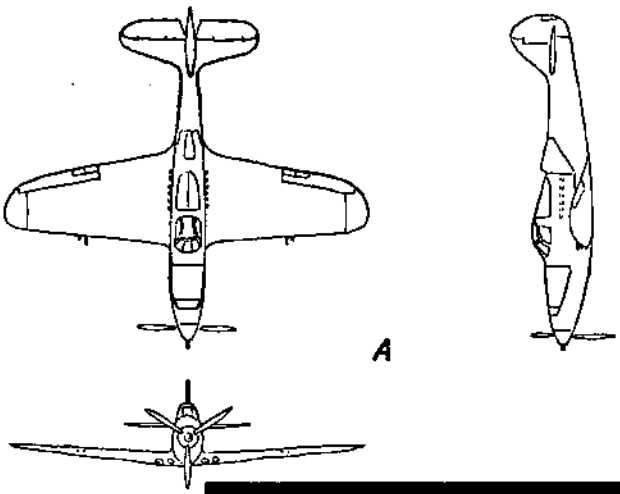
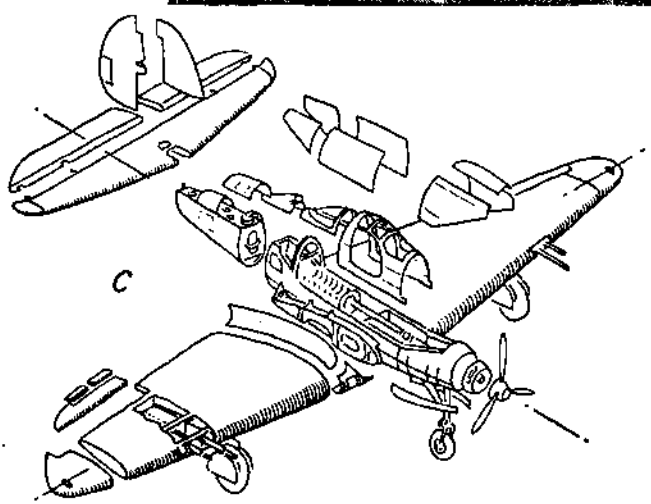


Army P-39 Airacobra

A - Three-view Outline Sketch

B - Half-tone picture reproduced from photograph

C - Exploded View



FRONTISPIECE

FREEHAND DRAFTING

A TEXT AND PROBLEM BOOK OF ENGINEERING SKETCHING

by

ANTHONY E. ZIPPRICH.

INSTRUCTOR OF MECHANICAL DRAWING,
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With an introduction by

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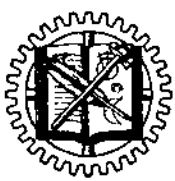
Consulting Engineer



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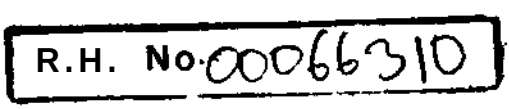

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PREFACE TO SECOND EDITION

Many special drafting courses that cover freehand drawing, isometric sketching and " production " illustration are now being offered in technical schools, and pre-induction training schools of every kind.

Because of the marked increase in the demand for freehand sketching instruction, particularly in aircraft and weapons of war, new material has been incorporated in this Second Edition, in the form of an additional chapter of text and twenty full-page plates. The steady annual demand for Freehand Drafting by schools and colleges, as well as by libraries, has encouraged the author to elaborate on the subject of Assembly Views and to make minor changes and additions in other parts.

Acknowledgment for aid in suggestions and source material is due the draftsmen and teachers consulted, and to the Bell Aircraft Corporation, Buffalo, New York, Popular Science, Hudson Park Branch of the New York Public Library, and Prof. Rouillion, Director of Mechanics Institute, New York.

To Carl L. Svensen, author of many textbooks on drawing, a special acknowledgment is hereby tendered for his careful editing, wise recommendations, and helpful advice.

A. E. Z.

May 15, 1943.

PREFACE

These explanatory plates and problems in Freehand Mechanical Drafting are the outcome of a number of years' experience in teaching and practice in the art.

Freehand Drafting is of especial value to those who do not find it convenient or who do not have the time to make drawings with instruments and as a consequence, this book is designed for mechanics, for salesmen, for executives, and for students in evening and trade schools. It includes about 170 problems and exercises, besides explanatory plates so arranged that a selection of problems from each chapter taught and studied in sequence, should result in the student gaining in a minimum of time a satisfactory ability to sketch industrial objects, and acquire the fundamentals of mechanical drawing. It is the sincere hope of the author that his work may prove of substantial, practical aid to the class of men interested.

The author wishes to express his appreciation of the advice and cooperation of Professor Carl L. Svensen and of Louis Rouillion, Director of Mechanics Institute of New York.

A. E. Z.

June 1st, 1924.

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INTRODUCTION

BY

CARL L. SVENSEN, B.S,, M.E., LL.D.

The many and frequent changes and improvements which are a part of present industrial practice, especially in the manufacture of aircraft and aircraft parts, and the many kinds of equipment for all purposes, make a working knowledge of freehand drafting or sketching, not only desirable but practically necessary.

The purpose of this book is to meet this universal need by presenting the graphic language (the language of industry) in a series of simple, progressive, and easily understood lessons. In this way a sufficient knowledge of the subject to be of real practical value in every-day work can be acquired without long or difficult study. The use of freehand methods provides a direct way of learning the meaning of drawings used in manufacture and construction of all kinds such as aircraft, motor vehicles, machinery, equipment, structures, and ships.

The ability to visualize material forms has become one of the important requirements of success for all who are engaged in engineering or industrial work. The best means for the development of this faculty is by a study of freehand drafting. The time required and the necessity of having extensive equipment impose many limitations upon the teaching and use of mechanical drawing. The tools of drafting are a convenience and under certain conditions are necessary for using the graphic language efficiently. However, it seems to be more and more necessary to point out the fact that the tools of drafting do not constitute the subject of drafting and that under many conditions they can be dispensed with to considerable advantage.

INTRODUCTION

Those who read and use the graphic language in the form of drawings greatly outnumber those who make them. The statement has often been made that drawing can be learned without the use of instruments. In this book a way has been provided for the systematic study of freehand drafting. Text illustrations and problems combine to furnish a means of developing the ability to read drawings and to make and use freehand sketches with assurance and skill.

Knowledge of a subject has no value unless that knowledge can be applied to a useful purpose. The illustrations and problems indicate many practical applications of freehand drafting or sketching. The only tools needed are a pencil and paper. With these the interesting fields of graphic description, invention, and drafting generally can be explored and used.

The value of freehand sketching cannot be overestimated for engineers, foremen, shop superintendents, squad leaders, mechanics, and all industrial workers in aircraft plants, equipment factories, and shipyards.

This book supplies the means for acquiring the ability to understand and to use practical drafting by presenting an adequate treatment of freehand methods.

CHAPTER I

MECHANICAL AND FREEHAND DRAFTING

The Language of Industry. — Information as to shapes, sizes, relative positions, materials, methods of forming and methods of assembling is necessary for the production of everything which is either built or manufactured. Some of this information can be given in words but most of it requires the use of a picture language which may or may not be conventionalized. This graphical, industrial, or engineering language includes the description of objects and constructions by single pictorial views and by multi-view drawings (made up of views composed of different kinds of lines arranged in a definite manner). All who plan or design and all who are engaged in the work of building or manufacturing must know something about making drawings and about reading drawings — they must understand the language of industry. When this language is '*' written " with instruments and tools it is called mechanical drafting, when it is " written " freehand, using only a pencil and paper, it is called freehand drafting or sketching.

Mechanical Drafting. — Drawings made with instruments and tools form the means of shape description and size specification for most engineering and industrial purposes. The theory upon which such drawings are based and the modifications which have been found desirable in practice constitute the subject of drafting — either mechanical or freehand.

Mechanical drawings are made with the aid of compasses, T-square, triangles, and scale. Where many drawings are made,

" drafting machines " are used for greater convenience and speed. Mechanical drawings include, not only drawings of machinery but constructive drawings for buildings, patterns, electrical work, sheet metal work, automobiles, ships, airplanes, and apparatus, or equipment of all kinds.

When the views are not too large the lines on the drawing may be the same length as those on the parts represented. When the distances are too great for this the views are drawn proportionally but of a smaller size using scales graduated for that purpose.

Freehand Drafting. — Freehand drafting or sketching is based upon the same theory and conventional practice as mechanical drafting. Sketches, however, are not restricted by the use of scales and tools, and permit of greater freedom in treatment. They provide a quick and convenient means of description or explanation for engineering and industrial purposes. Experience has shown that the best way to develop and fix ideas in the planning of industrial work or engineering design is by making sketches. This is equally desirable for a simple tool or an electric locomotive.

From Sketch to Blueprint. — As just stated a sketch is often the first step in the development of a design. When the idea has been tried out by making a number of sketches, the most promising of these are used as the basis of a design drawing made to scale. This drawing is used to develop the design, fix distances and sizes. From it, the detail or working drawings are made with dimensions, notes, and necessary information. A tracing of the pencil drawing is generally made on prepared tracing cloth or paper using black ink. From this single tracing as many blueprint copies as desired can be made. Often reduced copies are made by the Photostat or other processes.

Uses of Freehand Drafting. — The use of sketches for preliminary design has just been described.

Sketches have many uses in the aircraft industry (both multiview sketches and pictorial sketches) for specifying changes, for extra descriptions, and for explaining how parts are assembled.

An important use is for making sketches from an existing machine when the original drawings are not available. .These may be necessary to duplicate the machine. For this purpose regular mechanical drawings are often made from the sketches.

Broken parts of machinery are often sketched for repair or replacement purposes.

Experimental work for inventions or improvements in machines is often carried on by making working models or machines. Sketches provide the best method of recording progress until a satisfactory operation is secured. Mechanical drawings for manufacturing purposes can then be made from the sketches.

A sketch of an accident or breakdown of machinery, supplemented by notes, is often the most valuable form of report.

These few examples show that sketching is not only desirable but actually necessary for all who are engaged in manufacturing or industrial work. Skill in freehand drafting is the result of systematic practice.

Sketching Material. — A supply of paper, a pencil, and an eraser provide all the equipment necessary for making sketches.

Plain paper in pad form 8 by 10 inches is a convenient size much used in shops. Letter size 8½by 11 inches is generally available. Smaller pads that will fit the pocket serve very well for many purposes where small parts are to be represented or where small sketches give the desired information.

Cross-section or squared paper is sometimes useful. Lightly ruled vertical and horizontal lines $\frac{1}{16}$ inch or $\frac{1}{8}$ inch apart form squares which assist in securing good proportion and in sketching straight lines. This paper may be used for some sketches and practice work. It is not well to depend too much on the help given by the squares as most sketches are made on plain paper.

" Isometric " ruled paper is often used for pictorial sketching and is a convenient aid in keeping the directions of the lines and in sketching isometric circles and arcs.

Pencils are made in various grades of hardness. An F or HB

drawing pencil or a No. 1 writing pencil will give satisfactory results for most papers. Too hard a pencil is difficult to work with and too soft a pencil gives lines and figures that smudge easily and become indistinct.

CHAPTER II

FREEHAND LETTERING

Figures and notes which tell sizes and give necessary information, form a part of most sketches. Every sketch, no matter how simple, should have a title to tell what it is, who made it, and when it was made. Writing can sometimes be used. Most writing, however, is not easily read and it is frequently impossible to decipher hastily written notes after a lapse of time. In the interest of efficiency, lettering should be used on all sketches. Good lettering does help the appearance of a drawing or sketch but its real advantage is legibility which saves time and prevents mistakes.

Not everyone can become expert in lettering but all can learn the correct forms of the letters and the required proficiency is then simply a matter of practice. Good plain lettering is becoming so general that it is expected as a matter of course from all who make use of the graphic language.

Styles of Letters. — There are four general styles of letters, — Roman, Gothic, Script, and Block. A considerable variation may exist in each of these styles. Egyptian Hieroglyphics present a striking contrast when compared with the draftsman's single stroke letter of today, Plate 1, at B. Ancient Egypt is considered as the source of our alphabet which underwent changes by the Phoenicians and Greeks and finally reached the Romans who gave the letters the forms we now recognize.

Single Stroke Letters. — One style of letters will suffice for sketches. They may be either vertical or inclined and can be made with lines the width of a single pencil stroke. Such letters are called single stroke letters although they are really formed by a number of single strokes.

PLATE 1. Alphabets and Spacing.

Alphabets of vertical letters, both CAPITAL and lower case are shown on Plate 1. The capital letters can be arranged according to shape in four groups as follows: Right angle letters made up of straight lines at right angles to each other; Acute angle letters made up of straight lines at an acute angle with each other; Round letters made up of curved lines; and a remainder group made up of straight lines or straight lines and curves. Practice exercises are shown in connection with the groups of letters on Plate 2.

The proportions of the various letters should be observed. The letter I is formed by a single stroke, the letter W is wider than it is high, the letters A, M, V, X, and Y have a width equal to their height, and the remaining letters are less in width than height by varying amounts.

The vertical lower case or small letters can be arranged in groups as indicated on Plate 2. Note the proportions in comparison with the capitals on Plate 1. The small " a " is about two thirds as high as the capital or large A. The letters a, b, d, g, p, and q have the same " body " form. Other characteristics may be observed by a study of the letters as illustrated. Sometimes the body of the small letters is made one half the cap height, but if the capitals are not very large the two thirds proportion is better especially on sketches. Small letters can be made more easily and in less time than caps. Words composed of small letters have characteristic shapes which are familiar and therefore are quickly read.

Slant or inclined capitals and small letters are shown on Plate 1. These may be studied in the same way as the vertical letters. A few guide lines at an angle as shown will be of help in securing a Mniform slope for the letters.

Numerals and fractions require particular attention and should always be correctly formed. The fraction numbers are made a little smaller than whole numbers. The division line should always be horizontal.

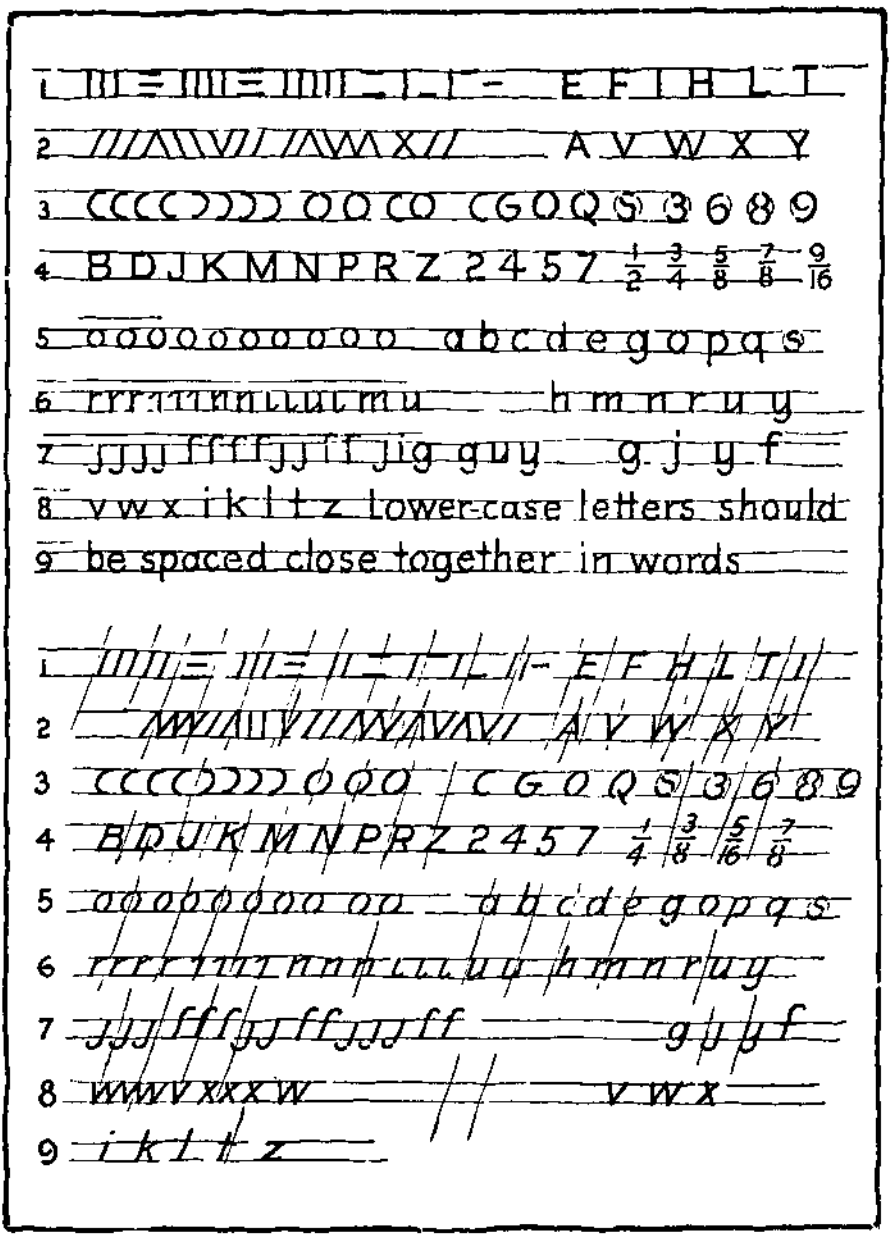


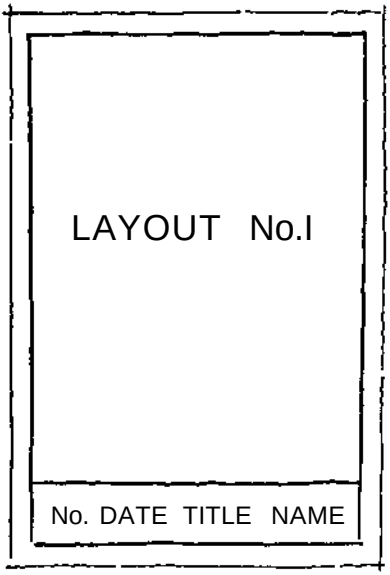
PLATE 2. Lettering Exercises.

Spacing. — After the shapes and proportions of the letters have been learned, it is necessary to combine them into words. So far as possible the letters should be spaced so that each word appears as a unit. Two illustrations of a distant sign board are shown on Plate 1. When viewed through the large end of a field glass there appear to be two horizontal gray bands; the lower one an even tint, and the upper one somewhat broken or uneven. Upon reversing the glass the observer discovers that the gray bands are words, and that the letters are poorly spaced in the upper word, but well spaced in the lower word. This illustrates the difference between poor spacing and good spacing. The letters *cannot* be placed equal distances apart but must be located so that the *areas* between them will appear about equal. This is not a simple matter. The difference in the shapes of letters and the different combinations of letters make it necessary to consider the placing of the letters as they occur in each word.

The only rule which can be given is this general one: *make the areas between letters appear as nearly equal as possible.* The application of this rule is illustrated at the bottom of Plate 1. In the first example of each word the letters are placed equal *distances* apart which results in unequal *areas* between the letters as shown by the shaded areas below the words. Note that these areas are more nearly equal in the examples of good spacing. Sometimes it is necessary to modify one or more of the letters slightly to obtain the desired result. Letters with vertical sides should be further apart than letters with slanting or open sides.

The plain lettering described in this chapter is all that is necessary for freehand sketches and general industrial purposes. Lettering of itself is a field for extensive study beyond the scope of this book. For those who wish to pursue the subject further a thorough treatment of freehand lettering will be found in Reinhardt's " Lettering for Draftsmen," and a comprehensive treatment of the different alphabets and the whole field of lettering in Svensen's " The Art of Lettering."

Paper for sketches may be any convenient size, but for most off he exercises in this book use either 8"x/0" 01 8½ x 11.



The border line shown improves the appearance and gives excellent practice in sketching.

It may be pjaced about "from edges.

Make-up of title will vary but it should give the job or sheet number, tell what the sketch is, who made if and when it was made

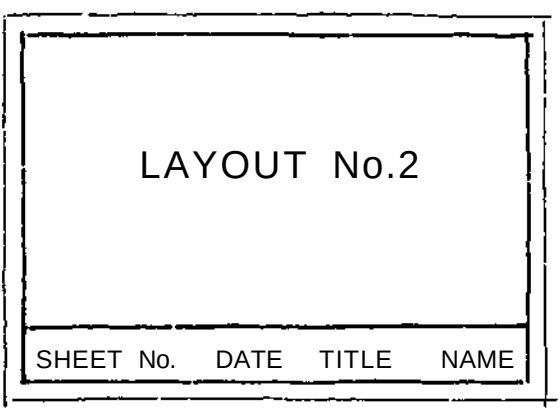


PLATE 3. Sheet Layouts.

Choice of Letters. — The alphabets of capitals and lower-case letters, both vertical and inclined, shown in this chapter are single-stroke engineering letters. The choice of letters, vertical or inclined, all capitals or capitals and lower-case is governed by company practice.

The American Standards Association recommended practice includes the following statements in regard to the sizes of lettering.

" It is not desirable to grade the size of lettering with the size of the drawing except when a reduced photographic reproduction of the drawing is to be made. In other words the size and weight of the lettering should be such as will produce legible prints from tracings either in pencil or in ink.

" Lettering should not be underlined except for particular emphasis"

Lettering Exercises. — As stated before good lettering is expected on industrial sketches. Either vertical or slant letters can be used and the student is advised to become proficient in one style before attempting the other. Use a well pointed pencil of about "H" grade. Practice carefully and without haste. It is necessary that some kind of guide lines be used for lettering even though they are drawn freehand.

For some of these exercises use squared paper if available.

SHEET LAYOUT. — The two layouts for sketching sheets indicated on Plate 3 are given for reference purposes. The use of a standard size sheet for all sketches will facilitate their preservation and handling.

EXERCISE 1. — Layout No. 1 of Plate 3. On upper half of sheet practice lines 1 and 2 of Plate 2. Make guide lines about ¼ inch apart at first and then repeat exercises with lines $\frac{1}{8}$ inch apart.

On lower half of sheet practice lines 3 and 4 in a similar manner. Do not hurry but observe each letter as made and compare it with copy. Patience is very necessary when beginning the study of lettering.

EXERCISE 2. — Layout No. 1 of Plate 3. Practice lines 5 to 9 of Plate 2. Make guide lines about ¼ inch apart for *body* of letters for first time, then reduce to $\frac{1}{8}$ inch and then estimate at slightly more than $\frac{1}{16}$ inch, or as directed by your instructor.

EXERCISE 3. — Composition. Letter first paragraph of this chapter using capital letters $^1/_8$ inch high.

EXERCISE 4. — Composition. Letter first paragraph of this chapter using lower case letters.

CHAPTER III

FREEHAND SKETCHING PRACTICE

MEMORANDA

CHAPTER III

FREEHAND SKETCHING PRACTICE

A conscientious study of the methods of sketching straight lines and curves and practice in using these methods forms the basis of useful sketching. Without such practice the resulting sketch is often misleading and seldom satisfactory. The only alternative is to use the draftsman's tools. This requires a longer time and does not allow the freedom of thought that goes with freehand sketching.

The ability to do fair sketching which will answer for most useful purposes can be acquired by anyone who will spend a little time in careful practice of the fundamentals explained in this chapter.

Horizontal Lines——The proper position for the hand when drawing horizontal lines is shown at the top of Plate 4. The arm should be kept close to the side and the pencil about at right angles to the line. Regardless of its length, a line must be sketched with an arm movement, that is the arm from elbow to fingers must travel along the line. When the hand alone is moved the resulting line will be irregular and slightly curved. This is a common fault with beginners.

Vertical Lines. — The position for the hand when sketching vertical lines is shown, on Plate 4. Use an arm movement with the arm well out from the body and keep the pencil at right angles to the line. Vertical lines may be sketched either up or down as indicated. When drawing from the top downward more of the hand rests on the pad or table. The method which seems the more natural will generally give the better result.

Slant Lines. — The general rule of keeping the pencil at right angles applies to slant lines as indicated on Plate 4. When drawing from lower left to upper right, hold the pencil as shown with

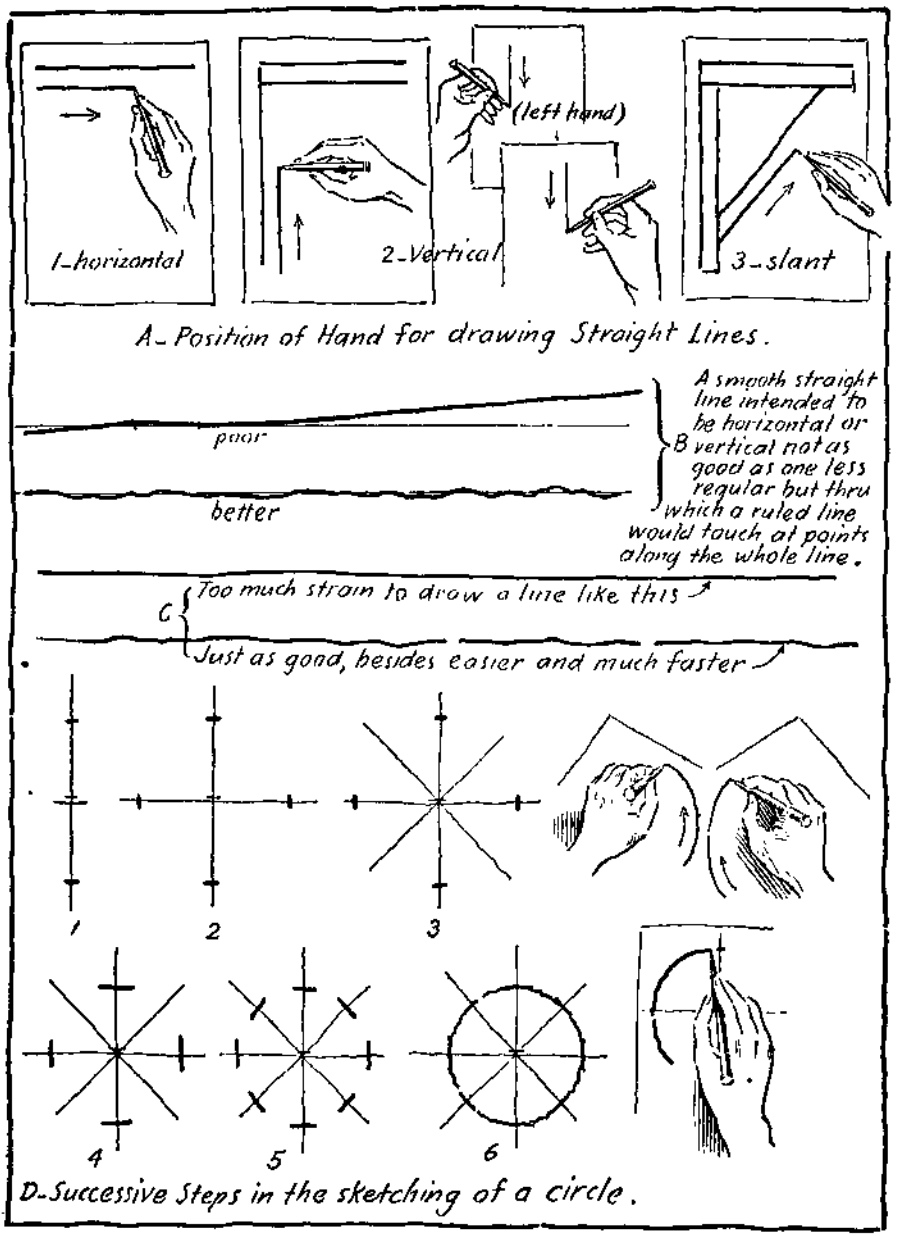


PLATE 4. Elements of Freehand Sketching.

the arm partly away from the body. In the reverse direction, lower right to upper left, it is best to turn the paper so that the line is horizontal and draw it as such.

The directions given apply also to LEFT HAND WORKERS with the important exception that horizontal lines must naturally be drawn from *right* to left.

Quality of Lines. — Beginners generally attempt to get horizontal lines perfectly straight and smooth and in doing this depart from the horizontal direction. It is not necessary that the line be perfectly straight but its direction is important. Draw reasonably fast, keeping the direction, even though the resulting line is somewhat wavy. The upper or lower edge of the paper will serve as a guide until practice has improved one's skill.

Two freehand lines are shown at C, Plate 4. The upper one while very smooth required too much attention in drawing. The lower line will serve about as well, is easier to draw and can be done much faster. Holding the pencil above the paper and drawing several imaginary lines before making them on the paper is good practice. These suggestions, of course, also apply to vertical and slant lines.

The use to which a sketch is to be put will determine the character of its workmanship. Moderate speed and reasonable accuracy in form and proportion are essential.

The Circle, Semi-circle, and Quarter Circle. — Ordinarily circles are sketched too quickly resulting in shapes that often bear faint resemblance to circles. First, sketch vertical and horizontal center lines of a greater length than the diameter of the circle. Make marks on these lines equal distances on each side of the vertical line and above and below the horizontal line as shown on Plate 4. It is comparatively easy to estimate the equal horizontal distances but an optical illusion must be overcome when estimating the vertical distances. When the two distances are equal the upper one will appear to be greater. This must be kept in mind when estimating equal divisions.

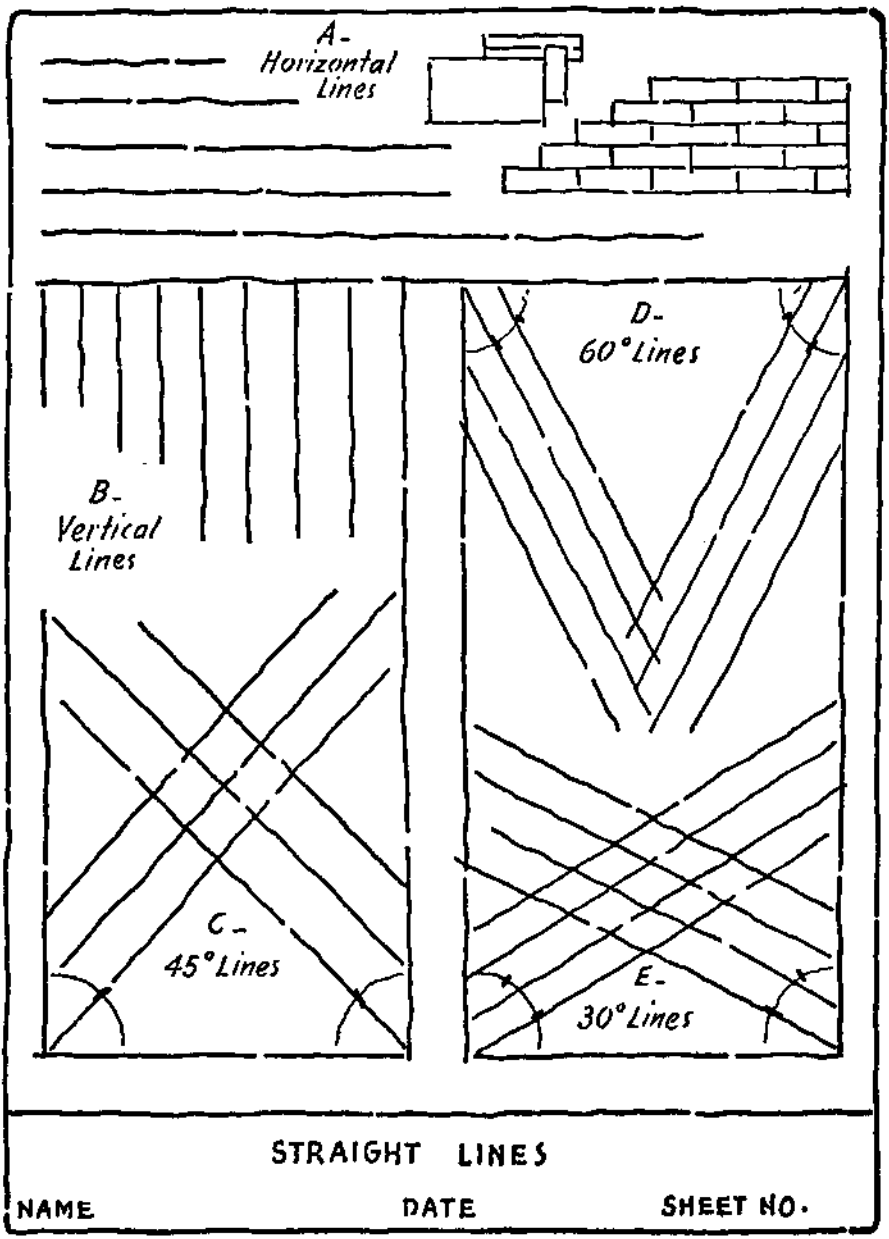


PLATE 5. Sketching Practice. Exercise 1.

After the vertical and horizontal distances are fixed, draw two-additional lines 45 degrees with the first two lines and mark off the same equal distances as shown. This gives eight points through which a circle may be drawn freehand. After a little practice four points will be found enough to guide one in sketching a fairly good circle. Semi-circles and quarter or part circles are sketched with the same care.

Tangents. — When curves meet straight lines or different curves, they must be joined smoothly. Tangent arcs are shown on Plates 6 and 7. The exact point of tangency or joint should not show plainly. This result can be obtained by sketching the arc or line past the point of tangency rather than trying to stop at the exact point.

Practice Exercises. — The ground covered in this chapter while apparently simple is very important. Practice of the exercises which follow will develop the skill which is necessary for the successful study and application of all that follows.

Plain paper with a surface that will " take " the pencil line well should be used for sketching. A size 8 by 10 inches or 8½ by 11 inches is desirable. Layout No. 1 of Plate 3.

EXERCISE 1. — Sketch the straight lines as shown on Plate 5 beginning with the horizontal lines at A. It is as important to learn to estimate equal distances between the lines as it is to get the lines in the right direTction. Note how the direction is estimated for the lines at an angle.

EXERCISE 2. — In the upper half of the sheet sketch quarter circles of different sizes. Estimate radii very carefully and use construction lines as shown at A on Plate 6. In the lower half of the sheet sketch the half circles shown at B and C and the figures as at D and E.

EXERCISE 3. —Lay out the sheet as before. In the upper half sketch several complete circles as shown at A on Plate 7. Use center lines and estimate radii very carefully. In the lower left hand part of the sheet sketch the exercises shown at B and C on Plate 7, but with the arcs forming continuous lines. In the lower right hand part of the sheet sketch the exercise shown at D on Plate 7. Construct carefully and make the resulting line continuous. Complete the figure.

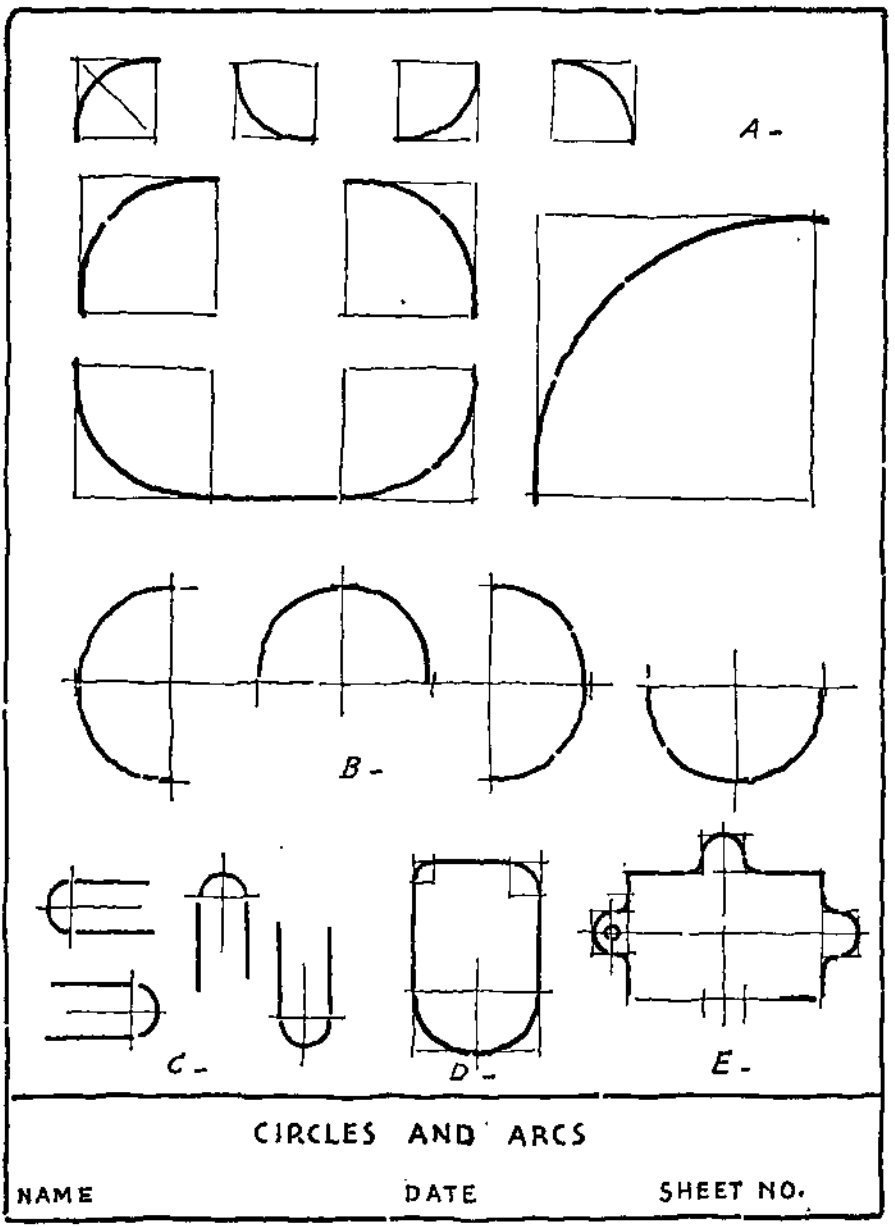


PLATE 6. Sketching Practice. Exercise 2.

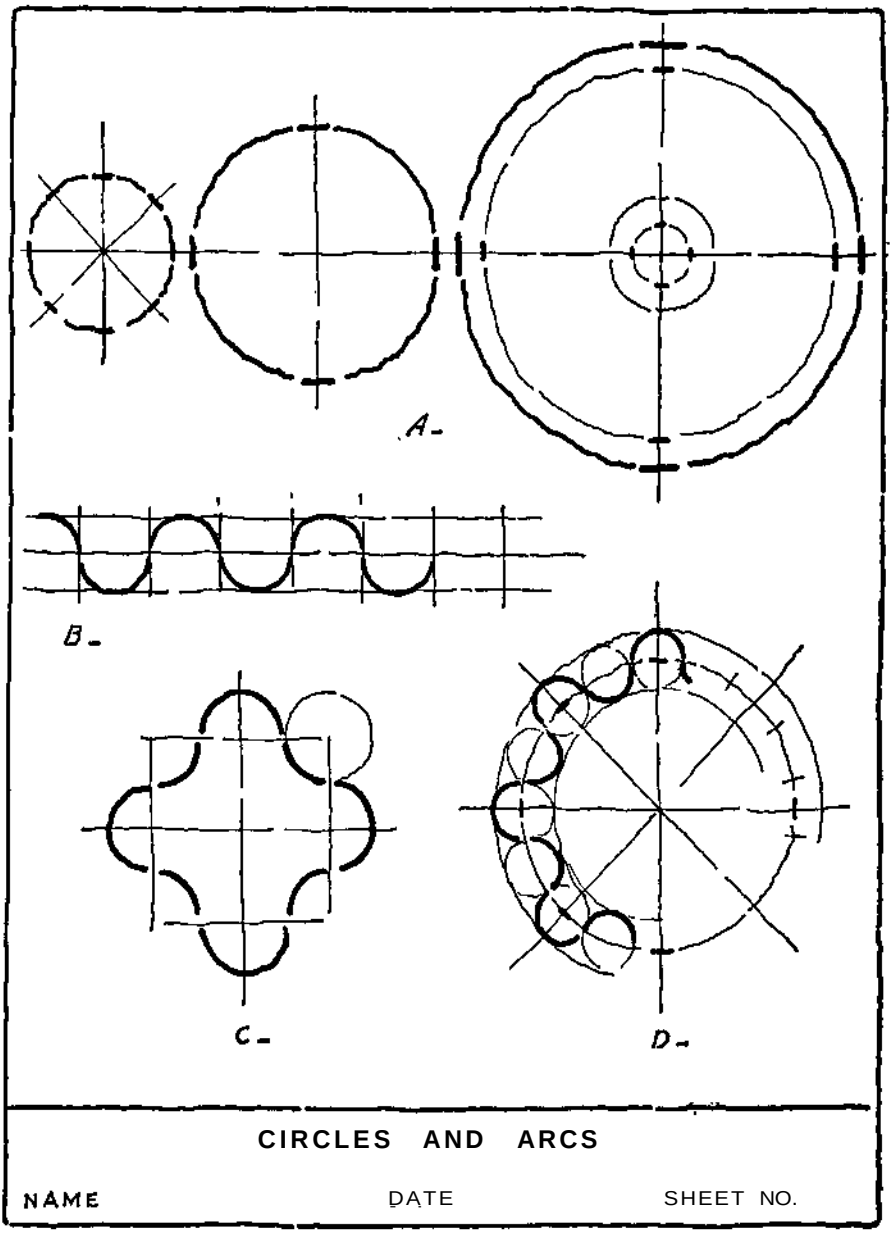


PLATE 7. Sketching Practice. Exercise 3.

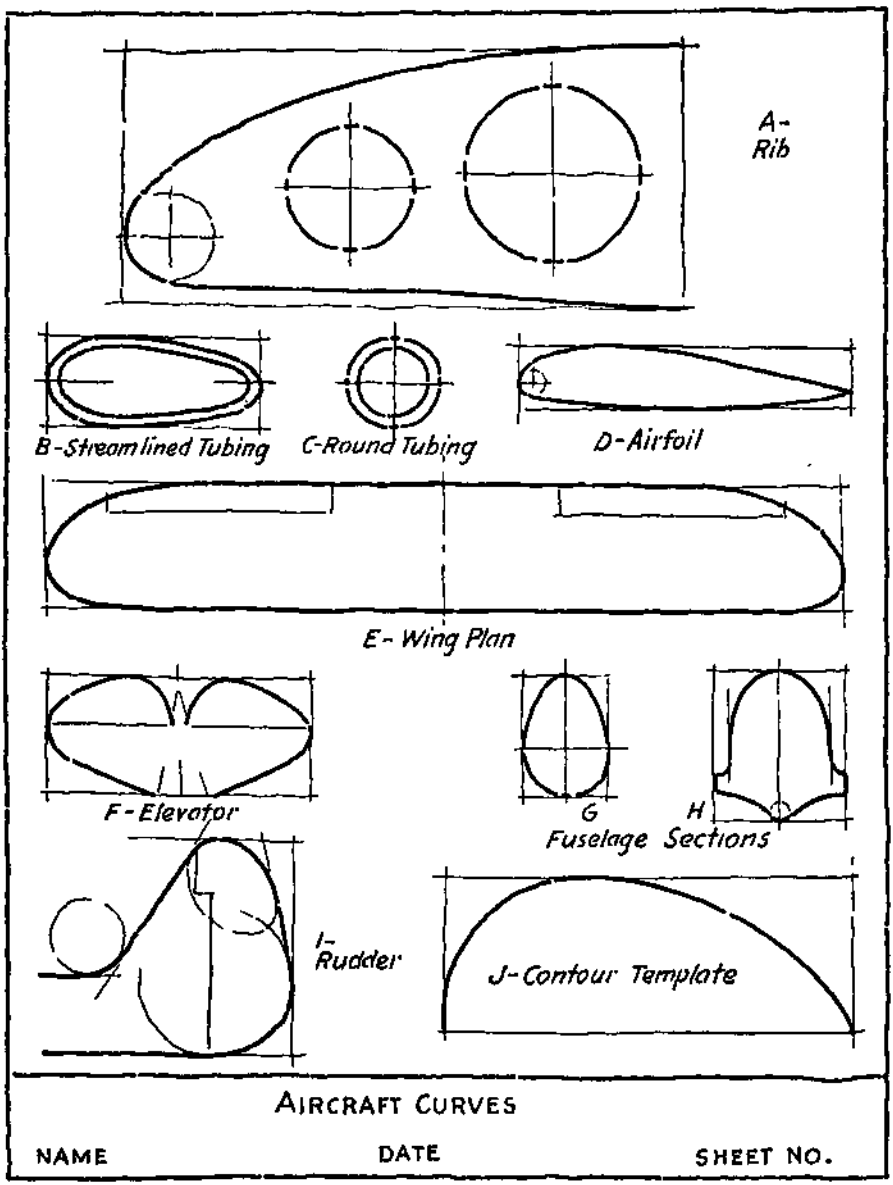


PLATE 7A. Sketching Practice. Exercise 4.

EXERCISE 4. —Block in carefully with straight lines and sketch the curves shown.

CHAPTER IV

GEOMETRICAL DEFINITIONS

MEMORANDA

CHAPTER IV

GEOMETRICAL DEFINITIONS

Geometry is the basis of mechanical drawing and other graphical methods of shape description. An understanding of certain geometrical definitions is important in the study of freehand sketching. A geometrical figure is composed of points, lines, and planes. Plane Geometry deals with figures which lie in a plane. Solid Geometry deals with figures which have length, breadth, and thickness. There are several other kinds of geometry which need not be considered at this time.

Uses of Geometry.— Most mechanical objects have geometrical shapes, or are composed of geometrical figures. For this reason a knowledge of the characteristics of the principal geometrical figures will be of great value in making freehand sketches. The architect, builder, carpenter, engineer, machinist, surveyor, and all who have to do with industrial work, make use of the principles of geometry in their daily practice. The illustrations and definitions given in this chapter are selected to aid in the sketching work which follows.

Point, Line, and Plane. — A point denotes position in space. It has no length, breadth, or thickness. A line is a figure which has length but no breadth or thickness. It may be formed or generated by a moving point. A plane surface or plane has length and breadth but no thickness. A straight line is the shortest distance between two points. Two straight lines are parallel when they lie in the same plane and always have the same distance between them.

A horizontal line is one which is parallel to the horizon or line where the sky and earth seem to meet, Plate 8 at B and C.

A vertical line is one which meets a horizontal line, leaning neither to the right or left. It is sometimes called an upright line or plumb line, Plate 8 at D.

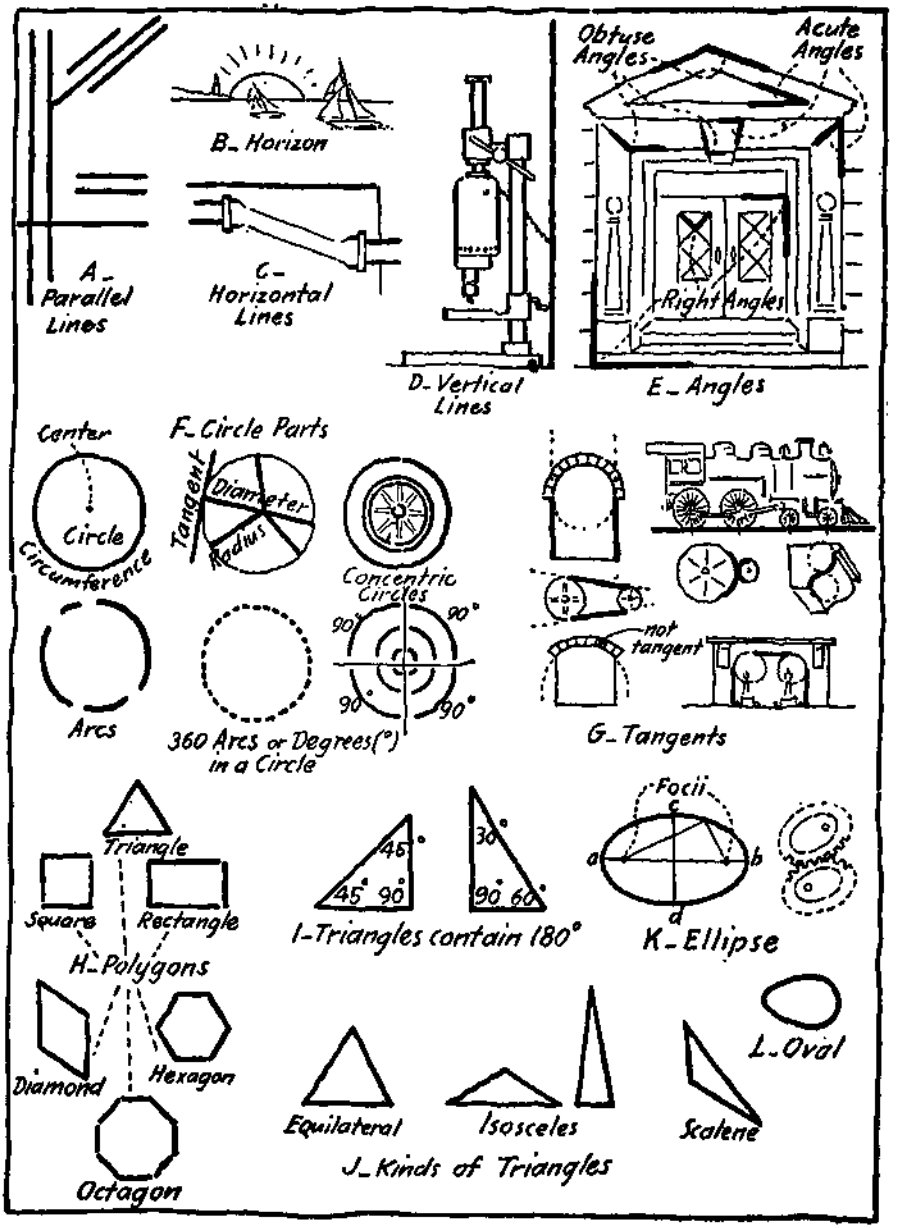


PLATE 8. Plane Geometry.

A perpendicular line is one which meets any straight line in the same manner. Note that vertical and perpendicular do not have the same meaning.

When two lines meet, the opening between them forms an angle, Plate 8 at E.

Circles, Arcs, Etc——A circle is a part of a plane surface, bounded by a curve all points of which are equally distant from the center point. The curve is called the circumference of the circle. Two or more circles of different sizes but having the same center are said to be concentric. The diameter of a circle is a straight line passing through the center, both ends terminating in the circumference. The radius of a circle is a line from the center to the circumference.

A tangent line is a straight line which touches a circle without penetrating it, even though continued. Tangent lines occur frequently in connection with half and quarter circles, Plate 8 at G. Circles tangent to each other also form a part of many views.

An arc is a part of a circumference. In mathematics the circumference is divided into 360 equal arcs or degrees (°). A vertical line and a horizontal line drawn through the center of a circle will divide the circumference into four equal arcs, each of which will contain 90°. If the circumference is divided into six equal parts, each one will contain $360° \div 6 = 60°$. Angles are measured by the arcs opposite them. Thus the angle formed by radii from the center to the ends of one quarter of a circumference is an angle of 90°, Plate 8. Such an angle is called a right angle. Angles of less than 90° are acute angles and of more than 90° are obtuse angles, Plate 8 at E.

Two other curved figures of interest are the ellipse and the oval. An ellipse, Plate 8 at K, is defined as a curve formed by a point moving so that the sum of its distances from two fixed points is a constant. These two points are called foci. One point is a focus. The longest line through the center (a-b) is called the major axis

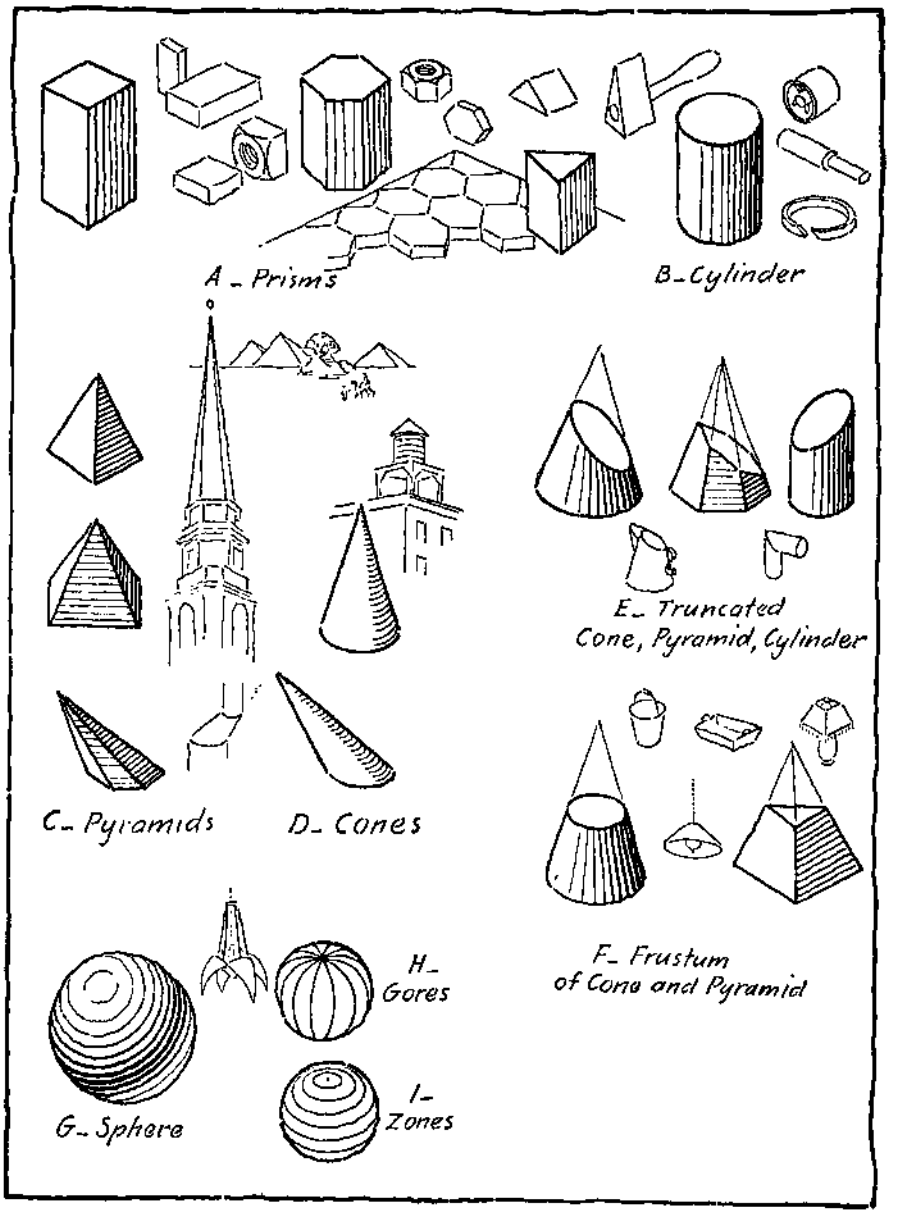


PLATE 9. Solid Geometry.

and the shortest line through the center (c-d) is called the minor axis. A circle when viewed at an angle appears as an ellipse.

An oval is an egg-shaped figure, Plate 8 at L.

Triangles, Quadrilaterals, and Polygons— A polygon is a part of a plane surface enclosed by three or more straight lines. A polygon with three sides is a triangle. Equilateral triangles have three equal sides. Isosceles triangles have two sides or legs equal. Scalene triangles have no two sides equal.

The three angles of a triangle always total 180°. Thus an equilateral triangle has three angles, each of 60°. A right-angled isosceles triangle has one 90° and two 45° angles. The right-angled scalene triangle used by engineers, architects and draftsmen, has one 90° angle, one 60° and one 30° angle.

A quadrilateral is a plane figure bounded by four straight lines. A parallelogram is a quadrilateral having its opposite sides parallel. A rectangle is a parallelogram having four right angles. A square is a rectangle with four equal sides. A rhombus or diamond-shaped figure has four equal sides and no right angles.

A polygon with five sides is a pentagon.

A polygon with six sides is a hexagon.

A polygon with seven sides is a heptagon.

A polygon with eight sides is an octagon.

Prisms, Cylinders, and Other Solids. — A solid bounded or enclosed by polygons is called a polyhedron. When two of the polygons are equal and parallel the solid is a prism. The shape of the equal bases determines the name of the prism, as triangular prism, square prism, hexagonal prism, etc. A prism with six faces, all of which are square, is a cube.

A number of other type solids are illustrated and named on Plate 9. A cylinder having a circle for base is called a circular cylinder. This form occurs most frequently in mechanical constructions. A right circular cone has a circle for its base and its vertex or point on a line perpendicular to the center of the circle.

Pyramids may have different shaped bases and are named accordingly, as triangular, square, rectangular, hexagonal, etc.

A truncated cone, pyramid, cylinder, or prism is one which has had the top part cut off by a plane at an angle with the base, Plate 9 at E.

A frustum of a cone or pyramid is one which has had the top part cut off by a plane parallel to the base, Plate 9 at F.

A sphere is a solid all points of whose surface are equally distant from an interior point called the center. The surface of a sphere can be divided into figures such as gores and zones. A gore is enclosed by two semi-circles. A zone is contained within two circles in parallel planes.

The brief treatment of geometrical figures and solids included in this chapter is intended to give what is actually necessary as a preparation for satisfactory progress in freehand sketching of mechanical constructions.

Practice Exercises. — Use layout No. 1 of Plate 3.

EXERCISE 1. — Sketch a vertical line to divide the working space into two columns. In the left hand column sketch the following figures and letter name of each one: equilateral triangle, isosceles triangle, scalene triangle, right triangle, square, rhombus, pentagon, and hexagon. In right hand column illustrate by a sketch and letter the name of each of the following: octagon, rectangle, circle, right angle, tangent line, concentric circles, ellipse, and oval.

EXERCISE 2. — Use layout No. 1 of Plate 3. Cut small illustrations from the advertising pages of mechanical magazines to illustrate parts which have forms based on the following: prisms, cylinders, cones, spheres, and parts of such solids. Paste these on your sheet, indicate type forms and letter the name of each one. If you know the technical name for the parts, letter it underneath the name of the geometrical solid.

CHAPTER V

PRINCIPLES OF PROJECTION

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PRINCIPLES OF PROJECTION

Methods of Representation. — Machines, buildings, ships, airplanes, and engineering constructions generally, have to be designed and represented by drawings before they can be manufactured or built. Various methods of making drawings are in use such as perspective, isometric, oblique, and orthographic projection.

Each method has certain advantages but the use of orthographic projection for industrial purposes is universal. The other methods while more pictorial have limitations which unfit them for general use in the planning and construction of engineering work.

A perspective drawing shows a machine or structure as it appears to the eye. If a square or oblong building is viewed from a high position it will appear to be narrower and shorter at the back than in front. A photograph or perspective of the building would be of value in conveying information as to its style, character, etc., but could not be used for giving the dimensions necessary for construction. This is because parts which actually are the same size appear to be different sizes depending upon how far they are from the observer.

The pictorial feature of perspective can be retained in the more practical forms of drawing such as isometric and oblique. In these, equal distances on the real construction are made equal distances on the drawing. Compare the different kinds of representation as shown on Plate 10. In the perspective, receding lines converge while in isometric or oblique they remain parallel. The effect is not as pleasing but such drawings are more easily made and used.

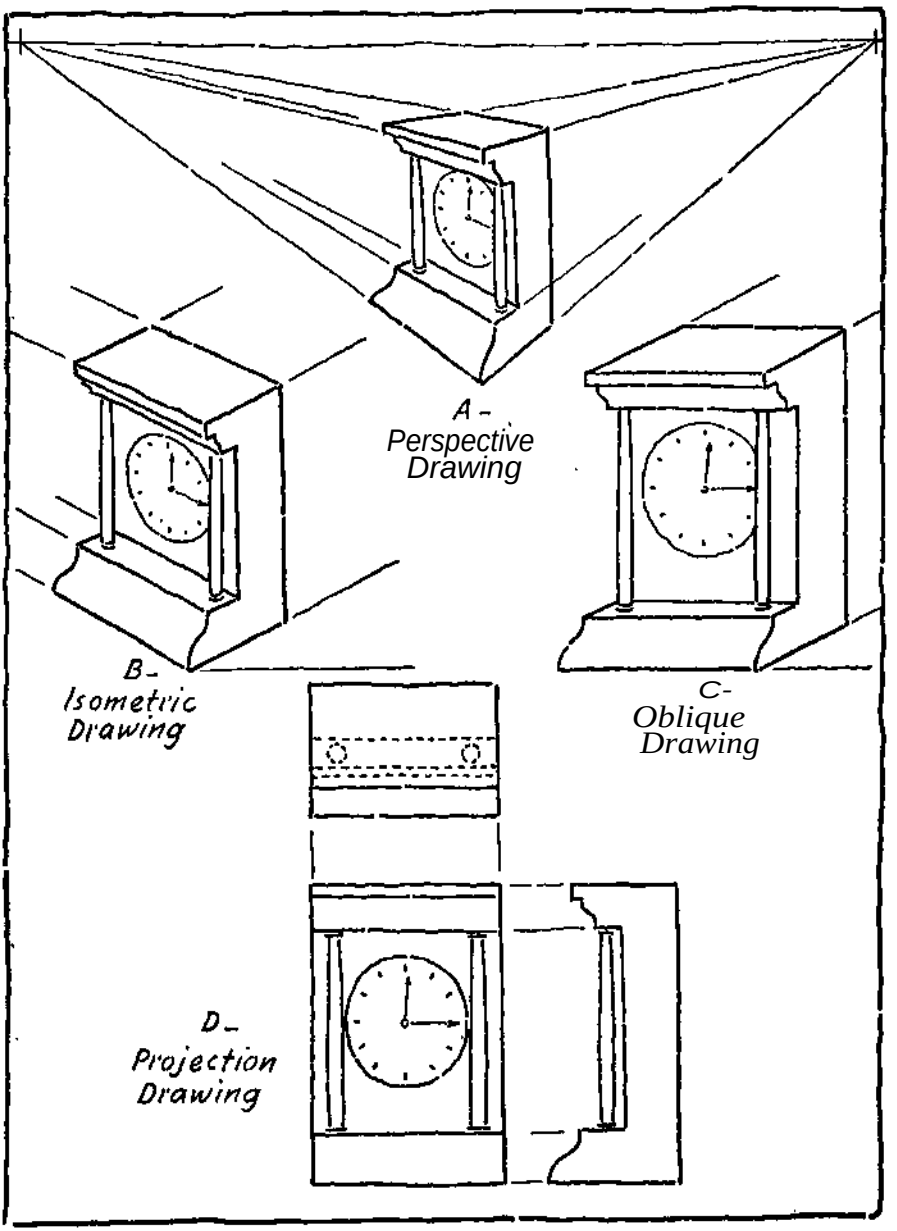

PLATE 10. Different Kinds of Drawings.

Working Drawings, — Working drawings are drawings which give directions for doing work. They must show the exact shapes and give dimensions or sizes. For this purpose views obtained by orthogiaphic projection are used. Generally these consist of front, side and top views. It will be necessary to understand just how such views are obtained in order to make drawings or sketches and to read shapes from shop drawings and blueprints.

The Planes of Projection. — In order to study the obtaining of views and their relation to each other, imagine three glass planes joined by hinges and forming one corner of a box, Plate 11.

Place the object within the box. The top, front, and side views can be drawn in their correct positions by tracing the outline and details on the three glass planes as shown. This will give top, front, and side views. Lines from the object, perpendicular to the planes, will intersect the planes and form the views. Such lines are called projection lines. When the box is opened the three views will be on a single flat surface. The complete drawing is shown at E with the views in their proper relation to each other. Note that the length appears on the front and top views, the height appears on the front and side views and the breadth on the top and side views.,

The top view is sometimes called a plan, the front and side views are sometimes called the front elevation and side elevation.

The projection box is, of course, not practical for everyday use in making drawings or sketches. It is essential, however, to remember how the planes open and to always place the views in their correct positions.

Representation of Hidden Surfaces. — Parts which cannot be seen when viewing an object from a given position must be represented in order to completely describe the shape of the object. Such parts are projected to the planes in the same way as the visible parts, but they are represented by " hidden " lines composed of short dashes. See the top view of the clock on Plate 10. The front and side views do not tell the shape of the two uprights. The hidden

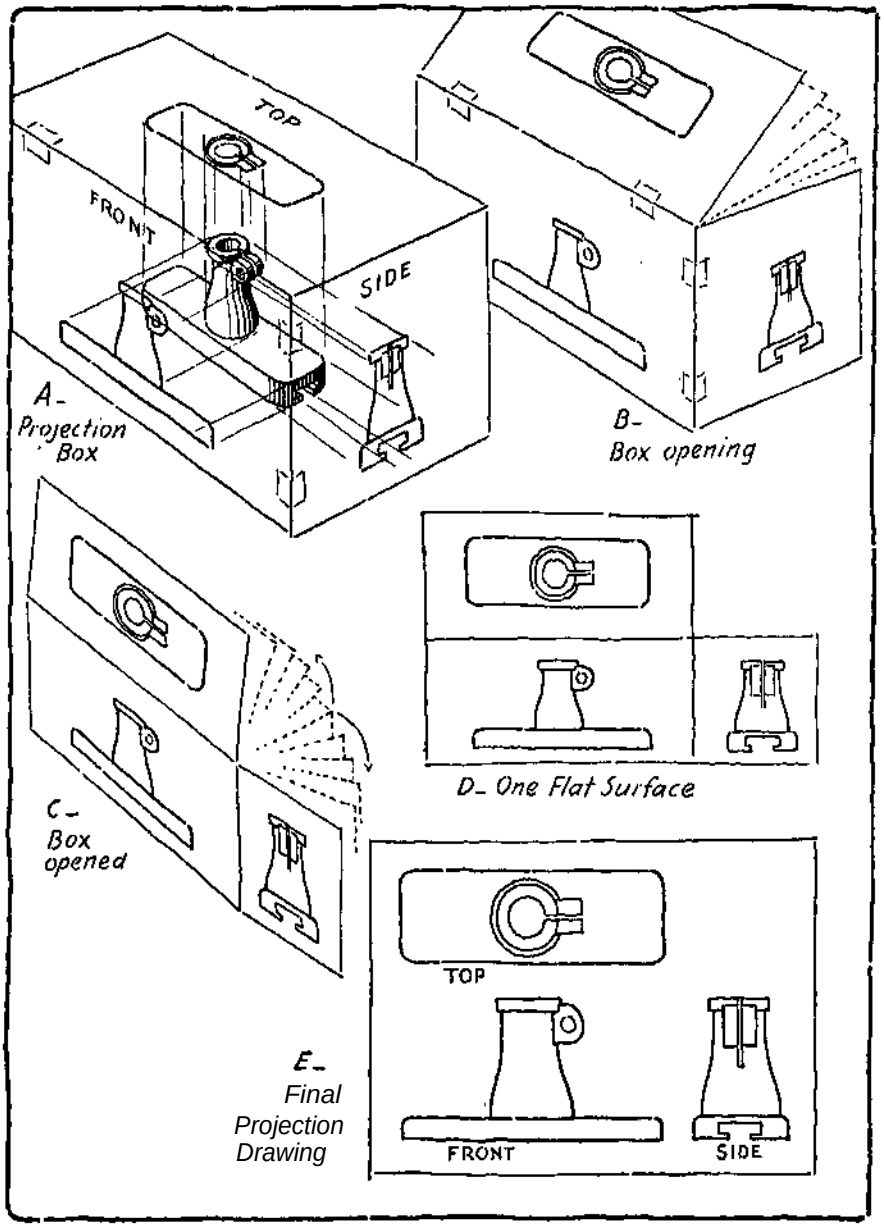

PLATE 11. " The Projection Box."

circles in the top are required to complete the description. On Plate 14 the surface of the groove is shown on the side view by a dotted line because it is hidden.

Obtaining Views from a Model——If the front view is drawn first the other views may be obtained by considering a model (real or imaginary) to be turned as the planes are turned. This is illustrated on Plates 12 to 16. Notice how the object is placed in position to obtain the front view, marked first position at A. The object is then turned so that the top of it can be seen and moved up directly above the first position into the second position, at B. Next consider the object to be returned to the first position and turn it so that the right side can be seen and move it directly to the right of the first position, as at C. The three views will then appear as at D. A little practice in placing actual parts or models in the positions described will help fix the principles of projection so that the views can be correctly drawn and correctly located.

Auxiliary Views.—When an object has a surface at an angle and the true shape cannot be shown on one of the regular planes, an extra or auxiliary view is used. This is illustrated at A on Plate 28. Very often auxiliary views are used to show only the part which is at an angle.

Problems.—The graphical description of shape as taken up in this chapter forms the basis of all industrial drawing. A complete working drawing requires the addition of dimensions to specify sizes and notes to give other information as explained in Chapter VII.

The problems which follow are graded in order of difficulty. The pictorial presentation is used to take the place of actual models. All of the problems need not be worked out but a selection should be made from each group.

Use layout No. 1 or. No. 2 of Plate 3 depending upon the size and arrangement of views. Do not copy the pictures but sketch the necessary views by the principles of projection. The dimensions on the pictures will fix the proportions, and should be kept in mind in planning and sketching the views. A sketch, of course,

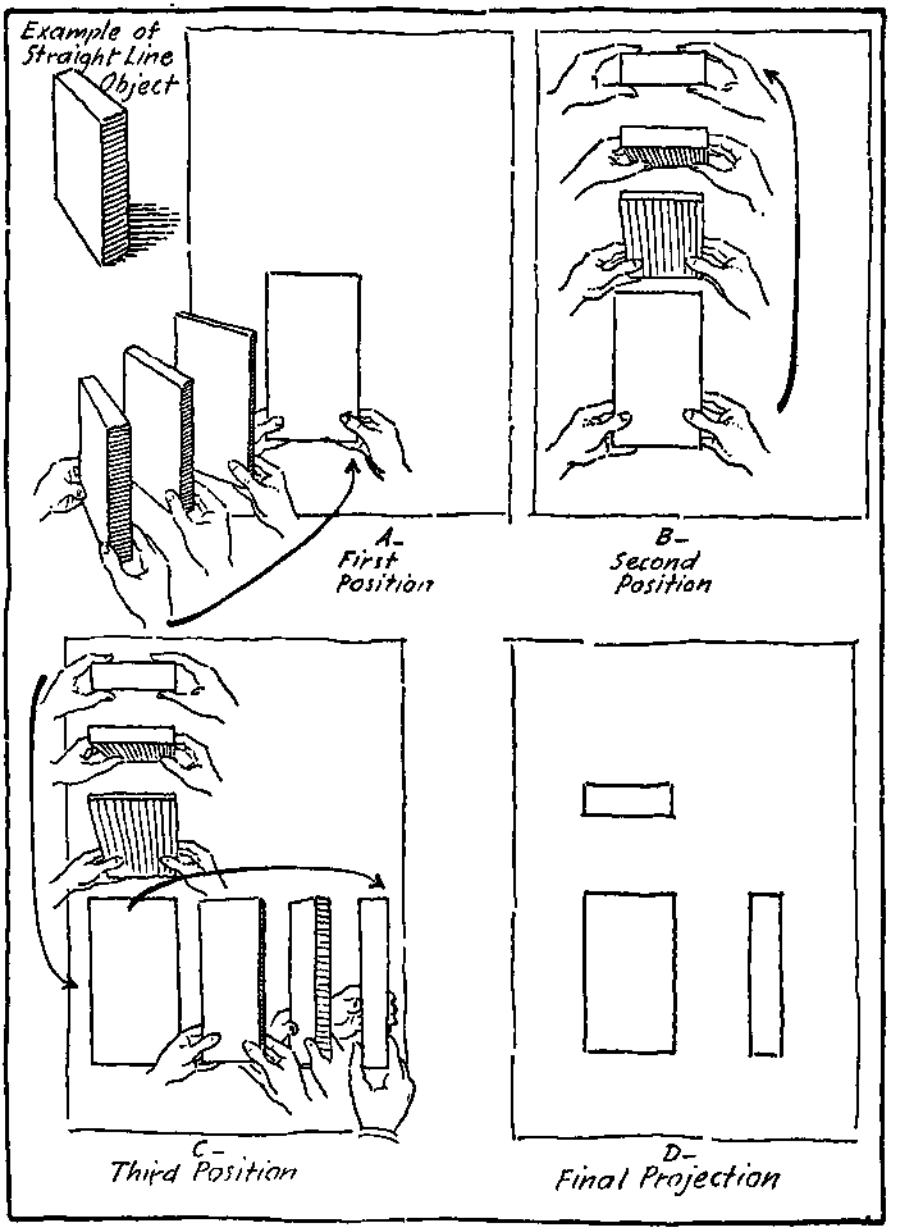

PLATE 12. Obtaining the Views of a Prism.

is not to be measured but if way out of proportion it frequently indicates careless thinking and is not as quickly read.

PROBLEMS 1 to 4, PLATE 17. — Simple objects with surfaces parallel to the planes of projection. Sketch the necessary views of each piece on a separate sheet.

PROBLEMS 5 to 12, PLATES 18 and 19. — Simple objects with inclined surfaces.

PROBLEMS 13 to 28, PLATES 20 to 23. — Hollow and indented objects.

PROBLEMS 29 to 40, PLATES 24 to 26. — Objects with cylindrical parts.

PROBLEMS 41 to 44, PLATE 27. — Objects with tangent surfaces.

PROBLEMS 45 to 48, PLATE 28. — Auxiliary views.

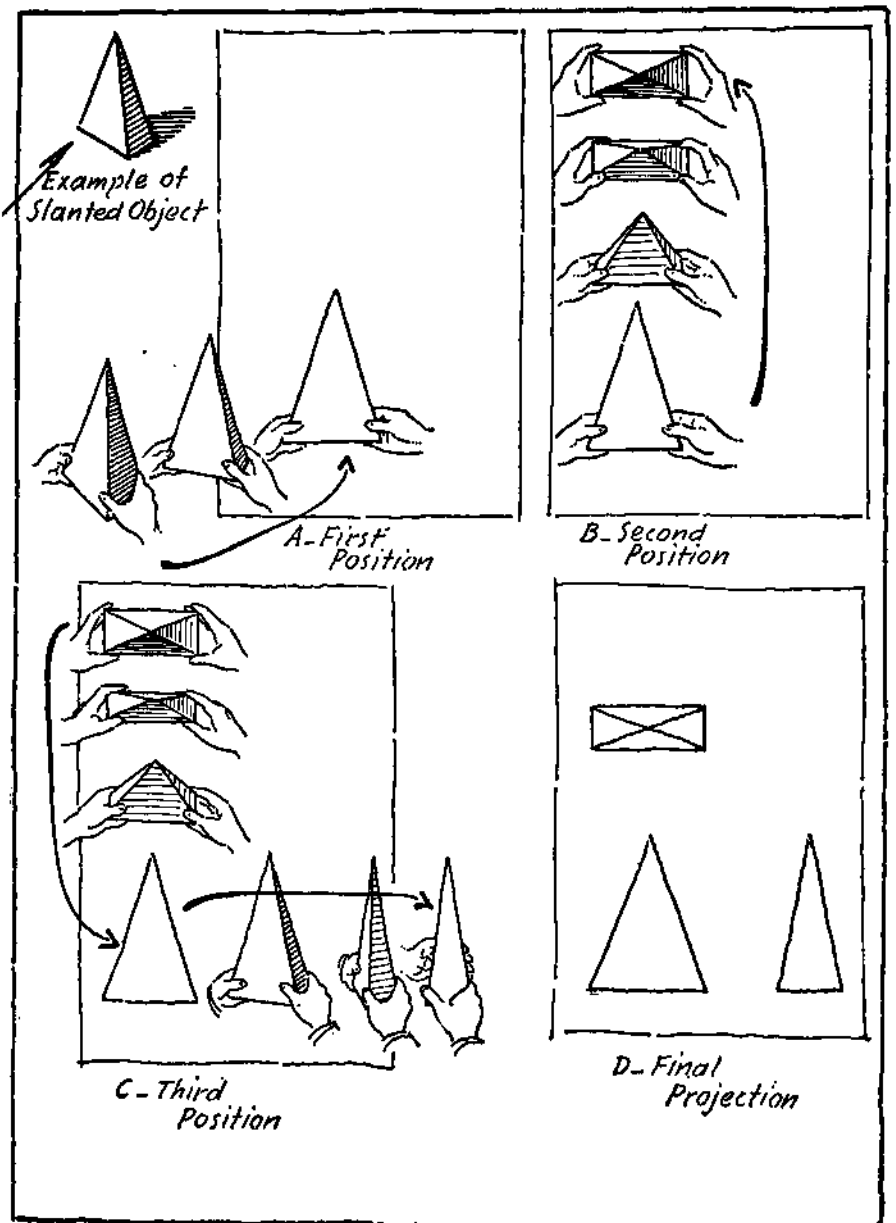

PLATE 13. Obtaining the Views of a Pyramid.

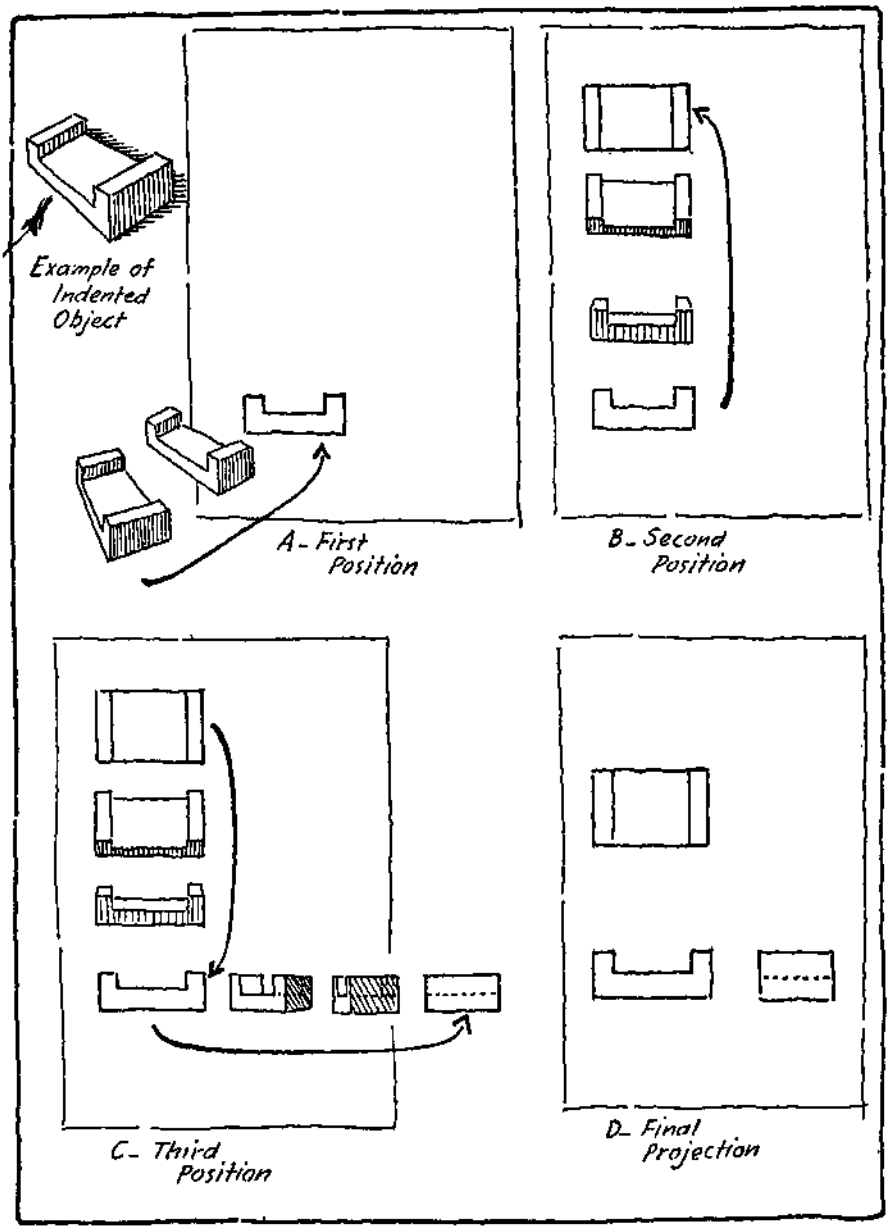

PLATE 14. Obtaining the Views.

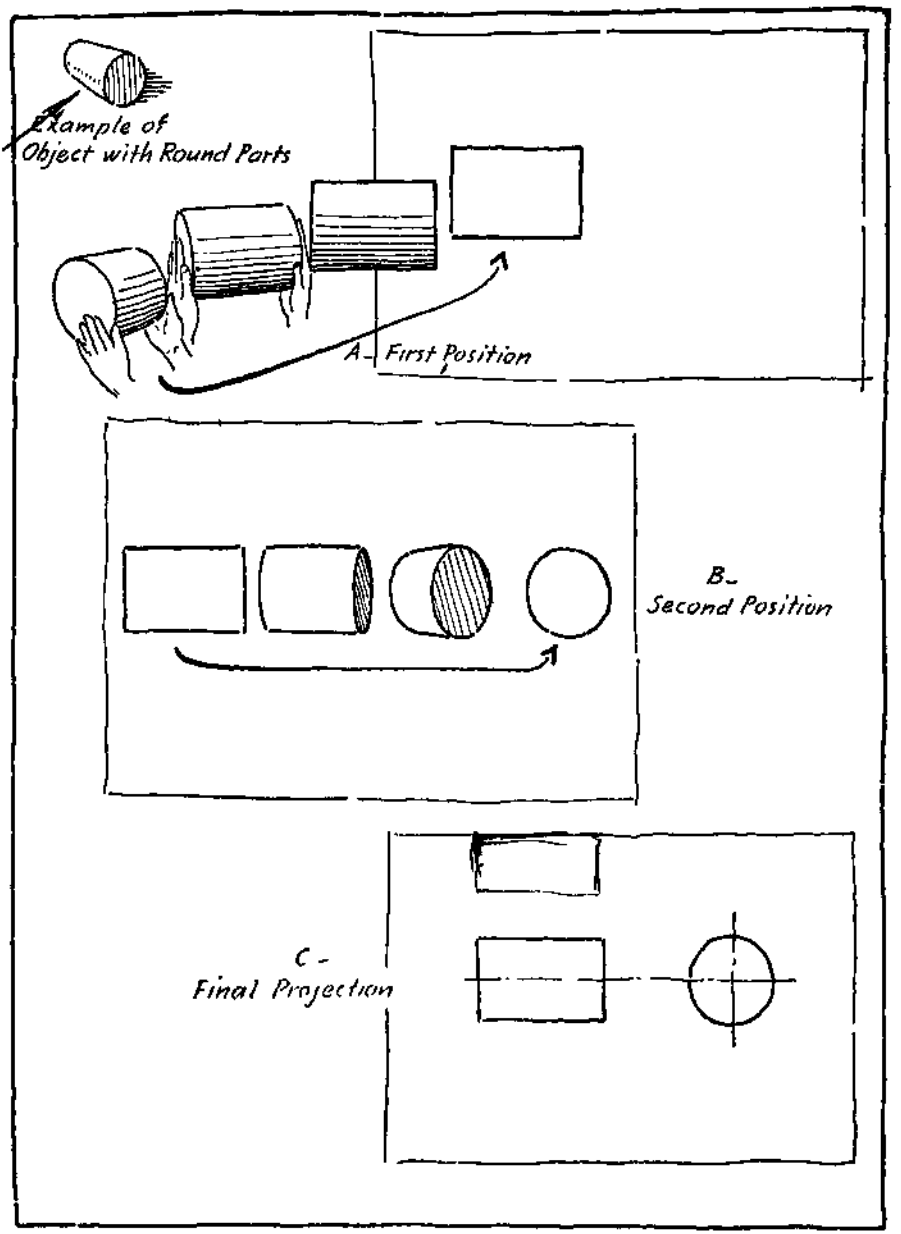

PLATE 15. Obtaining the Views of a Cylinder.

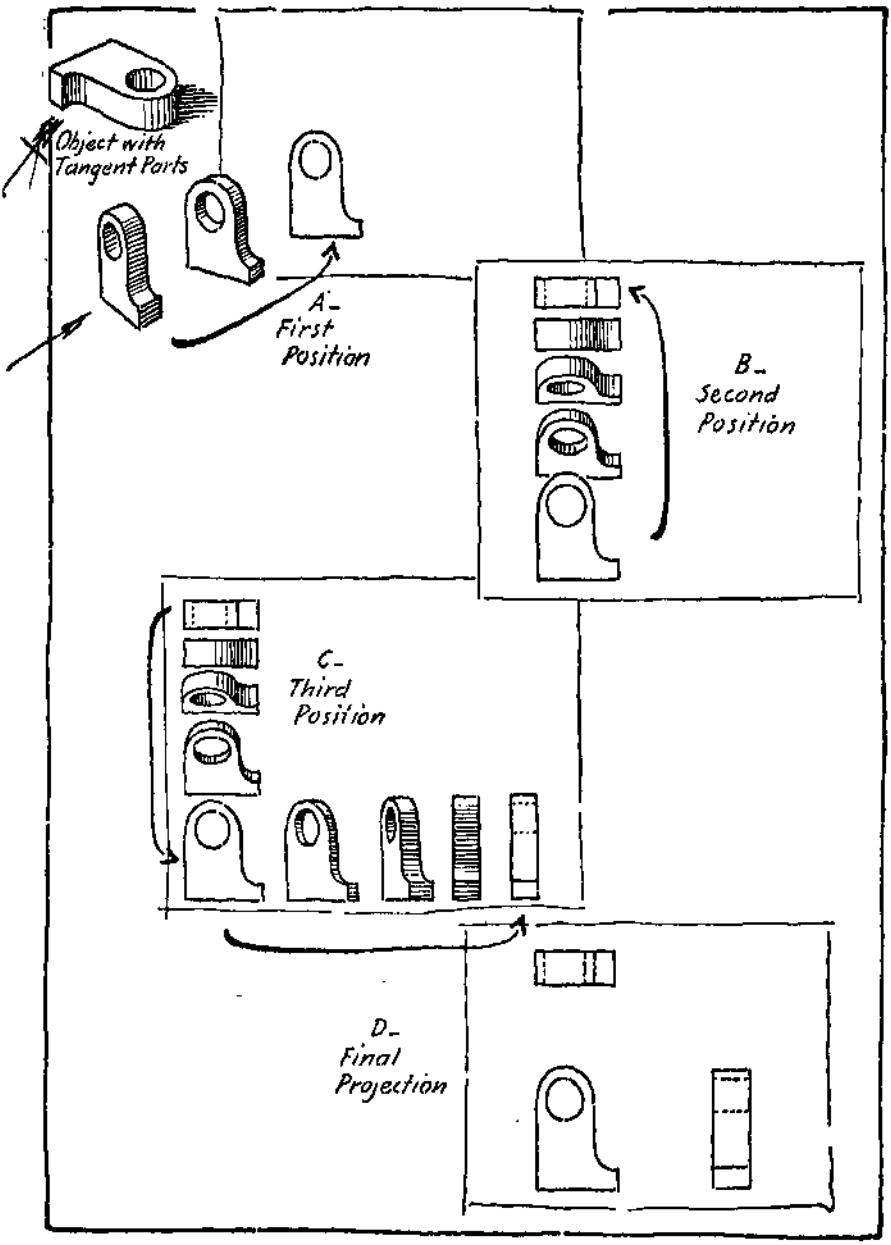

PLATE 16. Obtaining the Views.

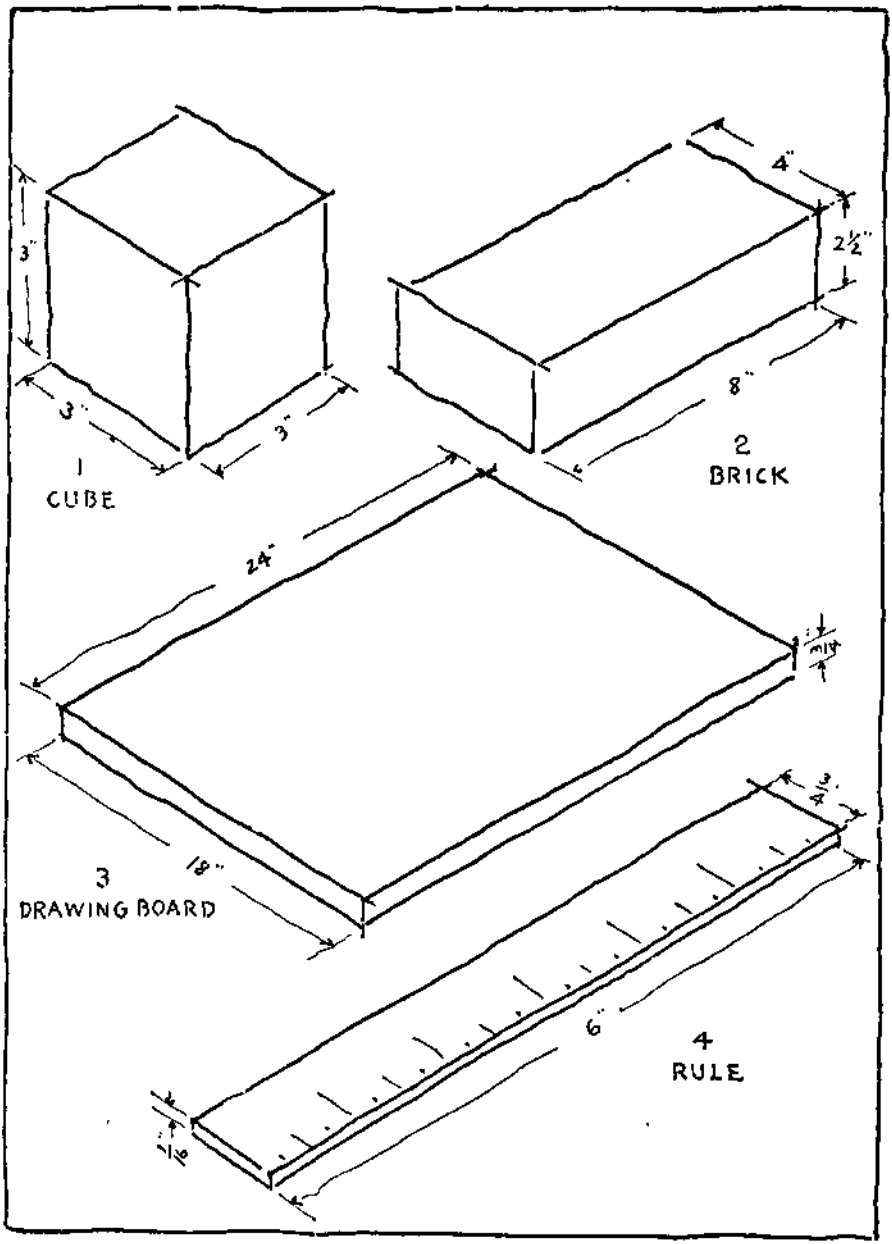

PLATE 17. Problems 1 to 4.

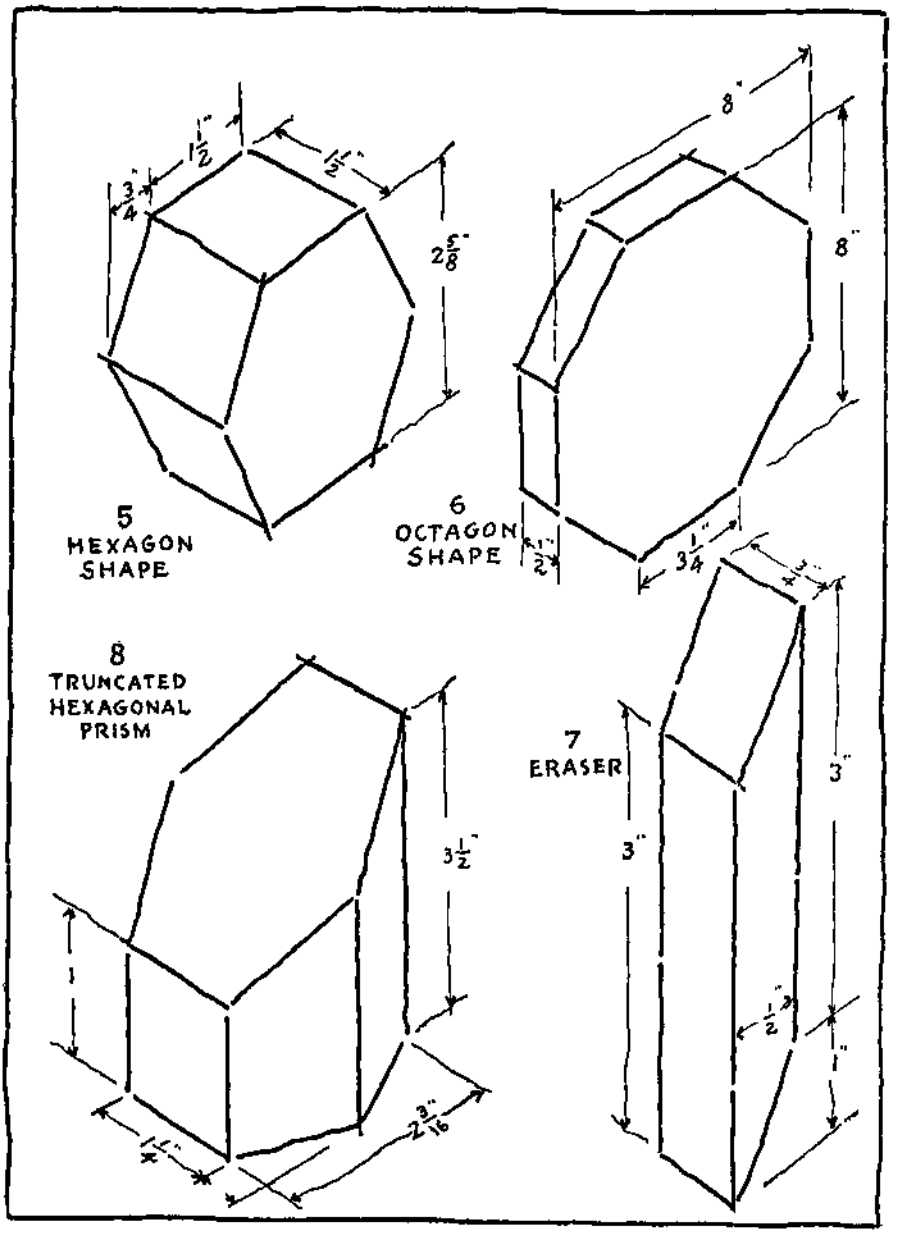

PLATE 18. Problems 5 to 8.

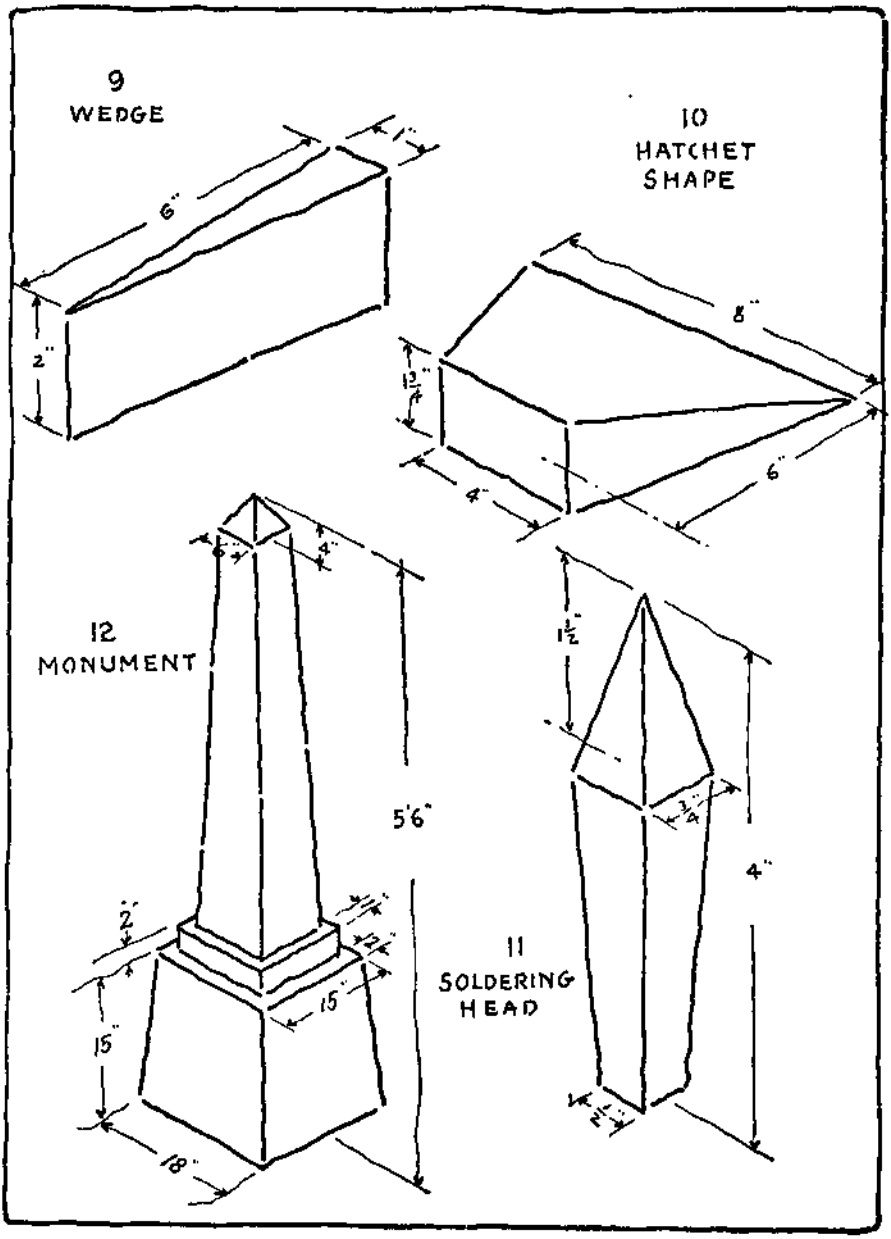

PLATE 19. Problems 9 to 12.

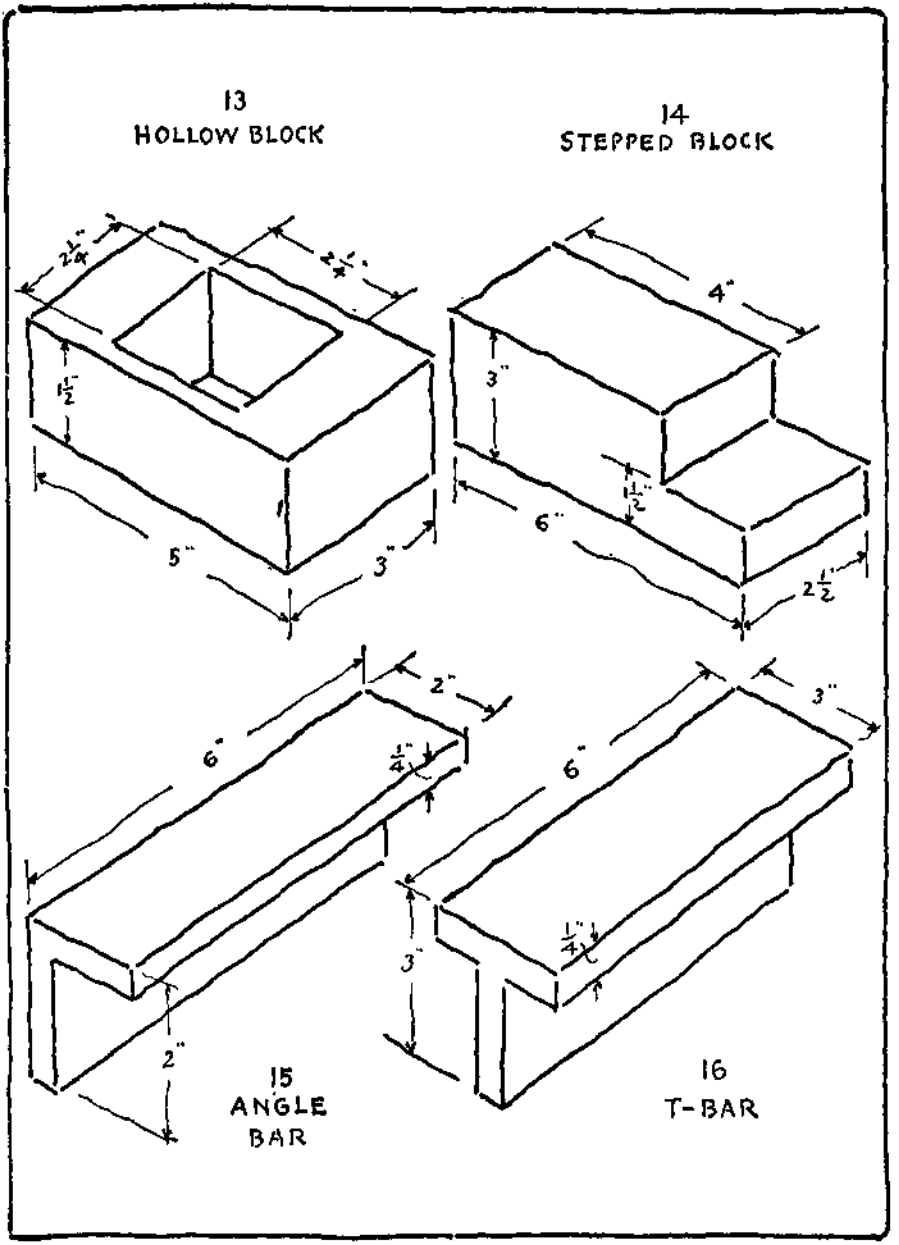

PLATE 20. Problems 13 to 16.

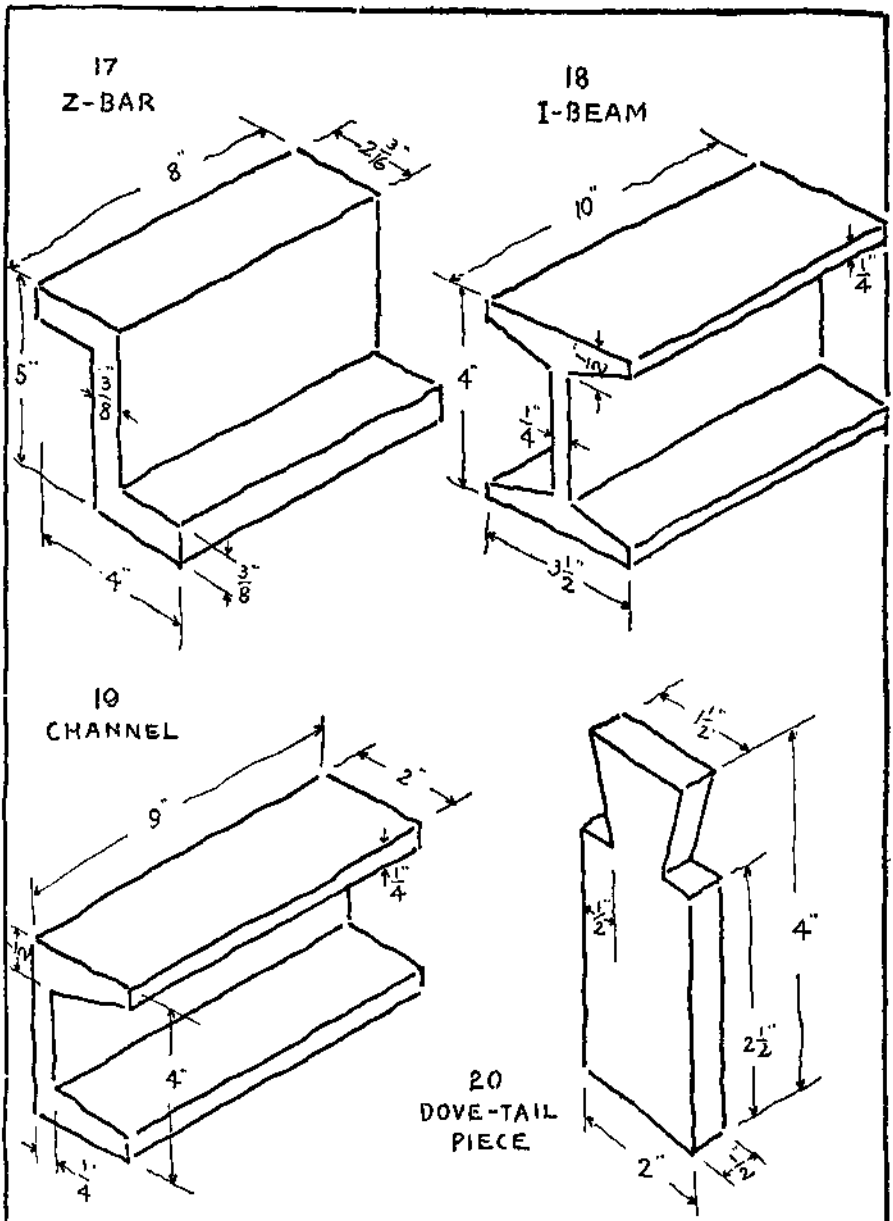

PLATE 21. Problems 17 to 20.

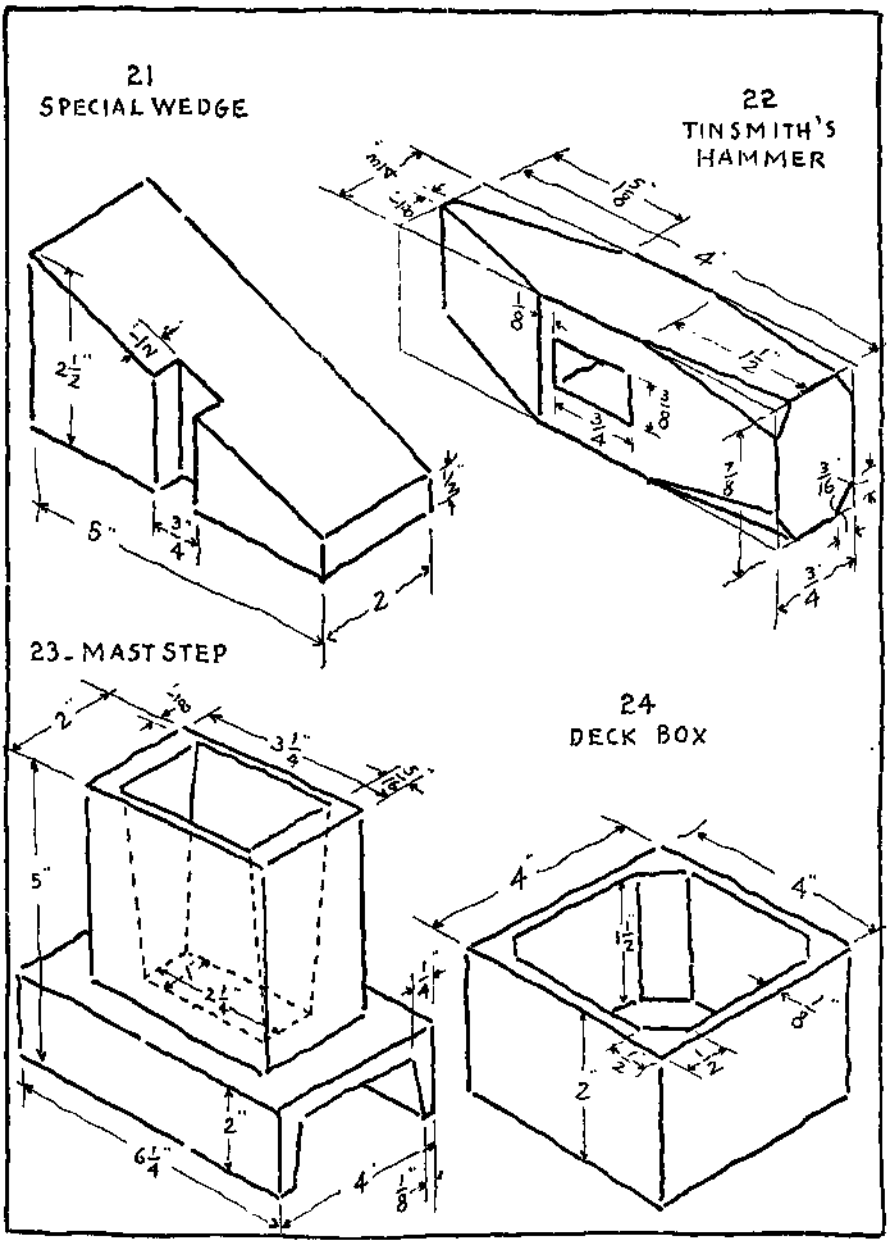

PLATE 22. Problems 21 to 24.

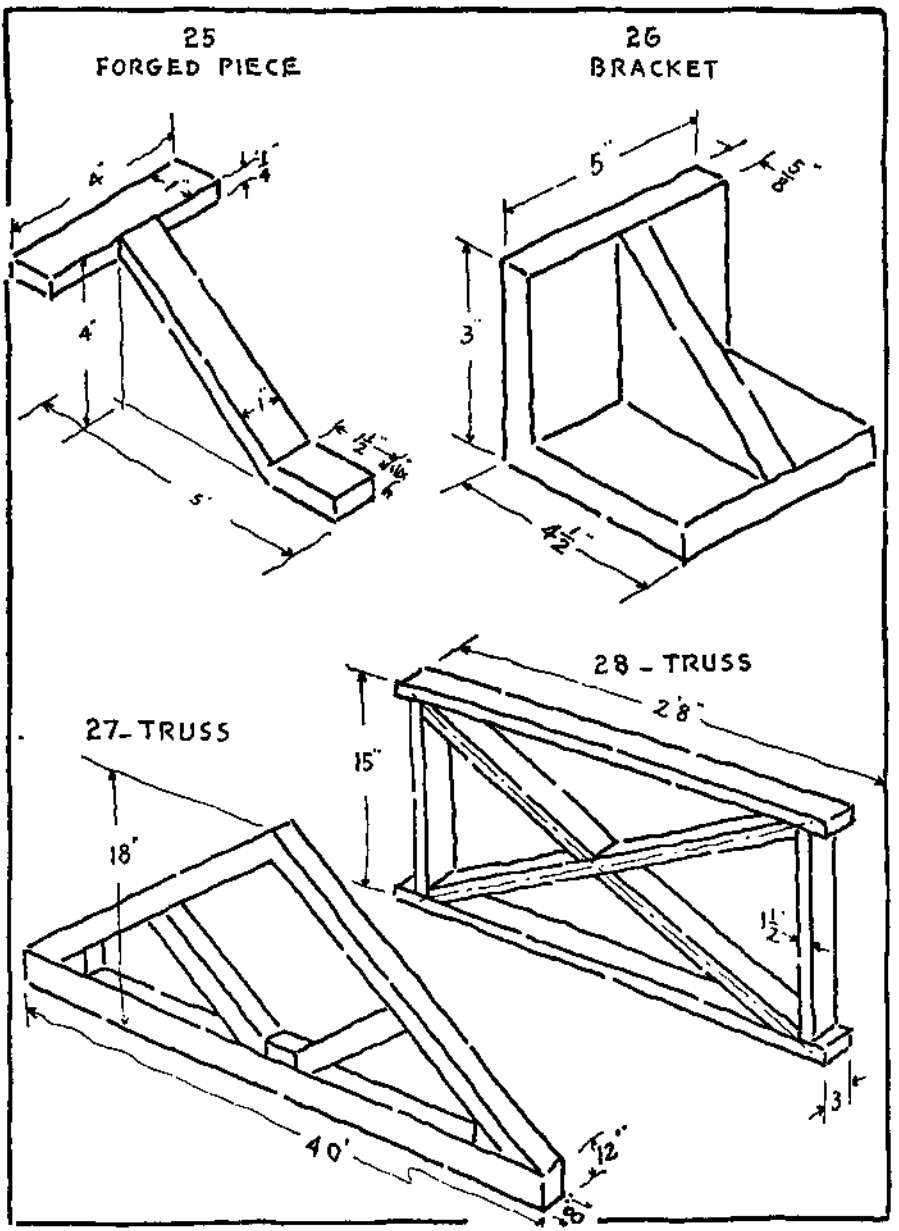

PLATE 23. Problems 25 to 28.

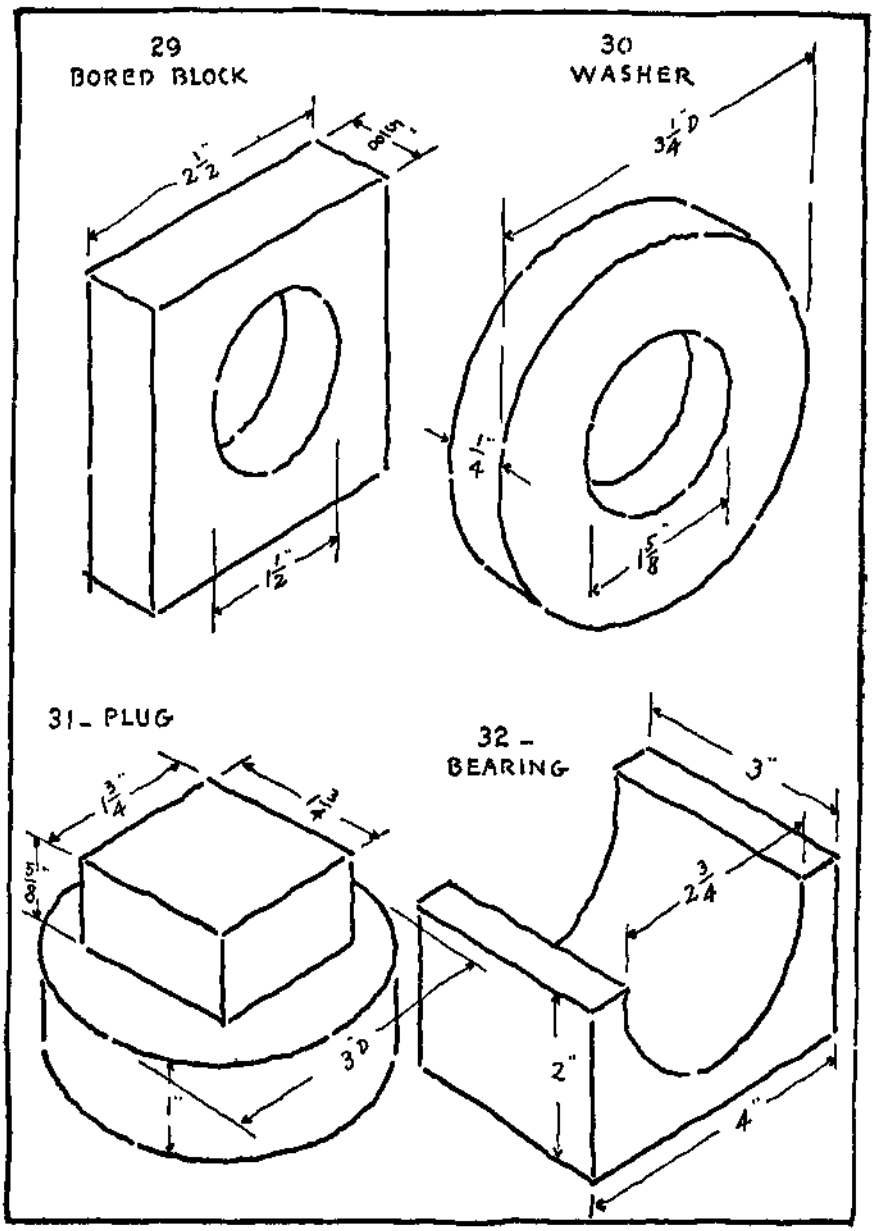

PLATE 24. Problems 29 to 32.

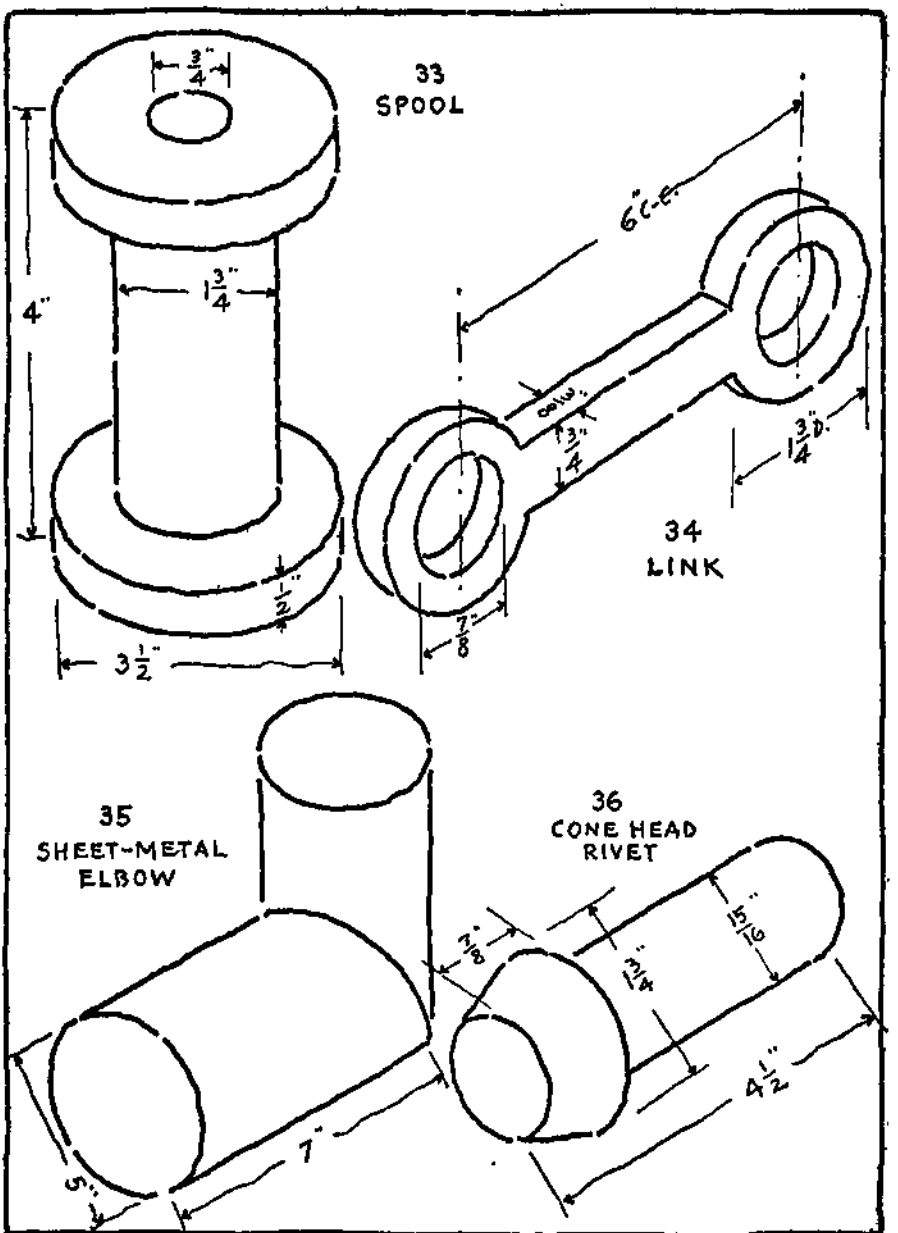

PLATE 25. Problems 33 to 36.

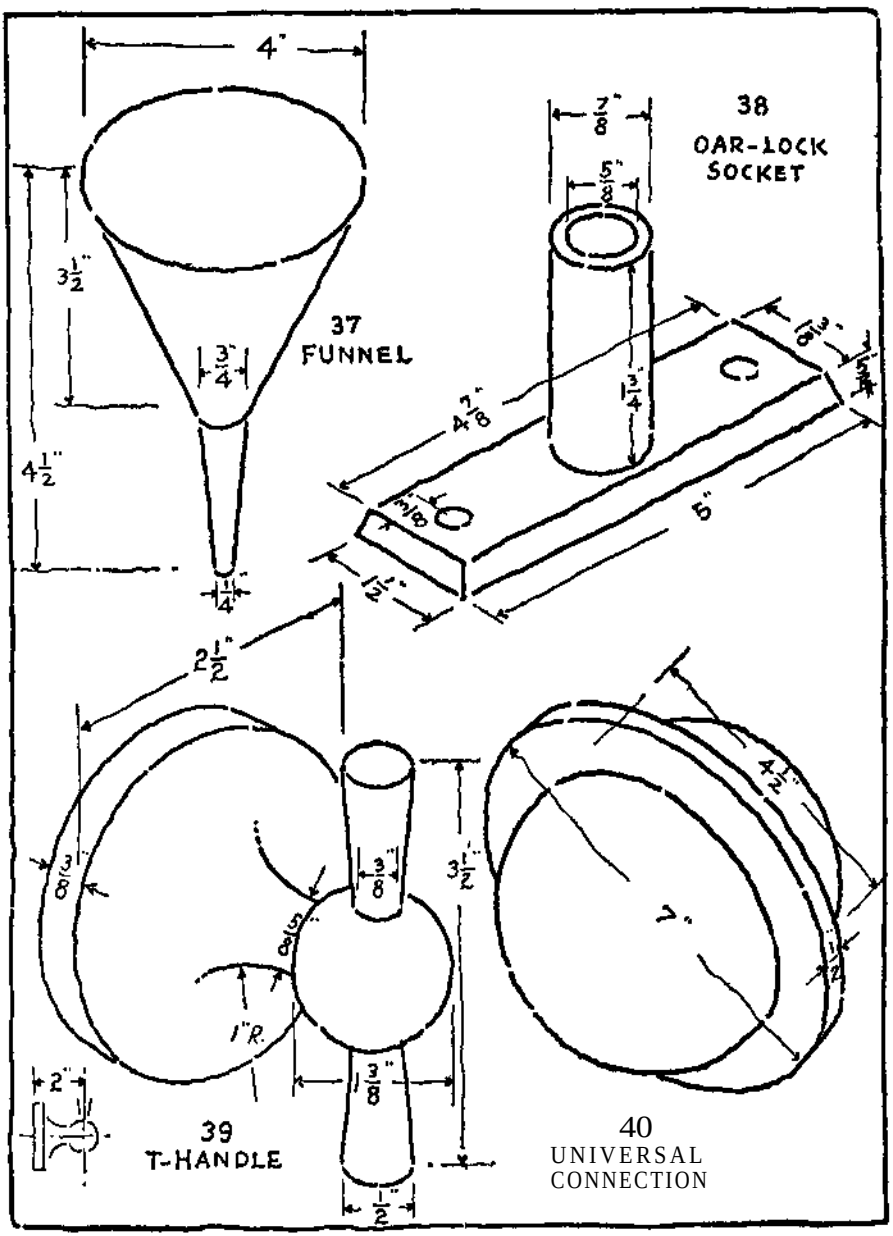

PLATE 26. Problems 37 to 40.

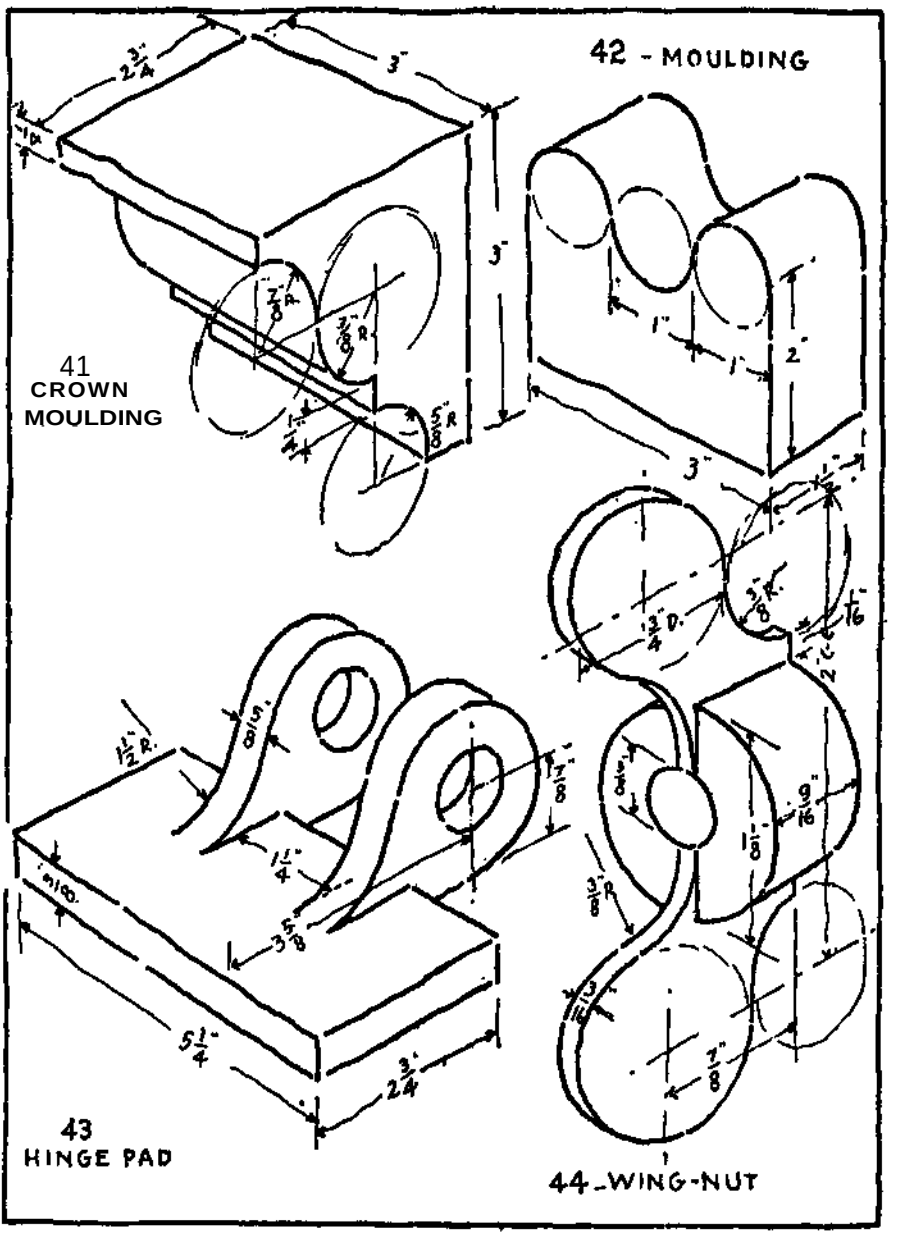

PLATE 27. Problems 41 to 44.

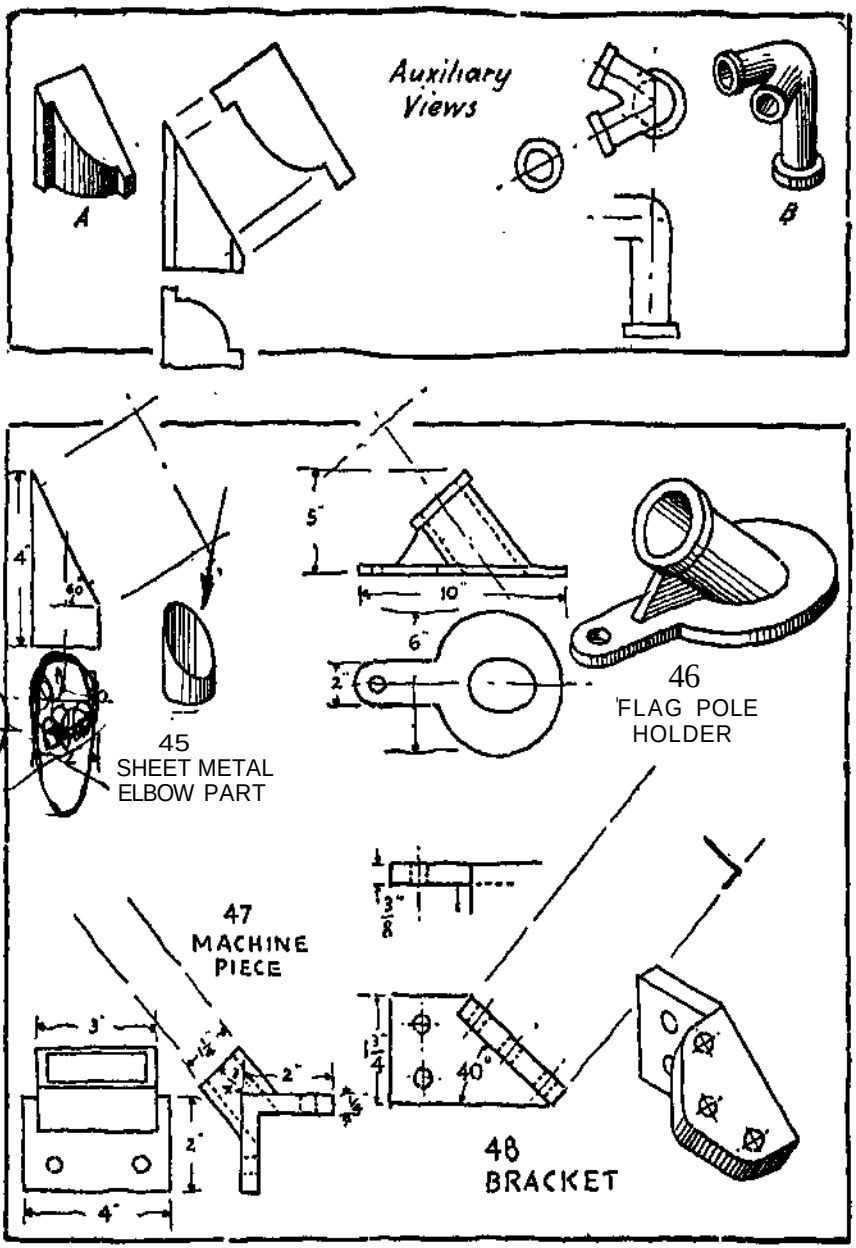

PLATE 28, Problems 45 to 48.

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CHAPTER VI
SECTIONAL VIEWS

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CHAPTER VI

SECTIONAL VIEWS

Representation of Interior Construction. — In the previous chapter interior or hidden constructions were shown by dotted lines. The character or amount of construction to be represented often makes such drawings hard to read. In such cases a method called sectioning is generally used.

Principle of the Sectional View. — This principle is illustrated at A on Plate 29 by the draftsman's wood ink bottle holder. Such an object could be clearly described by using dotted lines but it is used here for comparison. Imagine the object to be cut or sawed in two and the front part removed so that the hole is visible as shown in the picture. Views made to conform with this principle are given at B. The top view shows the position of an imaginary cutting plane and the front view shows the cut surface and the interior detail. The cut surface is indicated by a series of parallel lines drawn at an angle, generally 45°. The view is called a section or sectional view and the parallel lines are called section lines, sectioning or cross-hatching. The top view is shown complete because the cutting plane is only an imaginary one used to locate the sectional view.

The Imaginary Cutting Plane. — The principle of the sectional view makes use of an imaginary cutting plane. The part of the construction in front of the plane is removed and the cut surface and remaining parts are then drawn as they would appear.

The position of the cutting plane should be shown on one of the other views by a distinguishing line as illustrated. Sometimes arrows are added to indicate the direction in which the plane is viewed, especially when part or extra sections are made. When

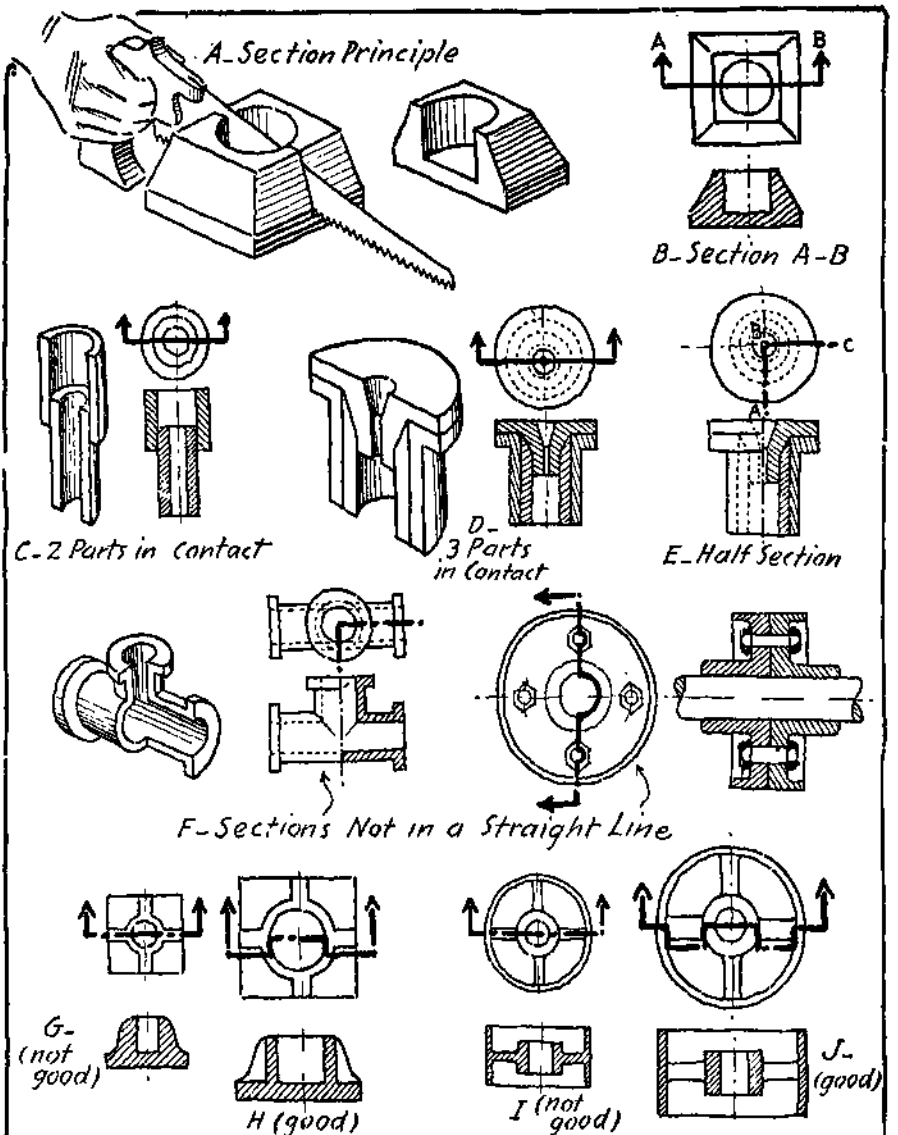

PLATE 29. Sectional View Studies.

the section is evidently through the center neither the cutting plane nor the arrows are necessary.

Kinds of Sectional Views. — When two pieces are cut by a plane they are sectioned in opposite directions, Plate 29, at C. As mentioned before the 45° slope is generally used but when more than two pieces are shown, 30° or 60° lines may be used, Plate 29, at D. The dotted lines representing invisible features beyond the cutting plane are often omitted especially if they confuse rather than help in the shape description. However, when they are necessary to show details or construction they must be used.

When an object is symmetrical, both the interior and exterior may be shown by a view which is half section and half elevation as at E and F, Plate 29. Such a view is called a half section, and is obtained by using two imaginary cutting planes.

Other terms which occur in sectional treatment are Longitudinal Section, Transverse or Cross Section, and Horizontal Section. A ship, cut through from bow to stern would be represented as a longitudinal section; if cut at right angles to this by a transverse section; and if cut parallel to the deck, by a horizontal section.

Treatment of Shafts, Bolts, Etc. — Shafts, spindles, bolts, screws, and other small solid parts are not shown in section. When they are part of a construction that is sectioned the cutting plane is imagined to pass around the curved surface. This allows such pieces to be shown as at F on Plate 29.

Exceptions to the Rule of Sectioning. — The previous article shows that it is not always necessary to cut straight through an object. There are conditions where a true section might be misleading. In such cases the 'cutting plane can be arranged to give a better representation. The section of the sod tamper at G, Plate 29 does not give as good a description as when the cutting plane is taken to give the sectional view at H.

The four-arm pulley appears to be webbed at I, while the treatment at J gives a correct impression. It is not necessary to indi-

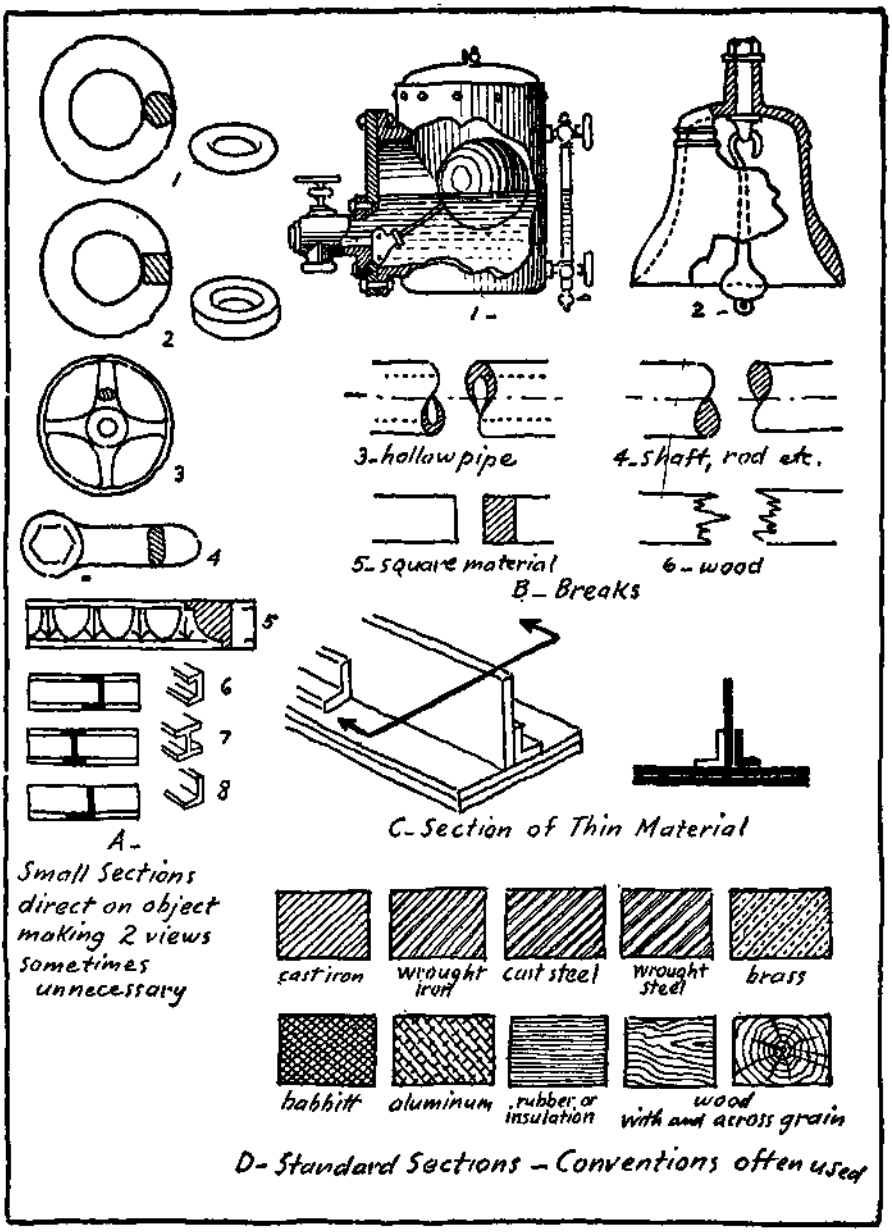

PLATE 30. Special Sections.

cate this variation in the cutting plane as such views are standard practice.

Special Sections——An extra view can often be avoided by placing a section on a full view as indicated at A on Plate 30. Architectural details such as mouldings and panels, furniture parts, etc., are often shown to advantage in this way.

Sometimes a partial section is shown by " breaking away " a part of an exterior view as at B, 1 and 2, on Plate 30. A long piece of uniform section may be " broken " as B, 3, 4, 5, and 6, Plate 30. The shape of the cross section is indicated by the break.

Long thin sections such as occur in structural work are difficult to cross hatch and are generally shown solid black. When plates, angle bars, etc., are in contact they are separated by a " white " line as at C, Plate 30.

Sectioned surfaces, in general, are best represented on sketches by the symbol for cast iron shown at D, on Plate 30. A note to tell the name of the material makes the description definite. On drawings other symbols are sometimes used such as those of the American Society of Mechanical Engineers which are given at D, Plate 30.

Problems. — A thorough understanding of the subject of sectional views is necessary for the making and using of industrial sketches and drawings. Problems should be selected from each group. The view to be sectioned should *not be copied* and changed but should be worked out at once as a section.

Use layout No. 1 or No. 2 of Plate 3 depending upon the size and arrangement of views. The section lines should be lighter and finer than the main lines of the views.

Section planes which are not continuous as those at H and J of Plate 29, are represented either straight across or as plain center lines on practical sketches. They are shown as on Plate 29 and on some of the problems for purposes of explanation and must not be copied when the problems are solved.

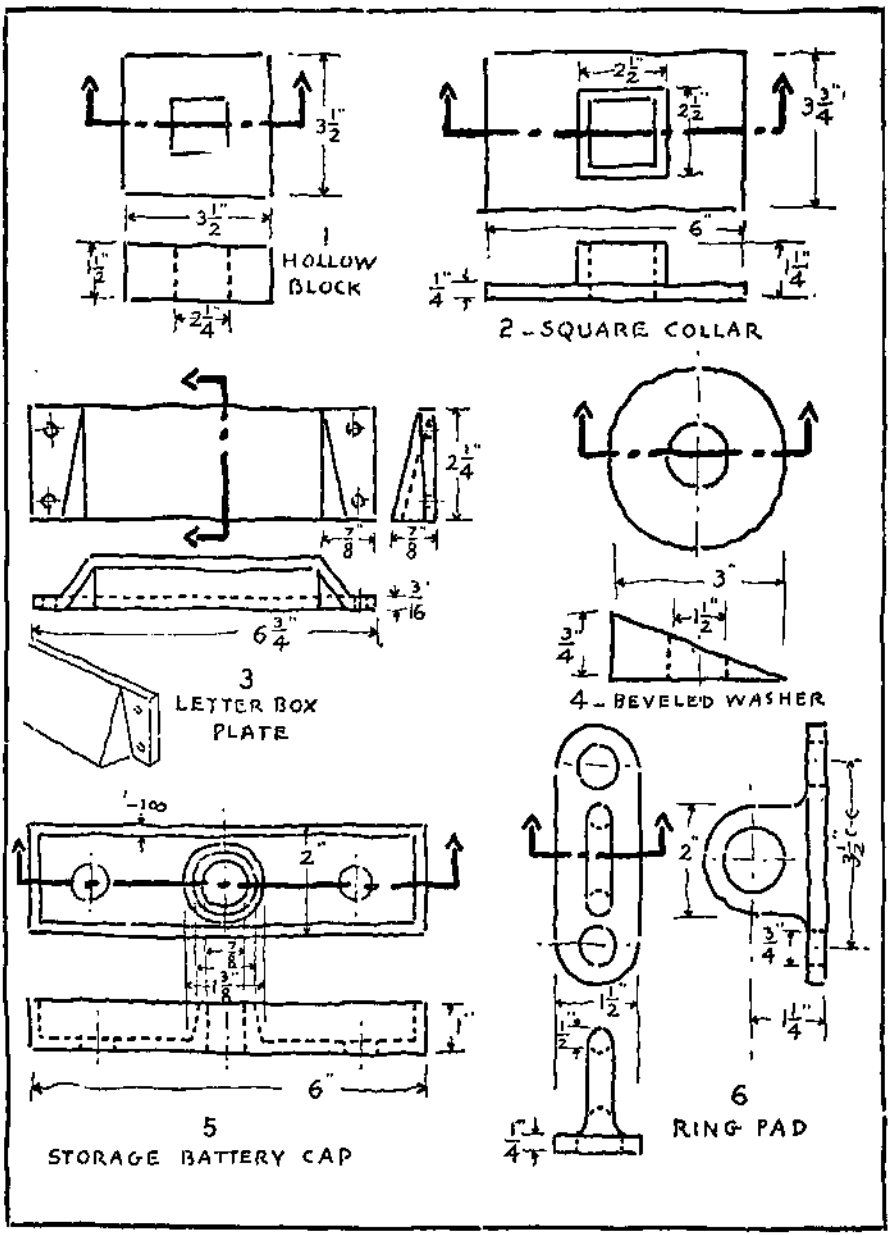

PLATE 31. Problems 1 to 6.

PROBLEMS 1 to 6, PLATE 31. — Sketch the necessary views showing the sectional views as called for by the cutting planes indicated.

PROBLEMS 7 to 10, PLATE 32. — Sketch the necessary views and sections as indicated or some views as half sections where desirable.

PROBLEMS 11 and 12, PLATE 33. — Sketch the necessary views and sections.

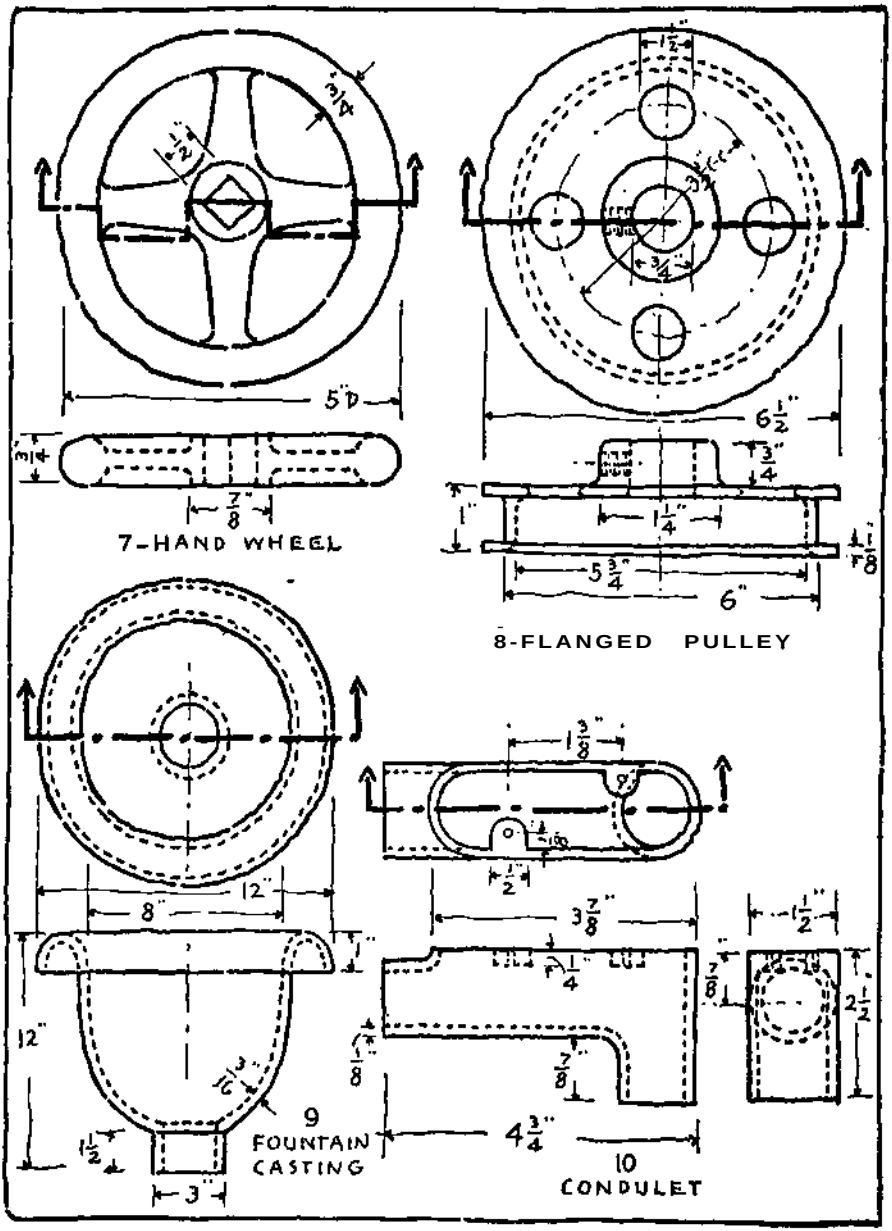

PLATE 32. **Problems 7 to 10.**

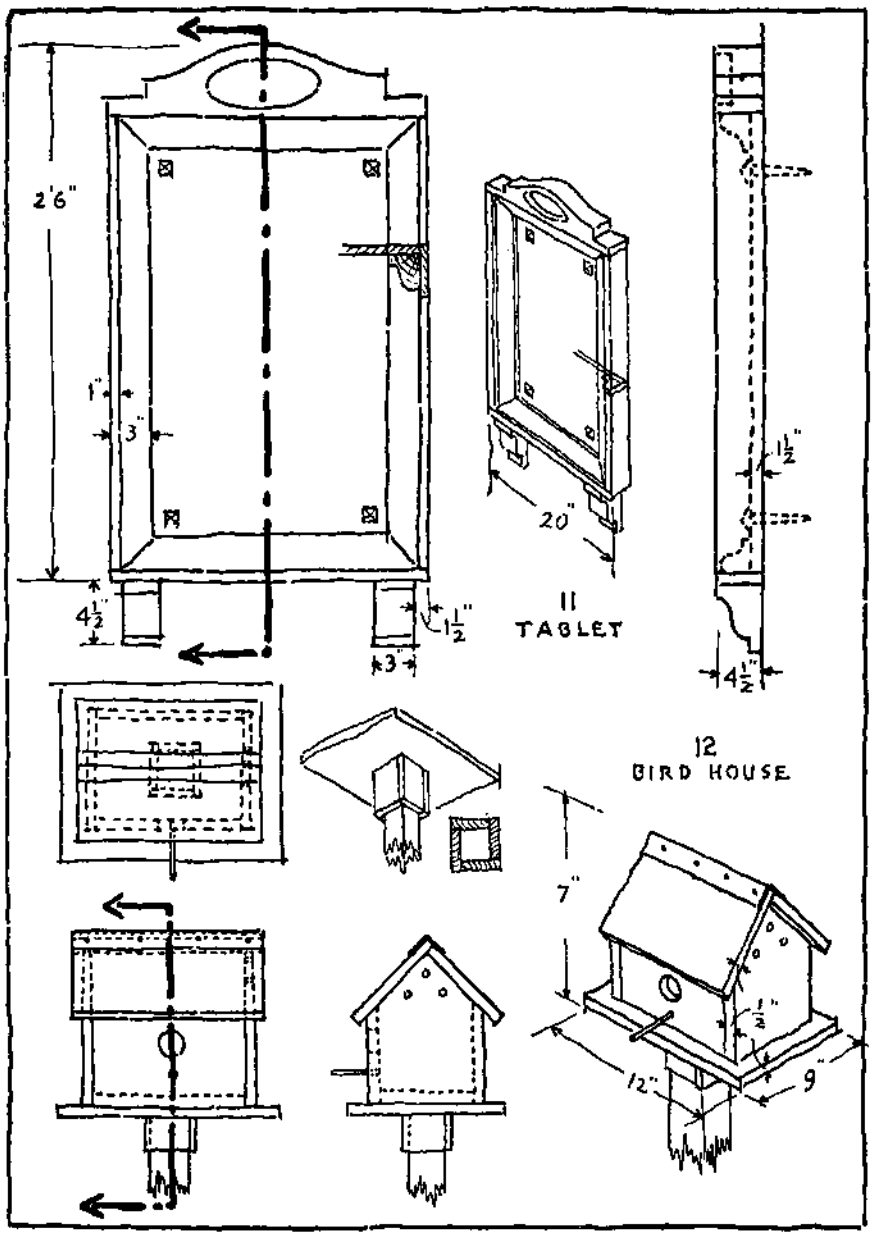

PLATE 33. **Problems 11 and 12.**

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CHAPTER VII
CONVENTIONAL PRACTICE

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CHAPTER VII

CONVENTIONAL PRACTICE

Conventional Methods. — Mechanical drawings and sketches could be made to conform strictly with the principles of geometry and projection. The use of the graphic language in the industries has shown that certain variations, symbols and conventional methods are often desirable. They save time, lessen work and often give a better description than purely theoretical methods. Precedent and long usage have sanctioned the use of a number of these conventional representations. Some are used in all branches of engineering drawing and some are peculiar to the different industries.

The fundamental principles, however, are the same for all branches of industry. The lines used for various purposes on drawings are practically standard, and their purpose and character must be understood. Each line has its own use and meaning. The lines used in this book are shown on Plate 34.

Full Lines. — These lines are used to represent visible edges and outlines. They are drawn as a continuous line and heavier than any of the other lines. This makes the shape "stand out" and results in a more easily read drawing.

Hidden Lines. — Features which are hidden from view are represented by a series of short dashes — called hidden lines. What is hidden or invisible in one view may or may not be hidden in another view.

Center Lines. — Center lines are used to indicate the axes of cylindrical and symmetrical objects and various other " location " purposes. On drawings they are generally made very fine "dot and dash " lines as shown on Plate 34. On freehand pencil sketches they are frequently made very light continuous lines.

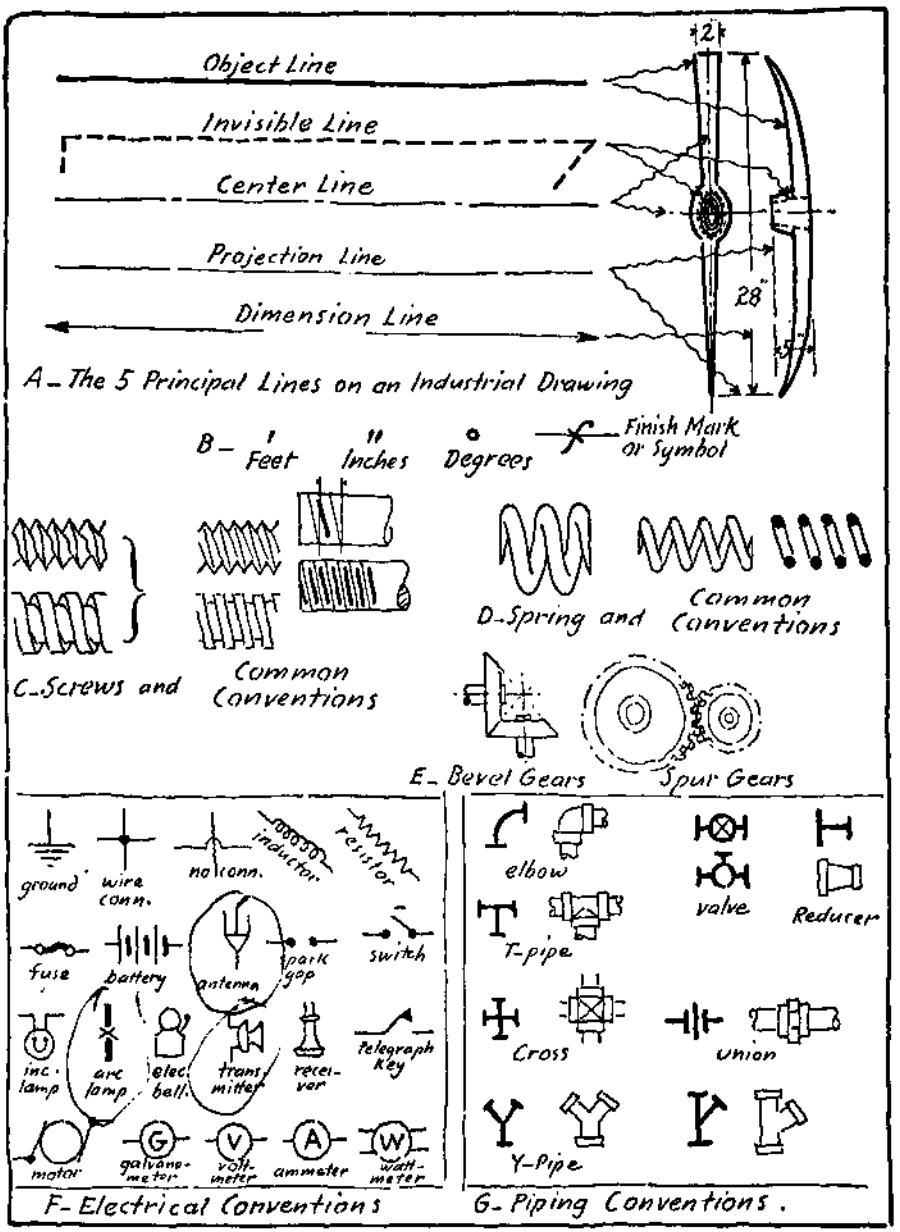


PLATE 34. Lines and Conventions.

Cutting Plane Lines. —Heavy dash and double dot lines used to indicate the edge of imaginary cutting planes for sectional views.

Extension Lines.— Thin continuous lines used to extend the lines of the views in order to locate dimension lines.

Dimension Lines. — These are lines which show the extent of the dimensions put on a drawing to tell the sizes of the parts. They are thin full lines with arrowheads at each end. A space is generally left for the dimension as shown. Dimension lines must always extend the full length of the dimension which they indicate.

Dimensioning. — The subject of dimensioning is very important and should be made a special study. A complete treatment will be found in the chapters on DIMENSIONING in Svensen's " Machine Drawing " and " Drafting for Engineers," both published by D. Van Nostrand Company, Inc., New York.

Some general rules for dimensioning follow:

General practice is to place horizontal dimensions to read from the bottom, and vertical dimensions from the right side. Aircraft practice is to place all dimensions to read from the bottom of the sheet and this is finding considerable acceptance in other industries.

Dimensions placed between views or outside of views are easier to read, especially if the views have a large amount of detail.

Do not repeat a dimension unless there is a real and important reason for so doing.

Where a series of dimensions occur as on a shaft or in other cases where a check is desirable, the over-all dimension should be given.

Holes, rounds, etc., are located by their centers. Such dimensions are often marked C-C (center to center).

When a dimension line is very short, arrowheads should be reversed and the figure placed between, or outside, the extension lines.

Symbols for feet, inches, degrees, and to indicate a finished or machined surface, are shown at B on Plate 34. Present practice where all dimensions are in inches is tending more and more to omitting the symbol for inches.

The purpose of dimensions, which is to specify sizes, should be kept in mind and should be made as complete and accurate as the description of shape.

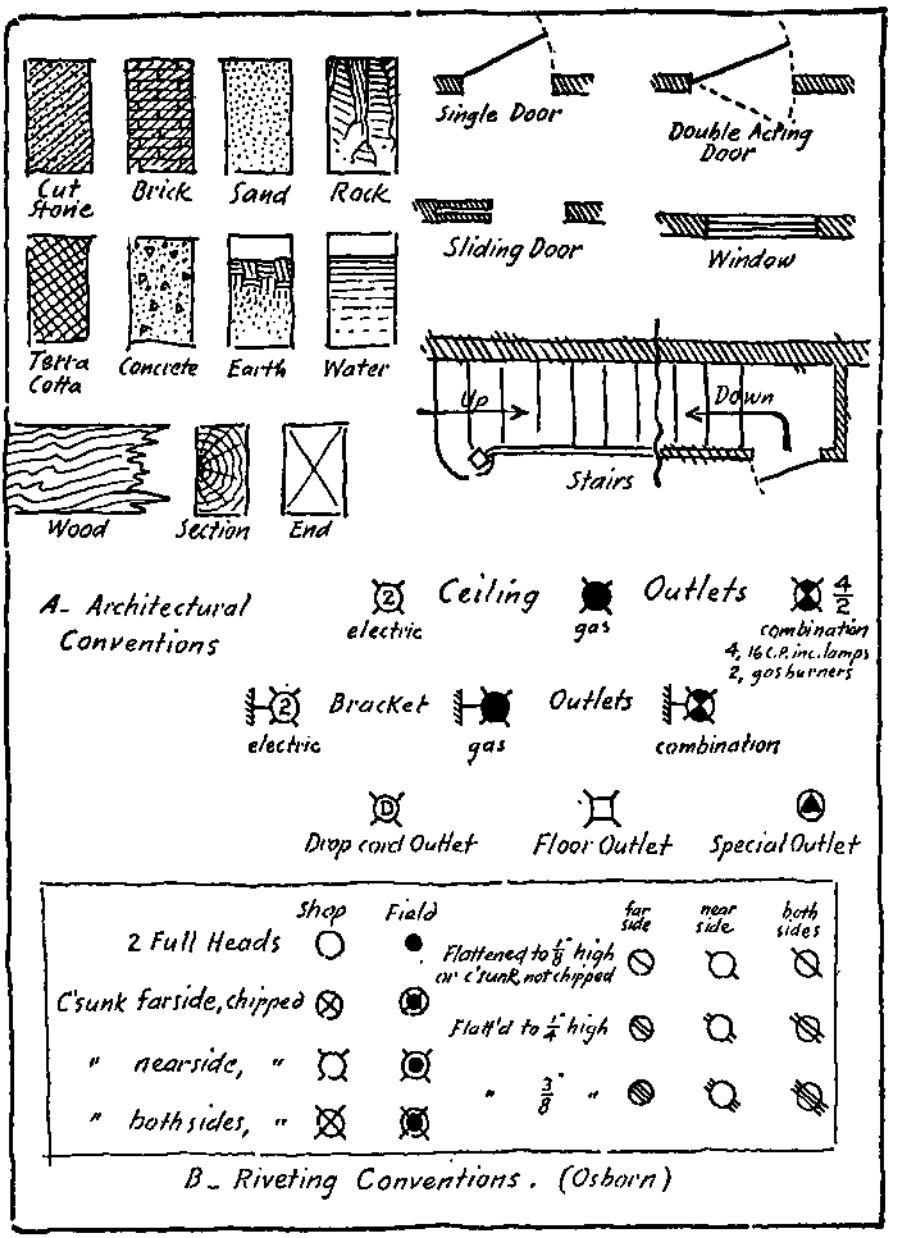


PLATE 35. Architectural and Structural Conventions.

Scale Drawings——Freehand sketches are made in estimated proportion without the use of a scale. Buildings, ships, bridges, plans, maps, and the like must be represented many times smaller than their size. In order to have proportions accurate an object may be drawn ½, ¼, $^1/_8$, or $^1/_{16}$ of the actual size or scale. Half scale means that each half inch on the drawing represents a full inch of the object and similarly for other fractions. Some draftsmen use special scales which are made for this purpose. When practicable, however, a full size drawing is to be preferred. Very small pieces, as the works of a watch, delicate machinery, etc., are drawn to an enlarged scale. Whether enlarged or reduced, the scale must always be given on a drawing.

When sketching freehand the proportions should be judged by eye as closely as possible. The correct proportions of the three main dimensions, length, breadth, and thickness should be estimated first. The other distances will follow from them. The addition of the dimensions will specify the actual sizes.

Conventional Representations. — A number of conventional representations used on different kinds of drawings are shown on Plates 34 to 36. These are not intended to be complete but will suggest some of the types of symbols used for various purposes.

It will be noted that most of the symbols have a certain resemblance to the features which they represent. This scheme makes the reading of such drawings easier than if arbitrary symbols were used.

Some conventions, notably electrical and piping, are largely diagrammatic, and a few lines are adequate to serve the necessary purpose. While practice is not uniform most symbols can be easily read. When necessary an explanatory diagram is shown on the drawings, as in the case of maps of the United States Geological Survey.

Working Sketches. — The subjects treated in this and the preceding chapters are a preparation for making use of the graphic language in the form of idea or invention sketches, executive

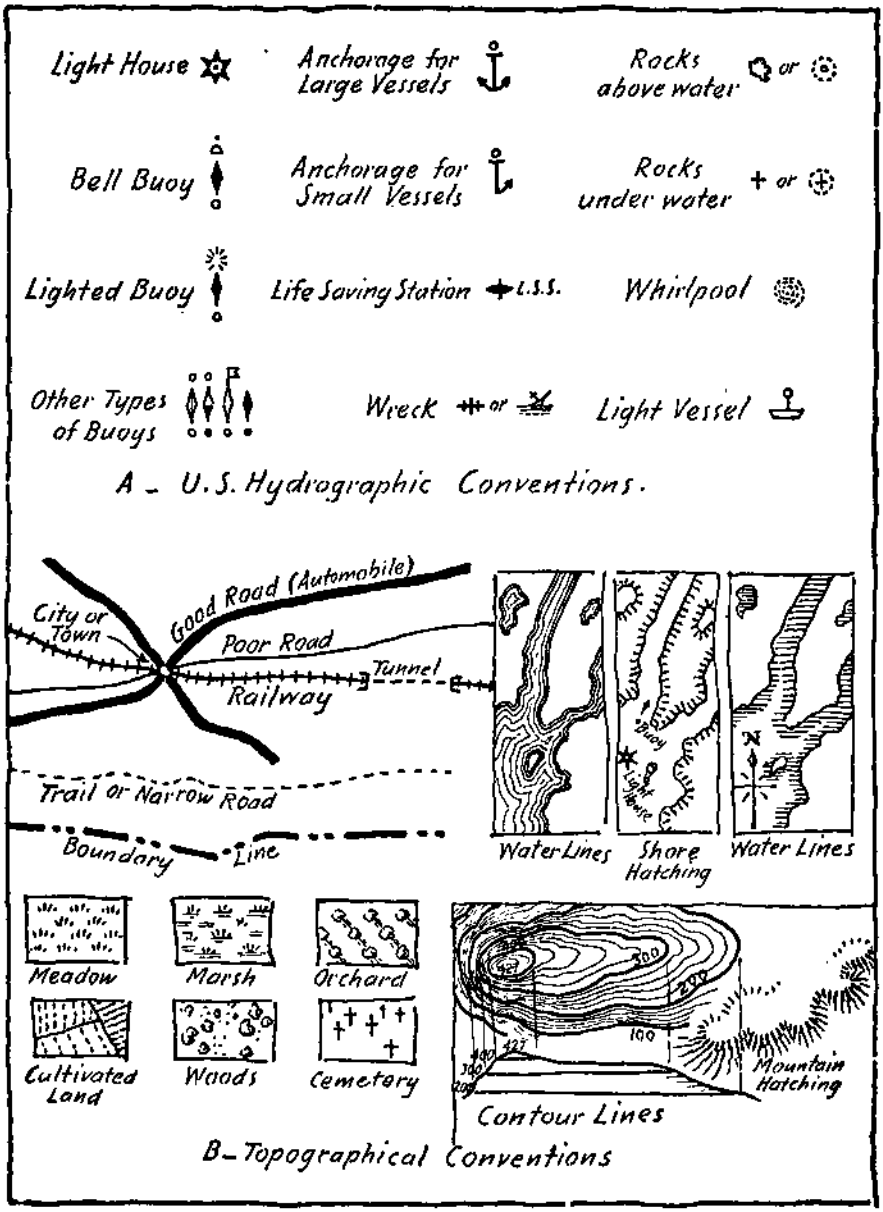


PLATE 36. Hydrographic and Topographical Conventions.

sketches, explanatory sketches, interpretation sketches, preliminary sketches, diagram sketches, working sketches, and other freehand graphic descriptions.

A shop sketch is probably the most definite for practice purposes as well as being a very useful type of sketch. The steps in the making of such a sketch are as follows:

Consider the object or construction to be described.

Choose the necessary views.

Outline or block-in the views.

Complete the details.

Sketch all the extension and dimension lines.

Fill in the dimensions. If sketch is made from machine or part, take measurements and insert each measurement in its place as soon as taken.

Add any notes which may be necessary to give information as to material, number required, kind of finish, etc.

Each of the steps above should be taken and completed in the order specified.

Problems. — The problems which follow will give additional practice in the work of the preceding chapters. They should, however, be carried to completion with dimensions and proper views, using sections or conventional treatment where necessary so that the result will be a practical and complete sketch for the conditions indicated.

PROBLEMS 1 to 4, PLATE 37. — Make complete working sketches for each piece.

PROBLEMS 5 to 8, PLATE 38. — Make complete working sketches for each piece.

PROBLEMS 9 to 12, PLATE 39.—Make complete working sketches for each piece.

PROBLEMS 13 to 16, PLATE 40. — Make complete working sketches for each piece.

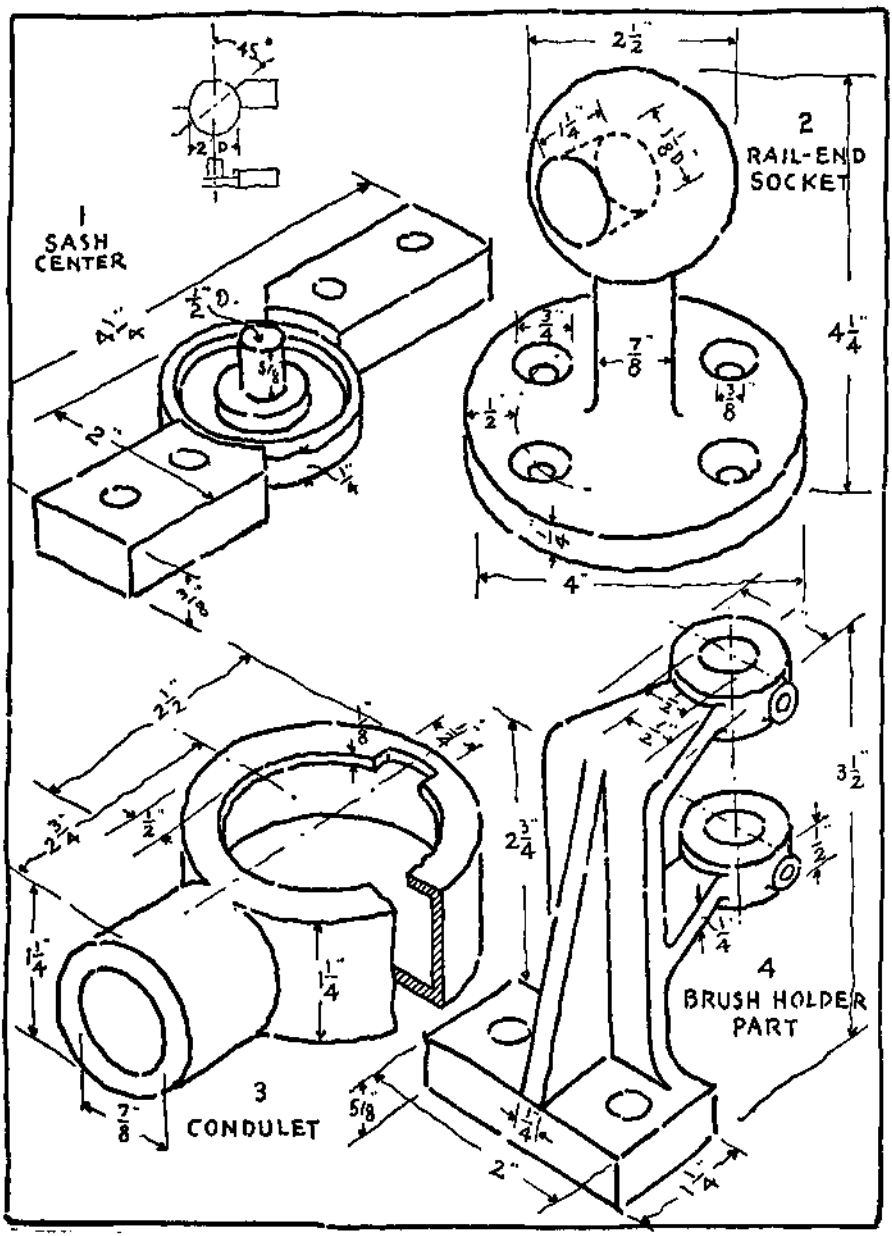


PLATE 37. Problems 1 to 4.

PROBLEMS 17 to 20, PLATE 41. — Make complete working sketches for each piece.

PROBLEMS 21 to 24, PLATE 42. — Make complete working sketches for each piece.

PROBLEMS 25 to 28, PLATE 43. — Make complete working sketches for each piece.

PROBLEMS 29 to 31, PLATE 44.—Make working sketches of a part of each of the two hand rails. Make a working sketch of a CHAIR LEG.

PROBLEMS 32 to 35, PLATE 45. — Make complete working sketches using sections as indicated.

PROBLEM 36, PLATE 46. — Make complete working sketch of the DECK PLATE, one view in section.

PROBLEM 37, PLATE 46.—Make a sectional view of the LONGITUDINAL BULKHEAD using the " blacked-in " section as shown for thin material on Plate 30.

PROBLEMS 38 and 39, PLATE 47.—Make sectional assembly views of the UNION and of the SPARK PLUG.

PROBLEMS 40 to 42, PLATE 48. — Make complete working sketches of each piece.

PROBLEMS 43 and 44, PLATE 49. — Make general assembly sketches as indicated in the small sketches.

PROBLEMS 45 to 50, PLATES 50 to 52. — Make general assembly sketches as indicated in the small sketches.

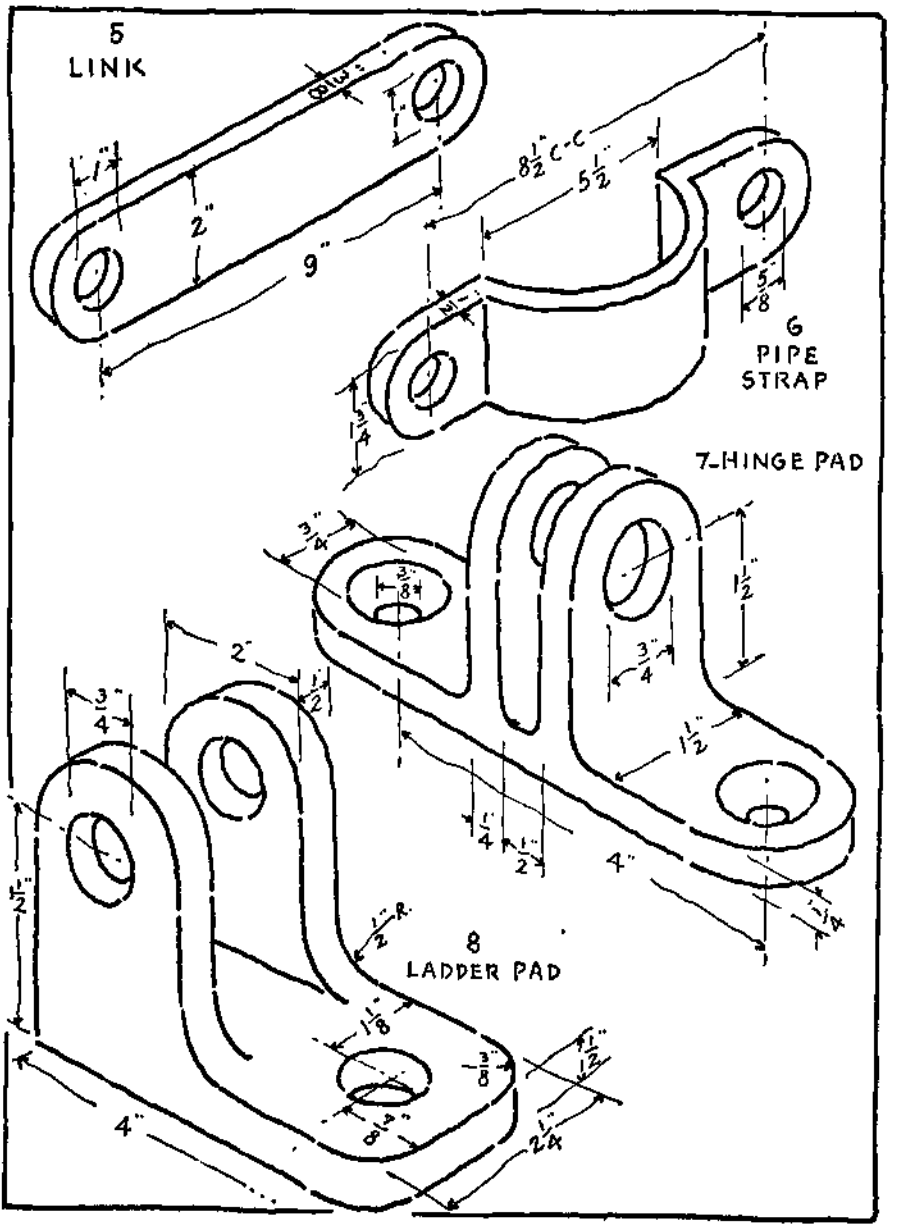
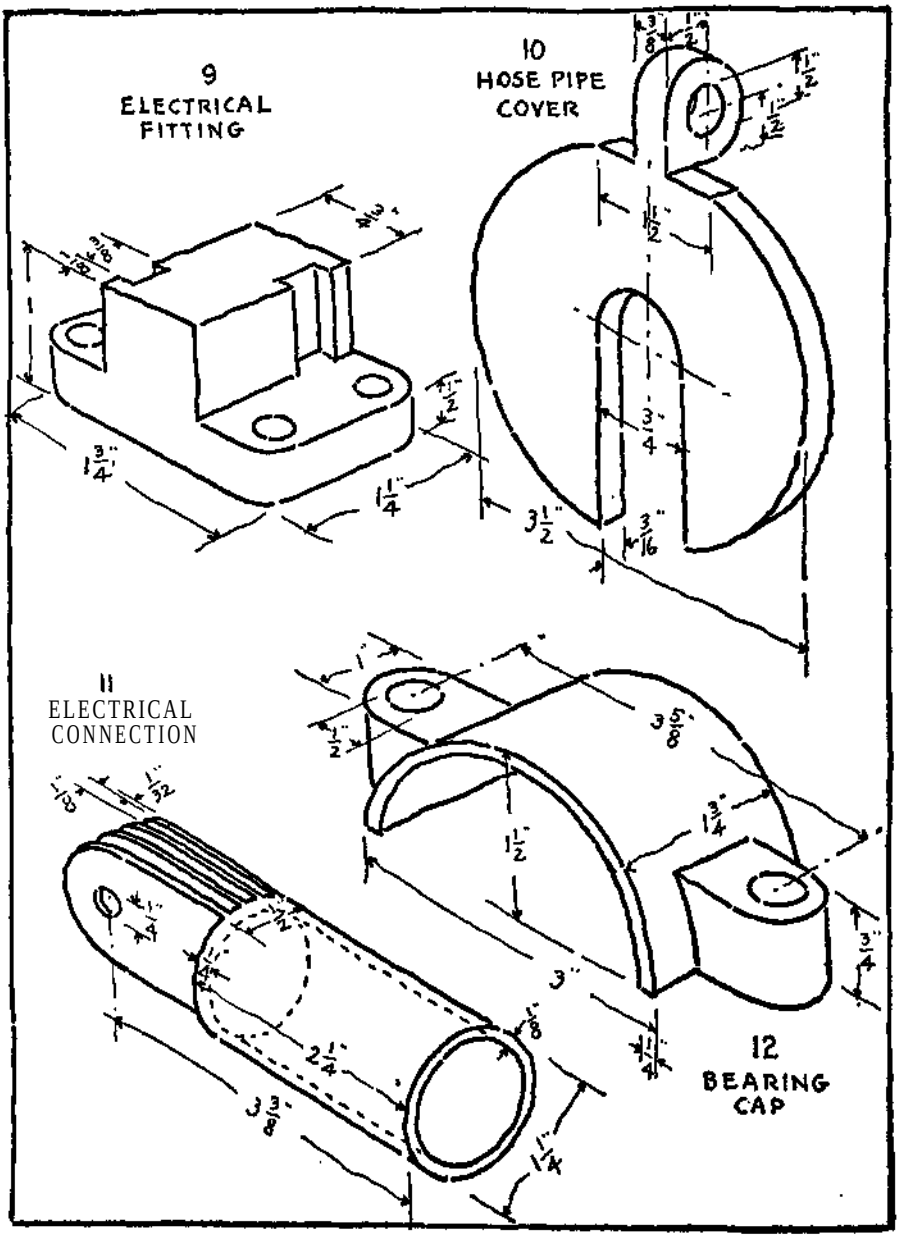


PLATE 38. Problems 5 to 8.



PLATS 39. Problems 9 to 12.

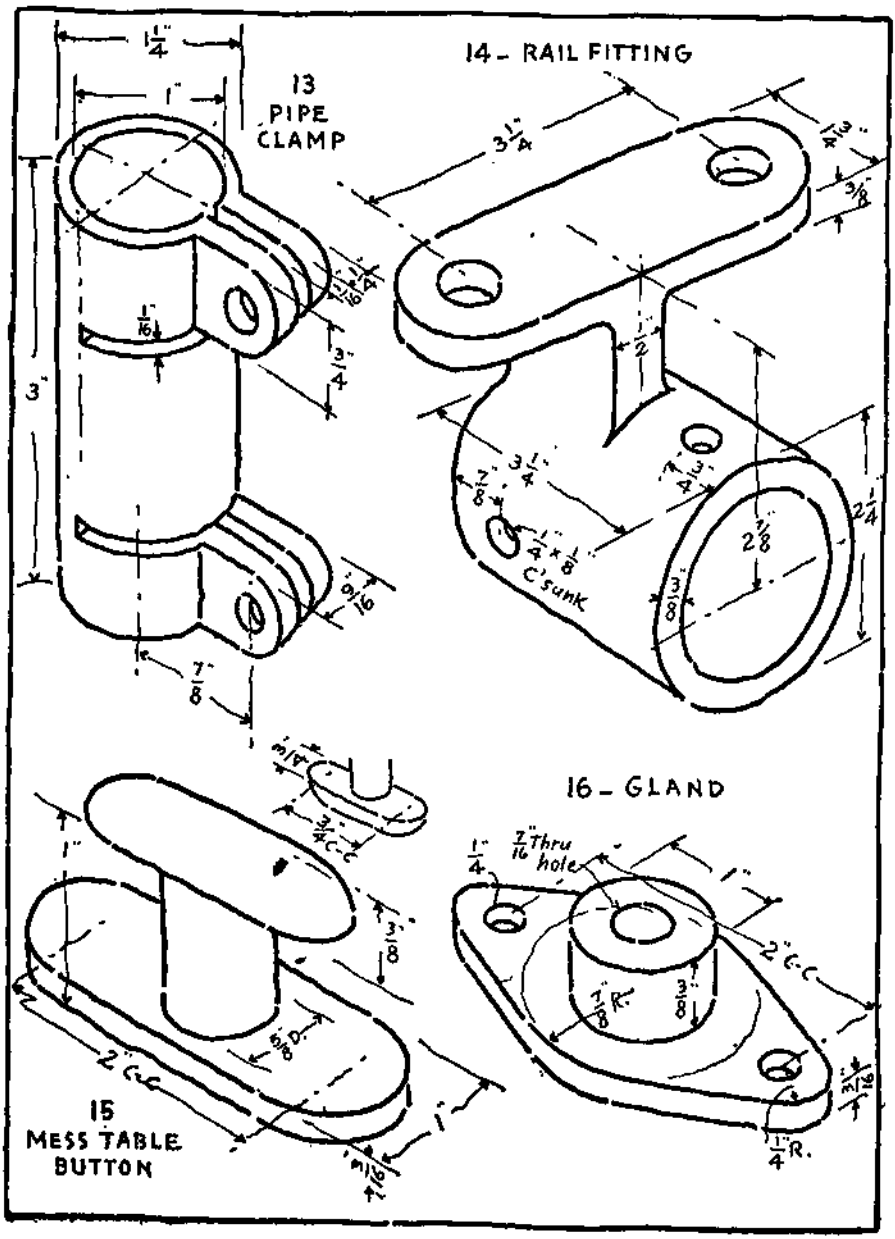


PLATE 40. Problems 13 to 16.

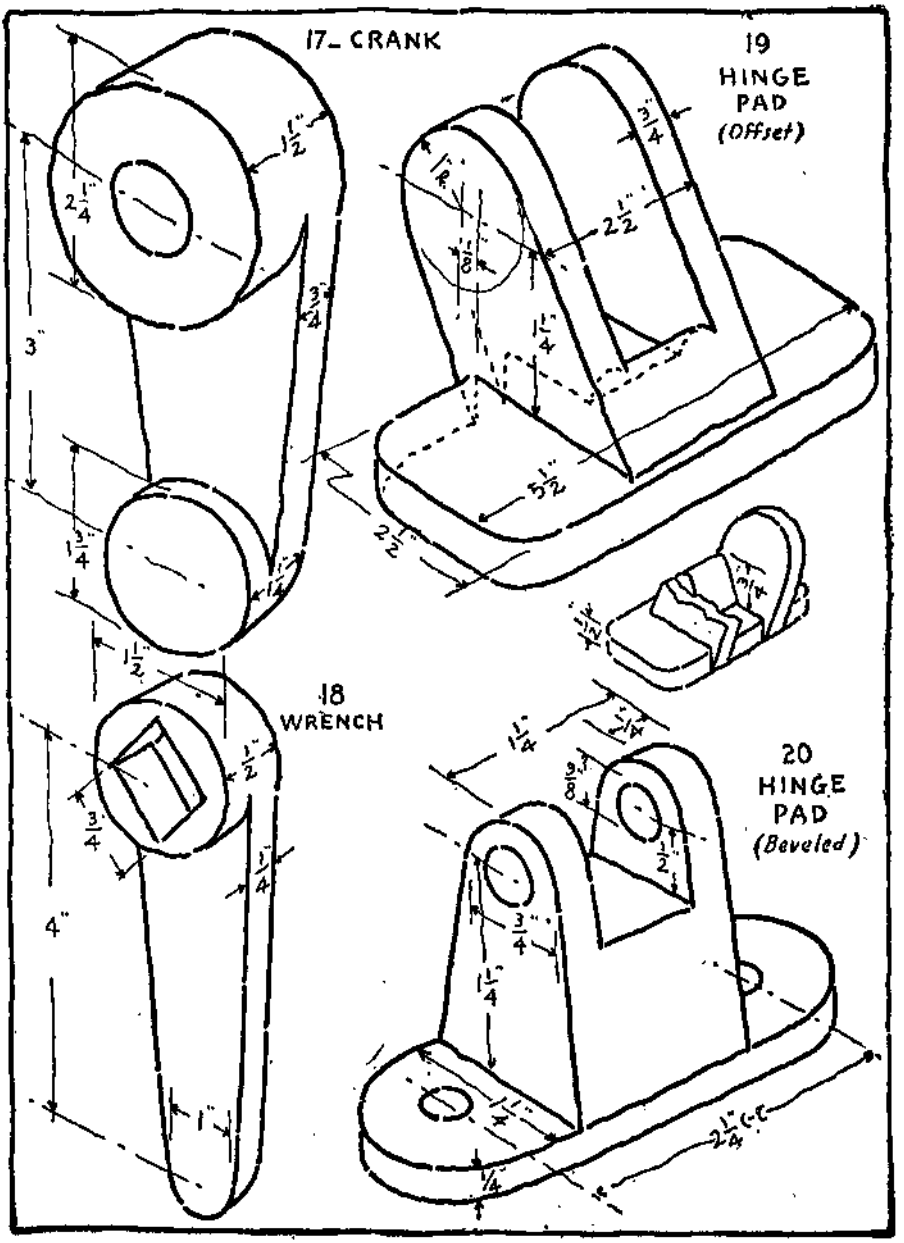


PLATE 41. Problems 17 to 20.

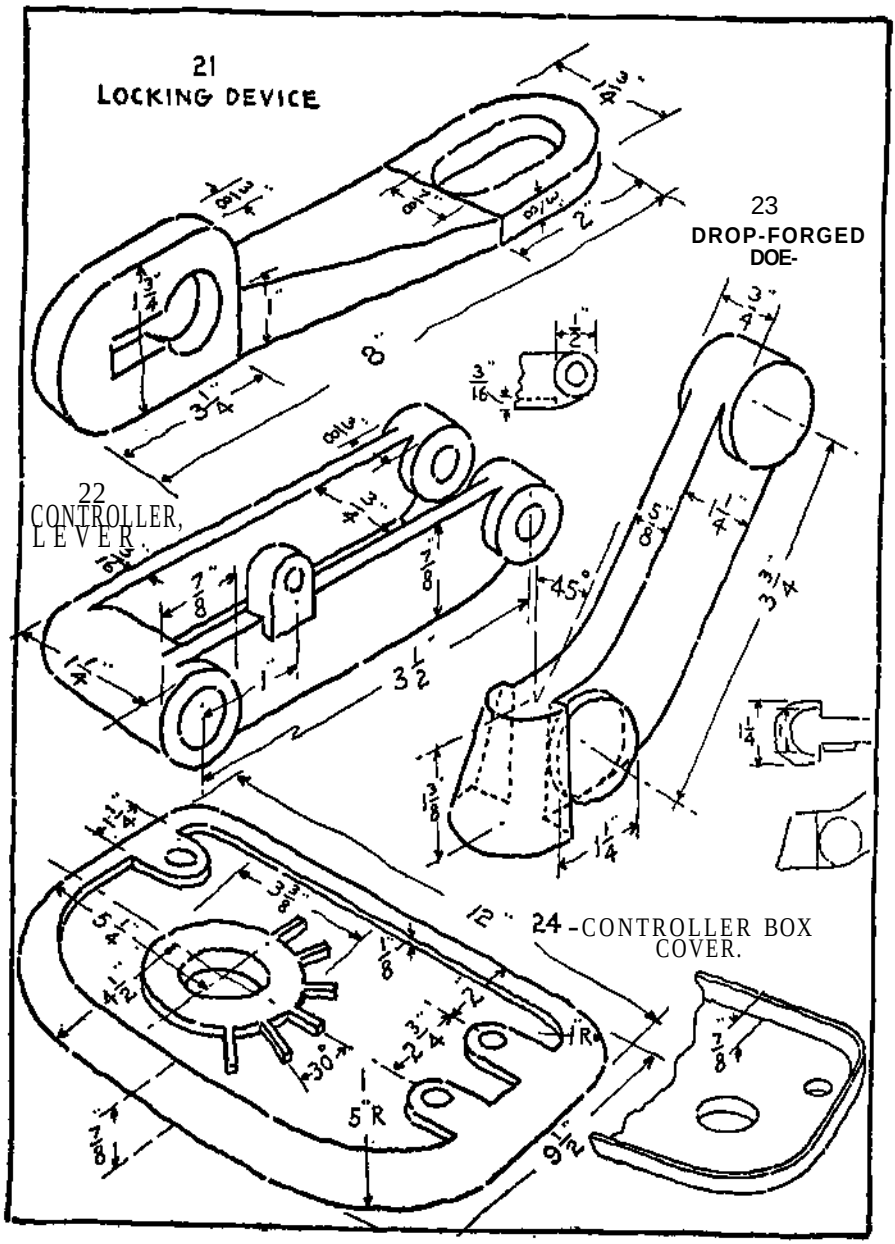


PLATE 42. Problems 21 to 24.

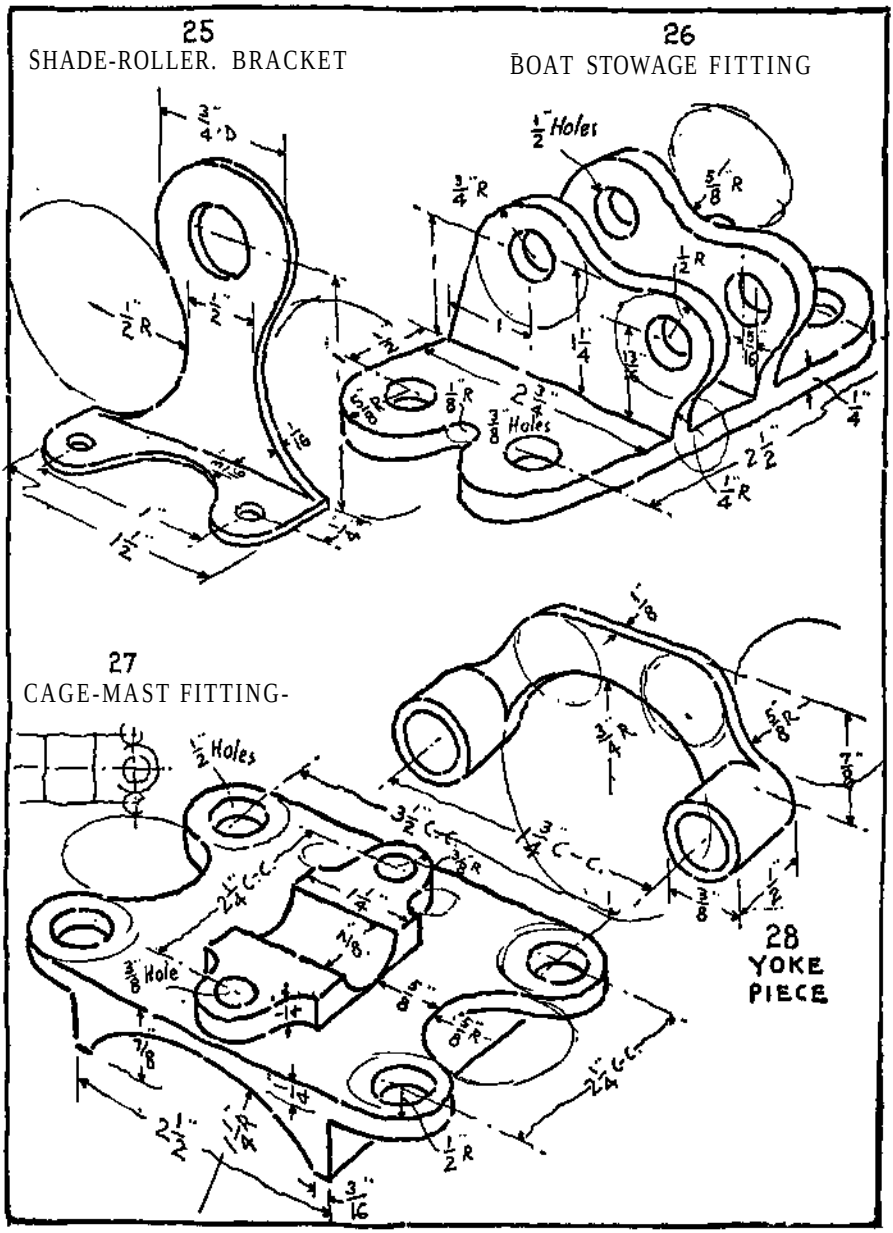


PLATE 43. Problems 25 to 28.

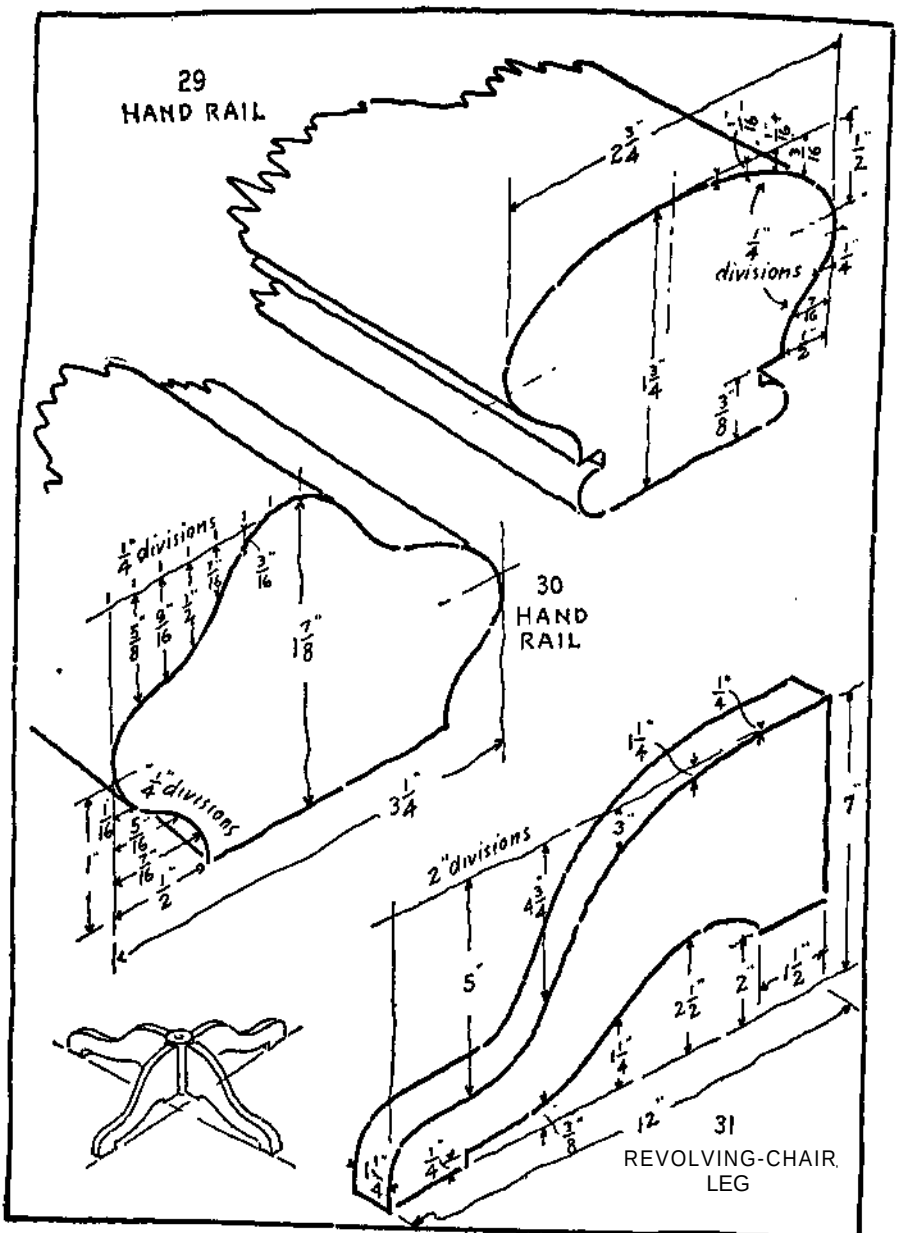


PLATE 44. Problems 29 to 31.

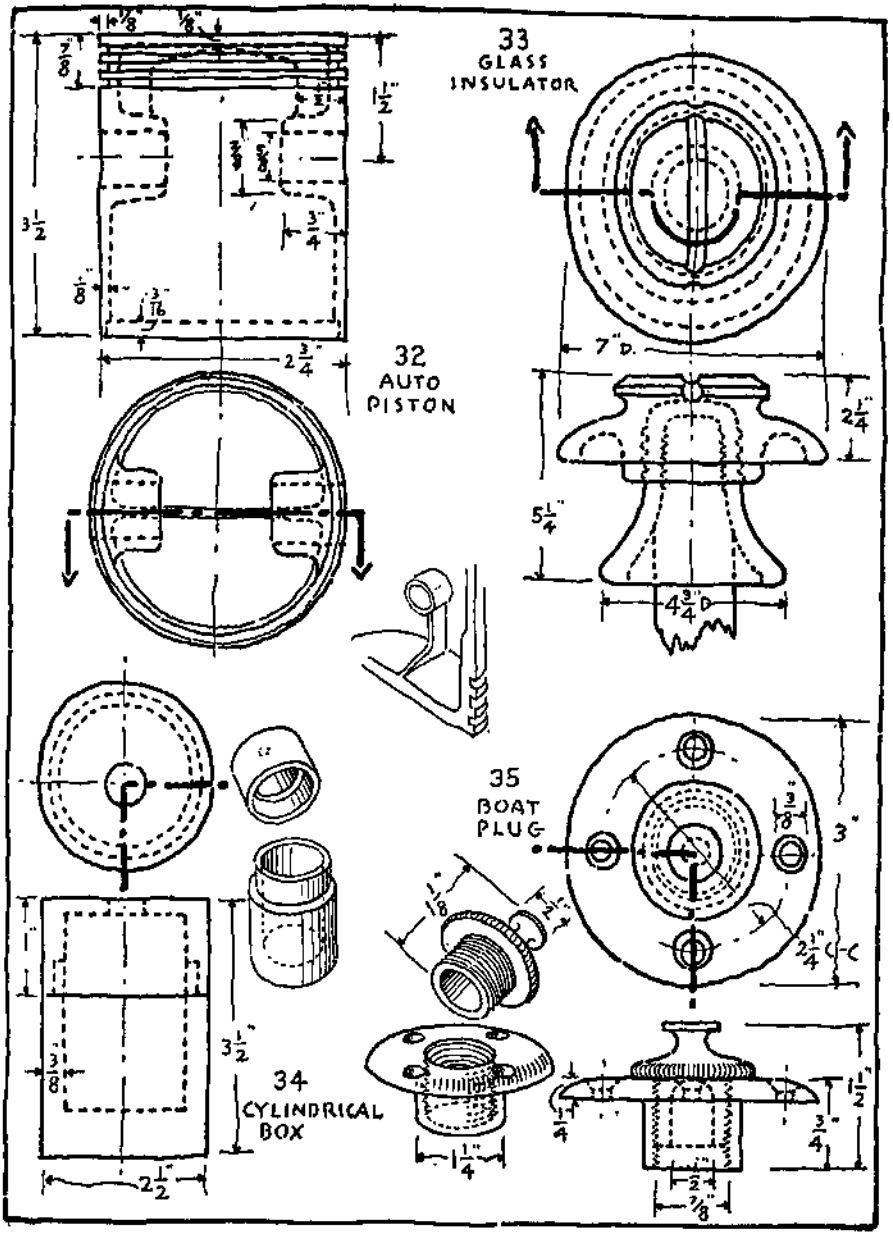


PLATE 45. Problems 32 to 35.

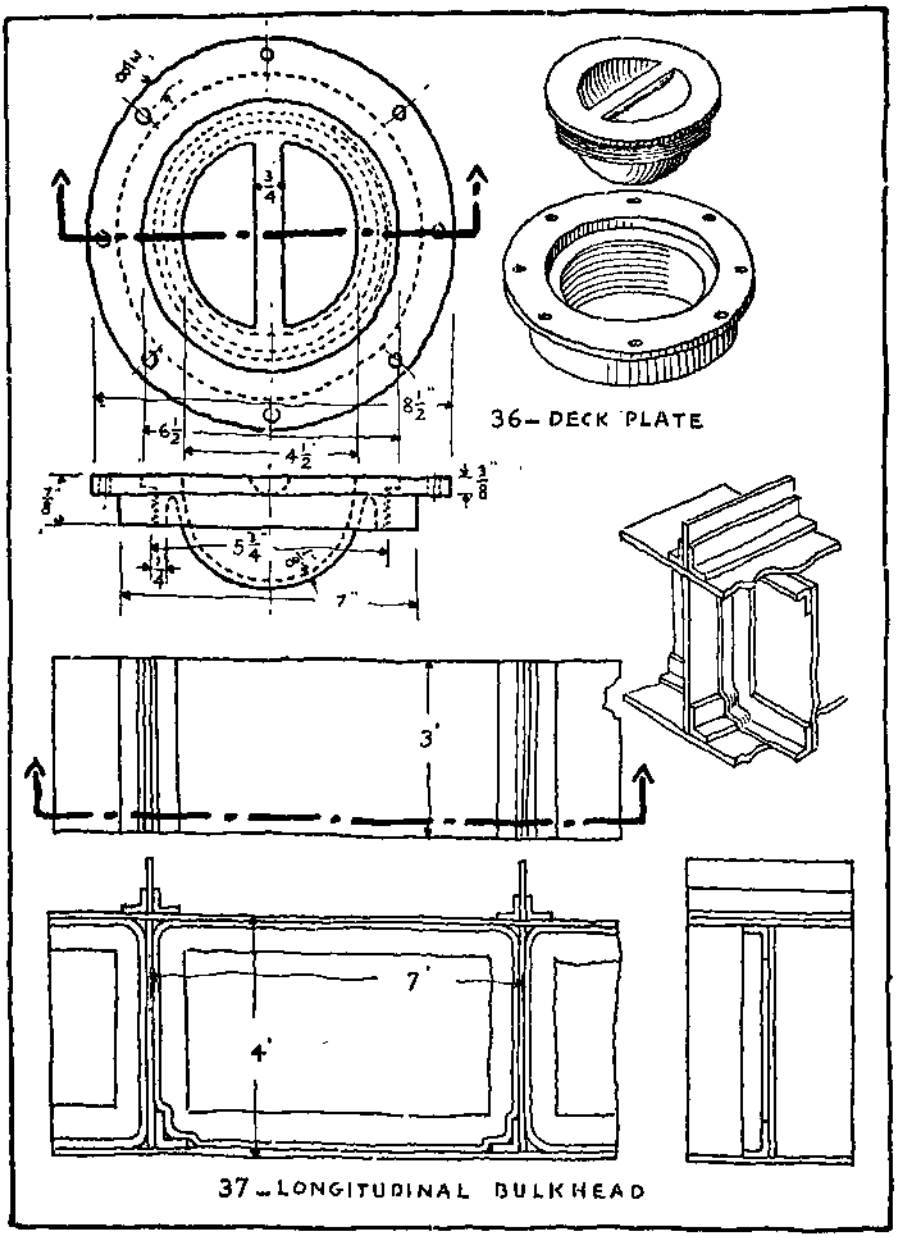


PLATE 46. Problems 36 and 37.

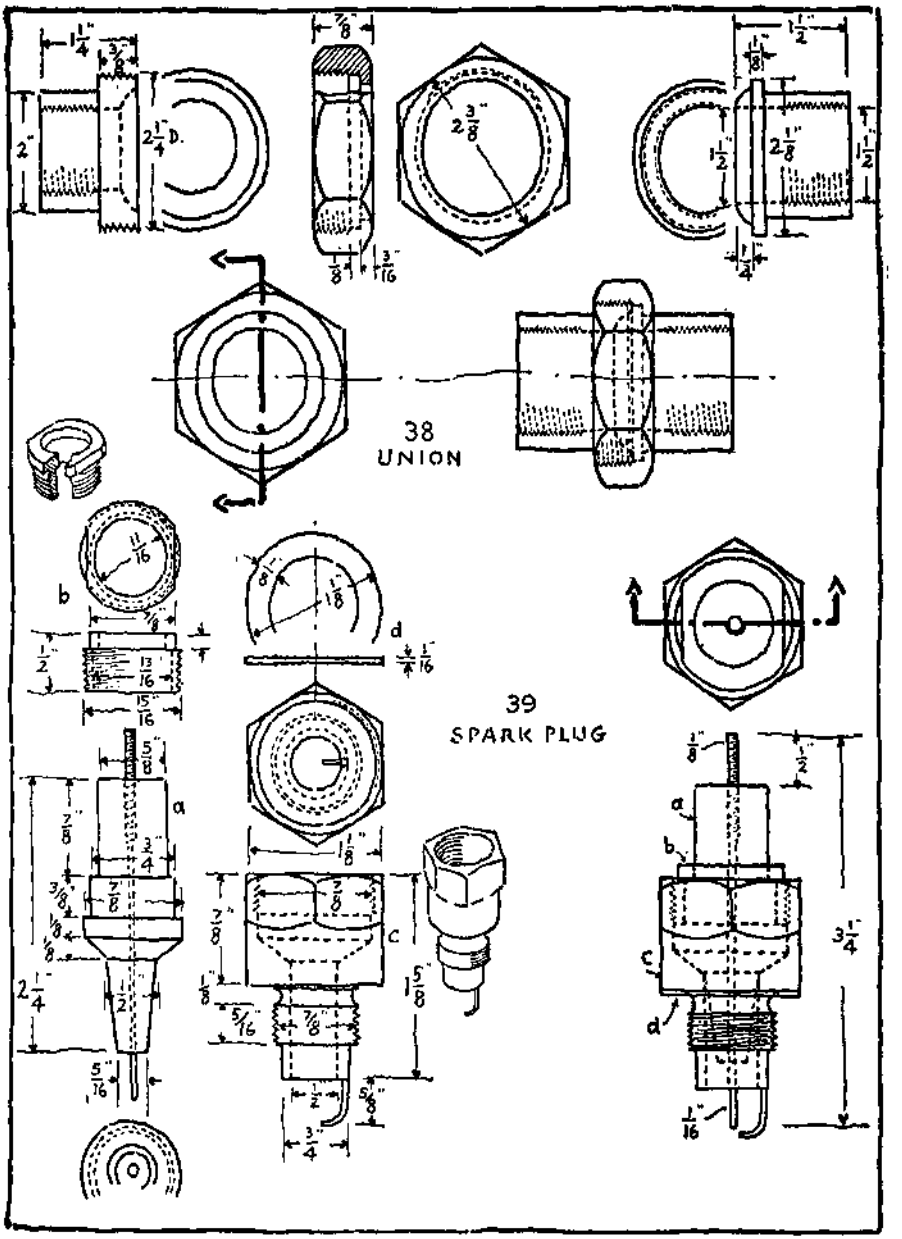


PLATE 47. Problems 38 and 39.

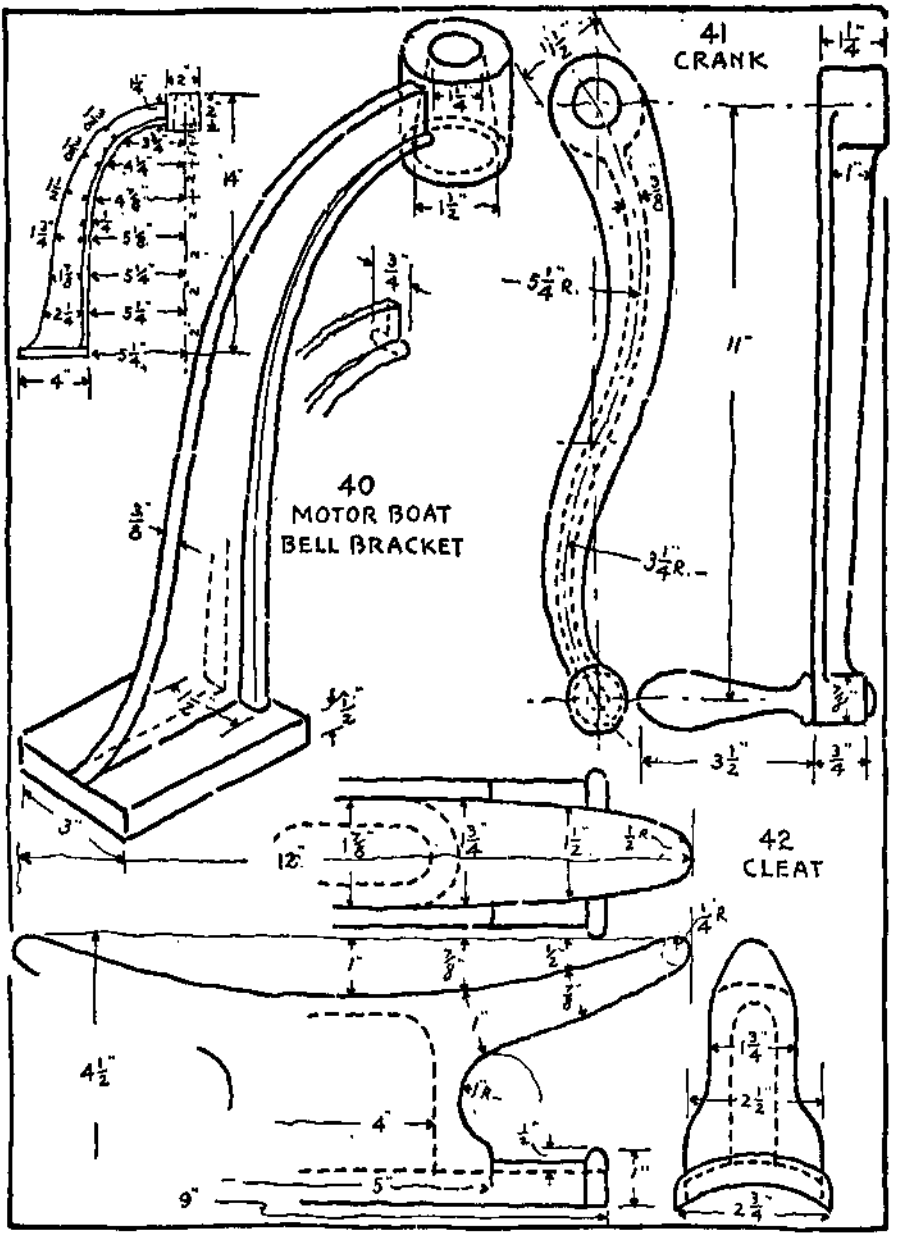


PLATE 48. Problems 40 to 42.

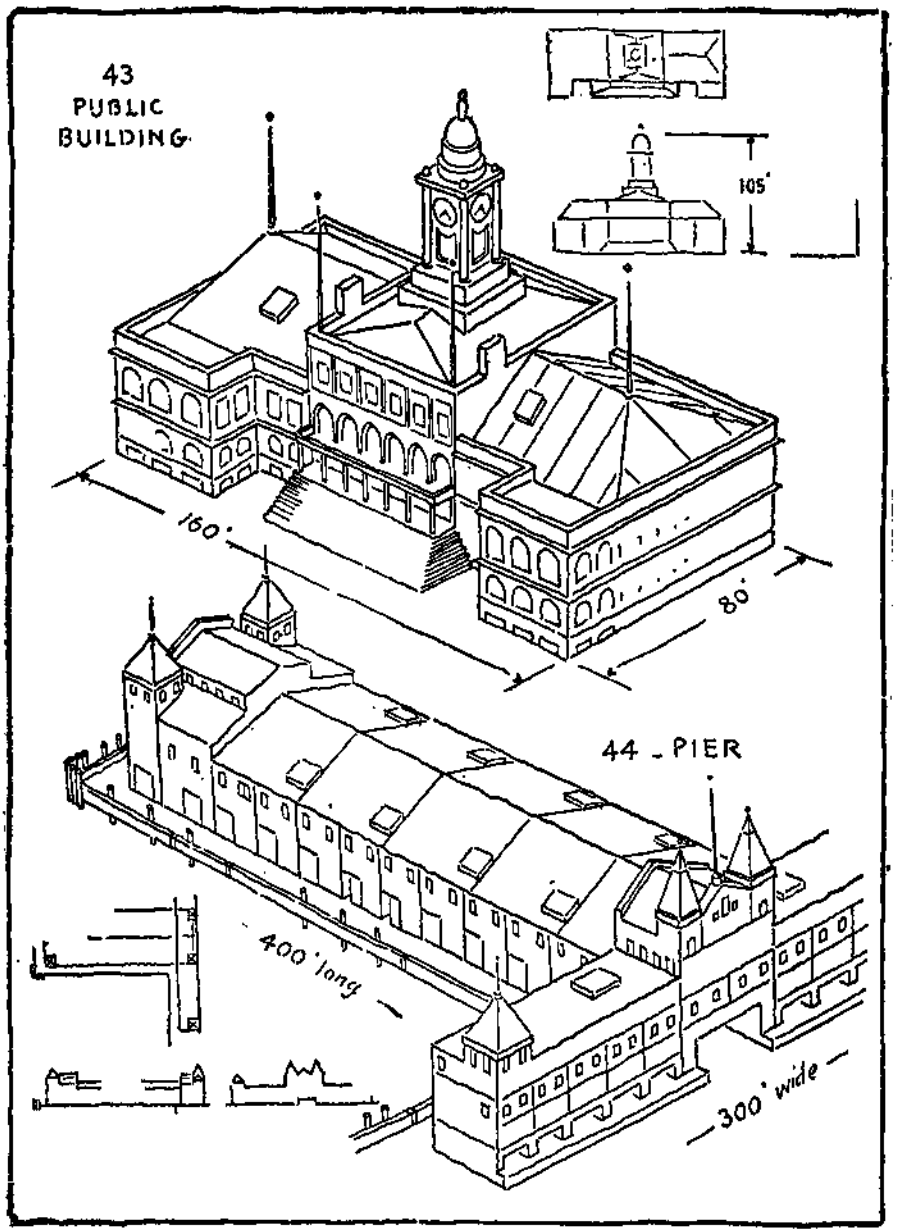


PLATE 49. Problems 43 and 44.

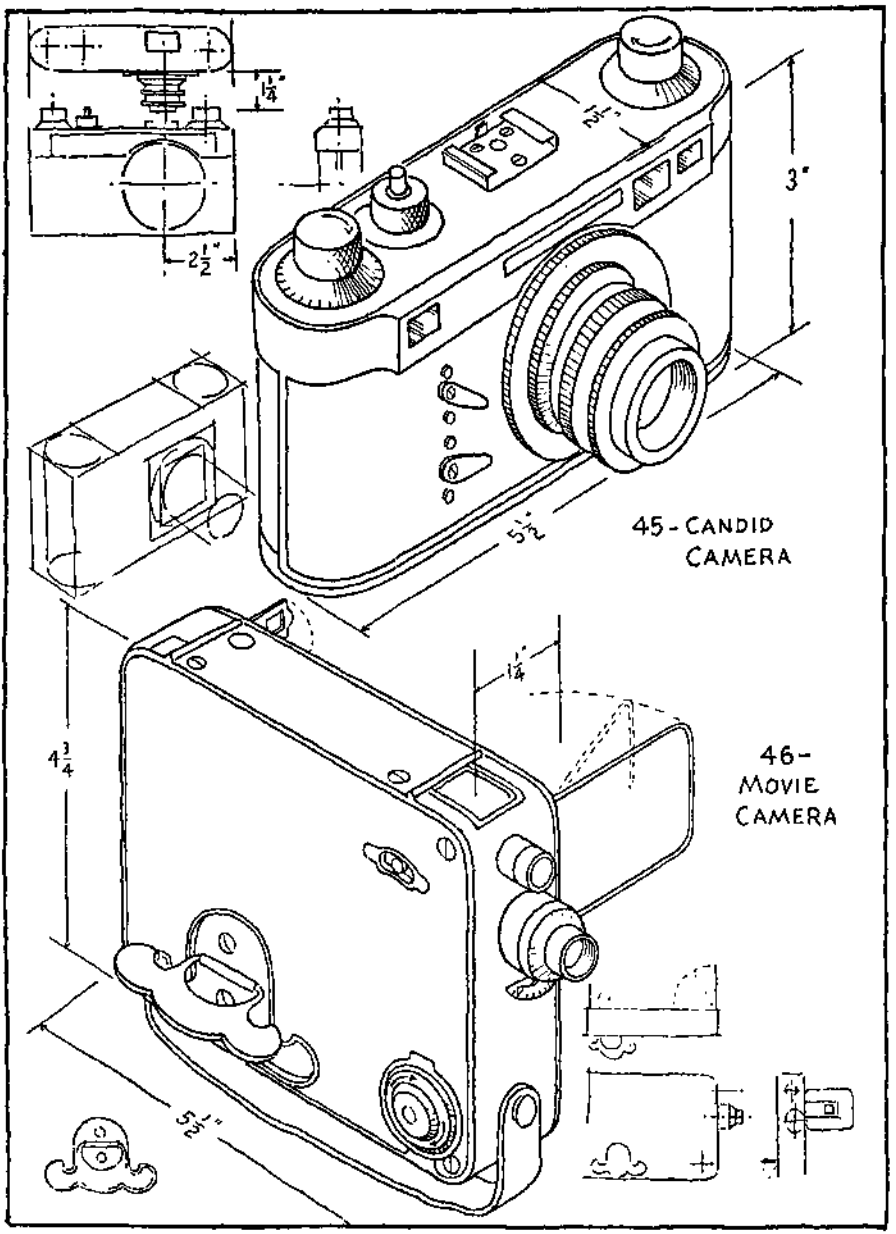


PLATE 50. Problems 45 and 46.

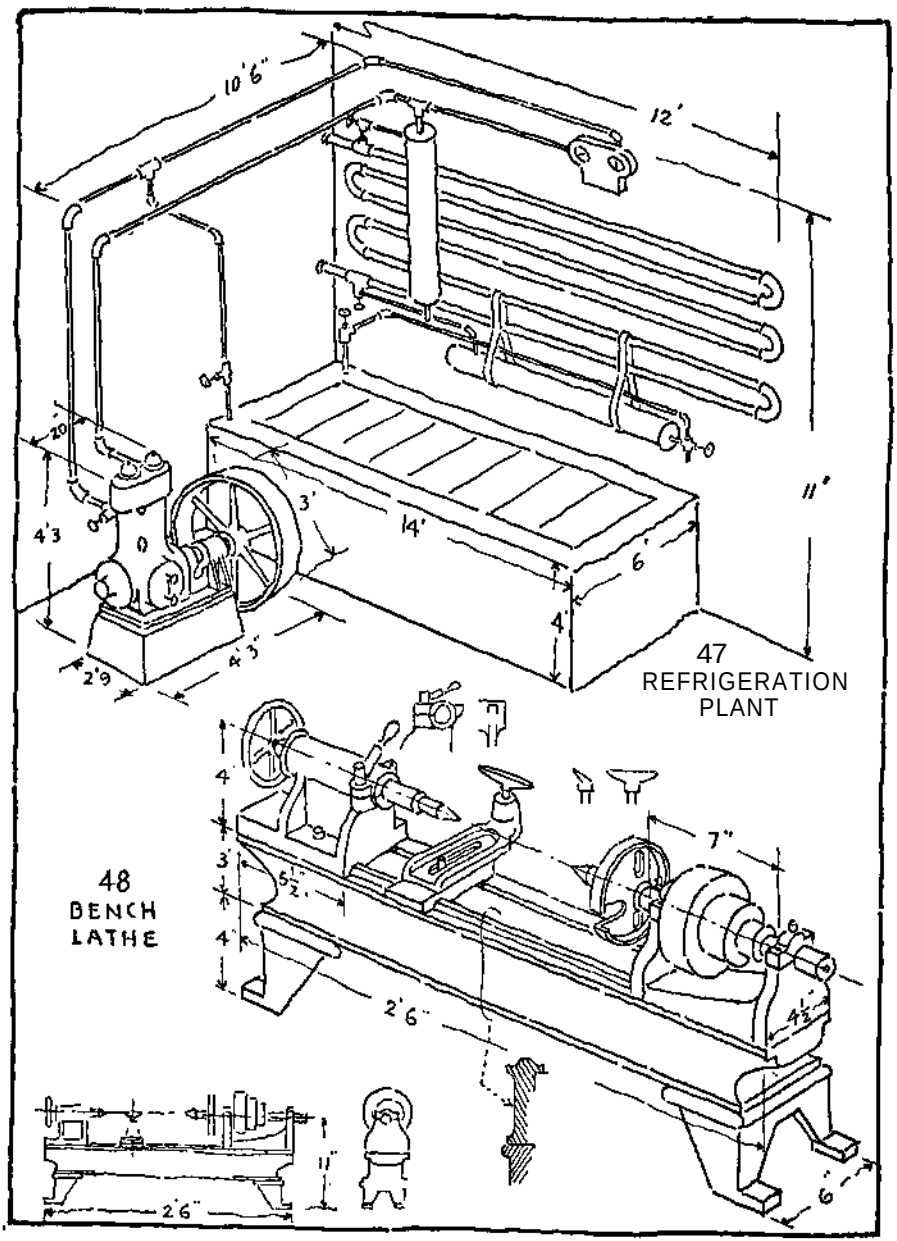


PLATE 51. Problems 47 and 48.

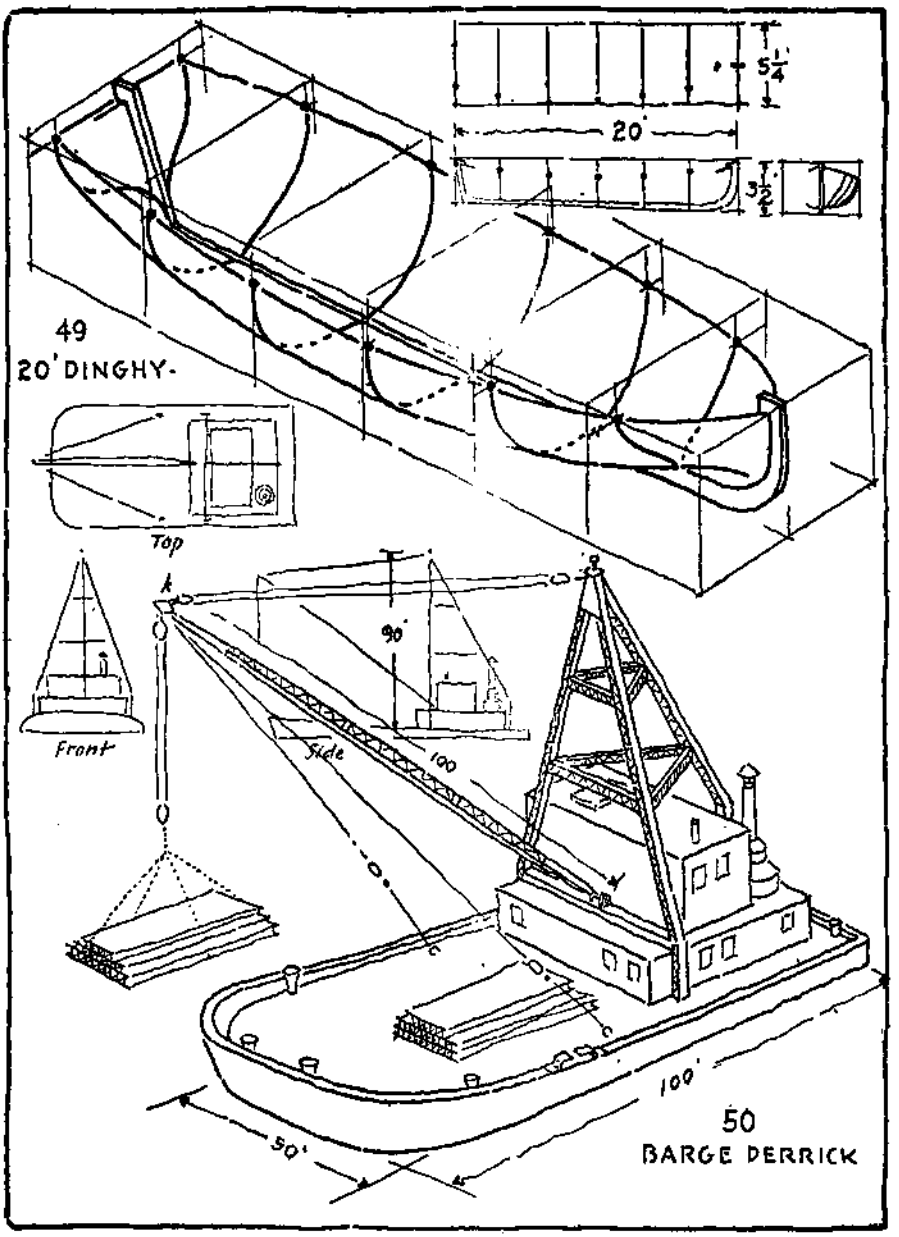


PLATE 52. Problems 49 and 60.

CHAPTER VIII

ISOMETRIC SKETCHING

MEMORANDA

CHAPTER VIII

ISOMETRIC SKETCHING

Kinds of Pictorial Representation. — The most satisfactory method of representation for mechanical purposes is by orthographic views. These are made and used by draftsmen and engineers in all countries. A knowledge of the principles of projection and of conventional practice is, of course, necessary for a thorough understanding and intelligent use of such drawings.

When anyone who is not familiar with these principles must be informed, other methods of representation are desirable. In the examination of a blueprint or its explanation to a customer or investor, the business man, financier, and promoter often finds himself at a disadvantage because of his inability to visualize quickly from the orthographic views. There are times when the shape of a piece of machinery is such that even technical men find difficulty in forming a mind's eye picture. This may apply to the whole drawing but generally it is only a part of the construction.

As an aid in overcoming the difficulties enumerated, various methods of pictorial representation are employed such as perspective, isometric, oblique, and cabinet drawing. All of these give a picture more or less like a photograph, showing the top, front, and side in one view instead of three as in orthographic projection.

Isometric drawings while less pleasing than perspective are based upon simple principles which can be easily understood. They are satisfactory for sketching mechanical constructions as can be seen by an examination of the illustrations in this book,

Uses of Pictorial Representation——Pictorial drawings have a very limited field of use compared with projection drawings. However, they have a distinct use in the following cases:

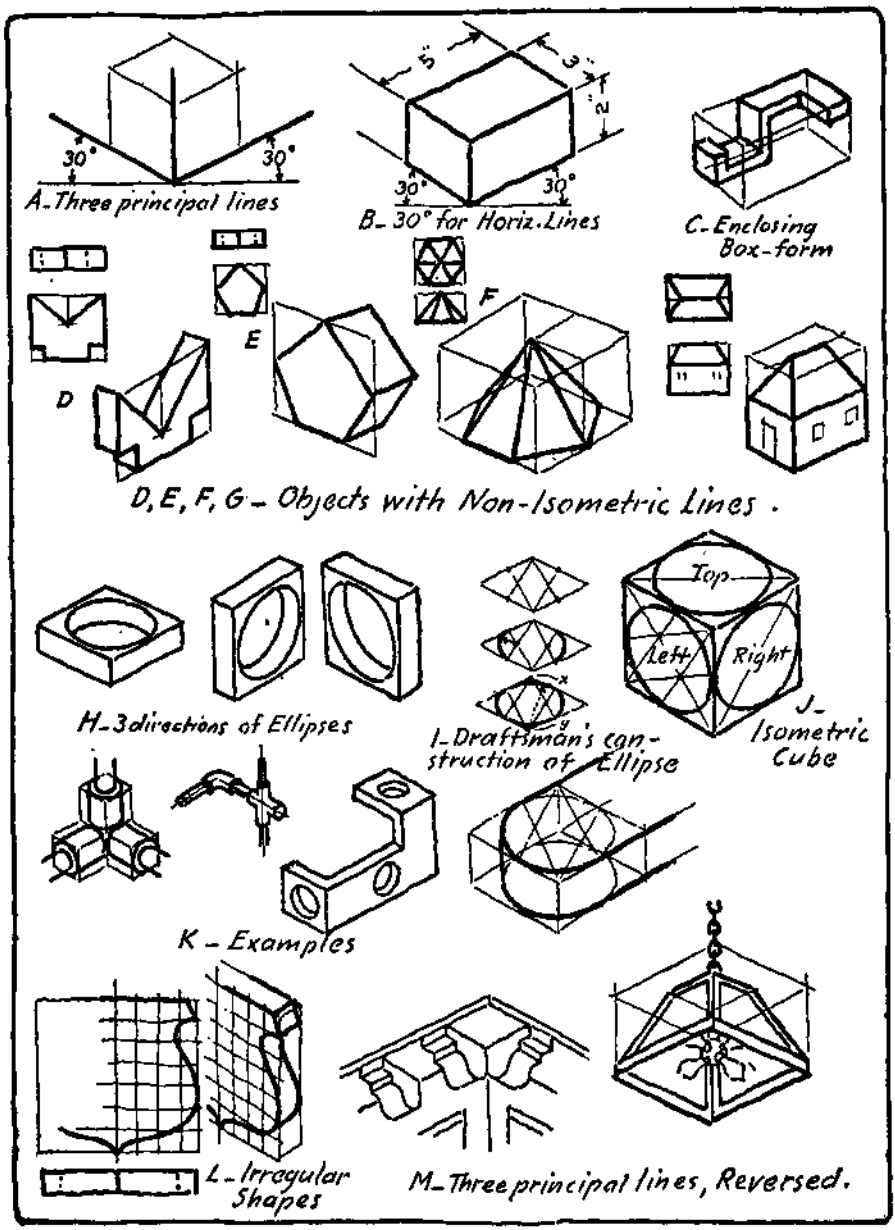


PLATE 63. Isometric Views.

For the explanation of orthographic views to non-technical men or others who are uninformed.

For Patent Office drawings of new inventions, especially if the device or design is complex.

For drawings used to promote the sale of a new device, machine, etc.

For plumbing, piping and refrigerating system drawings. Isometric drawings show the positions of the various features definitely and require very little time for reading.

For supplementing the working drawings in making clear details of interior building construction, woodwork, and joinery.

For illustrating trade catalogs, advertising matter and other literature which must be easily read or for the use of non-technical men.

Principles of Isometric Drawing. — For sketching purposes a few simple principles will give the information necessary for making isometric views. The object to be represented is placed in the position of a cube whch has three faces showing to an equal extent as at A of Plate 53. The three principal lines or axes form the basis of each drawing.

Two of these lines form angles of 30° with the horizontal and the third is vertical.

All measurements are made on the three principal lines, or lines parallel to them as at B, Plate 53. For sketches estimate distances on these lines. It is often convenient to consider the objects as enclosed in a box as at C.

Invisible edges are very seldom shown on isometric views as they tend to complicate the representation.

Non-isometric Lines—Lines which are not parallel to the three principal lines cannot be measured and are called non-isometric lines. Such lines are drawn by first locating their end points and then joining them as shown at D, E, F, and G, of Plate 53 and B of Plate 54. This is often conveniently done by enclosing the object in an imaginary box as indicated. Sometimes the ortho-

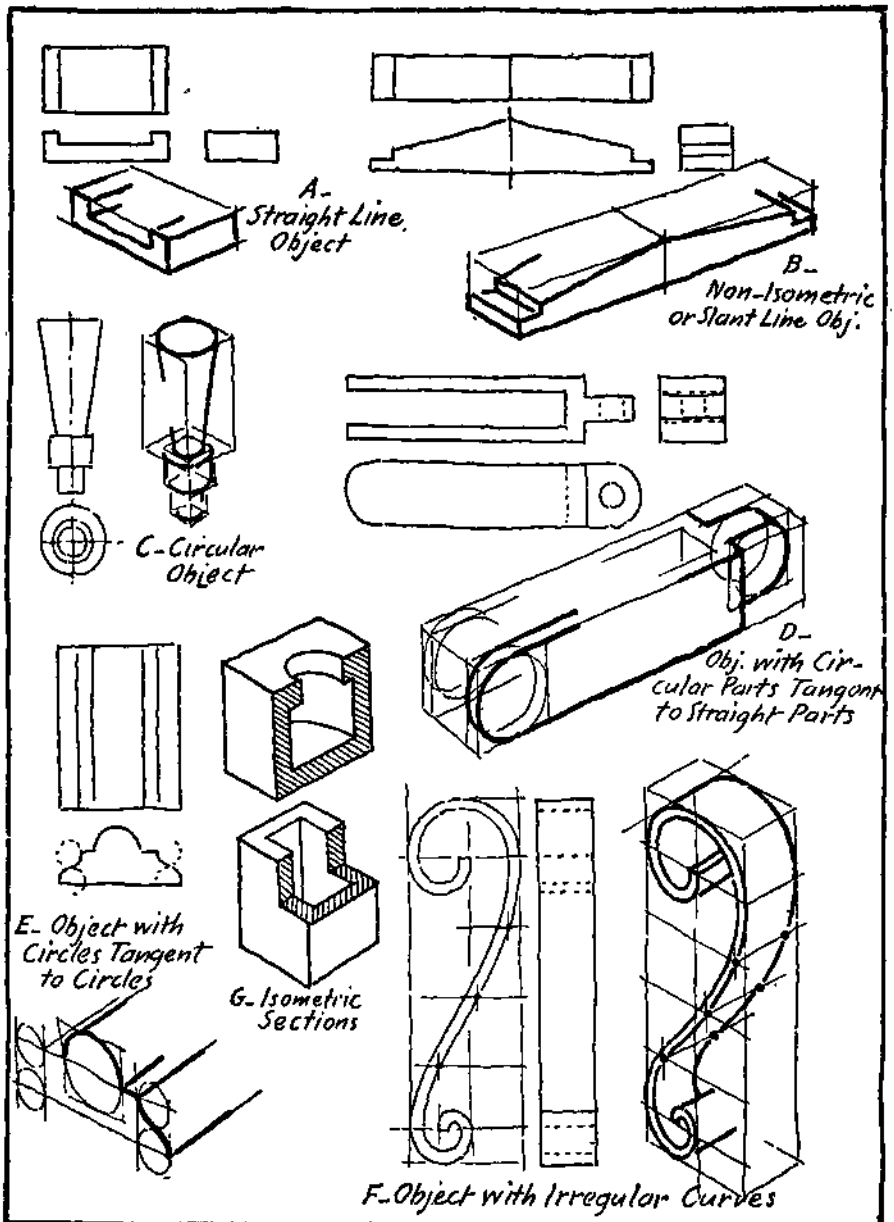


PLATE 54. " Blocking-in " for Isometric Views.

graphic views are made first as an aid in locating points on the isometric planes.

Circles and Curves. — Since the isometric planes are not parallel to the picture plane, it follows that circles will appear as ellipses. 4 circular hole will appear as at H, Plate 53. When drawing with instruments, an approximate ellipse may be constructed by circular arcs, as at I, Plate 53. From the obtuse angles draw lines to the centers of the opposite sides. Where these intersect will give centers for the small arcs. Complete the figure with arcs having centers at x and y. A similar construction can be used to advantage when sketching.

The appearance of the ellipses which represent circles on the three isometric planes can be understood by reference to the isometric cube shown at J, Plate 53. This is an important figure which should be remembered. Note that the long diameter of the top ellipse is horizontal. The left and right ellipses have their long diameters joining the acute angles of the enclosing face of the cube.

Parts of circles are constructed or sketched as parts of ellipses as indicated in the illustrations.

The isometric view of an irregular curve can be constructed by first making an orthographic view with offsets or squares. The enclosing figure can then be drawn in isometric with the same offsets or squares, which will locate points on the irregular curve, as at L, Plate 53 and F, Plate 54.

Isometric Sections. — Isometric views showing the interior details can be constructed in the same manner as for exterior views. In general the cutting planes are taken parallel to the faces of the isometric cube, Plate 54 at G.

Reversed Axes. — The axes may be reversed if necessary to show desired features as for an airplane, roof edge, coping or where important details are on an under surface. This is illustrated at M, Plate 53, which shows views from below.

Isometric Sketching Problems. — The exercises which follow are

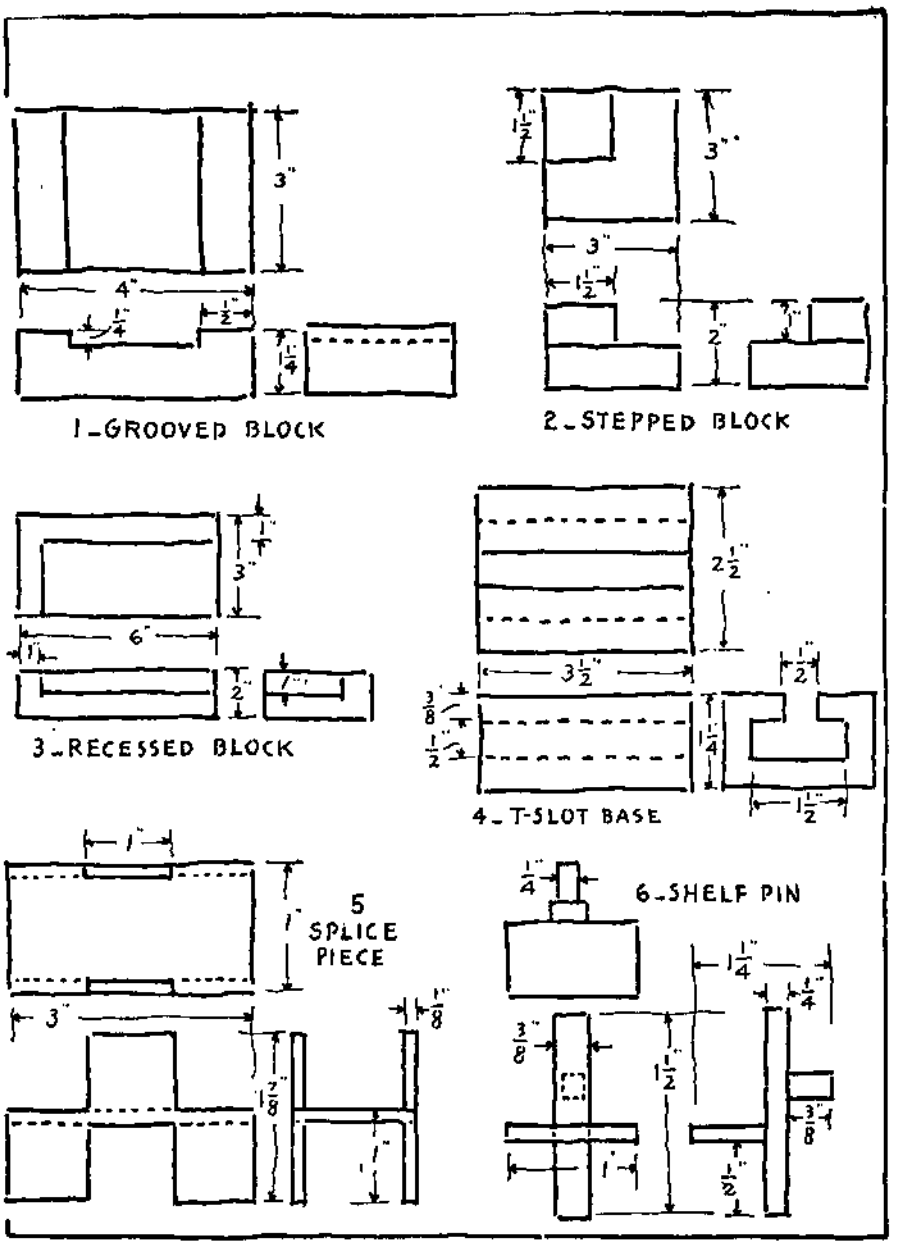


PLATE 55. Problems 1 to 6.

to be sketched as isometric views. First locate the three isometric axes or principal lines. Then block in an enclosing figure and proceed to fill in the details. System and order must be used and will make isometric sketching surprisingly easy. The method of procedure is illustrated on Plate 54.

Use layout No. 1 or No. 2 of Plate 3. Make construction lines very light so as to avoid too much erasing. It is not necessary that all the problems be worked but a selection should be made from each plate. Other problems may be selected from Chapter V if desired.

PROBLEMS 1 to 6, PLATE 55. — Sketch isometric views of each of the objects. Do not represent any invisible lines. Estimate distances along isometric lines.

PROBLEMS 7 to 12, PLATE 56. — Sketch isometric views of each of the objects shown. Construct imaginary boxes to contain the object and locate the ends of the non-isometric lines.

PRACTICE EXERCISES, PLATE 57. — This plate is for practice in sketching ellipses and should be fully understood before proceeding with the problems which follow. Always draw the enclosing straight line figure. The first row shows the isometric cube and the three faces separately. The second row shows four regular positions for half ellipses in a top plane. Representations in left and right faces are given in the third and fourth rows. Care must be taken when sketching half ellipses that they do not become half circles. Note the sharp bend as exaggerated in the small figure of each exercise. The last row gives applications of the practice exercises.

PROBLEMS 13 to 18, PLATE 58. — Sketch isometric views of each object. Construct imaginary boxes to enclose the objects and block-in for each circle. Do not make the sketches too small.

PROBLEMS 19 to 24, PLATE 59. — Sketch isometric views.

PROBLEMS 25 to 28, PLATE 60. — Sketch isometric views.

PROBLEMS 29 to 32, PLATE 61.—Sketch isometric views. Note the irregular curves which should be sketched as orthographic views and put into isometric by using squares or offsets as indicated at F on Plate 54.

PROBLEMS 33 to 37, PLATES 62 to 64. — Studies for practice in isometric representations of assembled constructions and machines.

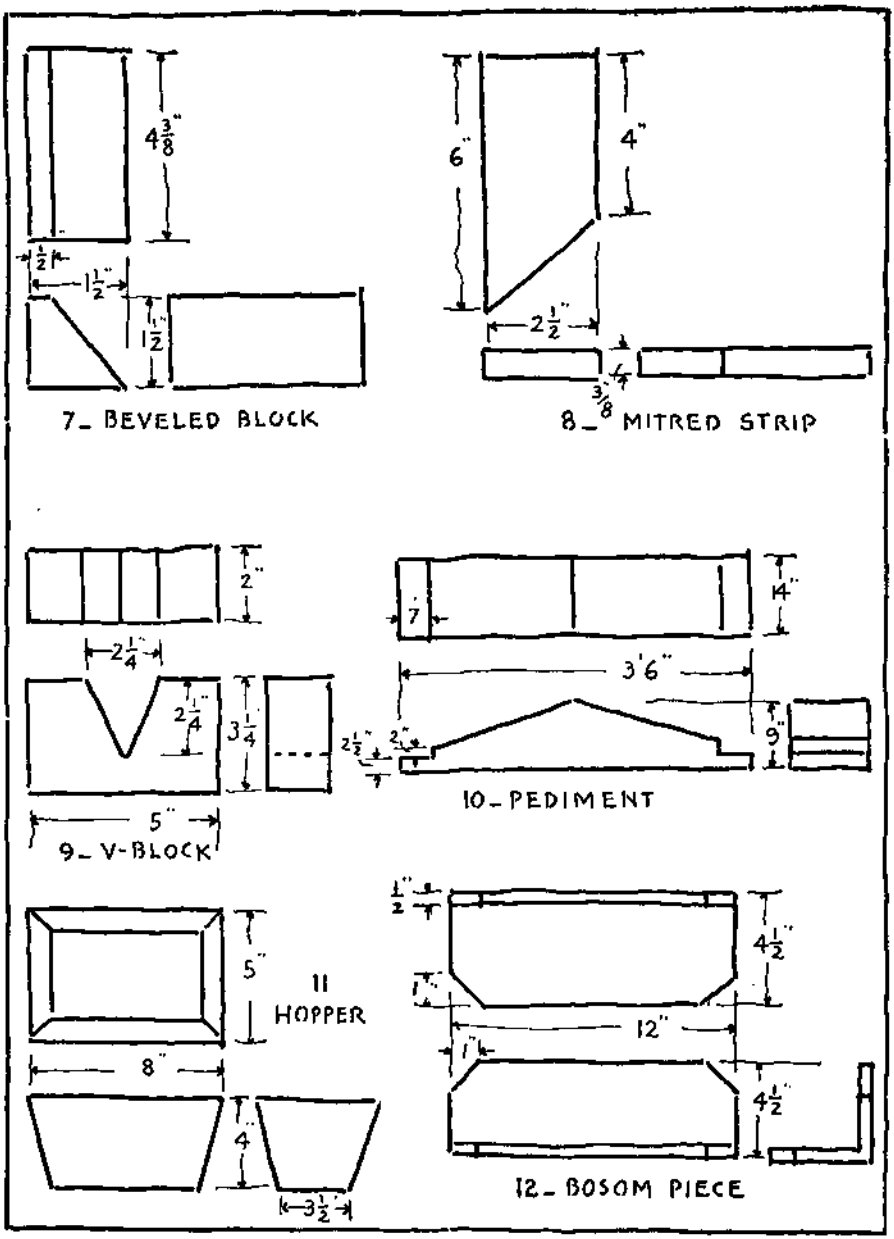


PLATE 56. Problems 7 to 12.

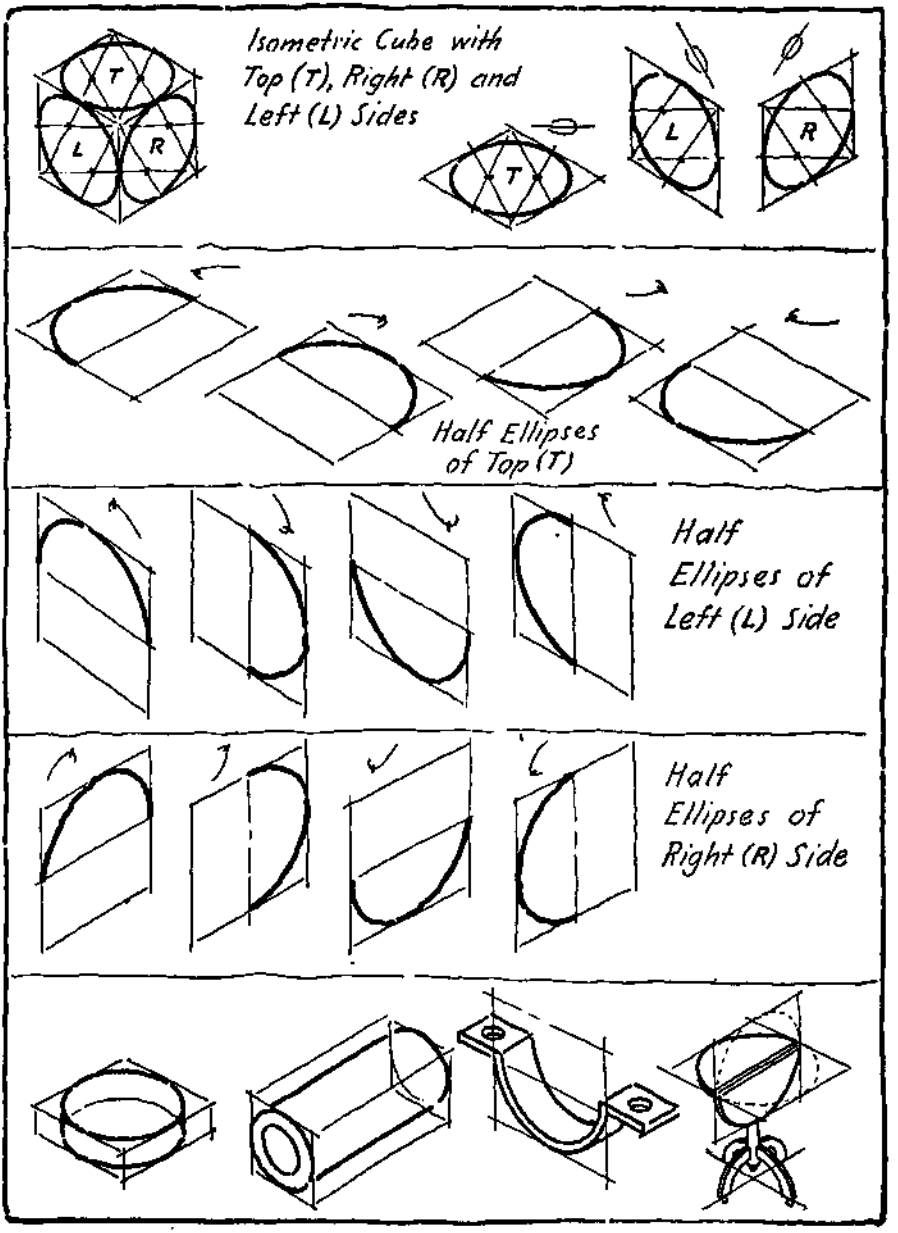


PLATE 57. Ellipse Construction. Practice Exercises.

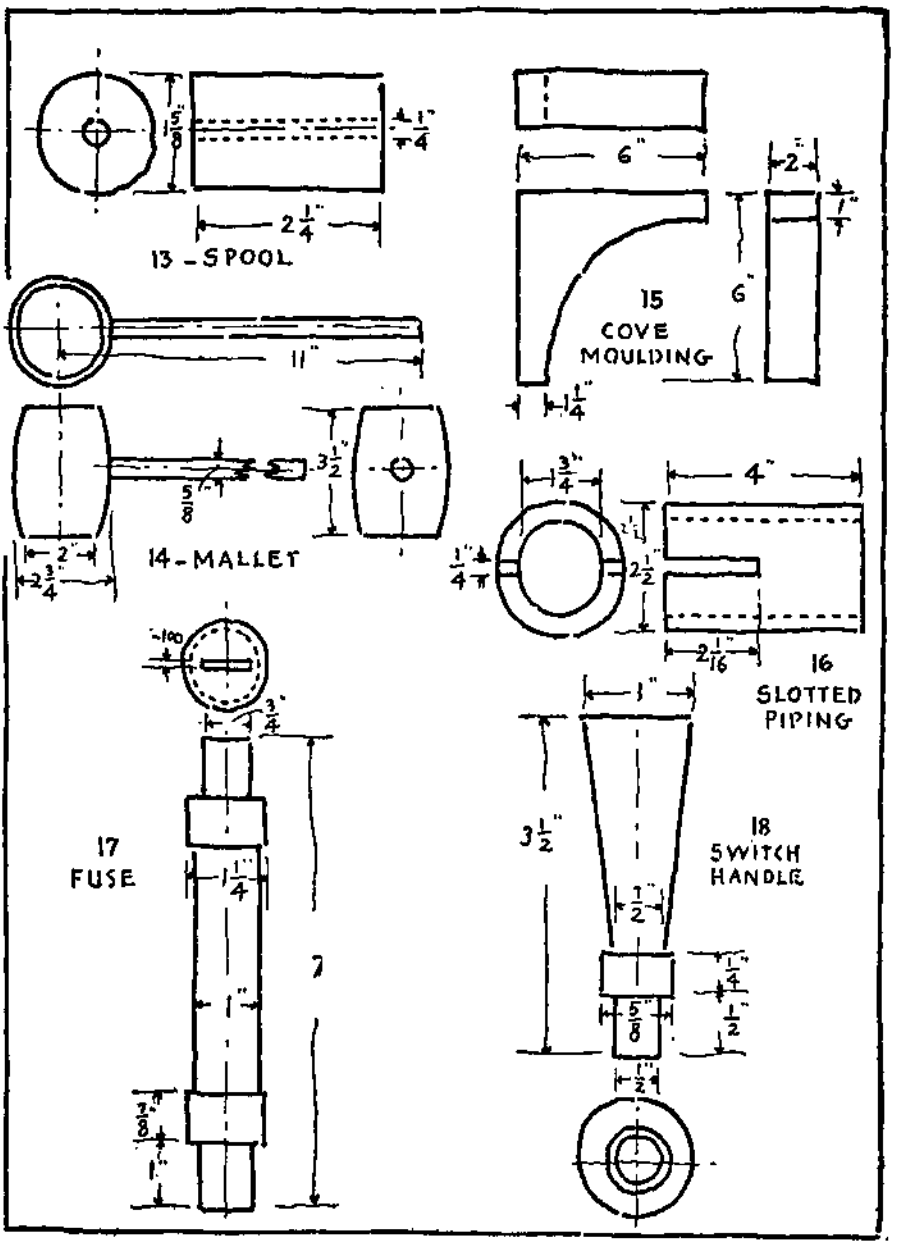


PLATE 58. Problems 13 to 18.

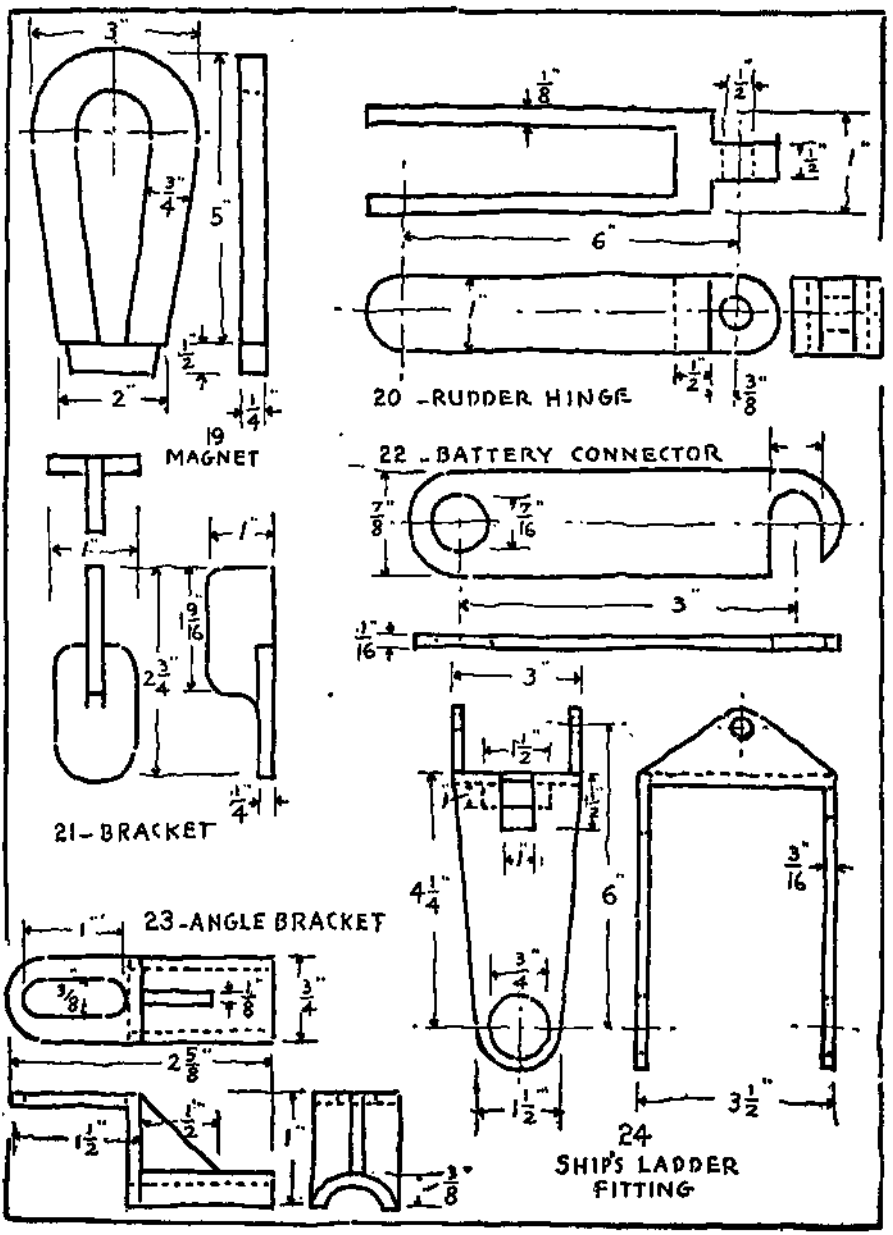


PLATE 59. Problems 19 to 24.

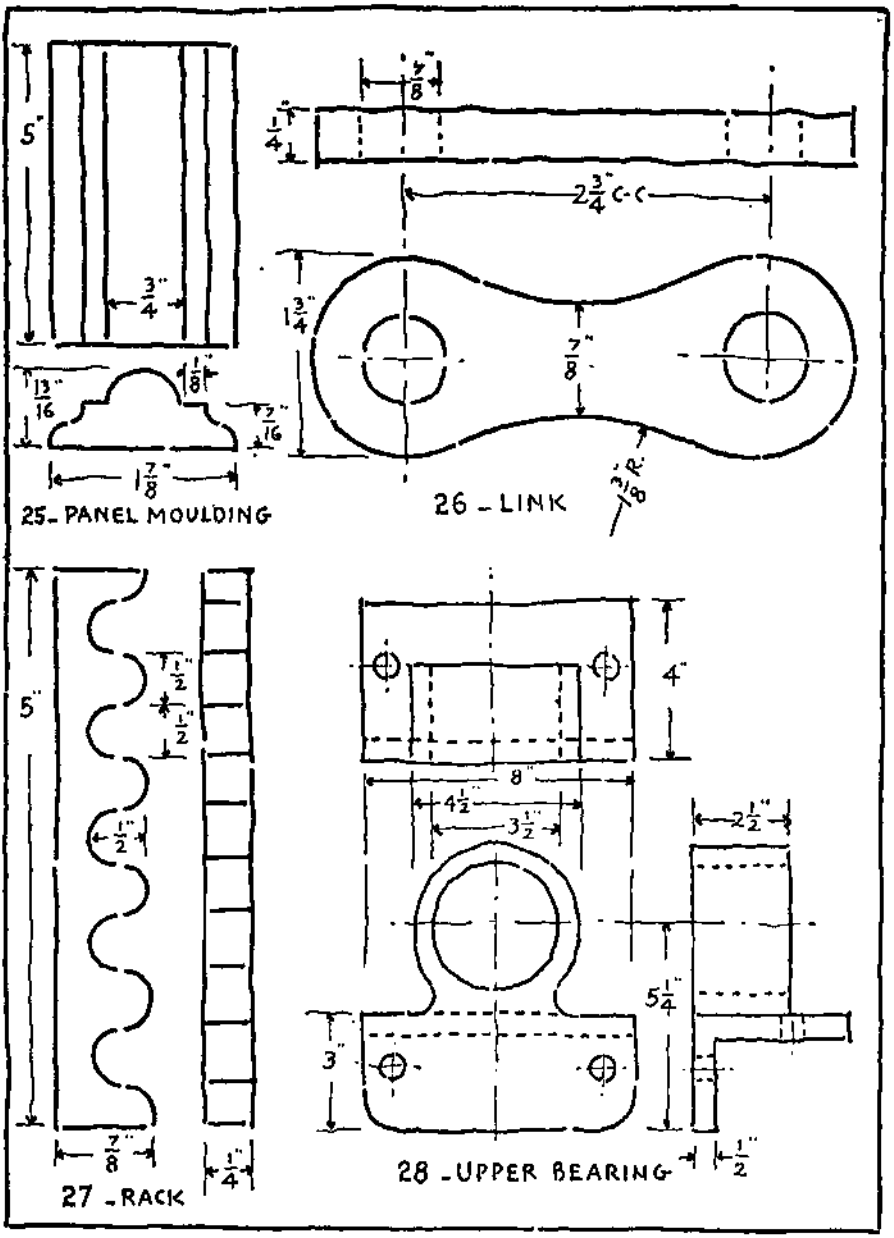


PLATE 60. Problems 25 to 28.

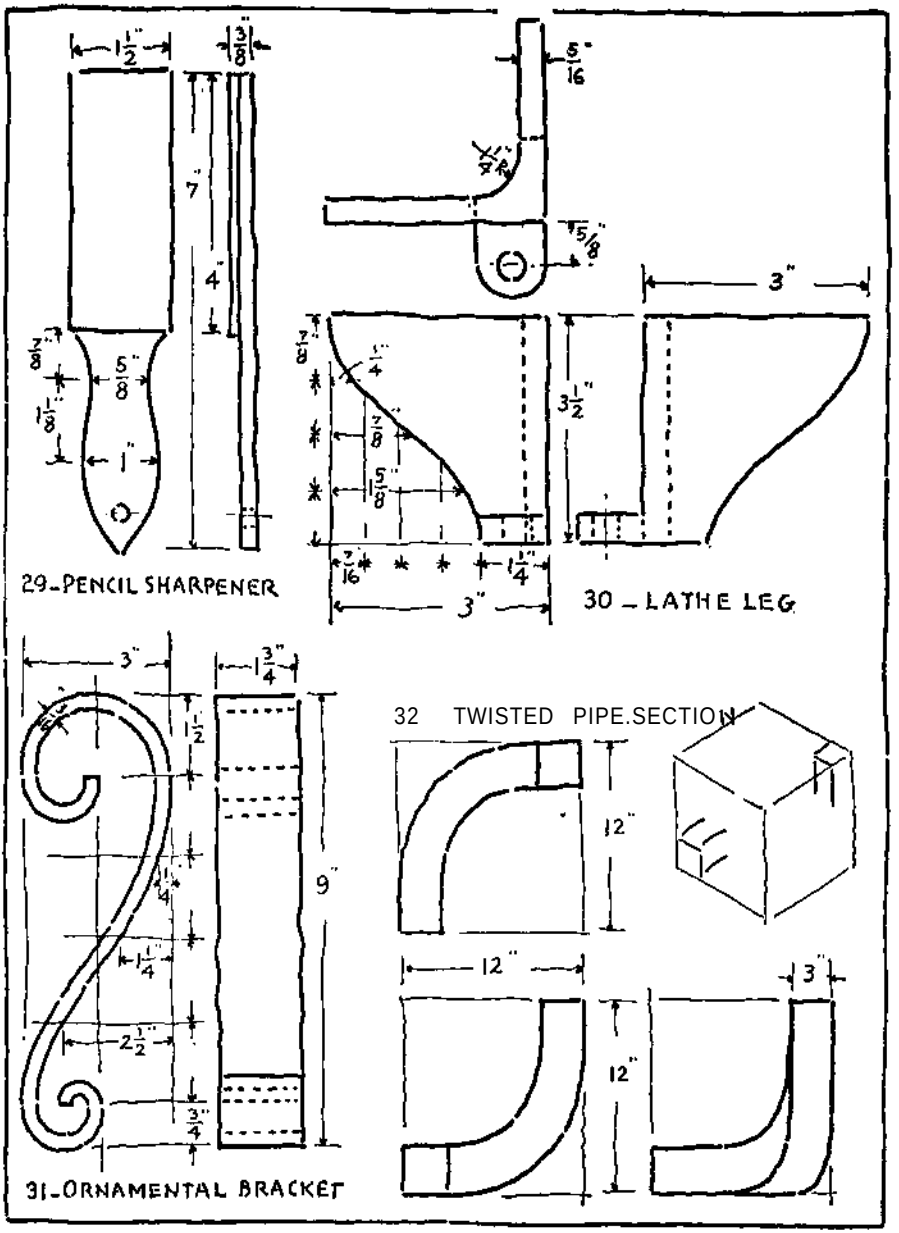


PLATE 61. Problems 29 to 32.

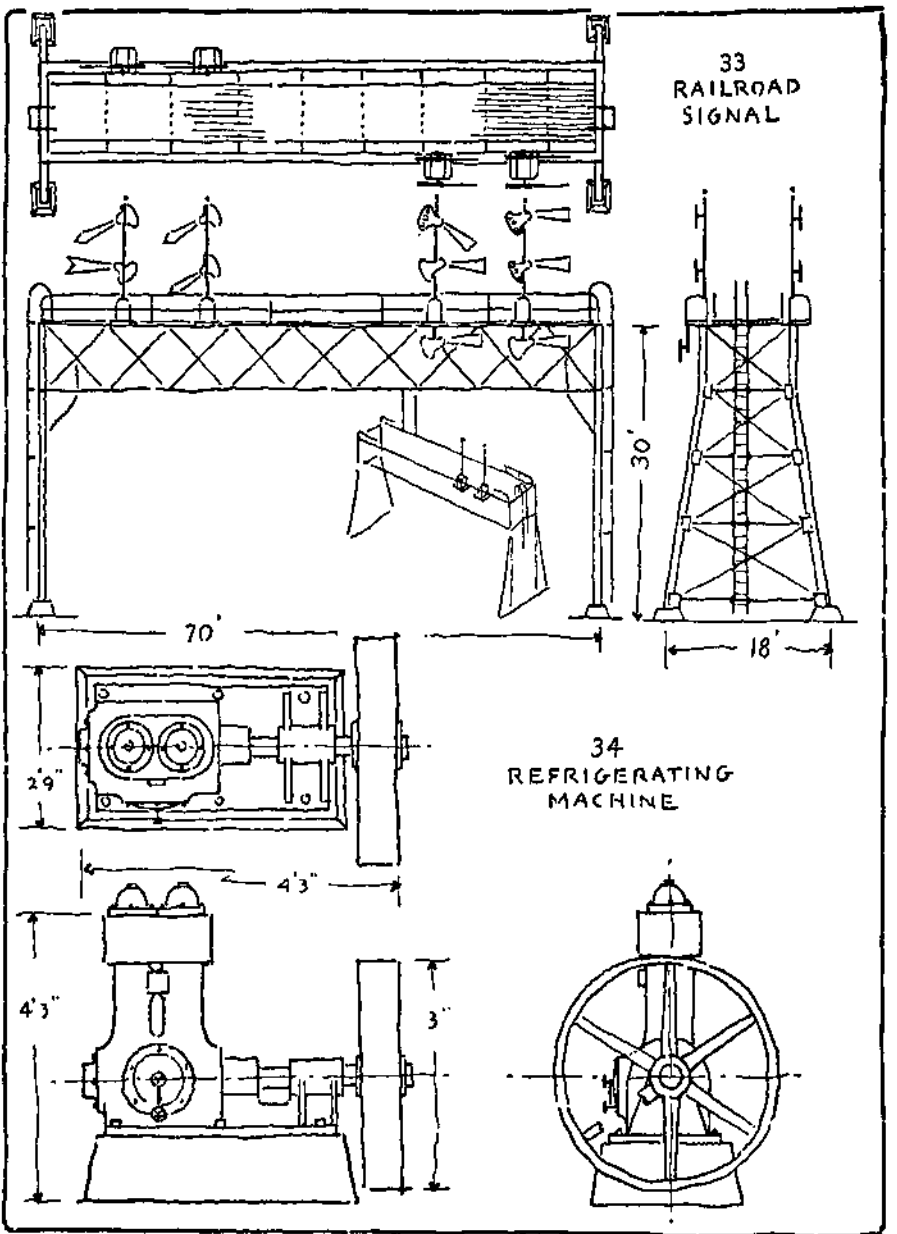


PLATE 62. Problems 33 and 34.

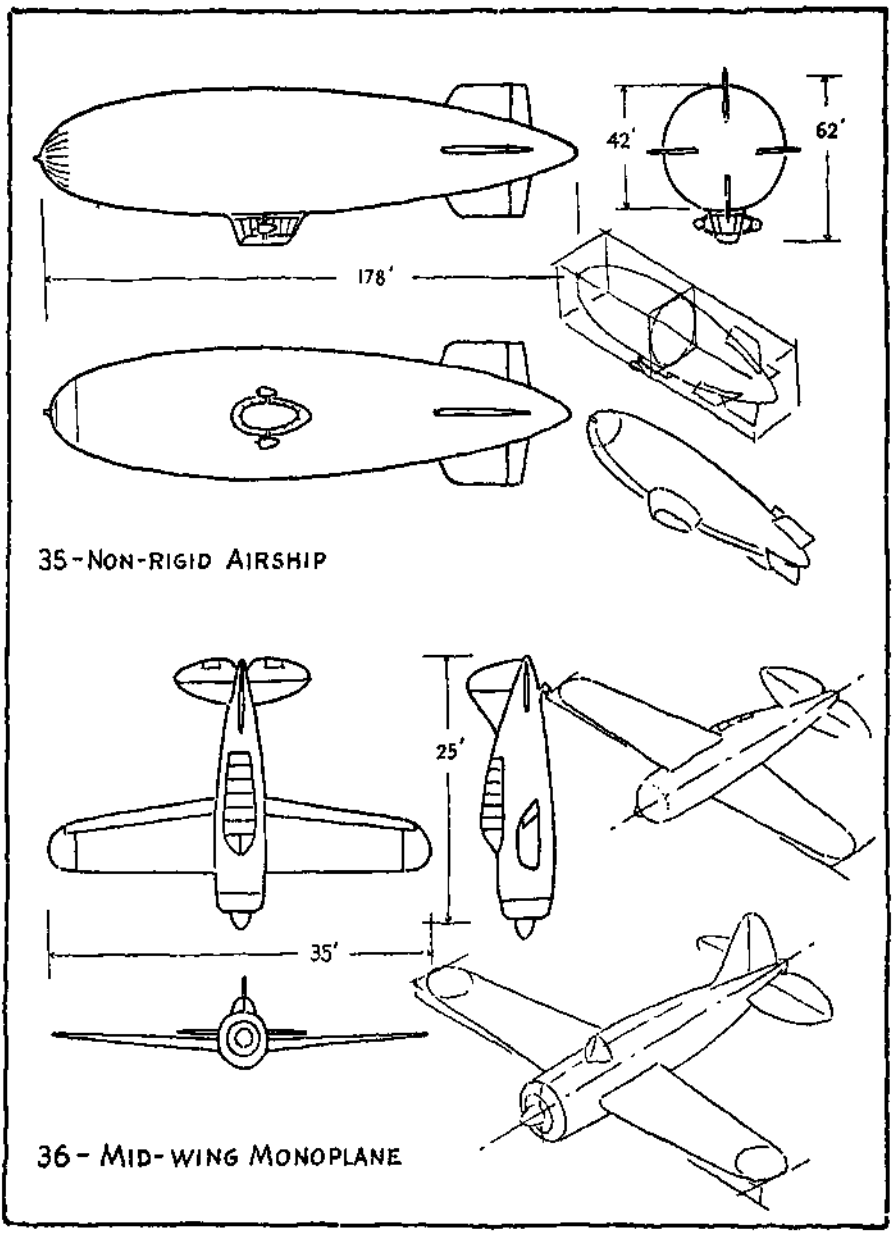


PLATE 63. Problems 35 and 36.

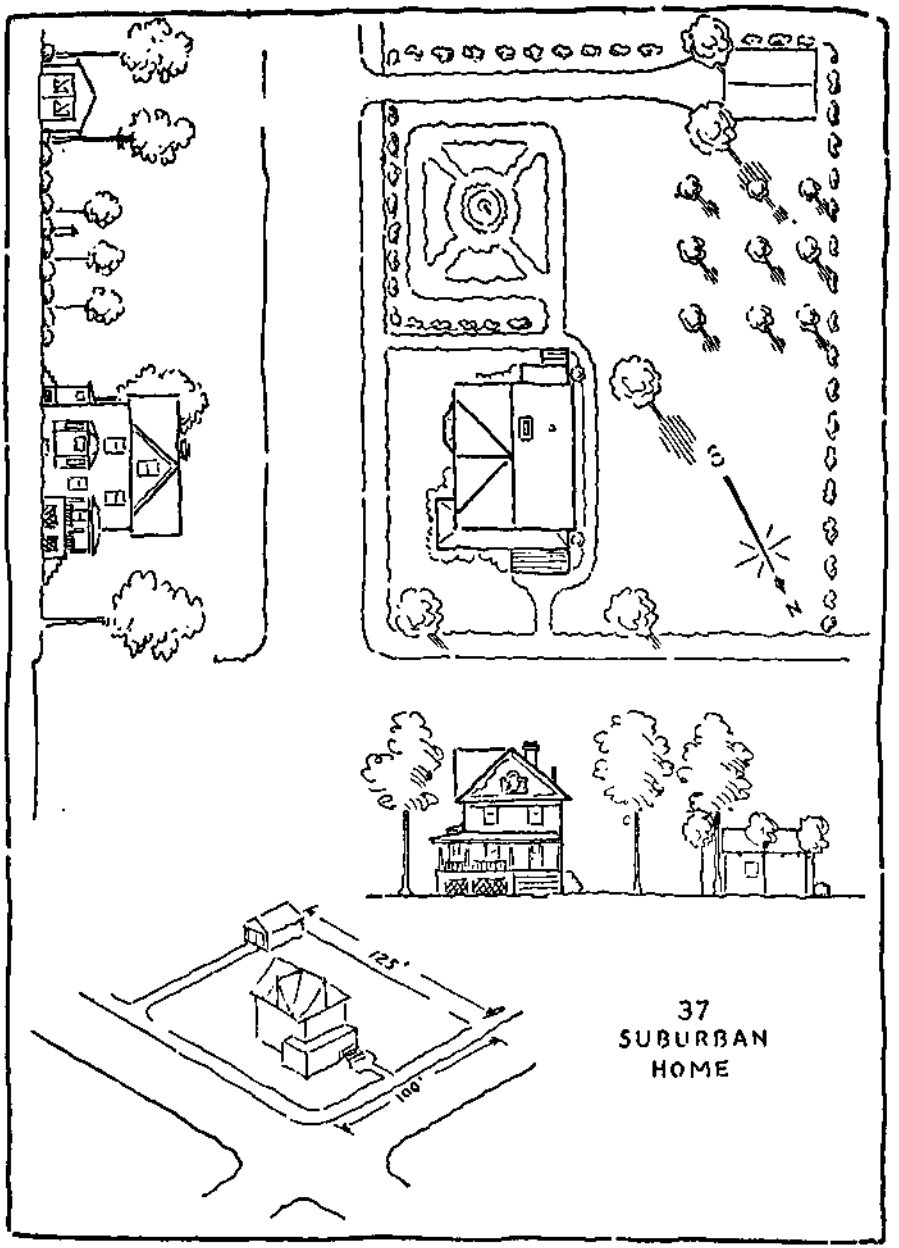


PLATE 64. Problem 37.

CHAPTER IX

ASSEMBLY VIEWS

When a machine or construction is made up of a number of parts it is often necessary to make a drawing to show where the parts are located, to show how they are put together, to show how they operate, to show how much space is occupied, to give foundation or erection information, to give piping, wiring or other installation dimensions, to show the appearance of the complete machine or construction, either from the outside or in section, and to give other necessary information having to do with the assembling of the parts. Such a drawing is called an assembly drawing or an " assembly."

On Plate 66 details are shown at Fig. A and an outline assembly at Fig. B. On Plate 67 an orthographic sectional assembly is shown at Fig. A and pictorial diagram assembly at Fig. B.

Assembly Drawings and Sketches. — The purpose for which an assembly drawing is to be used will determine the method of representation and the character of the treatment. If orthographic projection is used (Chapter IV) three views, top view or plan, front elevation, and side elevation are the usual views; Fig. A, plate 65. Where the side elevations are not the same, a fourth view may be added to show the differences. Sometimes a bottom view is necessary in addition to the top view or plan. For some purposes one or two orthographic views are sufficient for a particular purpose.

Assembly drawings do not follow any set rules as to treatment or amount of detail to be shown. They vary from severe outline views which omit center lines, hidden lines, dimensions, lettering, etc., to working assemblies which include a complete representation of all the parts with dimensions and notes. Assembly drawings may show some or all the details in section, may use phantom views, may be shaded, or may have a variety of treatments.

Special Assemblies and Layouts— Aircraft drafting, ship drafting, and sheet metal layout drafting frequently disregard certain of the principles of projection. Drawings of ships and sheet metal assemblies often follow the practice of superimposing the elevation on the top view or plan. Or the elevation may be placed above the top view or plan (first angle projection). Aircraft assembly drawings may have the views arranged to use the space available without regard to the projection from one view to the others. Such variations from true projection do not make it difficult to read the drawings as airplanes have three distinctively different outlines or silhouettes and can be identified. A study of airplane outlines in the field of aircraft spotting can be quite independent of mechanical drawing or sketching principles.

Pictorial Assemblies. — One-view assembly drawings or sketches made in pictorial form are finding increasing use. For many purposes they are more easily understood than the three views made in orthographic projection. Pictorial methods of representation mentioned in Chapter V include perspective, isometric, and oblique drawing. The principles of isometric drawing are used in this book as they are simple, easily applied and are generally effective for most industrial and manufacturing purposes. Isometric drawings or sketches are employed to translate the regular three-view drawings into pictorial views. Positions can be assumed to show three " faces" of the project: top, front, and right; top, front, and left; bottom, front, and right; bottom, front, and left. Such pictorial drawings and sketches can be read by workmen who are unskilled in reading regular projection drawings; Fig. B, Plate 65.

In the preparation of drawings and sketches for the weapons and machinery of war, isometric assemblies have achieved a more extended use than in the usual industrial fields enumerated in Chapter VIII, Isometric Sketching.

" Exploded" Assemblies. — Pictorial drawings and sketches of multi-part constructions and machines are sometimes made in a

manner to represent a dissection or explosion of parts. Such an exploded assembly is illustrated in the frontispiece and in Fig. C on Plate 65. Thus a multi-part construction as a building, an excavator, or an airplane can be represented in an isometric sketch or drawing (or in true perspective) with the individual parts or groups of parts spread out or separated from each other but in position to be moved together. Such exploded assemblies are in the nature of explanatory detail drawings and they are a positive advantage in shops where semi-skilled workers and others who are unfamiliar with blueprints are employed. Manufacturers of gyroscopes, airplane valves, airplanes, and in general the whole aircraft industry have adopted this practice to a considerable extent.

Analysis of Isometric Assembly Drawings. — The translation of a three-view assembly into a pictorial assembly sometimes may appear to be difficult. In such cases consider the basic geometrical shapes of the more important parts as well as the general enveloping form of the whole construction. This means to sketch the containing outline proportioned to the over-all dimensions, then sketch rectangular prismatic forms in the proper locations, and " whittle " them down to the cylindrical, pyramidal, conical, or other shapes and modifications of such solids. In this way it will be found to be a comparatively simple matter to produce a finished and satisfactory pictorial assembly. See Fig. D, Plate 65.

Sketching Large Assemblies. — Correct proportions in relation to the main dimensions of an assembly are as important and necessary in the representation of large constructions — a lathe, an airplane, a warship, or a " skyscraper " — as for a simple small casting.

When sketching from an existing construction of large size the proportions can be readily obtained by pencil measurement. To get the comparative length and height, hold a pencil at arm's length, and move the thumb up or down until the space between the top of the pencil and the thumb nail just includes the vertical dimension and do the same with the horizontal length. Then compare the

two distances and estimate the number of times (or fraction of times) one distance can be repeated in the other one. This is clearly shown step by step in Fig. E, Plate 65.

Isometric assembly sketches which have dimensions in one direction long in comparison with the others, can have the apparent distortion effectively reduced by making the lines parallel to the long dimension converge a slight amount as indicated in Fig. F on Plate 65.

Problems. — The exercises which follow are intended for use as substitutes for actual planes, motor cars, etc., in order to provide the practice which is necessary to make use of the principles explained in this Chapter. Sufficient graphic information is given for the adequate sketching of general over-all assemblies. These exercises should be supplemented by making sketches of actual machines and constructions. It should be borne in mind that considerable time and care are required to make suitable assembly sketches, either pictorial views or orthographic views.

PROBLEMS 1 to 7, PLATES 68 to 73. — Isometric pictures are given from which views are to be sketched in orthographic projection. Where it is more convenient, place the views without regard to usual positions as explained in the article on " Special Assemblies and Layouts." Satisfactory proportions can be obtained by applying the method of pencil measurement (illustrated on the small sketches of Plate 65) to the main dimensions of the drawing.

PROBLEMS 8 to 11, PLATES 74 to 77. — Orthographic or multi-view drawings are given from which isometric type pictorial sketches are to be made. The instructions given in Chapter VIII should be reviewed with particular attention to non-isometric lines, circles, and irregular curves. In a plane, the angle of a trailing edge, a leading edge, taper, and dihedral of wings and tail, are of major interest. They may be the only distinguishing features of two otherwise similar aircraft. Recognition of these points of difference will help in producing a good isometric pictorial sketch. When necessary, make pictures as viewed from above and from below. Reversed axes, as described in Chapter VIII, are to be used when the view is sketched from below the plane.

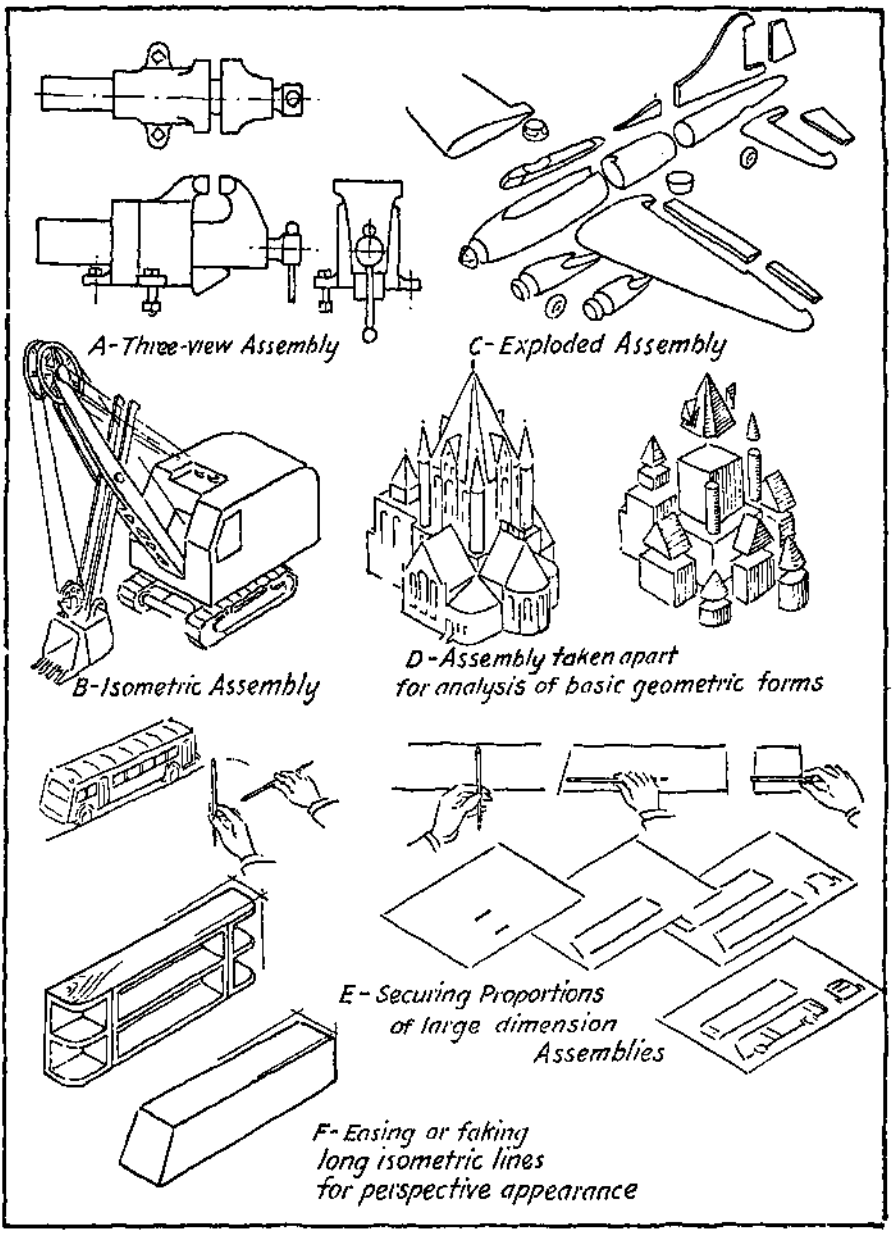


PLATE 65. Assembly View Sketching,

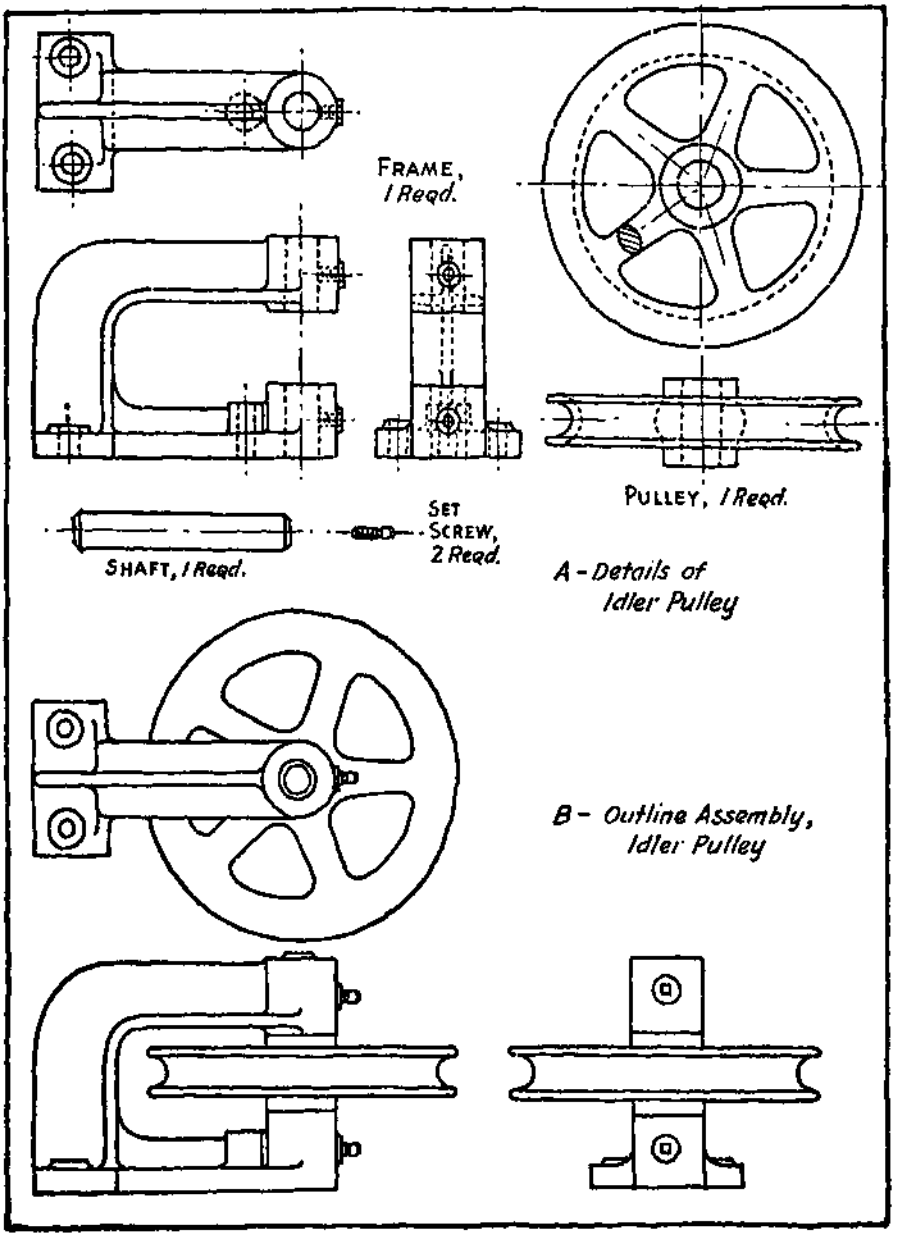


PLATE 66. Detail and Assembly Sketching.

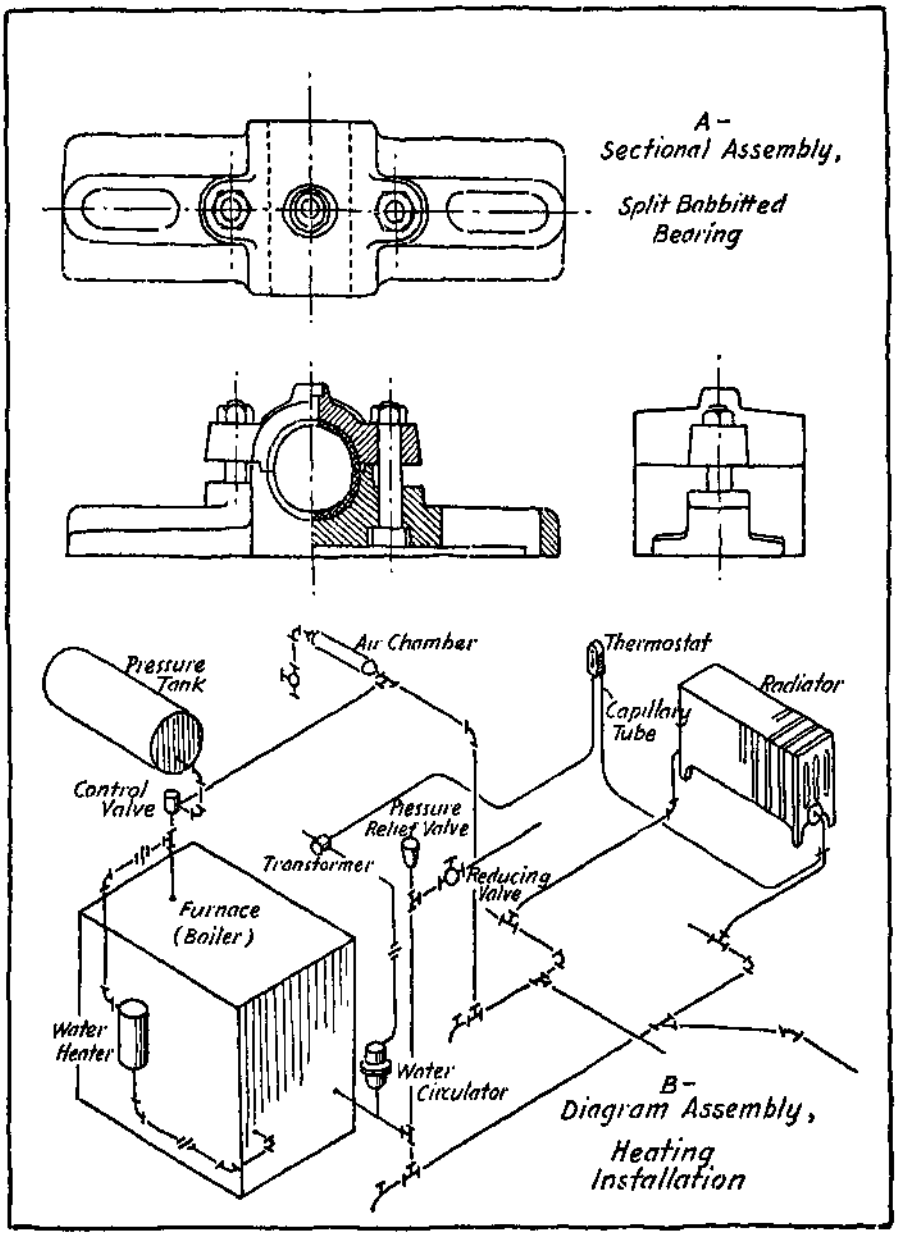


PLATE 67. Sectional and Diagram Assemblies.

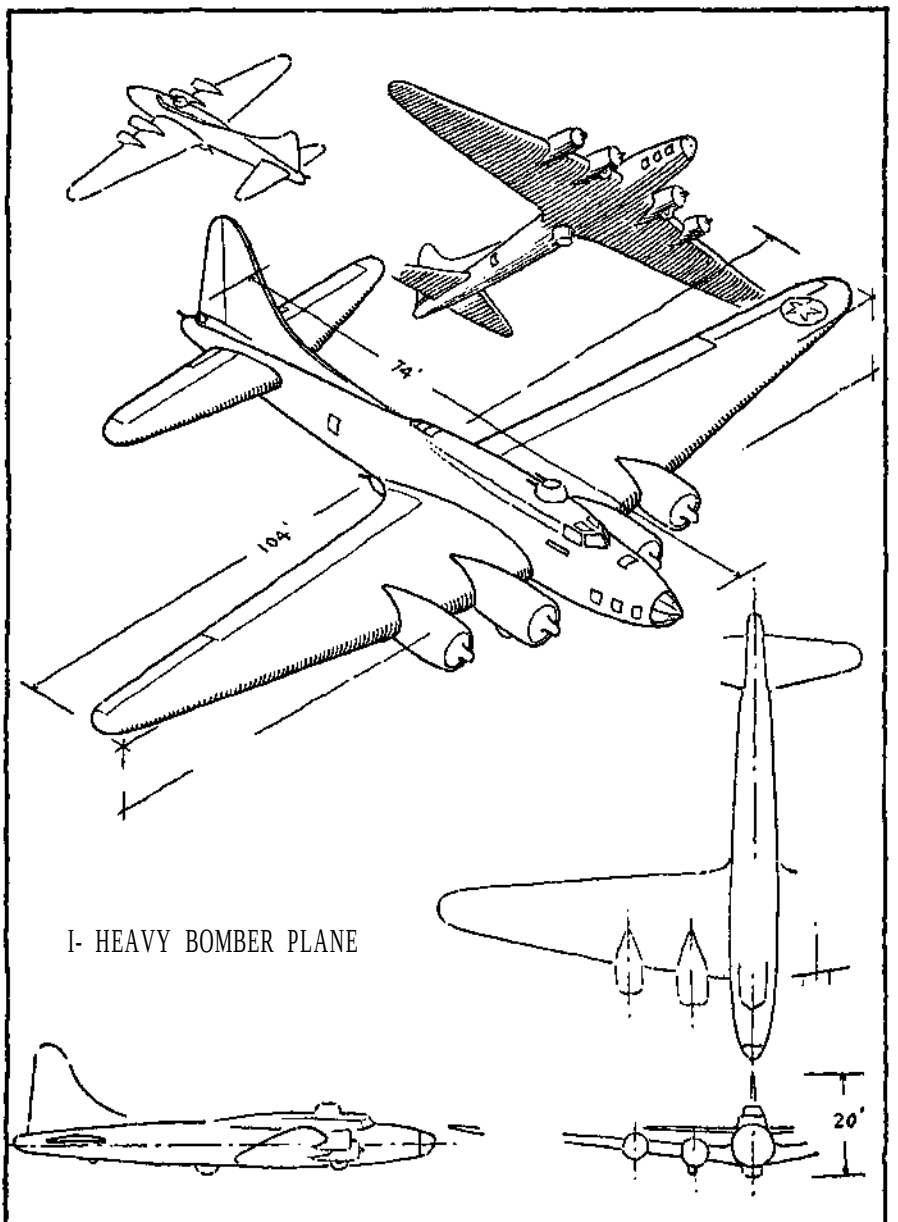


PLATE 68. Problem 1.

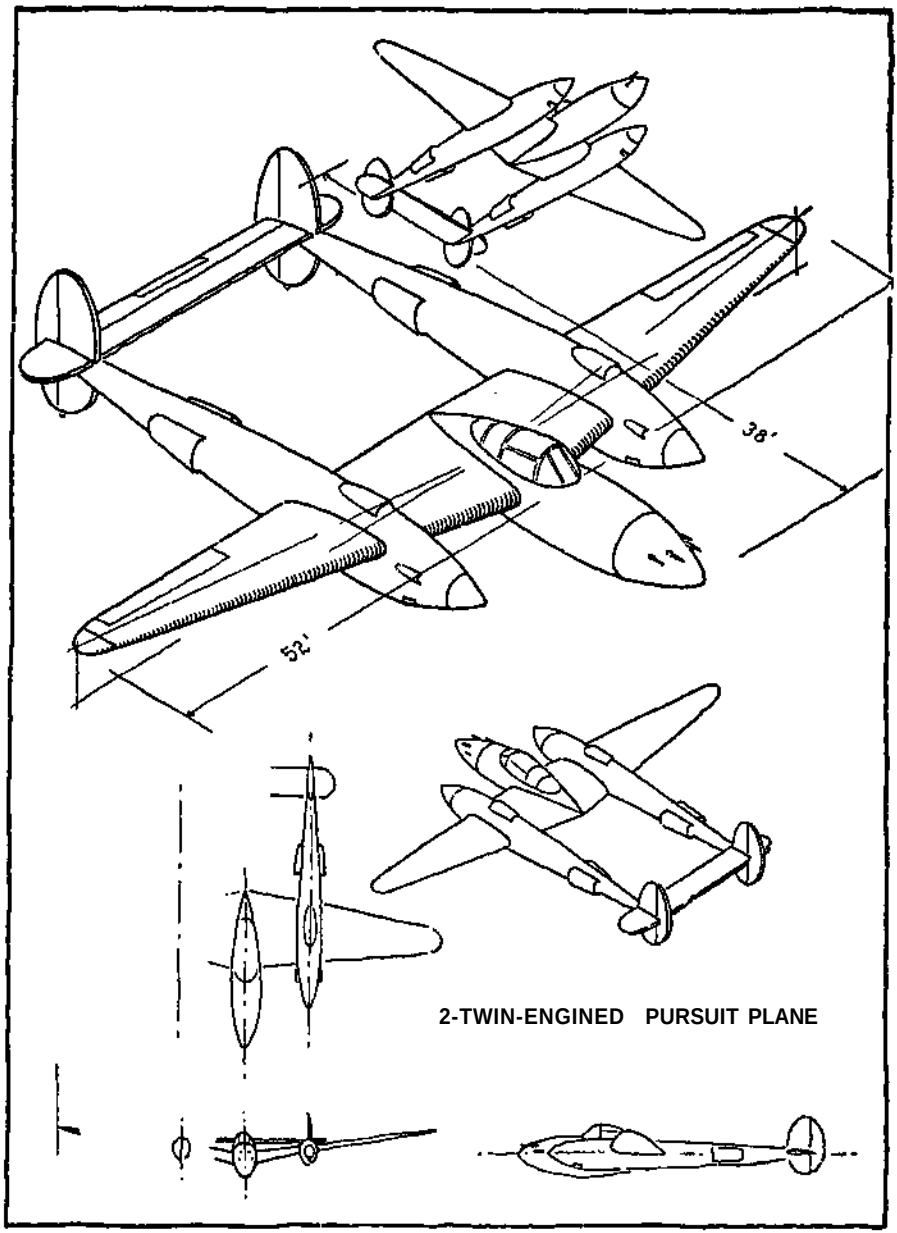


PLATE 69. Problem 2.

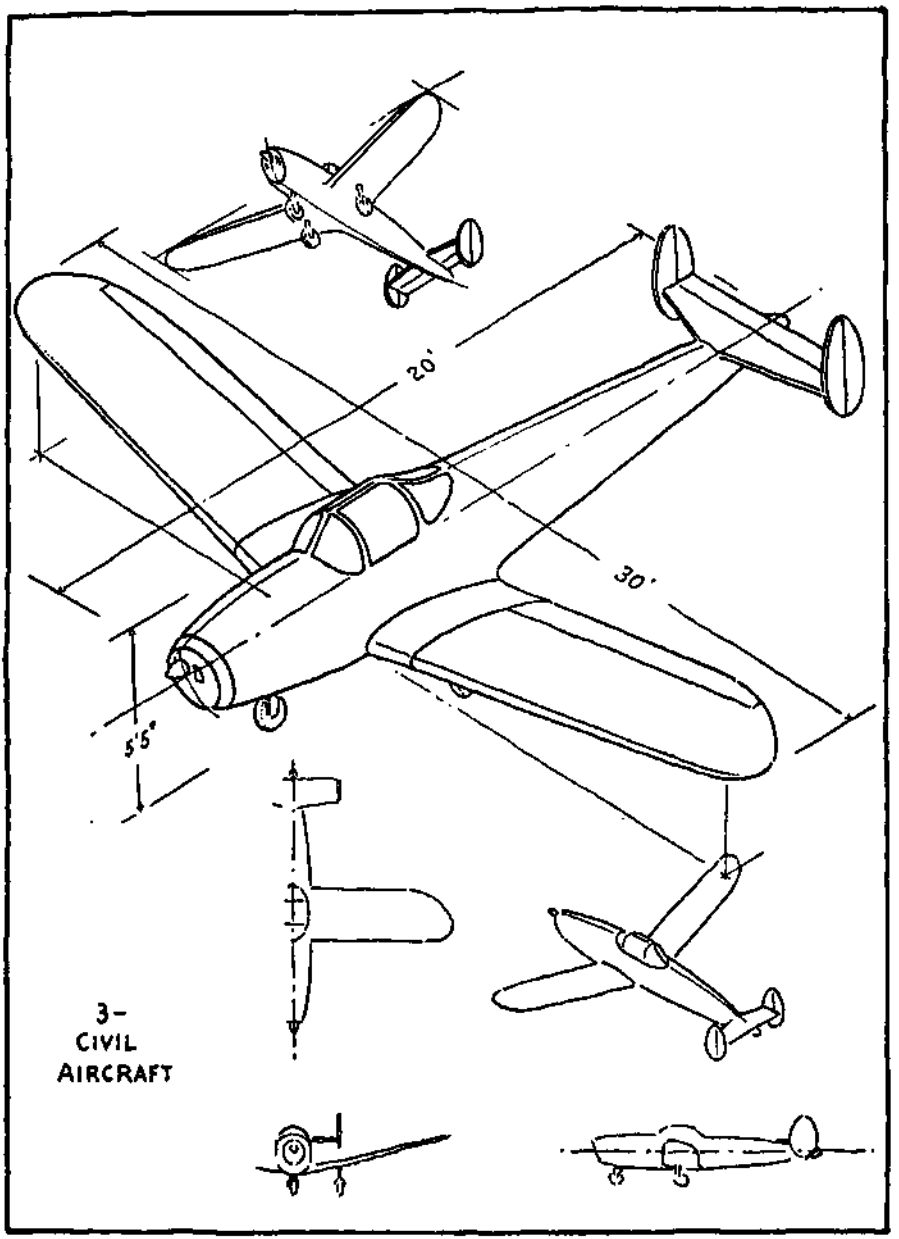


PLATE 70. Problem 3.

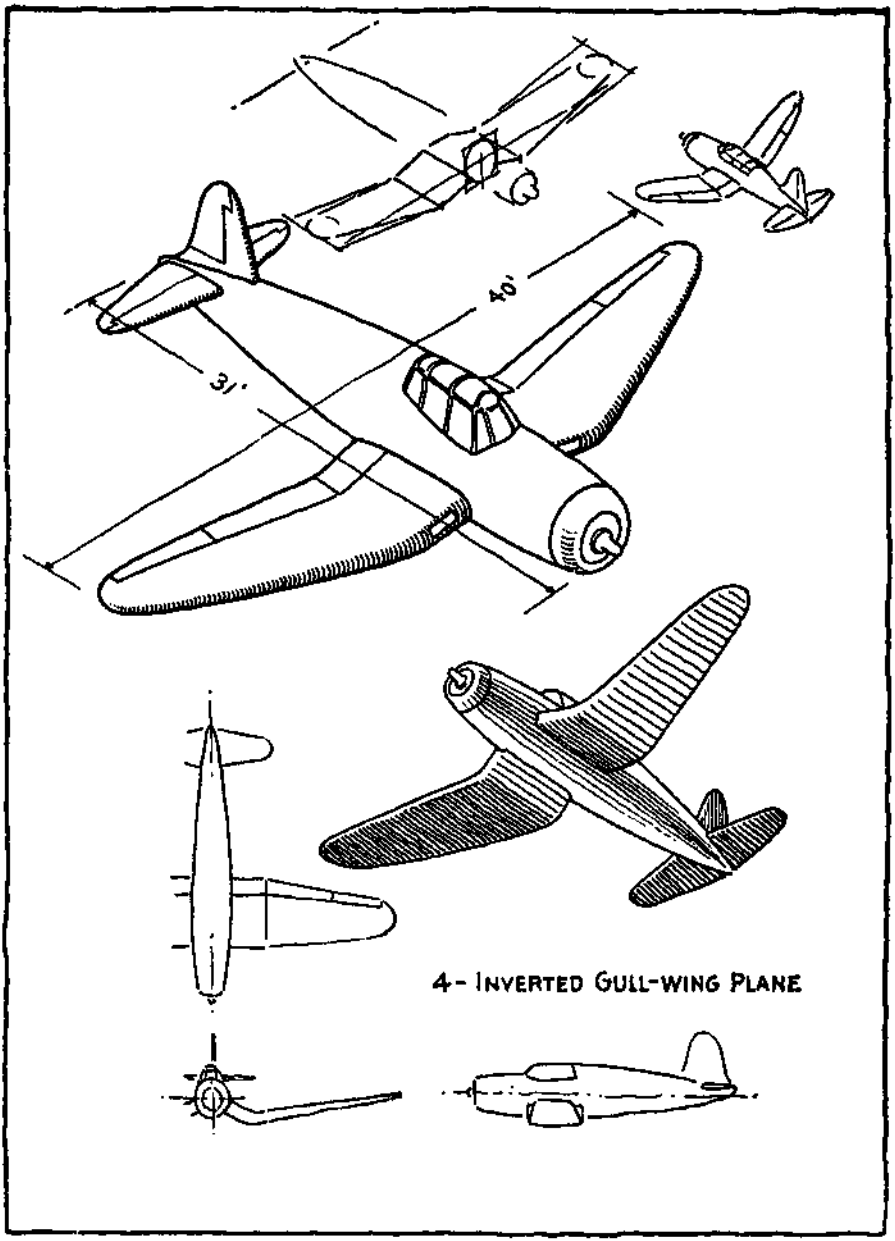


PLATE 71. Problem 4.

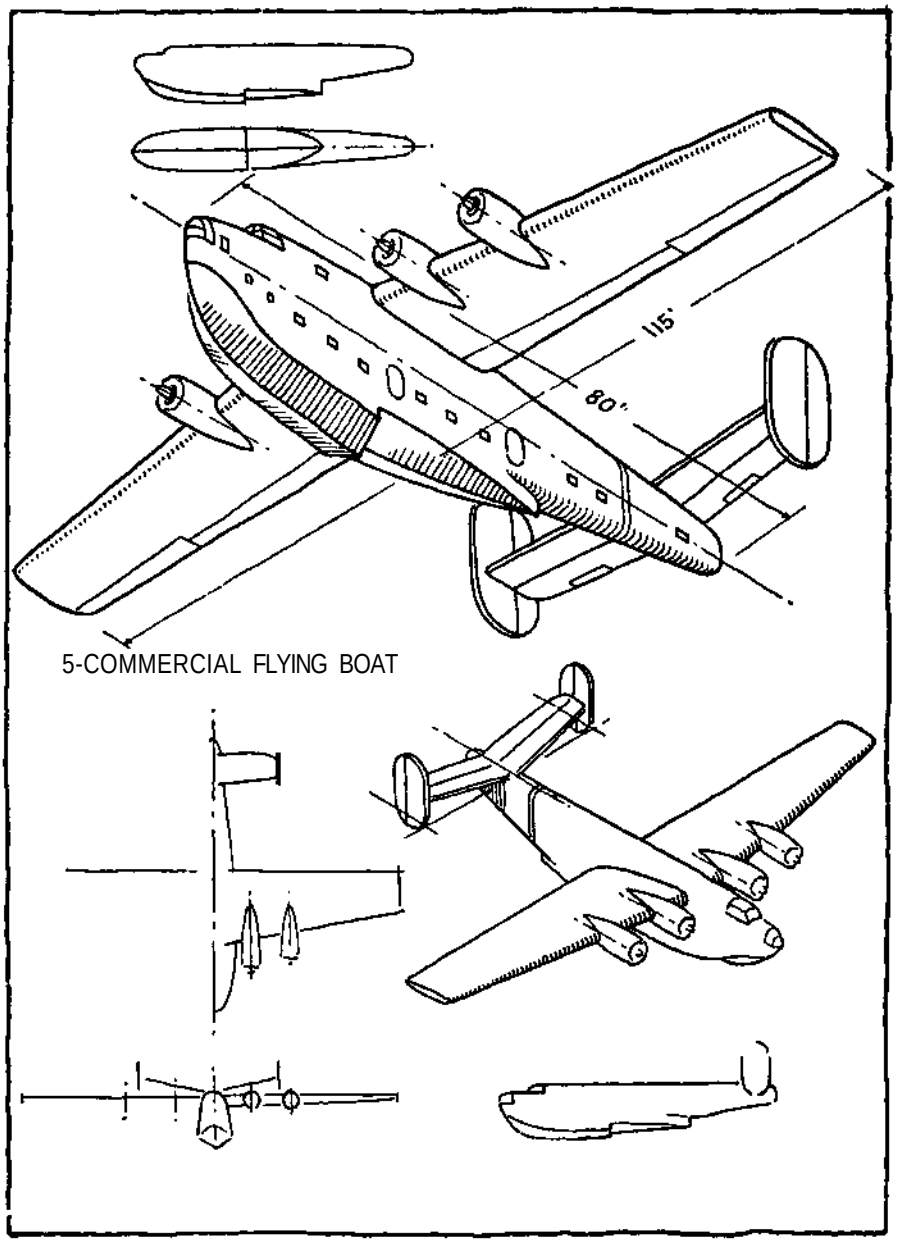


PLATE 72. Problem 5.

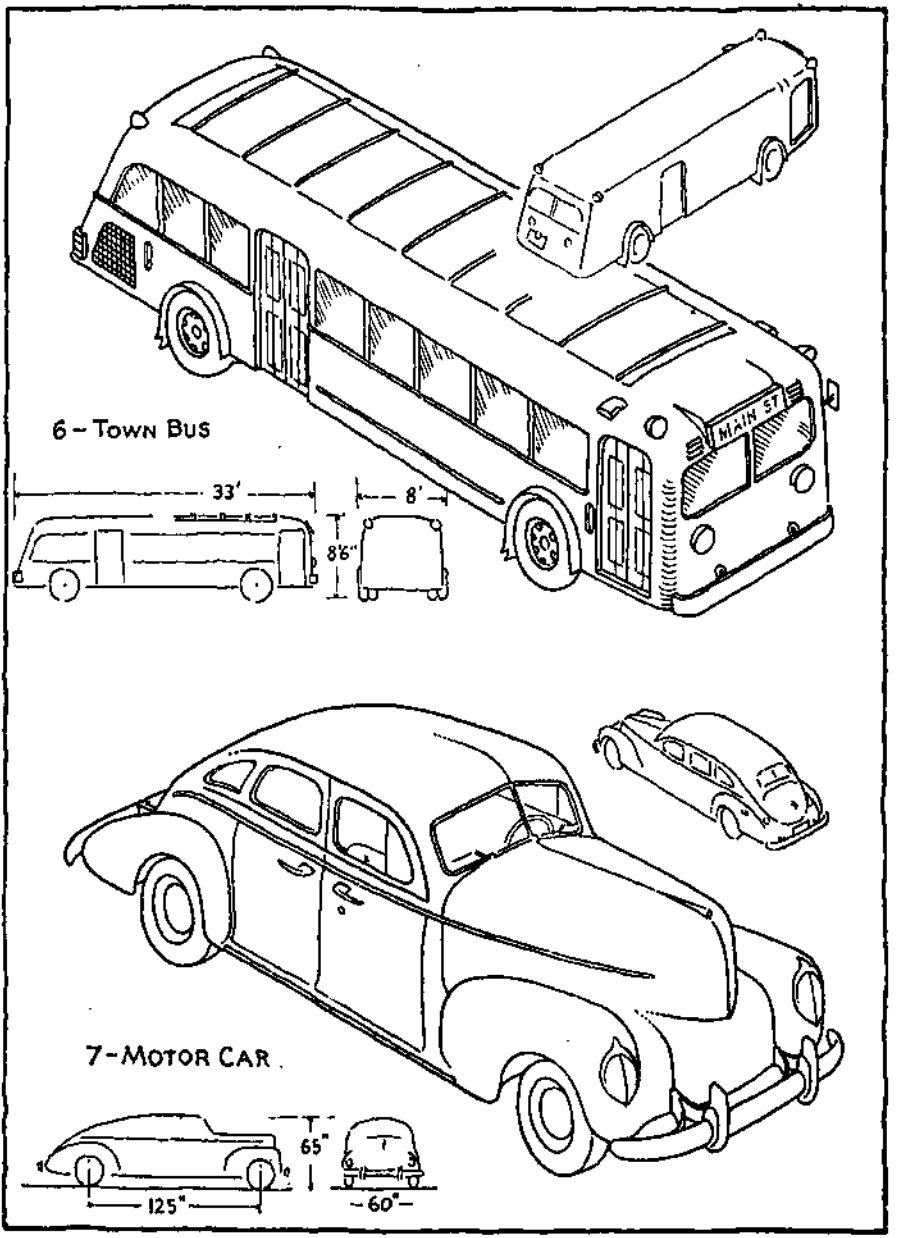


PLATE 73. Problems 6 and 7.

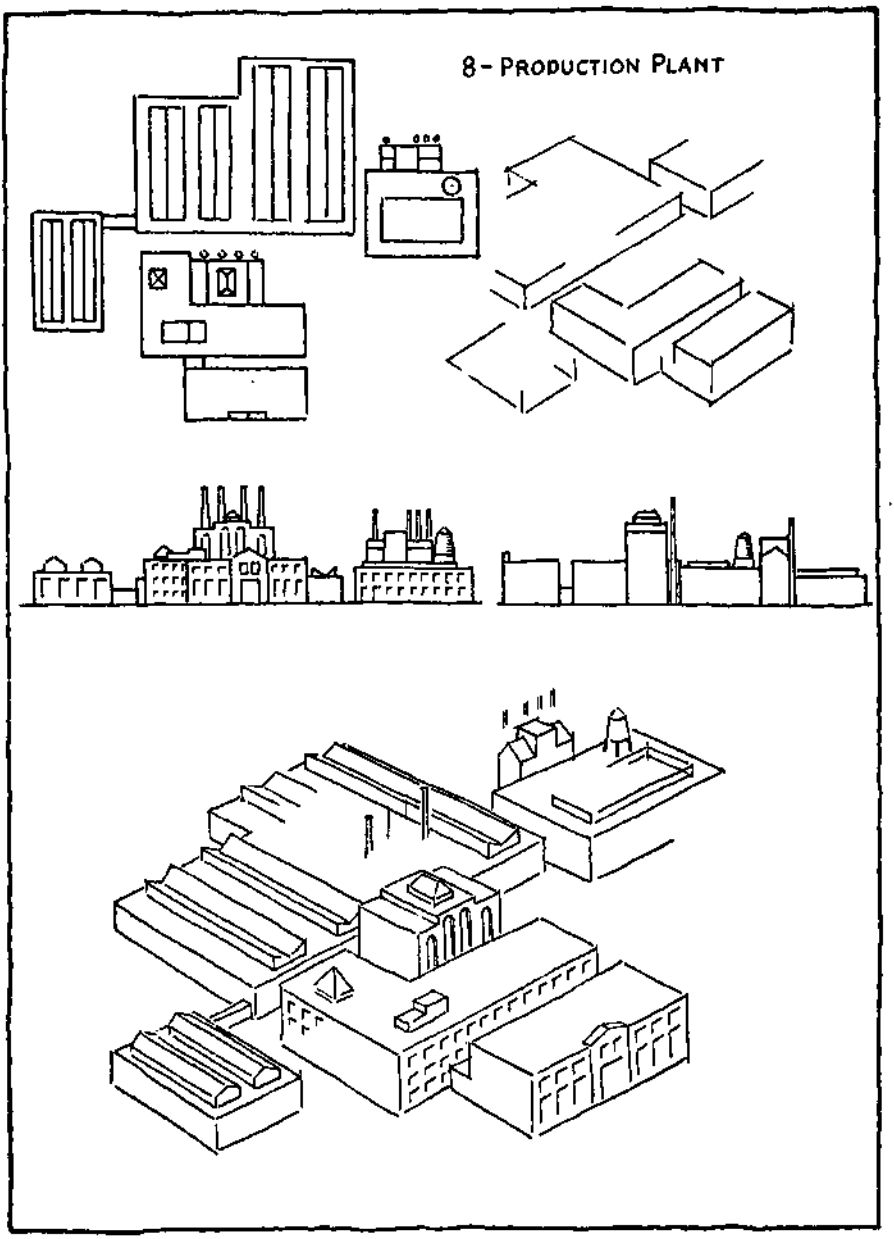


PLATE 74. Problem 8.

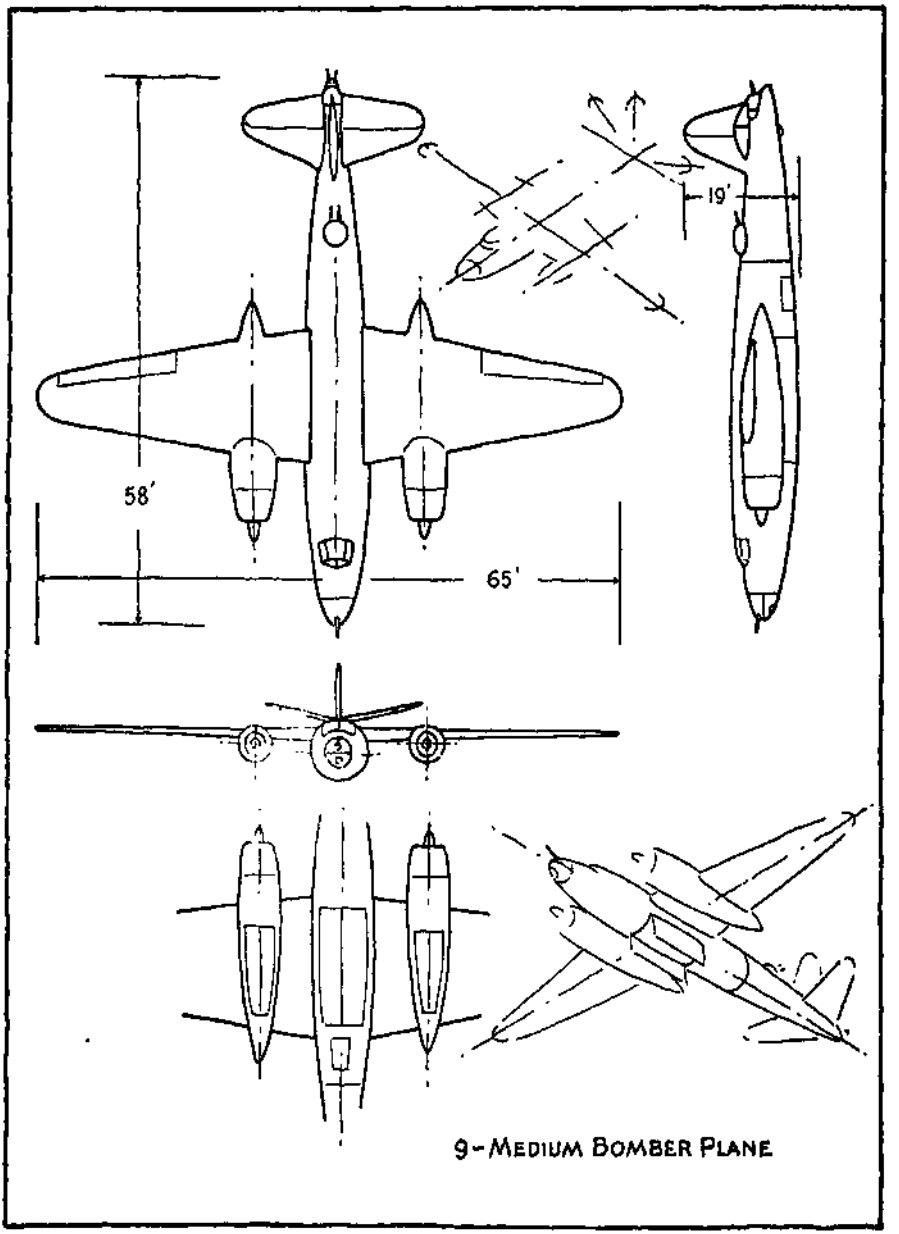


PLATE 75. Problem 9.

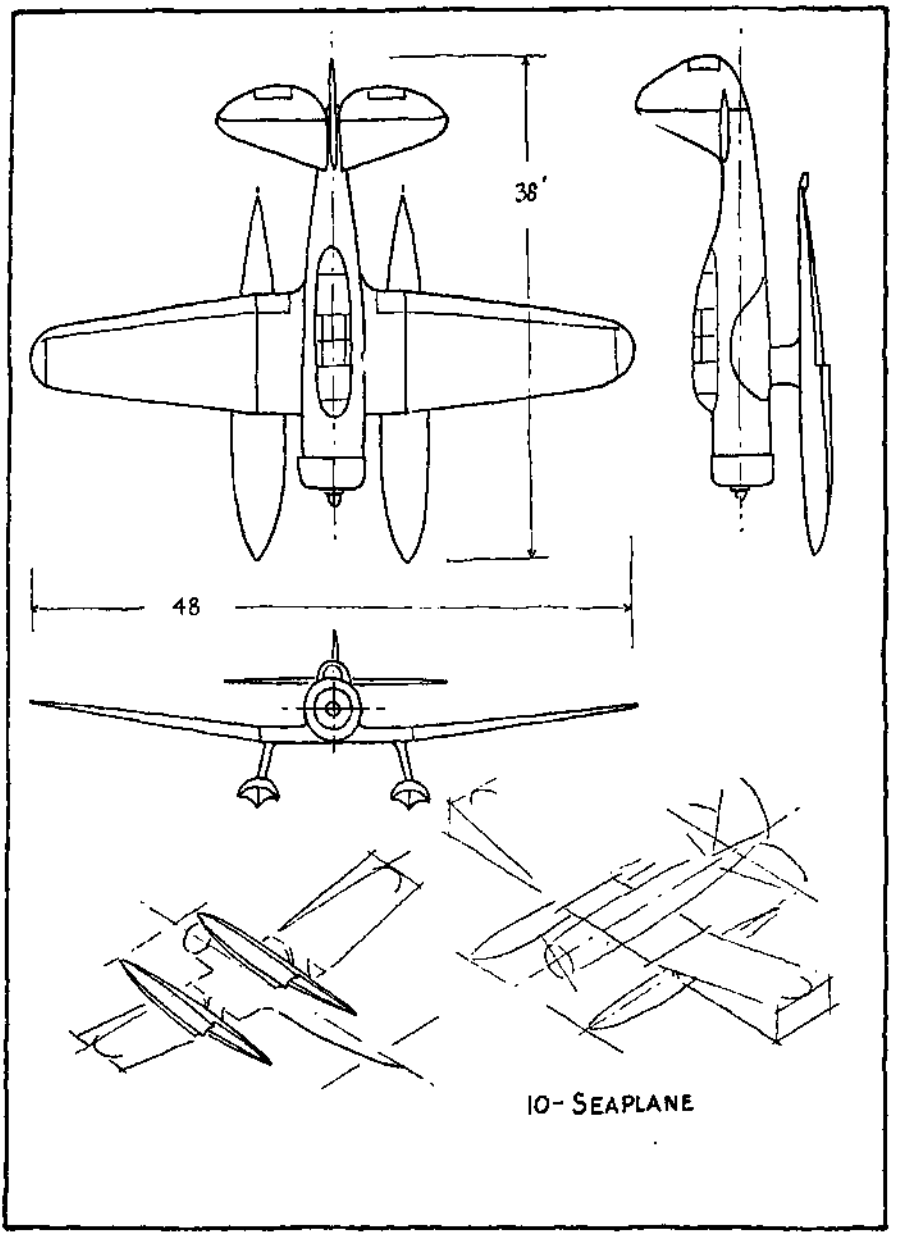


PLATE 76. Problem 10.

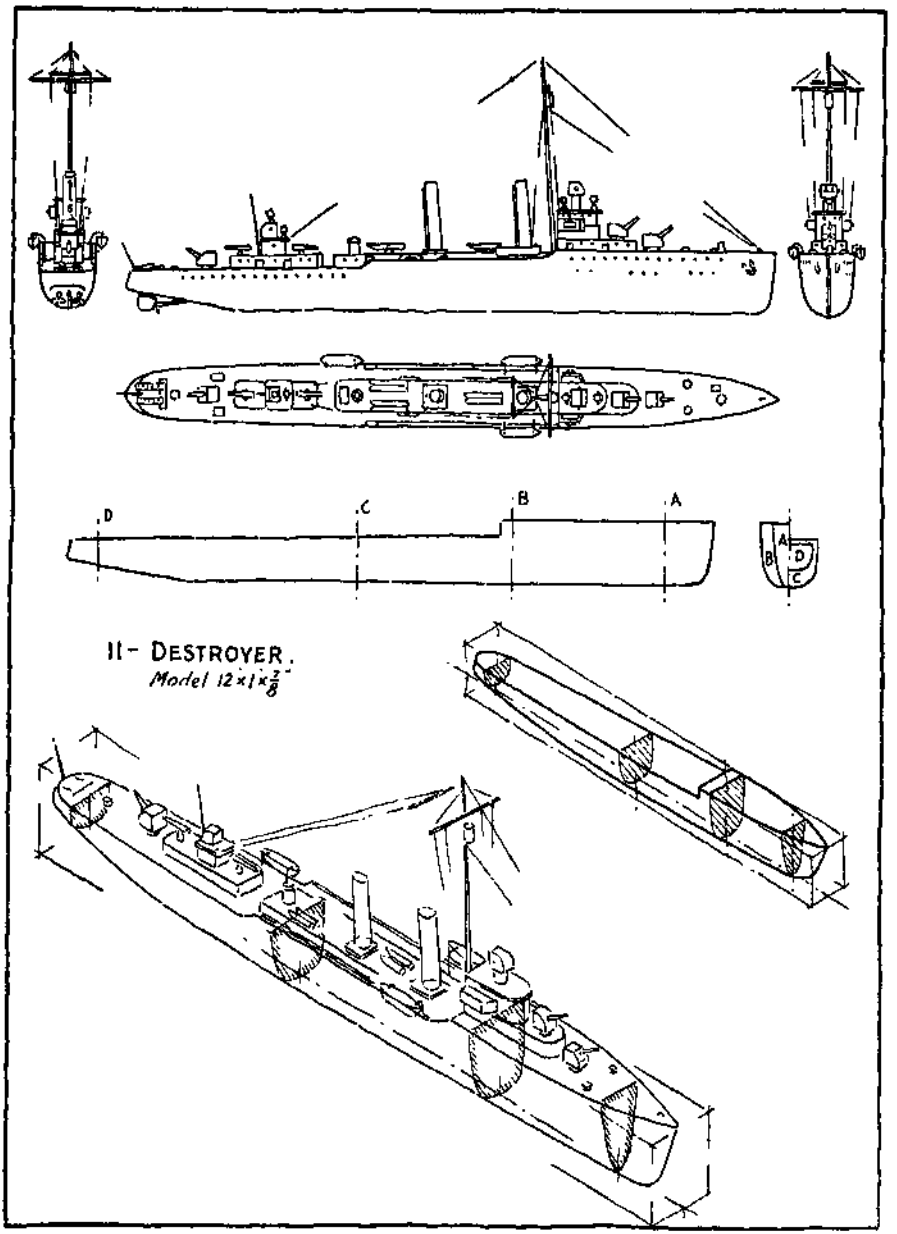


PLATE 77. Problem 11.

CHAPTER X

SHADED SKETCHES AND DRAWINGS

While shading is no longer used on working drawings, it is still used on certain classes of drawings where a pictorial effect is desirable.

Uses of Shaded Drawings— Shading is sometimes used on assembly drawings to make it easier to distinguish the different parts, especially when only one principal elevation of a machine or structure is made. It is helpful at times on shop sketches to bring out the shape quickly and clearly. Drawings for trade and technical journals, catalogs, and for similar purposes are often shaded. They are not only more attractive in appearance but are easily read. This applies to both regular view drawings and pictorial treatments.

Kinds of Shading. — Either outline shading or surface shading may be used as an aid in the representation of shapes, Plate 78, at M and N.

Outline Shading. — In order to produce a shadow, light is presumed to come from the upper left hand corner at an angle as illustrated at A, Plate 78. The shadow then falls to the right and bottom and might be represented as at B. On drawings it is reduced to the width of a heavy line, Plate 78 at C. When used such lines must, of course, be applied to all the views, top, front, and side. The light rays are considered separately for each view, as parallel and coming from the upper left hand corner at an angle of 45°. An inspection of the views at C, D, and M on Plate 78 will show where to place the shade lines. Use shade lines for lower and right hand edges of projecting parts. Use shade lines for upper and left hand edges of hollow or depressed parts.

Surface Shading—Views with surface shading are shown on Plate 78. In general, only the curved and sloping surfaces are

shaded. The position of the light rays, Plate 78 at E, illustrates the placing of the lines on a cylindrical surface. The heaviest of a series of parallel lines may be placed at the extreme right or bottom according to the position of the cylinder. A cone may be treated in the same way as shown at F. Note the shading on the hole at H.

Shading Isometric Drawings. — Plain isometric drawings are in pictorial form and are generally easy to read. Shading brings out the shape even more effectively and improves the appearance. Isometric drawings may be shaded on the edges or on the surfaces but the latter method gives the more satisfactory results. The light is assumed to come from above and the left.

Flat Surfaces. — Prisms, pyramids, and flat side objects are shaded with parallel lines. These can be vertical or parallel with the isometric angle, Plate 79 at A. Inclined surfaces receive more or less light than the regular isometric surfaces and accordingly are made darker or lighter. Horizontal surfaces are not shaded except when they represent the under side of an object as at C, Plate 79.

Curved Surfaces. — Cylinders and cones can be shaded as previously described for regular views, Plate 79 at D and E. Hollow cylinders have the shading on the opposite side as at D and I. Different methods are used for shading spheres but the one shown at F is a good one for either isometric or orthographic views.

An easy and practical method of representing where curved and flat surfaces join is given at G, Plate 79, and at C and D, Plate 84. The tangency of the surfaces can be made to show up well by using two or three heavy lines where the turn occurs. The method used at H, Plate 79, is more difficult and should not be attempted until after considerable experience.

The application of shading to isometric assembly drawings is illustrated on Plates 80 and 81. Note that this consists of shading the separate parts which make up the assembly.

This chapter is not intended to be a complete treatment of dif-

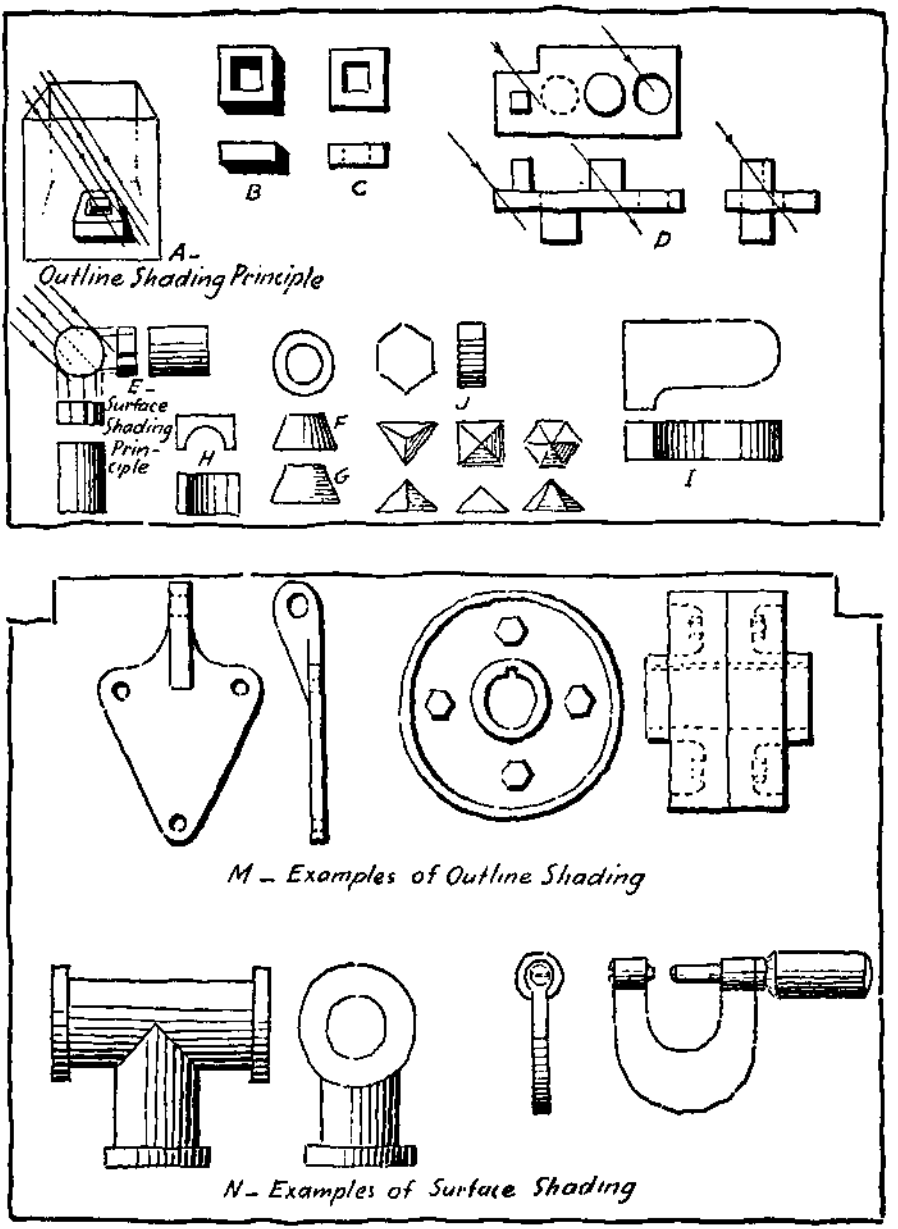


PLATE 78. Outline and Surface Shading.

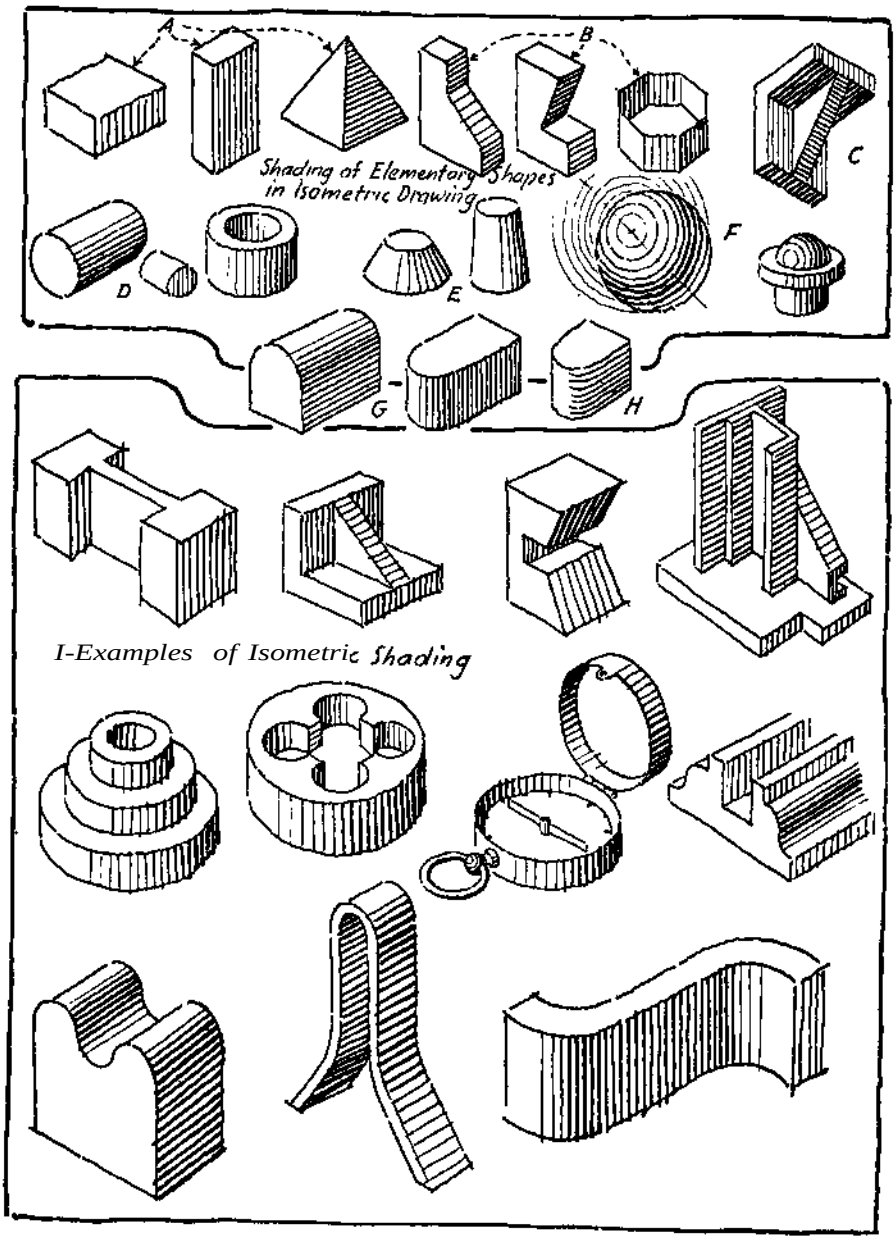


PLATE 79. Shading on Isometric Sketches.

ficult double curved surfaces and irregular shapes but does present sufficient methods and examples for the average draftsman's use. Practice will develop skill. If not well done it is better to omit shading altogether.

Problems. — Practice in applying the principles of shading to a selection of the problents which follow will serve to develop skill and confidence.

Use one of the layouts of Plate 3.

PROBLEMS 1 to 3, PLATE 82. — Represent the objects by views as shown. Use outline shading.

PROBLEMS 4 and 5, PLATE 82. — Represent the objects by views as shown. Use surface shading.

PROBLEM 6, PLATE 83.—Use an entire sheet to practice the shading strokes shown at A, B, C, D, and E. Use a rather soft pencil.

PROBLEMS 7 to 10, PLATE 83. — Represent the objects by isometric views as shown. Use surface shading.

PROBLEM 11, PLATE 84. — Use an entire sheet for the practice exercises shown at A, B, C, and D.

PROBLEMS 12 to 15, PLATE 84. — Represent the objects by isometric views as shown. Use surface shading.

PROBLEMS 16 to 20, PLATE 85. — These are problems for surface shading.

PROBLEMS 21 to 23, PLATE 86. — These are problems for surface shading.

PROBLEMS 24 to 27, PLATE 87. — These are problems for surface shading.

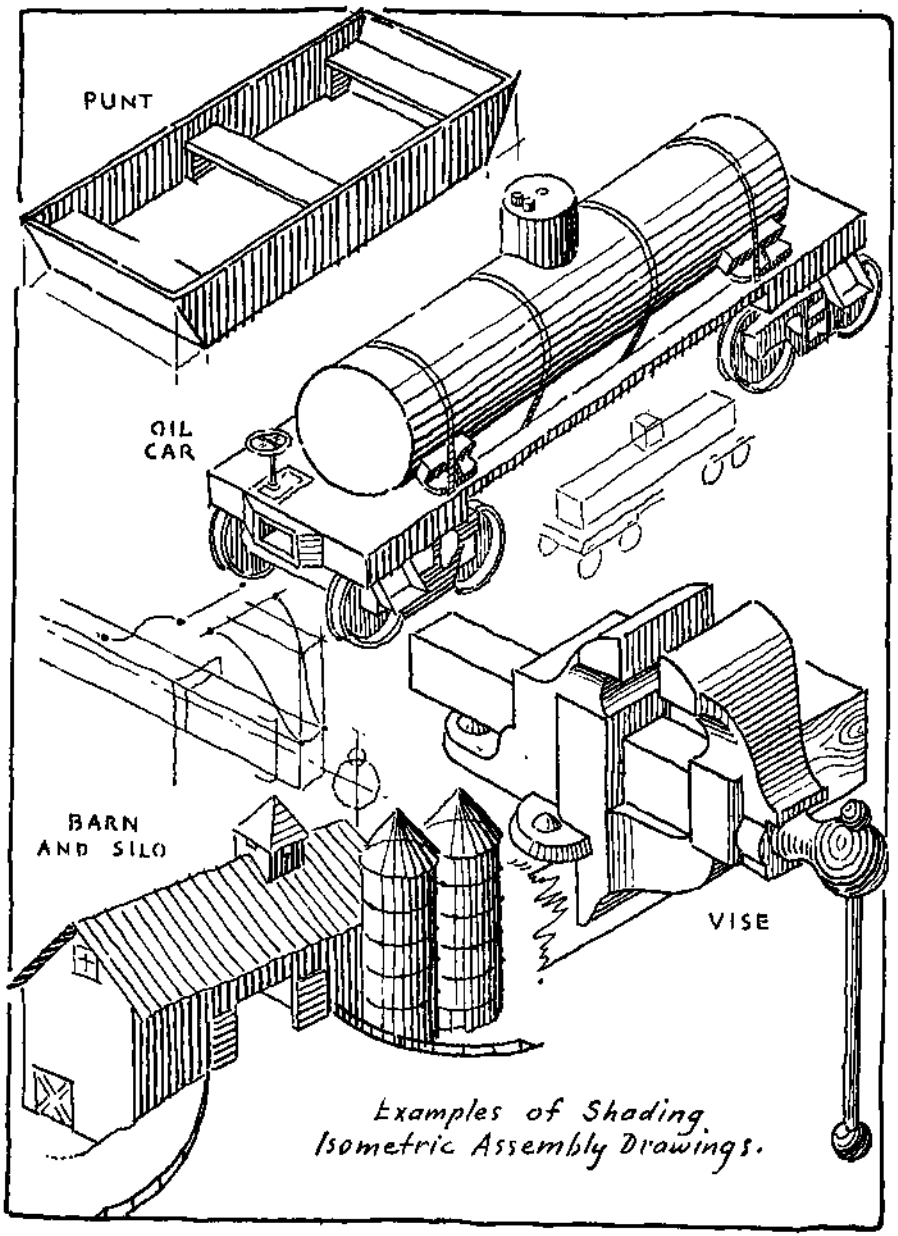


PLATE 80. Shading on Assembly Drawings.

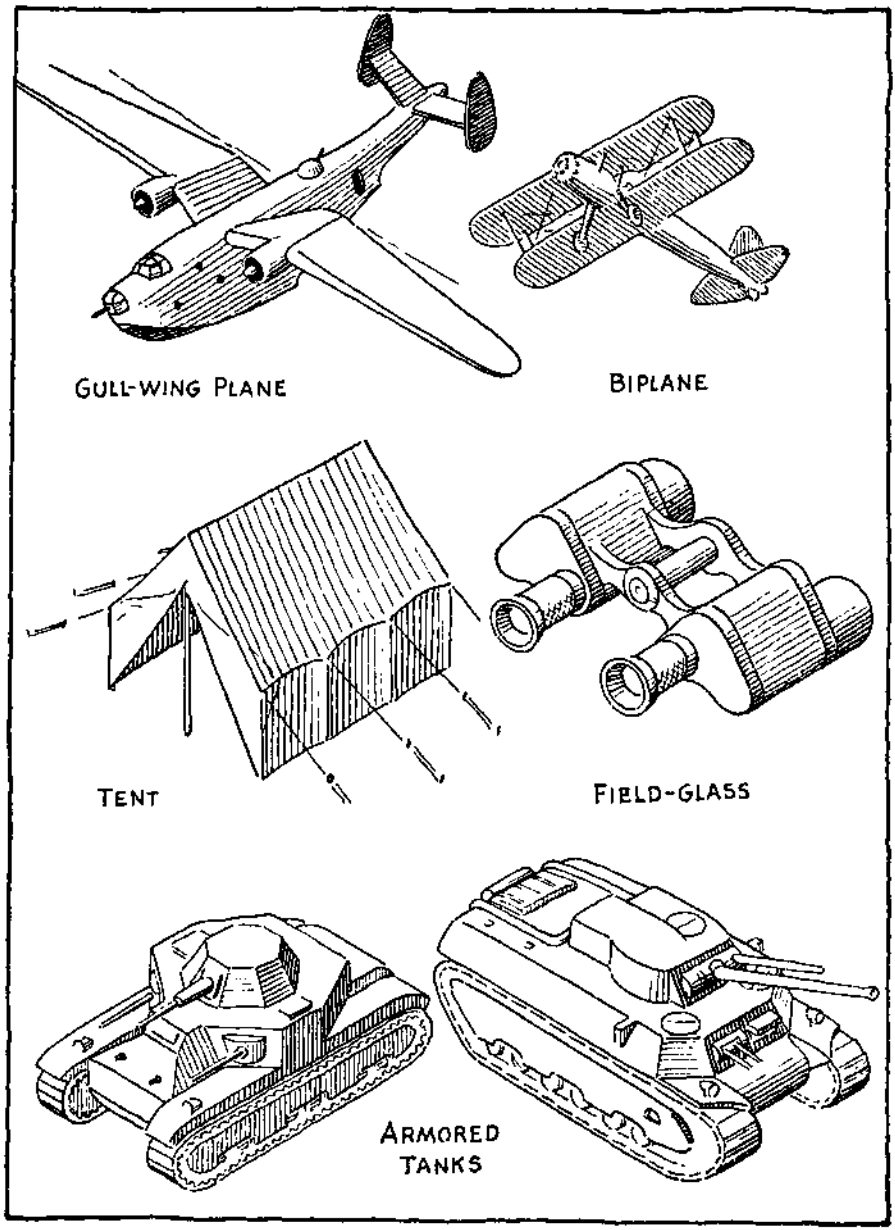


PLATE 81. Shading on Assembly Drawings.

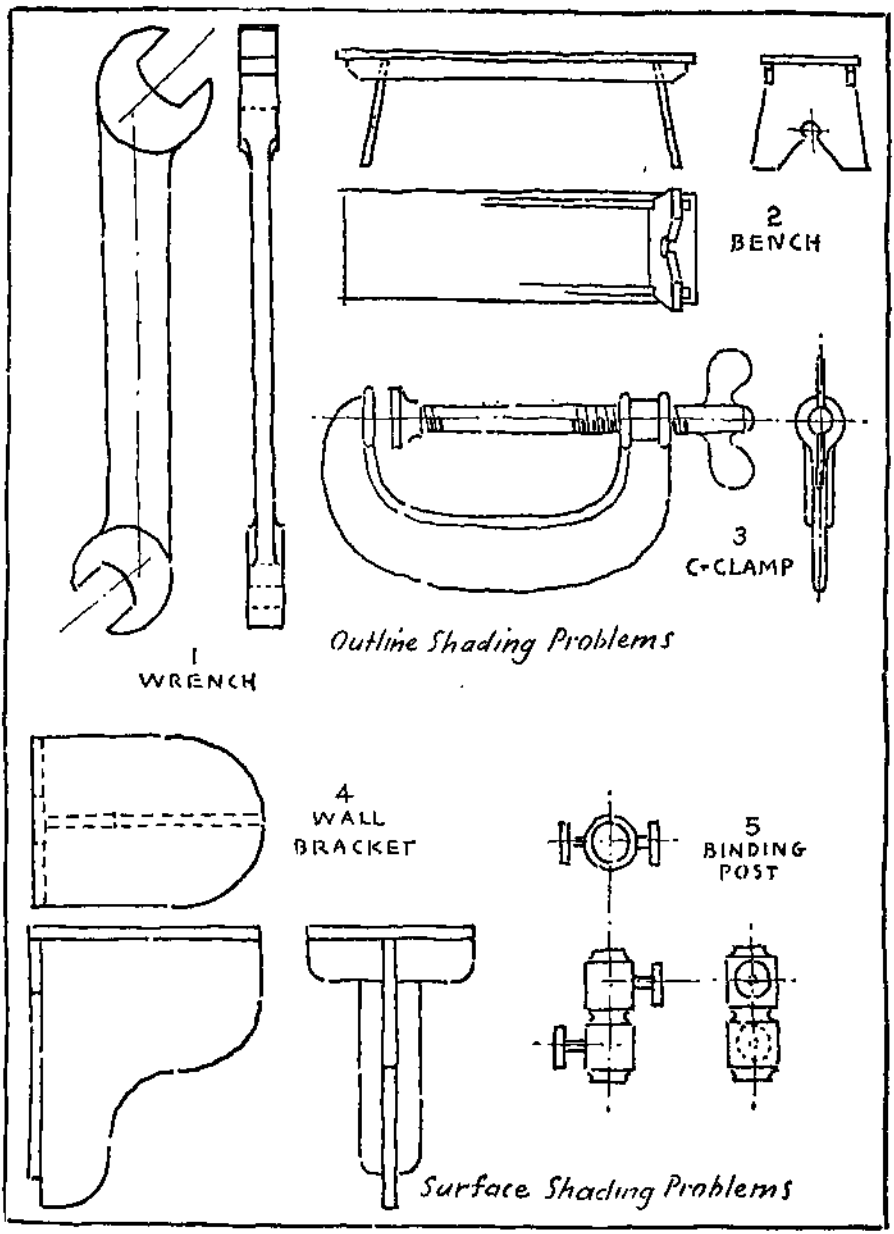
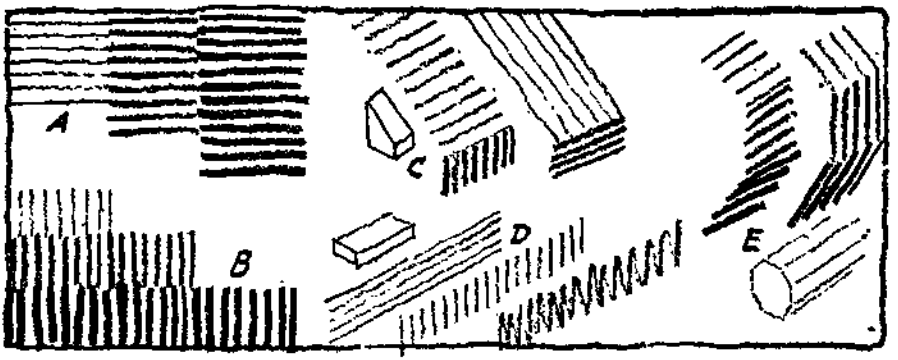


PLATE 82. Problems 1 to 5.



6- PRACTICE STROKES

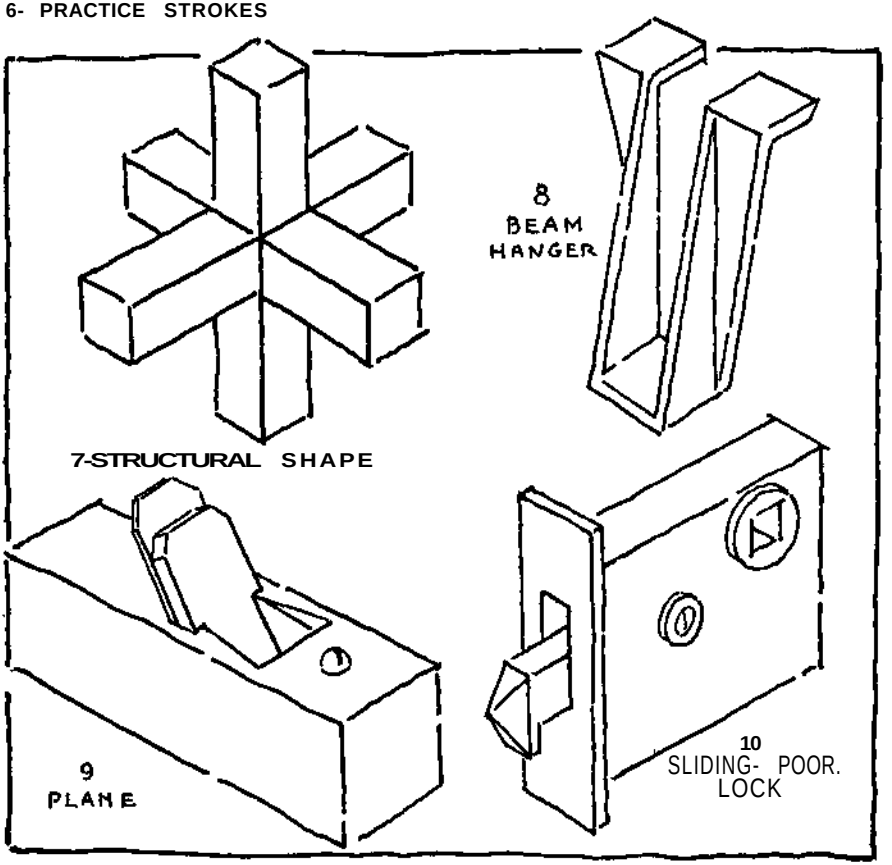
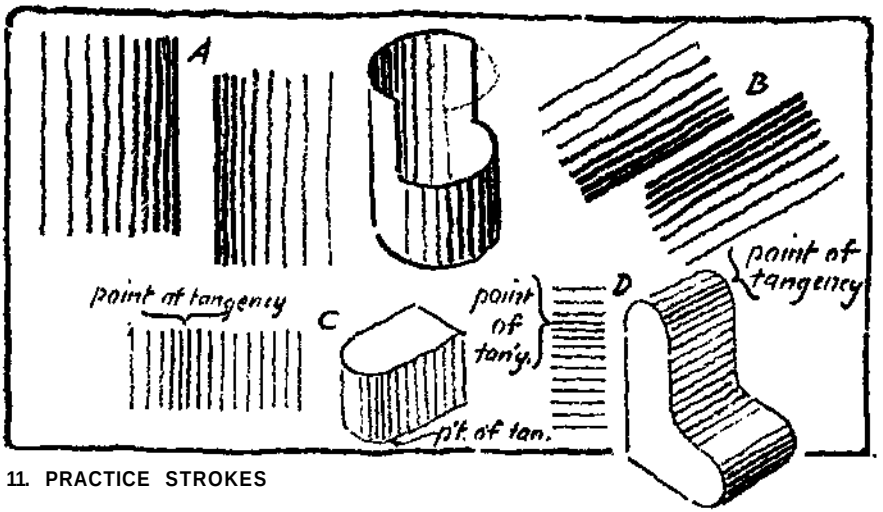


PLATE 83. Practice Strokes and Problems 6 to 10.



11. PRACTICE STROKES

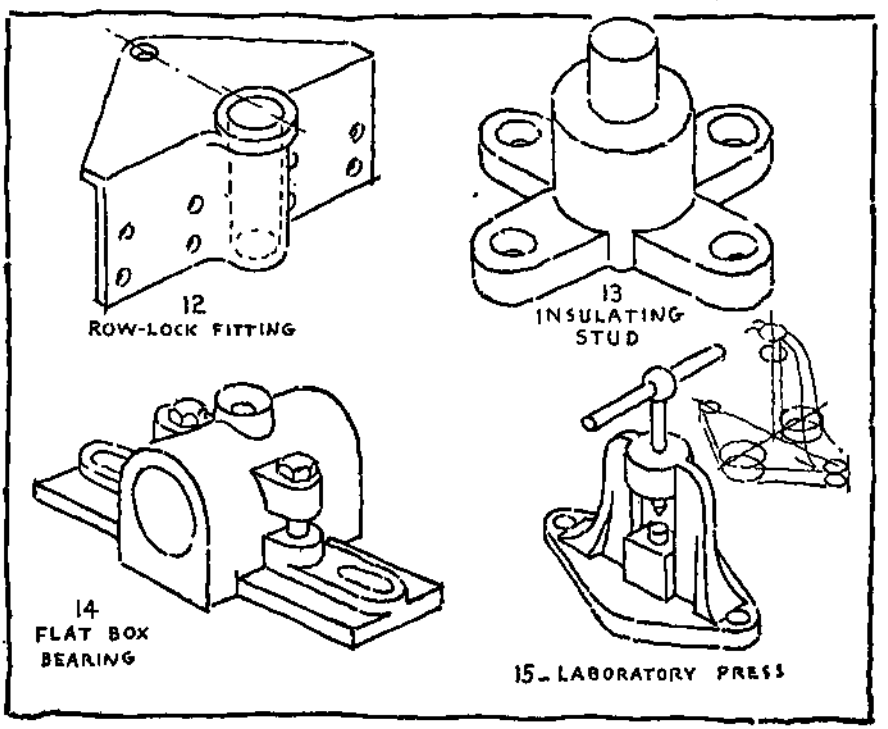


PLATE 84. Practice Strokes and Problems 11 to 15.

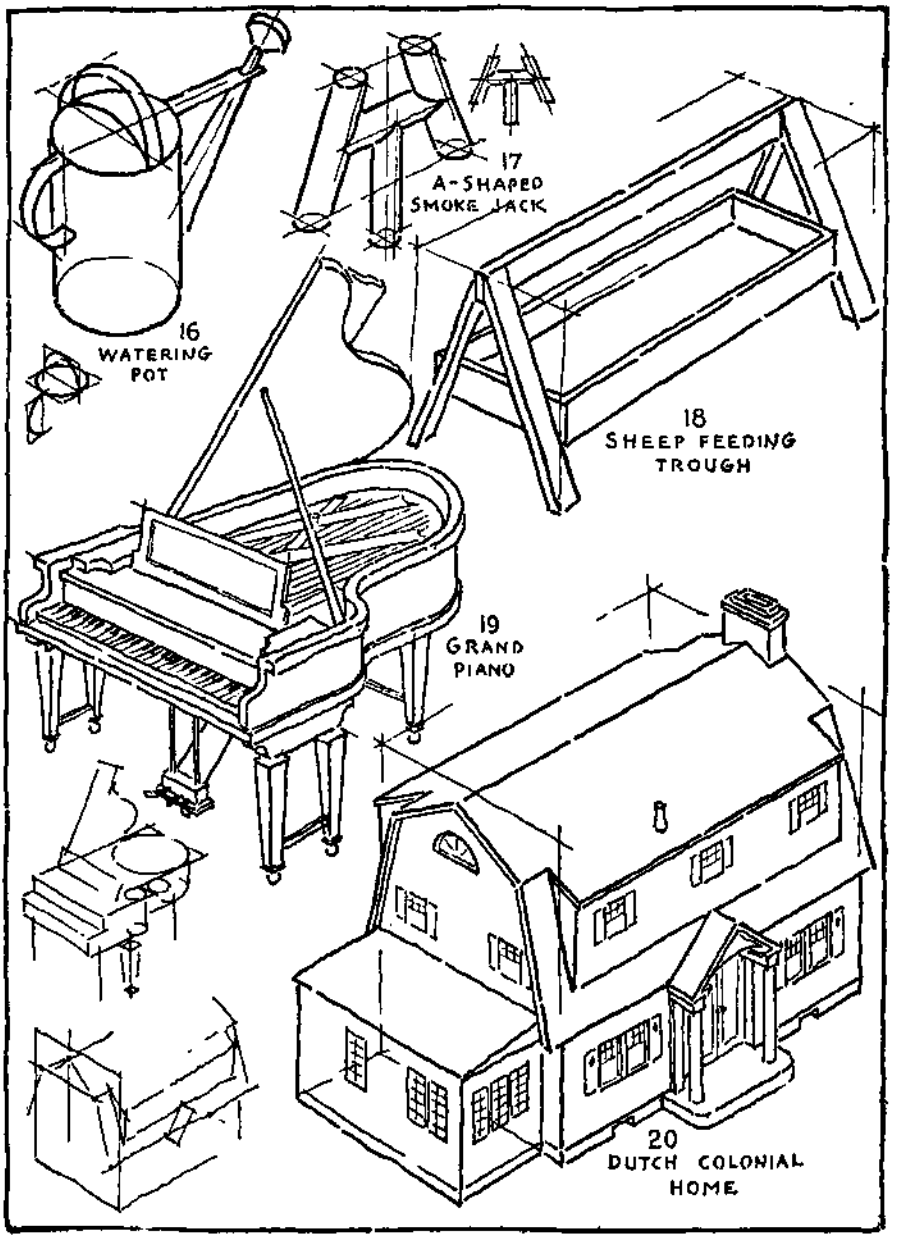


PLATE 85. Problems 16 to **20.**

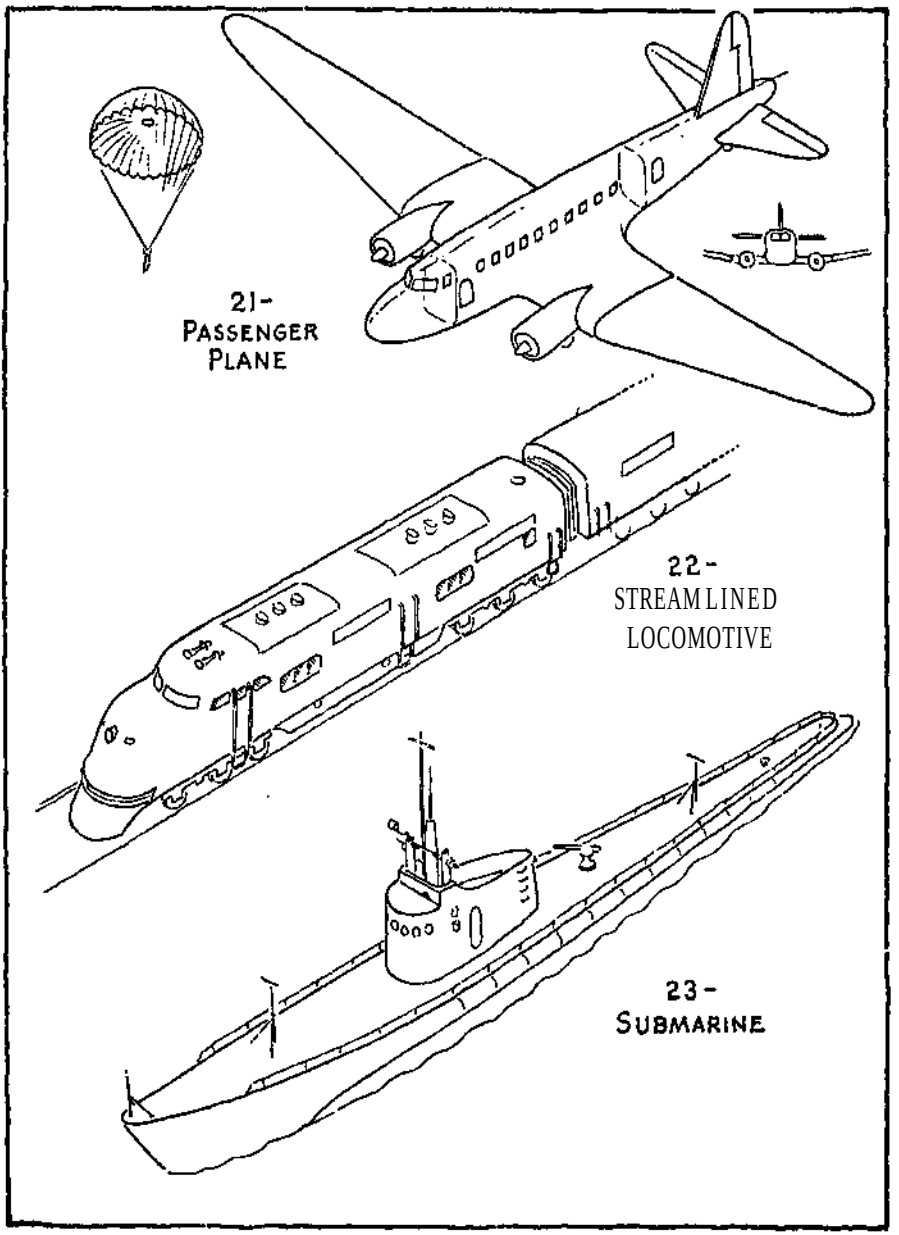


PLATE 86. Problems 21 to 23.

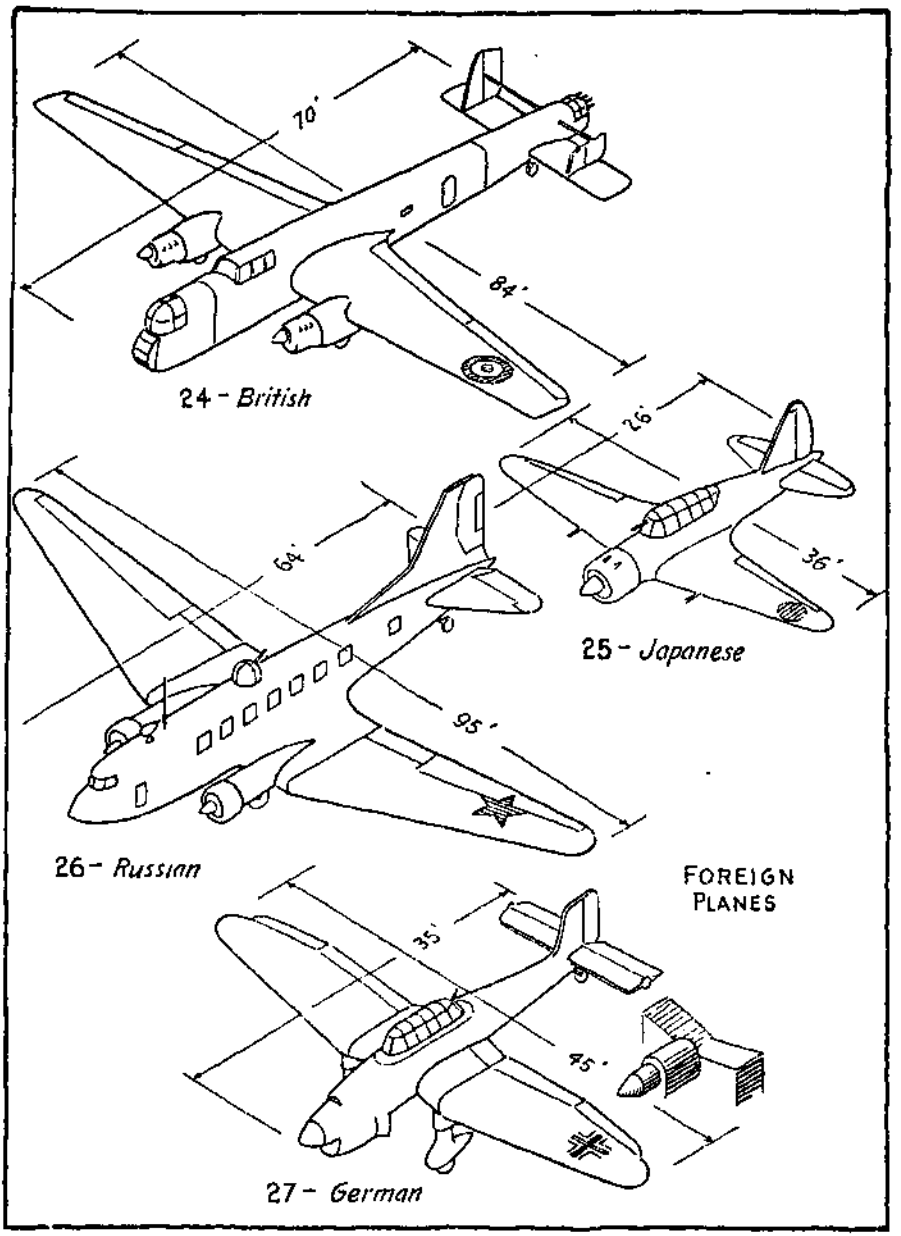


PLATE 87. Problems 24 to 27.

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