PART II

PRINCIPLES OF PROJECTION IN ARCHITECTURAL DRAWING

THE first practical work on the drawing board which demands attention is that of the mechanical representation of objects upon paper, and commonly designated as *mechanical drawing.* The methods and principles employed in these operations are essentially the same for all classes of constructive work, whether the subjects treated be machinery or buildings of whatever material, as stone, wood or sheet metal, or of any part of a subject necessary to be represented. Involving as it does the principles of abstract geometry, the science which treats of this class of representation is properly termed *descriptive geometry.*

Descriptive Geometry, therefore, as a science treats of the exact representation of forms upon planes, the planes employed being represented by the surface of the paper spread upon the drawing board; and the method by which the representations are accomplished is termed *orthographic* or right line of *projection.* To assist in gaining a correct idea of the theory of representation, we may pause to note, first, that objects become visible through the action of light which moves in straight lines, called rays, from the object toward the eye. In the natural operations of vision, the rays proceed in straight lines from all parts of an object viewed, toward the eye, from which it will be seen that they must converge. If now a plane (represented, for instance, by a plate of glass) be interposed between the object and the eye, the point of intersection with the plane of a ray from any point of the object would properly be termed the projection of that point and the ray itself would be termed the line of projection or the projector. In like manner the projections of all the points in the outline of the object, if they be marked upon the glass, which may be termed the plane of projection, would constitute an outline of the object upon that plane.

It will be seen farther that since the rays or projections converge toward the eye, the resulting outline upon the glass plate will be larger or smaller according as the intervening plate is farther from or nearer to the eye, the point of convergence. Following this course of reasoning still farther, the greater the distance between the object and the eye, the more nearly parallel will the rays become, hence if the object be placed at as great a distance from the eye as possible and the plane of projection be placed as close to the object as possible, the resulting image, or projection of the object upon the plane, will be very little smaller than the object.

In the operations of descriptive geometry the visual rays or projections are considered as being exactly parallel, with the result that the projection of any object upon a plane thus becomes the full size of the object and constitutes a view of the same upon which accurate measurements may be taken.

We have spoken of a plane (Def. 19, volume one) as having two dimensions and of solids (polyhedrons Def. 69, volume one) as having three dimensions; the projection of a solid upon a plane, therefore, is a view of the same in which two of its dimensions only can be shown. Thus if the plane is supposed to have been placed in a vertical position in front of any subject the resulting projection may show the hight and the length of the subject, and may thus be termed a front view. If, now, another projection of the subject be made upon a plane placed at right angles to the first, as, for instance, in a horizontal position, either above or below it, the rays or projections being carried vertically to intersect the plane, the resulting view, termed a plan or top view, will show the length and the width. Thus two projections of any subject made upon planes at right angles to each other are sufficient to give its three, that is, all of its dimensions, and the relative position of every part of it will be shown. While this is true, yet in modern methods of mechanical drawing, a representation of the subject upon a third plane placed at right angles to the other two is considered advantageous and desirable, if not always necessary.

The idea of three planes placed at right angles to each other can most easily be grasped by standing a book or the covers of a portfolio upon any horizontal surface, as the top of a table, in such a position that its back shall be vertical. If now the covers be opened until they are at right angles to each other, it will be seen that both are also at right angles to the table top because they are in a vertical position. Thus the three planes represented by the two covers of the book and the top of the table are all at right angles to each other.

A projection made upon another vertical plane placed at right angles to the first mentioned, say parallel to a side or end of the subject, would thus show the hight and the width, and altogether, in the three views, each dimension would be given twice. Thus the *hight* would be shown on the front and the side views, the *length* would be shown on the front and the top views, while the width would be shown on the side and the top views. The methods of projection can of course be extended to the construction of any number of views, as for instance, a view of both sides or ends and the back of the subject, or to a view projected obliquely at any desired angle, as when the subject contains an oblique surface which it is desirable to show in detail, by placing the plane of projection at the desired angle.

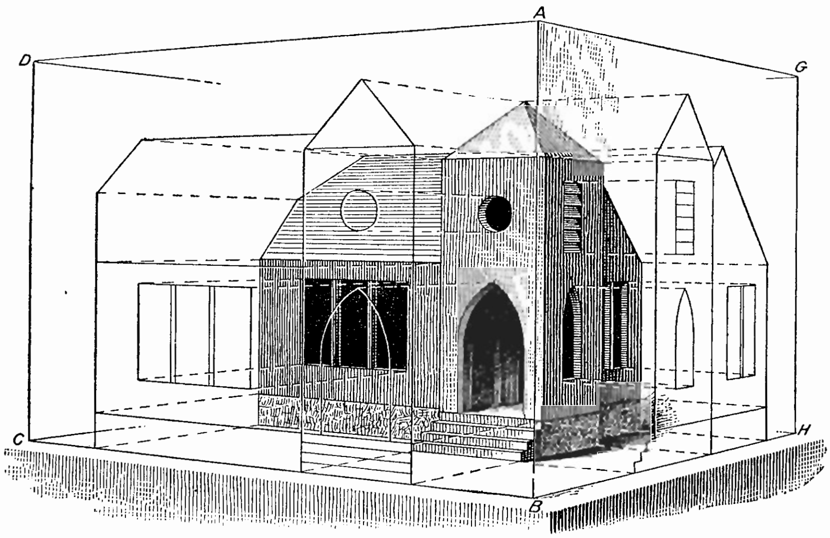

Fig. 84.—Theory of Orthographic Projection Illustrated by the Use of a Plane for Each Side of the Subject

The general idea carried out in the operations of orthographic projections can best be fixed in the mind by reference to Fig. 84, in which the subject to be represented is, in imagination, placed within a rectangular prism or box having glass sides which represent the planes of the several views. The rays or projectors are partially shown by dotted lines carried from the principal points of the subject to intersect the planes of projection at right angles. In the illustration, projections may be supposed to have been made upon the front, both sides and the top of the box, although those upon the top and the left or farther side have been omitted to avoid confusion of lines. When these have been completed, we may suppose the planes of the two sides and the top to be hinged to the plane of the front along the dihedral angles A B, C D and A D, and that the three planes mentioned are swung into one plane. All this having been done the several views would then appear as shown in Fig. 85, the lower part of which represents a plan of the glass box. The quarter circles, E E^1 and F F^1, show the movement of the side planes.

In mechanical drawing, any view is termed a "projection," the term being qualified when necessary by the position of the plane upon which the projection is made, as a "vertical" or a "horizontal projection." Projections made upon vertical planes are termed *elevations,* and projections made upon a horizontal plane are termed *plans.*

It sometimes becomes necessary to show upon a drawing that which could only be seen if the subject were cut by a plane passed through it in any desired position or direction. Such a view is termed a *section* and may be "longitudinal" if made by a vertical plane passed through the long way, or "transverse" if made upon a vertical plane passing through it the shorter way. In the case of buildings or machinery a plan is often a section on a horizontal plane passed through the subject some distance above its base.

The purpose of the idea illustrated and explained in Figs. 84 and 85 is to fix in mind the nature and relation which the several views that can be made of any given subject bear to each other, from which it appears that the elevation of the right end or side of an object appears at the right of the front elevation, while that of the left end appears at the left of the front and the top view, above. This seems to be the most logical system, inasmuch as, if the paper upon which the several views have been projected be folded along lines corresponding to A B and D C of Fig. 85 and then stood up on a level surface, in a manner to correspond with the sides of the glass box shown in Fig. 84, one in passing around the folded paper would thus see the several views of the subject in the same order or succession that

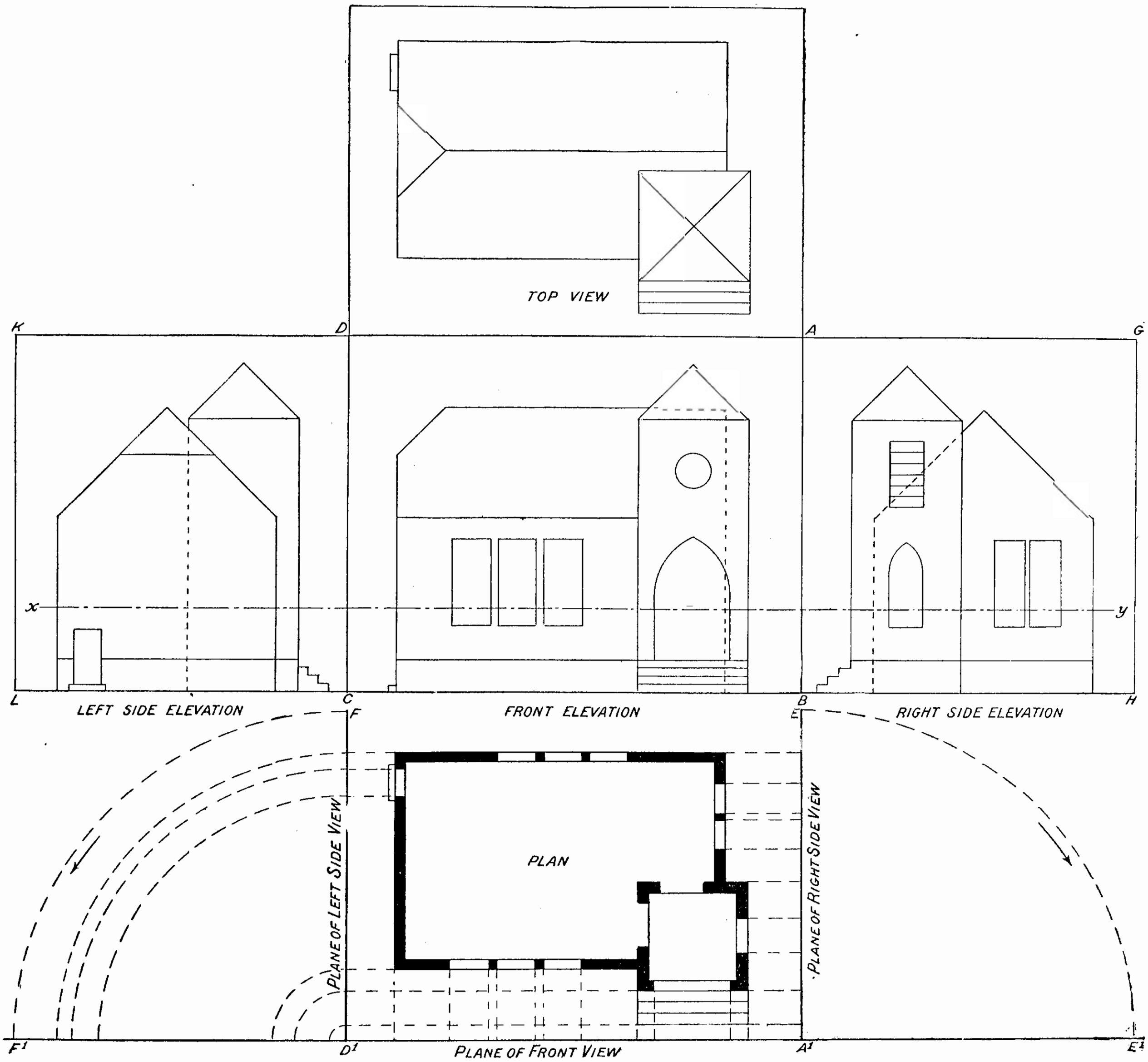

Fig. 85.—Planes of the Several Views Brought into One Plane

he would in passing around the subject itself. This system is now generally recognized in this country, and is so obvious in character that it should be accepted without question, and yet there are other methods based upon a different supposition with regard to the positions of the planes of projection by which the view of the right end appears at the left, and that of the left at the right of the main elevation.

It must be admitted that, in the varied operations of pattern drafting, it is not always convenient to strictly follow out this system, since for the purposes of convenience and efficiency it is often necessary to place the views otherwise, but a clear idea of these relations will be of great assistance to the pattern draftsman in obtaining many of the oblique views required in the course of some work.

It is especially desirable that the hinging of the planes along their lines of intersection just described be understood, as by this means a view upon any oblique plane is brought into the plane of the general view. This idea or method applies particularly in case of the intersection of pipes at various angles where a right section, or, in other words, a profile, of an oblique branch is necessarily upon an oblique plane, which, for use, must be brought into the plane of the view in proper relationship to the elevation.

The one great elementary idea of descriptive geometry is that of determining the position of a point in space by the measurement of its perpendicular distances from three planes all at right angles to each other, all as explained above. Put into the form of a practical problem, this principle may be stated as follows: Given the position of a point in one view, required to find its position in the other two views. The position, for instance, of one point in a desired section or view having been thus determined, the remainder of the required points follow in logical order.

Having, we hope, conveyed a clear idea of the character and relationship of the several views to each other and of the general theory of projection, we shall take up the work on the drawing board.

In the operations of mechanical drawing, it is of course understood that the several views of any subject are made before the subject is built, and therefore operations analogous to those illustrated in Fig. 84 are impossible, but since all of the views are to be constructed in one plane, as shown in Fig. 85, projections can be made from one view to another as the various points of the subject are located. Thus one view plays the part of a model, as it were, to all the other views. Especially is this true of the plan which is so drawn or placed upon the drawing board that its front or that side of which the principal elevation is desired is turned toward the draftsman, that is, toward the bottom of the board, as shown in Fig. 85. In proceeding with the work, then, projections are made from the front side of the plan to the elevation, that is, vertical lines are erected from all the angles in the outline of the plan, upon which the hights of parts represented by each are set up from a base line, called the ground line, as C B. This line is continued to the right and left to form the ground line of the other elevations, as shown by B H and C L.

In making projections from the plan to the side views one of two courses may be taken. In one case the plan must be turned one quarter around, so as to bring the side or end of which the elevation is desired toward the bottom of the board, as in the case of the front elevation, when the lines can be erected as before. In the other case, projectors can be carried to the right and left to cut the lines A^1 E and D^1 F, which represent respectively the planes of the right and the left side elevations, as shown. The points so obtained can then be swung around the points A^1 and D^1 as centers, to cut the horizontal lines A^1 E^1 and D^1 F^1, as shown at the left only, whence projections can then be made up into the side elevations.

The swinging around of the points described accomplishes upon the board just what has been done in theory by the hinging of the side planes upon the front, as described in connection with Fig. 84. This feature is fully shown in Fig. 85, only at the left of the plan, the projections from F^1 D^1 to the left side elevation having been omitted from the drawing, but the application of a T square or other straight edge will show the correspondence between the lines of the elevation and the points on F^1 D^1. In regard to the hights and all other matters of detail necessary to complete the elevation, these must be made to conform to the requirements of the case, or specifications, for the construction of elevations is usually a matter of design or conformity to requirements rather than merely making a drawing of something which already exists.

In mechanical drawing the students should note that several kinds of lines are used for different purposes.

The *outlines* of the subject represented should be a strong firm line, but not too heavy.

Lines representing parts which are *invisible,* but which it is necessary to show, should be dotted, as the outline at the left of the tower in the left side elevation, or that of the walls which are beyond the tower in the front and right side elevations, Fig. 85.

Projectors, when it is necessary to show them, should be represented by a series of short dashes, as in the plan of the same engraving.

Center lines are usually shown by a line consisting of a dash and two dots, although sometimes by a dash and one dot. So far as the pattern draftsman is concerned, either will do, but in drawings of machinery the latter is used to show the motion or travel of a moving point, or the line upon which a section is taken, as the line *x y* in Fig. 85.

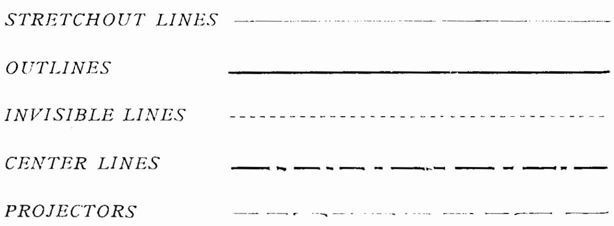

Fig. 86.—Lines Used in Mechanical Drawing

Stretchout lines, as well as *measuring lines,* are shown by a very fine continuous line, but not as heavy as those used for outlines.

Dimension lines are made the same as projectors, but have an arrow head at the ends to indicate the points between which the dimensions are taken. Fig. 86 shows how these lines should be drawn.

In the application of the principles of projection to the representation of geometrical forms, some general statements kept in mind will be of value, viz.:

The end view of a line is a point. A point, therefore, in one view may be the projection of a line in another view in which many points of importance are located.

The edge or side view of a plane is a line. Of two planes at right angles to each other, one may appear as a line while the other appears in full in the form of a plane figure.

A plane figure may be an elevation of a solid.

The principles which have been explained will now be put into practical use in the representation of some simple and familiar object. For this purpose a chimney top provides an excellent subject. The first thing to know evidently is the breadth and thickness of the chimney. Knowing the dimensions of a brick to be 8 × 4 × 2 inches, let us suppose it to be 28 × 16 inches. The plan will therefore work out as shown in Fig. 87. Having placed the plan thus drawn near the bottom of the paper as in Fig. 88, we first erect perpendiculars from all its angles indefinitely as a beginning of the elevation, as shown, drawing the lines at first lightly until it shall be determined just how much of them shall remain upon the paper. The next thing to be determined is the profiles of moldings to be used. These may be assumed to be those shown at A, B and C in Fig. 87, using that at A as a foot or neck mold, that at B as a cornice, and perhaps chamfering off the upper corner to form a finish, using a plain bevel or a small cove, as shown at C. Proceed therefore to place these in position at one side of the elevation, as shown at A and B of Fig. 88, when lines from their several angles or outer limits may be carried lightly across the elevation as shown, repeating the profiles (in a reversed position, of course) at the opposite side as shown by A^1 and B^1.

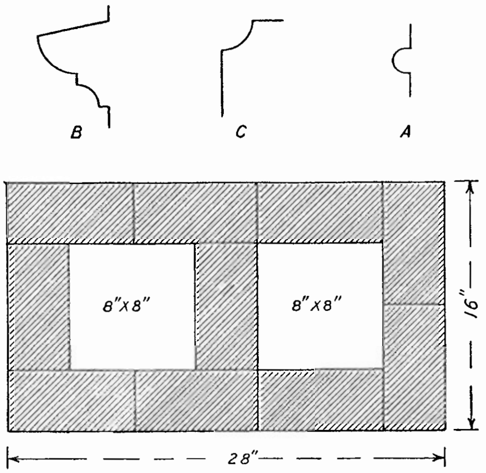

Fig. 87.—Plans and Profiles to be Used in Fig. 88

Suppose now, that it should be decided to introduce a gable in the cornice mold on the two wider sides of the chimney, leaving the narrow or short sides plain. First find the center line of the elevation by bisecting any one of the horizontal lines as at *e*, and through it drawing the vertical line *a b*. Allowing 18 inches as a suitable width for the gable set off 9 inches each way from *e* on the top line of the molding locating the points *c* and *d*, from which points draw lines at an angle of 45°, meeting upon the center line at *b*. Now, upon lines drawn at right angles across *c b* and *b d* at any convenient position, as at *x* and *y*, set off the several spaces in the width of the molding equal to the corresponding spaces on the line *m n*, as indicated by the small figures. Through these draw lines parallel to *c b* and *b d*, meeting in the center on the line *a b*, and draw the miter lines through the intersection at the bottom as shown by *c g* and *d h*. The whole design may now be completed by the addition of the small cove above referred to, just above the top point of the gable, as shown by profile C at the sides, the quarter circle being drawn from *i* as center. This completes the front elevation.

The plan may now be completed by projections carried from the elevation back to the plan, as shown, drawing first those from the several angles in the profiles at B and B^1, which will give the plan of that part of the molding which crosses the ends of the plan. Since the moldings are supposed to go entirely around the chimney, they must of course miter at the corners. We may therefore draw the miter lines from each corner of the plan by means of the 45° triangle and take the lines which represent the molding across the front and back of the chimney from the intersections of the lines first drawn, with the miter lines.

One other point demands careful attention. The roof on top of the profile B has been drawn slanting, as shown by *m p*, not as a matter of design, but as a wash, that is, to shed the water. As there is obviously no need of this on that part of the molding which forms the gable, one slant being enough, a peculiar shaped valley will thus be formed from *q* to *c*. This is shown on the plan by carrying projectors down from these points, remembering that point *q* is on the wall line while point *c* is at the nose of the mold, thus producing the oblique line $c^1 q^1$ there shown, which is the miter

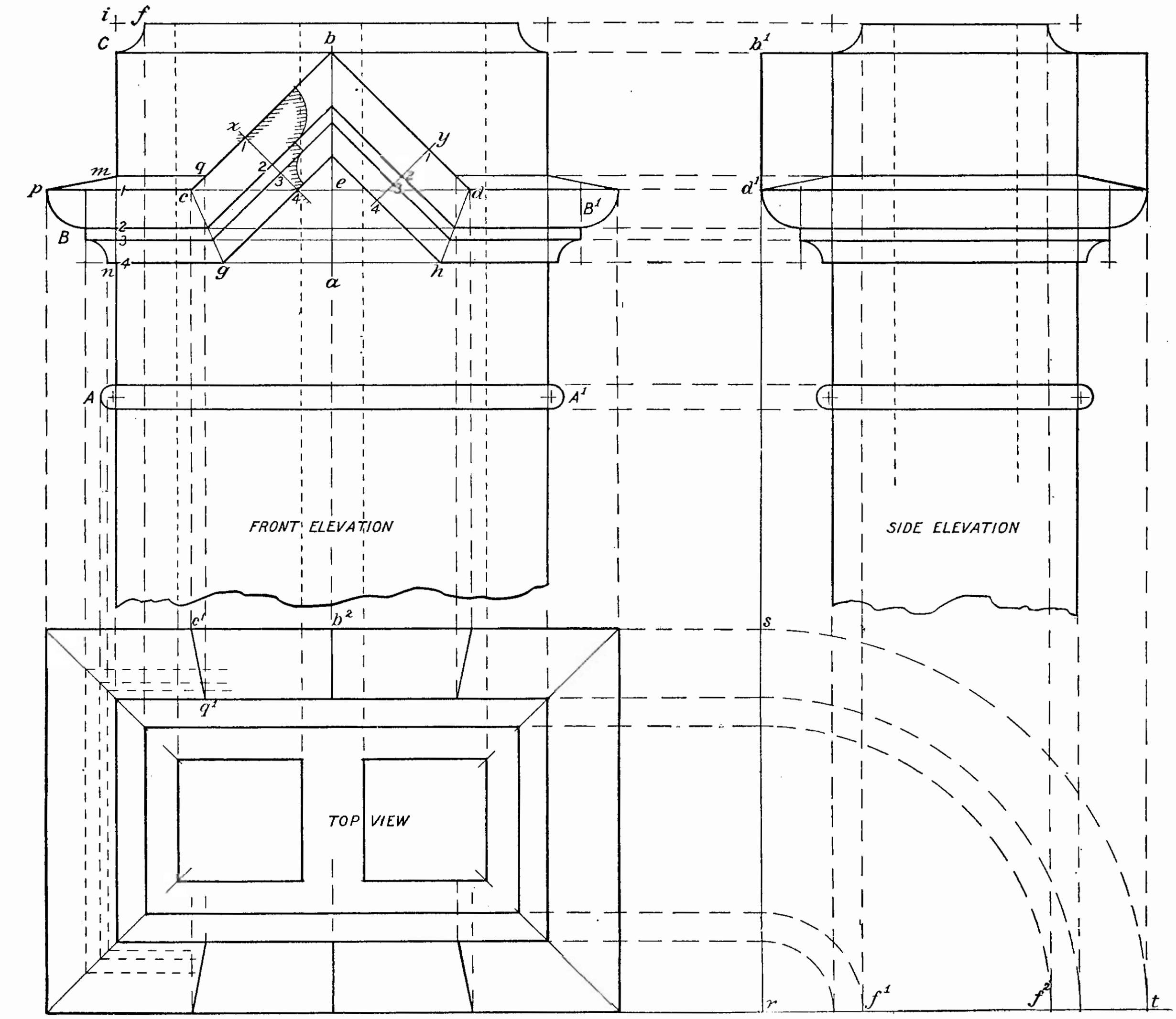

Fig. 88.—Practical Work in Mechanical Drawing

or joint between the two slanting surfaces, while the ridge *b* is shown in the plan by a right line, at b^2.

In constructing a side elevation, lines may be carried from the several points of the plan to any convenient vertical line as *r s,* as shown at the right, whence they may be carried through a quarter circle to the horizontal line *r t.* Projectors from the several points on *r t* are carried up into the side elevation to be crossed by projectors from the front elevation; all as clearly shown, thus locating all the required points. Note that the line b^1 d^1 is the projection of the oblique line *b d,* the space between it and the body of the chimney showing the roof of the gable.

These may be followed by a projector drawn from *f* to meet those brought up from the corresponding points f^1 and f^2 of the plan, as shown in the elevation. The showing of this member upon the plan will make it a top view, which being the case will render the small members in the lower part of profile B invisible, as well as the smaller mold at A. The lines which represent these members will therefore be drawn as invisible lines according to Fig. 86, as shown.

After all views in Fig. 88 have been completed, all lines called for by the elevation may be strengthened by using a somewhat softer pencil, as shown by the darker lines in the drawing and the remaining lines erased, as those shown between *c d* and *g h,* those drawn across the mold, as at *m n* and at similar places, and any others which in the preliminary work have been drawn farther than were required. To make the drawing really complete, invisible (dotted) lines should be projected up through the elevations from the angles of the flues in plan as shown.

An inspection of the drawing will now show that each and every point in any view is represented by a corresponding point in each of the other views, a matter which it is essential that the pupil should well understand since these operations are continually required in subsequent work.

In this figure the planes of the several views, though not indicated in the drawings, as in Fig. 85, are hinged upon the line of their intersection; thus the front and the side elevations are projections upon vertical planes which intersect upon a line, necessarily vertical, somewhere in front of and between the two views as indicated by the point *r* in the plan in Fig. 88, and the drawing of the quarter circles from the line *r s* to *r t* signifies the hinging or revolving of the plane of the side elevation to bring it in to the same plane with the front.

A custom frequently employed in working drawings is to draw the profile of a part, as a mold within the lines of the elevation in places where the exact relation of parts might not be apparent or where its presence may be required. For instance, in the inclined mold forming the small gables on the chimney above described (while it is of course understood that the profile here is the same as that shown at B) it becomes necessary to have the profile in position for use in the operations of laying out the pattern of that mold. The plane upon which a section of the mold would be taken can only be represented by a line as *x* 4, since its edge is presented to view. The plane of the section can therefore be brought into view only by hinging it upon the line of intersection with the plane of the front elevation, which is the line *x* 4, it being turned in either direction, according to convenience, until it becomes parallel to the plane of the view and thus shows the sectional view or profile, as shown at the right of the line. Profiles so drawn are always indicated by the shade lines placed upon the *inner side,* as shown. Thus the hinging of the oblique planes follows the same law which governs the vertical planes, and if once understood, there need be no chance of error.