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Radford's Cyclopedia of Construction

Carpentry, Building *and* Architecture

A General Reference Work on

MODERN BUILDING MATERIALS AND METHODS AND THEIR PRACTICAL APPLICATION TO ALL FORMS OF CONSTRUCTION IN WOOD, STONE, BRICK, STEEL, AND CONCRETE; INCLUDING ALSO SUCH ALLIED BRANCHES OF THE STRUCTURAL FIELD AS HEATING AND VENTILATING, PLUMBING, ELECTRIC WIRING, PAINTING, CONTRACTS, SPECIFICATIONS, ESTIMATING, STRUCTURAL DRAFTING, ETC.

Based on the Practical Experience of a
LARGE STAFF OF EXPERTS IN ACTUAL CONSTRUCTION WORK

Illustrated

TWELVE VOLUMES

THE RADFORD ARCHITECTURAL COMPANY
CHICAGO, ILL.

Radford's
Cyclopedia of Construction

Prepared under the Supervision of

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Bibliography of Construction

BEING A SELECTED LIST OF STANDARD WORKS COVERING VARIOUS PORTIONS OF THE GENERAL FIELD OF CONSTRUCTION

In addition to the vast store of up-to-date practical information never before published, the editors have embodied in the Cyclopedia of Construction the cream of the world's best literature in this field, giving in condensed form the substance of everything essential in the experience of the past to enable the worker of the present to meet every problem likely to be met with under the conditions of ordinary practice.

For the sake, however, of those who may be interested in pursuing further study along various special lines, we furnish a list of important works that have appeared covering different portions of the field.

In this connection, the editors wish to express their thanks to American manufacturers and dealers in the machinery and materials of construction, as well as to proprietors and patentees of various special mechanical devices and processes, for valuable data, illustrations and suggestions.

Authorities on Construction

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DRAFTING TABLE IN THE OFFICE OF A WORKING ARCHITECT.
Note case for reference books at right, and for current magazines and catalogues at left.

Preface

THE Building Industry, in its various branches, is more closely identified than any other with the marvelous engineering progress of the present day and the untold possibilities of the future. To put all classes of workers in familiar touch with modern methods of construction and the latest advances in this great field, and to bring to them in a form easily available for practical use the best fruits of the highest technical training and achievement, is the service which the CYCLOPEDIA OF CONSTRUCTION aims to render.

The work is pre-eminently a product of practical experience, designed for practical workers. It is based on the idea that even in the larger problems of engineering construction, it is not now necessary for the ordinary worker in concrete, or steel, or any other form of material, to attempt the impracticable task of exploring all the highways and byways where the trained engineer or technical expert finds himself at home. The theories have been worked out; the tests and calculations have been made; observations have been recorded in thousands of instances of actual construction; and the results thus accumulated form a vast treasure of labor-saving information which is now available in the shape of practical working rules, tables, instructions, etc., covering every phase of every construction problem likely to be met with in ordinary experience. This is perhaps most apparent in the sections on *Cement and Concrete Construction, Plain and Reinforced.* To this subject, on account of its supreme importance as a structural factor of the present day, three entire volumes are devoted, embodying the cream of all the valuable information which engineers have gathered up to date. Much of this practical information now presented in this Cyclopedia, has never before been published in any form. By its use, anyone is enabled to take advantage of the vast labors of others, and to bring to bear on any problem confronting him the results of the widest experience and the highest skill.

The keynote of the Cyclopedia is found in the emphasis constantly laid on the *practical* as distinguished from the *theoretical* form of treatment, in its total avoidance of the complicated formulas of higher mathematics, and in its reduction of all technical subjects to terms of the simplest and clearest English. Throughout the pages devoted to Steel Construction, for example, the mathematics of the subject have been eliminated to such an extent that *the reader will not find a single instance where even a square root sign has been used.*

In addition to the larger problems of engineering and building construction, one entire volume, as well as many chapters scattered through the work, is devoted to those smaller constructions that are of special interest to the teacher or student of manual training or the home shop worker of a mechanical turn of mind.

Inasmuch as a wider knowledge and a more intelligent grasp of the fundamental principles of construction and design will tend to greater efficiency on the part of workingmen, and to greater economy in production, the purpose of the CYCLOPEDIA OF CONSTRUCTION is one which will appeal strongly, not only to the men themselves, but also to the architectural and engineering fraternity as a whole.

The authors of the various sections are all men of wide experience whose recognized standing is a guarantee of reliability and practical thoroughness.

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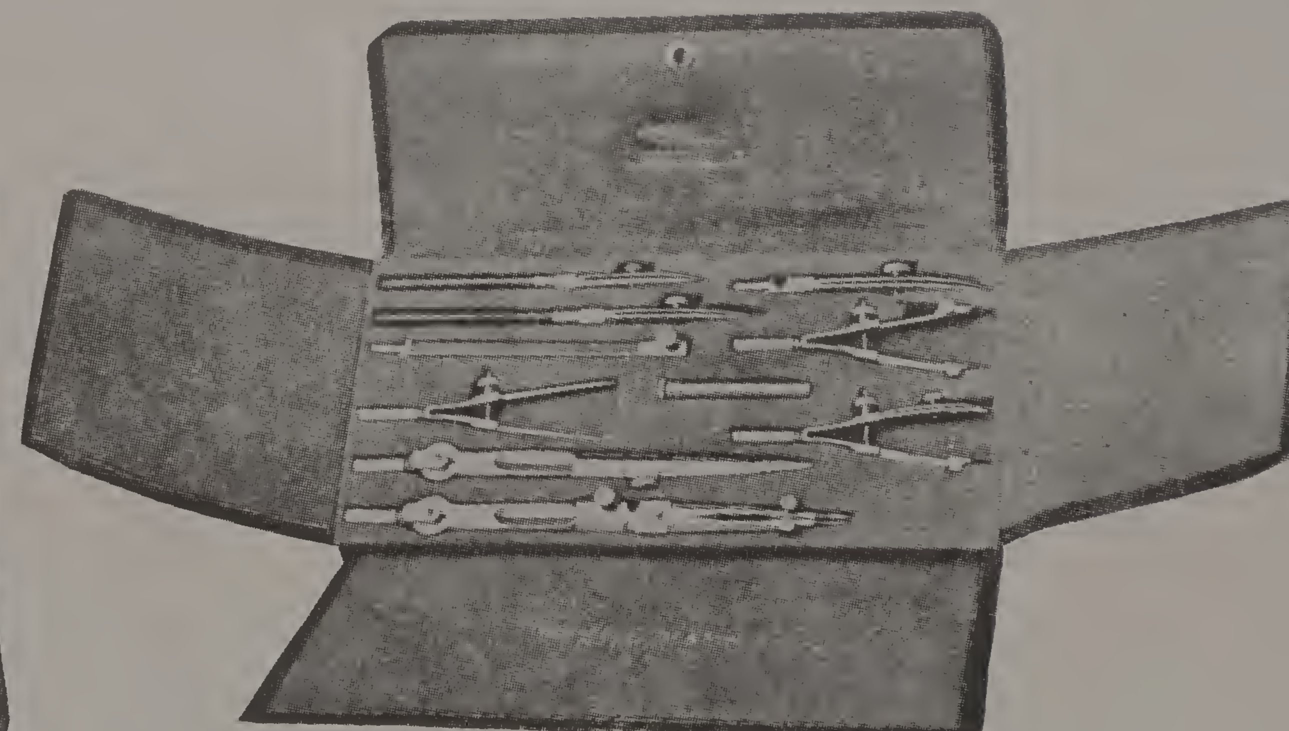


SETS OF DRAFTING INSTRUMENTS.

Fig. 1—In leather case, with stiff cover; Fig. 2—In leather pocket case, with limp cover and folding flaps.

PLATE 1—Mechanical Drafting.

Mechanical Drafting

INTRODUCTION

1. Mechanical drafting or drawing is the process of representing on paper, by means of one or more figures, the shape and size of an object, and the relation of its different parts one to another. It is the medium of communication between the designer or architect and the mechanic or builder, and, as such, has very great practical value. The engineer plans a bridge, the architect a building; their ideas are represented on paper by suitable mechanical drawings of the structures; and these drawings are turned over to the contractor or builder to show the shape, dimensions, and details required.

A knowledge of mechanical drafting is indispensable to the engineer, the architect, the contractor, the inventor, the carpenter, the machinist, and, in short, to everyone whose work lies along these or similar lines.

Mechanical drafting, as the name implies, is done chiefly by the use of instruments. Freehand drawing, however, is frequently used in connection with mechanical, especially in preliminary sketching and in ornamental work.

THE DRAFTSMAN'S OUTFIT

2. For a beginner to do good work, reliable tools are necessary. It is worth while to pay a little more money at the outset in order to have an equipment which will give satisfactory service. Perhaps nothing is more disheartening to a beginner than to have his best efforts meet with little success, on account of poor instruments. For mechanical drafting, the articles in most common use constituting the **draftsman's outfit** are the following:

Set of instruments.
Drawing board.
Thumb-tacks.
T-square.
Triangles.
Irregular curves.
Scales.
Pricker.
Erasers.
Pencils.
Ink.
Paper and tracing cloth.
Sandpaper or fine file.
Small oil-stone.

Besides these, there are many others which are used at times, especially by the professional draftsman—such as the protractor, erasing shield, burnisher, proportional dividers, section liner, beam compasses, steel straight-edge, pantograph, brushes, etc.

3. The **set of drawing instruments** is the item

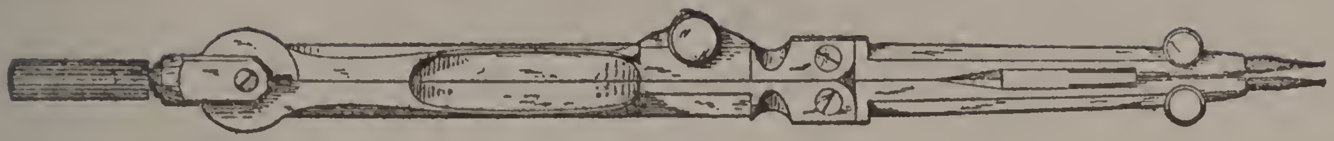


Fig. 3. Compass.

Fig. 4. Lengthening Bar.

Fig. 5. Compass Pen.

Fig. 6. Hair-Spring Dividers.

Fig. 7. Small Dividers or Bow Spacers.

Fig. 8. Bow Pencil or Small Compass.

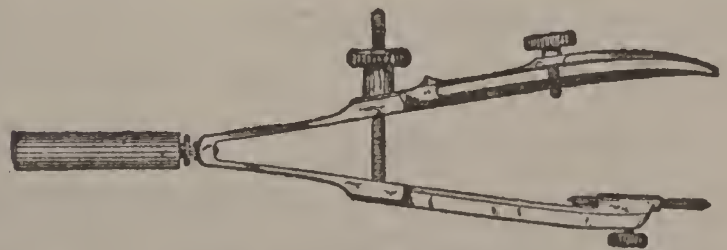


Fig. 9. Bow Pen.

Fig. 10. Ruling Pen.
(Cuts by courtesy of T. Alteneder & Co.)

of greatest cost, and should be selected very carefully. A good set purchased from some reliable house, will, with proper care, do good service for years. These sets are sold in various ways—some being put up in a leather case with a stiff cover; others, adapted especially for carrying in the pocket, being in a case with a limp cover and folding flaps. The various pieces may also be bought separately, if desired.

4. Figs. 1 and 2 show a set of instruments in two kinds of cases, Fig. 2 being the folding pocket style. In Figs. 3 to 10 the different instruments are shown separately.

5. Fig. 3 is the **compass.** One leg carries lead, the other a needle-point. Each leg is jointed, and the lower half of one leg is detachable at the joint. This is to provide for inserting the **compass pen** or the **lengthening bar.**

6. The **lengthening bar,** Fig. 4, is to enable the draftsman to draw pencil or ink circles larger than can be drawn with the ordinary compass. When the pencil leg is detached from the compass, the lengthener is inserted in its place, and the pencil leg or the compass pen fastened in its end.

7. The **compass pen,** Fig. 5, is for inking circles or circular arcs, and is inserted in the compass in place of the pencil leg.

8. The **hair-spring dividers** are shown in Fig. 6; and the **small dividers** or **bow spacers** in Fig. 7.

9. The **bow pencil** or **small compass** and the

bow pen are shown in Figs. 8 and 9 respectively.

10. The **ruling pen,** Fig. 10, is specially designed for ruling straight lines, the ordinary writing pen being wholly unsuitable.

11. The **beam compass** is shown in Fig. 11. This instrument is for accurately laying off dis-

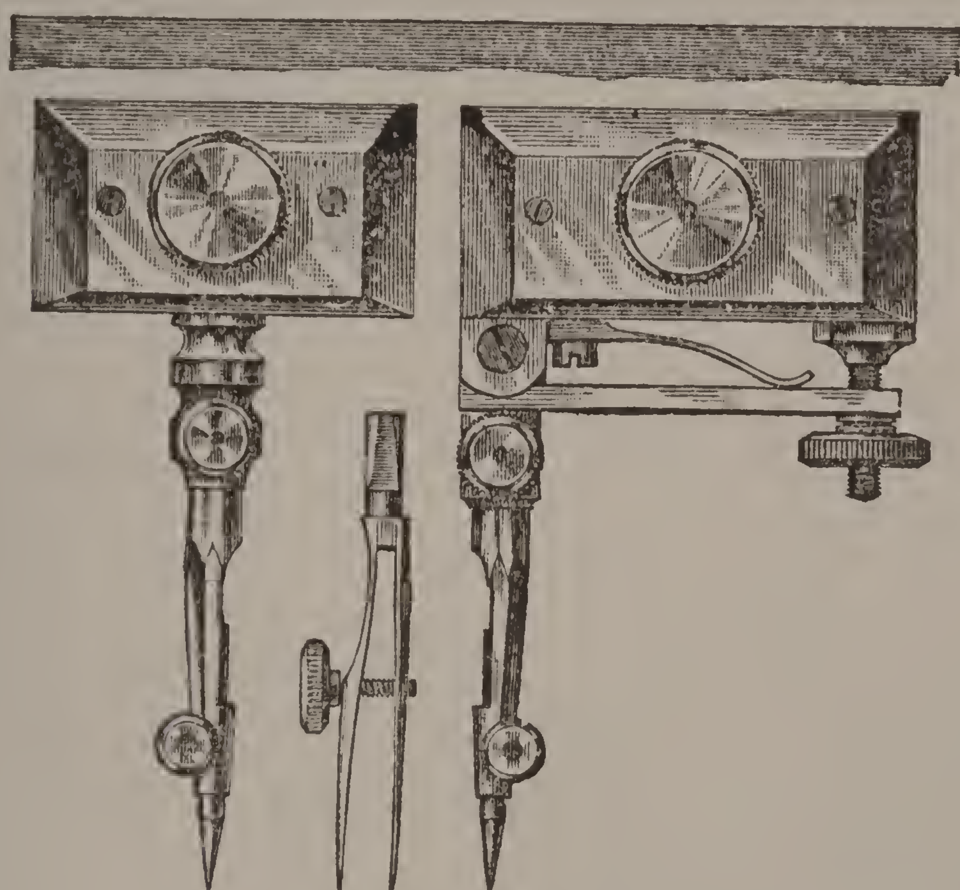


Fig. 11. Beam Compasses.

tances, and for drawing circles which are beyond the capacity of the ordinary dividers or compasses. It consists essentially of the beam (not shown in the drawing), a thin straight bar of hardwood, and two pieces which slide along the bar and which may be clamped to it at any desired distance apart. These sliding attachments are called **channels,** and carry one the needle-point, and the other the pencil or pen as desired. As shown at the right, there is a **micrometer screw** for obtaining great precision in setting the compass for any given distance or radius.

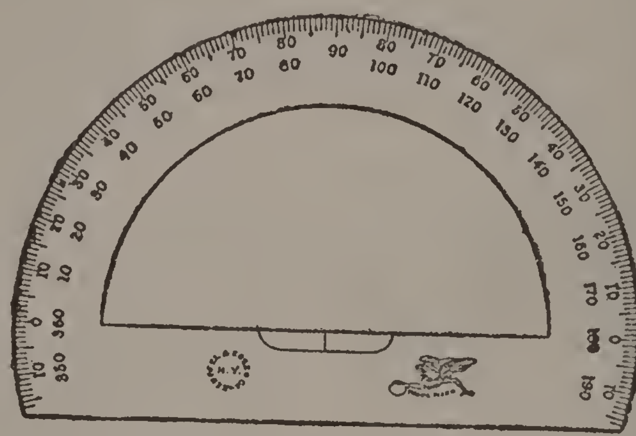


Fig. 12. Protractor.

12. The **protractor** is shown in Fig. 12. This instrument, while not in such constant use as some of the others, is nevertheless necessary at

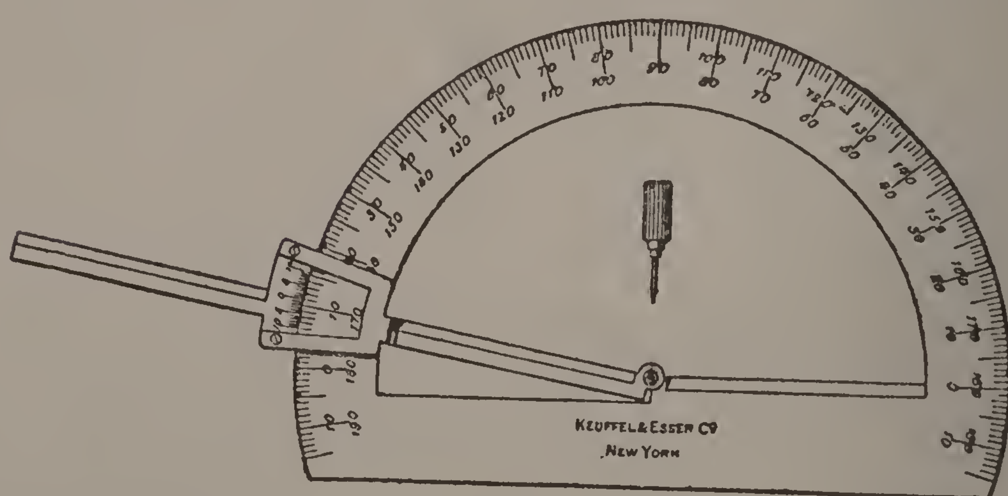


Fig. 12a. Semicircular German Silver Protractor, with Horn Center and Movable Arm.

times. It is made of various substances, such as metal, celluloid, cardboard, etc., and is used for laying out angles which cannot be obtained with the triangles and which cannot be easily constructed geometrically. The graduations represent degrees or subdivisions; and the center of the graduated circle is marked by a scratch or small notch on the line through the two zero points. A line drawn from the center of the circle through any point of division—as, for example, through 70—will make an angle of 70 degrees with the zero line of the protractor. Other angles may be drawn in a similar way.

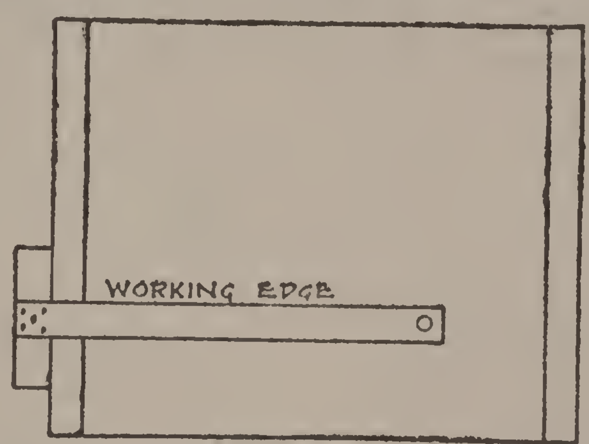


Fig. 13. Drawing Board and T-Square.

13. The **drawing board**, shown in Fig. 13, is used to supply a smooth, even surface on which to fasten the drawing paper. It should be made of straight-grained, well-seasoned soft wood; and the cleats at the ends of the board should have straight edges. Some cheap drawing boards have a strip of brass or steel screwed on at one end; these, however, are likely to warp, and are not to be recommended. The board should not be allowed to remain in the sun or near heating apparatus.

14. **Thumb-tacks** are short tacks with large flat or almost flat heads, especially used for fastening the paper to the drawing board. They may be pressed into the soft wood of the board

with the thumb. Unless the paper is of comparatively large size, four tacks—one through each corner—will be sufficient to keep the paper in place. Small-sized copper tacks may be used if preferred, as the heads of these offer less obstruction to the motion of the triangles and other implements.

15. The **T-square**, shown with the drawing board in Fig. 13, consists of a **blade** and a **head.**

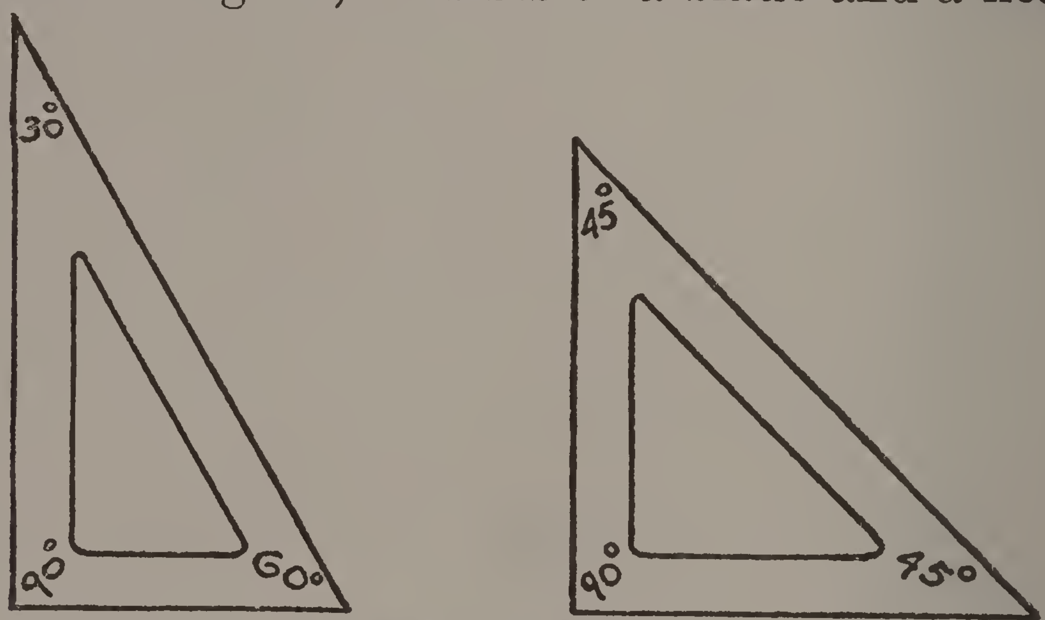


Fig. 14. Triangles.

The blade may be permanently fastened to the head, or the head may be provided with a clamp so as to be adjustable.

For a right-handed draftsman using the T-square against the left-hand side of the board, the upper edge of the blade is the **working edge,** as shown in Fig. 13. A good T-square should have a perfectly straight working edge, a straight working edge also for the head, and no motion between head and blade. The most accurate T-squares are made of steel, but very satisfactory ones are made of wood—some with plain edges, and others with edges of ebony or celluloid.

T-squares are made in various sizes, and numbered according to the length of the blade in inches. When not in use, the T-squares should

Fig. 15. Irregular or French Curves.

be hung up, using the hole in the end of the blade and should be kept out of the sunlight, and away from radiators or steam pipes.

16. Of the **triangles**, shown in Fig. 14, probably the best for all-round work are those made of celluloid, as these are fairly accurate, light, and more or less transparent. It is perhaps hardly necessary to state that celluloid is

highly combustible, and must therefore be kept away from fire.

Triangles are made in different sizes, and numbered according to the lengths of the edges. A 10-inch 45-degree triangle is one with each of the **perpendicular** edges 10 inches long; a 12-inch 30-degree 60-degree triangle has the long **perpendicular** edge 12 inches long; and so on for other sizes.

For general work, one should have at least four triangles—one large and one small 45-degree, 10 or 12 inches, and 5 or 6 inches, respectively; and two 30-degree 60-degree triangles—one large and one small. To prevent warping, triangles, when not in use, should be hung up out of the sun's rays.

17. **Irregular** or **French curves** of various shapes are shown in Fig. 15, and are used for drawing-in smoothly curved lines which are not arcs of circles.

18. **Scales.** First of all, scales are not used for ruling lines. All straight lines should be drawn either with the T-square or with a triangle. Scales are made in different shapes and lengths, the most common, perhaps, being the 12-inch length triangular or the flat with beveled edges.

Scales are also distinguished as **Architect's** and **Engineer's scales.** On the latter, it will be sufficient to say that the inch is divided into tenths or multiples of ten, and is used chiefly in scientific, machine, and engineering work.

The **Architect's scale** is shown in Fig. 16. By reference to the figure, it will be seen that the scale is triangular, and therefore has six faces for division. On one side of one face the scale is marked off into inches and divided in the usual way. On the other faces are ten different scales, marked at the ends ¼, ½, ⅜, etc.

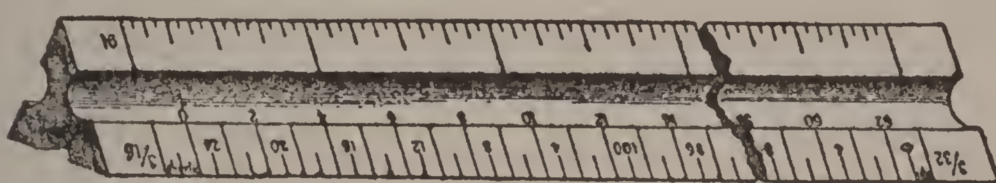


Fig. 16. Architect's Scale.

These numbers mean that the scale so marked is the scale ¼ inch to the foot, ½ inch to the foot, and so on.

Let the scale of ½ inch=1 foot be taken as an example. By actually examining a scale, the draftsman will see that the space at the end marked ½, which is actually one-half an inch in length, is divided into twelve equal parts, so that if one-half inch be taken to represent one foot, then each smallest space will stand for one inch. The other spaces at the right of the divided one are half-inches, and so will each represent one foot.

The use of the scale in making actual drawings will be explained later.

19. The **pricker** is a fine needle-point fastened in a convenient handle, and is used for accurately noting the position of a given point.

20. **Erasers** are frequently needed by the

draftsman for making changes or correcting errors in the drawing. They are of two kinds—for **pencil** and for **ink.** For erasing ink lines, a **sand-rubber eraser** or a **steel eraser** may be used. The steel eraser is a special knife sharpened to a keen edge. With this knife, most of the ink may be removed, then the remainder rubbed off with the sand or pencil rubber.

21. **Pencils.** Special pencils are required for drawing, the ordinary kind being as a general thing entirely unsuitable. Drawing pencils are marked at one end with a number or with one or more letters, to show the degree of hardness. The hardness of the lead varies from 7 or 8H, very hard, to one or more B's, very soft.

22. **Drawing ink** is made in two forms—the **liquid,** ready for use; and the **dry,** in stick form. If the latter is used, it is prepared by grinding with a little water in a stone saucer until the water containing the dissolving ink is perfectly black and of the desired thickness. The bottled inks are made in black and in colors. Some of these inks are made waterproof, not being affected by moisture. For general work, the bottled ink is recommended for satisfactory results and economy of time.

23. **Paper.** The kind of paper varies with the sort of work to be done. Drawings from which blue-prints are to be taken are commonly made on a cheap brown **detail** or **duplex paper,** or on thin, tough **white bond.** For nicely finished drawings, **cold-pressed** and **hot-pressed**

papers are excellent, the latter being especially adapted for ink work.

Another paper which is very satisfactory for ink drawing is the **normal,** which has a hard, smooth surface. For the highest grade of inked drawings, as for the Patent Office, for book work, etc., **bristol board** is preferred. This is a cardboard made of two or more layers; has a very hard, smooth surface; and gives very sharply defined and clean-cut lines.

24. **Tracing cloth** is used when drawings are to be reproduced in blue-prints for shop or field use. One side of the tracing cloth has a dull finish, the other side being shiny. Ink may be used on either side of the cloth. Erasers may be used as on drawing paper, except that the ink eraser or sand rubber should be used very carefully so as not to wear a hole through the cloth. Water ruins the surface for drawing.

Testing of Instruments

25. **Testing the T-Square.** Place on the board a sheet of drawing paper at least as long as the blade of the T-square, and, with a sharp, hard pencil, draw a line across the paper close against the upper or working side of the blade, Fig. 17. Then, without changing the position of the T-square turn the paper end for end; place the line to coincide as nearly as possible with the same edge of the T-square; and draw a line again. If the second line falls exactly upon the first, the edge of the T-square is straight; but if

the lines do not exactly coincide, the edge is not true, and should be made so with a plane or sandpaper.

If the edge of the T-square has been found straight, the working edge of the drawing board (the edge against which the head of the T-square slides), may be tested by applying to it the tested edge of the T-square.

26. **Testing the Triangles.** A common fault with triangles, especially the larger ones, is a

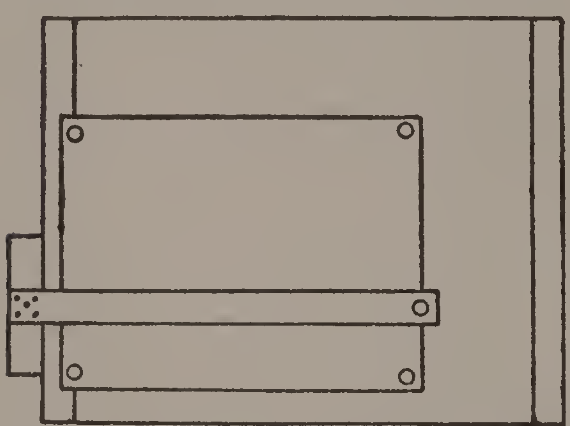


Fig. 17. Testing the T-Square.

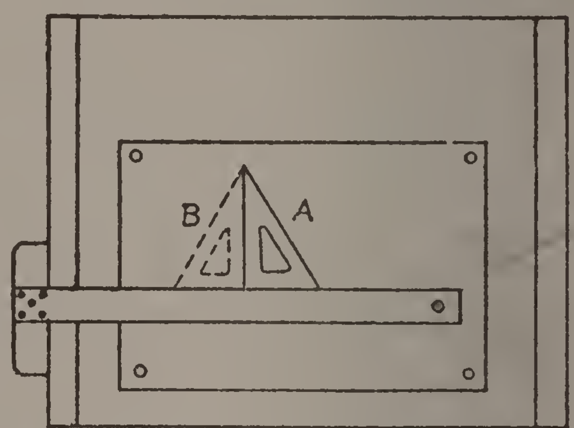


Fig. 18. Testing the Triangle.

lack of accuracy in the right angle; that is, one side is not exactly square or at right angles with the other side.

To test for squareness of the right angle (see Fig. 18), place one side of the triangle against the tested edge of the T-square as shown at **A**, and, with a very sharp, hard pencil, draw a line against the vertical edge of the triangle. Next turn the triangle over, **face-down,** in the position shown at **B**, and draw against the vertical edge a second line to coincide if possible with the first one. If the two exactly coincide, the right angle is true. Both the 60-degree 30-

degree and the 45-degree triangles should be tested in this way.

To test the 45-degree angles, if the 90-degree angle is found to be true, draw a 45-degree line with one of the short sides against the T-square; then turn the triangle over, and place the other short side against the T-square. If, in this position, a second 45-degree line can be drawn exactly coinciding with the first, the angle is exactly 45 degrees.

The 60-degree and 30-degree angles can be tested after the right angle has been found correct, by first drawing a T-square line on the paper, then drawing with the triangle against the T-square two 60-degree lines so as to form a triangle having the T-square line as a base. Next test with the dividers the relative lengths of the three sides. If they are exactly equal, the 60-degree and 30-degree angles are both correct.

HOW TO USE THE INSTRUMENTS

27. **Drawing Board, T-Square, and Triangles.** Tack a sheet of drawing paper on the board by a thumb-tack at each corner, and let the T-square rest on the paper, with the head against the left edge of the drawing board. If the draftsman is left-handed, he should use the T-square against the right edge of the board. If now a line be drawn on the paper against the blade of the T-square (Fig. 19), then the T-square slid along the edge of the board, and

other lines drawn in the same way, these lines will be parallel to one another.

In making drawings, the drawing board should either lie flat on the table or desk, or be raised slightly at the back, giving a forward inclination.

The pencil should always be **drawn, not pushed.**

Only the upper or working edge of the T-square is used in drawing.

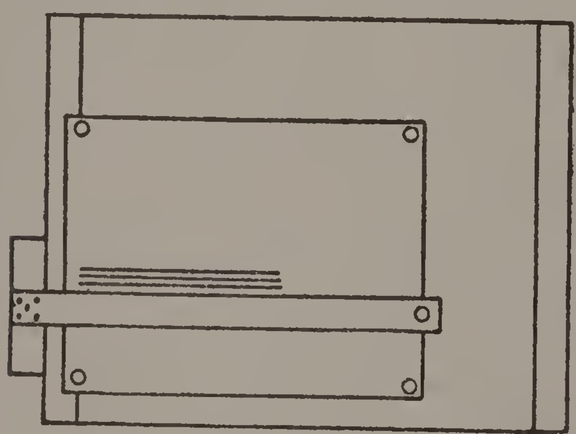


Fig. 19. Drawing Parallel Lines with T-Square.

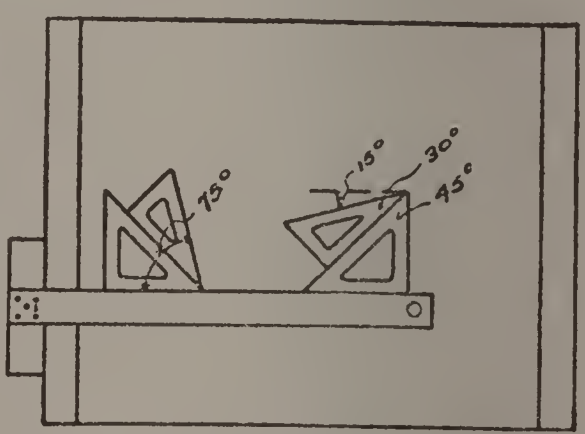


Fig. 20. Drawing Angles of 15 and 75 Degrees.

28. For **drawing vertical or inclined lines,** the triangles are used. When one of the shorter sides of a triangle is placed against the edge of the T-square, a vertical line may be drawn against one of the other sides, and a slanting line against the third side. This slanting line will be at 45 degrees for the 45-degree triangle, and at 30 or 60 degrees for the other triangle according to the side of the triangle which is placed against the T-square.

Lines making with the edge of the T-square angles of 15 degrees or 75 degrees, may be drawn by combining the 45-degree and the 30-degree 60-degree triangles, as shown in Fig. 20.

Inclined lines which are not at an even angle, may be drawn parallel to any desired direction as follows:

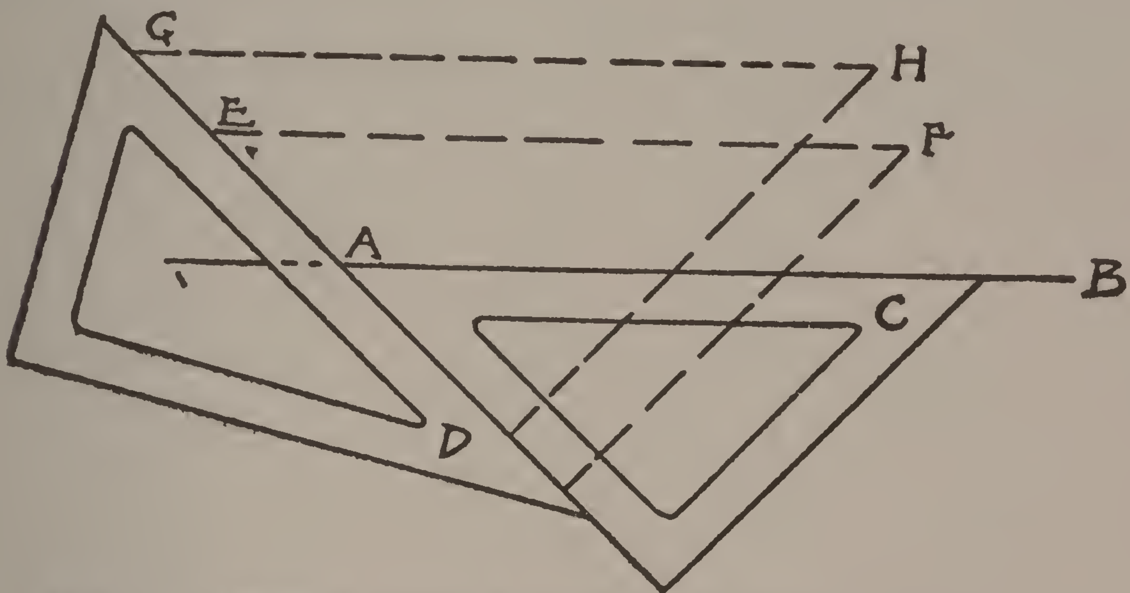


Fig. 21. Drawing Parallel Lines in Any Desired Direction.

In Fig. 21, **AB** is an inclined line, and other lines are to be drawn parallel to **AB** and above it. Place one triangle, as **C**, with one edge coinciding with line **AB**; and place another triangle, as **D**, against another edge of **C** as shown. Now, if triangle **C** slides along triangle **D** into the dotted positions, lines drawn against the upper edge of **C** will be parallel to **AB**; thus **EF** and **GH** are parallel to **AB**.

29. **To Draw Lines Perpendicular to a Given Inclined Line.** In Fig. 22, **AB** is the given inclined line. Place a triangle, as **C**, with its **longest** edge coinciding with the line **AB**; and place another triangle, as **D**, in contact with the lower left-hand edge, as shown. Next revolve the triangle **C** around, as shown by the arrows, into the

position **EFG**; then the long edge in the position **EF** is perpendicular to the line **AB.** Other lines perpendicular to **AB** may be drawn by holding triangle **D** fast, keeping **EG** against the edge of **D**, and sliding triangle **EFG** along the edge, when lines drawn against the different positions of **EF** will all be perpendicular to **AB**.

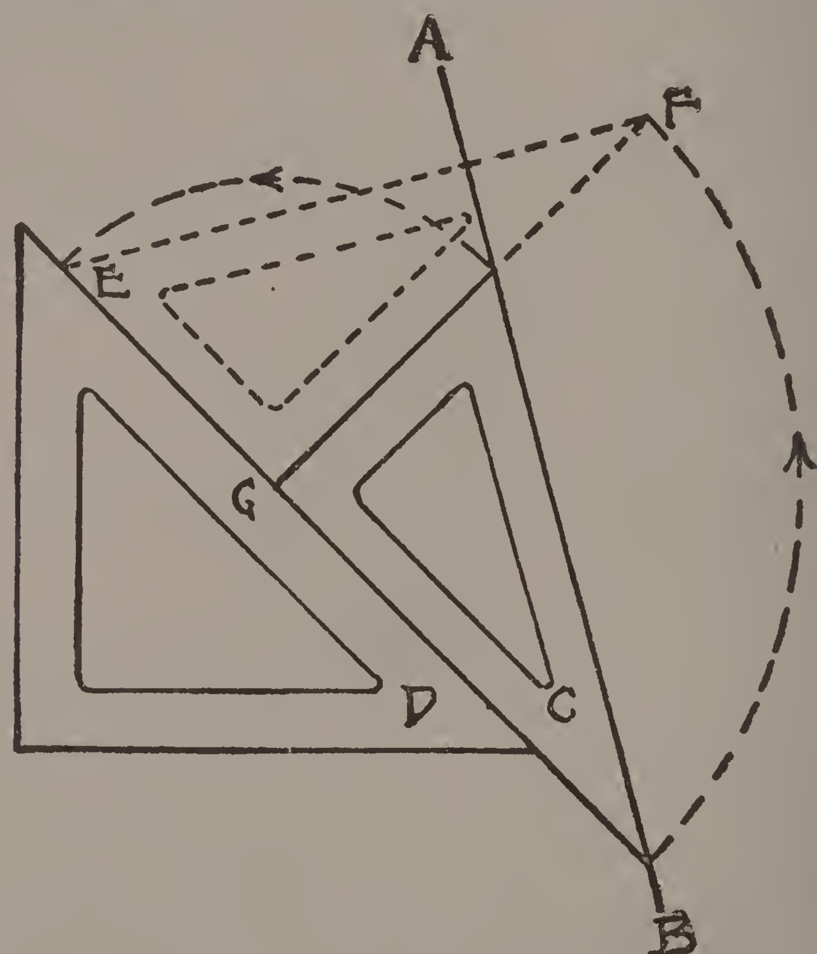


Fig. 22. Drawing Lines Perpendicular to a Given Inclined Line.

30. In connection with the T-square, it will be well for the beginner to remember the following **Don'ts**:

Don't change T-squares while making a drawing. If this must unavoidably be done at any time, see first if lines can be drawn with the second T-square which shall exactly coincide with the first. If not, unless the square has an adjustable head, the paper must be taken off the board, and then readjusted to agree with the second T-square.

Don't use the T-square for a thumb-tack hammer.

Don't use the working edge of the T-square as a straight-edge for trimming drawings.

31. In **laying out the border line** for a drawing, if the trimmed sheet is to be only a little smaller than the size of the paper, the center should first be found by means of the diagonals, and the border line laid from the center. If, however, there is ample paper, the border line may be drawn at once without finding the center.

32. **Pencils.** For line drawing, the pencils should be sharpened to a chisel edge, with corners rounded. It is an excellent idea to have the pencil most used sharpened at both ends, one with a chisel edge, and the other with a fine conical point. The latter point is used for making letters, numbers, marking points, etc. The compass lead may be sharpened to a chisel edge or conical point, although here the chisel edge is more satisfactory.

33. **The Architect's Scale.** Often, in actual practice, it becomes necessary to make a drawing either larger or smaller than the actual object. This is called **drawing to scale.** If, for example, the drawing is to be made one twenty-fourth actual size, then each dimension will be one twenty-fourth of the real size. To avoid

the necessity of dividing each dimension by 24 when making the drawing, the one twenty-fourth size scale is used. For one twenty-fourth size, one foot would be drawn as one-half inch; and one inch as one-twelfth of one-half inch, or one twenty-fourth inch. A scale of one twenty-fourth size is therefore spoken of as a scale of one-half inch to the foot, or, using the signs, $\frac{1}{2}'' = 1'$.

In Fig. 23 is shown one end of an Architect's triangular scale, in which the upper edge is divided to the scale of $\frac{1}{2}'' = 1'$. This would

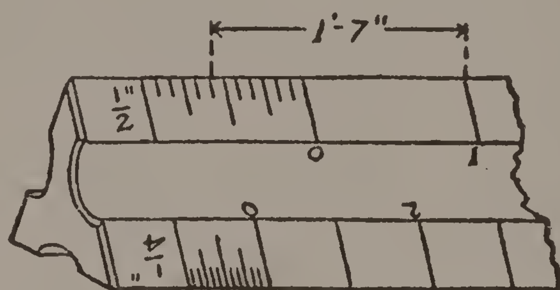


Fig. 23. Portion of Architect's Triangular Scale.

be used in making a drawing on the scale of $\frac{1}{2}'' = 1'$. The smallest spaces represent inches, and the longer undivided space between 0 and 1 represents one foot. No mental calculation, then, is necessary with this scale, as the required dimensions are laid off directly. For example, a length of 1 foot 7 inches would be laid off as shown in the figure.

The beginner should become familiar with the use of the scale, by actually laying off various dimensions in feet and inches, using the different scales in turn.

34. **The Compass.** Before using the com-

pass (Fig. 3), see that the lead and the needle-point project the same distance. In drawing circles, the compass should be held with the thumb and first two fingers at the extreme top, with the needle-point pressed on the paper only enough to hold it in place. When drawing large circles, the legs should be bent at the joints so that the lower part of each leg is vertical or nearly so.

35. **The Lengthening Bar.** The compass just described may be used for circles up to 6 or 7 inches radius; but above this distance, the **lengthening bar** (Fig. 4) should be used, which will enable one readily to draw circles up to 9 inches radius.

For larger circles, the **beam compass** (Fig. 11) should be used.

To attach the lengthening bar, loosen the screw which fastens the pencil leg, remove the leg, insert the lengthener, put the pencil leg in the other end of the lengthening bar, and tighten up both screws.

36. **The Hair-Spring Dividers.** The hair-spring dividers (Fig. 6) are used for laying off or transferring exact distances. This sometimes takes the form of dividing a given line, straight or curved, into a certain number of equal spaces, and it is in this kind of work that the hair-spring in the leg is especially useful. The screw in the leg is for fine adjustment, for, with any setting of the dividers, a slight turn of the screw changes the distance between the

needle-points by a very small amount. Setting up the screw increases the space, while turning the screw out lessens the distance between the points.

37. The **small dividers** or **bow spacers** (Fig. 7), are very useful for short distances where the large dividers would be awkward to handle.

38. The **bow pencil** or **small compass** (Fig. 8) is very convenient for circles or arcs of 1 inch

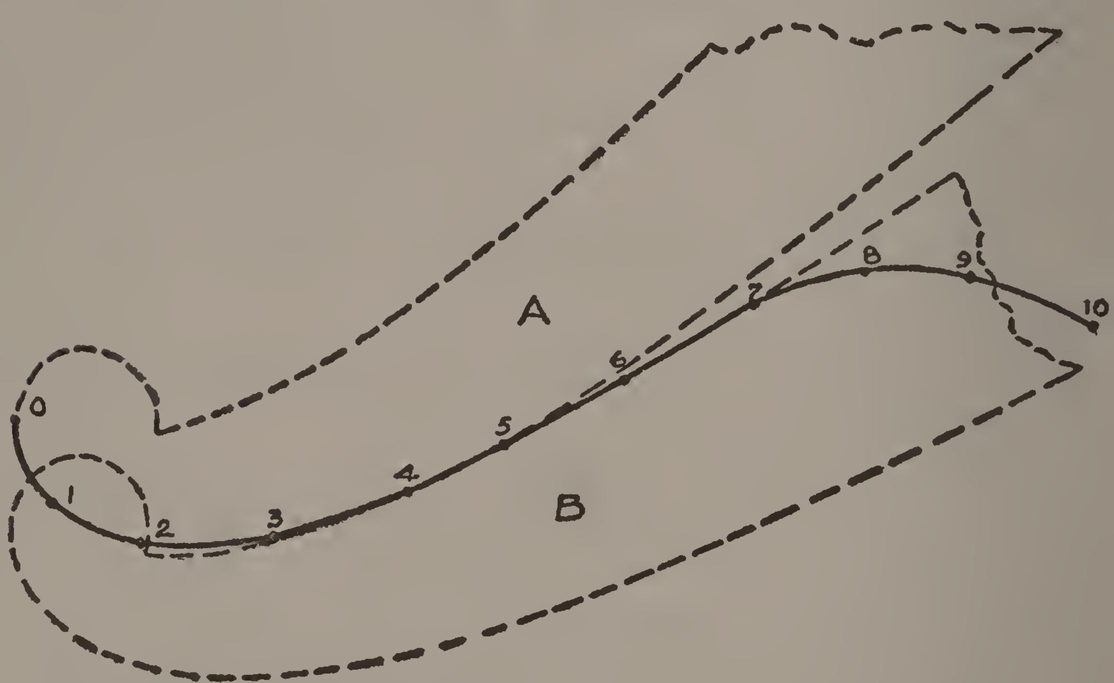


Fig. 24. Illustrating Use of Irregular or French Curves.

or less in radius. If a number of small circles of the same size are to be drawn, the setting is much less likely to be accidentally changed than with the large compass.

39. The **bow pen** (Fig. 9) is indispensable where very small circles are to be inked, and is preferable for circles up to 1 inch or 1¼ inches radius.

40. **The Irregular or French Curves.** Suppose that the points 0, 1, 2, etc., to 10, Fig. 24,

are to be connected with a smooth curve. First sketch a freehand curve through the points. Next take one of the irregular curves, and find a part of the edge which will coincide with the sketched curve for as long a distance as possible. Beginning at point 0, suppose that the edge can be fitted nearly to the point 5, as shown in the dotted position **A**. The curve may then be drawn against the edge in this position as far as the lengths are exactly coincident. The curve is then shifted to another position, as **B**, so that a further portion 5, 6, 7, of the sketched curve coincides with a part of the irregular curve, and also so that the curve in position **B** runs back and coincides with a part of what is already lined in.

Special attention should be paid to this latter statement, for, to insure a smooth, continuous curve, it is essential that when each new portion of the curve is drawn, the curved edge must also coincide with a part of what is already drawn. The remainder of the curve through points 7, 8, 9, and 10, may be drawn in a similar manner, either by the further use of the same irregular curve or by the aid of a different one.

41. **Inking.** In practical work, drawings very often have to be made in ink. This may be done in two ways. The pencil drawing may be lined in with ink, as in drawings for the Patent Office or for book work; or an ink drawing may be made on tracing cloth tacked on the

board over the pencil drawing. In either case, certain general rules apply.

42. **To ink with the ruling pen,** place a small quantity of ink between the points or nibs of the pen, using either a quill or a common writing pen. Care should be taken that no ink remains on the outside of the ruling pen, otherwise a blot is likely to result. In inking straight lines, the thumb-screw for regulating the width of line is always held away from the straight edge which guides the pen. Both nibs should rest equally on the paper, and the pen should be inclined slightly in the direction of its motion. The pen should always be **drawn** along, **never pushed.** In other words, the pen should always **follow** the hand.

For right-handed draftsmen, all horizontal lines are ruled from left to right; vertical lines which are drawn against the left side of the triangle are drawn **up**, and vertical lines ruled against the right side of the triangle are drawn **down.** The point of the pen must never quite touch the guiding straight edge, and this will not happen if the pen is not inclined either toward or away from the draftsman. The pen should be pressed against the straight-edge with only enough force to keep it in place; and no great pressure should be made on the paper.

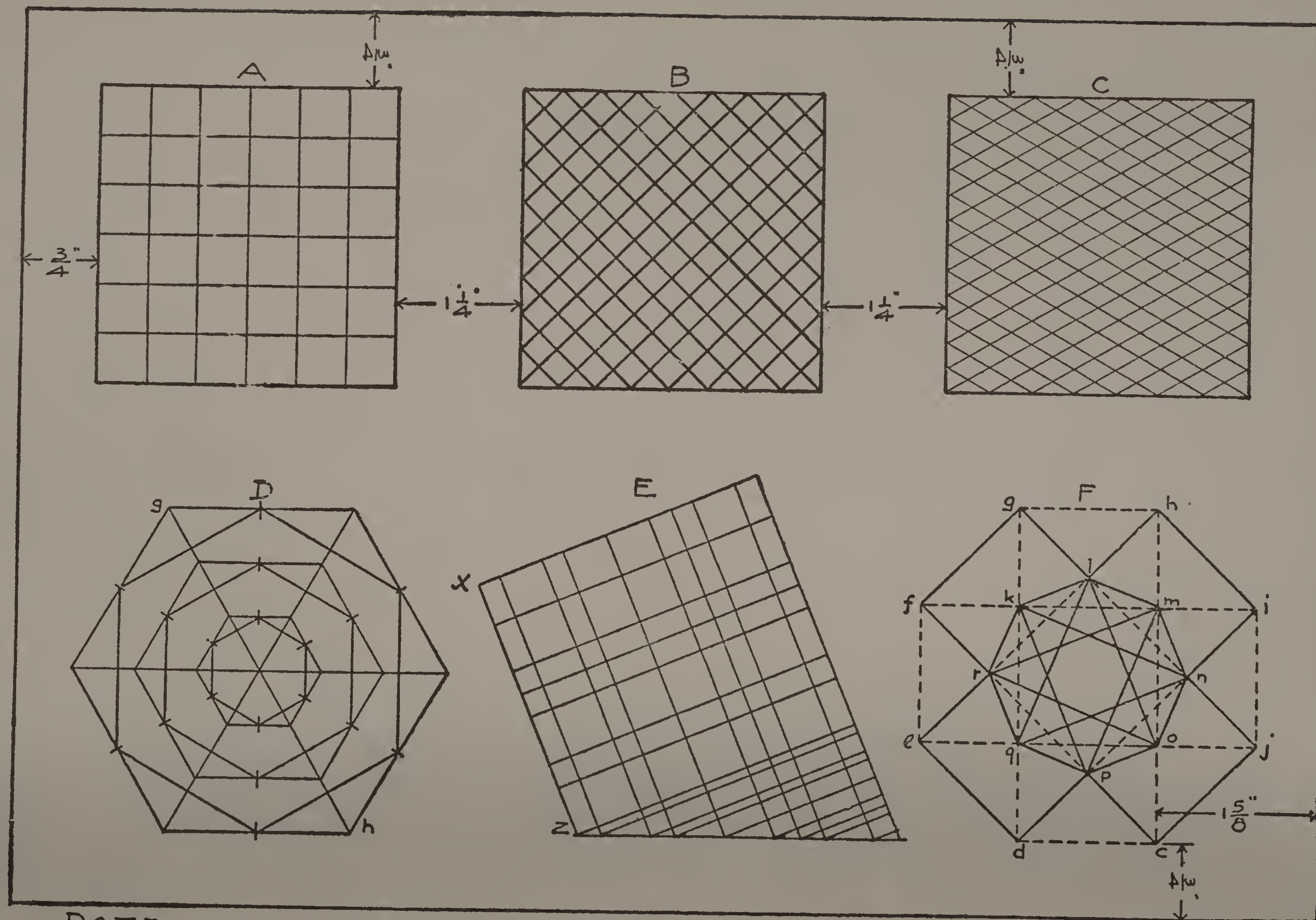
The pen is to be held by the thumb and the first two fingers, and grasped somewhere between the thumb-screw and the end of the handle, according to the convenience of the draftsman. To insure a line of even width throughout, the pen must have no motion except along the paper in the direction of the line being drawn.

An exception to this latter statement must be made for inking lines with the irregular curve; for then, besides holding the pen nearly vertical, it must be turned slightly in the fingers when passing around a sharp curve, so that the points may remain in the same position relative to the curved edge, and the inked line thereby retain the same width.

When inking fine lines, care must be taken to clean the pen frequently, as, with a fine line, there is a tendency for the ink to cake on the end of the pen. It is very convenient when inking, to have at hand a small glass of water, into which the pen may be dipped when it is to be cleaned.

There are three features of a good ink drawing—first, ink lines which exactly cover the original pencil lines; second, lines similar in character showing uniformity in width; and third, lines smooth and clean-cut in appearance, instead of broken and fuzzy.

43. **To ink with the compass**, it is necessary, for the best results, to have the legs of the instrument bent so that each is perpendicular to the paper. When it becomes necessary to use the lengthening bar, one hand should grasp it lightly near the end so as to steady the pen as the circle is drawn.



EXERCISES IN USE OF T-SQUARE, TRIANGLES, AND SCALES.

PLATE 2—MECHANICAL DRAFTING

44. **To Sharpen the Pen.** Unless the pens are in good condition, satisfactory work is difficult or impossible to obtain. Every draftsman should be able to keep his pens in good condition, and with care and practice he will be able to do this. After considerable use, the proper elliptical shape of the pen points will wear off, and the pen will no longer work well. The draftsman should then take the oil-stone, and, after screwing the points of the pen close together, draw it with a rocking motion to and fro on the stone, keeping the pen in a plane perpendicular to the face of the stone. This process—which, of course, still further dulls the pen—is to restore the points to the original shape. After the proper elliptical shape has been produced, the pen should then be held at only a slight inclination with the surface of the stone, and then rubbed, first on one side and then on the other, until the points are sufficiently sharp. Through all the process, the points should be kept screwed tightly together. No grinding is to be done on the inside of the pen.

PENCILING AND INKING

Exercises for Practice in Using the T-Square, Triangles, and Scales

PLATE 2

45. Plate 2 is to be laid out 10 inches by 14 inches, outside dimensions, with a border line 9 inches by 13 inches.

The paper used should be a good drawing paper, preferably a high-grade hot- or cold-pressed paper. The 6H pencil, sharpened with a chisel edge, should be used for drawing the lines; and a 5H or 6H with round point, for marking divisions from the scale. There are to be six figures, as shown.

Figs. **A** and **B** are squares, each 3 inches on a side, and located on the paper as shown in the plate.

Fig. **A** is for practice with the T-square and triangles on horizontal and vertical lines. In this figure, the left-hand and upper sides of the square are divided into ½-inch equal spaces. This is done by placing the scale on the line to be divided, taking a sharp, round-pointed pencil, and marking off the desired number of spaces without moving the scale.

The lines are then drawn through the points of division—one set against the edge of the T-square, and the vertical lines against the edge of a triangle placed against the working edge of the T-square.

Fig. **B** is for practice with the 45-degree triangle in two directions. The left-hand and lower sides of the square are divided into ⅜-inch equal spaces, using the scale as in Fig. **A**. From these points of division, lines are drawn with the 45-degree triangle, upward and toward the right. After these lines are drawn, another set of lines are drawn from the points on the left-hand side, and also from the points where the first set of lines cut the upper side of the square. If the work is accurately done, it will be found that the two sets of 45-degree lines cut each other at the bottom and right-hand sides exactly on the edges of the square.

In Fig. **C**, the 30-degree-60-degree triangle is the one used. The figure is not an exact square, being a little greater in width than height; so draw first the left-hand side, making it 3 inches long; then draw the top and bottom edges a little more than 3 inches, say 3⅛ inches. The left-hand side of the figure is then divided with the scale into ¼-inch spaces; and from these points, 30-degree lines are drawn, slanting upward and toward the right. Counting down from the top, take the point where the seventh 30-degree line cuts the upper edge; and from this point, draw a vertical line downward to form the right-hand side of the figure. Next, turn the triangle in the other direction; and from the points along the top edge, and also from the points on the left side, draw 30-degree lines, slanting downward and toward the right. From the points where these lines cut the bottom edge, the rest of the lines of the first set may be drawn. Accurate work will be manifested by a series of intersections falling exactly on the right-hand edge of the figure.

The purpose of Fig. **D** is to illustrate the use of the 30-degree-60-degree triangle, and incidentally to show the construction of the symmetrical six-sided figure called the **hexagon.**

First draw with the T-square the base line $1\frac{7}{8}$ inches long, $\frac{3}{4}$ inch above the lower border, and place the left-hand end $1\frac{1}{2}$ inches from the left border line. Next draw from the ends of this line 60-degree lines as shown, and measure very carefully on each the same length as the base, $1\frac{7}{8}$ inches. Then, from these last-found points, draw two other 60-degree lines upward, and mark off again the same length. These two points should lie at the same distance above the base line, and may be joined by drawing a line with the T-square, thus forming the top of the figure.

Next draw the diagonal lines of the hexagon, connecting the opposite corners. Now divide one of these diagonals, as **g-h**, into six equal spaces, using the scale. (This diagonal should measure exactly twice the length of one of the sides—that is, $3\frac{3}{4}$ inches.)

Drawing from these points of division horizontal lines and 60-degree lines to the next diagonals, and connecting the ends, there will be constructed two other hexagons like the first, but smaller.

Thus far, if the work is accurate, all of the lines are either T-square lines or 60-degree lines. Now, with the scale, find the middle point of each side of the outside hexagon, and connect these points. The lines joining these points should be either 30-degree lines or verticals. Do the same thing for the two inner hexagons, testing in the same way the inclined lines to see if they are at 30 degrees.

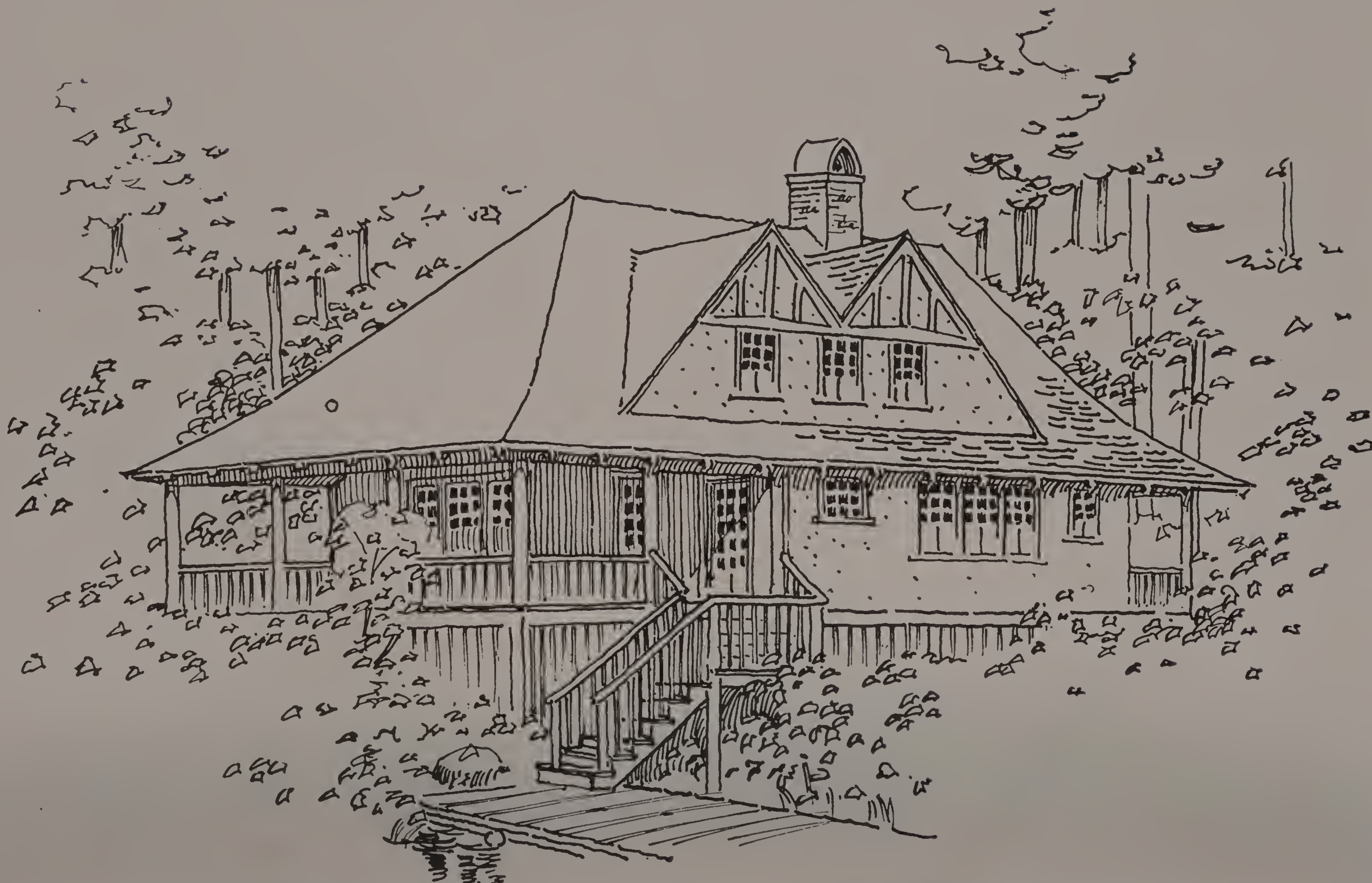
Fig. **E** is for an exercise in drawing parallels and perpendiculars by means of the triangles, without the aid of the T-square.

First fix the position of the point **x**, 4⅝ inches from the left border line, and 2½ inches above the lower border; and locate point **z** on the same T-square line as the base of Fig. **D**, and 1 inch to the right of **x**; and join **x** and **z**. Starting at point **z**, mark off on line **zx**, without moving the scale, the following distances in order: ½ inch, ¼ inch, ½ inch, ¼ inch, ¼ inch, and ½ inch. Then draw as a base line a T-square line through **z**, and set off in the same way the distances ¼ inch, ½ inch, ¼ inch, ½ inch, ½ inch, ¼ inch, ¼ inch, ½ inch, and ¼ inch; and through this last point, draw a line parallel to **zx**, as shown in Fig. 21. This line will be the right-hand boundary of the figure; and a line drawn through **x** at right angles to line **xz**, by the method of Fig. 22, will be the upper boundary of the figure. Now, by sliding one triangle along another, draw lines parallel to the upper boundary of the figure from the points on line **xz**, and also from the points on the base line. Draw also parallel to **xz** another set of lines from the points on the base line.

For Fig. **F**, locate the point **c** as shown, and make the base line **cd** 1⅜ inches long, making the short dashes each about ⅛ inch long. Then, from **c** and **d**, draw 45-degree lines upward, and make each one the same length, $1\frac{3}{8}$ inches, drawing them full lines. Next draw the dotted verticals; then the second pair of 45-degree lines; then the horizontal at the top of the figure. This produces the regular eight-sided figure **cdefghij**, or regular **octagon**. Draw the verticals **ch** and **dg**, and the T-square lines **fi** and **ej**, making them dash lines. The intersections of these lines give the four corners of a square **kmoq**.

Next, using the 45-degree triangle, draw **eh**, **di**, **gj**, and **fc**, making the parts solid and dotted as shown in the figure. These lines will intersect in the corners of a second square **lnpr**. Now connect the points **k**, **l**, **m**, etc., forming a regular octagon. Finally join **l** with **q** and **o**, **m** with **r** and **p**, **n** with **k** and **q**, **o** with **r**, and **p** with **k**, thus completing an **eight-pointed star.**

Inking. The sheet is to be inked—Fig. **A**, with lines of medium thickness; **B** with heavy lines; and **C** with fine lines; while **D**, **E**, and **F** are to be drawn with medium-weight lines. In Fig. **F** the dotted pencil lines are to be erased, not appearing at all on the finished ink drawing. Make as nearly as possible the same difference in weight of line between **A** and **B** as between **B** and **C**. For this first sheet, ink one figure at a time. Remember that ink lines must not be rubbed with the triangle or T-square until they are perfectly dry.



FREEHAND PERSPECTIVE DRAWING OF A SUMMER BUNGALOW.

GEOMETRICAL PROBLEMS

46. There are certain problems of geometrical construction which it is essential that the intelligent draftsman should know. We shall now present some of the more common of these problems.

PROBLEM 1

To Bisect a Given Straight Line

Let **AB**, Fig. 25, be the given line. With **B** as a center, and a radius greater than one-half

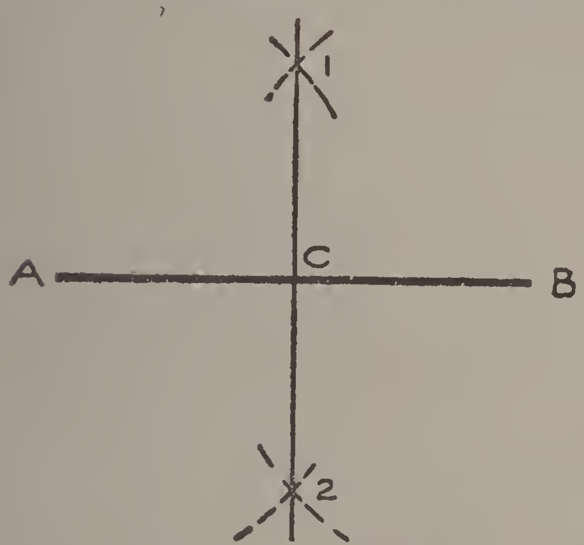


Fig. 25. Bisecting a Given Straight Line.

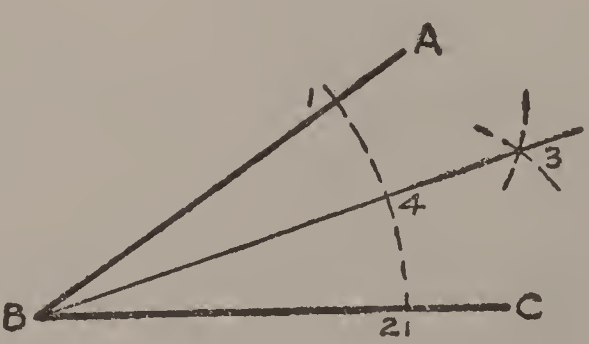


Fig. 26. Bisecting a Given Angle.

the length of the line, describe an arc above **AB**, and another below; and with the same radius, and **A** as a center, draw two other arcs above and below **AB**, cutting the first two arcs at the points 1 and 2. A straight line joining 1 with 2 will divide **AB** in two equal parts, bisecting it at point **C**.

NOTE 1—A circular arc would be bisected in the same way.

NOTE 2—The intersecting arcs will cross nearly at right angles, and accuracy thereby become easier to obtain if the radius used is taken (by eye) between two-thirds and three-quarters the length of **AB**.

PROBLEM 2

To Bisect a Given Angle

In Fig. 26, let **AB** and **BC** form the given angle at **B**. With **B** as center, and any radius,

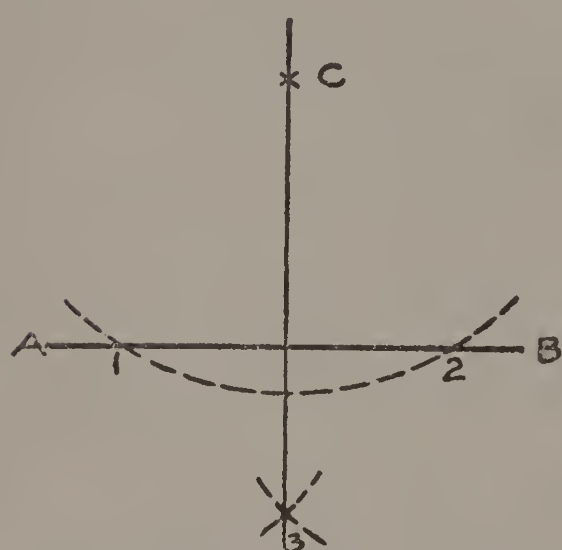


Fig. 27. Dropping a Perpendicular to a Line from a Given Point Outside.

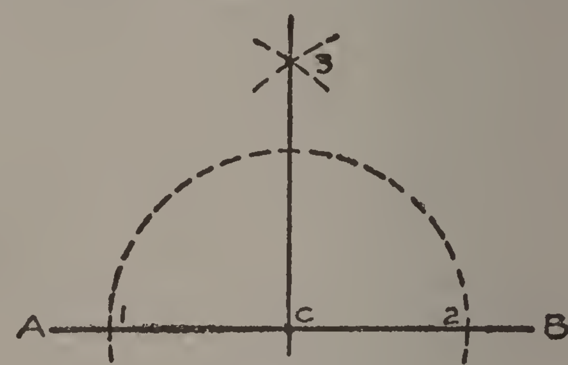


Fig. 28.

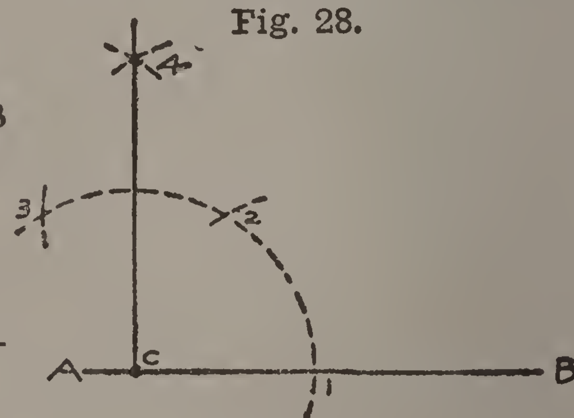


Fig. 29. Erecting a Perpendicular to a Given Line at a Given Point in the Line.

strike an arc cutting **AB** and **BC** in points 1 and 2. With point 1 as center, and any radius greater than one-half the distance from 1 to 2, strike an arc; and with the point 2 as center, and the **same radius**, draw another arc, cutting the one just drawn, in point 3. A line joining point **B** with point 3 is the bisecting line required.

NOTE—To test the exactness of the work, take the dividers, set one point at 4, open to point 1, then see if this span is the same as that from 4 to 2.

PROBLEM 3

To Draw a Perpendicular to a Given Line from a Given Point Outside

Let **AB**, Fig. 27, be the given line, and **c** the given point. With the point **c** as a center, and any sufficiently large radius, describe an arc cutting the given line in two points, as 1 and 2. Then, with 1 as center, and any convenient radius, strike an arc (preferably on the other side of the line from point **c**); and with center 2, and the **same radius**, strike another arc, intersecting the first one in point 3. Connect the point 3 with point **c**, and this will be the perpendicular required.

PROBLEM 4

To Erect a Perpendicular to a Given Line at a Given Point on the Line

FIRST CASE—When the given point is not very near either end of the line.

Let **AB**, Fig. 28, represent the given line, and **c** the given point. With **c** as center, and any radius, strike an arc cutting **AB** in points 1 and 2; then, with 1 and 2 as centers, and any suitable radius, strike arcs intersecting at 3. A line drawn from 3 to **c** will be the desired perpendicular.

SECOND CASE—When the point on the given line is at or near one end.

Let **AB**, Fig. 29, be the given line, and **c** the given point. With point **c** as center, and any radius, draw an arc cutting **AB** at point 1; then, with 1 as a center, and the **same radius**, strike an arc cutting the first one at point 2; and with 2 as center, and the **same radius**, draw a third arc, cutting the first arc again at point 3. Now, with 2 and 3 in turn as centers, and any convenient radius, strike two arcs intersecting at point 4. A line joining 4 and **c** is the required perpendicular.

PROBLEM 5

To Draw a Line Parallel to a Given Line and at a Definite Distance Away

In Fig. 30, let **AB** be the given line, and one inch the required distance away for the desired

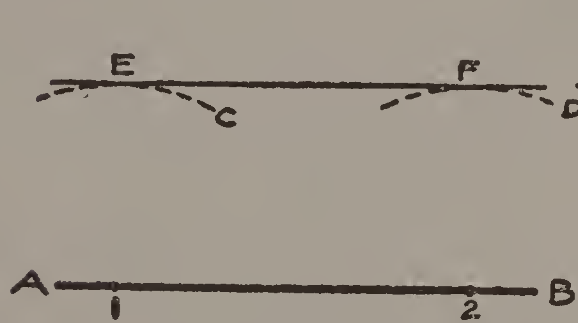


Fig. 30. Drawing a Line Parallel to a Given Line at a Definite Distance Away.

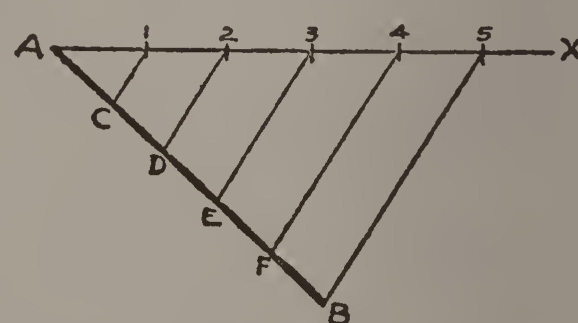


Fig. 31. Dividing a Straight Line into a Desired Number of Equal Parts.

line. With any two points on the line **AB**, as 1 and 2, and the distance one inch as radius, describe two arcs, as **C** and **D**; and with the edge of the triangle, draw a line **EF** just touching or just tangent to these two arcs, and this will be the required line.

NOTE—The greater the distance of one line from the other, the less accurate is this construction. For a considerable distance between the two lines, an accurate construction would be to erect perpendiculars at points 1 and 2 by the method of Problem 5, mark points on these perpendiculars at the required distance from **AB**, and draw the required line through these points.

PROBLEM 6

To Divide a Given Straight Line into Any Desired Number of Equal Parts

Let **AB**, Fig. 31, be the given line to be divided into, say, five equal parts. This construction is, of course, in case the division cannot be exactly made with the scale. From either end of the line, as **A**, draw a straight line **AX** of indefinite length, at any convenient angle; and lay off on **AX**, beginning at **A**, any five equal spaces, **A**-1, 1-2, 2-3, 3-4, and 4-5. Join point 5 with **B**; and from points 4, 3, 2, and 1, draw by means of the triangles (Article 28) parallels to 5-**B**, intersecting **AB** in points **F**, **E**, **D**, and **C**, and these points will divide **AB** into five equal spaces.

PROBLEM 7

To Construct One Angle Equal to Another

In Fig. 32, let the angle **ABC** be the given one, and let it be required to construct on **DE** as one side an angle equal to **ABC**. With **B** as center, and any radius, describe an arc cutting **AB** and **BC** at points 1 and 2; and with **D** as center, and the **same radius**, strike a second arc **F** meeting **DE** at point 3. Then take 2 as

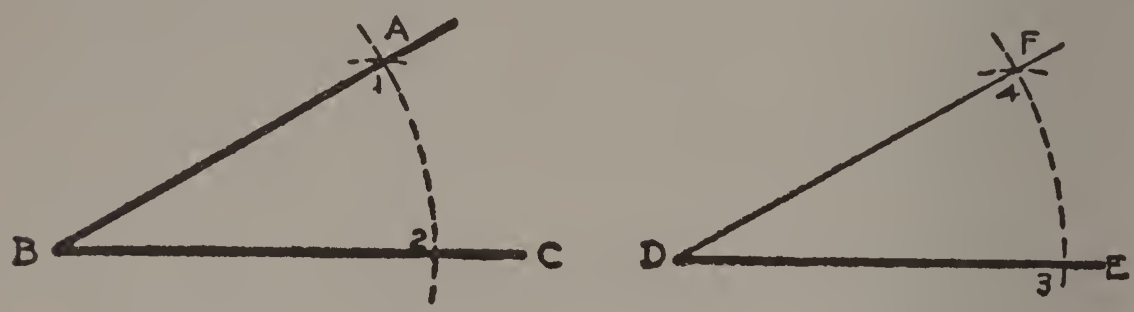


Fig. 32. Constructing One Angle Equal to Another.

center, and draw a short arc through point 1; and with this radius, and 3 as center, draw a short arc intersecting arc 3**F** at 4. Then a line connecting 4 and **D** will form with the line **DE** an angle equal to **ABC**.

PROBLEM 8

To Draw a Circle through Three Points Not in the Same Straight Line

In Fig. 33, **a**, **b**, and **c** are the given points. Connect **a** with **b**, and **b** with **c**; and then, by

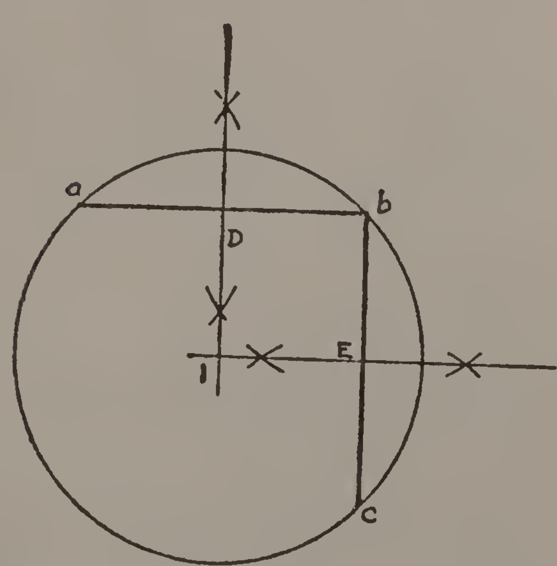


Fig. 33. Describing a Circle through Three Given Points.

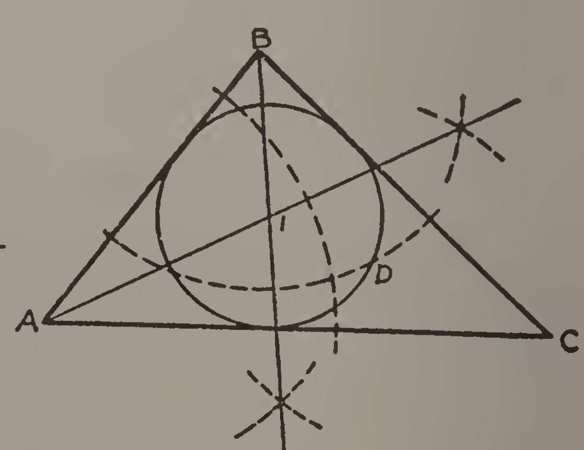


Fig. 34. Inscribing a Circle in a Triangle.

the method of Problem 1, bisect each line. These bisectors **D** and **E** intersect at a point 1, which is equally distant from **a**, **b**, and **c**. Hence this point is the center of a circle which will pass through the three points.

NOTE—As three points not in the same straight line may always be connected to form a triangle, it follows that this construction may be used for drawing a circle through the three corners of a triangle, or as it is called, **circumscribing a circle about a triangle.**

PROBLEM 9

To Inscribe a Circle in a Given Triangle

Let **ABC**, Fig. 34, be the given triangle. By the method of Problem 2, bisect any two of the angles of the triangle, as the angle at **A** and the one at **B**; the bisecting lines will intersect

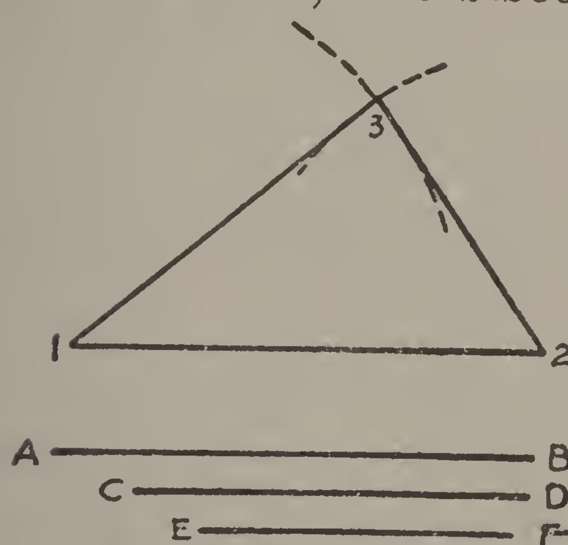


Fig. 35. Constructing a Triangle of which Sides are Given.

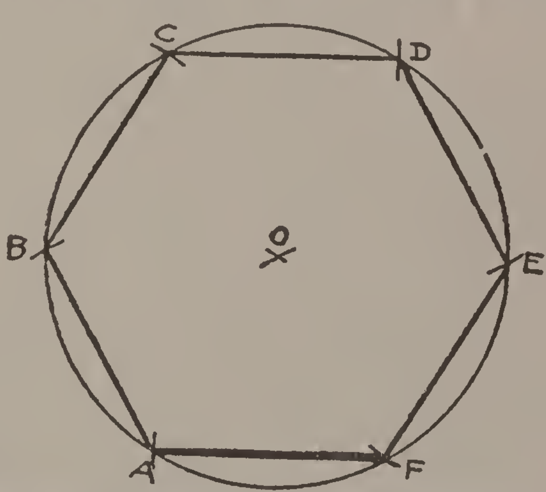


Fig. 36. Constructing a Regular Hexagon of which One Side is Given.

each other at point 1. This point is equally distant from all three sides of the triangle; hence, with 1 as center, the required circle **D** is drawn just tangent to the sides of the triangle, and is the required inscribed circle.

PROBLEM 10

To Construct a Triangle, Having Given the Lengths of the Sides

In Fig. 35, let **AB**, **CD**, and **EF** be the lengths of the sides. Draw line 1-2, and make it equal to **AB**. Then, with point 1 as center, and a radius equal to one of the other sides, as **CD**, strike an arc; and with point 2 as center, and a radius equal to the remaining side, **EF**, draw another arc, intersecting the first one at point 3. Join 3 with 1 and 2, and the triangle is completed.

PROBLEM 11

To Construct a Regular Hexagon, Having Given One Side

In Fig. 36, **AF** is the given side. With points **A** and **F** as centers, and a radius each time equal to length **AF**, strike arcs intersecting in point **o**; and with **o** as center, and the **same radius**, draw a circle through **A** and **F**. Then, with **A** as center, and the **same radius**, draw a short arc cutting the circle at **B**; then, with center **B**, radius unchanged, cut the circle again at **C**; repeat this process, beginning with **F**, obtaining points **E** and **D**. Draw **AB**, **BC**, **CD**, **DE**, and **EF**, and the hexagon is constructed.

NOTE 1—A polygon of any number of sides which has all of its corners in the circumference of an enclosing circle, is said to be **inscribed** in the circle.

NOTE 2—The length of the radius of a circle may be spaced around the circumference exactly six times.

PROBLEM 12

To Construct an Ellipse, Having Given Two Axes at Right Angles (or the Rectangular Axes)

Let **AB** and **CD**, Fig. 37, be the axes, each line bisecting the other. The point **o** will be the center of the ellipse. The longer axis **AB** is the **major axis**; the shorter one **CD**, the **minor axis.** With center **O**, and radius equal to **Ao**, describe an arc cutting **AB** in points **x** and **y**. These points are termed the **foci** of the ellipse.

The construction to be given depends upon the interesting property of the ellipse, that, no

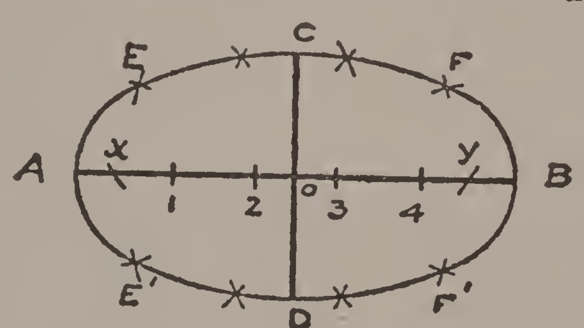


Fig. 37. Constructing an Ellipse, Having Given the Rectangular Axes.

matter what point on the curve be taken, the sum of its distances from the foci is always the same, and is equal to the length of the major axis. Hence, to find points on the curve, mark off on **AB**, between **x** and **y**, any number of points, as 1, 2, 3, 4, etc. Then, with **x** and **y** as centers, and radius equal to **A**-1, strike four short arcs, two above and two below **AB**; and with the same centers, and radius equal to 1-**B**, describe four other arcs, cutting the first four at **E**, **E′**, **F**, and **F′**. Repeat this process for the other points marked on **AB**, taking next **A**-2 as length of first radii, and 2-**B** as that of the second, obtaining four more points; and so on for the remaining points. The curve should be first sketched freehand through the points found, then drawn in smoothly with the irregular curve.

PROBLEM 13

To Construct an Ellipse with a Trammel, Having Given the Rectangular Axes.

In Fig. 38, **AB** and **CD** are the axes of the desired ellipse. The trammel **K** may be a strip of stiff paper or thin cardboard. On one of the straight edges of the trammel, mark off the length **EF** equal to **A**o; and from **E**, mark off

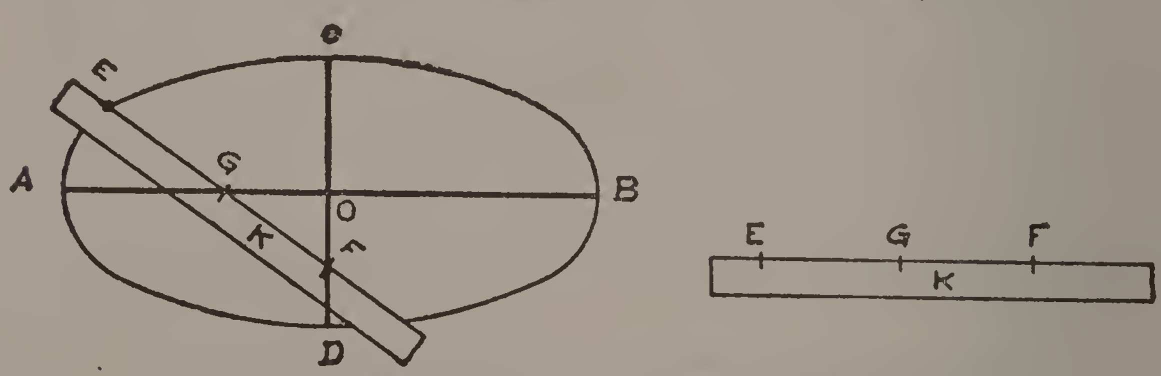


Fig. 38. Constructing an Ellipse with a Trammel.

EG equal to **C**o. Now take the trammel, place it so that point **G** will be on the major axis **AB**, and point **F** on the minor axis **CD**; then point **E** will be at one point of the required curve, and the point may be marked on the paper with a sharp-pointed pencil or a fine needle-point. Then, by placing the trammel in other positions, with **G** on **AB**, and **F** on **CD**, point **E** will indicate other points on the required ellipse.

Approximations

47. Often, in practical work, an **approximation** will answer the purpose as well as an exact geometrical construction.

For example, let it be required to find a straight line equal in length to a given curved line.

In Fig. 39, let **AB** be the given curved line. It is required to find on **CD** a length equal to

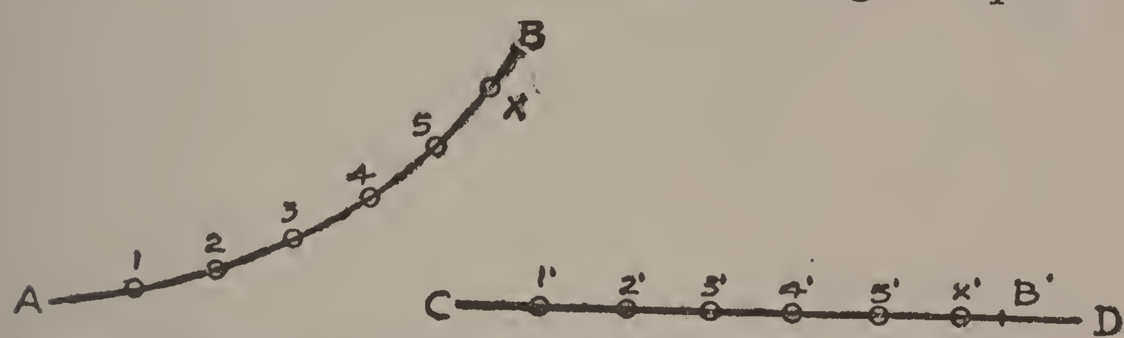
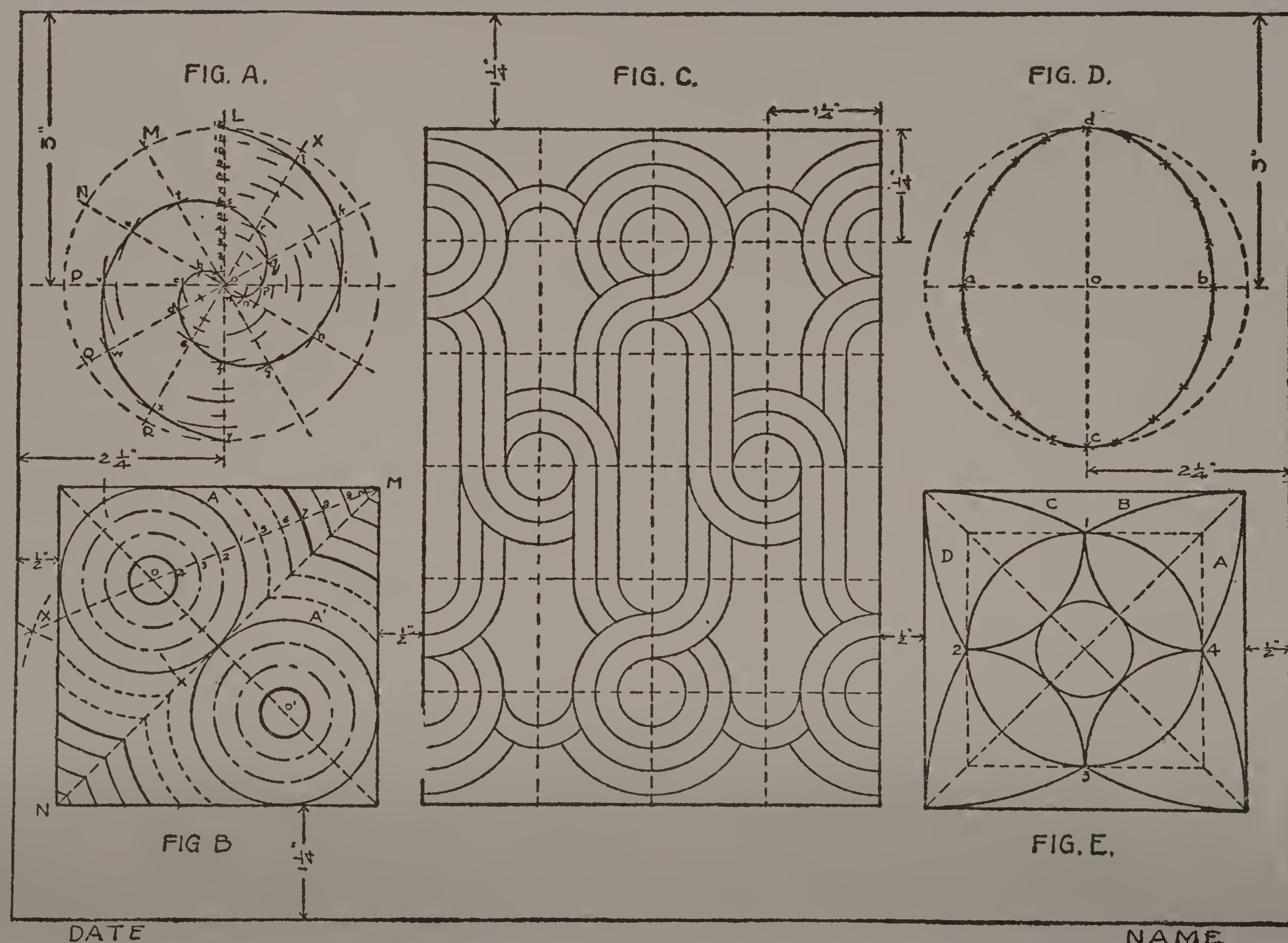


Fig. 39. Finding a Straight Line Equal in Length to a Given Curved Line.

AB. Taking the dividers, and starting at **A**, lay off any number of short, equal spaces **A**-1, 1-2, 2-3, etc., up to **X**. (The distance from the point **X** to **B** should be less than one of the equal spaces.) Then, with the same setting of the dividers, begin at **C**, and lay off the same number of equal spaces as far as **X′**. Measure in the dividers the distance **XB**, and lay it off from **X′** to **B′**. Then the length **CB′** is practically equal to **AB**. The curve, which may or may not be the arc of a circle, is said to be **rectified** along **CD**.

NOTE—Should the distance **XB** be too short to take accurately with the dividers, the distance 5-**B** may be divided into two spaces, and these laid off from 5′.



EXERCISES IN USE OF COMPASS AND IRREGULAR CURVES.

PLATE 3—Mechanical Drafting.

Again, suppose the circumference of a circle is to be divided into perhaps eleven equal parts. This is most readily and accurately done by trial, using the hair-spring dividers. Assume first some radius, lay this around the circumference; and if the setting is not found exact the first time, adjust slightly by means of the hair-spring screw, space again around the circumference, and proceed in this way until the exact spacing is found.

Exercises in the Use of the Compass and the Irregular Curves

PLATE 3

48. Plate 3 is laid out 11 inches by 15 inches, with a border line 10 inches by 14 inches. All of the figures are to be accurately penciled; then all are to be inked. Figs. **A** and **D** are for practice with the irregular curves; and Figs. **B**, **C**, and **E** for practice with the compass. The figures are located as shown on the plate. For Figs. **A** and **D**, the irregular curve should be used in accordance with the instructions of Article 40.

Penciling. Fig. **A** represents one turn each of two equal **spirals**. This particular kind of a spiral is called the **Spiral of Archimedes**. Make first the outside circle 3½ inches in diameter, and divide the circumference into any number of equal parts, as twelve in the figure; and draw the diameters. Divide any radius, as **OL**, into the same number of equal parts. Then, with **O**

as center, and radius **O**-1, strike an arc cutting the first radius at the left in point **a**; then, with the same center **O**, and radii **O**-2, **O**-3, **O**-4, etc., to **O**-11, strike arcs cutting respectively radii **ON**, **OP**, **OQ**, etc., to **OX**, thus determining the various points of the curve, **o—b—f—k—12.** The other spiral, **o—n—s—y**, is constructed in a similar way.

In Fig. **D** the diameter of the circle is 3½ inches, and the short diameter of the ellipse is 2¾ inches. The points on the ellipse may be found either by the method of Problem 12, above, or by the use of a trammel (Problem 13); and then these points are joined with the irregular curve.

Fig. **B** is for practice in drawing lines of different kinds with the compass.

In penciling, make the lines of uniform width. The square is 3½ inches on a side. The points **O** and **O′** are the centers for the circles and arcs. To locate point **O**, bisect the angle between the diagonal and the upper side of the square, by the line **Mx**, and point **O** is the intersection of this bisector with the other diagonal. Point **O′** may then be located on the other side of the diagonal **MN**. The circles **A** and **A′**, tangent to the sides of the square and to the diagonal **MN**, are next drawn. Then, from point **1**, mark off on the bisector **Mx** ¼-inch spaces, three to the left, and six to the right. With center **O**, and radius **O**-2, draw the circle next inside of **A**, and, before changing the setting of the compass, draw the corresponding circle from center **O′**. In this same way, draw all the other circles and arcs, using each center **O** and **O′** before changing the setting. Make the circles and arcs dotted, dot-and-dash, or full, as shown in the figure.

The so-called **dotted lines** through points 5 and 6 are really composed of short dashes a little less than 1/8 inch in length. Care should be taken to make these dashes uniform in length. Similarly, the short and long dashes of the circles through 2 and 3 should be drawn with care, to insure a pleasing and uniform appearance.

Fig. **C** is intended for practice in the accurate use of the large and small compasses, and also in the accurate use of the scale. The rectangle in which the design appears is laid out as accurately as possible 5 inches by 7½ inches. It is then divided into 1¼-inch squares; and on the exactness of the spacing depends largely the accuracy of the final result.

An experienced draftsman could set the scale along the side of the rectangle, and mark off accurately the 1¼-inch divisions without moving the scale. The beginner, however, can obtain greater accuracy by using the hair-spring dividers.

First set the dividers or the scale to 1¼ inches, and test the exactness of the setting by spacing along the scale several times, noticing whether, at the last position, the point of the dividers exactly coincides with the proper division of the scale. The dividers with this setting should then be used to space off on two adjoining sides of the rectangle. Through these points of division, the lines forming the small squares are drawn with the triangle and T-square. The centers of the circles and arcs are at the corners of the small squares, as shown in the drawing. The smallest radius is 3/8 inch, and the radii increase by 1/4 inch, so that the largest radius is 1 1/8 inches. For accuracy it is essential that all arcs or circles of the same radius be drawn with one setting of the compass.

For the penciling, draw first all the arcs, then the straight lines. Of course, in the pencil work, it is needless to attempt to stop the arcs exactly at the straight lines, as this can be done when the drawing is inked.

In Fig. **E**, the outside square is 3 1/2 inches on a side. With the corners of the square as centers, draw the arcs **A**, **B**, **C**, and **D**, and through the points of intersection, 1, 2, 3, and 4, draw with triangle and T-square the smaller square. Draw the diagonals of the larger square; and with the intersection of the diagonals as center, draw the circle through 1, 2, 3, and 4.

Next, with the corners of the smaller square as centers, draw the arcs 1-4, 4-3, 3-2, and 2-1; and lastly, draw the smallest circle as in the figure, tangent to these four arcs.

Inking. The border line should be of the same weight as the heavy lines of Fig. **B**. Make

A FINE EXAMPLE OF PEN-AND-INK RENDERING.

all the full lines on the sheet of medium width, except as shown in the drawing for Fig. **B**; and make all construction lines fine, short-dash lines like those of Fig. **B**. In Fig. **B**, the diagonals need not be inked. In Fig. **C**, do not show the construction squares in the finished drawing. In Fig. **D**, show the axes of the ellipse as construction lines. In Fig. **E**, the diagonals and the smaller square should not be inked.

PROJECTION

49. The term **projection** as used in mechanical drafting, may be explained as follows:

Assume any object, as a cube, and a plane above it and parallel to the upper face, as in

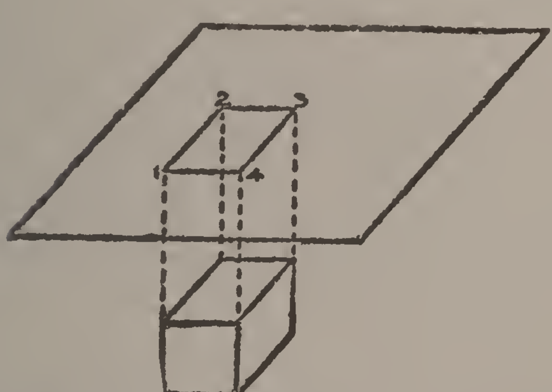


Fig. 40. Illustrating Principles of Projection.

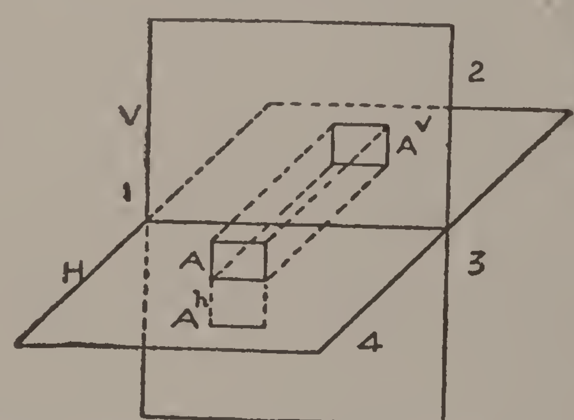


Fig. 41. Illustrating Planes of Projection.

Fig. 40. Now, if parallel lines be drawn from the corners of the cube, and perpendicular to the plane, these perpendiculars will meet the plane in the points 1, 2, 3, and 4; and lines joining these points will give the four-sided figure 1-2-3-4, which is called the **projection** of the cube upon the plane. The projection, then, of the cube made in this way, is simply a square equal in size to one of the faces of the cube.

There are various kinds of projection, as **orthographic** or **orthogonal, oblique, isometric, axonometric,** etc.; but the first is of most practical value, and will receive the principal consideration. Where the simple term "projection" is used, orthographic will be understood.

Orthographic Projection

While projections may be made on any planes, those most commonly used are one vertical and the other horizontal in position, being thus at right angles. The line of intersection of the two planes is called the **ground line,** or **GL.** These planes are known as **planes of projection** or **co-ordinate planes,** and for brevity may be referred to as **V** and **H.** The position of the planes is as in Fig. 41.

In this figure, let **A** represent a square placed parallel to the V plane, and with two of its sides

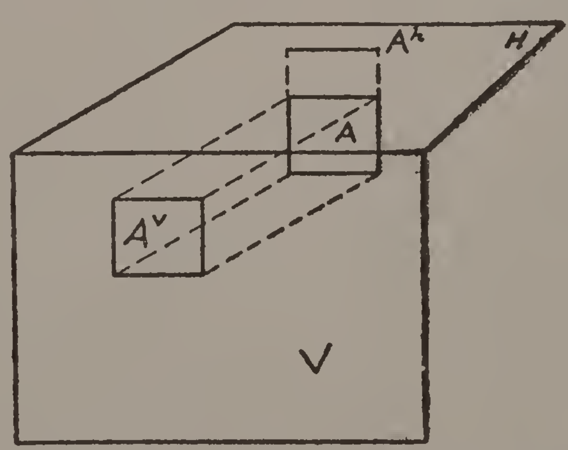


Fig. 42. Projections of a Square in Third Angle.

perpendicular to the H plane. Then the projection on the V plane, a square equal to **A**, is shown at $\mathbf{A}^v$, while the projection of **A** on the H plane is merely one line, $\mathbf{A}^h$.

It will be seen that four angles are formed by the intersection of the two planes. These angles, or **quadrants,** are distinguished as **first, second, third,** and **fourth,** as indicated by the numbers, and are always in this same order. For practical purposes, drawings are made as if the object were in either the 1st or the 3d angle.

50. Fig. 42 shows a square **A** in the 3d angle, placed parallel to V, and two edges perpendicular to H. It is projected **up** to H, giving $\mathbf{A}^h$ for the H projection; and **forward** to V, giving $\mathbf{A}^v$ as the V projection.

51. **Plans and Elevations.** In practical work, the term **plan** is used instead of **H projection;** and an H projection or plan, unless otherwise expressly stated, is always a view of the top or upper side of any object; hence a plan may often be spoken of as a **top view.**

Similarly, **elevation** is the usual term for **V projection,** and means a view of the **front side** of an object, or sometimes a view of the **right or left side.** In actual drawing, the H plane is taken as the plane of the paper as it lies on the drawing board; and the V plane, as an imaginary plane vertical in position and directly in front of the draftsman.

It must be noted that when the plan and the elevation of any object are both made on the same sheet of paper, one can be neither to the right nor left of the other; but one must be drawn on the paper vertically over the other.

The drawings of Figs. 40, 41, and 42 are pictorial, and not actual projections.

52. **Actual Projections.** In Fig. 43, a T-square line **GL** may represent the V plane as seen from above; and the whole surface of the paper, the H plane. Then any object in the first or the fourth angle would be projected on H on the near side of **GL**; and any object in either the second or third angle would be projected on the further side of **GL**.

The actual plan and elevation of the square

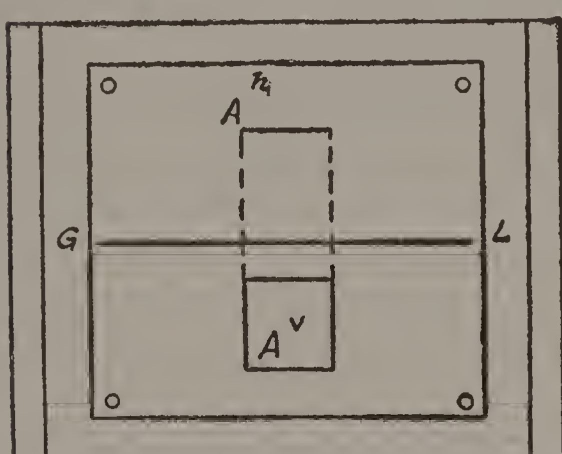


Fig. 43. Illustrating Principles of Projection.

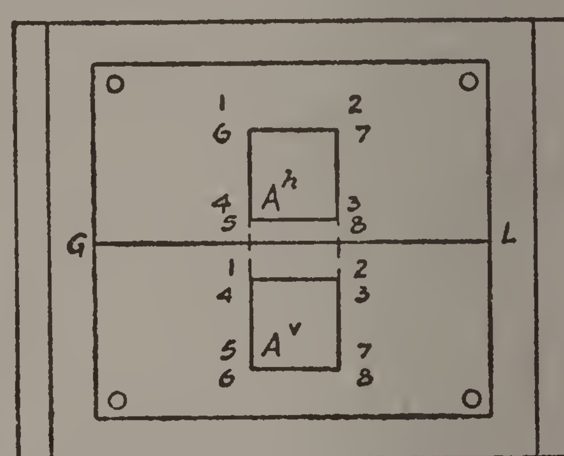


Fig. 44. Projections of Cube in Third Angle.

shown pictorially in the preceding figure may now be made. A straight line $\mathbf{A}^h$ parallel to the V plane and on the further side of V, will be the H projection or plan of the square; and the square, in its full size below **GL**, will represent the projection on V.

Suppose that the plan of a cube placed in the third angle is to be made; and let the cube be placed with the top and bottom level, and the side faces perpendicular to V. Then, in Fig. 44, the plan will be shown as at $\mathbf{A}^h$, equal to one side of the cube; and the distance between A^h and **GL** is the distance that the cube is behind the vertical plane.

Next, for the elevation or front view of the cube, the paper must be considered as the V plane, and the **GL** as H seen edgewise. Then, as the cube is below the H plane, its projection on V will be below H as seen edgewise—that is, below **GL**. This elevation of the cube will be a square A^v, vertically below A^h. The corners of the cube may be numbered, calling the four **upper** corners 1, 2, 3, 4, and the four **lower** ones 5, 6, 7, 8. The two projections A^v and A^h are squares of equal size, which is evidently as

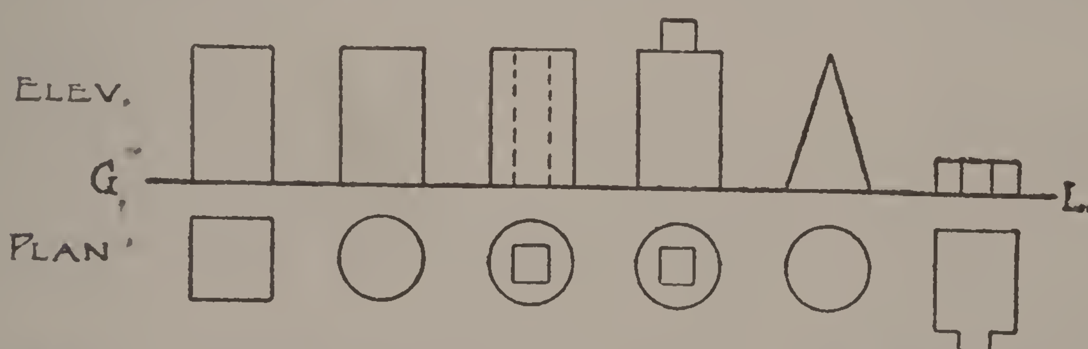


Fig. 45. Elevations and Plans of Simple Objects—First Angle.

it should be, since each face of the cube is of the same size, and each view is taken at right angles with the face.

53. **The Co-ordinate Planes Seen Edgewise.** The **GL** sometimes represents H, seen edgewise, and sometimes V seen edgewise. When considering a plan or top view, **GL** is V seen edgewise; but when regarding an elevation, **GL** is H seen edgewise.

Examples. In Fig. 45, six simple objects are shown, all in the first angle. Reading from left to right these are: Square prism; round bar or cylinder; the same with a square hole from one end to the other; the same cylinder again, but with a small block placed on the upper end; a circular cone standing on H; and a short joist with a tenon on the front end.

Fig. 46 shows the elevation and plan of a common hexagonal nut. The double dotted lines

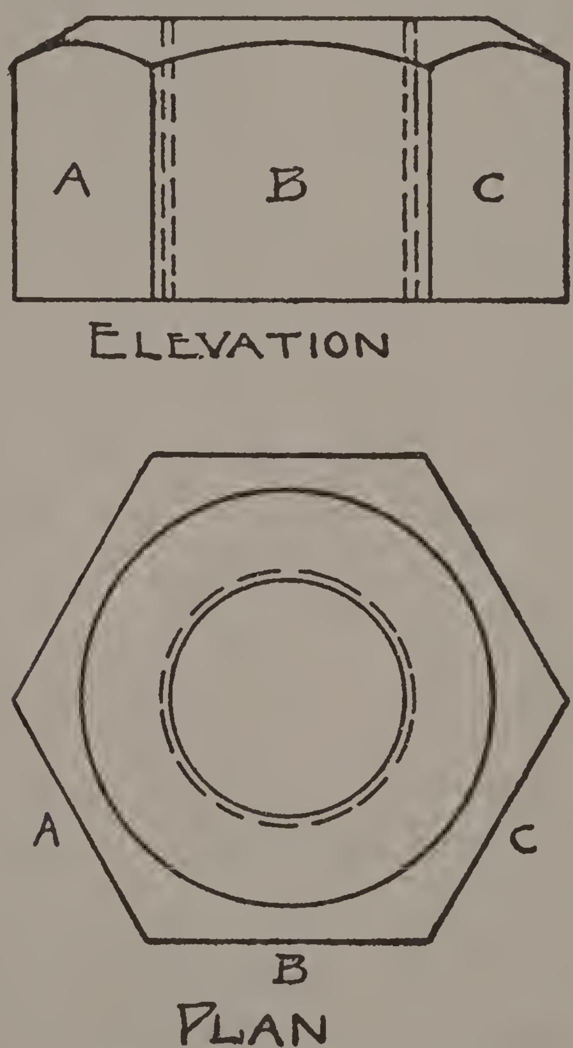


Fig. 46. Hexagonal Nut.

of the elevation, and the two inner circles of the plan, indicate that the nut is threaded.

Notice that the thickness or height of the nut is shown on the elevation; while the true distance between the parallel faces is given only in the plan. Each side of the nut is shown in its real width on the plan; but on the elevation, of the three front sides **A**, **B**, and **C**, **B** alone is shown in the full width, **A** and **C** appearing very much narrower. This illustrates several very important principles of projection, which may be stated thus:

54. (a) If any flat surface is parallel to H or V, it will be drawn on that plane in its real size and shape; but if a surface is oblique to H or V, its projection or view on that plane is less than the true size, and does not show the exact shape.

Observe that although the face **A**, for example, is oblique to the V plane, it does not follow that all its dimensions are oblique. The height of the face **A** is not affected by the inclination of the surface with the vertical, and hence is shown in its true length in the elevation.

55. (b) If any edge of a solid, or any single line, is parallel to either H or V, it will be shown on that plane in its true length.

These principles are still further illustrated in Figs. 47, 48, and 49. Fig. 47 shows a square prism placed with its length vertical. Notice the numbering of the top and bottom. Why are some of the faces in elevation shown in their true size? Only one dotted edge appears. (A dotted edge in any projection is understood to mean an edge which is not visible in that view.)

56. In Fig. 48, a regular hexagonal pyramid is given standing on its base, and with its axis

ab perpendicular to H. This solid has six sloping surfaces and one base. Of these seven faces, the base alone appears in its true size.

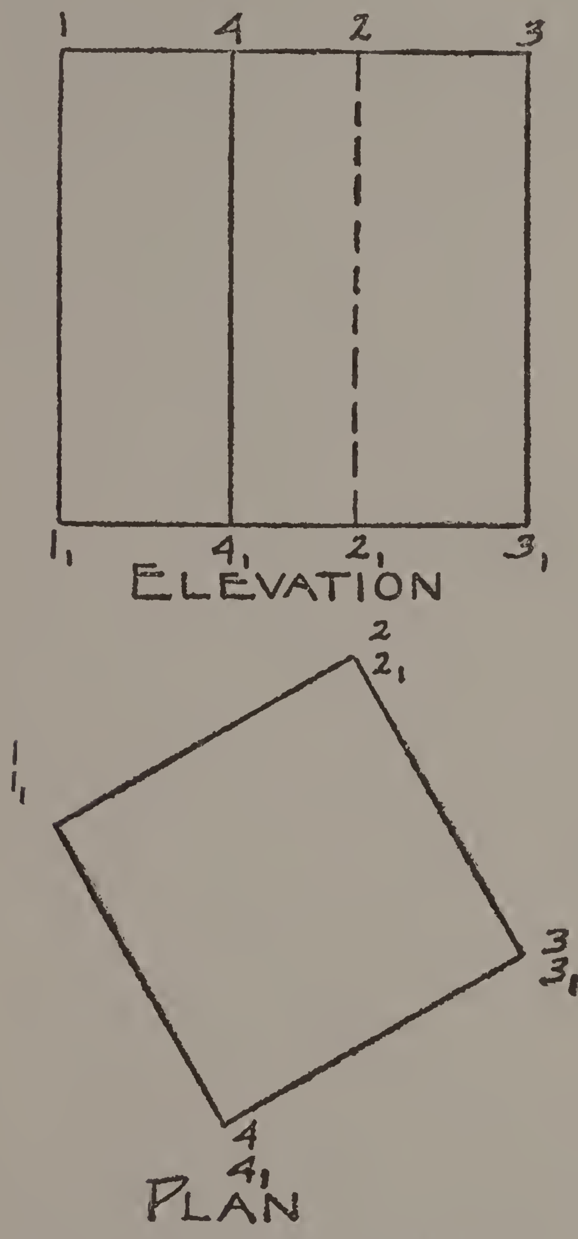


Fig. 47. Elevation and Plan of Square Prism with Length Vertical.

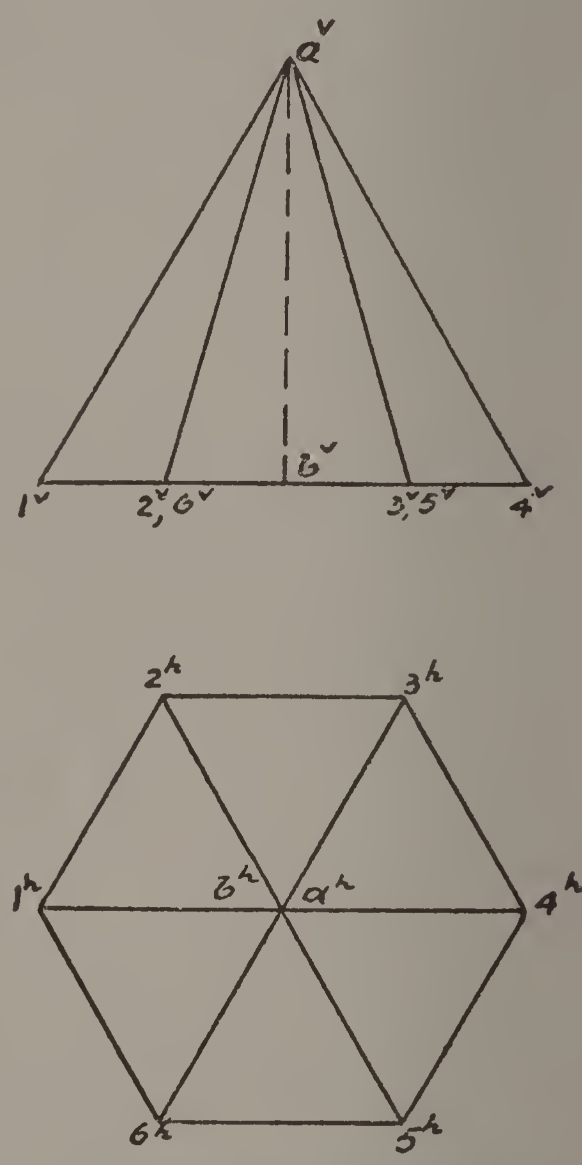


Fig. 48. Regular Hexagonal Pyramid with Axis Perpendicular to H.

Two of the inclined edges, **a**-1 and **a**-4, are shown in their true lengths in elevation at a^v-1^v and a^v-4^v, since the lines in space are parallel to the vertical plane.

57. Fig. 49 is precisely the same object as in Fig. 48, but placed in a different position.

In this position, the base is parallel to V, the axis, **a-b** perpendicular to H, and the apex away from the draftsman. Note the dotted lines in the elevation, the only visible part of the solid in elevation being the base. The edges **a**-1 and **a**-4 are now parallel to the horizontal; hence their true lengths are $\mathbf{a}^h$-1^h and $\mathbf{a}^h$-4^h. The base 1-2-3-4-5-6 is parallel to V; hence perpendicular to H; and its H projection is the straight line 1^h-2^h. . .4^h. The base in the preceding figure is perpendicular to V, and its V projection is the straight line 1^v-2^v. . .4^v.

The statement of the principle involved is as follows:

58. If a surface is perpendicular to H or V, it will be seen edgewise in that view, hence will appear simply as one line.

59. In these three figures on the prism and pyramid, it may readily be seen that it would be impracticable to draw first the view showing the side faces. For example, in Fig. 47, the widths of the surfaces in elevation are not known until the plan is drawn. Hence, to draw a prism, or pyramid, or other object of a similar character, **draw the base or the end view first.**

This direction applies with equal force in other cases of a more practical nature—for example, the slope of a roof is shown at its true angle in an end view.

60. **Direction of Oblique Lines; Slope.** A line may be parallel to one plane and oblique

to the other, or it may be oblique to both planes. This latter position will be meant when a line is referred to simply as an **oblique line.** The term **slope** refers to the direction of a line oblique to one or both of the co-ordinate planes. In this treatise the word **backward,** when

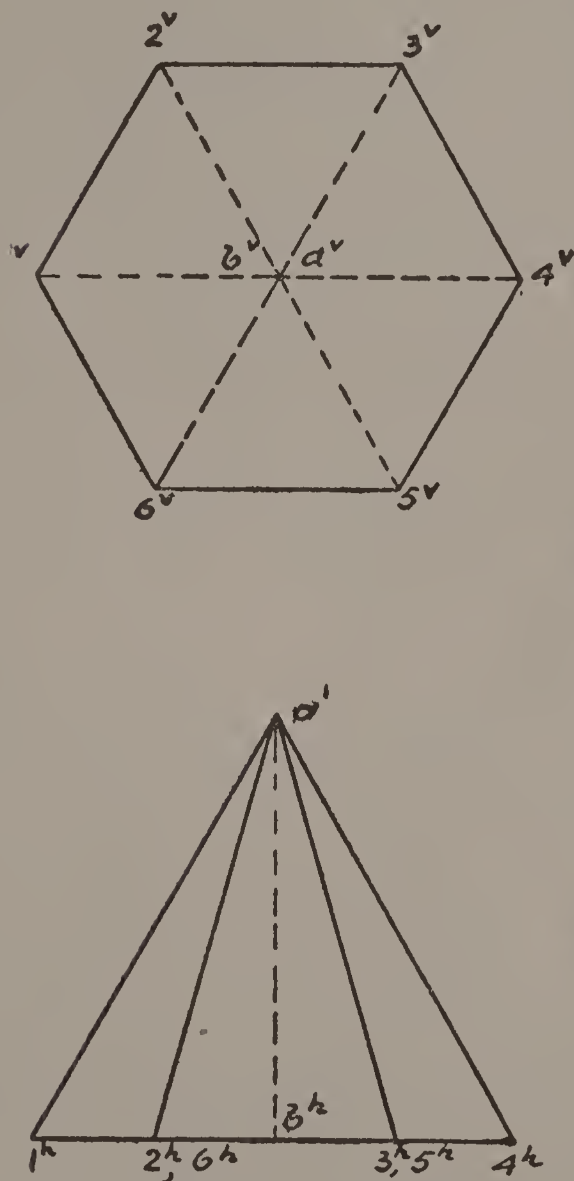


Fig. 49. Regular Hexagonal Pyramid with Base Parallel to V.

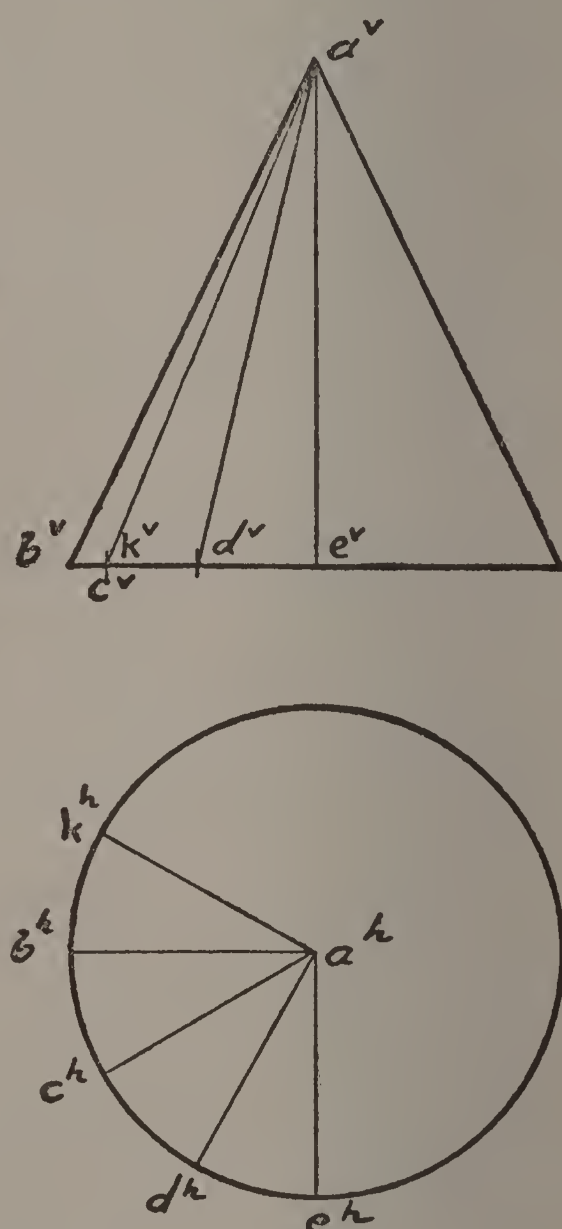


Fig. 50. Right Circular Cone.

applied to the slope of a line, means **away from** the draftsman; and **forward** means **toward** the draftsman.

Thus, if a line is said to slope upward, backward, and to the left, the upper end of the line must be away from the draftsman and toward his left. In the same manner, a line sloping downward, backward, and to the right, has its lower end away from the draftsman and toward his right. If a line slopes simply forward and to the left, for example, then neither end is lower than the other, and the line is in a horizontal position, with its left-hand end toward the draftsman.

As illustrations of slope of lines, **a-1** in Fig. 48 slopes downward and toward the left; **a-4**, downward and toward the right; **a-2**, downward, backward, and toward the left; **a-6**, downward, forward, and toward the left; **a-3**, downward, backward, and toward the right; and **a-5**, downward, forward, and to the right.

61. **Projection of Oblique Lines.** A right circular cone is shown in Fig. 50. The vertex is **a**; and **a-b**, **a-c**, **a-d**, **a-e**, and **a-k** are various elements of the cone. On reflection, it will be seen that all of these lines have the same actual length in space. These lines are also all equally inclined to the horizontal plane, and therefore the H projections are all of the same length. Next, referring to the elevation, a^v-b^v shows the actual length of **a-b**; a^v-c^v, a^v-d^v, and a^v-e^v show gradually decreasing lengths, a^v-e^v being the shortest of all.

This difference in length corresponds to the fact shown in the plan, that **a-e** makes the greatest angle with the V plane. That is, **the greater the angle that a line makes with a plane of projection, the less will be the length of its projection on that plane.**

Observe also that **a^h-c^h** and **a^h-k^h** make the **same** angle with V; therefore the lines **in space** must make equal angles with V; and their V projections, being coincident, are of the same length. Hence lines of equal length which have the same inclination with V, are projected on V in equal lengths.

From the above, it follows that, for a line of definite length, the length of its projection on any plane is determined wholly by the angle the line makes with the plane. If the line makes the greatest possible angle with the plane (90 degrees), then the projection on the plane has no length, but is simply a point.

62. **Revolution of a Figure around Some Line as an Axis.** In Fig. 51, consider first the rectangle **abcd**, placed horizontally, and having its long edges perpendicular to V. Then **$a^hb^hc^hd^h$** is the true size and shape of the figure. The rectangle is perpendicular to V, and therefore (Article 58) is shown on V as a single line **a^vc^v**. Now let the rectangle revolve up like a trap door, on **a^hb^h** as an axis. Then points **d** and **c** will revolve in arcs of circles having points **a** and **b** respectively as centers. These circles will be perpendicular to the axis **ab**, and hence parallel to V, so that a circle drawn on V, with center at **a^v**, and with radius

a^v-c^v, will be the projection of the circles described by points **c** and **d** in space.

As the rectangle turns about axis **a-b**, it remains always perpendicular to V, and its projection on V will remain a straight line. Then, when the rectangle has swung up through 45 degrees, for instance, its V projection will be a line $a^vb^vc^v_2d^v_2$, making 45 degrees with the

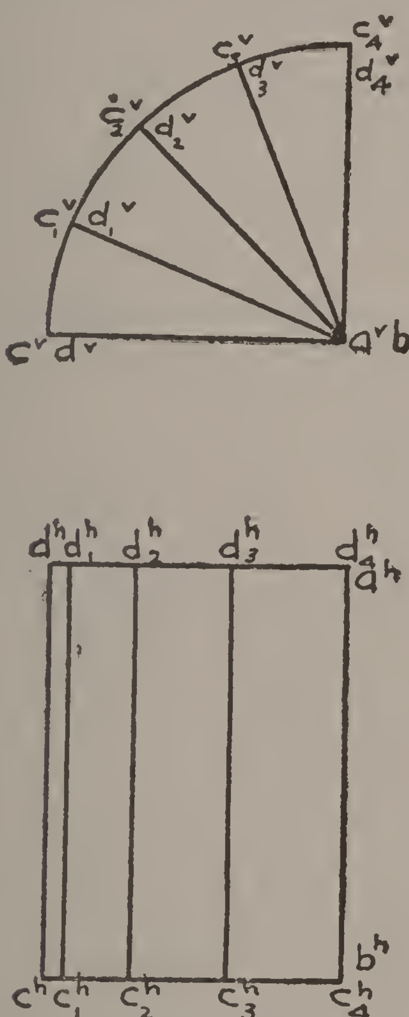


Fig. 51.

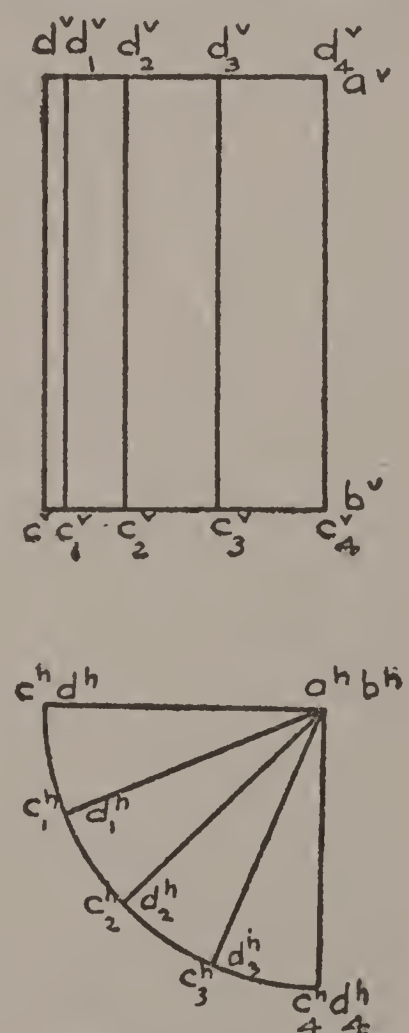


Fig. 52.

Illustrating Revolution of a Rectangle around an Axis.

horizontal; and its plan or H projection, showing less than the real width, will be $a^hb^hc^h_2d^h_2$.

The other oblique positions are found in the same way—the elevation first, then the plan. Finally, when the rectangle is revolved through

90 degrees into a vertical position, the H projection becomes merely the one line $\mathbf{a^hb^hc^h_4d^h_4}$.

In Fig. 52, the rectangle **abcd** is placed in a vertical position and parallel to V. It is then revolved like a door on its hinges about **a-b** as an axis, the successive positions appearing in plan at $\mathbf{a^hb^hc^h_1d^h_1}$, $\mathbf{a^hb^hc^h_2d^h_2}$, etc., until the supposed door is wide open in the position $\mathbf{a^hb^hc^h_4d^h_4}$. The corresponding elevations $\mathbf{a^vb^vc^v_1d^v_1}$, etc., are

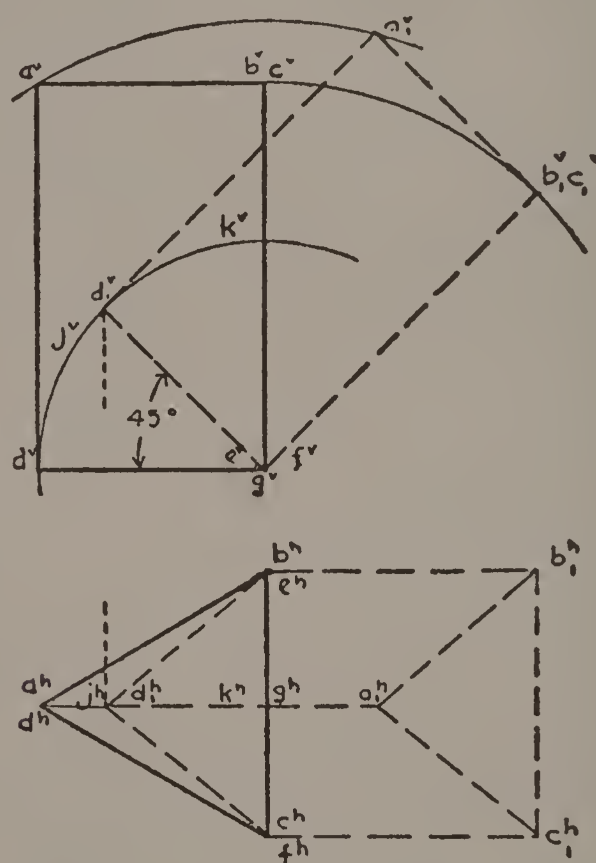


Fig. 53. Drawing a Triangular Prism.

then constructed by projecting directly from the plan.

63. Suppose that it is required to draw a triangular prism standing on one end, and with one edge of the base at right angles with the V plane, Fig. 53. According to the preceding directions, the base is drawn first, placed in a

horizontal position, and with the right-hand side perpendicular to V. The elevation may then be drawn as before explained.

Now let the object be revolved around the edge **e-f** of the base as an axis. In revolving in this way, it is evident that every point of the prism will move, except the edge **e-f**, which is the axis. A little thought will show that each corner that moves will move in a circle. For example, the corner **d** of the base will revolve in the arc of a circle the center of which is at point **g**, the radius of the circle being therefore **d-g**. The line **d-g** is perpendicular to **e-f**, and must so remain as it revolves. This means that the line **d-g**, parallel to the V plane at first, will remain parallel; and the circle described by point **d** in space will be parallel to V, and will be projected on V in its true size. The arc $d^v j^v k^v$ then represents the circle described by the motion of point **d**; and on H, this circle appears as the straight line $d^h j^h k^h$, parallel to V.

In the same way, the other corners, **a**, **b**, and **c**, will each travel in a circle parallel to V. Then, if the prism be revolved through an angle of 45 degrees, each line of the elevation will simply revolve through this angle, with no change in length; and the resulting V projection will be the rectangle $f^v {d^v}_1 {a^v}_1 {b^v}_1$, exactly the same size and shape as $a^v b^v f^v d^v$, but inclined at 45 degrees with the horizontal. This rectangle will be the new V projection of the prism; and, remembering that each point in revolving moves in a circle parallel to V, the new H projection may be found by dropping perpendiculars from d^v_1, a^v_1, and b^v_1-c^v_1, to meet parallels drawn from d^h, a^h, b^h, and c^h, thus determining the points d^h_1, a^h_1, b^h_1, and c^h_1. These points, when joined in the proper order, give the new plan as shown by the dash lines in the figure.

64. The principles of such revolution may be explained as follows:

(a) **If any object, no matter how complex, be revolved about an axis perpendicular to V, the V projection will remain unchanged in shape and size, but will revolve to different positions with respect to the horizontal.**

(b) **The H projection, on the other hand, changing shape and size, will be found directly below (or above) the new V projection, and each point will be at the same distance from V as before revolving.**

A similar statement will apply with merely an interchange of V for H, and H for V, in case an object be revolved about a vertical axis.

Fig. 54 shows the same prism as in Fig. 53; but in this figure, the new position has been moved a little to the right so as to clear the first position. Placing in this way takes more space, but is clearer, and should always be used if the figure to be revolved is complicated. Notice that in the plan of the second position, the upper end and the two upper sides are visible, while the lower end and the under side are invisible.

65. **Third Plane of Projection or Profile Plane.** Many times, the two views of an object as plan and elevation, are sufficient to describe

the object completely; but in other cases a third view is required to give a satisfactory idea of the object in question. Sometimes, in addition, a sectional view may be necessary to show fully every detail.

The third view usually taken is in a direction perpendicular to that of the plan and the eleva-

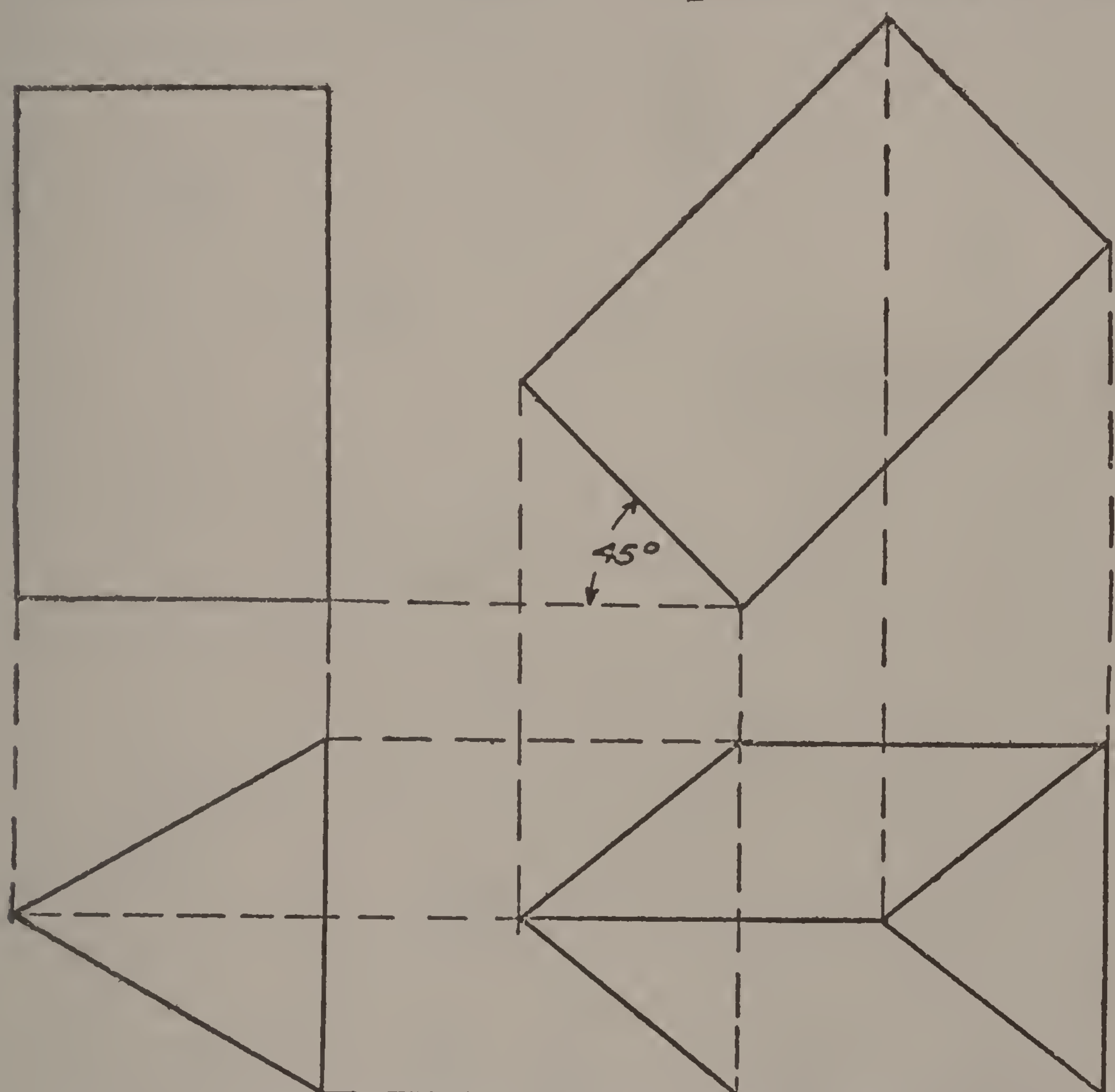


Fig. 54. Drawing Triangular Prism of Fig. 53 in Another Position.

tion. That is, for a rectangular object—as a cube or a square prism—there may be the top view or plan; the front view or elevation, and the third, a **profile view** or **end view**. The direction of the profile view in comparison with the other two, is shown in Fig. 55, in which are represented the plan, elevation, and end or profile view of the outlines of a cabin. The end view is taken looking in the direction of the arrow.

It should be noted that the breadth of the end view is the same as that of the plan, while the height is equal to that of the elevation.

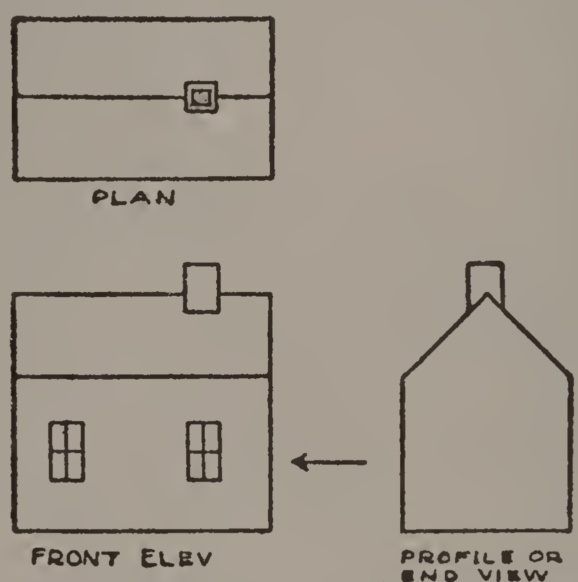


Fig. 55. Showing Direction of Profile View as Compared with Plan and Elevation.

On comparing the three projections, it will be seen that the length is shown in plan and elevation, the width in plan and profile, the height in elevation and profile, and the slope of the roof in profile only. In making the three views, the profile or end view, in accordance with Article 59, should be drawn first.

66. **Third-Angle Projection.** Three views of a rectangular block, with parts of the top and bottom cut away, are shown in Fig. 56. In this figure, as in the preceding one, the arrangement customary in many drafting offices has been followed—of placing the plan above, the eleva-

tion beneath, and the end or profile view at one side. Where this custom is adopted, the view of the right-hand end is placed either at the right of the elevation, or of the plan; a view of the left-hand end is placed at the left; and so on. This is known as **third-angle projection.** Thus, in the figure, the end view is a view of the right-hand end of the block.

This figure is an example of a case where the plan and elevation do not make the meaning of the drawing sufficiently clear and do not make

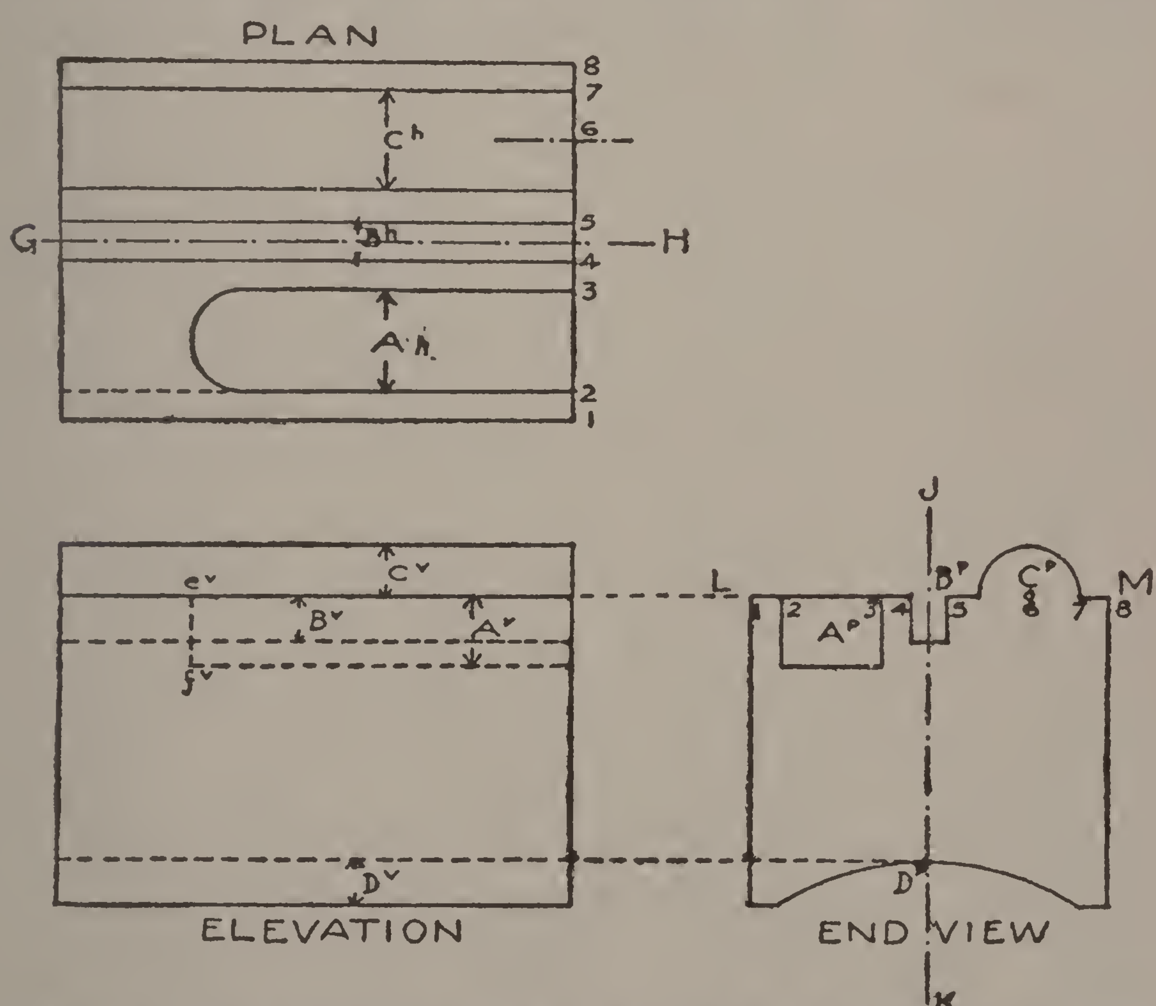


Fig. 56. Plan, Elevation, and End View of Rectangular Block with Parts of Top and Bottom Cut Away.

the shape of the object apparent; hence the end view is required. The end view bears the letters **A**^{p}, **B**^{p}, etc. The small **p** at the upper right-hand of the letter stands for **profile,** in the same way that a small **v** on the elevation means **vertical,** and a small **h** in plan means **horizontal.**

The end view gives at once a much clearer idea of the object than either plan or elevation. What is marked $\mathbf{A}^v$ on the elevation, and $\mathbf{A}^h$ on the plan, in the profile view at $\mathbf{A}^p$ is shown to be a slot. By reference to $\mathbf{A}^h$, it will be seen that the slot does not extend the entire length of the block, and is rounded at the end. The vertical dotted line $\mathbf{e}^v$-$\mathbf{f}^v$ represents the left-hand end of the slot **A.** In comparison with **A,** $\mathbf{B}^p$ represents a narrower slot of less depth, and one which extends the whole length of the piece. This latter statement accounts for the fact that $\mathbf{B}^p$ is left open at the top, while $\mathbf{A}^p$ is closed. The part lettered $\mathbf{C}^h$ and $\mathbf{C}^v$ is found on the profile view to be a rounded projection appearing at $\mathbf{C}^p$.

Assuming, for the sake of illustration, that the plan and elevation are drawn, and that the end view is to be constructed from them, it would be done as follows: Draw first a center line **G-H** on the plan; then, at any convenient distance to the right of the elevation, draw a vertical line **J-K** for the center line of the end view. Since vertical heights will correspond on the end view with those of the elevation, a T-square line through lower edge of **D** will give the level of base of the required view; and a second T-square line through the lower edge of $\mathbf{C}^v$ will locate the flat part of the top of the block.

Next, the width of the end view must be the same as that of the plan; hence the distance from the center line **G**-**H** to point 1 is taken, and laid off on the end view from **J**-**K** along the line **L**-**M** to the left, giving point 1; and point 8 is located in the same way to the right of **J**-**K**. Vertical lines drawn through 1 and 8 will give the general outline of the end view. Then, measuring for the remaining points, and laying off from the center line each time, points 2, 3, 4, 5, etc. are located, those on the near side of **G**-**H** being measured to the left of **J**-**K**, and those on the further side to the right.

Next the depths of the slots as shown on the elevation are projected over with the T-square to the end view, and $\mathbf{A}^p$ and $\mathbf{B}^p$ completed. Having located on the end view point 6 as a center, the half-circle $\mathbf{C}^p$ is drawn with the radius 6-7, taken from the plan. The upper edge of the shallow groove $\mathbf{D}^v$ is projected across to **J**-**K**, becoming the highest point of the curve. The radius of the curve being given, its center is found on **J**-**K**, and the curve drawn-in as the arc of a circle, thus completing the end view.

67. Let it be required to draw a wooden chest of given length, breadth, and depth, and to show the cover opened through 150 degrees. Evidently this is a case which requires the end view to be drawn first. This end view is first drawn from the given dimensions at **A**, Fig. 57, showing the cover opened at the given angle. The ends of the chest are supposed to be nailed

to the bottom and sides, which are represented in view **A** by the dotted lines.

The front elevation, **B**, is taken looking at **A** in the direction of the arrow. This elevation will show the length and height of the chest, and will show the cover in its real length, but narrower than its true width. The different heights are projected over with the T-square from **A** to **B**. In a view of **A** in the direction of

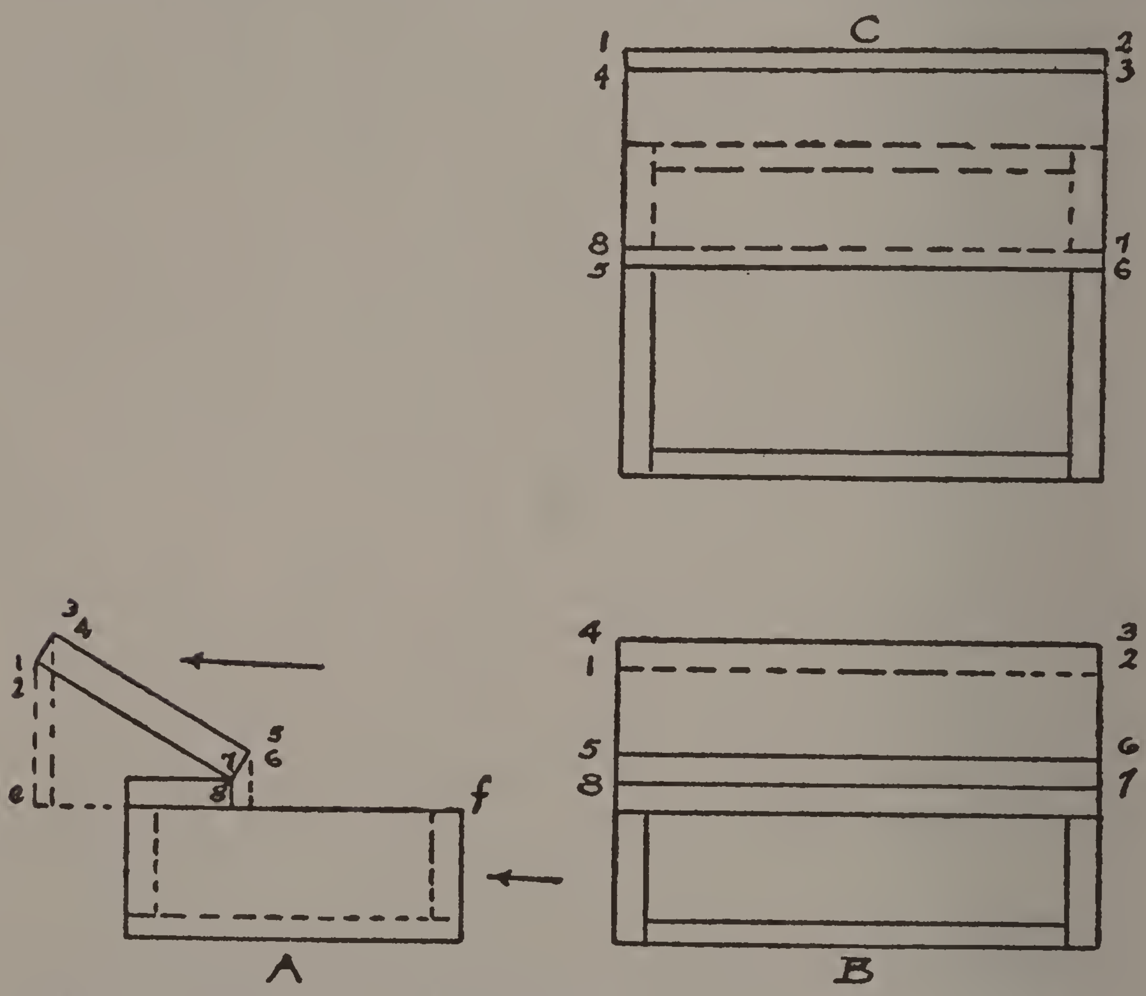


Fig. 57. Profile and Projections of Chest with Cover Open.

the arrows, 1-2, the extreme left-hand edge of the cover, will not be seen; hence this is drawn with the dotted line 1-2 in view **B**. The plan, **C**, shows the length and width of the chest, the extreme width of the chest and cover together being equal to the distance **e-f** of the end view **A**.

In this view also, the cover appears in less than its real width. Note carefully that the cover 1-2-3-4-5-6-7-8 is shown less in width in elevation than in plan. This is simply because the cover is more nearly horizontal than vertical; hence, in looking from above, the cover appears more nearly flat-wise, and therefore nearly in its real width; while, viewed from the front, the cover is seen more nearly edgewise, and thus shows narrower.

This affords an exercise in **reading a drawing**—that is, in obtaining from the various views an exact understanding of the different parts of the object represented, and also of the object as a whole. This figure, and also Figs. 51 to 55, illustrate an important principle.

68. This principle may be stated as follows:

The size of the projection of any given surface on a plane is determined by the angle which the surface makes with the plane of projection. If the surface is actually parallel to the plane of the drawing, then it will appear in its true size; if the surface is perpendicular to the plane, it will be seen edgewise simply as a line.

69. Suppose that a square prism is to be drawn standing on one corner, and in an oblique position so that its long edges are inclined at 30 degrees with the horizontal, and that the prism inclines upward to the right and away from the draftsman. To draw the object in this oblique position, in which none of the faces and none of the edges will be parallel to either plane,

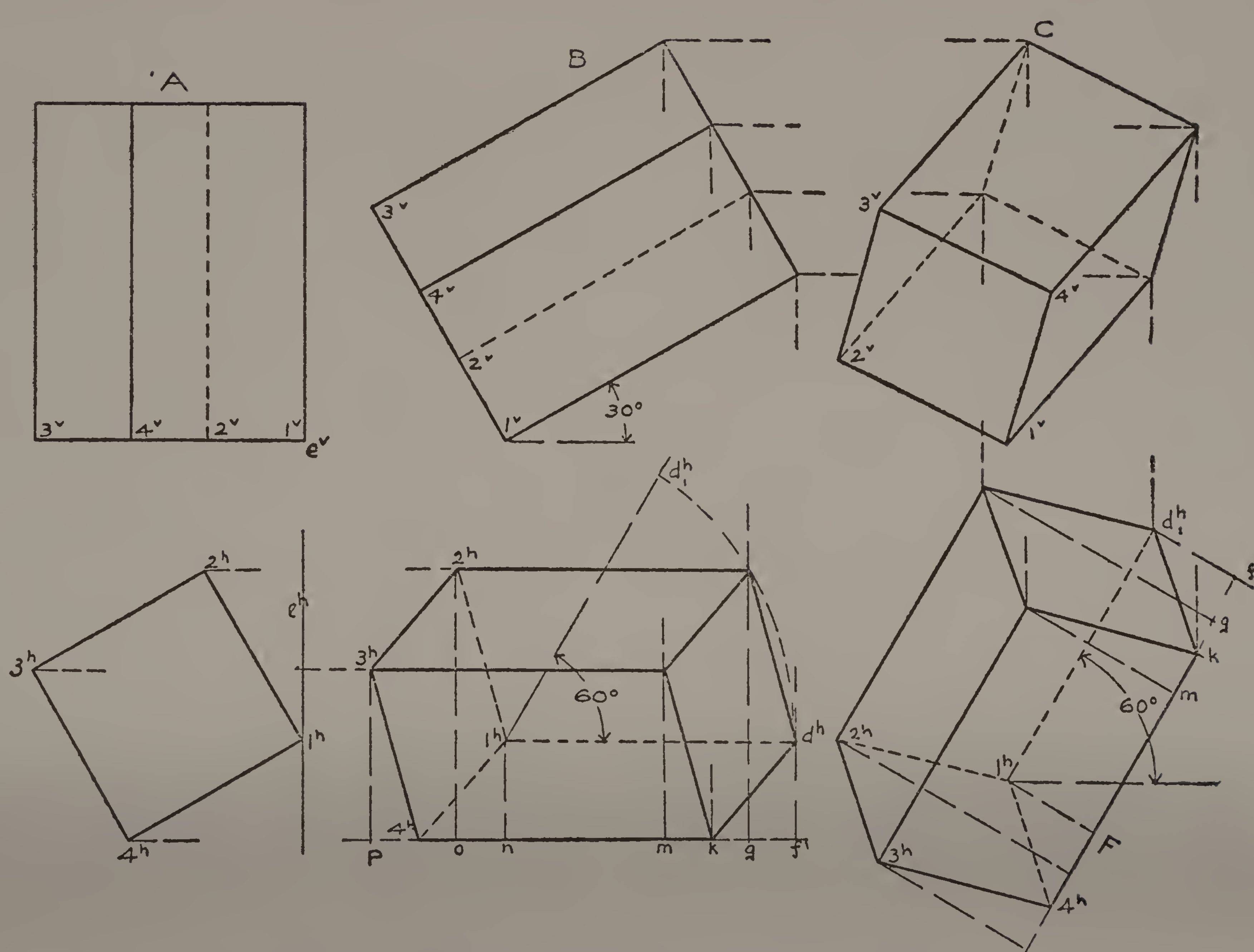


Fig. 58. Drawing a Prism in an Oblique Position.

requires first the construction of two simpler positions.

The prism is first placed with its base on H, and its faces at any convenient angle with V, as 60 degrees and 30 degrees. This position is shown at **A**, Fig. 58. Next, let the prism be revolved about an axis perpendicular to V through the right-hand corner of the base. This axis is lettered 1^h-e^h on the drawing. The prism is revolved until its axis or its long edges make 30 degrees with H.

In this kind of a revolution, the V projection does not change shape or size, and will make with the ground-line the same angle that the prism makes with H (Article 64). Hence the elevation can be transferred from **A** to the 30-degree position at **B**, with point 1 on H.

The plan may then be constructed as in Article 63, Fig. 53, each point of the plan falling vertically below its corresponding elevation, and in a T-square line to the right of the same point in the plan of **A**. The edges of the prism now make the required angle of 30 degrees with the horizontal, and one corner is on H; but the final inclination has yet to be given.

In order that the prism shall have the inclination specified, it must be turned from the position of **B** so that the upper end will be away from the draftsman, and the lower end toward him. This may be done by considering the prism to revolve about a **vertical** axis through point 1. Each point of the prism will then move in a horizontal circle through whatever angle is desired. In this case, let the prism revolve about the vertical axis through 60 degrees; then point $\mathbf{d}^h$ will move to $\mathbf{d}^h$, in the arc of a circle, and 1^h-$\mathbf{d}^h$ will be the new H projection of the edge **1-d**.

In the same way, every other edge will revolve through an angle of 60 degrees, and will have its length unchanged. The new or revolved plan will therefore be of the same shape and size as before this second revolution. For the sake of clearness, this revolution is not made upon Fig. **B**; but, instead, the plan is drawn in Fig. **C** as it would appear after the revolution. The lowest corner 1 may be taken in any convenient position, and 1^h-$\mathbf{d}^h_1$ is drawn at once at 60 degrees equal in length to 1^h-$\mathbf{d}^h$ of Fig. **B**.

The plan of **C** is constructed equal to that of **B** by a method of **rectangular co-ordinates**, or **offsets**. In the plan of **B**, perpendiculars are drawn from each corner to the front edge 4-**k**. These perpendiculars intersect the edge, or the edge produced, in points such as **f**, **g**, **m**, etc. Then, through $\mathbf{d}^h_1$, Fig. **C**, a perpendicular is drawn to **1**-$\mathbf{d}^h_1$, and $\mathbf{d}^h_1$-**f** is made equal to $\mathbf{d}^h$-**f**; and through **f**, a 60-degree line will represent the position of the edge 4^h-**k**. The distance **f-k** of **B**, laid off from **f** of **C**, will give corner **k** in Fig. **C**. Then in **C**, lay off from **f** the distances **f-g**, **f-m**, **f-n**, etc.; and at these points, erect perpendiculars to 4^h-**k** (these perpendiculars are 30-degree lines), and make these perpendiculars equal respectively to those of **B**. In this way the remaining corners of the prism are located, and the plan completed.

The elevation may now be constructed from the plan, if it is remembered that in the revolution around a vertical axis the **heights** of points remain unchanged. Hence, if the corners in the plan are projected vertically up and to the same heights as in the elevation of **B**, the desired points of the elevation will be determined. Notice which end of the prism is visible in plan, and which in elevation. In following out the figure as drawn, care should be taken to imagine the shape and position of the object in space as described by its projections.

70. The projections of a cylinder or cone may be drawn in any oblique position by a process similar to the one just considered.

Let it be required to construct the plan and elevation of a right circular cylinder in the first angle, placed with its axis at an angle of 45 degrees with the vertical plane, its V projection inclined at 30 degrees with H; and let the cylinder slope downward, forward, and to the right. First, note with which co-ordinate plane the axis is to make the given angle. In this case, the given angle is 45 degrees with V. Then draw the cylinder in the first position perpendicular to V, as in **A**, Fig. 59. Divide the base into any number of equal parts, as in the figure, and project these points to the plan.

Now, if a vertical axis, as **X**, be taken

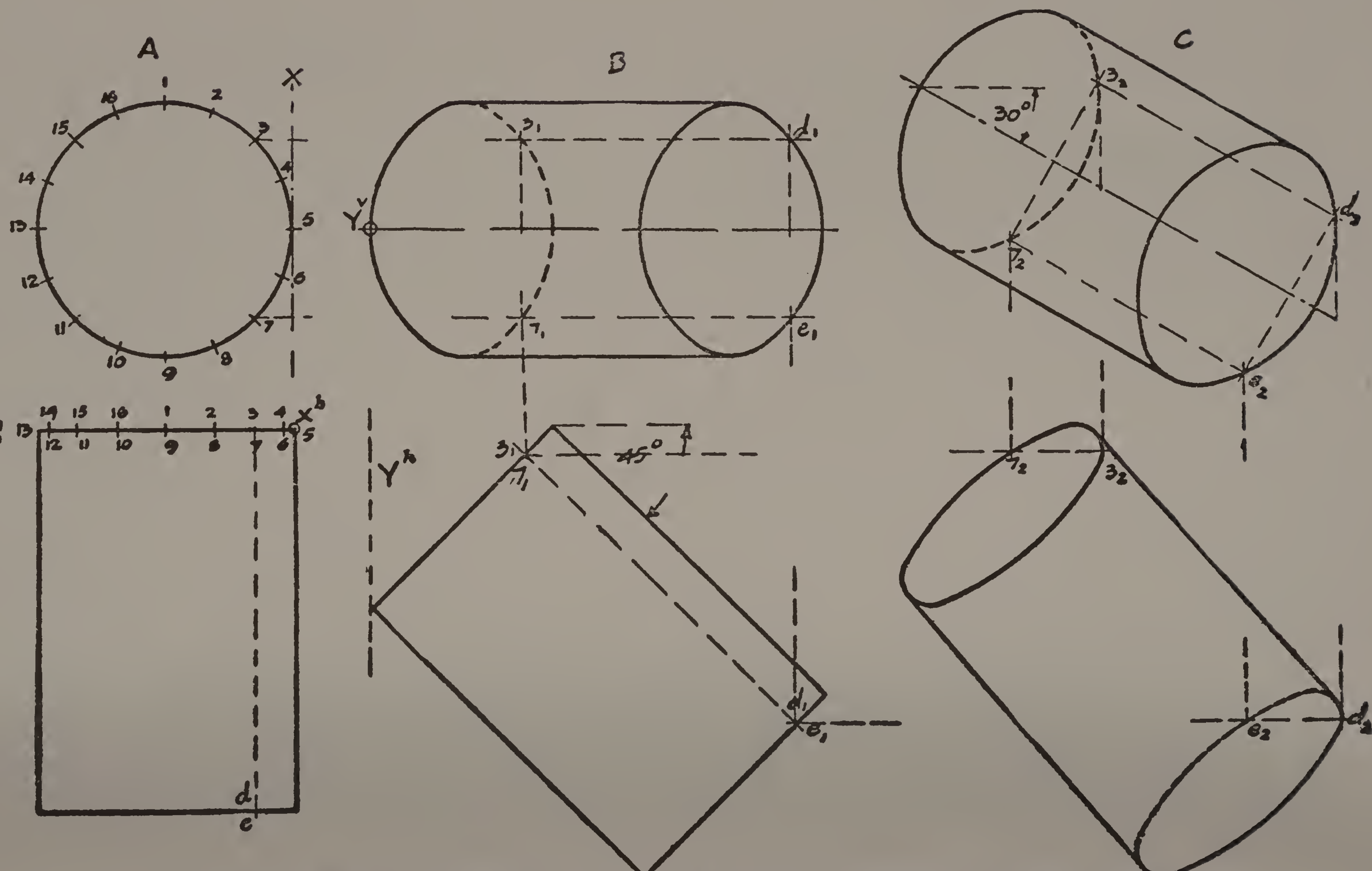


Fig. 59. Drawing Projections of a Right Circular Cylinder in Oblique Position.

through any convenient point, as 5 on the back end, the cylinder may be revolved until it makes the required angle of 45 degrees with V. In this revolution, the cylinder will remain parallel to H, and its plan will be unchanged in size and shape; hence, in **B**, the plan of **A** is placed at 45 degrees with V, sloping forward and to the right.

Since, in the revolution about the vertical axis **X**, each point has moved in a horizontal plane, it follows that the heights of points above the H plane have not been altered. Therefore, from the points of division on the ends of the cylinder in the plan, project for the elevation to the same level as the corresponding points in elevation **A**.

The construction is shown for the points 3 and 7 on one end, and for **d** and **e** on the other. This construction will give a series of points on each end of the cylinder. These points should be joined by the use of the irregular curve, producing the two ellipses in the elevation.

For the last position, **C**, the cylinder must be revolved from the position of **B** without changing the angle of 45 degrees with V, until the final oblique position is reached. As the angle with V must not be changed, this second revolution must be made about an axis perpendicular to V. The axis **Y** may be imagined to pass through any convenient point, as the extreme left-hand point of Fig. **B**. In this revolution (Article 64), the elevation does not change shape or size, but simply its position. Hence, in Fig. **C**, the elevation of **B** is drawn at the specified angle of 30 degrees with H, points 3_2, 7_2, d_2, and e_2 corresponding to the points 3_1, 7_1, d_1, and e_1 of Fig. **B**.

The plan may now be obtained by projecting to meet T-square lines from the plan of **B**.

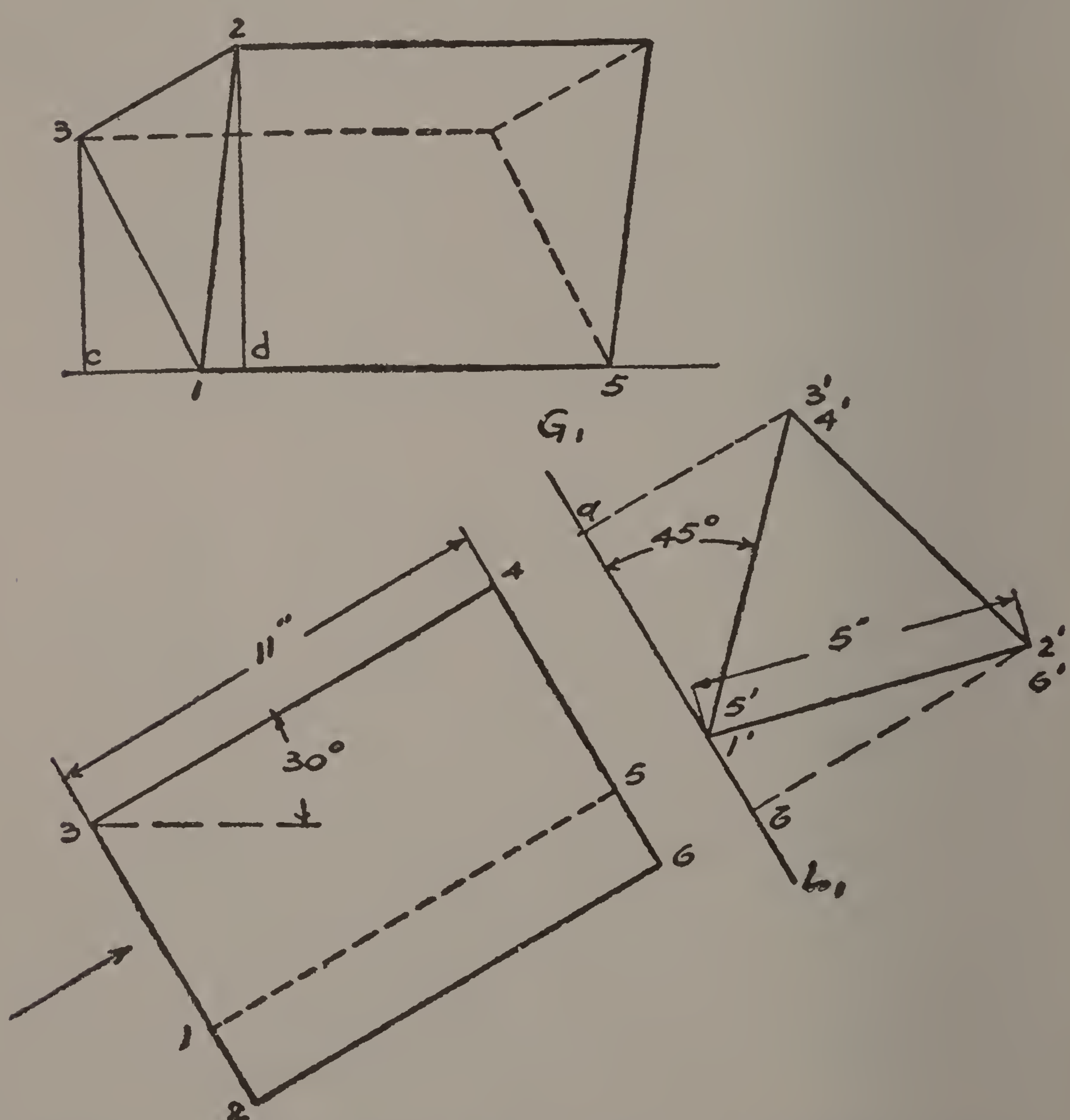


Fig. 60. Drawing Plan and Elevation of Triangular Prism.

71. Auxiliary Planes of Projection. It has been shown in previous figures that often an end view must be made before constructing other views. Many times this end view may be made on H or V. Sometimes, however, it may be necessary or convenient to take an end view in a direction at right angles with neither V nor H.

72. Let it be required to draw the plan and elevation of a triangular prism as represented in Fig. 60.

Let the ends of the prism be equilateral triangles 5 inches on a side. The axis of the prism is to be 11 inches long, inclined at 30 degrees with V, backward and toward the right; the lowest edge of the prism is to be on H; and one face is to make 45 degrees with H. In this position, it is evident that a top view will not show the end at all, and a view taken in the usual direction for elevations will show the end, but not in its true size. If, however, a view be taken in the direction of the arrow—that is, parallel to the direction of the axis—this view will be at right angles to the end of the prism, and the end will show in its real size and position. To take a view in this direction is equivalent to projecting the prism on a new V plane parallel to the end of the prism, or—which is the same thing—perpendicular to the axis.

Hence, to make the construction, draw a line as $\mathbf{G_1}$-$\mathbf{L_1}$ in any convenient position perpendicular to the direction of the axis. This may be considered to represent the H plane seen edgewise when looking in the direction of the arrow. Then, with any point on H for the lowest corner, as 1′, the end view of the prism is drawn showing the true size and slope, and one under face at 45 degrees with H. The width of the face 1-3-4-5 will appear in plan equal to the distance **a**-1′; and the width of face 1-2-6-5 equal to distance 1′-**b**, while the width of the upper face 2-3-4-6 will equal the length **a**-**b**.

With these widths and the given length of the prism, the plan might now be constructed without any further reference to the end view. It is, however, more convenient and more draftsman-like, to draw at any convenient distance from G_1L_1, and parallel to it, a line 4-6 as one end; to project at right angles to G_1L_1, **a** to 4, 5′ to 5, and **b** to 6; then to draw from these points the edges 11 inches long and at right angles to the end 4-5-6, and finally draw the other end 3-1-2.

For the elevation, 1-5 is drawn on the H plane as the lowest edge, and directly above 1-5 in the plan. The height of 3-4 above H is seen in the end view as 3′-**a**, and the height of 2-6 as 2′-**b**; hence, in elevation, these edges will appear at these respective heights above the plane of 1-5. The distance 3-**c** is therefore made equal to 3′-**a**, and 2-**d** equal to 2′-**b**. In this elevation, the end 1-2-3, nearer the draftsman, is visible.

73. **Summary of Important Principles.** The important principles above brought out, may be summarized as follows:

(a) An elevation always shows differences in height (if any difference in height exists) between different objects, or differences in height between different parts of the same object.

(b) A plan or top view means the same thing no matter whether the drawing is in the first or third angle; similarly, an elevation or front view is the same figure for either first or third angle.

(c) For any given object, upper edges or surfaces are visible in plan, and edges or faces on the front are visible in elevation.

(d) A line perpendicular to a plane of projection appears on that plane simply as a point.

(e) A line is shown in its true length in any view, only when the line is parallel to the plane on which the view is drawn.

(f) A plane surface is shown in its true size, only when it is parallel to a plane of projection.

(g) A surface perpendicular to a plane of projection is seen edgewise on that plane, and appears as a single line.

(h) When one line is revolved about another line as axis, each point in the first line moves in a circle whose center is on the axis, and the plane of the circle is perpendicular to the axis.

(i) The length of a given line, or the size of a given surface, as seen in projection, is determined wholly by the angle which the line or surface makes with the plane of projection; the greater the angle made with the plane, the less the size of the projection.

74. It will be found that the exercises given below will, if worked out, afford helpful practice in applying the principles of projection.

Exercises in Projection

Exercise 1—Place in First Angle. Draw the plan and elevation of a square prism, with its edges vertical, and with two of its faces at 30 degrees with the vertical plane. The base of the prism is 2 inches square, and the length is 4 inches. Show a circular hole 1 inch in diameter bored through from one end to the other.

NOTE—Two positions are possible, for the face at 30 degrees with V may be inclined either to the left or to the right.

Exercise 2—Third Angle. Draw the plan and elevation of a prism of the same shape and size as in Exercise 1; but place the prism perpendicular to V, and make two faces incline at 60 degrees with H. Show the hole in the prism as before.

Exercise 3—Third Angle. Draw the plan and elevation of a right circular cone with the base horizontal and the vertex **down.** The base is 3 inches in diameter, and the altitude is 4 inches. Locate the base ½ inch below the H plane, and the center of the base 1¾ inches from V.

Exercise 4—First Angle. Draw the plan and elevation of a regular hexagonal pyramid standing on its base. Make the left-hand **front** edge of the base at an angle of 45 degrees with V. Each side of the base is to be 1½ inches long, and the altitude of the pyramid is to be 4 inches.

Exercise 5—First Angle. Draw the plan and elevation of a rectangle placed parallel to V, with its long sides perpendicular to H. Make the rectangle 4 inches by 2½ inches. Cut off the upper right corner by a 45-degree line drawn through the middle of the top side. Now revolve the rectangle **forward** about its left-hand side as an axis, through 180 degrees, and show the respective projections at the 30, 60, 90, 120, 150, and 180-degree positions.

Exercise 6—Third Angle. Draw the plan and the elevation of a pile of three blocks placed as follows: each one of the three blocks lies on its widest face; all of the blocks have their corresponding edges parallel; the lowest block is on the H plane; the next higher one is placed in the center of the top of the lowest one; and the top block is in the center of the second. All three blocks are rectangular, and all have their long edges inclined at 60 degrees with V, backward and toward the left. The bottom block is 5 inches by 2½ inches by ¾ inch; the middle one is 4 inches by 2½ inches by ½ inch; and the top one is 3 inches by 2½ inches by ¼ inch.

Exercise 7—Construct a profile view of the blocks in Exercise 6, looking from the right.

Exercise 8—First Angle. Construct the plan and elevation of a rectangular prism 4 inches by 2 inches by 1½ inches. The long edges are parallel to both H and V. Place the prism so that the lower back face makes 30 degrees with H.

Suggestion—The end or profile view must be drawn first.

NOTE—Two solutions are possible, since the lower back face may be taken either as the wide or the narrow one.

Exercise 9—Third Angle. Draw the plan and elevation of a right triangular pyramid, placed with its axis parallel to both V and H, with the apex at the left of the base. Locate the axis of the pyramid 3 inches from H, and 2½ inches from V. The axis is to be 4 inches long, and the base is to be an equilateral triangle 2 inches on a side. Let the lower front edge of the base incline at 45 degrees with the horizontal plane.

Exercise 10—First Angle. Draw the plan and elevation of a regular hexagonal pyramid, with its axis parallel to both V and H, and with its apex at the right of the base. Place the lowest corner of the base on the H plane, and make the lowest front edge of the base at an angle of 15 degrees with H. The axis of the pyramid is 5 inches long, and each edge of the base is 1½ inches.

Exercise 11—First Angle. Draw the plan and elevation of a rectangular prism 5 inches by 2 inches by 1½ inches, when the long edges are horizontal and are placed at an angle of 45 degrees with V, backward and to the left. Make the lower front face one of the wide ones, and let it make an angle of 30 degrees with H.

Suggestion—An end view must first be drawn.

Exercise 12—First Angle. Draw the plan and elevation of a right circular cylinder of 2 inches diameter and 5 inches length. The cylinder is placed in a horizontal position, making 45 degrees with V, backward and to the right.

Exercise 13—Third Angle. Make three drawings of a regular hexagonal pyramid of which the altitude is 4 inches, and the edge of the base 1½ inches. In the first figure, make the plan and elevation showing the base horizontal, and the apex above the base; and place the left-hand front edge of the base at 45 degrees with V. In the second figure, show the projections after the pyramid has been revolved through 45 degrees about an axis perpendicular to V, so that the axis of the pyramid slopes downward and to the left. In the third figure, revolve the plan of the preceding figure through 30 degrees clockwise, and construct the corresponding elevation.

Exercise 14—First Angle. Draw the plan and elevation of a right circular cone in three positions. The diameter of the base is 3 inches, and the altitude is 4 inches. In the first position, draw the plan and elevation with the cone standing on the apex, and with the base horizontal. In the second position, draw the plan and elevation after the cone has been revolved through 60 degrees about an axis perpendicular to V, so that the axis of the cone slopes downward and to the right. For the third position, revolve the plan of the second position counter-clockwise through 45 degrees about a vertical axis, and construct the corresponding elevation.

INTERSECTION AND DEVELOPMENT.

75. **Intersection.** When two surfaces meet at an angle so that if either one were extended it would actually cut the other surface, the line of meeting is called the **intersection** of the two surfaces.

The line of intersection may be straight or curved, according to the nature of the surface.

Planes, as the simplest kind of surfaces, will be considered first.

76. **Development.** By the term **development** is meant a figure showing the true size and shape of the surface of any given solid, when the surface has been rolled or spread out on a plane. A **true development** is obtained when **all** of the surface is made to coincide with a plane, without overlapping or folding. Such a development, when cut out of paper or thin sheet metal, and properly bent or rolled up, will reproduce the original solid.

Some surfaces are truly developable, and others are not. Among the former are all surfaces composed of planes, as those of prisms and pyramids, all cylindrical, and all conical surfaces. The most familiar solid which has a non-developable surface is the sphere.

Intersection of Planes

77. The intersection of two planes is evidently always a straight line. Familiar

examples of this kind of intersection are to be found on every hand. The edge of a box is the line of intersection of two adjoining sides, which are planes; the ridgepole of a pitch roof is the line of intersection of the two sides of the roof; and so on in great number.

78. In Fig. 61, a triangular pyramid stands on its base, and several lines of intersection are shown. The slanting edges of the pyramid are the lines of intersection of the sloping faces.

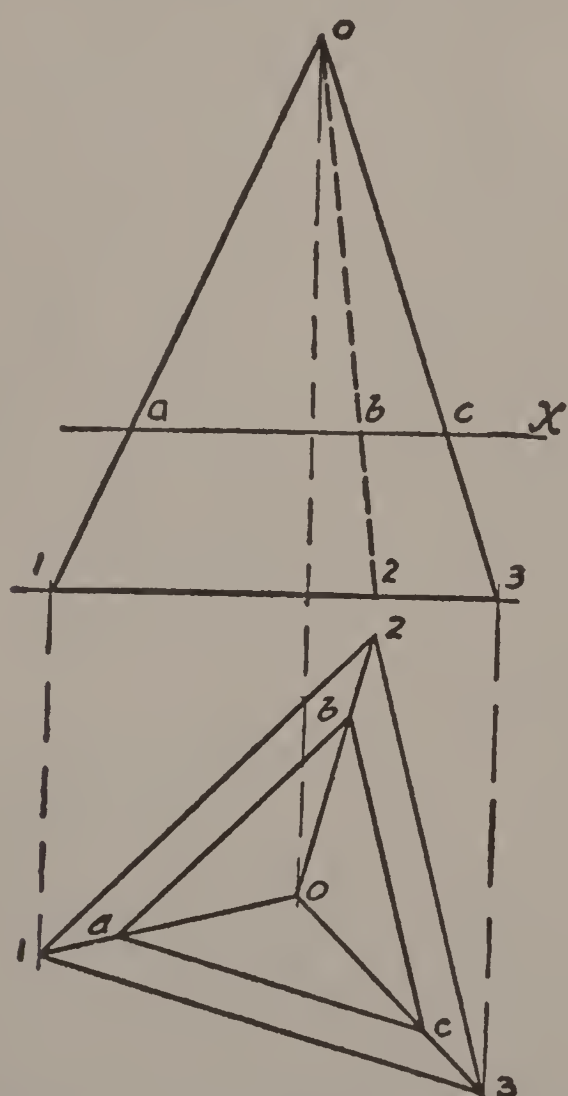


Fig. 61. Triangular Pyramid Intersected by a Plane.

Let **X** represent a plane seen edgewise. Then **X** is parallel to the H plane, and perpendicular to V. This plane cutting the pyramid will intersect all of the inclined faces, giving thereby three lines of intersection. The plane **X**, seen edgewise in elevation, cuts the slanting

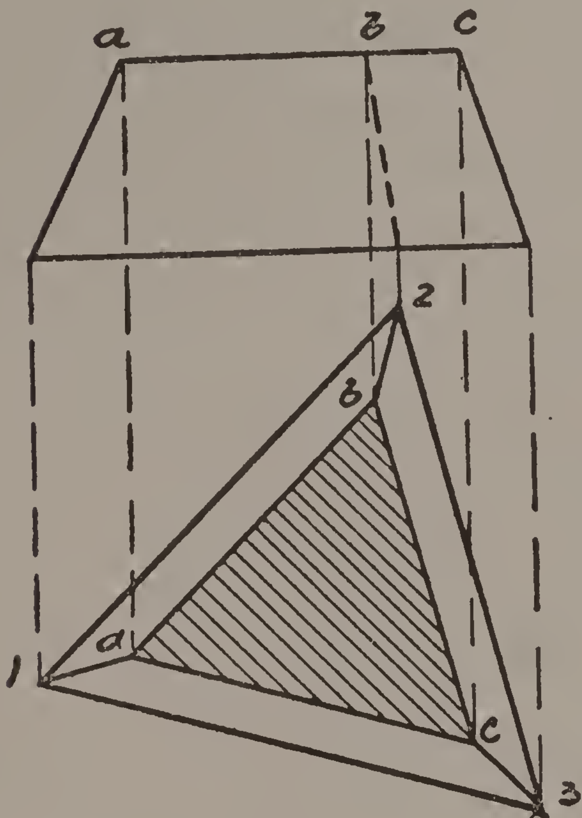


Fig. 62. Showing Section of Triangular Pyramid Cut by Plane.

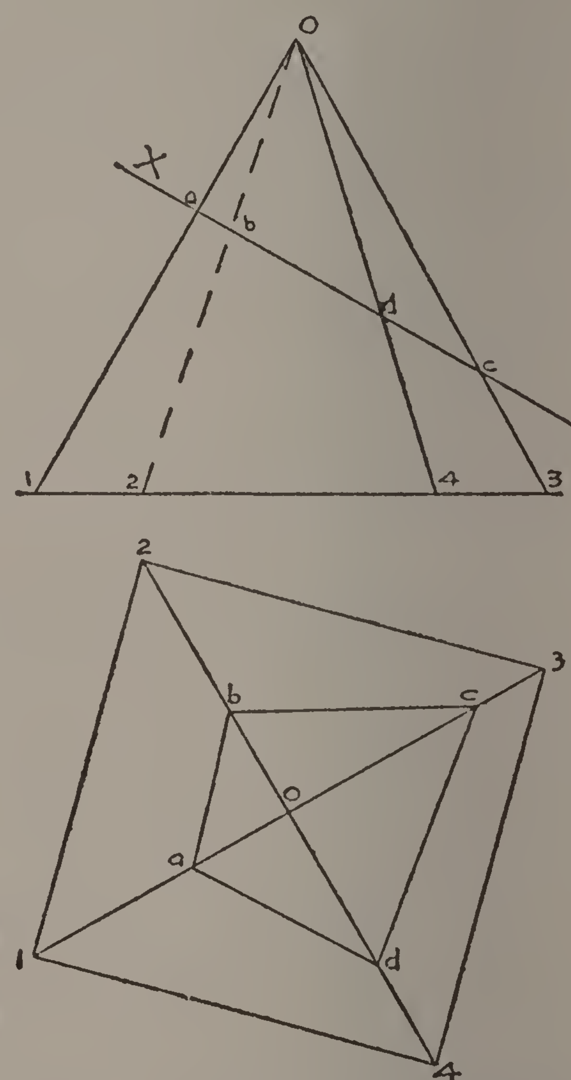


Fig. 63. Elevation and Plan of Square Pyramid Cut Obliquely by a Plane.

edges in points **a**, **b**, and **c**; and these points are found in plan directly below on the corresponding edges.

As the plane cuts edge 0-1 at **a**, and 0-3 at **c**, it will cut the face 013 in the line joining **a** and **c**; and, by joining point **b** with **a** and **c**, the other two lines are determined, and the whole intersection **abc** completed.

Two features of the intersection should be noted:

First, it is a triangle. This must always be the case when the pyramid is triangular and the intersecting plan cuts all three edges, even if the plane should not be parallel to the base.

Second, the sides of the triangle **abc** are respectively parallel to the edges of the base of the pyramid. This parallel relation is due to the fact that the plane **X** in this case is parallel to the base.

79. It may be proved by geometry that if any prism, pyramid, cylinder, or cone is cut by a plane parallel to the base, the intersection is always a figure like the base in shape, and parallel to it in position.

80. Fig. 62 shows the same pyramid with the part above plane **X** removed, showing in plan the actual surface cut by the plane.

81. Fig. 63 is a square pyramid standing on its base, and cut by a plane **X**. The plane **X** in this figure is oblique to H, but the intersection **abcd** is found by the same process as before. Notice here, that while the intersection has as many sides as the base, it is not parallel to it.

82. Fig. 64 shows a square pyramid in the first angle, intersected in a similar way by a plane **X**; it shows also the development of the pyramid.

Let us see how to construct the development.

Each sloping face of the pyramid is an isosceles triangle, and the base is a square; so the development will consist of four equal triangles and a square, joined together and shown in their true sizes. The pyramid may be considered to be placed with its vertex at o', the edge o-a at o'-a', and the face **oab** in contact with the plane of the paper. Then the triangle **oab** must be shown in its true size at $o'a'b'$.

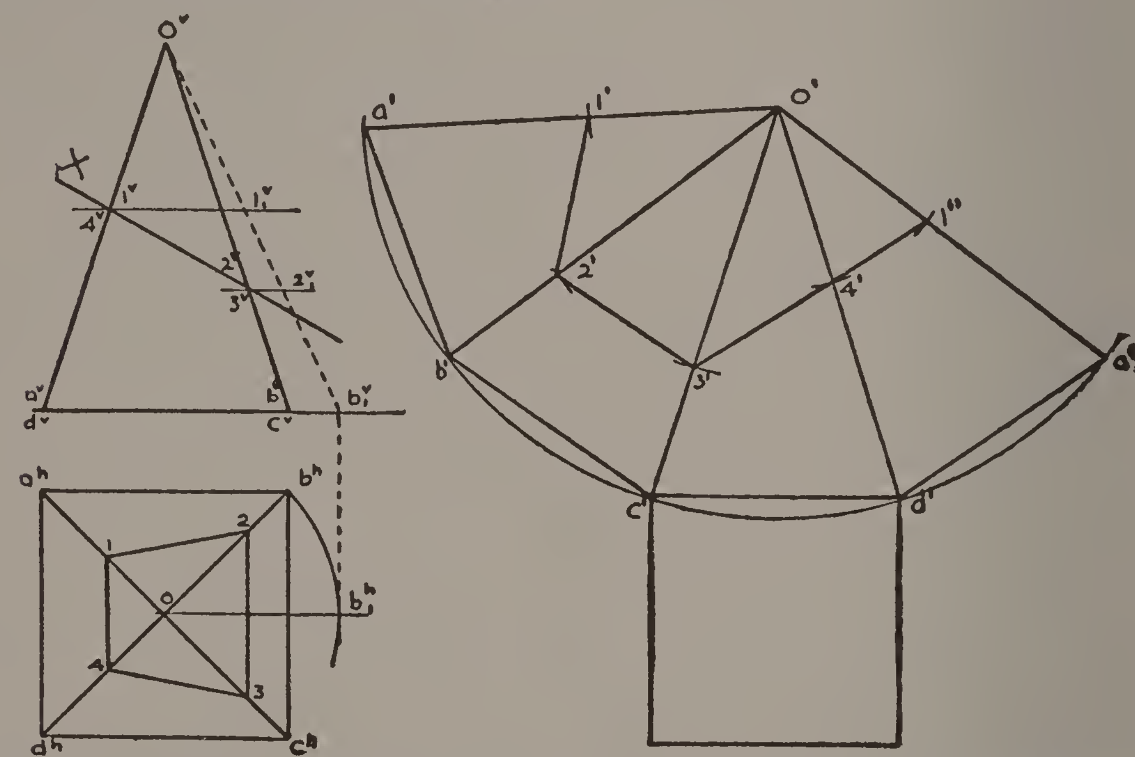


Fig. 64. Square Pyramid in First Angle, Intersected by a Plane. Development of Pyramid Shown at Right.

It is then necessary to find the true length of the sides of the triangle **oab**. The H projection o-b^h does not show the true length of the line; neither does the V projection o^v-b^v. Let the pyramid be revolved about its axis through 45 degrees, so that o-b^h will move to o-$b^h{}_1$. Then the line **o-b** will be parallel to V; and its projection on V, when found, will show the true length of the line. In revolving, the apex **o** will not move, and the point **b** will stay on H; hence b^v_1 will be projected from b^h_1 to the plane of the base or the GL, and o^v-b^v_1 will be the true length of the line **o-b**.

All of the sloping edges of the pyramid are evidently of the same length, and the edges of the base are shown in plan in their true lengths; so the development may be constructed, laying down first the true size of the triangle **oab**, joining to the edge **o′-b′** the next face **obc**, and then in turn the other two faces.

The square, representing the base, may be constructed on any short side, as at **c′-d′**. The most expeditious construction is to take a radius equal to o^v-b^v_1, strike an arc through **a′** from center **o′**, and on this arc, with the dividers or compasses, step off the length a^h-b^h four times, obtaining **b′**, **c′**, **d′**, and **a″**. These points are then connected and joined with **o′**.

The lines on the development showing the intersection of the plane **X** are next found. The point 1, for example, will appear in development on the line **o′-a′** at its **real distance** from **o′**. This real distance from **o** may be found in elevation by drawing a horizontal line from 1^v to cut o^v-b^v_1 in point 1^v_1, thus determining o^v-1^v_1 as the real distance. The reason for this is that if the pyramid be revolved about its axis until o-a^h takes the position o-b^h_1, the V projection will then coincide with o^v-b^v_1, and the point 1 will appear on o^v-b^v_1 at the same height as before revolution. The length o^v-1^v_1 is then laid off from o′, giving 1′. The real length from o to 2 is similarly found by a horizontal line from 2^v to 2^v_1. The lengths o-4 and o-3 are respectively equal to those of o-1 and o-2. The points 1′, 2′, 3′, 4′, and 1″ are then located and joined, thus completing the required development.

In connection with the construction for finding the true length of the line o-b, it should be remarked that it is not really necessary to think of the entire pyramid as revolving, for the same result is reached if the line alone be revolved about a vertical axis through o.

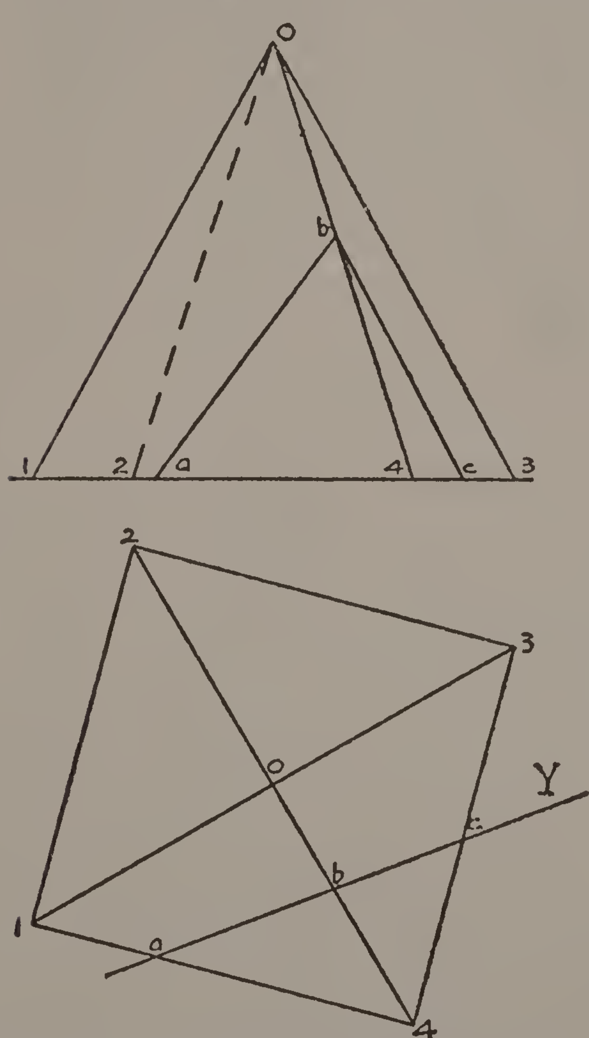


Fig. 65. Square Pyramid Cut by Plane Perpendicular to H.

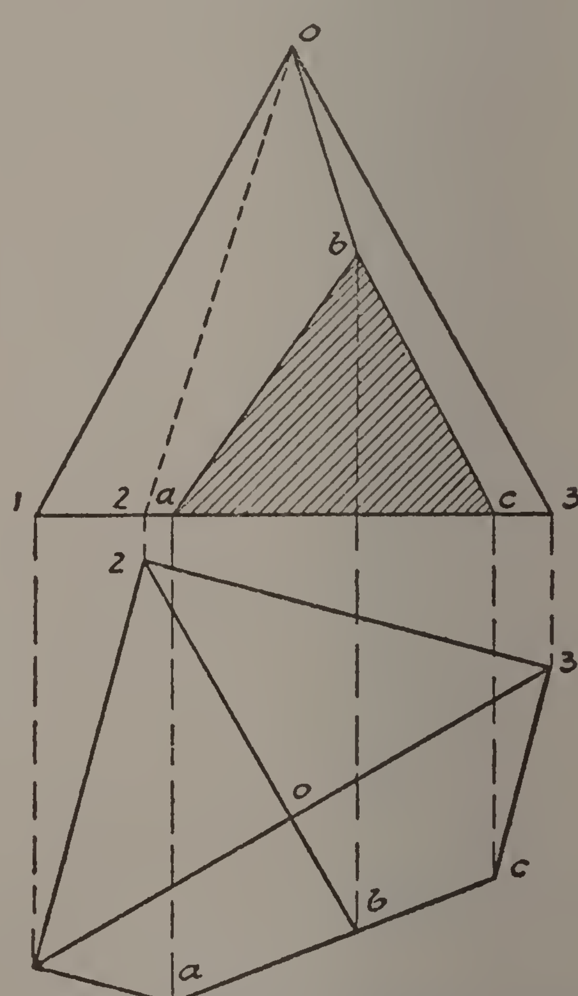


Fig. 66. Square Pyramid with Corner Cut Off.

83. A square pyramid like that of Fig. 63, is shown again in Fig. 65, but intersected by a

plane **Y** perpendicular to H. Plane **Y** is therefore seen edgewise in plan. The points of intersection **a**, **b**, and **c** are projected to the elevation and connected, thus determining the lines **a-b** and **b-c**. The plane in this position cuts two edges of the base and one sloping edge.

In Fig. 66, the same pyramid is shown again, but with the corner cut off. This gives rather a clearer idea of the intersection, or **section**, as it is called, cut by the plane **Y**.

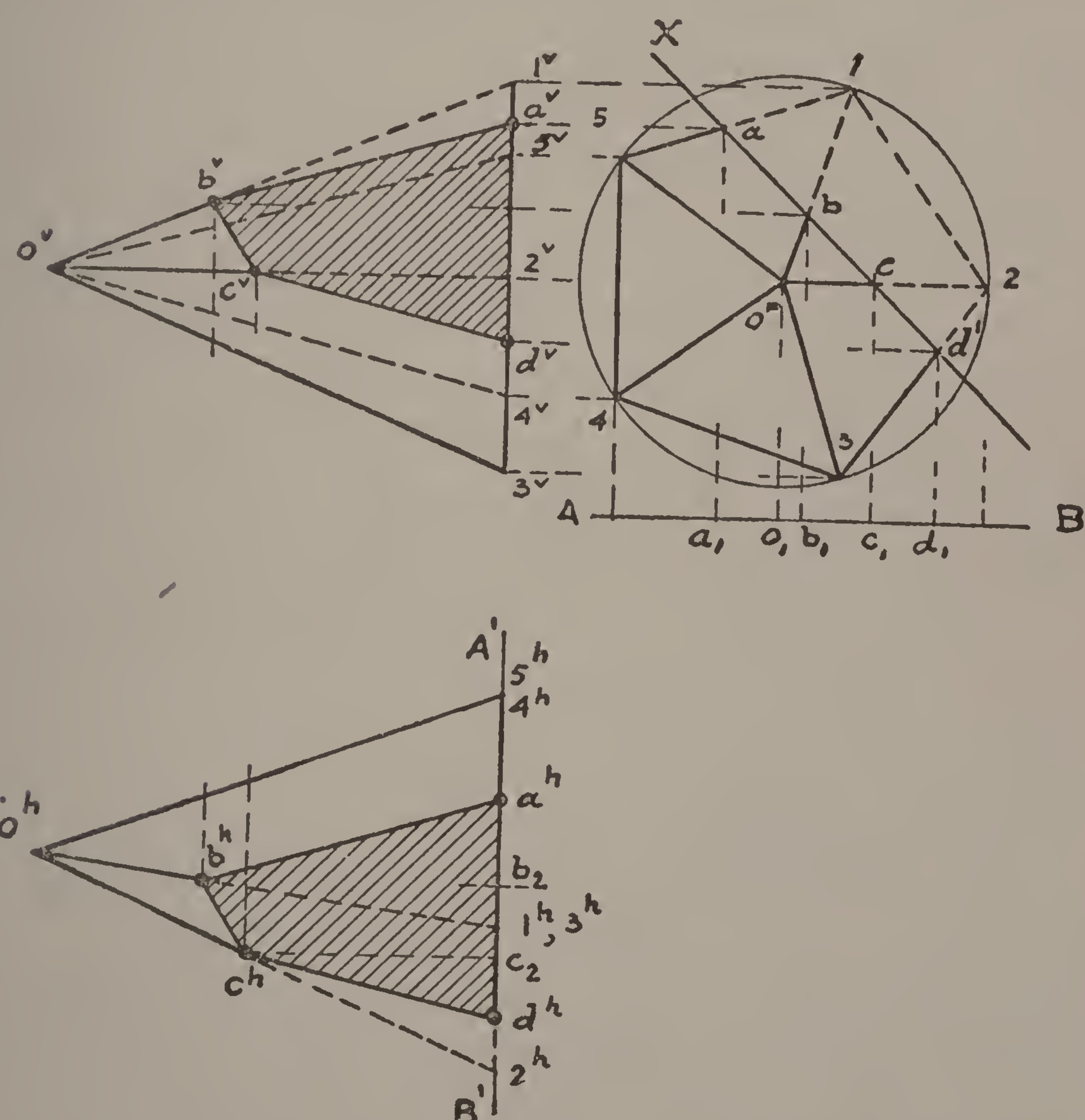


Fig. 67. Elevation, Plan, and End View of Regular Pentagonal Pyramid.

84. A regular pentagonal pyramid, with elevation, plan, and end view, is given in Fig. 67.

The pyramid has its axis parallel to both V and H; hence its base is seen edgewise in both plan and elevation. The pyramid is placed in the first angle, and the end view is drawn first. In this view the base is drawn in its full size. From the end view, the front elevation and the plan are constructed, the elevation being a view in the direction of the arrow.

The construction of the elevation of the pyramid should be apparent from the figure, and the plan is drawn by the principles of Article 66, which may be again referred to here. As the plan is a top view, the width of the base will be the same as on the end view. Hence the process is to project in the end view the corners of the base upon any horizontal line, as **A-B**, and transfer this line with its points of division to the position **A′-B′**, directly below the base in the elevation. The apex $\mathbf{o}^h$ may then be located and joined with the corners of the base $1^h2^h3^h4^h5^h$.

Let **X** be a plane at right angles to the base of the pyramid. Then the plane in this position will intersect the three faces 0-1-5, 0-1-2, 0-2-3, and also the base of the solid.

The plane cuts the edges in the points marked **a**, **b**, **c**, and **d**. These points may be found in elevation at the same height, by the use of the T-square. Point **a**, on the edge of the base, is located at $\mathbf{a}^v$, point **b** on 0^v-1^v, and point **d** on the base at $\mathbf{d}^v$.

To locate $\mathbf{c}^v$, however, it is first necessary to find $\mathbf{c}^h$ in plan, then project for $\mathbf{c}^v$. The points in the end view are projected to **A-B** at points $\mathbf{a}_1$, $\mathbf{b}_1$, $\mathbf{c}_1$, and $\mathbf{d}_1$; and these points are then spaced off in the plan at $\mathbf{a}^h$, $\mathbf{b}_2$, $\mathbf{c}_2$, and $\mathbf{d}^h$. The points $\mathbf{b}^h$ and $\mathbf{c}^h$ are then found by T-square lines on 0-1 and 0-2 respectively. The section is lined in considering the part of the pyramid to the right of plane **X** as removed.

Intersection of a Plane with a Curved Surface

85. It has been shown that the intersection of a plane with a pyramid or prism is found by connecting points in which the plane cuts the edges of the solid. In the case of a solid with a curved surface, as a cone or cylinder, the only edges are the base edges. There may, however, be straight or curved lines drawn on the surface, and the intersection of the plane with these lines be found, thereby locating points on the required curved intersection.

86. In Fig. 68 is shown a right circular cone standing on its base, and intersected by a plane **X**, which is at right angles with V. The base may be divided into any number of parts—in this case twelve—and the elements of the cone drawn, as 0-1, 0-2, 0-3, etc. These elements are cut by the plane in points showing in elevation as **a**, **b**, **c**, etc., and these points are then projected to corresponding elements in plan.

The points **d** and **m** are located in the plan as follows: Pass a plane **Z** through the points **d** and **m**, and parallel to the base of the cone. Then **Z** will cut the cone in a circle whose diameter is **x-y**; and this circle, lying on the surface of the cone, will evidently pass through the points **d** and **m.** The circle **x-y** is drawn in plan, and, by its intersection with the elements 0-4 and 0-10, fixes the position of the points **d** and **m.** A smooth curve drawn in plan through the points **a, b, c, d,** etc., is the projection of the required intersection. The section is an ellipse, and its real size and shape are not shown in plan.

We shall now proceed to the development of

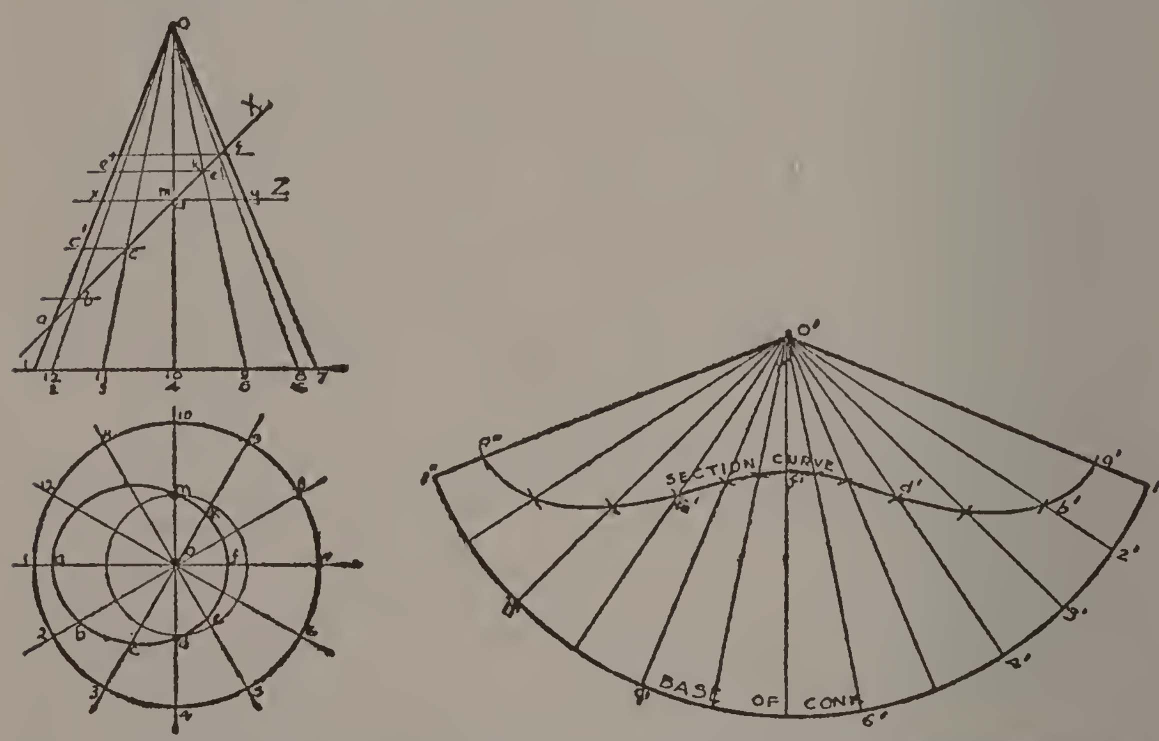


Fig. 68. Right Circular Cone Cut by Plane at Right Angles with V. Development Shown at Right.

the cone and the section cut by plane **X.** The cone may be supposed to be placed with its vertex at 0′, and the element 0-1 at 0′-1′; the cone is then rolled until all of the curved surface has come into contact with the paper. As the cone rolls on the plane, the various elements will take positions such as o′-2′, 0′-3′,—0′-6′ to

0′-1″, and the edge of the base will develop into the curve passing through the points 1′, 2′, 3′,—1″. As all of the elements of the cone are the same length, the points 1′, 2′, 3′, etc., will all be at the same distance from 0′; that is, they will lie on the arc of a circle struck from 0′ as center. The radius of the circle is the true length of any element of the cone, as shown by 0-1 in elevation. The positions of the points 2′, 3′, etc., are found by taking in the dividers the distance between any two consecutive points of the base as seen on H, and laying this off from 1′ twelve times. Lines joining these points with 0′ will represent the positions of the elements in development.

As regards the development of the section cut by plane **X**, the different points of the curve may be found on the elements by laying off from 0′ the true distance from the points of intersection to the vertex 0. The distance 0-a in elevation is a true length, since 0-1 is parallel to V (Article 73, e). The point a′ is then located at once. The true distance of the other points from the apex may be found by projecting horizontally from the points in elevation to 0-1, on which line their true distances from 0 are shown. These distances are then laid off from 0′ on the respective elements; and a smooth curve drawn through the points will be the section curve required.

Attention is called to the fact that the length of the developed base 1′, 2′, 3′,—6′—1″ is not exact, since, in the first place, it is impossible with the dividers to measure exactly the length of a curve; and in the second place, because it is likewise impossible to apply exactly with the dividers any given distance along a curve. It should be said, however, that by taking points sufficiently close together a very good approximation indeed can be obtained.

87. Fig. 69 shows an example of a cone standing on its base and intersected by a plane **Y** perpendicular to H.

Elements of the cone are drawn as before, except that it is unnecessary to draw any on the

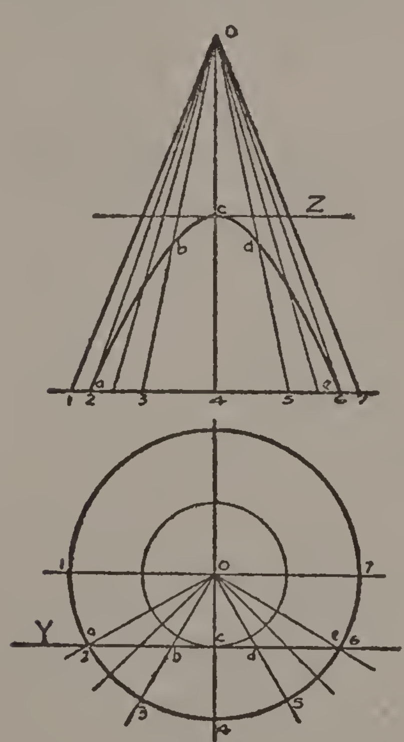


Fig. 69.

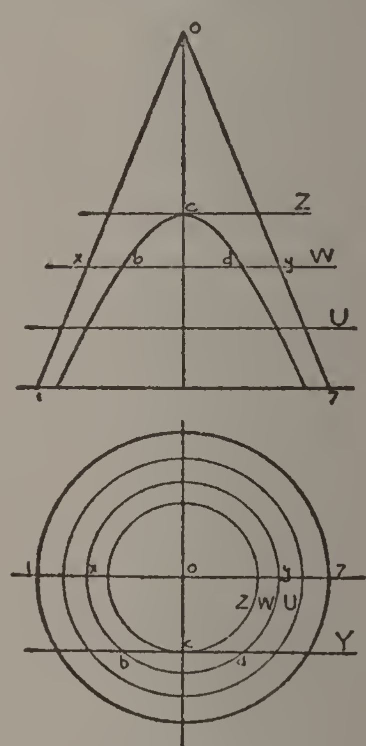


Fig. 70.

Cone Intersected by Plane Perpendicular to H.

further side of the cone. In plan, the elements are seen to intersect plane **Y** in points **a**, **b**, **c**, **d**, and **e**, which are then projected to the elevation onto the corresponding elements. It will be noticed that in elevation the points **a** and **b** are quite a considerable distance apart; so two more elements are drawn in plan, one between 0-2 and 0-3, and one between 0-5 and 0-6. These elements determine two more points on the curve. The highest point **c** cannot be found in elevation by direct projection, but is located by a special construction.

A circle with center 0 is drawn on the plan passing through **c**. Considering this circle as lying on the surface of the cone, it will intersect all of the elements, and will lie in a plane parallel to the base. For convenience, the points in which the circle intersects the two outside elements, 0-1 and 0-7, are used, and projected to 0-1 and 0-7 in elevation; then the plane **Z** is the plane containing the circle, and **c** in elevation is where **Z** cuts element 0-4. This section curve is shown in its true size and shape in elevation, and is known as a **hyperbola,** this name being given to the curve cut from any cone by a plane parallel to the axis.

88. In Fig. 70 are shown the same cone and the same cutting plane **Y**; but the curve is found without the use of any but the two outside or contour elements 0-1 and 0-7. The highest point **c** is first determined as in Fig. 68. Other planes between **Z** and the base are then taken. Let **W** be one such plane. Plane **W** cuts a circle from the cone, the diameter of which is **x-y**. A circle with this diameter may then be drawn in plan, intersecting plane **Y** in points **b** and **d**. These points are in plane **W**, and hence are

located in elevation by projecting from the plan to plane **W**. Points on **U** and on as many other planes as may be chosen, are obtained in the same way.

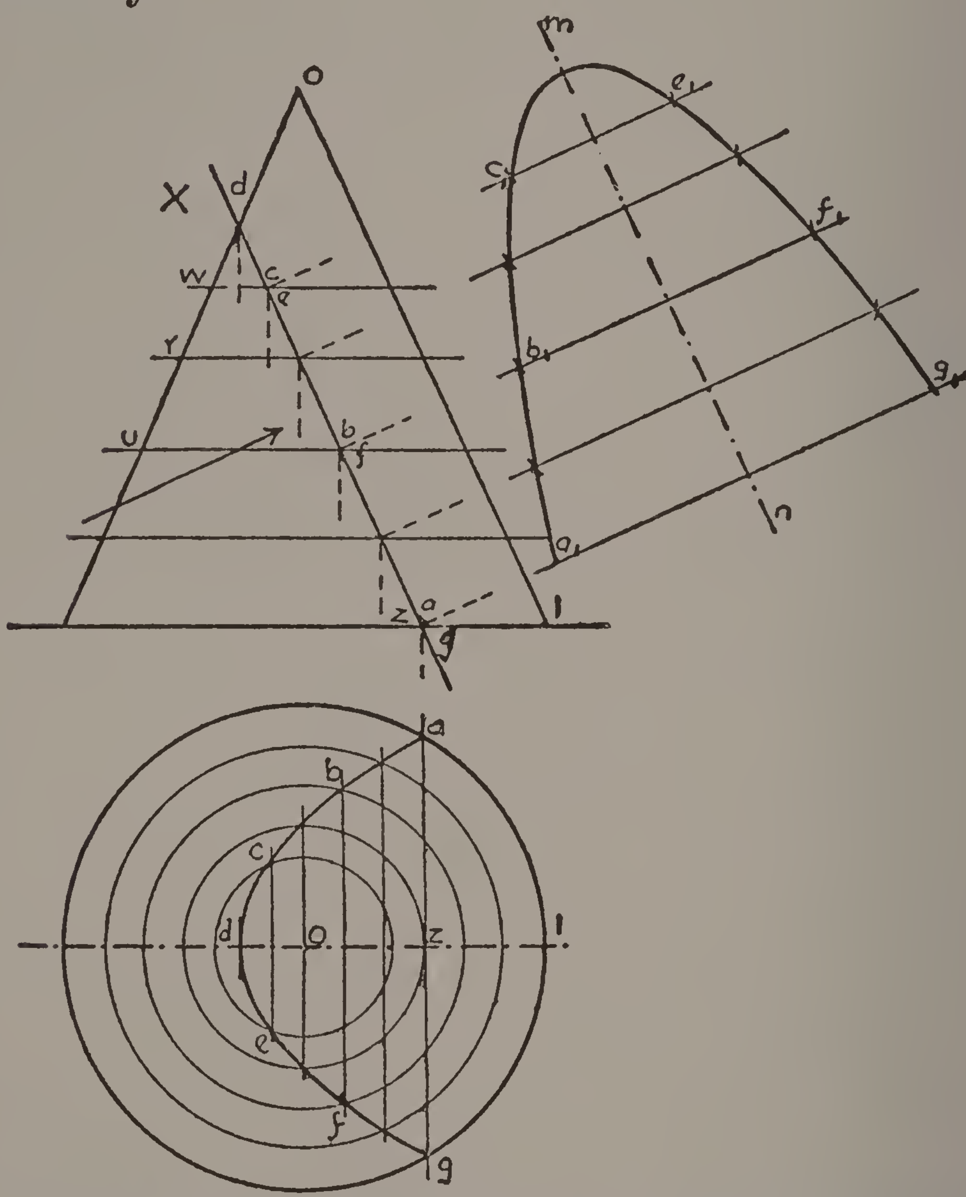


Fig. 71. Cone Cut by Plane Parallel to One Element, Giving Curve Known as Parabola.

Very often this method of construction is better than that of Fig. 68, on the score of accuracy. By referring to Fig. 68, it will be seen that, owing to the steep inclination of elements 0-3 and 0-5, when **b** and **d** are projected from the plan, their exact position on 0-3 and 0-5 is a matter of some uncertainty.

89. **Auxiliary Planes.** Planes such as **Z, W,** and **U,** in the last three figures, introduced to work out or facilitate some part of the solution, are called **auxiliary planes.**

90. Still another form of curve results when, as in Fig. 71, the cutting plane is taken parallel to one element. The plane **X,** perpendicular to V, is parallel to the element 0-1. The plan of the intersection is found by the method of Fig. 70. The curve in this case is a **parabola,** in accordance with the definition of geometry, that "the curve cut from a cone by a plane which is parallel to one and only one element is called a **parabola.**"

The **true size of the section** may be found by a simple construction. The curve is evidently symmetrical with respect to a line **d-z,** which is the axis of the curve and is represented in its true length in elevation. If, now, a view of the curve be taken in the direction of the arrow, the true size and shape will appear. The actual distance between points **c** and **e,** for example—that is, the true width of the curve at that part—is shown in plan as the length **c-e.** The true widths **b-f** and **a-g** are similarly shown. It will be seen, then, that while **in plan** the true width of the curve at any part is shown, the real distances along the axis **d-z** are not there shown. For example, the distance from **d** to line **c-e** is not a true length. But these distances along the axis are shown true length **in elevation,** from **d** to **c-e, d** to **b-f,** etc.

Hence, to show the true size of the curve as seen in the direction of the arrow, all that is necessary is to combine the true lengths of the elevation with the true widths of the plan. Therefore, at any convenient distance, draw **m-n** parallel to **d-z**; project with the triangles from **c**, **e**, **b**, **f**, etc., at right angles to **m-n**; and make the widths c_1-e_1, b_1-f_1, and a_1-g_1, equal respectively to **c-e**, **b-f**, and **a-g**, half of each on either side of the axis **m-n**.

Intersection of a Plane with a Cylinder

91. A right circular cylinder standing on its base and cut by a plane **X** perpendicular to V, is drawn in Fig. 72. The development of the

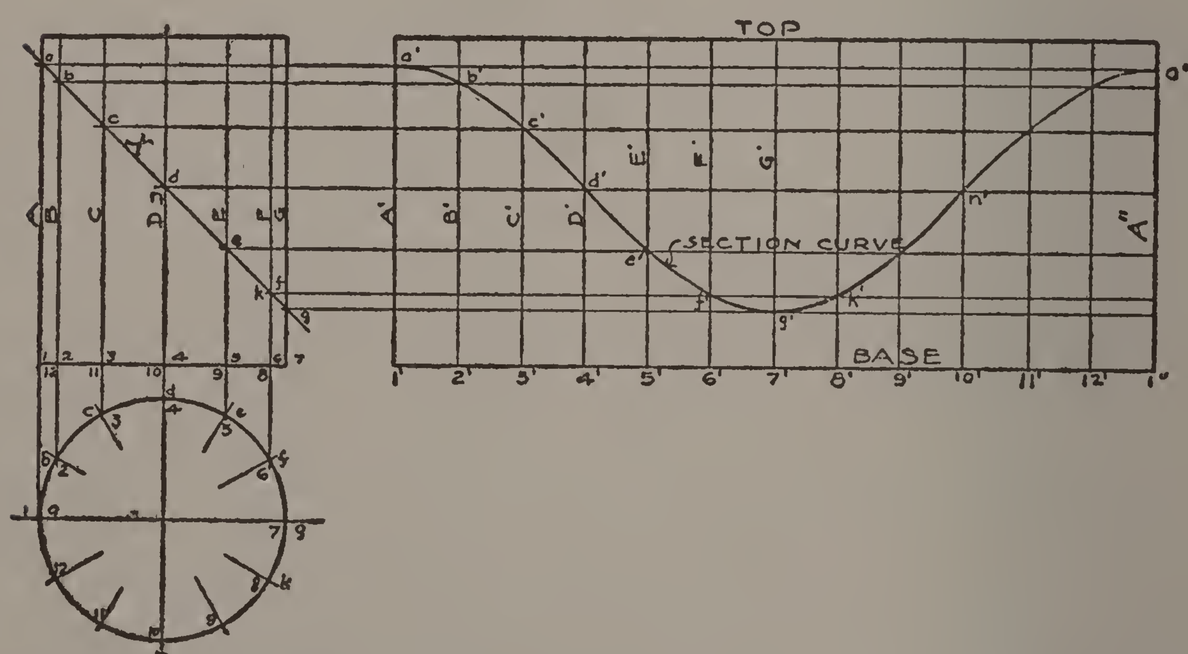


Fig. 72. Right Cylinder Cut by Plane Perpendicular to V. Development of Cylinder Shown at Right.

cylinder is also shown. As in the case of the plane cutting the cone, elements of the cylinder are drawn, and the points noted in which the plane cuts the elements. The base is here divided into twelve equal parts, and twelve elements drawn. The plan of the intersection will coincide with the plan of the cylinder, since the whole convex surface is projected in the circle.

Development of the Cylinder and of the Curve of Intersection. Let the cylinder be placed with point 1 of the base at point 1′, and element **A** at **A′**, on the plane of the paper. Now imagine the cylinder rolled on the paper until the entire curved surface has come into contact with the paper, and element **A** is again on the paper at **A″**, parallel to **A′**. The distance between **A′** and **A″** is therefore the shortest distance around the cylinder as measured around the base.

As the cylinder rolls from **A′** to **A″**, the base remains always in a plane perpendicular to the elements, and hence perpendicular to the plane of the paper. Therefore, as the cylinder is developed, the edge of the base rolls out in the straight line drawn from 1′ perpendicular to **A′** and extending to **A″**. The approximate distance around the base is laid off in the development, by taking the chord of one of the equal divisions of the base, and spacing it twelve times along 1′-1″, locating the points 2′, 3′,. . .6′. . .1″. Lines drawn through these points at right angles to the developed base, will be the developed positions of the numbered elements. The lengths of the elements are taken directly from the elevation, since the true lengths are there shown; and a straight line through the upper ends of the elements will be the development of the top of the cylinder. The development of the curved surface of the cylinder is therefore the rectangle as shown.

The development of the section curve is obtained by locating the points **a**, **b**, **c**, etc., in the development on their respective elements, and at the true distance from the foot of the element. These distances are all shown in the elevation, and consequently may be transferred at once to the development; and a smooth curve drawn through **a′**, **b′**,. . .**e′**. . .**n′**. . .**a″** will be the developed curve.

Intersection of Solids

92. Points on the intersection of solids—that is, on the intersection of their surfaces—are the points in which lines of either surface intersect the other.

93. **Visibility of the Lines of Intersection.** The intersection of two solids, viewed from any given direction, is in general partly visible and partly invisible. The rule for visibility is that **visible parts of the intersection must always be the intersection of visible parts of each surface.** Thus the intersection of the upper parts of two surfaces would be visible in plan; while the intersection of the upper side of one with the under side of the other would not be visible.

94. **Intersection of Solids Bounded by Plane Surfaces.** When one solid of this class—as, for

example, a pyramid—intersects another pyramid or prism, the intersection will consist of one or two figures bounded by straight lines. Points on such an intersection may be determined by finding where the edges of either solid intersect or pass into the faces of the other.

95. A square prism standing on its base, is intersected by a triangular prism with its axis parallel to both V and H, Fig. 73. The end view at the right shows the left-hand end of the horizontal prism. The points in which the edges of the triangular prism intersect the faces of the other prism, will be shown at once in plan, since in plan the surfaces of the square prism are seen edgewise. The edge 3-4 intersects the face **adef** at a point seen in plan as $\mathbf{m}^h$, and the V projection $\mathbf{m}^v$ is found in elevation on 3^v-4^v.

Similarly, edge 2-6 cuts the same side **adef** at point **n**. Then the line **m-n** is the intersection of one side 2-3-4-6 of the triangular prism with the side of the square prism. In elevation, **m-n** will be a visible line (Article 93).

The next edge, 1-5, evidently does not intersect the face **adef**, but cuts the adjoining side **abgf**. The face 1-2-6-5 must then cut both faces of the other prism in a broken line, running from point **n** to the point in which the face 1-2-6-5 cuts the edge **a-f**, and continuing from this point to point **q** on the face **abgf**. The point where the plane 1-2-6-5 cuts the edge **a-f** is found in the end view. In the end view, a part of

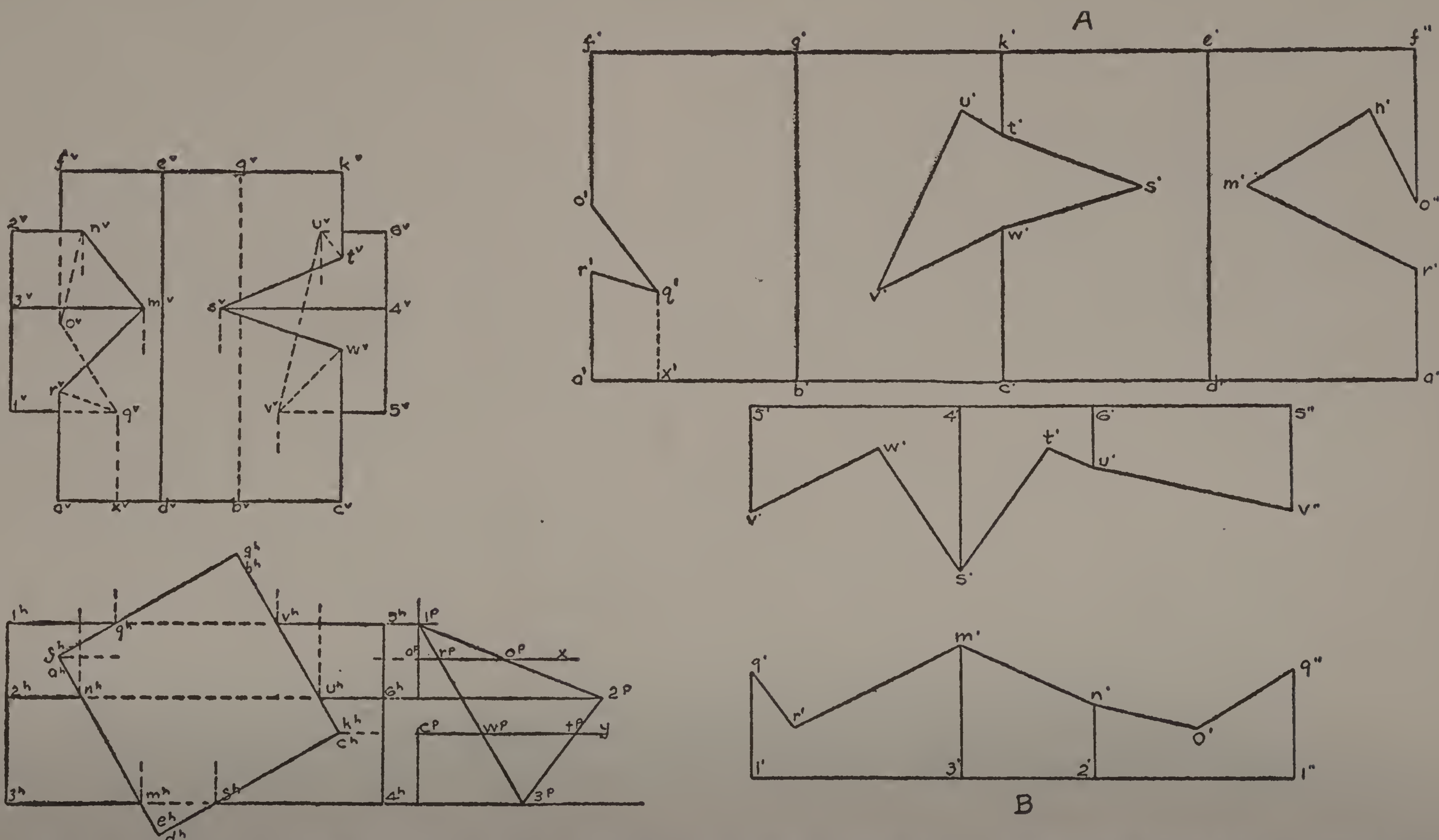


Fig. 73. Square Prism Intersected by a Triangular Prism. Development of Prisms Shown at Right (A and B).

the edge **a-f** is shown as the T-square line a^p-**x**. The plane 1-2-6-5 is seen edgewise in line 1^p-2^p, and cuts a^p-**x** at point **o**.

The point **o** on edge **a-f** is at a distance a^p-o^p higher than the edge 1-5; hence the length a^p-o^p is laid off in elevation above 1-5, locating o^v. The intersection of face 1-2-6-5 is the broken line **n-o-q**. In a similar way, the under side 1-3-4-5 breaks around the edge **a-f**, the point **r** also being located from the end view. The figure **mnoqrm** is the intersection of the triangular prism with the left-hand sides of the vertical prism.

By the same method, the intersection on the two right-hand faces is found to be the figure **stuvw**. The visibility of the intersection and of the edges of the solids, should be studied until perfectly understood.

Development of the Prism. The square prism is shown developed at **A**, Fig. 73 (the ends are not shown in the development). The four sides of the prism are equal rectangles whose length is shown in elevation, and width in plan. Beginning with face **abgf**, the developed faces of the prism will appear as the four equal rectangles shown in the figure.

Location of the Intersection on the Development. Beginning with face **abgf**, the points **r** and **o**, which fall on the edge **a-f**, are located at the same distance from **a** as in elevation. The point **q** is at a perpendicular distance f^h-q^h from the edge **a-f**, and at a distance above **a-b** equal to the height **x**^{v}-**q**^{v} as shown in elevation. The point **q′** is then located by means of these two distances, and then joined with **o′** and **r′**.

Next consider the intersection **tuvw** on the face **bckg**. Points **t** and **w** are located at once on the edge **c′-k′** at **t′** and **w′**; and **u** and **v** are determined in position at **u′** and **v′** in the same way as for point **q**.

It is essential to note that the distance of **u′** and **v′** from the edge **c′-k′** must be taken from the plan, and not from the elevation. The figure **t′u′v′w′** is the developed intersection on this face.

For the next face, **cdek**, the points **t′** and **w′** are already found, and **s′** may be determined as already explained. On the face **dafe**, the intersection develops as shown at **o″n′m′r″**.

Development of the Triangular Prism. The triangular prism is developed at **B**, in the same figure. The method is similar to the preceding one, the distances of the points from the end of the prism being measured in either the plan or the elevation, and the distance from the long edges measured on the end view of the prism. The corresponding points have been lettered the same in both developments.

96. **Intersection of a Prism with a Pyramid.** In Fig. 74 is shown a rectangular prism intersecting a square pyramid. The pyramid stands on its base, and the prism has its edges but not its faces parallel to the H plane.

In this case, none of the sides of either solid are seen edgewise in either plan or elevation; hence another view is necessary. This view, drawn at **X**, is taken in the direction of the arrow so as to show the prism endwise; for in this position the faces of the prism are seen edgewise as straight lines, and the intersection may be determined in part as in the preceding case.

In the projection **X**, the base of the pyramid is at right angles to the direction of the view that is perpendicular to the edges of the prism, and the height of the pyramid is the same as in elevation.

In this example, the edges of the pyramid and prism have been lettered with capitals, and the points when found have been numbered. The plan will be adopted of beginning at some point, and tracing the intersection around in the same direction until completed.

Starting with the edge **A** of the pyramid, it is found in view **X** to intersect face **FE** of the prism at point 1, and 1^h and 1^v are located. Next, **B** cuts the same face **FE** in point 2, and 1 and 2 are joined in plan and elevation, the line 1-2 being visible in plan and invisible in elevation. The next edge of the pyramid, **C**, does not cut the face **FE**. There must, however, be an intersection of **FE** with the side **BC** of the pyramid, since **FE** cuts the edge **B** at 2.

Let it be imagined for a moment that face **FE** is extended in width so that **C** cuts it at **m**, then a line joining 2 and **m** would be the

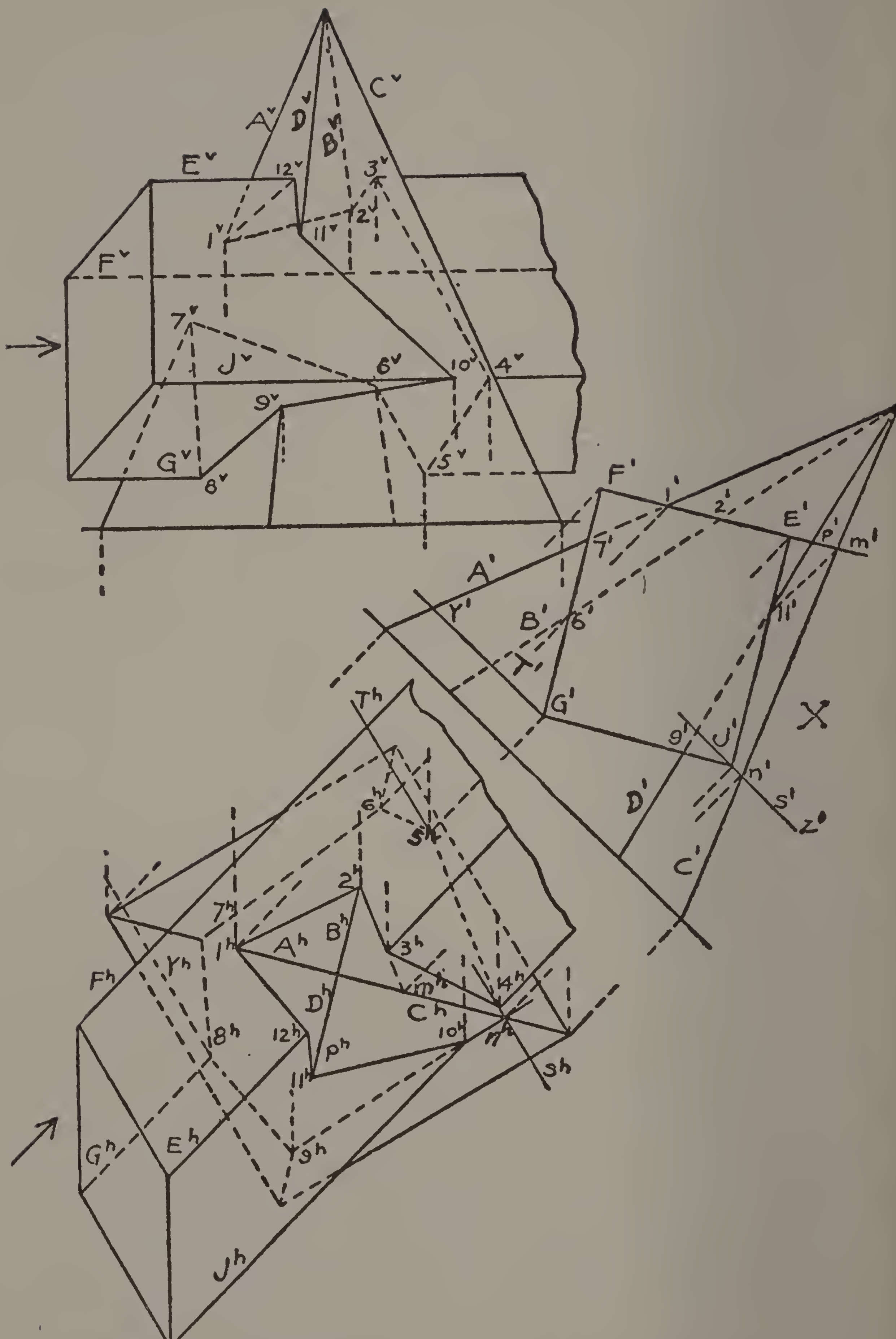


Fig. 74. Rectangular Prism Intersecting a Square Pyramid.

intersection of **FE** with side **BC** of the pyramid. The imagined widening of **FE** would not alter the direction of the intersection, but only the length, so the portion 2-3 of 2-**m** is the actual intersection wanted.

It should also be noted that point 3 is where edge **E** intersects the face **BC** of the pyramid. The intersection is continued on **BC** by the intersection of face **EJ** of the prism, running from 3 to where **J** cuts the face **BC**. This point on **J** is found in this way: If a plane parallel to the base be passed through **J**, it will cut the pyramid in a square parallel to the base (Article 79); and one corner of the parallel square is shown in view **X** as **n′** on **C′**; and line **S** on face **BC**, and parallel to the edge of the base, is one side of the square. The edge **J** intersects line **S** (see view **X**), and, as line **S** is on face **BC** of the pyramid, this point (4) is where **J** cuts the face of the pyramid. Point 4 is then connected with 3.

Similarly, by the use of line **T**, edge **G** is found to pierce the face **BC** at point 5, which is the next point of the intersection. The remainder of the intersection is found in the same way. The visibility in plan and elevation is determined as previously explained (Article 93).

In projecting the points from the plan to the elevation onto the edges **B** and **D**, it is difficult to determine the exact V projections, owing to the steep slope of **B** and **D**. The position of the points in elevation, however, may be tested by observing that in view **X** the perpendicular distance of any point from the base is simply the height of the point, and the height of the point in elevation should be the same.

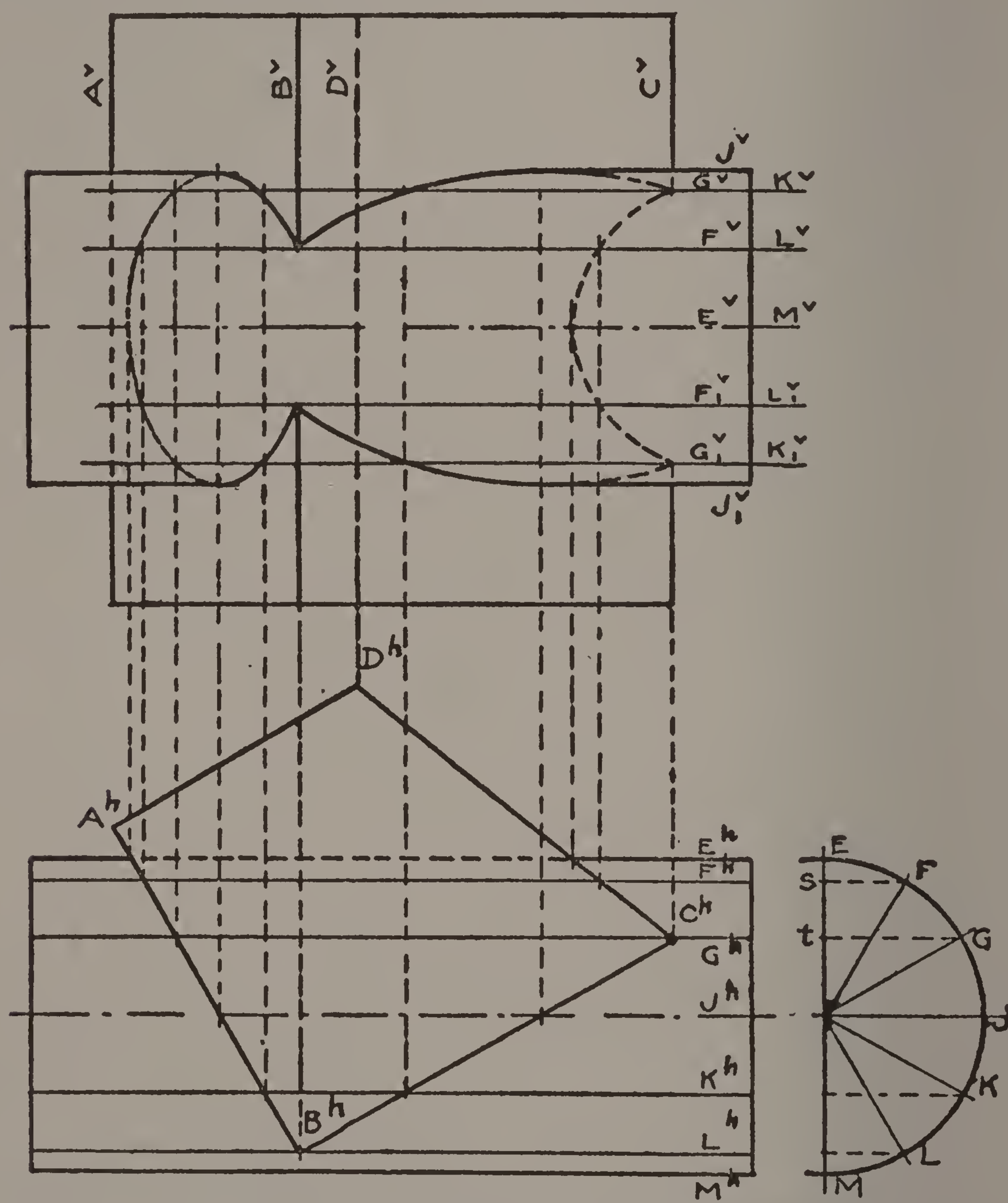
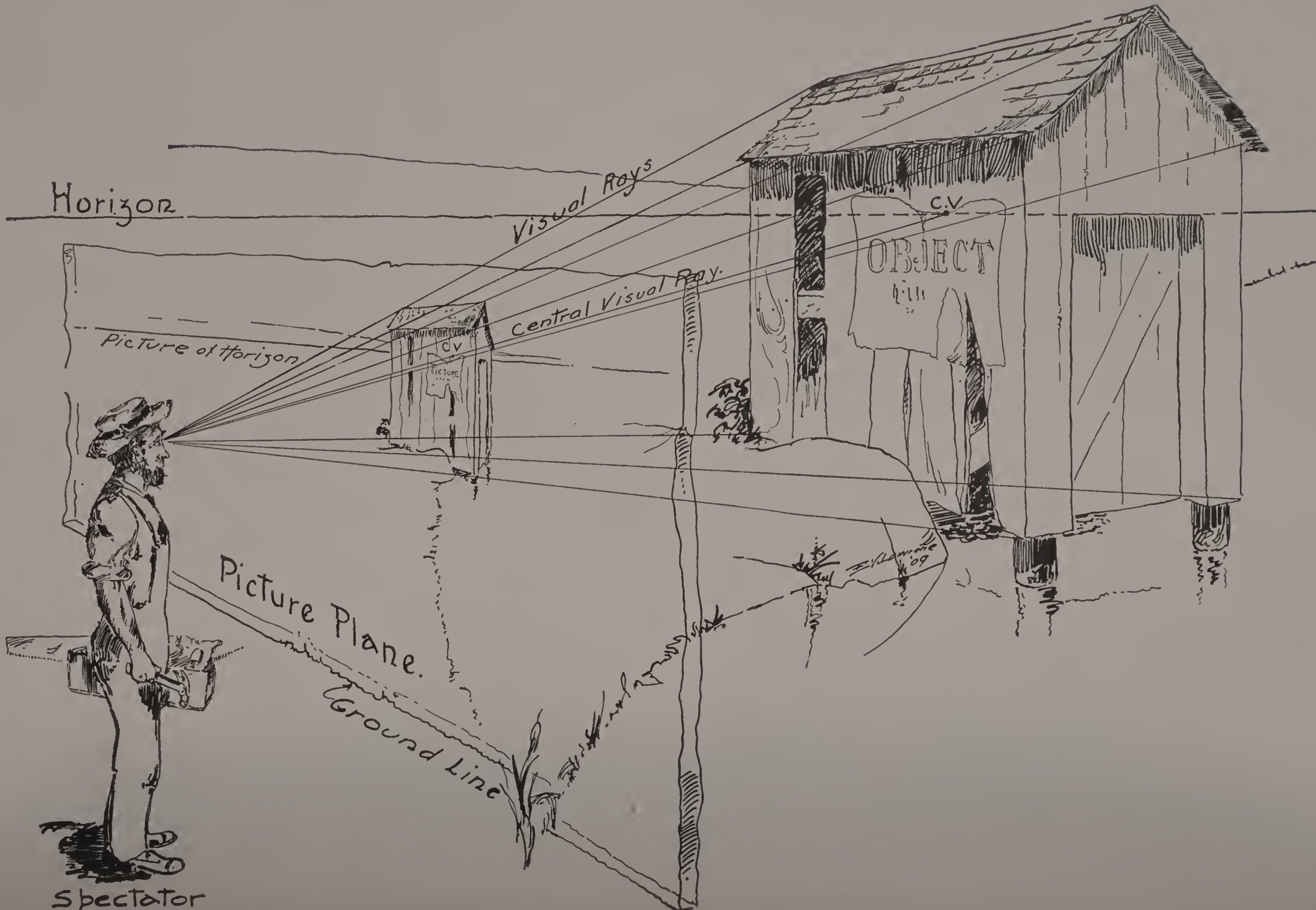


Fig. 75. Intersection of Circular Cylinder with an Irregular Four-Sided Prism.

97. Intersection of a Cylinder with a Prism. Fig. 75 represents the intersection of a circular cylinder and an irregular four-sided prism. The two are placed in the first angle, the prism



ILLUSTRATING THE ELEMENTS OF PERSPECTIVE.

standing on its base and the axis of the cylinder parallel to both V and H.

The intersection in this case will consist of three curved lines, one on face **AB**, one on **BC**, and the third on **CD**. The cylinder may be considered as piercing the prism, and points will be found in which lines on the cylinder intersect the faces of the prism.

As the cylinder, strictly speaking, has no edges parallel to its length, lines or elements may be drawn on the cylinder by the aid of the half end view shown at the right. This half end view is sufficient because the intersection on the upper half of the cylinder will be perfectly symmetrical with that on the lower half. The semicircle is now divided into some number of equal parts, say six, by the points **E**, **F**, **G**, etc., to **M**; and these points, when projected over to the plan in T-square lines, become elements of the cylinder. These elements are at different distances above the center of the cylinder, as shown in the end view. Element **F** is at a height **F-s** above the horizontal center plane of the cylinder; element **G**, at a height **G-t**; and so on. The elements may then be drawn in elevation by making them at their respective heights above the center. These elements are all on the upper half of the cylinder, but a corresponding set should be drawn on the lower half, by spacing similarly below the center line.

It is now a simple matter to find in the plan the points where the elements of the cylinder cut the prism, then to project to the elevation and obtain the required curve. This construction is similar to that of Fig. 73. When projecting the points of intersection from the plan, as for example the point where **F** intersects the face **AB** of the prism, the point on the under side of the cylinder, on $\mathbf{F}^v{}_1$, should also be located at the same time.

It is always important, in such an intersection, to find the points in which the cylinder cuts the edges of the prism—in this case **B** and **C**; and if the elements **L** and **G** did not happen to pass through **B** and **C**, additional elements would have to be drawn through **B** and **C**, in order to determine their exact points of intersection with the cylinder.

Notice carefully the visible part of the intersection, which is in accordance with Article 93.

98. **Intersection of Two Curved Surfaces.** In Fig. 76, a cone standing on its base is shown intersecting a cylinder with its axis parallel to both **V** and **H**. At the left, **A** is the profile view of the cone and cylinder, showing the right-hand end of the latter. This view **A** shows the relative position of the cone and cylinder, and would be drawn first if the figures were to be drawn from given data.

The distance **X-y**, for example, is the distance that the axis of the cylinder is in **front** of the axis of the cone as shown in plan.

From the position of the solids as shown in this view, it may be seen that the intersection

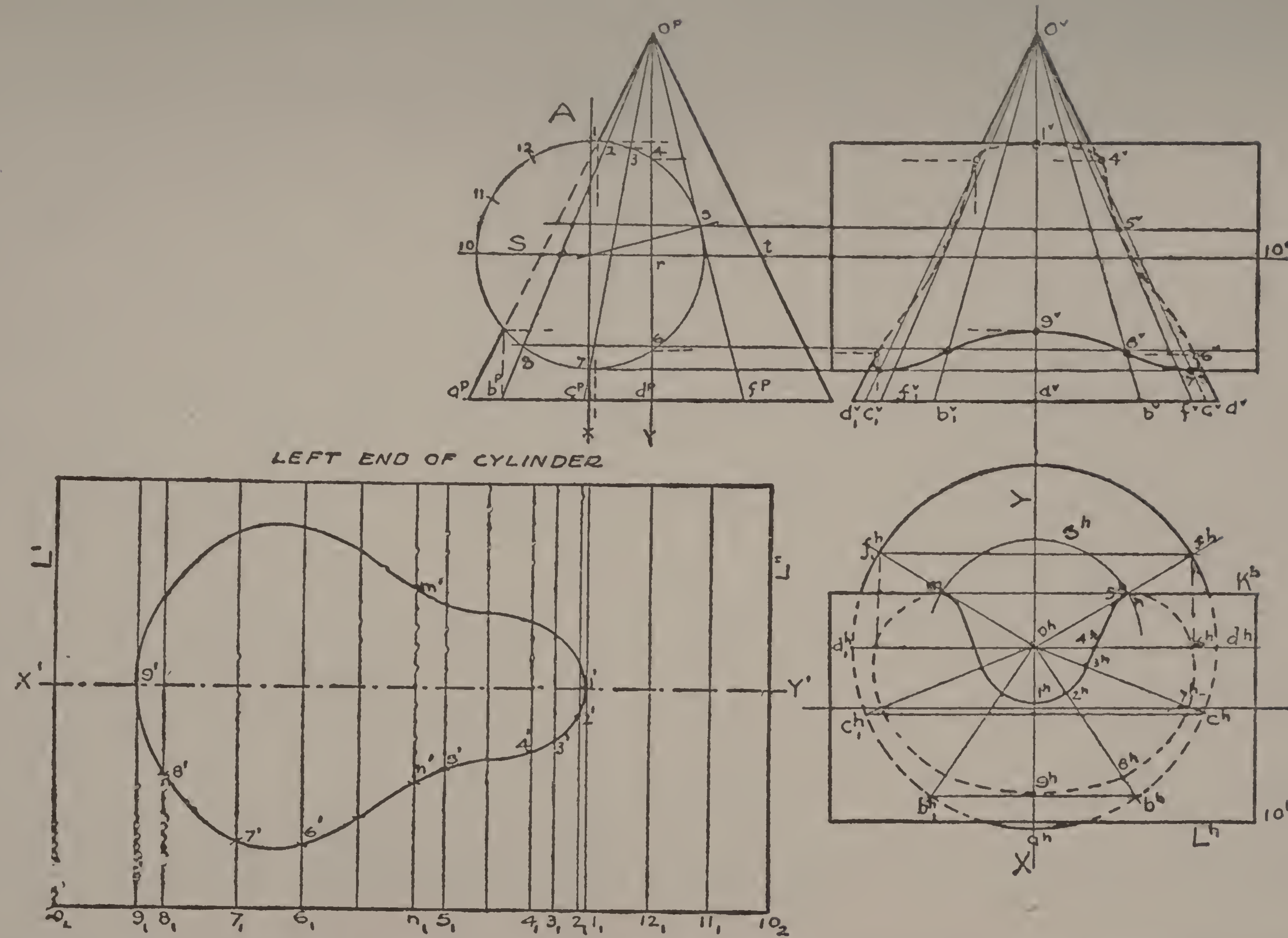


Fig. 76. Cone Intersecting a Cylinder. Developments of Cylinder and Curve of Intersection Also Shown.

will consist of a single closed curve. If, however, the cylinder were smaller and shown in end view entirely within the cone, then there would be two separate curves.

As the cylinder is shown endwise in this profile view, the method of solution will be to draw lines or elements on the cone, and find in the profile view where they intersect the cylinder. These points of intersection may then be transferred to the plan and the elevation.

A number of elements of the cone are drawn in view **A**, as o-a, o-b, o-c, o-d, and o-f, o-a and o-f being the extreme left-hand and right-hand elements which have any contact with the cylinder. These elements are next drawn in plan by laying off the distances d^p-a^p, d^p-b^p, d^p-c^p, etc., from o^h along the line **X-Y**. Through these points on **X-Y**, lines drawn perpendicular to **X-Y** locate points f^h, f^h_1, c^h, c^h_1, b^h, and b^h_1, and the elements are then drawn through these points and o^h.

The elements may now be drawn in elevation. The intersection in this case will be exactly symmetrical in plan and elevation with respect to the line o-a. This is because each element in view **A**, except o-a, represents two elements equally spaced on either side of o-a—as o-c and o-c_1, o-b and o-b_1; and so on.

The points of intersection on the right-hand half are numbered from 1 to 9 inclusive. Points 1 and 9 are projected with the T-square from view **A** to element o-a in elevation; points 4 and 6, to element **o-d** and also to element **o-d_1** in elevation, thus locating points on both halves at the same time; and other points are found in the same way.

With the exception of points 1 and 9, the points are then projected directly to the plan onto the corresponding elements of the cone. Points 1 and 9 are transferred directly from the end view to the plan, their horizontal distances from the axis **o^p-d^p** being laid off in plan from **o^h** along **X-Y**.

Points **m** and **n**, where the curve in plan touches the outside element of the cylinder, might be found the same way as the other points. That, however, would require in view **A** an element drawn very close to **o-f**; so another construction is used. In view **A**, the center plane **S** of the cylinder will contain both outside elements **K** and **L**, and will cut from the cone a circle **S** of radius **r-t**. This circle **S** is then drawn in the plan, and its intersection with **K** gives the points **m** and **n** required. This latter construction might be used, if desired, in finding the entire intersection.

Development of the Cylinder. Beginning with the element **L**, which passes through point 10, and placing 10 at 10_1, the outline of the cylinder is developed as a rectangle, as in Fig. 72, except that, instead of making a new division of the base into equal parts, the points already found are used. Thus the points 9, 8, 7, 6, etc., are taken from the end view, and spaced off at 9_1, 8_1, 7_1, etc., in the development. The arc between 1 and 10, Fig. **A**, is divided into three equal spaces. The right-hand end of the cylinder is made the lower side of the development.

Development of the Curve of Intersection. The points of the intersection are located symmetrically on either side of **X-Y**; so **X-Y** is drawn on the development at **X′-Y′**, at the same distance from the end of the cylinder as in plan.

Beginning with point 1 on **X′-Y′**, the distances from **X-Y** of the other points, 8, 7, 6, etc., are measured in the plan; and then, in the development, these distances are laid off on the corresponding elements, both above and below **X′-Y′**, thus obtaining at once both halves of the developed intersection.

Approximate Developments

99. Of curved surfaces, it may be said in general that only those can be truly developed which contain straight lines on their surfaces, and which, in addition, when brought into contact with a plane, will touch in only one straight line.

100. It is possible, however, to construct for non-developable surfaces one or more figures which will have nearly the same total area as the given surface, and which, when properly joined and bent or curved, may be made to assume nearly the shape of the original surface. Such a figure is called an **approximate development.**

Essential Principles of Intersection and Development

101. When a plane cuts one or more lines, an edgewise view of the plane will determine the various points of intersection.

102. If a cone, cylinder, pyramid, or prism be cut by a plane parallel to the base, the section will always be a figure parallel to the base and similar to it in shape.

103. The intersection of a plane with a curved surface is determined by means of the points in which the plane cuts lines on the surface. These lines may be either straight or curved, according to the nature of the surface.

104. The intersection of two surfaces is determined by means of the points in which lines on either surface intersect the other.

105. For the intersection of two surfaces, the points are first found in the projection which shows an end view of one of the solids. Two such end views may be necessary.

106. A development shows the true length of any line, straight or curved, which lies on the given surface.

107. A right circular cone develops into a sector of a circle, in which the radius is equal to the length of an element of the cone.

108. A right circular cylinder with both ends parallel will develop into a rectangle, whose length is that of the cylinder and breadth is equal to the circumference of the base.

PRACTICAL PROBLEMS

109. We shall now make some applications of the principles of intersection and development to the solution of practical problems.

PROBLEM 1

Given Cross-Section of Gutter, and Pitch of Roof, to Find Cross-Section of Rake Moulding which will Miter with Gutter

Let the cross-section of the gutter be as shown in $\mathbf{A}^v$, Fig. 76A, and let the slope of the roof be 30 degrees. The angle of miter, as given in the plan, is 45 degrees. Lines drawn from $\mathbf{a}^v$, $\mathbf{b}^v$, $\mathbf{c}^v$, and $\mathbf{d}^v$, parallel to the pitch of the roof, will represent edges of the raking moulding, these same edges being shown in plan parallel to the V plane, which may here be considered as the end wall of the house.

To find the cross-section of the moulding is an application of the principles just studied. A plane cutting the moulding at right angles to its length will show the true cross-section required.

As the edges of the moulding are parallel to V, the cross-section plane will be perpendicular to V, and will be seen edgewise on V. It may be taken at any convenient distance from the gutter, as in the position **X-Y**. This plane will intersect the edges drawn from **a**, **b**, etc., in the points **n**, **m**, **p**, and **t**. Since the surface between **p** and **t** is curved, it will be necessary to make use of lines drawn on the curved surface, starting from points such as 1, 2, and 3

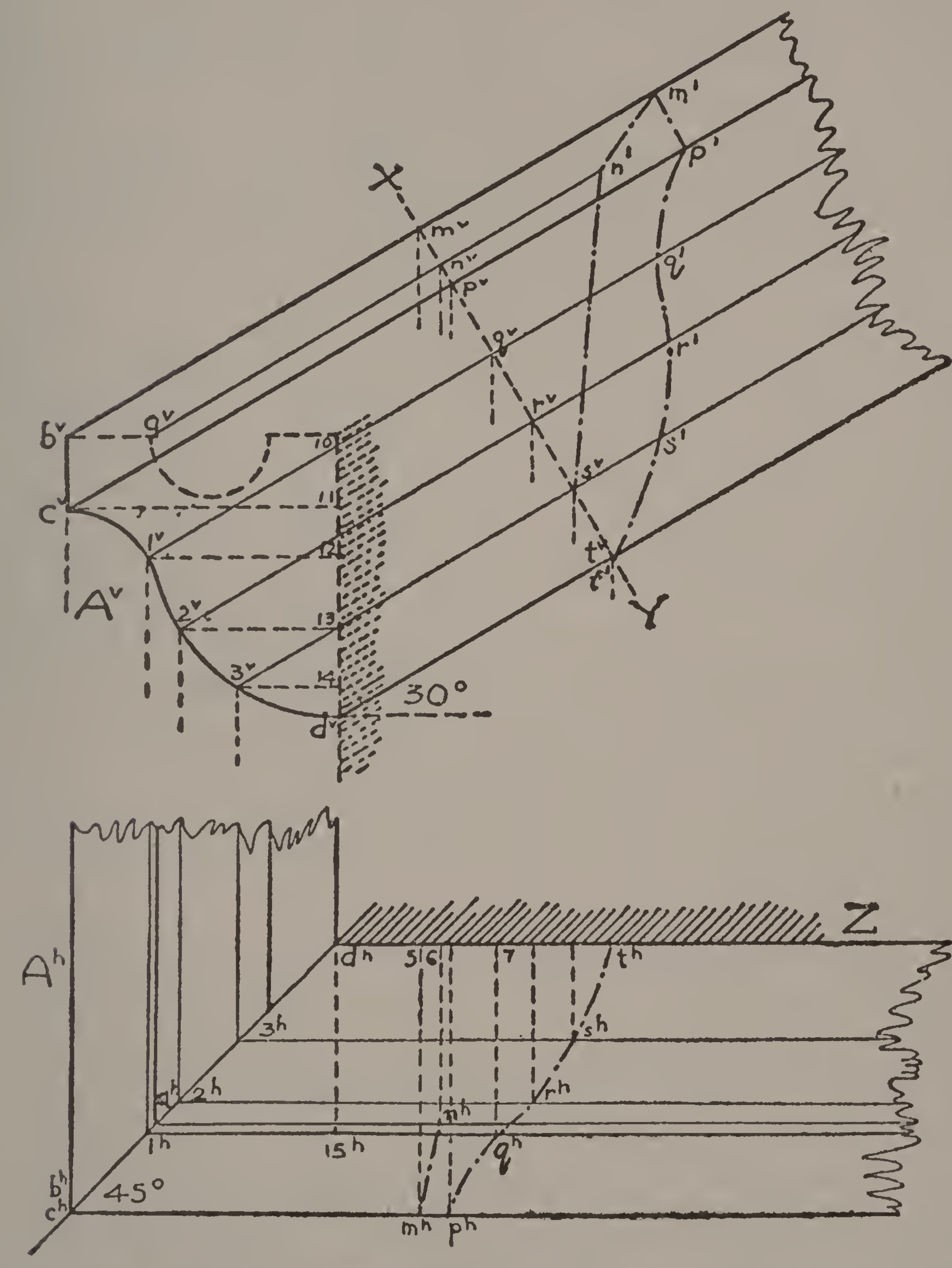


Fig. 76A. Finding Cross-Section of Moulding to Miter with Gutter.

on the curved outline of the gutter. The plane **X-Y** cuts these lines at the points **q**, **r**, and **s**. The plan of the section cut by plane **X-Y** is not the true size and shape, since plane **X-Y** is not parallel to H (Article 54).

If plane **Z** represents the plane of the end of the house, then the edge of the moulding drawn through **d** is in this plane; and the other points of the cross-section, **m**, **p**, **q**, etc., stand out from this plane the distances which are shown in plan from $\mathbf{m}^h$ to **Z**, from $\mathbf{q}^h$ to **Z**, etc. Hence, if plane **X-Y** be revolved about an axis in plane **Z**, the distances from **Z**, as $\mathbf{m}^h$-5, $\mathbf{n}^h$-6, $\mathbf{q}^h$-7, and so on, will revolve at right angles to **X-Y**; and when the plane of the section coincides with **Z**, the distances will show on V in their true lengths at $\mathbf{m}^v$-$\mathbf{m}'$, $\mathbf{n}^v$-$\mathbf{n}'$, etc. This process worked out for each point will give $\mathbf{n}'$, $\mathbf{m}'$, $\mathbf{p}'$....$\mathbf{t}^v$ as points on the outline of the section as seen lying on V, and hence shown in its true size and shape. The back edge $\mathbf{n}'$-$\mathbf{s}^v$ may be drawn at any convenient angle. The figure $\mathbf{n}'$, $\mathbf{m}'$...$\mathbf{r}'$...$\mathbf{t}^v$ is therefore the required cross-section.

If, in a problem like this one, the miter is at the usual angle of 45 degrees, there is a very short construction as follows: Let the horizontals $\mathbf{c}^v$-11, 1^v-12, 2^v-13, and 3^v-14 be drawn. The line 1^v-12, for example, is equal to 1^h-15^h; and, as the miter is 45 degrees, 1^h-15^h is equal to $\mathbf{d}^h$-15^h; that is, 1^v-12 is equal to $\mathbf{d}^h$-15^h. Hence, if the distance 1^v-12 is taken and laid off from $\mathbf{q}^v$ at right angles to **X-Y**, the point $\mathbf{q}'$ on the true size will be determined.

In the same way, it may be seen that $\mathbf{b}^v$-10 is equal to $\mathbf{m}^v$-$\mathbf{m}'$; 2^v-13 to $\mathbf{r}^v$-$\mathbf{r}'$, and so on. Hence the short construction for finding the true cross-section is to draw the horizontals $\mathbf{b}^v$-10. . . 1^v-12. . . 3^v-14, and lay off these distances from **X-Y** as shown.

PROBLEM 2

To Construct the Development of a Sheet-Metal Moulding

Fig. 76B shows a moulding mitered at both ends. The elevation is given complete, and the

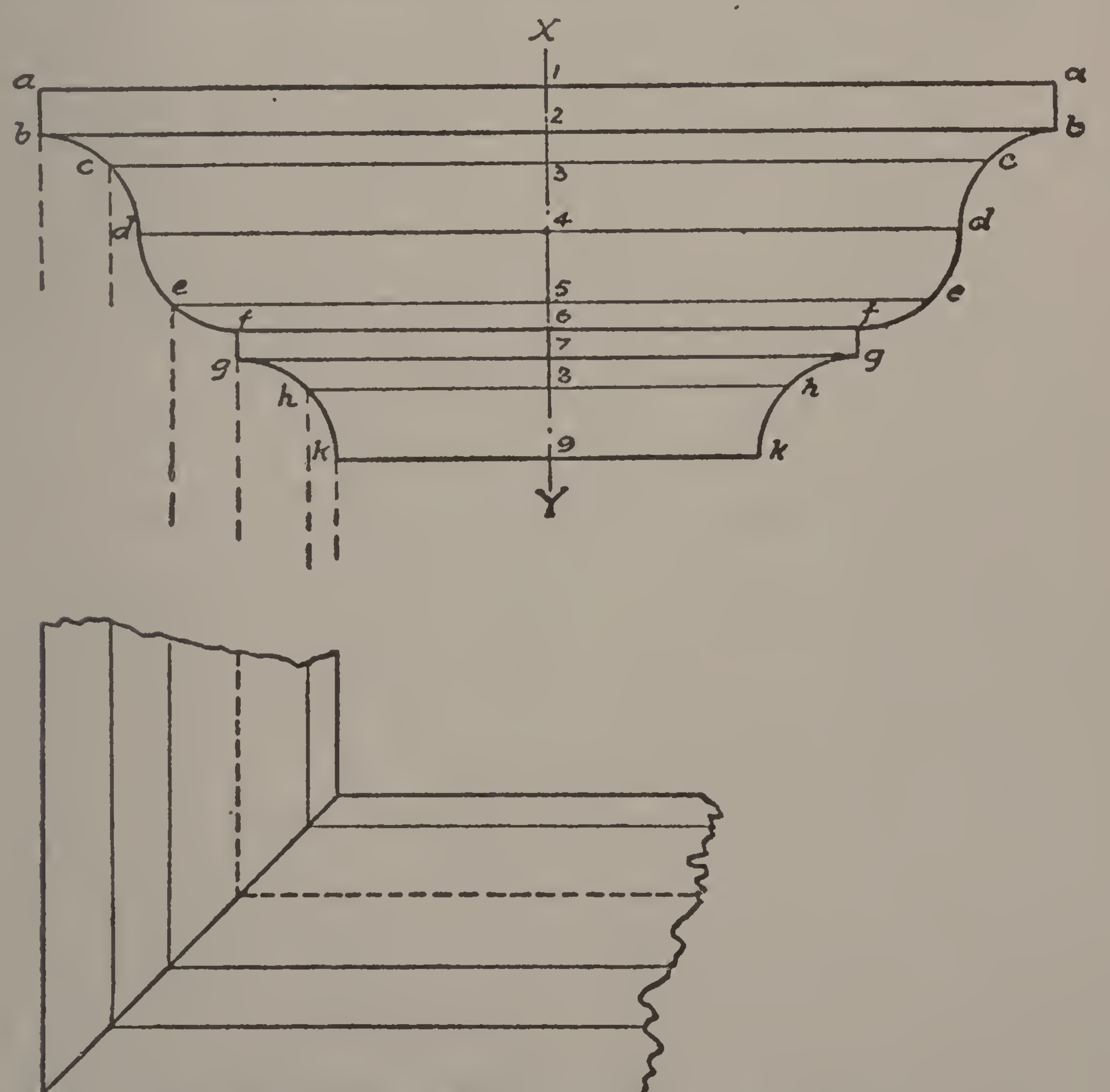


Fig. 76B. Moulding Mitered at Both Ends.

plan shows the miter at the left end. The surface of the moulding is partly curved, and partly plane. To make the development, proceed according to the principles of the development of a cylinder, under Article 91.

Since the moulding is symmetrical at both ends, a center line **X-Y**, from which to take measurements, is drawn in elevation. The given moulding miters with two others at right angles to it on miter planes at 45 degrees; hence the three mouldings are alike in cross-section. The

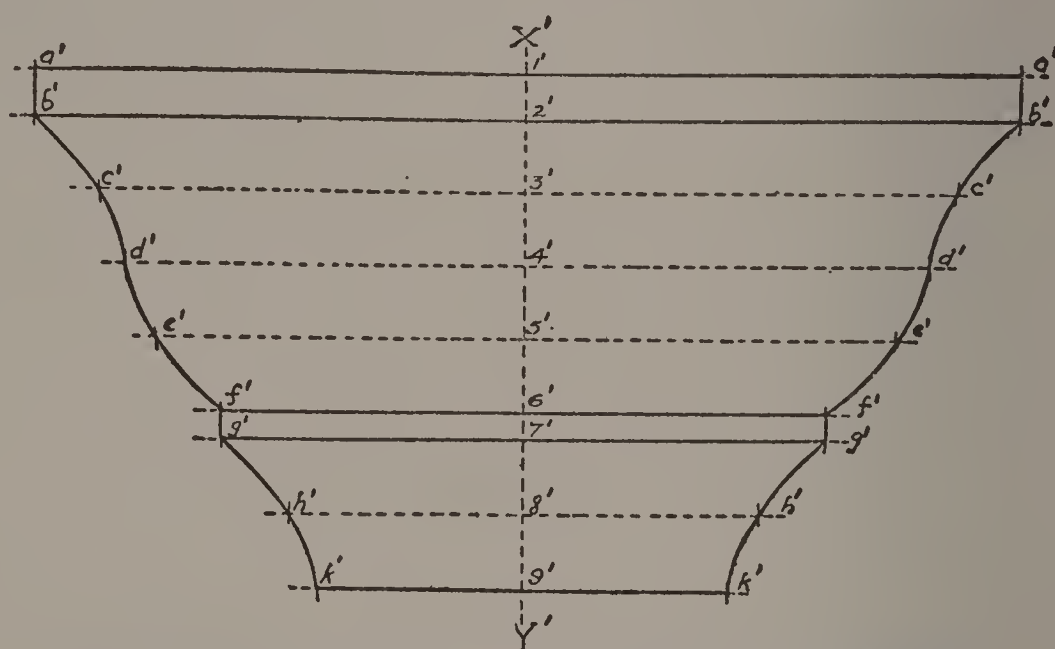


Fig. 76C. Development of a Sheet-Metal Moulding.

curved outline at either end of the given moulding must represent the true shape or end view of the other moulding, as each other moulding is perpendicular to the given one. The curved outline at either end is then also the true cross-section of the given moulding, and the width of the developed moulding will be equal to the length of the line **a**, **b**,. . .**e**,. . .**k**.

The development is drawn in Fig. 76C, where **X′-Y′** represents the position of **X-Y**, and the width 1′. . . .9′ is equal to the length **a**, **b**,. . .**e** . . .**k**. The lines **c-c**, **d-d**, **e-e**, and **h-h** are lines drawn on the curved surface in order to get the development.

The distances **a-b**, **b-c**, **c-d**, **d-e**, and so on, to the point **k**, are then laid off along **X′-Y′**, giving the points 1′, 2′,...5′,...9′; and through these points, lines are drawn indefinite in length and perpendicular to **X′-Y′**. On these lines, the half-lengths 1-a, 2-b, etc., taken from Fig. 76B, are laid off, locating the points **a′a′**, **b′b′**, **c′c′**, up to **k′k′**. These points, when joined, give the ends of the required development.

PICTORIAL DRAWING

110. Graphical representations which give more or less of a picture effect, are sometimes very useful adjuncts to practical drafting.

To the untrained eye, such a drawing—of a building, for example—conveys a much clearer idea than plans and elevations. The same would be true of any other complicated structure. These pictorial drawings are of various kinds, as **perspective, oblique projection,** and **isometric drawing.** Of these three kinds, the first alone is the true picture drawing showing the actual appearance of any object as seen by the natural eye.

Unfortunately, however, the principles of perspective, while not difficult, are harder to acquire than those of oblique projection or isometric drawing, and the process of constructing an accurate perspective drawing is longer and more tedious.

It is also true that in many cases the somewhat distorted isometric or oblique projections will supply to the mind all the pictorial assistance that is necessary. The present section of this treatise will deal principally with **isometric drawing** and **oblique projection.**

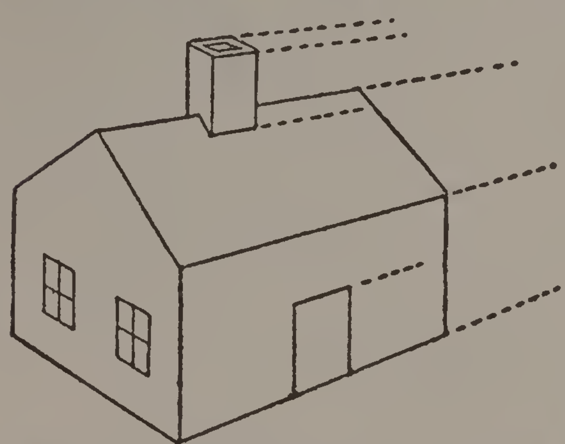


Fig. 77. Perspective View of Cabin.

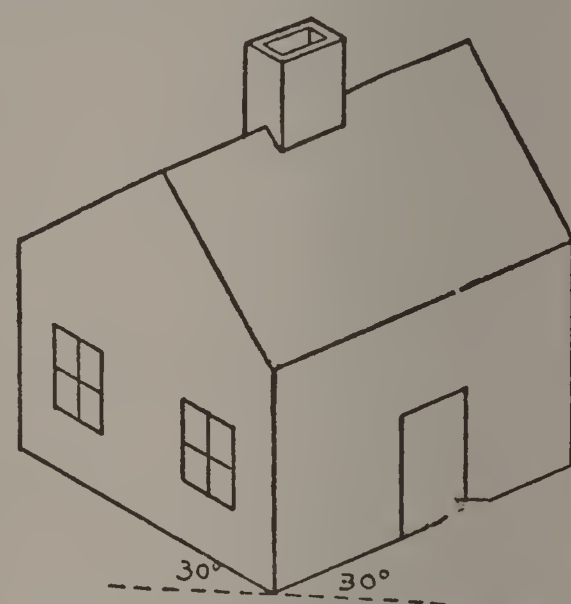


Fig. 78. Isometric Drawing of Cabin.

Fig. 79. Oblique Projection of Cabin.

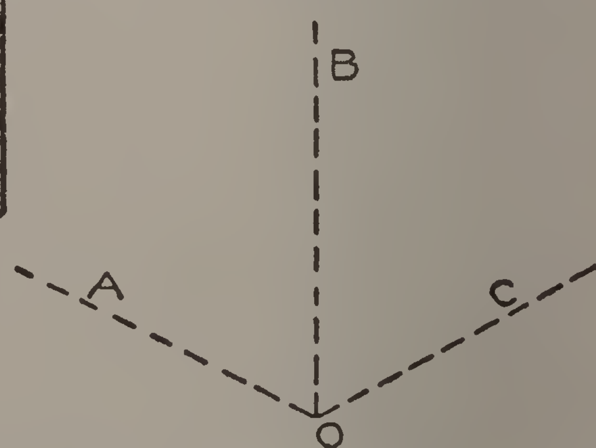


Fig. 80. Isometric Axes.

111. For the sake of comparison, the same cabin has been shown in Figs. 77, 78, and 79, in the three different ways, Fig. 77 being a perspective view; Fig. 78, an isometric drawing; and Fig. 79, an oblique projection. In all three

views, the vertical edges of the cabin are drawn as vertical lines, and therefore parallel.

In Figs. 78 and 79, all the other lines and edges which are actually parallel in space are drawn as parallel lines; but in the perspective of Fig. 77, the other lines which are really parallel in space are drawn as converging lines—as, for example, the edges of the roof and the ridge, the top of the doorway, etc.

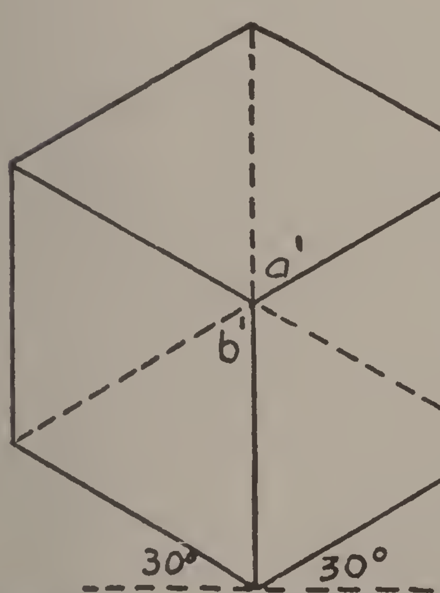


Fig. 81. Simple Isometric Representation of a Cube.

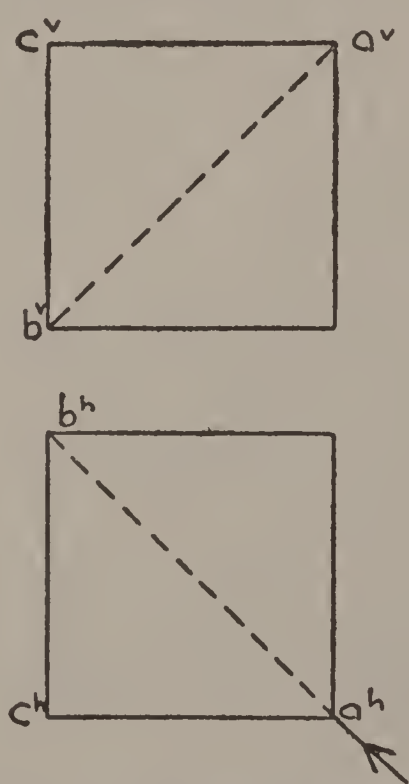


Fig. 82. Illustrating Direction of View for Isometric Drawing of Cube in Fig. 81.

Isometric Drawing

112. The principles of isometric drawing are best illustrated by reference, first, to a simple rectangular object as a cube or square prism. In such a solid there are three sets or systems of parallel edges; and in the simplest isometric drawing, these edges are drawn in three fixed

directions, respectively parallel to what are called the **isometric axes.** These three axes are shown in Fig. 80, **B** vertical, and **A** and **C** at 30 degrees with the horizontal.

In any isometric drawing, lines parallel to the isometric axes are drawn in their true lengths.

113. The simplest isometric representation of a cube is shown in Fig. 81, except that ordi-

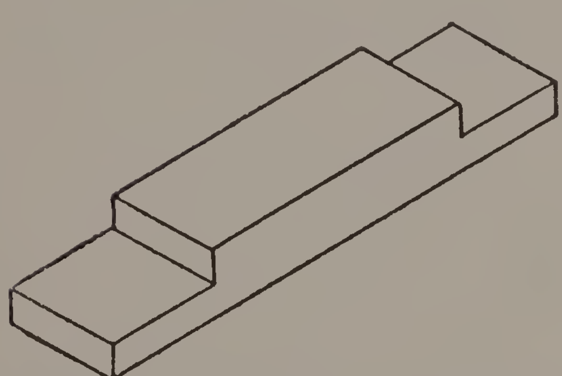


Fig. 83. Isometric of a Joist.

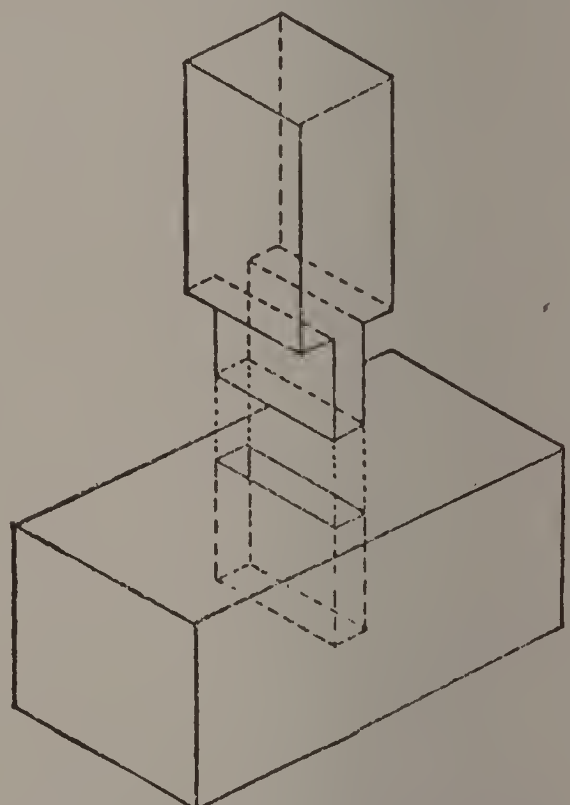
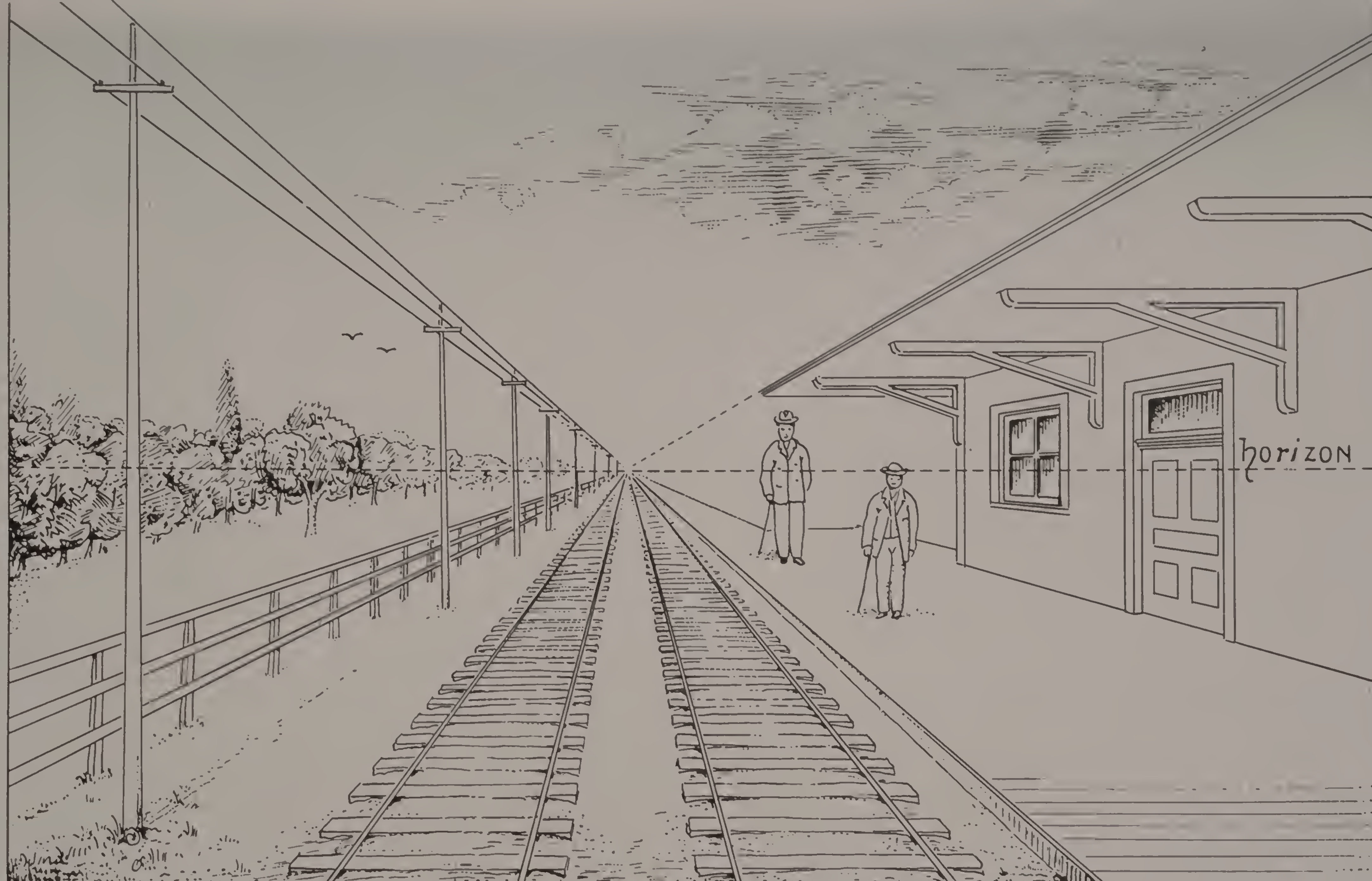


Fig. 84. Isometric Drawing of Post and Sill, Showing Mortise and Tenon.

narily the dotted edges are omitted. All of the edges in this figure are full-length, and are either vertical or at 30 degrees with a horizontal. The drawing represents the cube in the position of Fig. 82, with the view taken in the direction of the diagonal of the cube, as indicated by the arrow. That that is the direction



ILLUSTRATING VANISHING POINT AND NECESSITY OF DRAWING OBJECTS IN PROPORTION.
Two men of same actual height, but one in background appears much the taller.

of the view, is shown in Fig. 81, from the fact that the lower back corner of the cube is directly behind the upper front corner **a**.

The isometric view may be taken through either corner **a** or **c**, but always in the direction of a diagonal of the cube. Note that while the edges are shown in their true lengths, the angles are not shown in their true size.

Isometric drawing is especially appropriate for showing framing, mortises, tenons, etc.

114. A simple isometric is given in Fig. 83, where a piece of joist is shown ready for halving together with two other pieces.

115. The isometric of a post and sill, showing a mortise and tenon, is drawn in Fig. 84.

116. **To Draw an Isometric from a Given Plan and Elevation.** Let $\mathbf{A}^v$ and $\mathbf{A}^h$, Fig. 85, be

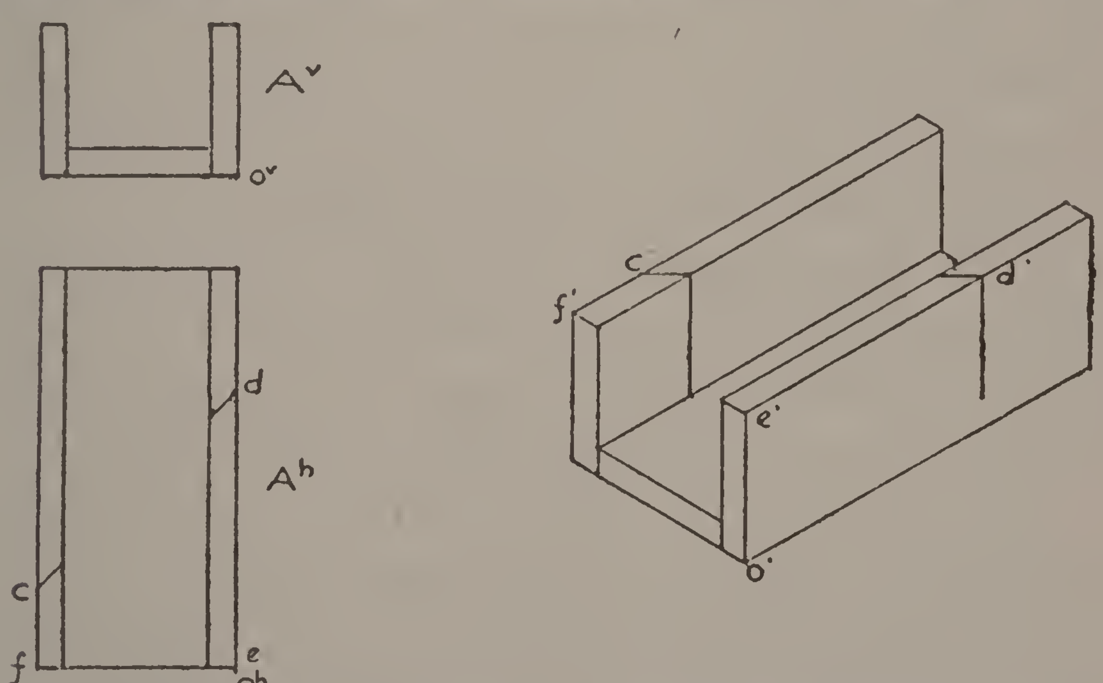


Fig. 85. Drawing an Isometric of a Miter Box from Given Plan and Elevation.

the elevation and plan of a **wooden miter box,** and let **O** be chosen for the lowest corner of the isometric. Then the horizontal edges of the box will be 30-degree lines in isometric; the vertical edges, vertical lines; and the real lengths will be shown (compare Figs. 81 and 82). Then, from **O′** draw a 30-degree line to the right, equal to the length; one to the left, equal to the width; and one vertical, equal to the given height.

The rest of the box may then be drawn, showing the thickness of the bottom and sides. The 45-degree saw-cut **c-d**, as shown in plan, is transferred to the isometric by simply laying off from **f′** and **e′** respectively the distances **f-c** and **e-d**, and joining **c′** and **d′** across the top of the box. The vertical cut showing on the sides of the box is then drawn in.

117. Simple rectangular objects, as those of Figs. 83, 84, and 85, can usually be drawn at once from given dimensions without reference to plan or elevation. In more complicated cases, however, the plan and elevation are generally desirable, and often they are necessary.

118. **Non-Isometric Lines.** Non-isometric lines are those which cannot be shown parallel to the isometric axes. This classification embraces oblique straight lines and also curves.

An oblique line may be located in isometric drawing, by fixing the position of the ends of the line by co-ordinates; and the isometric of a curve is made by locating a sufficient number of its points in isometric by means of co-ordinates, and then drawing a smooth curve through these points.

119. Fig. 86 shows plan and elevation of a **prismatic block with two faces cut off obliquely.** To construct the isometric, let **d** be taken as the lowest corner of the isometric, and located at **d′**. The base may readily be drawn with the edges as 30-degree lines. The lines **b-c** and **a-f** are oblique, and cannot be drawn in isometric

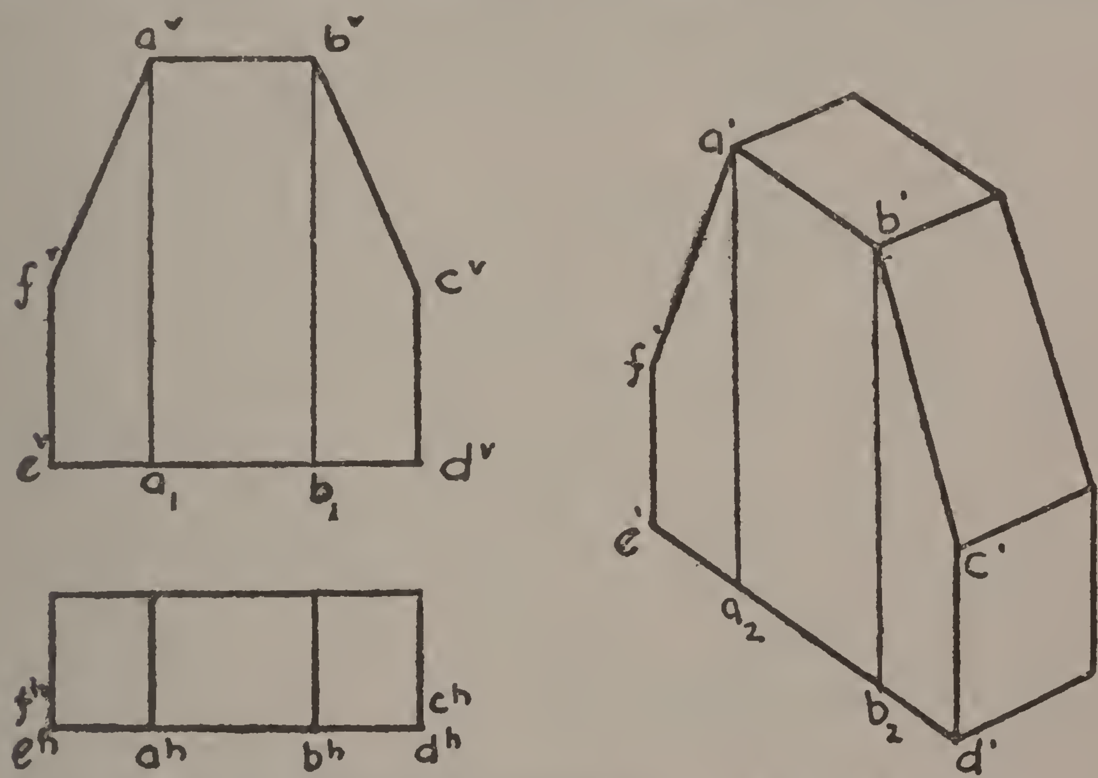


Fig. 86. Prismatic Block with Two Faces Cut Off Obliquely.

at the same angle. Point **c** may be located at once, since **d-c** is a vertical line. Point **b** is located in projection by means of the horizontal distance $\mathbf{d}^v$-$\mathbf{b}_1$, and the vertical height $\mathbf{b}_1$-$\mathbf{b}^v$.

These lines will show parallel to the isometric axes, and may be laid off in their true lengths. Hence, from $\mathbf{d}^1$, lay off $\mathbf{d}^1$--$\mathbf{b}_2$, equal to $\mathbf{d}^v$-$\mathbf{b}^1$, and erect the vertical line $\mathbf{b}_2$-$\mathbf{b}^1$, equal to $\mathbf{b}_1$-$\mathbf{b}^v$, thus locating point $\mathbf{b}^1$.

The point $\mathbf{a}^1$ is determined in a similar way by means of the co-ordinates d^1-a_2, equal to d^v-a_1, and a^2-a^1 equal to a_1-a^v. The left-hand side may then be completed. Next the 30-degree edges from a^1, b^1, c^1, and d^1 are made equal to the thickness, and the edges of the back then drawn in and the isometric completed.

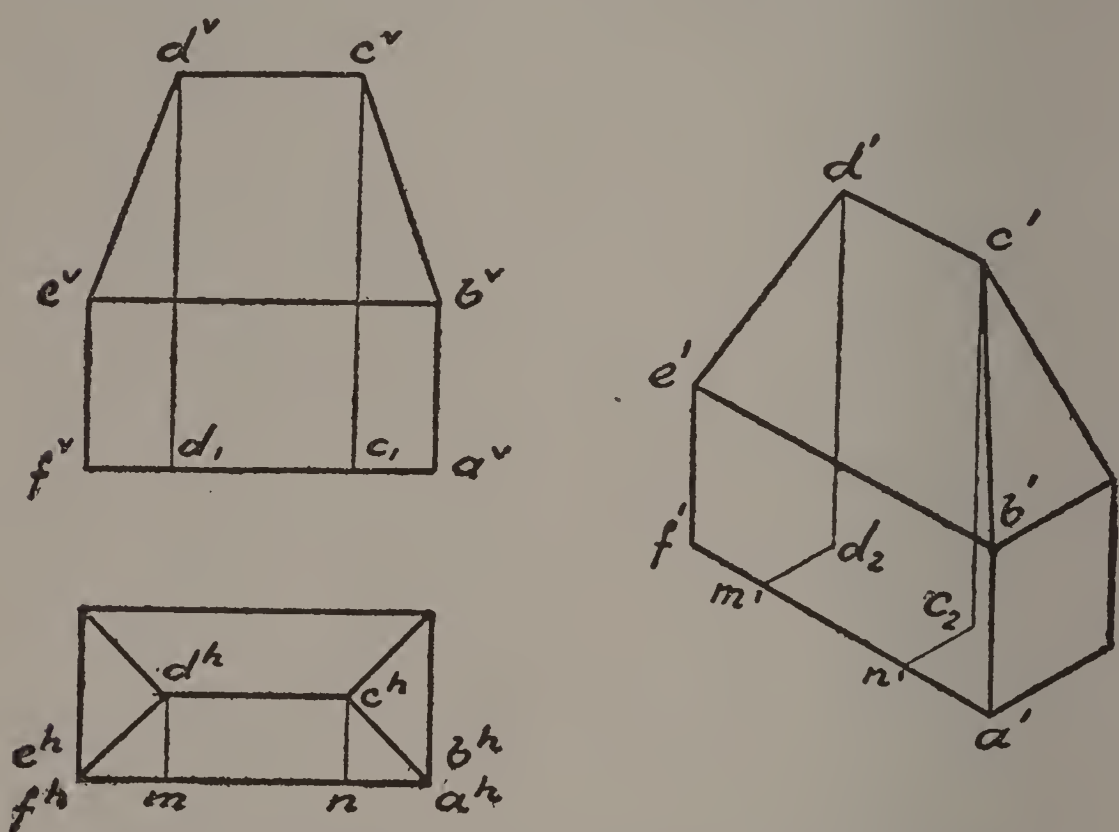


Fig. 87. Drawing a Wedge-Shaped Block in Isometric.

120. To draw a **wedge-shaped block** in isometric, refer to Fig. 87. The base is drawn in isometric as before, and the vertical edges may be drawn immediately, obtaining points b^1, e^1, etc. The point c^1 is located in isometric by means of three co-ordinates or distances, taken from the projection. First, the horizontal distance a^h-n, laid off at a^1-n^1; second, another horizontal distance c^h-n drawn at n^1-c_2; and third, the vertical height c_1-c^v, laid off at c_2-c^1. The point c^1 is thus fixed in position by the three

co-ordinates parallel to the isometric axes. The rest of the figure may then be easily finished.

121. **Isometric of Curved Lines.** Points in the isometric of circles or other curved lines, are also determined by means of co-ordinates parallel to the isometric axes.

122. A cube having one circle traced on the top and another on the front, is given in Fig. 88. Taking **O** at **O′**, the isometric of the cube

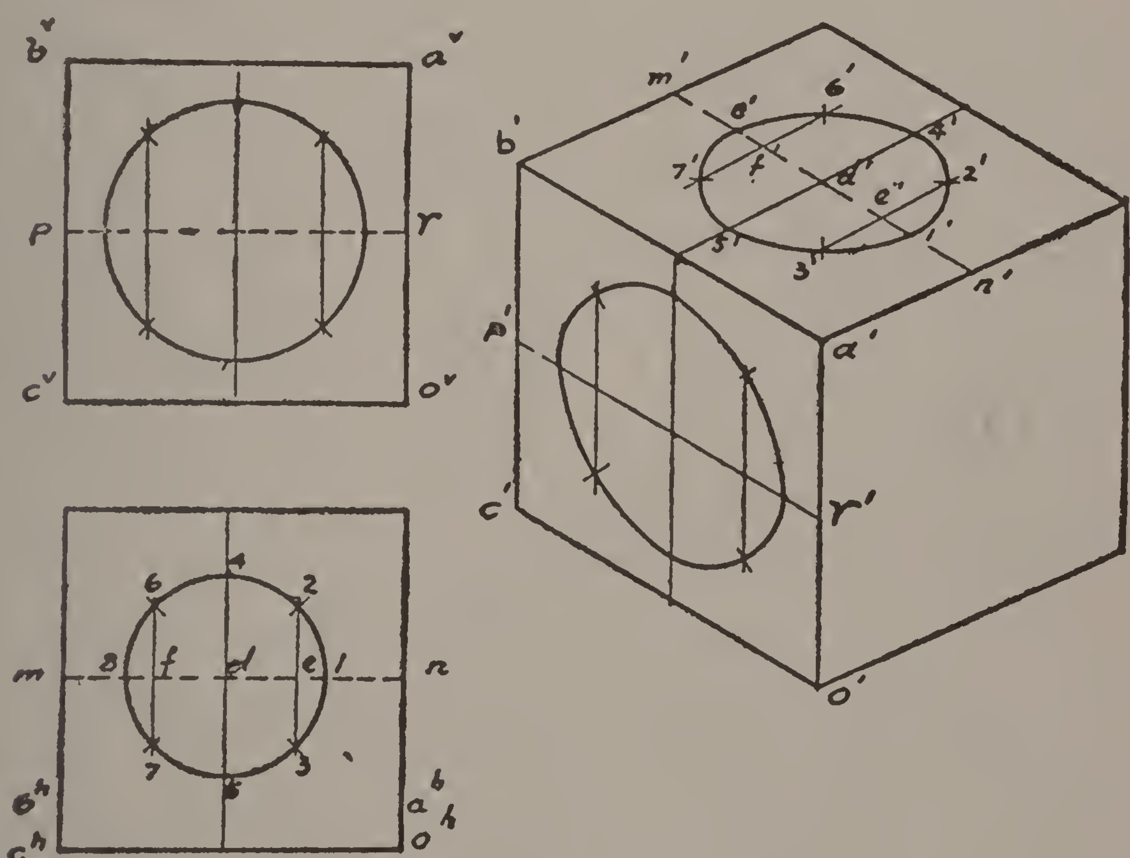


Fig. 88. Illustrating Isometric of Curved Lines.

is drawn. The circles will then be constructed in the top and the left front side.

Taking first the smaller circle in the top, divide it into any number of equal parts, as eight in the figure. The points might be located by means of co-ordinates from the front edge **a-b** of the square; but it is better to refer them to the horizontal center line of the circle (8-1), which, when produced, is the diameter **m-n** of the square. Next draw the other diameter of the square passing through 4-5. The two diameters are drawn in the isometric, and points 1 and 8 are located on $\mathbf{m^1}$-$\mathbf{n^1}$ by laying off $\mathbf{d^1}$-$\mathbf{1^1}$ and $\mathbf{d^1}$-8^1 equal to the radius, and points 4′ and 5′ are then found on the other diameter at the same distance from the center $\mathbf{d^1}$.

In the plan, lines 2-3 and 6-7 are parallel to the diameter 4-5, and will be shown parallel to 4^1-5^1 in isometric. From the center $\mathbf{d^1}$, mark off on $\mathbf{m^1}$-$\mathbf{n^1}$ the distances $\mathbf{d^1}$-$\mathbf{e^1}$ and $\mathbf{d^1}$-$\mathbf{f^1}$, equal respectively to **d-e** and **d-f**; draw 2′-3′ and 6′-7′; and lay off both ways from $\mathbf{e^1}$ the distance **e**-2, thus fixing 2′ and 3′. The same distance is laid off from $\mathbf{f^1}$, locating 6′ and 7′.

The ellipse, which is the isometric of the circle, is then drawn through the points. The axes of the ellipse will lie on the diagonals of the isometric square.

The larger circle in the vertical face of the cube is similarly constructed, using the horizontal diameter **p-r** and the ordinates as shown in the figure. The axes of this ellipse will likewise lie on the diagonals of the face of the cube.

123. **Isometric of a Vertical Cylinder.** The plan of the cylinder is shown at **A**, Fig. 89. The first step is to circumscribe a square about the circle, with the sides respectively parallel and perpendicular to a T-square line. As this is a

plan of the cylinder, the sides of the square will be 30-degree lines in isometric.

Let **O** be placed at **O′**, and the isometric square drawn. The circle of the base is then drawn as in the preceding case. From each point in the base, vertical lines are drawn equal to the desired length of the cylinder, thus locating points on the circle of the upper end. The

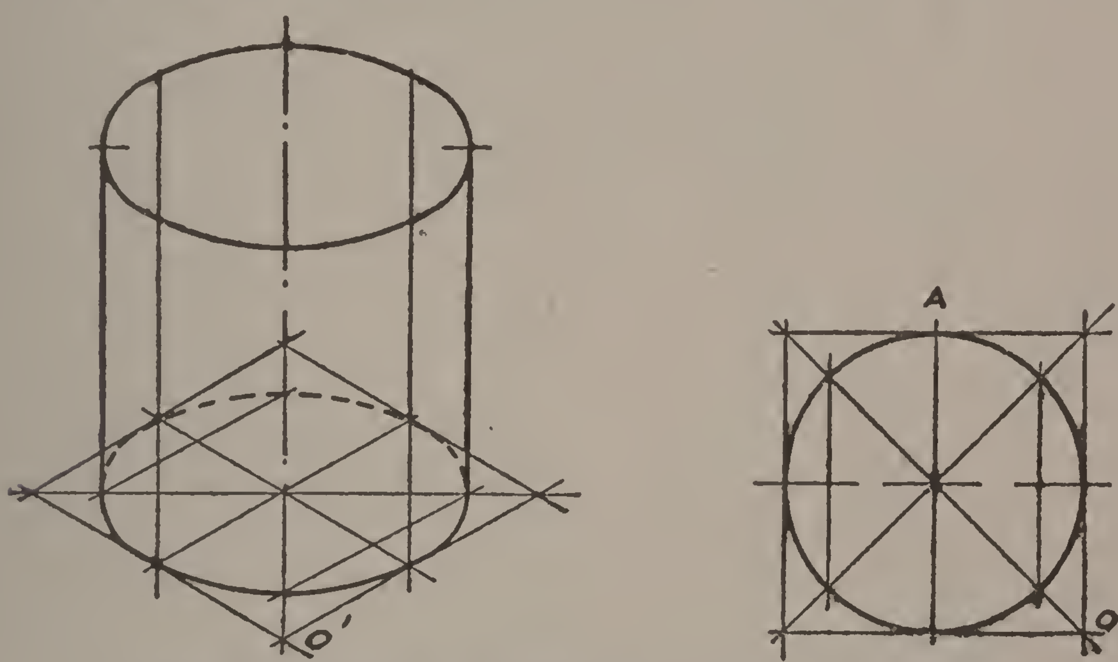


Fig. 89. Drawing Isometric of a Vertical Cylinder.

two vertical lines on the outside will be tangent to the bases, and will form part of the outline.

124. **Isometric of a Cone.** Let it be required to draw a right circular cone with its axis horizontal. If the axis is horizontal, the base will be vertical. Hence, draw an elevation of the base at **A**, Fig. 90, and circumscribe a square. Let **O** be placed at **O′** and taken as the lowest corner of the isometric. As **A** is an elevation, two sides of the square are vertical lines, and must be so drawn in the isometric. The iso-

metric circle is then drawn as before, using the diameters of the square and the given co-ordinates.

A line drawn from the center of the base at 30 degrees to the left, will represent the axis,

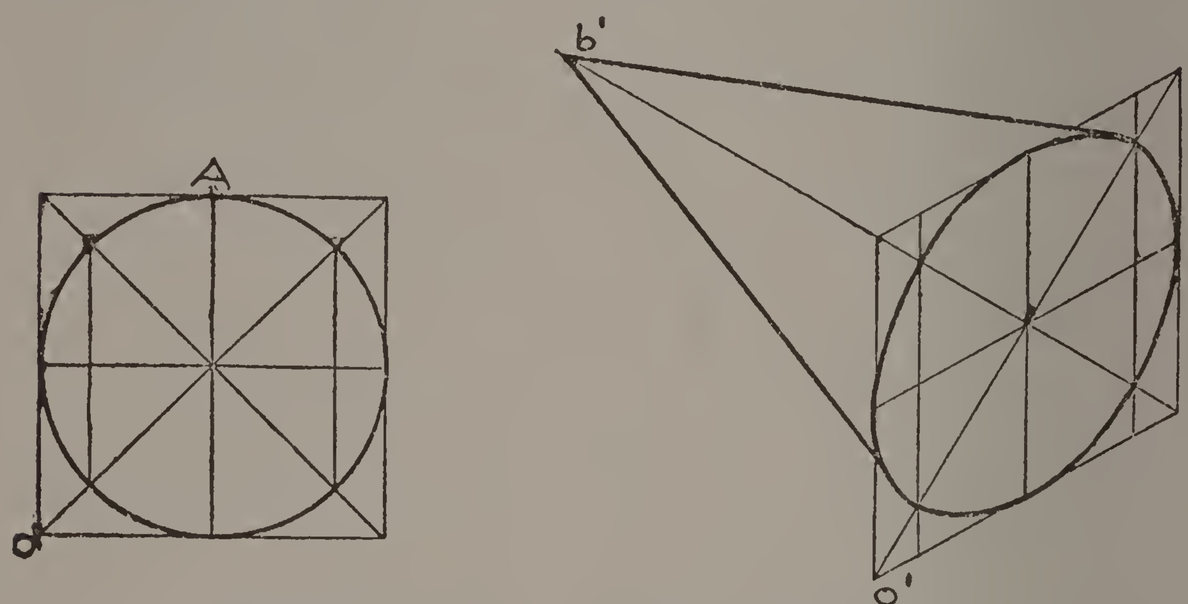


Fig. 90. Drawing a Cone in Isometric.

which is perpendicular to the plane of the base. On this axis the desired altitude of the cone is laid off, locating the apex **b′**. Lines drawn from **b′** tangent to the base, complete the view of the cone.

NOTE—Although only eight points have been used for the circles in the given figure, for larger figures or for more accurate results more points would be necessary.

125. The **isometric of a wooden bracket** is shown at **B** in Fig. 91. At **A** are drawn two views—the front elevation, and the left side elevation giving the thickness. The isometric is constructed as shown in the figure.

Oblique Projection

126. Oblique projection differs from isometric drawing in that one face of an object is usually represented in its true size and shape as if parallel to the plane of the drawing, while the edges perpendicular to this face are drawn at any convenient angle, as 30, 45, or 60 degrees, either to the right or left.

In Fig. 92 are shown the three angles of inclination for the case of a cube.

Cavalier or **cabinet projection** is the term

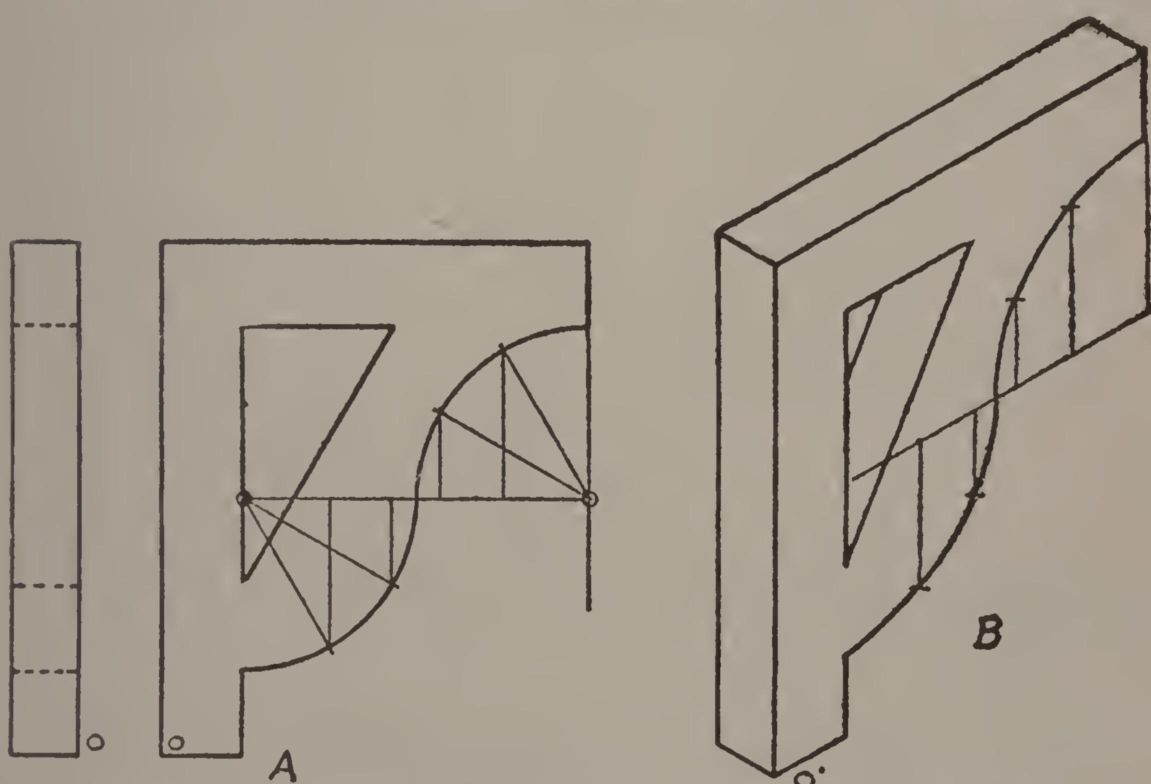


Fig. 91. Drawing the Isometric of a Wooden Bracket.

applied to oblique projection when the 45-degree inclination is used.

The lines in oblique projection corresponding to the isometric axes, are as shown in Fig. 93, one vertical, one horizontal, and one oblique (in this figure 45 degrees). Any line or edge which can be drawn in oblique projection parallel to the 45-degree line, will be shown in its true length.

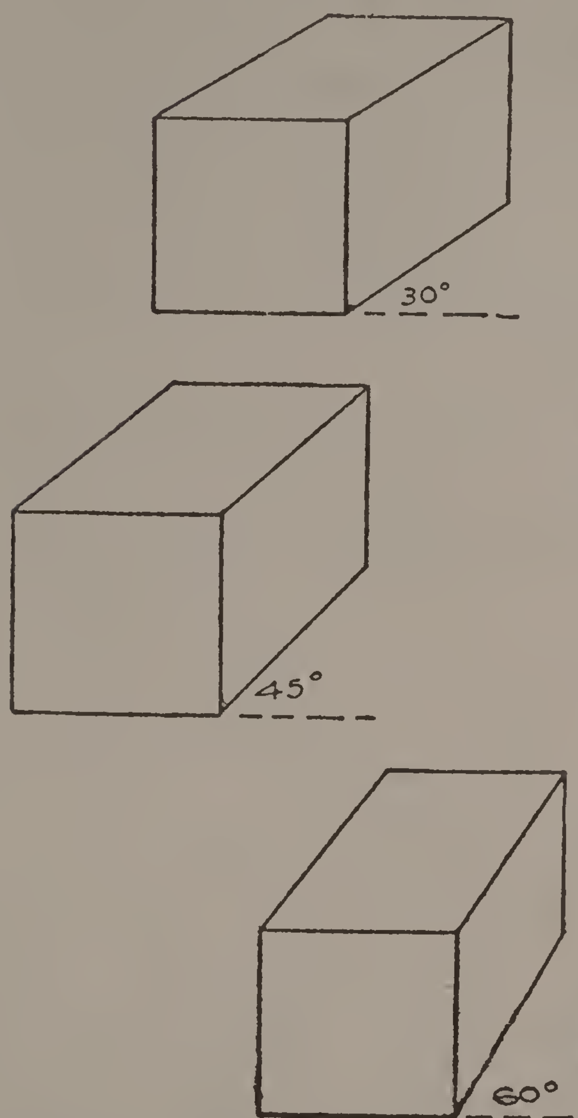


Fig. 92. Showing Angles of Inclination in Oblique Projection of a Cube.

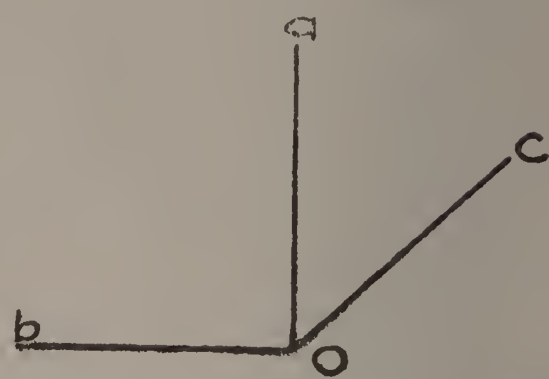


Fig. 93. Lines in Oblique Projection Corresponding to Isometric Axes.

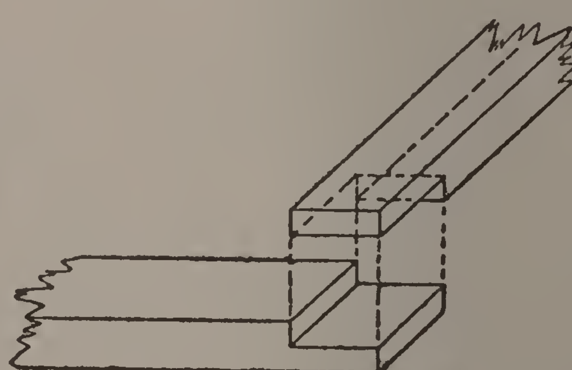


Fig. 94. Joists with Ends Cut for Halving.

This system of representation is perhaps a trifle simpler than isometric, since not only all lines parallel to o-a or o-b are shown in their true lengths, but also all lines parallel to the plane of o-a and o-b.

On account of this property, an oblique projection is often more easily made than an isometric—as, for instance, in the case of circles or curves which lie in a plane parallel to the plane of the drawing. Lines which are neither parallel nor perpendicular to the plane of the front face of the object, must be located by means of properly chosen co-ordinates, as in the case of isometric.

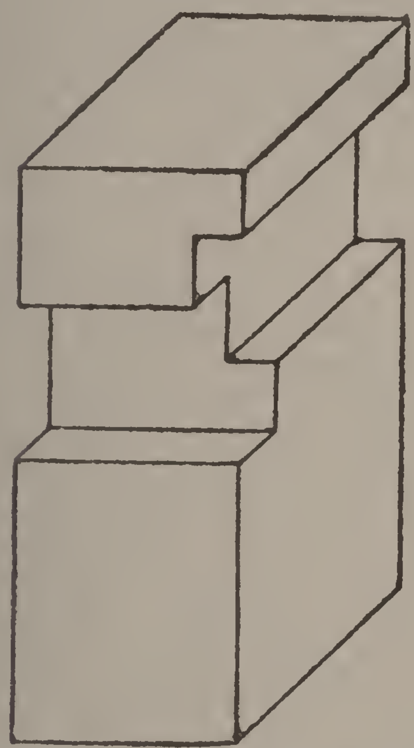


Fig. 95. Square Post Partly Cut Away on Front and Sides.

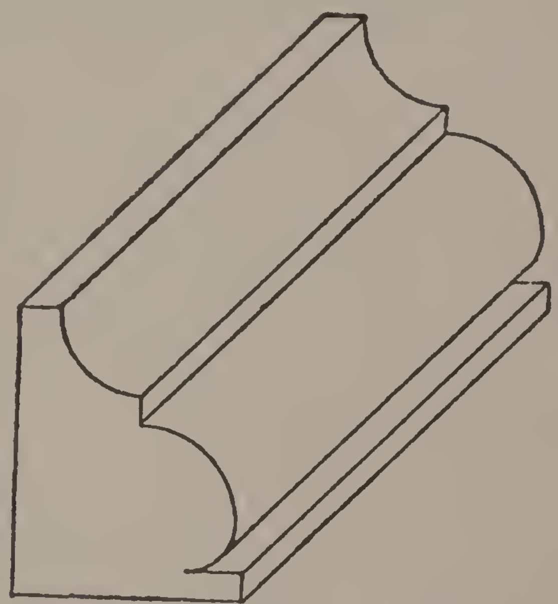


Fig. 96. Moulding in Oblique Projection.

127. Two pieces of joist with the ends cut for halving together, are shown in Fig. 94. All of the edges are either parallel or perpendicular to the plane of the front face, and are therefore shown true length.

128. Fig. 95 shows a square post, with parts cut away on the front and side.

129. A short piece of moulding is represented by oblique projection in Fig. 96. The curves of both the front end and the back end, are shown in their true size and shape. From

such a drawing, a plan and elevation might readily be constructed.

130. An **arch with a skew face** is shown in plan and elevation in Fig. 97. This case will illustrate the use of co-ordinates in the construction of the oblique projection. As the front face of the arch which is projected in the line

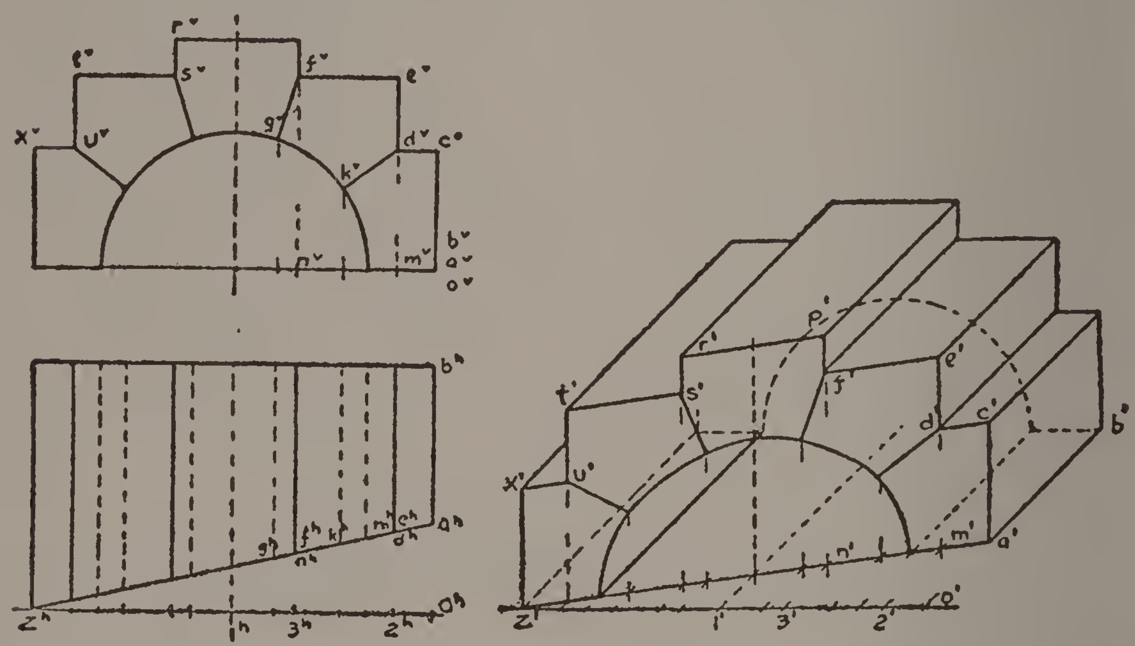


Fig. 97. Arch with Skew Face.

a^h-z^h is not horizontal, it will not be shown true size in the oblique projection, and the various points must be determined by co-ordinates. First draw through z^h a horizontal line, and produce a^hb^h to meet it at o^h, and take the position of o^h at o' for the oblique projection. Then $o'z'$ represents o^hz^h.

Next, a' is located on the 45-degree line through o', at a distance equal to o^ha^h. The line joining a' with z' is the **base line** of the face of the arch.

To locate the **front faces of the arch stones,** proceed as follows: Point **c′** may be found immediately by making the vertical line **a′-c′** equal to a^vc^v, and a vertical through **z′** of the same length will give one corner of the left-hand stone. It is desirable to locate the remaining corners with reference to the center line through 1′, since the points are symmetrically located on either side.

The next point **d**, together with the symmetrical point on the left side of the arch, is at a distance from the center line equal to 1-2. This distance is in the plane of o^hz^h, and so will be laid off in its true length at 1′-2′. Next, the point **d** is at the perpendicular distance 2^h-d^h from the vertical plane of o^hz^h, and this distance will appear as the 45-degree line through 2′, locating a point **m′** on the base line of the front face of the arch. The point **d′** is then found in a vertical line through **m′** at a height equal to m^vd^v.

Next in turn, **e′** is located by the vertical line through **d′**; and **f′** found by the co-ordinates 1^h-3^h, 3^h-n^h, and n^v-f^v.

The rest of the corners are located similarly.

Since parallel lines must show parallel in oblique projection, the lines **p′-r′**, **e′-f′**, **s′-t′**, **c′-d′**, **u′-x′**, and **a′-z′** should all be parallel. The long edges of the stones are drawn back at 45 degrees, their lengths being taken directly from the plan.

As the back end of the arch is in a plane perpendicular to the length, it follows that if it were all drawn in, it would be of the exact size and shape of the given elevation.

In fact, a more direct method of construction for the oblique view would be to construct the back end first, true size and shape; then, from each point, draw lines forward at 45 degrees, with lengths equal to the lengths in plan. This short construction, of course, would not be applicable if the back face had any other direction.

131. The reader should work out the following exercises for himself.

Exercises for Practice

(a) Draw an isometric view of a circular cylinder 2 inches in diameter and 4 inches long, placed with the axis horizontal. Show the elements of the cylinder running backward and to the right. Show a square hole ¾ inch in diameter cut through the center of the cylinder from end to end.

(b) Draw the isometric of a regular hexagonal pyramid when the base is in a vertical plane. Take for the lowest corner of the isometric, point **0** as indicated in the elevation, Fig. 98. Make each edge of the base 1¼ inches long, and the altitude of the pyramid 4 inches.

(c) Make the isometric of the stairs shown in Fig. 99, taking **0** as the lowest corner of the isometric. Scale, ½ in.=1 ft.

(d) Make the isometric of the moulding shown in cross-section in Fig. 100, taking **0** as the lowest corner. Make the length of the

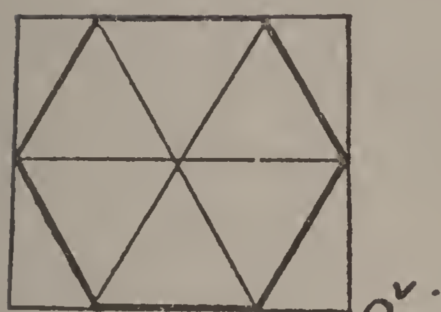


Fig. 98. Elevation of Hexagonal Pyramid with Base Vertical.

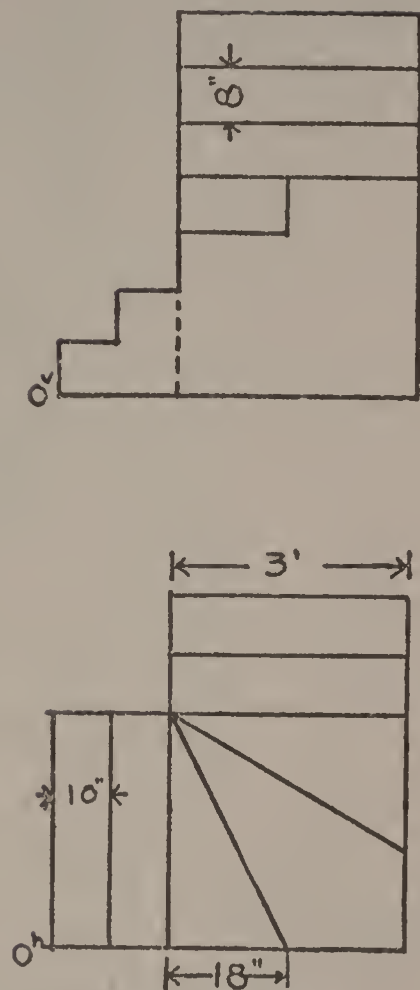


Fig. 99. Stairway.

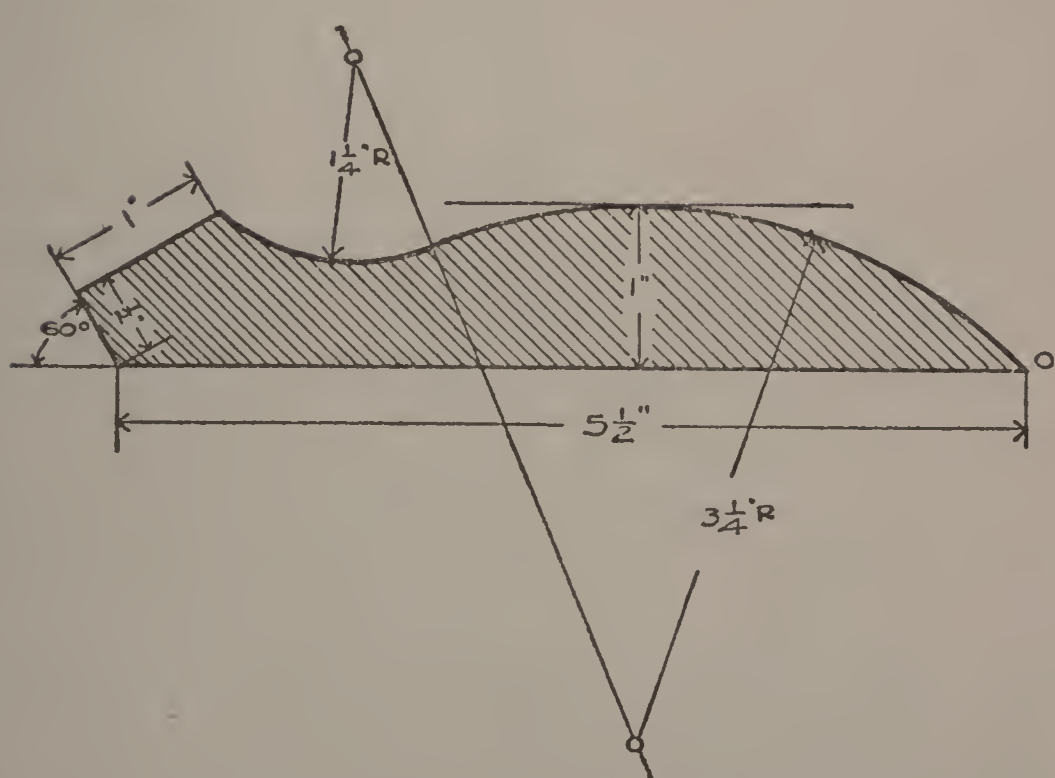


Fig. 100. Cross-Section of Moulding.

moulding 8 inches. This may be drawn half-size, if desired. Before drawing the isometric,

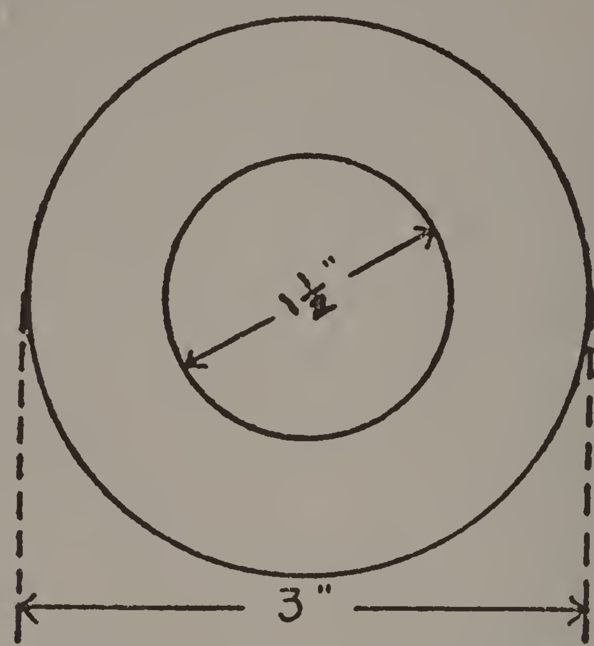


Fig. 101. Frustum of a Cone.

the section must be drawn from the given directions.

(e) Draw in oblique projection a right circular cone standing on its base. The diameter

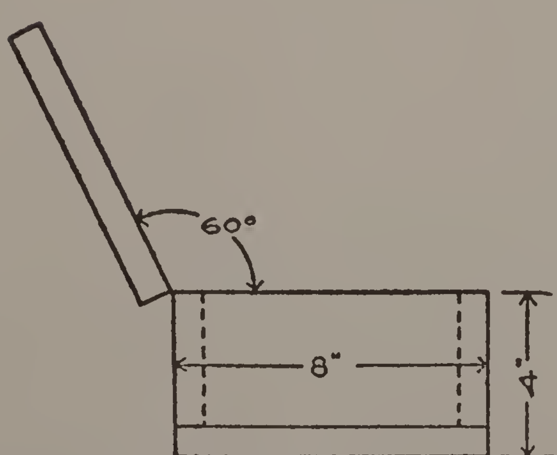


Fig. 102. End View of Wooden Box.

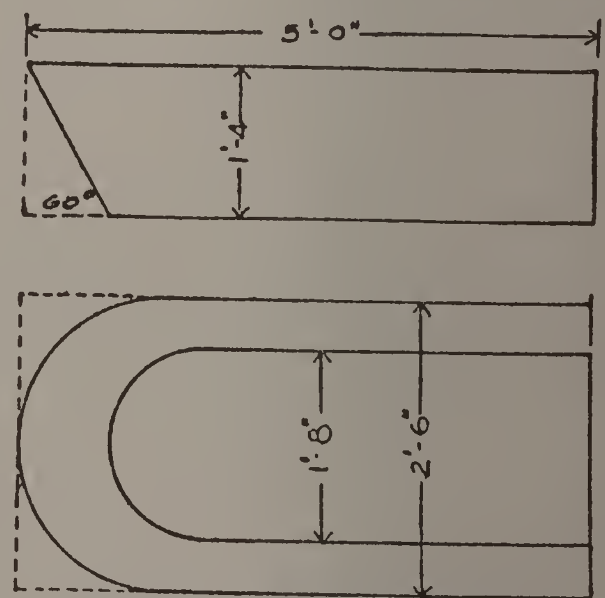


Fig. 103. Metal Bathtub.

of the base is 2 inches, and altitude is 4 inches.

(f) Make the oblique projection of the frustum of a cone, which is shown in elevation

AN EXAMPLE OF PARALLEL PERSPECTIVE.

in Fig. 101. The axis of the frustum is $3\frac{1}{2}$ inches long.

(g) Draw the oblique projection of a wooden box, of which an end view is shown in Fig. 102. The length is 12 inches. The box, including the cover, is made of $\frac{7}{8}$-inch stock, with the ends nailed onto the sides, and the bottom nailed to the ends and sides. Make the drawing one-quarter size.

(h) Draw in oblique projection the metal bathtub shown in Fig. 103, disregarding the thickness of the metal. Show the length horizontal, and the width at 45 degrees. Scale 1 inch=1 ft.

PRACTICAL DRAFTING

The Draftsman's Qualifications

132. Before taking up the subject of **working drawings**, a few words may be said concerning the **draftsman** himself.

There are draftsmen good, bad, and indifferent. There is the man who apparently has no concern about his employer's interests, yet perhaps wonders why his salary does not increase. Another type is the man who, although able to make mechanically an excellent drawing, is nevertheless but little better than an animated drafting machine. He can make a drawing when he has explicit directions to follow; but alas for the drawing when there is to be a little brain supplied!

Last and best is the real draftsman—the one who is alive and alert, and whose hands and brain work in conjunction. He is well-grounded in the theoretical principles of his work; he is the man who knows the "why." He must be painstaking and ready to learn. Sloppy and careless work is inexcusable in a draftsman. As has been said by a leading architect of the young man just entering the profession, "He must be prepared to draw heavily on his common sense." He must learn to use his time with discrimination. In many cases, time spent in securing great accuracy or fine finish in a drawing is time wasted.

The position of draftsman, if successfully filled, may often be the stepping-stone to something better. The one who is best serving his employer's interests, and thereby fostering his own, will not be content to do or know only what is absolutely required. He will broaden his mind and increase his own value by acquiring some knowledge of related lines of work. He will, in short, be prepared so that when a vacancy occurs higher up, he will be just the one to receive the promotion.

133. **Employer's Point of View.** The man who makes his business a success necessarily looks at the commercial value of the draftsman's work, and very soon learns who is making good, and who may be relied on. In these times of strenuous competition, the margin of profit is often narrow; consequently the employer will advance those who make his success possible,

and dispense with the services of those who have no interest beyond their own salaries

WORKING DRAWINGS

134. A working drawing is one which is designed for actual use in the shop or field. It is the drawing which goes out from the drafting room, and which conveys to the mechanic or builder instructions as to the machine, bridge, building, or other construction which is to be made. It must contain all the different views and dimensions necessary to enable the workman to go ahead and construct the thing required.

In order that the drawings may be readily understood by the mechanics, they must be made in accordance with customary drafting practice.

135. **Detail Drawings; Assembly Drawings.** For objects of more or less complicated structure—as buildings or machines—two kinds of drawings are necessary: the **detail drawings,** showing different parts separately; and the **assembly drawings**, showing the object as a whole.

If drawings are required of some object which is already constructed, in order that duplicates may be made, then **preliminary drawings** or **sketches** are first made. Dimensions and measurements are made directly from the object, and placed on the preliminary drawings or sketches. It is especially important that these sketches shall contain all necessary views and dimensions, as the object in question may be miles away from the drafting room, and the sketches are the draftsman's sole guide when making the final drawings.

For making these sketches, the draftsman should have a pad or notebook of cross-section paper, one or two triangles, a compass, a two-foot rule, and a pair of calipers.

When an object is to be made for the first time, the **design** is first prepared by the engineer or designer from a consideration of the necessary relations between the different parts and the requisite properties of the same. The head draftsman may then take the design, and work up the necessary details to a point where the drawings can be finished by the other draftsmen.

136. An important requirement which should be kept in view in making working drawings is **clearness.** The drawing should have but one meaning. To this end, enough views must be given, so that for the object represented no uncertainty shall exist as to its shape and proportions.

These different views should be placed near enough together, so that they may be readily compared, but not so close that there will be any tendency to confusion. When certain necessary information cannot be conveyed by the drawing alone, **explanatory notes** must be given on the same or another sheet.

137. **Kinds of Lines.** Drawings are easier to read, and the meaning is made clearer, by the

use of several kinds of lines, differing according to the purpose for which the line is to be used. The conventional types of lines for various purposes are shown in Fig. 104. The **full line** and the **dotted line** should be of the same width; the **center line, dimension line,** and **construction line** should all be of the same width, and narrower

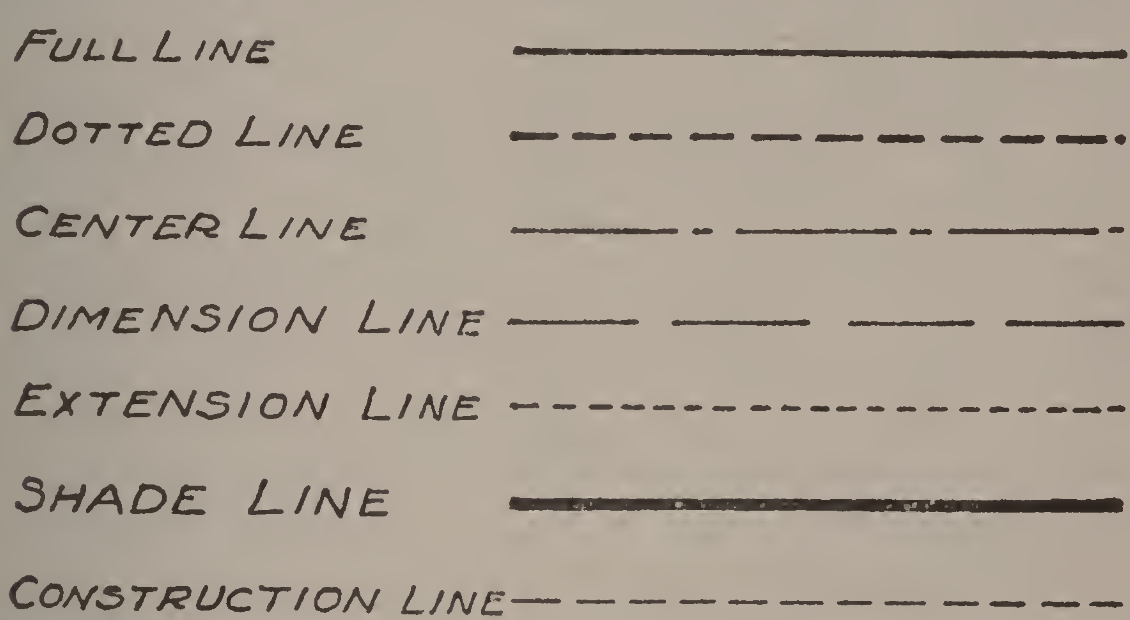


Fig. 104. Conventional Lines Used for Various Purposes in Mechanical Drafting.

than the first two; the **extension line** should be fine, and the **shade line** heavy.

For the broken lines, there is no standard length for the long or short dashes; but for a neat and properly made drawing, the short dashes of the so-called dotted line should be of equal length; and similarly, for all the broken lines, the like dashes when repeated should be of uniform length.

Many draftsmen are careless about their dash and dotted lines, with the result that their drawings are very likely to have a slovenly appearance.

138. **Shade Lines.** These are heavy lines, as shown in Fig. 104, applied to certain parts of the drawing. They are used principally for the sake of imparting character and relief to the figures. Shade lines are not essential, and in some drafting offices are dispensed with almost altogether. They do, however, give to a draw-

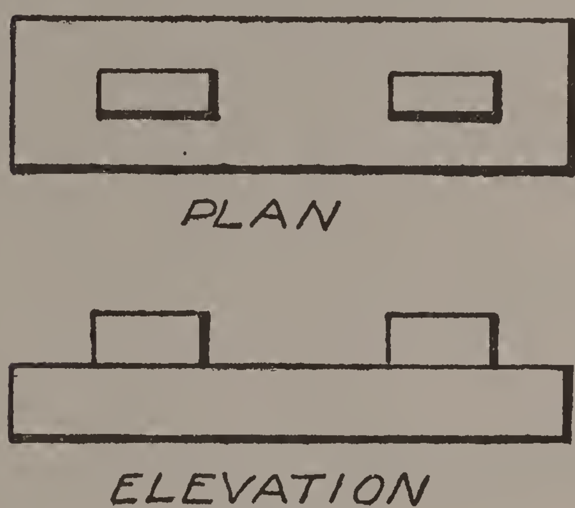


Fig. 105.

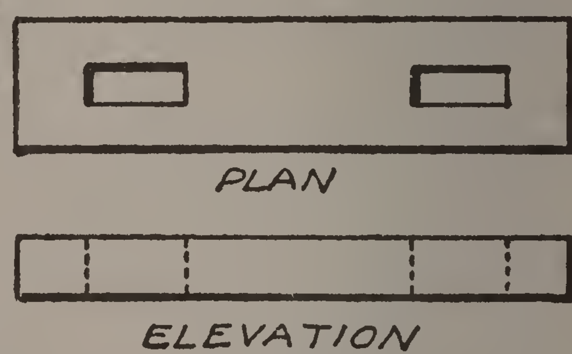


Fig. 106.

Illustrating Use of Shade Lines.

ing a certain finish which would otherwise be lacking, and in some cases materially assist in making clear the object represented.

How Shade Lines are Used. Theoretically, shade lines are the lines or edges which separate light from dark surfaces; practically they are applied to certain lines of the drawing according to a conventional system. Shade lines are applied only to lines which represent **edges** of an object; and, in the system most generally adopted, the **right-hand and lower edges** in both plan and elevation are the shaded lines.

Examples of Shade Lines. In Fig. 105 is shown a stick with rectangular pieces projecting up from the surface. The right-hand and lower edges of the stick are shaded in both views; and in the plan, the right-hand and lower edges of the two uprights are also shaded; while in the elevation, only the right-hand edges are made shade lines.

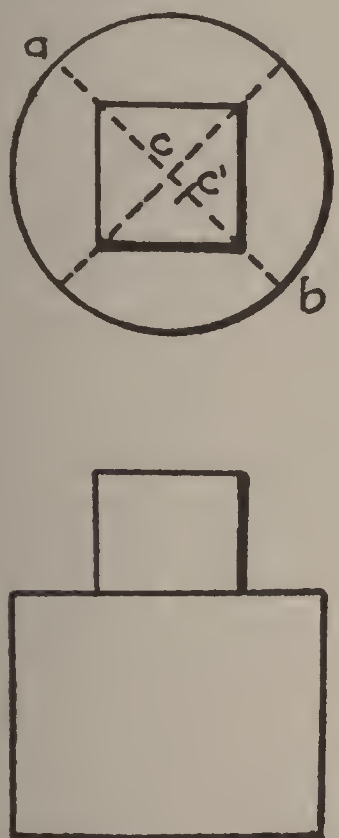


Fig. 107.

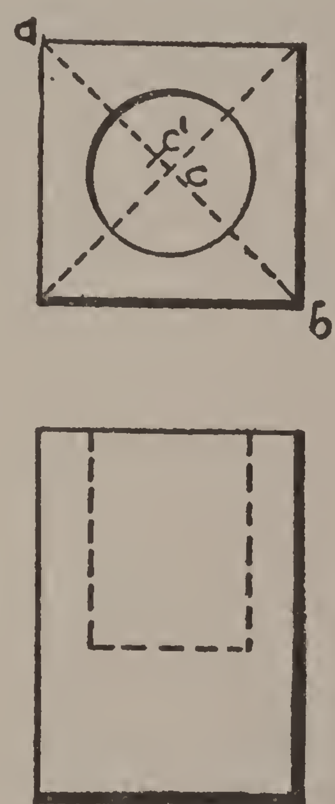


Fig. 108.

Illustrating Shading of Circles.

Fig. 106 represents the same stick with holes instead of uprights. Notice, in the plan, the change in the position of the shaded edge. This is in strict conformity with the rule, since the upper and left-hand edges of the opening are the lower and right-hand edges of that portion of the object. It is in cases like these that shade lines have practical value in assisting to make clear the actual meaning of the drawing.

Shading of Circles. The shade line of a circle always begins and ends on a 45-degree line, as shown in Fig. 107 and 108, the 45-degree line in this position marking the division between what may be called the lower and right-hand edge and the upper and left-hand edge. The shade line begins at the extremities of the 45-degree diameter, with the same width as the unshaded part, and gradually increases in width. This smooth and pleasing effect is produced by drawing the other 45-degree line, **a-b**, shifting the center **c** slightly to **c′**, and, with the **same radius**, drawing over the part to be shaded.

The excess width of a shade line over the ordinary line is generally placed on the **outside** of the area inclosed by the figure. Exceptions occur when the placing of the shade line in this position would unduly distort the figure or tend to produce a jagged effect.

139. **Blue-Prints.** The form in which a working drawing goes out from the office to the shop, or field, or wherever the actual construction is to be made, is the **blue-print.** The steps which lead up to the final form of blue-print are: first, **pencil drawing**; second, **tracing**; and third, the **blue-print.** Sometimes the second step is omitted, as will be explained later.

Assuming that the preliminary sketches are made, a **scale** at which the drawings are to be made is then chosen. The particular scale to be used is determined by various considerations. The drawing should be on a scale large enough so that the different views and dimensions may be clearly read; but, on the other hand, they should not be unnecessarily large and unwieldy. Various scales are used in engineering and machine work. Sometimes certain parts or pieces are drawn greater than full size. In this country, common architectural practice is to make drawings at a scale of ¼ in.=1 ft., with details at ¾ in.=1 ft., and also details at full size.

The scale decided upon, the **center lines** of the various views are laid out, the outlines blocked in, and then the details supplied. Where the different views are on the same sheet, the constructions of each should be carried on at the same time.

The pencil drawing may be made on **brown duplex paper**, on **thin white bond**, or on **tracing cloth**. No matter which kind is used, the lines should be bold and distinct; and to this end, the pencil used should be not harder than 3H, and in some cases softer.

The Tracing. If the penciling is done on the duplex paper, a tracing is next made. This is done in ink on the tracing cloth, which for this purpose is tacked on the board over the drawing. Some draftsmen prefer to ink on the dull side of the tracing cloth; and some, on the side with the glossy finish. In either case, the surface should first be rubbed over with powdered chalk, in order to remove all grease from the surface. The chalk must then be brushed off, and the surface is then ready for the ink. In case the pencil drawing is made on the bond paper or on the tracing cloth, it may be inked directly, and no separate tracing is required.

A common fault with beginners is to make the lines on a tracing too fine. In order to secure a good blue-print the lines on the tracing must be fairly heavy. This is also true of letters and numbers.

The Blue-Print. The blue-print, which reproduces the original drawing with white lines on a blue ground, is obtained from the inked tracing or inked drawing, and is made on a sheet of specially prepared white paper which may be bought ready for use. One side of the paper is rendered sensitive to the light by means of a chemical coating.

To make the print, the tracing or inked drawing is placed **face up** on the sensitized side of the prepared paper; the two are put in a printing frame, and exposed to the sunlight or a powerful electric light. The light acts on the prepared surface, changing it to a permanent blue color except where the surface is covered by the inked lines. The time needed for the exposure will vary according to the intensity of the light and the speed of the paper—from less than a minute to half an hour or more.

After exposure, the print is taken from the frame, and placed in a tank of running water, which dissolves and washes away the parts of the coating that were protected by the inked lines above, but which has no effect on the parts that have been acted upon and fixed by the action of the light. The sheet is next taken from the tank, hung up to dry, and is then ready for use.

140. **Dimensioning.** Dimensions are usually placed on a drawing so as to **read from the bottom and from the right hand.** Clearness is of great importance in dimensioning; and on this account, if for no other reason, the figures should be plainly made and heavy enough so as to stand out somewhat from the drawing. There

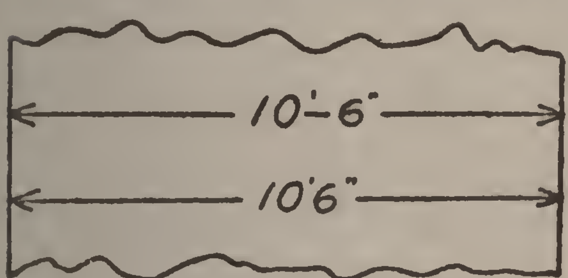


Fig. 109. Correct and Incorrect Methods of Indicating Dimensions.

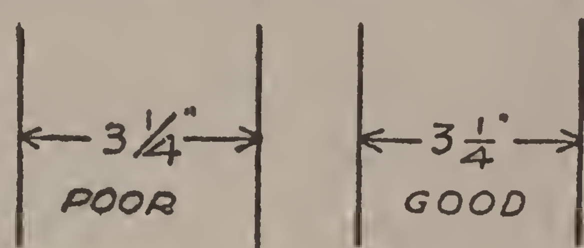


Fig. 110. Good and Bad Methods of Indicating Fractional Dimensions.

must be no confused tangle of dimensions; dimension lines should not needlessly cross, and the dimensions must be separated enough so as to be clearly read. **Arrow-heads** are used at the ends of the dimension lines (with one or two exceptions), to show exactly between what two points or lines the given dimension applies..

Dimensions are expressed on a drawing in inches, or in feet and inches, depending upon the distance and also on the choice of the draftsman. In some drafting rooms, dimensions up to two feet are expressed as inches; and above that, in feet and inches. In others, any distance over twelve inches is indicated in feet and inches.

Where the dimension is stated in feet and inches, a short dash should always be placed between the feet and the inches, that no mistake may be made in reading it. Fig. 109 shows the upper dimension correct, written **with** the dash; and the lower one wrong, **without** it. The dash

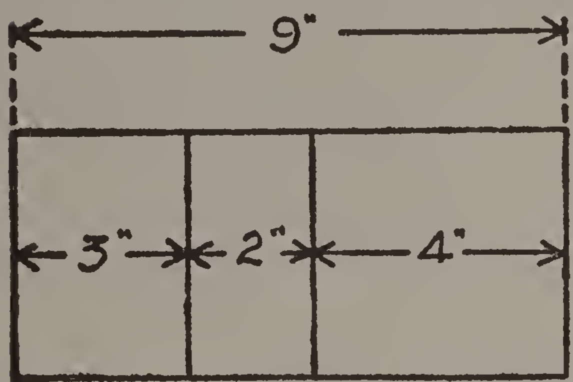


Fig. 111. Illustrating Use of Extension Lines.

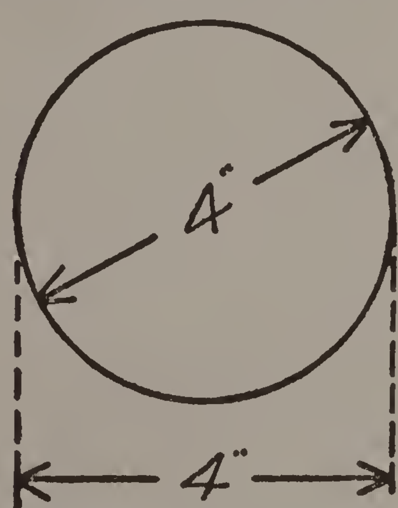


Fig. 112. Use of Extension Lines in Dimensioning a Circle.

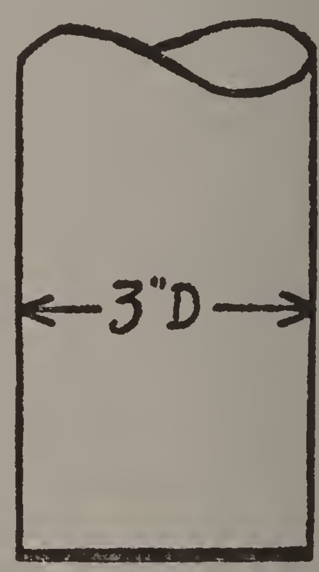


Fig. 113. One Method of Dimensioning Diameter of Cylinder.

line between the arrows is the dimension line.

Fig. 110 illustrates a good and a bad way of showing a fractional dimension. The line of the fraction should always be parallel to the dimension line, never inclined.

Extension Lines. In Fig. 111, the short-dash lines extending above the figure at either end are extension lines. Extension lines are used for the extension of lines between which a dimension is to be placed, so that the dimension may be given outside of the figure. In this way, confusion is often avoided. Extension lines are also often used in dimensioning a circle or circular piece, as shown in Fig. 112. Fig. 112 also shows the circle dimensioned inside.

Where a whole circle is drawn, the diameter should always be given, rather than the radius;

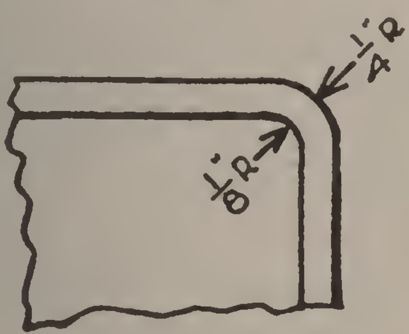


Fig. 114.

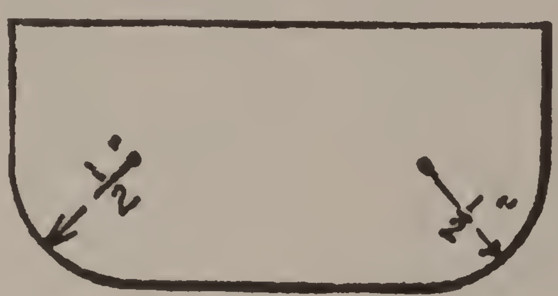


Fig. 115.

Methods of Dimensioning Arcs of Circles.

and the dimension line should pass through the center.

If, as in Fig. 113, the diameter of a rounded piece, as a cylinder, is given elsewhere than on the end view, the dimension figure should be followed by **D** or **Dia.** (for "Diameter").

Where an arc of a circle is given, indicate the radius instead of the diameter, as shown in Figs. 114 and 115. Where there is sufficient room, the center of the arc should be enclosed in a small freehand circle, and the dimension placed between the center and the arc as in Fig. 115; otherwise the length of radius should be given as in Fig. 114, followed by the letter **R** to denote "Radius."

When an arc is given, use only one arrow-head.

When a number of holes are equally spaced around a circle, give the diameter of circle passing through centers, as in Fig. 116. If the holes are all of equal size, it is sufficient to give the diameter of one or two.

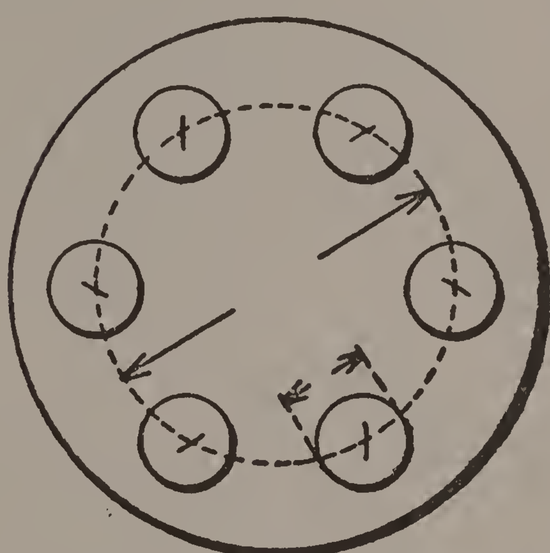


Fig. 116. Dimensioning Holes Equally Spaced around a Circle.

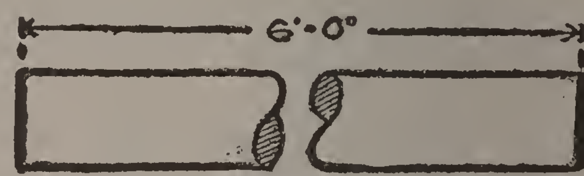


Fig. 117. Breaking in Two to Show Over-All Dimensions.

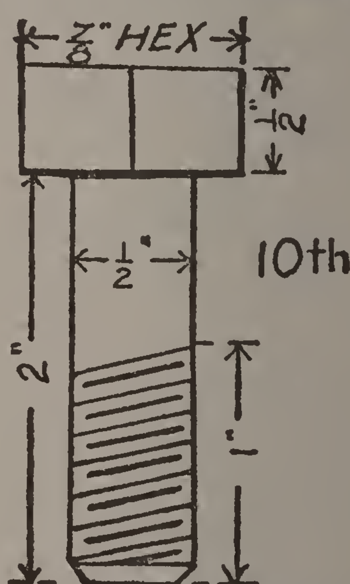


Fig. 118. Half-Inch Bolt, with Dimensions.

Besides the necessary dimensions of all the different parts of the object represented, the **extreme outside dimensions** should usually be given. These are known as **over-all dimensions,** and should be given so that the workman will not be obliged to add the several dimensions in order to obtain the required size. If a very long piece is to be shown, it may be represented as broken in two, and therefore drawn less in length than would otherwise be necessary, the dimension being given as if the whole length were shown (see Fig. 117).

Distribution of Dimensions. Where there are several views of an object on one sheet, the appearance will be improved and the drawing will be easier to read, if the dimensions are distributed among the different views. In any case, however, where there would be likelihood of error, the same dimension should be placed on more than one view.

Dimensioning of Bolts. For a bolt, one view—showing the length—is all that is required. Fig. 118 shows a half-inch bolt with all the necessary dimensions. In addition to the diameter of the bolt, the thickness of the head, and the length under the head, there should also be given the length of either the threaded or the unthreaded portion. The number of threads per inch should also be briefly given—as 10th, 12th, etc., as the case may be. For a bolt with a hexagonal or an octagonal head, the **short** diagonal is given. If the head of the bolt were round, **D** would be substituted for **HEX**; if square, **SQ** would be used, etc.

141. **Finished Surfaces.** When metal surfaces are to receive a smooth finish in the shop, the **edge view** of the surface is marked on the drawing with an italic **F**, as shown in Fig. 119. If all of the surfaces are to be finished, a note is made, "**F** all over."

142. **Duplication of Parts.** If two or more

parts or pieces are to be made exactly alike, as bolts, pins, rods, etc., one figure is drawn and

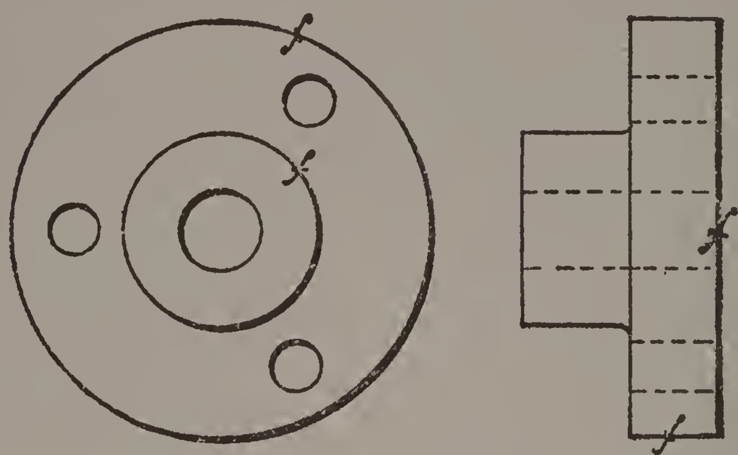


Fig. 119. Method of Indicating Finish for Metal Surfaces.

dimensioned, and a note added: "Make 2 (or 8, or 10, etc.) of this," specifying the desired number.

Sections

143. It is often convenient, and sometimes necessary, to take a plane cutting through the object, remove one portion, and show the cut surface, or **section.** This may be necessary in order to give a clear idea of interior or hidden parts, whether the object be a small piece, or an office building, or a masonry structure. It may sometimes be inconvenient to show the external shape of an object by an end view; and in such a case a section, placed as in Fig. 120, may be shown instead. The shape and proportions of a fluted column may also be well shown in section, as in Fig. 121.

144. **Cross-Hatching.** When sections are made on a working drawing, it is customary to distinguish between the various materials rep-

COLONIAL ENTRANCE TO HOUSE AT HOPKINTON, MASS.

resented, especially in the case of metals, by a system of one or more sets of parallel lines covering the sectioned surface. The surface treated in this way is said to be **cross-hatched.** In the matter of cross-hatching, there is no universally accepted standard for all substances; and indeed, in some drafting rooms, the kind of hatching is arbitrarily chosen.

When, on a working drawing, different materials are shown in section, they should be dis-

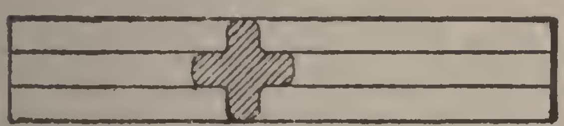


Fig. 120. One Method of Indicating Shape by Sections.

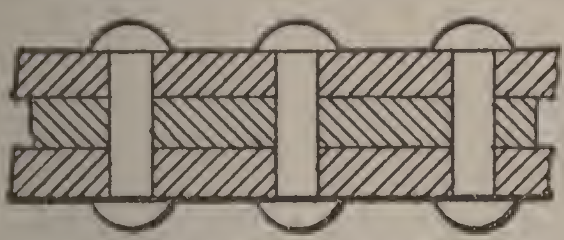


Fig. 122. Method of Cross-Hatching Sections of Adjoining Parts.

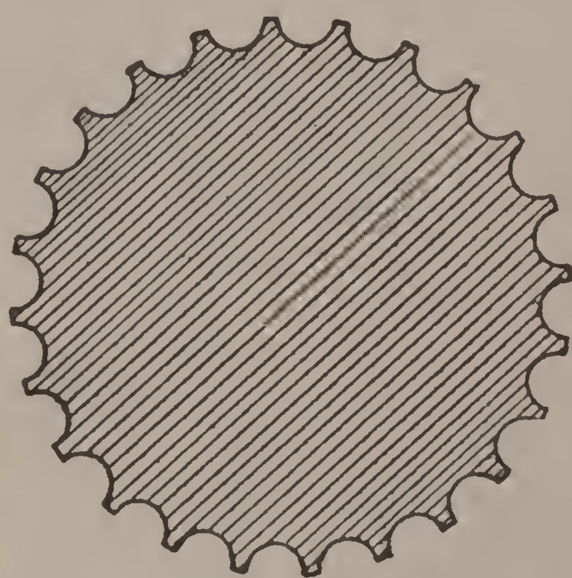


Fig. 121. Section of a Fluted Column.

tinguished by cross-hatching; and somewhere on the sheet, there should be placed small blocks of the kinds of cross-hatching used, giving the names of the materials which they are intended to represent. When, in section, two adjoining parts are shown, the cross-hatching on the two parts should run in different directions, as in Fig. 122.

Fig. 123 shows blocks of cross-hatching as used for some of the common substances with which the draftsman has to deal.

On architectural working drawings, stone and terra-cotta are represented in section, and also in plan and elevation, as shown in Fig. 124.

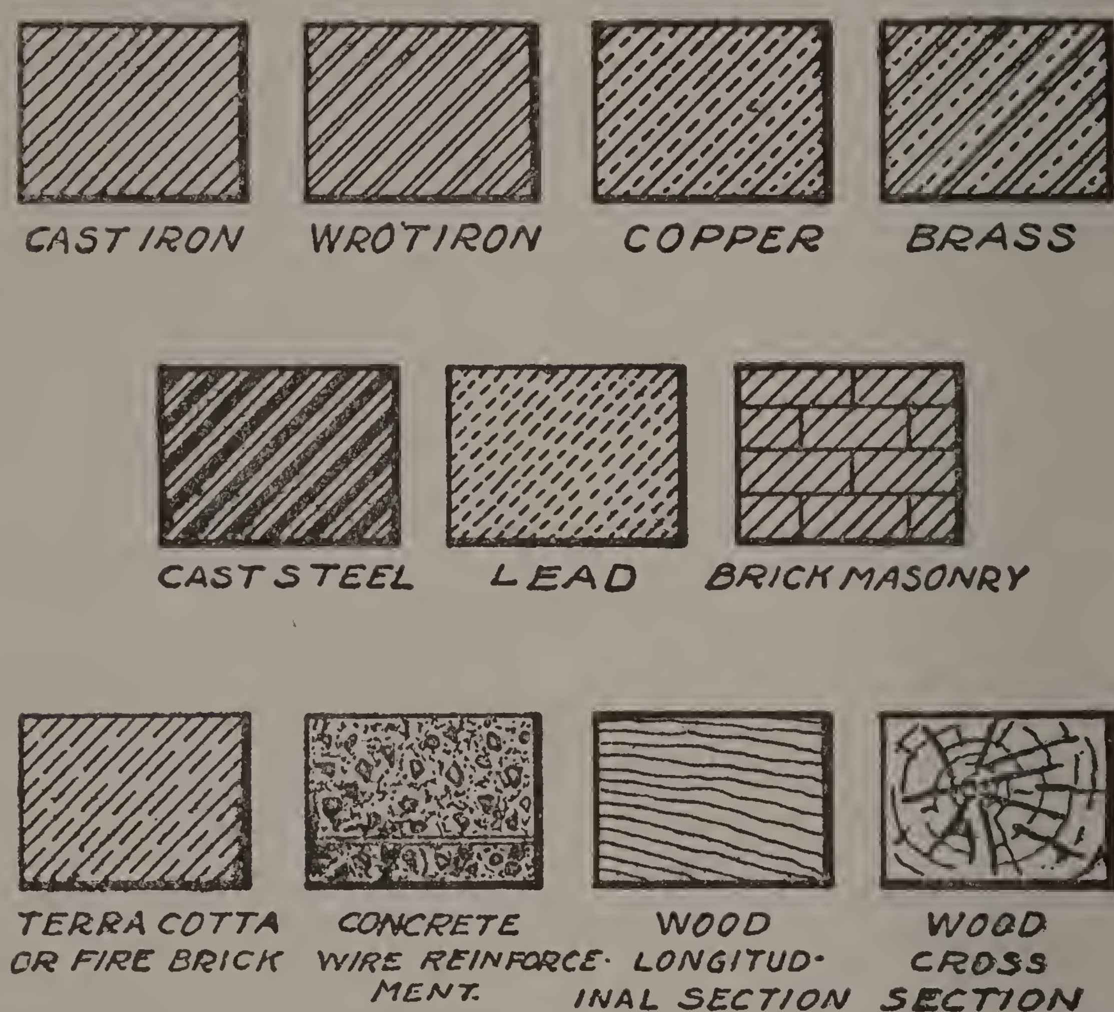


Fig. 123. Conventional Representations of Common Materials of Construction.

If, in architectural drawings, colors are used, they may be chosen as follows:

Brick	Light red.
Concrete	Payne's gray, mottled.
Glass	New blue.
Old work	Gray or black.
Slate	Indigo.
Steel and iron	Prussian blue.
Stone	Raw umber or Payne's gray.

Terra-cotta .... Burnt umber.
Wood .... Yellow ocher.

LETTERING OF DRAWINGS

145. The lettering on a working drawing, while not the most important feature, nevertheless demands some attention. The appearance of an otherwise good drawing may be quite spoiled by poor or inappropriate lettering. The letter for practical use must first be legible, and it must admit of being rapidly and easily made.

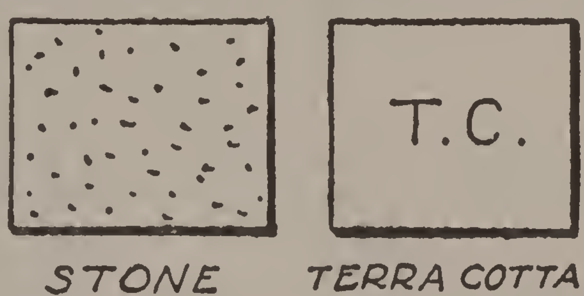


Fig. 124. Conventional Representations of Stone and Terra-Cotta on Architectural Drawings.

A very considerable difference exists between the styles of letters used in engineering and machine drawing practice, and those used in architects' offices.

Figs. 125 to 128 inclusive are examples of good, plain letters for **engineering** and **machine drawing**. This style of letter is known in machine drawing as the **Gothic**. The inclined letters are especially suitable for notes on the drawings.

For architectural working drawings, a style of letter is used which is derived more or less directly from the Roman capitals. This style of letter, of which examples are shown in Figs.

ABCDEFGHIJ
KLMNOPQR
STUVWXYZ
1234567890

Fig. 125.

abcdefghijklmn
opqrstuvwxyz

Fig. 126.

ABCDEFGH
IJKLMNOPQ
RSTUVWXYZ
1234567890

Fig. 127.

abcdefghijklmn
opqrstuvwxyz

Fig. 128.

Examples of Good, Plain Letters Suitable for Engineering and Machine Drawings.

129 and 130, admits of a freer and easier treatment than do those usually found on machine drawings.

Spacing. Whatever the style of letter used, the general effect will be marred or improved according as the spacing is bad or good. For the correct spacing, no hard and fast rule can

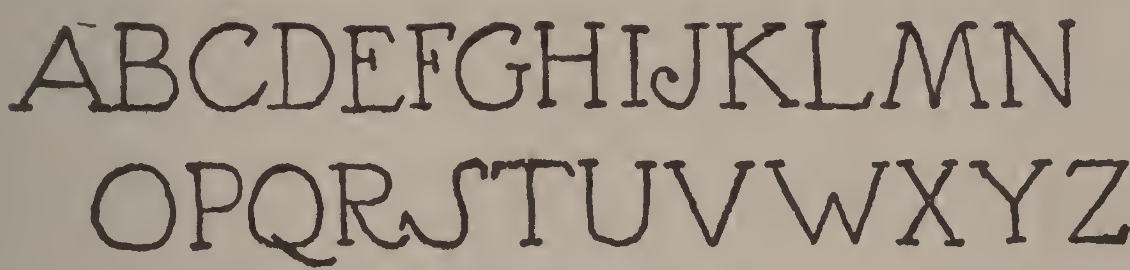


Fig. 129.

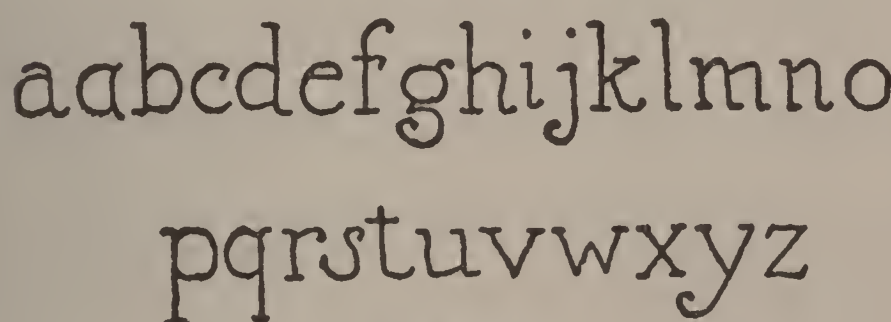


Fig. 130.

Form of Letter Suitable for Architectural Working Drawings.

be given; but it may be said in a general way, that the letters should be so placed that the area of the spaces between them should be about equal.

The amount of time that can be devoted to lettering a working drawing, is in general comparatively small; so the bulk of the lettering is done freehand, except on important titles for particular work, where some instrumental construction may be used. A careful study of the letters given in the figures, coupled with painstaking practice, will put the beginner on the road to facility in making the various letter forms.

Working Drawings for Building Construction

146. These, as already stated, are usually drawn to the scale of ¼ in. = 1 ft., with details at ¾ in. = 1 ft., or full size.

The number of drawings required for the building of a house necessarily varies somewhat

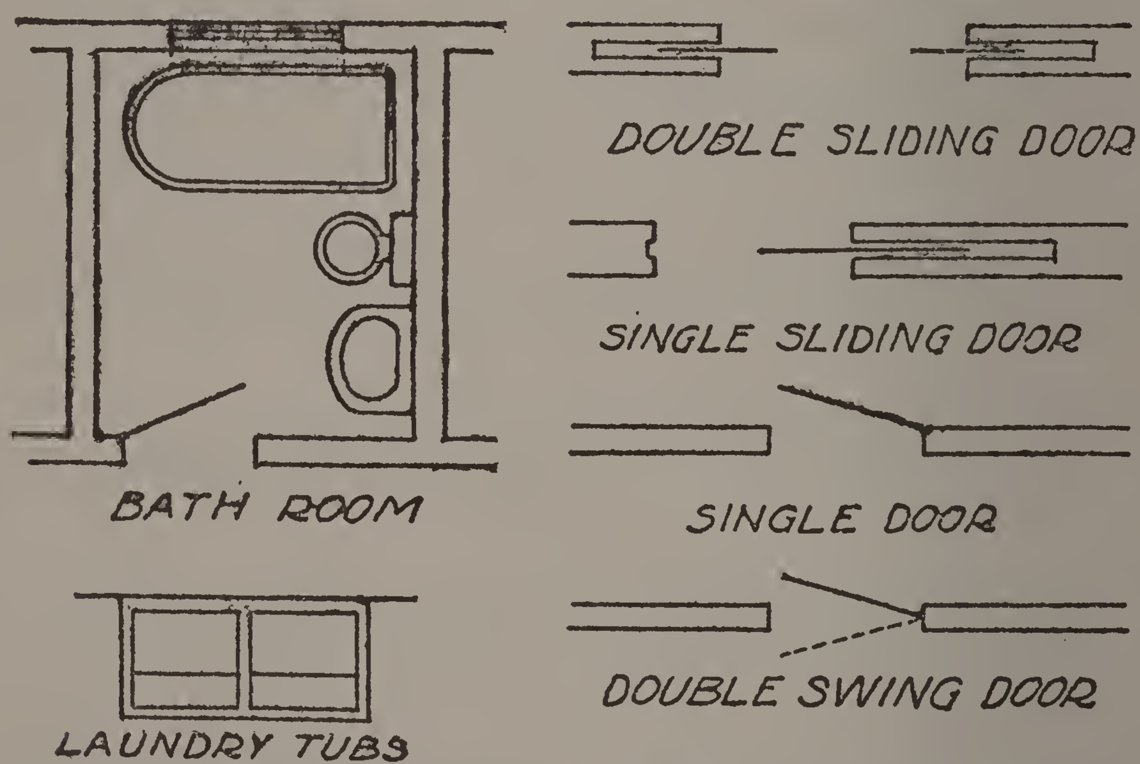


Fig. 131. Conventional Method of Representing Some Common Details of Construction on Working Drawings.

according to its character. There should be, however, plans of each floor, including the roof and the basement or foundation plan. There should be also as many elevations and sections as may be necessary fully to explain the construction. Plans of the different floors, showing the framing, may also be required.

For particular details, such as cornices, window casings, balusters, mouldings, etc., it is good practice to draw the details at full size. Isometric and perspective are also often very helpful in the case of complicated details.

Conventional Representations. In Fig. 131 is shown the usual manner of representing on a working drawing some familiar details.

147. **Working Plans for a Residence.** In Figs. 132 to 139 inclusive, are shown the working plans for a two-family house.

Fig. 132 is the **basement** or **cellar plan.** Notice the over-all dimensions, and the dimension lines drawn as faint full lines. It is often the custom on tracings for blue-prints to draw construction or dimension lines with a narrow, full, red line. The red line prints much fainter than the black. Observe also the use of the conventional representations for the stonework, the windows, and the single-swing doors.

In the first and second floor plans, Figs. 133 and 134, the arrangement of the rooms is the same. The door between the dining room and pantry is one of the double-swing kind, as indicated on the drawing. The stairs up to the third floor are above the ones down to the first. Notice that here confusion is avoided by the irregular break in the stairs, and by the use of the arrows with the words "Up" and "Down." Observe that the center lines of the windows are located from the walls of the house.

In Figs. 136 to 139 inclusive are shown four

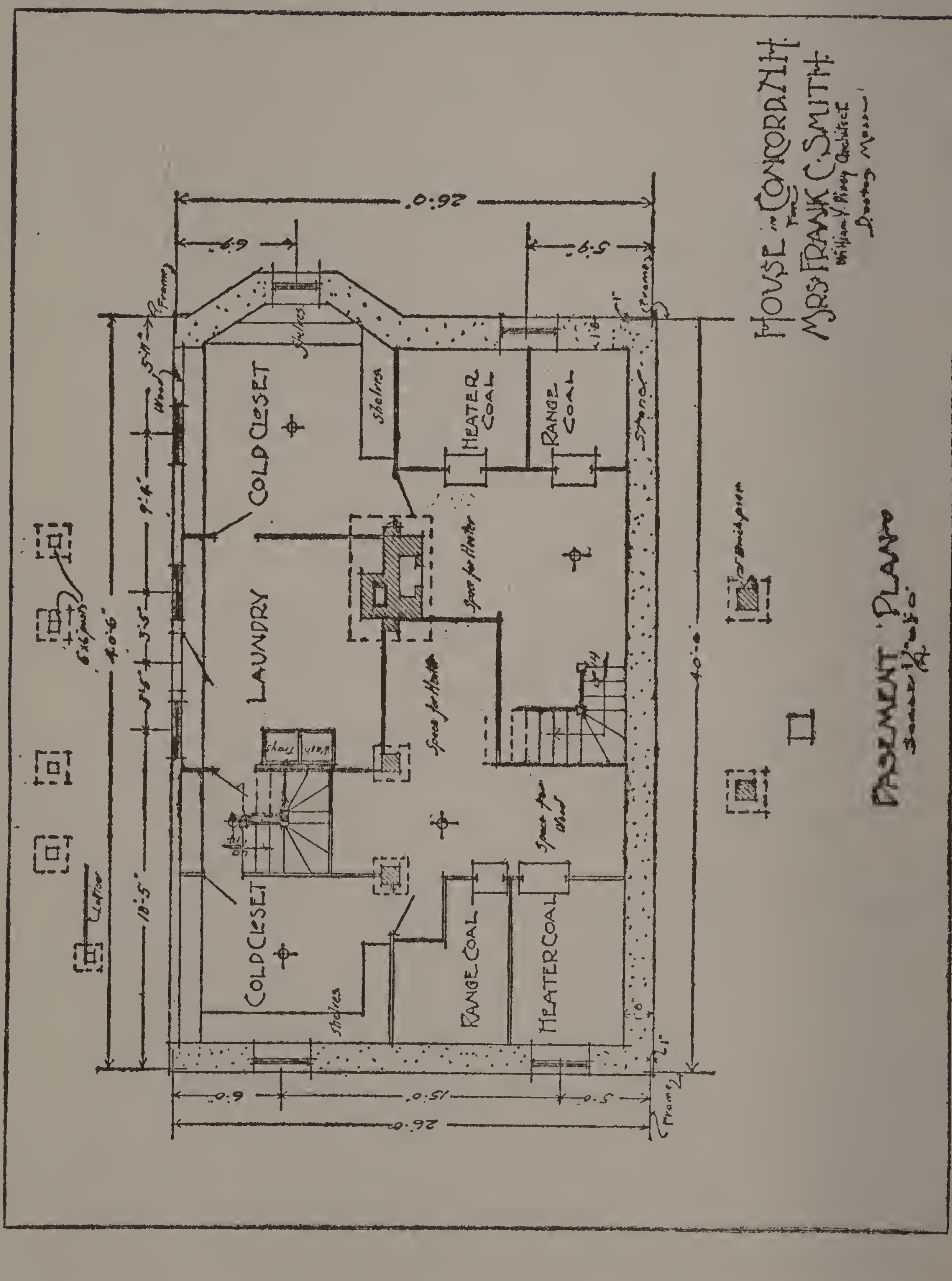


Fig. 132. Example of Working Drawing—Basement Plan for a Residence.
The scale indicated applies, of course, only to the original-sized drawing, not to the reduced reproduction here given.

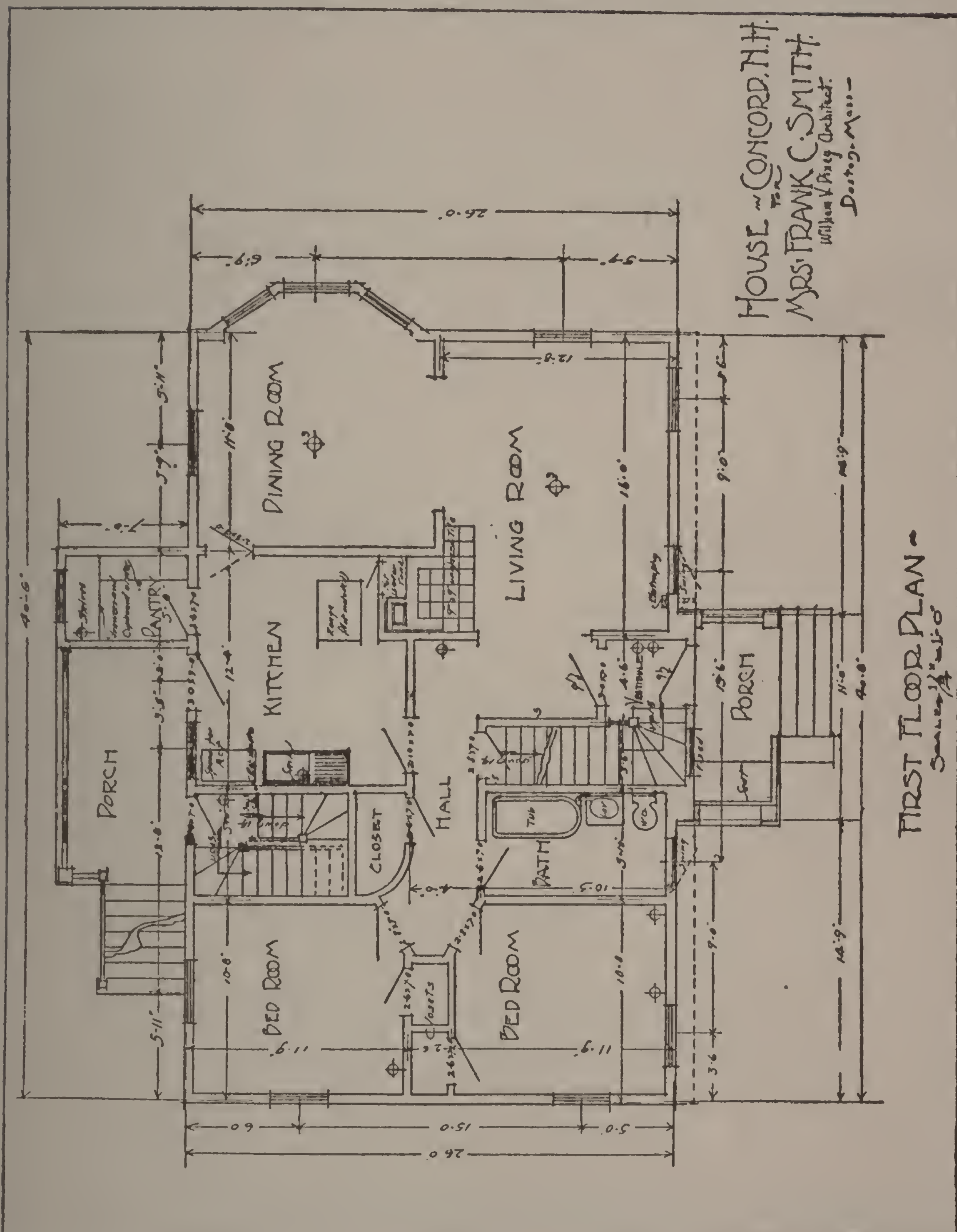


Fig. 133. First-Floor Working Plan for a Residence.

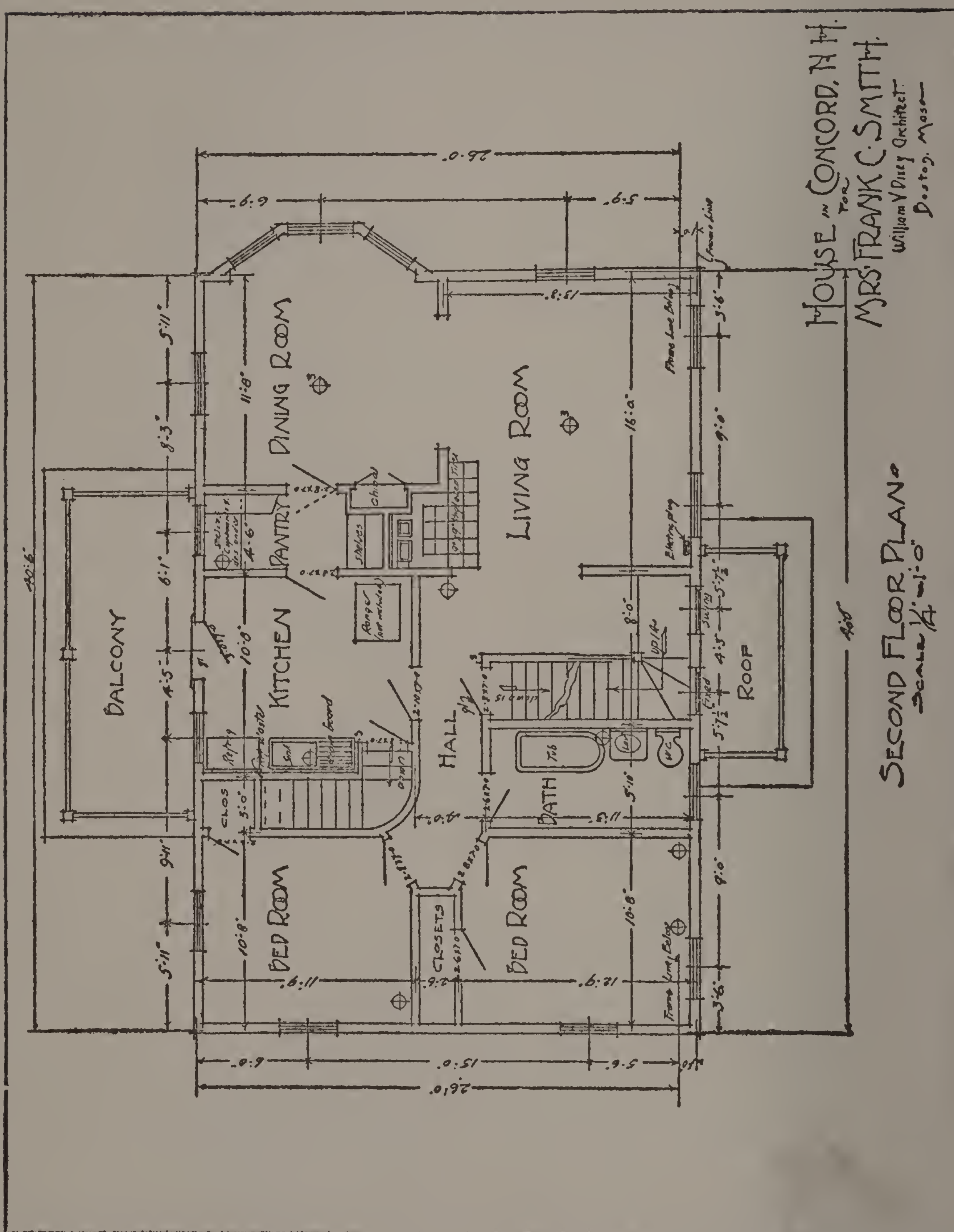


Fig. 134. Second-Floor Working Plan for a Residence.

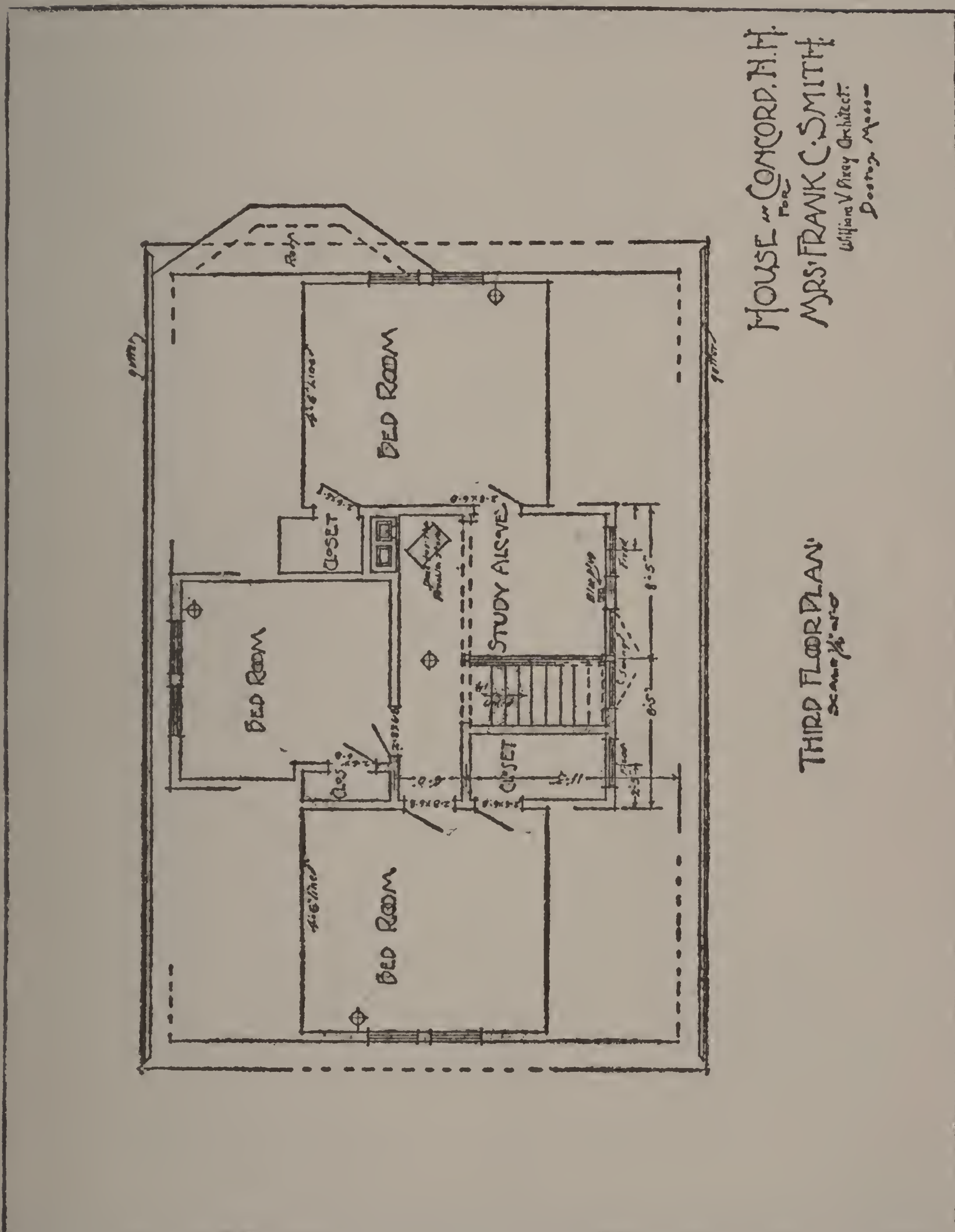


Fig. 135. Third-Floor Working Plan for a Residence.

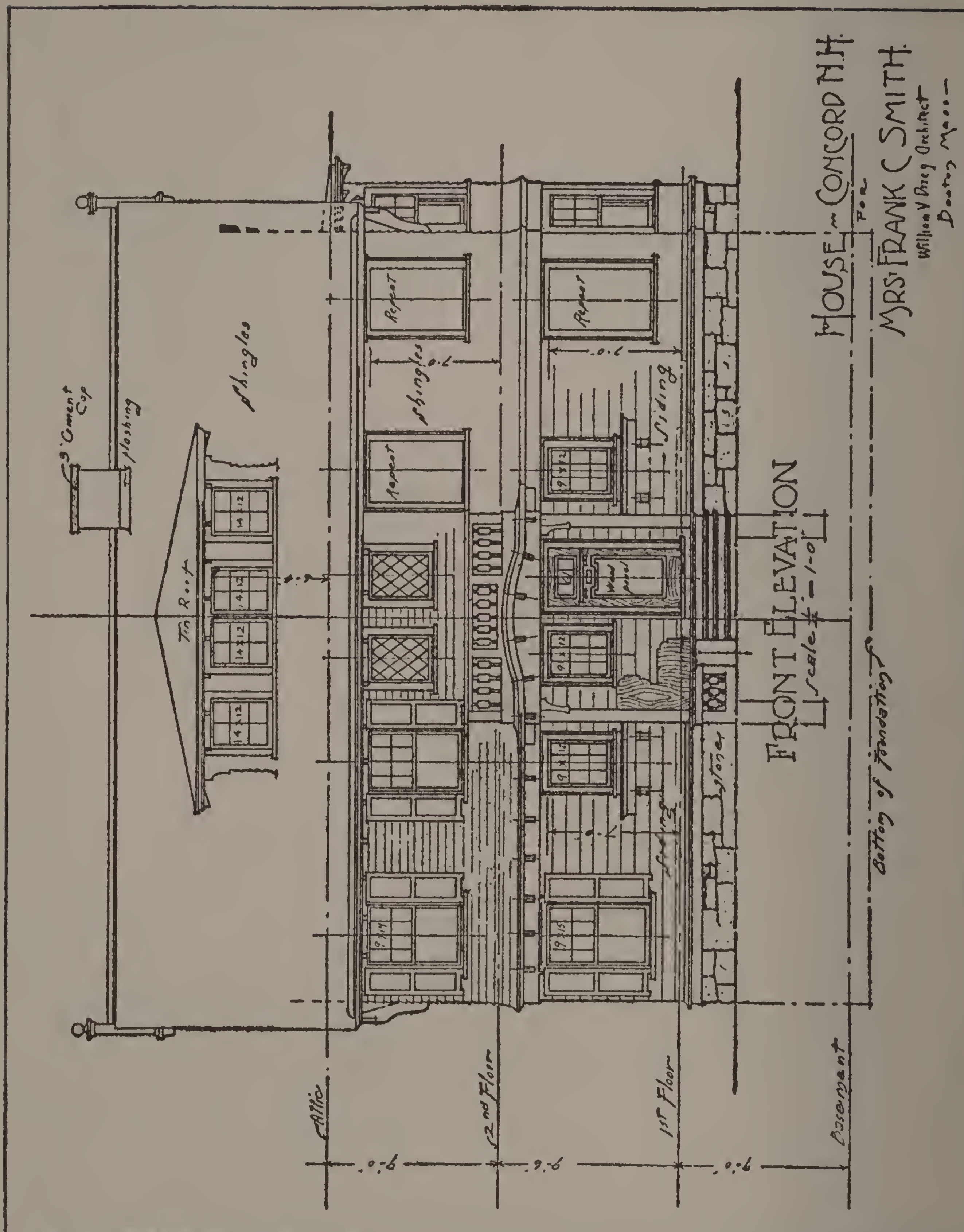


Fig. 136. Front Elevation for a Residence.

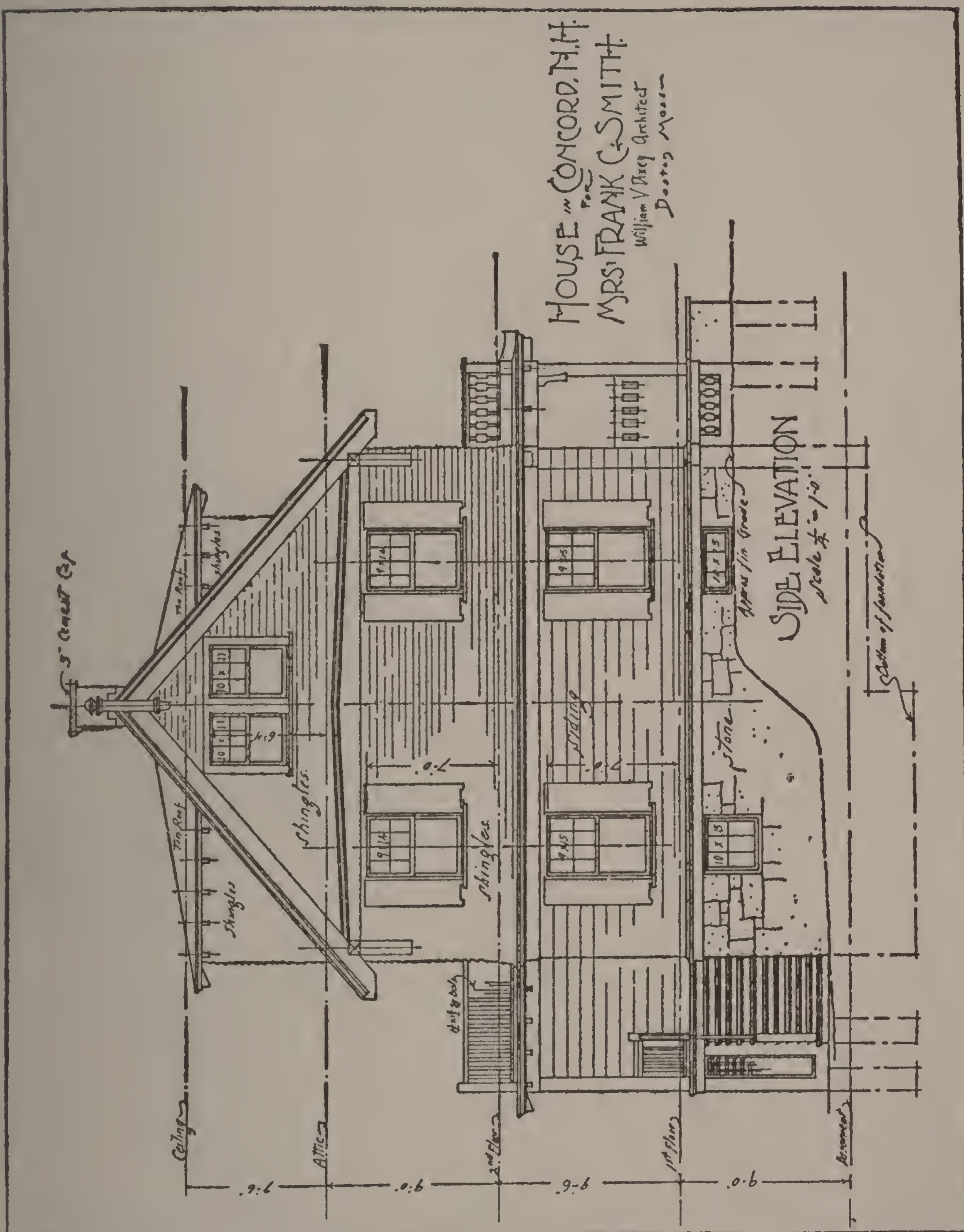


Fig. 137. Left Side Elevation for a Residence.

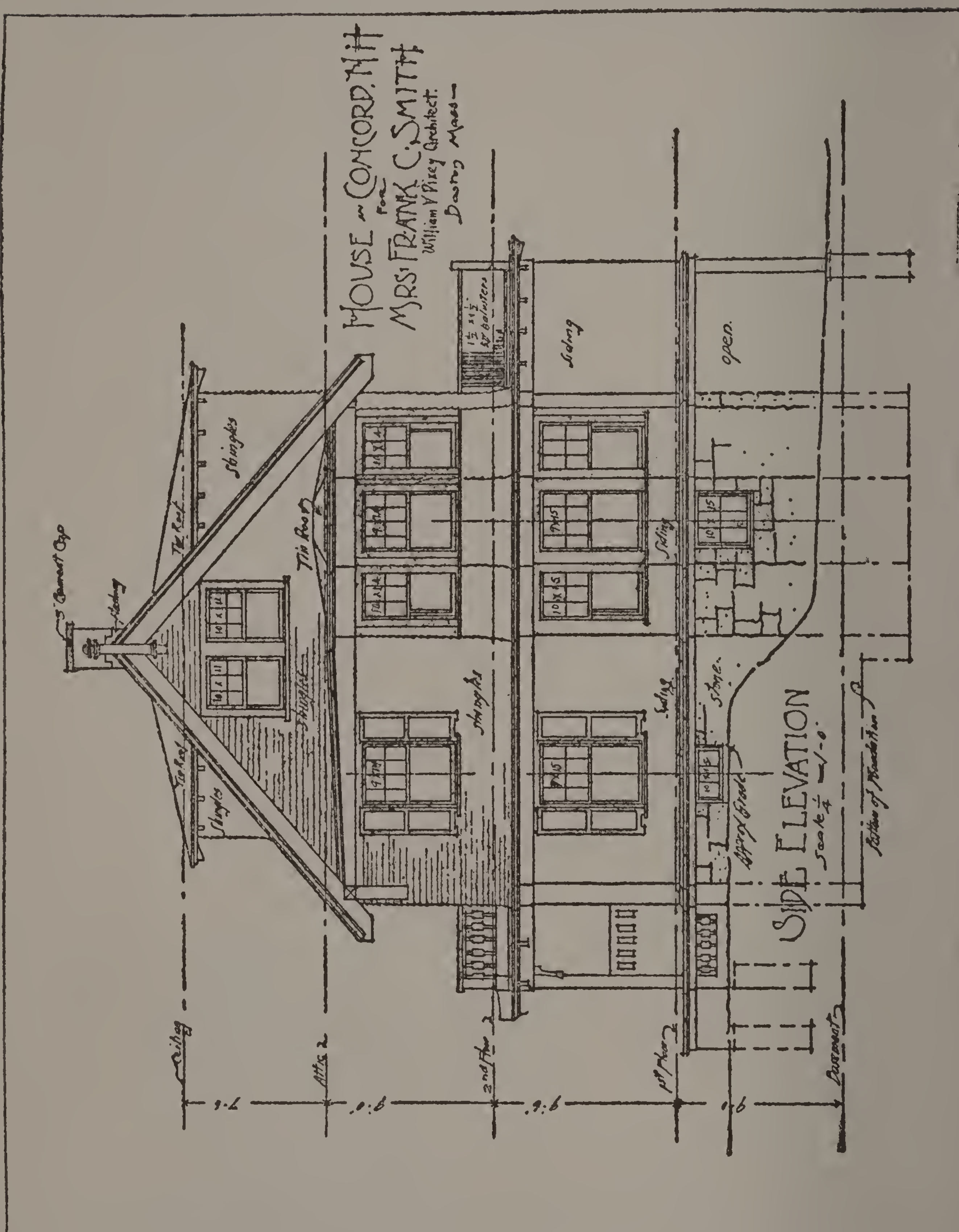


Fig. 138. Right Side Elevation for a Residence.

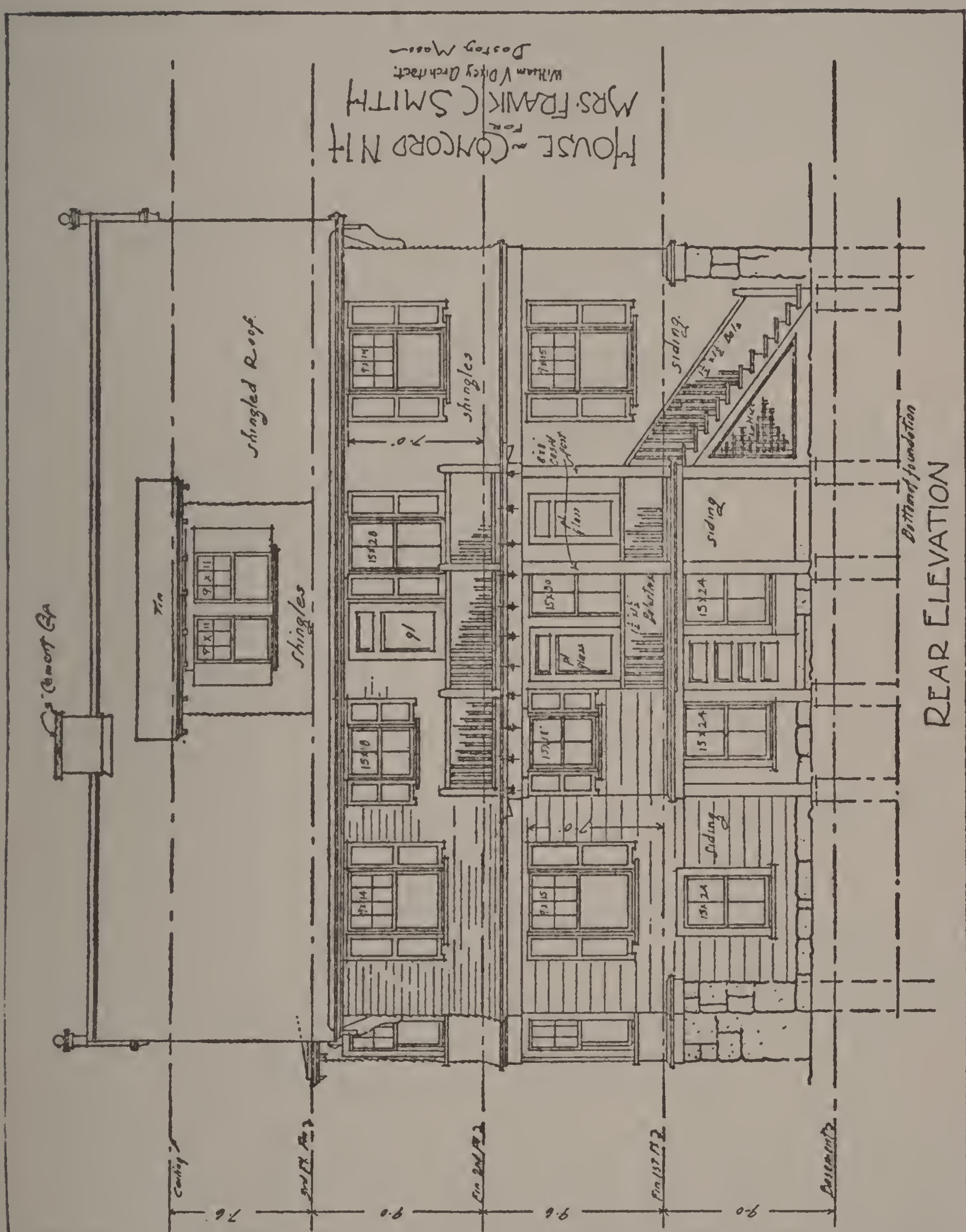


Fig. 139. Rear Elevation for a Residence.

elevations. Care should be taken to compare the different views to see that Fig. 137 is the left side elevation, and Fig. 138 the elevation of the right side. The elevations are to show the distances between floors, arrangement of windows and sizes of glass, and in general the exterior finish, as shingles, siding, etc.

For these drawings a separate roof plan was not required.

STRUCTURAL DRAFTING

148. By **structural drafting** is meant the drafting of the iron and steel framework which enters so largely into the construction of the steel bridge and the modern office or commercial building.

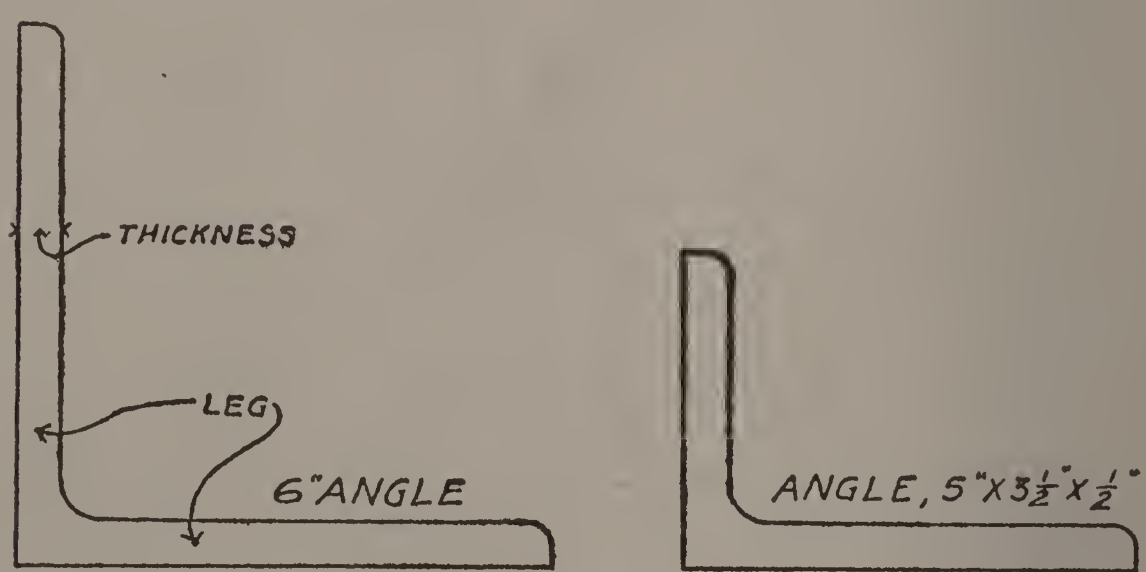


Fig. 140. Steel Angles with Even and Uneven Legs.

It is impracticable within the limits of the present work to enter into any extended discussion of the theoretical and practical questions which arise in connection with this subject; and it is therefore the intention to

ILLUSTRATING EVIL EFFECT OF DISREGARDING BUILDING LINE.

present only the elementary principles and fundamentals, with examples from actual practice. Equipped with this understanding of the essentials, the draftsman should be able to

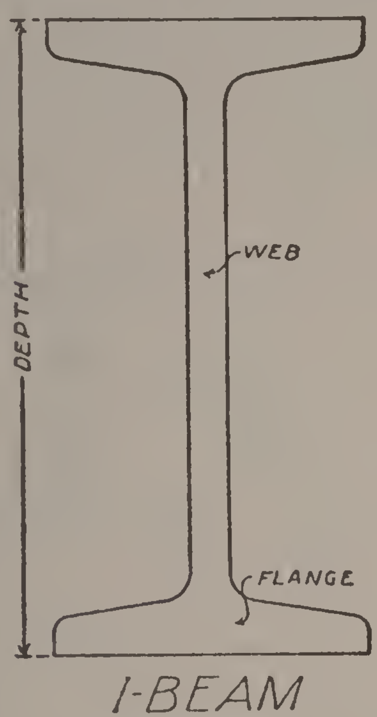


Fig. 141.

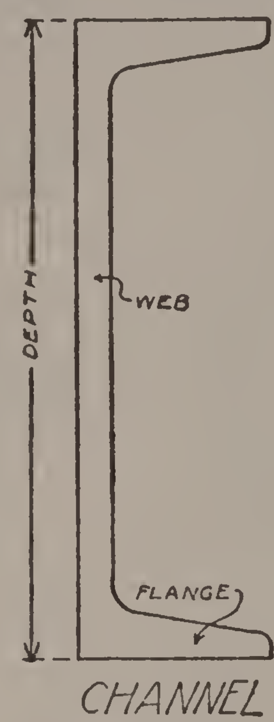


Fig. 142.

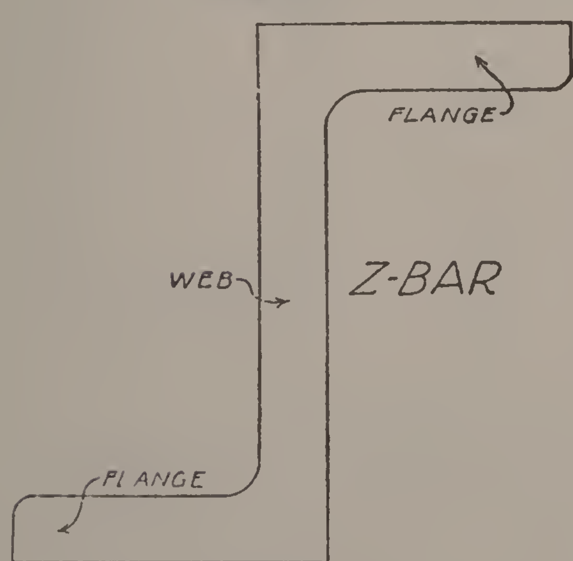


Fig. 143.

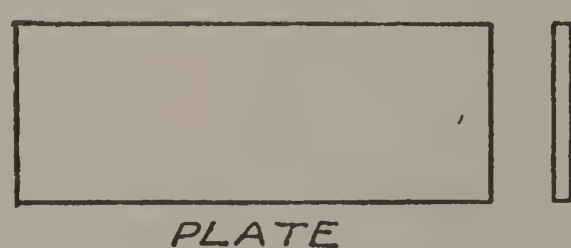


Fig. 144.

Representations of Steel Shapes.

readily fall into line with the practice in any particular drafting room.

The various pieces which are used in steel building construction are largely of certain standard shapes and sizes which are rolled in the mills. Types of the usual elementary forms are shown in Figs. 140 to 144. These views show the pieces endwise, thus representing the actual shape. The **angles**, Fig. 140, with even and uneven legs, are made in various standard sizes, and are listed in the handbooks issued by the various steel companies.

Fig. 145.

Fig. 146.

Fig. 147.

Fig. 148.

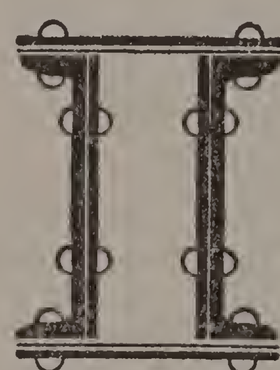


Fig. 149.

Fig. 150.

Forms of Riveted Columns.

Solid and Built-Up Members. The **beams, girders**, and **columns** may be of one piece, or composed of some of the elementary parts riveted together. Thus a beam or girder may be of the I-beam style, Fig. 141, in one solid piece; or it may be formed as in Fig. 146, of a plate and four angles riveted together.

Angles (Fig. 140), **channels** (Fig. 142), **Z-bars** (Fig. 143), and **plates** (Fig. 144), are the elementary parts most used in the construction of built-up girders and columns. The I-beam is commonly used as a beam or girder, while the uprights or columns are usually of the built-up variety.

Figs. 145 to 152 show in section some of the common forms of riveted columns. These

Fig. 151.

Fig. 152.

Forms of Riveted Columns.

columns, as shown in the figures, are variously made up of angles, plates, channels, Z-bars, and lacing or lattice-work. The light lines of Figs. 145 and 148 indicate lattice-work or lacing (see Figs. 153 and 154); and the heavy lines of the other figures are plates. Fig. 145, for example,

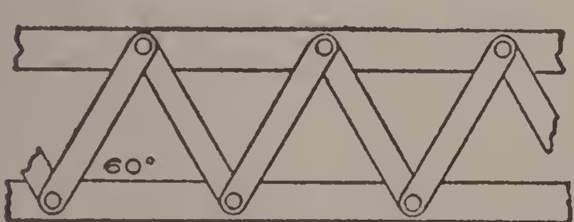


Fig. 153.

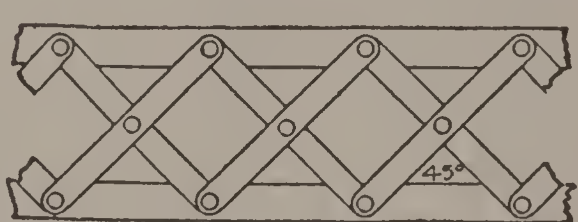


Fig. 154.

Types of Lattice-Work or Lacing.

is the section of a column composed of four angles latticed together. Fig. 147 represents a column formed of four angles riveted to a middle plate and reinforced by two other plates at the top and the bottom. In these figures, the narrow spaces left between the members which are riveted together are for the sake of showing the arrangement more clearly, and of course do not mean that such spaces exist on the actual column.

Rivets and Bolts. In fastening the various steel shapes together, rivets or bolts are used. When bolts are employed, they are generally square-headed, with V threads, and are represented in the customary manner (see "Dimensioning of Bolts," under Article 140).

Rivets are very largely used for fastening together the different members of a built-up beam or column, and for making connections with other beams. The hole for the rivet is made from $^1/_{32}$ inch to $^1/_{16}$ inch larger than the rivet. Rivets are driven hot, the metal being forced to fill the slightly larger hole. Riveting is done in two ways, by hand and by machine.

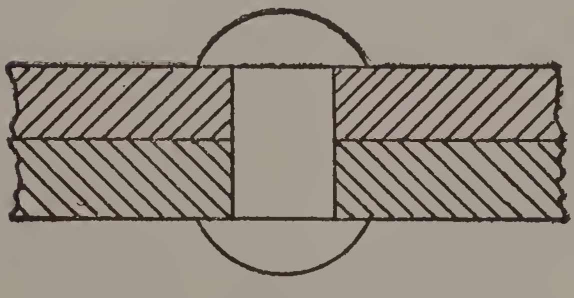


Fig. 155. Machine-Driven Rivet.

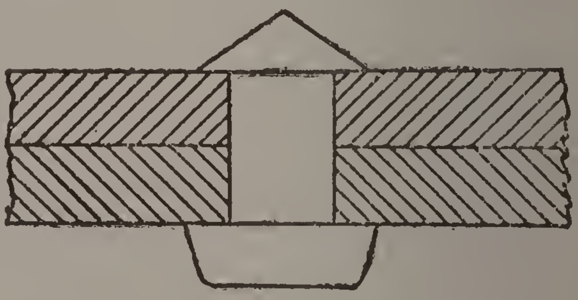


Fig. 156. Hand-Driven Rivet.

Fig. 155 shows a machine-driven rivet; and Fig. 156, one driven by hand. As far as practicable, riveting is done in the shop, and this is known as **shop riveting**; some riveting, however, must necessarily be done at the place of construction, and this is known as **field riveting**.

On the drawing, the rivets to be shop-driven are shown in position with the heads drawn; while for those to be riveted in the field, only the holes are shown, blacked in. This distinction is illustrated in Fig. 157, which is taken from a working drawing of one end of a bridge strut. This strut is composed of four angles

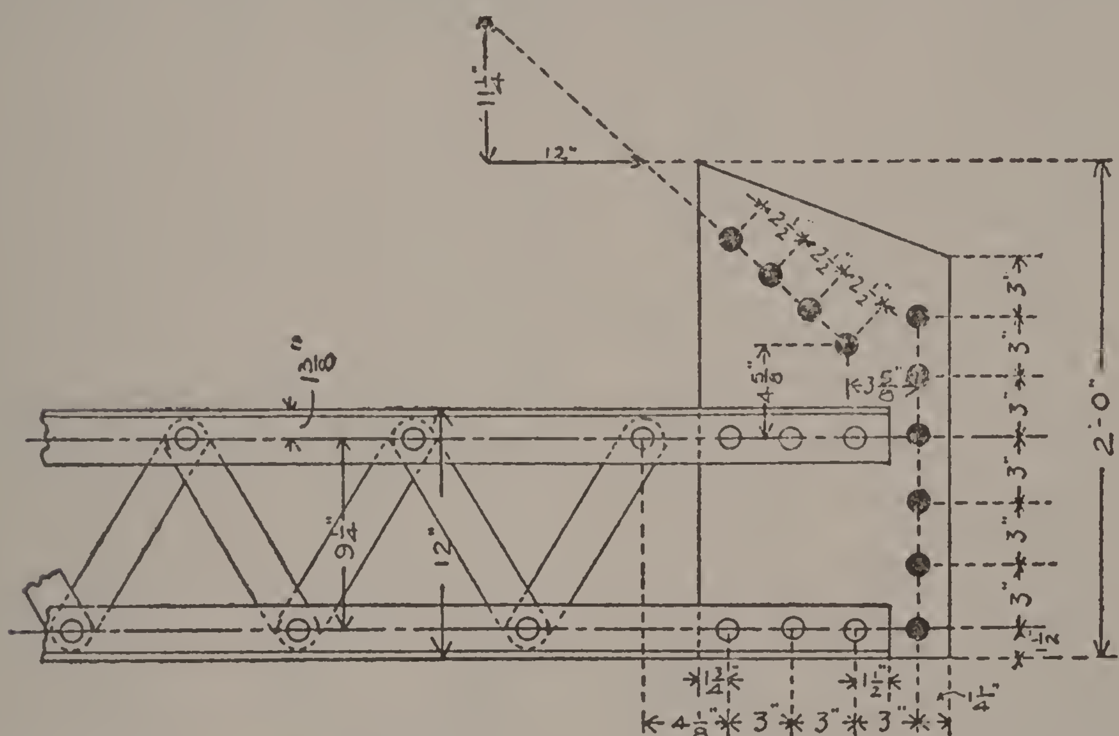


Fig. 157. Illustrating Method of Indicating Shop and Field Rivets.

laced together, like the column shown in section in Fig. 145, two angles at the top, and two at the bottom. The blank circles at the ends of the lacing bars, and those at the ends of the angles, are the heads of the shop-driven rivets, while the black holes are for the rivets which are to be driven in the field. These latter rivets are those by which the strut is to be fastened in position.

Besides the general distinction between shop-driven and field-driven rivets, other differ-

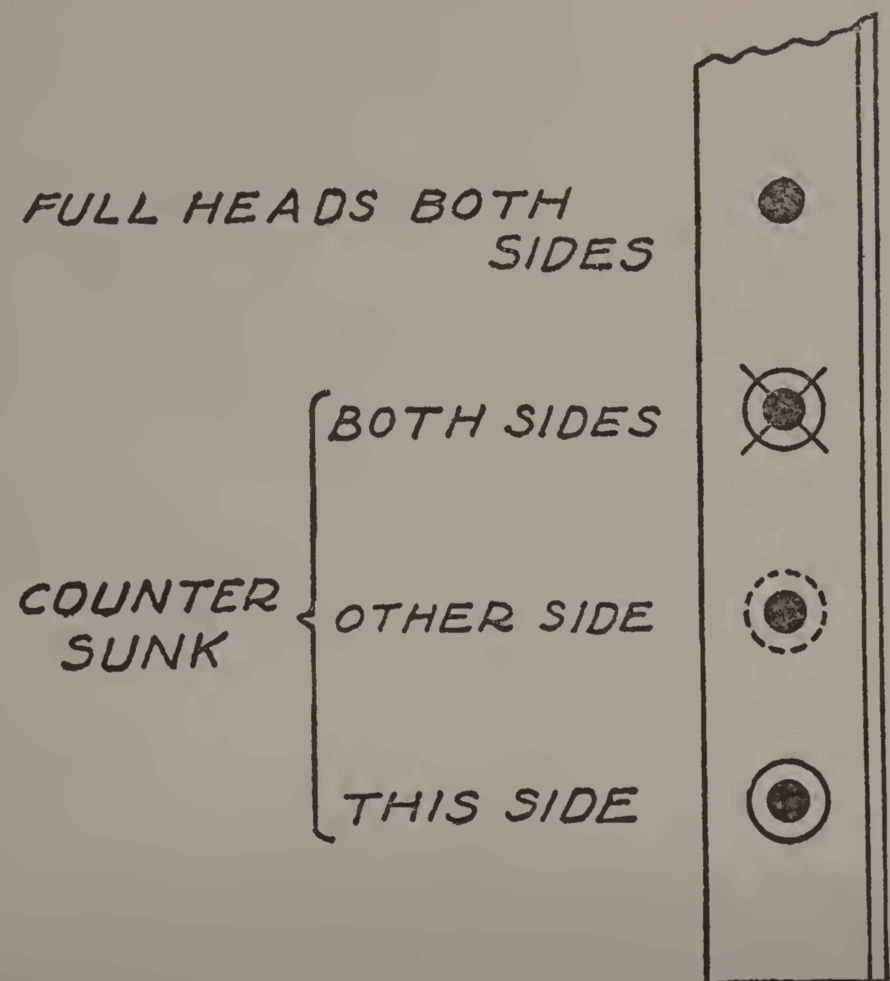


Fig. 158.

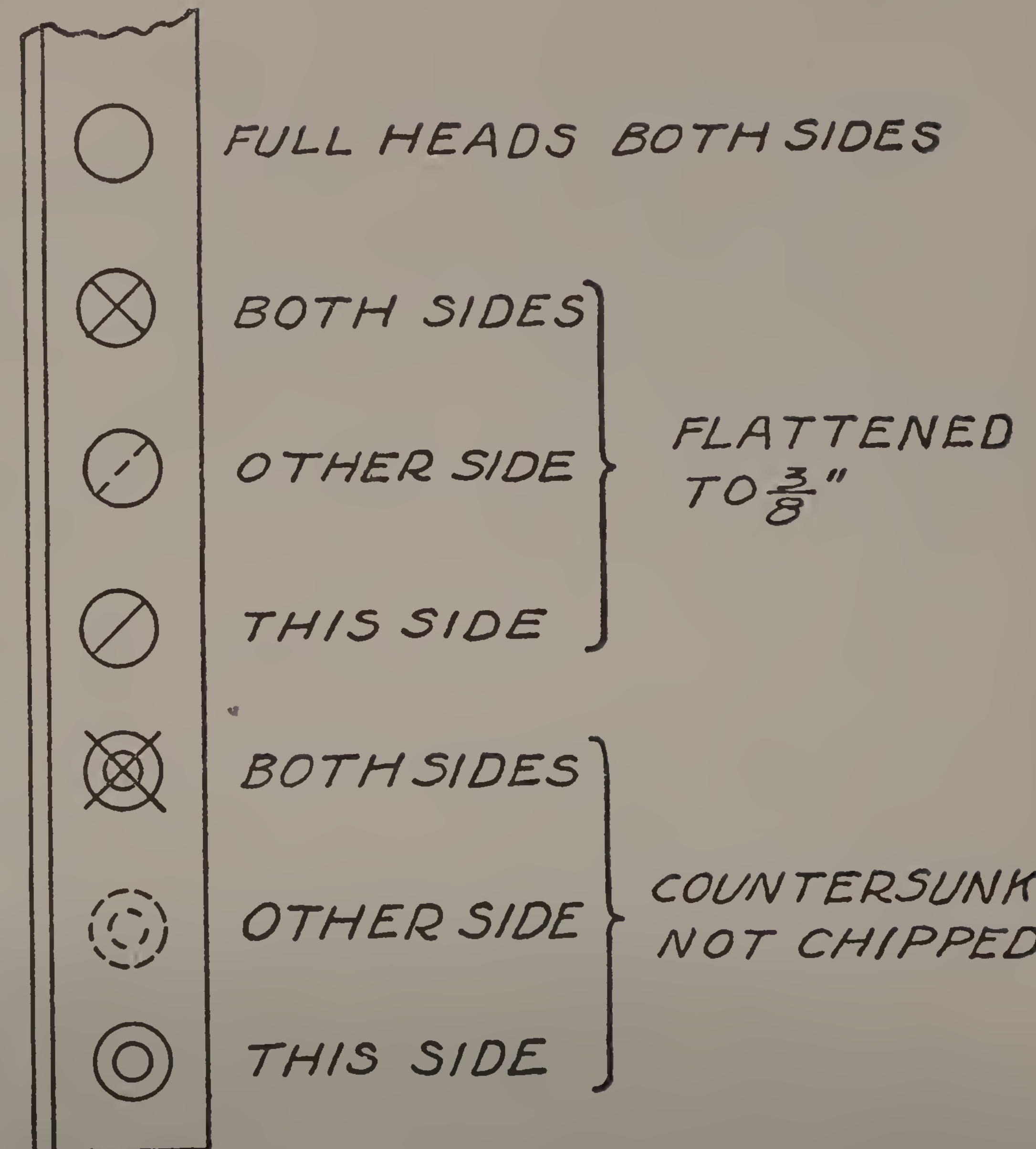


Fig. 159.

Conventional Methods of Indicating Kinds of Heads for Rivets—Standard of American Bridge Company.

ences are made in the drawing to denote the kind of **rivet-head.** The conventional manner of indicating the kind of head to be made on a rivet is shown in Figs. 158 and 159, which are according to the standard of the American Bridge Company.

It will be seen that the distinguishing feature for field riveting is the small blackened

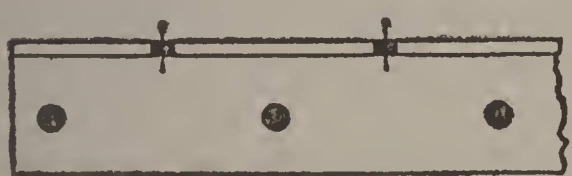


Fig. 160. Rivet-Holes, Shown Black for Field Riveting.

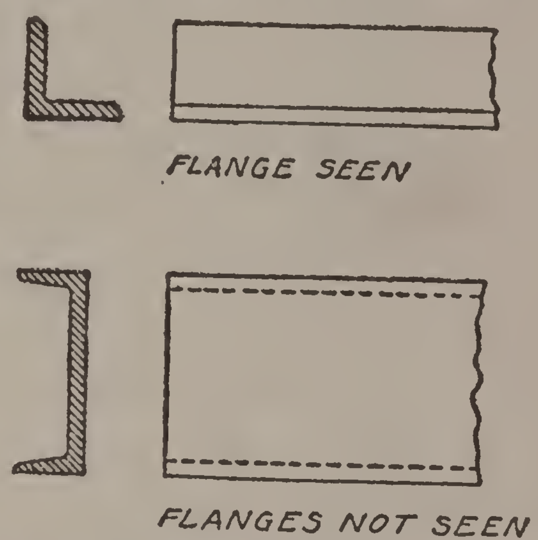


Fig. 162. Method of Indicating Flanges.

Fig. 161. Method of Indicating Equal Spacing of Rivets.

circle, while all of the different heads for the shop rivets are left light. A small inner circle invariably stands for at least one countersunk head. On the side or end view of a structural shape, if the rivet is to be driven in the field, the rivet-hole is shown black, as in Fig. 160.

When a line of rivets is to be located with equal spaces between, it is better to express the spacing as in Fig. 161, rather than to repeat

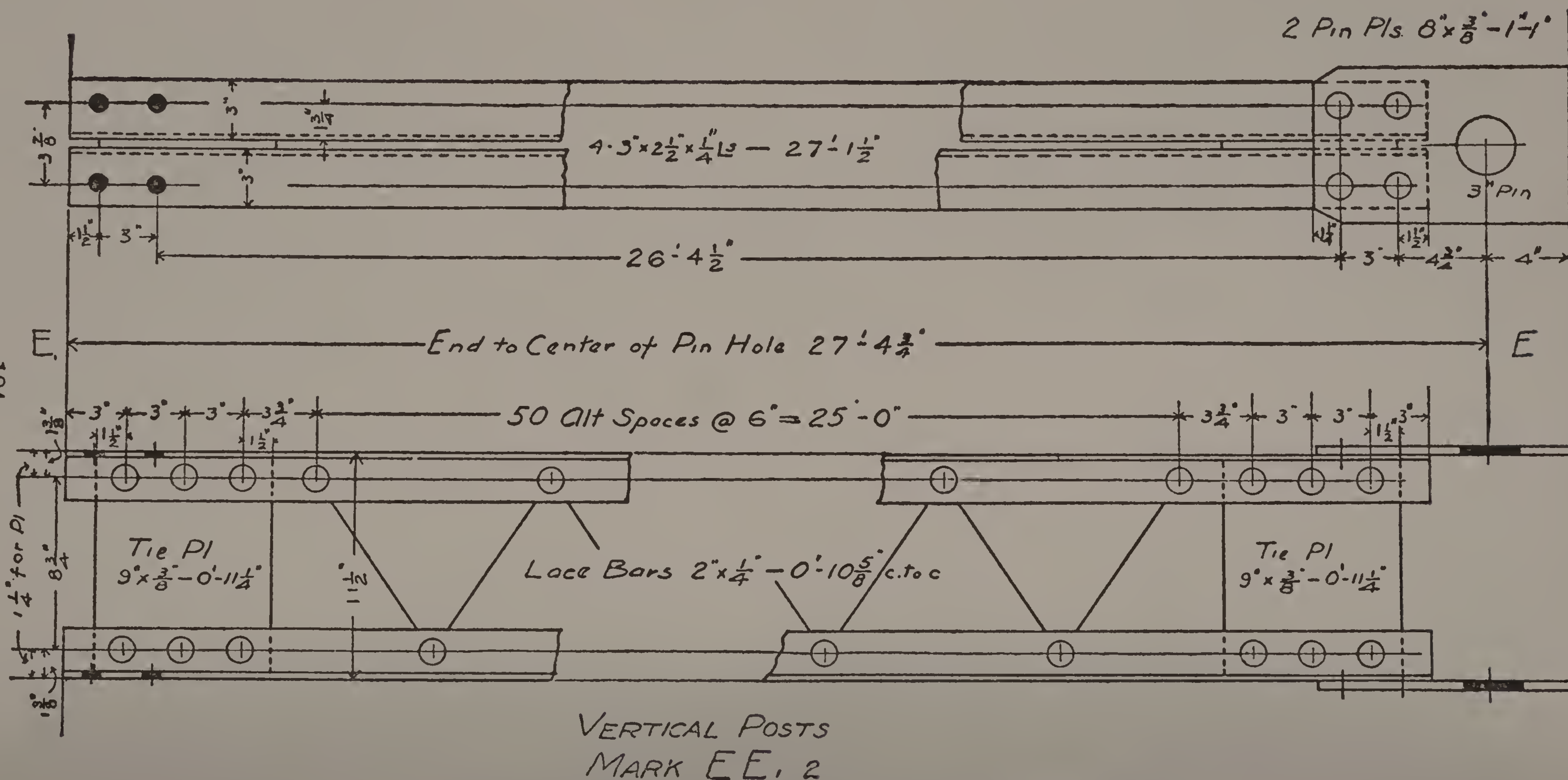


Fig. 163. Details of Vertical Post for Steel Bridge.

many times the same dimension. In case the total distance does not divide evenly by the number of spaces, the total distance may be given, and also the number of equal spaces required.

When the side view of an angle or channel is shown, the flange is represented by two parallel lines—both full, if the flange is on the near side; and one or more dotted, if the back of the shape is shown (see Fig. 162). A similar practice obtains if the other shapes are shown.

Details of a Vertical Post. Fig. 163, from a drawing of the Pittsburg Bridge Company, is the plan and elevation of a vertical post for a steel bridge. The post is made up of four angles laced together. The angles are fastened together at the ends by tie-plates, which, like the lacing bars, pass between the angles and are riveted to them. On the plan (the upper figure), the number (4) of angles used is given, together with the size, 3 in. by 2½ in. by ¼ in.; the symbol for angles is used, instead of the written word; and the total length of the angles is given. The hole for the 3-inch pin is located from each end of the pin-plates; and its distance from the further end of the angles is also shown.

The expression "50 Alt. Spaces @ 6″ = 25′-0″," lettered just above the elevation, means that fifty alternate spaces between rivets, each space equal to six inches, amounts to a total distance of twenty-five feet between the first and last rivets of the series. The term **alternate spaces** means that each 6-inch space is the distance that any rivet in one row is in advance of the nearest rivet in the other row. The distance, therefore, between any two consecutive rivets in the same row is 12 inches. Notice that the lacing bars are indicated merely by the center lines, and that the length as given is from center to center.

This drawing illustrates actual drafting-room practice, such as the customary method of representing the angles, the manner of locating the rivet centers, the giving of the overall length of the angles, and also the distinction between the shop- and the field-driven rivets. According to the drawing, all of the rivets are to have full heads, both sides (see Figs. 158 and 159).

BUNGALOW DESIGN RENDERED IN PEN AND INK.

Architectural Drafting

It would be a commonplace to insist on the advantage to all property owners and to all classes of workers engaged in building construction, of a knowledge of the principles of architectural design. It is equally important that they should know how to read and interpret intelligently the working drawings that are the guides to the details of actual construction, and, if need be, to make these drawings themselves.

GENERAL REQUIREMENTS

The first impression given by a set of drawings applies as well in Architecture as in any other line of work. So often we hear it said, "It certainly makes a good impression." Applying this same principle to architecture, let us consider a few general requirements in order to finish a set of plans in the best manner, and also have them appeal to a person not familiar with architectural work.

The drawings should be complete in every respect. They should be fully dimensioned with plain figures; all material plainly marked by arrows; each room named, for the sake of reference; and the various parts of the work carefully explained by explanatory notes. Make these notes clear, concise, and with no mistaking the part to which they refer. While the title of each page may be lettered in a more elaborate letter, make all explanatory notes plainly lettered. Drawings in general have but few notes of explanation. Make it a rule to explain fully all the questionable portions of a building. This applies to the plans, as well as the elevations, sections, and details. In the arrangement of notes, if there are those that do not refer to any particular portion of the drawing, place these notes over the sheet, to make it well balanced. Do not try to crowd them into one corner of the sheet or along one edge. Place them where they will make the drawing as a whole look the best.

Architectural drawings should have some character to them; the lines should be firm and straight, making them a full, even thickness. Very often good drawings are spoiled by the lines being very poor and also too faint. Use a good, heavy line, and make it look as if it was there for a purpose.

One way in which a drawing can be made attractive and "snappy," as you will hear architects say, is to overrun all corners and intersections of lines, slightly. In mechanical drafting other than the work of the architects, it is always required to stop the lines at the corners, making the drawing exact and very mechanical in appearance. The architect, however, is

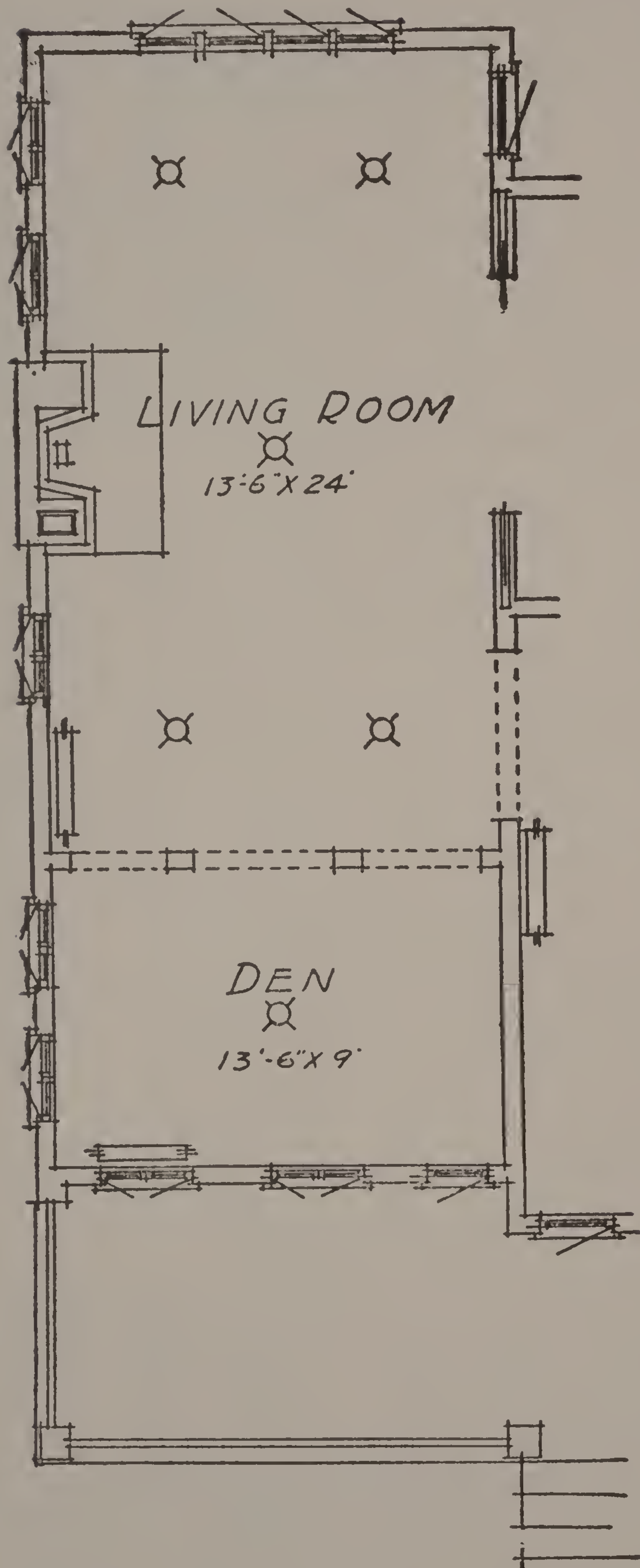


Fig. 1. Part Plan, Showing Method of Overrunning Corners.

allowed some liberties in his work. He will resort to methods, to improve the looks of his drawings, which would not be permissible in other work.

Referring to Fig. 1, it will be seen that the corners and intersections are emphasized by the overrunning of the lines. This does not mean long lines past the corners, but just enough to show a sharp intersection. A little practice will soon enable a draftsman to do this work skilfully, and once this method is adopted it will be used on all future work, as there is no comparison in the general attractive appearance of two drawings, in one of which this method is used, and in the other the strict mechanical method is adhered to. The actual time consumed in getting out a drawing is less with the method described than with the true mechanical drawing, in which it is necessary to start and stop at exactly a certain point. In mechanical drawing, it is frequently necessary, after two lines at an angle have been drawn, to go over the first line in order to continue it a short distance to the exact corner.

Very often, a few minutes spent on careful lettering, indicating materials, and an additional explanatory note, will be the winning feature of a set of drawings.

Too much emphasis cannot be placed upon always being on time, whether in office work or in getting out drawings. When a time is set for the completion of any drawing, or a time of meeting arranged, have your work ready at that time, and keep your appointment exactly as arranged. Before setting a time of completion, be sure you are giving yourself time to do the work completely, and then see to it that your work is ready at that time.

The architect's services usually consist in preparing the necessary studies or preliminary sketches, working drawings, specifications, and large-scale and full-size details, together with a general supervision of the work. For this service, there is usually a price based upon a minimum percentage of the completed work. This percentage varies in different States and localities, from 3½ to 7 per cent. As the work progresses, or different sets of drawings are completed, payments are made. If we consider the architect receiving five per cent commission, one-fifth the entire fee is due upon the completion of the preliminary sketches, two-fifths upon the completion of the working drawings and specifications, the balance being paid as the work progresses. This percentage is based on the total cost of the buildings. These prices are those adopted by the Chicago Architects' Business Association. Should work on the drawings be abandoned, a charge should be made for services for the amount of work done.

This will give an idea as to the general prices charged, and the usual times of payment. It does not pay to do work at a small percentage, for the work on the drawings and specifications will necessarily have to be inferior and incomplete.

The scales at which drawings are usually made are 1/8 in., 1/4 in., 1/2 in., 3/8 in., 3/4 in., 1 1/2 in., and 3 in., to the foot. These are convenient for all parties concerned. We see that by using the first three scales we can use the regular divisions on a rule, without having an architect's scale. The last scales are also convenient for the same reason. Take, for instance, a detail drawn at 3-inch scale; then we see that 1/4 inch equals one inch, and an ordinary rule can be used to advantage. On the actual construction work, the foreman always uses his two-foot rule for scaling the drawings; and if the above scales are used, they are easily read from an ordinary rule.

A complete set of drawings should include a survey, or City Engineer's plan, of the lot, on which the outline of the building is marked; a foundation plan; a plan for each floor; a roof plan; an elevation of each side of the house; all necessary 3/4-inch scale detail sections; all necessary elevations of interior finish; large-scale details of the window-frames and sash and interior trim; and any other details of unusual construction. After the contract is let, then get out full-sized details.

Should any changes be necessary after the drawings are completed, secure the owner's written order for such changes. If everything

DORMER WITH DECORATIVE FEATURES FROM ANCIENT AMERICAN INDIAN DESIGNS.

OLD ENGLISH INN WITH LATTICED DORMER.

is in writing, there can be no cause for dispute, especially in the matter of changes.

METHOD OF GETTING OUT DRAWINGS

The prospective client, by appointment or otherwise, meets the architect in his office. The general scheme is talked over, and the various subjects are discussed, such as the lot, location, size, etc.; the amount to be put into the building, or the cost; the time of beginning and completion; the owner's general idea of the requirements; and the architect's fee. A time is set for the getting-out of the preliminary sketches. All of this information is arranged, and entered in a book for future reference.

At the appointed time, the client appears again, and the preliminary sketches are talked over, changed, and revised, and any new information is noted. After another visit or two by the client, the sketches are accepted. The working drawings are begun, usually made at 1/8-inch or 1/4-inch scale. These drawings are carefully inspected by the head draftsman, numbered, dated, and signed.

These drawings are then reproduced by some method—usually blue-printed—bound, and sent to the contractors for bids or proposals on the work. After the contract has been let, the full-sized drawings are made.

ARCHITECTURAL DRAWINGS

Architectural drawings may be classified as follows:

- Preliminary Drawings
  - Sketches
  - Perspective Sketches
  - Competition Drawings
- Working Drawings
  - General
  - Detail
    - Scale Details
    - Full-Size Details

Preliminary Drawings

Preliminary drawings are small studies of the proposed new work, freehand or otherwise, at a small scale, finished in an attractive manner. There are three classes of preliminary drawings—namely, Sketches, Perspectives, and Competitive Sketches.

Preliminary Sketches. In architectural work, no matter whether you are an architect dealing with an owner or client, or a draftsman getting out working drawings, it is always better to make a preliminary sketch of the arrangement, detail, etc., as it saves time and much erasing and changing on the scale drawings. By preliminary sketches we mean the sketching freehand on paper to show exactly just how you will draw it with the T-square and triangles.

Let us consider the architect dealing with a client. The first thing is an arrangement of the rooms, or the plan is first studied. For this work, tracing paper will be found very easy to work with and very convenient. The use of a sheet of co-ordinate paper under the tracing paper will be found very convenient. The squares on the co-ordinate paper will serve as a guide in drawing straight lines; and also the squares as ruled on this paper can be used as a scale—one square representing one unit, as a foot or an inch.

Very often the owner of the proposed new building will have some scheme or arrangement of rooms that he would like; therefore, try to have him give you a rough sketch of such arrangement; even a drawing with single lines for walls, and cross-lines indicating windows, will be very helpful. A drawing as shown in Fig. 2 is just what you want from your client.

Having received either this sketch or a list of the requirements, you are ready to start your preliminary sketches. Spread down the co-ordinate paper, and over this lay a sheet of tracing paper. These may be held down with thumb-tacks or weights of some sort placed on opposite ends. Assume each square of the paper to represent some unit, as one inch, or one foot, or ten feet; and lay out first the property lines. Then commence on the building proper. Make no attempt at trying to make exact lines; let these sketches be more of freehand drawing. Mark off the approximate sizes of rooms by rectangles, and try the various arrangements,

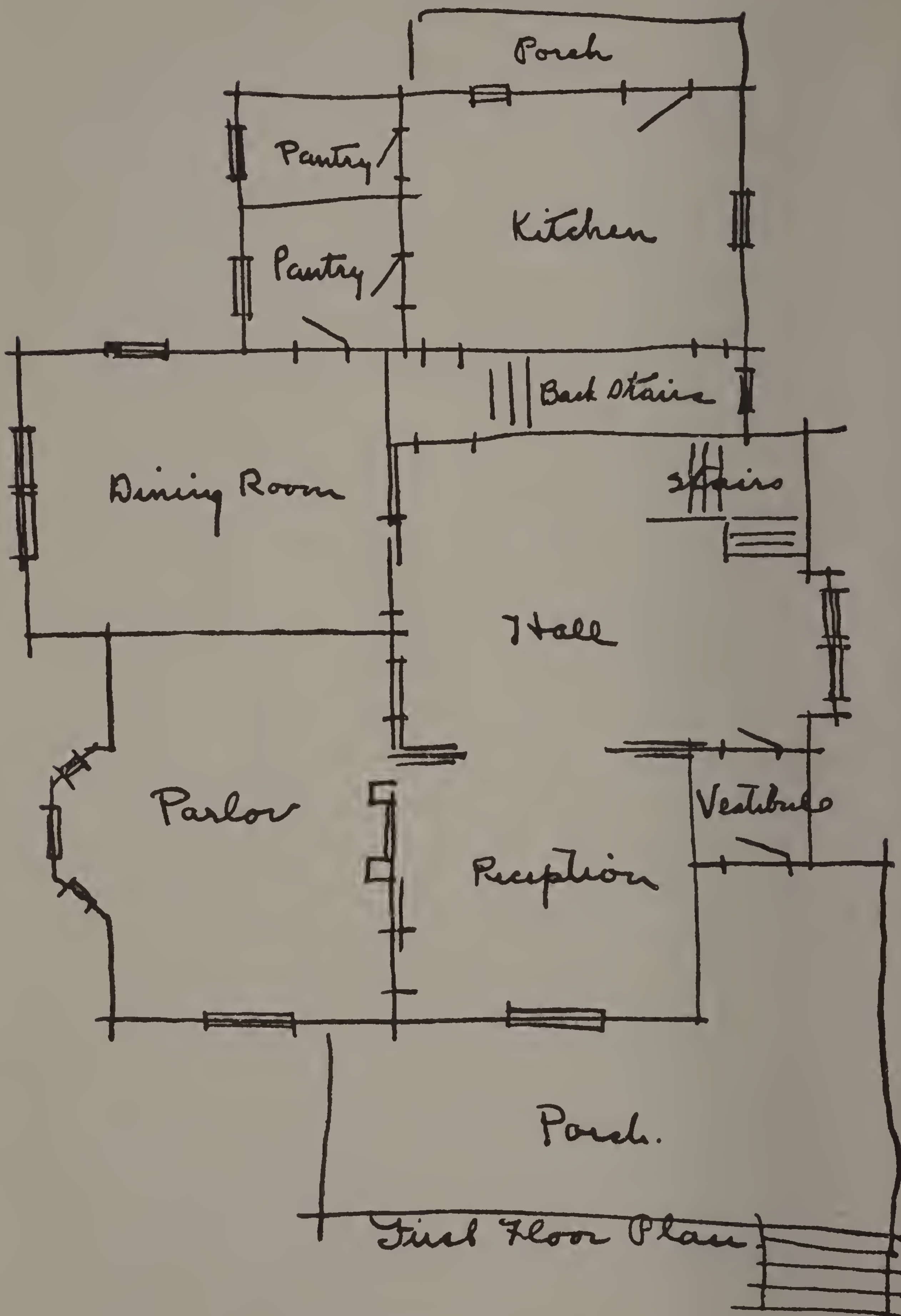


Fig. 2. A Single-Line Sketch Submitted, from which the Architect Gets an Idea of the Arrangement.

endeavoring to secure an ideal arrangement. Make no attempt at trying to show double lines for wall lines; let it be a free and easy sketch of single lines.

Don't be satisfied with one arrangement of the given requirements. Over this first sketch lay another sheet of tracing paper. Perhaps you can use some parts of the first sketch, and revise other parts. Study your problem, and be fully acquainted with the requirements. After completing this second arrangement, try to imagine difficulties that this arrangement would present, and how they might be remedied. Make another sketch; don't be satisfied until you have made half a dozen different sketches. After having considered all the possible arrangements of the requirements, then take the sketches, spread them all out before you, and see if you have solved the problem.

Now commence with a clean sheet of tracing paper over the co-ordinate paper, and make finished sketches; that is, lay out the wall lines carefully, put in the windows and doors, letter the rooms, and get these drawings into shape to submit them to the client. Make them so that he will understand clearly the arrangement you have sketched.

For filling in the walls to indicate the walls and the windows, it will help the appearance to color the walls on the back side of the paper with the pencil. This gives a subdued color to the walls, and increases the clearness of the plan or drawing.

Prepare small sketches of possible treatment of the elevations, and submit these also with the plan. These will now do for you to submit to your client (see Fig. 3). Be very sure that you have studied the problem thoroughly, and be prepared to answer all questions your client will probably ask. The client will very soon form an opinion of your ability by the way you handle his work.

When these first preliminary sketches are ready, notify your client, unless you have had a previous time of meeting set. If this be the case, then be sure to have your work ready for him at the appointed time. Remember, your client is a busy business man, a man who is always used to keeping his appointments, and expects everyone to keep theirs.

After these first sketches have been submitted, and carefully gone over, make an appointment for the next meeting, at which time you will have the final preliminary sketches ready. There will always be changes and additions on these sketches; and the fewer times the client has to be consulted, the better impression you will make. Therefore, after this first meeting, understand thoroughly your client's objections and changes, ask questions to make sure you do understand, and go back to your office determined to make the revisions

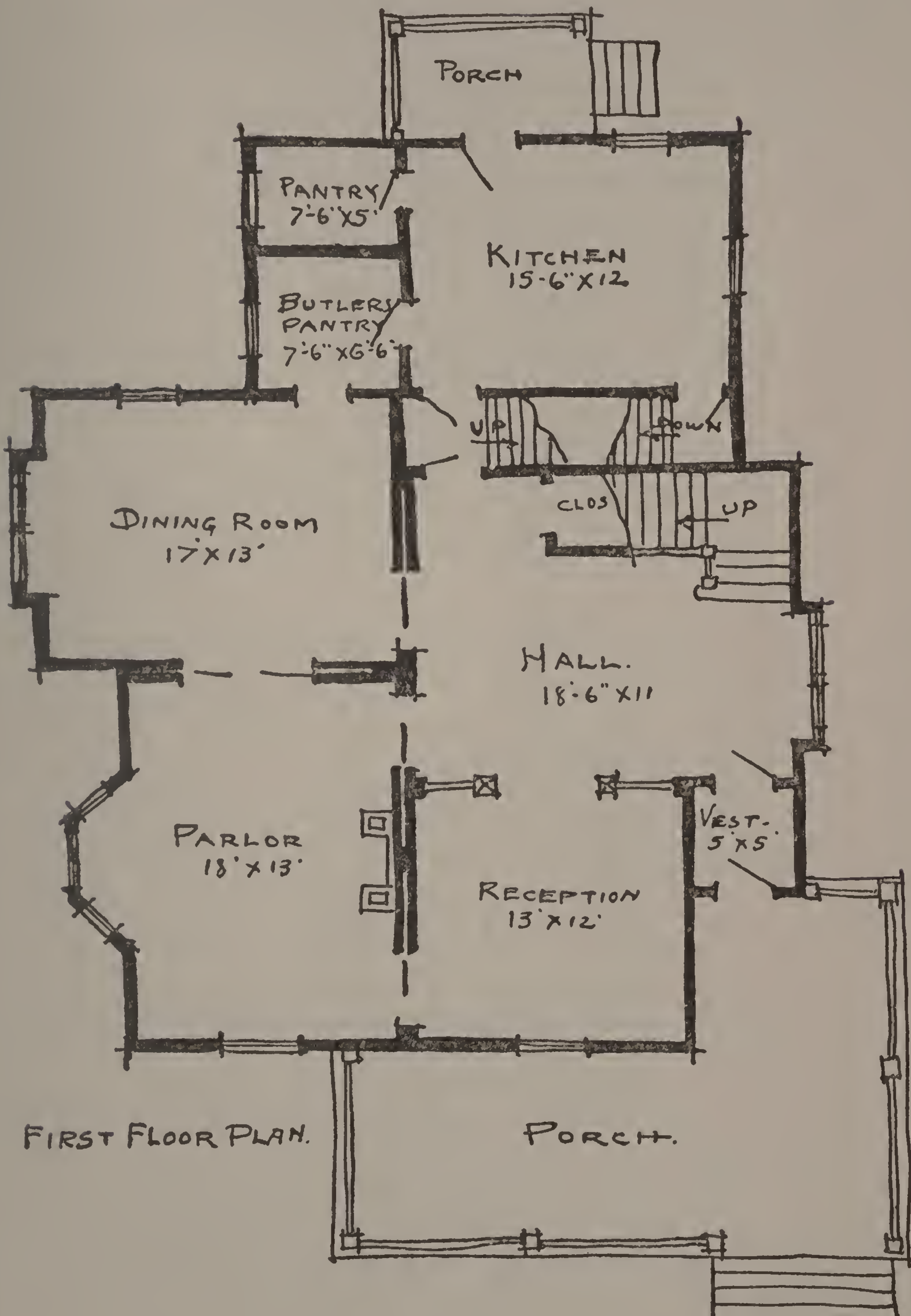


Fig. 3. **First Sketch Ready to Submit to Owner.**
Original drawn at scale of 1/8" = 1'-0", all freehand and drawn on co-ordinate paper.

and that the next sketches submitted will be approved.

For the next sketches, it is very often more satisfactory to use the T-square and triangles, and a scale, and make small, sketchy drawings. Tack down your tracing paper, and lay out to a small scale the general arrangement (Fig. 4). Every little detail need not be attempted on these sketches; but make them straight-line drawings, using more care in the finishing of such drawings. Make all plans necessary, showing the arrangement on all floors; also an elevation. Make them attractive, and letter completely.

The next meeting with your client should be the last one so far as the sketches are concerned. Have him look over all your sketches closely; go over them with him, pointing out the changes, telling him the advantages to be gained by this or that arrangement, and convince him that you know your business. He will finally see things your way, and he will tell you to go ahead with the work. If you see he is satisfied with the arrangement as shown him on the sketches, secure if possible his initials of approval (in ink) on each sheet. Don't ask him to "sign these sketches," as if you were an owner and he a lease-holder. If there is anything a business man hesitates to do, it is to sign his name to a paper of any kind. Use a little tact, tell him that you want him to be perfectly satisfied; and in order for him to be sure he is going to

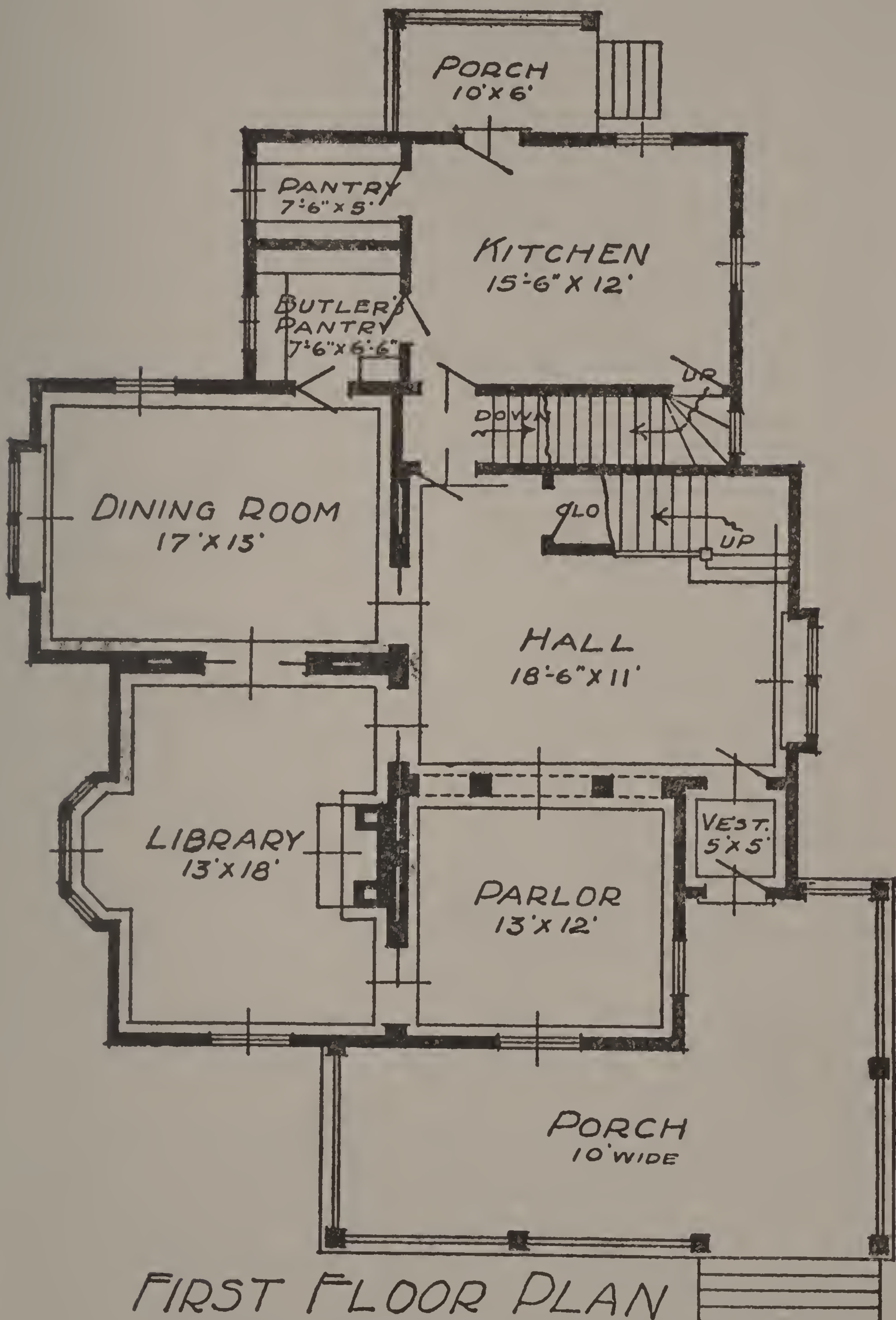


Fig. 4. Final Preliminary Drawing.
Drawn with T-square and triangles to scale.

get the arrangement that suited him, he can O. K. the sketches that he approves, and thereby have a check on the working drawings so that they will be sure to be what he wants. On the other hand, you are protecting yourself by this signature. Very often your client may forget that he ordered this or that change in your sketches; he might in some cases refuse to pay you your agreed commission, because you did not do this or that thing which he ordered. If you have his signature on the sketches, and you have followed these sketches exactly, you will not fear the outcome should the case go to law for settlement.

The same general method of procedure will apply if you are a draftsman getting out scale details. Get out freehand sketches on tracing paper, several of them; decide which is the best method before making the regular scale details. If you are a new man in an office, submit your best sketch for the construction to the head draftsman, and let him see that you are studying your work, endeavoring to get the best method. Learn to make your sketches clear and well executed. This comes only by practice in sketching.

Much time and money can be saved on the cost of getting out the drawings if only you learn to make these sketches well and complete, so that when you are ready to make the final drawings, you can start and know definitely just what they will include.

It will be found very convenient to use a soft pencil. Never use a hard pencil on your drawings, no matter whether they are the sketches or scale drawings.

It is very necessary for a draftsman to know how to make preliminary sketches. Very often a new draftsman's ability along architectural lines is tested by these preliminary sketches, their make-up, the method of getting them out, and the time taken to get them ready. If a firm finds out that you can make attractive and yet practical preliminary sketches, you will soon find out that you will not be required to serve your time at tracing drawings or details, as most draftsmen have to do upon entering a new office.

Perspective Sketches. A **perspective** is a representation of a building or object as it appears from a fixed point. These sketches are usually drawn at a small scale, either freehand or mechanically. The lines should be lightly drawn or sketched, as strong lines will be objectionable in the **rendering** or **coloring** of the drawing. The rendering may be in pencil, ink, watercolor, or sometimes in crayon, and prepared upon almost any kind of paper (see Fig. 5).

Competition Drawings. These are more or less preliminary sketches. As a general thing it is only occasionally that a firm enters a competition; but if it should, let the draftsman show that he knows how to prepare such drawings. By **competition drawings**, we mean drawings that are submitted in a competition. The firms may be invited to submit competition designs, in which case it is called a **closed competition;** or the requirements may be published in some

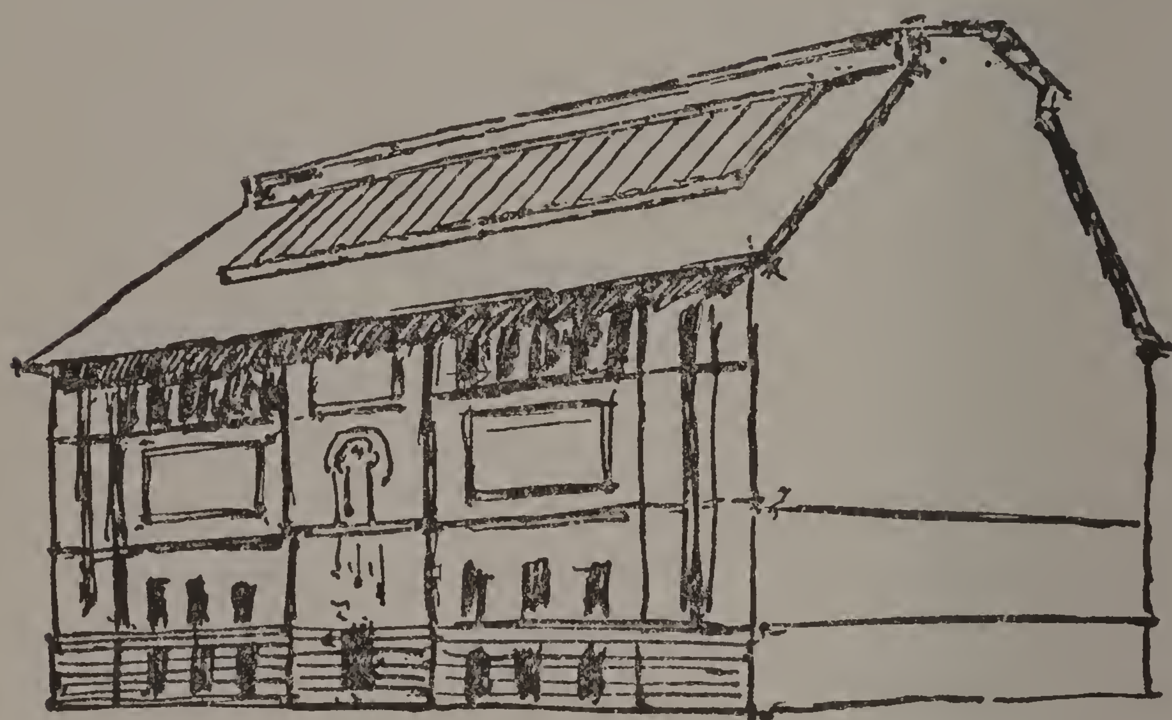


Fig. 5. A Freehand Perspective Sketch.

architectural paper, and anyone may submit drawings, in which case it is called an **open competition.** The drawings submitted for the open competition are more of the nature of sketches than in the closed competition. Usually, in the closed competition, each firm invited to submit drawings will be paid for their work even though unsuccessful in being the winner. There is generally a sum paid for such drawings. Thus, in a closed competition, an architect is paid for his time and can afford to get out a better class of drawings. These are usually drawn on regular drawing paper, carefully laid out to scale, and all inked in. The sheet is then water-colored and made as attractive as possible in this manner. In other words, these drawings are laid out as carefully, except at a much smaller scale, as working drawings; only the important dimensions are put on.

In the open competition, the work is usually done on tracing paper. The plans are laid out at a small scale, made very sketchy, and the pencil is allowed much freedom in the lines. With this sort of drawing, it is necessary to study the requirements, make sketches, and decide for yourself which answers the requirements the best. There will be no client to criticise your work, but you will have to do this for yourself and submit your sketches as final sketches to the client. The first-floor plan is laid out, and the surrounding premises are also laid out. Trees and shrubbery also are put on; and walks, drives, and gardens are shown. Since this is on tracing paper, very little water-color is used. Use the pencil to show everything, and upon your ability to use your pencil—and a soft one, too—will depend much of the success of your drawings. After these sketches have been made, they are lettered and titled attractively, and then mounted on cardboard. This mounting is usually done by pasting the corners only, and not attempting to paste the whole drawing. Ordinarily, a border of some sort is placed around the card, and any other finishing touches that will make the drawing attract attention are added. Thus we see that competition drawings are only preliminary sketches finished a little better than for the ordinary class of work.

Should you be successful in the competition, the method of getting out the working drawings, scale details, and other drawings, is the same as for any other work.

The chances are that you will rarely have a chance to get out competition drawings; but should the opportunity come, grasp it, and do your best.

Working Drawings

By **working drawings** we mean drawings complete in every respect, with dimensions, sizes of rooms, etc. In other words, they are the drawings giving all the necessary information to completely build the structure as drawn. This division of drawings may be divided into **general** and **detail drawings**, the latter being subdivided into **scale** and **full-size.**

The architect who is mindful of his client's welfare will furnish a complete set of drawings. The clearest, simplest, and most exact working drawing is the best. Some architects feel that working drawings do not require the best work. The making of good, clear, complete drawings cannot be emphasized too strongly.

The Plan. In the plan we see an arrangement of the rooms for the different floors that approaches the ideal as nearly as possible. The plan should present the conveniences of arrangement. In the following description we shall consider the plan of a residence, as it will clearly set forth the logical arrangement of parts. The description, as noted, will be limited to residence work, since this class of building is likely to afford a student his first opportunity for independent, original work.

The same reasoning could be extended and applied to any class of building. Usually the first-floor plan is worked out first, as it is the most important, since the greater part of the day is spent in this portion of the house. The upper floors, being used almost entirely for bedrooms or minor rooms, can be worked out to conform to the outline of the first-floor plan. The basement usually is devoted to the heating apparatus and its accessories, the laundry, storerooms, and such. Therefore, the first-floor plan will govern the outline of the basement walls; and the basement rooms will be arranged inside the basement walls, as determined by the first-floor plan.

In residence work we see two classifications—the **city house** and the **country house.** The city house gets its sunlight from the front and rear, being usually built in between adjacent houses where there is no chance of sunlight from the sides. A country house gets its light from all four sides; that is, it is built in a part of town where the lots are of sufficient width to give plenty of light and air. The city house usually has a lot 20 to 30 feet wide, and it is a question of the best arrangement for light as well as comfort. The country house usually has a lot 50 to 60 feet wide; and it is not uncommon to see a house built on two lots, giving all the more room.

Let us, therefore, consider the first-floor plan. Upon entering a residence, we usually step into a **vestibule.** This room, while small and inferior, yet is one of the most important rooms in the house. The vestibule should be **well lighted,** which can be done by means of glass in the front door, by side lights along the sides of the door, by a transom, and by glass in the door leading into the living room. The vestibule should be provided if possible with a closet (it need not be large), in which a person's everyday hats and wraps may be kept, also all rubbers and umbrellas. It is very evident that this will be the first need upon entering a home—a place to dispose of one's coat, hat, etc., before entering the home proper. It is all the more urgent in a mild, rainy climate. In case a closet cannot be provided, there should be a seat with a hinged cover, and a stand for umbrellas, with the usual furniture for holding the coats and hats. This room, as already said, need not be large, as usually not more than two people are ever in the room at the same time. In some residences there is no vestibule, but it is almost a necessity in the best class of work.

DESIGN FOR A CARRIAGE SHELTER.

From the vestibule, we now come to the **reception room.** This room is usually large, with but little furniture. The main stairway leads up from one side of this room and is made quite ornamental. The other side is usually open, or separated by columns or grill-work from the living room. At one end of the reception room, one frequently sees a fireplace, more or less elaborate.

Turning now to the **living room,** let us study the requirements of this room. Here is the room the family will spend most of the time in. Often one end is set apart for a nook or library. There should be a large open room with a fireplace of brick or stone or tile or other suitable material, ornamental or plain, or the mantel may be of wood.

Provide plenty of windows, especially on the sunny side of the house. Nothing will dispel gloomy feelings or worry quicker than plenty of sunlight and fresh air. For the nook, if there is one, build in shelves for books, put in a seat with a hinged cover, also a fireplace. In this room, the quiet hours of the day are spent; therefore make it comfortable and convenient. A very convenient arrangement is to place a seat on one side, with bookshelves on the other; also a few shelves at one end or above the seat, for current books or periodicals. Provide a plate-rail around this nook, for the placing of china, ornaments, or bric-a-brac.

Opening from the living room we usually

find the **dining room**, separated by sliding doors. This room should be more or less private, but by means of double doors it may be thrown open when desired. In the dining room, build in a sideboard, and provide a small shelf or two for pretty china, vases, or ornaments. Back of these shelves a mirror is usually set. A French beveled-plate mirror is used in the best work. There should be the "counter," or the main shelf, projecting from two to six inches beyond the shelves and drawers below. Below the counter, provide a long drawer that will take a table-cloth as folded when laundered. A drawer for silver is also directly under the counter. Below this, there may be either drawers for other table linen, or shelves enclosed by glass doors for displaying china or cut glass. This sideboard should be made an attractive feature of the room. There might also be another case of shelves and drawers for additional table linen and dishes. There should be a plate-rail around the room, on which to hang cups or to place china or ornaments. This room should have, if possible, an east exposure, since the first meal of the day should be served in a bright, cheery atmosphere.

It will be necessary to have a **serving pantry** between the dining room and kitchen. There should be double-acting doors. This greatly facilitates the carrying of dishes from one room to another. In this pantry should be a wide shelf or counter which will be used in the preparation of the meal. Above are shelves with sliding doors, and below are drawers for different articles of food. Provide always plenty of drawers and shelf room. In a small room, sliding doors will be found much more convenient than swing doors, as they are much more easily handled and take up much less room in opening and closing. If possible, there should be built in this room a refrigerator. If not here, place it in the kitchen. This refrigerator should be provided with an outside door through which the ice may be replenished from the outside, thereby doing away with the ice man coming in at all hours and in bad weather tracking mud into the house.

The **kitchen**, while in the rear of the house, requires careful thought. The housekeeper usually spends the greater part of the morning here; therefore give this room, if possible, an east exposure. Make the windows low enough so that a person sitting can see out. For the kitchen table and sink, have a window near. This will not only be an aid to better light, but will give the housekeeper a chance to see out through the window. Place a sink as near the pantry and dining room as possible; also, as mentioned above, so as to be near outside light. In the kitchen will be found a cooking range or gas stove, or both. Place these, if possible, where they will get a cross-draft; in other words, place them between a door and a window, or between windows, so that the odor during the preparation of a meal will be carried away. Of course there is necessary a flue for the range, and there should also be one for the gas stove to carry off the odors of the gas and the ovens. The kitchen table should be convenient to the stoves. There should be built-in shelves and cupboards for the kitchen-ware and the pots and kettles. Either in the serving pantry or somewhere in the kitchen, provide a tilting bin for the flour. This can be very easily done by making the bin pivoted at the outside corners, to allow the bin to tilt out. Hooks or pivots for swinging a barrel of sugar would also be a great convenience. Do not make the kitchen large; make it small, compact, and convenient, to save the housekeeper all unnecessary steps. There will also be necessary rear stairs, one to the basement and one to the attic. These stairs should be about 3 feet 6 inches wide, as boxes, furniture, etc., are all taken up or down these stairs; so do not make them too small.

Having decided upon a satisfactory arrangement of the lower floor, we now consider the upper floors. These are devoted to the **bedrooms** and other rooms where more privacy is desired, such as the **sewing room**, the **study**, or the **nursery**. As has been said, the first-floor plan determines the outline of the second-floor plan. The number of bedrooms is determined by the size of the family. There will be required also a guest room and a servant's room.

As to the requirements of a bedroom, make ample-sized rooms. The usual articles of furniture will be the bed, a dresser, a chiffonier, a small table, and sometimes a writing desk or an additional table of some sort. Provide plenty of closet room, with a window, if possible, in it. In the closet should be a number of shelves, a hook strip around the three sides. The closet should be finished, so far as plaster and inside finish are concerned, as well as the other rooms. The question of closets is important; therefore, consider them an essential part of every house.

On the second floor provide a **bathroom** convenient to all rooms, yet far enough away from the main hall to be private. The bathroom is usually crowded into any remaining space that may be left after bedrooms have been consid-

Fig. 6. Layout of a Very Small Bathroom.

ered. This, however, is not a satisfactory way of doing, since the bathroom should be as convenient in arrangement as any other room. In the bathroom the usual necessary fixtures are a bathtub, a lavatory or wash-bowl, and a water-closet. In more expensive homes a foot-bath and a sitz bath are provided; sometimes a shower bath also. There should be ample room for the placing of these fixtures, with plenty of room around them. In Fig. 6 is shown the smallest room that can accommodate the necessary fixtures. While this will serve in the cheapest houses, yet the arrangements shown in Figs. 7 and 8 are much better.

Should more fixtures be added, the room

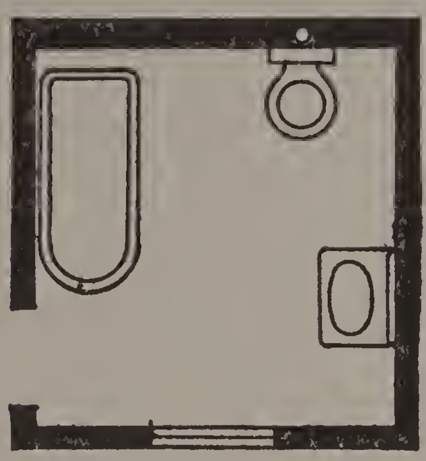


Fig. 7.

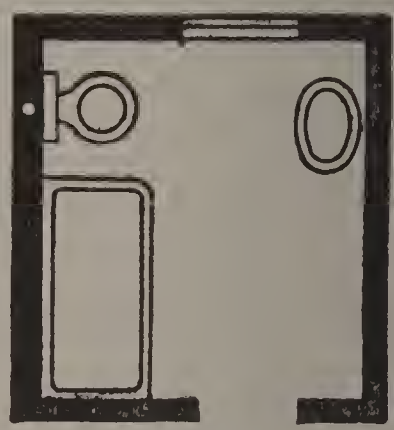


Fig. 8.

Two Plans of Commodious Bathrooms.

should also be made larger to accommodate them. There will also be required a medicine chest, usually built into the wall directly above the lavatory, or these can be bought at furniture stores, ready to hang on the wall. There should always be a mirror in the door of this chest. Provide a built-in closet with swing doors for the upper half and drawers for the lower half. The finish of this room, as well as the shape of the mouldings, should be such that the dust will not easily settle on them, and that they may be frequently washed to remove any accumulation of dust.

In most homes, the two main floors are all that are required for living rooms. The **attic** is usually low, and can be fitted up with storerooms. The construction of the roof should be such that soot and dirt cannot come through. This is ordinarily accomplished by using building paper under the shingles or roof covering. There should be an attic stairs, convenient and easy of ascent.

For the **basement**, the **furnace** will require a part of the space, together with a **coal room.** This coal room should be built dust-tight, and have a window convenient to a driveway for the unloading of coal. The size of coal room for different classes of coal, is indicated below under the heading "Dimensions." There should be a **laundry** with laundry tubs, or a room where the family washing may be done. The remaining space in the basement may be divided to suit the owner's wishes; sometimes a work-room, a store-room, a drying room, a shop, may be placed here.

It is very essential to have a **concrete floor** over the entire basement. This will do away with a great deal of dirt and dust that otherwise would be carried from the basement all over the house. There should be an outside entrance, as well as an entrance from the kitchen or serving room.

Thus we see the usual requirements for the different rooms of the house. The essential rooms have been considered. In addition to these, if the price will warrant it, there may be other rooms and conveniences, such as a den or study, additional store-rooms, an extra guest room, a nursery, a pantry off the kitchen for storing the supplies of the kitchen. A clothes-chute would be very convenient also. This chute is a vertical shaft connecting the bathroom with the laundry in the basement. There is a door into this chute at the bathroom, and one on the first floor. It should be lined with wood, with the pieces placed vertically to offer no obstructions to the passage of clothes. The purpose is evident, being a means of conveying the soiled linen from the second and first floors to the basement, and thereby saving carrying them from all over the house in a basket to the basement.

In summing up this portion of the work, let the draftsman put in all conveniences in the way of cupboards, shelves, and drawers wherever there is a space, corner, or portion of a wall. In this way you make a favorable impression upon the housekeeper, and if this is done, the "battle is more than half won."

Fig. 9 is a first-floor plan, showing the arrangement, the dimensions, and all necessary information to give the builder a complete understanding of the work.

The Elevation. Having considered briefly the general methods used in the drawing of architectural **plans**, we shall now consider the **elevations.** By elevations we mean the different "views" of the building. These should show exactly the appearance of the building when completed.

Use of the Orders. It will be assumed that the reader is familiar with the Orders of Architecture (see below under heading "Orders of Architecture"), and that he knows the names of the various parts of an Order.

From a study of the Orders, we see that each one has three main divisions, the **entablature,** the **column,** and the **pedestal.** These are in turn divided into parts, the entablature consisting of the **cornice,** the **frieze,** and the **architrave;** the column has a **capital,** a **shaft,** and a **base** or **plinth;** and the pedestal, a **cap,** a **die,** and a **base.** Generally speaking, an elevation—especially the principal one—shows these component parts of an Order. They may not be classically correct in proportions, but the parts are more or less prominent, and should be used as a basis for design of all classes of work.

Let us take a **residence** for an example. Study an elevation of a good type of this class of building. We see that the **basement wall** up to the first-floor line corresponds to the pedestal of the column, a strong, massive part to support the building above. This pedestal is usually capped by a projecting course we call a **water-table**—that is, a board or strip projecting from the face of a wall to turn the water from the side of the building away from the foundation. This corresponds to the base or plinth of the column. Above the water-table, the part of the house extending to above the top story windows corresponds to the shaft of the column. Very often this column effect is emphasized by means

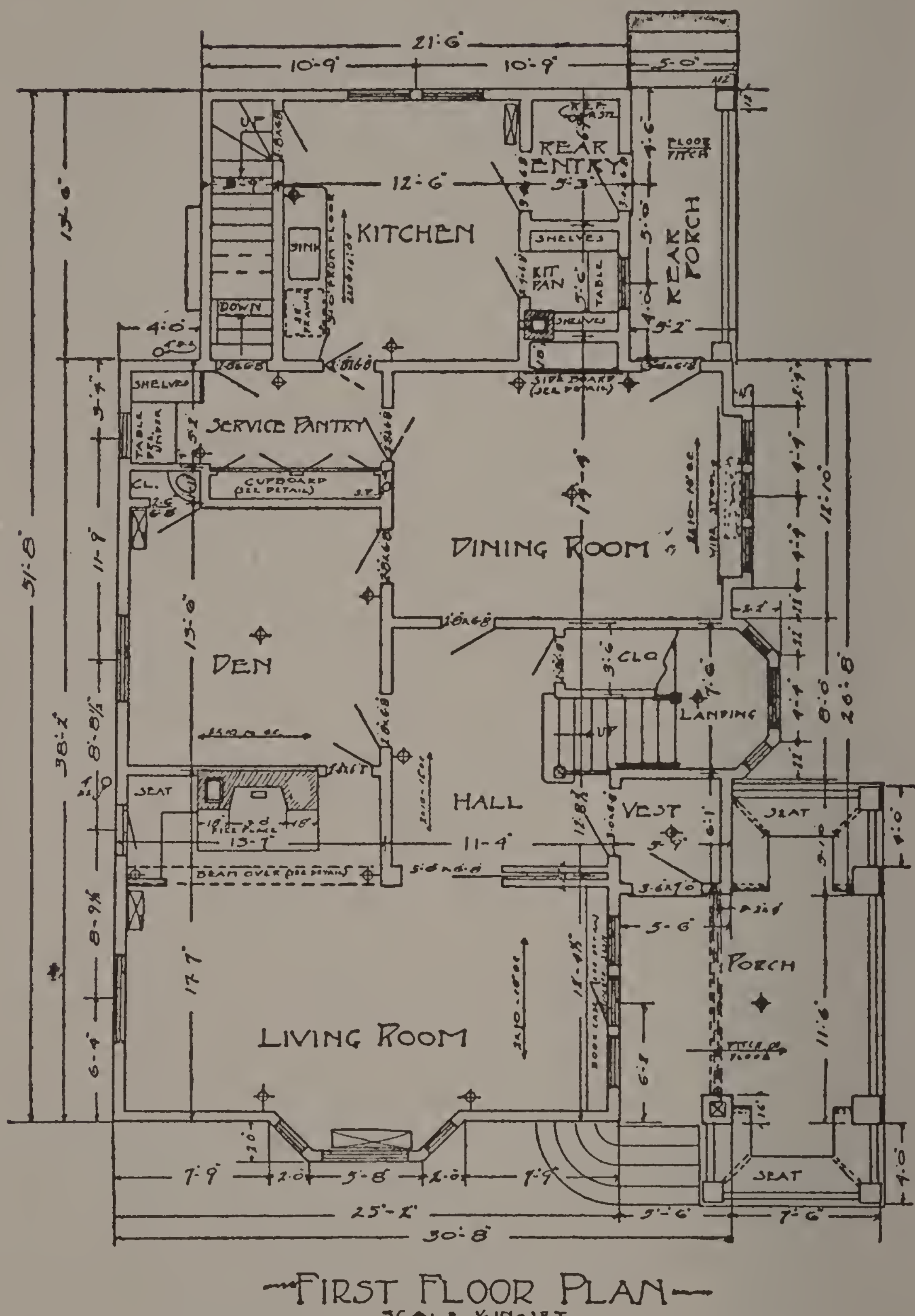


Fig. 9. First-Floor Plan of a Residence at Champaign, Ill. The scale reproduced is valid only as referring to the original-sized drawing.

of corner boards at the corners of the building. At the head of the top windows, or in that vicinity, we see a horizontal board or moulding, marking the division between the column and the entablature. Sometimes this entablature is divided by another moulded course, indicating the frieze and the architrave. There is always a **cornice** of some sort, very often corresponding to the cornice of the Order; this may vary from the true profile to a small projection, such as a few projecting courses of brick.

In the modern **office building** we see the lower stories marked by a projecting stone course; below this, the walls are of stone, and usually present a solid, substantial base upon which rests the upper part of the building. The column is indicated either by pilasters or column-like projections from the main face of the building, or by a three-quarter column fastened to the building. The upper stories, depending upon the height of the building, are placed in the entablature.

It is worth while to study this feature in all classes of building, in order to design intelligently.

Thus we see that the Orders of Architecture are really the basis for all our designs. This same applies to any type of building, being more marked in some classes of buildings than others. The **Colonial residence** or **Colonial Architecture** adheres strictly to this basis of ornament. If detached or free columns are used for porch construction, then we see the component parts of the Order carried out exactly. Therefore, in any building, use the Order to start the general elevations, and elaborate or suit the elevation to the class of building.

Characteristics of Types of Buildings

Let us now consider the general types of buildings for different purposes. The **residence,** for instance, usually has the appearance of a quiet, restful place. The types of doors, windows, and roof lines are in general similar, there being large windows and plenty of them. Residences thus constitute a class marked by well-known and easily distinguishable general characteristics.

Consider a **library.** We see here a closer adherence to the Orders than in many other types of structure. Usually there is a pillared entrance of some form or other; the windows are all large and dignified. The roof is covered with tile or some other more expensive covering. In general, libraries are a dignified class of buildings, easily distinguished as such, and usually quite costly.

In **schoolhouses** we see a class of buildings with large areas devoted to windows, not usually of very great height, and with a tower of some outline. There may be large, blank walls, which make this class of buildings all the more distinct.

The **office building** generally has numerous windows, not usually grouped but placed one above the other, and is rather plain in treatment except at the cornice.

The **warehouse** forms another excellent example of the exterior indicating the purpose of the building. In this type, we see small windows, some barred, with heavy doors, showing it to be a building of great strength and fire-resistance.

Thus endeavor, in designing any building, to make it indicative of the purpose for which it is designed. Study carefully from examples or from pictures these characteristics, and apply these principles to designs you may submit.

General Composition of a Building or Treatment of Elevations. A few words about the general composition or elevation of a building might be said. There are a few principles involved that will be an aid in deciding upon the character of the elevation.

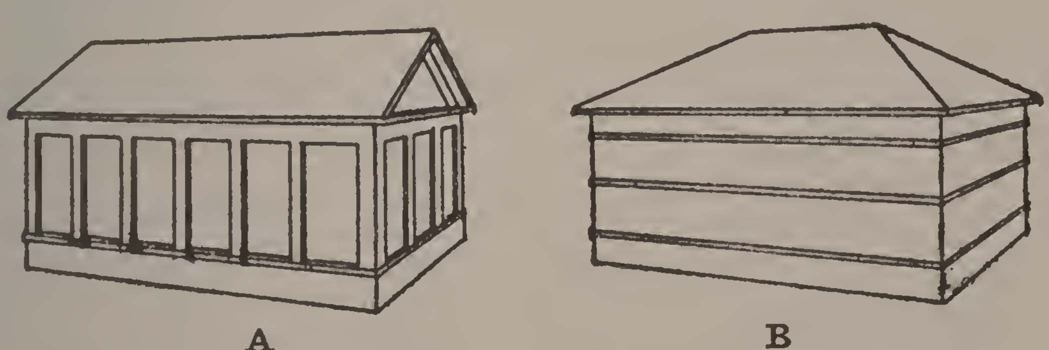


Fig. 10. Illustrating Method of Treating Elevations.
In A, vertical lines are emphasized, adding to the appearance of height; in B, emphasis is laid on the horizontal lines, adding to breadth and length of structure.

The adjoining buildings will sometimes have a certain influence upon the treatment of the elevation. Should the new building be placed between two buildings taller and larger in every way, then some means to increase the general height must be used. Should there be plenty of room and the buildings on either side be far enough away so that they will not be seen or included in the general view of the new building, then the design may be anything in keeping with good design. If the present buildings are large and massive, covering a good deal of ground, then we shall treat the new elevation correspondingly. In Fig. 10 are shown the results, on the same building, of different treatments of elevation. In **A** we see vertical lines emphasized, as they tend to increase the height. Such a treatment of the elevation should be used if the location were between two taller buildings. In **B** on the other hand, the horizontal lines are emphasized. There is the sill course or water-table at

A B

Fig. 11. Two Typical Methods of Treating Windows.

the first-floor line; then a belt course about the second-floor line, and a course at the attic line. These tend to lengthen the general appearance, and would be in keeping as mentioned above for the third condition. In **A**, we see that the cornice is made smaller; while in **B**, the eaves are given a greater projection, thereby giving another horizontal line. **A** and **B** are exactly the same size in plan and also in height to the eave line; yet there is no mistaking which appears the taller.

This is the fundamental principle in the design of an elevation. Having then this start for the elevation, carry out the same principle in the windows, either grouping them and keeping them low, for the design **B**; or else use single windows with a pier or wall space between. Very often, if the ceilings are high enough, windows may have a transom bar and transom, thereby increasing the height. In the treatment around the windows, for **B**, we shall use merely a cap of some kind with no vertical lines; while for **A** we shall make use of an outside trim with a cap. See Fig. 11.

In all our designs, it has been attempted to emphasize either the vertical lines or the horizontal lines. This is but one—the most important one, however—of the points to consider as to the general character of the elevation. The purpose of the elevation is to give an effect that will be pleasing to the eye, and at the same time fulfil the requirements of the plan as to the arrangement of windows and story heights; and very often it will make the property more valuable. For, consider two residences offered for sale at the same price, with the same surroundings. One has been built with no idea as to design or relation to the surrounding buildings; the other has been treated to correspond with the existing conditions, has been made attractive by the arrangement and style of windows, and the cornice has been designed to give a certain effect to the other parts of the design. There is no question which would be the best investment. Work, then, with this end in view, as if it were your own builidng, and you wanted it to be the very best for the money.

In drawing the elevations, usually each side of the house is shown on the drawings. The **front elevation** is made the most complete. The owner wants to see how his building will look when completed; therefore show the materials. If the walls are shingled, indicate by lines that there are to be shingles—not by covering the entire front with perfectly regular, mechanical lines representing the shingles, but with patches here and there over the entire front. Indicate by arrows and lines, similar to dimension lines, where the shingles are to be used. Indicate the brick of the foundation above grade the same way. Show the type of windows you expect to use; show the correct profile or outline of the cornice; the general design of the front door and the porch and steps; indicate the glass in the door, whether double strength, plate, or beveled-plate glass. In short, make this front elevation complete, so that an owner can see just the materials used, where used, and just how the building will look from the front. Very often the stairs are dotted on this elevation to show just how they go

DESIGN FOR AN ARCH, FROM SAXON-NORMAN DETAILS.

up to the next floor above; but this is not to be recommended, as it detracts from the general appearance of the elevation, and there are other and better methods of indicating stairs, as explained later.

Very often there will be a small section of the house on the same sheet with the front elevation.

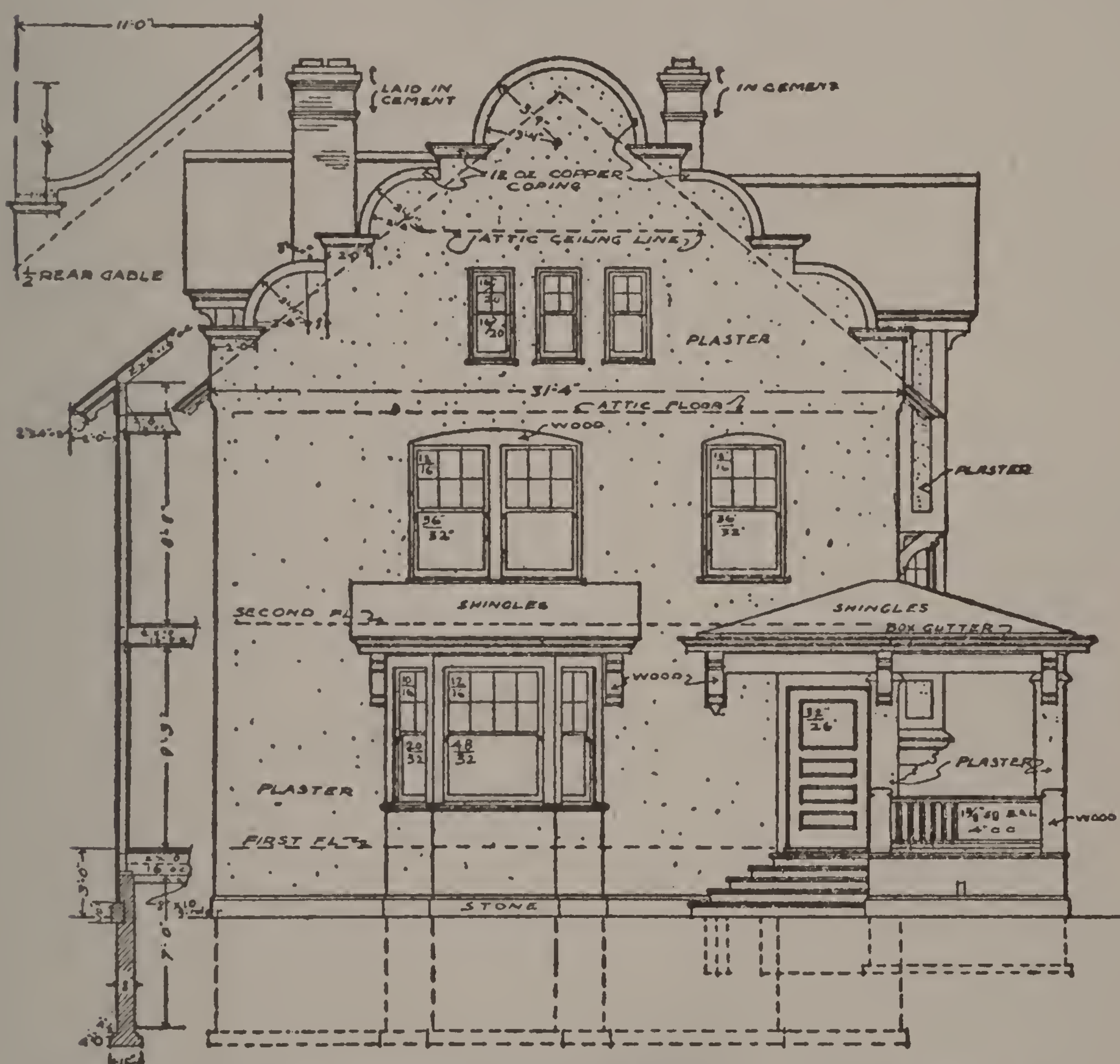


Fig. 12. Front Elevation of a Residence at Champaign, Ill.
Outline emphasized.

This is used to give the heights of the floor-lines, the window lines, and the cornice lines, and not for showing of details. This is not objectionable, as the section is a separate drawing entirely from the elevation, and will give a means of showing the above data without marking them directly on the elevation.

Too much emphasis cannot be laid upon the method of finishing the front elevation. A little time and careful work spent on this drawing will very often confirm a favorable impression on the owner. The style of letter used and the arrangement on the sheet should all tend to make the drawing attractive.

As a final touch, it will be found very desirable, after the elevation is complete, to outline the building with a heavy line, thus emphasizing the general outline of the building, while the other lines are all uniform but lighter (see Fig. 12).

The **side and rear elevations** should also be complete in that they should show the exact materials used and the exact size and spacing of the openings; but they need not be so carefully drawn nor so carefully lettered as the front elevation, since they are more or less a secondary consideration.

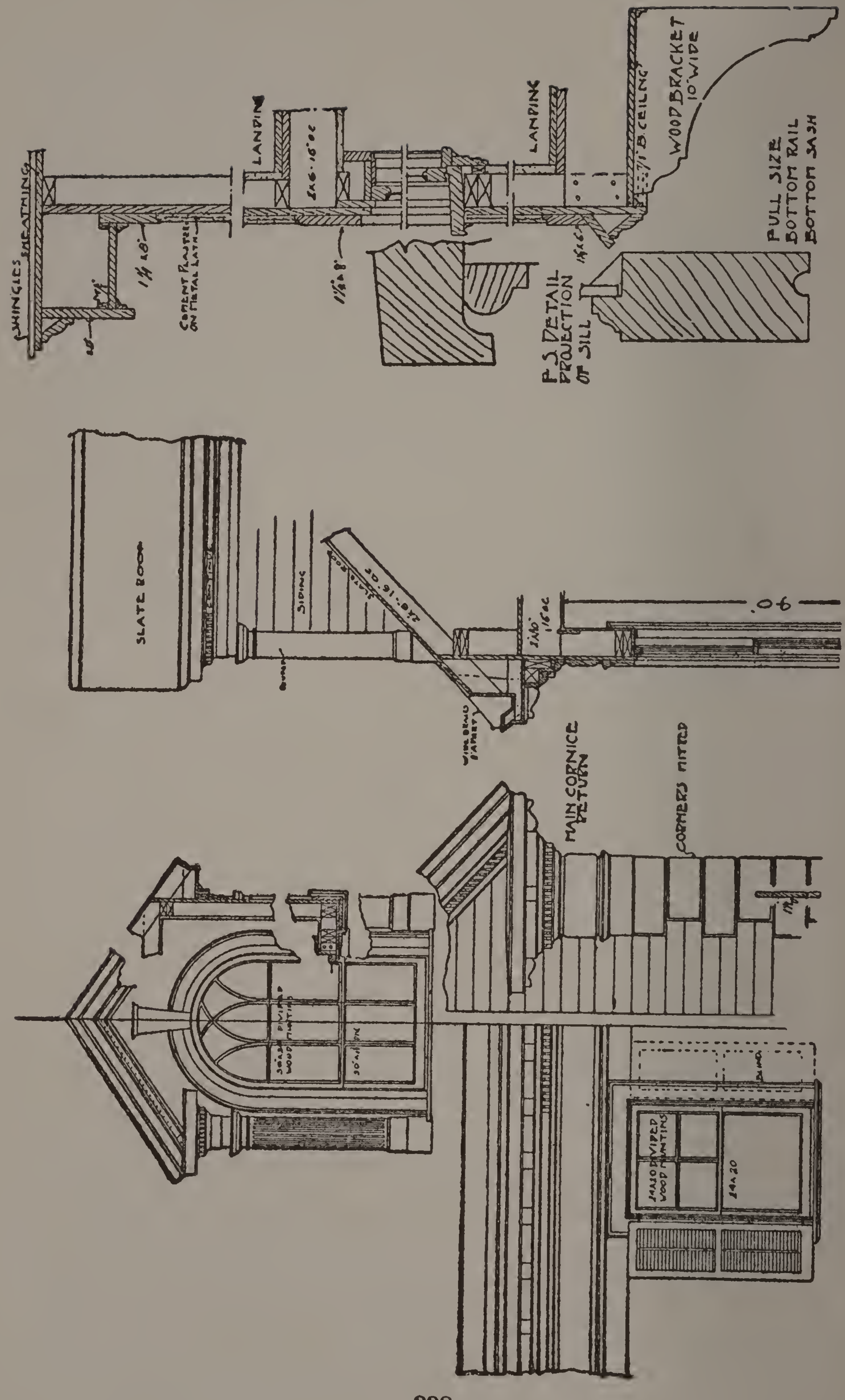
The **location of openings** should be studied with the idea of the general effect on the elevation, as well as on the necessary arrangement for the rooms. In other words, do not locate all openings on the plans definitely without studying the elevations also. Be sure that the openings are correctly located on the elevations so that the plans and elevations will agree, and not merely put on the elevations where they look the best without any reference to the plans.

To sum up, make the elevations true pictures of the building when completed; indicate the extent of all materials; study the design, making it typical of the class of building in hand, and make it complete in every respect.

Scale Details

The Section. Having completed the plans and elevations, it will be necessary to make large-scale sections through different parts of the building. A section should be shown through every portion of the building that is of different construction from others. These sections are usually of a larger scale than the plans and elevations.

In Fig. 13 we see the method of drawing and finishing these details. A scale very convenient for use is three-quarters of an inch equals one foot (or, as it is often called, a "three-quarter-inch" scale). The purpose of these sections is to show exactly how the building is to be put up—the method of supporting the cornice on the plate; the roof sheathing and covering; the construction of the gutter, with all materials named; the ceiling joists and method of support on the outside wall; the lath and plaster; the wall sheathing and siding or shingles; the picture mould; the detail of the inside window trim; the base around the room; the second-floor construction, showing size of joists and method of support on the wall; the composition of the floor, whether double or single, or any paper between


SHINGLES
SHEATHING
LANDING
LANDING
WOOD BRACKET 10" WIDE
FULL SIZE BOTTOM RAIL BOTTOM SASH
F.S. DETAIL PROJECTION OF SILL
SLATE ROOF
SIDING
MAIN CORNICE RETURN
CORNERS MITRED

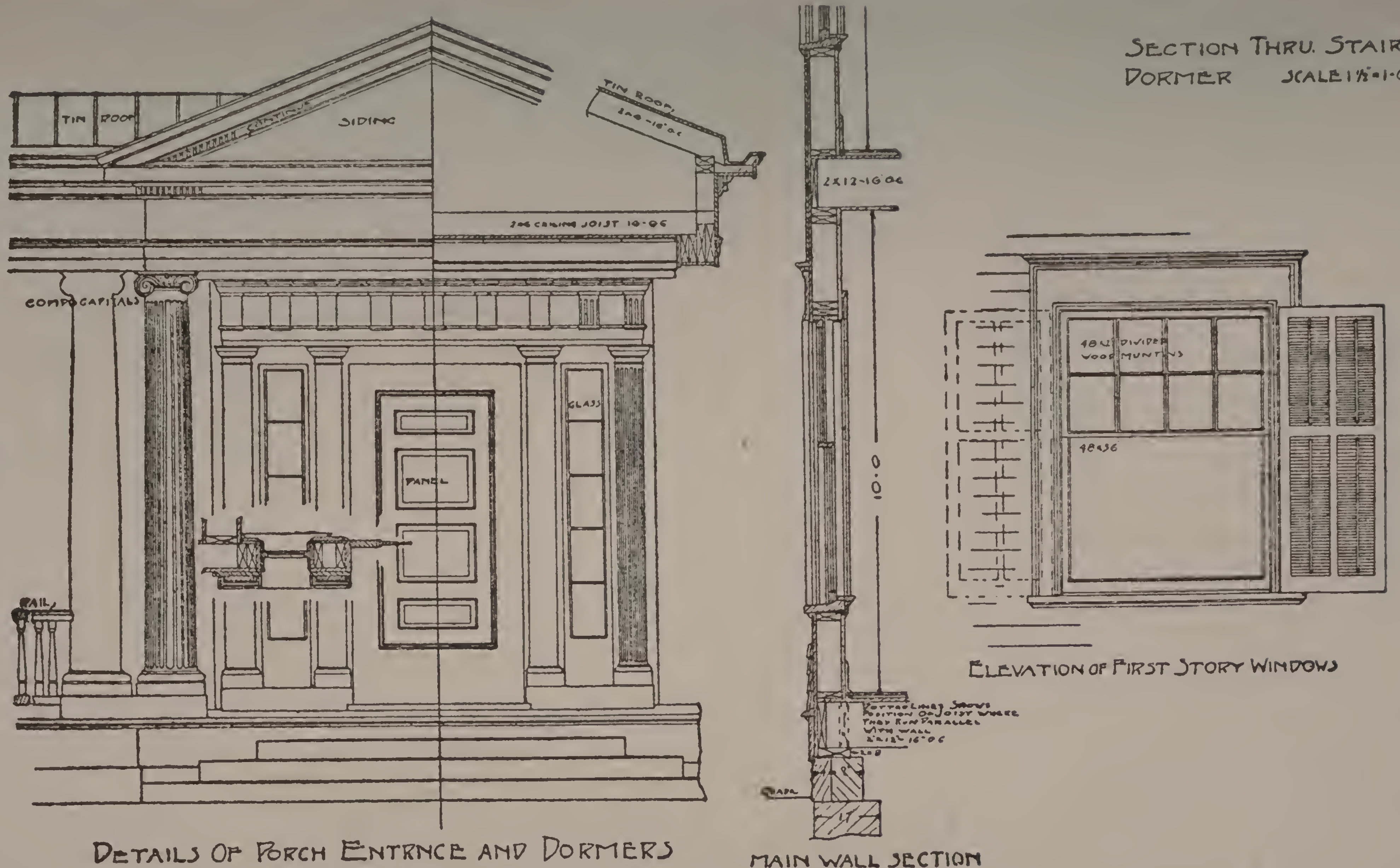


Fig. 13. Scale Details of a Residence at Albany, N. Y.

the floors; the lath and plaster of the ceiling below; the details of the window construction, trim and stool or inside sill; the base around the room; the method of supporting the frame wall upon the basement wall; the water-table; the thickness of the basement wall; the level of the ground on the outside; the basement floor inside; and the footing.

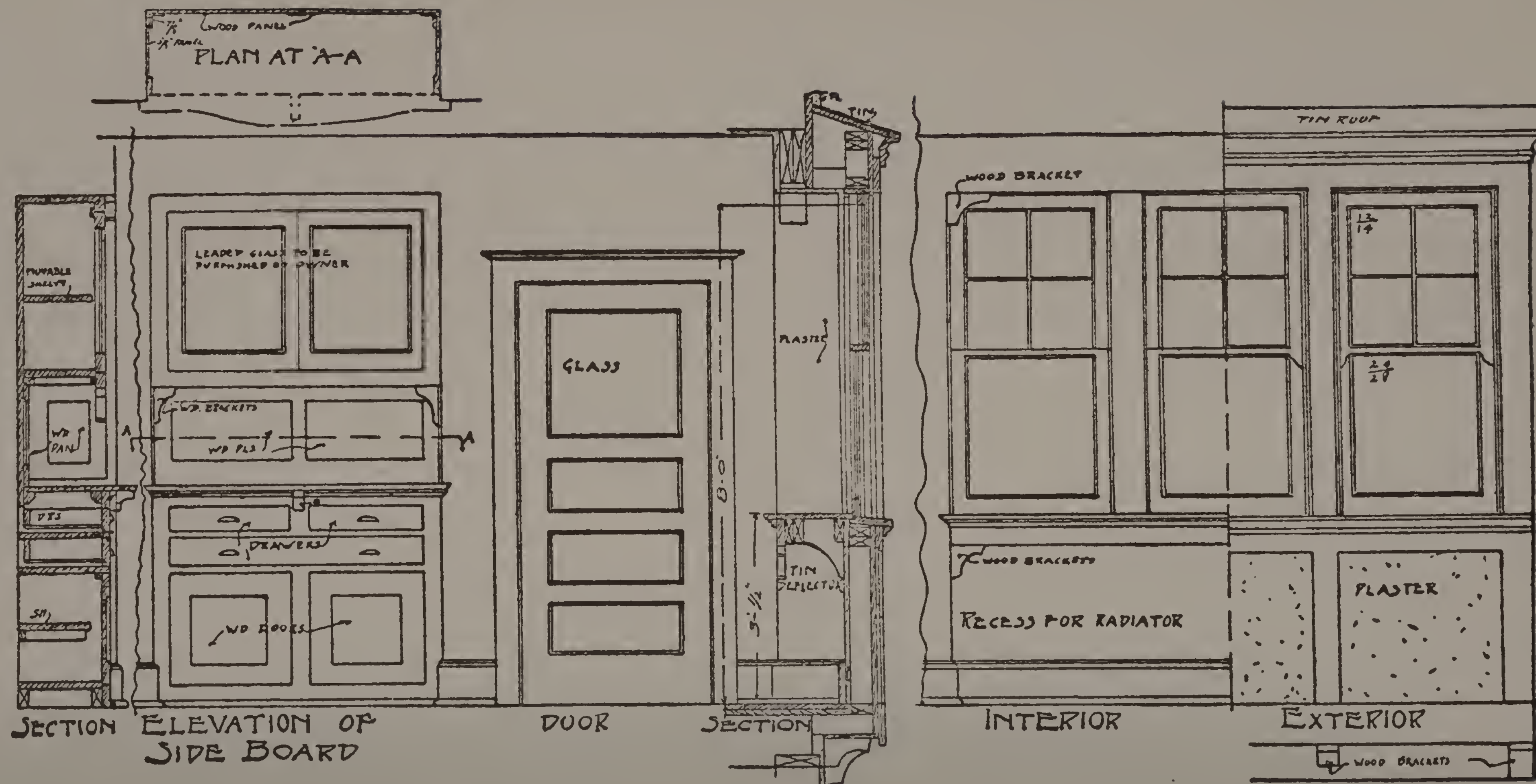
Use plenty of dimension lines and explanatory notes. In dimensioning story heights, always give from finished floor-line to finished floor-line, or from floor to ceiling; never dimension the thickness of the floor construction. In other words, referring to Fig. 13, we shall get into trouble by trying to specify exactly the thickness over all. This should be left without a dimension, by showing the plaster, noting the size of joists, and showing the floor, whether one or two thicknesses, let it come what it will. The thickness of the plaster will vary slightly; a 2-inch by 10-inch joist is not 10 inches deep; neither is a floor of two thicknesses 2 inches thick. Thus we see it is rather an uncertain dimension.

A sheet is usually devoted to these details. Sometimes as many as half a dozen different sections are drawn for a residence, each showing differences in construction.

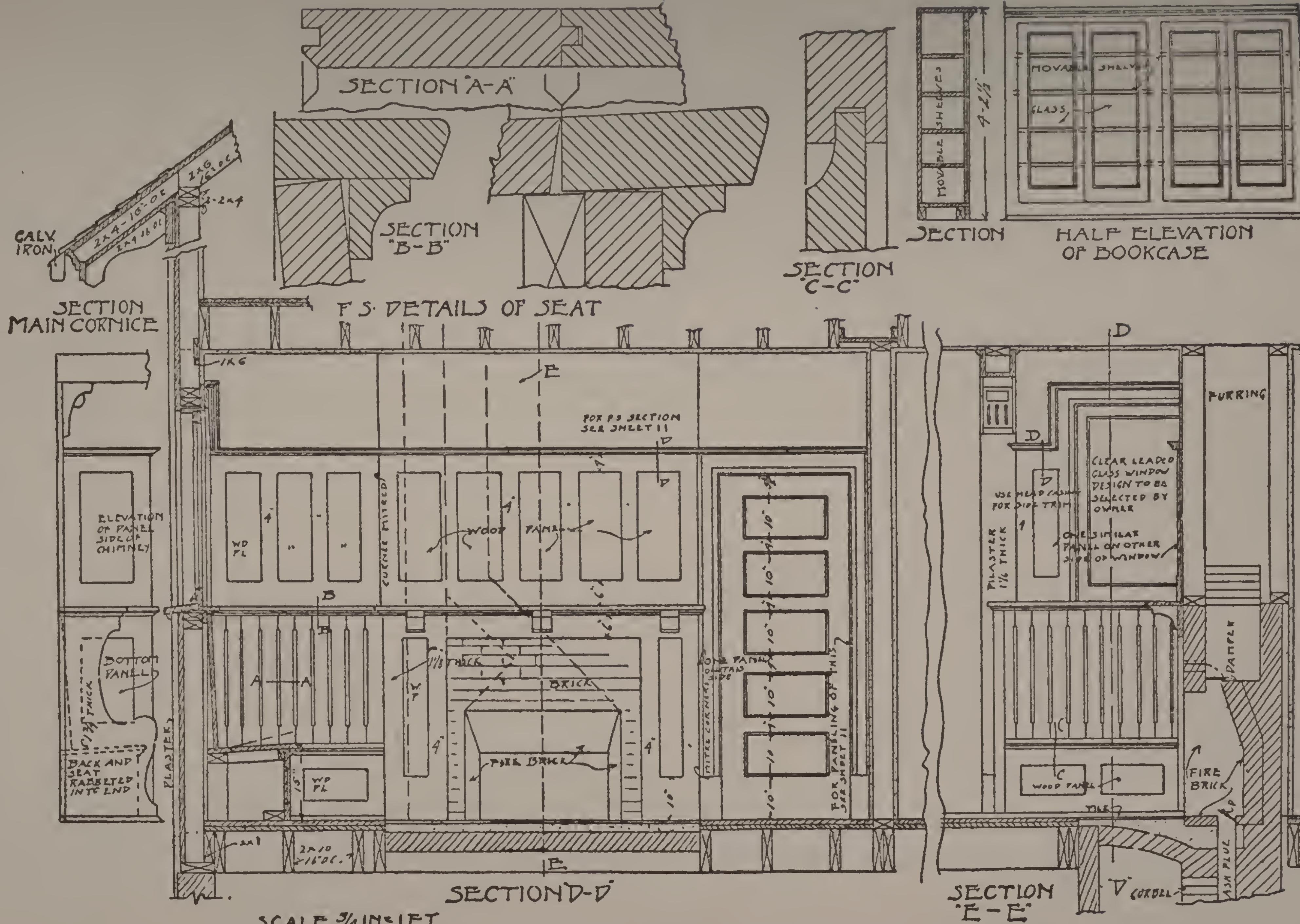
Be very careful to note on the plans just where each section is taken, and put corresponding letters on the title for the section. The use of notes and plenty of them cannot be urged too strongly. The small working drawings are very unreliable as to details; and consequently the more details, the better the contractor will understand just exactly what he is to furnish, and will therefore be able to figure the more closely. These details, well executed, will prevent many disputes between contractor and architect, and between architect and owner, as well as save the "extra" bills from the contractor which are sure to arise from incomplete drawings.

Cross-hatch or cross-section all sections or materials that are cut in two, using some standard symbol, as elsewhere indicated, on the drawings. This makes a much better looking drawing, and makes it much easier to interpret.

To indicate further the general treatment of the interior finish, the rooms having anything in the way of a paneled wainscot, beamed ceiling, or finish around a fireplace, also the sideboard, cupboards, and pantry fittings, should all be shown. The best and perhaps the most common method is to draw at one-quarter-inch scale the different elevations of the rooms, showing exactly the height, width, and any features of unusual arrangement. Should opposite sides of a room or any sides be similar, after putting the title on one drawing, note under it: "Opposite, north, south, etc., sides similar." There is usually one sheet of just such drawings as this to accompany the regular set of drawings. Since plans are usually submitted to competitive contractors, there is not the chance of one pro-



Details of Dining Room.



Details of Living Room.

Fig. 14. Part Details of a Residence at Champaign, Ill. Originals drawn at scale of ¾" = 1'-0".

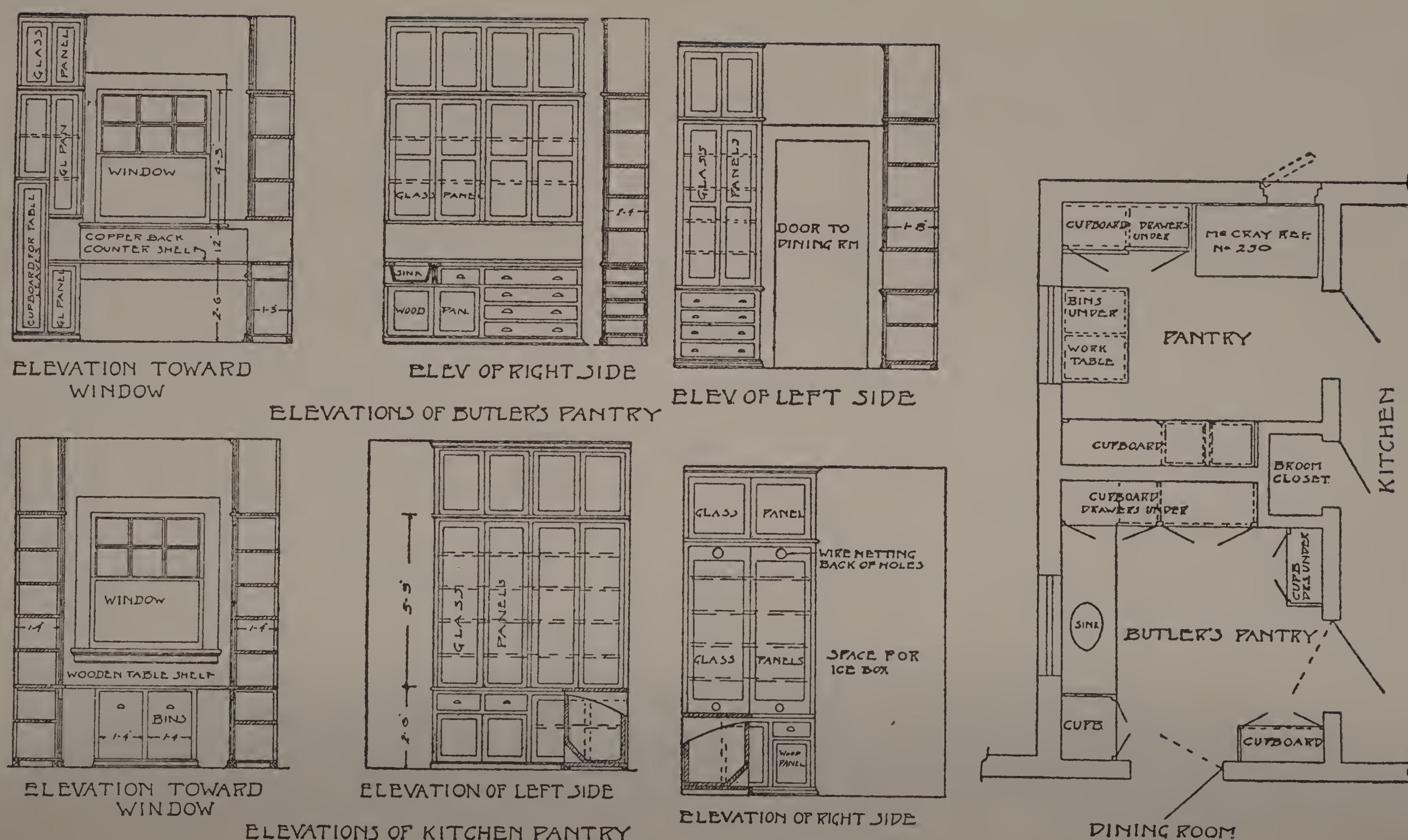


Fig. 15. Cupboard Details of a Residence at Albany, N. Y.

posal or bid being lower than another because certain things were overlooked or purposely omitted.

In Fig. 14 we see drawings of elevations and sections of various portions of a living room and dining room, giving all necessary information.

Fig. 15 illustrates completely the drawings necessary to show a pantry and butler's pantry.

Full-Sizing. After the contract has been awarded, the general working drawings will have to be supplemented by drawings of different portions of the work at a large scale. Usually these are drawn at actual or **full size.** In order to have your profiles and outlines made just as you intended, this method of drawing all parts of construction at the actual size is imperative.

Take an example. You wish the plate-rail in the dining room made just so. Then you will have to draw this part of the work the actual size. If you do not do this, the contractor will put in a plate-rail of a stock pattern; that is, he will select some pattern that he can buy from a planing mill, and will use this. It is the cheapest way to do, for him; therefore you cannot blame him for saving anything he can, if the exact style is not definitely shown.

In full-sizing, it will be well for the draftsman to be familiar with the usual method of doing things, making his details practical as well as indicating the profile. The cornice should be shown; the interior finish; the method of making the window-frames; all unusual woodwork; the construction of the beams for a beamed ceiling; all sheet-metal work, such as gutters, cornices, etc.; all stonework, such as water-tables, window-sills, and door-step; all plaster work, such as ornamental cornices, and method of supporting under unusual conditions. You will hear it asked: "Why is it necessary to spend all this time detailing, when the contractor or the planing mill have their own way of doing these things?" There is just the point. They certainly have a way of doing things; but naturally their way is the cheapest way; therefore, give them details of how you want this work done, and see that it is done your way. Dimensions on full-size details are unnecessary.

Fig. 16 is a reproduction of a sheet of full-size details.

A word might be said as to the method of getting out these details. The drawing is first made on **detail paper,** a heavy yellow paper. A soft pencil should be used, as it makes the lines more distinct and is easily changed or erased. After the drawing is completed on this paper, then use a cheap, thin paper, and trace through, using a broad, heavy line and colored crayon for cross-sectioning the sections of the work. Yellow is generally used for wood, red for brick, green for stone, blue for iron or steel, and brown for terra-cotta. A second tracing is also made. Thus we have three copies of each detail—one for filing in the office for future reference, and

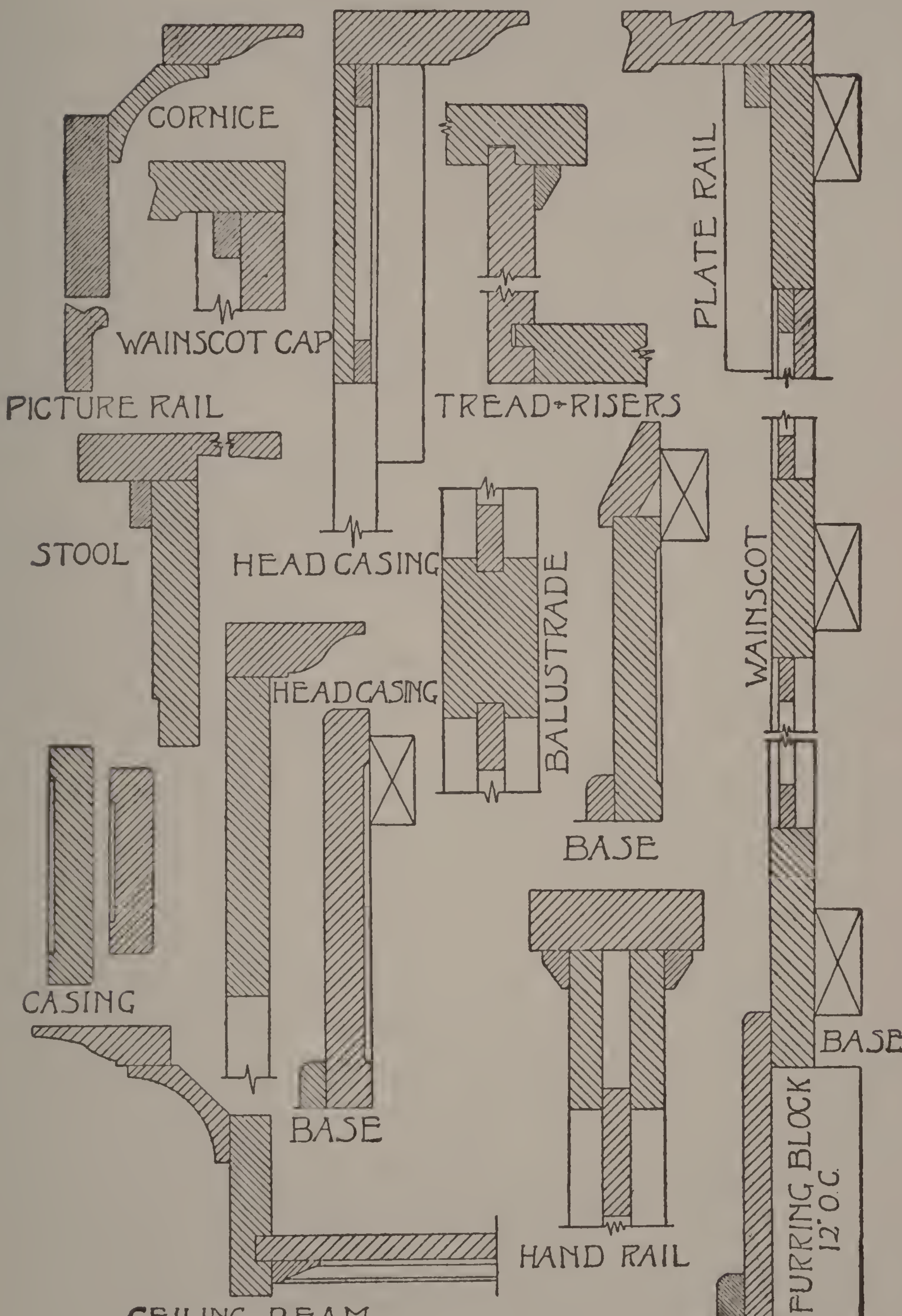


Fig. 16. **A Sheet of Full-Sized Details**

two for the contractor. One of the copies made on tracing paper is usually kept in the office, since it can be folded up to a convenient size and filed, the original and one copy on thin paper going to the contractor.

REPRODUCING DRAWINGS

The question of the method of reproducing drawings is an important one as to cost and time consumed. New methods are being advertised on the market every day.

Blue-Printing. The blue-print process is the commonest, and generally speaking the cheapest. There is a chemically prepared paper which is sensitive to the light. The paper is treated with a solution of citrate of iron, ammonia, and red prussiate of potash, and is placed in a dark room to dry. The drawing has previously been prepared on tracing cloth or paper. When the blue-print paper is dry, place the drawing, face down, on a sheet of glass, usually held in a wooden frame; over this, lay the blue-print paper, with the sensitive side down; over this, place a layer or two of soft cloth similar to Canton flannel, and over this place a board backing.

Turn the frame over now, and expose to the sunlight for a few minutes, depending upon the intensity of the sunlight. After exposure, remove the blue-print paper, which has turned to a dark bronze color, and place it in a tank of water. Gradually the print comes out in white lines, leaving the background blue. These white lines were directly under the ink lines of your drawing, and the sun therefore could not attack that portion of the paper. Hence the water washed off the blue-print solution, leaving the white paper.

A little experience will soon teach how long to expose in different kinds of weather. Prints may be made on cloudy days, and have sometimes been made even during a mist. The exposure, of course, must be much longer on such days. The prints from such exposures are not so clear, distinct, and "sharp-cut" as those made on bright days. When possible, avoid making blue-prints on dark days, if you expect the best results.

Paper for blue-printing can be procured ready to use, from dealers all over the country, at a nominal cost. This is machine-prepared, and is more satisfactory than home-made.

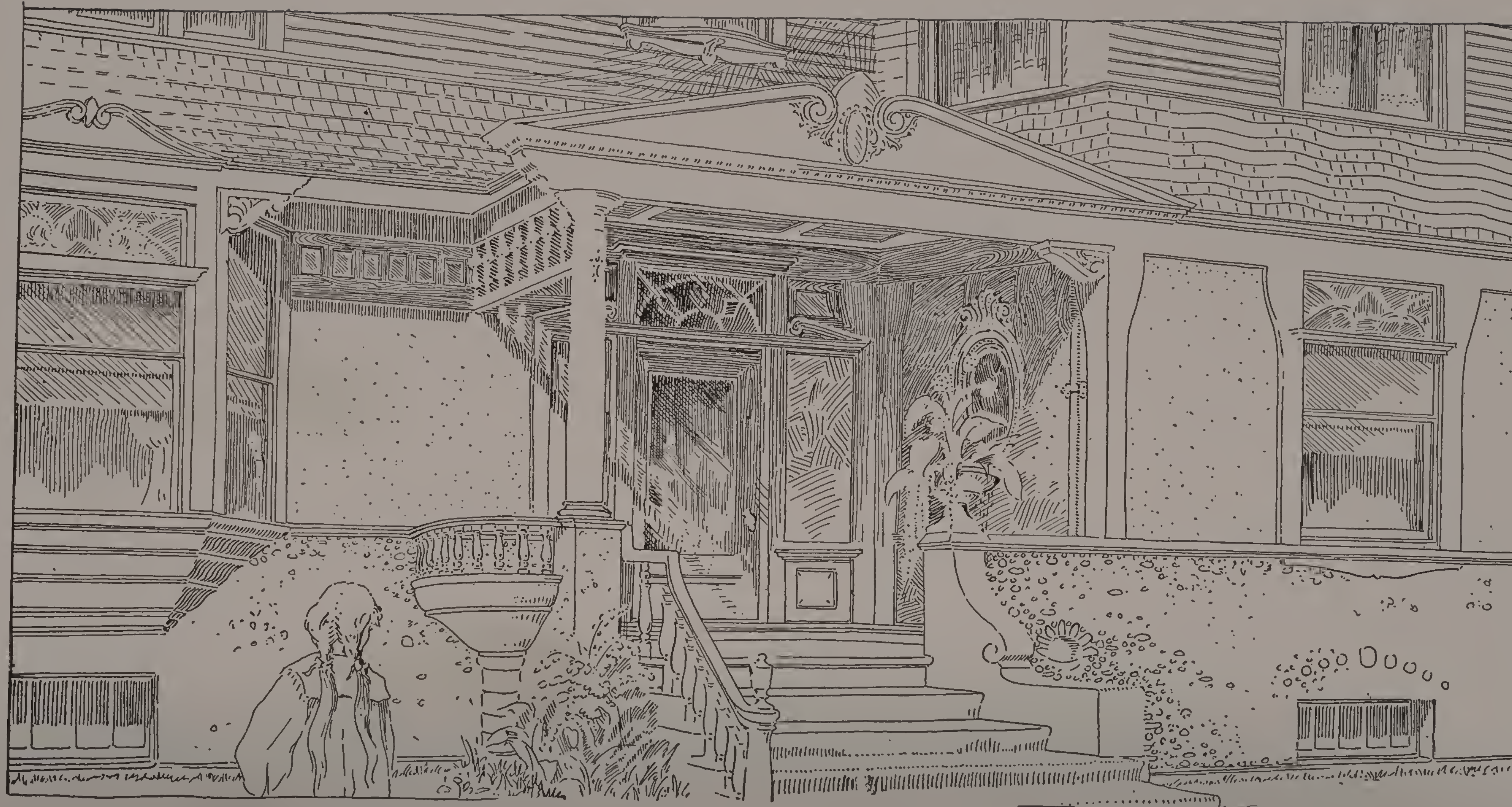
Blue-prints are hard on the eyes, and, having a blue background, cannot be dimensioned, noted, or to any great extent changed. Should small alterations be necessary on the blue-print, use a solution of common soda and water with a pen. This is not very satisfactory, but in cases where changes are necessary it will do.

White-Printing. From working drawings, **white prints** can be made. This kind of print is just the reverse of the blue-print. Here we have blue lines on a white background. In order to make white prints, a **negative** first has to be made from the drawing. The paper used for the negatives is specially prepared and exposed and washed in the same way as blue-prints. When washed and dry, it is a real negative, on which all pencil lines are white and the background is black so as to exclude the sun—all the reverse of the drawing. This negative is then used by placing it over regular blue-print paper. The sun passes through the white lines, and is excluded from the rest by the black background. Upon washing the blue-print paper, the lines having been exposed to the sun are changed to blue; and the background, not having the sun on it, is washed off, leaving the white paper.

This process makes a much better looking drawing than a blue-print, and is not so hard on the eyes. The cost is a little higher, on account of the negative; but after the negative is made, the cost is the same as for blue-prints.

Aligraphy. Another process, known as **Aligraphy,** has been patented. By it, drawings can be reproduced on linen or paper, and the lines are practically as black as the original. They closely resemble etchings. For very fine work, this process makes splendid reproductions; but it is more expensive than any of the processes above mentioned.

Hectograph Process. Another common method of reproducing drawings is the **hectograph process.** This consists in making the drawings with suitable aniline inks, and then placing them face-down on a gelatine pad. After



WELL-RENDERED DESIGN FOR AN ENTRANCE, SHOWING HARMONIOUS ADAPTATION OF A GREAT VARIETY OF ELEMENTS.

being in contact for about two minutes, they are removed, and blank paper is brought in contact with the pad, being in turn removed. It will be found to give a complete drawing similar to the original in scale, color, etc. Upwards of thirty-five copies may be taken off, depending upon the intensity of the original.

The pad may be made as follows: 1 part of white glue to 5 parts by weight of glycerine. Soak the glue over night, in just enough water to cover it. Bring to the boiling point slowly, without burning; then add the glycerine, and thoroughly mix. Pour into a shallow pan; remove all air-bubbles from the surface with a stiff card; and allow to cool. Before using each time, wash thoroughly with a sponge and allow to dry partially before applying the drawing; also wash well immediately after using, to remove all traces of ink.

The proportions may be varied slightly for different climates. A cold climate will require more glycerine, and a warm climate more glue. The pad should be stiff enough to resist pressure from the fingers when firmly pressed upon it.

Other additional ingredients are sometimes used. Perhaps they have their advantages; but the mixture as described has been used very successfully. Often, in very hot weather, after a pad is made, it may seem too soft to work well. In such a case, placing the pan on a cake of ice will harden the mixture and make it satisfactory.

A cheaper pad may be made by using a mixture of a special clay and glycerine. While not giving so many prints as the glue pad, it can be used more economically for large drawings. Hectograph pencils may be had in many colors, which are used for making full-size details. These drawings are copied in the same way as the regular pen-and-ink drawings.

The hectograph process is gradually gaining in favor, and in some localities it is used extensively. It has several features to commend it:

(1) All materials can be represented in appropriate colors.

(2) Copies are very cheap, and can be made on paper or prepared cloth.

(3) The draftsman finds it convenient when making revisions, as parts of the drawing can be cut out and a correct portion inserted. No matter how badly the drawing is cut and patched, the prints are perfect.

(4) In assembling different drawings on a sheet, they may be shifted at will, and a better arrangement secured.

(5) When a sheet is composed of small drawings, the draftsman may work over the small drawings more comfortably than if compelled to work on a large sheet.

The hectograph process, however, has some drawbacks, which may be indicated as follows:

(1) Small details cannot be shown so clearly, as the lines must be quite heavy if a number of prints are required.

(2) The drawings fade more or less if exposed to a bright light, but they are permanent enough for most work.

(3) Some draftsmen do not like to use the inks, as

they are sticky and soil the fingers. This, however, should apply only to the inexperienced.

Hectograph inks may be purchased of dealers everywhere, in all colors. Below are suggested colors for various sections of materials:

Purple—For lines in general, outlines, profiles, etc.; also for sections of plaster, and concrete.

Red—For dimension lines, and for sections of brick-work.

Blue—For iron, steel, flashing, etc., in section.

Brown—For sections of terra-cotta.

Green—For sections of stone or marble.

Yellow—For wood.

For the blue-print process, the drawing to be reproduced is preferably done on tracing cloth, on the rough side, in black ink. Erasures may be made on this, and the work corrected; but the finished drawing has to be complete in every respect, as every line is reproduced just as drawn.

For the hectograph process, we shall need to make the lines much heavier, and may use colored inks. Mistakes cannot be erased, but are cut out, and a new piece of paper placed over the hole, and the drawing continued.

Tracing cloth makes the most satisfactory material all around for the original drawing. It is translucent or semi-transparent, will make good prints by almost any process, and is much more desirable than paper for filing away and for constant use in the drafting room.

The use of colored inks is not to be recommended. They make the tracing look very pretty, but they print very poorly, some shades of green being hardly visible on the blue-print. Red reproduces very faintly, and when this color is used for dimension lines they should be heavy. Black is the most serviceable color to use. In steel detailing, the entire drawing is done in black—even dimension lines.

ARCHITECTURAL FORMS

Having considered the general method in the drawing of architectural plans, we shall now consider some of the general forms employed to represent different parts of the work.

Conventional Forms and Symbols. First there must be some adopted form for representing materials. It will be found throughout the country, that each architectural firm has its own architectural forms and symbols. This is rather confusing, since it requires a draftsman changing offices, or Building Departments checking plans, to become familiar with the symbols as used by each office.

In Plate A are given some general forms for representing materials.

Fig. 1 represents brick. A section of a brick wall should be sectioned as shown, by parallel lines at 45 degrees, slanting down to the left. It might be well to repeat here what has been said about the use of colored inks for drawing. Except for dimension lines, avoid the use of colors. The materials may be indicated as shown

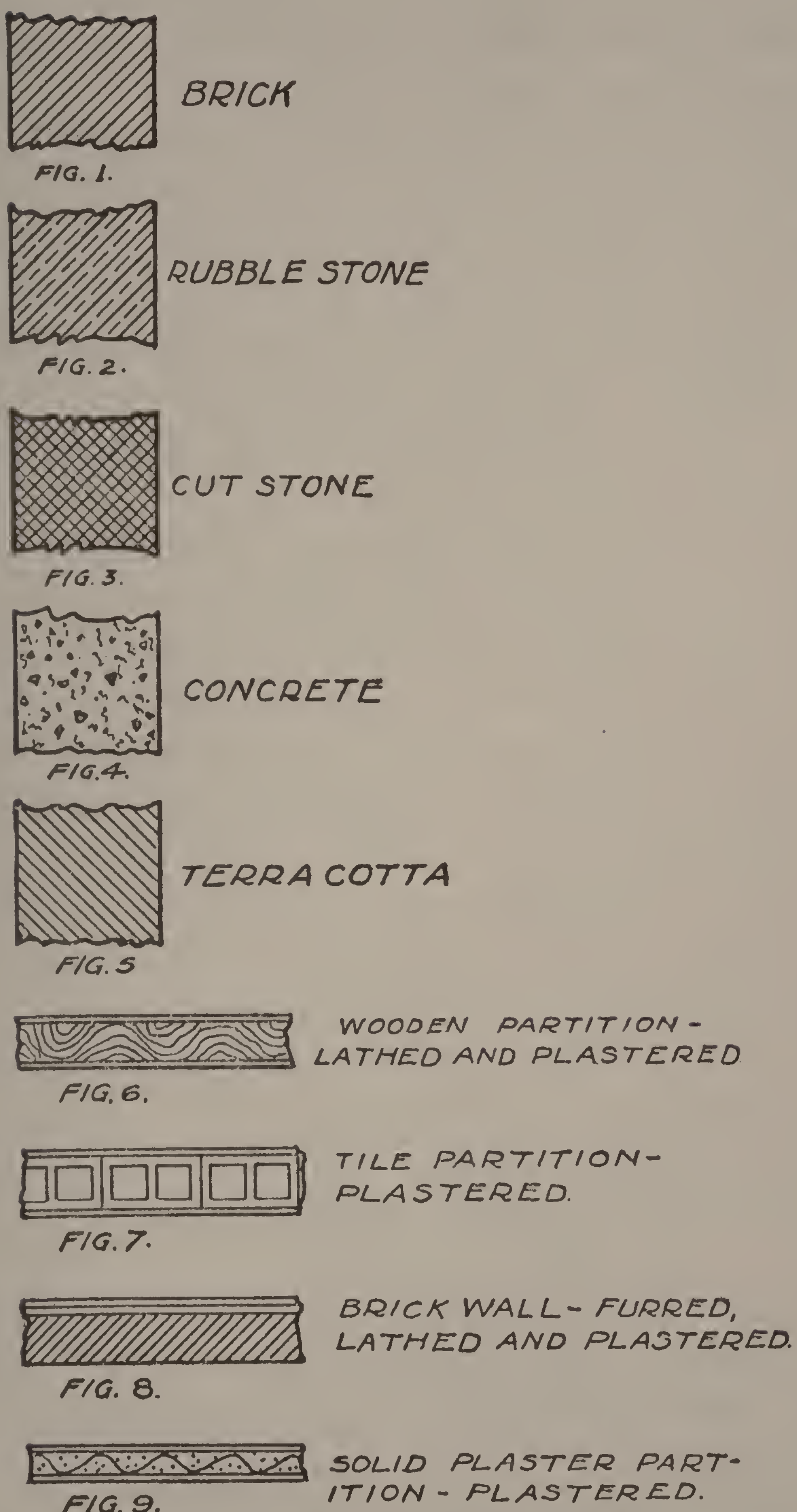


Plate A. Conventional Symbols for Representing Materials on Architectural Drawings.

by varying the texture of the line and also by different forms of dotting.

Fig. 2—We use alternating lines—solid and dashes—at 45 degrees to represent rubble stone such as is found in most basements.

Fig. 3—We use solid lines running at 45 degrees to each other and in opposite directions, to represent cut-stone work such as sills for windows and doors, chimney caps, and any kind of finished or dressed stone.

Fig. 4 represents concrete. This symbol is composed of small, wavy lines, with occasional triangular shapes to represent the stone. This symbol may be used to represent the concrete such as would be used in a solid wall or reinforced concrete for floors and other similar constructions.

Fig. 5 illustrates the method of showing terra-cotta. This is the same as for brick, with the lines running in the opposite direction.

For representing an interior partition of a frame building, the method shown in Fig. 6 is perhaps the most satisfactory. Plaster is represented by parallel lines to opposite sides of the wall.

Very often, in fireproof buildings, partitions are built of hollow tile and plastered on both sides. Fig. 7 illustrates the method of indicating such a partition.

Where a brick wall is furred on the inside and then plastered, we use the ordinary symbol for the brick wall, and show the plaster away from the wall, as in Fig. 8.

Very often, instead of using the partition as shown in Fig. 7, it will be built up solid of plaster 2 inches thick with a layer of expanded metal imbedded. This partition is shown in Fig. 9. It will be found a very satisfactory partition, requiring less floor space, and equal in every way to any other fireproof partition.

On the basement plan, various **lines of pipe** should be shown. There should be a porous tile drain, in damp soils, all around the outside of the basement walls, at the footing line. Such drains are constructed of porous farm tile, laid with butt joints and no cementing of any kind. The tile being porous, the water in the soil percolates through the walls of the tile, and is carried away. These drains are indicated as shown in Plate B.

For the sewer connections inside the building, and extending at least six feet outside the basement wall, the pipe should be cast-iron and have calked joints. Such pipes are shown on the basement plan as in Plate B. Connected to this cast-iron pipe outside the basement wall, a vitrified tile drain should be used, with cemented joints. Such pipe is also shown in Plate B. All these pipe lines should be shown in black on the drawing.

There are certain lines used in a drawing for reference, such as **axis lines**—that is, when a room or building is symmetrically arranged

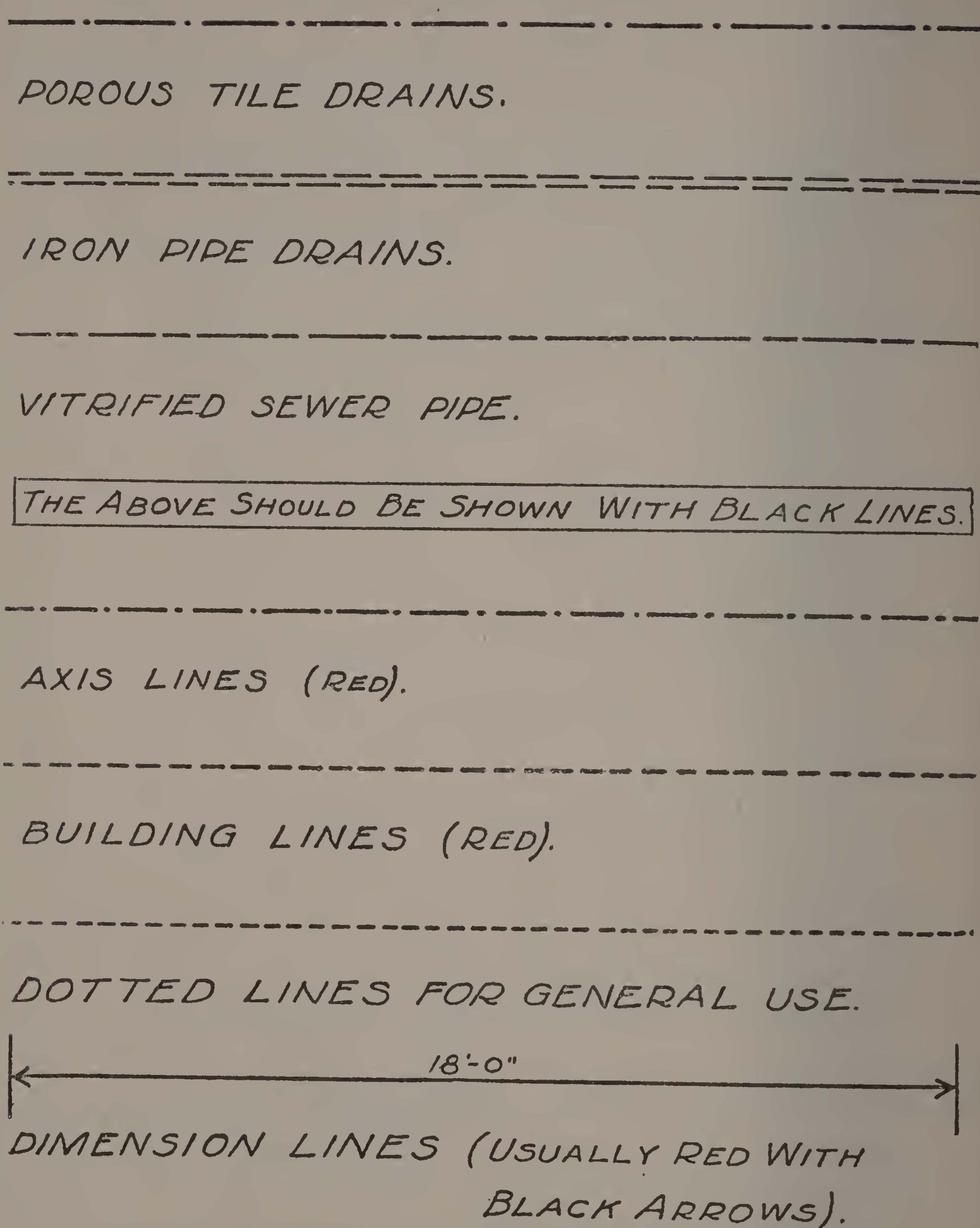


Plate B. Conventional Methods of Representing Drain and Sewer Pipe, Axis Lines, Building Lines, Dimension Lines, etc.

around a center line. In order to make such axis lines distinct from general lines, they are usually made as shown in Plate B.

When there are offsets or projections on a wall, such work is measured from certain lines established as **building lines** (see Plate B). Usually the outside wall line of the first story is taken as this reference line; and the basement wall line, the second-story line, the eave line, etc., are all measured as projecting from this line.

All **dimension lines** are to be noted as shown on this same plate, in which the arrow-heads are black, the connecting line is red, and the figures are in black, always above this line. This is the best practice, though sometimes dimensions are placed in the center of the line, the line being stopped to allow the figures to be inserted. This method takes more time and is not so practical, since the dimension line is broken and in some cases there might be a dispute as to just how much the dimension is intended to include.

For **lighting**, there are standard symbols adopted by the National Electrical Contractors' Association of the United States. These are published on a card convenient for reference, and copies may be had by applying to the Secretary. Another form of symbols has been adopted by the Boston Society of Architects, copies of which may also be had on application. The latter symbols are shown on Plate C. These are given for convenience in laying out plans, and are not

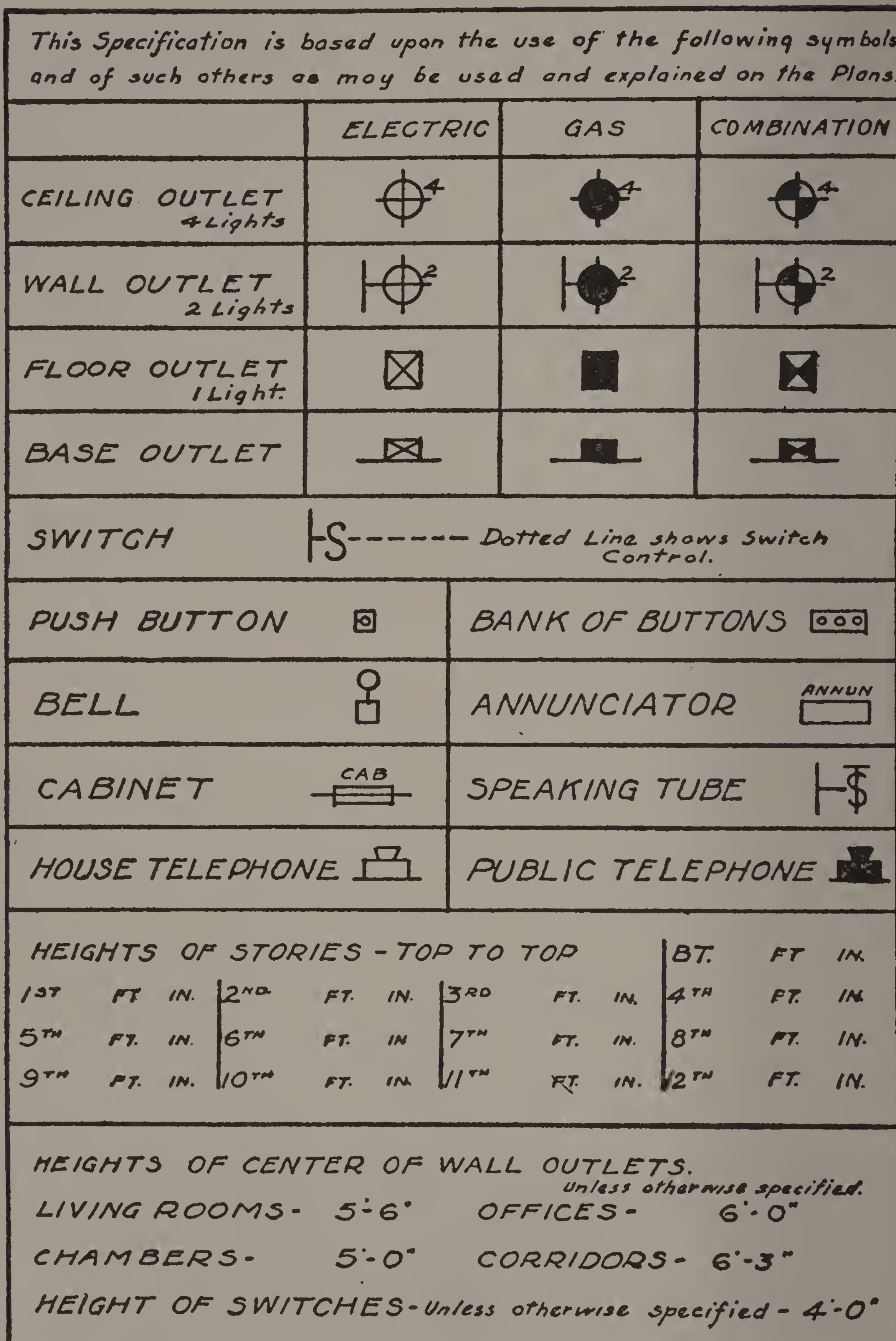


Plate C. Standard Symbols for Representing Fixtures, Electric Outlets, etc.
Adopted by the Boston Society of Architects.

intended to be complete in every respect. It is essential to show the location of the light outlets in all rooms; also whether they are to be gas, or electric, or a combination of both. Push-buttons, bells, and telephones are also indicated. If these locations are not shown, the contractor for this work will naturally place them in a posi-

A B

Fig. 17. Conventional Symbols for Heating Apparatus. A—Steam or Hot-Water Radiator; B—Hot-Air Register.

tion requiring the least amount of pipe, wire, etc. Therefore show all of these fixtures, and there can then be no dispute as to the true intent of the plans and specifications.

For the **heating**, about all that is necessary is to show the location of the registers or radiators, marking the number of square feet of radiation on each radiator. The usual method is shown in Fig. 17 (**A**) for steam or hot water, and in Fig. 17 (**B**) for hot air. The specifications should

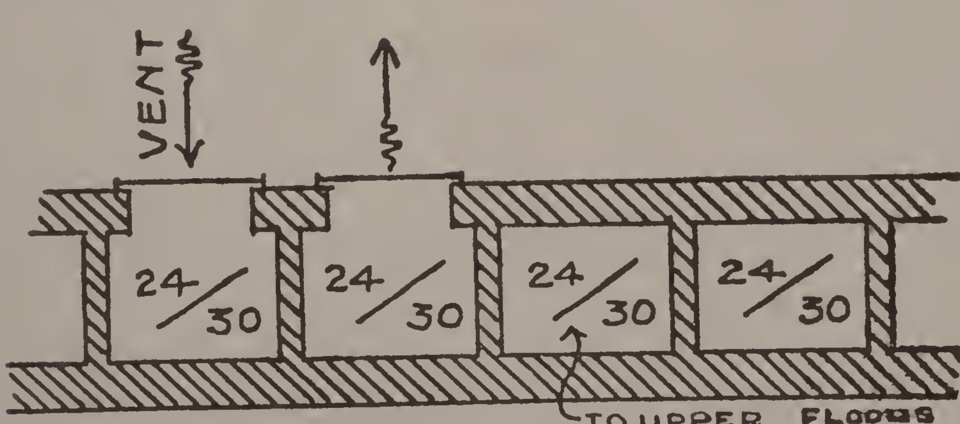


Fig. 18. Conventional Representation of Flues for Air Supply and Ventilation.

describe the kind of heat, and go into detail about pipe, fittings, etc.

In hospitals, public buildings, and school-houses, where there are a number of occupants in each room, it will be necessary to furnish a **fresh-air supply,** also a **vent flue.** These are all figured, and should be located conveniently.

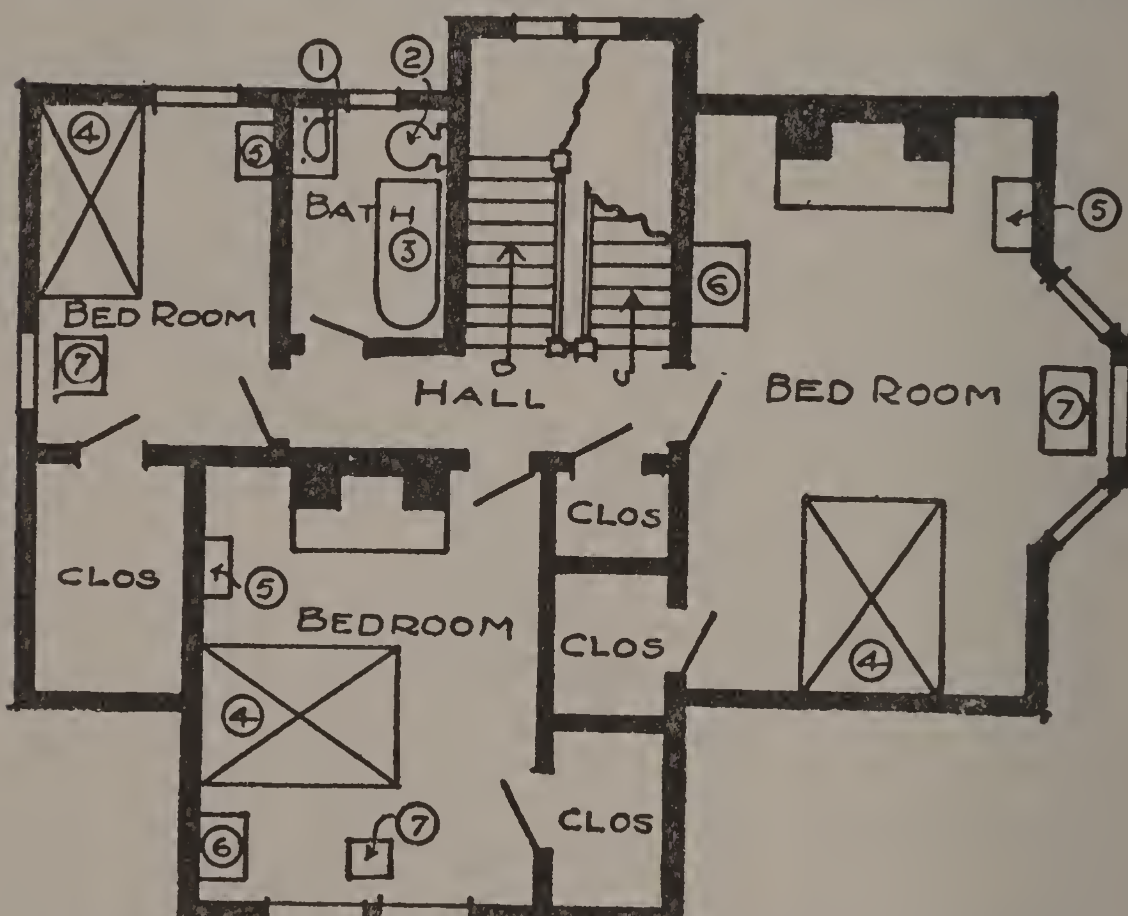


Fig. 19. Sketch Plan Showing Arrangement of Furniture.

The method of figuring the correct location for such work will be considered under "Heating and Ventilating." The conventional method of showing flues for air supply and ventilation is shown in Fig. 18.

For **furniture,** certain conventional forms are used, and shown on all plans. The furniture of the bedrooms and bathrooms is usually laid out on the plans, since these are usually made as small as practicable; therefore the furniture and fittings are laid out to make sure that there will be room to get them all in. This applies to the cheaper classes of houses, for in the larger and more expensive residences the rooms are always amply large to accommodate all the furniture and fittings desirable. In Fig. 19, a bathroom and bedrooms are laid out, the furniture being indicated by numbers, (1) representing the lavatory or wash-bowl, (2) the closet, (3) the bathtub, (4) the bed, (5) the chiffonier, (6) the dresser, and (7) a table or writing desk. See also Fig. 20.

Sometimes a client has furniture he wishes to put into a new home. It will be found very convenient to get the dimensions of such furniture, and cut out pieces of cardboard the exact sizes of this furniture according to the scale of the plan. Then lay them on the plan as drawn, and see how they will fit wall spaces, nooks, etc. By this method, pieces can be arranged, and it will very soon be shown whether or not the rooms will accommodate the furniture. This will be found very convenient in all classes of work (see Fig. 20).

Below are given the dimensions of some of the common pieces of furniture. These sizes will vary somewhat, but in general they will be accurate enough in laying out work.

Dining Tables—3 ft. 6 in. to 4 ft. wide, and to extend to 10 ft. to 12 ft. by extra leaves, and 2 ft. 5 in. high..

Writing Tables—2 ft. 6 in. high.

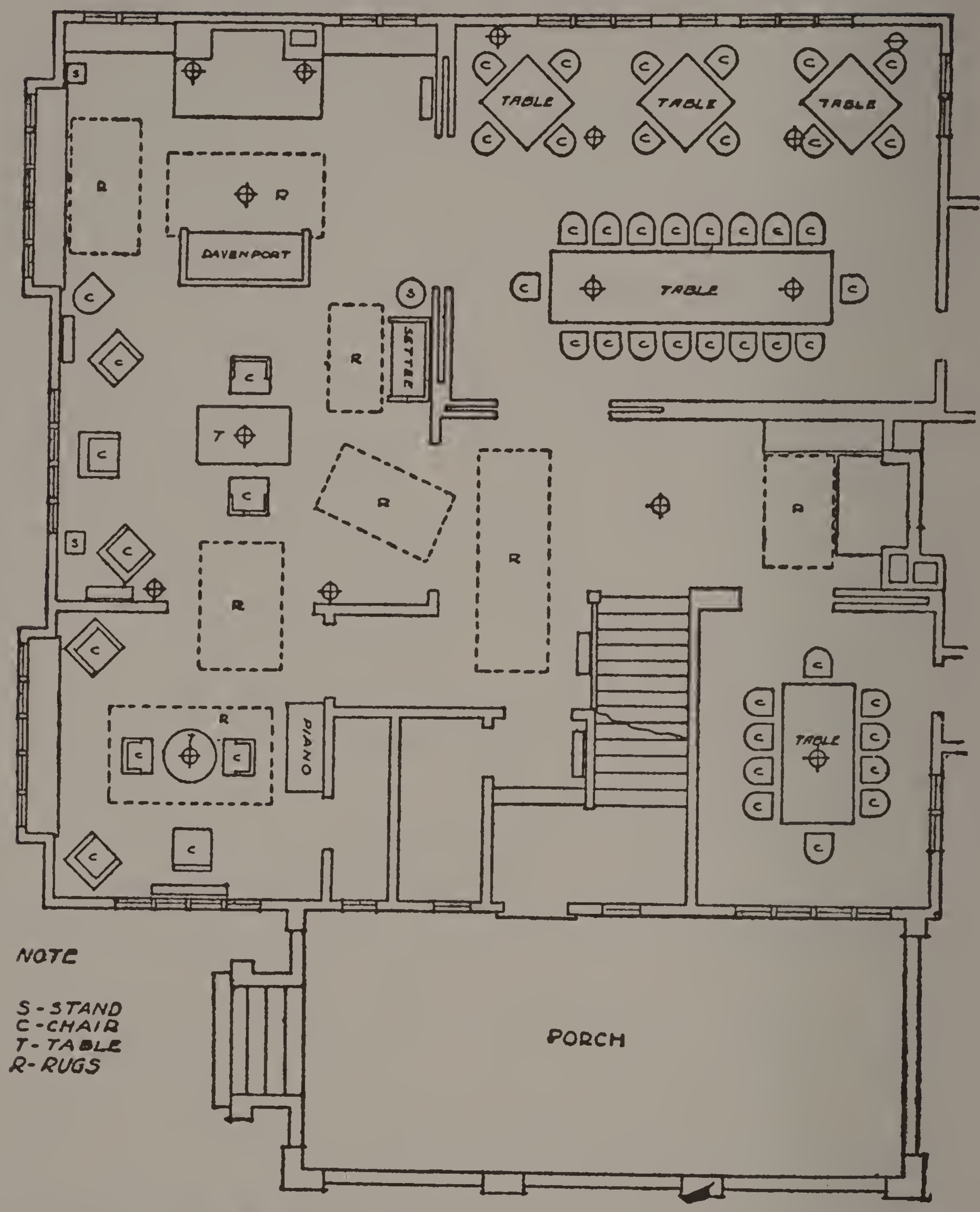


Fig. 20. Plan Showing Method of Laying Out Furniture and Rugs.

Carving Tables—3 ft. high.
Ordinary Tables—2 ft. 6 in. high.
Beds, Single—3 ft. 6 in. wide;
Beds, Three-quarter—4 ft. to 4 ft. 6 in. wide;
Beds, Double—4 ft. 6 in. to 5 ft. wide.
All beds should be 6 ft. 8 in. long inside.
Dressers—1 ft. 6 in. to 2 ft. by 3 ft. 5 in.
Couches—2 ft. 6 in. by 6 ft. 8 in.

Chiffoniers—2 ft. by 3 ft., and 4 ft. 6 in. high.

Sideboards vary according to design, 4 ft. to 6 ft. long, and from 2 ft. to 2 ft. 2 in. deep.

Pianos, Upright, vary, being usually 3 ft. 3 in. by 6 ft. 6 in. long, and 4 ft. to 4 ft. 9 in. high.

Bookcases—10 in. to 16 in. deep, any length and height.

Chairs and Seats—Usually 17 in. high at front, 16 in. at back, and the seat is usually 17 in. high by 16 in. inside; the back, from 1 ft. 6 in. to 1 ft. 8 in. high, slightly inclined at the top.

For plumbing fixtures, consult any plumbing catalogue. The washstand varies, 18 in. deep by 2 ft. long being about the minimum. The bathtub varies from 3 ft. 6 in. to 4 ft. 6 in. long, about 1 ft. 11 in. high above the floor, and 2 ft. wide across the rim. Closets are about 1 ft. 4 in. wide, and about 2 ft. from the wall.

Ranges—26 in. to 30 in. by 36 in. by 42 in.

Ranges, Gas—26 in. by 34 in.

Lunch Counters—Height, 3 ft. 3 in.
Stool, 2 ft. 2 in.
Counter projects 9 in. and is 2 ft. 2 in. wide.
Foot-rest, 7 in. high and 9 in. from counter.

Urinals—26 in. to 30 in., center to center.

Rugs—4 ft. 6 in. by 7 ft. 6 in. up to 11 ft. 3 in. by 15 ft.

The above dimensions are only general, but will be of assistance in laying out the furniture of a house.

MATERIALS OF CONSTRUCTION

There will be found a great variety of materials for the construction of buildings, nowadays. In some localities, one material will be used more than others; for instance, in the vicinity

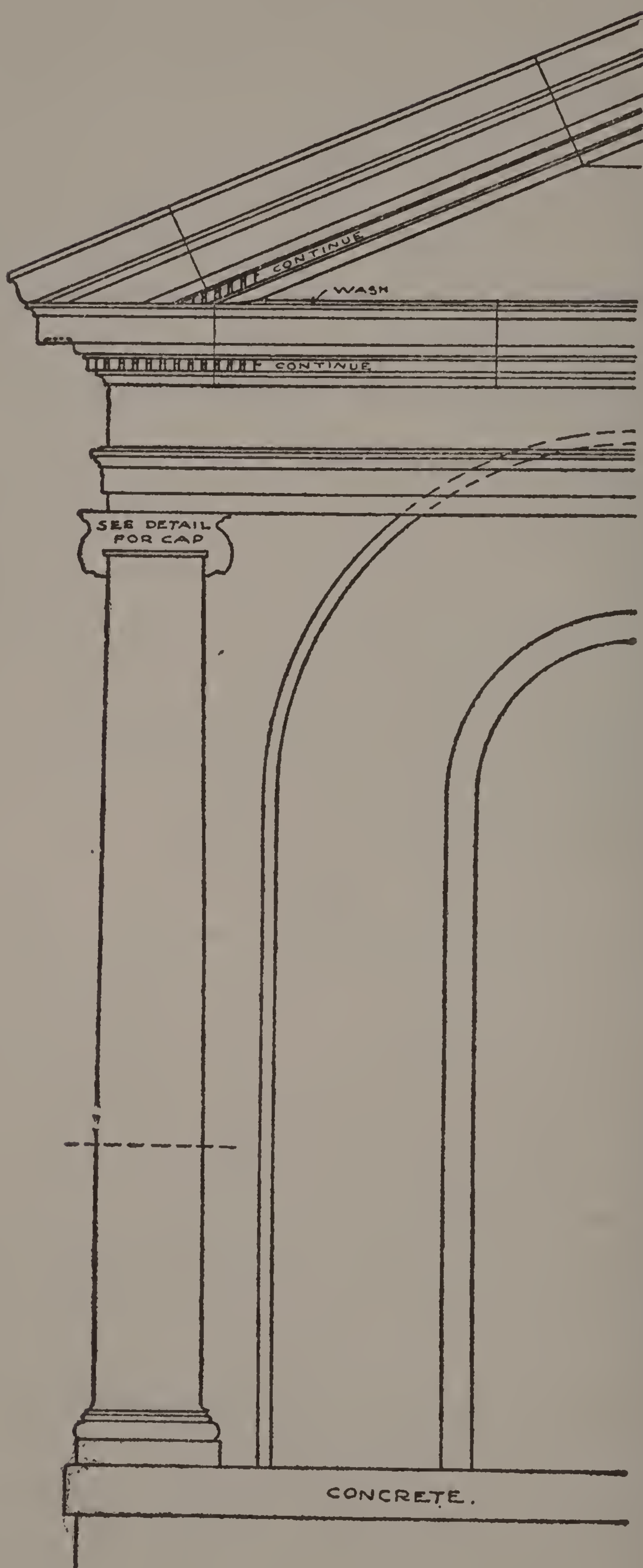


Fig. 21. Elevation of a Porch.
See also Figs. 22 and 23.

SHADOWS CAST UPON AN ORDER OF ARCHITECTURE.

PLATE D—ARCHITECTURAL DRAFTING.

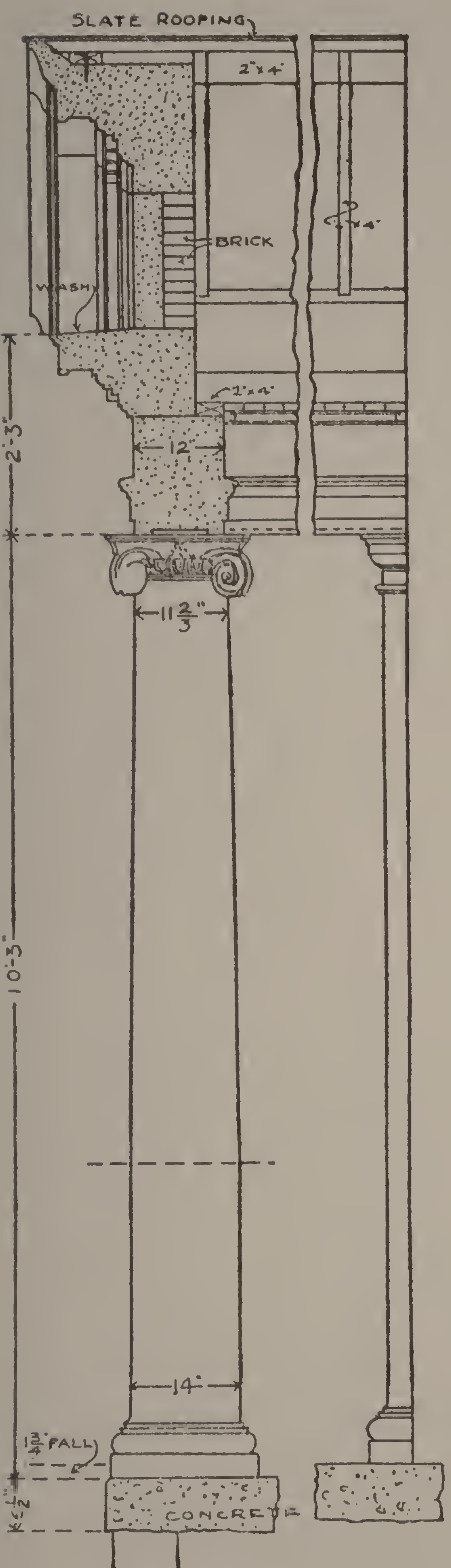


Fig. 22. Porch of Fig. 21 Detailed for Stone Construction.

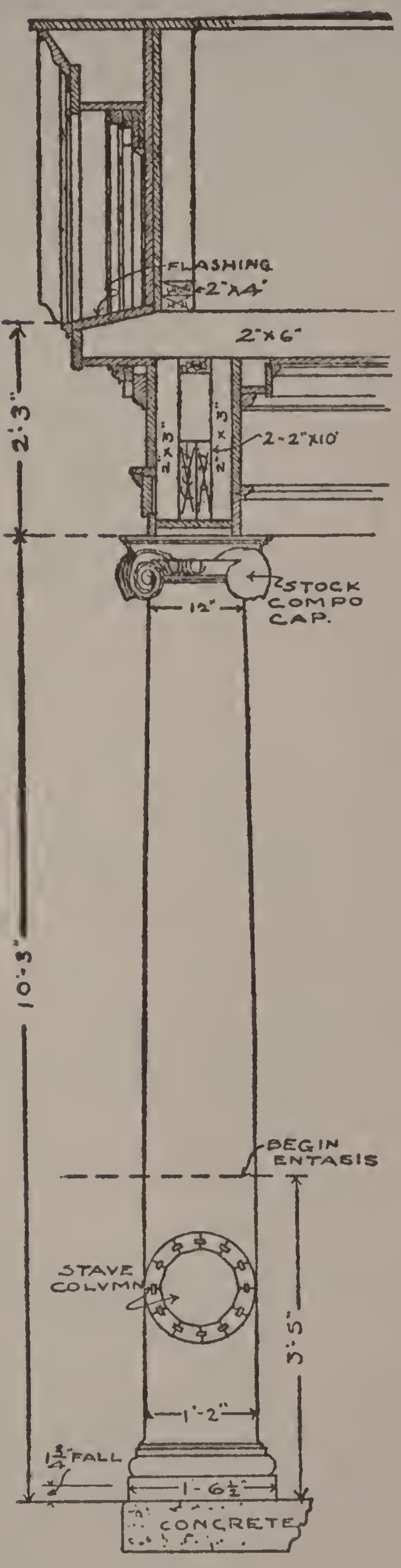


Fig. 23. Porch of Fig. 21 Detailed for Wood Construction.

of a stone quarry, stone will usually be cheaper than anything else—even in some cases cheaper than wood. Should your client be interested in a brick concern, brick would undoubtedly be used. In a locality where timber is cheap, that material would be largely employed.

For the cheaper class of work, we find wood to be the cheapest material, although, within the past ten years or so, wood has advanced in price at a great rate. The kind of wood used will vary with each locality. In some sections—especially the South—yellow pine will be used; in our Western States, fir and local varieties will be selected. An architect in a new locality, therefore, should become familiar with the local woods used, and should govern his work, such as spans of beams, interior finish, etc., by these conditions. The use of terra-cotta for the facing of masonry walls, for ornamental courses, cornices, and window-sills, is quite common. Since this is a product made of clay, properly mixed, moulded, and burned, it can be treated as plainly or as elaborately as the design of the building warrants. Terra-cotta, of course, is used only with masonry, such as brick, stone, or concrete.

Fig. 21 shows the elevation of a porch, and Fig. 22 shows this porch detailed for stone construction; while Fig. 23 shows the same porch detailed for wood.

SHADES AND SHADOWS

In order to prepare sketches and make them attractive, a brief treatment of **Shades and Shadows** will be taken up, the main general rules and principles being explained, which may be applied to ordinary architectural drawing.

By the use of shades and shadows, very important effects are produced. The general proportions of the cornice, for example, are emphasized by using shadows. The relative amount of window area to wall area is clearly shown by the use of shadows.

The light is always assumed as coming over the left shoulder of the person looking at the drawing, and at an angle as explained later. This assumption is always made, being merely a conventional or customary way of considering

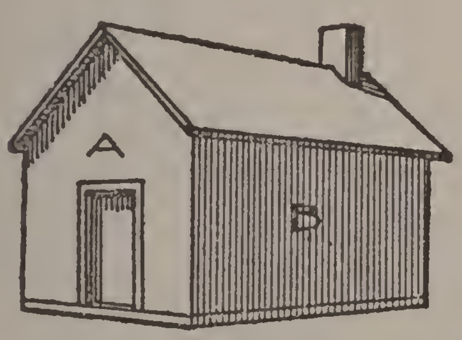


Fig. 24.

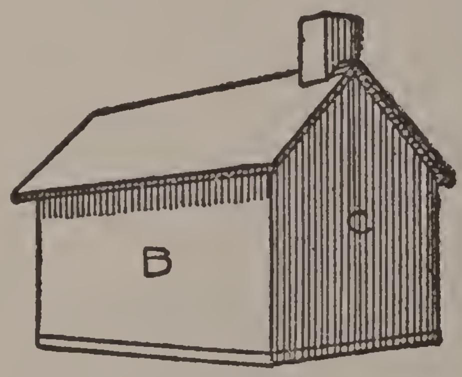


Fig. 25.

Illustrating Conventional Method of Considering Rays of Light in Architectural Drafting.

the light. The idea intended is to produce the same effect on a drawing that the sun in this one position would produce on the building. While the sun would actually produce a shadow on one side of the building at one time, and on another side at another time, in architectural drawing this variation is not shown. No matter what elevation or side of the building is being considered, the light is always from the same direction.

Thus we see that in Figs. 24 and 25 the sun really would make one side always in shadow, but we do not so consider it. In Fig. 24 we see the side **A** is in sunlight, and the side **B** is in shade. Looking now at Fig. 25, we see side **B** in sunlight, and **C**, which was the rear end, now in shade. This is the conventional method of considering the rays of light for architectural drawings. No matter what elevations or drawings are considered, or how many of the same building on the same sheet, the direction of the rays of light is fixed.

Perhaps it will make the understanding of this subject clearer if we define the terms **shade** and **shadow.** That portion of a building or drawing is said to be in "shade" which is turned away from the assumed rays of light; or, it receives no rays of light, in contrast to the sides which are in light or upon which the light falls.

If a body is placed between the light and a plane upon which the rays might fall, such a body will prevent a portion of the rays from striking the plane, thereby causing a shadow upon the plane.

All rays of light are assumed as parallel and considered as straight lines.

The rays of light are assumed as coming over the left shoulder, or sloping downward and backward. This is the diagonal of a cube. The projections of this diagonal in the vertical plane and in a horizontal plane are at 45 degrees, while the true angle of the diagonal with the plane is slightly less than 35 degrees 16 minutes. If we assume the side of the cube as 1, then the true length of this diagonal is nearly one and three-quarters. In Fig. 26, we see the cube and the diagonal drawn as a heavy line with an arrow-

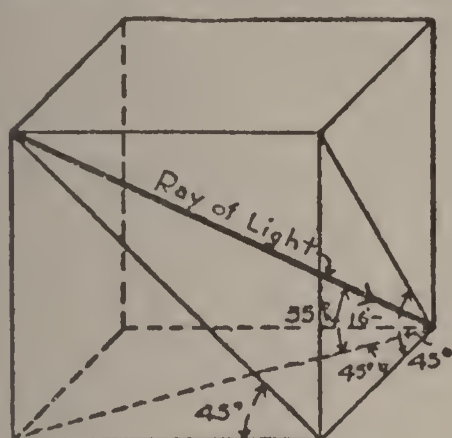


Fig. 26. Drawing Showing Assumed Direction of Light.

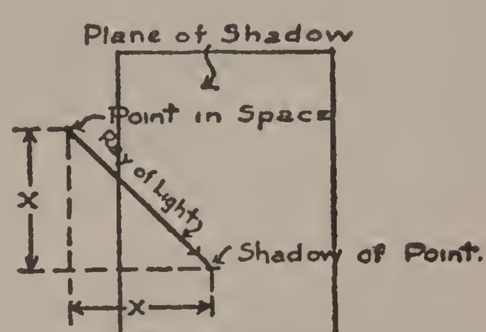


Fig. 28. Elevation of Point and Shadow.

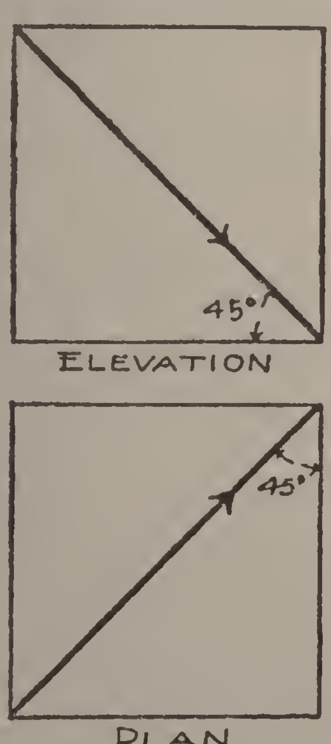


Fig. 27. Elevation and Plan of Cube of Fig. 26.

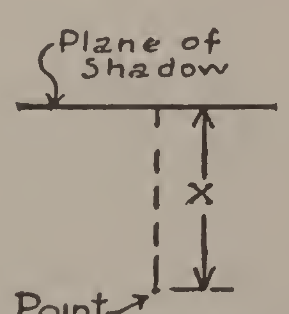


Fig. 29. Plan of Point in Space and Plane.

Shadow of a Point in Space.

head indicating the direction of the light. Fig. 27 shows the elevation and plan of the same cube.

The **shadow of a point** is where the ray of light surrounding the point intersects the plane upon which the shadow falls. In Fig. 28, we see the light surrounding the point, and intersecting the plane, giving the shadow of the point upon the plane. The shadow is located as far down and as far to the right of the point in space as the point is from the surface or plane upon which its shadow falls. Fig. 29 shows the plan of the point, its distance from the plane, and the plane.

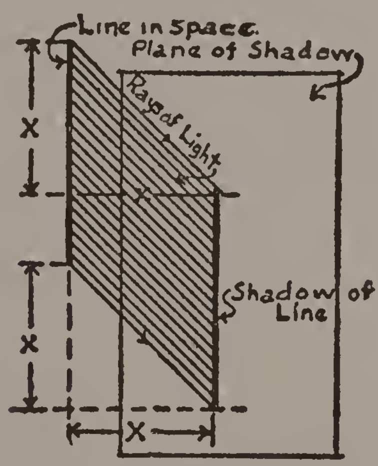


Fig. 30. Elevation of Line and Shadow.

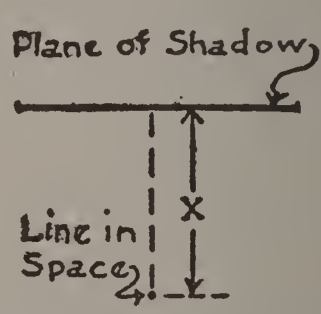


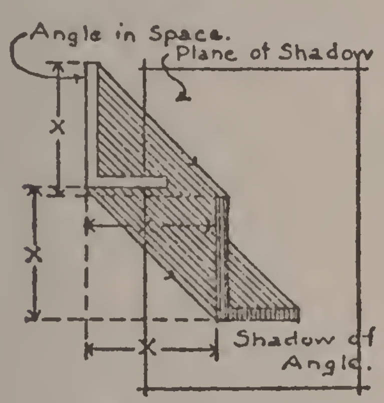
Fig. 31. Plan of Line in Space and Plane.

Shadow of a Line Parallel to Plane of Shadow.

The **shadow of a straight line** in space is the intersection of the light surrounding this line with the plane of shadow. By casting the shadows of the extremities of the line and connecting these points of shadows, we have the shadow of the line. All points of the line in space will cast shadows upon the plane as far down and as far to the right as the point is from the plane.

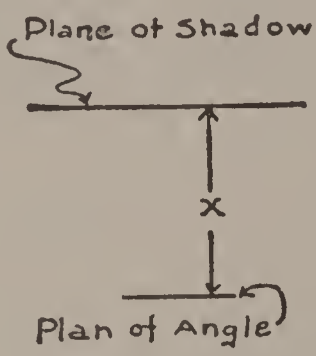
If the line is parallel to the plane, the shadow will be equal in length and parallel to the line itself. See Fig. 30 for an elevation, and Fig. 31 for the plan of the line and plane.

If the line in space is not a straight line, then the shadow of the line may be found by casting the shadows of any number of points on the line, and connecting these. The greater the number of points of shadows cast, the greater will be the accuracy of the work. In Fig. 32



ELEVATION

Fig. 32.



PLAN

Fig. 33.

Shadow of an Irregular Shape which is Parallel to Plane of Shadow.

we see the shadow of an angle or L-shape cast on the plane of projection; Fig. 33 shows the plan of the angle.

The shadow of a straight line perpendicular to the plane upon which the shadow falls, is a straight line at 45 degrees, no matter what the outline of the surface is upon which the shadow falls (see Figs. 34, 35, and 36).

The shadow of a straight line parallel to the plane upon which the shadow falls, is an irregular line giving the true outline of the surface (see Fig. 37).

The shadow of a perpendicular line on a roof is therefore a line which gives the true slope of the roof, since the line is parallel to the plane, and therefore casts a shadow the true shape of the surface upon which it falls.

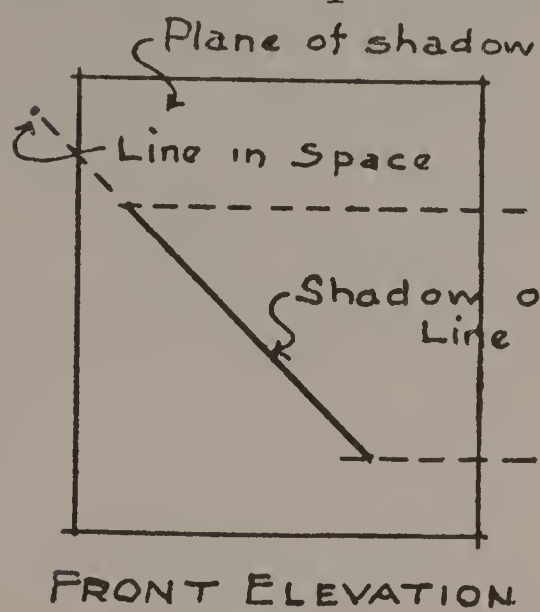


Fig. 34.

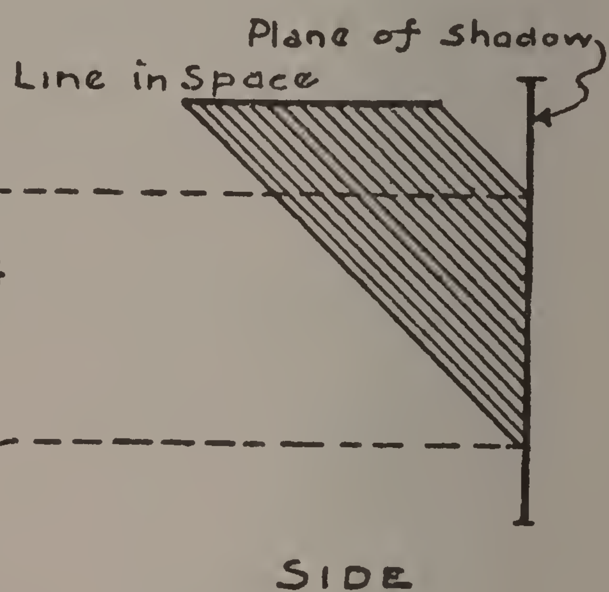


Fig. 35.

Shadow of a Line which is Perpendicular to lane of Shadow.

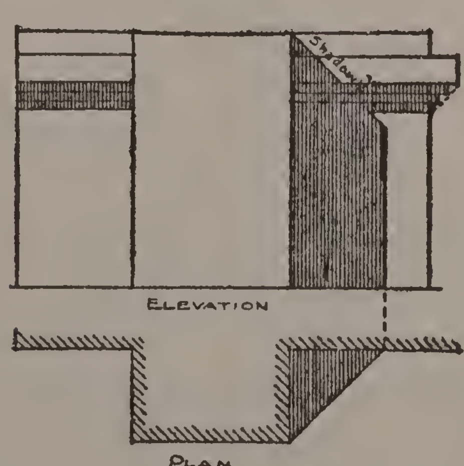


Fig. 36. Showing Shadow of a Line Perpendicular to Plane of Shadow.

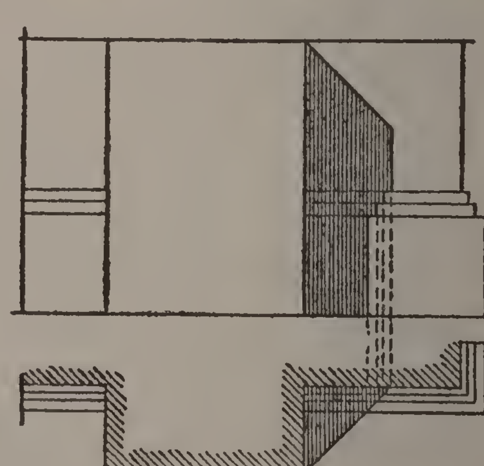


Fig. 37. Showing Shadow of a Line Parallel to Plane of Shadow on a Moulded Surface.

The shadow of a straight line inclined to the plane upon which the shadow falls, is a straight

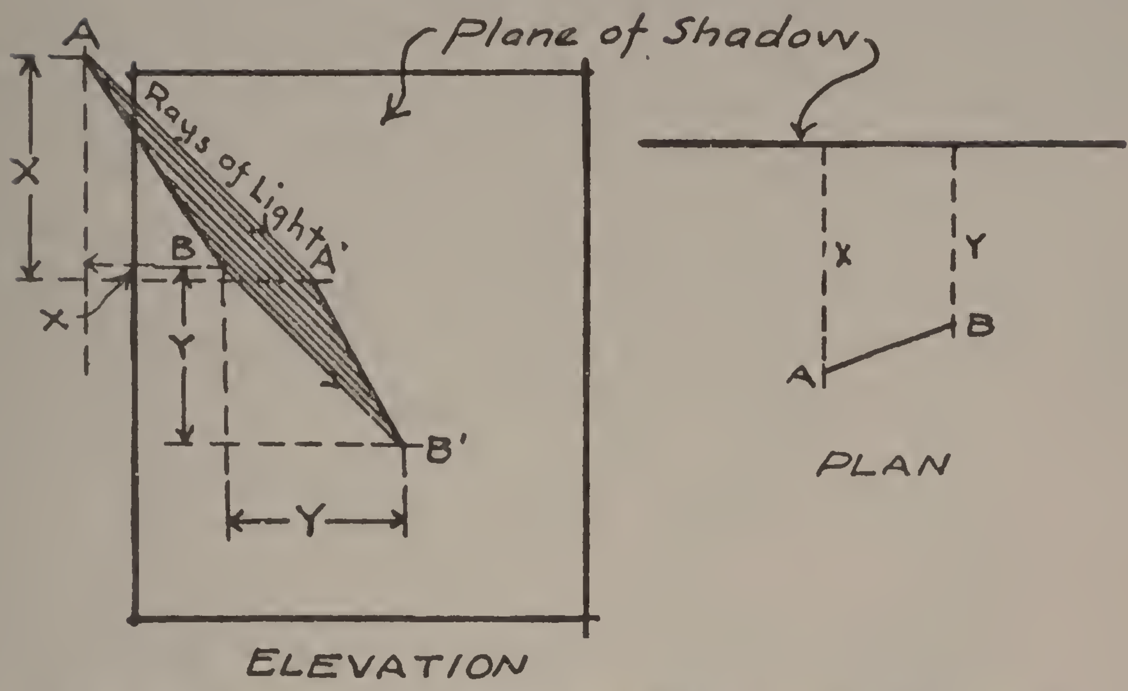


Fig. 38 Shadow of a Line Inclined to Plane of Shadow.

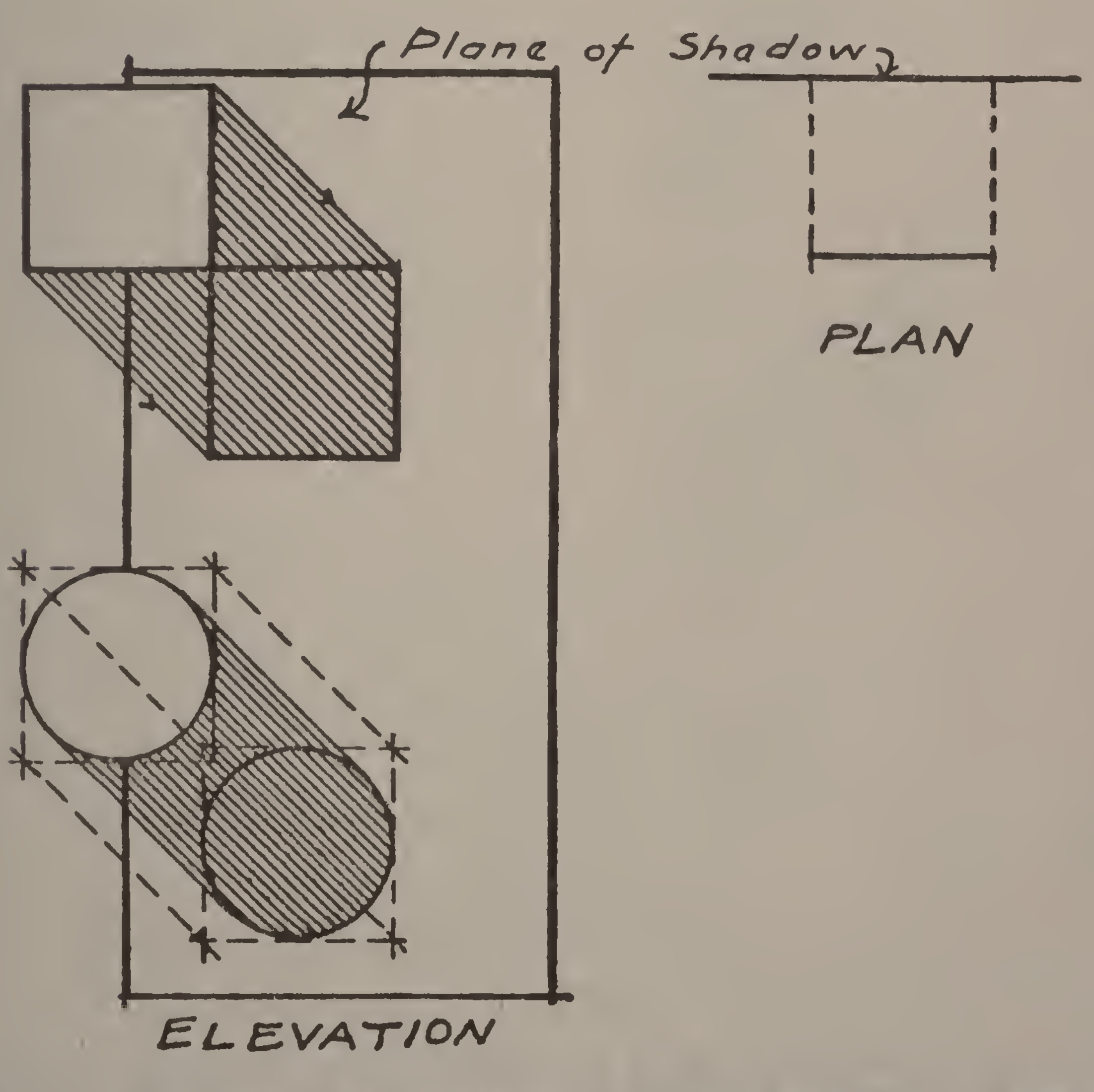


Fig. 39. Shadows of a Square and a Circle Parallel to Plane of Shadow.

line connecting the shadows of the ends of the line (see Fig. 38).

As in the case of a line parallel to the plane upon which the shadow falls, the shadow is equal in length and parallel to the line, so it is with **surfaces**—the square, rectangle, octagon, etc. If parallel to the plane of shadows, the shadow

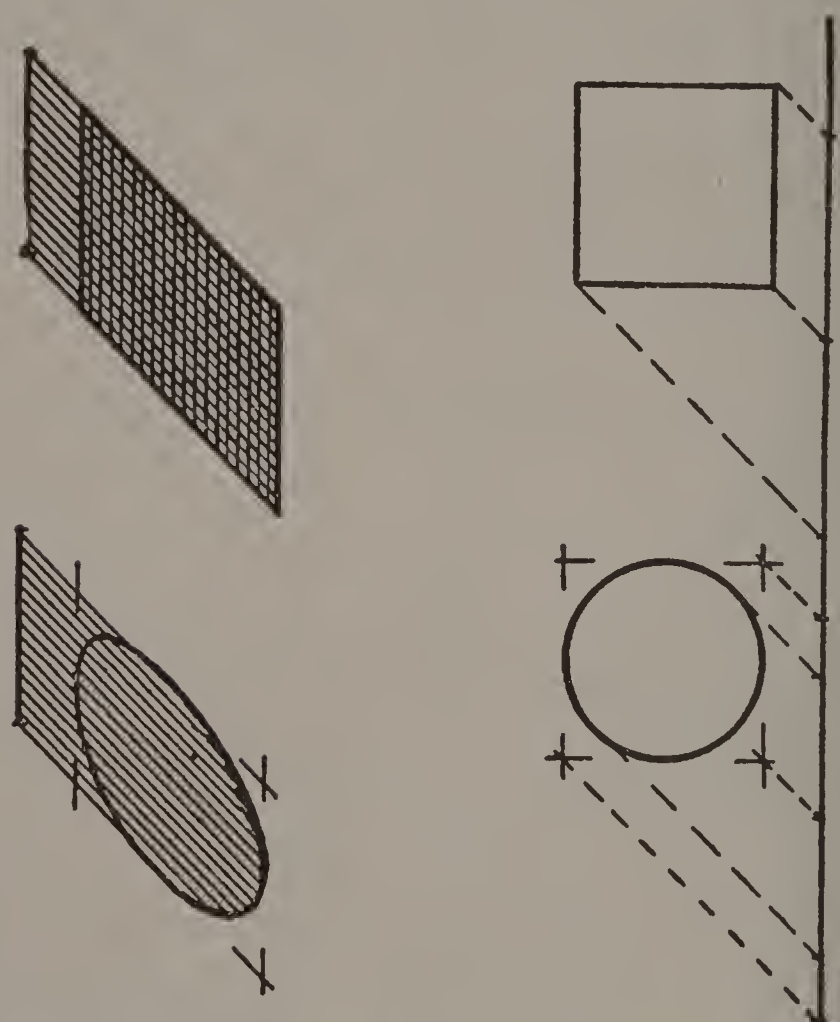


Fig. 40. Shadows of a Square and Circle Perpendicular to Plane of Shadow.

will be equal in size and shape to the figure (see Fig. 39).

A square perpendicular to the plane of shadow will cast a diamond-shaped shadow, for two of the lines are parallel to the plane, and two are perpendicular to the plane (see Fig. 40).

Having stated a few principles of casting shadows, these will be applied to a few common examples.

Take an example of a brick projecting from a wall (Fig. 41). We apply the principles as

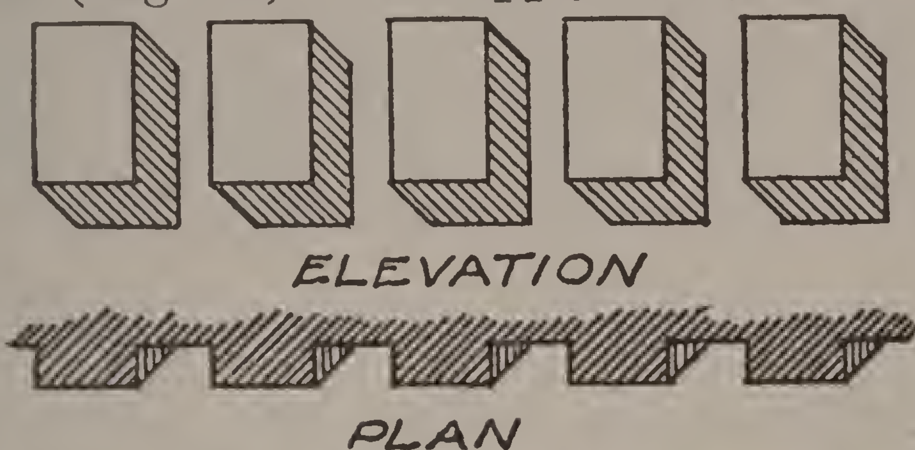


Fig. 41. Shadows of Projections from Plane of Shadow.

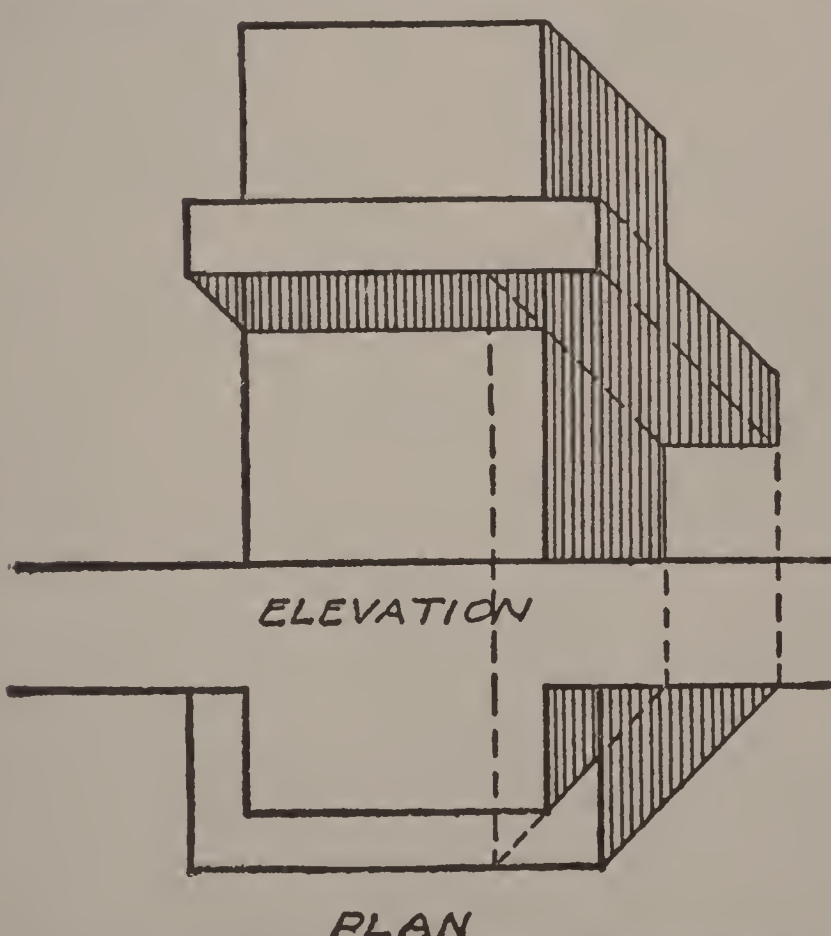


Fig. 42. Illustrating Principles of Shadows.

stated, to each edge of the brick. The top, bottom, and side faces of the brick are perpendicular to the plane, therefore the shadows will be rectangular in shape.

Figs. 42 and 43 show a further application of the foregoing principles.

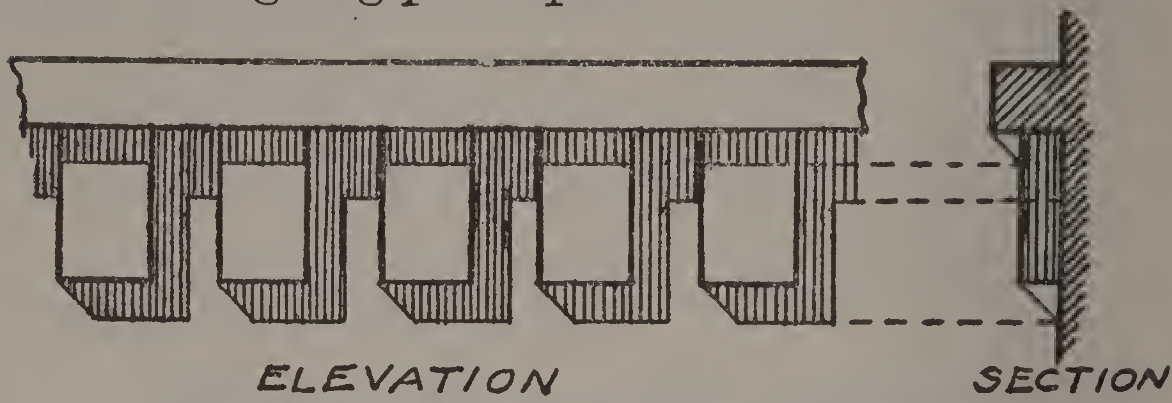


Fig. 43. Illustrating Principles of Shadows.

Plate D shows the shadows as cast upon an Order of architecture, illustrating also how much clearer the drawing is when it has the shadows worked out on it.

The above principles will give a general understanding of the subject.

DETAILS OF CONSTRUCTION

It is essential to know the usual method of detailing different portions of the building. For the clear understanding of some of the important parts of a building, there have been prepared some typical details. The reader, having become familiar with the details shown, can adapt them to any sort of building.

Cornice. The cornice is the projection at the top of the building, made more or less elaborate. There are several kinds of cornices—the **box cornice,** as shown in Fig. 44, and the **open cornice,** as shown in Fig. 45 (a and b). Referring to Fig. 44, there is the **crown-mould A,** the **fascia B**; the **planceer** or **soffit C**; the **lookout D**; the

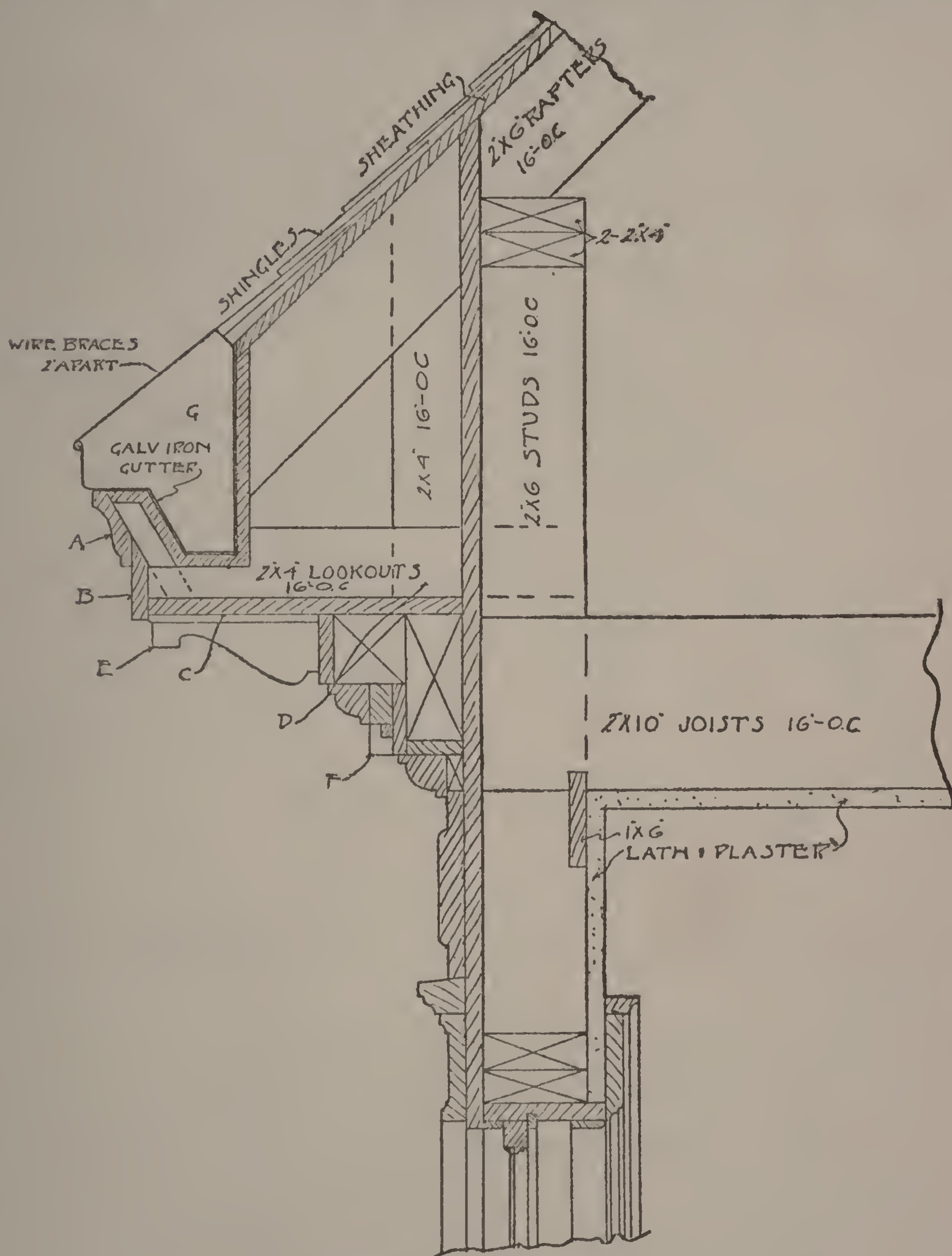


Fig. 44. Box Cornice.

brackets E; the **dentil course F.** Not all cornices have all these parts. The plainer ones may be without the brackets **E** and the dentils **F**; or more elaborate cornices may have more members. The closed cornice always has the gutter built into the upper members; the open cornice

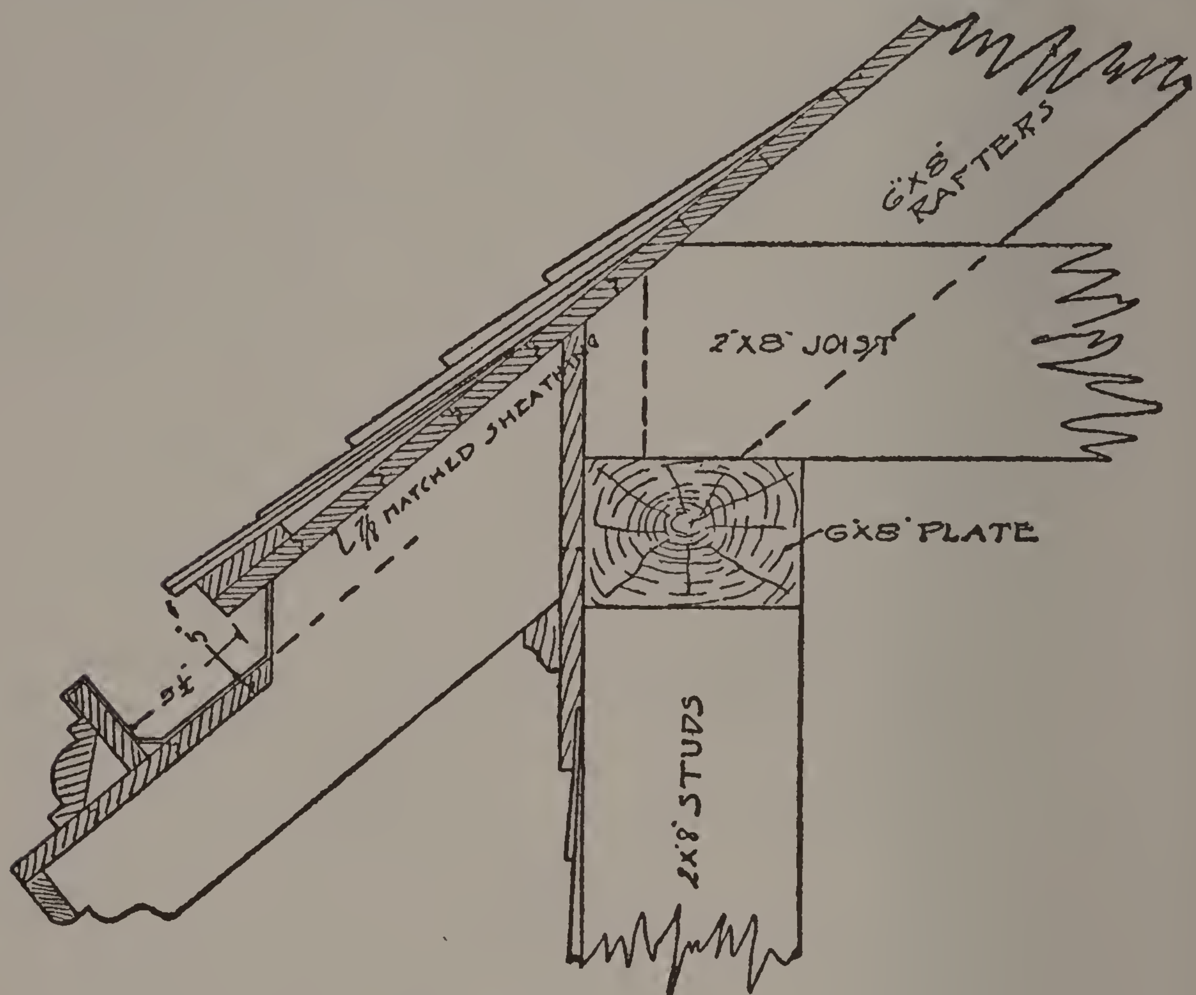


Fig. 45a. Open Cornice.

has a hanging gutter, as shown in Fig. 45 (a or b).

The **gutter,** in the best work, is made of copper; in ordinary work, of galvanized iron; and in the cheapest class of work, tin is used. The durability of these materials is in the order named, the copper wearing usually the life of the building. Galvanized and tin gutters have to be kept well painted; but even with good care, the life of these two materials is limited.

One important feature of a good gutter is to have the metal run well up under the roofing material, and out over the crown-mould. This keeps any water from overflowing up under the roof if the gutter becomes choked with ice or leaves. The gutter should be well pitched or graded to the outlets. The gutter outlets are in turn connected to leaders or down-spouts. These down-spouts are made, usually, of the

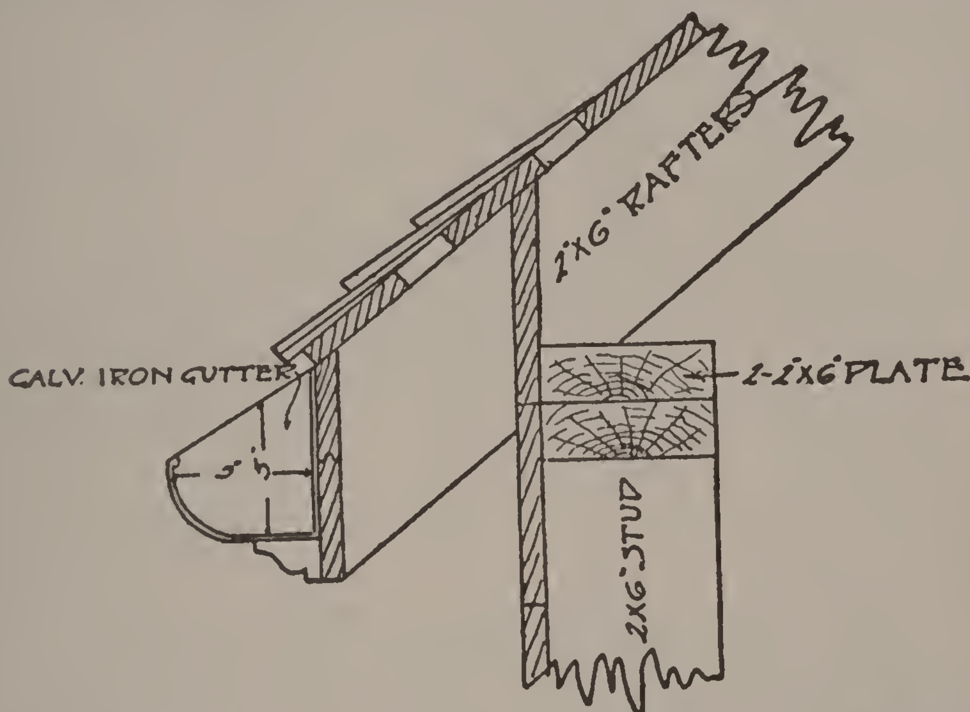


Fig. 45b. Type of Open Cornice Known as Close-Eave Cornice.

same material as the gutter. The shape of the down-spouts may be either round or rectangular; a very common form is made of corrugated iron, either round or rectangular. The gutter, especially if a hanging gutter, must be securely fastened to the roof at intervals of two or three feet, by means of some sort of hanger. The down-spouts must be securely fastened to the wall by some approved method.

Floor Construction. The floor construction does not vary much (see Fig. 46). In this figure we have the usual construction and method of support at the second or upper floor line. The **joists** must be of ample size, not only to carry

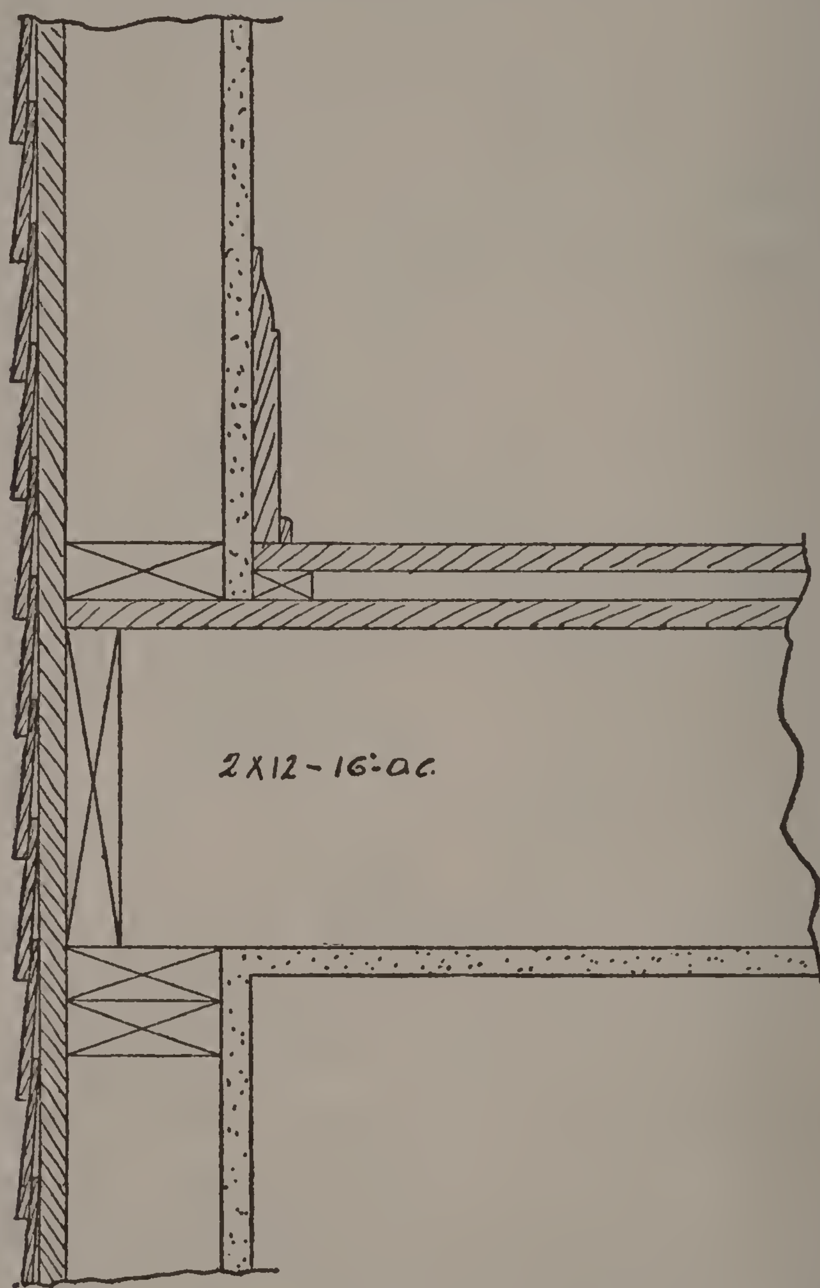


Fig. 46. Common Floor Construction at Second-Floor Line.

the load safely, but to be stiff enough not to sag or vibrate under a load, since this would crack the plastering or the ceiling below. On the joists is laid an **under-floor**, usually of boards ⅞ inch thick, laid diagonally at 45 degrees with the joists, and spiked with two nails on every joist. The flooring laid in this manner braces the building, and resists any tendency to twist.

In the best construction, we use some sort of **deafening material** between the upper and under floor, to deaden sound. The upper floor is of maple, oak, or yellow pine of matched or tongued-and-grooved boards, with the boards parallel to one side of the room. This floor is **blind-nailed**; that is, the nails are driven in at the intersection of the tongue and the vertical edge, as shown in Fig. 47. This keeps all nail-

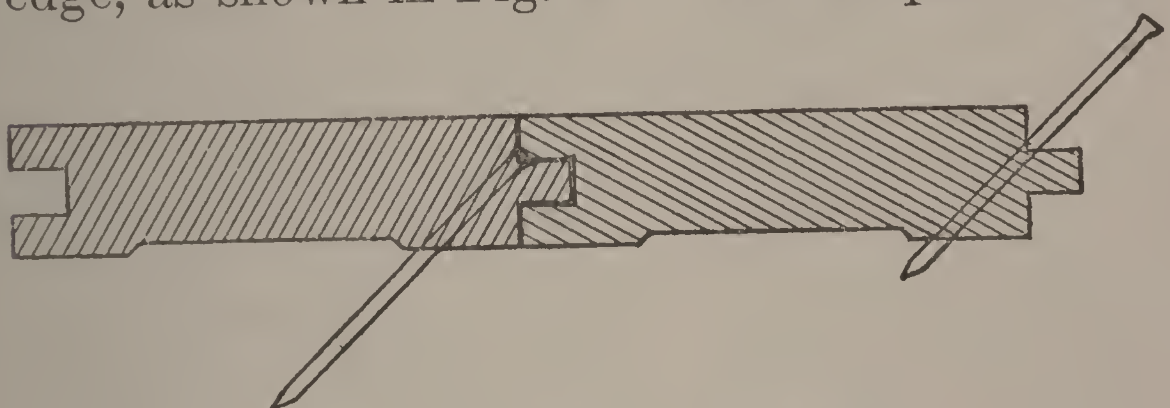


Fig. 47. Section Showing Blind-Nailing.

heads hidden from view. The upper floor should be thoroughly kiln-dried—that is, dried artificially to drive out the greater part of the moisture, so that when it is finally laid, it will not dry out in the building and open up ugly cracks. For this reason the finished floor should not be laid until the plastering is thoroughly dry. The under side of the joists is lathed and plastered.

Around openings, chimneys, or stair-wells, the joists are supported at the ends by means of a **header**, or a joist running at right angles to them, to which they are securely spiked; or they may rest on top of a ribbon or ⅞-inch board let into the studding, the construction being similar to the support for the ceiling joists as shown in Fig. 44.

At the first-floor line, we have to build a **sill** upon the basement wall; this sill forms a support for the joist, and also gives a nailing for the studding. The method is clearly shown in Fig. 48.

Lath and Plaster. The interior finish of almost all residence work is lath and plaster. The walls, if of wood, and the ceiling, are lathed with good, sound lath, free from blue sap or bark, and of white pine or spruce. They should be spaced at least ¼ inch apart, and the plaster pressed firmly onto them so as to make sure that there will be a good key for holding the plaster. All lath on vertical walls should be put on horizontally, and there should not be a vertical joint of more than 18 inches between any series of laths. Under no consideration should lath be put on a vertical wall other than horizontally. In hot weather, it will be well to wet the lath before applying the plaster, as then they will not absorb so much water from the plaster.

Plaster is usually put on in three coats for woodwork, and in two coats for brickwork. The first coat consists of slaked lime, sand, and long, clean cattle hair or fiber, this hair or fiber being used to make the plaster hold together better.

The first or **scratch coat** is applied and

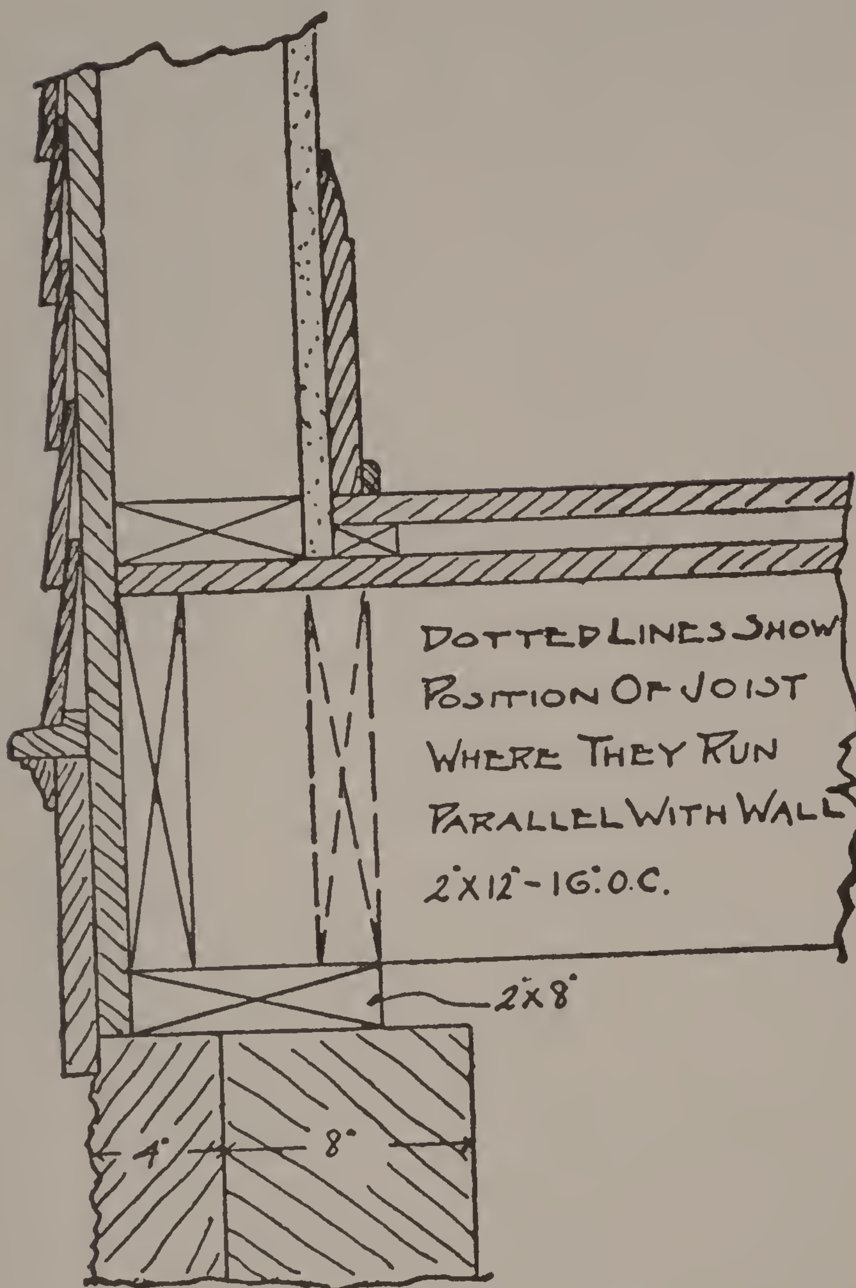


Fig. 48. Floor Construction at First-Floor Line.

pressed well into the spaces between the lath. It is this plaster getting in between the lath and falling over onto the lath, which forms the key or clinch for the plaster. This coat is then scratched with the trowel all over, in all directions. This scratching roughens up the surface, and makes a better surface for the second coat to adhere to.

The second or **brown coat** is a mixture of lime putty, sand, and a little hair or fiber, and is applied after the scratch coat has partially dried. This brown coat is brought out to a true line for all walls and ceilings, and corners are made true and sharp. There are placed around all openings and back of all chair rails, base-boards, etc., small strips 7/8 inch thick for three-coat work, and 3/4 inch thick for two-coat work, by 1½ inches wide. These are called **grounds,** and serve as a guide for the plaster (see Figs. 71 and 72). The third coat, sometimes called the **white** or **skim coat,** is a mixture of lime putty and white sand, with a little plaster of Paris. This is a thin, white coat, put on and rubbed down until hard, giving a hard white surface. Sometimes marble dust is added, which makes it harder and gives a little more polish to the surface. If a sand finish is desired, instead of the white coat as above described, the third coat is mixed with lime putty and coarse sand.

Flashing and Counter-Flashing. By flashing and counter-flashing is meant metal protection for the intersection of surfaces, to keep out the weather. Take an example of a chimney going through a roof. Some means must be provided to prevent snow and water from coming in through the space between the vertical side of the chimney and the roof. This is accomplished by using sheet metal—either copper, galvanized iron, or tin—and fastening it under the roof covering, turning it up against the chimney, as shown in Figs. 49 and 50, the piece marked **A.**

To prevent the water running down the side of the chimney, a cover-piece, called the **counter-flashing**, is fastened into a mortar joint of the brickwork, and turned down over the flashing. The counter-flashing should extend to within two inches of the bottom of the flashing. This same method of protection applies to joining a roof to a vertical wall, the protection at the outside of a window-frame, or any other place needing similar protection.

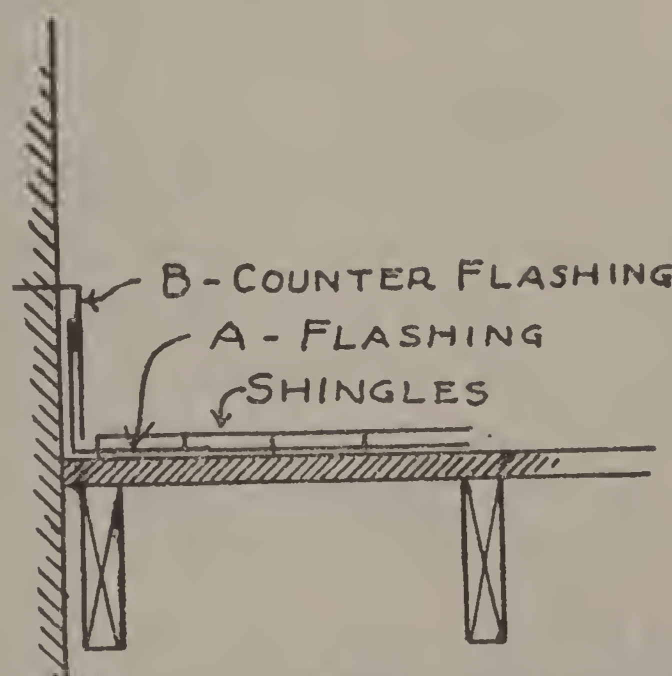


Fig. 49. Section Showing Flashing and Counter-Flashing.

Shrinkage. A word might be said about shrinkage. All lumber, when exposed to heat, will shrink, owing to the moisture drying out. In all wooden construction, all parts should be carefully framed together to reduce the shrinkage to a minimum. One common error in framing is shown in Fig. 51. The girder rests upon the post below, and the post from above rests upon the girder. We can see at a glance

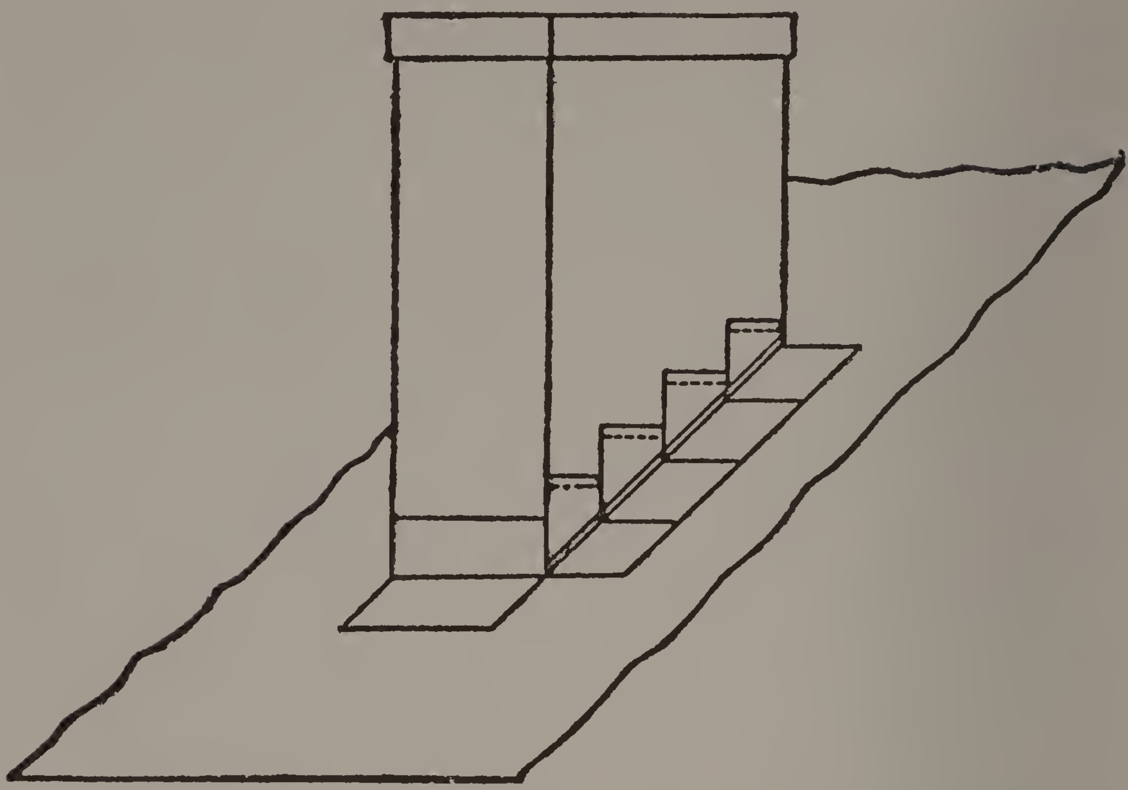


Fig. 50. Flashing and Counter-Flashing around a Chimney.

what happens when the girder commences to dry out. It will shrink, causing the post above to settle, which will affect the part of the building carried in this way. Fig. 52 shows a much better way of framing these posts. The post above rests directly on the post below; and the

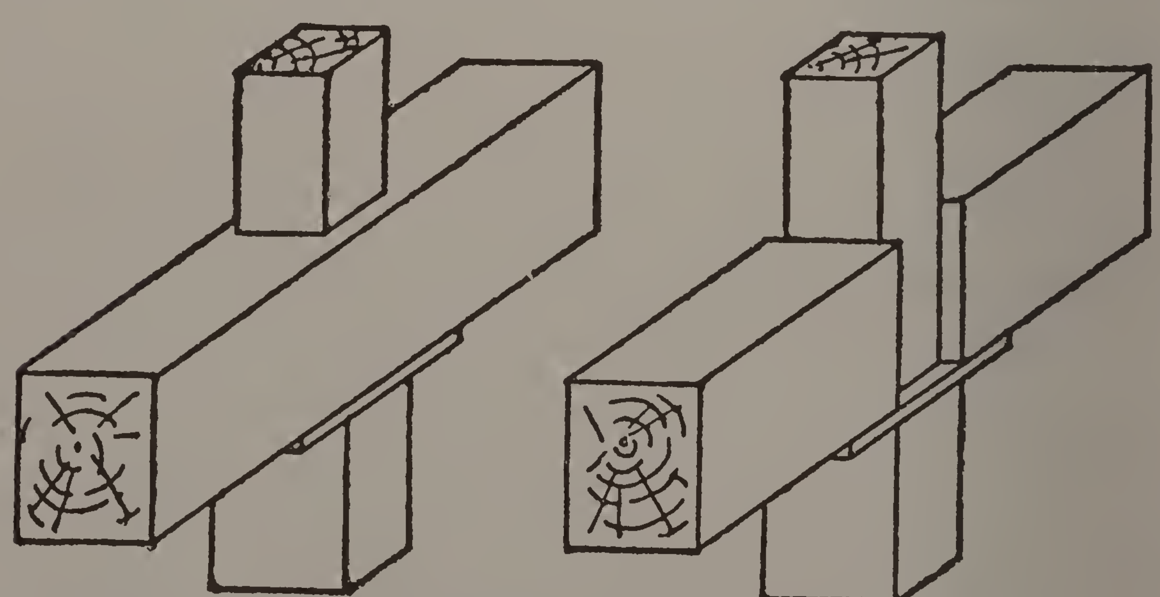


Fig. 51. Erroneous Method. Fig. 52. Correct Method.
Framing of Posts and Girders to Counteract Effects of Shrinkage.

girder is carried by the steel plate as shown, or by means of a cast-iron post-cap. By this means the shrinkage in the girder does not affect the

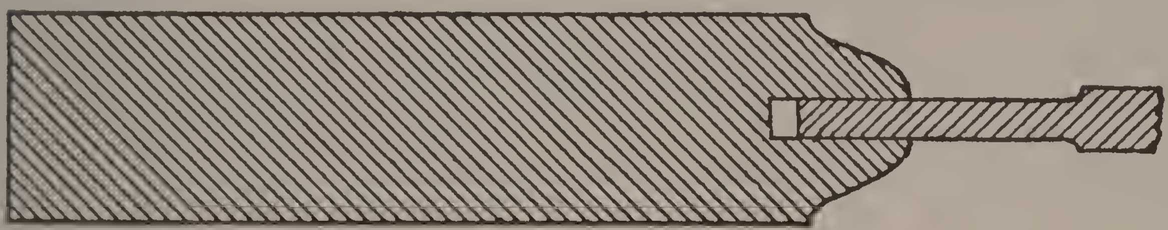


Fig. 53. Section of Solid Door.

construction above. Carry out this same idea in all framing. When one partition comes over another, carry it on the cap of the partition below, and not on top of the floor construction.

Doors. Doors are of two kinds—the **stock door** and the **built-up door.** The stock door is made solid, with a simple bevel called an **O. G.** (or **Ogee**). The stock doors are usually 1⅛ inches, 1⅜ inches, and 1¾ inches thick (see Fig. 53). The built-up door has a core of ⅞-inch pieces of pine glued together; this is covered with thin sheets of wood ⅛ inch thick, called

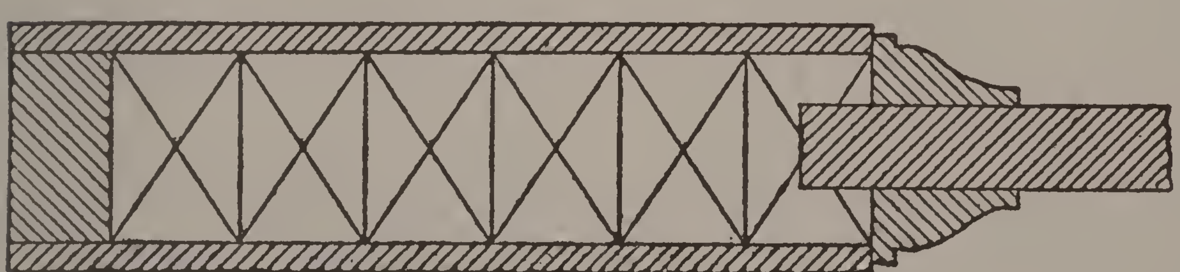


Fig. 54. Typical Section of a Built-Up Door.

veneer, which is firmly glued to the core. The veneer is made of wood to match the interior finish of a residence.

Fig. 54 shows a typical section of a built-up door; and Fig. 55 shows elevations of different doors, with the names of the various parts of a door.

All openings, either door or window, should have the rough framing doubled around them.

At the bottom of the door we have the **threshold**, which is a raised piece, usually of oak or some other hard wood. This gives a chance for the door to swing clear of the carpet or rugs. For different details of door trim, etc., see Fig. 56.

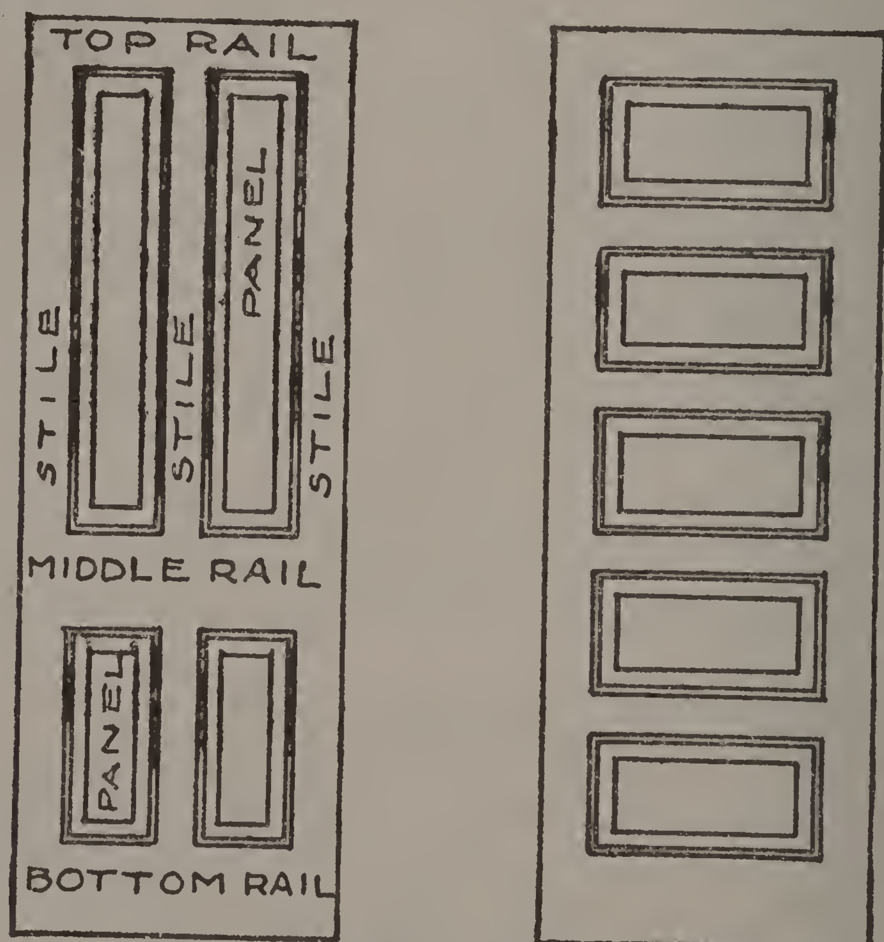


Fig. 55. Types of Paneled Doors.

The door is hung in a wooden frame which is securely fastened to the framing of the house. The inside and outside casing covers the space between the door frame and the rough framing. See Fig. 56 for a section through a door.

Porch Construction. In Fig. 57 (also Fig.

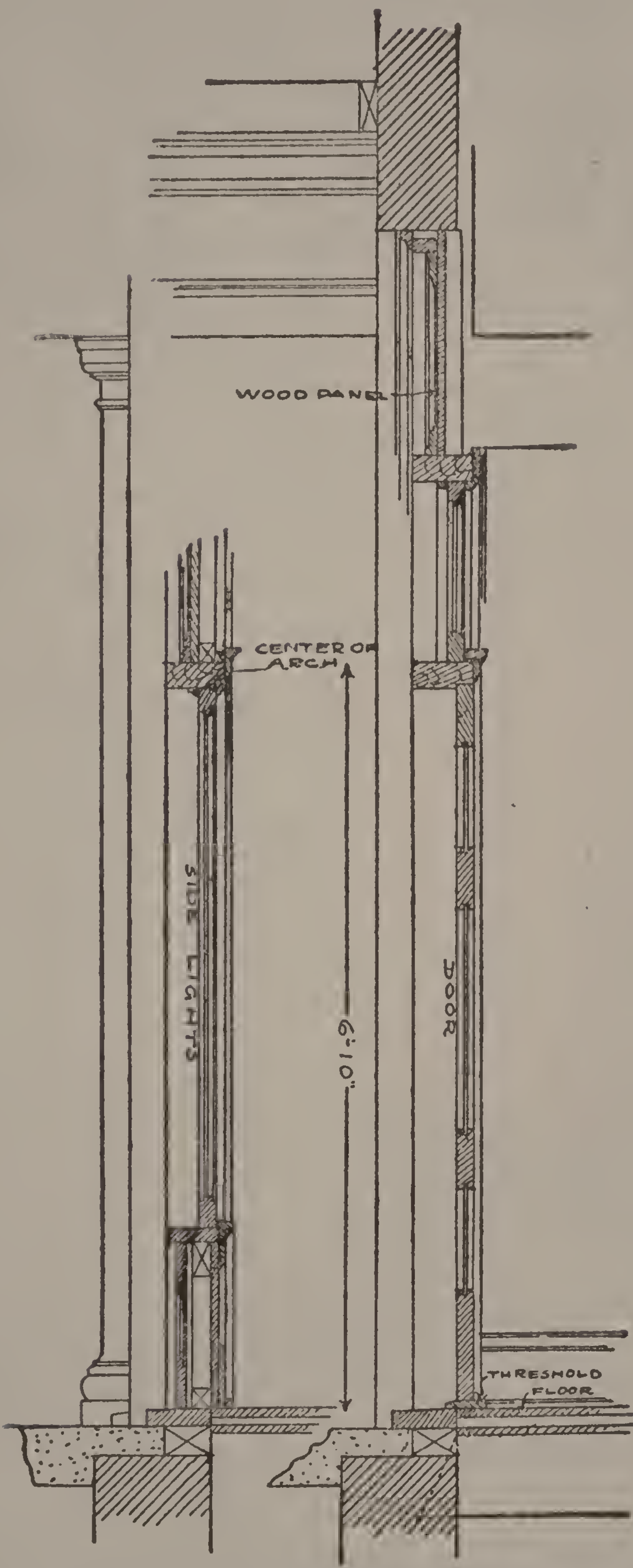


Fig. 56. Sections of Front Door and Side Lights.

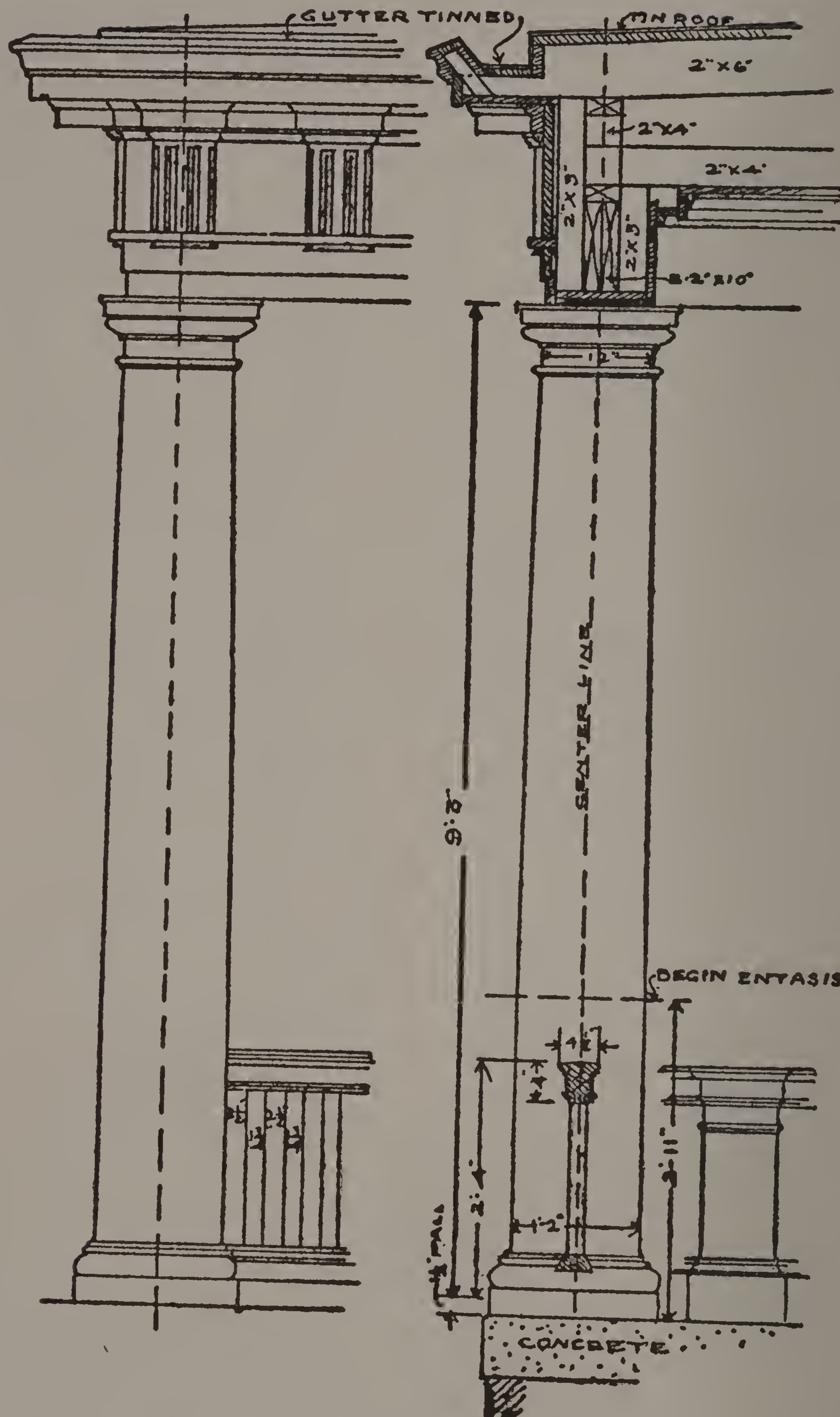


Fig. 57. Part Elevation and Section Showing Method of Porch Construction.

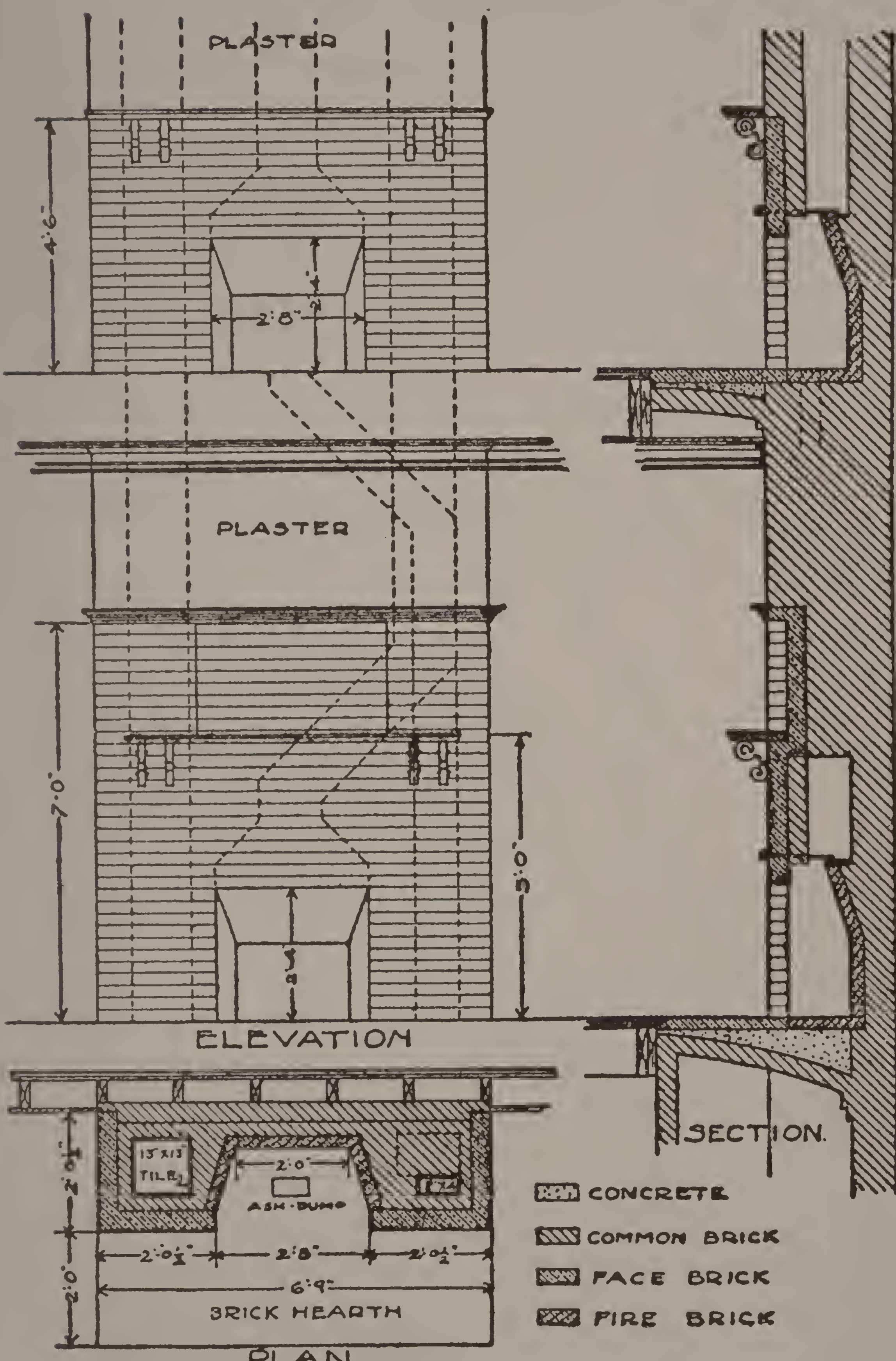


Fig. 58. A Typical Fireplace Construction.

23), we see a part elevation and a section showing the method of porch construction. The floor construction will be the same as for ordinary floor construction, except that only one thickness of flooring is used, and the boards must run at right angles to the house, and have a slight pitch away from the building. This allows the water to drain away from the building. In the best construction, the flooring is put together with white lead, thus insuring a perfectly tight joint to keep the water from soaking in at the joints, and thus causing the floor to rot.

Fireplaces. Fig. 58 shows a typical fireplace construction. The flues are all dotted on the

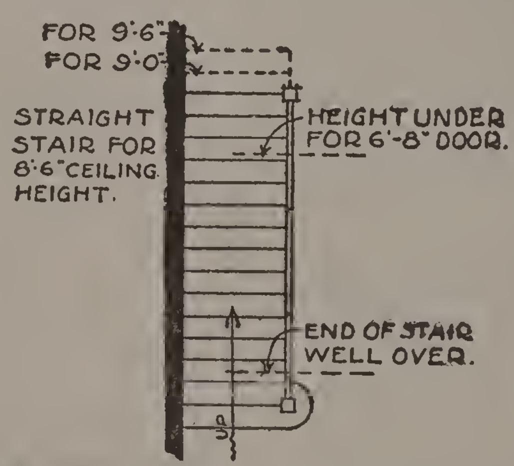


Fig. 59. A Simple, Straight Stair.

elevation. There should be an **ash-chute** from each fireplace connected to an **ash-pit** in the basement. There should be a damper in the throat of the fireplace to regulate the draft. All fireplaces should be lined with firebrick.

Stairs. For stair construction, see Figs. 59 to 65 inclusive. The simplest stairway is the one that has no turns in it, or the one shown in Fig. 59. As laid out, this stair is for an 8 ft. 6

in. ceiling. Should the ceiling be higher, other risers may be added.

In Fig. 65 are shown the customary details. The **riser** is known as the vertical portion, and the **tread** as the horizontal portion. The main supports are usually 2 by 10-inch or 2 by 12-inch, notched to fit the treads and risers, and are

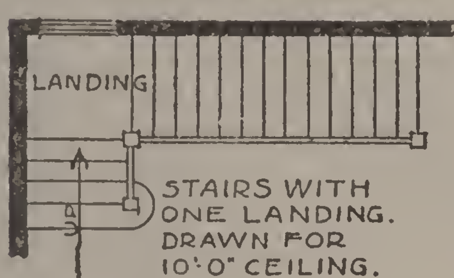


Fig. 60.

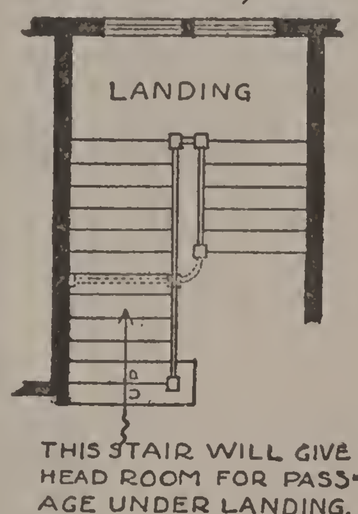


Fig. 61.

Types of Stairs with One Landing.

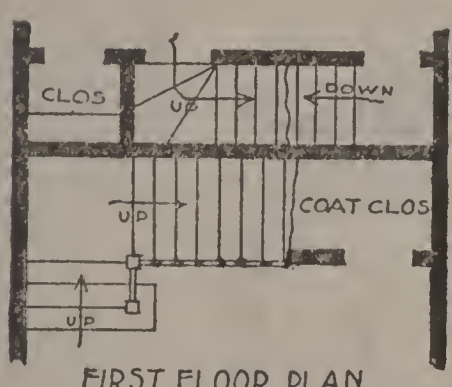


Fig. 62.

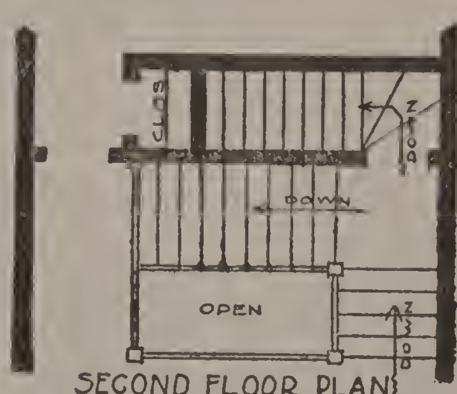


Fig. 63.

Combination Front and Back Stairs.

called **carriages**. The **balusters** are the upright spindles or ornamental pieces supporting the hand-rail.

Various heights of riser to tread have been tried, but the one found most satisfactory is to make the riser from 7 inches to 7½ inches. The usual rule for figuring the treads and risers is

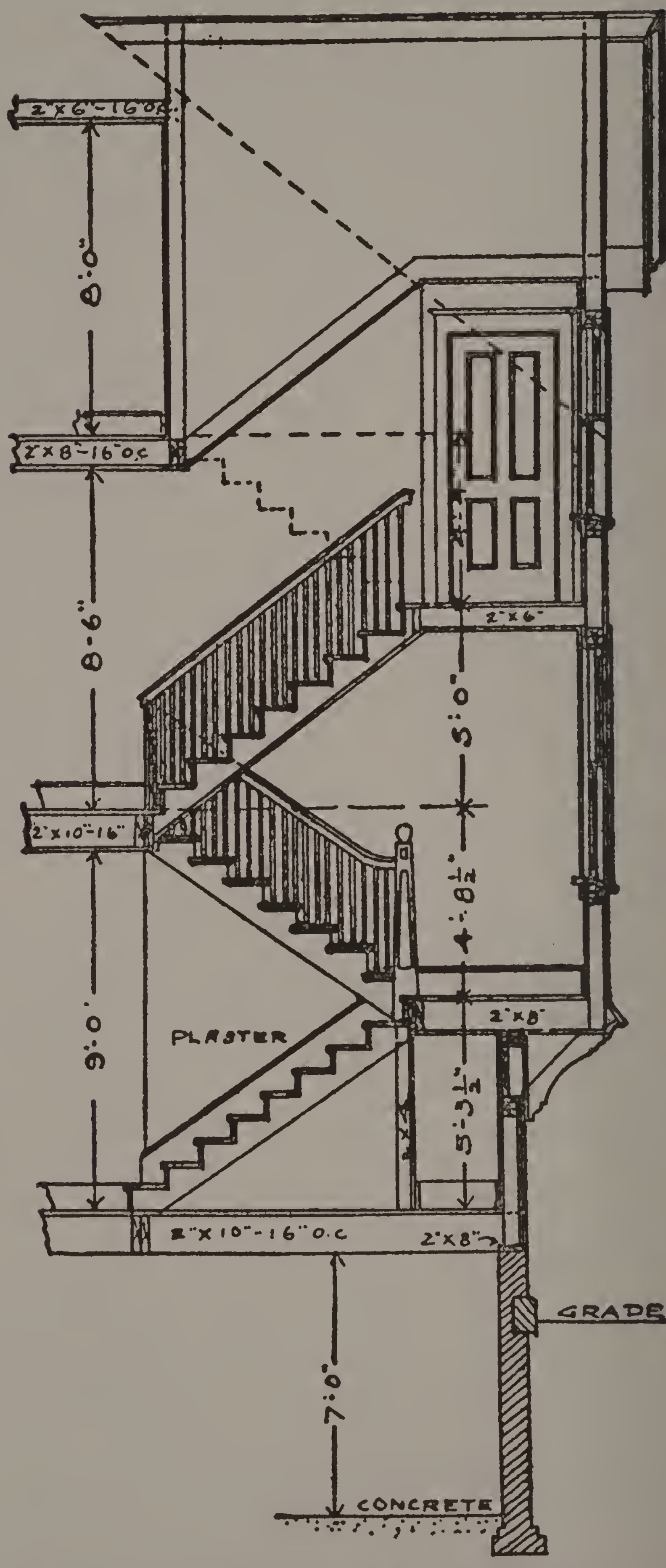


Fig. 64. Elevation of Stairway, Giving Necessary Information.

to make the sum of a tread and riser equal to 17 inches or 17½ inches. From this we see that the higher the riser, the narrower will be the tread. If we make the riser 7½ inches, then the tread should not exceed 10 inches. The width of tread is exclusive of the **nosing**, which is usually 1½ inches.

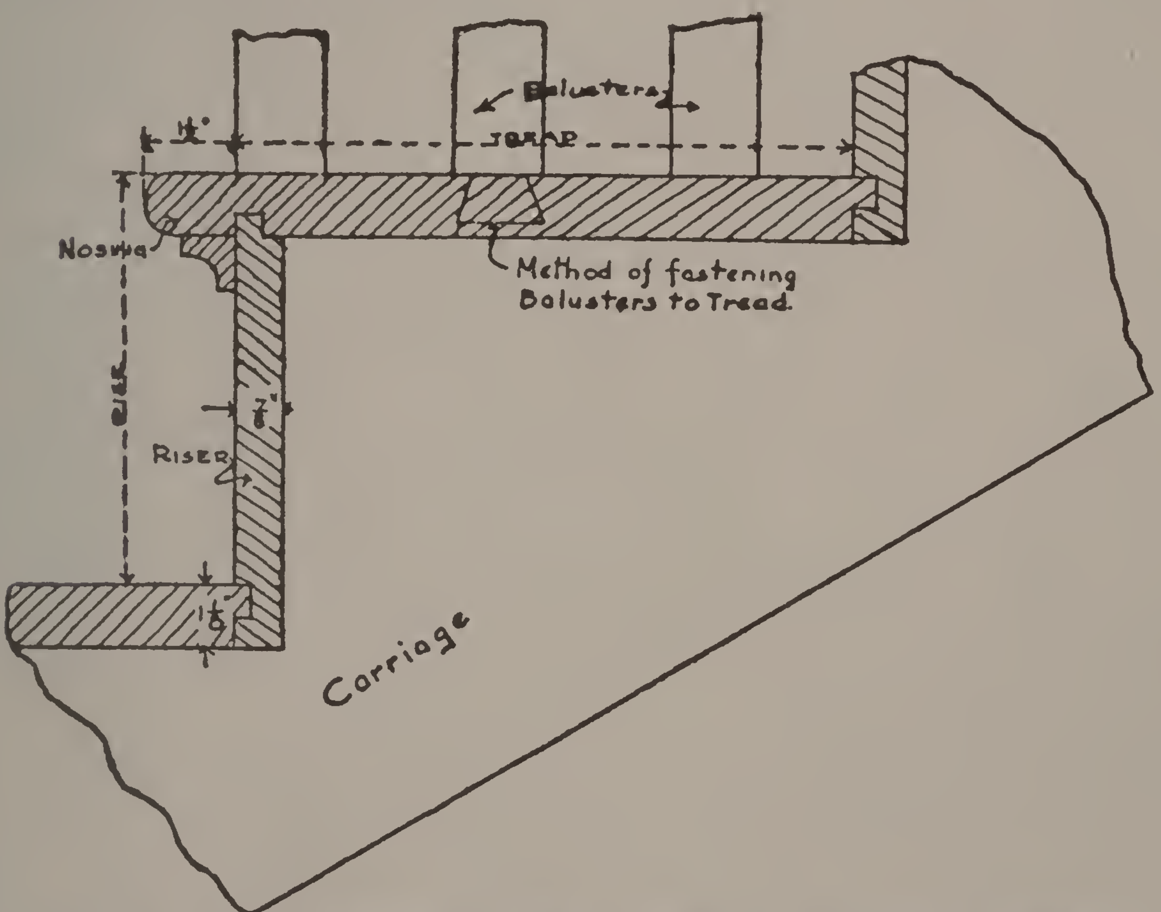


Fig. 65. Section through Stairs, Showing Customary Details.

Stone stairs, or stairs without a nosing, will have to be wider.

For figuring the number of risers, divide the height from floor line to floor line (in inches), by the height of one riser; the result will be the number of risers.

Fig. 60 shows a stairway with a landing. Fig. 61 is another form of stair with a landing.

Fig. 62 is a combination front and back

stairs. There are separate stairs up to the landing; then the back stair joins the main stair. Fig. 62 is the first-floor plan, and Fig. 63 the second-floor plan, of the same stairs.

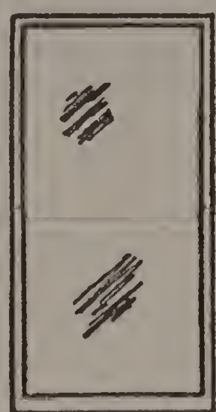


Fig. 66. Single-Light Window.

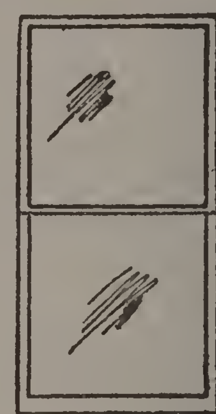


Fig. 67. Two-Light Window.

Where possible, put a coat closet under the stairs. This space cannot be utilized for anything but a basement stair or a closet. Usually there is a basement stair in the rear of the house.

Fig. 64 shows an elevation of the stairway, giving all necessary information.

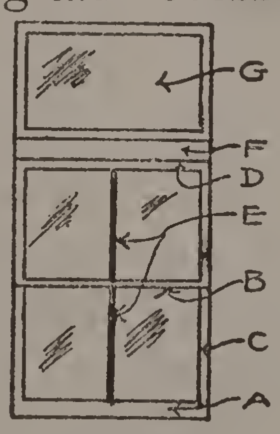


Fig. 68.

Fig. 69.

Types of Window Construction.

Windows. There are various types of windows used in the construction of buildings. The plainest is the **single-light window** shown in Fig. 66. This is either pivoted, hinged, or fixed to slide.

ILLUSTRATING METHOD OF SKETCHING.

Notice the absence of hard, mechanical lines and sharp corners, and the use made of the shadows for indicating surfaces.

PLATE E—ARCHITECTURAL DRAFTING.

The windows are usually designated according to the number of panes of glass they contain, Fig. 67, for example, being a two-light window. Very often a large glass space is divided into smaller areas by means of horizontal and vertical strips called **muntins,** as shown in Fig. 68. The lower sash slides up, while the upper one is usually fixed in place; this upper sash is called a **transom.**

When windows are grouped in twos or threes, they are separated by means of vertical divisions. These divisions are called **mullions.** The weights of the sash usually travel in these (see Fig. 69).

The **sash** is usually the movable frame that contains the glass. A **double-hung window** is one in which the sash are counterbalanced by iron weights so that the sash will slide easily up and down in grooves in the frame. The sash of a window may be hinged to open like doors, in which case the window is called a **casement window.** If the sash are hung on pivots, either vertically or horizontally, we speak of the window as a **pivoted window.**

Referring to Fig. 68, **A** is the **lower rail** of the sash, usually from 2½ to 3 inches wide; **B** is the **meeting rail,** from 1 to 2 inches wide; **C** is the **stile,** usually 2 inches wide; **D** is the **upper rail,** of the same width as the stile; **E** indicates the **muntins,** which divide the sash into small areas; **F** is the **transom bar,** or the

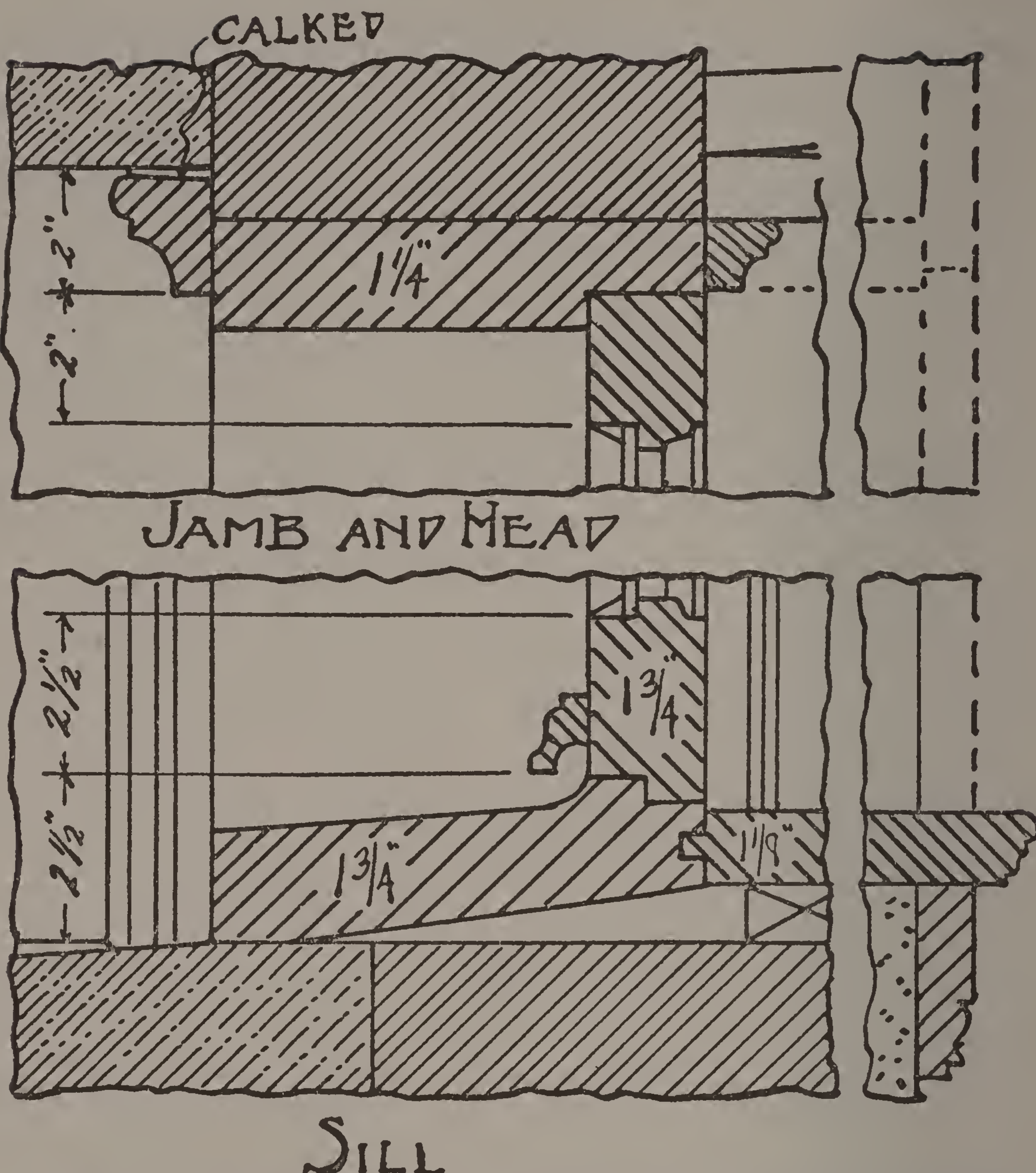


Fig. 70. Typical Detail of Plank-Framed Basement Window.

fixed bar between the transom **G** and the double-hung sash below.

The usual thicknesses of sash are 1⅛ inches for small windows, to 1⅜, 1¾, and sometimes 2¼ inches, depending upon the size of sash. The larger the window, the heavier the sash must necessarily be.

In Fig. 70 we have a **plank-framed window.** This is the same kind of frame required for the casement window as shown in Fig. 76. Fig. 70 is the typical detail for cellar window construction. The windows usually have a single sash which may be divided by muntins into smaller

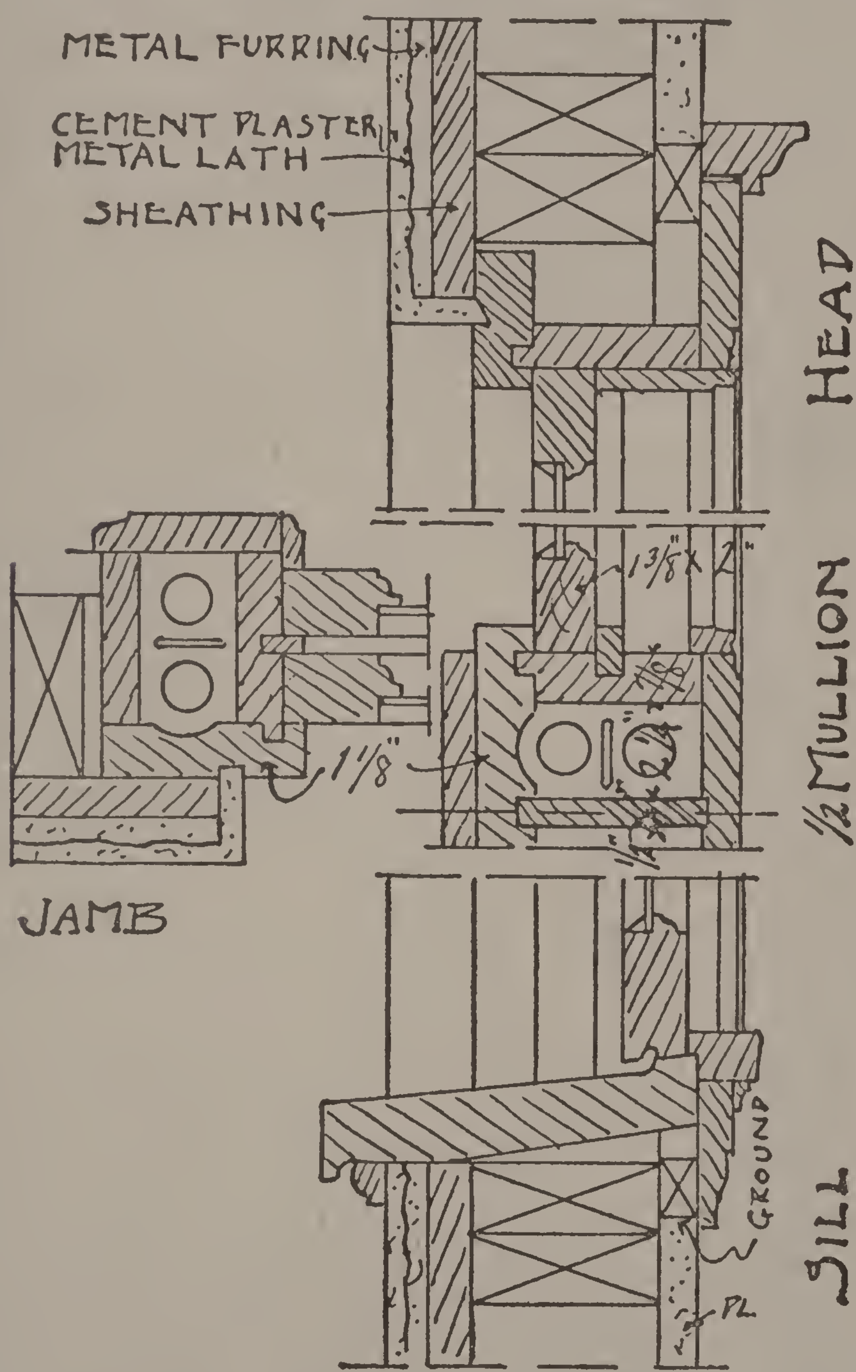


Fig. 71. Double-Hung Window, Outside of Building Plastered.

lights. Notice the projection on the bottom rail, which serves as a drip for all water coming from the glass. Such windows are usually hung at the side or top. Fig. 70 is detailed for a

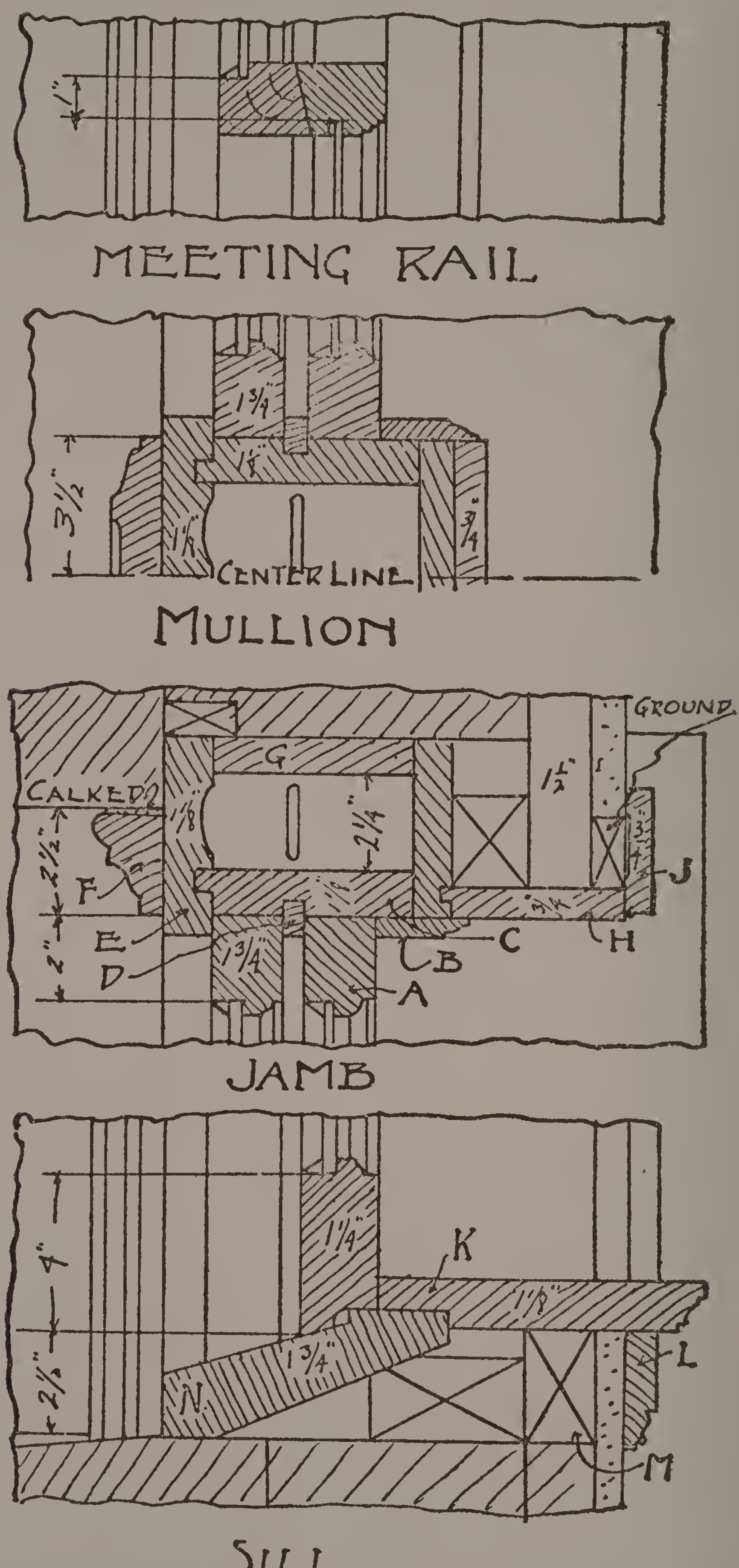


Fig. 72. Double-Hung Window for a Brick Wall.

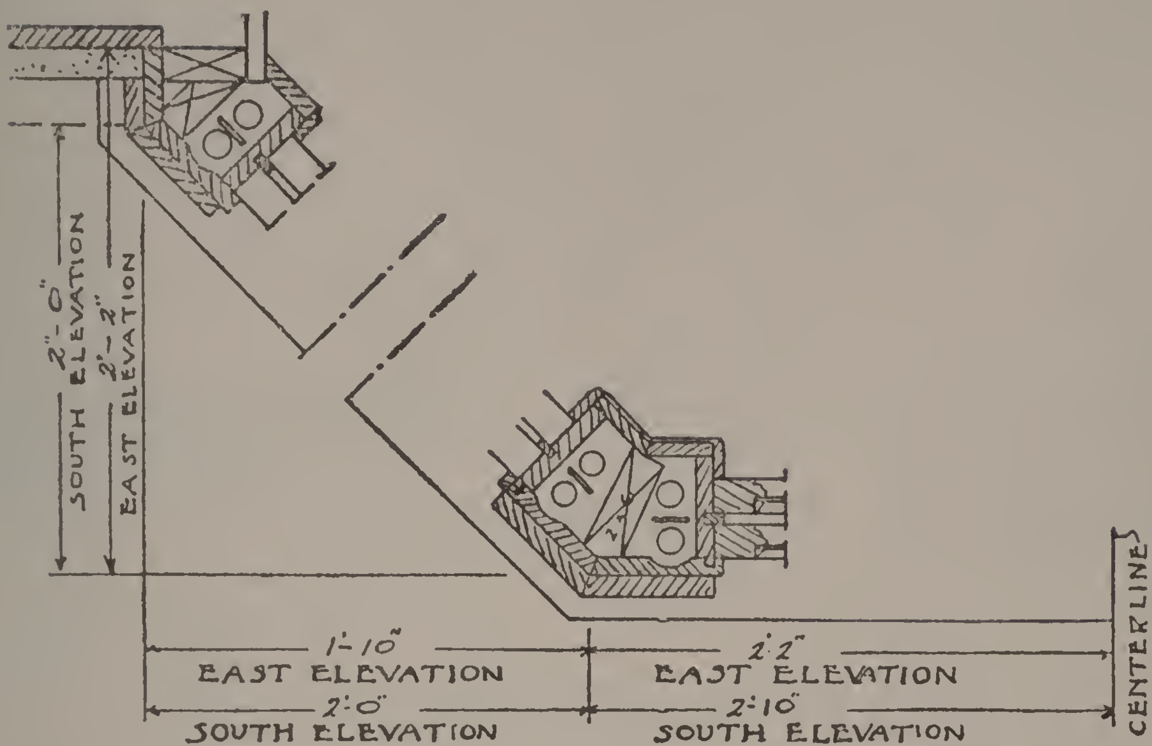


Fig. 73. Part Section Showing Details of Bay Window Construction.

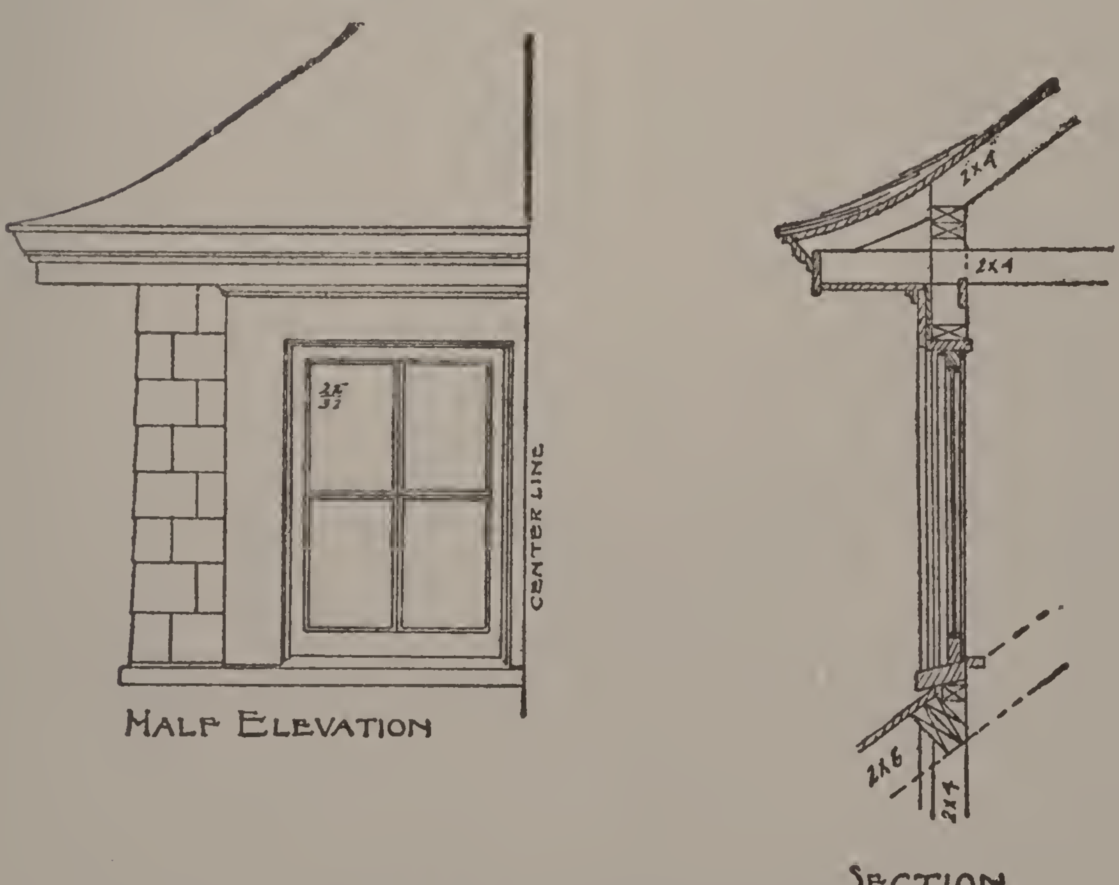


Fig. 74. Details for a Dormer or Roof Window.

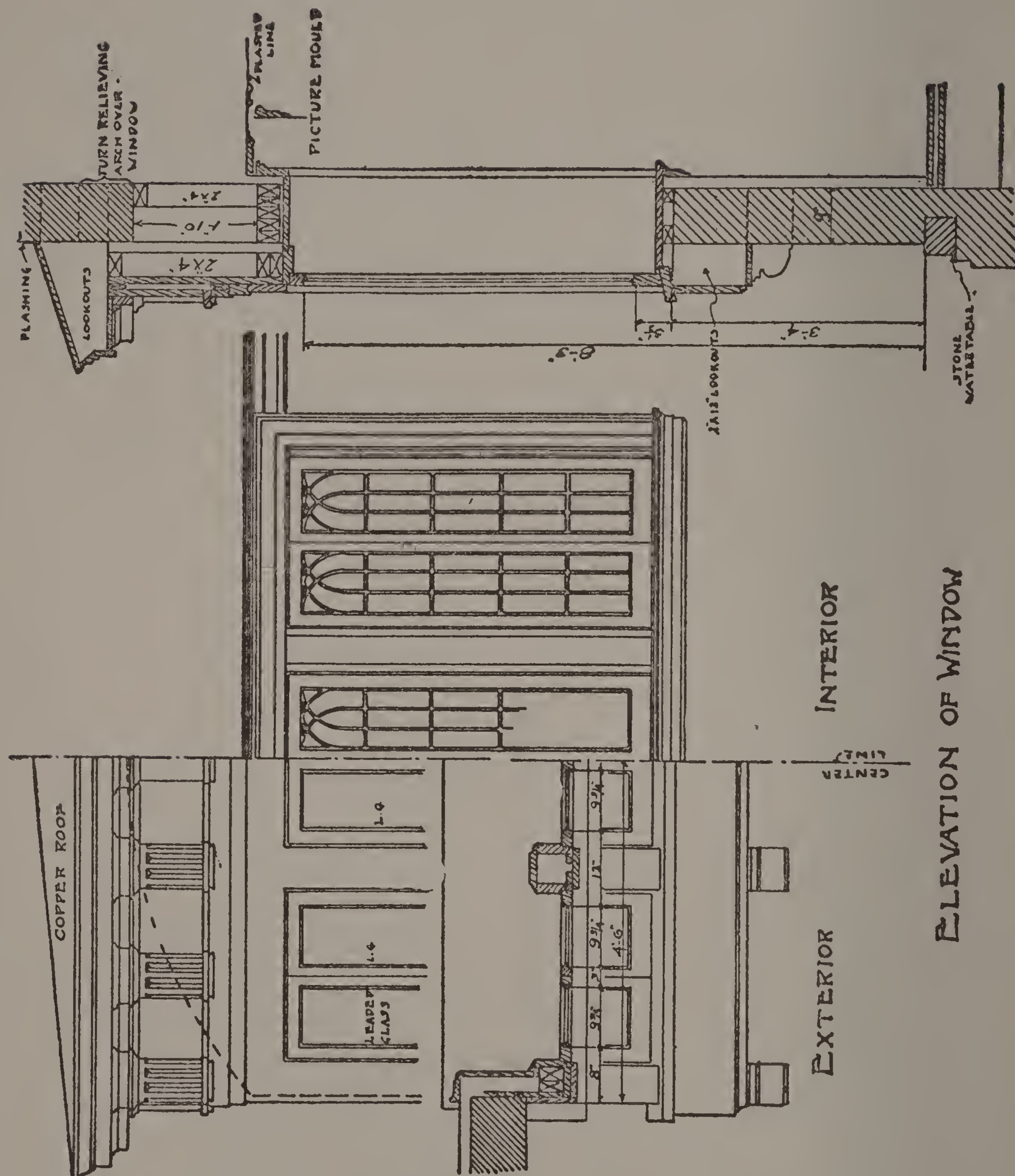


Fig. 75. Showing Details of Construction for Projecting Bay Window.

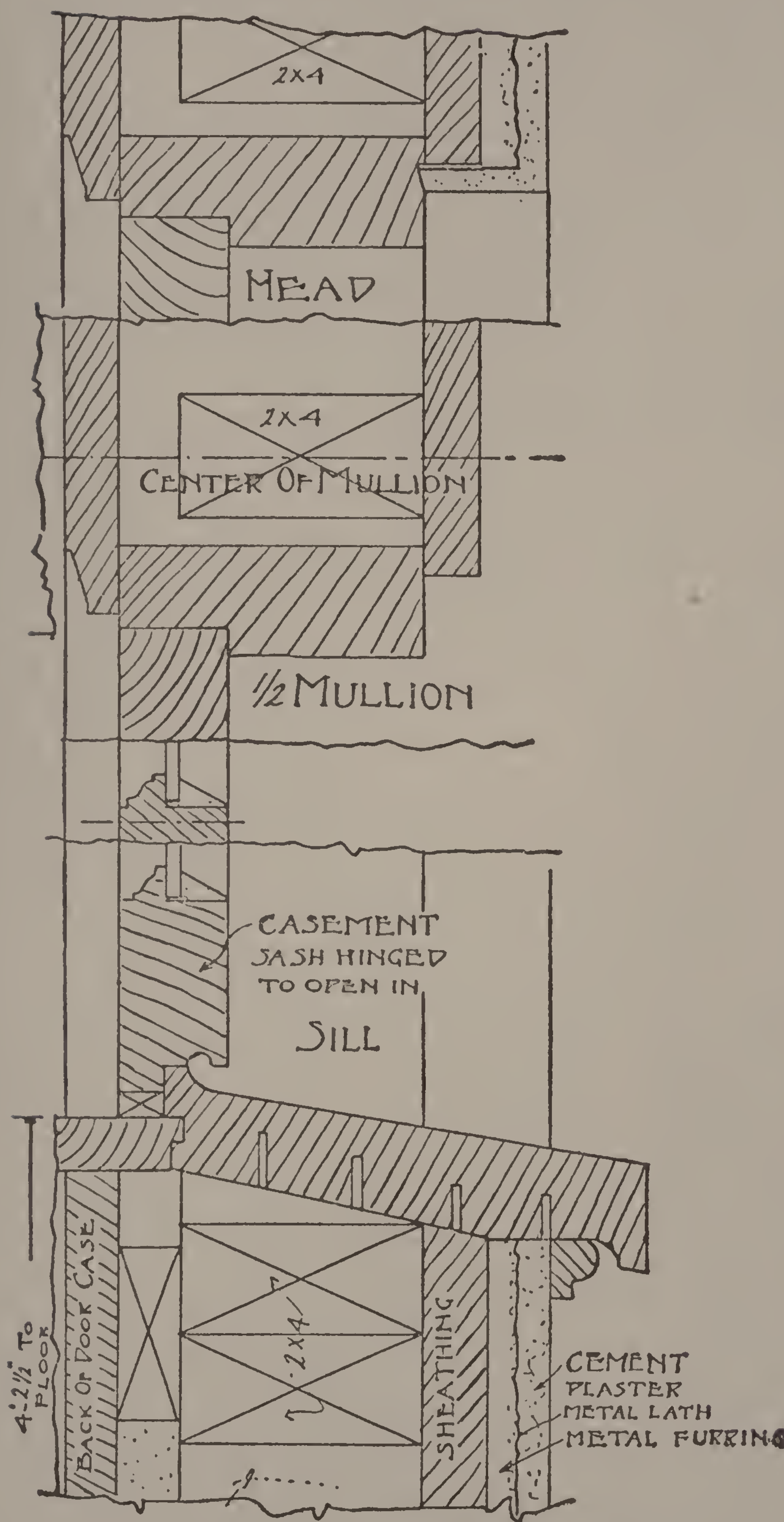


Fig. 76. Details of Casement Window.

brick wall, although the same detail will apply to a frame wall.

In Fig. 71 we have the details and dimensions for a double-hung window in a frame wall, the exterior of the wall being plastered. In Fig. 72 we have the details for a double-hung window in a brick wall. Notice that there is very little difference in construction. The parts of the construction are named for the sake of clearness, **A** being the **sash**, **B** the **inside stop**, **C** the **pulley stile**, **D** the **parting strip**, **E** the **outside casing**, **F** the **brick mould** or **staff-head**, **G** the **back lining**, **H** the **sub-jamb**, **J** the **inside casing**, **K** the **stool**, **L** the **apron**, **M** the **ground**, and **N** the sill.

In Fig. 73 we have the construction for a **bay window**, showing the boxes, sash, etc.

Fig. 74 shows the details for a **dormer** or **roof window.**

Fig. 75 shows the construction for a projecting bay window, the sash being hung to swing out. We have shown a half exterior view, a half interior view, and a section.

Fig. 76 shows the details of a **casement window** in which the head, mullion, and sill, with all adjoining construction, are shown. Notice the grounds or guide for the plaster work, as spoken of under "Lath and Plaster."

Fig. 77 shows the interior elevation of the door and window trim, with a large-scale drawing of the exact profiles of this trim. The trim, and in fact all interior woodwork, are fastened

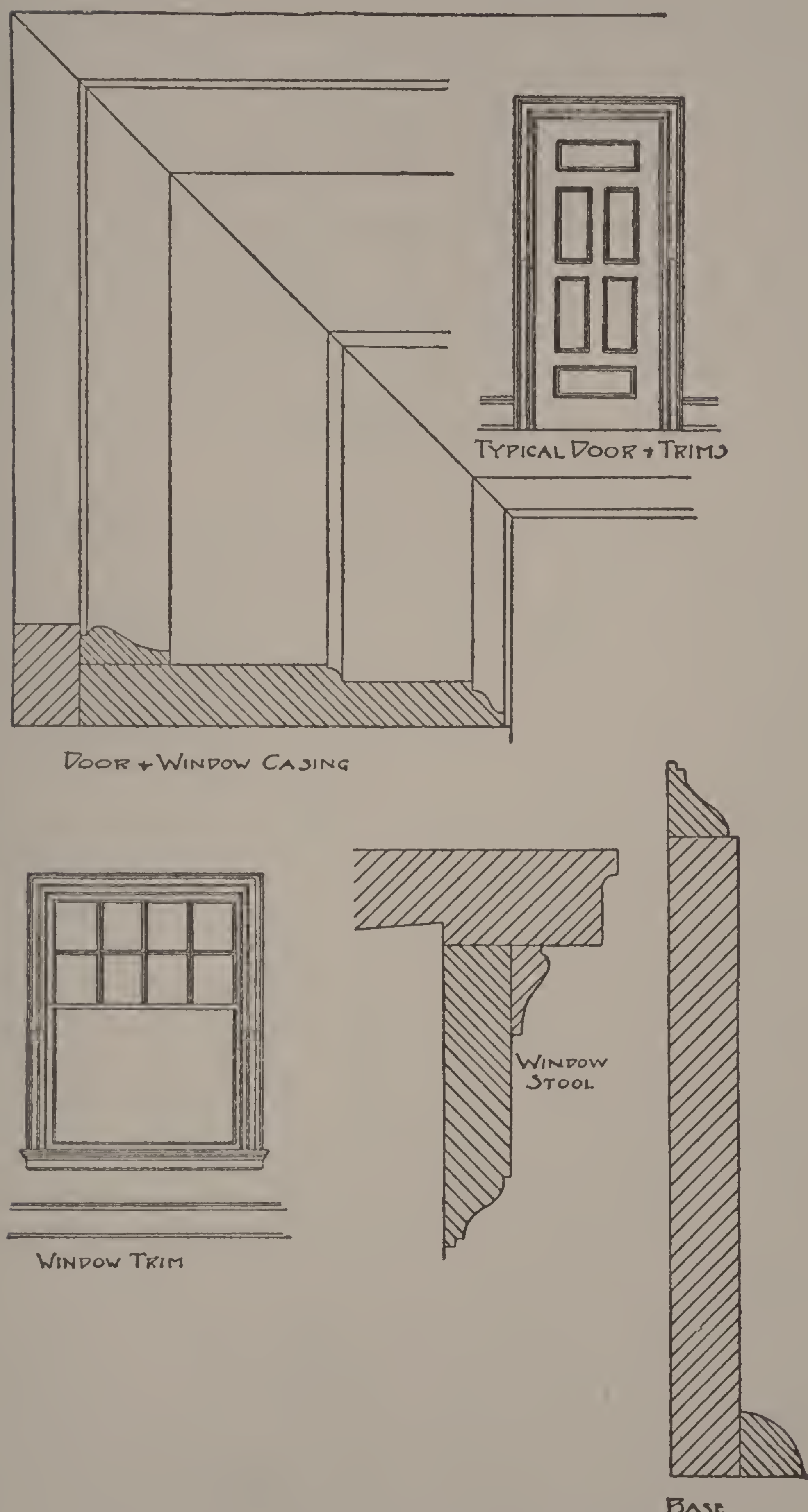


Fig. 77. Details of Window and Door Trim.

to the grounds, which are set to serve as guides for the plasterer, and which should be placed back of all interior finish. The base shown is the finish at the floor-line. The base is nailed to grounds; and the quarter-round mould at the floor is nailed to the floor, to cover the crack at the joining of the base and floor-line.

SKETCHING

In all architectural work, the art of **sketching** is important. To be able to show one's ideas clearly and artistically, or to reproduce some form or object in a pleasing manner, is indeed an essential qualification for the draftsman as well as the architect. Some have a natural ability to sketch, which lacks but the pencil and paper to give a true expression of the idea of the mind; while others acquire the art of sketching only by diligent study and persistent practice. Many instances have proven the fact that one may have ability, but that it needs developing, just as in the case of the mathematician, who becomes an expert in the higher mathematics by a gradual training from the simpler problems on up through more complex ones. Because one has not ability that is apparent at the outset, is no criterion whereby we may judge of his ability along any particular line. Learn to sketch, as it is a valuable asset for the architect.

Fundamental Principle. To the beginner, the object usually presents itself as made up of small portions, and ordinarily he will make an attempt to show all the small details, overlooking the main mass or body of the object. The first thing is to be able to see the object as it really is, as it would really appear to the best advantage when sketched roughly and quickly. Learn to look at the general grouping of the different portions, and their relation to one another. The beginner attempts to draw the object as he sees it at close range, while the experienced person draws it as it appears at a distance. The tendency of the beginner is to represent everything with hard, sharp, and exact lines which are known from actual knowledge of the object to exist, although they do not really appear so. Learn to study the general proportions as expressed by the shadows, rather than by the exact outlines bounding each surface. Studying an object for sketching is really a study of the shadows. In all sketching, the proportion is the fundamental principle. Having correctly represented the proportions, then represent the object by means of the shadows as cast upon the object, and let the details be merely an after consideration. Learn to see the object correctly, and the representation by lines will come by practice.

Pencils and Paper. The pencil is present on all occasions; therefore it is used a great deal in sketching. Pencils may be obtained in all degrees of **hardness** and **softness.** Drawing pencils are usually denoted by **H**, **HH**, etc., for hard pencils, up to **8H**, which is a very hard lead; the soft pencils are denoted by **B**, **BB**, etc., up to **4B** for very soft pencils. An intermediate grade known as an **HB** is between the hard leads commencing with **H** and the soft leads commencing with **B**. This is a very convenient grade to use for all kinds of work. A good drawing pencil should contain no grit.

As a general rule, the larger the drawing, the softer the pencil, since the lead in the soft pencils is larger than that in the hard pencils. Therefore, it is rather difficult to make a small drawing with a really soft pencil. As stated above, the most satisfactory pencil for all-around work is the medium grade or the **HB** pencil.

The pencil should never be sharpened to a point. Cut away the wood, leaving the lead its full size; and by a few strokes on a piece of scratch paper, wear off the sharp edge, until you have a line the full thickness of the lead.

Hold the pencil comfortably between the fingers, not in a cramped position, but free and easy. The length of line, the position on the paper, and the width and intensity of the lines will determine just which movements of the fingers, wrist, or arm are the best suited to the work. In all work, avoid bending over the drawing; sit upright so that the drawing may be all seen at a glance. The paper should always be at right angles to the line of sight, to insure the best work.

The paper should have a somewhat rough texture for the best work, although some very pleasing sketches have been made upon smooth paper. Never use a glazed paper. The smooth paper requires greater care in its use, it being harder to erase anything successfully. A good grade of tracing paper makes a very good paper for sketches with a medium-soft pencil.

Method. Begin sketching by drawing parallel lines horizontally; then make them vertical; then slanting lines—endeavoring all the time to make them all of the same width and intensity. After exercises in the drawing of straight lines, try circles and ellipses. Then sketch familiar household articles. From these, let the student take up more difficult work, learning to see objects as they actually appear to the eye, and not as they are really known to exist.

Referring to Plates E and F, notice the method used for indicating surfaces. Instead of covering the side of the building with long, mechanical, parallel lines, the lines are made short, and broad, and break joint so as to give an uneven surface. The eaves are all represented by the shadow they produce, there being no definite line for the edge of the roof. For the corners of the building, there is not a hard, sharp line, but a broken, irregular line. The doors and windows are all represented by the shadows they cast.

It will be noticed that the shadow is the thing to reproduce. If the shadows are shown in their true relative proportions, in intensity and size, we are reasonably sure of a satisfactory sketch. For such work, the object is

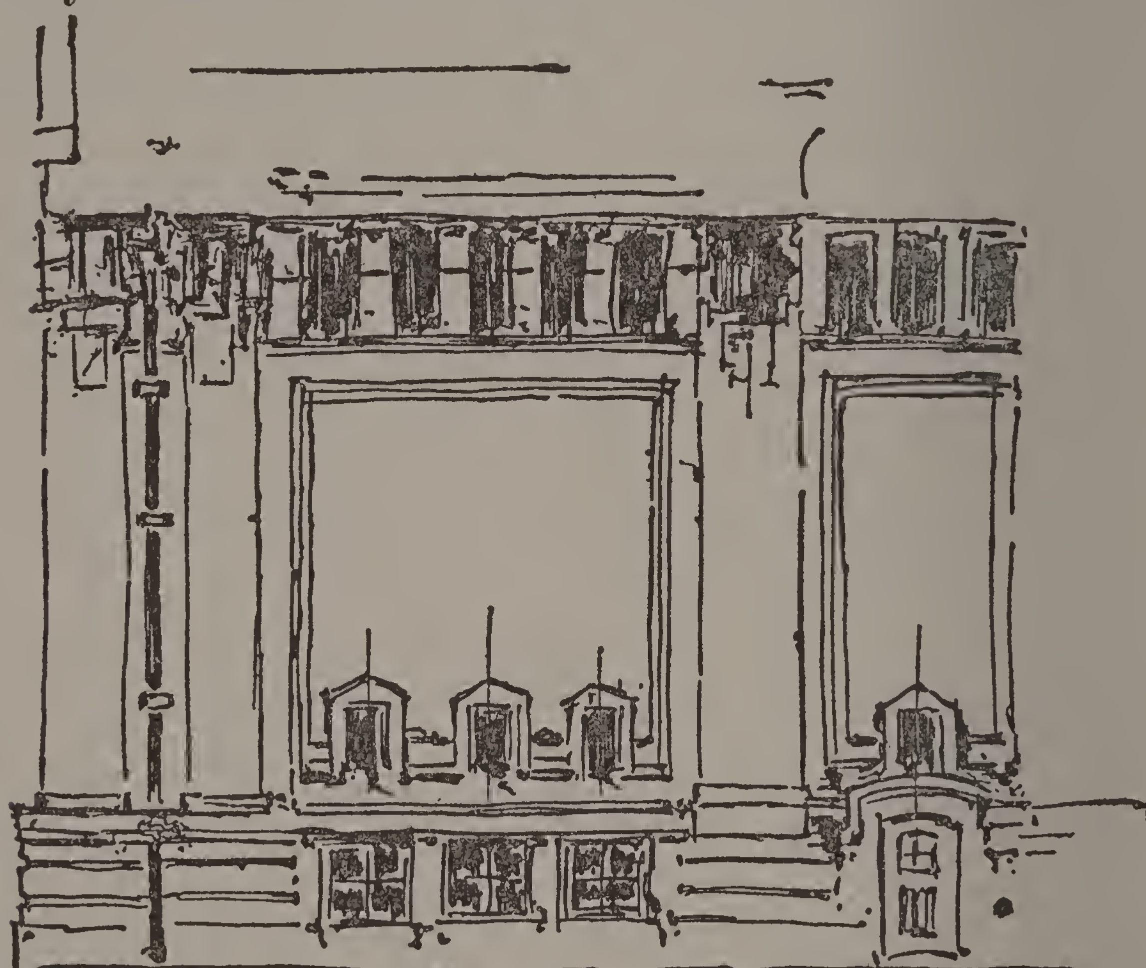


Fig. 78. A Quickly-Made Preliminary Sketch.

usually outlined with a light line, to get the proper lines and proportions; in other words, just enough lines are given to show the proper relation of dimensions.

Having outlined the object, then commence with the soft, broad pencil, and indicate the texture and shadows by varying intensities of lines.

Practice will give you the best training for developing the art of sketching. It is not enough to study work already done, analyzing lines and surfaces. Actual work and practice in drawing and sketching will do more for you than any mere study of sketches.

Learn to make preliminary sketches quickly, and yet indicate general proportions and outlines (see Fig. 78). This sketch was made in about five minutes' time, while the architect was talking to his client. Some of the finer points of the original pencil sketch are necessarily lost in the pen-and-ink reproduction from which the cut was engraved. The figure represents a possible treatment for a boiler house. This is a good example of a preliminary sketch, there being no particular time spent in the drawing and very few straight lines used, yet, when the sketch is studied, we can see the general effect that such a building would produce in sunlight.

Make your sketches have some "snap" to them. Let each line be firm, starting and stopping in a way that shows it to be there for a definite purpose. Use plenty of free and easy lines, and also black lines. Do away with sharp lines, and never use hard pencils for this work.

For the purpose of **laying out drawing**, either for pencil, pen and ink, or pen-and-ink rendering, a sketch will be shown to illustrate clearly the quickest and most satisfactory method. See Fig. 79, where the sketches are all rather

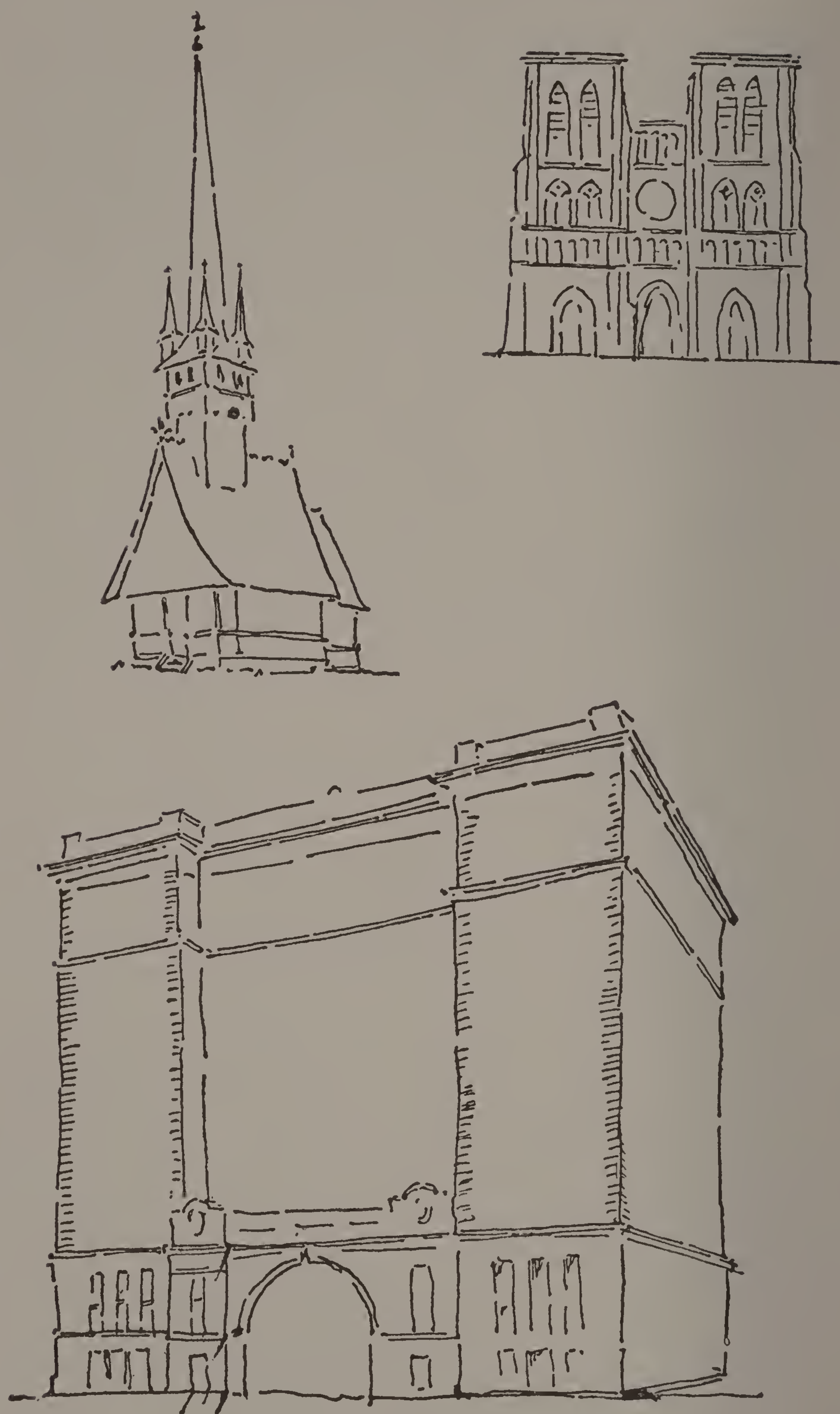


Fig. 79. Sheet of Drawings Laid Out with a Sense of Proportion.

ILLUSTRATING METHOD OF SKETCHING.

Notice the free and easy movement of the lines, and the prominence given to the use of shadows.

PLATE F—ARCHITECTURAL DRAFTING.

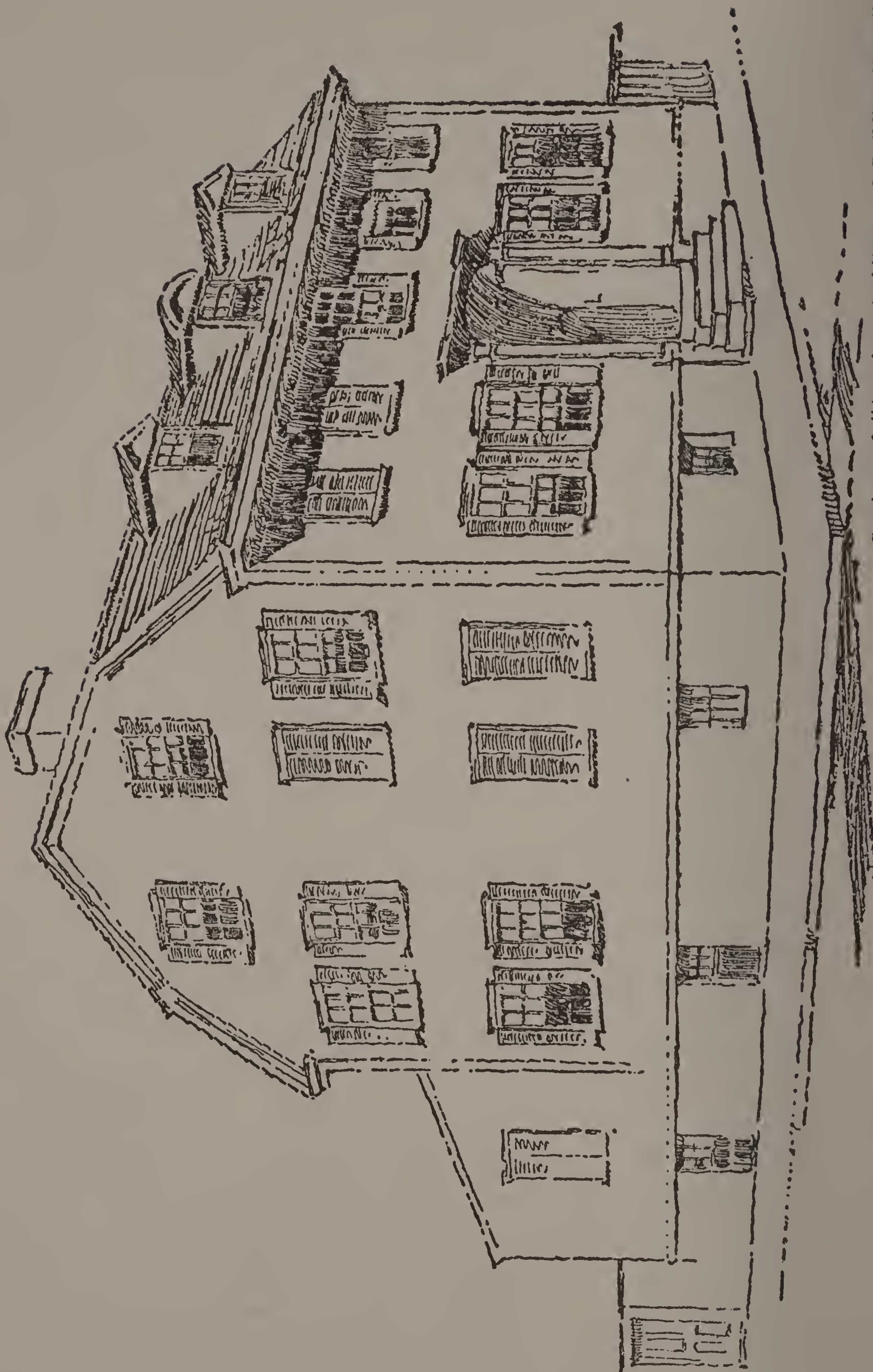
rough or uneven, but the general drawing shows the effect of proportions. The lines, instead of being long and continuous, are made up of short lines almost joining.

PEN-AND-INK RENDERING

Finished drawings may be **colored** or **rendered** in a number of ways. The method of **pen-and-ink rendering** is very often used. It is indeed an accomplishment to be able to render in pen and ink successfully. This usually comes only from long and patient work in practicing. A drawing may also be rendered in **pencil,** or colored by means of **water-colors.**

For pen-and-ink rendering, any black ink will do. A good grade of India ink is very satisfactory and convenient. There was a time when all drawing inks were made by grinding a stick of India ink in water on a stone bed; but now prepared inks are used almost entirely. The pens should be fairly large, and have a medium point; the tendency of beginners is to use too fine a point. Any good-quality tracing paper may be used.

The outline of the work may be made upon scratch paper; and, by placing the tracing paper over it, the ink rendering can be made directly over the outline. Papers with soft surfaces should be avoided, since the ink will have a tendency to spread, the points of the pen will often catch and spatter ink, and erasing is



Courtesy of "American Architect and Building News."

Fig. 80. Illustrating General Method of Rendering a Building in Pen and Ink.

almost impossible. Good bristol board makes a satisfactory surface to work upon.

All lines should be firm and uniform, and series of parallel lines should give an even texture or appearance to a surface. Avoid the stiff, hair lines, which are too fine to give any character to the work. In making ink lines, while the general direction of the line may be straight, yet a line slightly wavy, or a line such as would be made by the trembling of the hand, is not objectionable.

Use care in drawing lines to make them as uniform as possible, and exercise care in the starting and stopping of lines. Lines should naturally be a little heavier at the ending than at the beginning.

Referring to Fig. 80, we see in this drawing, the general method of rendering a building in pen and ink. The window-panes, instead of being hard, sharp lines, are made by a series of parallel lines representing the shadow. Notice the treatment of the roof, the shadow of the cornice, and the general lines of the building.

Fig. 81 shows the use of parallel lines entirely for the texture of the wall, and also for the shadows.

Fig. 82 shows a very attractive drawing. Study the foliage around the house; see how it has been represented by lines, sometimes straight and sometimes curved. The distance to the background is obtained by the quality

Courtesy of "American Architect and Building News."

Fig. 81. Illustrating Use of Parallel Lines in Pen-and-Ink Rendering.

Courtesy of "Inland Architect and News Record."

Fig. 82. A Well-Executed Example of Pen-and-Ink Rendering.

of the line; the further away the background, the lighter the line. Study the lines representing the wall and roof surfaces. Notice that the lines in general are not straight, but are more or less irregular. The shadows in Figs. 81 and 82 are composed of entirely different kinds of lines. Probably the best and easiest method is by the use of vertical lines. Notice, generally speaking, that there are no long lines. If it is necessary to make such a line, let it be represented by a series of short lines, with their ends almost touching. The tendency of the beginner is to make the rendering all too light. Put in some black, somewhere, as it makes the drawing more in contrast, and emphasizes other portions of the work.

Plate G is a good example of a sketch rendered in pen and ink.

WASH DRAWINGS

Water-colors or **India ink** for coloring drawings, are used for the best work, almost entirely. By means of color or by the use of India ink for a monotone, the shades and shadows can be emphasized and the drawing made much more attractive. The usual method of procedure is to have the paper upon which the drawing is to be made, stretched tight upon a board; then cast the shadows, marking the outlines faintly with a hard pencil; then clean the drawing with a soft eraser; finally, have all materials ready for applying the washes, and then start the color work.

Materials. The usual materials for wash drawings are: the colors or the India ink; a number of brushes (one a bristle brush and the others soft camel-hair or Japanese brushes); plenty of receptacles for holding the color in its various shades, also one large receptacle for clean water. Porcelain or china dishes made especially for this work may be purchased from any dealer in artists' materials. In addition to the above, a soft sponge and a number of blotters will be necessary. The paper should have a rough finish, as this takes the color or wash much better than paper with a smooth or glazed surface. Hot-pressed and cold-pressed papers of good quality are largely used for this work. The cold-pressed is a little rougher than the hot-pressed and is perhaps more frequently used. A good tracing paper may be used if the color is applied thick and in spots, or where no attempt at a true wash drawing is made. Care will have to be exercised in the use of tracing paper, as too much water will spoil the work.

As mentioned above, the paper upon which the drawing is made has to be **stretched tight** on the drawing board. This may be done after the drawing has been made, although it will be found much more convenient to stretch the paper first, and then make the drawing. To stretch the paper, it should be thoroughly wetted all over, and kept wet until it is firmly fastened in place; this wetting causes the paper to expand. On the four edges of the paper, for about an inch back from the edge all around, place glue or drawing-board paste. The paper, being expanded by the water, should now be fastened or pressed down onto the board, working opposite edges at the same time. Do not attempt to stretch the paper perfectly tight. Be careful to see that the edges of the paper are in contact with the board, and run the back edge of a pocket-knife all around, to insure the glue or paste on the edge of the paper coming into contact with the board.

After the paper is thus stretched, take all surplus water off by means of a sponge, and dry the paper as much as possible with the sponge. Allow the paper to stand until thoroughly dry, when it will be found that the paper has shrunken tight and smooth, giving a good surface for the drawing, and the rendering will be much easier because the paper is held firmly in place. Be very careful to see that the paper is stuck to the board all along each of the four edges, before allowing the paper to dry.

After the drawing has been made, the shadows are cast with light pencil lines. Clean the drawing with a soft eraser, either of kneaded rubber or of "sponge" rubber. These erasers remove the general surface dirt without affecting the lines materially.

The use of an India ink wash will be described, although the same treatment will be true of colors. The drawing should, of course, be inked very carefully before any tinting is started. The erasing of lines should be done very carefully as the surface of the paper, if rubbed too hard, will be abraded—so that when colors are applied they will soak in instead of remaining on the surface. The drawing may be very carefully washed after the inking is completed, with a soft sponge; this removes surplus ink and leaves the lines more subdued.

Method of Applying Wash. Having the drawing all ready to render, a few principles must be followed to insure the best results. Have your water, color, brushes, blotters, and sponge, all handy; have plenty of clean water convenient; for heavy or dark shades, apply several washes of a lighter value, instead of putting the heavy color on all at once.

Having once started the wash, carry it on continuously, without allowing it to dry; any mistakes can be remedied after the wash is completed, but the wash should never be interrupted to rectify mistakes. Lighten the wash by the gradual addition of clean water; be careful to take the color from the top of the dish, to avoid getting the sediment. Always take about the same amount on the brush, and do not allow the brush to become too dry before adding more, as this will dry much quicker on the paper, and the addition of more will cause a streaked or mottled effect.

Having reached the bottom of the drawing, take up any standing water or color with a blotter, as it will make a bad appearance if this is all allowed to stand and dry. The board should be tilted slightly, so that the wash will have a tendency to move downward; and it should be left in this position until the color is dry. Do not attempt to patch or add color to any portion of the drawing that has commenced to dry.

Having put into a saucer enough of the ink for the drawing, apply the brush to the surface of the ink, soaking up a brushful. If the drawing is of any considerable size, a wide, flat brush of camel's hair can be used to better advantage than a pointed brush. The pointed brush, however, will be the one most used on ordinary-sized drawings.

With the brush filled with the ink, apply to the upper edge of the drawing, carrying it across the top and gradually working it downward, adding more ink as the brush becomes drier. Since all work is darker at the top and gradually shades lighter, as the wash is carried down the sheet, add a little clean water each time, until, at the bottom or last application of the brush, it should contain almost clear water. This shading from darker at the top to lighter at the bottom is a conventional way of rendering plans.

Plate H (lower figure), shows a plan rendered in this way, the darker effect being obtained by a series of light washes and not by a single wash.

The brush is held in much the same way as a pencil, the hand being entirely free from the paper, or perhaps at times resting on the little finger.

In case of any blotches or other objectionable portions, these can be remedied with a little care. Take the sponge and dip it into clear water. Sop the portion thoroughly, allowing enough time for the water to soak into the color; then apply a clean blotter, and soak up the water. Be very careful not to rub the blotter over the surface. If very carefully done, the trouble can be remedied, and the drawing will scarcely show the spot.

Be careful, in all work, not to allow dust or hairs from the brushes to remain on the drawing. These may be removed with a toothpick, by slightly moistening the end of the toothpick in the mouth and carefully lifting the objects off the drawing. For lines that have overrun after the wash has become dry, take the bristle brush, moisten it in clean water, and rub gently over the color outside the line. When the water has soaked into the color, use the blotter. The trouble can be remedied by one or two such treatments.

The methods of procedure described above concern the application of flat washes.

It will take considerable practice to render well. The beginner is advised to make several sheets of such work as described above, before attempting a plan or elevation. Use the washes on the elevations to show shadows, or the portions in shade. See Plate H (upper figure), which shows an elevation rendered in the conventional way.

Water-colors are applied or "floated on" in the same manner as the India ink washes. Remember that in the use of colors you will have to be very careful to have a dish and a brush for each color, as the least particle of color in the clear water will sometimes change the color of some other dish if the two are used. Clean color boxes, brushes, and water are the first requisites of good rendering in color.

Colors may be obtained either in tubes, similar to oil paints, or in pans, which are small dishes of color. These should all be kept in a water-color box. There are usually two palettes or lids to this box, on which the colors may be mixed. If there is to be any quantity of color used, these palettes will not be large enough, and the dishes should be used.

In the use of either color or India ink, apply enough color to give the drawing some character; make it "snap;" do not commit the oft-repeated offense of having your drawing look "sickly" or have a washed-out appearance. Attack the problem of rendering, with determination; put on the colors as colors, and not as if you were afraid of spoiling something.

Red, blue, and yellow are commonly called the three **primary colors**, and in combination will give the intervening tints or colors of the prism. Thus blue and yellow will give green; red and yellow will give orange, and red and blue will give violet or purple, the tints varying according as one or the other color predominates in the combination.

ORDERS OF ARCHITECTURE

In the study of architectural history, we turn to the Greeks and Romans for a great many fundamental principles of design. We see that they had proportions for everything. Adopting some unit, the building was designed and erected with this as a unit. They had certain arrangements of a cornice, a column, and a base which have been handed down for ages. All of the parts had certain relations to one another in size. This combination we have called an **Order**.

We have four Orders which are used in architecture—the **Tuscan**, **Doric**, **Ionic**, and **Corinthian**. (See Figs. 83 to 86.) A fifth Order—the so-called **Composite Order**—combines features of the others.

It will be noticed that all the ornamentation on the mouldings has been omitted for the sake of clearness in revealing the important proportions. Each Order has the three main divisions —the **entablature**, **column**, and **pedestal**. In our architectural design, the base or pedestal is

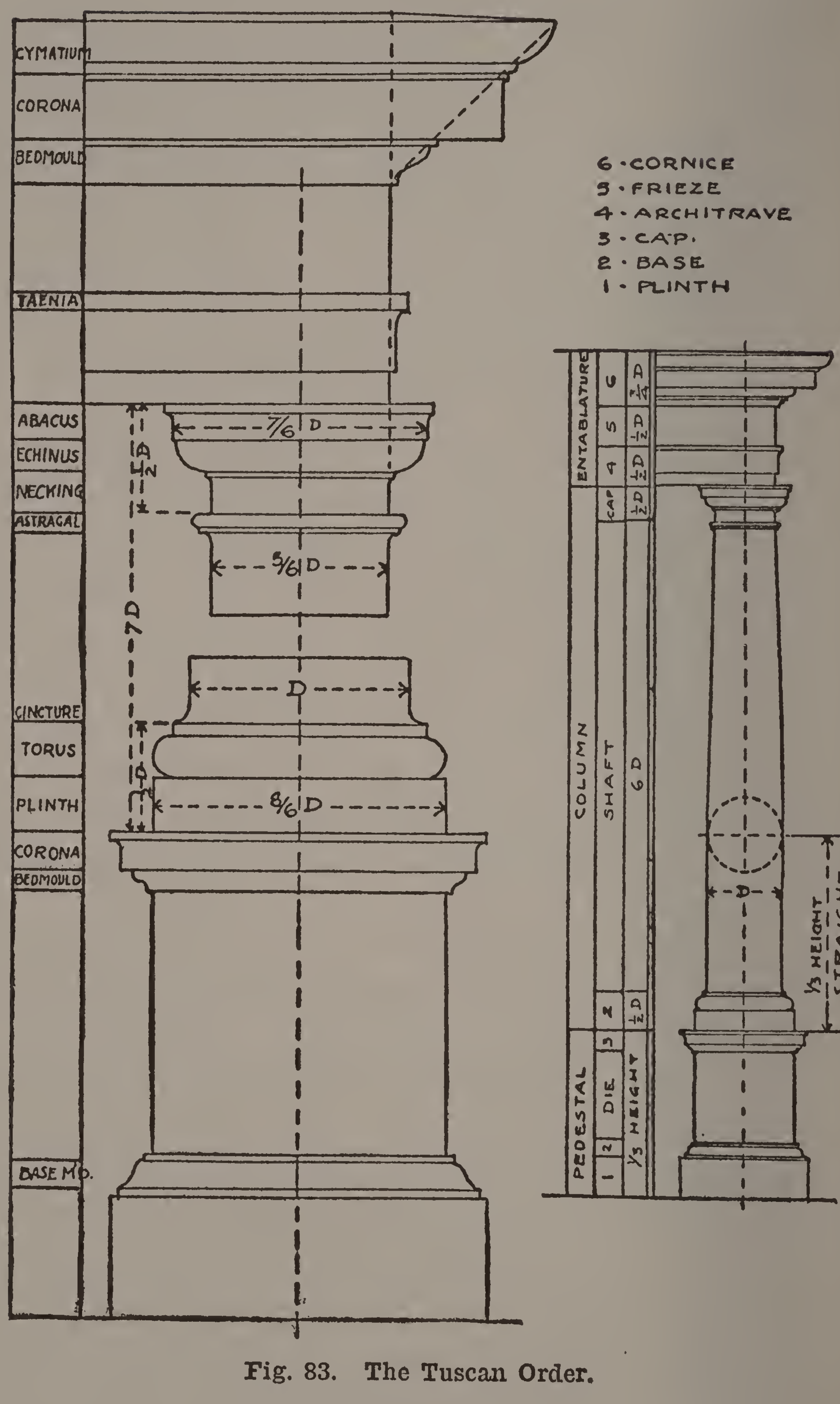


Fig. 83. The Tuscan Order.

usually omitted. As will be seen from the drawings, the entablature has three divisions—the **cornice, frieze,** and **architrave**; the column is divided into the **cap, shaft,** and **base**; the pedestal, into the **cap, die,** and **base.**

The entablature varies from 1¾ to 2½ times the diameter of the column. The cornice projects from the face of the column a distance equal to the height of the cornice in all cases except in the Doric Order. The frieze is a flat band or surface, sometimes ornamented. The architrave may be made of a single band, or it may be divided into a number of bands.

The column has a **capital** or top, varying from a plain cushion to the elaborate cap of the Corinthian and Composite Orders. The shaft, in some Orders, is perfectly plain, while in others it is fluted. All columns have a taper at the top. The shaft is carried up straight for one-third the height; and from this point it tapers. This tapering is called **entasis.** The shaft rests on a base which consists of a **torus** and a **plinth,** or a series of toruses called an **Attic base.**

The **diameter of the column** at the straight portion is used as the **unit of measurement** for all other parts.

Fig. 83 shows the **Tuscan Order,** with the principal proportions. This is the simplest Order, being perfectly plain. It is used a great deal for porches, or for lower stories where there are a series of Orders above.

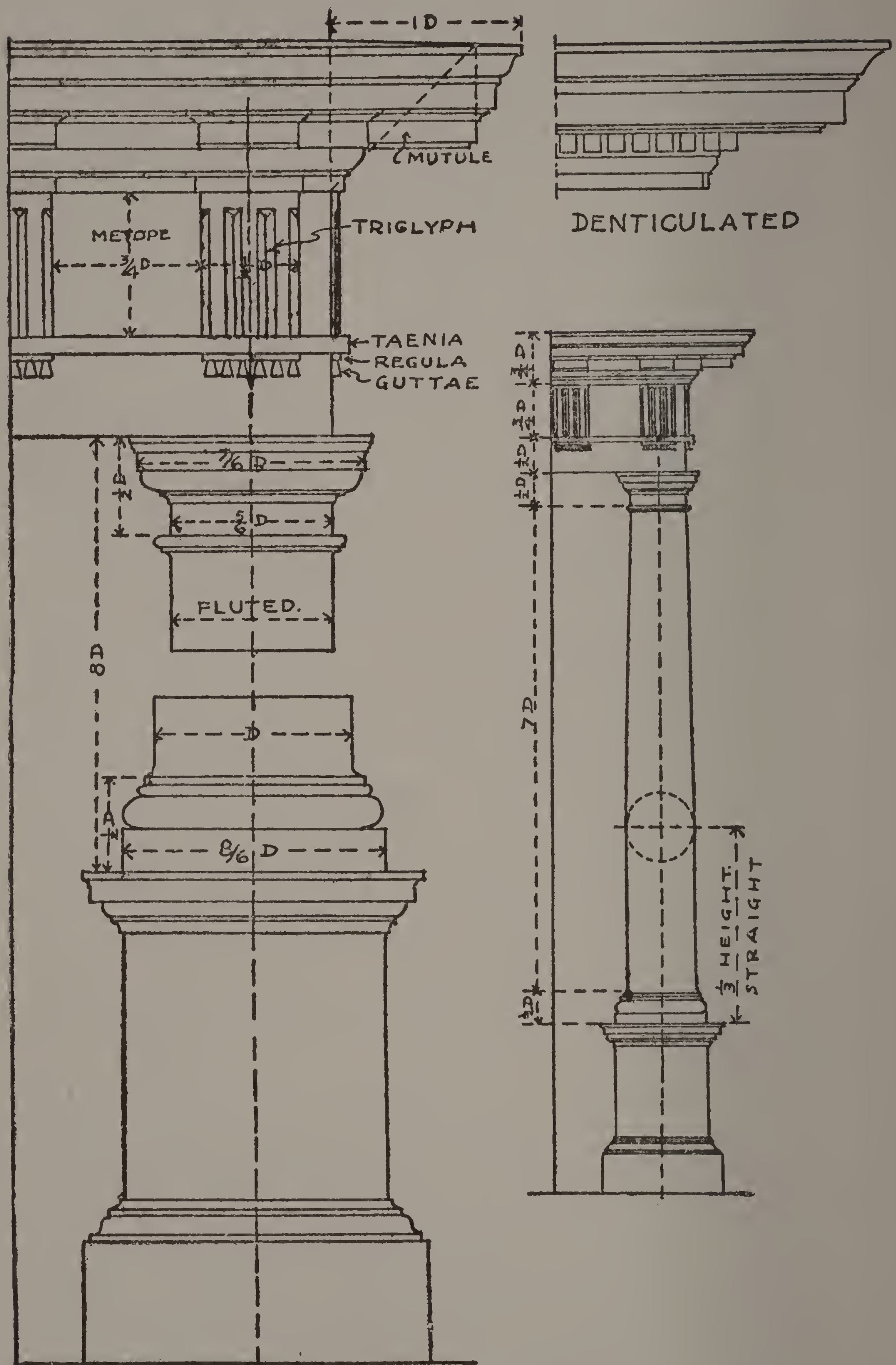


Fig. 84. The Doric Order.

Courtesy of the University of Illinois.

SKETCH RENDERED IN PEN AND INK.

PLATE G—ARCHITECTURAL DRAFTING.

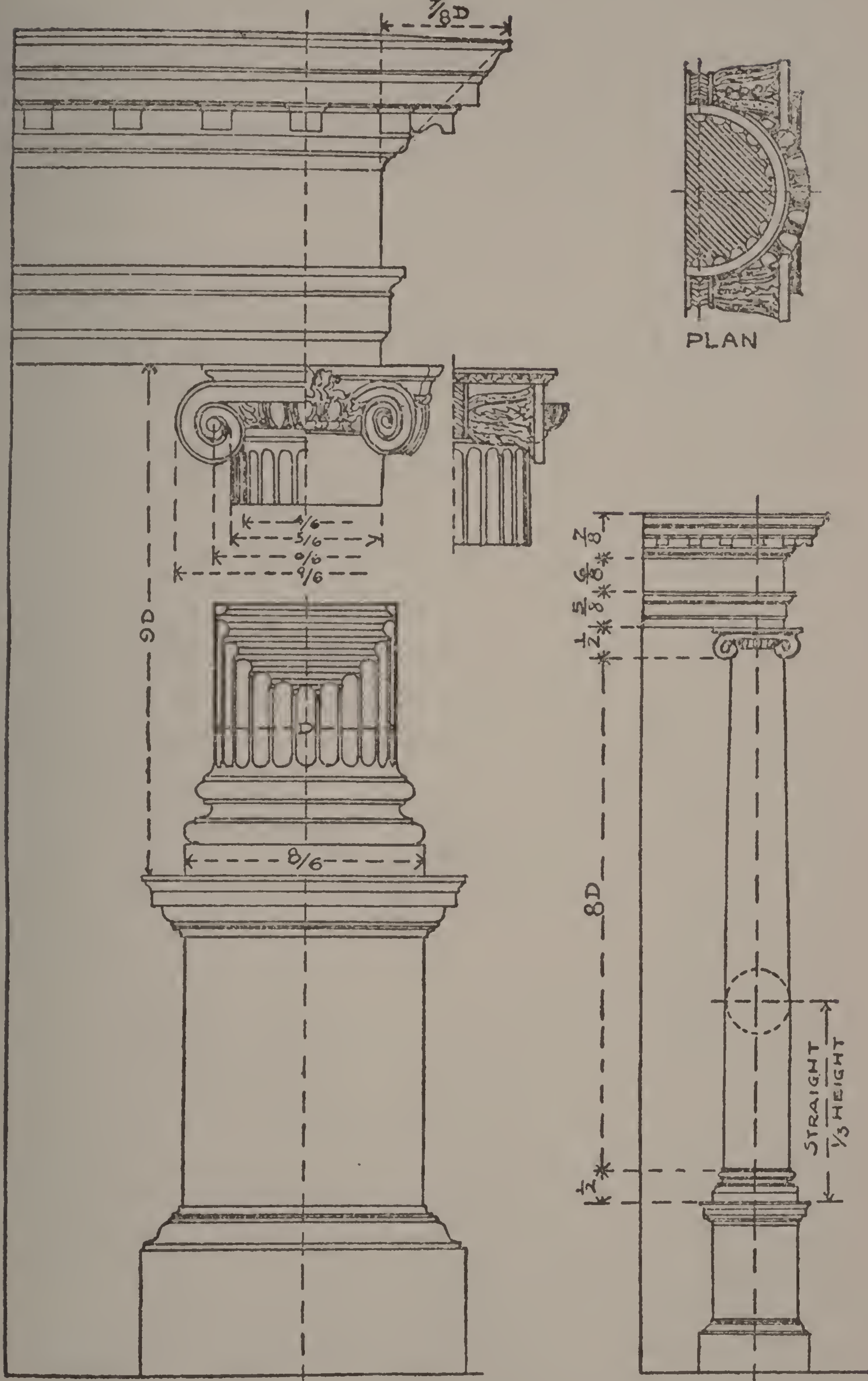


Fig. 85. The Ionic Order.

Fig. 84 shows the **Doric Order.** This has a great deal of ornament, both on the soffit of the **corona** (the projecting, crowning member of the cornice), and on the mouldings. In most modern designs, we see this Order modified more or less.

There are two types of cornices used with the Doric Order—one with the **mutules** (projecting flat blocks ornamented on the under surface); and the other with the **dentils** (a course of small cubes in the bed-moulding). The general profile of the cornice is different in the two types. The shaft is very often fluted.

Fig. 85 shows the **Ionic Order,** with the principal proportions. The cornice may have brackets called **modillions,** or it may have the dentils. The capital for the column varies, the left-hand half showing the **cushion capital,** and the right half shows the **volute** turned at 45 degrees, thus giving all faces alike. The shaft is fluted, and the mouldings are usually ornamented.

Fig. 86 shows the **Corinthian Order.** The main difference from the other Orders is the capital, which is highly ornamented by means of **acanthus leaves.** This Order is probably the most dignified, and is also the most expensive. Sometimes the shaft is fluted. The mouldings are all greatly ornamented.

There is a variation of the Corinthian Order, called the **Composite Order,** already referred to. The chief difference is in the volutes

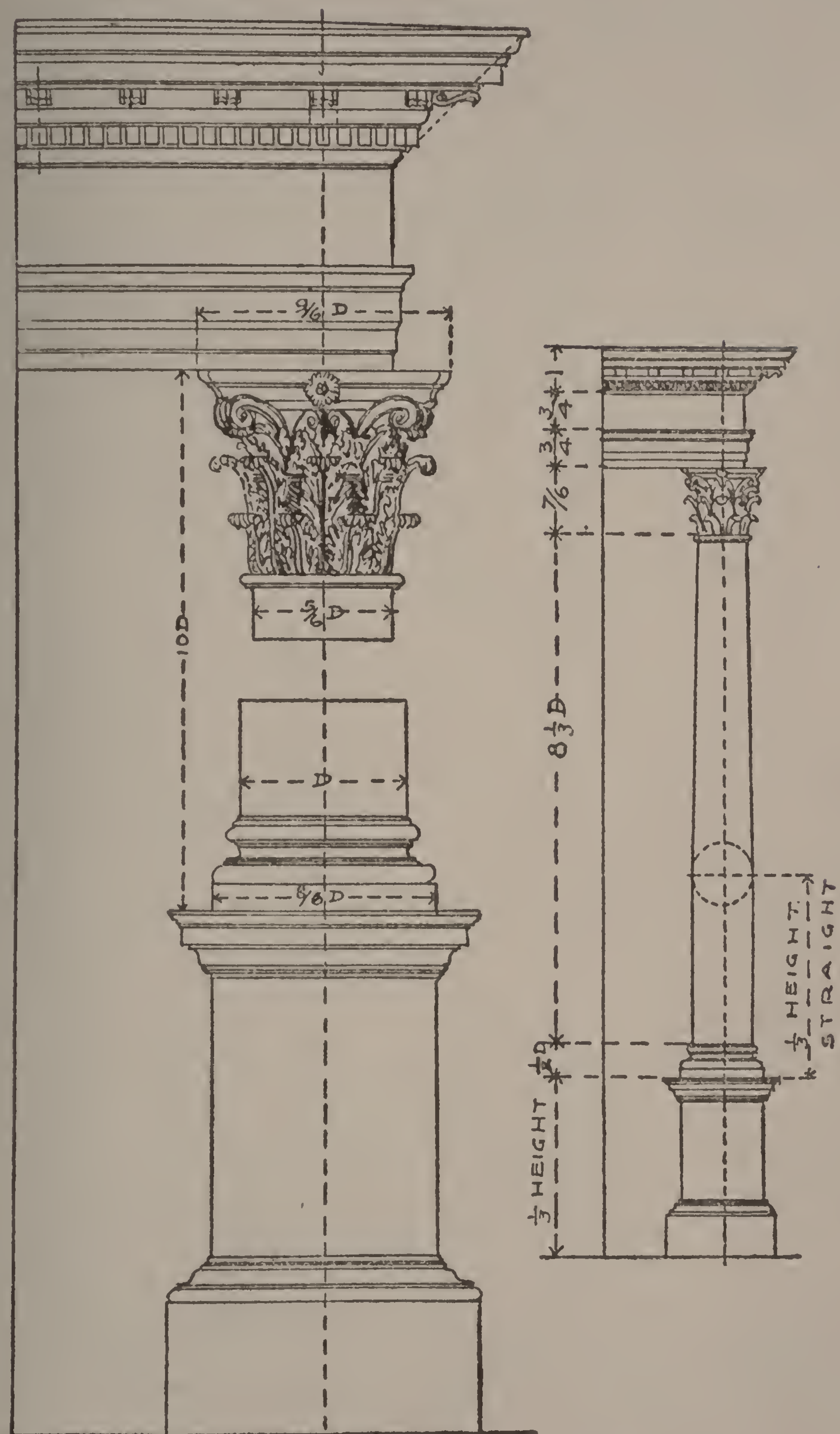


Fig. 86. The Corinthian Order.

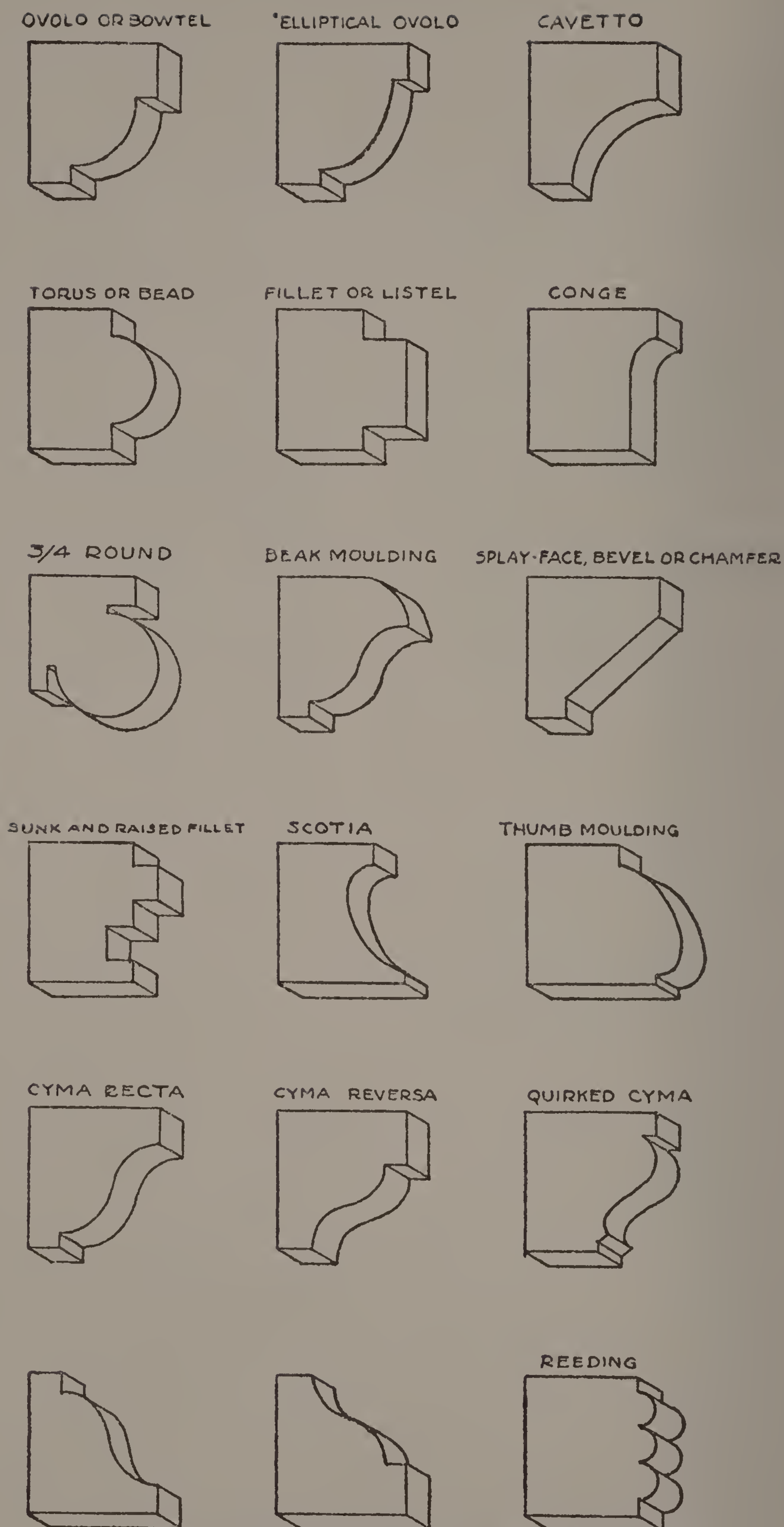


Fig. 87. Common Forms of Classic Mouldings.

of the capital, they being much larger and turned out the same way as in the true Corinthian.

All of these Orders are modified to a greater or less degree in all applications of them, each architect making changes to conform to general styles he is using on the building. The proportions, however, cannot be varied much without spoiling the general effect of the Order.

Fig. 87 gives some of the common forms of **mouldings,** with the corresponding names.

ARCHITECTURAL LETTERING

Good lettering is an essential requisite of a good set of plans. A drawing poorly executed but lettered attractively and well, will look a great deal better than one which is well drawn but which is poorly lettered. Therefore, at the start, let it be said that a draftsman needs to be a good letterer as well as a good draftsman.

We find lettering used with the earliest art of the Egyptians. These ancient people expressed their thoughts by means of symbols, more or less geometrical in outline. These inscriptions we find in the oldest of our Biblical writings; they were worked in stone and written on their papyrus. The forms used are called **hieroglyphics,** and students of ancient languages have been able to translate these strange characters.

The Greeks and Romans had characters very similar to ours. We have copied their forms, and use them to-day for our letters. Some of the inscriptions on the ancient Greek and Roman temples are splendid examples of lettering, as to both form and spacing.

The first principle to remember is that good lettering comes from **freehand** work, and not a mechanical product. The tendency of the beginner, especially, is to make all letters by means of straight edges and drawing instruments. The difference in the two methods is evident when we compare work of the two kinds. The printed letter such as is used for newspaper headlines, and the title as executed on a set of drawings, show very clearly that the former is too mechanical and stiff, while the latter, if well executed, is much the more attractive. Then again, freehand lettering can be adjusted to the general type of the drawing.

After the graceful ease and ready adaptability of freehand work, the next requisite in good achitectural lettering is **simplicity.** The simpler the letter, the easier made, and the better the general effect. Examples illustrating this can be seen in the effect of highly ornamental letters in newspaper advertising.

Learn to make the titles the same as a freehand sketch. Make plenty of strokes of the pencil; get the general shape of the letters, and the spacing. Do not attempt to make each letter with one stroke of the pencil.

After having made the title with several outlines, then go over this, and the final lettering can be done from this sketch of the letters. Get the general proportions and shapes first, together with the spacing, before trying to get a finished title. Develop the title as a whole, and let the small details of each letter be the last thing attempted.

The effect of the spacing of letters upon the general appearance of the title, will be seen from the accompanying illustrations of examples. Study the available space for the title;

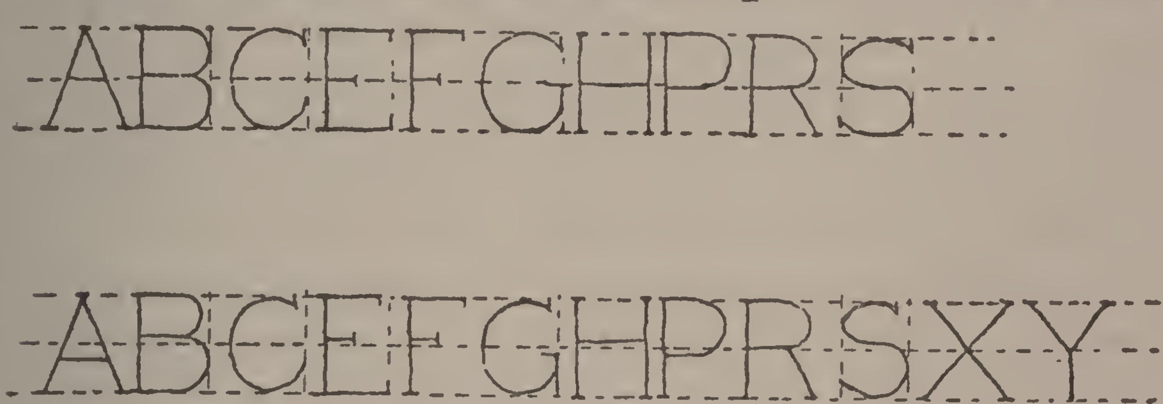


Fig. 88. Forms and Proportions of Letters.

and make the size, style, and spacing of the letters to suit the conditions. The guide lines, with perhaps a few lines limiting the edges of the letters, are the only mechanical lines that should be used.

It will be well to consider some of the letter forms, in order to understand just how they are made to look the best. See Fig. 88. The A is made wide enough at the bottom to give the appearance of stability. The cross-line should always be below the center, for, if exactly on the center, the upper portion appears too small for the base. The B should have the upper half smaller than the lower, both as to the width and the cross-line. It appears over-balanced if the upper half is made exactly like the lower half. The C should have the upper projection of the curve a little less than the lower. E should be smaller above the center line than below. The cross-line of F, H, and R should be the same. G should be similar to C in the greater projection of the lower part of the curve. P, because it has no lower portion, should be made a little larger than one-half the height. S should have the upper half the smaller. X and Y usually have their intersection on the center line.

By keeping these facts in mind, the appearance of the letters will be much improved.

For different styles of titles, where certain types of letters are used, the above rules will be modified; but for general work they should be followed.

Single-line letters are used almost entirely in lettering plans and drawings.

Spacing of Letters. As to the spacing, there is no set rule for standard dimensions; but a few rules may be given as a guide. Letters which have vertical and parallel sides coming together, are spaced the greatest distance apart. Take H and B, for example; these require the largest space. In case of a curve, as an O or a C, with an N or an H, the spacing will be about two-thirds of that for the H and the N. This same rule will hold for the curve of a D with an N or M or any letter with a vertical line.

If two curves come together—as, for example, a C and a G, or a B and a C—the space is slightly less than for N and O.

If A and V come together, make the lower point of the A come directly under the upper point of the V; there should be no vertical space between these letters. A or V, with O or B, will have about the same spacing as two curves, such as B and C or C and O.

While the above rules are only general, yet they will serve as a guide.

When **marks of punctuation** are used, the spacing will have to be increased over that of the regular arrangement. The spacing between words depends upon the style of letter used and the available space. Increasing the spacing will make the words more prominent.

In doing all letter work, it should first be penciled completely, before any inking is done. It is much easier to erase and make changes while the title is still in pencil than after it is inked. The ink will emphasize all irregularities.

The tendency of the beginner is to use too fine a pen. A new pen is always hard to work with, since it makes a thin hair line. Sometimes a new pen can be made to work more easily, by heating the point with a match. This will render it more flexible, although the pen will not last so long. Be very careful to make the same thickness of line for all parts of the letters, and for all letters of the title. It will require practice to be able to use the pen satisfactorily.

The inks can be any of the ready-mixed India inks. These are very satisfactory, and are much more convenient than grinding the ink from an India ink stick. Since the prepared inks evaporate and therefore thicken when exposed to the air, the cork of the bottle should always be at once replaced after filling the pen. Some grades of black writing ink may be used, although the India ink is much more satisfactory.

Almost all of the drawing papers will take ink. Tracing paper and tracing cloth are used a great deal. Bristol board is used where lettering is employed, as for an inscription, or where it is not a part of a drawing.

In lettering, first rule the guide-lines in pencil; then pencil the letters, and then ink. There is no rule for holding the pen; be sure to learn to have a free and easy stroke. By practice, learn to have a uniform line; and have confidence in your ability before you start. Usually the beginner is a little backward when starting the lettering on a sheet. By practicing vertical lines, inclined lines, and curves, one gradually learns the use of the pen. It should be noted that the strokes are all downward; and a curve, as for O, is made up of a series of strokes. There will be difficulty in getting straight lines and curves of the same size.

In penciling, always use a soft pencil, one free from grit. Make the lines as light as possible, so that they can be erased with as little pressure as possible. Keep the paper as free from erased lines as possible, as the erasing tends to destroy the general surface of the paper, and makes it much more difficult to ink properly upon it. Should a mistake be made, after the ink has become thoroughly dry, use an ordinary pencil eraser, and rub gently in all directions. Stop at short intervals to allow the eraser to cool, as it will smear the ink if it becomes too hot from rubbing. After the erasing, take some smooth, hard surface—be sure it is clean—and rub gently over the erased surface to give a smooth finish to the paper. Some think that a regular ink eraser is necessary to remove the ink; but the pencil eraser will do the work better and leave the surface of the paper in much better condition. The work of erasing will be slow and tedious, but it should be carefully done.

The **size of letter** will depend upon the space, if the space is limited. Otherwise the letter should be made to correspond to the size of the drawing, a large, full-size drawing requiring a large letter, while a quarter-inch scale drawing will require a small letter. By a careful study of proportions, one can make a drawing look the best. Poor judgment in this respect will often spoil a well-drawn plan.

Titles are put on every sheet of a set of drawings. Each drawing on the sheet must have a single-line title; and each sheet must have a title complete, giving the name of the work, the client's name, the location, the scale, and sometimes the date. For the convenience of the architect, he usually places in one corner his name, the number of the sheet, the job number, the initials of the different men who made the drawing, and the date. This gives him his record for filing the set of drawings.

Choose a style of letter that will be clear and simple. While the architect has more liberty in the choice and spacing of letters than the engineer, yet the fundamental principle is clearness. Capitals are used almost entirely for titles, and small letters for notes of all kinds.

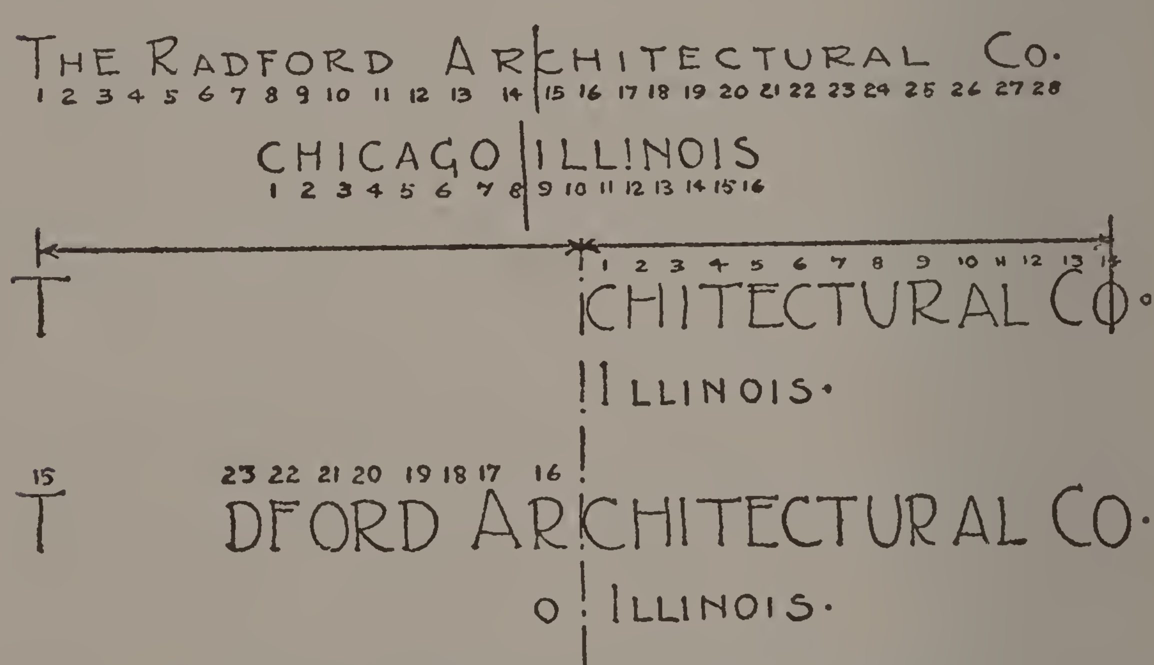


Fig. 89. Method of Centering a Title.

In laying out a title, there is usually a certain space it will have to occupy; therefore the title must be centered about a vertical center line through this space. The method of centering a title is shown in Fig. 89. Decide upon the wording, and write out each line as it is to be copied. Upon a piece of scratch-paper, spell out the letters in each line, numbering each letter in order, and also the spaces between the letters. The center of each line is then evident.

Lay out the center line of the space to be occupied on the drawing, and, after drawing the guide-lines, start at the center line, and commence sketching in the letters, first to the right, as shown in the third line, Fig. 89. Thus the right half of the title is sketched first. Now take a piece of paper, and lay off to the left the same distance as the right half extends to the right. This gives us a starting point for the left half. This part may be worked either from the left to the right, or, as shown in the fifth line, the letters may be placed in the order as

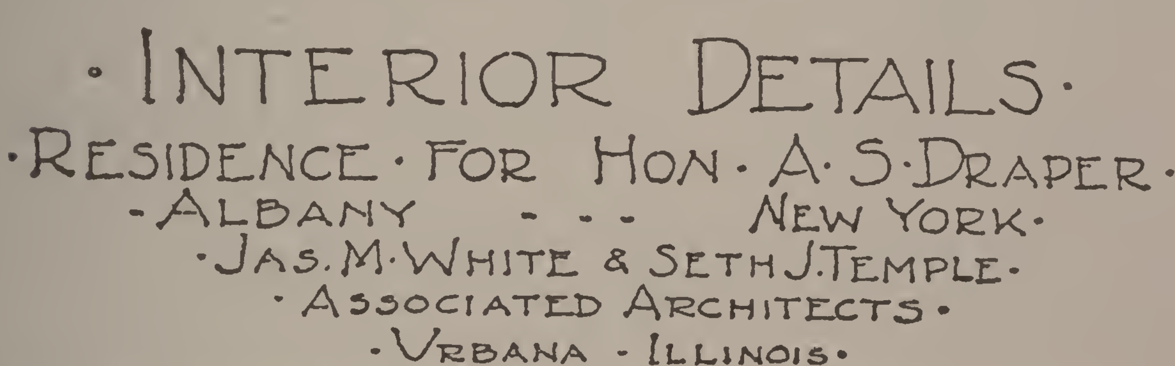


Fig. 90. Arrangement of a Title Showing Symmetry but not Mechanical Stiffness.

numbered. A little experience will enable one to lay out a title quickly and accurately in this manner.

Having the general arrangement in pencil, go over it carefully, and make the letters, properly spaced and in good outline. The title is then ready for inking. In all titles, let the composition or spacing be such that while the title as a whole shall be symmetrical, its general

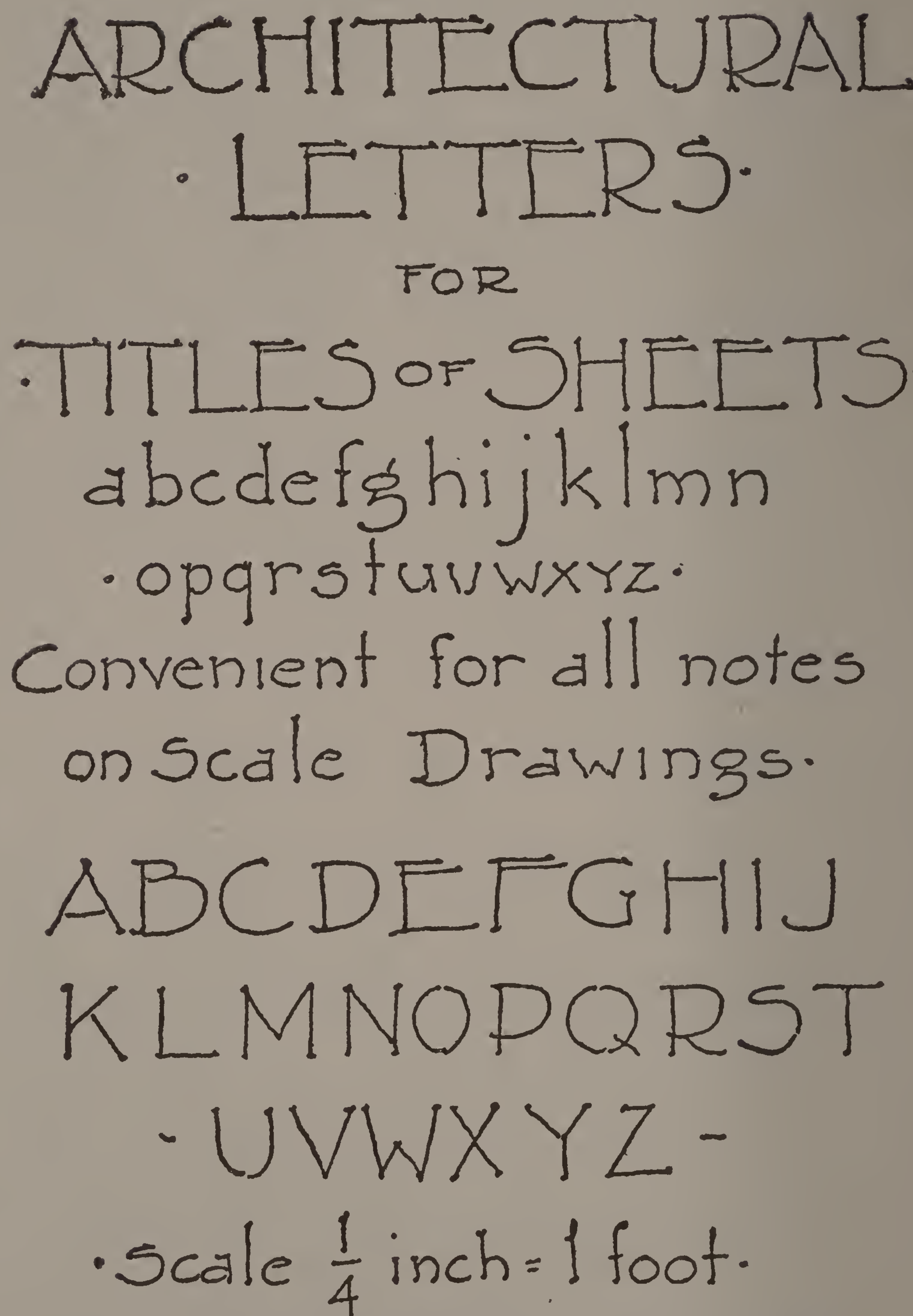


Fig. 91. Easily-Made Letters for General Drawings.

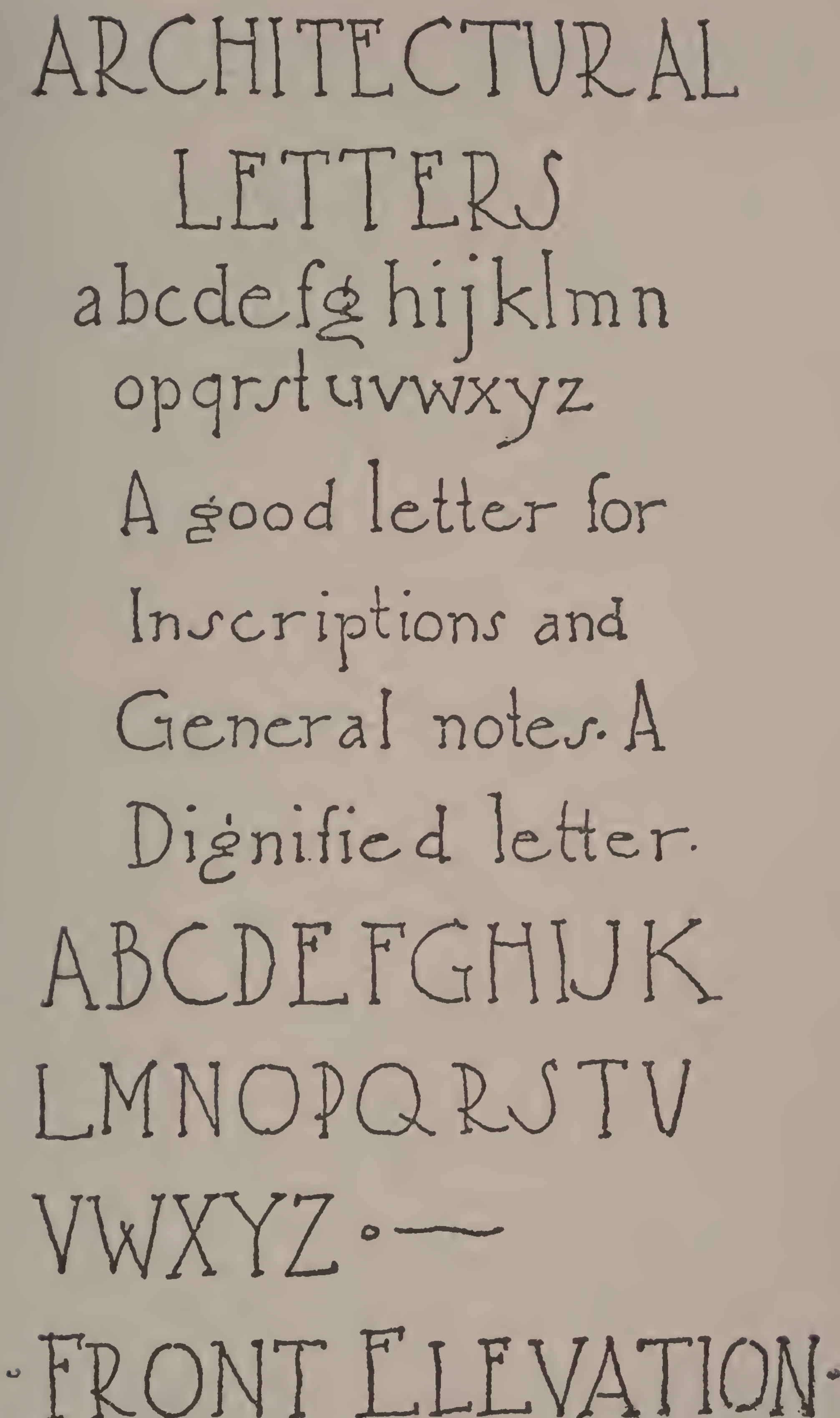


Fig. 92. A Dignified Type of Letter for Inscriptions, General Notes, etc.

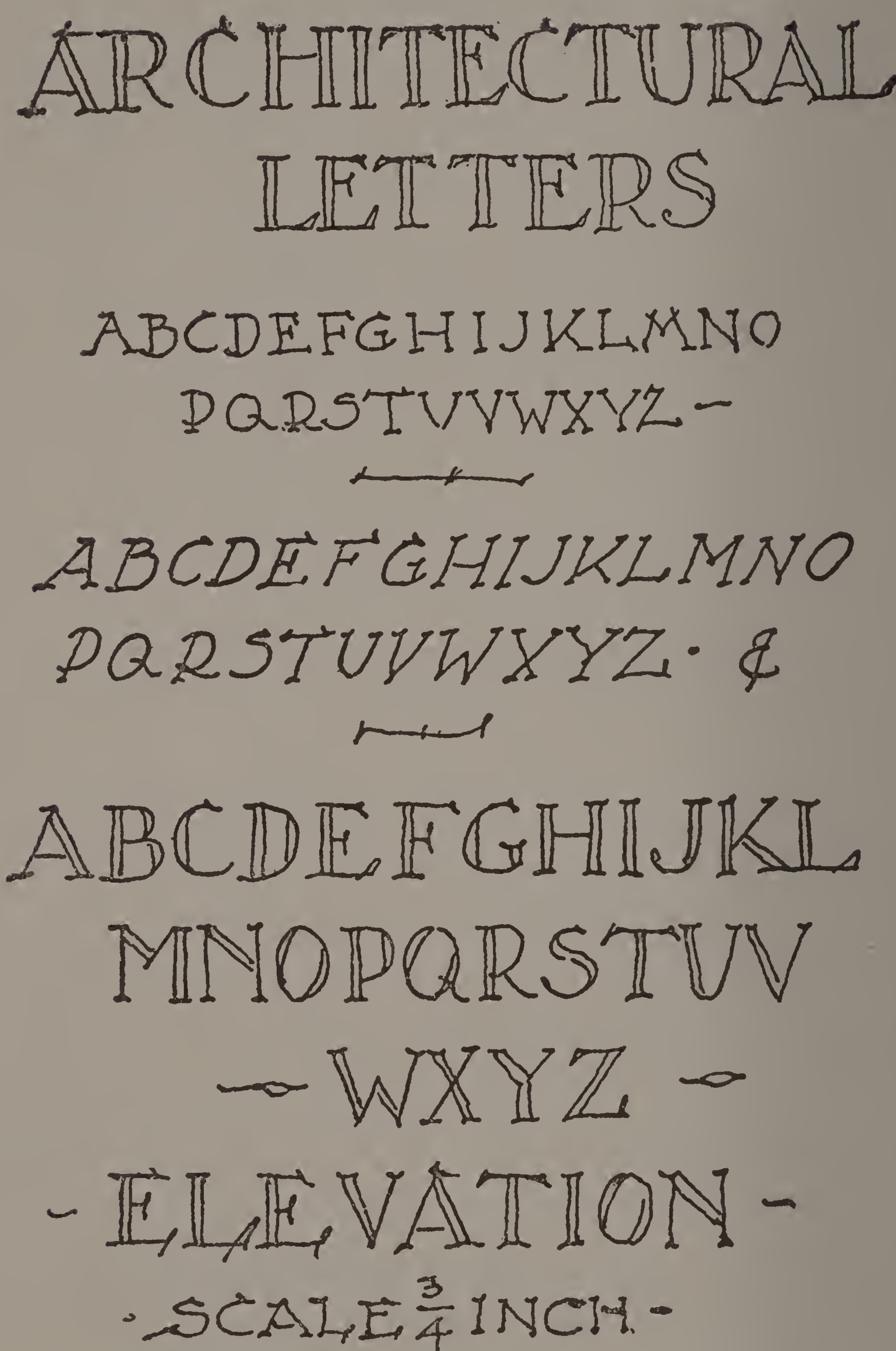
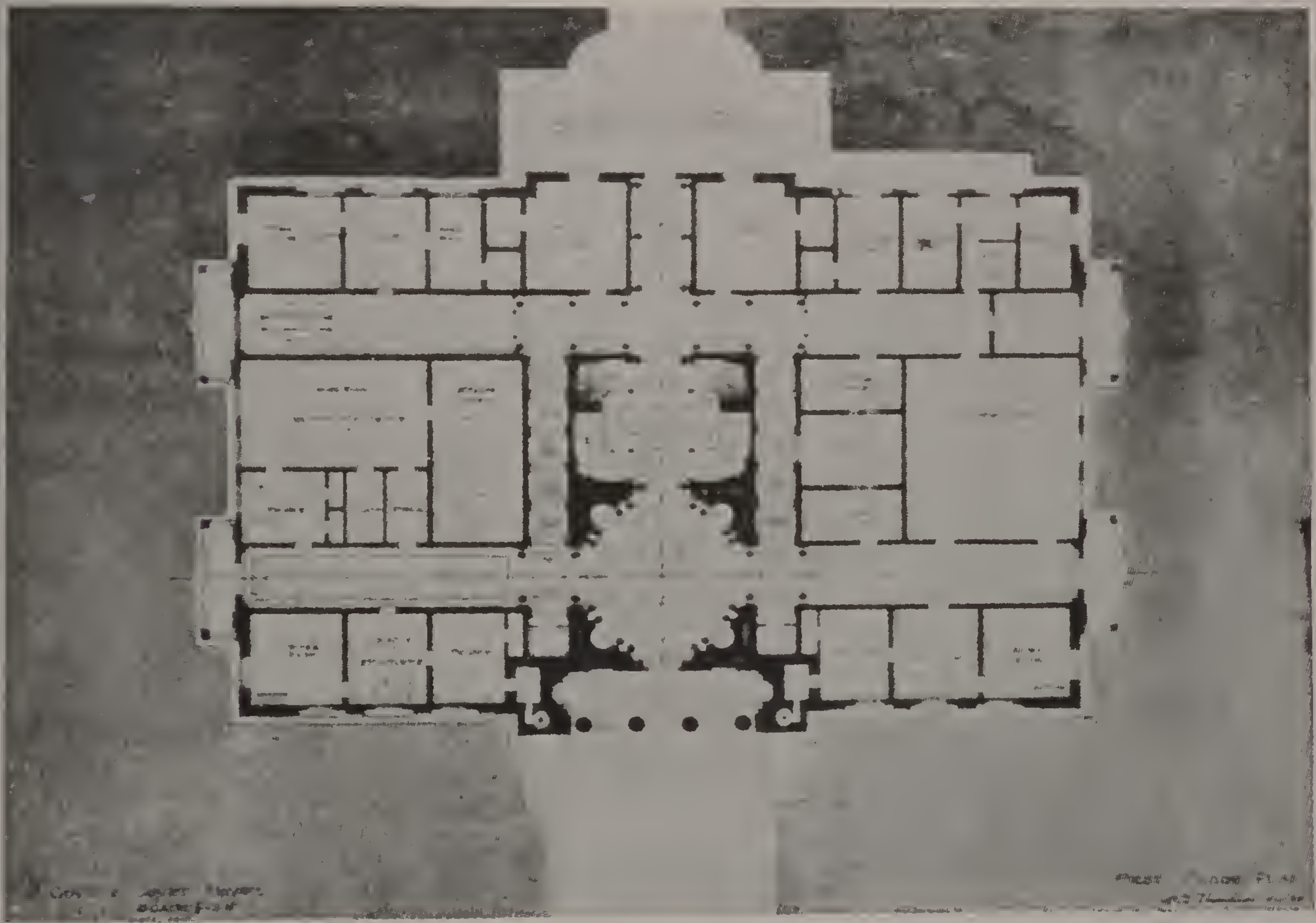


Fig. 93. Showing Double-Line Letters Used Largely for General Titles.

DESIGN OF A COURT HOUSE FOR A SMALL CITY.



Courtesy of Armour Institute of Technology.

ELEVATION AND PLAN RENDERED IN WASH.

PLATE H—Architectural Drafting.

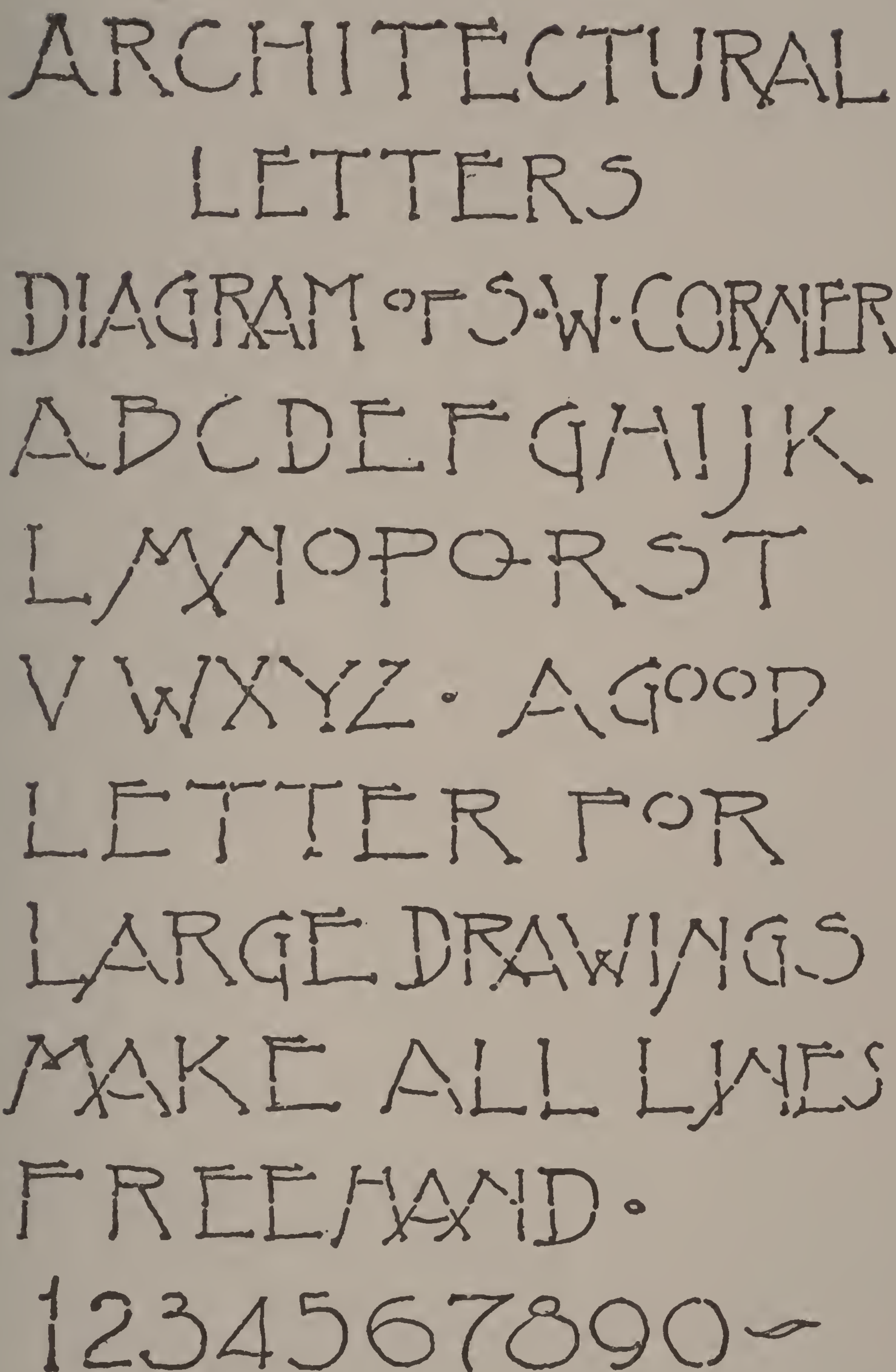


Fig. 94. Letters Suitable for Large-Scale and Full-Sized Details.

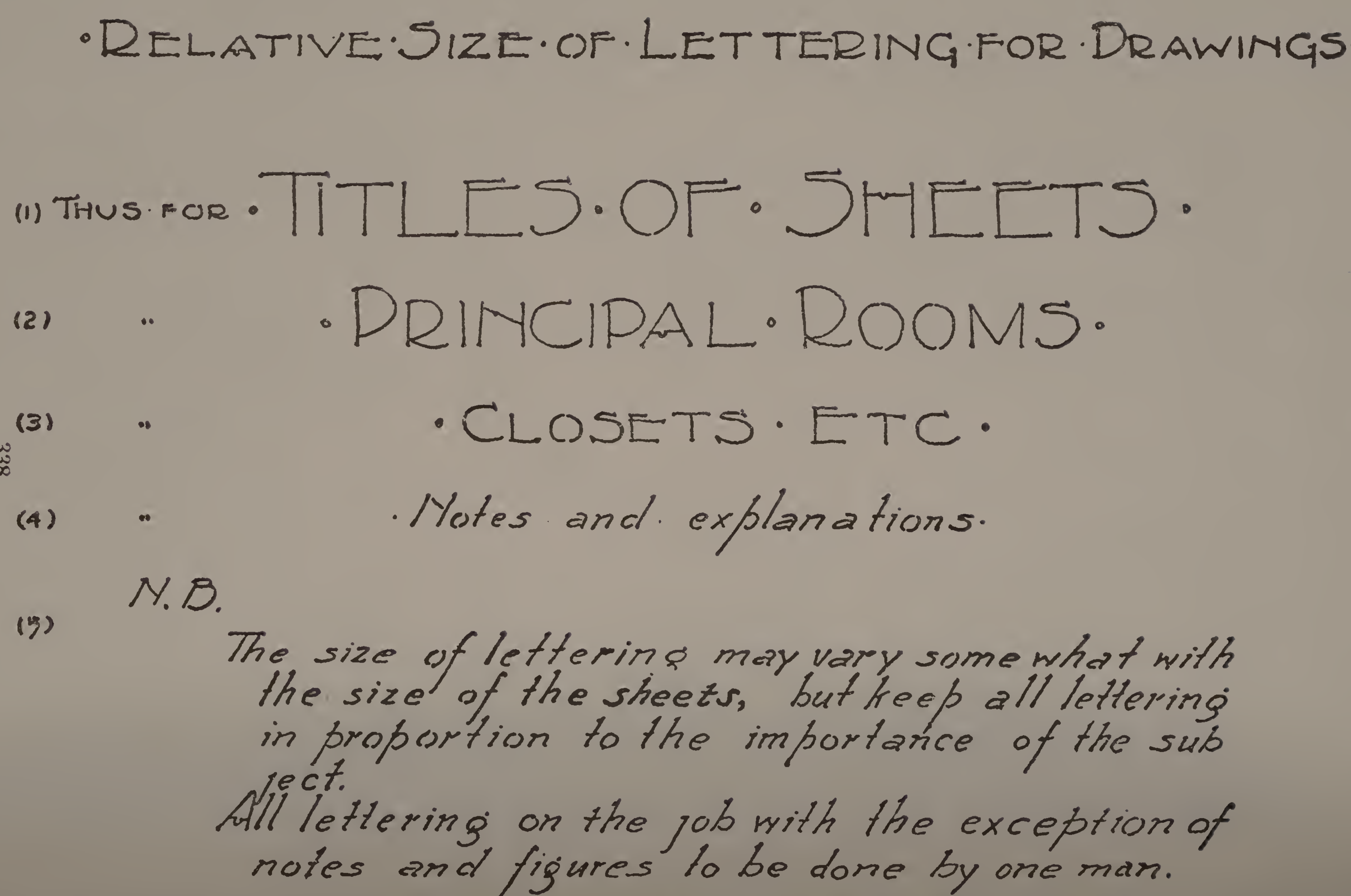


Fig. 95. Sheet Showing Relative Sizes of Letters to Use on a Drawing.

Fig. 96. A Good Form of Slanting Letter for Large Work and Full-Sized Details.

outline shall not be inclosed by straight lines. A line, for example, connecting the ends of the different lines of a title should not be straight, but irregular, as shown in Fig. 90. Try to avoid making the lines exactly the same length. Where the same general title is to be used on a number of drawings of a set, it is very convenient to make the title in pencil on a piece of paper, and trace it through the tracing cloth for the finished drawing. This saves a great deal of time. and gives a uniform title for every sheet.

The styles of letters mostly in use by architects are shown in Figs. 91 to 96.

Fig. 91 presents an easy substantial title, quickly made, and very clear. This form of letter will be found very satisfactory for general drawings.

Fig. 92 shows a type of letter largely used. It has a dignified appearance, is suitable especially for inscriptions on tablets or buildings, and is quickly and easily made.

Fig. 93 shows a form of double-line letter, very quickly made; this letter is used largely for general titles.

Fig. 94 shows a good style of letter to use on full-sized details and large-scale details. It is made by several strokes of the pen. Long lines are hard to make; therefore the long lines are made up of a series of short lines. When well done, it makes a very attractive form of letter to use. The figure is small, and the true values of the broken lines do not show up as they do on large work.

Fig. 95 is a sheet showing the relative sizes of letters to use on a drawing. The small letters may be made either slanting or vertical.

It is much easier to make a slanting line than a vertical line. Irregularities show less in slanting letters than in vertical letters, and for this reason some architects use a slanting letter entirely. The vertical letter, however, is much more dignified, and, when well done, is more satisfactory.

Fig. 96 is a good form of slanting letter for full-size detailing and large work.

It is as true of drafting as it is of every other branch of worthy human endeavor. Experience is the one great and indispensable teacher. Just as we learn to sing by singing, and to build houses by building them, so we learn to draw by drawing; and it is only by persistent practice on the part of the draftsman that the highest proficiency can be acquired.

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