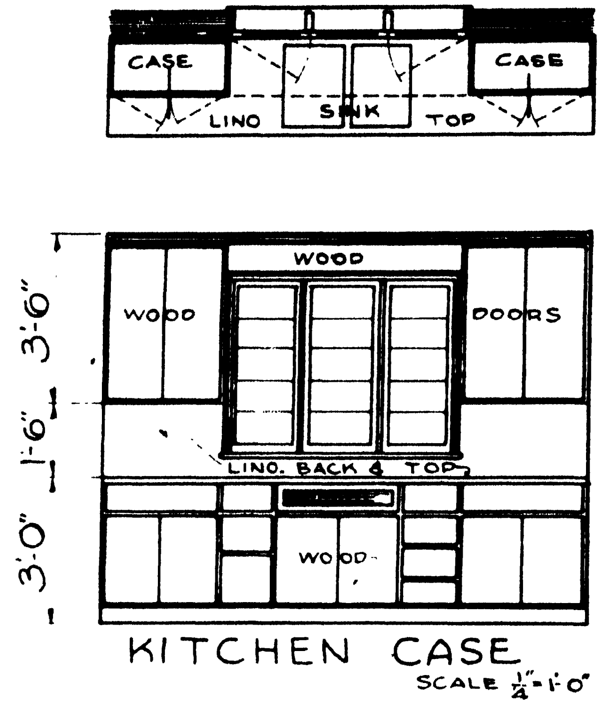


Fig. 256—KITCHEN CABINETS

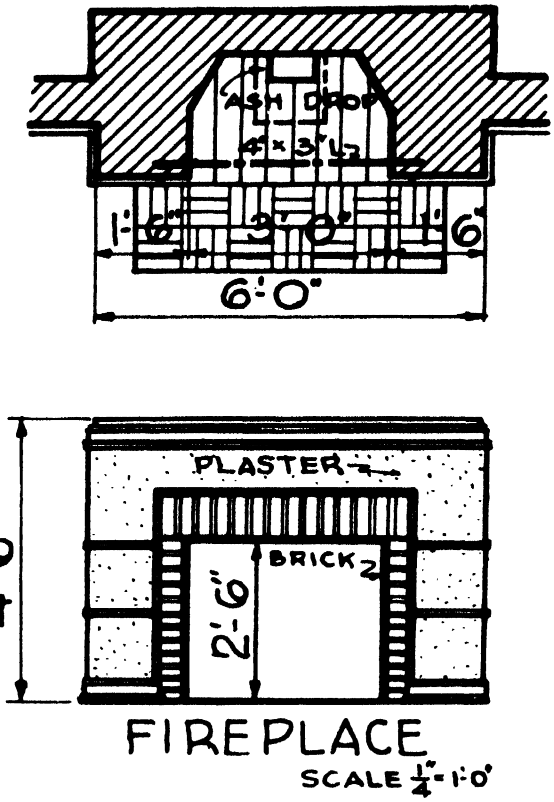


Fig. 25 —FIREPLACE PLAN AND ELEVATION

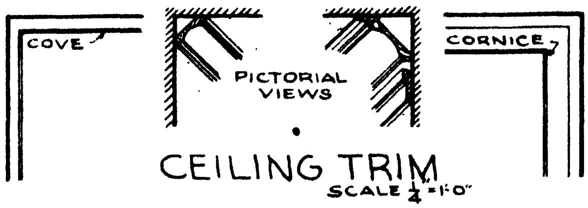


Fig. 258—CEILING MOLDINGS

may be checked with the next larger group. The figures should always be placed above the dimension line in architectural and structural drawings.

In making the working drawings, the first floor plan is generally made first, then the second floor, and then the basement; the elevations are made in the most convenient order. Figures 261 to 268 show a complete set of working drawings for a six-room house with attached garage. An actual photograph of the house built from these drawings is shown in Figure 269. Compare these with the architect's rendering of the same house, Figure 259.

DETAIL DRAWINGS

Detail drawings are a part of working drawings just as are plans, elevations, and sections. There are always some parts of a structure that need to be drawn to a larger size to show exactly how they are to be built. Figure 257 shows the detail drawing of a fireplace. Figure 268 shows a sheet of details that complete the working drawings of the house.

METHODS OF CONSTRUCTION

Details and methods of construction are many and varied. Construction methods vary in different localities, with different building codes, and with the experience of the builder. In general, there are three types of common construction—frame, brick or stone veneer, and solid masonry. Exterior frame walls are constructed with

Fig. 259—PERSPECTIVE OF A SIX-ROOM HOUSE

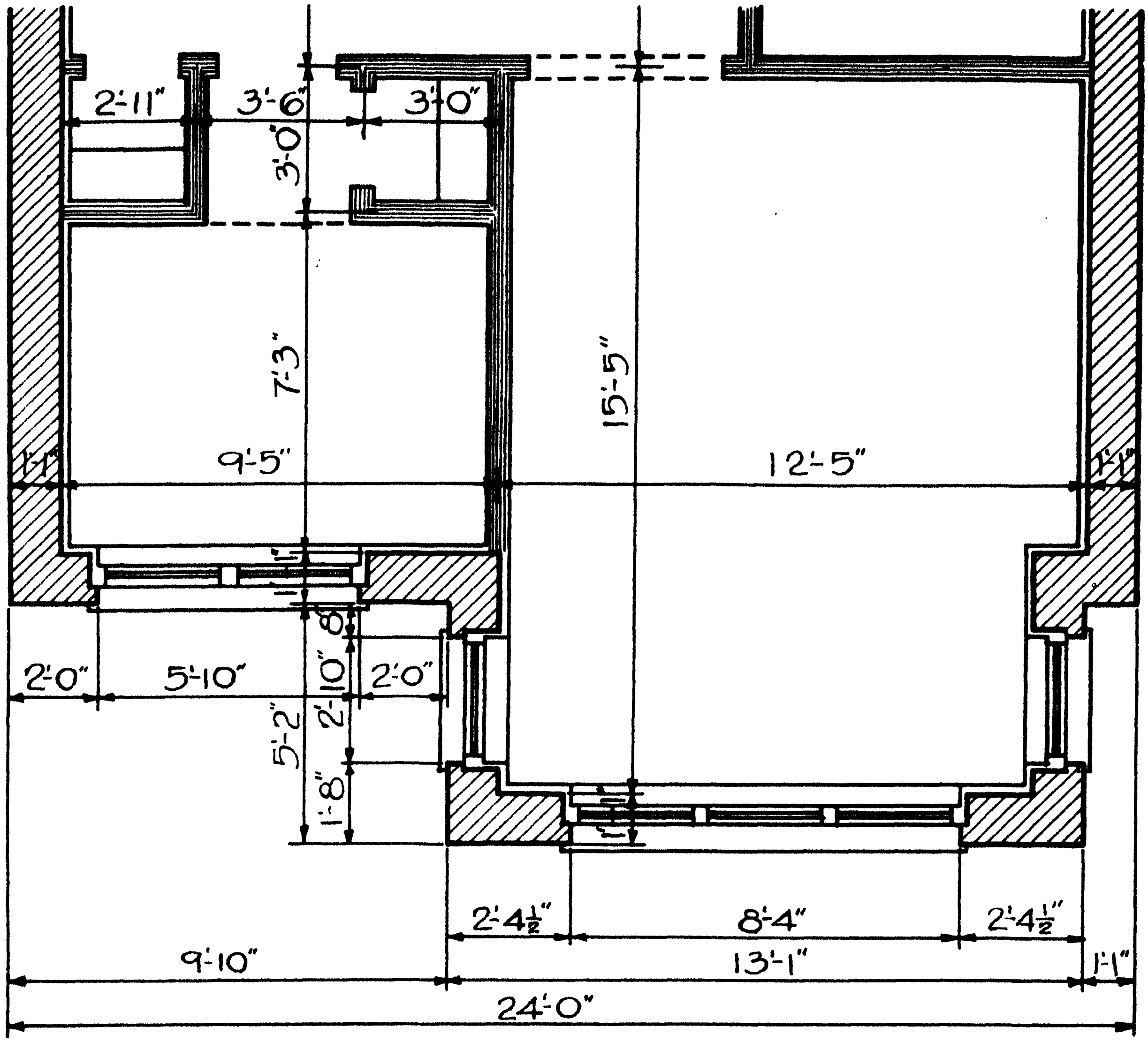


Fig. 260—ARCHITECTURAL DIMENSIONING

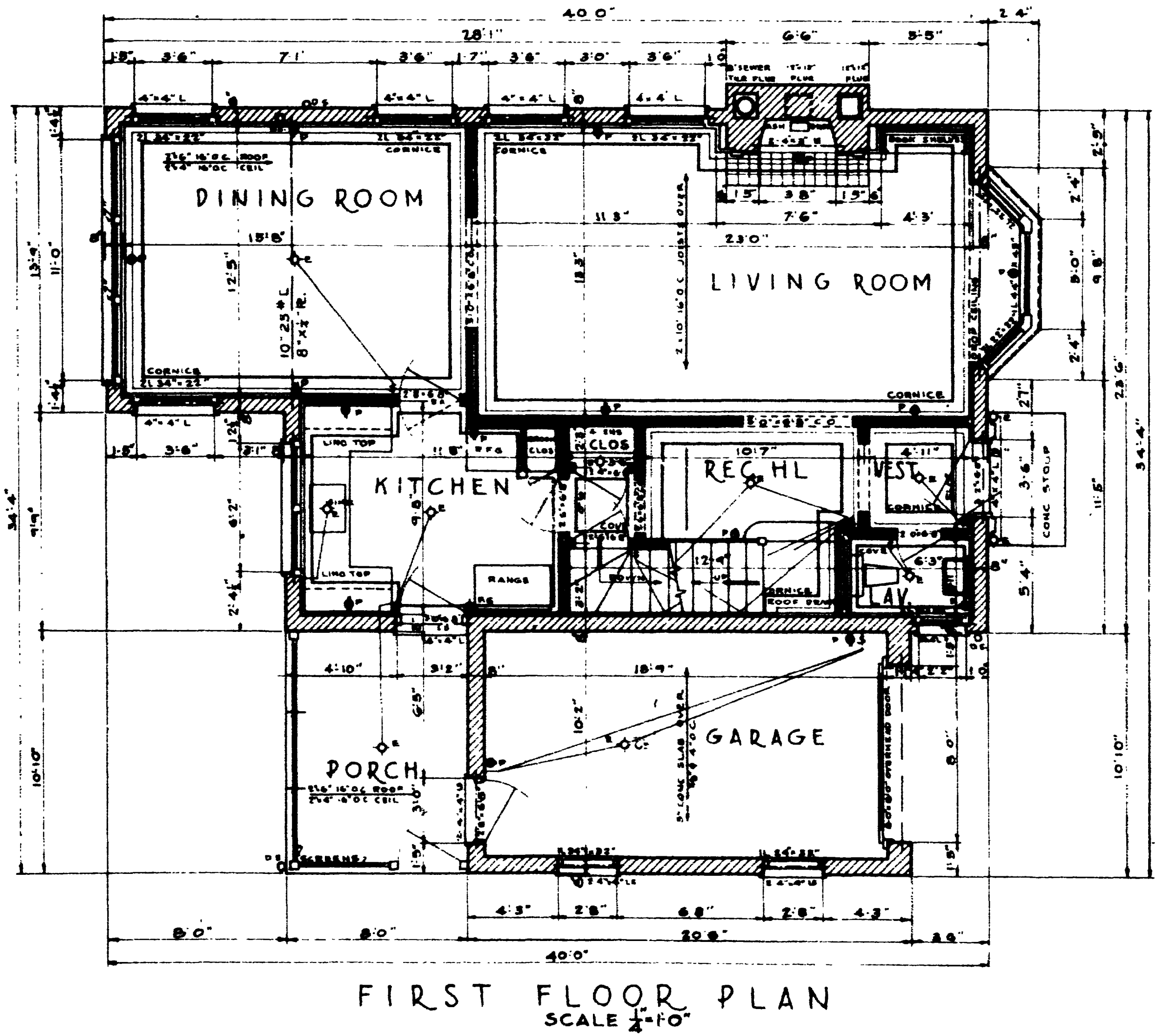


Fig. 261—FIRST FLOOR PLAN OF SIX-ROOM HOUSE

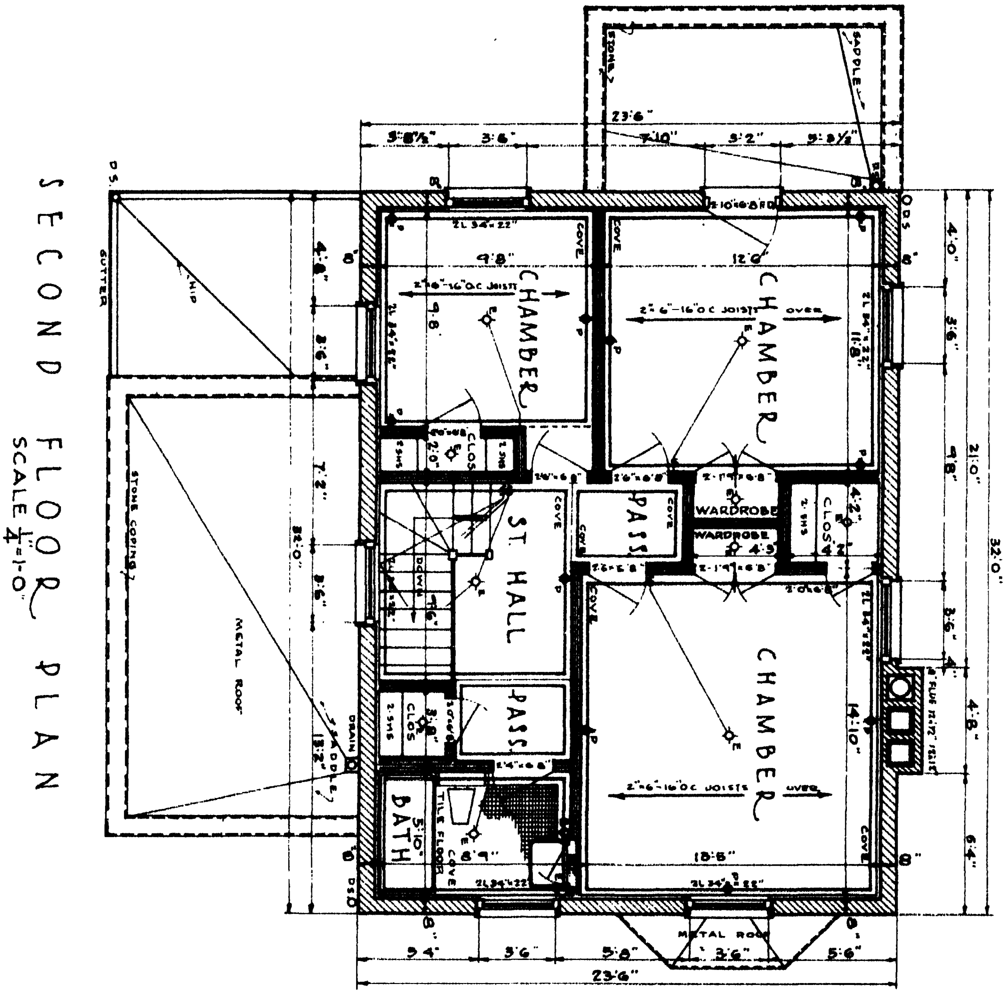


Fig. 262—SECOND FLOOR PLAN

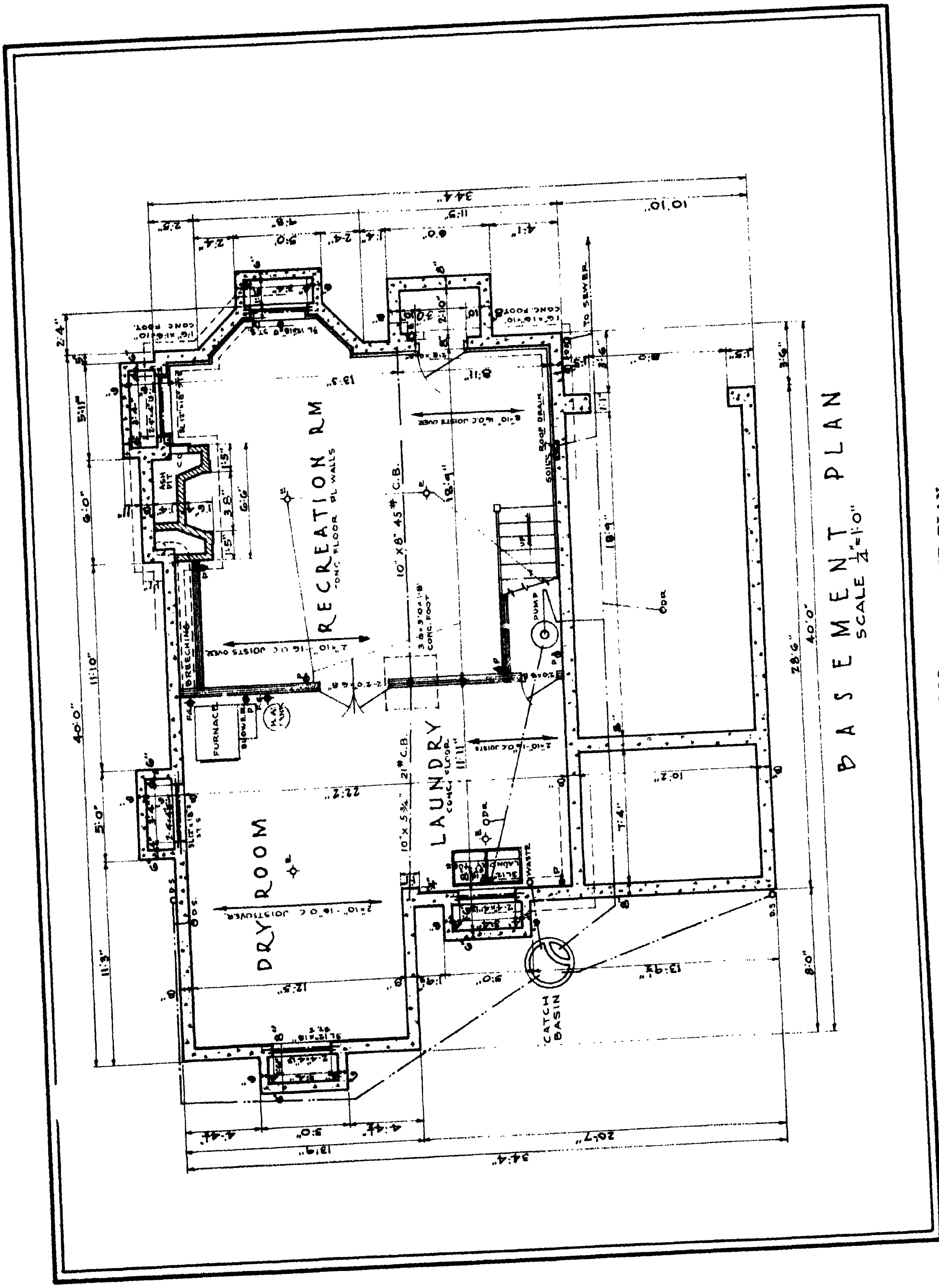


Fig. 263—BASEMENT PLAN

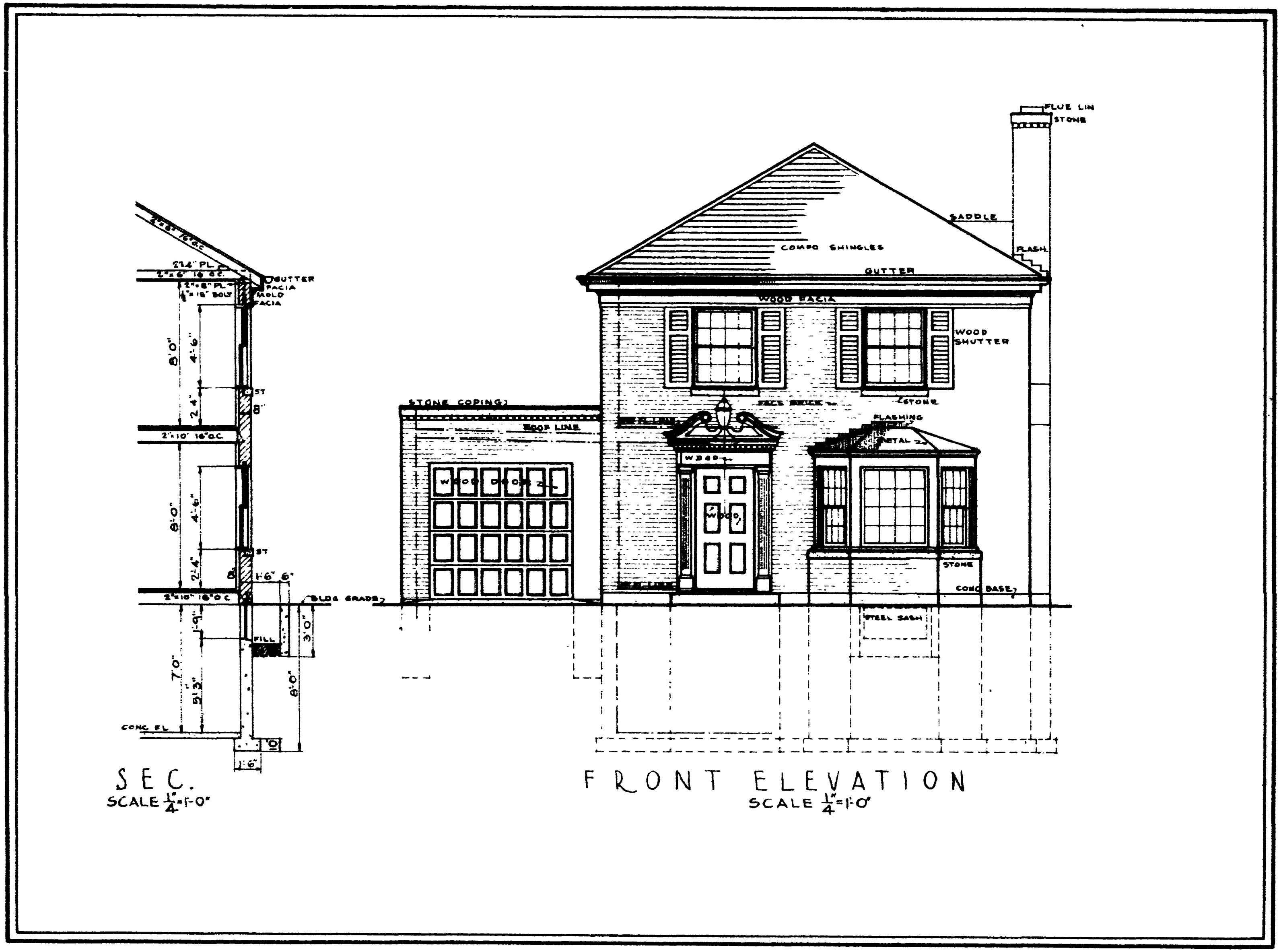


Fig. 264—FRONT ELEVATION AND WALL SECTION

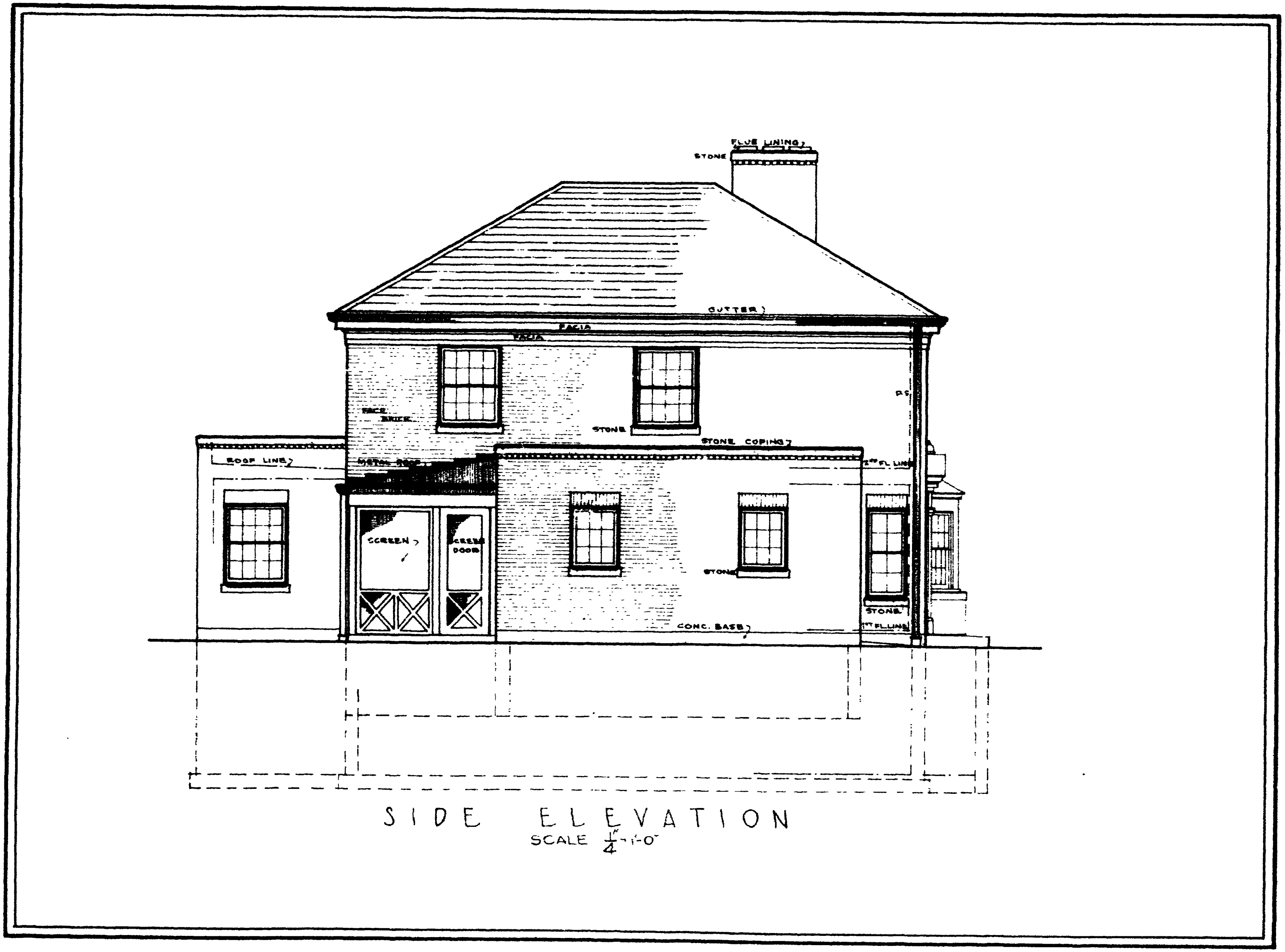


Fig. 265—RIGHT-SIDE ELEVATION

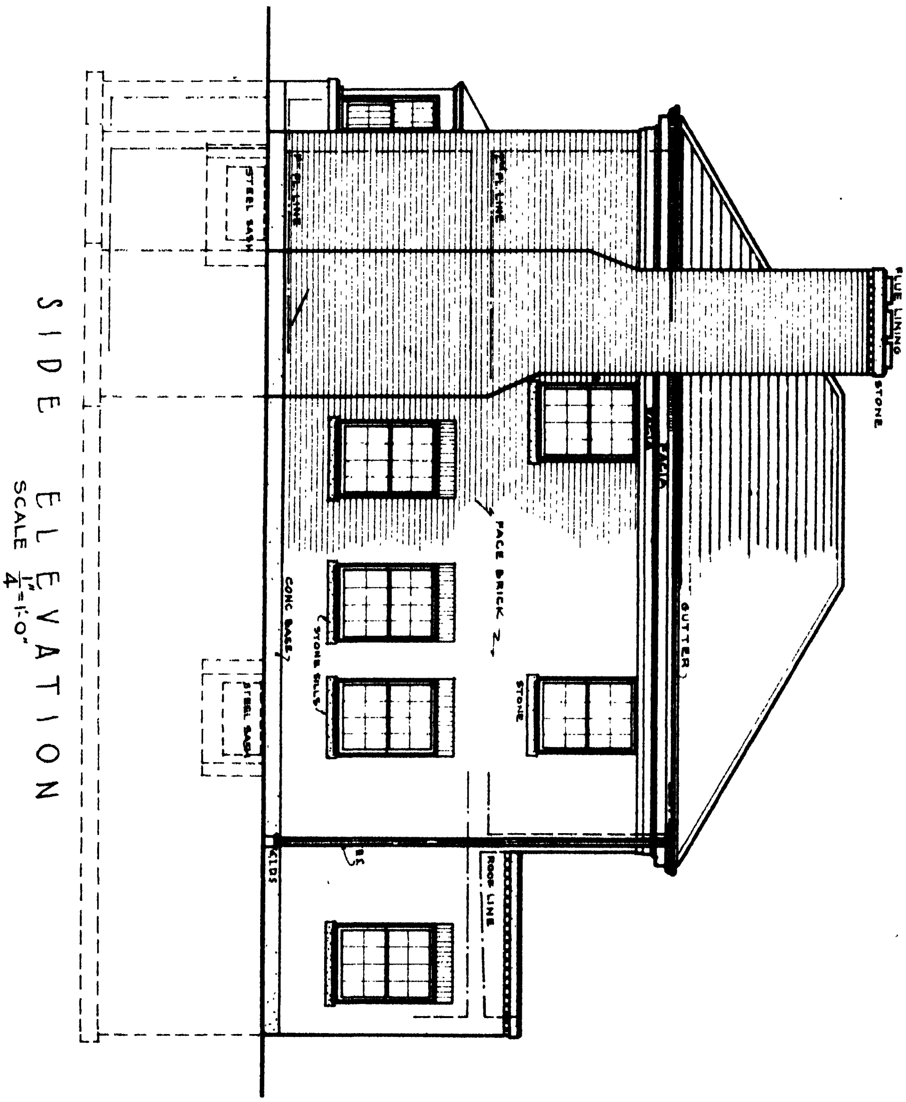


Fig. 266—LEFT-SIDE ELEVATION

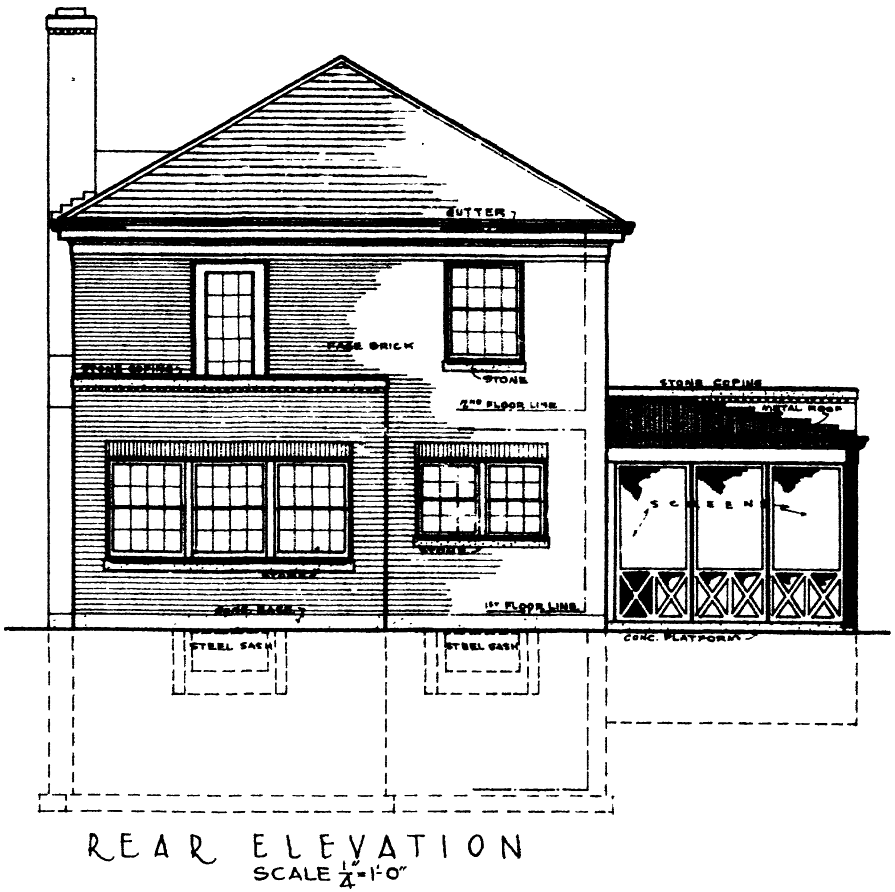


Fig. 267—REAR ELEVATION

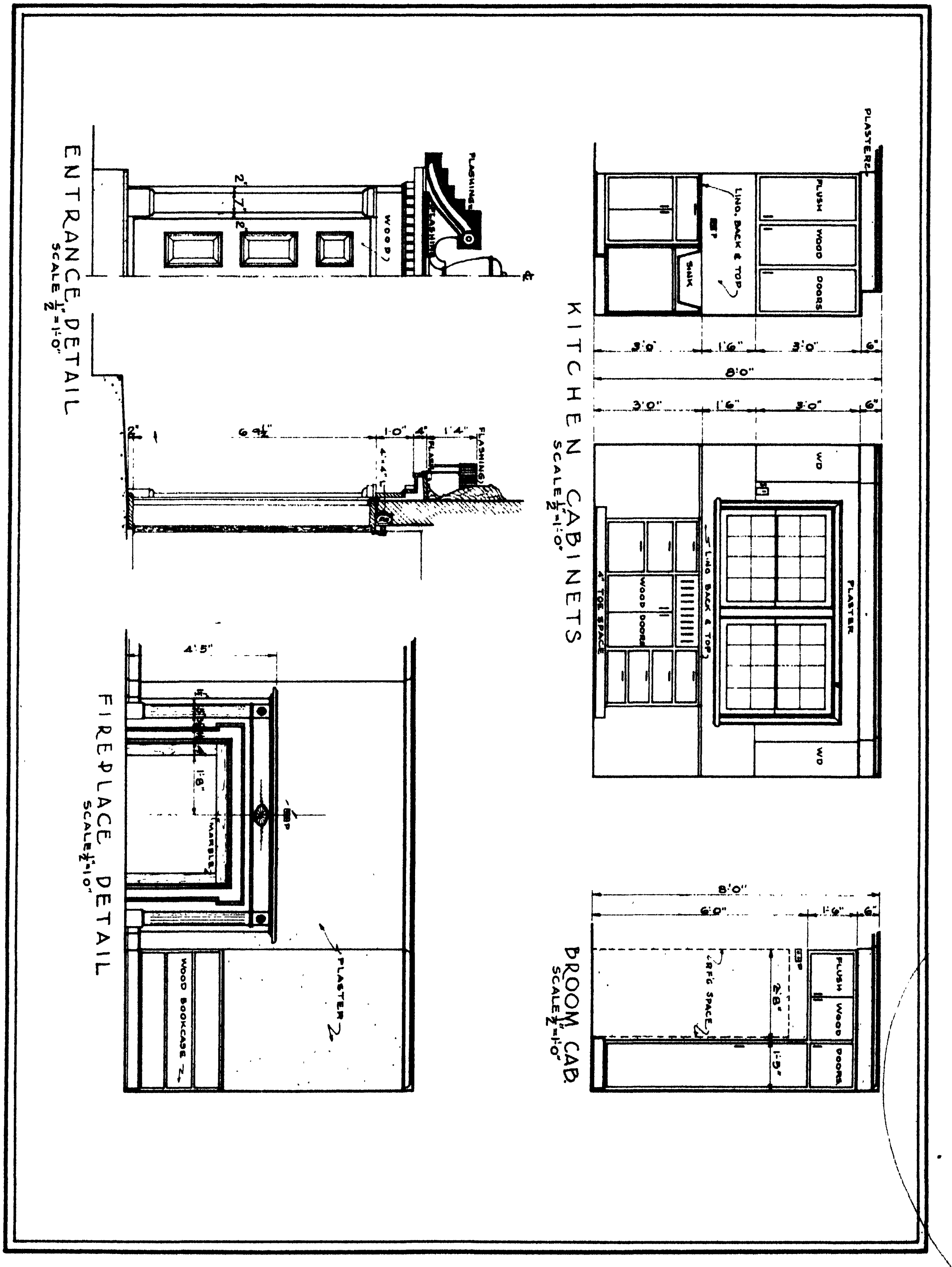


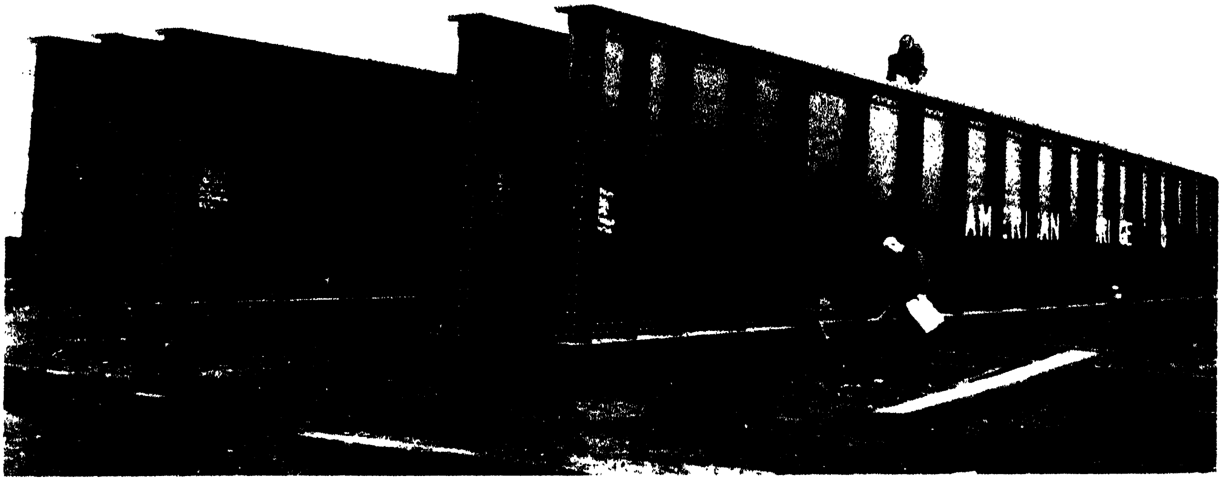
Fig. 268—DETAILS OF F

Fig. 269—PHOTOGRAPH OF A SIX-ROOM HOUSE

2″ x 4″ studs, rough sheathing, paper and siding or shingles on the outside and with lath and plaster on the inside. Brick or stone veneer walls are constructed with 2″ x 4″ studs, rough sheathing, paper, and 4″ brick or stone veneer on the outside and with lath and plaster on the inside. A solid masonry wall is constructed to brick widths or stone thickness with furring, lath, and plaster on the inside. Each of these methods of construction necessarily has its own corresponding set of details worked out to give the best results. In studying different plans watch for the different types of construction and observe the details of each type.

SPECIFICATIONS

The working drawings prepared by the architect cannot cover all the legal aspects, business procedures, and specifications for the qualities of materials and workmanship. A set of specifications is prepared by the architect to cover these matters. The set is usually composed of several sections. Among these is usually a statement of the general conditions, which takes care of the necessary legal and financial matters. Then there is usually a specification for each of the various trades, such as the masonry, carpentry, plumbing, electrical, heating, sheet-metal, plastering, and painting trades. There may be other specifications



Courtesy American Bridge Company

Fig. 270—LARGE STRUCTURAL STEEL GIRDERS

if the building is quite large. Each of these sections states the qualities of materials and workmanship that will be acceptable on the job for the particular trade. With all the specifications and working drawings, estimates can be secured and the building can be completely built as desired by both the client and the architect.

SUMMARY

Many different styles, kinds, and sizes of houses have been built to suit man's needs. Materials available, climate, and social and cultural conditions have affected the planning and design of homes as well as public buildings.

The training of the architect must be broad and must cover many fields in addition to his professional training, particularly in business, because his dealings are mainly with contractors and businessmen. He must be able to handle his clients tactfully and work from their sketches and ideas to produce preliminary and finally finished drawings and specifications.

In architectural lettering more freedom is permitted in style of letter and weight of line than in engineering lettering. Architectural conventions and symbols have been established to cover section lining used for indicating materials, as well as doors, windows, plumbing fixtures, furnaces, electrical connections, and many other standard items.

Working drawings are prepared from the preliminary sketches. Preliminary drawings usually consist of a perspective and floor layouts. The final working drawings include all plans, elevations, sections, and details necessary for the construction of the building.

There are in general three kinds of construction—frame, brick or stone veneer, and solid masonry.

Specifications are written to cover the legal and business procedures as well as the qualities of materials and workmanship to be employed during the construction of the building. Usually a separate specification is written for each trade.

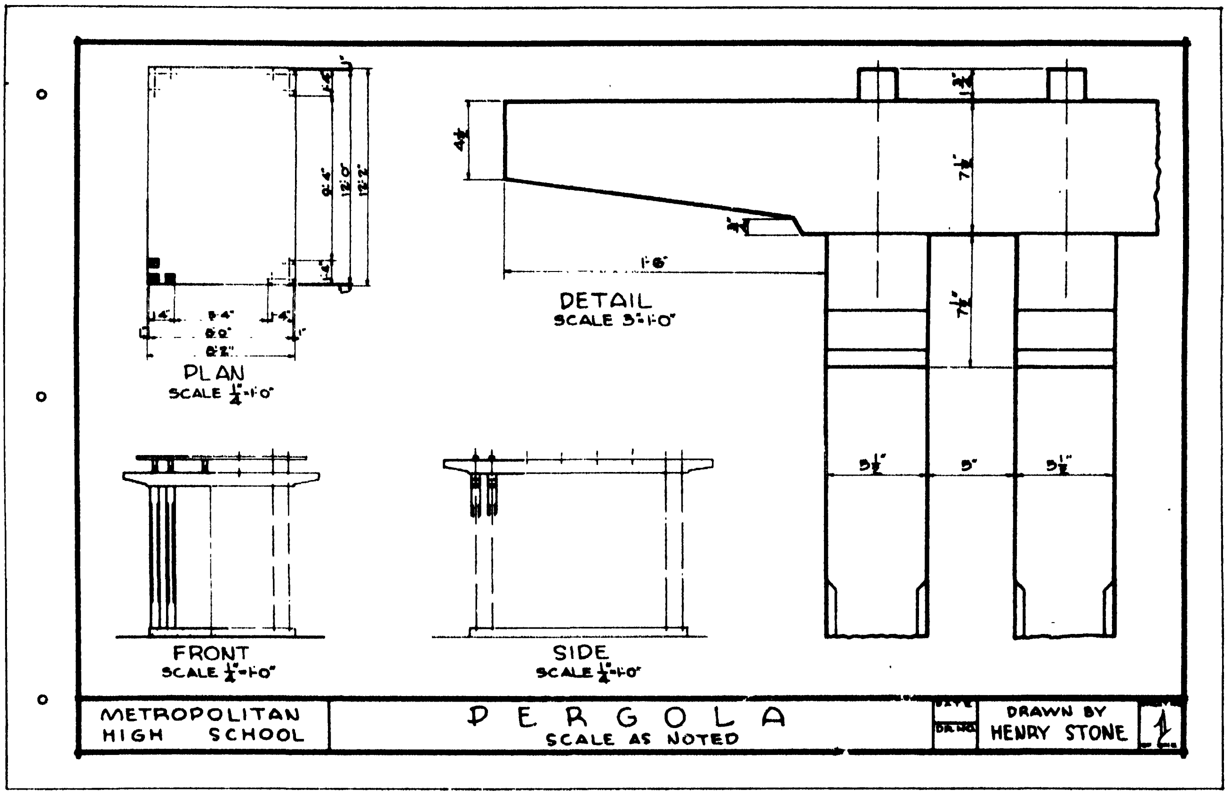


Fig. 271—A PERGOLA (PROBLEM)

A PERGOLA

This and the other drawings for this unit may be made on tracing paper rather than the regular drawing paper if desired. A larger size sheet may also be used. An 11″ x 17″ size is recommended.

From Figure 271 draw front and side elevations and the top of a pergola. Use the scale ¼″ = 1′-0″ except for detail. Draw detail 3″ = 1′-0″.

A SCOUT CABIN

Make front and side elevations, floor plan, and details of the cabin sketched in Figure 272.

CONVENTIONS AND SYMBOLS

Draw the conventions and symbols shown in Figure 273. Study the sheet layout to determine the spacing before attempting to do any drawing.

A GARAGE

Make a complete set of working drawings for a garage. The sketch given in Figure 274 is not complete, but you should make your drawing complete. Use the scale ¼″ = 1′-0″.

A FRAME COTTAGE

Make a complete set of working drawings and the necessary details of the frame cottage shown in Figure 241. Use the scale ¼″ = 1′-0″.

A BRICK HOUSE

Make a complete set of working drawings of the brick house shown in Figures 261 to 268. You may make any alterations you desire. Since this house has two floors, it is suggested that you make your drawings on tracing paper. Much of the

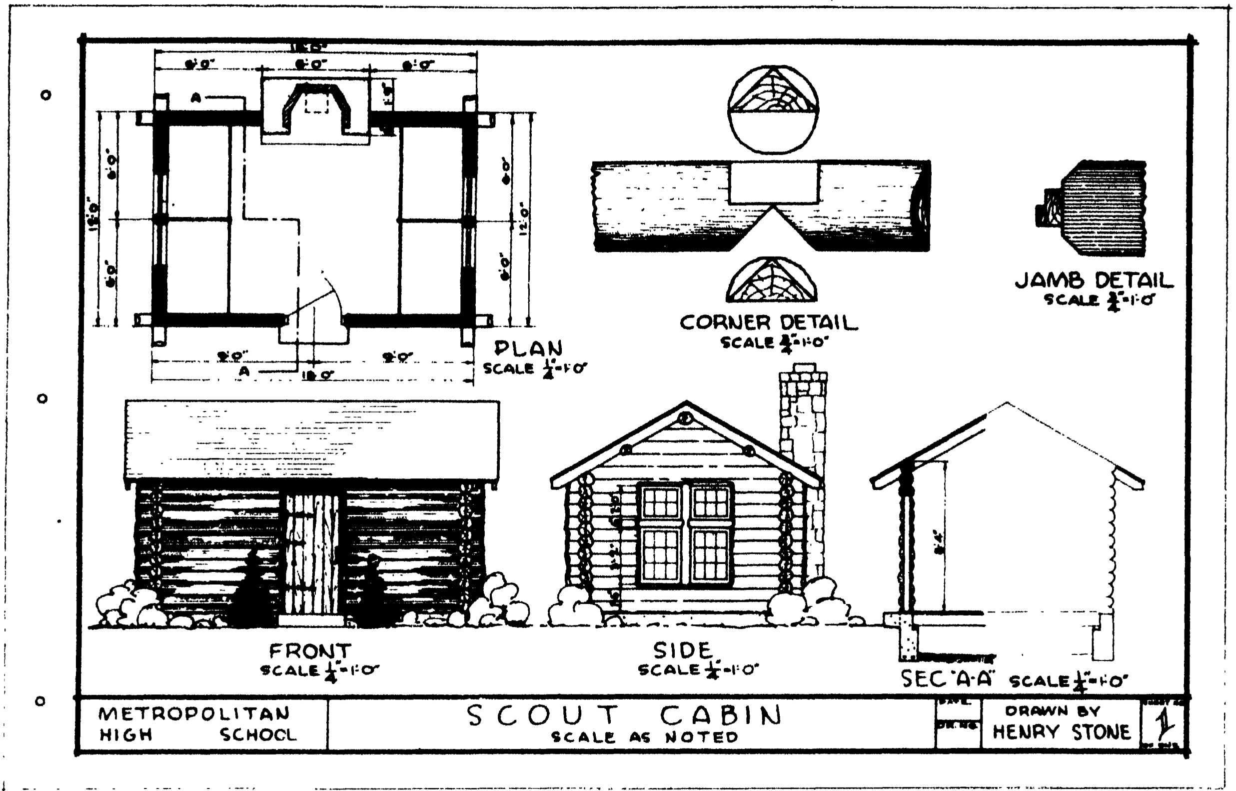


Fig. 272—A SCOUT CABIN (PROBLEM)

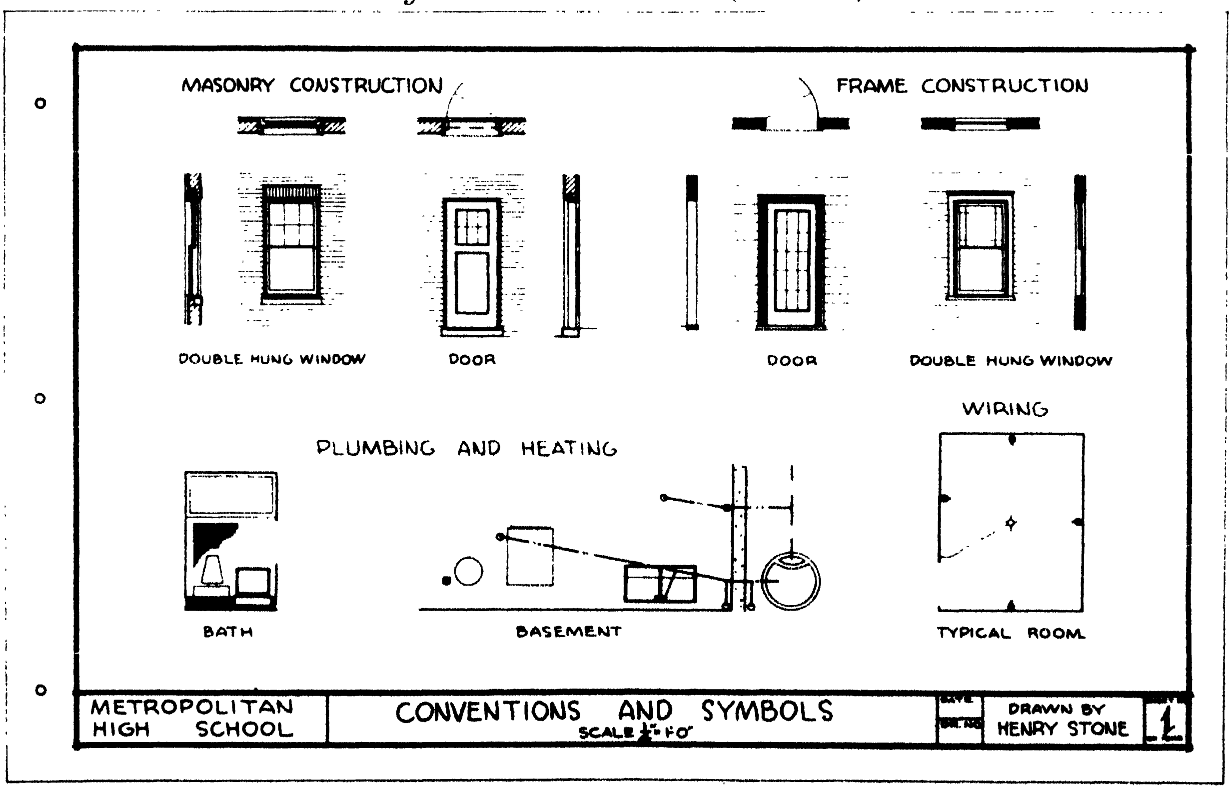


Fig. 273—ARCHITECTURAL CONVENTIONS AND SYMBOLS (PROBLEM)

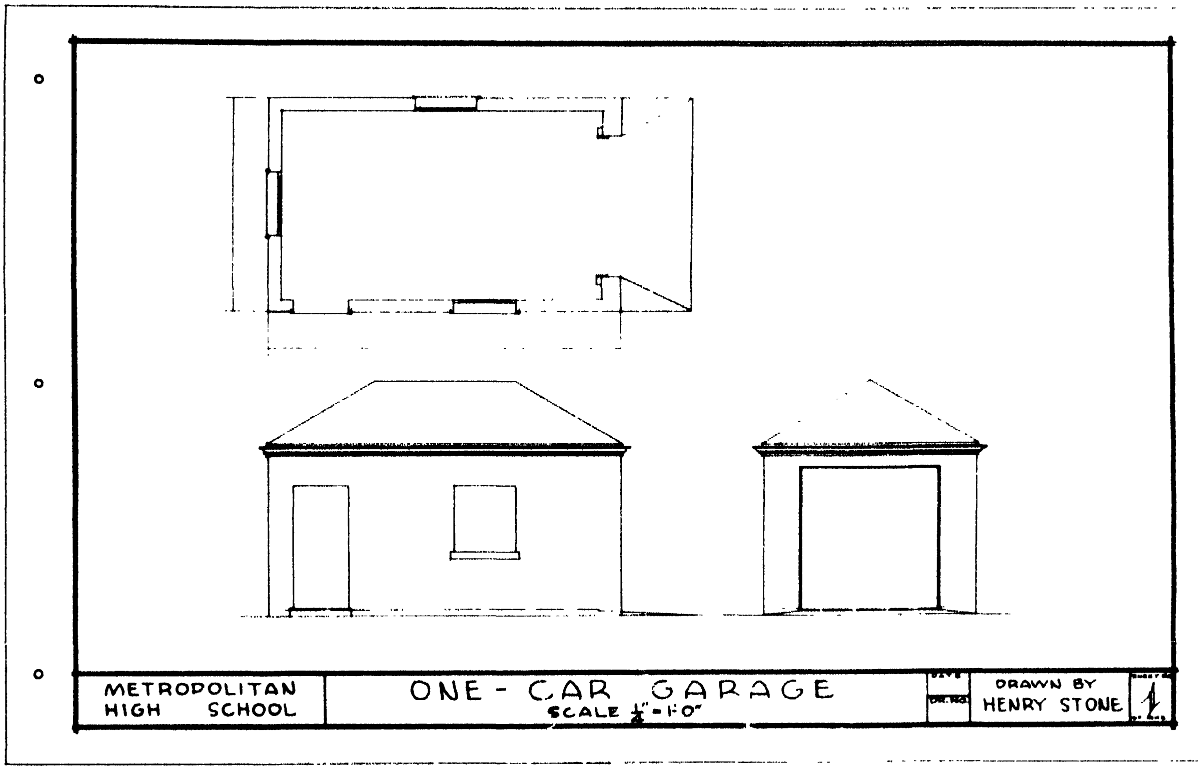


Fig. 274—A ONE-CAR GARAGE (PROBLEM)

work may then be traced from the first floor plan in making the plan of the second floor. For these drawings also use the scale $\frac{1}{4}'' = 1'\text{-}0''$.

QUESTIONS

1. Name a few of the factors that influence the architecture of a locality.
2. What are some of the duties of an architect besides drawing plans?
3. Why are symbols used in architectural drawing?
4. Most architects draw directly on tracing paper or cloth. Why?
5. What is the difference between a brick veneer house and a brick house?
6. Are the windows in your home double hung or casement?
7. What are architectural specifications?
8. Find out what the duties of a contractor are.
9. What is the first drawing you would make in starting to plan a house?
10. In brick buildings openings in the walls are left for doors and windows. What supports the brick above these openings?

TOPICS FOR DISCUSSION

1. Choose one of the common architectural styles and write a paper on its origin and development, illustrating with sketches some of the important characteristics of this style.
2. Many cities have zoning laws or building ordinances. Find out what some of these laws are in the city where you go to school. Report to the class.

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GRAPHS AND MAPS

GRAPHS

Graphs or charts have been used for centuries to present facts in a form easily understood. Today newspapers, magazines, and books use them to interpret many kinds of information. Numerical data, such as tables or columns of figures, cannot be compared easily, and often a reader does not take or have the time to interpret them. If such facts are presented in graph or chart form, a clear comparison may be made immediately.

A teacher uses graphs or charts in the field of education. The engineer uses graphs to solve problems, and the doctor uses graphs or charts to get a complete picture of the patient's progress. In all forms of athletics graphs or charts are kept of various activities. Graphical representation is the outstanding method of presenting statistical data in a condensed and easily read form.

There are four commonly used methods of graphical representation—line graphs, bar graphs, area graphs, and solid, or volume, graphs. While there are other kinds of graphs, they are usually variations of these.

Line Graphs

The line graph shown in Figure 275 is the simplest form of graph. Figure 275 shows the minimum stopping distances for automobiles under ideal conditions. If the graph is studied, it will be noticed that a car may be brought to a halt in a much shorter distance when it is traveling 30 miles per hour than when making 60 miles an hour. A car going 30 miles per hour can be stopped under ideal conditions in 80 feet, while a car speeding at 60 miles per hour requires over 280 feet.

The line graph shown in Figure 276 gives the average weekly earnings during a ten-year period for men in the manufacturing industries in Chicago. In what year were the earnings lowest?

A line graph is made by plotting two sets of figures in relation to each other on axes formed by two lines perpendicular to each other intersecting at a point, as shown in Figure 277. The zero point is called the origin. The horizontal line is the X axis, or *abscissa;* the vertical line is the Y axis, or *ordinate*. The *grid* is the background rulings, on which the points representing the numbers are located. It is wise not to have too many background lines; use only as many as are needed for the comparison desired. The graph lines connecting the points should be heavy. The variable values on all graphs should start at 0, or a break line should be used.

Constants, or numbers representing values that do not change, are placed on the horizontal, or X, axis. *Variables*, or numbers representing values that change, are located on the vertical, or Y, axis. The

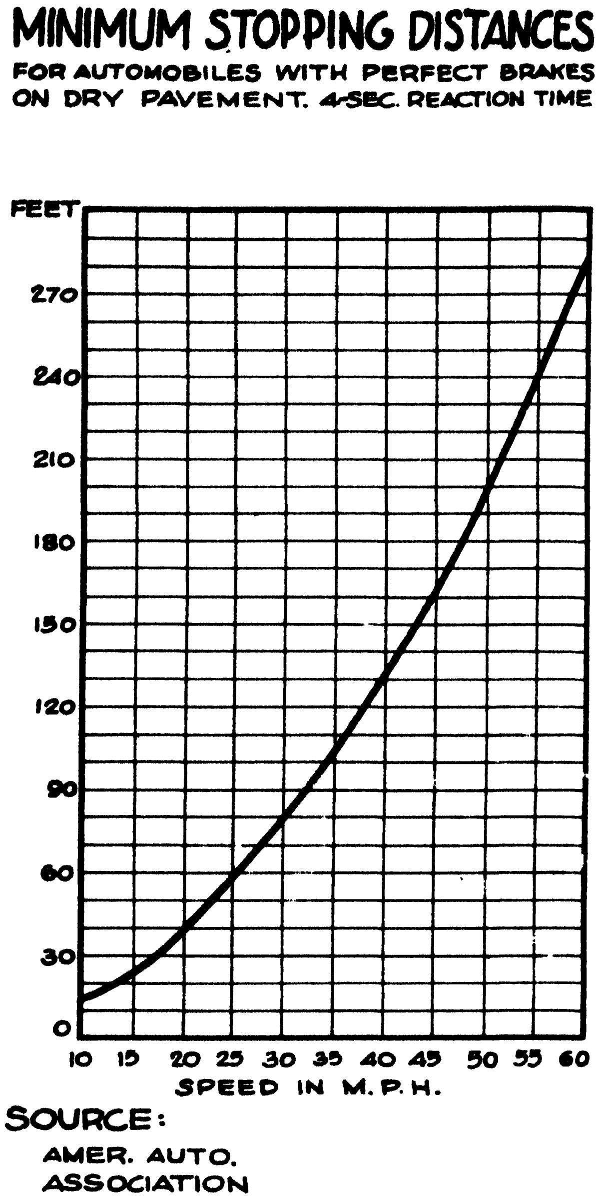

Fig. 275—A LINE GRAPH

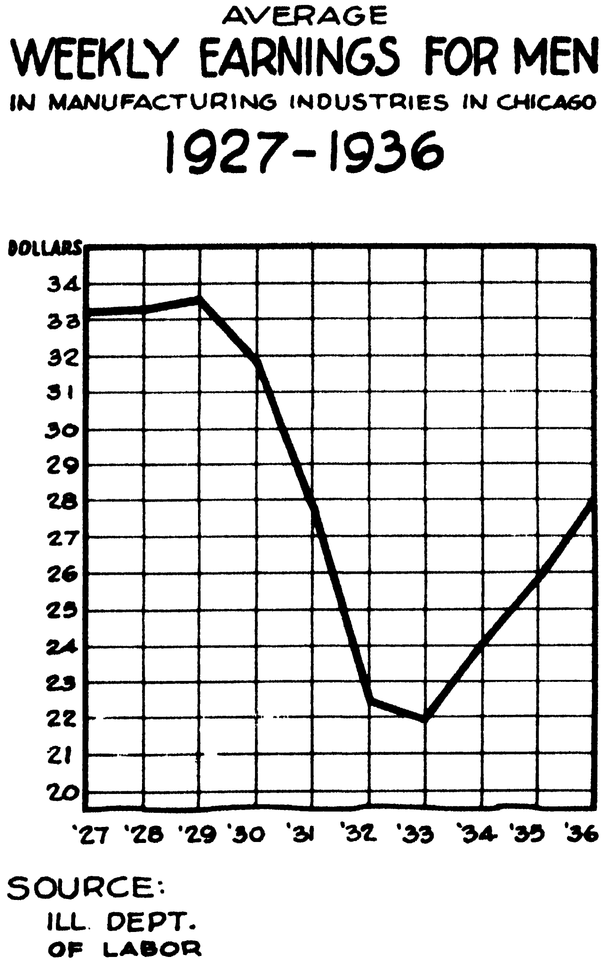

Fig. 276—ANOTHER LINE GRAPH

points representing combinations of X and Y values are connected with straight lines or curves. In the graph (Figure 277) showing passenger air travel in the United States during the period of 1928–1936, the years are constants and are placed on the abscissa, while the passengers carried vary and are shown on the ordinate.

All graphs should be properly labeled with definite titles. If two or more lines indicating different variables are to be drawn on the same graph, they should be labeled or identified by means of a key or legend. Figure 278 is a graph giving the safe loading for 2″ timbers. Three sizes of 2″ timbers are used, 2″ x 6″, 2″ x 8″, and 2″ x 10″. The graph shows the comparative strength of the different sizes as the length of *span* of the timber is increased.

Bar Graphs

Bar charts, or graphs, such as are shown in Figure 279, are used extensively in comparing quantities, absolute values, or percentages. This form of chart is most effective with a limited number of bars. The bars should be made wide enough so that

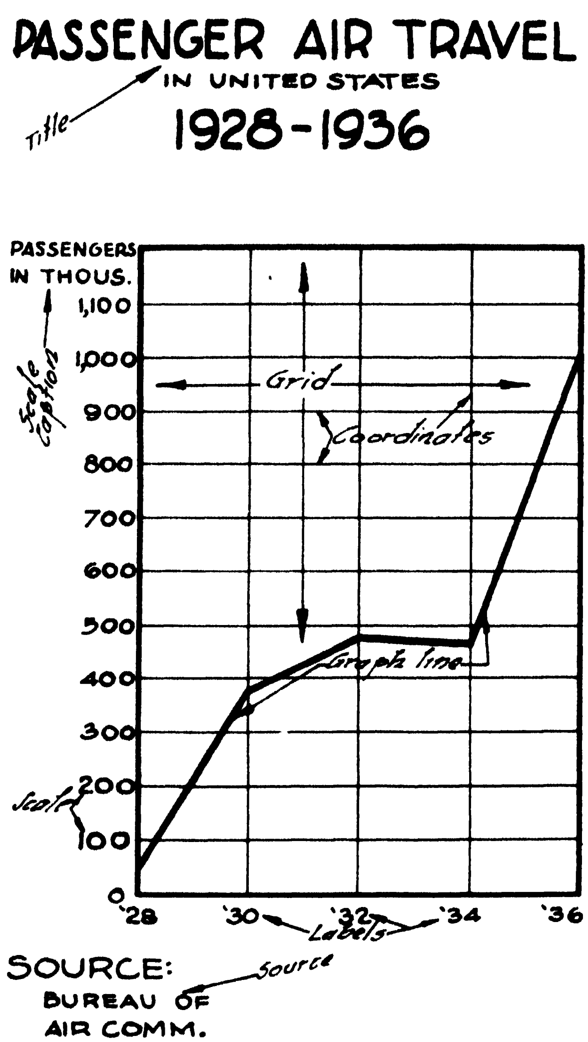

Fig. 277—NAMES OF PARTS OF LINE GRAPH

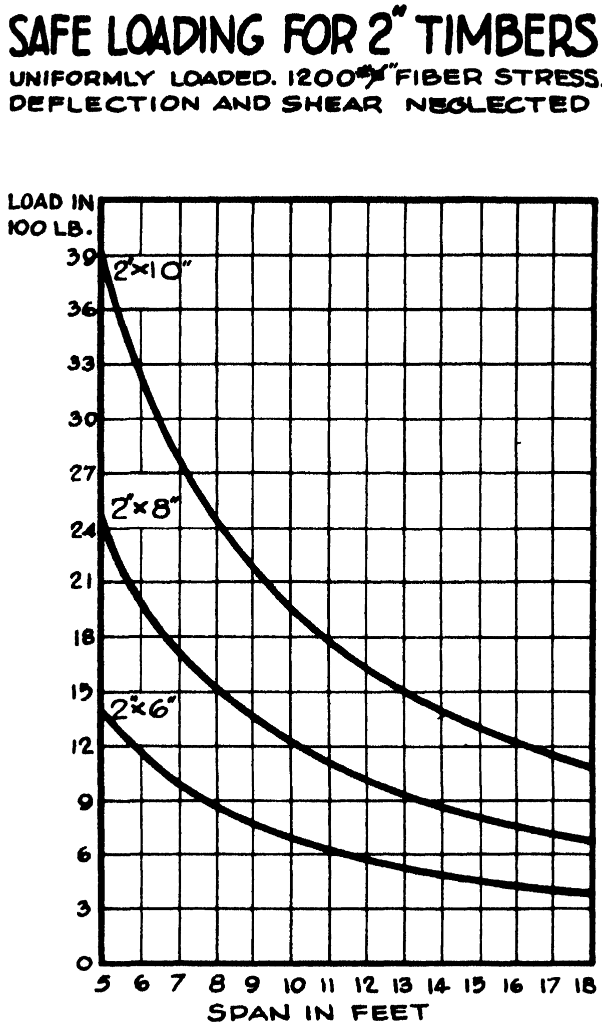

Fig. 278—THREE LINE GRAPHS ON THE SAME GRID

they will stand out. The spaces between bars should be equal, and the spacing may depend upon the size of the chart. The length of each bar represents a certain percentage or quantity. Bar charts may be drawn either in vertical or horizontal style.

A simple vertical bar chart is shown in Figure 280. This graph shows Bob Feller's strike-out average for the first ten games during the 1940 season. A glance at the graph shows in what game he struck out the most batters. In what game did he strike out the fewest batters?

Figure 281 is a horizontal bar chart that shows the all-time consecutive game hitting records for the major leagues. Joe Di Maggio broke the established record for hits in consecutive games in 1941 when he hit safely in 56 games.

The single-bar chart is an easy one to make. Figure 282 shows the per cents of materials needed to make concrete. While vertical single-bar charts are easier to letter, horizontal charts are also used.

Pictorial multiple-unit bar charts are used extensively in newspapers and magazines because they are easy to read and readily attract attention. Figure 283 is a pictorial

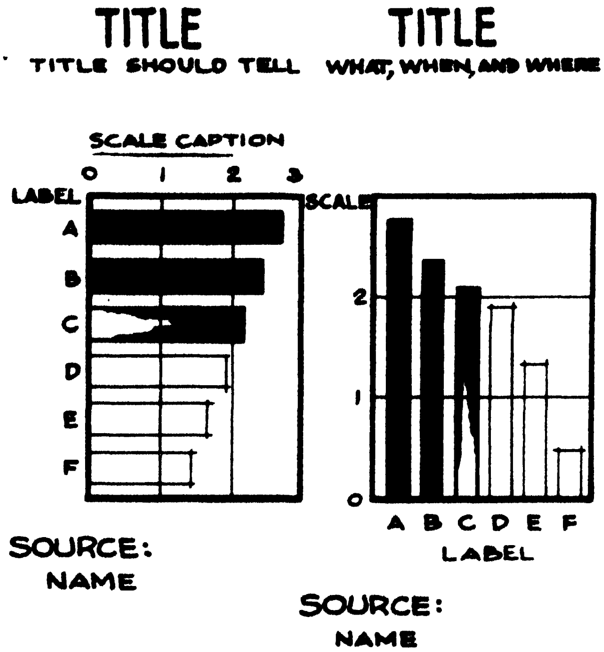

Fig. 279—BAR GRAPHS

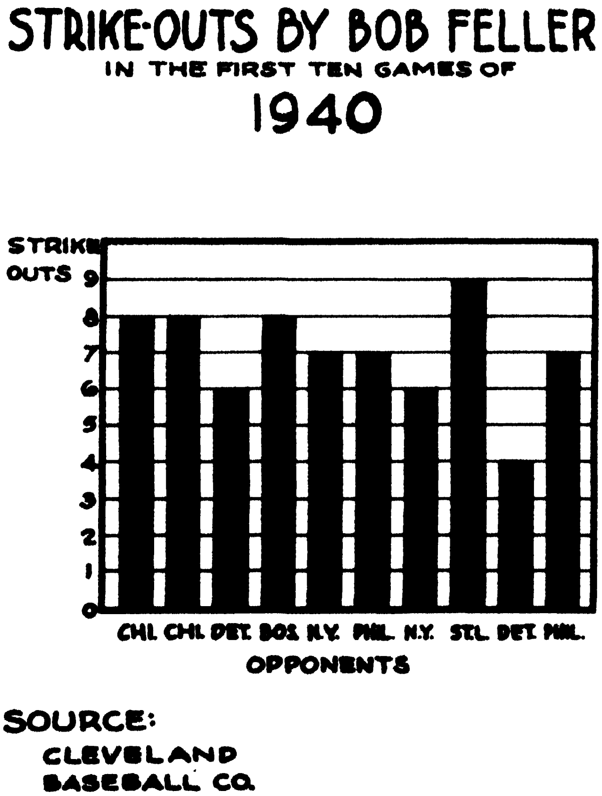

Fig. 280—A VERTICAL BAR GRAPH

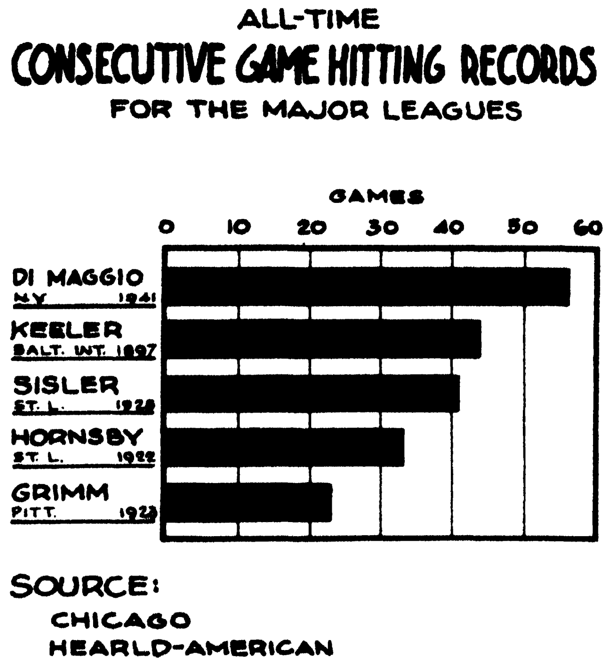

Fig. 281—A HORIZONTAL BAR GRAPH

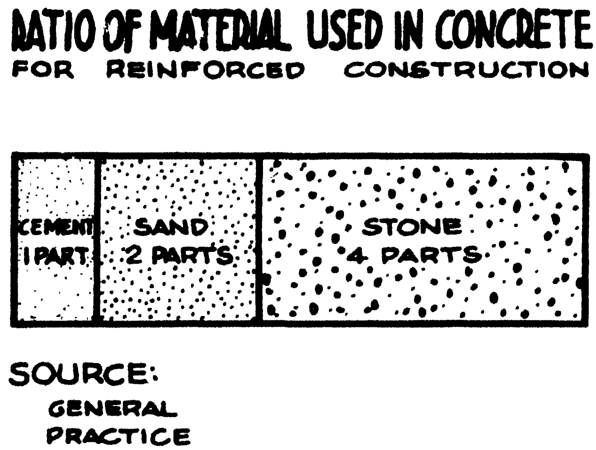

Fig. 282—A SINGLE-BAR CHART

chart showing comparative travel-time schedules by airplane and train between New York and San Francisco. The pictorial chart is similar to a bar graph except that pictures are used instead of bars.

A bar graph is constructed by first preparing the grid. The lines are evenly spaced, and only as many are used as are needed. The grid should be arranged so that the longest bar will nearly reach the top or right side of the grid.

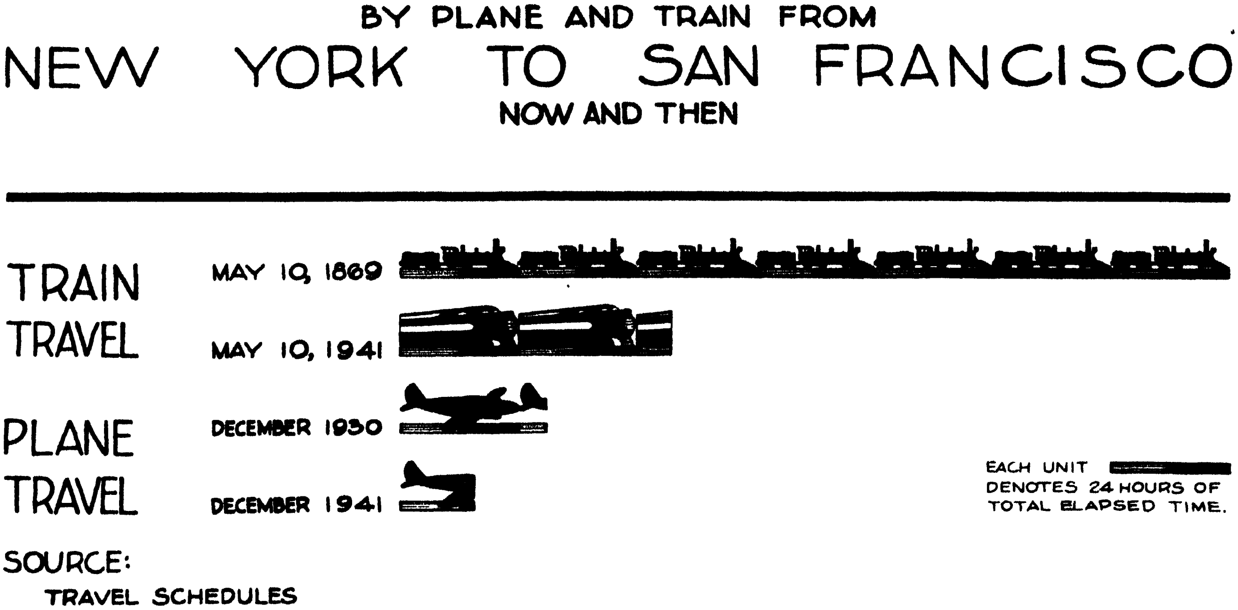

Fig. 283—A PICTORIAL MULTIPLE-UNIT BAR CHART

Values indicated along the axis should be in round numbers. Place these values at the left of the vertical bar graph, at the top or bottom of the horizontal. The labels are placed on the horizontal axis directly below the bars of the vertical bar graph, at the left of the horizontal.

Place the bars, constructed to their scale-value length, on the grid. These bars should be located so that the spacing between them ranges from one half to the full width of a bar.

Area Graphs

The common types of area diagrams are shown in Figures 284 and 285. The pie chart (Figure 284) is popular and easily constructed. It is useful in making percentage comparisons of a single total divided into parts. The graph segments, which resemble pieces of pie, account for the name. A table could tell the same story, but it would be harder to get the entire picture from it.

The circle or pie chart is begun by drawing a circle. The size should be large enough so that the segments can be clear and its caption can be easily lettered.

Think of the circle as divided into 100 parts. As the circumference of a circle is 360°, 1 per cent ($\frac{1}{100}$) of the circle will equal $\frac{360}{100}$, or 3.6, degrees. Indicate on the circumference the correct number of degrees for each segment. The number of degrees will correspond to the percentage the segment represents (3.6 x the number standing for the per cent). The data should be used in the order of size, beginning with the largest amount and continuing down to the smallest. The sum of all the divisions should equal the whole circumference.

Connect the per cent divisions with lines to the center of the circle. Crosshatch each segment and label it in the "window," or clear space. The title, source, and footnotes go above or below the chart.

The area chart (Figure 285) is used when only two or three quantities are to be compared. It is difficult to make an accurate comparison unless the shapes are simple since the plotted areas must be made proportional. Figure 285 shows the

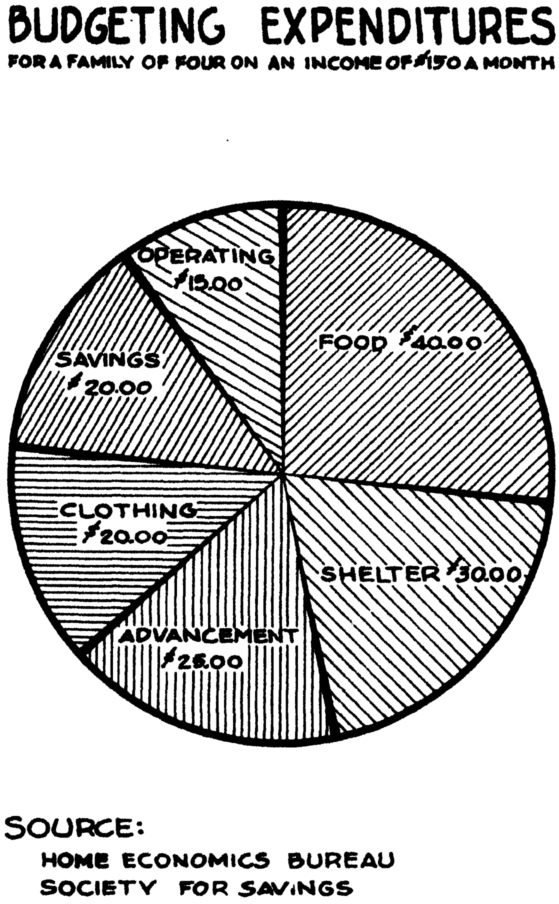

Fig. 284—A CIRCLE, OR PIE, CHART

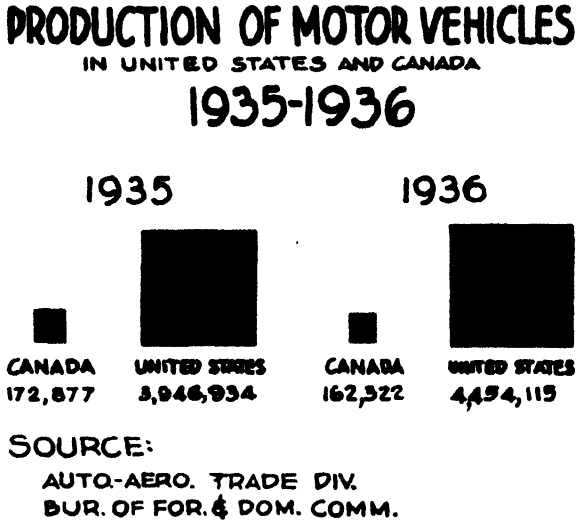

Fig. 285—AN AREA CHART

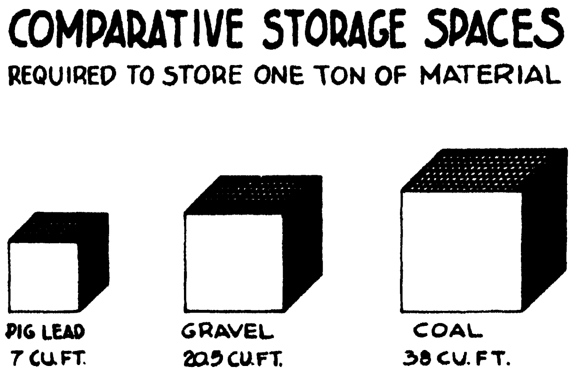

Fig. 286—A SOLID GRAPH USING CUBES

production of motor vehicles in the United States and Canada during 1935 and 1936.

Solid Graphs

Solid graphs are used to make pictorial comparisons. Here too figures are needed for accurate comparison. Solid graphs seem three-dimensional and the volumes proportional. Common kinds are the geometric figure and the pictorial figure.

Figure 286 is a solid graph using cubes to show comparative storage spaces required to store one ton of material. Which material of the three materials represented requires the smallest space per ton?

Another solid graph is shown in Figure 287. This uses spheres to compare the gallons of water pumped daily in Chicago during two different years, 1854 and 1940.

Organizational Graphs

Figure 288 is an organizational chart, or graph, that shows the manner in which a student council functions. The council is made up of the school leaders and officers as well as delegates from the various clubs and rooms. There are a number of different types of organizational charts.

MAPS

Map making is an important activity. Without maps it would be difficult to tell just where the limits of a country are, how

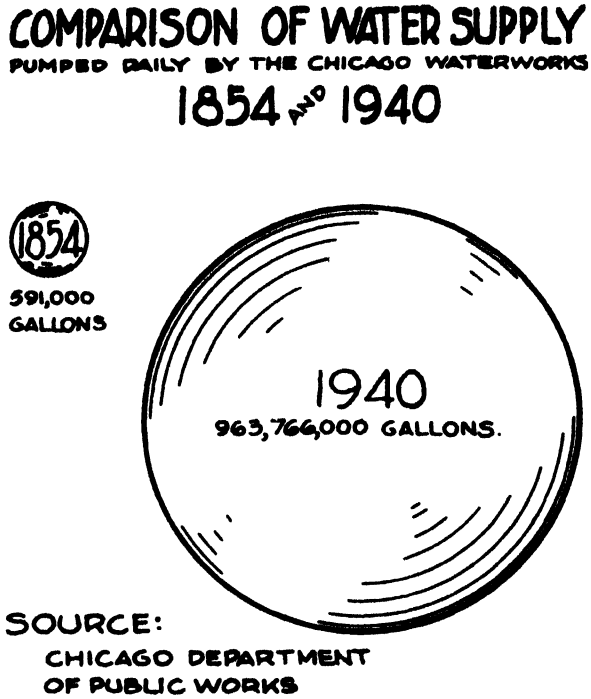

Fig. 287—A SOLID GRAPH USING SPHERES

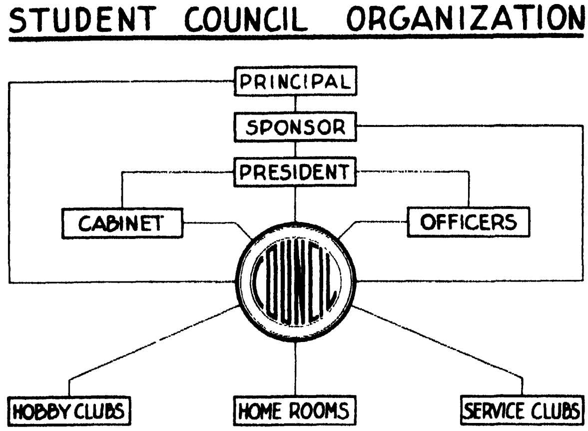

Fig. 288—AN ORGANIZATIONAL CHART

the country is shaped, and where the cities and towns are located. Map making is almost as old as civilization. History and geography books sometimes include some of the early maps of the world and also early maps of the United States. Compared with modern maps, these older ones are incomplete and often inaccurate. One of the men who did some of the early surveying in this country was none other than George Washington, our first president.

THE CIVIL ENGINEER

Map making, the surveying of rights-of-way for railroads and motor highways, and the planning and building of bridges and dams are all included in the work of the civil engineer. He also plans and builds sewers and water systems and filtration plants. All of these projects must be planned before they are built, and many plans and maps are needed for use during their construction.

The civil engineer needs considerable ability in mathematics and drafting; a four-year college course is ordinarily required. While civil engineering may not pay as well as some of the other engineering fields, it may be largely out-of-door work and, although strenuous, is healthful. The time spent indoors is mostly occupied with the making of maps or plans from information and notes taken in the field.

MAKING A SURVEY

The gathering of notes for maps is known as *surveying.* Usually either the surveyor or a special map draftsman works from the field notes in making the maps.

Because the data must be accurate, the surveyor uses a *transit* and *rod* to measure angles, distances, and differences in height, or elevation. The transit, which looks somewhat like a telescope, is mounted on a tripod. A transit contains a compass, so that measurements may be made in relation to north and south. A steel tape called a *chain* is sometimes used in surveying to measure distances.

The surveyor may make a circuit of straight lines through the area he is mapping. This circuit is called a *traverse.* The circuit is continuous and ends at the start-

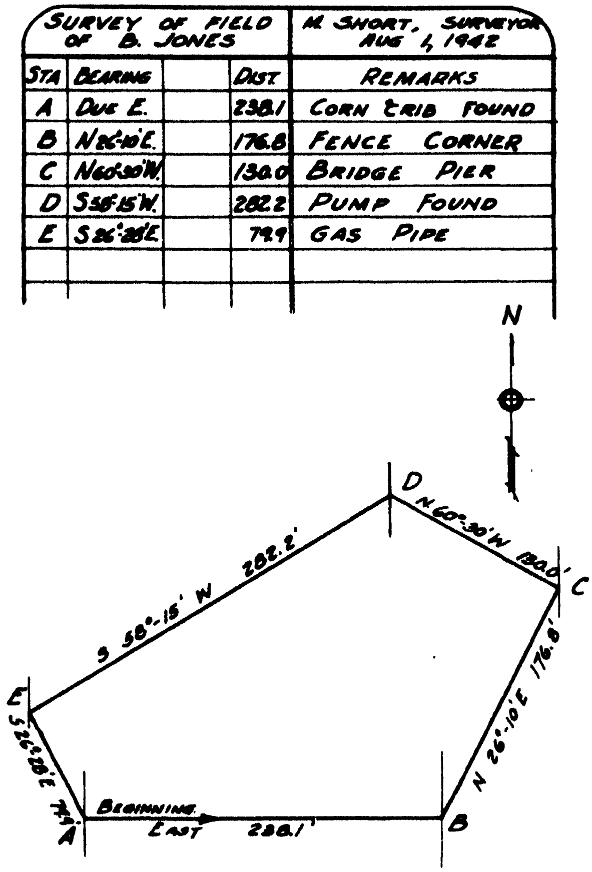

Fig. 289—FIELD NOTES AND A TRAVERSE

ing point. Each point where a new angle is taken is called a station; the distance from station to station is a *course.* The important or prominent points on each side of a course are located by means of *side shots* taken with the transit. The measurements taken give the angle, the direction in relation to north and south, and the distance of the point from the station. Each measurement giving the station, the distance, and the bearing, or *direction,* is marked in a notebook; landmarks are also noted. A set of field notes and a traverse are shown in Figure 289.

KINDS OF MAPS

The common *geographic* map shows the areas subject to different governing authorities, or the political boundaries, and the more important towns, cities, lakes, and rivers. Mountain ranges may also be indicated. When the size and location of various physical features are important considerations the scale of the map is quite large and the map becomes a real orthographic top view, or *topographic,* map (see Figure 290). Some of the common symbols used in topographical map drawing are shown in this figure. If the map represents the relative elevations of the ground surfaces, it is called a *relief* map. If contours are used with elevations marked, the map is a *contour* map.

Nautical, or sea, maps (see Figure 291) usually show distinguishing features of the shore line, the depth of the water, and the location of shallows and other places of danger for sea travel. Aeronautical maps assist the flyer in locating his destination. There are also railway and highway maps.

The type of map determines the details that are to be shown. A map on which every detail was drawn would be a jumble of words and figures. Remember that other persons should be able to read the map as easily as the one who makes it. Therefore, in drawing a map, make it clear and legible and put in it only the necessary details.

SUMMARY

Today newspapers, magazines, and books use charts, or graphs, to present data so that clear comparisons may be quickly made. One of the most commonly used kinds of graphs is the line graph. On the background, or grid, one or more sets of data may be plotted. There are several kinds of bar graphs—horizontal, vertical, single, and pictorial multiple-unit. The pictorial multiple-unit graph uses silhouetted figures in place of bars; this is an attractive and easily interpreted kind of graph. A popular area graph is the pie chart, which is used to portray percentage

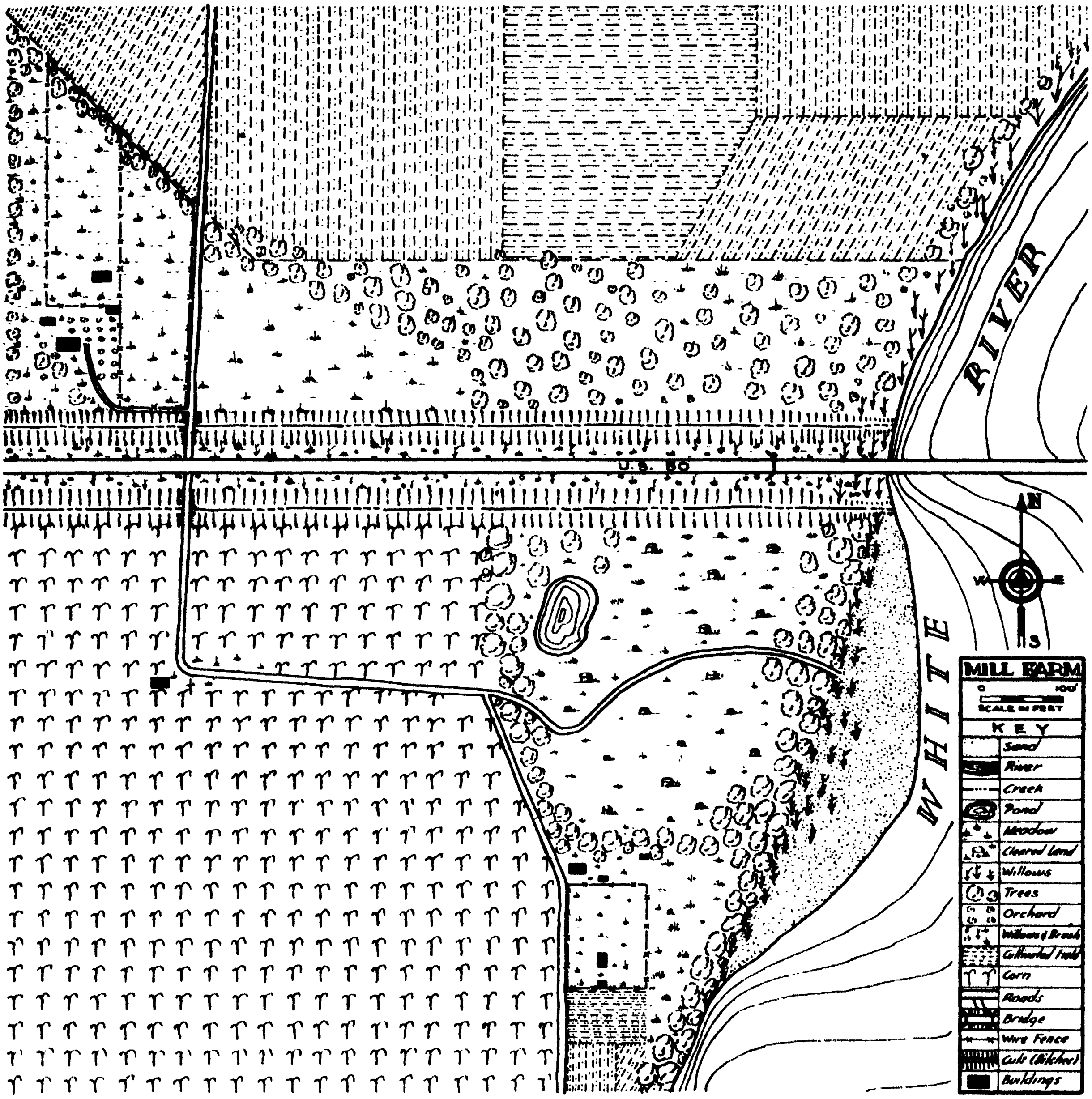

Fig. 290—A TOPOGRAPHIC MAP

comparisons of a single total divided into parts. Solid graphs represent three-dimensional objects for the comparison of different quantities. Organizational charts are drawn to show the relationships of the various offices of an organization.

Map making is a very old science. However, some of the old maps were lacking in many details. The gathering of data for map making is called surveying. The common instruments used by a surveyor are the rod, transit, and chain. A surveyor makes a traverse, on which there are points called stations. From these side shots are taken to determine angles, directions, and distances. Maps may be geographic, topographic, relief, contour, nautical, aeronautical, railway, or highway.

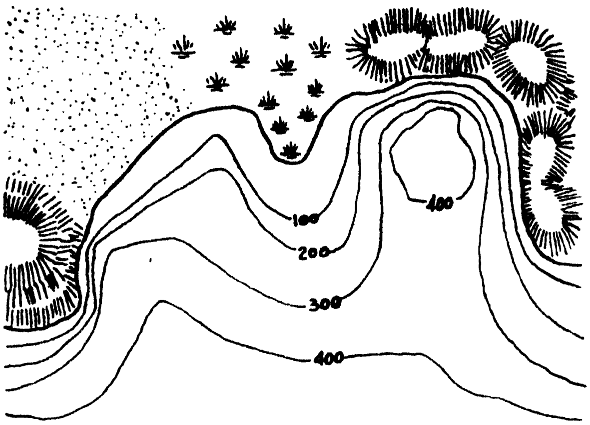

Fig. 291—A NAUTICAL MAP

LINE GRAPHS

Problem 1—Temperature Graph

Make a temperature line graph. Lay off the number of degrees on the vertical axis; the range from 0° to 100° should be plotted. On the horizontal axis lay off the hours. Use the following data.

TEMPERATURES IN CHICAGO
FOR 24 HOURS ENDED 2 A.M. JUNE 29

3 A.M.....72°	Noon.....87°	8 P.M.....88°
4 A.M.....72°	1 P.M.....89°	9 P.M.....84°
5 A.M.....71°	2 P.M.....91°	10 P.M.....81°
6 A.M.....71°	2:15.....*92°	11 P.M.....80°
7 A.M.....71°	3 P.M.....89°	Midn't.....78°
8 A.M.....72°	4 P.M.....89°	1 A.M.....77°
9 A.M.....78°	5 P.M.....90°	2 A.M.....77°
10 A.M.....82°	6 P.M.....91°	
11 A.M.....85°	7 P.M.....90°	* Highest

Source—Weather Reports

Problem 2—Tonnage of Vessels Entered and Cleared at U. S. Ports

Make a line graph showing the tonnage of both American and foreign ships entered and cleared at United States ports according to the figures at the top of the next column. Use two lines. A broken line may be used to represent one group of ships and a solid line to represent the other one. Then it will be easy to distinguish between the two groups.

YEAR	TONNAGE	
	AMERICAN SHIPS	FOREIGN SHIPS
1934	45,920,623	80,335,916
1935	44,932,470	82,269,688
1936	43,325,347	87,391,668
1937	39,389,412	98,779,828
1938	39,676,370	105,617,806
1939	35,634,839	104,434,695
1940	38,809,334	93,277,545

Source—U. S. Bureau of Foreign and Domestic Commerce

When very large numbers, such as the foregoing, are the basis of a graph, use only round numbers; for example, 39,389,412 would be plotted as 39.4, and a statement would be placed on the graph to the effect that the round numbers represent millions of tons. Such procedure is common in making graphs.

BAR GRAPHS

Problem 1—Value of School Buildings in Illinois

Make a vertical bar graph showing the value of school buildings in the state of Illinois in the following years.

YEAR	VALUE
1910	$ 88,819,664
1920	171,518,064
1930	441,075,353
1938	517,458,200

Source—Illinois State Department of Education

Problem 2—Production of Portland Cement

Make a horizontal bar graph of the Portland cement production in the United States.

YEAR	NUMBER OF 376-POUND BARRELS
1920	100,023,000
1925	161,659,000
1930	161,197,000
1935	76,742,000
1939	122,259,000

Source—Department of Interior, Bureau of Mines

SINGLE-BAR GRAPHS

Problem 1—How Criminals Fare in the Courts

Make a horizontal bar graph using the following data regarding those charged with serious crimes in twenty-five states in one year: total number of cases 70,265; number convicted 54,929, or the per cent of the total convicted 78.2; number not convicted 15,336, or the per cent of the total not convicted 21.8.

Source—U. S. Bureau of Census

Problem 2—Composition of Type Metal

Make a horizontal bar graph showing the composition of type metal. Use the following data: lead 69%, antimony 19%, and tin 12%.

Source—General practice in making foundry type

AREA GRAPHS

Problem 1—How I Spend the Day

Make a pie graph showing how you spend the twenty-four hours of a typical day. Make separate items of everything requiring more than one hour. Those requiring less than one hour may be grouped as miscellaneous.

Problem 2—Comparison of Basketball and Football Playing Areas

Make an area graph comparing the area of a basketball court (40′-0″ x 80′-0″) and the area of a football field (160′-0″ x 360′-0″, from goal post to goal post). Be sure to use the same scale for each area. These areas may have characteristic markings, such as foul and goal lines.

PICTORIAL MULTIPLE-UNIT GRAPHS

Problem 1—Passenger Automobile Production in the United States (1910 to 1940)

Make the graph, using small automobiles in the graph.

Year	Number of Cars
1900	4,192
1910	181,000
1920	1,905,560
1930	2,784,745
1940	3,692,328

Source—American Automobile Association

Problem 2—Airplane Production in the United States (1935 to 1940)

Make a graph of the number of airplanes built in each of these years. Draw a small plane to represent a group—say, 500 planes—on the graph.

Year	Number of Planes
1935	334
1936	515
1937	621
1938	875
1939	1219
1940	3162

Source—U. S. Civil Aeronautics Authority

SOLID GRAPHS

Problem 1—Weights of Various Materials

Make a solid graph, using cubes isometrically or spheres, comparing the weights of 1 cubic foot of each of the following metals.

Metal	Weight per Cubic Foot in Pounds
Aluminum	159.7
Iron (cast)	449.2
Copper	550.4
Silver	657.1
Lead	709.5
Gold	1205.6

Problem 2—Coal Production in the United States from 1936 to 1939

Make a solid graph. Each unit should be made to represent the total coal production in each year. These figures include both anthracite and bituminous coal. They do not, however, include coal from mines not served by railroads.

Year	Number of Short Tons
1936	493,668,000
1937	497,387,000
1938	394,644,000
1939	444,552,000

Source—Department of Interior, Bureau of Mines and Bituminous Coal Division

ORGANIZATIONAL CHART

Make an organizational chart showing the entire organization of your school, city, classroom, or club. Use an arrangement similar to the one shown in Figure 288.

MAP OF CAMP

Make a map of a Boy Scout camp, schoolyard, city park, or your home. Use symbols similar to those shown in Figure 290. Be sure that enough data have been collected before you start the drawing.

TRAVERSE

Using the map you have just drawn, select suitable points and make a traverse. Use your protractor.

QUESTIONS

1. What are the common methods of graphical representation?
2. What is a grid?
3. Is it possible to present more than one set of data on the same grid?
4. What are constants? Variables?
5. What kind of information is presented in a pie chart?
6. Can a single-bar graph and a pie graph present the same data?
7. What is the chief difference between a pictorial multiple-unit graph and a regular bar graph?
8. What is the purpose of an organizational chart?
9. Describe the work of the surveyor.
10. Name several kinds of maps.

TOPICS FOR DISCUSSION

1. Study all the issues of a daily newspaper for one month with reference to the number of graphs, the number of each different kind of graph, and the type of information presented in each graph. Report to the class.
2. Consult your encyclopedia or other books in regard to some of the instruments a surveyor uses, such as a transit, rod, chain, and plumb bob, and describe how each is used.

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UNIT XII

TRACING, BLUEPRINTING, AND DUPLICATING

TRACINGS

As a single drawing is limited in its use, several different processes have been developed for duplicating drawings. The simplest and most economical process is blueprinting. Many blueprints may be made from one tracing. Thousands of prints of the same drawing are used in the automobile and airplane industry.

A tracing is necessary before a blueprint can be made. Formerly, and in some drafting rooms today, the original drawing was completed, the transparent tracing paper or cloth was placed over the drawing, and the drawing was then traced on this paper or cloth. The best tracings are those made on tracing cloth with black drawing ink. However, in industry today a great many drawings are made directly on tracing cloth and are blueprinted whenever a print is needed, whether the drawing is finished or not. Many tracings are left penciled on this cloth and never inked.

One of the more commonly used tracing papers is vellum, a form of parchment paper. Here the line work and lettering are done in pencil, and the drawing may be blueprinted as are tracings on tracing cloth. Tracing paper has some disadvantages, for it tears easily, does not wear well, and becomes brittle with age. Therefore it is not so well suited for permanent tracings. It is used, however, for preliminary drawings and where it is not necessary to keep the tracings permanently.

Onion-skin tracing paper is more transparent than vellum but also much more delicate. There are many other tracing papers, each of which is suited to a particular use.

Tracing cloth, which is more expensive than vellum, is made of a fine linen or cotton fabric treated with a starch preparation to make it transparent. The dull side is better to work on as it takes ink more readily.

Drawing ink is a special ink made of lampblack and a quick-drying liquid. Carbon and shellac are also mixed in it to make it waterproof.

THE TECHNIQUE OF TRACING

If the tracing is to be done in pencil either on tracing cloth or paper, the technique is the same as that you have already learned for drawing. There is one point, however, that must be kept in mind; the blacker the pencil line on the tracing, the whiter the line will appear on the blueprint. All lines of any one type should be even in width and should be good black lines.

As you know, tracings may be inked; that is, all the line work may be done in ink instead of pencil. Ink may be used on both tracing paper and tracing cloth, but it is seldom used on paper since tracing paper is not used for permanent tracings.

A great amount of care must be taken in inking. All straight lines are drawn with

Fig. 292—INKING WITH A RULING PEN

a ruling pen. See Figure 292. This figure also shows the correct way of holding the pen. Both nibs should touch the surface of the cloth at all times. It is necessary to use the ruling pen immediately after filling it or the ink will clog or dry. It is equally important not to put too much ink in the pen, since too much ink may cause a blot. The ruling pen should be kept clean at all times.

All lettering is done freehand with a regular penholder and a pen point suited to the type of lettering to be done. For fairly large letters a ball point should be used. For letters too small to be made with a ball point, a Gillott 303 or 404 pen point may be used.

Freshly inked lines and letters must be protected until dry; otherwise they may become smeared.

The following is the procedure to be used in making tracings:

1. Place the drawing on the board, using a T square to line it up and then fasten.

2. Cut a piece of tracing cloth or vellum paper to a size about ½″ larger than the drawing sheet to be traced. Standard sizes with printed titles are ordinarily used in industry.

3. Use the dull side of the tracing cloth; draftsmen find the dull side is easier to work with.

4. Stretch the tracing cloth or paper smoothly over the drawing and fasten with Scotch tape.

5. Dust chalk lightly over the tracing cloth or paper. A blackboard eraser is best for spreading the dust. Chalk dust removes the oily surface. A specially prepared tracing powder may be purchased if desired.

6. Wipe off the dust chalk and try out your ruling pen on scrap paper to get proper width of line. Then proceed to ink the drawing, beginning at the top and left.

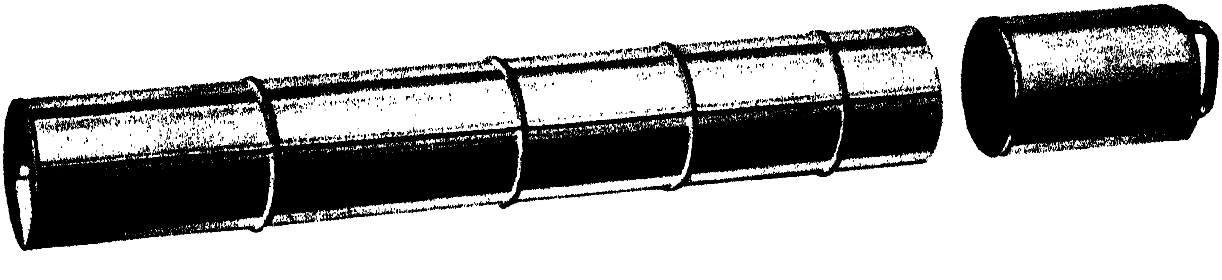
7. The order of inking is as follows:

(*a*) Circles, arcs of circles, and curves
(*b*) Horizontal lines
(*c*) Vertical lines
(*d*) Inclined lines
(*e*) Center lines, horizontal and vertical respectively
(*f*) Section lines
(*g*) Dimension and extension lines
(*h*) Arrowheads
(*i*) Dimension numerals and notes
(*j*) Title and subheading
(*k*) Border

Check the finished drawing for errors and omissions.

8. Clean the tracing and remove it from the board. A tracing cloth that has only ink lines may be washed with a cleaning fluid, as naphtha, gasoline, or carbon tetrachloride, or it may be cleaned with art gum.

The tracing is now ready for reproduction, and as many prints may be made from it as are needed. Industrial organiza-



Courtesy C. F. Pease Company, Chicago

Fig. 293—A LIGHTTIGHT CONTAINER FOR BLUEPRINT PAPER

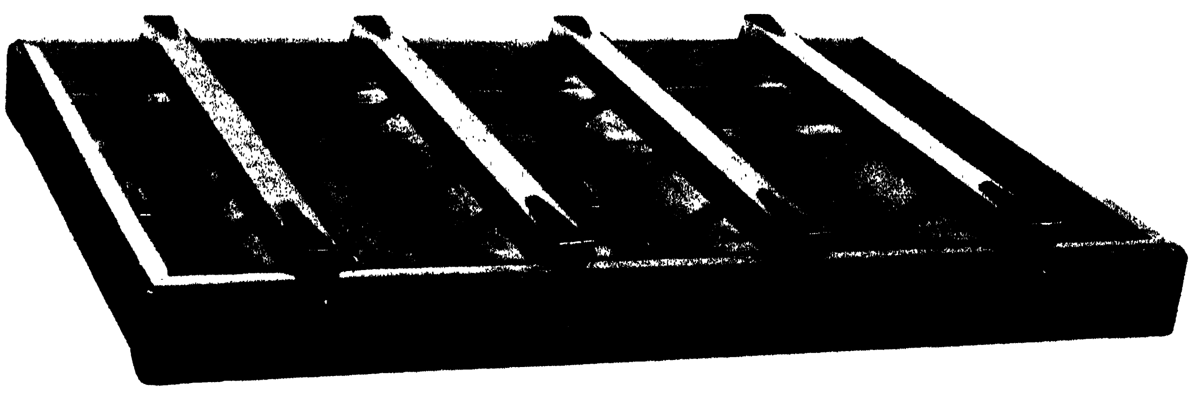
tions have a file for tracings, which are used only in making prints. Blueprints only are used in the shop, while the tracing remains in the file.

BLUEPRINTING

The blueprint method of duplication is one of the most common methods used in industry. Some high schools and many drafting rooms have the equipment necessary for blueprinting. This equipment includes blueprint paper, sun printing frame or blueprinting machine, washing tray, and drying apparatus.

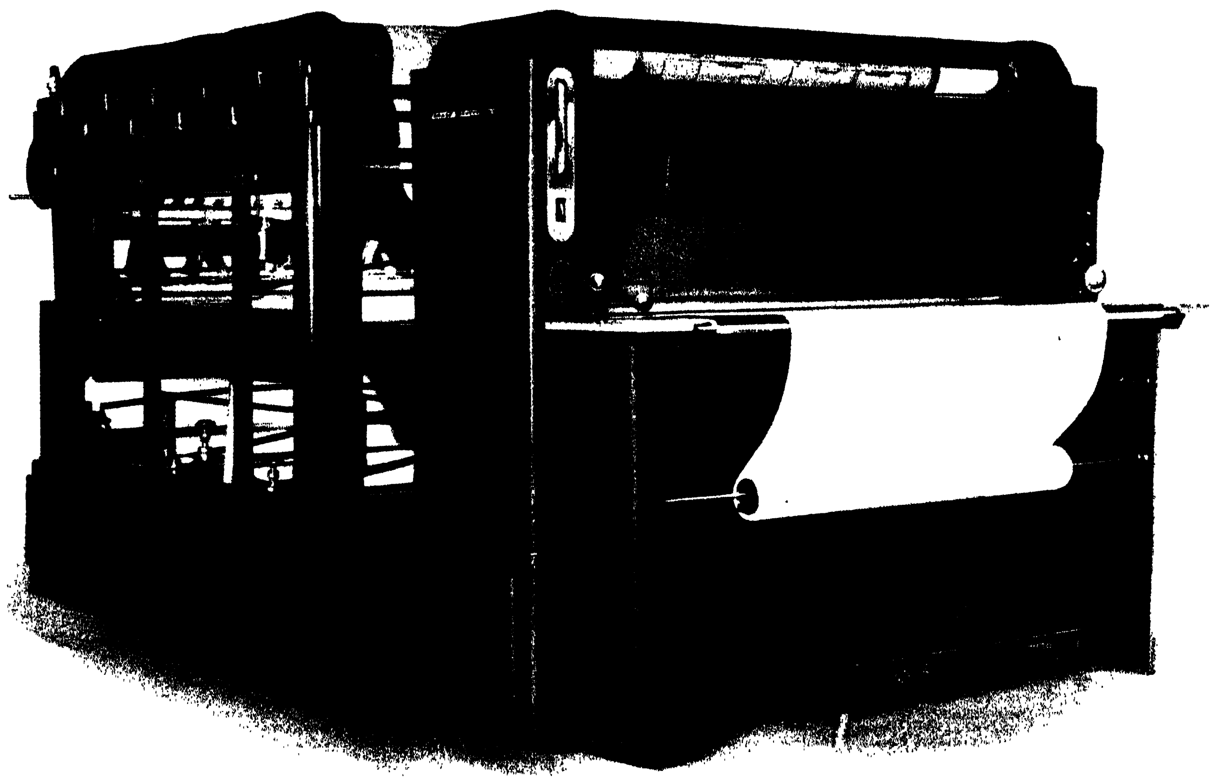
The coated side of blueprint paper is very sensitive to strong light. Blueprint paper is at first yellowish green and is soluble in water. When exposed to light, it turns blue and is not soluble in water. When a tracing is placed on a piece of sensitized blueprint paper and exposed to strong light, the paper turns blue in those areas not covered by ink figures, lines, and the like. As the light does not penetrate these, there is no action on the paper beneath them. When the blueprint is placed in water, the coating corresponding to the lines of the tracing is washed off, leaving white lines and figures on a blue background.

The exposure time for making a blueprint depends upon the brilliancy of the light and the kind of tracing to be printed. It takes from two to five minutes to make



Courtesy C. F. Pease Company, Chicago

Fig. 294—A SUN FRAME



Courtesy C. F. Pease Company, Chicago

Fig. 295—A MODERN BLUEPRINTING MACHINE

a blueprint, depending upon the light. There are modern machines that develop, wash, and dry blueprints in just a few minutes. These are found in blueprinting companies and companies doing large amounts of blueprinting for themselves. Blueprints can be made by sunlight or electrical machines, but regardless of the method the principle is the same.

MAKING BLUEPRINT PAPER

If blueprint paper is not purchased, it can be made from ordinary white paper that is not too absorbent. Two chemicals are used to make blueprint paper, ammonium citrate of iron and potassium ferrocyanide. Two solutions are made, one using 1 ounce of ammonium citrate of iron and 6 ounces of water and the other using 1 ounce of potassium ferrocyanide and 6 ounces of water. These solutions may be kept indefinitely if the bottles are corked well. The paper is prepared by mixing equal parts of the solutions and applying the liquid with a soft brush. Dry the paper in a dark place and then store it in an airproof and moistureproof can, as shown in Figure 293. Blueprint paper will not last indefinitely.

USING THE SUN FRAME

The sun printing frame shown in Figure 294 is the type used in many high schools. It consists of three parts—the frame, the glass, and a removable felt-padded back. It resembles an old-style picture frame and can easily be constructed if you wish to make one.

Courtesy C. F. Pease Company, Chicago

Fig. 296—A BLUEPRINT DRYING MACHINE

The procedure for making a blueprint in the frame is as follows:

1. Place the frame on a table or flat surface with the glass or front part down.
2. Remove the back of the frame.
3. Place the tracing in the frame with the inked side toward the glass.
4. Place the blueprint paper on the tracing with the coated side next to it.
5. Place the back on the frame, making certain that the paper and tracing are smooth and in line.
6. Then place the frame in the sunlight or under artificial light. The time for exposure will depend on the intensity of the light and the quality of the paper.
7. Remove the blueprint and place it in a washing tray for several minutes.
8. Hang the print up to dry.

If the white lines do not come out clearly, the print may be immersed in a potassium bichromate solution for about a minute and washed again in clear water. This procedure will make the blue darker, and it is also effective in bringing back an overexposed or burned print.

BLUEPRINTING MACHINES

Since there is a great demand for blueprints in industry, many types of machines have been developed to supply the need. One of the outstanding pieces of blueprinting equipment is shown in Figure 295. This machine will print, wash, and deliver a sheet 54 inches wide at the rate of 8 inches to 24 lineal feet per minute. In addition to washing and drying the print, the machine delivers it in a finished condition, perfectly flat. Illumination for exposure is provided by means of arc lamps and reflections.

Where speed is not essential, less expensive models may be procured. Many machines do just the blueprinting. The washing must be done by hand, and the drying is done in a drying machine. (See Figure 296.)

OTHER PRINTING PROCESSES

Ozalid prints are developed directly from pencil drawings. They have dark reddish brown lines on a white background. These prints are developed by exposing them to strong ammonia fumes contained in an airtight developing machine.

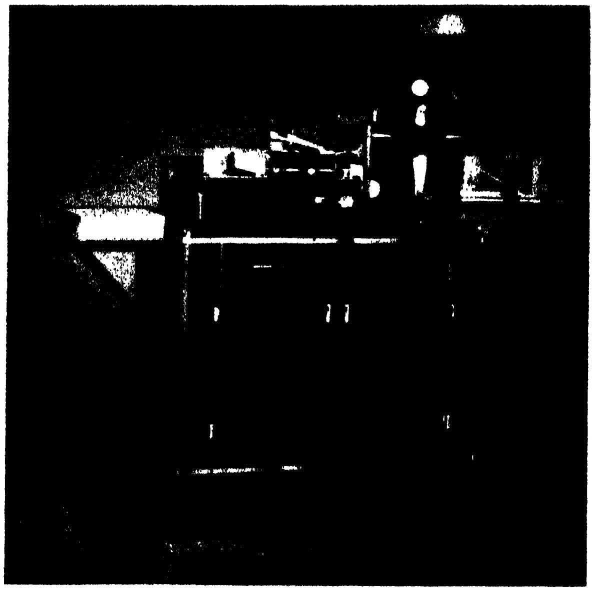
Vandyke prints are made on a thin, sensitized paper that turns dark brown on exposure. A reversed negative of a tracing may be made by exposing the underside of the drawing to the sensitized side of the paper. A positive print may be made on blueprint paper. This would be blue lines on a white background.

BW paper gives black lines on a white background. The print is made directly from the original tracing. The procedure is used extensively in industry where positive prints are desired.

DUPLICATING MACHINES

If a number of drawings (fifty or more) are needed, lithoprinting is sometimes used. This is a form of photolithography and is reasonable in cost.

Many schools possess some type of duplicating machine that will aid them in making bulletins, programs, charts, maps, or small notices. You will find that your school probably has one or more means of duplicating. They include mimeograph, ditto, hectograph, Neostyle, and many other devices. Figure 297 shows a modern mimeograph machine, which is extensively used for duplicating.



Courtesy A. B. Dick Company, Chicago

Fig. 297—A MODERN MIMEOGRAPH MACHINE

PHOTOGRAPHIC PROCEDURE

Various types of machines have been developed for photographically reproducing drawings, maps, charts, or other forms of written, drawn, or printed material. The copies may be enlarged, reduced, or in actual size.

A photostat machine has been developed for photographic reproduction purposes. It consists of a special camera, developing pan, fixing tray, drier, and other equipment necessary to reproduce prints photographically. This machine comes in various types and sizes. It is used extensively in industry. A print made by this machine has white lines on a dark background if the print is made from a black on white original drawing. If this print is photostated, the result is a black-line print on a white background.

SUMMARY

As a single drawing is limited in its use, several different processes have been developed for duplicating drawings. The simplest and most widely used method is blueprinting. A tracing is necessary before a blueprint can be made. Tracings may be made on tracing paper or cloth and may be executed in either pencil or ink. Ink tracings on cloth are made when permanent tracings are desired.

Blueprints may be made in sun frames or in blueprinting machines. Modern blueprint machines make the blueprint and wash and dry it in one operation. Other prints are the ozalid and vandyke prints and those made on BW paper.

Mimeograph, hectograph, and ditto devices are used to duplicate small-size drawings and specifications. Photographic processes are used to make photostats, which reproduce drawings and the like.

PENCIL TRACING ON VELLUM

With the advice of your instructor choose one of the drawings you have made—for example, the drawing based on Figure 211—and make a pencil tracing of this drawing on vellum or other tracing paper. Use a soft pencil, such as an HB.

INK TRACING ON VELLUM

It is wise to practice a little with the ruling pen on scratch paper before attempting to make an ink tracing. Choose a problem in machine drawing and trace it on vellum or other tracing paper. The drawing based on Figure 215 would be a suitable drawing to trace. Work slowly and carefully while inking.

PENCIL DRAWING ON TRACING CLOTH

Make a pencil drawing on tracing cloth of an object assigned by your instructor. In pencil tracing, extreme care must be exercised to keep the tracing clean.

INK TRACING ON CLOTH

The ink tracing you made on vellum has given you a little experience with the ruling pen and compass, experience that will help you to do the ink work on the more expensive tracing cloth. With the aid of your instructor select one of your drawings made earlier in the year and make an ink tracing of it on tracing cloth.

QUESTIONS

1. For what different purposes are tracing paper and tracing cloth used?
2. Why is blueprint paper almost universally used by architects and engineers today?
3. Why is the sun frame not generally used to make blueprints?
4. What is meant by a blue-line print?
5. What is a vandyke?
6. Describe some process other than blueprinting used to duplicate drawings.
7. Why should one never leave blueprints exposed to strong sunlight?
8. How should blueprint paper be stored?
9. Why is it unwise to use tracings in the shop where manufacture takes place?

TOPICS FOR DISCUSSION

1. Before the days when blueprinting was common, other means of duplicating drawings were used. One of these methods was lithographing. Prepare for the class a complete description of this process.
2. Before drawings are released for blueprinting, they should be carefully checked for errors or omissions. Make a check list to guide a checker in making sure that the drawing is correct.

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