TRIANGULATION

Applied to Sheet Metal Pattern Cutting

A Comprehensive Treatise for Cutters, Draftsmen, Foremen and Students; Progressing from the simplest phases of the subject to the most complex problems employed in the development of Sheet Metal Patterns; With practical solutions of numerous problems of frequent occurrence in sheet metal shops.

By F. S. KIDDER

Illustrated by means of 124 engravings in line and half-tone, including many reproductions of photographs of sheet metal models, made expressly for this work.

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Preface

The great and increasing demand for irregular forms to be made from sheet metal has made Triangulation an important factor in Sheet Metal Pattern Development. This has induced the writer to lay before the sheet metal worker, a work designed for the purpose of enabling him to acquire a thorough understanding of this branch of Pattern Cutting.

Triangulation has in many instances been a subject of more or less mystery. However, from a study of Geometrical works, we conclude that its secrets have long been known.

Few, if any writers upon Sheet Metal Pattern Development have seen fit to interpret it in a manner which affords the average worker an opportunity of grasping its underlying principles. The universal practise of most writers upon this subject has been to lay before the student worked out examples to be copied, little, or no attempt being made to convey an understanding of the principles employed, which is of the utmost importance.

No amount of time devoted to copying Chinese characters would enable one to understand them, nor will any amount of time consumed in copying pattern demonstrations enable one to understand the use and purpose of lines there found.

In all examples of pattern development lines are presumed to be upon the surface of the object. Upon determining the lengths of said lines, and the distances they are from each other, we are enabled to place them upon the plane of development in their proper lengths and relative positions, thereby securing points through which lines are traced which represent the boundaries of the required pattern.

There is a great sameness in the principles and methods which may be applied to many examples. In other words, if we grasp the reason for, and the use of each and every line in one problem, we are prepared to use those same principles and methods for all.

Forms which must be treated by Triangulation are such that the rectilinear elements of their surfaces are neither parallel or convergent lines. Therefore to determine their lengths we must assume a supplementary plane for each, or employ the right angled triangle. To secure their relative positions, we must presume that the surface of the object is divided into triangles.

Some idea of Orthographic Projection will be of service to the one who aspires to become proficient in this branch of pattern development, although the solving of a great number of the more common problems is but a simple operation.

This work is submitted with every confidence that if attention is devoted to the subject matter enclosed, one will be enabled to more clearly understand the principles involved in Triangulation as Applied to Sheet Metal Pattern Development.

F. S. K.

TRIANGULATION

CHAPTER I.

Elementary Principles.

Triangulation is a term which has in recent years been applied to certain operations in Sheet Metal Pattern Development, although said operations have long been explained in works upon Descriptive Geometry, where is found the declaration that the true length of a right line in space may always be found in the hypothenuse of a right angled triangle, whose base is equal in length to the horizontal projection of the line, and whose perpendicular is equal to the difference in length of the vertical projectors from the extremities of that line.

Triangulation as applied to sheet metal pattern development, is the act or process of dividing into triangles, also the results thus secured; specifically, the laying out and accurate measurement of a network of triangles presumed to be upon the surface of the object, and shown upon its geometrical representation which has been correctly delineated.

Triangles with which we deal are considered as plane triangles, although not strictly so, since a plane triangle is presumed to lie in one plane, and is bounded by three right lines. A triangle which is presumed to be a portion of the curved surface of an object will not lie in one plane. In many instances one side at least of said triangle is not a right line but a curved one. Thus many triangles involved in triangulation as applied to sheet metal pattern development are mixtilinear triangles. However, the magnitude of the variation is so small, that it may consistently be considered as a negligible quantity.

To Draw a Triangle.

As an aid in securing a clear conception of the most elementary principles involved, we may for the moment presume that we have given us three, four and five inches as the lengths of three sides of a triangle.

By the use of our compasses and straight edge, we are enabled to draw such a triangle by first drawing a line three inches long, as illustrated at *a b,* Fig. 1.

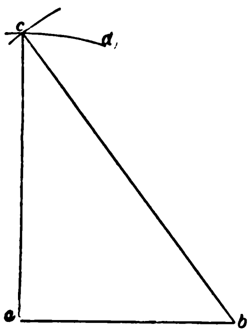


Fig. 1. Illustrating a method of drawing a triangle to given dimensions.

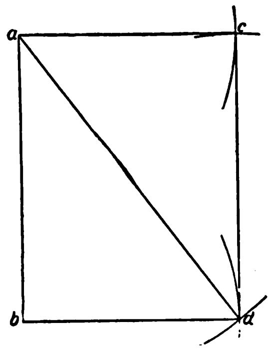


Fig. 2. Illustrating a method of drawing a parallelogram when the length of its diagonal is known.

With compasses set to a span of four inches, place one point at *a,* and describe the arc *c d.* Since the length of one side of the required triangle is four inches, the vertex of one angle must lie in the arc *c d,* and as the third side is required to have a length of five inches, the compasses may be adjusted to a span of five inches, and with point *b* as center, we may describe the small arc as at *c,* thus locating the vertex of the third angle in its correct relative position. Lines may be drawn connecting points as shown in Fig. 1, thus forming the three sides of the required triangle. Here *a b* is the base, *a c* the perpendicular, and *b c* the hypothenuse.

To Draw a Parallelogram.

To draw a figure which is known as a parallelogram, to given dimensions, the magnitude of at least one angle, or the length of its diagonal, must be known.

As for example, we have given us the lengths of two parallel sides as four inches, and the distance between the extremities of these lines as three inches. We draw a line whose length is four inches, as illustrated at *a b*, Fig. 2.

Since the extremities of the line forming the opposite side are to be three inches from points *a* and *b*, we may adjust our compasses to a span of three inches, and with points *a* and *b* as centers, describe arcs as shown at *c* and *d*. As these arcs have been drawn with a radius of three inches, every point of which they are composed must be three inches distant from their respective centers *a* and *b*. Therefore to locate the line which forms the second four inch side, the magnitude of at least one angle, or as above stated, the length of the diagonal must be known. Presuming this to be five inches, we adjust our compasses to a span of five inches, and with point *a* or *b* as center, describe a small arc intersecting the first as at *d*, thereby locating the vertex of the angle as at *d*, in its correct relative position. Since the side *c d* is known to be four inches long, point *c* is located as shown; lines are now drawn to complete the required figure.

Thus as will be noted, the parallelogram has been drawn by knowing the lengths of three sides of one of the two triangles of which it is composed.

Some Suggestions.

The student is advised to cut from sheet metal or cardboard two pieces, the forms of which are shown at Figs. 3 and 4. These forms may be looked upon as the forms of the top and base of an object which transforms from square to octagon, the square in this example being considered as the base.

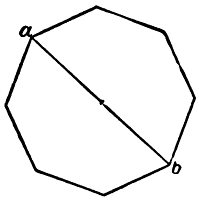


Fig. 3. Illustrating a form to be cut from sheet metal or cardboard.

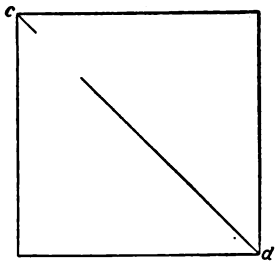


Fig. 4. Illustrating a form to be cut from sheet metal or cardboard.

Something for a center support as a block of wood whose ends have been made parallel, may be secured, and of a length suitable for the vertical hight of an object whose size of base and top have previously been established in the pieces spoken of, and shown in Figs. 3 and 4. These pieces may be fastened to the block of wood, and so arranged that lines *a b,* and *c d,* as shown at Figs. 3 and 4, will be parallel; with the center of the top directly above the center of the base, as illustrated at Fig. 5.

We now have a form about which a flexible but non-elastic material (paper) may be formed, which if marked or trimmed at top and base, will when removed, supply a pattern for an object whose dimensions have been established in said form, the surface of which may be looked upon as being composed of triangles. The lengths of sides of the square and octagon furnish the length of one side of each triangle. The lengths of the remaining two sides of each triangle in this example, will be found in the distances points *a* and *b* of the top are from point *d* of the base, or, in the true lengths of lines *a d* and *b d,* Fig. 6.

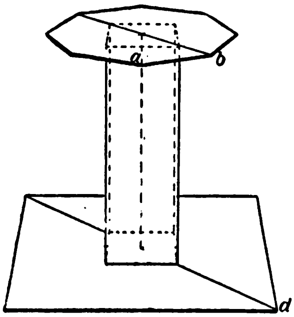


Fig. 5. Illustrating the relative positions the two pieces of sheet metal or cardboard should occupy.

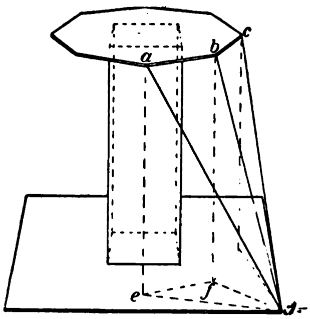


Fig. 6. Illustrating triangles from which the true lengths of lines may be secured.

It may be here remarked that in this example, it is only necessary to determine the lengths of two lines which represent the sides of one triangle, since there are in reality, but two lengths of side in the triangles forming the whole surface of the pattern, as will be hereinafter shown. If lines be dropped from points *a* and *b,* as shown at *a e,* and *b f,* Fig. 6, which are perpendicular to the top and base, lines may be drawn as *e d,* and *f d.* We then have in the true lengths of lines *a e* and *b f,* the perpendiculars of right angled triangles, the bases of which are *e d* and *f d,* when, as is clearly shown by Fig. 6, the true length of each line is found in the hypothenuse of its respective triangle.

From what has been stated above, the student will note that with the form previously constructed as shown at Fig. 5, he could drop imaginary lines as illustrated at Fig. 7, from the vertex of each angle of the octagon to the base, as in points *g h i j k o n* and *m,* and if lines be drawn upon the base to connect these points, he will have duplicated the form as previously established in the top.

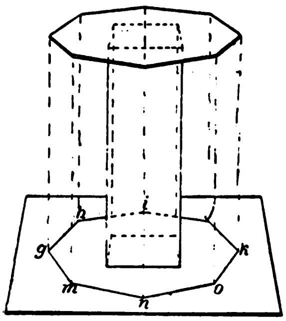


Fig. 7. Illustrating principles by which a plan is obtained.

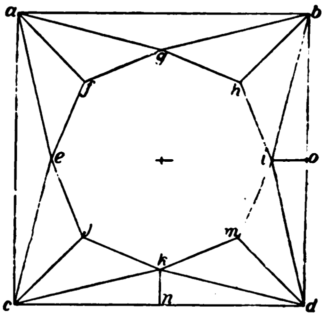


Fig. 8. A plan of the object.

Thus, as will be noted, the same results would have been secured, had we constructed a diagram as shown at Fig. 8.

A Plan.

This diagram consists of the square *a b c d,* which is the exact form and size of the base, and is known as a plan of that portion of the object. The octagon *e f g h i m k j,* is the exact form and size of the top, and is known as a plan of that portion.

Since in orthographic projection, the intersection of two planes demands a line, we draw lines as shown at *e c, j c, k c, k d,* etc., Fig. 8, which represent in plan the sides of triangles of which the surface of the object is composed.

As the sides of the square and octagon supply the true lengths of one side of each triangle, we have simply to determine the true lengths of sides represented in lines *k d, m d,* etc., to furnish all measurements necessary for completing a pattern. It has been previously shown that each of these lengths may be found in the hypothenuse of a right angled triangle, whose base is equal in length to the line in plan, and whose perpendicular is equal to the vertical hight of the object.

DIAGRAM OF TRIANGLES.

In any convenient position we may draw lines as shown at *a b,* and *b c,* Fig. 9, which are at right angles

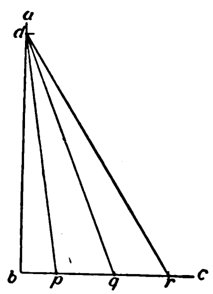


Fig. 9. Diagram of triangles from which true lengths are obtained.

to each other. Set off from *b* upon line *a b,* a distance equal to the vertical hight of the object as at *d.* Upon referring to the plan Fig. 8, we find that two of the lines radiating from the vertex of each angle of the square are of equal lengths, and since the upper extremities of these lines are all at the same distance from the base, it follows that the true lengths of lines of which these are a plan, are equal in each group.

Upon measuring lines as *k d,* and *i d* of the plan, they are found to be of equal lengths, therefore in this example there are but two lengths to be determined, unless for convenience, we assume two additional lines as *k n,* and *i o,* thereby enabling us to designate one quarter of the object in plan, as *k m i o d n,* which may be duplicated for the other three equal parts. Having previously located point *d,* Fig. 9, we may set off from point *b* upon line *b c,* distances equal to lengths of lines *k n, k d,* and *m d,* as in points *p q* and *r.* Upon drawing lines as shown at Fig. 9, we have in the length of line *d p,* the true length of a line of which *k n* is a plan, in *d r* the true

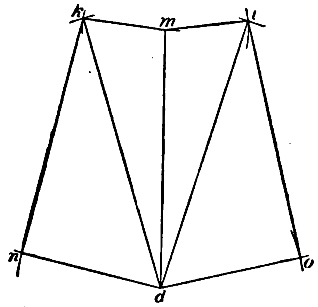


Fig. 10. Pattern for one-quarter of the object.

length of a line of which *k d* is a plan, and in *d q* the true length of a line of which *m d* is a plan.

We are now in a position to develop a pattern, one quarter of which is shown at Fig. 10, since the plan Fig. 8, and the diagram of triangles Fig. 9, supply all necessary measurements for that purpose.

The Pattern.

In any convenient position draw a line whose length is equal to length of line *d q* Fig. 9, as shown at *m d* Fig. 10.

It may be remarked that this line is in reality the line shown in perspective at *b d,* Fig. 6, and that there are two additional lines radiating from point *d,* as shown in perspective by *d a,* and *d c.* The distances between the extremities of those lines at *a* and *c,* Fig. 6, are found in lengths of lines *m k,* and *m i,* Fig. 8. With compasses set to a span equal to the length of line *d r,* Fig. 9, and with point *d,* Fig. 10, as center, describe arcs as shown at *k* and *i.* With compasses set to a span equal to length of lines *k m* or *m i,* Fig. 8, and with point *m,* Fig. 10, as center, describe arcs as also shown at *k* and *i,* thereby locating those points in their correct relative positions.

Presuming that only one quarter of the pattern is to be developed as shown, and that the seam is required to be upon a line as shown at *k n* or *i o* of Fig. 8, there is an additional line radiating from points *k* and *i,* as shown in plan at Fig. 8. The true lengths of these lines have been found in *d p,* Fig. 9, therefore the compasses may be set to a span equal to the length of that line, and with points *k* and *i,* Fig. 10, as centers, the small arcs may be drawn as shown at *n* and *o.* Since the plan, Fig. 8, supplies the true length of one side of the triangles *k n d,* and *i o d,* the compasses may be set to a span equal to the length of line *n d* or *d o,* Fig. 8, and with point *d,* Fig. 10 as center, describe the small arcs cutting the first at points *n* and *o,* when lines may be drawn as shown, which completes the pattern for one quarter of the object.

This is all that is necessary, since it may be duplicated for the remaining three equal parts, or the lengths of lines as shown may be used in rotation to develop the whole pattern.

CHAPTER II.

A Simple Transitional Fitting from Square to Round.

When the sheet metal worker is called upon to secure the pattern for a fitting as illustrated at Fig. 11, i. e., from square to round, with the center of the top directly above the center of the base, he may employ the principles explained in Chapter I.

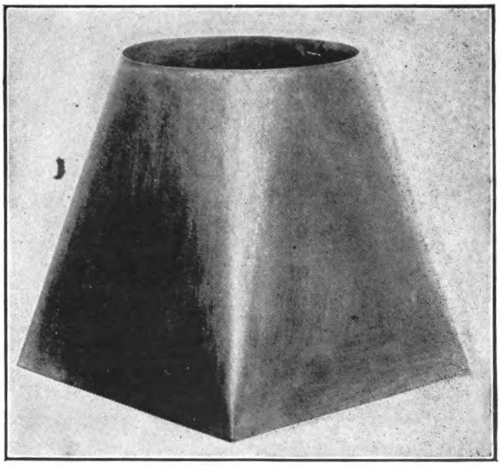


Fig. 11. *Photographic View of a Fitting of Common Occurrence in the Sheet Metal Shop.*

In all examples of pattern development, where some portion of the object for which a pattern is required is represented by a circle, said circle must be divided into parts. The points of division forming these parts, are in reality, the vertices of angles forming a polygon of as many sides as the parts into which the circle has been divided. The vertices of angles at points *e f g h,* etc., of Fig. 8, Chapter I, may be looked upon as points of division in a circle whose diameter is equal to the major diameter of the polygon. However, since eight parts are too few to divide a circle into, we would have divided that circle into a greater number. The author has found sixteen to be quite effective, although a still greater number will more closely approximate the circle.

A Plan Drawn to Given Dimensions.

Presuming that it is required to secure the pattern for a fitting as illustrated at Fig. 11, to given dimensions, the square *A B C D,* Fig. 12, is drawn to the size of the

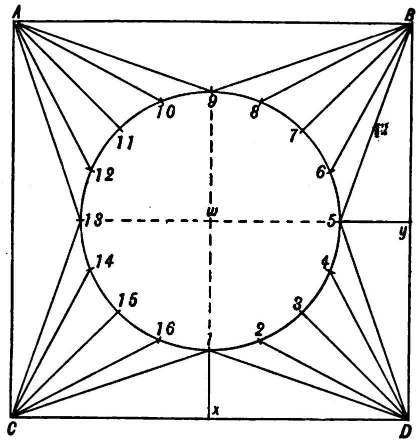


Fig. 12. *The Plan of the Fitting Illustrated in Fig.* 11.

base, and its center located as at *w.* With point *w* as center, a circle is drawn equal to the required diameter of the top, as shown at *1 2 3 4,* etc. Since this is an example of Triangulation, the surface of the object is presumed to be divided into triangles.

To secure the plans of said triangles, the circle is divided into parts as shown. This is accomplished by first dividing the circle into four parts by lines parallel to the sides of the square, as shown by the dotted lines, *1 9* and *5 13*. Each quarter of the circle is then divided into four equal parts. This forms the points of division of the circle into four groups, as *1 5, 5 9, 9 13,* and *13 1.* Lines drawn from the points of division in each group to the vertex of the adjacent angle as shown, will complete a plan of the fitting, together with the plans of triangles, which in reality, form the required pattern.

Size and Form of Triangles.

Since, as has been previously explained, the triangles whose plans are shown in the diagram, Fig. 12, form the pattern, we must determine their exact size. This is accomplished by securing the lengths of lines which form said triangles. As will be noted, the plan supplies the length of one side of each, i. e., there are four whose bases form the square, and the length of one side of each remaining triangle is found in the distances the points of division of the circle are from each other. Therefore we have simply to determine the true lengths of lines forming the remaining two sides of each triangle shown. This is still further simplified in examples where the form is symmetrical as in this case, inasmuch as corresponding lines in each quarter of the plan are of the same length.

Upon examination, we find that lines *1 D* and *5 D* are equal in length, also *2 D* and *4 D*. Therefore there are but three lengths to be determined, as *1 D, 2 D* and *3 D,* unless we introduce two additional lines as *1 x* and *5 y,* to locate one-quarter of the plan, or the seam, thus making one additional length to be determined, as *1 x*.

The student should have little difficulty in comprehending the lines shown in plan, i. e., *1 x, 1 D, 2 D* and *3 D,* inasmuch as they are presumed to be upon the surface of the object. The upper extremities of said lines are at points *1 2* and *3* of the top, and their lower extremities are in points *x* and *D* at the base; therefore in reality these lines are inclined to the base. If we dropped lines from points *1 2* and *3,* perpendicular to the plane of the base, their intersections with that plane will locate points whose distances from point *D* have previously been determined in the plan. The student may refresh his memory upon this by referring to Fig. 6, Chapter I, where perpendicular lines are shown in perspective as *a e* and *b f,* which are in reality equal in hight to the vertical hight of the object. Thus it will be noted that such

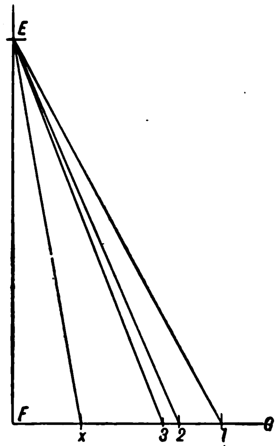


Fig. 13. *Diagram of Triangles from which True Lengths are Secured.*

lines supply the necessary lengths of perpendiculars for all triangles employed in securing the true lengths of those lines which are in reality inclined to the planes of the top and base of the object.

The distances these lines (i. e., perpendicular lines as shown at Fig. 6) are from point *D* at their intersection with the plane of the base have previously been determined in the plan, Fig. 12; we therefore use the lengths of lines *1 x, 1 D, 2 D* and *3 D* as the bases of said triangles.

On the Construction of Triangles.

To construct the necessary triangles, draw the indefinite right lines at right angles to each other, as *E F* and *F G,* Fig. 13, which intersect at point *F.* Set off upon the vertical line from *F,* a distance equal to the vertical hight of the object, as shown at *E.* Set off also from *F* upon the horizontal line, distances equal to the lengths of lines *1 x, 1 D, 2 D* and *3 D,* found in Fig. 12, as shown by points *x, 3, 2,* and *1,* Fig. 13. From these points lines are drawn to *E* as shown, thus securing the lengths of all lines necessary to develop the pattern, since the plan supplies the remaining lengths.

The Pattern.

To develop one-quarter of the pattern as shown at Fig. 14, draw the line *3 D,* making it of a length as found at *3 E,* Fig. 13. With compasses set to a span equal to distances between points *3* and *2,* or *3* and *4,* of Fig. 12, place one point at *3* of the pattern, and describe small arcs as shown at *2* and *4.* With compasses set to a span equal to length of line *2 E,* Fig. 13, place one point at *D,* and describe small arcs as also shown at *2* and *4,* thus locating these points in their correct relative positions.

From points *2* and *4* as centers, small arcs are drawn with a radius equal to the distance between points *2* and *1,* or *4* and *5.* With point *D* as center, and with a radius equal to the length of line *1 E,* Fig. 13, describe arcs as also shown at *1* and *5,* thus securing the correct relative positions of those points.

Upon referring to the plan, we note that there are two additional triangular surfaces to be added to complete the pattern for one quarter of the object as shown; these are the triangles bounded by lines *1 x, x D* and *D 1,* also *5 D, D y,* and *y 5.* Since the plan supplies the true lengths of one side of these triangular surfaces, we set our compasses to a span equal to length of line *x D* or *y D* of plan, place one point at *D* of the pattern, and describe arcs as shown at *x* and *y.* With points *1* and *5*

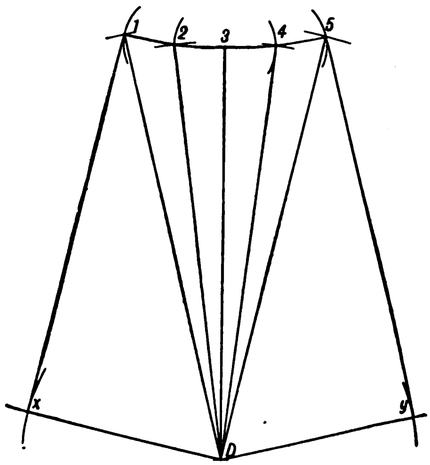


Fig. 14. *Pattern for One Quarter of the Fitting as Illustrated at Fig.* 11.

as centers, and the length of line *E x,* Fig. 13, as radius, place one point at points *1* and *5,* and describe arcs as also shown at *x* and *y,* thereby locating these points. Lines are now drawn as shown, thus locating the boundaries of triangles, which, having been placed in their correct relative positions, supply the required pattern for one quarter of the object, which may be duplicated for the remaining three equal parts.

The Necessity of a Clear Conception of the Principles Involved.

If the student fails to secure a clear conception of the principles as here set forth, he is earnestly advised to review the work, since the author has made an honest endeavor to explain the most elementary principles involved. To the one who aspires to become proficient in this branch of pattern development, a knowledge of those principles is of the utmost importance. The practice has been too often to work from copy rather than to make a study of the principles involved. This is hardly more calculated to make a pattern cutter, than so much time spent in copying music would be to make a musician. It is precisely the same with the subject in question; the various lines employed in pattern development can be copied by almost any novice, but no amount of copying will enable him to understand them. On the other hand, if one becomes thoroughly conversant with the principles involved, and secures a clear understanding of the meaning of every line drawn, the solving of complicated problems is but a simple operation.

CHAPTER III.

The Oblique Cone.

Attention will now be directed to the Oblique Cone, and the method of securing the pattern for same. This is a simple example containing principles which may be employed in securing the patterns for a variety of forms.

In the compilation of this work, the author has assumed no previous knowledge of orthographic projection on the part of the student. As the examples demand some knowledge of this, an explanation of the principles involved will be entered into as the work progresses.

The Plan.

A plan is defined as being a drawing of anything, showing the parts in their proportion and relation. The surface upon which a plan is drawn is a horizontal one, and in this work we shall presume that the object to be represented is directly above it.

In securing the location of points which it becomes necessary to represent in plan, vertical lines are presumed to be dropped from said points, and their intersections with the surface upon which the plan is drawn, are the plans of those points.

Fig. 15 illustrates an oblique cone with a number of right lines upon its surface, and its plan. Fig. 16 is a geometrical representation of a similar cone, and is looked upon as a plan.

The purpose of Fig. 15 is to convey to the student in a pictorial way, an understanding of the relation the plan bears to the object itself. Here, as will be noted, an oblique cone with a number of right lines upon its surface is suspended directly above the horizontal surface *A B C D*. The method of securing a plan of said cone should be apparent from lines shown. As will be noted, the foot of the perpendicular line *E E'* is a plan of the

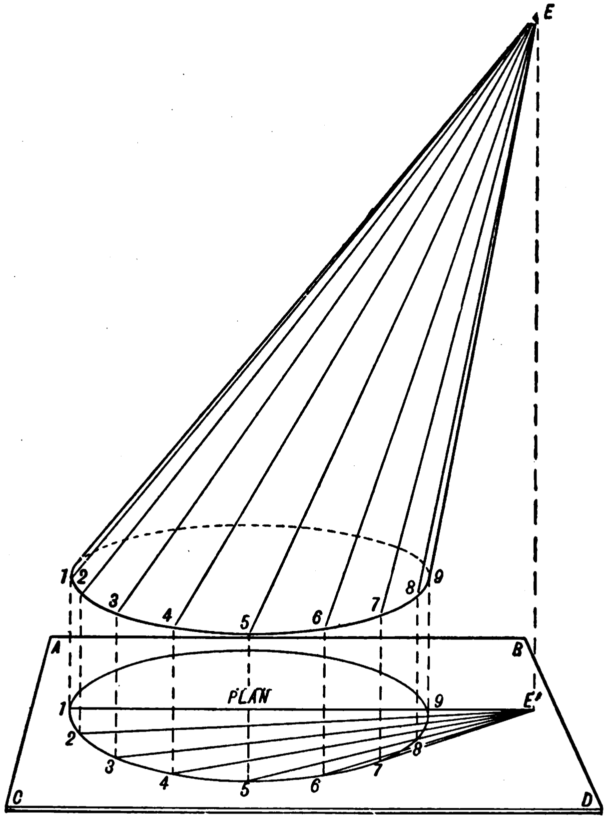


Fig. 15. *An Oblique Cone Having a Number of Right Lines Upon Its Surface, and Its Plan.*

vertex *E,* and the foot of each perpendicular let fall from the numbered points of the base is the plan of its respective point. Since lines shown upon the surface of the cone are right lines, and converge to the vertex *E,* lines may be drawn from numbered points of the plan to *E′*, to secure plans of those lines.

Dividing the Surface of the Oblique Cone.

When called upon for a pattern for an oblique cone, certain data must be at hand in the form of a specification, i. e., the diameter of the base, the vertical hight of the vertex above the plane of the base, and the distance the vertex is removed from a point directly above the center of the base. Presuming these to be known, and to be as shown at Fig. 16, where the circle is drawn equal in diameter to the diameter of the required cone, a line is

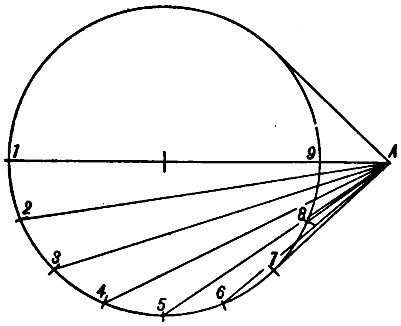


Fig. 16. *A Plan of an Oblique Cone.*

drawn through the center of said circle as *1 9*. Upon this line a point as *A* is located, which is at a distance from the center of circle equal to the distance the vertex of the cone is removed from directly above the center of the base.

Since the line *1 9* divides the diagram into two equal parts although opposite, we shall only consider one part, as it may be duplicated for the other. One-half of the circle is divided into a number of equal parts as shown, and lines drawn from these points of division to point *A*.

In this manner the plan is secured of not only the cone, but of a number of right lines upon its surface, which divide said surface into triangles.

The work of securing the pattern is a matter of determining the dimensions of these triangles, and placing them upon any surface, a portion of which will then constitute the pattern. Since the distance between points of the circle is the true length of one side of each triangle, the remaining measurements are secured by de-

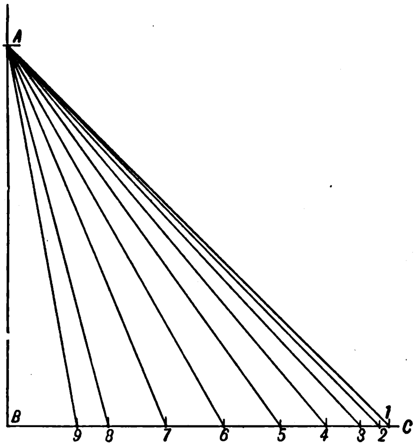


Fig. 17. *Diagram of Triangles.*

termining the true lengths of lines which connect points of the base and the vertex. As said lines intersect at point *E*, Fig. 15, the true length of each will be found in the hypothenuse of a right angled triangle, whose perpendicular is equal to the vertical hight of the required cone.

Constructing Necessary Triangles.

The method of constructing these triangles is clearly shown at Fig. 17, where indefinite right lines *A B* and *B C* have been drawn at right angles to each other, and intersecting at point *B*. The vertical hight of the required cone is set off from *B* upon the line *A B,* as at *A*. Since each line shown in plan, Fig. 16, i. e., *A 1, A 2,* etc., supplies the true length of the base of a triangle, whose hypothenuse is the line in its true length, we may set off from *B* along line *B C,* distances found from *A,* Fig. 16, to points *1, 2, 3,* etc., as shown in similarly numbered points of Fig. 17. The distances found from point *A,* Fig. 17, to the numbered points upon line *B C,* are the true lengths of similarly designated lines whose plans are shown in Fig. 16. Thus all necessary data is at hand to enable us to complete the pattern.

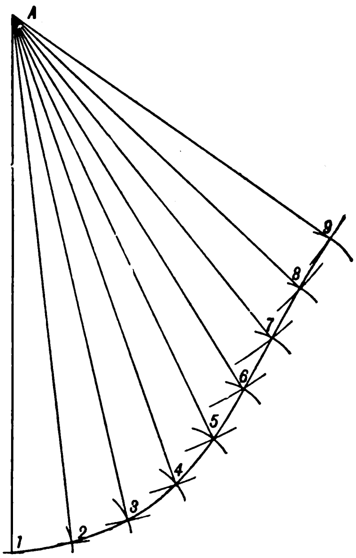


Fig. 18. *Semi-pattern for an Oblique Cone.*

The vertices of all triangles of which the surface of the cone is composed, are at the apex of said cone, therefore the lines forming two sides of each of those triangles will radiate from point *A* of the plan, or pattern, as shown.

To Secure the Pattern.

To develop the pattern as shown at Fig. 18, draw the line *A 1* in any convenient position, making its length equal to the length of line *A 1,* Fig. 17. Since line *A 2* also radiates from point *A* of the pattern, the compasses may be set to a span equal to the length of line *A 2,* Fig. 17, and with point *A* of the pattern as center, the small arc is drawn as shown at *2,* Fig. 18. Then will one extremity of line *A 2* lie in said arc, and at a distance from point *1* equal to the distance between points *1* and *2* of the plan, Fig. 16. Therefore, if the second arc is drawn as shown, with point *1* as center, and the distance between points *1* and *2* of the plan, Fig. 16, as radius, the exact location of said line is established. The true size, form, and position of the remaining triangles of which the surface of the cone is composed, may be determined in a similar manner. For example, point *A* of the pattern, Fig. 18, is a constant center from which small arcs are drawn whose radii are equal to lengths of lines *A 3, A 4, A 5,* etc., Fig. 17. Successive numbered points of the base are used as centers, with the distance similarly numbered points are from each other as shown in plan, Fig. 16, as radii, to locate those points as shown, Fig. 18.

Fig. 18 shows the pattern for one-half the cone which may be duplicated for the remaining equal portion. Had it become desirable to secure the pattern in one piece, points and lines as here shown could have been duplicated upon the opposite side of line ***A 1.***

CHAPTER IV.

A Transitional Fitting from Rectangular to Round Which Makes An Offset.

Fig. 11, Chapter II, illustrated a fitting making a transition from square to round, with the center of the top directly above the center of the base. The sheet metal worker is frequently called upon for a fitting making a similar transition, but whose top is not in the same relative position, i. e., it may be what is ordinarily termed straight on one side, or it may be required to offset. In examples of this description, there is little or no variation in the methods to be employed. The same principles are involved, providing the ends are parallel.

The Specification.

From the specification a conception of the object is secured. This is purely a mental process; clear conceptions may be formed in the dark, or by one blindfolded. Some difficulty may be experienced by the novice in forming clear conceptions of the objects from their specifications, although the power of doing so is essential in pattern development, since before an object can be represented, it must be known what that object is. This power may be cultivated and increased by practice. The conception is formed from the specification, by knowing the size and form of the base, the size and form of the top, and the distance the plane of the top is above the plane of the base, also the position the top is required to occupy as regards the base.

The student is advised to look upon Fig. 19 as the specification for a fitting, the pattern of which is required. As indicated, the base is to be rectangular and 12 x 16 inches in size, the fitting to have a round top 10 inches in diameter. The vertical hight of the object is to be 16 inches, i. e., the perpendicular hight between the planes of the top and base, is 16 inches. The center of the top is located directly above a line which divides the rectangle longitudinally into two equal parts as shown, but 7 inches from its central point.

To Draw the Plan.

The student may picture the above conditions in his mind, and we will proceed to draw the necessary plan. To represent the base in plan, draw the rectangle *A B*

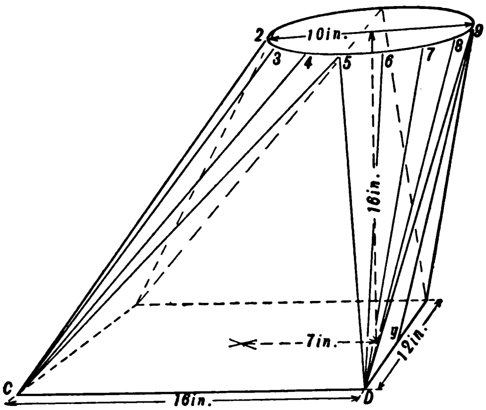


Fig. 19. A Pictorial Specification for a Fitting.

D C as shown at Fig. 20, with lengths of sides of 12 and 16 inches. Fig. 20 includes a scale to which the diagrams in this problem have been drawn (i. e., Figs. 20, 21 and 22), and if the student desires, he may take measurements as there shown, and apply to those diagrams as we proceed with the explanation.

A line is drawn through the center of the rectangle, and parallel to its longest side as *x y*. The center of the rectangle is, of course, the center of the line *x y*, as shown at *z*. Locate a point upon line *x y*, *7* inches from point *z* as *w*, then will point *w* be a plan of the center of the top, or a point to be used as a center about which a 10 inch circle is to be drawn. This circle is a plan of that end, and completes a plan of the fitting.

Plans of Triangles.

To secure the plans of triangles, which when combined constitute the surface of the fitting, or its pattern, the circle is first divided into four equal parts by lines parallel

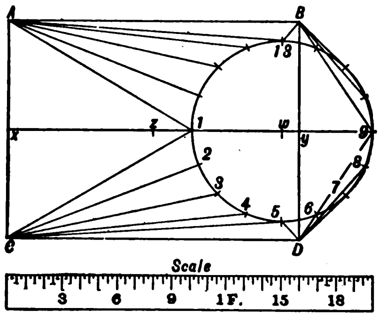


Fig. 20. The Plan of a Fitting, together with the Scale to which it has been Drawn.

to the sides of the rectangle, as shown in points *1 5 9* and *13*. Divide each quarter of the circle into the same number of equal parts as also shown. Draw lines from all points thus secured in each quarter of the circle, to the vertex of its adjacent angle of the rectangle, as shown at *1 C, 2 C, 3 C, 4 C, 5 C, 5 D, 6 D*, etc. This completes the plans of the above spoken of triangles, which constitute the whole surface of the fitting. However, since the line x y divides the plan into two equal parts, the covering for one part will, when reversed, or formed in the opposite direction, supply a covering for the remaining part, therefore it is only necessary to consider one half of the plan. Several of these triangles are shown in perspective in Fig. 19, and by the aid of this figure the student should have little difficulty in comprehending the positions of said triangles upon the surface of the fitting.

The Value of Perspective.

The object of the author in presenting Fig. 19 has not only been to present a specification in a pictorial way, but to illustrate triangles whose plans are shown in Fig. 20. With the plan of each triangle before us, which when combined with all the others, will constitute the surface of the fitting, or its pattern, the next step is to determine the true form and size of each, and place them upon the surface, a portion of which will constitute the pattern.

Another logical deduction which may be applied to examples in pattern development, is to consider each line separately, and determine their true lengths and relative positions.

To Determine the Size and Form of Each Component Triangle.

The size and form of a triangle can be determined if the lengths of the three sides of which it is composed are known. Thus the question rests upon our ability to determine the true lengths of lines shown in plan, and the relative position these lines should occupy when placed upon the plane of development. Here, as in foregoing examples, the true lengths of a considerable number of the lines are shown in plan, i. e., those lines which form the outline of the top and base. However, those lines which connect points of the base with points of the top are not shown in their true lengths and must be determined by the use of the right angled triangle, as shown at Fig. 21.

To Determine the True Lengths of Lines.

The true lengths of lines as shown at Fig. 21 are determined by drawing the lines *E F* and *F G* at right angles to each other intersecting at point *F*. From *F* upon line *E F,* set off a distance equal to the vertical hight of the fitting (16 inches). From *F* upon the line *F G,* set off distances equal to lengths of lines in plan,

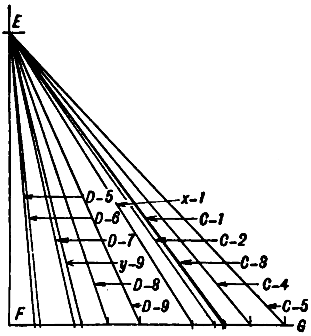


Fig. 21. A Diagram of Triangles from which True Lengths have been Secured.

Fig. 20, as *1 C, 2 C, 3 C,* etc., and from said points draw lines to point *E*. Then will each line represent the true length of its respective line in plan. Upon completing the diagram of triangles as shown at Fig. 21, we may proceed to develop the pattern as follows.

To Develop the Pattern.

The true length of line *1 x* shown in plan, Fig. 20, is found in line *1 x,* Fig. 21, therefore we may place that line in its true length in any convenient position as at *1 x* of the pattern, Fig. 22. The line *x C* of the plan is there shown in its true length, therefore we may set the compasses to a span equal to the length of line *x C,* Fig. 20, and placing one point at *x* of pattern, Fig. 22, describe the small arc as at *C*. With the length of line *C 1,* Fig. 21, as radius, and with point *1* of pattern as center, de-

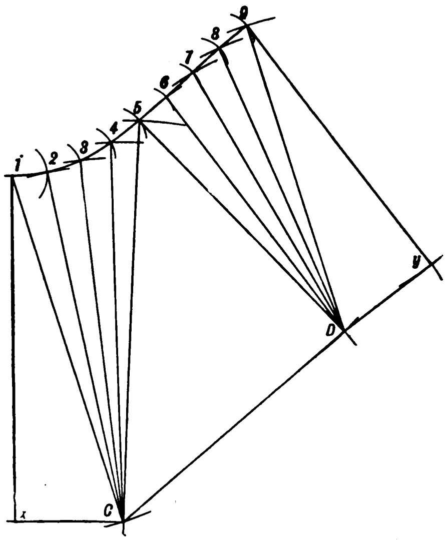


Fig. 22. The Semi-pattern for a Fitting as Illustrated at Fig. 19.

scribe the second small arc at *C* of the pattern, Fig. 22, thereby locating that point, or line *1 C,* in its correct relative position.

Upon referring to the plan, Fig. 20, we note that there are four additional lines radiating from point *C,* and that the distances between the upper extremities of those lines are equal to the distances between points of division of the circle. Therefore we use the lengths of those lines in rotation, i. e., *C 2, C 3, C 4,* and *C 5,* Fig. 21, as radii, with point *C,* Fig. 22, as center, to describe small arcs as shown at *2, 3, 4* and *5* of pattern, Fig. 22, then with distances between numbered points of the circle as shown in plan, Fig. 20, as radii, and using the numbered points of the pattern in rotation as centers, we describe small arcs as also shown at *2, 3, 4* and *5* of the pattern, Fig. 22.

We note that point *D* upon the surface of the object is at a distance from point *C* equal to the length of line *C D* of the plan, Fig. 20. Therefore we may set our compasses to a span equal to the length of line *C D* of the plan, Fig. 20, and placing one point at point *C* of the pattern, Fig. 22, describe the small arc as at *D*. Point *D* of the pattern must then lie in some point of this arc. The true distance from point 5 to *D* upon the surface of the object as shown in perspective at Fig. 19, and in plan, Fig. 20, is the length of line *D 5* in the diagram of triangles, Fig. 21. Thus we may use the length of this line, i. e., *D 5* of the diagram of triangles, as radius, and point *5* of the pattern, Fig. 22, as center, to describe the second small arc as shown at *D,* thereby locating that point, or line *D 5,* in its correct relative position.

The plan, Fig. 20, clearly shows four additional lines radiating from point *D*. The upper extremities of these lines are at a distance from each other equal to the distance between points of the circle. Therefore we may use the true lengths of these lines in rotation, which are found in the diagram of triangles, Fig. 21, i. e., *D 6, D 7, D 8,* and *D 9* as radii, and with point *D* of pattern as center, to describe small arcs as shown at *6, 7, 8* and *9,* and the distances between similar numbered points of the circle, Fig. 20, as radii to be used successively with points *5, 6, 7* and *8* of the pattern, Fig. 22, as centers, to locate these points in their correct relative positions, as shown.

The plan, Fig. 20, or the pictorial view of the object, Fig. 19, shows a triangular surface as *9 D y,* which may now be added. Since the true length of line *D y* is shown in plan, we may use that length as radius, with point *D* of the pattern, Fig. 22, as center, to describe the small arc as at *y,* then will point *y* of the pattern lie in some point of this arc.

We find that the true distance from point *9* to *y,* is the length of line *y 9* of the diagram of triangles, Fig. 21. Therefore we use that length as radius, with point *9* of the pattern, Fig. 22, as center, to describe the second small arc as shown at *y* of the pattern, thus locating that point in its correct relative position, which completes the pattern for one-half the fitting.

The Order of Numbering May Be Reversed.

It may be here explained that while the author has designated one end of the longest line presumed to be upon the surface of the object as *1,* he could as consistently have reversed the order of numbering, thereby placing *1* in the position now occupied by *9,* i. e., it makes no material difference which part of the pattern is first developed.

It may be further explained that each part of the plan, Fig. 20, i. e., those parts included between points *1 C 5,* or *5 D 9,* may be compared to an inverted oblique cone, and that the patterns for those portions are developed in the same general manner as for the oblique cone.

CHAPTER V.

A Twisted Transitional Fitting.

Attention is here directed to a form as illustrated at Fig. 23, which is an excellent example for practise, since it may be represented by a comparatively few lines.

It may be here remarked that it requires far more study to conceive the forms whose patterns may be de-

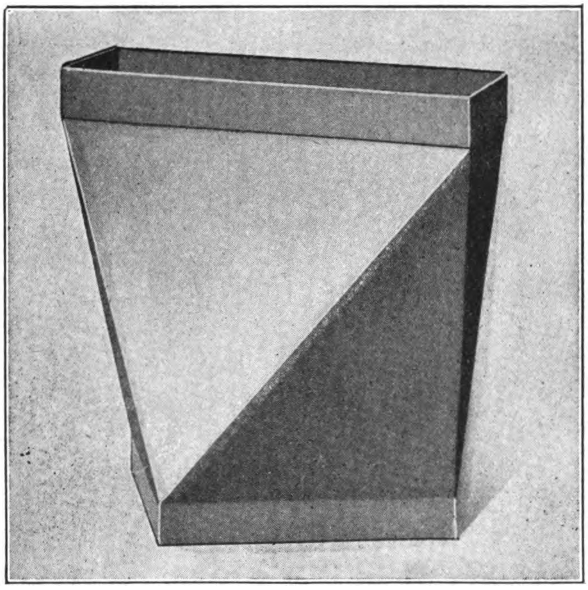


Fig. 23. The View of a Fitting whose Form is Somewhat Unusual.

veloped by triangulation, than to secure an understanding of the few principles involved after the form has been conceived. Therefore the best advice to be given to those who desire to secure a clear understanding of this branch of pattern cutting is to give the unusual form the same careful attention that they may devote to the more common ones. The fitting, as illustrated at Fig. 23, is in reality the connection between two rectangular pipes whose forms of cross-section are not identical yet of approximately the same area. It will be noted that the sides of said pipes are not parallel, i. e., the fitting performs a twist.

Fig. 24 is a perspective view of a fitting of this description and its plan. This has been introduced for the pur-

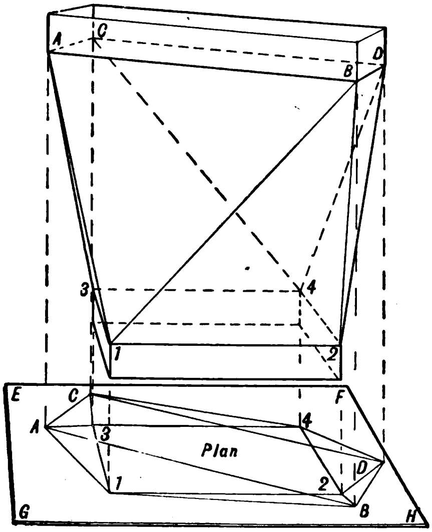


Fig. 24. The Fitting and Its Plan, Shown in Perspective.

pose of enabling the student to secure an understanding of the relation the plan bears to the object itself, since it may be somewhat difficult to form a conception of the object from its plan, Fig. 25.

Principles Which Govern the Work of Drawing a Plan.

It should be remembered that Fig. 25 is a geometrical representation, and the one which must be employed to secure the pattern, while Fig. 24 is a perspective view of the object which is presumed to be suspended directly above the horizontal surface *E F G H*. As will be noted, vertical lines have been dropped from points of the object to intersect this surface, thereby illustrating the principles which govern the work of drawing a plan as shown at Fig. 25.

From the above, and by the aid of Fig. 24, the student will readily understand that the rectangles, *1 2 3 4* and

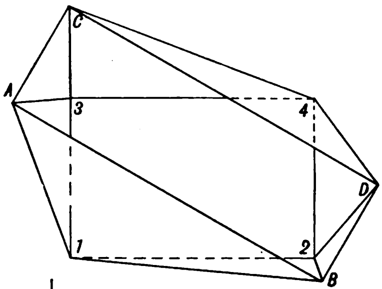
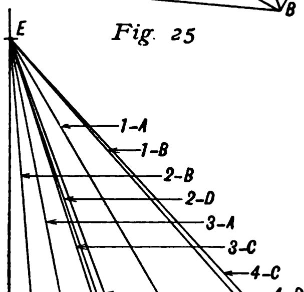


Fig. 25



Figs. 25 *and* 26. 25, *A Plan of Fitting;*
26, *Diagram of Triangles.*

A B C D, are the cross-sections of pipes to be connected. These have been placed in the same relative positions that said pipes or collars would occupy if the object was viewed from above, and with the point of sight moving in such a manner as to bring every point viewed in a line perpendicular to the horizontal surface upon which the plan is supposed to be drawn.

It may be remarked that only the irregular portion is being considered, since the collars at each end are here looked upon as separate and independent parts, whose patterns do not involve triangulation.

The Surface of the Fitting.

We note that the surface of the fitting is made up of eight triangles. These triangles, when combined and placed in their correct relative positions upon a flat surface, will constitute the pattern, therefore their true form and dimensions must be determined. This, as will be noted, makes the plan an important factor in the solution of the problem.

The plan of each triangle of which the surface of the object is composed, is secured by drawing lines from each angle of the rectangle *A B C D,* to two adjacent angles of the rectangle *1 2 3 4,* or conversely, from each angle of the rectangle *1 2 3 4* to two adjacent angles of the rectangle *A B C D.* Thus a plan of the fitting is completed, as shown at Fig. 25.

It will be noted that points *1 2 3 4* are at the base, and points *A B C D* are at the top of the object, therefore lines as *A 1, A 3, B 2,* etc., are the plans of lines which connect points of the base to points of the top, and are oblique to the planes within which the top and base are situated. However, since we know the vertical hight of the object, we know the vertical distance between the extremities of those lines. This distance is the length of one side of all triangles which it becomes necessary to construct to secure the true length of lines connecting points of the base with points of the top, which are the boundaries of triangles upon the surface of the fitting.

Size and Form of Triangles.

If the true form, size, and relative positions of said triangles can be determined, they may be placed upon a flat surface in those sizes and positions to complete a pattern. The dimensions of said triangles will be determined in the same manner as has been previously explained, i. e., the lengths of those lines which form sides of the above spoken of triangles, and connecting points of the base to points of the top, are found by the use of the right angled triangle, as shown at Fig. 26. Here the lines *E F* and *F G* are drawn at right angles to each other, intersecting at the point *F*. The vertical hight

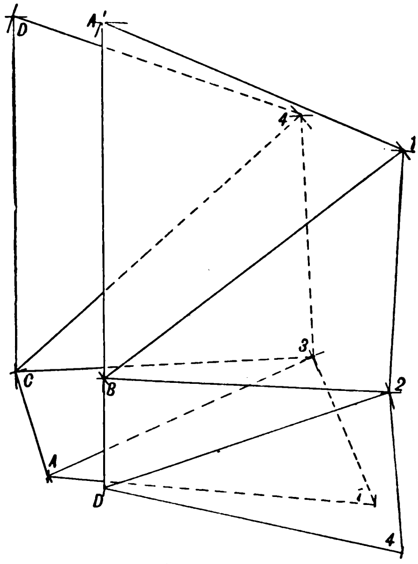


Fig. 27. Pattern.

of the object is set off from point *F* upon the line *F E*, as at *E*.

The lengths of lines shown in plan as *1 A, 3 A, 3 C, 4 D,* etc., are set off upon line *F G* from point *F*, as shown. Lines are drawn from said points to point *E* to supply the true lengths of lines shown in plan, or those lines which connect points of the base to points of the top. The lengths of those sides of the triangles which form the base or top of the fitting, are found in their true lengths in plan, since the true forms of pipes to be connected are there shown.

The Pattern.

With these lengths determined, the pattern is secured as shown at Fig. 27, where, to economize space, it is shown in two parts, a portion of one part being represented by dotted lines. The student who has given attention to the above will note that points *A B C* and *D* are at angles of the top, and shown in each view, *i. e.*, if the pattern was wrapped about the object, these points would occupy positions as represented in the several views.

On Dividing Diagrams which Represent the Ends of the Object.

When each end of the object for which a pattern is required can be represented by rectilinear diagrams, there is no necessity of dividing said diagrams into parts, since the vertices of their angles are used as points of division. However, when one or both of its ends must be represented by a curvilinear diagram, said diagram must be divided into parts.

Here the student should recognize the fact that these points of division are in reality, points upon the end of the object, to which lines are presumed to be drawn from points upon the opposite end. Since these lines are considered as straight lines, they should be so located as to allow them to be straight when placed upon the object. If this is not accomplished some error must exist in the pattern, and if there is considerable variation in these lines, i. e., if they are presumed to be straight and are so located as to cause them to be considerably curved, there must be some distortion in the fitting when made from the pattern. It is quite possible to so locate these

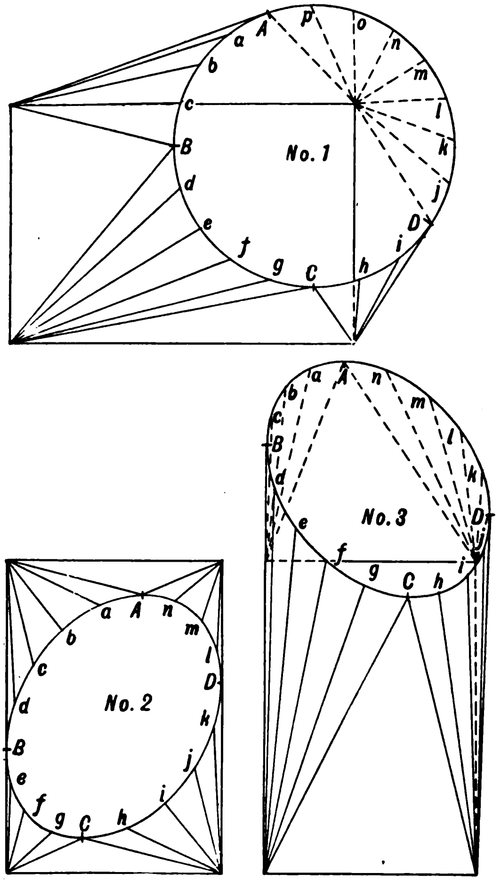


Fig. 28. Plans of Fittings.

lines as to preclude the pattern being formed into its required shape without a stretching or drawing of the material. Each individual case requires some attention to this, as it is a difficult matter to apply a fixed rule to all.

Fig. 28 contains diagrams which may be looked upon as plans of fittings. No. 1 is a fitting making a transition from rectangular to round, the round end being so placed as to require the lengths to be secured of practically all lines presumed to be upon its surface and shown in plan, i. e., the plan cannot be divided into equal parts. No. 2 is a plan of a fitting from rectangular to elliptical; the major axis of the ellipse has here been placed directly above the diagonal of the rectangle, therefore this diagram could be divided into two equal parts. However, as here shown, the better course would be to determine the true lengths of all lines. No. 3 is the plan of a fitting whose form and size of its ends are the same as those shown at No. 2, but not in the same relative positions. Here, as with No. 2, the better course to pursue when developing the pattern, is to determine the true lengths of all lines shown, or the true form and size of all triangles of which its surface is composed.

To locate triangles presumed to be upon the surface of fittings whose plans are at Nos. 1, 2 and 3, the curvilinear figures are divided into parts, and said points of division should be so located as to allow right lines to be drawn upon the object from the corners of one end to these points at the other. This is accomplished by dividing the diagrams as shown. The points *A B C D* in each are the important ones, and having located these in satisfactory positions, the intermediate points as *a b c d*, etc., may be located at pleasure, i. e., each part of the curve contained between points *A B C* and *D* may be divided into any convenient number.

After having located lines whose approximate positions are shown at Fig. 28, the process of securing the pattern is substantially the same as has been explained in Chapter IV.

CHAPTER VI.

THE PATTERN FOR THE FRUSTUM OF AN OBLIQUE CONE.

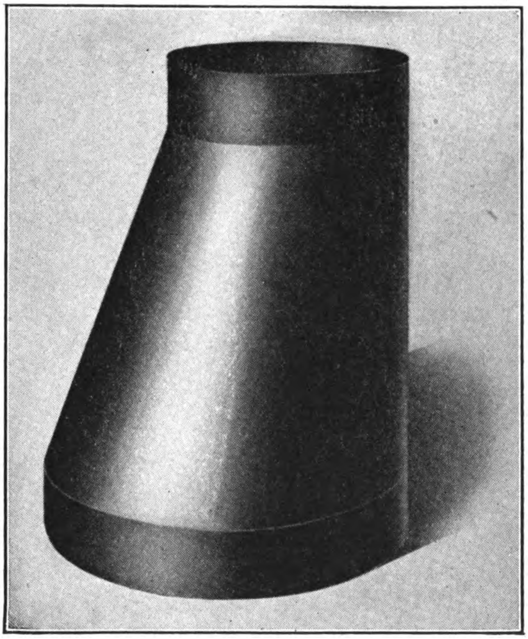


Fig. 29. The Frustum of an Oblique Cone.

As has been explained, the surface of the object for which a pattern is required, may be presumed to be divided into triangles. In foregoing chapters, forms have been selected whose rectilinear elements divide said surfaces into triangles. Attention will now be directed to forms whose rectilinear elements of their surfaces do not divide said surfaces into triangles, therefore additional lines must be introduced.

ELEMENTS OF A SURFACE.

It may be here explained, that lines drawn, or presumed to be drawn upon the surface of the cone or cylinder, are termed elements of that surface, and if drawn in positions which admit of their being right lines, they are known as rectilinear elements.

Thus we note upon referring to Fig. 12, Chapter 2, that lines *D 1, D 2, D 3,* etc., are plans of rectilinear

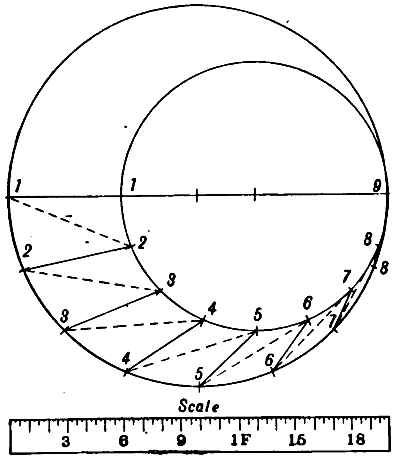


Fig. 30. The Plan of a Fitting Illustrated in Fig. 29.

elements presumed to be upon the surface of the object represented. Similarly, upon referring to Fig. 16, Chapter III, lines as *1 A, 2 A, 3 A,* etc., are plans of rectilinear elements of the conical surface.

PATTERN FOR THE FRUSTUM OF AN OBLIQUE CONE.

Presuming the pattern is required for a fitting as illustrated at Fig. 29, the specification must supply the diameters of the top and base, together with its hight and the relative positions of its ends. In this example, it has been presumed that one side is perpendicular to the plane of its ends, or, what is sometimes termed, straight on one side. This form is the frustum of an oblique cone. The most simple and efficient diagram which will represent the object is a plan as shown at Fig. 30. This assumes the object to occupy a position as shown at Fig. 31.

Scenographic and Orthographic Projection Compared.

It may be well to here explain that Fig. 31 is a pictorial view of the object, and its plan. This is a scenographic representation and of no particular value beyond its use

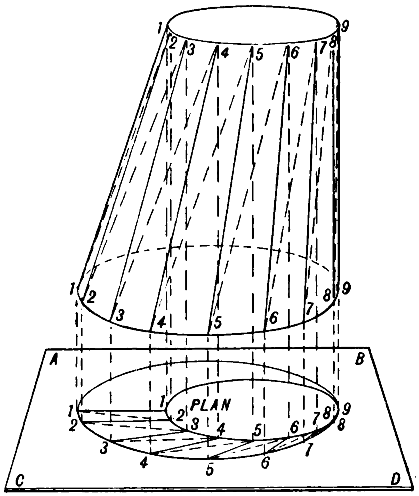


Fig. 31. Pictorial View of the Fitting and Its Plan.

to convey to the reader an understanding of the position the object occupies as regards its plan.

In continuation of the above, it may be stated that in representing objects according to the principles laid down for perspective, the eye is imagined to be stationed in one particular place, called the point of sight, from which all the visible parts of the figure are supposed to be seen. In orthographic projection, with which we are chiefly concerned, the case is very different, inasmuch as the eye is supposed to be in a direct line with every part viewed, or, in other words, to move over the object in such a manner as to be directly opposite to every part represented. The visual rays are therefore parallel, whereas in perspective they converge to a point.

A Geometrical Representation, or a Plan.

Fig. 30 is a geometrical representation or a plan of the object, which has been drawn to the scale appended, presuming the dimensions to be as follows: Diameter of base, 20 inches; diameter of top, 14 inches; hight, 21½ inches, with one side perpendicular to the plane of its ends.

The circles have been placed in the same relative position as the ends of the object would appear if viewed from above as in orthographic projection. A line as *1 9,* drawn through the center of each circle, divides the plan into two equal parts, therefore it only becomes necessary to consider one part. As will be noted, one half of each circle has been divided into an equal number of equal parts, as *1, 2, 3,* etc. Lines drawn between points of the same number in each circle as shown, supply plans of lines which are presumed to be upon the surface of the object. The above spoken of lines are clearly shown in perspective at Fig. 31.

As has been previously explained, the development of the pattern rests upon our ability to determine the lengths of these lines and place them upon a flat surface in their correct relative positions. The plan supplies the distances these lines are from each other at their extremities in the points of division of the circle.

THE RIGHT ANGLED TRIANGLE.

By the use of the right angled triangle, we may secure the lengths of these lines as has been explained in foregoing chapters, i. e., draw two indefinite right lines at right angles to each other, as *A B* and *B C,* Fig. 32, and set off from *B* upon the line *A B,* a distance of 21½ inches, as at *A*. Set off from *B* upon the line *B C,* dis-

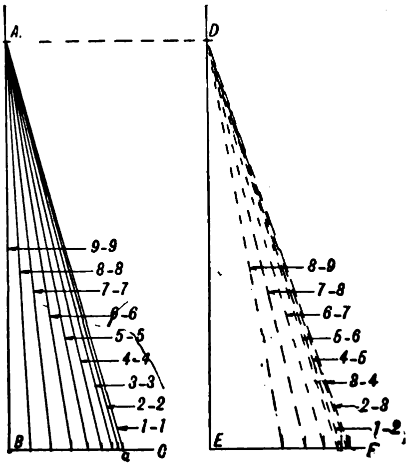


Fig. 32. *Diagram of Triangles.*

tances equal to lengths of lines *1 1, 2 2, 3 3,* etc., which are shown in plan Fig. 30, as shown upon line *B C,* Fig. 32. Then will the distances from *A* to those points upon line *B C,* supply the true lengths of similarly numbered lines shown in plan at Fig. 30, or in perspective at Fig. 31.

ADDITIONAL LINES MUST BE ASSUMED.

Upon attempting to develop the pattern with the data now before us, we find that these lines cannot be placed in their correct relative positions upon a flat surface.

To enable the reader to realize this, we may attempt to develop the pattern by drawing a line in any convenient position, as *1 1* of the pattern, Fig. 33, whose length is shown in the distance between points *A a,* Fig. 32, which is known to be the true length of line *1 1* upon the surface of the object. With the extremities of this line as centers, draw arcs whose radii are equal to the distances between points *1* and *2* of the large and small circle of the plan, Fig. 30. Since the radii of these arcs are in reality the distances between the extremities of

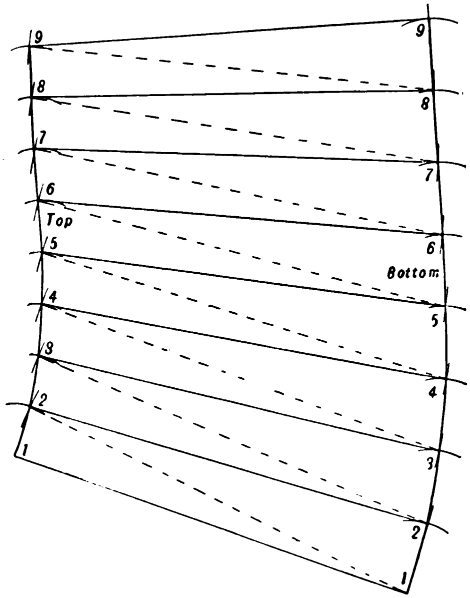


Fig. 33. Semi-pattern.

lines *1 1* and *2 2* upon the surface of the object, the extremities of line *2 2* must lie in points of said arcs. As these arcs may be conceived as being formed of a great number of points, no two of which are in the same position, although at the same distance from their centers, which are the extremities of line *1 1,* it is yet a difficult matter to accurately locate the extremities of line *2 2.*

However points *1* and *1,* Fig. 33, have been located in definite positions. Since points *2* and *2* must lie in arcs which have been drawn with points *1* and *1* as centers, if the true distance between points *1* at the base and *2* at the top of the object was known, we could then locate point *2* upon the pattern. This applies as well to practically all designated points shown in plan.

To determine those lengths we draw lines as *1 2, 2 3, 3 4,* etc., Fig. 30, thus securing the plans of lines connecting those points. As has been frequently explained, the lengths of those lines will be secured by the use of the right angled triangle as follows: Draw lines *D E* and *E F,* Fig. 32, at right angles to each other. Set off from *E* upon the line *E D,* a distance equal to the vertical hight of the object as at *D.* Set off from *E* along the line *E F,* distances equal to the lengths of lines *1 2, 2 3, 3 4,* etc., Fig. 30. Then will the distances from those points to point *D* represent the true lengths of those lines, i.e., *1 2, 2 3, 3 4,* etc., as shown at Fig. 32, thereby securing the true lengths of all lines necessary to develop the pattern.

As will be noted upon examination of Fig. 33, these lines describe a zigzag path which crosses and recrosses the pattern, turning at the top of same at distances equal to distances between points of division of the small circle in plan, and at the bottom of pattern at distances equal to distances between points of division of the large circle in plan.

Developing the Pattern.

To develop the pattern we may draw in any convenient position, a line whose length is equal to line *1 1,* Fig. 32. From the extremities of this line describe arcs whose radii are equal to the distances between points of division of the large and small circle in plan, Fig. 31. With the compasses set to a distance equal to the length of line *1 2,* Fig. 32, place one point at point *1* of the pattern, (i.e., that end of line *1 1* which may be selected as the bottom of the pattern) and describe the small arc as at *2* at the top, then will the intersection of the small arc locate the upper extremity of line *2 2*. With point *2* at the top of pattern Fig. 33, as center. and with the length

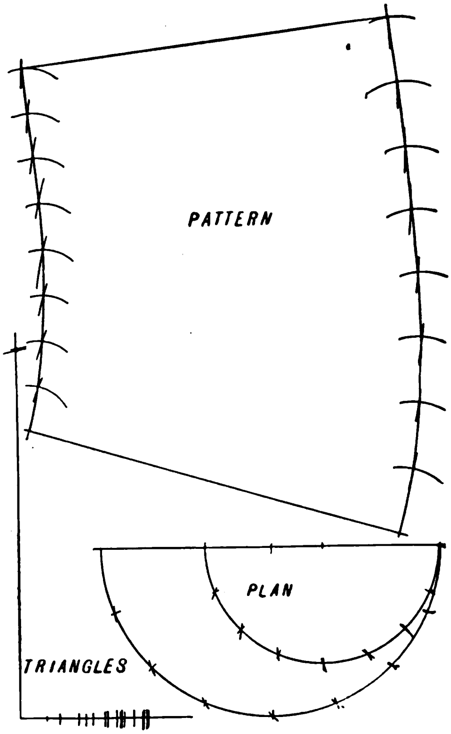


Fig. 34. *Drawing showing how the Pattern may be Secured with the Least Number of Lines.*

of line *2 2* secured from Fig. 32 as radius, describe the small arc as shown at *2* at the bottom of the pattern. This, as will be noted, locates line *2 2* in its correct relative position.

This completes what we may term, one section of a covering for the object. These sections are clearly shown in plan Fig. .30, and in perspective, Fig. 31, therefore the reader should have little difficulty in completing the pattern, since the same operations are involved to secure the true form of all sections shown in Fig. 33, although different lengths of lines must be employed, i. e., we must use the proper length for each line drawn.

Lines drawn to connect points as *1 1, 2 2, 3 3,* etc., have usually been drawn solid, while those drawn between points as *1 2, 2 3, 3 4,* etc., have been drawn dotted, the only purpose of which is to avoid confusion.

Necessity for Lines in Pattern Development.

In a demonstration of pattern development, lines are drawn to illustrate the relation between points presumed to be upon the surface of the object, although the demonstrator subjects himself to considerable criticism from some whose knowledge of pattern development is limited.

The remark is frequently heard: Well, that may be all right, but he makes too many lines. This proves conclusively that the speaker has not stopped to consider. Designated points and lines are as necessary in a geometrical demonstration as the letters of the alphabet are necessary to a printed page.

However, when one becomes familiar with the operations required for the solution of a problem, that problem may be worked out in such a manner as to appear greatly abbreviated as shown at Fig. 34, where the same results are secured as in the demonstration where Figs. 30, 31, 32, and 33 have been shown in an endeavor to illustrate principles involved.

CHAPTER VII.

A Transitional Fitting from Oblong to Round.

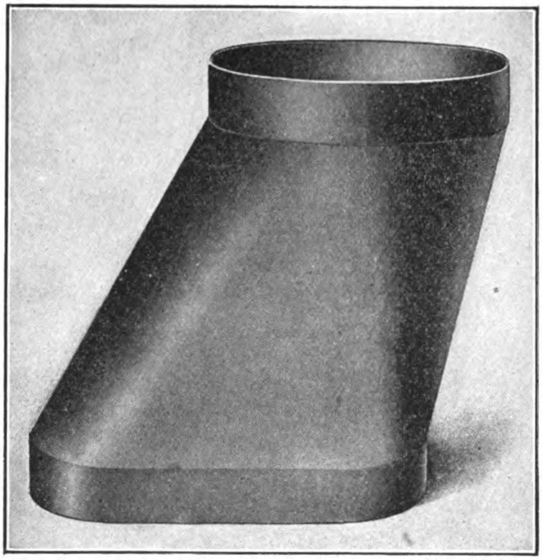


Fig. 35. A Fitting Making a Transition from Oblong to Round.

Methods have been explained in foregoing Chapters which may be employed to secure the patterns for practically all irregular forms whose ends are parallel. However, for the purpose of conveying to the student an understanding of the application of those methods to a variety of forms, one or two additional examples will be introduced before entering into a discussion of those forms whose ends are not parallel.

Fig. 35 illustrates a fitting making a transition from oblong to round. This. or a modification of it, is a form which is frequently demanded, i.e., we find it in many branches of sheet metal work, and made from all gauges of material. It is a fitting making a connection between two pipes whose axes are parallel, but not in one line. A change in the relative position of its ends demands little or no change in the methods to be employed in securing its patterns. We could as consistently look upon the oblong end as the top. It is, in a measure, a combination of forms which have been discussed.

The Plan.

The plan is secured by drawing diagrams which represent cross sections of pipes to be connected in their correct relative positions. The surface is represented as

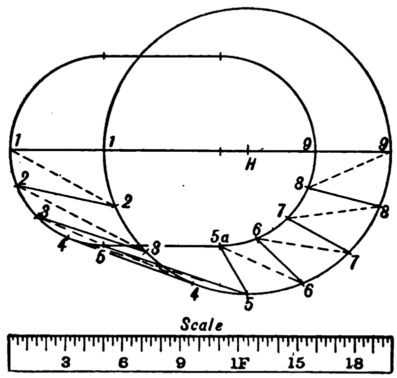


Fig. 36. The Plan.

being divided into triangles by dividing these diagrams into parts, and drawing lines between points of division.

Presuming the pattern is required for a fitting as described above, whose diameters of oblong end are 10 and 16 inches, diameter of round end 15 inches, and 18 inches in hight, also making an offset of 4 inches, or, in other words, the round end is required to project 4 inches beyond one end of the oblong, we would proceed as follows: Draw the oblong diagram to those dimensions as shown in plan, Fig. 36, in which a scale is given to verify measurements as given. Draw a line as *1 9* through the points from which the semi-circles have been drawn which constitute the ends of the oblong. Extend this line from point *9* of the oblong, a distance equal to the required offset (4 inches), as at *9* of the circle.

Locate a point upon line *1 9* at a distance from point *9* of the circle equal to one half the diameter of the top (7½ inches) as at *H,* then will point *H* be a center from which a circle is drawn to represent a plan of the top as shown. Since the line *1 9* divides the plan into equal parts, as has been previously explained, it is only necessary to consider one part, as it may be duplicated for the other equal part.

Divide the semi-circle representing one-half of the round end into a number of equal parts, as at *1, 2, 3, 4,* etc., then will a point as *5* divide the semi-circle into two equal parts. Determine the length of the straight line which constitutes one side of the oblong, as between points *5* and *5 a* of that diagram. Divide the curved portions of the oblong diagram, i.e., those semi-circles included between points *1* and *5,* also between *5 a,* and *9,* into the same number of equal parts as each half of the semi-circle representing the round end has been divided into, as shown. Draw lines *1 1, 2 2, 3 3, 4 4, 5 5, 5a 5, 6 6,* etc., as also shown in plan, Fig. 36. These lines are now looked upon as plans of lines presumed to be upon the surface of the object.

As will be noted, the above lines are not sufficient to represent the surface as being divided into triangles; However, upon drawing lines as *1 2, 2 3, 3 4, 4 5, 5a 6, 6 7,* etc., we find the whole surface of one-half of the object represented has been divided into triangles.

Right Angled Triangles.

Our next operation is to determine the true lengths of these lines, or the true distances between designated points of the base and top. This is accomplished by the use of the right angled triangle, as has been frequently explained, and here shown at Fig. 37, where, to avoid confusion two sets are employed.

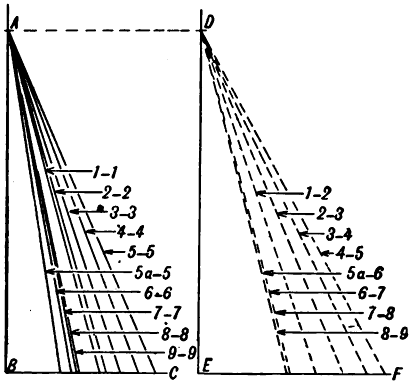


Fig. 37. Diagram of Triangles.

As will be noted, the perpendiculars of all triangles, Fig. 37, are equal to the vertical hight of the object, or 18 inches, as shown at *A B* and *D E*. The bases of said triangles being equal to lengths of lines in plan, as shown in spaces from *B* and *E* along lines *B C* and *E F*, thus locating points between which lines may be drawn to secure the true lengths of those lines shown in plan which divide the surface of the object into triangles, and connect points of the base with points of the top.

The Pattern.

As has been explained, we may look upon the lengths of lines in the diagram of triangles as the distances between points of the base, and points of the top. Since the plan supplies the distances between these points along the base and top, all necessary measurements are before us to develop the pattern, and the mental process may run through our minds somewhat as follows: Draw in any convenient position upon the plane of development, a line whose length is equal to the length of line *1 1* found in the diagram of triangles, Fig. 37. Decide which end of this line shall be at the base of the fitting and mark accordingly, as shown. The distances between points *1*

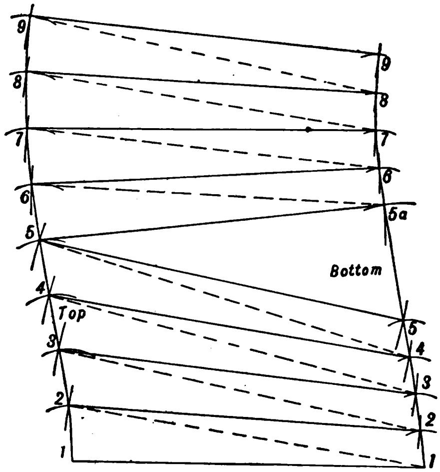


Fig. 38. *The Pattern for One-half of the Fitting.*

and *2* at the base and top of the object are shown in plan, therefore we describe arcs with these distances as radii, and with points *1* and *1* of the pattern as centers, when points *2* and *2* must lie in these arcs.

We have the true distance between points *1* of the base and *2* of the top, in the length of line *1 2* of the diagram of triangles, therefore if we describe an arc with this radius, and point *1* at the bottom of the pattern as center, its intersection with the first small arc at *2* must be the exact location of point *2* at the top of the fitting, or pattern.

With the compasses set to a span equal to the length of line *2 2* found in the diagram of triangles, and with point *2* at the top of the pattern as center, describe the second small arc at the bottom of the pattern when the line *2 2* may be drawn, thereby completing what may be looked upon as one section of the pattern or covering of the object, as shown in plan Fig. 36, at *1 2 2 1*.

The next step is to draw two additional arcs with points *2* and *2* of the pattern as centers, and with distances as found between points *2* and *3* of the plan as radii. The distance between point *2* at the base and point *3* at the top of the object is shown in the length of line *2 3* of the diagram of triangles, which we may use as before to secure the exact location of point *3* at the top. In a similar manner we use the length of line *3 3,* found in the diagram of triangles, to locate point *3* at the bottom of the pattern.

Two more small arcs are added as before, using points *3 3* of the pattern as centers, when points *4 4* of the top and base may be located by transferring the distances as found in the lengths of lines *3 4* and *4 4* of the diagram of triangles. In the same general manner as has been explained, points *5 5* of the pattern may be located as shown.

We find, upon referring to the plan, that there are two lines radiating from point *5* of the circle, which are the plans of lines which connect point *5* of the top to *5* at the base, also *5* at the top with *5a* at the base, and including two sides of a flat triangular surface upon the side of the object. The diagram of triangles supplies in the length of line *5a 5,* the distance from point *5* to *5a* upon the surface of the object, therefore we may use that distance as radius, with point *5* at the top of the pattern as center, to describe a small arc as shown at *5a.* The plan supplies the distance from point *5* to *5a* at the base of the object, and using that distance as radius, with point *5* at the bottom of the pattern as center, we may describe an arc, cutting the first at *5a,* thereby locating point *5a* upon the pattern in its correct relative position.

Since the remaining points shown upon the pattern are located in the same manner as heretofore explained, it seems that one will have little difficulty in completing the pattern as shown. Those who have given this work the attention that the subject demands, beginning with the first Chapter, should now be in a position to develop the patterns for a variety of forms whose ends are parallel, although some care must be exercised when designing them.

Forms of Fittings.

When the centers of the ends are approximately in one line which is perpendicular to the planes of said ends, the fitting may be made comparatively short. However, in every instance a moderate length is more convenient since the change of form is less per unit of length, therefore the metal responds more readily when forming it to its required shape. When the offset is considerable, and it is desirable to preserve the capacity of the fitting, i.e., the area of its cross section, it becomes necessary to increase its length. For example, Fig. 39 illustrates transitional offsets, or connections between round and rectangular pipes, where the offset is as shown. If the fitting is made as shown at *A,* its capacity at *a b* will be considerably reduced. However, if its length is increased as shown at *B,* its capacity at *a b* will be correspondingly increased. Conditions will not at all times permit of this increase in length, therefore we must resort to a form of fitting as shown at *C.* Here, as will be noted, that portion which forms the transition is con-

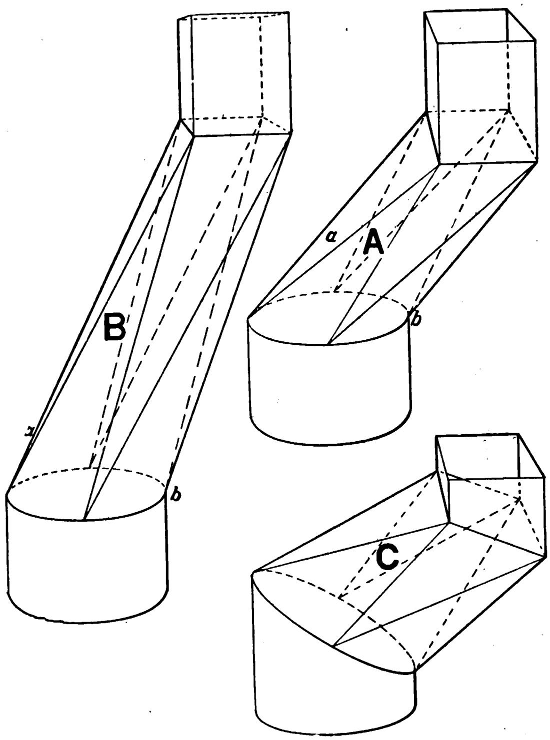


Fig. 39. Forms of Fittings.

nected to pipes which have been cut obliquely, and in many instances the ends of the center portion will not be parallel. To develop patterns of this class demands a somewhat greater understanding of the science, and is explained in subsequent Chapters.

CHAPTER VIII.

A Two Pronged Fitting Which Can Be Made in One Piece.

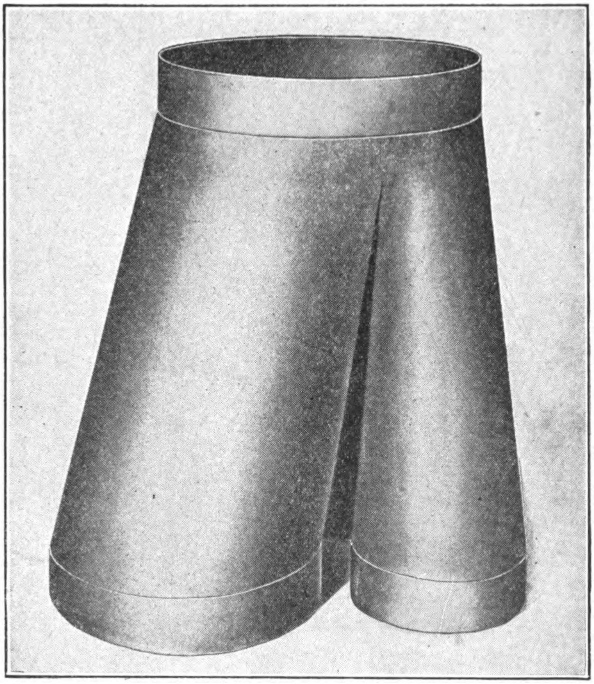


Fig. 40. Pictorial View of a Two-pronged Fork.

A two pronged fitting as illustrated at Fig. 40, made from one piece, supplies an interesting and instructive example in pattern development.

The student's attention is directed to this as one worthy of careful attention, since a clear understanding of the positions of triangles which must be presumed to compose its surface when the pattern is developed, will without question, advance one's understanding of other forms which will be encountered.

Many modifications may be made of it without materially changing the methods of securing its pattern, providing its ends remain parallel.

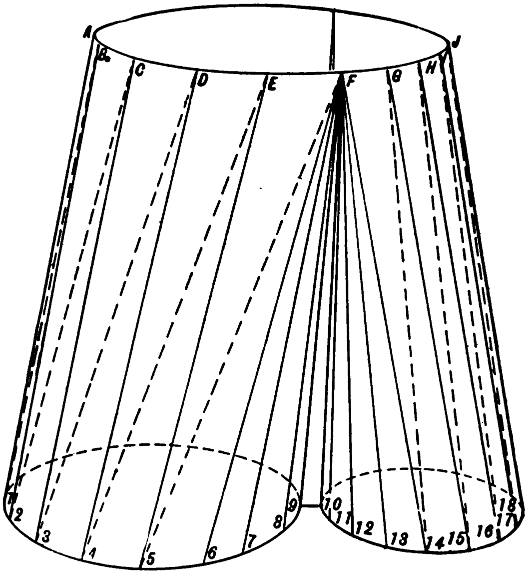


Fig. 41. *Pictorial View of the Fitting, Showing Triangles Presumed to be Upon its Surface.*

There is, perhaps, no ironclad rule which must be followed in locating the above spoken of triangles, although they should be so located as to allow all lines which are the boundaries of said triangles to be as nearly straight lines as possible when placed upon the surface of the object.

Some judgment will also be necessary to determine what amount of the collar here shown as the top shall be devoted to each prong of the fitting. Fig. 41 shows the body of the object in a pictorial way, and the triangles the author has presumed to be upon its surface.

Upon giving Fig. 41 attention, the student will note that the body of the object is composed of parts of oblique cones. As for example, where a number of full lines radiate from a single point, that portion of its surface included within those lines is a portion of an oblique cone, and that portion of its surface where broken lines are shown which alternate the full lines, is a portion of the frustum of an oblique cone.

Therefore, as above stated, the whole surface is composed of portions of oblique cones whose bases and vertical hights are of varying dimensions.

On the Characters Used in Pattern Demonstrations.

The multiplication of characters to designate similar points in different diagrams employed to solve a problem in pattern development, is always a source of annoyance. Therefore in an endeavor to reach the reader's mind directly through the medium of the eye, the author has made it an almost universal rule to designate similar points by the same character in each diagram. As, for example, points *B* and *2*, Fig. 41, are the upper and lower extremities of line *B 2*, and this line is shown in plan, Fig. 42, between points *B* and *2*. In the diagram of triangles line *B 2* is shown in its true length, and designated as *B 2*.

The pattern shows line *B 2* in its correct relative position, with one extremity at the top, while the other is at the bottom, and if the pattern be wrapped about the object as shown at Fig. 41 in a manner as to allow line *B 2* to coincide with line *B 2* there shown, all other designated points or lines must also coincide.

On the Plan.

Since the plan of an object as here illustrated may be divided into two equal parts, one part as shown at Fig. 42 will fulfil every requirement in developing its pattern. On the other hand, it may in some instances be advisable to draw a complete plan, for the purpose of securing a clearer understanding of the object and its surface. This must be done if it is required to secure the pattern for an object whose surface cannot be divided into equal parts.

It may be here explained that to secure the pattern for an object whose surface cannot be divided into equal parts, the whole surface must be represented. This does not imply that there are any additional principles to be applied, but simply that there is an increased number of lines whose lengths and positions must be determined.

If the pattern cutter has any difficulty in securing the pattern for an object whose surface cannot be divided into equal parts, it is very likely due to his inability to form a clear conception of the object. One who finds himself thus handicapped should devote some time to the study of the relation the plan bears to the object, and remember, as stated above, that there are no additional principles involved, simplv an increased number of lines to be dealt with.

The First Step to Secure the Pattern.

The first step to secure the pattern for an object as illustrated at Fig. 40 is to draw a plan, or a portion of it. This, as has been previously stated, should be as simple as the nature of the object will permit. Since the fitting is designed to make connection between three round pipes whose axes are parallel, we may presume to view these pipes from above as in orthographic projection, and draw the circles in plan which shall represent the cross-sections of said pipes as shown at Fig. 42, assuming the diameters of these pipes to be as shown. Here the semi-circle *A E J* is a plan of one-half of the top, and the small semi-circles constitute a plan of one-half of the base.

The next step is to determine what amount of the larger semi-circle shall be devoted to each small semi-circle, or, in other words, what part of the top shall be devoted to each of the small collars. In this instance, five-eighths of the arc *A E J* has been devoted to the large collar at the base, and three-eighths to the small one, i.e., the point *F* is connected by lines to each small semi-circle.

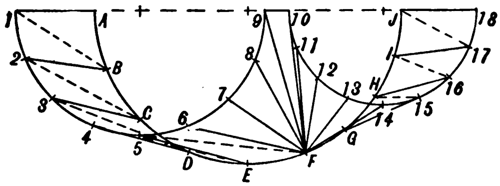


Fig. 42. *Semi-plan.*

We may now divide each of the semi-circles into an equal number of equal parts as shown from *1* to *9*, and from *10* to *18*. If each semi-circle is divided into eight parts, as here shown, the point *F* is located without further trouble, thereby locating six points as *A, B, C, D, E* and *F*, which may be connected to similar points of the base as shown by lines *1A, 2B, 3C, 4D, 5E,* and *6F*. These lines may now be looked upon as being elements of the surface of the frustum of an oblique cone, and the pattern for that portion may be secured in the same manner as explained for that form in Chapter VI. We may now connect points *7, 8* and *9* to *F*, and look upon that portion of the object as a portion of an oblique cone. The surface represented in plan within the triangle *9 10 F* is a flat surface.

That portion of the large semi-circle between *F* and *J* may now be divided into one-half the number of equal parts that the semi-circle *10, 14, 18* has been divided into (in this case four), and lines drawn as *F 14, G 15, H 16, I 17,* and *J 18.* The remaining points as *10, 11, 12* and *13* may be connected to *F,* thereby securing the plans of lines which are presumed to be upon the surface of one-half the object, and shown in a pictorial way at Fig. 41.

Triangles.

The lengths of the above spoken of lines are now employed as the bases of triangles whose perpendiculars are

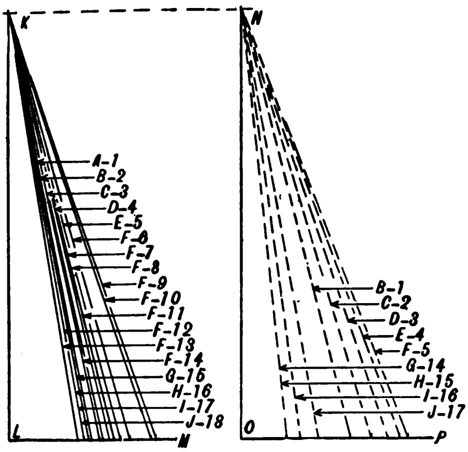


Fig. 43. Diagram of Triangles.

equal to the vertical hight of the fitting as shown at Fig. 43, where *K L* is presumed to be equal to that hight. The length of lines in plan are set off from *L* along line *L M,* and these points connected to *K,* thereby securing the true lengths of all full lines shown in plan.

Since portions of the fitting are parts of the frustums of oblique cones, some additional lines must be assumed to completely divide the surface into triangles. These lines are shown in plan, and in Fig. 43 as broken lines, and their lengths are secured in the same general manner as has been explained and shown at Fig. 43.

The Pattern.

Having before us the true lengths of all lines necessary to develop the pattern, we may proceed by drawing in

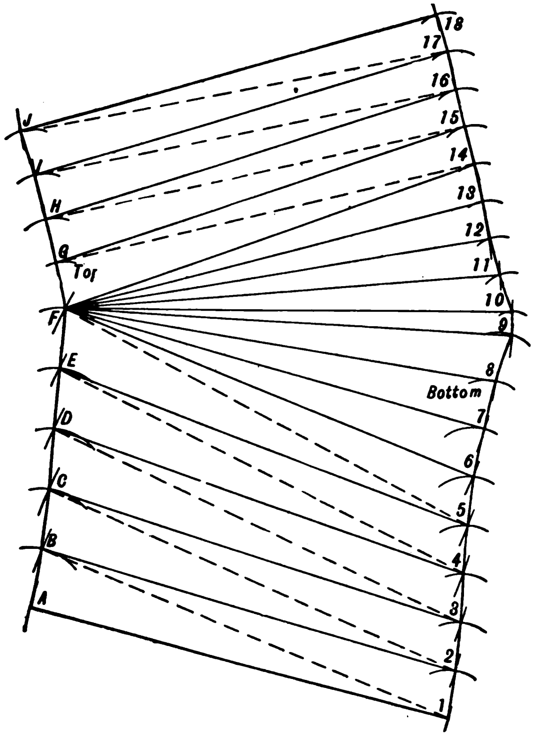


Fig. 44. The Semi-pattern.

any convenient position upon the plane of development, a line whose length is equal to the length of line *A 1*, Fig. 43, as shown at *A 1*, Fig. 44. The distance from *A* to *B* is found in plan, and the true distance from *1* to

B is the length of line *B 1,* Fig. 43, thus enabling us to locate point *B* in its correct relative position upon the plane of development, as shown at Fig. 44.

Point *2* may now be located, since the plan supplies the true distance from *1* to *2,* and the diagram of triangles supplies in line *B 2,* the true distance from *B* to *2.* Points *C, D, E* and *F* at the top, and *3, 4, 5* and *6* at the base, may all be located in the same general manner.

Presuming that line *F 6* has now been located upon the plane of development, a glance at the diagrams will show that lines *F 6* to *F 14* inclusive, all radiate from point *F.*

The diagram of triangles supplies the true lengths of these lines, and the plan supplies the true distances said lines are from each other at their extremities, therefore little trouble should be experienced in locating points *6* to *14* upon the bottom of the pattern as shown. Since the remainder of the required semi-pattern, or points *G, H, I* and *J,* also *15, 16, 17* and *18,* are located in the same general manner as were similar points shown at the left side of Fig. 41, the reader should have little difficulty in completing the work as shown.

It may be remarked that slightly more accuracy may be obtained by first locating upon the plane of development, that surface within the triangle *F 10 9,* and then adding the triangles at each side of this. This, as will be noted, eliminates some opportunity for error which may have been committed in the early part of developing the pattern. However, this is a matter for the operator to decide, since if care be used the difference will be slight.

When it is Required to Fit the Ends of the Object to Round Collars Whose Circumferences Have Been Established.

There is a constant ratio between the circumference of a circle, and its diameter, the value of this ratio to six figures is 3.14159; however, for all ordinary purposes, 3.14 is sufficiently accurate; therefore we may determine the diameter of any circle whose circumference is given, or, we may determine the circumference of any circle whose diameter is given, by either multiplying or dividing as the case may require. As for example, diameter multiplied by 3.14 equals the circumference, or the circumference divided by 3.14 equals the diameter.

When the circle is drawn and divided into a number of equal parts, for example, twenty-four, each part represents one twenty-fourth of its circumference, and as ordinarily measured each space is a straight line, or the chord of an arc. Since the chord is always less than the arc it subtends, the twenty-four spaces along a right line will very likely be something less than the figured circumference, thereby introducing some error. Therefore, if the circles be drawn in plan as accurately as may be, and their known circumferences set off upon right lines, these lines may be divided into the same number of equal parts as the circles have been divided into, and these spaces upon right lines employed as the correct distances to be set off upon the pattern, some more accuracy may be obtained.

CHAPTER IX.

SOME PRINCIPLES OF ORTHOGRAPHIC PROJECTION AS APPLIED TO TRIANGULATION.

To secure the pattern for an object whose ends are not in parallel planes demands a greater knowledge of orthographic projection. The reader will note that in foregoing examples a plan of the object, together with a knowledge of its vertical hight was sufficient to enable us to determine the true lengths of all lines presumed to be upon its surface and shown in plan. The reason for this is found in the fact that all points of the top are the same vertical distance from the plane of the base, or, all points of the base are at the same vertical distance from the plane of the top.

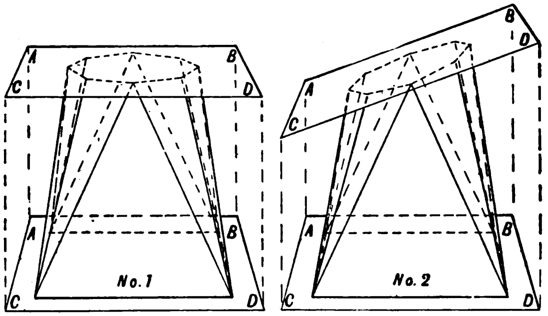


Fig. 45. A Pictorial View of Transition Pieces and the Planes Within which their Ends are Situated.

When the ends of the object are not parallel a more complicated problem is encountered, since there is variation in the distances between the planes of its ends. Therefore some method must be employed which will enable us to determine the distance between different points which may be conceived as being located within those planes. The above is clearly shown at Nos. 1 and 2, Fig. 45.

Fig. 45 shows, in a pictorial way, objects making a transition from square to octagonal, and the planes *A B C D,* within which the ends of those objects are situated. It is apparent upon examination of No. 2, that the perpendiculars of triangles employed to secure the true lengths of lines, must be of varying lengths. In an endeavor to convey to the reader an understanding of the principles involved to secure those lengths, some elementary discussion relating to the point, right line, and plane will be introduced.

On the Representation of a Point Upon the Vertical and Horizontal Planes of Projection.

Since the relative positions of points, lines and planes must be determined when the solution of the more complex problems in pattern development are attempted, we shall first consider the surfaces upon which they are represented. As has been previously explained, a plan is usually drawn upon a surface which is presumed to be horizontal. An elevation can be, and is many times, drawn upon the same surface, but intended to represent the object when viewed from positions which are at right angles to those assumed for the plan. Therefore if the object is to remain stationary, the surfaces upon which the plan and elevation are to be drawn must be presumed to be at right angles to each other. Thus we have what are known as the vertical and horizontal planes of projection.

As for example, the surface *A B C D,* No. 1, Fig. 46, represents the surface upon which a plan and an elevation may be drawn. A line, real or assumed as *I L*, divides this surface into convenient parts. The lower portion as *I L C D* remains in a horizontal position, while the upper portion as *A B I L* is looked upon as

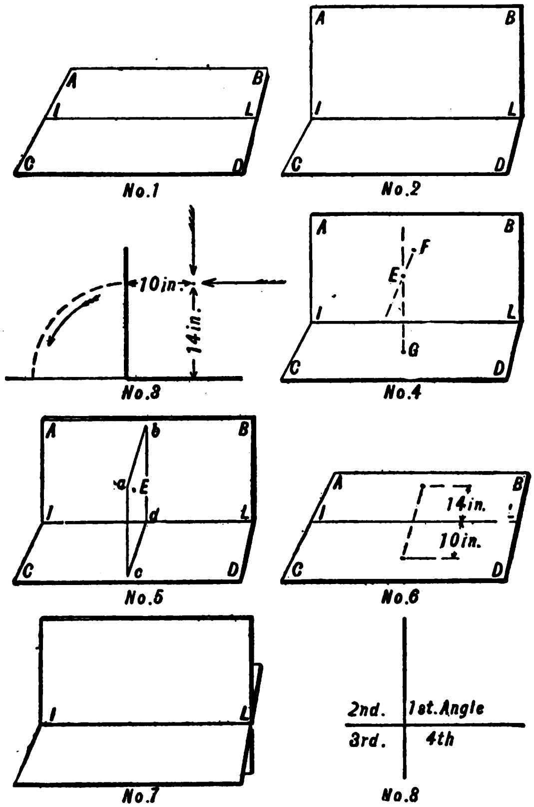


Fig. 46. Illustrating the Principal Planes of Projection.

being in a vertical position, as illustrated at No. 2, Fig. 46. That portion of the surface as shown at *I L C D* is known as the horizontal plane of projection, and that shown at *A B I L* as the vertical plane of projection. The line *I L* is the intersecting line between the two planes.

As these planes are presumed to be capable of indefinite extension there is no limit as to size.

The above spoken of planes, i.e., the vertical and horizontal, are known as the principal planes of projection, and are sufficient for many, but by no means all, of the ordinary operations of pattern development. In addition to the above there are the profile and oblique planes, which must be employed at times to secure desired results. However, since a knowledge of the first is essential to the study of the others, the author will for a time confine himself to the representation of the point, right line, and plane upon the vertical and horizontal planes of projection, and, as the work progresses, endeavor to explain the positions and value of the profile and oblique planes.

The object to be represented is presumed to occupy a position in space above the horizontal, and in front of the vertical plane. It may be here explained that space is unlimited extension in which all bodies are situated. The absolute position of bodies or objects cannot be designated except in a relative way, i.e., by referring them to each other, or to objects whose positions are assumed. In orthographic projection all objects are referred to the planes of projection.

Since representations of objects upon the planes of projection are composed of lines, and as lines are made up of points, we may direct our attention for the moment to the projection of a single point.

The point, which is the least of geometrical magnitudes, if considered as a visible particle, can be located in space by giving its distance from each of the two principal planes of projection.

Presuming a point is located 14 inches above the horizontal plane, and 10 inches in front of the vertical plane as shown at No. 3, Fig. 46, then a pictorial view of the planes and point as at *E* is shown at No. 4, Fig. 46. If from point *E* in space, a perpendicular line be let fall to the horizontal plane, the foot of the perpendicular as *G* is the horizontal projection or plan of the point. If in like manner, a perpendicular be drawn to the vertical plane, the point of intersection with that plane, as at *F*, is the vertical projection of the point, or its elevation. These perpendiculars are called the projecting lines of the point.

It will be noted that this places the plan of the point at the same distance from *I L* as said point is known to be from the vertical plane, and the position of its elevation is at the same distance from *I L* as the point is known to be above the horizontal plane. The converse of this may be assumed, i e., the location of the point in space is determined by its projection upon the vertical and horizontal planes, since its plan is 10 inches in front of the line *I L*, the point itself must be 10 inches in front of the vertical plane, and since the elevation of the point is 14 inches above *I L*, the point itself must be 14 inches above the horizontal plane. If a plane which is perpendicular to the two planes of projection be passed through point *E* in space, as shown at *a b c d*, No. 5, Fig. 46, said plane would cut a right line from each, i.e., the vertical and horizontal planes of projection, as illustrated by lines *b d* and *d c*, No. 5, Fig. 46, which are at right angles to *I L*. Therefore the elevation of a point will be found in a line drawn from the plan of said point perpendicular to *I L*, or the plan of a point will be found in a line let fall from the elevation of said point and perpendicular to *I L* when the vertical plane has been so revolved as to be parallel to the horizontal as shown at No. 6, Fig. 46.

In other words, the plan and elevation of a point are found in a right line drawn perpendicular to *I L*. Its distance above line $I\ L$ is equal to the distance said point is above the horizontal plane, and its distance below line $I\ L$ is equal to the distance said point is in front of the vertical plane. This, as will be noted, places the elevation above the plan in every instance. Thus we have what is commonly known as a first angle projection.

On the Relative Positions of the Plan and Elevation.

There is a tendency among draftsmen to place their elevation below the plan, or, in many cases, in what seems to be the most convenient position for them at the moment. This the writer believes is more likely to confuse than enlighten. Geometrical authorities state that the first angle is sufficient for all ordinary operations, and as it is by far the most simple of comprehension, the author will in every instance locate his object in the first angle. This is in line with the teachings of an English instructor in civil engineering, and a writer on orthographic projection who has always been held in high esteem.

In explanation of the above it may be stated that geometry teaches that the intersecting line is not a limiting line, but the line where two planes which are capable of indefinite extension intersect or cross one another, as shown at No. 7, Fig. 46. This forms four equal angles as shown at No. 8, Fig. 46, where an edge view of the planes is shown. The object may be looked upon as being situated within either of these angles. Thus when the vertical plane is presumed to be revolved into the plane of the paper, the elevation will occupy a position dependent upon the angle within which the object is situated. This then explains to some extent, the different positions taken for plans, elevations, and sections.

Geometrical authorities also state that the point of sight is always at an infinite distance above the horizontal and in front of the vertical plane, which is within the first angle, hence all objects situated within this angle can be seen. Objects situated within either of the other angles are concealed more or less by the planes of projection. Lines that are given or required are made full if they can be seen, but are dotted if concealed by other objects, or by the planes of projection. Auxiliary lines, or lines used to aid in the construction of a problem, are always dotted.

Many broken or dotted lines found in a pattern demonstration are included simply as an aid in conveying an understanding of the problem, although it must be admitted that in many instances said lines are erroneously looked upon by the novice as confusing the demonstration.

CHAPTER X.

THE REPRESENTATIONS OF OBJECTS ON THE VERTICAL, HORIZONTAL, PROFILE AND OBLIQUE SUPPLEMENTARY PLANES OF PROJECTION.

Having explained in Chapter IX the principles involved in the representation of a single point upon the vertical and horizontal planes, attention will now be directed to the representation of that solid known as a

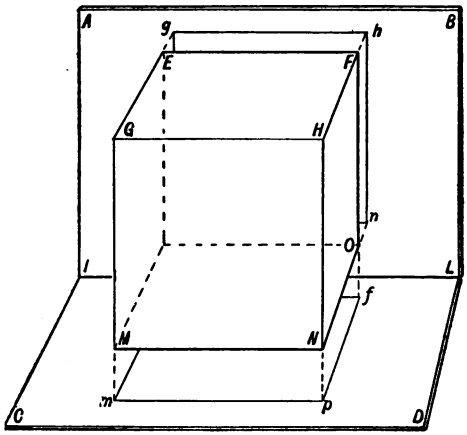


Fig. 47. A Pictorial View of the Vertical and Horizontal Planes, together with a Cube Located Within the First Angle.

cube upon these planes. It will be remembered that a cube is a solid bounded by six equal faces or squares and having all its angles right angles.

Fig. 47 is a pictorial view of the vertical and horizontal planes in their assumed positions, with the cube suspended in space in front of the vertical and above the horizontal plane, with two of its faces parallel to each. If the cube be viewed from above, with the point of sight moving over the object so as to place every point viewed in a line perpendicular to the horizontal plane of projection, a square equal to one of its faces would represent it as shown at *a b c* and *d,* Fig. 48.

Perhaps this will be more fully comprehended if we presume to drop plumb lines from the vertice of angles E F G and H, Fig. 47, to intersect the horizontal plane

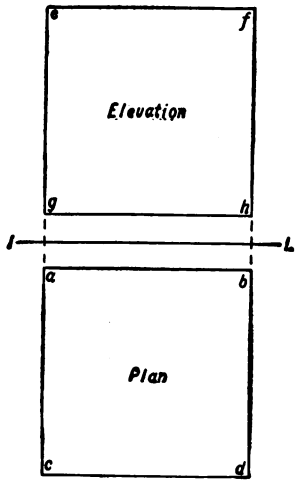


Fig. 48. *The Plan and Elevation of a Cube.*

in points *m p* and *f,* where lines are drawn to connect them, thus forming a square equal to one face of the cube. It should be noted that point *m* is not only the plan of point *G,* but the plan of point *M* as well, also the plan of line *G M,* or any number of points along the line *G M.* This deduction is not confined to the line *G M,* but can be applied to all lines which are perpendicular to the horizontal plane of projection. Line *m p,* Fig. 47, is not only the plan of line *G H,* but of the line *M N* also, or a plan of any line which may be drawn upon the surface *G H N M,* and intersecting lines *G M* and *H N.*

Thus it will be noted that a point in plan may represent a point in space, or a line which is perpendicular to the horizontal plane of projection. Likewise a line in plan may represent a line in space either parallel or oblique to the horizontal plane, or it may represent a plane which is perpendicular to the horizontal plane of projection.

The elevation of the object is secured by drawing a square equal to one of its faces, directly above the square which is looked upon as a plan, as shown at *e f g* and *h,* Fig. 48. This is also illustrated at Fig. 47, where the lines *G E, H F,* and *N O* if produced, would intersect the vertical plane *A B I L* in points *g h* and *n,* thus locating points which may be connected to form an elevation as shown at *g h* and *n*. Here the point *g* is not only the elevation of points *G* and *E,* but of any number of points along the line *G E,* likewise the point *h* is an elevation of points *H* and *F,* or of any number of points along the line *H F*. Similar conclusions may also be drawn for the line *N O*. The line *g h* is not only an elevation of *G H,* but the elevation of line *E F* as well, and line *g h* is also an elevation of the face *E F H G,* or of any line which may be drawn upon that surface which intersects lines *E G* and *F H*. Therefore a line in elevation may represent a line in space which is parallel or oblique to the vertical plane of projection, or it may represent a plane which is perpendicular to the vertical plane of projection.

In proof of the above, we may presume to draw a line from *G* to *F* upon the upper face of the cube, Fig. 47. It will then be noted that the line *g h* is its elevation, and a line drawn from *m* to *f* would then be its plan, thus showing that this line is oblique to the vertical plane of projection.

It should be remembered that Fig. 47 is a pictorial view of the cube and planes of projection, which is introduced for the purpose of giving a clearer understanding of the principles involved, while the plan and elevation proper is at Fig. 48, presuming the cube to be of a size as shown.

If the reader has become sufficiently interested he will do well to provide himself with a drawing board and a few accessories, which he may obtain from almost any dealer in artist's materials. The drawing board should be of convenient size, say 23 x 31 inches. He will also require a T-square which has a blade about equal in length to the drawing board; two triangles, one 8 inch 45 degrees, and one 10 inch 60 and 30 degrees, a few thumb tacks, a lead pencil and rubber. Almost any grade of paper may be used. In regard to drawing instruments, a pair or two of compasses will be all that is required.

If the student will perform a few experiments which the foregoing should suggest, by the aid of pieces of cardboard, and remember that the plan of a point or line will always be found directly beneath it, and that the elevation is always found directly back of it, the above will no doubt be made quite clear, and place him in a position to grasp additional facts which will aid him as a pattern cutter.

The Profile Plane.

The profile plane is an additional plane assumed to be perpendicular to the principal planes of projection, i.e., the vertical and horizontal. No. 1, Fig. 49 illustrates at *A B L I* the vertical plane, and at *I L D C* the horizontal plane, then ***a b c d*** is a profile plane, and a representation upon this plane is termed a profile. The profile plane may be presumed to be revolved about a perpendicular axis as the line *b c,* into the plane of the paper, or about a horizontal axis as the line *c d,* and may be located either to the right or left of the assumed position of the object.

The line about which the profile plane is presumed to be revolved becomes an intersecting line when the projection upon that plane is constructed in the same general manner as has been explained for projection upon the principal planes.

The profile plane is often of the greatest use, which is

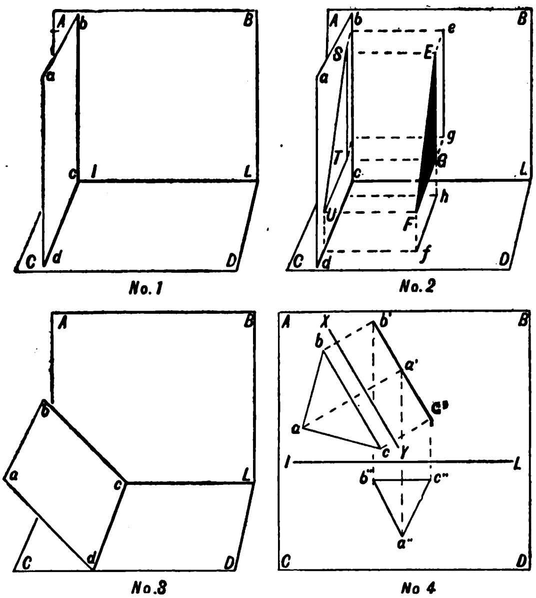


Fig. 49. Illustrating the Profile and Oblique Supplementary Planes.

illustrated in a simple example at No. 2, Fig. 49. A triangle as *E F G* is presumed to be suspended in space so that its surface is perpendicular to the vertical and horizontal planes of projection. The line *f h* is a plan of said triangle, and the line *e g* is its elevation. To secure the true form of the triangle or the length of its longest side, it must be revolved until it becomes parallel to the plane upon which it is represented, or an additional plane assumed, which is here shown as the profile plane ***a b c d.***

This plane being parallel to each of the three sides of the triangle, its representation upon that plane will be its true form, as shown in a pictorial way at *S T U*.

Supplementary Oblique Planes.

It is frequently found convenient to make use of what is known as oblique planes. The object is represented upon these, its position being fixed as regards the principal planes. The positions of such planes are determined by conditions of convenience, and therefore depend upon the nature of the object, but they are, in most cases, such that these planes are perpendicular to one of the principal planes. The oblique plane is shown pictorially at No. 3, Fig. 49. For example, *A B L* is the vertical and *C D L* the horizontal plane of projection, then *a b c d* is the oblique plane.

To illustrate the use of the oblique plane, let it be presumed that the surface *A B D C* of No. 4 in Fig. 49, is a surface upon which a right angled triangle is to be represented in plan and elevation, when its position is as follows: The surface of the triangle is at an angle of 60 degrees to the horizontal plane, with its longest side parallel to the vertical plane. If a line as *X Y* be drawn at an angle of 60 degrees to the line *I L*, this line, i.e., *X Y*, may for the moment be looked upon as the intersecting line between the vertical and a supplementary plane which makes an angle of 60 degrees to the horizontal plane, then draw the triangle upon this plane in its true form, keeping its longest side parallel to line *X Y* as shown at *a b c*. Draw upon the vertical plane to the right of line *X Y* a line as *b′ a′ c′* parallel to line *X Y*. Project points *a b c* as shown at *b′ a′ c′*, then will the line *b′ a′ c′* be a representation of the triangle upon the vertical plane.

Its plan is secured by dropping lines from points b' a' c' perpendicular to I L, and locating points upon these lines at distances from I L as found from the line X Y to points a b c, as shown at b'' c'' a'', after which lines are drawn to complete the plan as shown. It will be noted that the line b c as shown in plan at b'' c'' is considerably foreshortened for the reason that this line as at an angle to the horizontal plane of projection.

As has been previously stated, the principles employed to secure patterns for forms whose ends are not parallel are somewhat complex. On the other hand, if one secures a clear understanding of the principles employed to secure the patterns for one form, he may employ those principles for all. He who considers the art of pattern cutting worthy of attention will find that a study of its principles is of the utmost importance.

The work may here seem to be somewhat extended; however, the student is cautioned not to turn it aside and wait for something which seems for the moment to be more in the line of this work, since, if the principles as herein explained are not fully comprehended by the pattern cutter, he can never become a master of his art. The study of individual pattern demonstrations, and the pursuit of this or that one's methods may enable one to develop a considerable number of patterns, but at what moment something which we have never seen may come before us no one can foretell. There are but few principles to be understood which may be applied to those forms which are secured by triangulation, and since the writer has undertaken the task of explaining those principles, he trusts that the student will withhold judgment until he has given the work considerable attention, thus placing himself in a position to comprehend the principles involved in the pattern problems which follow.

CHAPTER XI.

The Pattern for a Fitting Whose Ends Are Not in Parallel Planes.

The difference in appearance of diagrams used by different operators to secure the pattern for one and the same object is due absolutely to the position each in-

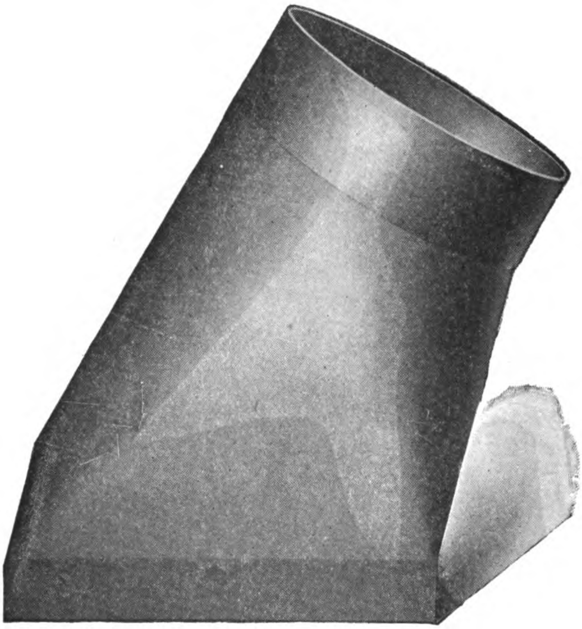


Fig. 50. Photographic View of a Fitting Whose Ends Are Not in Parallel Planes.

dividual assumes the object to occupy as regards the planes of projection. It is hardly to be expected that all will conceive it as being in the same position, therefore there is variation.

In looking over a considerable number of demonstrations, the writer finds but slight if any reference to the planes of projection. As has been stated, an object can only be located as regards the planes of projection; this being true, it would seem important that the pattern cutter should understand the use and value of said planes.

Upon referring to Fig. 51, the reader will note three pictorial representations of the irregular portion of one form as illustrated at Fig. 50, but occupying different positions as regards the surface upon which said form is represented as resting.

When the pattern is required for a fitting of this class, at least two views will be necessary to enable us to determine the true lengths of lines presumed to be upon its surface. To simplify the problem rests upon our ability to assume the object to be in such positions as to allow the simplest of these diagrams to represent it in plan and elevation.

Should we assume the object to occupy a position as shown at A, Fig. 51, the plan of the top will then be an ellipse. To draw this ellipse in its correct form and dimensions, we may assume a supplementary oblique plane, which is not a particularly difficult operation. However, since this involves the use of an additional plane, perhaps the problem will be simplified by revolving it about a horizontal axis until the plane of the round end becomes parallel to the horizontal plane of projection, as shown at either *B* or *C*, Fig. 51.

It may be here explained that the plan of the object when presumed to be in positions as shown at *B* or *C*, Fig. 51, will be similar, and that the only variation which will exist will be in the position of the elevation as regards the intersecting line.

In an endeavor to explain the principles involved in problems of this nature, a position of the object as shown at *C,* Fig. 51, is first assumed. As a second example, the same object will be assumed to occupy a position as shown at *A,* Fig. 51, and the plan and elevation drawn, with its pattern developed, thereby illustrating the use of the

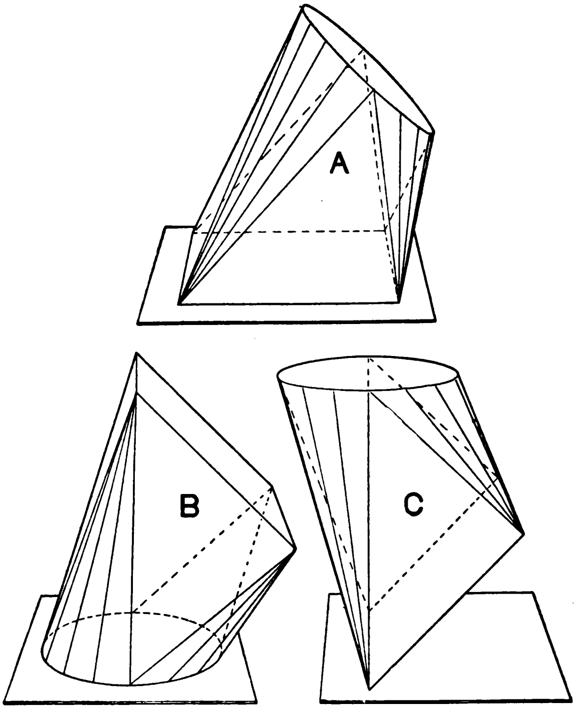


Fig. 51. *Scenographic Representation of One Irregular Form Occupying Different Positions.*

oblique supplementary plane. This will clearly show how two patterns which finish the same may be developed from two sets of diagrams presenting a wide variation in appearance. These diagrams are, in fact, the representations of the original object, which simply occupies different positions as regards the principal planes of projection.

To Develop the Pattern for an Object as Illustrated at Fig. 50, Presumed to Be in a Position as Shown at *C*, Fig. 51.

For convenience in verifying measurements, a scale has been included in Fig. 52. It has been presumed that the object has dimensions as follows: base, square with a length of side of 16 inches; top, round and 14 inches in diameter; vertical hight of the shortest side, 8¼ inches; overhang of the shortest side, 3 inches; inclination of the planes within which the top and base are presumed to be situated, 45 degrees.

The first step is to draw diagrams which will correctly represent the object in plan and elevation. In this instance the elevation is first drawn, since it may be completed without reference to other diagrams. It is in reality a section of the object.

To secure this elevation, we may draw at a suitable distance above the line *I L,* Fig. 52, and parallel thereto, an indefinite right line as *1 9 F.* From some point upon this line, as at *m,* draw a line at an angle of 45 degrees to *I L,* as *A B m,* then will the elevations of the top and base of the object lie in some portions of these lines.

Since the vertical hight is 8¼ inches upon the shortest side, we may employ the steel square to locate point *9* of the top by allowing one edge of the blade to lie parallel to the line *A B m,* and with the 8¼ inch mark of the tongue intersecting the line *1 9 m,* draw a line as *9 k.* As the top overhangs 3 inches upon this side, we lay off 3 inches from point *k* as shown at *B.* We are now enabled to locate point *A,* since we know it must be 16 inches from *B* along line *A B,* and as the top is 14 inches in diameter, we can also locate point *1* in like manner. Upon drawing lines *A 1* and *9 B,* the elevation is completed.

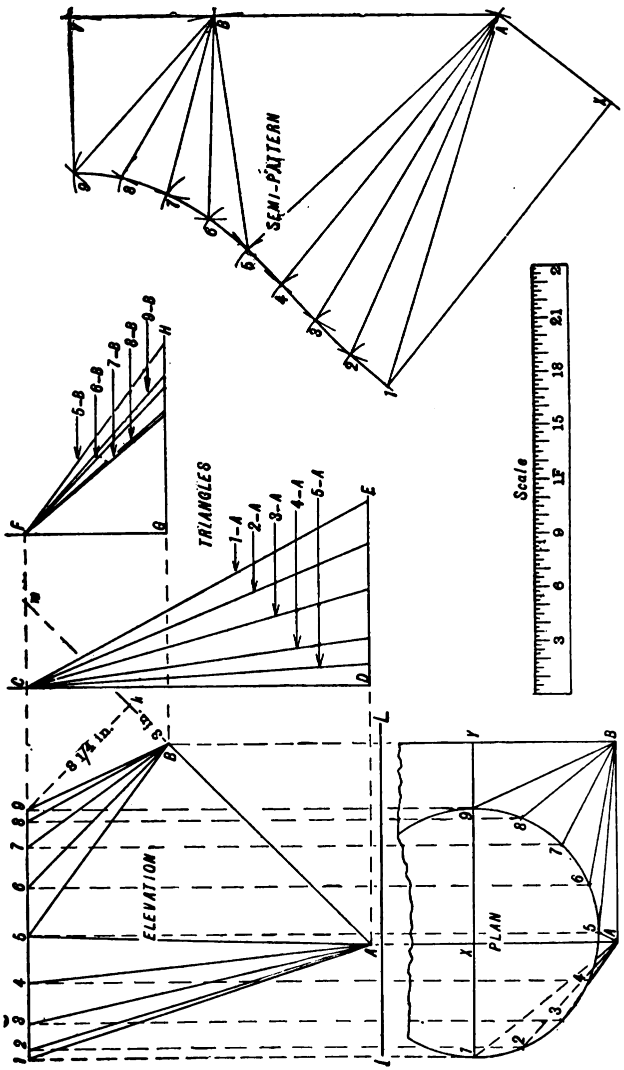


Fig. 52. Plan, Elevation, Diagram of Triangles and Pattern of a Form as Shown at Fig. 50.

The Plan.

The top is round and parallel to the horizontal plane, therefore a circle whose diameter is equal to the diameter of the top will represent that end in plan, its position being determined as clearly shown by construction lines. The object being composed of equal and opposite halves, we shall only concern ourselves with one half, or that portion of the plan shown below line *1 X 9 Y*.

Two sides of the base may be represented in plan by drawing lines from points *A* and *B* of the elevation perpendicular to the line *I L*. In other words, points *A* and *B* of the elevation are in reality the end elevations of lines which are perpendicular to the vertical plane of projection, and as the specification supplies their length, i.e., 16 inches, it only becomes a question of locating their extremities in plan. Since the line *1 X 9 Y* represents the center of the object, these lines may be made 8 inches in length from points *X* and *Y*, thereby locating points *A* and *B* upon the horizontal plane as shown in plan, where line *A B* is drawn to complete this view.

Locating Lines Which Divide the Surface of the Object Into Triangles.

With the plan and elevation completed, we are now in a position to locate lines which will divide the surface into triangles. This may be accomplished by dividing the semi-circle *1 5 9,* Fig. 52, into a number of equal parts, thereby locating a point as *5,* which divides the semi-circle into two equal parts. From point *A* of the plan draw lines to each of the points of division in one part, as shown at *1 A, 2 A, 3 A, 4 A,* and *5 A*. From point *B* draw lines to each of the points of division in the remaining part as *5 B, 6 B,* etc. This, as will be noted, divides the whole surface of one half of the object into triangles.

The elevations of points upon the round end may be secured, as is clearly shown by the vertical projectors, i.e., lines *1 1, 2 2, 3 3,* etc. All lines radiating from point *A* in plan connect points of the semi-circle from *1* to *5,* and all lines radiating from point *B* connect points from *5* to *9,* therefore to secure elevations of these lines is but a simple matter.

The True Lengths of Lines.

It may be here explained that these lines are the plans and elevations of lines presumed to be upon the surface of the object, and do not represent their true lengths except in two instances, i.e., *1 X* and *9 Y* of the plan. Here, as will be noted, *1 A* and *9 B* of the elevation supply those lengths, since lines represented in plan at *1 X* and *9 Y* are parallel to the vertical plane. All others are at an angle to the planes of projection, therefore the right angled triangle is employed to secure their true lengths; as for example, the distance from point *A* to each of the several points *1, 2, 3, 4* and *5* of the circle, also from *B* to *5, 6, 7, 8* and *9,* represent the length of base of a right angled triangle whose hypothenuse will furnish the true length of the line. Therefore we draw in any convenient position lines at right angles to each other, as *C D* and *D E,* also *F G* and *G H* of the diagram of triangles, Fig. 52. Set off from points *D* and *G* along lines *D E* and *G H,* distances found in plan, as is clearly shown.

Vertical Hight of Triangles.

The vertical hight of each triangle is governed by the difference in hight of the extremities of the line for which the triangle is constructed. Upon examination we find that in this example the difference in hight of the extremities of those lines can be represented in two distances. Since those lines radiating from point *A* of the elevation all terminate in a line which is parallel to *I L,* we use one vertical hight for all triangles employed to secure the true lengths of lines radiating from point *A* of the plan or elevation, as shown at *C* of the diagram of triangles. As will be noted, similar conditions prevail in the case of all lines radiating from point *B,* therefore the distance from *G* to *F* of the diagram of triangles is the vertical hight of all triangles employed to secure the true lengths of lines radiating from point *B.* Upon drawing lines as shown, i.e., from the points of division upon the base lines *D E* and *G H* to points *C* and *F,* the true lengths of these lines are determined.

The Pattern.

Having located a number of right lines which may be presumed to be upon the surface of the object, and having determined their true lengths, we are now in a position to place those lines upon the plane of development in their correct relative positions.

Beginning with line *1 X* of the plan, we find its true length is *1 A* of the elevation. Therefore we draw a line of this length upon the plane of development, as shown at *1 X* of the pattern. We note that line *1 A* of the plan radiates from point *1* and terminates at point *A* at the base of the object. The distance from *X* to *A* at the base of the object is equal to the distance between points *X* and *A* of the plan, therefore we may set our compasses to a span equal to the distance between *X* and *A* of the plan, and placing one point at *X* of the pattern, describe a small arc as at *A*.

Since the line *1 A* radiates from point *1,* and its true length is as shown in the diagram of triangles, we use that length as radius, and with point *1* of the pattern as center, to describe a second small arc at *A* of the pattern, thereby locating that point. We note that lines *A 1, A 2, A 3, A 4* and *A 5* all radiate from point *A* upon the surface of the object, therefore we use point *A* of the pattern as center, and the true lengths of these lines as radii in rotation to draw small arcs as shown at *2, 3, 4* and *5* of the pattern. The upper extremities of said lines must lie in these arcs, and at distances from each other equal to the distance between points of division of the circles shown in plan, since in this example the circle in plan is the true form and size of that end of the object.

Using these spaces, and beginning at point *1* of the pattern, the second small arcs are drawn, thereby locating points as shown at *2, 3, 4* and *5* of the pattern. Line *5 B* radiates from point *5* in plan and elevation, and as the true distance between points *A* and *B* is shown in the elevation, which is 16 inches, it is but a simple matter to locate point *B* of the pattern. The remaining work of completing the semi-pattern is but a repetition of the earlier operations, using the true length of each line in rotation, and should hardly need further explanation.

The following chapter is devoted to a second demonstration wherein identical results are obtained by the use of diagrams whose appearance may, at times, lead the novice to believe that entirely different methods were employed to secure the pattern for a form as shown at Fig. 50.

However, upon devoting some attention to each chapter, it will be noted that the different appearance is due to the changed position assumed for the object.

CHAPTER XII.

The Pattern for a Fitting Whose Ends Are Not in Parallel Planes. Second Demonstration.

In Chapter XI, methods were discussed which may be employed to secure the pattern for an object as illustrated at Fig. 50, when it is presumed to occupy a position as shown at *C*, Fig. 51. In this Chapter methods are discussed which may be employed to secure identical results when the object is presumed to occupy a position as shown at *A*, Fig. 51.

It may be well to explain that the two demonstrations are for the purpose of illustrating the different positions the object may be assumed to occupy as regards the planes of projection, and yet secure the same results in the finished pattern. It should also be understood that these demonstrations are not for the purpose of recommending either. The pattern cutter must decide which he can best comprehend and employ. No doubt additional positions will be conceived by those who give the matter careful attention.

The elevation is first drawn as shown at *1 9 B A*, Fig. 53, and consists, as before, of a section of the object, although here the base line *A B* is parallel to *I L*.

The base line *A B* now becomes what may be looked upon as the edge elevation of a square surface whose length of side in this instance is 16 inches. The line *1 9* becomes the edge elevation of a circular surface whose diameter is 14 inches. Measurements as here given may be verified from the scale included in Fig. 53.

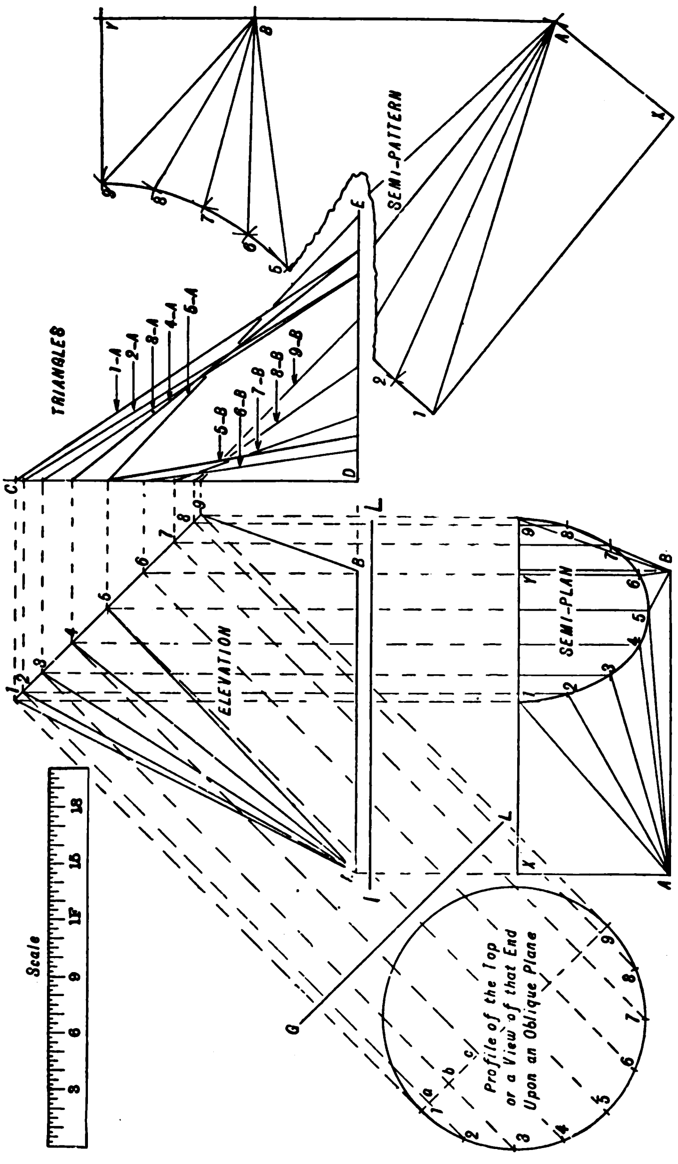


Fig. 53. Diagrams Employed and the Pattern Secured in the Second Demonstration of Developing the Pattern for an Object as Shown at Fig. 50.

Upon referring to Fig. 52 in Chapter XI, it will be noted that these so-called surfaces occupy the same relative positions as there shown. Since the object consists of two equal but opposite halves, and either may be duplicated for the other, we shall only concern ourselves with one-half—i.e., that half nearest the eye.

Since the square end is parallel to the horizontal plane, the semi-plan of the base becomes a rectangle whose dimensions are 8 x 16 inches, as shown in plan at *X A B Y*. The semi-plan of the top or round end becomes a semi-ellipse, since the circular surface referred to above is oblique to the horizontal plane. To draw this ellipse, we assume an oblique supplementary plane parallel to the surface to be represented.

Thus in any convenient position, draw a line parallel to *1 9* of the elevation as *G L,* Fig. 53. This line becomes the intersecting line between a supplementary plane and the vertical plane of projection. Since the supplementary plane whose intersecting line is *G L* is parallel to the top or round end of the object, we may draw upon it, in a position as indicated by the oblique projectors *1 1, 2 2, 3 3,* etc., a circle whose diameter is equal to the round end, which in this instance is 14 inches.

Divide this circle into two equal parts by a line parallel to *G L.* Divide one half of this circle into an equal number of equal parts as shown at *1, 2, 3, 4,* etc., of the circle upon the oblique plane. Project these points of division to line *1 9* of the elevation, thereby locating points whose positions have previously been established upon the oblique plane. Points thus secured in elevation, with the exceptions of *1* and *9,* may be looked upon as the end elevations of lines which connect portions of the circle nearest the eye to points of the right line whose projection upon the oblique plane is *1 9*. Since these lines are represented in elevation by points, they must be perpendicular to the vertical plane, therefore parallel to the horizontal plane of projection. The plans of said lines will be found in lines let fall from points *1, 2, 3, 4,* etc., of the elevation, perpendicular to *I L*.

Importance of a Knowledge of Orthographic Projection.

The question now presents itself, "What is the distance from that point to the point beyond?" This is a question which frequently arises in pattern development, and a correct answer is the solution of many problems. However an ability to answer all such questions can only be acquired by a knowledge of Orthographic Projection, the fundamental principles of which were discussed in Chapters IX and X.

Since we have confined ourselves to developing the pattern for one half of the object, we may look upon the line *X Y 9* of the semi-plan, Fig. 53, as a line which divides that diagram into two equal parts, and is, of course, farthest from the eye. Therefore we are chiefly concerned in determining the lengths of lines which connect these points of the round end nearest the eye, and terminate at *X Y 9*.

As previously stated, the plans of lines whose end elevations are in points *1, 2, 3, 4,* etc., of the elevation, are found in lines drawn from these points perpendicular to line *I L,* as *2 2, 3 3, 4 4,* etc. The intersections of said lines with line *X Y 9* must be the extremities of those lines which are farthest from the eye. Upon determining their lengths, their extremities nearest the eye may be located.

The line *1 9* of the profile divides that circle into equal parts, therefore the plan of point *1* is a point upon line

X Y 9 as shown at *1* of the plan. The length of line *2*, whose end view is at *2* of the elevation, is shown at *2 a* of the profile, and this distance set off from line *X Y 9* gives us point *2* of the plan. The length of line *3* in plan is *3 b* of the profile, and *4* is *4 c* of the profile. In like manner the lengths of additional lines shown are set off from the line *X Y 9* of the plan to secure points through which the curve is traced. This is a plan of the top of the object.

Points thus located are used as points to which lines are drawn from the vertices of angles at *A* and *B*, to secure the plans of lines presumed to be upon the surface of the object, thus dividing said surface into triangles. The elevations of said lines are now drawn in the same general manner as was explained in the first demonstration, and here shown in the elevation, Fig. 53.

In this example as with the first, the true lengths of lines whose plans are *X 1* and *Y 9* are found in elevation in lines *1 A* and *9 B*. The true length of each remaining oblique line will be found in the hypothenuse of a right angled triangle whose base is equal in length to the plan of the line, and whose perpendicular is equal in length to the difference in hight of the extremities of that line from *I L*, as clearly shown in the diagram of triangles.

Upon examination of the diagram of triangles, Fig. 53, it will be noted that the lines *C D* and *D E* have been drawn at right angles to each other, and form two sides of the right angled triangle from which we secure the true lengths of lines. The hypothenuse of each is located by first setting off from *D* along the line *D E*, the length of the line in plan, and locating points along line *C D* equal in distance from *D* to the vertical hight of the line shown in elevation.

As for example, the length of line *A 1* in plan is set off as shown from *D* on the line *D E*. The vertical hight of line *A 1* shown in elevation is at *C*, and a line is drawn to said points as shown at *1 A* of the diagram of triangles. This line, as will be noted, is the true length of line *A 1* upon the surface of the object. It is only to be remembered that the true lengths of all remaining lines are secured in a similar manner, as clearly shown by construction lines in the diagram of triangles.

In transferring the lengths of lines, we may use the same general methods as explained in previous demonstrations. The first line to be placed upon the plane of development is *1 X*, whose true length is shown at *A 1* of the elevation. The lines *X A*, *A B*, and *B Y* are in their true lengths in plan, and the true length of line *1 A* is found in the diagram of triangles as above described. In fact the length of each line whose true length is not shown in plan or elevation is found in the diagram of triangles.

If it is remembered that the true distance between indicated points of the top is found between similar points upon the circle shown upon the supplementary plane, and as the diagrams have been drawn to the scale included, one should have little difficulty in securing a clear understanding of this, a second demonstration of developing the pattern for an object whose specifications were given in Chapter XI.

CHAPTER XIII.

A Transitional Elbow from Round to Rectangular

The fitting illustrated at Fig 54, whose most common use is found in furnace work, supplies us with a comparatively simple example in pattern development. A fitting of this class may be modified in many ways and

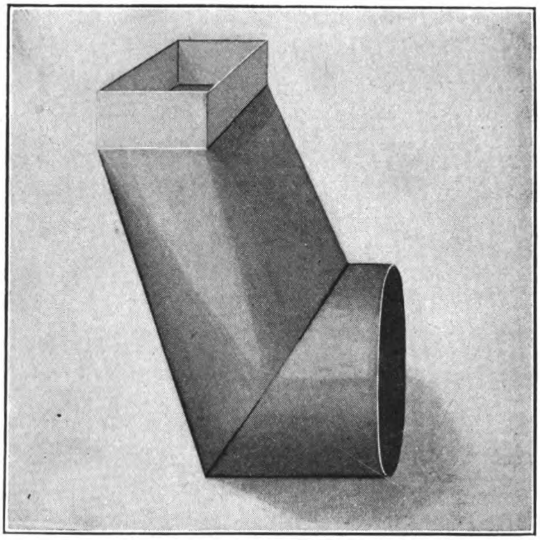


Fig. 54. Photographic View of a Transitional Elbow.

not materially alter the method of securing its pattern. For convenience, we shall presume it to be made to given dimensions, which may be verified by the use of the scale in Fig. 55.

We propose to secure the pattern for a fitting which will make a right angled connection between a round and a rectangular pipe, whose dimensions are as follows: Diameter of round pipe 15 inches, cross sectional dimensions of the rectangular pipe of 6 x 24 inches. Their relative positions are shown in the elevation Fig. 55, since the line *A B* of that view is the edge view of the lower extremity of the rectangular pipe, and that portion included within the lines *1 9, 9 a, a b,* and *b 1* represents one extremity of the round pipe. It will be noted that the round pipe is here shown to be cut oblique to its axis, and to this the irregular portion of the fitting is connected.

The Irregular Portion.

The irregular portion, with which we are chiefly concerned, becomes a form making a transition from elliptical to rectangular, the ends of which are not parallel. This presents a problem which is not unlike some previously explained; however, if we attempt to follow those methods it will be difficult to determine the exact form and size of the elliptical end. This can be accomplished theoretically, but in practice it is somewhat difficult to work with the accuracy demanded when the irregular portion is to be seamed to the round collar. Other methods than those previously shown will give more accurate results in practice, and are illustrated and explained in this demonstration.

Plan and Elevation.

The most simple diagram which will represent the object shown at Fig. 54 is a section, and shown as an elevation in Fig. 55. At least two views are necessary to enable us to secure the true lengths of lines presumed to be upon the surface of the object, therefore the next work will be to draw the second view, which is a semi-plan. Since the object is composed of two equal but opposite halves, it is only necessary to represent one-half in plan.

To secure this semi-plan, we let fall perpendicular lines from points *A* and *B* of the elevation, and make them 12 inches in length from *I L,* as shown at *X A* and *Y B.* Upon drawing the line *A B* as shown, the semi-plan of the rectangular pipe in its assumed position is completed.

That portion of the elevation included within the lines *9 1, 1 b, b a,* and *a 9* represents a round collar which has been cut obliquely, and to secure a plan of this it will be most convenient to locate a number of elements upon its surface. Therefore in any suitable position to the right of line *G L,* draw a semi-circle whose diameter is 15 inches. This constitutes a profile, or an end view of the round collar upon a profile plane, of which *G L* is the intersecting line between it and the primitive vertical plane.

Divide the semi-circle into a number of equal parts as shown. From said points of division right lines are drawn parallel to line *I L* to intersect the miter line *1 9.* These points of intersection upon the miter line, as at *1, 2, 3, 4,* etc., are now looked upon as the end elevations of lines which are perpendicular to the vertical plane of projection; therefore their plans will be found in lines let fall from said points at right angles to *I L,* as shown. The lengths of these lines are found in the distances similarly numbered points of the semi-circle are from the line *G L.* These lengths are set off from the line *I L* in plan, as also shown. This, as will be noted, locates points through which the curved line is traced to complete a semi-plan of the oblique end of the round collar.

Points located as above described may now be connected by lines to points *A* and *B* as shown, to supply

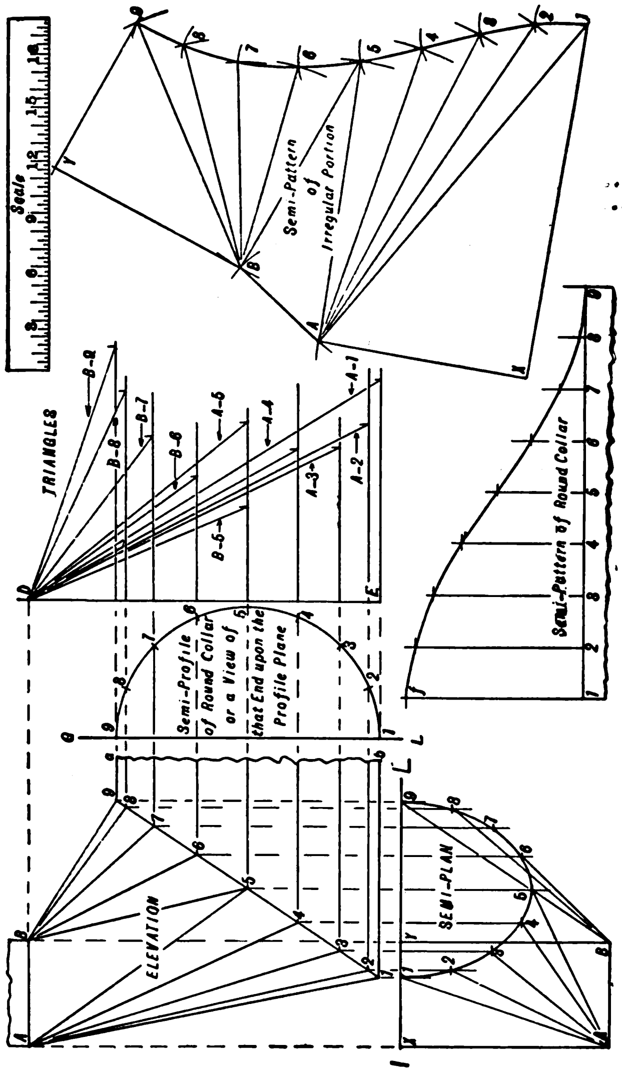


Fig. 55. Plan, Elevation and Semi-pattern for a Transition Elbow.

the plans of lines presumed to be upon the surface of the object, and utilized as measuring lines to be transferred to the plane of development, although their true lengths must yet be determined. The elevations of lines whose plans are shown at *A 1, A 2, A 3, A 4, A 5, B 5, B 6, B 7, B 8* and *B 9* of the semi-plan, Fig. 55, are secured by drawing lines from points *2* to *5* inclusive to *A,* and from *5* to *8* inclusive to *B,* as shown in the elevation.

True Lengths of Lines.

The true lengths of these lines are secured by the use of the right angled triangle, as shown in the diagram of triangles, where the line *D E* is used as the perpendicular for all, with a common vertex at *D.* The horizontal lines of the elevation, as *1 1, 2 2, 3 3,* etc., represent the hight of the lower extremities of these lines—i. e., the lower extremity of line *A 2* is at point *2* of the elevation, and so on for all lines shown.

The vertical distance from those lines to line *B D* is the perpendicular hight of each triangle, and the lengths of these lines in plan is the base of each triangle, as will be clearly shown if the reader, by the use of his compasses, will compare measurements.

Having determined the true lengths of lines shown in plan and elevation, we may proceed to transfer these lengths to the plane of development in the process of securing the pattern.

To Develop the Pattern.

There is shown in plan at *A X 1* a triangular surface whose edge elevation is the line *A 1* of that view. Since the line *X 1* is parallel to *I L,* its true length is *A 1* of the elevation, and this length is transferred to line *X 1* of the semi-pattern. From point *X* of the semi-pattern draw a line perpendicular to *X 1,* and set off a distance from *X* equal to the length of line *A X* of the semi-plan, as shown at *A* of the semi-pattern. Upon drawing the line *A 1,* the true form of the triangular surface has been placed upon the plane of development.

It may be well to here explain that where right triangular surfaces are shown in plan, those triangles will be right angled in their true form; therefore we may transfer them to the plane of development in the manner as above explained, or employ our compasses to transfer the length of each of the lines of which the triangle is composed. The author has made a practice of employing his compasses to transfer the lengths of lines. If the resulting triangle is right angled, a portion of his work is proven.

Upon examination we find five lines radiating from point *A* of the plan or elevation, Fig. 55, whose true lengths are shown in the diagram of triangles. Therefore we may use these lengths as radii, and with point *A* of the pattern as center to describe small arcs as shown at *2, 3, 4* and *5* of the semi-pattern of the irregular portion. Since the distances between the lower extremities of these lines are not shown in plan and elevation, they must be determined. As has been previously stated, this can be done approximately by securing the true form of the oblique section of the round pipe, and will be explained below. For the present we shall pursue the more accurate and simple method of first developing the pattern for the round collar. As this may be looked upon as the pattern for one section of an elbow in round pipe, the miter line of which has been located, it is not an example in triangulation.

The same elements are employed to secure this pattern as are shown in elevation, therefore the lower extremities of lines whose true lengths are shown in the diagram of triangles must intersect these elements of the cylinder at the miter cut. This being understood, the reader will realize that the distance between lines as *A 1, A 2, A 3,* etc., at the lower extremity of the irregular portion, must be the same as shown between similarly designated elements upon the miter cut of the round collar. Therefore

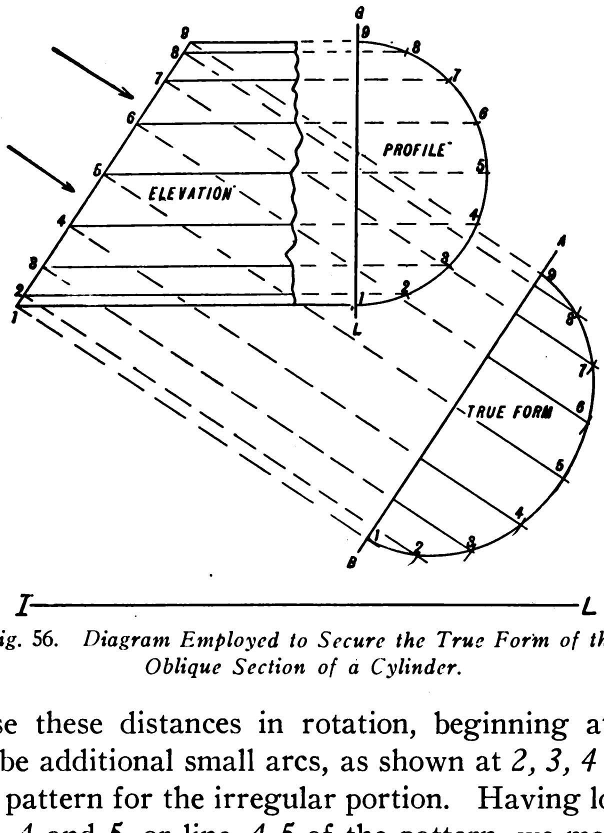


Fig. 56. Diagram Employed to Secure the True Form of the Oblique Section of a Cylinder.

we use these distances in rotation, beginning at *f* to describe additional small arcs, as shown at *2, 3, 4* and *5* of the pattern for the irregular portion. Having located points *A* and *5,* or line *A 5* of the pattern, we may add the triangular surface shown in plan and elevation at *A 5 B.*

The line *A B* is in its true length in either plan or elevation; therefore we may set our compasses to a span equal to the length of line *A B* of the elevation, and placing one point at *A* of the pattern, describe the small arc shown at *B*. From the diagram of triangles we secure the true length of line *5 B*, which we use as radius, with point *5* of the pattern as center, to draw the second small arc as also shown at *B*.

There are five lines radiating from point *B* in elevation, whose positions may be located upon the plane of development in the same general manner as was explained for those radiating from point *A*. Presuming the extremities of line *B 9* to have been located, the remaining triangular surface, *B Y 9* may be added, since from the plan we secure the true length of line *B Y*, and in the elevation the true length of line *Y 9* is found in line *B 9*.

It is by no means necessary that the semi-circle or profile shall be divided into the number of parts shown in this demonstration. Divide the profile into any equal number of parts desired. More parts will increase the work, and increase the accuracy to some extent.

Form of the Round Collar at the Mitered End.

The true form of the oblique section of a cylinder is an ellipse,* the minor diameter of which is equal to the diameter of the cylinder. The major diameter is dependent upon the length of the miter line, when it can be looked upon as the edge view of a plane which has cut said cylinder. Therefore, in this instance, the true form of the round collar at the miter cut is an ellipse whose

* No part of a true ellipse is a part of a circle, therefore any method which involves arcs drawn from centers will not produce a true ellipse. Approximate ellipses drawn in this manner are sometimes known as false ellipses, and in some instances are found to be sufficiently accurate.

minor diameter is 15 inches, and whose major diameter is approximately 18 inches, and can be drawn by any method which secures a true ellipse.

Perhaps the most desirable course to pursue is to secure this ellipse by projection as follows: Draw the side elevation of the cylinder as shown in Fig. 56. Draw a semi-circle whose diameter is equal to that of the cylinder as shown in the profile. Draw a line as *A B*, parallel to the miter line.

We now have what may be looked upon as the side elevation of one half of the cylinder, showing the miter line, and drawn upon the primitive vertical plane. To the right of the elevation is the profile plane, with the line *G L* as the intersecting line between this and the primitive vertical plane. To the right and below, the true form is shown upon an oblique supplementary plane, which is also perpendicular to the primitive vertical plane. This is a projection of that portion of the cylinder represented in elevation by line *1 9* upon a plane parallel to it, when viewed as indicated by arrows.

The semi-circle shown as a profile is divided into a number of equal parts, and from these points of division lines are drawn parallel to *I L* to intersect the miter line. From points thus secured as *1, 2, 3,* etc., upon the miter line, project lines perpendicular to *A B* as shown. From the intersections of these lines with *A B,* set off distances as found from line *G L* to similarly numbered points of the semi-circle, thereby securing points through which the curve of the ellipse may be traced.

The distances between points of the ellipse are substantially the same as found by the more simple method of first determining said distances by developing the pattern for the round collar. We can, if we choose, use that form for the base, and develop the pattern in the same general manner as was explained in Chapter XI. However, this process will be found to be more complicated, and less accurate in pattern problems of this class.

CHAPTER XIV.

TRANSITIONAL OFFSET FROM ROUND TO RECTANGULAR.

Throughout this work the author has endeavored to direct the reader's attention to the importance of an understanding of the principles involved. To those who have followed the work, it must have become evident that the solution of all problems coming under the head of

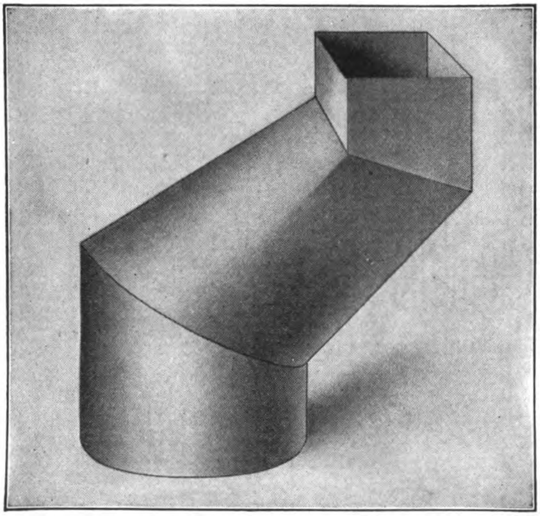


Fig. 57. Photographic View of a Transitional Offset.

Triangulation presents a great sameness. An understanding of how best to draw the first diagrams to represent the object for which a pattern is required is an important factor.

Attention is here directed to the transitional offset as shown pictorially at Fig. 57. The offset is for the purpose of making connection between a round and a rectangular pipe. The diagrams shown have been drawn to the scale appended. The diameter of the round pipe is 14 inches, with cross-sectional dimensions of the rectangular pipe of 7 x 20 inches, whose relative positions are shown in plan and elevation, Fig. 58.

The Capacity of the Fitting.

It will be noted upon examination of the elevation that both the round and rectangular pipes have been cut obliquely. This has been done, as has been previously explained, for the purpose of preserving the capacity of the fitting, whose most common application is found in furnace work, although similar examples will occasionally come before the sheet metal worker in other lines.

The specification tells us that in this instance, a transition is required between a 14 inch round pipe and a 7 x 20 inch rectangular pipe, with an offset of 8 inches as shown, and to be accomplished in a distance of 14 inches. With the above information in hand, it is but a simple matter to draw an elevation as shown by the boundary lines of that diagram, Fig. 58.

An Analysis of the Fitting.

The positions of lines which represent the connecting, or miter lines between the collars and the center irregular portion are by no means arbitrary, although their locations must be governed to some extent by existing conditions. Having located these lines to our satisfaction, somewhat as shown in elevation, we find from an analysis of the problem that the fitting is composed of three parts, i.e., we have a round collar with one end cut obliquely, which may be looked upon as one piece of an elbow in

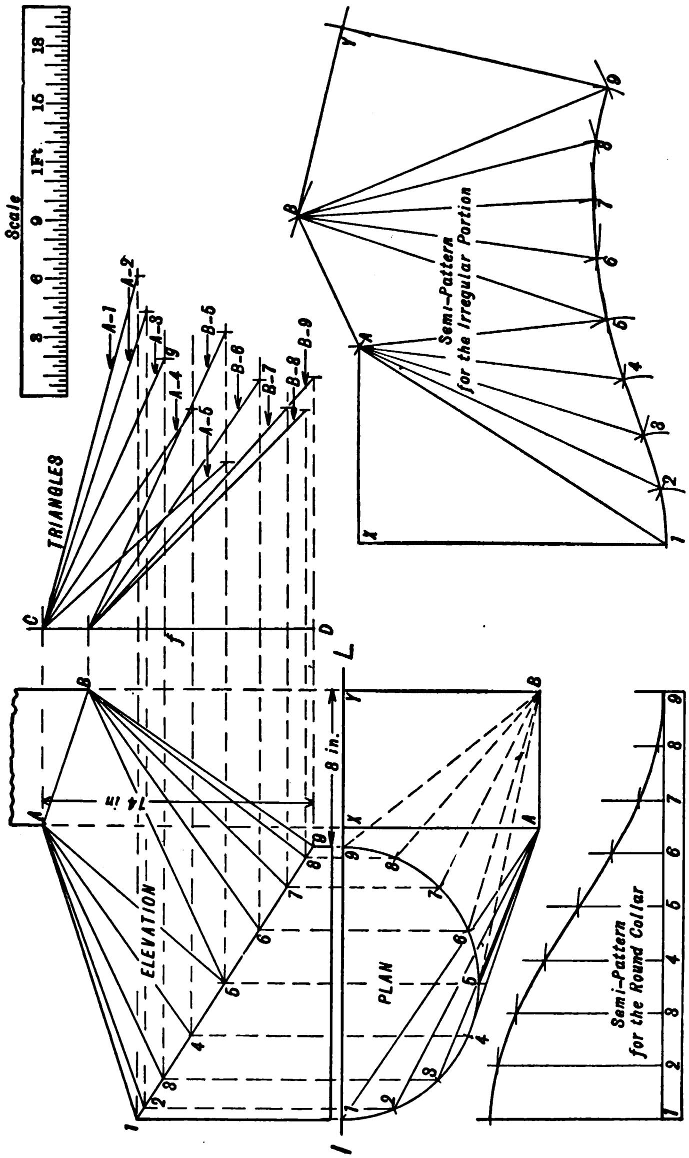


Fig. 58. Elevation, Semi-plan and Semi-pattern for a Transitional Offset.

round pipe. A collar for the rectangular pipe, which is also cut obliquely, and a center portion, which is an irregular one, making a transition from elliptical to rectangular, the ends of which are not parallel. To develop the pattern for this piece is the subject matter of this chapter.

It may be explained that to secure this pattern it is by no means necessary to follow the course here recommended, although some course must be pursued which will enable the worker to determine the true lengths of lines presumed to be upon the surface of the object. Since the diagrams shown in Fig. 58 are about as simple as the nature of the problem will permit, one will hardly go astray if he follows them absolutely.

The Plan.

After having drawn an elevation, which is in reality a section of the object, the next step is to secure a plan, or at least a semi-plan, as the fitting is here shown to be composed of two equal but opposite halves.

The semi-plan of the round collar is a semi-circle with a diameter of 14 inches, and in a position as shown. A semi-plan of the rectangular collar in its assumed position is a rectangular diagram, as *X A B Y* of the plan, and in position as clearly shown by the vertical projectors.

Divide the semi-circle of the plan into an equal number of equal parts, thereby locating one point which divides it into two equal parts as *5* of the plan. Draw lines from all points thus located upon the arc *1 5* to point *A,* and from points upon the arc *5 9* to point *B* as shown in plan. This secures the plans of lines which we presume to be upon the surface of the fitting. The elevations of the above lines are secured by projecting lines from points as *1, 2, 3, 4,* etc., of the semi-circle, perpendicular to *I L* to intersect the oblique line *1 9* of the elevation as at *1, 2, 3, 4,* etc., of that view. From these points upon the oblique line *1 9,* lines are drawn to points *A* and *B* as shown in elevation to secure elevations of lines whose plans have previously been drawn.

True Lengths of Lines.

Having now before us the plans and elevations of lines which are presumed to be upon the surface of the fitting, it remains to determine their true lengths and relative positions, also to place them upon the plane of development in those lengths and positions. The plan of the line supplies the base, and the difference in hight of the extremities of the line as shown in elevation, supplies the perpendicular of a right angled triangle, whose hypothenuse is the true length of the line, as is clearly shown in the diagram of triangles.

As for example, we select line *3 A* of the plan; its elevation is *3 A* of that view. The difference in hight of the extremities of that line has been determined by drawing lines to the right from points *A* and *3* of the elevation, and parallel to *I L* as *A C* and *3 f.* Then C *f* is the difference in hight of the extremities of line *3 A,* or the perpendicular of a right angled triangle whose base is equal in length to line *3 A* of the plan, or *f g* of the diagram of triangles. Similar work and reasoning will enable one to secure the true lengths of all lines radiating from points *A* and *B* of the plan. When the true lengths of all lines have been secured as shown in the diagram of triangles, the pattern can quickly be developed as shown.

The Pattern.

Beginning with the line whose plan is *1 X,* we find its true length in line *1 A* of the elevation. This length is set off upon the plane of development as at *X 1* of the pattern. The true length of line *1 A* of the plan is found in *1 A* of the diagram of triangles. Its lower extremity is at point *1* in all views, and its upper extremity at *A* is at a distance from *X* equal to the length of line *X A* of the plan.

We have in this demonstration four additional lines radiating from point *A,* whose true lengths are shown in the diagram of triangles, and since said lines radiate from a single point, we have only to determine the distances between their lower extremities. Should the reader experience any difficulty in comprehending this, he is advised to refer to Chapter XIII, where this feature was explained to some length.

Upon developing the semi-pattern for the round collar as shown, these distances are secured and used as radii to draw small arcs in rotation, thereby locating the lower extremities of lines as shown at *A 1, A 2, A 3, A 4* and *A 5.* Presuming that the line *A 5* has been located upon the pattern as shown, an examination of the plan and elevation shows that the triangular surface *A 5 B* should now be added.

The true length of line *B 5* is found in the diagram of triangles. Using this length as radius and with point *5* of the semi-pattern as center, a small arc is drawn as shown at *B* of the pattern. The true distance from *A* to *B* is shown in the length of line *A B* of the elevation. Therefore that length is used as radius with point *A* of the semi-pattern as center, to draw the second small arc at *B,* thereby locating the upper extremity of line *B 5* upon the pattern as shown.

There are also in this example, four additional lines radiating from point *B.* As before, the true lengths of these lines are found in the diagram of triangles, which may be used as radii in rotation, using point *B* of the pattern as center, to describe small arcs as shown at *6, 7, 8,* and *9.* The true distances between these points are found, as before, between similarly numbered elements of the round collar upon the miter cut. Using these in rotation, the second small arcs are drawn to intersect the first, thereby locating points which are in reality the lower extremities of lines *B 6, B 7, B 8* and *B 9,* as shown upon the pattern. Having drawn the line *B 9* upon the semi-pattern, the remaining triangular surface as there shown is located by first locating point *Y.*

We find upon examination that the true distance between points *B* and *Y* is the length of *B Y* of the plan, and that the true distance between points *9* and *Y* is the length of line *9 B* of the elevation, thereby enabling us, by the use of our compasses, to locate point *Y* as shown upon the pattern.

Upon drawing lines *B Y* and *Y 9* the semi-pattern is complete, which when duplicated, and formed in the opposite direction, will combine with the pattern here shown, to complete the irregular form necessary to make connection between the round and rectangular pipes when cut obliquely as shown in elevation.

CHAPTER XV.

A Three Pieced Tapering Elbow.

The solution of the problem here presented should interest the pattern cutter, although the demand for a fitting of this class is limited. An endeavor is made in this example to satisfy a popular demand for something out of the ordinary. Therefore the fitting, as shown in Fig 59, has been presumed to be what is commonly known

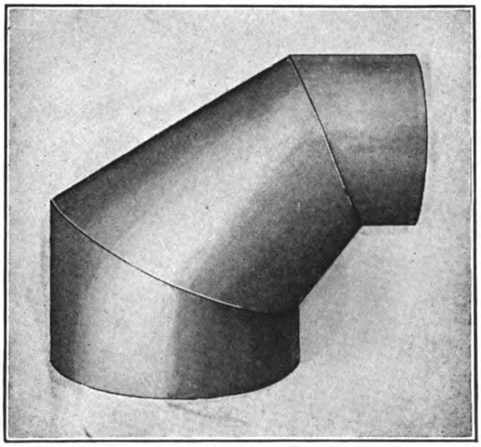


Fig. 59. Photographic View of Three-pieced Tapering Elbow.

as flat on one side. This necessitates the developing of the pattern for the whole irregular portion, as one half cannot be duplicated for the other.

In examples of this nature there are no additional principles to be applied, but it adds to the complication of lines shown in the diagrams. Unless they are given careful attention, no doubt these diagrams will appear complicated. On the other hand, some attention to this will pave the way for one to successfully develop patterns for those objects which have more or less of a distorted form, since some principles as here explained, may be applied to practically all such examples.

The scenographic representation of the object, and the planes within which it is presumed to be situated, as shown at Fig. 60, has been introduced in an endeavor to show to some extent, in a pictorial way, the value and

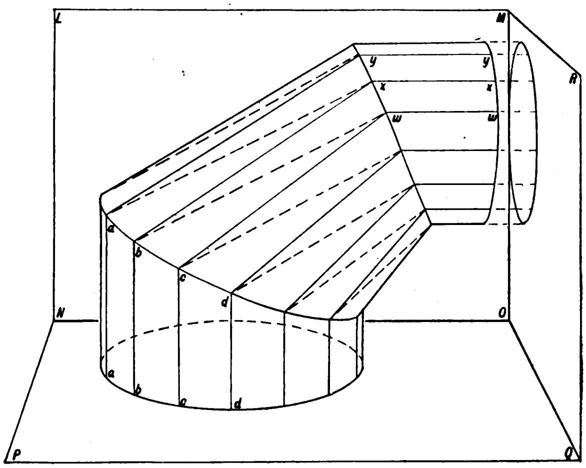


Fig. 60. Scenographic Reproduction of Elbow and Lines Presumed to Be Upon Its Surface, Also the Planes Within Which It Is Presumed to Be Situated.

positions of lines whose plans and elevations are shown in Fig. 61.

It will be noted that the fitting consists of three parts, i.e., there are two round collars placed in positions which are in this instance, at right angles to each other, and one piece forming a center portion. This demonstration deals chiefly with the center portion, since the round collars are but parts of elbows in round pipe of different diameters. The center portion is in reality a transition, or a change of form to make the necessary connection as shown. The ends of this piece are elliptical, since said ends connect cylinders which have been cut obliquely. Therefore we could determine the size and form of the oblique ends of the round pipes or collars, and consider the center portion as a transition whose ends are elliptical and not in parallel planes, although perhaps the more simple course to pursue is as will be here explained.

The Elevation.

The most simple diagram to be drawn which will represent a fitting as illustrated at Fig. 59, is an elevation somewhat as shown at Fig. 61. The author has used the word "somewhat" for the reason that considerable change may be introduced into the fitting and yet employ the same methods of securing its patterns. The positions of the miter lines are by no means arbitrary, although in this instance they have been given the same inclination that would prevail in a three pieced elbow in round pipe.*

The Plan.

Having drawn the diagram to represent the object, which is to some extent a section as shown by the boundary line of the elevation, Fig. 61, the plan may be proceeded with. The large circle in plan is drawn to the diameter of the large collar, and in a position as shown. To secure a plan of the small collar involves somewhat more detail. The small collar in this example is parallel to the horizontal plane, with one end cut obliquely. A plan of the oblique end becomes an ellipse. To secure this ellipse, we presume lines to be upon the surface of the

* If the reader desires information on the development of patterns for elbows in round pipe, he will find that the book "Elbow Patterns for all forms of Pipe" explains this in every detail.

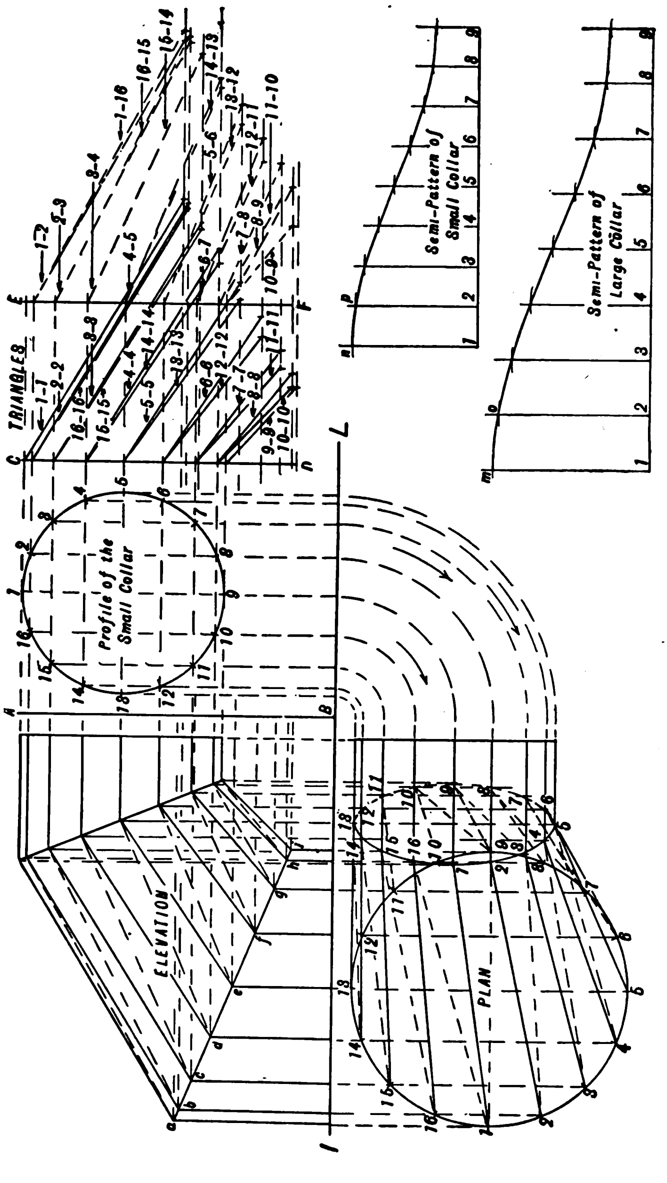


Fig. 61. Plan, Elevation, Diagram of Triangles and Semi-patterns of Round Collars.

collar, and to locate those lines we introduce the profile plane. As for example, a circle is drawn to the right of the elevation whose diameter is equal to the diameter of the small collar, and in a position as shown. For convenience, this circle is divided into an equal number of equal parts, and from said points of division, lines are drawn parallel to line *I L* to intersect the miter line of the small collar. Such lines are known as elements of the cylindrical surface, and their left hand extremities are now points in the ellipse. In other words, those lines terminate at the miter line, since said miter line is looked upon as the edge view of a plane which has cut said cylinder, and since this plane is represented in elevation by a right line, it must be perpendicular to the primitive plane of projection.

From points secured by the intersections of the elements of the cylinder with the miter line, perpendicular lines are drawn of indefinite lengths below the line *I L,* then points in the ellipse must lie in some points along these lines. From what has been explained in previous demonstrations, it should be understood that when the profile of the small collar was drawn, an additional plane was presumed which is known as a profile plane, and the line *A B,* presuming it lies in the plane of the paper, may be looked upon as a vertical axis upon which said profile plane may be presumed to revolve.

This is shown in a pictorial way at Fig. 60, where *L M O N* represents the vertical plane, *N P Q O* the horizontal plane, and *M R Q O* the profile plane. The line *N O* is the intersecting line between the vertical and horizontal planes, while *M O* corresponds to the line *A B* of the elevation, Fig. 61. Since the line *A B* of the elevation lies in the vertical plane, its plan must be a point in line *I L,* as at *B,* Fig. 61. If perpendicular lines be drawn from the points of division of the circle in elevation to intersect line *I L,* said lines must be distant from line *A B* equal to the distance points are from which these lines have been drawn from the primitive vertical plane.

If these distances are revolved about the point *B* upon the horizontal plane, then said distances are located upon that plane. Lines now drawn through these points so revolved, and parallel to the line *I L,* will intersect vertical lines drawn from the miter line in points which are located in the ellipse as at numbered points of that diagram.

Relative Position of the Large Circle in Plan.

It may be explained that the large circle in plan which represents the large collar must be placed in its correct relative position. For example, if the fitting is to be made in two equal halves, then the axis of each collar will be represented in plan at the same distance from line *I L,* but if in an instance as here shown, where one side of the fitting is flat and composed of two unequal parts, then the circle in plan which represents the large collar must be so placed as to allow one side of the fitting to be represented in plan by a line parallel to *I L.*

Presuming lines to have been drawn whose intersections upon the horizontal plane are points in the ellipse, as shown in plan, Fig. 61, we are now in a position to locate lines which are looked upon as being upon the surface of the object, somewhat as follows: Divide the large circle in plan into the same number of equal parts as the small circle of the profile has been divided into. Draw lines from each point of the large circle to a similarly numbered point of the ellipse, as *1 1*, *2 2*, *3 3,* etc. This secures plans of the above spoken of lines. To secure the elevations of said lines, project vertical lines from the points of division of the large circle to intersect the miter line of the large collar in elevation. Lines drawn, as shown by full lines upon the irregular portion in elevation, supplies elevations of those lines whose plans are *1 1, 2 2, 3 3,* etc.

A Practical Demonstration.

If the reader has any difficulty in comprehending this, he is advised to lay out two collars something like those whose semi-patterns are shown in Fig. 61, with a number of equi-distant parallel lines, as shown at *1, 2, 3, 4,* etc., of those patterns. Form them, and secure them in positions as suggested by the diagrams. He may then presume to draw strings between the extremities of the equi-distant lines, using care that the first one is from the longest line of each collar. He will then find that the strings so drawn will include the form for which the pattern is required, and the strings may be looked upon as elements of that surface.

The reader may draw upon his imagination to see this in Fig. 60, where lines as *a a, b b, c c* and *d d* are the equi-distant parallel lines, or elements of the large collar. Lines as *y y, x x,* and *w w* are the equi-distant parallel lines or elements of the small collar, and lines as *a y, b x,* and *c w* represent the strings. As these strings include the surface of the required form, it is evident that we have only to determine the length of each string and the distance they are from each other to develop the pattern.

However, since the strings represented by the full lines will not divide the surface into triangles, we are obliged to introduce additional lengths of string, as shown by the broken lines. These must be represented in plan to secure the pattern from the diagrams. This is accomplished, as will be noted, when the broken lines are drawn as *1 2, 2 3, 3 4,* etc., in Fig. 61.

The True Lengths of Lines.

With the plan and elevation complete as shown at Fig. 61, we now proceed to secure the true lengths of lines presumed to be upon the surface of the object, i.e., we may construct our triangles. This is but a simple operation if it is remembered that the plan of the line supplies the base, and from the elevation the perpendicular is secured. For example, we may draw indefinite horizontal lines through the points of division of the profile as shown. From the intersections of lines presumed to be upon the large collar with its miter line as at *a, b, c, d,* additional horizontal lines are also drawn.

In any convenient position we may draw a perpendicular line as *C D* of the diagram of triangles, and presume the perpendicular of a number of triangles to lie in this line. For example, we select the line *1 1* of the plan and set off its length from *C D* upon the horizontal line drawn from *a* as shown. The point *C* represents the vertical hight of the upper extremity of that line, therefore upon drawing a line as *1 1* of the diagram of triangles, the true length of that line is before us.

This operation must be repeated for each line represented, since there is no guarantee that any two will be of the same length. It should also be remembered that the true lengths of those lines, as *1 2, 2 3, 3 4,* etc., shown as broken lines, must also be secured. This is accomplished in the same general manner as has been explained for the full lines, and shown in the diagram of triangles where the upper extremities terminate at line *E F.*

The Pattern.

To locate lines upon the plane of development which we have presumed to be upon the surface of the object, in their correct lengths and positions, now becomes a simple, although a somewhat prolonged operation. In practice it may be well to develop the pattern as the true lengths are secured. This course will very likely render one less liable to error, inasmuch as each length may be utilized when determined, thereby avoiding to some extent, that complication of lines shown in the diagram of triangles.

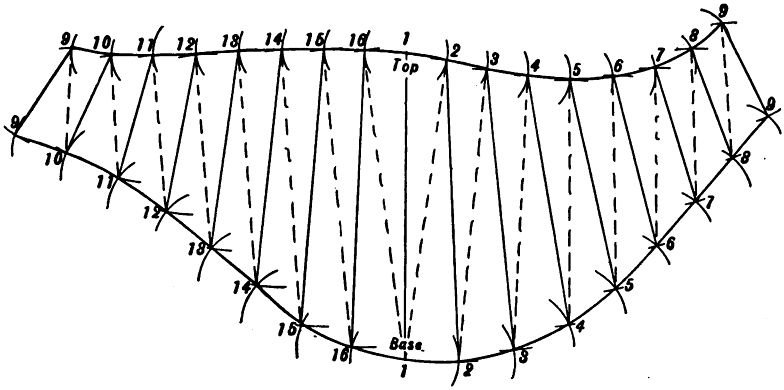


Fig. 62. Pattern for Center Piece of Elbow.

The distance lines are from each other at their extremities is clearly shown upon the mitered ends of the collar patterns, which we shall presume to have been first developed. Since these patterns are but portions of elbows in round pipe, we will pass directly to the pattern for the center piece. In examples of this nature it may be well to first place the longest full line as *1 1* upon the plane of development in its true length, as found in the diagram of triangles. By working each way from this line so located, we may avoid some additional opportunity for error.

No attempt will be made here to describe in detail the method of locating each and every line shown, since that simply involves duplicate operations, as has been frequently explained in foregoing demonstrations. However, we will select a few lines as an example, and if the reader comprehends the methods of locating these, he will have little difficulty in completing the pattern as shown. For example, first draw line *1 1* in its true length upon the plane of development. The lower extremities of line *2 2* and *16 16* are distant from the lower extremity of line *1 1* equal to the distance between elements *1* and *2* at the miter cut of the semi-pattern for the large collar as *m o*, Fig. 61. Therefore we set our compasses to a span equal to the distance between points *m* and *o*, place one point at the lower extremity of line *1 1* of the pattern Fig. 62, and describe small arcs as shown at *16* and *2* at the base. It may be explained that for convenience in this example, that end of the center piece which joins the small collar has been designated as the top, and that portion which joins the large collar as the base.

The upper extremities of line *2 2* and *16 16* are distant from the upper extremity of line *1 1* equal to the distance between points *n* and *p* of the semi-pattern for the small collar, Fig. 61. Therefore we set our compasses to the distance *n p* of the pattern for the small collar, place one point at the upper extremity of line *1 1* of the pattern, Fig. 62, and describe small arcs as shown *2* and *16* at the top. The extremities of lines *2 2* and *16 16* must now lie in some points of these arcs.

To determine the exact location of the above spoken of points the broken lines are employed. In other words, if we can determine the true lengths of lines *1 2* and *1 16* we can definitely locate points *2* and *16* at the top of the pattern. Therefore we set our compasses to a span equal to the length of line *1 2* found in the diagram of triangles, and placing one point at *1* of the base, describe the second small arc as at *2* of the top. With compasses set to a span equal to the true length of line *2 2* found in the diagram of triangles, place one point at *2* of the top of the pattern, and describe the second small arc as shown at *2* of the base. With compasses set to a span equal to the true length of line *16 16,* also found in the diagram of triangles, place one point at *16* of the top and describe the second small arc shown at *16* of the base. Lines may now be drawn as shown at Fig. 62 to complete what may be looked upon as two sections of the pattern for the center piece. To complete the pattern, these operations just described are continued, using each true length found in the diagram of triangles, as is clearly shown by the construction lines.

It will be noted that the broken lines shown in plan upon that portion of the object which lies furthest from the eye, connect points in a reverse order from those shown nearest the eye. This not only allows one line in elevation to represent two lines in reality, but allows us to work both ways from line *1 1* of the pattern.

When the pattern is completed it must be formed in the proper direction to allow it to be placed in position as shown in plan. Care should also be used in connecting the collars, i.e., lines as *1 1, 2 2,* etc., should be continuous, or the fitting will be distorted.

CHAPTER XVI.

THE SHIP'S VENTILATOR.

The ship's ventilator as illustrated at Fig. 63, should be of interest to the prospective pattern cutter, chiefly for the reason that it suggests principles and methods which

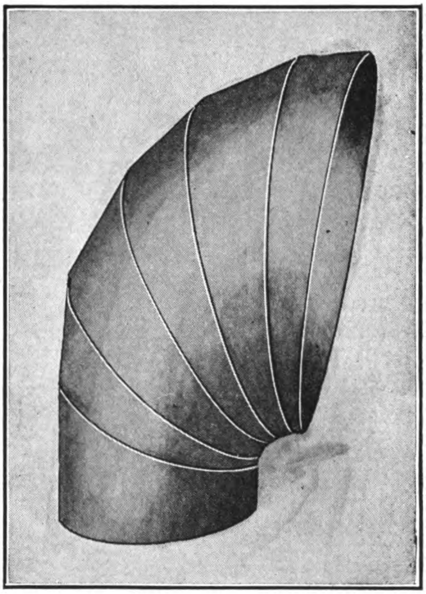


Fig. 63. Photographic View of a Ship's Ventilator with a Round Mouth.

may be introduced in the development of patterns for many fittings of a similar nature.

To the reader who has followed this work it should have become evident that the form of the ends of the object for which a pattern is required must first be established. The author was at one time asked: "How shall I proceed to secure the pattern for a ship's ventilator?" The reply was: "First determine what form it shall be at the miters; beyond this your patterns are but simple examples in triangulation."

This is a point which is often overlooked by those who are slow to realize that in practically all examples where triangulation is to be applied the form of the ends of the object must first be established. This is precisely what is accomplished when a formula is introduced for the construction of the diagrams to represent a ship's ventilator. When the diameter of base, or pipe to which it is to be connected, is the known quantity, the formula which follows has been used to some extent:

FORMULA FOR A SHIP'S VENTILATOR WITH A ROUND MOUTH.

Diameter of base × 2 = diameter of mouth.
Diameter of base × 1½ = radius of back.
Diameter of base × ¼ = radius of throat.
Angle of mouth to the horizontal 80 degrees.

The form of all pieces to be round at each end, and of diameters equal to the lengths of miter lines shown in the resulting elevation.

This formula has been worked out in Fig. 64 to the scale appended, presuming the base to have a diameter of 16 inches, and the fitting to be made in six pieces. It will be noted that the back and throat have been divided into the same number of parts, i.e., into as many parts as the fitting is to have pieces. Lines drawn between these points of division represent the miter lines. As has been previously explained, each miter line may now be looked upon as the edge elevation of a circle whose diameter is equal to the length of the line. There must be as many patterns as pieces in the ventilator, although one-half of each piece may be duplicated for the other half.

To Reduce the Problem to Its Simplest Form.

The most desirable course to pursue in examples of this class is to construct separate elevations of each piece, with one end parallel to the intersecting line (*I L*) as shown at Fig. 65.

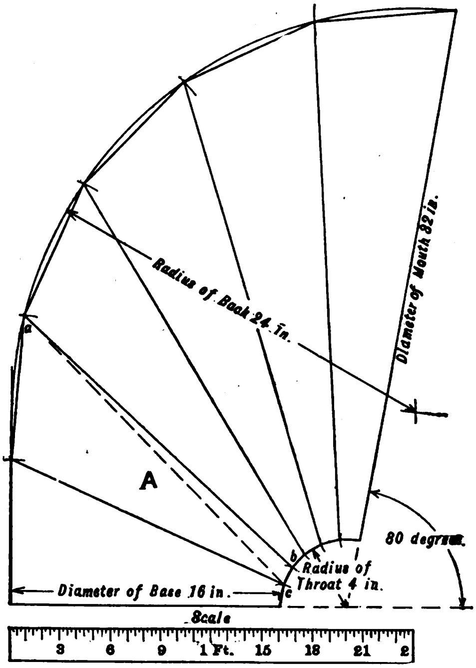


Fig. 64. Side Elevation of a Ship's Ventilator.

The elevation in Fig. 65, as will be noted, is an elevation of that portion of the object marked *A* in Fig. 64, it having been revolved in such a manner as to place the line *a b* of Fig. 64 parallel to the intersecting line. To transfer that diagram is but a simple matter if we draw, or presume to draw, the line *a c* Fig. 64, which then divides that section into triangles, and may be transferred by the use of our compasses and straight edge.

Having drawn the elevation of section *A,* Fig. 64, as shown at Fig. 65, the plan is secured by drawing semi-circles as shown, i.e., we draw a semi-circle in plan whose diameter is equal to the length of the base line, for a plan of the base. To secure a plan of the top, a supplementary oblique plane is assumed whose intersecting line in this instance is the oblique line *9 1* of the elevation. Above this line, as shown, a semi-circle is drawn whose diameter is equal to the length of line *1 9.*

Divide each semi-circle into the same number of equal parts as shown. Draw lines from the points of division of the semi-circle representing the true form of the top, perpendicular to the oblique line *9 1* to intersect that line as shown in points *1, 2, 3, 4,* etc. From these points, i.e., *1, 2, 3, 4,* etc., upon the oblique line *9 1* of the elevation, draw indefinite lines perpendicular to the line *I L.* Set off distances upon these lines below the line *I L* equal to the length of similarly numbered lines which cross the semi-circle representing the true form of the top. A line traced through points thus secured supplies a plan of the top, together with a number of points which are utilized in developing the pattern.

Draw full lines between points of the same number in plan as shown. This supplies plans of lines presumed to be upon the surface of the object. However, since these lines do not divide the surface into triangles, additional lines must be assumed. Plans of these are secured when the broken lines are drawn, as *1 2, 2 3', 3 4,* etc.

If the reader has any difficulty in comprehending this, he may cut from sheet metal or cardboard a form as indicated by the semi-circle in plan, the elevation, and the true form of the top, Fig. 65. When this is cut, it may be bent at an angle of 90 degrees upon the lines which represent the base and top in elevation. He will then have a form which is illustrated to some extent in Fig. 66, although it is there represented as a solid. By placing this in the angle formed by the two planes which are at right angles to each other, also shown in Fig. 66, and remembering that the plan of a point is always directly

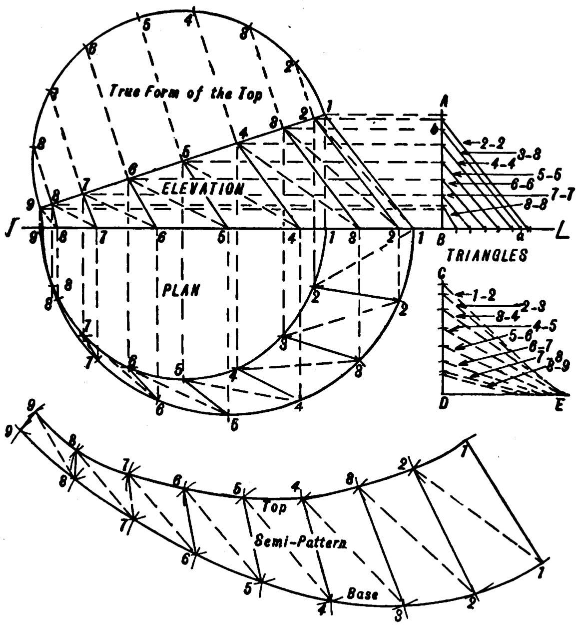


Fig. 65. Plan, Elevation, Diagram of Triangles and Semi-pattern for One Piece of a Ship's Ventilator.

beneath it, and that the elevation of a point is always back of it, the reader will have before him an illustration which should enable him to fully comprehend the plan and elevation shown in Fig. 65.

Fig. 66 also shows, in a pictorial way, both the full and broken lines presumed to be upon the surface of the object. However, it should be remembered that Fig. 66

is purely pictorial, and will not supply the true lengths of those lines. These true lengths must be secured, as in all other examples of triangulation, i.e., by the use of the right angled triangle.

The Pattern by Mechanical Methods.

We sometimes hear of instances where the worker has formed the sheet metal or cardboard as suggested above, and then wrapped paper about its face to secure the pattern. This mode of procedure will, of course, supply the pattern, since our patterns may always be looked upon as the envelopment of a solid whose form is that of the required object.

The True Length of Lines.

Having before us the plan and elevation as shown at Fig. 65, we must determine the true lengths of lines whose positions are indicated in that diagram. To accomplish this we may draw indefinite horizontal lines, i. e., parallel to the line *I L,* from points along the oblique line *9 1* of the elevation, and in a convenient position erect a perpendicular line as *A B* of the diagram of triangles. This determines the lengths of the perpendiculars of all triangles. The lengths of lines as found in plan are set off from *B* along the line *B L,* as shown. As for example, the length of line *3 3* of the plan is set off from *B,* thereby locating a point as at *a.* A glance at the elevation shows us that the upper extremity of line *3 3* is at a distance above the horizontal plane equal to the length of line *B b,* therefore upon drawing a line as *a b,* the true length of line *3 3* is determined.

It should be understood that methods as above explained must be applied to every line whose plan is not parallel to the line *I L.* The true lengths of those lines whose plans lie in or are parallel to the line *I L,* as *1 1* and *9 9* are found in the elevation, since a triangle has been constructed there whose base is equal to the line in plan, as shown in one instance at *1 1 1.* Therefore it becomes unnecessary to prolong the search for these lengths.

The lengths of broken lines are determined in precisely the same manner, although to avoid confusion in this

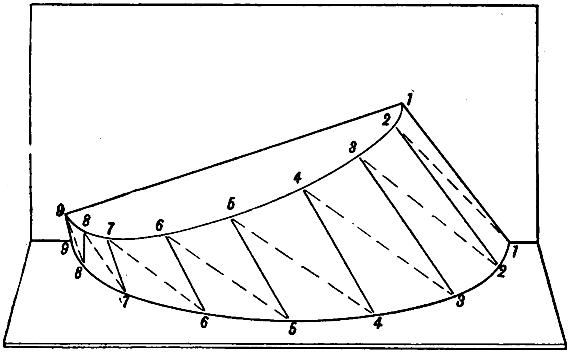


Fig. 66. Scenographic Representation of One-half of One Piece of a Ship's Ventilator, Looked Upon as a Solid.

demonstration a separate diagram of triangles has been constructed, as shown at *C D E.* Here it will be noted that distances from *B* along the line *B A* have been set off from *D* along the line *D C,* thereby locating points which are at the same distance from a common base line, as *D E.* The lengths of broken lines as found in plan are set off from *D* along the line *D E,* when points are connected as shown to secure the true lengths of those lines.

The Pattern.

To develop the pattern we draw upon the plane of development a line whose length is found in the oblique line *1 1* of the elevation, and designate that end of the line which shall be at the base of the pattern. The broken line *1 2* radiates from point *1* at the base, and is distant from point *1* at the top equal to the distance from *1* to *2* of the true form of the top, therefore we set our compasses to that distance, and with point *1* at the top of the pattern as center, describe a small arc as at *2*. With compasses set to a span equal to the length of line *1 2* found in the diagram of triangles, place one point at *1* of the base, and describe a small arc as at 2 of the top.

The intersection of these arcs, i.e., at *2* of the top, locates point *2* of the pattern in its correct relative position, and upon drawing the line *1 2* of the pattern, the triangle shown at *1 1 2* of the plan, has been constructed in its true form. We now add the triangle shown in plan at *1 2 2* by using the distance from *1* to *2* of the circle in plan as radius, and with point *1* at the base of the pattern as center to describe the small arc shown at *2*, then the lower extremity of line *2 2* must lie in some point of this arc.

To locate the exact position of that point, we set our compasses to the length of line *2 2* found in the diagram of triangles, and with point *2* at the top of the pattern as center, describe the second small arc as shown at *2* of the base. Lines may now be drawn to complete what may be termed one section of the pattern. The above operations continued, placing each length shown in the diagram of triangles in its proper position, will complete the pattern as shown at Fig. 65. It may be well to again direct the reader's attention to the fact that the distances between the upper extremities of full lines are found in the semicircle representing the true form of the top and not in the semi-ellipse shown in plan.

On the Division of Circles.

It is a difficult matter to lay down fixed rules for dividing circles to secure the best results; however, for the purpose of avoiding confusion, circles have been divided into sixteen parts throughout this work. In many instances this number is sufficient, especially if care be used when cutting the pattern, i.e., if the outline within which points are situated should be curved we may employ the eye to complete that curve. The old adage, the more points the more accuracy hardly holds good in a greater part of our work. In fact the writer has noted instances where it was folly to employ so many spaces, since some error committed was multiplied to that extent which exceeded the slight discrepancies which would exist had a less number been employed.

It is hardly worth while to consume additional time unless there is hope of increased accuracy. On the other hand, there are instances, as in this demonstration, where an increased number will no doubt increase the accuracy, since we presume the broken lines as *1 2, 2 3, 3 4,* etc., to be right lines, whereas if lines were drawn between these points upon the surface of the object they must become more or less curved, therefore error exists. More points of division would correct this to a considerable extent.

CHAPTER XVII.

On the Tapering Elbow to be Made in Any Number of Pieces.

The tapering elbow is a fitting occasionally demanded. No doubt in some instances it is best developed by presuming it to be the frustum of a right cone which has been cut obliquely to its axis. This makes every piece of an equal flare throughout, therefore somewhat difficult to connect.

Where the difference in the diameter of the end is not great, the tapering elbow is best developed as so many pieces of an elbow in round pipe, by gradually reducing the diameter of each piece, and compensating for this in the miter seams. There are occasionally instances where a departure from the above is desirable, when we may perhaps secure our patterns by triangulation.

An attempt to show the relation between the ship's ventilator with a round mouth, and the tapering elbow, is somewhat a departure from fixed customs of the past, nevertheless there is close relation if we are allowed to modify the elbow slightly. It has been generally conceded that the right section of each piece in a tapering elbow should be round. However, a slight variation from this would hardly be apparent in some of the larger work if it is made in a considerable number of pieces, i.e., five or more.

The modification spoken of is to make each piece round at each end, and with some method of drawing a side elevation, a problem in close relation to the ship's ventilator is before us. The purpose of the writer is not to prolong this work beyond a reasonable discussion of principles and methods which may be employed to secure the patterns for all forms where triangulation is to be applied. Therefore he will simply attempt to show the relation the tapering elbow may be made to bear to the ship's ventilator with a round mouth.

Since the development of one piece of the ship's ventilator has been explained, the reader should have little difficulty in securing patterns for the tapering elbow, beyond drawing the first diagrams to represent a side elevation. In the specifications for a tapering elbow, we may find a fixed radius of throat, or a fixed radius of back, or it may be required to have an equal flare at back and throat, thus making a fixed radius for the center.

Some Suggestions.

The writer suggests methods as illustrated at Fig. 67 for drawing elevations of tapering elbows. Here it has been presumed that the elbow is to be made in six pieces, and at an angle of 90 degrees. However, it will be readily understood that the number of pieces, or the required angle, will make no material difference in the methods to be pursued, although the inclination of the miter lines will, of course, be dependent upon the angle and number of pieces.

In No. 1 a given radius of throat has been assumed at *A B,* and the arc *B C* drawn with that radius. The miter lines are drawn of indefinite lengths at the same angle that would prevail for an elbow of a constant diameter. Using the same methods that would be employed for an elbow of a constant diameter, the elevations of the pieces at the extremities of the tapering elbow are drawn in positions as shown, thus establishing the lengths of two miter lines, i.e., *m o* and *n p*.

To secure a symmetrical form it is fair to presume that the remaining miter lines, i.e., *d e, f g,* and *h k,* should be of proportionate lengths. These proportionate lengths may be secured in many ways, one of which is shown at No. 4, Fig. 67. In No. 4 the line *D E* is drawn to a length equal to the length of miter line *n p,* and a distance set off from *E* equal to the length of miter line *m o,* as at *F*. The line *F D* is divided into as many parts as there are remaining pieces in the elbow, thus securing points as *1, 2,* and *3*. The upper extremities of the miter lines in No. 1 are now located by setting off from *k* along the miter line *k h,* a distance equal to *E 1* in No. 4; from *g* along the miter line *g f* a distance equal to *E 2,* and from *e* along the line *e d,* a distance equal to *E 3*. With points connected as shown at No. 1, an elevation is completed, when a given radius of throat is demanded.

In No. 2, Fig. 67, a given radius of back is assumed as *G H,* and an arc drawn as shown. The elevations for the pieces at the extremities of the elbow, and the miter lines, are drawn in the same manner as was explained for No. 1. Here it will be apparent that the lower extremities of the miter lines as at *s, t,* and *u,* may be located in positions which suit our fancy, or, in other words, in positions which will give the fitting the best form when finished.

In No. 3, a given radius of center is assumed as *X Y,* and the arc *Y W* drawn as shown. The elevations for the pieces at the extremities of the elbow, and the miter lines are again drawn in positions as shown, and in the same manner as has been suggested for Nos. 1 and 2. Here we use the same lengths of miter lines as was used in No. 1, although points on the arc *Y W* are looked upon as the centers of those lines, i.e., we set off one-half the length of each on either side of the arc *Y W*. By drawing lines to connect points which have been located in this manner upon the miter lines as shown, an elevation is completed.

It will be noted that this gives the fitting a symmetrical

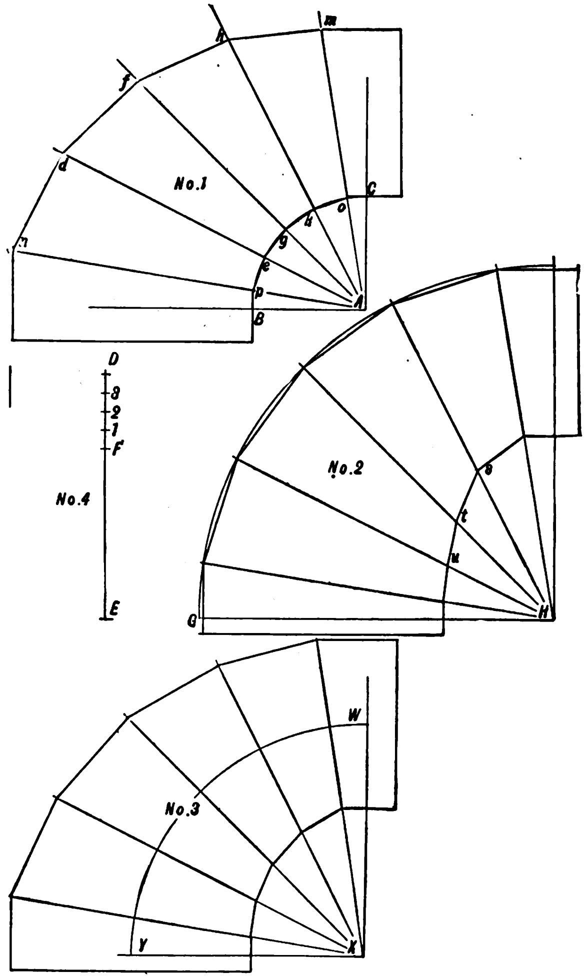


Fig. 67. Side Elevations of Tapering Elbows.

form when viewed from the side, and allows the ends to be comparatively straight for connecting. There is, of course, some slight distortion in these pieces, which is the outcome of making both ends round when not parallel.

Assuming that each piece in the elbows whose elevations are shown in Fig. 67 is to be round at each end, and of diameters equal to the lengths of lines which represent those ends in elevation, we have an exact counterpart of the ship's ventilator when a formula is supplied for a side elevation of that object. To secure the pattern we may proceed in precisely the same manner as has been explained for the ship's ventilator.

In discussing this matter with a man familiar with this class of work, the question was raised: "What shall we do if it is required to make the elbow straight on one side?" The reply was: "If you wish to secure the pattern for an elbow of this class when the ends are what you call 'off center' construct your plans accordingly. This will demand a full plan for each piece, as one-half is not a duplicate of the other. Therefore the complete pattern for each piece must be developed."

To Draw the Plan When the Elbow is to be Straight on One Side.

Fig. 68 is shown in an endeavor to illustrate methods which may be employed to draw the plan when a fitting of this class is required, which is commonly known as "straight on one side." It is, in fact, presumed to represent the piece marked *A* in the elevation for the ship's ventilator, if it was required to make that piece straight on the side furthest from the eye, and with the form and diameter of the ends remaining the same. As will be noted, the elevation is substantially the same as shown in Fig. 65, Chapter XVI.

For the plan a circle is drawn equal in diameter to the length of the base line and in a position as indicated by the vertical projectors. We may now presume the oblique line *X Y* of the elevation Fig. 68 to be the intersecting line between the vertical plane and a supplementary oblique plane.

Draw in position as shown a circle whose diameter is

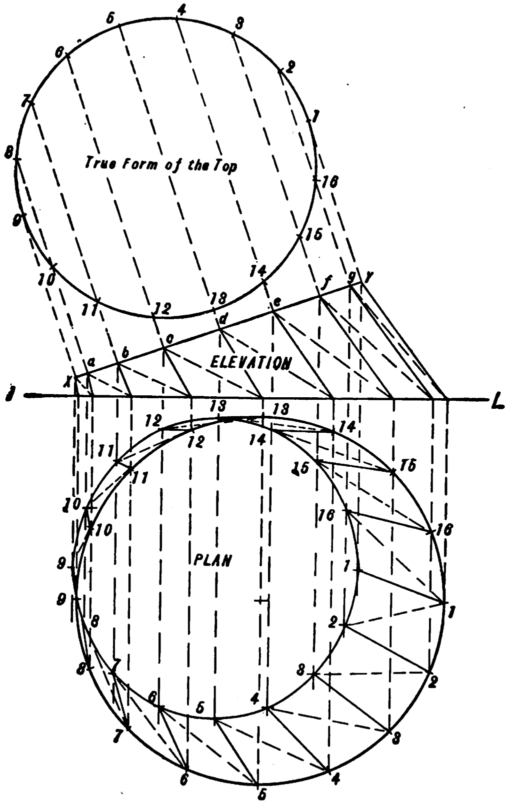


Fig. 68. Methods That May Be Employed to Draw the Plans When a Tapering Elbow Is Required to Be "Straight on One Side."

equal to the length of the oblique line *X Y*, using care to place it at the same distance above the line *X Y* as the large circle in plan has been placed below the line *I L*. This represents the true form of **the top.** Divide each circle into the same number of equal parts as shown. From the points of division of the circle which represents the true form of the top, project lines to intersect the oblique line *X Y* as shown at points *a, b, c, d,* etc. From these points of intersection, i.e., *a, b, c, d,* etc., draw indefinite lines below and perpendicular to the line *I L*. Points as *a, b, c, d,* etc., may be looked upon as the end elevations of lines which cross the top.

The plans of these lines are some portions of the perpendicular lines drawn below the line *I L* from said points. Since the lengths of these lines are shown in the lines which cross the circle representing the true form of the top, it only remains to locate their extremities in their correct relative positions.

It will be noted that point *d* is in reality an elevation of the line designated as *5 13* upon the true form of the top. The extremities of this line are distant from the vertical plane equal to the lengths of lines *d 5* and *d 13* of the true form of the top. Therefore if we set off below the line *I L* upon line shown at *5 13* of the plan, distances as found from *d* to *5* and *d* to *13* of the true form of the top, those points are located in plan as shown. Continue this operation until each point has been located in plan.

A line traced through these points forms an ellipse, which is a plan of the top and may be numbered as shown. Draw lines between points of the same number located upon the circle and ellipse in plan, and plans of full lines presumed to be upon the surface of the object are secured. When broken lines are drawn as *1 2, 2 3, 16 15, 15 14,* etc., plans of those lines are also secured.

It may be explained that to avoid confusion in the elevation, lines have been drawn in such a manner as to allow one line in elevation to represent two in plan. Having now before us the plan and elevation for each line presumed to be upon the surface of the object, we construct triangles to secure their true lengths in the same manner as was explained for the ship's ventilator. Lines placed upon the plane of development in lengths as found in the diagram of triangles so constructed, and in their correct relative positions, supply points through which lines are traced to secure the pattern.

CHAPTER XVIII.

TRANSITIONAL ELBOW IN RECTANGULAR PIPE.

There is a demand for the transitional elbow in rectangular pipe in some branches of sheet metal work. To satisfy this demand, passable results may be secured by applying triangulation to the development of its patterns, although the author has never seen an example wherein ideal results were obtained when the throat and heel were cylindrical.

This can be attributed to the fact that a portion of such forms is in close relation to the form known as the Right Helicoid. The Right Helicoid is a warped surface, and cannot be obtained without a drawing or stretching of the material when made from sheet metal.

In the following demonstration it has been presumed that one side of the elbow, or that which is commonly known as one cheek, is to be flat. This has been the case in nine out of ten examples which have come to the author's notice.

PLAN AND ELEVATION OF THE ELBOW.

Fig. 69 shows the plan and elevation of an elbow of this class. Here it will be noted that the throat and heel have been cut obliquely, as shown by lines *A B* and *A C* in elevation. The elevation of a short collar at one end is shown by *D A E F,* and *B C G H* is the collar when looking into the other end. The plan clearly shows the throat and heel.

To secure the true lengths of lines presumed to be upon those parts, we divide the curved portion of said

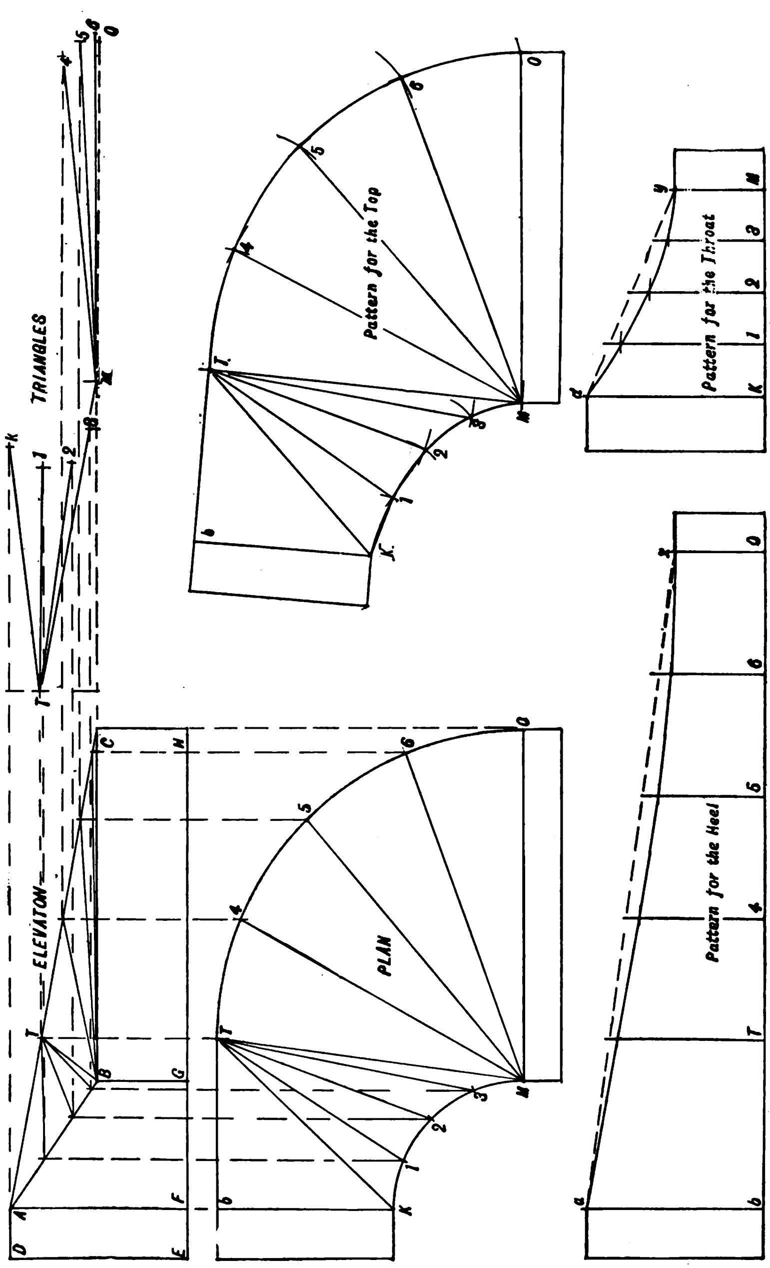


Fig. 69. Plan, Elevation, Triangles and Patterns for a Transitional Elbow in Rectangular Pipe.

lines into convenient parts as shown at *T 4 5 6 0,* and *K 1 2 3 M*. From these points of division lines are projected to intersect the oblique lines *A B* and *A C* of the elevation, as also shown. The patterns for the throat and heel are now secured as for any cylindrical form which has been cut obliquely, i.e., in the same manner that the patterns are secured for an elbow in round pipe. In other words, the above spoken of points of division may be looked upon as plans of elements of the cylindrical surface, and since the plan supplies the distance between these elements, we have only to determine their lengths to develop the patterns for the throat and heel as shown.

The points of division previously located upon the arcs in plan are also utilized as points between which lines are drawn, and presumed to divide the surface of the upper cheek, or top, into triangles. The elevation clearly shows these lines, although in a problem of this class, they are by no means necessary, since measurements may be secured from the patterns for the throat and heel. These lines in elevation may at times be an element in avoiding confusion, and may also be utilized as here shown, to determine the difference in hight of the extremities of lines upon the surface of the elbow of which they are the elevation.

True Lengths of Lines Upon the Top.

Presuming the patterns for the throat and heel to have been secured as shown at Fig. 69, our next work is to determine the true lengths of those lines which cross the upper cheek, and shown in plan at *T K, T 1, T 2, T 3, T M,* also *M 4, M 5, M 6,* and *M 0*. This is accomplished by the use of the right angled triangle as shown in the diagram of triangles Fig. 69, since from the plan we secure the length of base for each triangle, and from the elevation the perpendicular is secured.

It may be here explained that in case the work is large, and it is desirable to avoid making a plan and elevation, we may look upon the lower cheek as a plan, and draw lines upon that surface which shall represent the triangles presumed to be upon the opposite cheek. From the patterns for the throat and heel we can determine the difference in hight of the extremities of those lines, thereby securing the perpendiculars for all triangles.

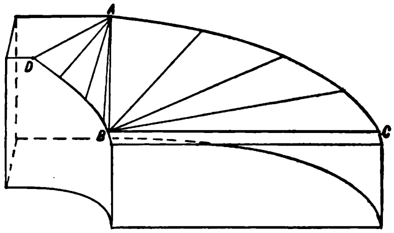


Fig. 70. Scenographic Representation of Elbow in Rectangular Pipe.

These triangles may of course be drawn upon the surface which constitutes the lower cheek, although in this we have constructed separate diagrams. To secure a better understanding of this, the reader may construct his elbow as the patterns are secured, thereby placing a model before him.

Pattern for Upper Cheek or Top.

The pattern for the upper cheek is secured by placing lines in their true lengths and positions upon the plane of development, as shown in the pattern for the top, Fig. 69. As for example, the surface shown in plan at *b K T* is triangular; *b K* is the true length of one side of the triangle, and the true length of *b T* is secured either from the elevation, or from the pattern for the heel. The true length of line *T K* is secured from the diagram of triangles. The true lengths of the four remaining lines radiating from point *T* are also found in the diagram of triangles. The distance these lines are from each other at the throat is secured from the pattern for that portion. By applying the same reasoning to those lines

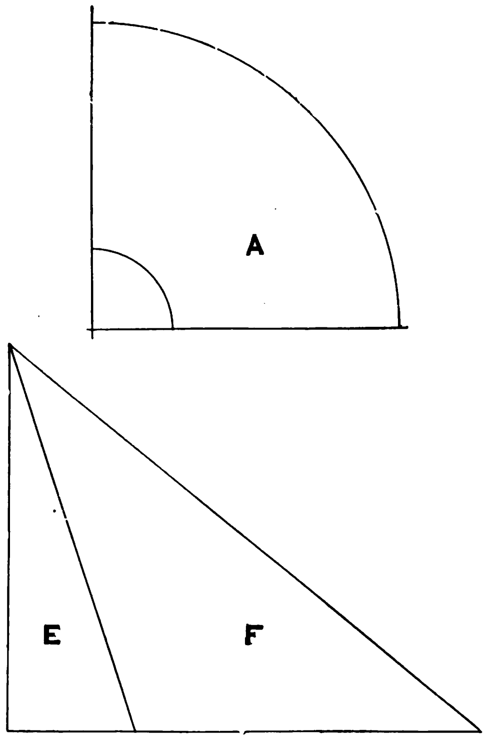


Fig. 71. Parts of Object to Be Constructed as An Experiment.

radiating from point *M,* it is but a simple operation to develop the pattern for the upper cheek as shown.

Variation in Methods.

The work of securing the patterns for an elbow of this class may be somewhat simplified by cutting the upper edge of the throat and heel upon straight lines, as shown by broken lines *a x* and *d y* of the patterns for the throat and heel, thereby dispensing with an elevation. When this course is pursued, the method of developing the pattern for the upper cheek differs in no material respect, since lines may be located upon those portions which are to form the throat and heel, whose plans will be points *K 1 2 3 M* and *T 4 5 6 0* of the plan as shown.

Breaks or Bends in the Upper Cheek or Top.

Either mode of procedure demands that there be breaks or bends in the material upon lines *A D, A B,* and *B C* shown in the scenographic representation of an elbow in

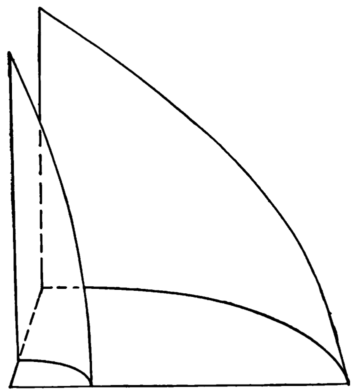


Fig. 72. Object Constructed from Parts Shown in Fig. 71.

Fig. 70. These breaks or bends are the objectionable feature, although difficult to eliminate, especially if the rise is considerable, from the fact that the surface resembles the above spoken of surface, the Right Helicoid.

A Simple Experiment.

If the reader is of an experimental turn of mind, and wishes to prove beyond question the truth of the above statement, he may draw two concentric arcs as shown at *A* Fig. 71, and cut from sheet metal two triangular pieces whose base lengths are equal to the length of the arcs, and whose perpendiculars are equal as shown at *E* and *F*, Fig. 71. Form these triangular pieces so that their bases will conform to the arcs shown at *A*, and construct an object as illustrated at Fig. 72. He may then use any flexible but non-elastic material to cover the space between the two cylindrical forms, and endeavor to fit it to the upper edge of each at the same time, thereby supplying a surface known as the Right Helicoid.

The author has found it a difficult matter to convince the average man that this surface is warped and cannot be developed without a stretching or drawing of the material. He therefore suggests the above experiment as a proof that this surface cannot be developed absolutely, even though triangulation be applied.

CHAPTER XIX.

A TRANSITIONAL ELBOW FROM ROUND TO ELLIPTICAL.

Herein will be discussed methods to secure the patterns for an elbow as shown in a pictorial way in Fig. 73, i.e., a four pieced elbow from round to elliptical.

This problem is closely related to others previously ex-

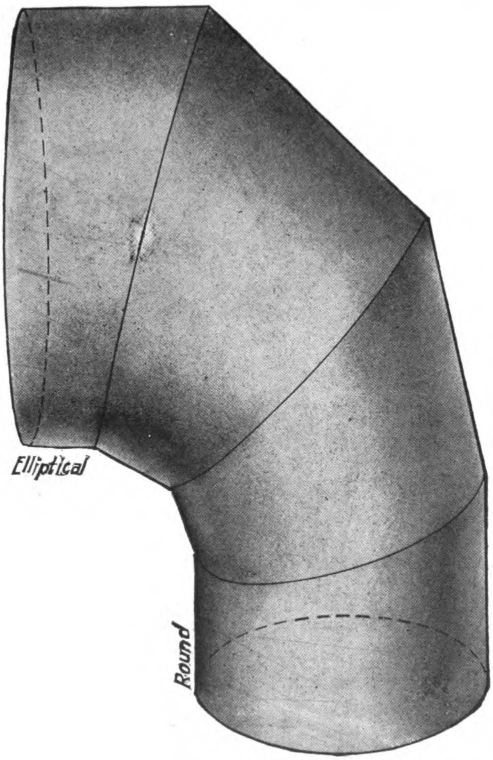


Fig. 73. Transitional Elbow from Round to Elliptical.

plained, although there are a few new features involved. The problem is not a difficult one beyond the fact that it is somewhat prolonged, since there are four separate and distinct patterns to produce.

It may be well to here explain that no doubt in practical work, the demand will be for an elbow made in five, six or seven pieces.

This work has been designed to illustrate and explain the principles involved. Therefore the illustrations have been reduced to as simple examples as are consistent with the problems in hand. The author's sole object being to enlighten rather than confuse.

Since the principles involved would be the same regardless of the number of pieces, he trusts that those principles may be best comprehended from the more simple examples. Moreover, if one succeeds in securing the patterns for an elbow of this class made in four pieces, he will have little difficulty in securing the patterns for the elbow made in a greater number of pieces.

In the following example, it has been presumed that the specification demands an elbow of 90 degrees to make connection between a 16-inch round pipe, and an elliptical pipe, whose major and minor diameters are 24 and 12 inches respectively. A scale has been appended in Fig. 74 to enable the reader to more readily follow the work by comparing measurements.

In a problem of this class, a complete plan of the elbow entails a considerable outlay of labor, and is unnecessary. Therefore it has been omitted. Beyond this, it has been presumed in this example that the axis of each piece is in one plane, or what is commonly known as "on center". Thus it is only necessary to draw one-half of each profile, as all semi-patterns may be duplicated for the other half.

As will be noted in Fig. 74, a semi-circle has been drawn as shown at *A*, the diameter of which is equal to the diameter of the round pipe, or 16 inches. At any convenient distance above the line *I L* draw a line as shown, or at a distance equal to the required length of the round collar as *B C*. Presuming the required radius of

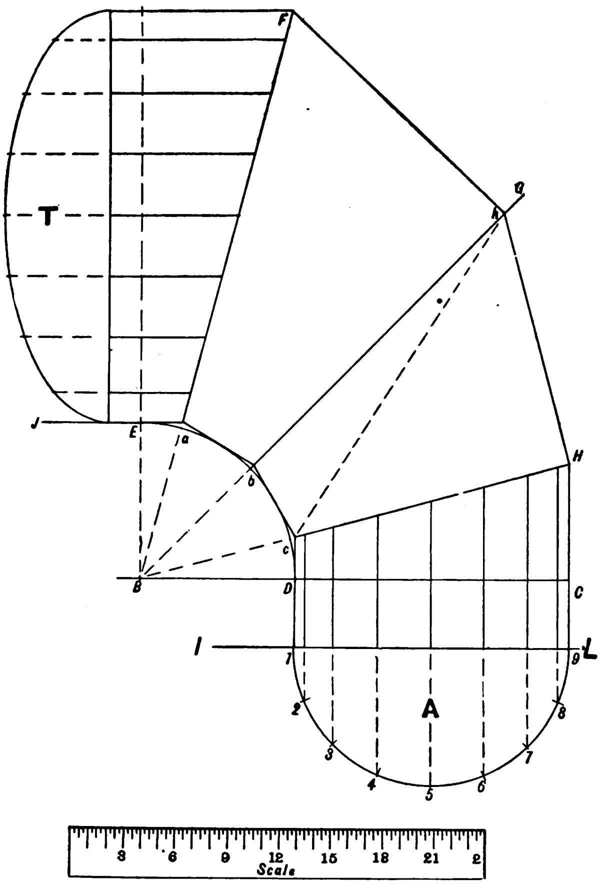


Fig. 74. Side Elevation and True Form of Ends of Elbow in Fig. 73.

throat is 9 inches, then point *B* is the center from which an arc is drawn, the radius of which is 9 inches, as shown at *E D*. We may now treat the arc *E D* in the same manner that a similar arc would be treated for an elbow of a constant diameter, as shown at *a, b* and *c,* i.e., locate points through which miter lines would be drawn presuming the elbow was to be a four-pieced elbow in 16-inch round pipe.

Through these points of division, draw lines as shown at *B a F, B b G,* and *B c H,* which will represent the miter lines of the elbow. From point *E* draw the line as shown at *E J*. Above this line draw a semi-profile of the elliptical end of the elbow with the major axis at right angles to line *E J* as shown at *T*.

The arc *1 9* is divided into an equal number of equal parts as shown at *1, 2, 3, 4,* etc., and lines projected from said points of division to intersect the miter line *c H,* thus securing an elevation of the round collar, or the true lengths of the rectilinear elements of the cylindrical surface. From this the pattern may be secured as for any elbow the diameter of which is constant. In like manner the semi-profile of the elliptical end is divided into an equal number of equal parts as shown at *T,* and lines projected to intersect the miter line *a F* as shown. This supplies two views of the elliptical collar, and the pattern for that portion may be secured as recommended for all parallel forms.

To Establish a Form for an Intermediate Section.

When following this mode of constructing an elbow, we have two cylinders, one circular and one elliptic, which have been cut obliquely, and forming two of its sections. Since the two intermediate sections are to connect these upon the miter lines *c H* and *a F* Fig. 74, it follows that one end of each must be of a suitable form and size to make said connections. Therefore in this example, the only unknown form is that upon the miter line *b G.*

This form can be arbitrarily established. However, it is not to be recommended, since it is a somewhat difficult undertaking to establish a form which will be productive of satisfactory results in the finished elbow. The author suggests that a form be found which will be in proportion to the two forms previously established upon the miter lines *a F* and *c H.*

The two diameters of this, the required ellipse for a suitable form of the elbow on line *b G,* may be secured by graphical methods as was explained for a similar example in the seventeenth chapter, or as it may be arrived at somewhat as follows:—We find that the ellipse which is the true form of the right circular cylinder upon line *c H,* will have dimensions of approximately 16½ and 16 inches as the major and minor diameters. In like manner we find that the ellipse which is the true form of the right elliptic cylinder upon miter line *a F,* has dimensions of approximately 12 and 24¼ inches. The difference then in the two major diameters is 8¼ inches. We may divide this difference in this case by 2 which gives us 4⅛ inches. This may be either added to 16½ or deducted from 24¾, which gives us 20⅝ inches as the major diameter of the required ellipse, which we shall presume to be the true form upon line *b G.*

In like manner we find that the difference between 12 and 16 is 4 inches. This divided by 2 is 2, which added to 12 or deducted from 16 equals 14 inches, the minor diameter of that ellipse. We can now definitely locate the point *h* as shown upon the miter line *B b h G,* since it will be 20⅝ inches from point *b* as shown at *h.* Since the forms for each end of the two intermediate sections are elliptical, and it is necessary that these forms be drawn to secure the patterns for these sections, we could employ any convenient method for securing them.

THE ELLIPSE.

There are many ways of describing that curve known as the ellipse, and it makes no material difference how it is secured. It may be well to here explain that in the strictest sense, no part of an ellipse is a part of a circle. Therefore methods recommended for what is known as the false ellipse, i.e., those drawn from centers, will be somewhat in error, although the variation in many

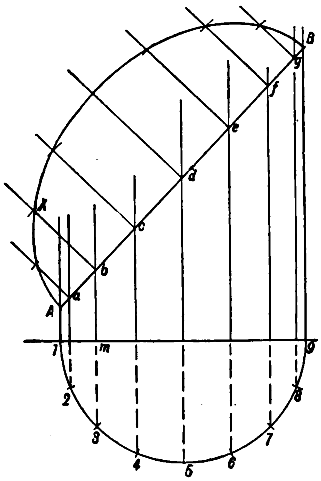


Fig. 75. Methods of Securing True Form of Oblique Section of Cylinder.

instances will be insignificant and may be consistently ignored. On the other hand, the author believes that the more accurate methods of securing that curve are to be desired.

As for example, the oblique section of a right circular cylinder is an ellipse, the diameters of which are dependent upon the diameter of the cylinder, and the angle at which said cylinder is presumed to be cut. By keeping this in mind, we are always prepared to locate points in an ellipse of given dimensions, as will be explained.

The true form upon miter line *b h,* Fig. 74, in this example, is an ellipse with diameters of 14 and 20⅝ inches. To secure this form we may draw a semi-circle, the diameter of which is *14* inches, as shown at Fig. 75, and divide said semi-circle into a convenient number of equal parts as shown at *1, 2, 3, 4,* etc. From these points of division project lines at right angles to line *1 9,* as also shown.

Thus we have before us the plan and elevation of a semi-cylinder which we shall presume to cut at a suitable angle to give us a length of 20⅝ inches for the section line, as *A B*. Points as *a, b, c, d,* etc., thus secured, are looked upon as the end elevations of lines which cross the semi-cylinder, and the horizontal projectors from points *2, 3, 4,* etc., i.e., from said points to the line *1 9,* are the plans of those lines, and are in this instance, their true lengths.

Draw lines from points *a, b, c,* etc., perpendicular to line *A B*. Set off distances upon said lines as found in plan, as for example, the distance from *m* to *3* is set off from *b* on line *b X,* and so on for all lines shown. We have thus secured points in the required ellipse. To facilitate our work, we may cut a templet from this, for the purpose of duplicating this curve whenever it becomes necessary in diagrams which must be drawn to secure the patterns for the two intermediate sections.

Since the semi-patterns for either intermediate section are secured by duplicate operations, but using somewhat different measurements, one only is discussed in this demonstration, i.e., that included between points *c, b, h, H,* Fig. 74. The form of one end of this section is elliptical, as shown at Fig. 75. Therefore in constructing the necessary diagrams to secure its pattern, we may first draw the semi-ellipse *1, 2, 3, 4,* etc., as shown at Fig. 76, and look upon this as a plan.

Above this as shown, we duplicate the elevation of section *c b h H,* Fig. 74, by first presuming the line *1 9* to be an elevation of what we may now term the base. To locate the remaining points, i.e., *e* and *H,* in their correct relative positions, we may divide our primitive elevation, Fig. 74, into triangles as shown by the broken line *c h*, and construct similar triangles at Fig. 76, thereby securing a duplicate elevation in a somewhat changed position.

The necessary form of the elbow upon line *c H,* Fig. 74, is also elliptical, and may be secured by determining the true form of the 16-inch round pipe upon line *c H*. This form drawn in a position as shown at *a e i,* Fig. 76, supplies a plan of the base, an elevation, and the true form of the top. The true form of the top as here represented, is presumed to be upon an oblique supplementary plane, and the line *a i* is the intersecting line between this, and the vertical plane.

Plan, Elevation and Diagram of Triangles.

An examination of the construction lines shown in Fig. 76 should render the work of drawing a complete plan and elevation of the semi-section a simple matter.

As will be noted, horizontal lines are drawn from points on line *a i,* which are at a distance from *I L* equal to the vertical hight for all triangles. From the base of some vertical line as at *Y,* we may set off distances as found in the lengths of full lines drawn in the usual manner between similar points in plan. From the base of some vertical line as at *X,* we also set off distances as found in the lengths of the indirect, or broken lines which have also been drawn in the usual manner. Lines are drawn from points thus located, to the respective intersections of horizontal lines and the lines extending from

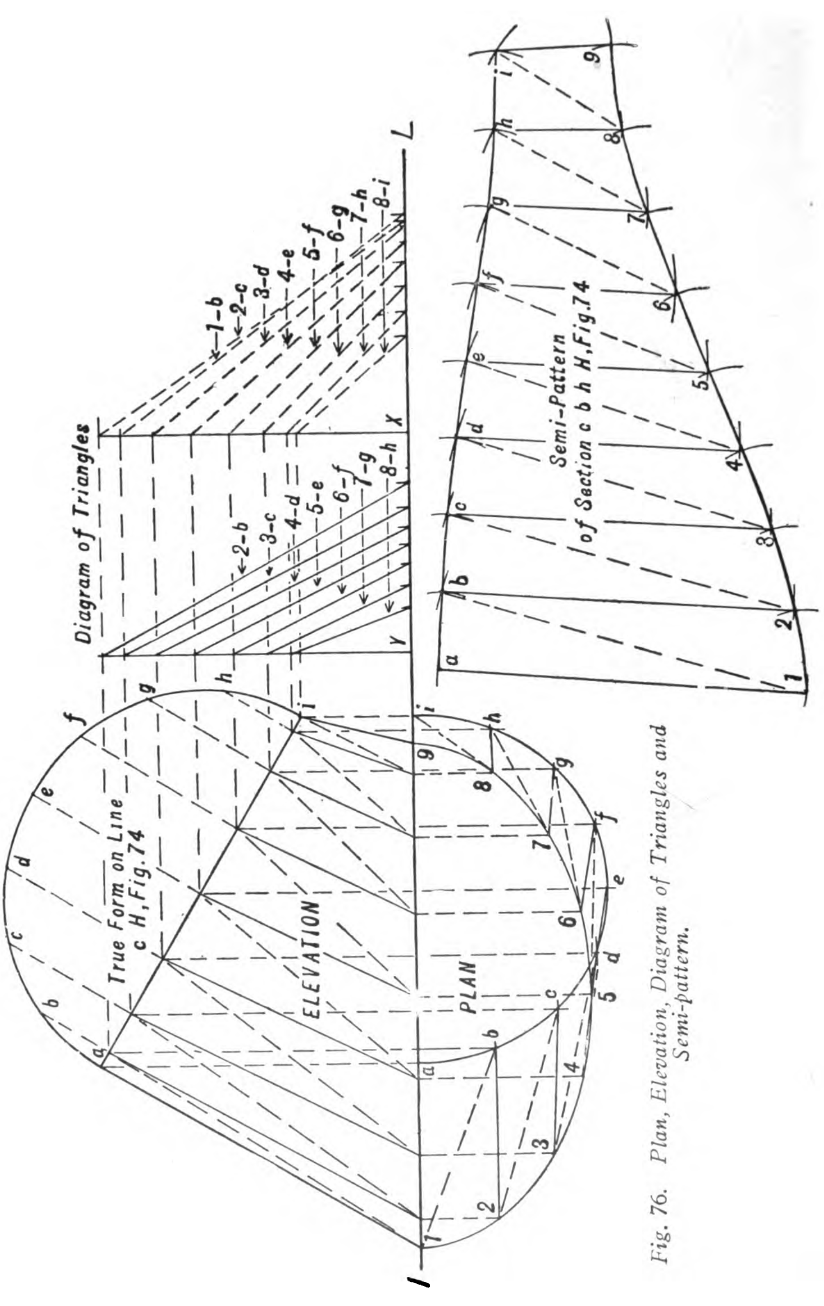


Fig. 76. Plan, Elevation, Diagram of Triangles and Semi-pattern.

Y and *X,* thereby determining the true lengths of lines shown in plan.

Thus in the diagram of triangles we have the full lengths of necessary lines shown in plan, and from the plan and the true form of the top, we determine the distances said lines are from each other at their extremities.

THE PATTERN.

To secure the pattern as shown, we draw a line in any convenient position upon the plane of development, the length of which is *a 1* of the elevation, as *a 1* of the pattern, Fig. 76. Line *2 b* is distant from *a 1* at the lower extremity equal to the distance between *1* and *2* of the plan, and at the upper extremity equal to the distance between *a* and *b* of the true form of the top.

To locate these points upon the plane of development, we use points *a* and *1* of the pattern to describe arcs, the radii of which are equal to the distances said lines are from each other; then the extremities of line *2 b* must lie in some points of these arcs. We find from the diagram of triangles that the true distance from *1* at the base to *b* at the top, is the length of the broken line *1 b* in the diagram of triangles.

Using this as radius and with point *1* of the pattern as center, we describe the second small arc as at *b,* thereby definitely locating the upper extremity of line *2 b* upon the plane of development. Since the true length of line *2 b* is also found in the diagram of triangles, we use that as radius, and with point *b* as center, describe the second small arc as at *2,* thereby completing what may be looked upon as one section of the semi-pattern. With these operations repeated for each section shown in plan, and using proper distances as found in the several diagrams, the pattern is completed as shown.

Should the student become interested in securing patterns for a form of this nature which is required to be "off center" or flat on one side, it may prove to his advantage to re-read Chapter XVII.

Application of the So-called Rule of Thumb.

It may at least be interesting to note that the so-called rule of thumb could have been introduced to secure the pattern by mechanical methods, by cutting from sheet metal a form as shown at Fig. 76, i.e., that bounded by line *1 a e i 9* and *5*, then bend upon lines *a i* and *1 9* to form an object as shown at Fig. 77. If a piece of paper be wrapped about the curved face of this and marked, the

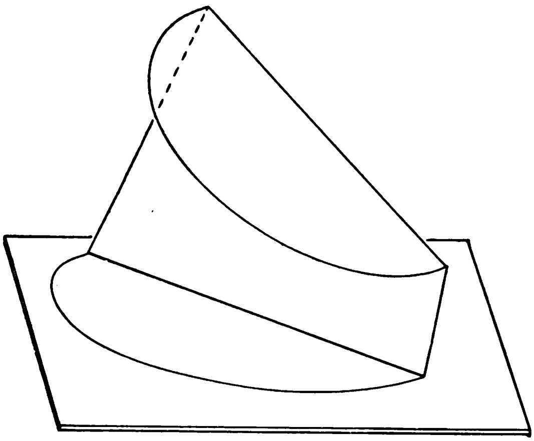


Fig. 77. Object from Which Pattern May Be Secured.

pattern sought is secured, providing of course, that the semi-elliptical forms are at right angles to what may now be termed the back.

This is explained in the fact that all sheet metal patterns are what may be looked upon as the envelope of a solid, the form of which is that of the required object.

Triangulation is but the process of measuring these surfaces, and applying these measurements to the plane of development for the purpose of locating points in the outline which bounds the pattern.

CHAPTER XX.

THE HELICAL ELBOW.

The helical elbow is somewhat of a novelty in the sheet metal industry, and can hardly be recommended for general work. Other forms of ducts may usually be designed which will fulfil the requirements to better advantage. On the other hand, we may meet with an insistent demand for a fitting of this class. Therefore it seems desirable to discuss it in this work, although perhaps it makes the rule somewhat elastic when placed under the head of Triangulation.

Fig. 78 shows in a pictorial way a helical elbow exposed in the corner of a room and presumed to make connection between a pipe or duct passing through wall *A* and a similar pipe passing through wall *B*, which is at right angles to wall *A*. The pipe or duct in wall *B* is at a greater distance from the floor than that in wall *A*, therefore a considerable rise or pitch is demanded in the elbow while making a revolution of 90 degrees. In other words, the pipe or duct is required to revolve about the corner of the room as an axis and to have an equal rise for every unit of revolution. The heel and throat are but portions of a right circular cylinder, and the top and bottom or two cheeks, should be that surface known as the right helicoid.

It has been previously stated that the right helicoid is a warped surface and cannot be developed or forced into shape without a drawing or stretching of the material. On the other hand, we can secure passable results by introducing a series of breaks or bends, as will be hereinafter shown. Measurements are shown in Fig. 78, and the following diagrams have been worked to those measurements by using the scale in Fig. 79. It may be well to remind the reader that the distances in Fig 78

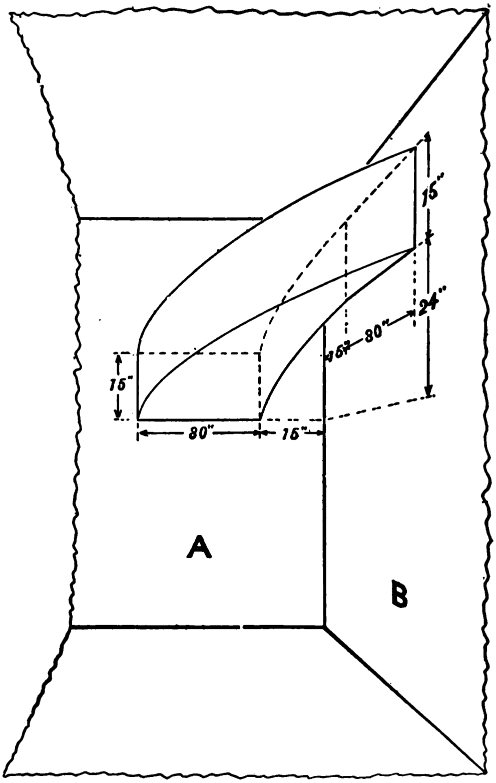


Fig. 78. Scenographic Representation of Helical Elbow in a Room Corner.

cannot be compared with the scale, since that drawing is purely scenographic.

From measurements shown in Fig. 78 it is but a simple operation to draw a plan. As for example, we draw a right line as *C D,* Fig. 79, and look upon this as a plan of wall *A,* Fig. 78. A line drawn from *D* perpendicular to *C D,* as *D E,* may likewise be looked upon as a plan of wall *B*. Then the point *D* is the plan of the vertex of an angle formed by the two walls of the room, or the axis of the elbow.

On examination of Fig. 78 we note that each end of the elbow is 15 inches distant from the corner of the room. Therefore we use that distance as radius and with point *D,* Fig. 79, as center, describe an arc of 90 degrees, as shown at *F G*. This arc is then looked upon as a plan of the throat. With the same point as center and with trummels set to a span of 45 inches as shown in Fig. 78, we describe the larger arc as also shown in Fig. 79. We have then before us the plan of the required elbow.

From the specification of the elbow, i.e., it must have a gradual rise throughout its 90 degrees of revolution, we conclude that the upper and lower edges of the throat and heel must describe in space that form known as the helix.* From the definition of the helix as given in the note below, we may also conclude that any right line drawn obliquely across the envelope of a right cylinder, will, when said envelope is developed into a cylinder, describe a helix in space. The angle at which this line should be drawn is dependent entirely upon the required rise or pitch of the helix, in the whole or part of a revolution.

Patterns for Throat and Heel.

Presuming the reader has acquired an understanding of the above, we may now proceed to secure patterns for the throat and heel by representing upon the plane of

* The Helix is designated as the path of a point, which, while revolving uniformly around an axis, also moves uniformly in a direction parallel thereto. This curve then lies upon the surface of a cylinder, cuts all its rectilinear elements at the same angle, and becomes a right line when the cylinder is developed into a plane.

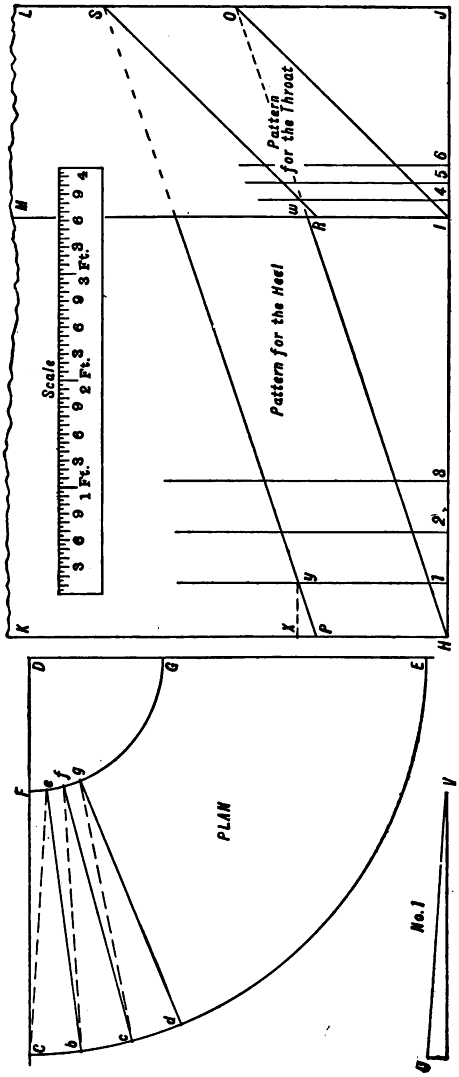


Fig. 79. Plan of Elbow and Pattern for Throat and Heel.

development the envelopment of the cylindrical forms, the plans of which are shown in Fig. 79. This is accomplished by drawing right lines equal in length to the lengths of those arcs, and through the extremities of said lines drawing additional lines perpendicular for the first, as shown at *H I* and *J,* Fig. 79. To confine Fig. 79 within reasonable bounds, one pattern has been made to overlap the other to some extent. This necessitates one being transferred when the pattern is cut.

As for example, the line *H J* is equal in length to arc *C E,* and a portion of the same line as *I J,* is the length of arc *F G.* We look upon the surface *H K L J* as the envelopment of a cylindrical form the plan of which is arc *F G.* We note from Fig. 78 that the rise of the elbow is to be 24 inches in its revolution of 90 degrees. Therefore we locate a point 24 inches from *J* upon line *J L* as at *O.* Lines drawn from points *H* and *I* to *O,* then represent the lower edges of the throat and heel upon the pattern. Since the pipe to be connected is shown to be 15 inches high, we locate points as *P R* and *S,* which are 15 inches above points *H I* and *O.* On drawing lines as *P S* and *R S,* the patterns for the throat and heel are completed, as shown.

We may here explain that when following this course to secure a connection as shown in Fig. 78, some distortion will exist together with some reduction in the capacity of the duct. This distortion may be modified, and the capacity increased, as will be hereinafter explained. For the present we shall presume that the elbow is to be made precisely as shown in Figs. 78 and 79.

Patterns for the Top and Bottom.

To secure the patterns for the top and bottom of the elbow, we may divide the arc *C E,* Fig. 79, into four equal parts, and sub-divide the first division from *C* into *3* or more equal parts as *b, c,* and *d.* By the use of our straight edge we draw lines as *b e, c f,* and *d g,* which are divergent lines from point *D,* and cut the arc *F G* in points *e f* and *g.* Points as *b c* and *d* upon arc *C E,* are now looked upon as the plans of elements upon the above spoken of cylindrical surface, of which *K H L J* is the covering. Therefore we may locate one or more points upon line *H J,* with distances between as found between *c b, b c,* or *c d* of the plan, as shown at *1, 2* and *3.* Lines are drawn perpendicular to said lines as shown, and intersecting those lines which represent the top and bottom of the pattern for the heel of the elbow.

In like manner we locate points along the line *I J* with distances between as found between points *F* and *e,* etc., on arc *F G* of the plan, as shown at *4, 5,* and *6.* From said points perpendicular lines are erected to intersect lines *R S* and *I O,* which are the top and bottom boundary lines of the pattern for the throat. The true distance between points, the plans of which are *C, b, c,* etc., is then found between points *P* and *y* of the pattern. Likewise we find the true distance between points, the plans of which are at *F, e, f,* etc., between points *R* and *w* of the pattern for the throat.

All divergent lines from point *D* shown in the plan are perpendicular to the corner of the room, or horizontal. Therefore broken lines as *C e, b f,* etc., of the plan, are in reality at an angle to the horizontal, dependent upon the rise of the elbow between those points, i.e., that vertical distance as shown between *P* and *X* of the pattern. To secure true lengths of broken lines shown in plan, we construct a triangle as shown at No. 1, Fig. 79, with base equal in length to line *C e* of the plan, and the perpendicular of which is *P X* of the pattern. Then *U V* is the true length of not only *C e* of the plan, but of all similar lines shown or assumed.

Having before us the lengths of all lines which we presume to be upon the pattern, and as the pattern is but a series of triangles joined together, the dimensions of which are equal, we can, if thought more convenient, cut one section from sheet metal, the plan of which is *C F e b,* Fig. 79, and shown at *C F e b* of the pattern, Fig. 80. This section may be duplicated upon the plane of development to complete the whole pattern, or we may use our trummels in the usual manner. However, since in this instance the pattern is composed of twelve equal sections, all similar measurements will be equal, as is shown at the pattern, Fig. 80. Care must be used in this to secure accurate lengths for the throat and heel, which should be equal to those lengths shown at *P S* and *R S,* Fig. 79. As is indicated at Fig. 80, the inside of the top cheek is shown.

The full and broken lines which bound the several triangles of which this piece is composed, are also a key to the direction the metal should be bent. That is, the metal is to be bent up on the broken lines, and down on the full lines. The angle of these bends is dependent upon the rise of the elbow and the radius of the throat, i.e., the radius of its plan. As for example, we look upon the surface *C F e b,* Fig. 79, as a plane which may be revolved about the line *C F* as an axis. Presuming this to have been revolved in a manner to elevate point *e 1* inch above point *F,* then point *b* would be considerably more than *1* inch above point *C.* However, since in reality the elbow is no higher at point *b* than it is at point *e,* a bend is necessary upon line *C e.*

We could as consistently assume a bend on a line drawn from *F* to *b,* since it would make no material difference except to demand the bend in the opposite direction. Thus it is but a simple matter to establish in theory the angle at which the metal should be bent upon those lines. However, since this bending process serves our purpose in another way, the exact angle in every instance

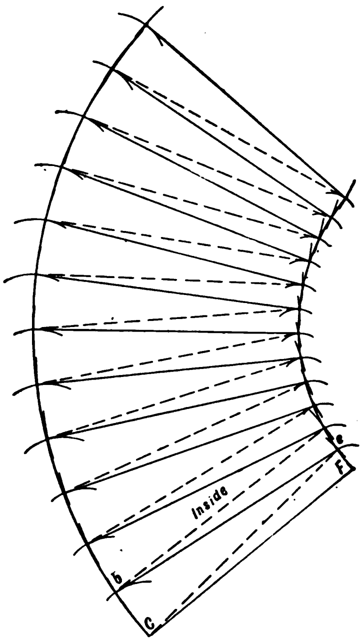


Fig. 80. Pattern for Top and Bottom of Elbow.

has little or no effect upon the required results. There is a super-abundance of material in the center of the cheek, and by making these bends, and drawing out the edges so as to make the cheek appear somewhat as shown at Fig. 81, the required twist is developed. Too little twist denotes that there has not been a sufficient quantity of material consumed in the center, and too much twist denotes that too much material has been consumed. Therefore we must make the bends shallower or deeper as the case demands.

LOSS OF CAPACITY WHEN USED AS A DUCT.

Some loss of capacity will be found in an elbow of this class, as well as some distortion, where said elbow makes connection with ducts of a given area of cross-section. As for example, in this instance it has been presumed that the elbow is to connect ducts with cross-sections of 15 x 30 inches. We find upon referring to Fig. 79 that

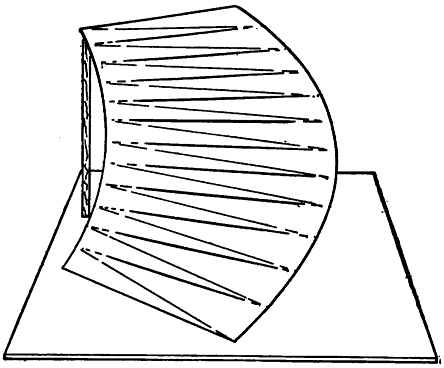


Fig. 81. *Pictorial Representation of Top or Bottom, Showing Breaks or Bends.*

the width of the heel is approximately 14 inches and of the throat approximately 10½ inches. This, as will be noted, makes an average of 12¼ inches, or in a primitive way, we find that the elbow will average 12¼ x 30 inches.

Fig. 82 is included for the purpose of conveying to the reader through the medium of the eye, an understanding of this Upon examination, it will be noted that this diagram shows in a pictorial way, portions of the heel and throat of the elbow connected to the duct. The heel and throat are in reality strips of material cut at the ends at a suitable angle to secure the required rise in a given length. As for example, the heel and throat must rise to the same level while passing around cylindrical forms of varying diameter. Therefore that which passes around the cylindrical form of the least diameter must have the most rise per unit of measurement upon the base of the cylinder. Thus in every instance the throat must have a greater relative rise than the heel. Since vertical lines upon each are of equal lengths, the material which forms these portions must be of varying widths, dependent upon the radius of those parts.

The Right Helicoid.*

Fig. 84 has been constructed to conform to the definition of a right helicoid, which was given in the eighteenth

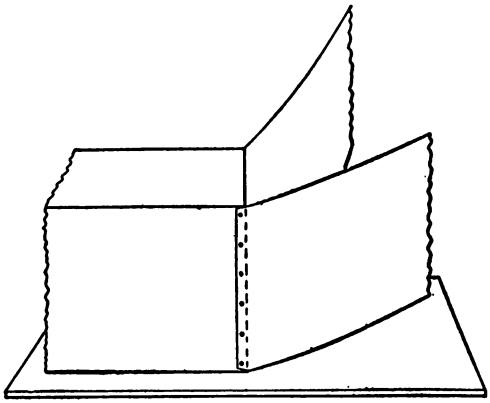


Fig. 82. Portions of Throat and Heel Connected to Duct.

chapter, also in the note below. The vertical line *E* is presumed to be the vertical axis. The thirteen horizontal lines are presumed to be one line which has been revolved

* The right helicoid is a surface which may be conceived as being generated by a right line revolving about an axis, and perpendicular to it; also moving uniformly parallel to said axis. A surface so generated is usually presumed to lie between two concentric cylinders.

about the vertical line E, and shown in different positions which are 7½ degrees distant from each other while making a quarter revolution.

Presuming the total rise to be 24 inches, the rise for

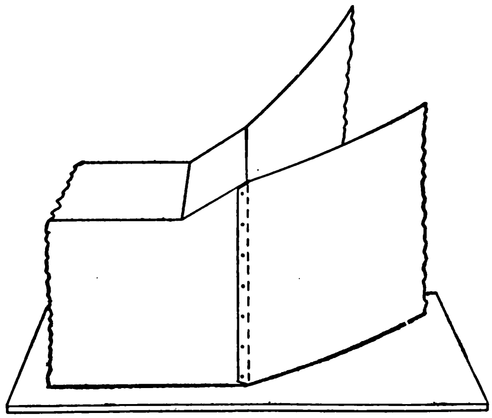


Fig. 83. Duct Enlarged at Intersection of Duct and Elbow.

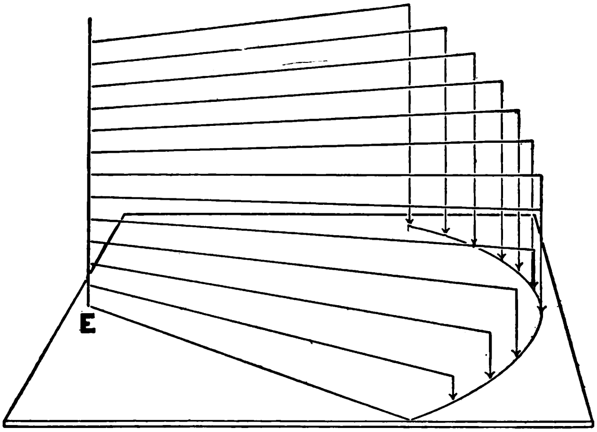


Fig. 84. Generation of Surface Known as Right-Helicoid.

each position would then be 2 inches. Arrow heads point out the plan of the path which the right hand extremity of this line would describe in space while being revolved. From this we conclude that with a given rise for the elbow, as the throat and heel approach the axial line the pitch increases, and conversely, as these parts recede from the axial line the pitch decreases, i.e., the relative pitch to the base of cylinders of which they may be conceived as being a part. When the radius is Zero, the throat becomes a vertical line. As the throat of the elbow recedes from the axial line, loss of capacity and distortion decrease.

Fig. 83 offers some suggestions in a pictorial way on how the capacity of the elbow may be maintained and distortion modified by increasing the hight of the duct at the intersection of duct and elbow. This will become necessary at each end of the elbow, that is, that modification shown in Fig. 83 would be also applied to the bottom of the duct in wall *B*.

CHAPTER XXI.

When it is Required that a Round Pipe Should Join the Frustum of an Oblique Cone.

> An interesting and instructive problem when it is required that two elements of the conical form shall lie in planes which are at right angles to each other, and perpendicular to the plane of its base, with one element of the cylinder in one of said planes.

While this problem is an unusual one, the author has occasionally noted instances where a fitting of this kind has been demanded. It is an instructive problem, as it involves the use of the supplementary plane and the introduction of intersecting surfaces to secure points in the line of contact between the cylinder and conical form.

The intersecting surfaces, or cutting planes, the use of which will be pointed out in this demonstration, are important factors in the solution of many problems. They are many times employed in examples which are so simple that an understanding of their use is of small importance. On the other hand, the more complex examples demand an understanding of their use and importance. It has been here presumed that the patterns are required for a fitting as described above, and shown in a pictorial way in Fig. 86.

The Plan and Elevation.

A plan is the first step in developing the patterns for this kind of fitting. We may therefore draw two lines at right angles to each other, as *I L* and *L D,* Fig. 87, and look upon said lines as the plans of planes within which two elements of the conical form are situated. The plan of each end of the conical form will be secured when circles are drawn at the required diameters, and tangent to *I L* and *L D.* When the vertical hight of the conical form is known, an elevation of that part is secured in the

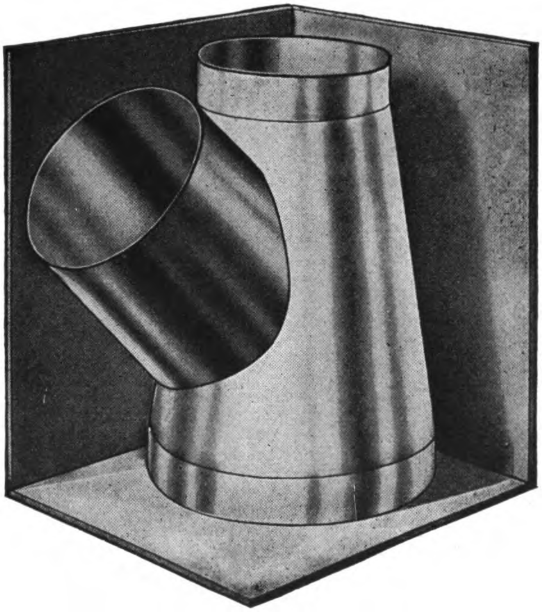


Fig. 86. Cylinder Intersecting Frustum of a Scalene Cone.

usual manner, and clearly shown by construction lines in Fig. 87.

The first step in securing an elevation of the intersecting collar is to draw parallel lines as *e J* and *1 V,* Fig. 87, at the required angle, and at a distance from each other equal to the diameter of that part. A partial plan of the collar is secured by drawing a line as *C 6,* which is parallel to *I L,* and at a distance from it equal to its diameter. We may now look upon a portion of the line *I L* as one element of the cylindrical form, i.e., that element which is farthest from the eye in elevation.

Rectilinear elements of the conical form, or lines presumed to be upon its surface, are located in the usual manner, after having presumed one point of division of each circle to be the exact point of tangency between said circles and the line which is a plan of the tangent plane, as shown at point *1* of each circle in plan.

The elevations of these lines are secured in the usual manner, as is clearly shown by the vertical projectors. The next work is to locate points in the line of contact between the round collar and the conical form, as these points must be located before we can proceed with the patterns: These points are in reality one extremity of rectilinear elements of the cylindrical form which constitutes the round collar, and are best represented upon a plane which is parallel to said elements. This is precisely what we have in the elevation shown. In proof of the foregoing, it will be recalled that all rectilinear elements of a cylindrical form are parallel to the axis of that form, therefore parallel to each other.

Upon examination it will be noted that a portion of the line *I L,* Fig. 87, is looked upon as a plan of one element of the round collar, therefore parallel to the vertical plane.

Intersecting Surfaces or Cutting Planes.

In all cases where what may be looked upon as one solid of revolution, such as a cylinder, cone or sphere, is joined, or made to penetrate as it were, another solid, a line is developed which is called the line of contact in the above, and also known as the line of penetration. This line of penetration is the important factor in examples

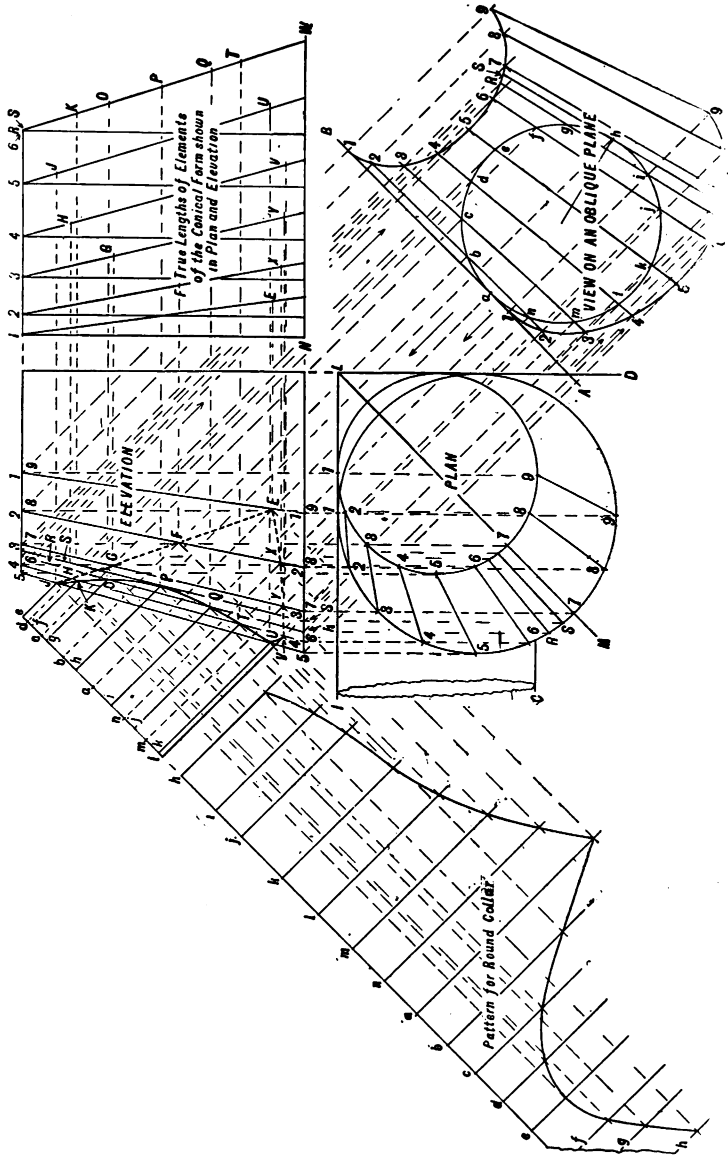


Fig. 87. Diagrams Representing Object Shown in Fig. 86, Upon Vertical, Horizontal and Oblique Planes, Together With Diagram of Triangles and Patterns for the Round Collar.

of this class, since we are hopelessly defeated unless it can be represented.

Points in this line are located by the use of intersecting surfaces, i.e., by dividing each form by planes common to both. These surfaces, or planes, may be either perpendicular, parallel, or inclined to the planes of projection, or the axis of the form. However, to simplify the work

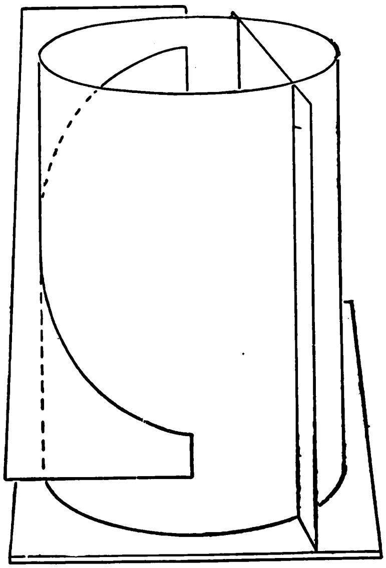


Fig. 88. Graphic Representation of the Cutting Plane.

of finding the projection of said lines developed by said planes, it is desirable to fix upon a direction for the intersecting surfaces which will give the most simple form, i.e., right lines or circles. The same problem may be simplified, or made more complex by the location of these planes.

For example, a cylinder may be cut by a plane oblique to its axis, thus developing an elliptical form as shown in a pictorial way at the left of Fig. 88. Since the elliptical form is usually secured by locating a number of points, it prolongs the work and invites confusion if there is a number in any one problem. If the cylinder be cut by a plane parallel to its axis, the form of section developed is a rectangle as shown at the right of Fig. 88. Here as will be noted, a true form of section may be represented by right lines.

Fig. 89 shows in a pictorial way two intersecting cylinders which have been penetrated by a plane. As will

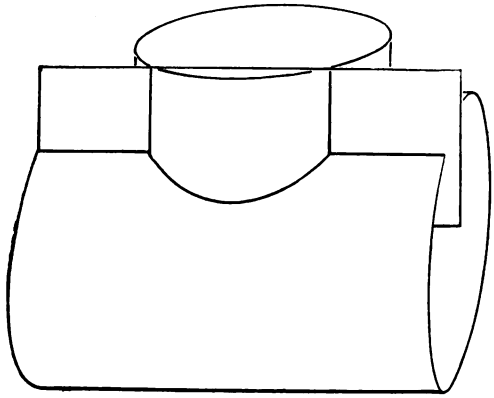


Fig. 89. Graphic Representation of Two Intersecting Cylinders Cut by a Plane.

be noted, the intersecting surface is parallel to the axis of each cylinder, thereby cutting rectilinear elements from each. The intersections of said elements form points which are in the line of contact between the vertical and horizontal cylinders. This is precisely what our aim is to accomplish in the problem before us.

From an analysis of the problem secured from the diagrams in Fig. 87 we conclude that intersecting surfaces may be so located as to cut rectilinear elements from each form. The next work is then to find a plane upon which a representation of the object may be drawn, and said surfaces located. The position of this plane is found when a line as *A B,* Fig. 87, is drawn perpendicular to lines *1 V* and *e J.* That is, the line *A B* is now looked upon as the intersecting line between the vertical and an oblique plane.

Relative Positions of Planes of Projection.

Fig. 90 shows in a pictorial way the relative positions of the planes of projection. As, for example, we have before us the horizontal plane, above this is the vertical plane, and to the right is the oblique plane. Between the eye and the vertical plane there is suspended an object of which two faces are parallel to the vertical, with the remaining four faces at an angle to the horizontal, and perpendicular to the vertical plane.

Since the oblique plane is parallel to the two smaller faces of the object, its representation upon that plane will be its true form when viewed in the direction indicated by the arrow *A.* The position of the diagram which represents the object upon the oblique plane is determined by the position of the object in space. This position is indicated by the plan and elevation. Thus the representation of the object will be at the same distance from the vertical plane as its plan, which is shown directly beneath it upon the horizontal plane.

A Model May Prove of Service.

If any difficulty is experienced in securing an understanding of the planes as shown in a pictorial way at Fig. 90, a crude model may be constructed, which will no doubt prove of considerable value in securing that understanding. After having constructed a model of the planes, an object may be held in position as shown, and viewed as indicated by the arrows, remembering that in every case the point viewed is in a line perpendicular to the plane upon which it is represented. We may thus secure a clear understanding of the plan, elevation and representation of the object upon the oblique plane. It should also be remembered that Fig. 90 is simply a pictorial representation.

Since a portion of *I L,* Fig. 87, is a plan of one element of the round collar, the collar itself must be tangent to the vertical plane. Therefore if a circle be drawn upon

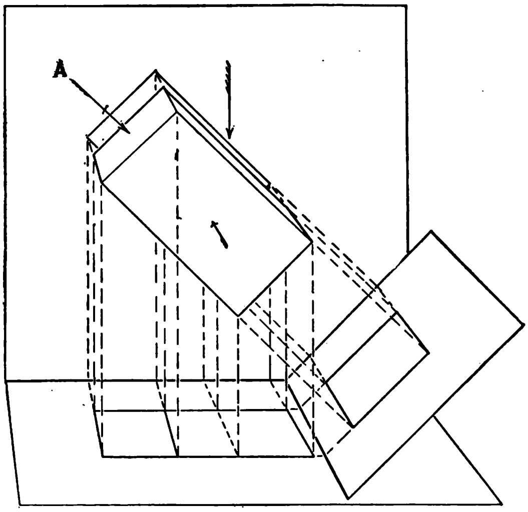


Fig. 90. Graphic Representation of An Object In Space and Upon Vertical, Horizontal and Oblique Planes.

the oblique plane in a position as shown, and of a diameter equal to the known diameter of the round collar, a representation of it is secured upon that plane. Each element of the conical form shown in plan and elevation may be represented upon the oblique plane as indicated by the oblique projectors, remembering that the upper and lower extremities of these lines will be of the same distance from the line *A B* as similarly designated points are from line *I L* in plan. The representations of rectilinear elements of the cylindrical form upon the oblique plane are in points *a b c d e* etc., of the circle. The representations of said elements or lines in elevation are located as shown by the oblique projectors from said points.

Since elements of the conical surface which were first located in plan do not cross or intersect all parts of the circle when represented upon the oblique plane, some additional lines must be introduced. In other words, when said elements are looked upon in the oblique projection as the representations of planes which cut rectilinear elements from each form, there is not a sufficient number, therefore we locate lines as *R R* and *S S*. These lines can be located by dividing the curved lines between points *6* and *7* of each end of the conical form shown in the oblique projection, into the same number of equal parts, after which those lines may be drawn through similar points of division. The positions of said lines upon the conical form may then be very closely approximated, or they may be projected in the usual manner as shown, to the elevation and then to the plan, which will thus secure their exact location, providing this work is done accurately.

It will be noted that the line *S S* in the oblique projection, when looked upon as the representation of a plane, cuts but one element from the cylinder, as shown at *h,* therefore becomes a tangent plane.

To locate points which lie in the line of contact in elevation, we look upon points of the circle as *a, b, c, d,* etc., in the view upon the oblique plane, Fig. 87, as the representation of lines, the lower extremities of which intersect elements of the conical form. As for example, the lower extremity of line *a* is at its intersection with the conical element *1 1,* and when shown in elevation is at point *E*. Likewise lines shown at *b* and *h* in the oblique projection terminate upon coming into contact with the conical element *2 2*, and shown in points *F* and *X* of the elevation. By similar reasoning we locate the remaining points which lie in the line of contact, as *G, H, J, K, O, P, Q, T, U, V* and *Y*. In locating the above points, some attention must be devoted to determining upon which side said points are situated. This work will be simplified if we remember that those points shown upon the oblique plane which are farthest from the line *A B*, are nearest the eye in elevation, and conversely, those points which are farthest from the eye in elevation are nearest the line *A B* upon the oblique plane.

Pattern for the Round Collar.

Having located points in the line of contact between the round collar and the conical form as shown in elevation at points *E, F, G, H*, etc., we are now in a position to secure the pattern for the round collar.

Lines as *b F, h P, i Q*, etc., of the elevation, are the elevations of rectilinear elements of the cylindrical surface, and are represented upon a plane which is parallel to said elements, therefore shown upon that plane in their true lengths. Points as *a, b, c, d, e, f*, etc., upon the oblique plane, furnish us with the distance said elements are from each other upon the round collar.

Therefore we may, in any convenient position, draw parallel right lines at distances from each other as found upon the circle in the oblique projection, as shown at the pattern for the round collar. One extremity of all rectilinear elements of the round collar terminates at its upper edge in one right line when said surface is developed into a plane. The lower extremities of said lines or elements are in points *E, F, G, H*, etc., of the elevation.

Therefore we simply transfer lengths as found in elevation to similarly designated lines upon the plane of development to locate points through which a line may be traced to represent the boundaries of the pattern for the round collar, as is clearly shown in Fig. 87.

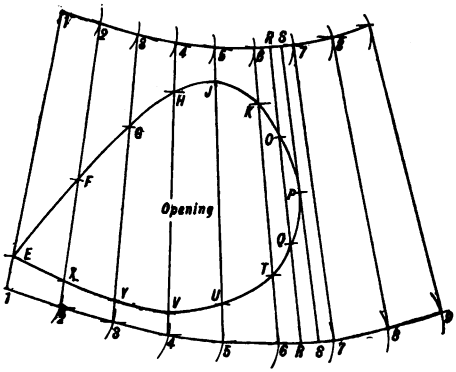


Fig. 91. *Pattern for the Required Opening in the Conical Form.*

The one who has followed this work will have little difficulty in developing the pattern for the conical form, since this has been fully explained in the early chapters, therefore reference to that is here omitted. However, attention is directed to the fact that the only line which divided the plan of the conical form into equal parts is that shown at *M L*.

If the pattern for the conical form was the sole consideration, its elevation would be best drawn upon a plane, the intersecting line of which is parallel to line *M L*. As this demonstration is for the purpose of illustrating methods which may be pursued to secure the pattern for the intersecting collar and the required opening in the conical form, the diagrams are best drawn as shown at Fig. 87.

The following explanation has been written on the presumption that the reader is in a position to develop the pattern for the frustum of an oblique cone, and locate right lines upon said pattern, the plans of which are shown in Fig. 87. It will be recalled that in this demonstration a number of those lines have been looked upon as elements cut from that form by intersecting surfaces, which also cut rectilinear elements from the round collar, and the intersections of said elements located points in the line of contact between the round collar and the conical form.

Locating Points In Required Opening.

To locate points in the outline of the required opening, we must determine the exact points along the conical elements at which the cylindrical elements intersect them. In this demonstration it is presumed that lines as shown in plan and elevation have previously been located upon the pattern, and that our purpose is to locate points along said lines, which are in reality in the line of contact.

Upon turning attention to Fig. 87 we note that triangles have been drawn whose longest sides are equal in length to those conical elements which are intersected by elements of the round collar. The method of drawing these triangles will no doubt be apparent, since the base lines of all are in the line *N W*, which is in reality a continuation of the base line of the fitting in elevation, and that the vertical hight of all is equal to the vertical hight of the conical form. Each triangle is designated by a number at the top. The true length of any one line is then found by reference to the character at the top of the triangles. As for example, the true length of line *3 3*, shown in plan and elevation, is found in the hypothenuse of the triangle marked *3* at the top, and so on for all lines shown.

Points of Contact in Elevation.

Since we have in elevation the elevations of a number of points of contact between the round collar and the conical form, we may project said points parallel to the base of the fitting, and locate them upon corresponding lines in the diagram of triangles as shown at Fig. 87. For example, we may select the conical element *3 3*, when it is noted that said element contains two points of contact as *G* and *Y*. Horizontal lines are drawn from said points to intersect the oblique line *3* in the diagram of triangles. These points of intersection are then the exact point of contact along the conical element *3 3*, and in their correct location as regards the extremities of that element.

Or we may select the conical element *R R*, when we find points of contact as *Q* and *O*; these points may then be projected to the oblique line marked *R* in the diagram of triangles, to locate points *Q* and *O* in their correct positions along the conical element *R*. *R*. By continuing this work for each point shown, in a manner as explained above, we are enabled to locate all points shown in elevation. Since in this example the conical elements *R R*, *S S* and *6 6* are found to be of equal lengths, all are represented in one line in the diagram of triangles.

Having now before us the exact location of points of contact along the rectilinear elements of the conical form, we may transfer them to our pattern, presuming said pattern to have been developed as shown at Fig. 91. That is, we shall presume that the pattern has been developed, and that lines as shown in plan and elevation at *1 1*, *2 2*, *3 3*, etc., to have been located thereon. To locate these points along said lines is but to transfer distances as found in the diagram of triangles to similar lines of the pattern, taking all distances in the diagram of triangles from the line *N W*.

For example, we set our compasses to a distance equal to the distance from the line *N W* to point *E*, on the oblique line *1* of the diagram of triangles, and mark a similar distance upon element *1 1* of the pattern from its base, thereby locating point *E* as shown. In a similar manner we locate points *F* and *X* in the line *2-2* of the pattern, and so on for all points shown in the elevation. After which a line is traced through said points to complete the outline of the required opening, as shown, Fig. 91.

The lengths of the lines which represent the opening in the conical form should now measure approximately the same as the lower edge of the pattern for the round collar, and if this proves to be the case, it is a fair indication that our work is correct.

CHAPTER XXII.

A Branched Fitting Commonly Known as "Breeches."

In some branches of sheet metal work, there is a constant demand for the branched fitting. As an introductory problem to satisfy this demand, we shall here

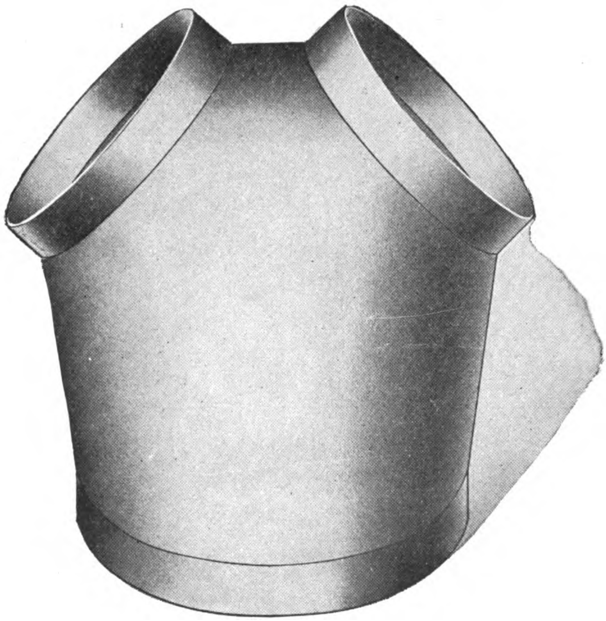


Fig. 92. Photographic View of the Fitting.

presume that the pattern is required for a fitting as shown in a pictorial way at Fig. 92. Said fitting is designed to make connection between a trunk line and two smaller branches. The axes of all to be in the same plane, with the smaller pipes radiating from, or converging to the trunk line at an angle of 45 degrees.

This is a problem wherein the necessary diagrams may be curtailed to a considerable extent in developing the pattern. However, to place before the student the reason for, and the use of these curtailed diagrams, we shall first consider a complete plan and elevation.

A COMPLETE PLAN AND ELEVATION.

Having before us the required measurements, we may first draw a horizontal line as *A B,* Fig. 93, whose length is equal to the diameter of the large pipe. From the center point of this line as at *C,* erect a perpendicular as *C D.* Set off from *C* along line *C D,* a distance equal to the required length of the fitting as at *E.* Through the point *E* draw a horizontal line as *F G.* Upon line *F G,* and at each side of point *E,* set off one-half the required distance between the small collars as at points *F* and *G.* From points *F* and *G* draw lines as *F H* and *G J,* which are at an angle of 45 degrees to line *C D.* Set off distances along said lines equal to the diameter of small collars, as shown at *H* and *J.* Draw lines as *H A* and *J B* to complete a view which is in this instance, looked upon as an elevation, or a section of the fitting taken upon line *K M.*

When said diagram is looked upon as an elevation, a view of the fitting upon the horizontal plane is secured by first drawing a circle whose diameter is equal to the length of line *A B,* and in a position as shown, i.e., its center is in some point along the line *C D* produced.

Lines as *H F* and *G J* are looked upon as the edge view of circles whose diameters are equal to the diameter of the small pipes. As will be noted, said circles are perpendicular to the vertical plane, and at an angle to the horizontal, thus the representations of said circles upon the horizontal plane will be elliptical. To draw these forms in their correct relative positions, we draw semi-circles as shown, which are in reality semi-profiles of the round collars. Divide said semi-profiles into a convenient number of parts as shown, and project these points of division to lines *H F* and *G J*, as also shown. From points thus located along lines *H F* and *G J*, we drop vertical projectors to the horizontal plane.

From any convenient point along line *N M*, Fig. 93, we may draw a semi-circle whose diameter is equal to the diameters of the round collars, and divide said semi-circle into the same number of equal parts as the semi-profiles have been divided into. From said points of division we draw lines parallel to line *I L* as shown. Then will points secured in the intersections of these lines with the vertical projectors, be points in the plans of the openings to which the round collars are to be connected. As for example, if we look upon point *a* in the elevation as the end of a line which is perpendicular to the vertical plane, and whose length is equal to the length of line *b b* shown in the semi-circle *M*, the broken line *d d* in plan becomes a plan of that line. Since the positions of all other points which must be located in plan are secured by similar work and reasoning, the student should have little difficulty in comprehending, or drawing diagrams as shown at Fig. 93.

With the plan as shown at Fig. 93 before us, we note that said diagram is capable of being divided into four equal parts, i.e., by lines *K M* and *C N* produced. Thus we conclude that diagrams may be drawn to represent one-quarter, and measurements thus obtained duplicated for the three remaining parts.

From an analysis of the fitting derived from its plan and elevation, Fig. 93, we also conclude that there are two portions which closely resemble the conical form, and between these there are two flat triangular surfaces.

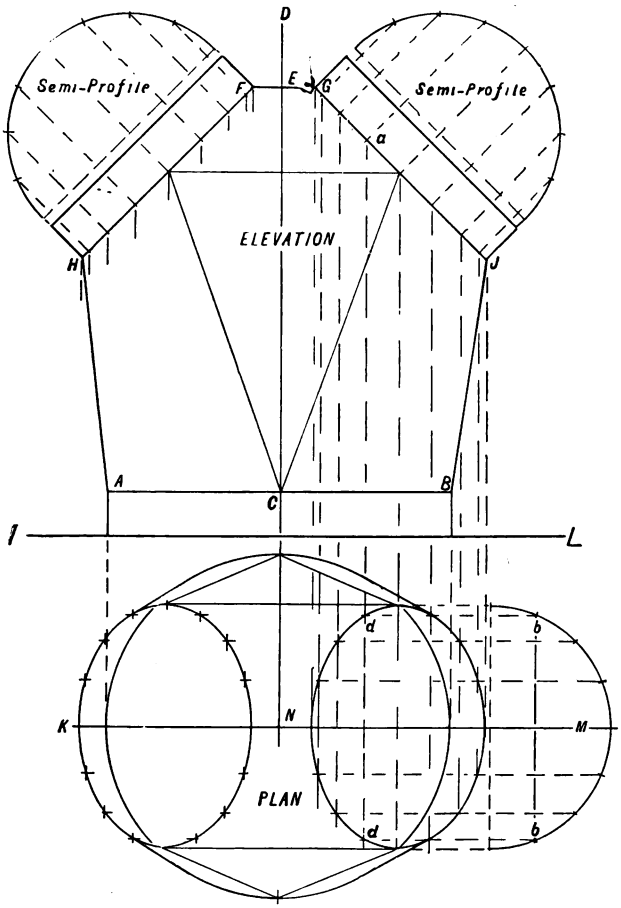


Fig. 93. The Branched Fitting Represented in Plan and Elevation.

The upper portion, or that to which the upper half of each collar is to be connected, is a form which when cut at the required angle, supplies a semi-circle as its section.

Since the lengths of lines presumed to be upon one-quarter of the fitting may be duplicated for the remaining three-quarters, we may, when the pattern is developed, curtail our diagrams as is shown in Fig. 94, i.e., it is only necessary to represent but one-quarter of the object in plan and elevation.

A Curtailed Plan and Elevation.

To draw a plan and elevation as shown at Fig. 94, we first draw the quarter circle in plan, to a diameter equal to the required diameter of the large collar. Through the point from which the quarter circle was drawn as at *X*, we draw a perpendicular line, and set off a length equal to the required length of the fitting, as *1 a*. From point *a*, draw the horizontal line *a e*, locating point *e* at a distance from *a* equal to one-half the required distance between the round collars. From a point *e*, draw a line at the required angle to *1 a*, as *e 5*. Locate the point *5* at a distance from *e* equal to the required diameter of the small collar. From the center point of line *e 5*, draw a semi-circle whose diameter is equal to the length of line *e 5* as shown. Divide said semi-circle into a number of equal parts, and project said points of division to the line *e 5*, as also shown at *2 3 4* and *b c d*.

From some point along the line *5 X*, draw a quarter circle whose diameter is equal to the required diameter of the small collars as at *Y*, and divide this arc into the same number of parts as was a similar arc shown in the semi-profile, as at points *2 3* and *4*. Draw indefinite horizontal lines through these points to intersect lines dropped from points *1 2 3 4* and *5* on the line *5 e*, then will these intersections be points in the line which is a plan of the fitting on line *1 5* of the elevation.

Divide the quarter circle in plan into the same number of parts as the arc *1 5* of the semi-profile has been divided into. Project said points of division to a horizontal line drawn through the lower extremity of line *A 1,* thus locating points as *1 2 3 4* and *5* at the base of the fitting in elevation. As will be noted, we have thus

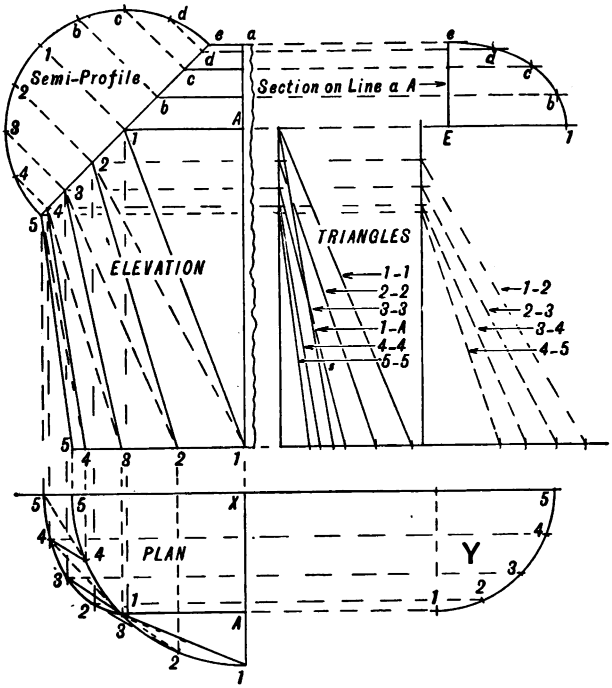


Fig. 94. Diagrams from Which the Pattern May Be Secured.

located lines in plan and elevation which may be presumed to be upon the surface of the fitting, and which we shall use to develop the pattern.

The plan and elevation before us supply the distances said lines are from each other; however, their lengths must be determined, therefore we construct a diagram of triangles as shown.

The method of constructing the diagram of triangles is substantially the same as with all examples in this branch of pattern development, and to those who have followed this work, it is but a simple operation. As a matter of fact it is folly for one to attempt the solution of a problem of this nature without having first acquired some understanding of the more simple examples.

As will be noted upon examination of Fig. 94, the elevation supplies the perpendicular hight for all triangles. For example, the triangle which must be constructed to secure the length of line *1 A* on line *1 A X* of the plan, has a base equal to the length of line *1 A* on the line *1 A X,* and a perpendicular equal to the length of the vertical line *A 1* of the elevation.

The base of a triangle from which we may secure the true length of line *1 1* shown in plan and elevation, is equal to the length of line *1 1* of the plan, with a perpendicular equal to the vertical distance between the extremities of that line shown in elevation, and so on for all lines presumed to be upon the surface of the fitting.

It must be remembered that the rectilinear elements as *1 1, 2 2, 3 3,* etc., are not sufficient to develop the pattern, therefore additional lines must be introduced, as shown in broken lines *1 2, 2 3, 3 4,* and *4 5,* and whose true lengths are also shown in the diagram of triangles.

To Develop the Pattern for the Irregular Portion

Having determined the true lengths of lines presumed to be upon the irregular portion of the fitting, and shown in plan and elevation, we may proceed to develop the semi-pattern for that part, when our line of reasoning may run somewhat as follows: Since we are to develop a half pattern from the diagrams before us, we must duplicate practically all measurements found in those diagrams. Therefore we draw in any convenient position, a line, some portion of which is the line *1 A,* as shown at the vertical line *1 A,* Fig. 95. Having located a point as *1* at the base of the pattern to our satisfaction, we set off along that line a distance equal to the

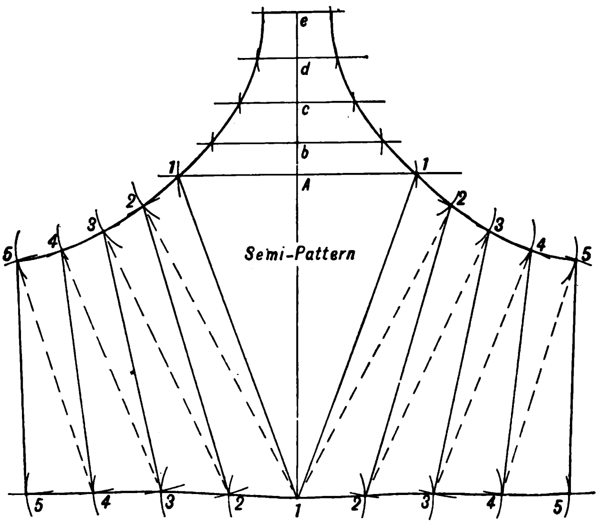


Fig. 95. *Semi-Pattern for the Branched Fitting Shown at Fig.* 92.

true length of line *1 A* found in the diagram of triangles, as shown at *A* of the pattern. This is a line which divides the flat triangular surface of the fitting into two equal parts.

Through point *A* of the pattern, we draw a line perpendicular to the first, making it of a length each side of *A* equal to the length of the horizontal line *1 A* of the elevation, as shown at *1 A 1* of the pattern, Fig. 95. To complete the boundaries of the flat triangular surface, we draw the lines *1 1* as shown.

The distance between lines *1* and *2* at the base of the fitting is found in the first division of the quarter circle in plan. Using this distance as radius, and with the point *1* at the base of the pattern as center, we draw two small arcs as shown. With compasses set to a span equal to the distance between points *1* and *2* of the semi-profile, we use the points *1* at the top of the pattern as centers and draw arcs, as also shown. With the length of line *1 2* found in the diagram of triangles, and with point *1* at the base of the pattern as center, describe small arcs cutting the first at the top of the pattern, as shown in points *2*. Then will point *2* be the upper extremity of the rectilinear element *2 2*. With the point *2* at the top of the pattern as center, and with the length of line *2 2* found in the diagram of triangles as radius, we draw arcs cutting the first at the base of the pattern, thereby locating the lower extremity of the rectilinear element *2 2* in its correct relative position.

To complete the pattern for the irregular or lower portion of the fitting as shown, is but a repetition of the work as explained above, using the length of each line shown in the diagram of triangles in rotation to locate said lines in their correct relative positions, remembering that the true distances between the lower extremities of said lines are secured from distances points of division are from each other in the quarter circle in plan which represents the large collar, and that the true distances between the upper extremities of said lines are secured from the semi-profile.

Fig. 96 will no doubt be of service in securing an understanding of this, since that Fig. shows in a pictorial way the semi-pattern formed to its required shape, with said lines upon its surface.

On the Portion of the Fitting Which May Be Looked Upon as a Parallel Form.

The portion of the fitting shown in Fig. 94 above the horizontal line *1 A,* is a parallel form whose cross-section or profile will show a semi-ellipse, or in this instance, i.e., in Fig. 94, where it is presumed that one-quarter of the fitting only is represented, said section will then be a quarter ellipse as shown at section on line *a A*. Therefore to develop this portion of the pattern, we may

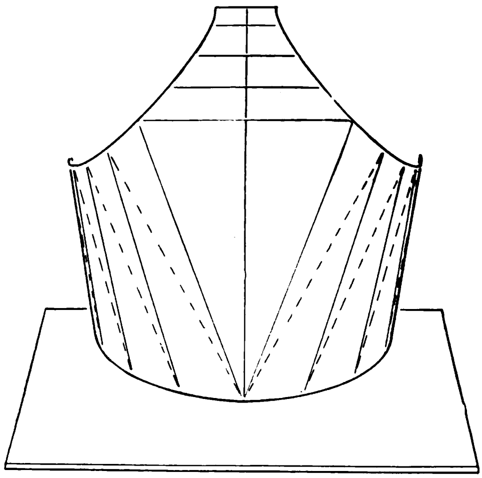


Fig. 96. Pictorial Representation of the Semi-Pattern When Bent to Its Required Form.

look upon the horizontal line *1 A* and lines above it, as *b c d* and *e,* as rectilinear elements of that surface, and in this instance, said elements are in their true lengths. If then we can determine the distance these elements are from each other, the development of that surface is but a simple matter. As will be noted, the section on line *a A* shows in points *1 b c d* and *e,* those distances. This section is drawn by projecting indefinite horizontal lines from points *1 b c d* and *e* as shown, and in any convenient position erecting a perpendicular as *E e*. From the line *E e,* set off distances on the several lines as shown. As for example, the distance from line *E e* to *d* is that found between points *d* and *d* of the semi-profile, and so on for each line represented.

Presuming an understanding of this is secured, we may now complete the semi-pattern. That is, we draw lines parallel to line *1 A 1* of the pattern at a distance from each other equal to those distances found between similarly designated points in the section *a A,* and locate points upon said line each side of line *e A* of the pattern, at distances as found in the elevation, i.e., the length of the horizontal line shown in elevation whose left hand extremity is at point *b,* is set off each side of the pattern on the horizontal line which intersects point *b.*

By applying similar methods to the remaining lines shown in elevation, or those whose left hand extremities are in points *c d* and *e,* we are enabled to complete the semi-pattern as shown.

Some Variation May at Times Be Desirable.

It is by no means necessary that the pattern be developed precisely as here shown. In other words, we may if we wish, select other positions for the seams, or we may introduce more seams. For example, we may make the main body of the fitting in one piece; and that portion between the collars at the top as a separate piece, with seams on each side on a line as *1 A 1* of the pattern, or, we can if we wish, cut the whole from one piece.

Since lines which are presumed to be upon the surface of the fitting, and represented in plan and elevation are presumed to be right lines, we should at all times use care in their location. That is, their positions should be so taken as to allow said lines to be as nearly straight as possible if placed upon the surface of the object. In this example, slightly more accuracy may be obtained by presuming the broken lines to connect points as *5* of the base to *4* of the top, and so on. However, some slight inaccuracy will usually appear in examples of this nature. On the other hand, we should not be too quick in assuming an error. Be sure your metal has been made to assume its intended form before judgment is passed.

CHAPTER XXIII.

A Simple Two Pronged Fitting.

Fig. 97 illustrates a two pronged fitting of the most simple order. No doubt a form as here shown will receive some criticism, which may in some instances be justifiable. However, since it is a problem containing

Fig. 97. Photographic View of the Fitting.

principles which may be employed in securing the patterns for the more popular forms of branched fittings, it is here introduced in an endeavor to convey to the student that understanding necessary to enable him to develop the patterns for the more complicated forms.

As illustrated at Fig. 97, the axes of all collars are in one plane, or as we hear it in the shop, it is "on center." A change of the plan places all collars tangent to one plane, or what is commonly known as "flat on one side."

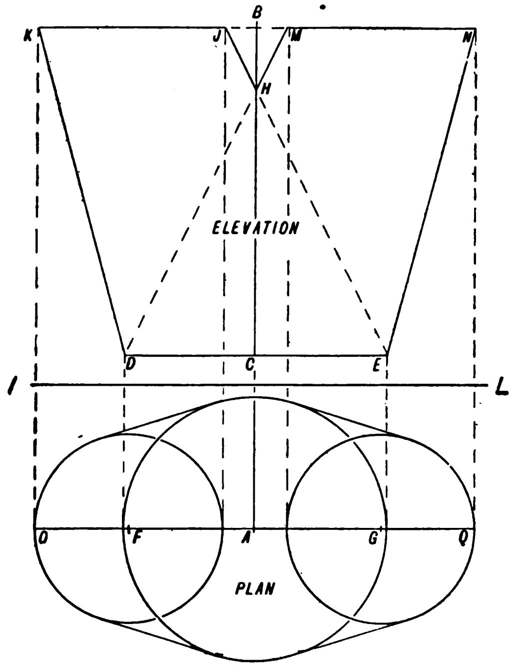


Fig. 98. The Plan and Elevation of a Fitting as Shown at Fig. 97.

For the moment we shall presume that the pattern is required for a fitting as illustrated at Fig. 97, and as the work progresses, endeavor to explain the methods which may be pursued to secure the pattern when it is required that the fitting shall be "flat on one side."

Diagrams to Represent the Object.

Simple diagrams will in this instance represent the object in plan and elevation, as shown at Fig. 98. To draw these diagrams, we may first draw a circle whose diameter is that of the main stem, as shown at *F G*. From the center of said circle as at *A*, draw an indefinite vertical line as *A B*. Locate a point along this line as *C*, which shall be in the base line of the fitting in elevation. Draw a horizontal line through point *C* as *D C E*, and project points *F* and *G* of the large circle in plan to the line *D C E*, as at points *D* and *E*. Set off from *C* along the line *C B*, a distance approximately equal to the length of line *F G* as shown at *H*. Draw lines as *E H J* and *D H M*. At a reasonable distance above point *H* on lines *D H* and *E H*, locate points as *J* and *M*. Through points *J* and *M* draw horizontal lines as shown, and set off distances equal to the diameters of the small collars as shown at *K* and *N*. Draw lines as *K D* and *N E* to complete the diagram here looked upon as an elevation. Perpendicular lines dropped from points *K J M* and *N* to intersect the line *O Q* locate points through which the circles are drawn to represent the small collars in plan.

The Length of the Fitting at the Intersection of Its Prongs.

The distance set off along line *C B*, as *C H* is by no means arbitrary, since as will be noted, it represents the length of the fitting at the intersection of its prongs. On the other hand, it has been found that a fitting of this class assumes a somewhat more symmetrical form when this length is made approximately equal to the diameter of the main stem. Make it more or less if conditions demand it, although a great departure from this rule will be found to distort the fitting.

The Form of the Object at the Intersection of Its Prongs.

From an analysis of the fitting represented in plan and elevation at Fig. 98, we conclude that a portion of the elevation as shown at *K J D E* may be looked upon as the elevation of the frustum of a scalene cone, and that the two circles directly beneath it are the plans of the upper and lower extremities. If the conical form be cut away to the right of line *C H,* the remaining portion to the left of that line will then supply one prong of the fitting, and since the conical form is cut away through the center of its base, it may be duplicated for the opposite prong. As will be noted, this mode of procedure allows the conical form to establish the form of the fitting at the intersection of its prongs. This, the author believes to be the most satisfactory course to pursue, since distortion at this point will thus be eliminated, or at least reduced.

It is not to be understood that a form cannot be preestablished for the object at the intersection of its branches and results secured, providing one is competent to establish a suitable form. Where the axes of all collars are in one plane as here represented, this is not a particularly difficult task. On the other hand, if the collars are required to be tangent to one plane, this work becomes more complex.

Diagrams from Which a Pattern May Be Secured.

When the pattern is required for a branch of given dimensions, we may secure the patterns for the frustum of a scalene cone, with diameters of its ends equal to those of the required fitting, and cut away a portion as above described. Upon examination of Fig. 98 we note that the line *O Q* divides the plan into equal parts, and that the line *C A* produced, also divides that diagram into equal parts, therefore we curtail our diagrams as shown at Fig 99. Here as will be noted, there is shown the semi-plan and elevation of the frustum of a scalene cone. To develop the pattern for this, and locate lines as shown in plan and elevation is but a simple operation, and has been fully explained in foregoing chapters. Therefore to avoid undue repetition, it is here presumed that the student is in a position to develop the pattern for the frustum of a scalene cone from diagrams as shown at Fig. 99. The complete semi-pattern is here shown for the conical form, together with full lines presumed to be upon its surface, and shown in plan and elevation as *1 1, 2 2, 3 3,* etc.

It should be remembered that this pattern was not developed without the use of the indirect or broken lines, although here omitted in an endeavor to avoid all unnecessary confusion. If the student fails to secure an understanding of the methods pursued to secure the pattern for the frustum of the oblique or scalene cone as here shown, some attention given to chapter 6 should clear this portion of the problem.

To Locate the Line upon the Pattern Which is at the Junction of the Prongs.

We may look upon the line *A 5* of the elevation, Fig. 99, as the edge view of a plane which intersects or cuts away a portion of the conical form, and the line *5 5* as its plan. Said plane thus intersects the conical element *5 5* at the base of the object, and cuts elements *4 4, 3 3, 2 2,* and *1 1,* as shown in points *A B C* and *D*. We may then construct a diagram of triangles in a position as

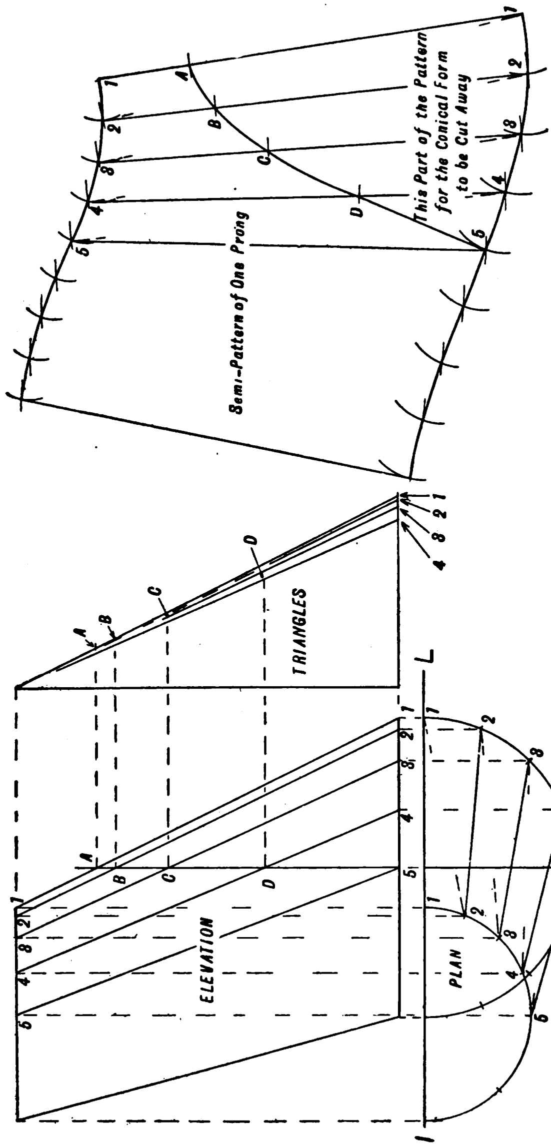


Fig. 99. Semi-Plan, Elevation, and Semi-Pattern.

shown, which will furnish the true lengths of the conical elements *1 1, 2 2, 3 3* and *4 4,* and draw horizontal lines from points *A B C* and *D* of the elevation, to intersect similar elements in the diagram of triangles, as shown. This will, as may be noted, supply the exact positions of points along said elements at which the cutting planes intersect them. To locate said points upon the pattern,

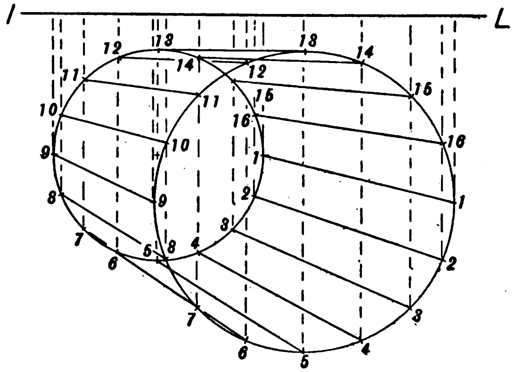


Fig. 100. *Showing a Plan to Be Substituted When It is Required That the Fitting Be "Flat on One Side."*

we transfer distances as found in the diagram of triangles to similarly designated lines upon the pattern, thereby locating points as *A B C* and *D* of the semi-pattern.

A line traced through said points is the line upon which the conical form should be cut away, and which is at the junction of the prongs when the pattern is duplicated, and bent into its required form.

It should be remembered that the pattern shown at Fig. 99 is simply the pattern for one-half of one prong, and must be duplicated for the other half. In other words, the body of the fitting will require four pieces of the pattern as here shown.

To Secure the Pattern for the Fitting When It Is Required to be "Flat on One Side."

When it is required that the fitting shall be flat on one side, the plan may be drawn to conform to this demand by drawing the circles which represent the ends of the object, tangent to one line. Fig. 100 is a diagram which fulfils this requirement in so far as one prong is concerned. If said diagram be substituted for the plan shown in Fig. 99, we may proceed in the same manner as has been explained, although it must be remembered that since this diagram cannot be divided into equal parts by lines which are parallel or perpendicular to *I L,* the true lengths of all lines must be secured, i. e., those lines presumed to be upon the surface of the object, and connecting points at the base and top.

Points of division have been so taken in Fig. 100 that the elevations of said lines remain the same. As for example, the line *2 2* in elevation, Fig. 99 is the elevation of a line, the horizontal projection of which is *2 2* of the plan, and so on. When Fig. 100 is substituted for the plan shown in Fig. 99, we note that a portion of the lines in elevation, then become elevations of not only those lines nearest the eye, but of similar lines which are farthest from the eye. As for example, the line *2 2* in elevation is not only the elevation of a line the plan of which is *2 2,* but also represents a line whose plan is *15 15,* Fig. 100, and so on. However, since lines shown in plan, Fig. 100, are of unequal lengths, the true lengths of all must be determined separately, thereby creating additional work and lines in the diagram of triangles. In addition to this, the whole pattern for one prong must be developed, and will be found to assume a somewhat different appearance from that shown in Fig. 98.

After the pattern has been duplicated to form the opposite prong, care must be used in forming, i.e., those parts must be formed in opposite directions to allow said parts to occupy correct positions when the fitting is assembled.

CHAPTER XXIV.

A Two Pronged Fitting Whose Prongs Are Unequal.

The chief difficulty which is usually encountered when an attempt is made to develop the pattern for an unequal branched fitting as illustrated at Fig. 101 is to establish

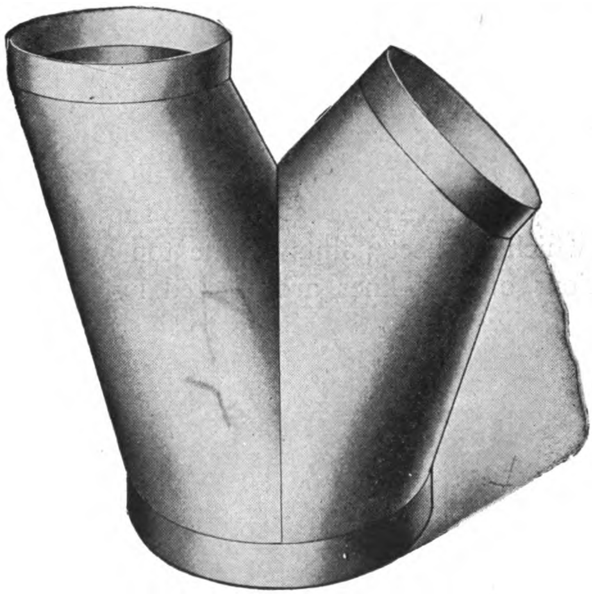


Fig. 101. *Photographic View of the Fitting.*

a suitable form at the junction of its prongs. Therefore our first work will be to discuss methods which may be pursued to establish that form.

Upon comparing Fig. 97 in Chapter 23 and 101, it will be noted that one prong of Fig. 101 is a duplicate of the left hand prong of Fig. 97: thus if we can determine the true form of a fitting as shown at Fig. 97 at the junction of its prongs, we have established a form for that part of the fitting as shown at Fig. 101.

To Establish the Form of the Fitting at the Junction of Its Prongs.

When following a course as here suggested, we presume one prong of the fitting to be a portion of the frustum of an oblique cone, and determine the true form upon the line which represents the junction of the prongs in elevation, which may be accomplished as shown at Fig. 102.

Upon examination of Fig. 102, it will be noted that there is shown the plan and elevation of the frustum of an oblique cone, a portion of which will supply one prong of the required fitting. Fig. 102 also shows a number of lines which connect points of the top and base. The elevations of said lines are located by projecting the points of division of the circles to lines parallel to *I L* which represent the top and base of the object in elevation.

The line *5 13* in plan Fig. 102, is a plan of a plane which cuts away a suitable portion of the conical form, since it passes through the center of the large circle, and as said line is perpendicular to *I L,* the line *5 D* is an elevation of said plane. This plane thus cuts the conical elements or lines which connect points of the top and base in points *E F G H J K* and *L,* and intersects elements at the base of the fitting in points *5* and *13.* The distance above the base of the object at which said plane intersects or cuts these elements is shown at points *A B C* and *D* of the elevation.

Thus we have definitely located in plan and elevation a number of points upon the surface of the conical form which were created by the plane in penetrating that form. Since the position of a point in space may always be determined from its plan and elevation, we may pro-

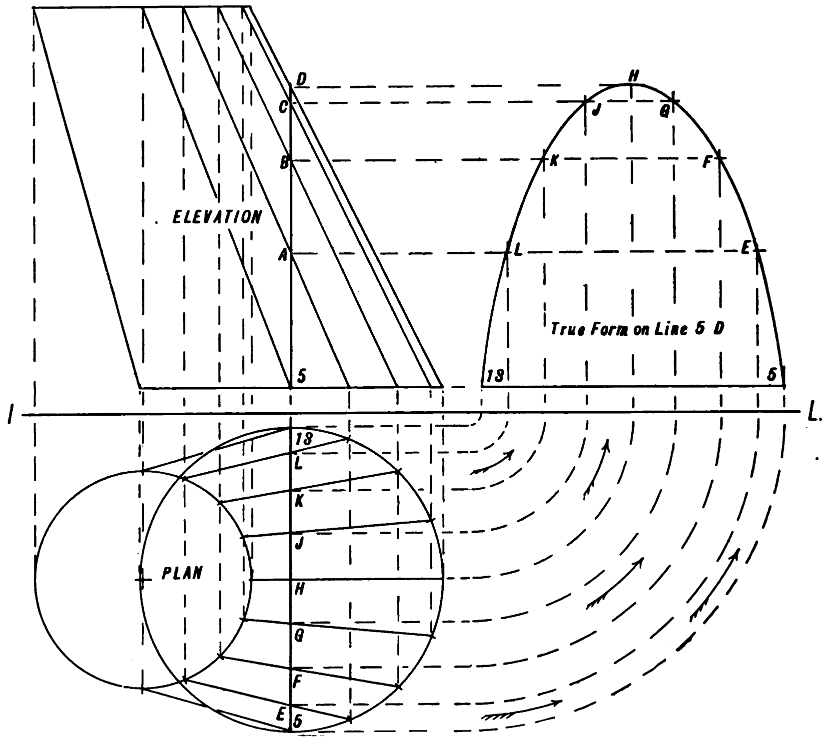


Fig. 102. *Plan, Elevation, and True Form of Section.*

ceed to locate those points in their correct relative positions by erecting perpendicular lines at distances from each other as found between points along the line *5 13* of the plan as shown at the true form. Said lines are now intersected by lines projected from points *D C B* and *A*, thereby locating points as shown at *5 E F G H J K L* and *13* of the true form on line *D5*. A line traced through said points will then supply the form of the fitting at the junction of its prongs.

Other lines of reasoning may of course be applied to this operation to secure identical results, as for example, the point *B* in elevation may be looked upon as the end elevation of a line which is perpendicular to the vertical plane, the length of which is the distance between points *F* and *K* of the plan, and so on for all lines shown.

Having established the form of the fitting at the junction of its prongs, we may proceed to develop the pattern for the right hand prong as shown at Fig. 103. Here as will be noted, an elevation may be drawn to satisfy the demand. In this instance it has been presumed that the lines *A 5, 5 1, 1 1* and *1 9* supply an elevation for a suitable form. With the elevation drawn in outline, our next work is to secure a plan of the object, together with lines presumed to be upon its surface.

It will be noted that Fig. 103 shows a semi-plan of the frustum of an oblique cone, which was used as one prong of the fitting discussed in the last chapter. In this manner the lower extremities of lines presumed to be upon the surface of the right hand prong may be conveniently located as shôwn. As the length of line *1 9* represents the diameter of the small collar, we draw a semi-circle as at *E,* which then becomes a profile of that portion of the object. Thus we have a semi-circle which is perpendicular to the vertical plane and at an angle to the horizontal, a plan of which will be semi-elliptical as shown. To secure this semi-ellipse divide the semi-circle *E* into the same number of equal parts as was the semi-circle which represents the base of the conical form. Said points of division of the semi-circle *E* are projected to the line *1 9* as shown in points *2 3 4,* etc. From these points of intersection along the line *1 9* vertical lines are dropped to the horizontal plane and made of a length below the line *I L* as found in the semi-circle *E*. In this manner points are located in plan as *2 3 4*, etc. A line traced through said points then supplies the semi-ellipse which is a plan of the semi-circle whose edge elevation is the line *1 9*.

The construction lines shown in plan and elevation Fig. 103 clearly show the method employed to locate lines which we shall place upon the plane of development in their true lengths and positions to secure points through which the outline of the pattern is drawn. As for example, those lines whose upper extremities are in points *6 7 8* and *9*, connect points as *A B C* and *D*, which are the lower extremities of elements of the conical form when said form has been cut away, and are in reality points *A B C* and *D* of the true form on line *A 5*. The true form on line *A 5*, as shown at Fig 103, has been established in the same manner as shown in Fig. 102; however, in this instance, only one-half is shown, or that portion represented in plan, since the fitting is that commonly known as "on center." Those lines whose upper extremities are in points *1 2 3 4* and *5* connect points in the lines which were originally presumed to be in the base of the conical form. Broken or dotted lines must be employed as in practically all examples of triangulation.

TRIANGLES.

To determine the true length of lines presumed to be upon the surface of the object and now located in plan and elevation, triangles are constructed in the usual manner. The length of base for each triangle is found in the plan, and the perpendiculars are secured from the

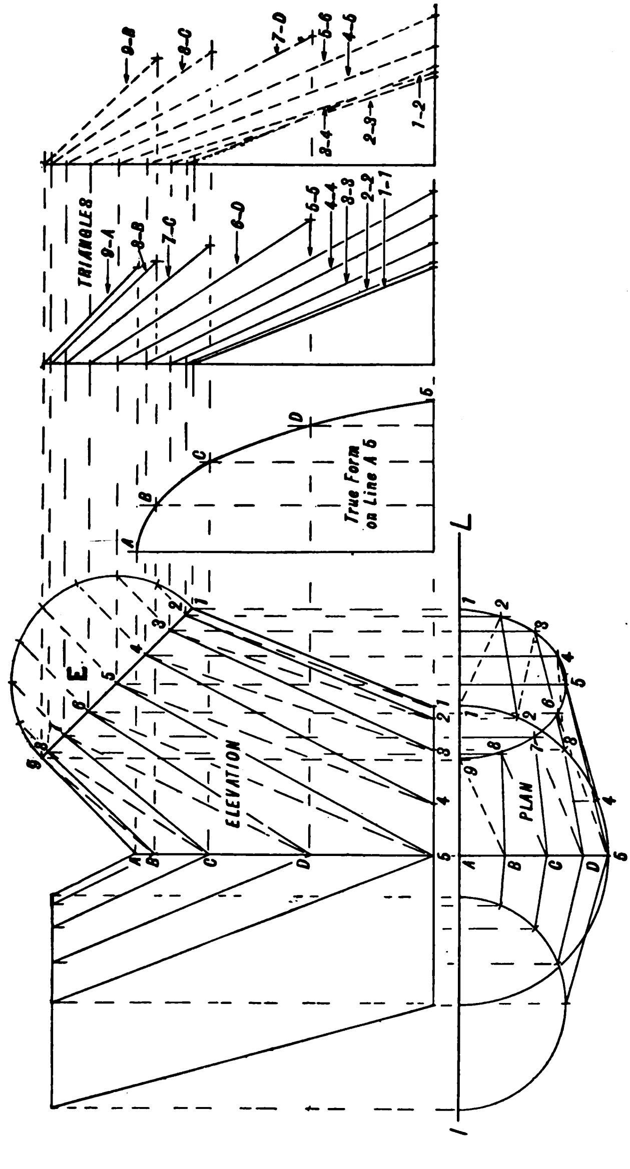


Fig. 103. Semi-Plan, Elevation, and Diagram of Triangles.

elevation, as is clearly shown by the horizontal projectors.

The Pattern.

Having before us in the diagram of triangles Fig. 103, the true lengths of lines which are presumed to be upon the surface of the object, and previously located in plan and elevation, we may proceed to develop the pattern

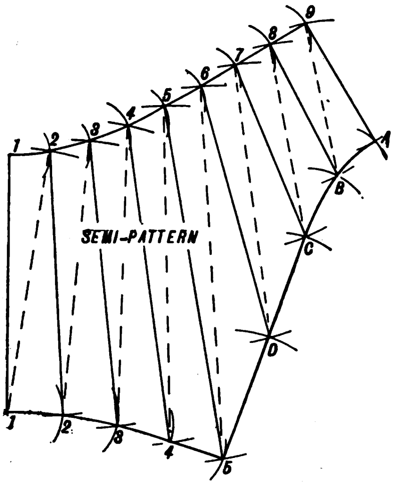


Fig. 104. *Semi-Pattern for One Prong of a Fitting as Shown at Fig.* 101.

somewhat as follows: In any convenient position upon the plane of development we draw a line whose length is equal to the length of line *1 1* of the elevation, or as found in the diagram of triangles and shown at *1 1* of the semi-pattern, Fig. 104. The distance between lines *1 1* and *2 2* at their extremities is the distance between points *1* and *2* of the large circle in plan for their lower extremities, and one space of the semi-circle *E* at their upper extremities. Therefore we set our compasses to a span equal to the distance from *1* to *2* of the large circle in plan, and from the lower extremity of line *1 1* of the pattern, describe a small arc as shown at *2*. With compasses set to a span equal to one space of the semi-circle *E*, place one point at the upper extremity of line *1 1* of the pattern and describe an arc as also shown. The upper and lower extremities of line *2 2* must then lie in some points of these arcs.

We note that the broken line *1 2* shown in plan and elevation connects point *1* at the base with point *2* at the top, and point *2* at the top is in some point of the small arc just drawn. Therefore we set our compasses to a span equal to the true length of line *1 2* found in the diagram of triangles, and describe a second small arc whose center is point *1* at the base of the pattern. In this manner we definitely locate the upper extremity of not only line *1 2*, but line *2 2* as well. The lower extremity of line *2 2* is in the small arc at the base of the pattern, therefore we draw a second arc whose radius is equal to the true length of line *2 2*, and whose center is point *2* at the top of the pattern. The point of intersection between those arcs as at point *2* at the base of the pattern must then be the lower extremity of line *2 2*.

By similar work and reasoning, we are enabled to locate lines upon the plane of development as shown in Fig. 104. The pattern cutter should not lose sight of the fact that the distances as *5 D, D C, C B* and *B A* shown at the pattern are in theory at least, secured from the true form on line *A 5*.

In practise a more accurate course to pursue is to secure these measurements from the pattern for the left hand prong, which we may presume to have been first developed. This, as will be noted, not only increases our accuracy, but enables us to develop the pattern for each prong without first finding the true form at the junction of the prongs.

It may be here remarked that as has been previously stated, a form could have been established for the junction of the prongs, and the pattern for each prong de-

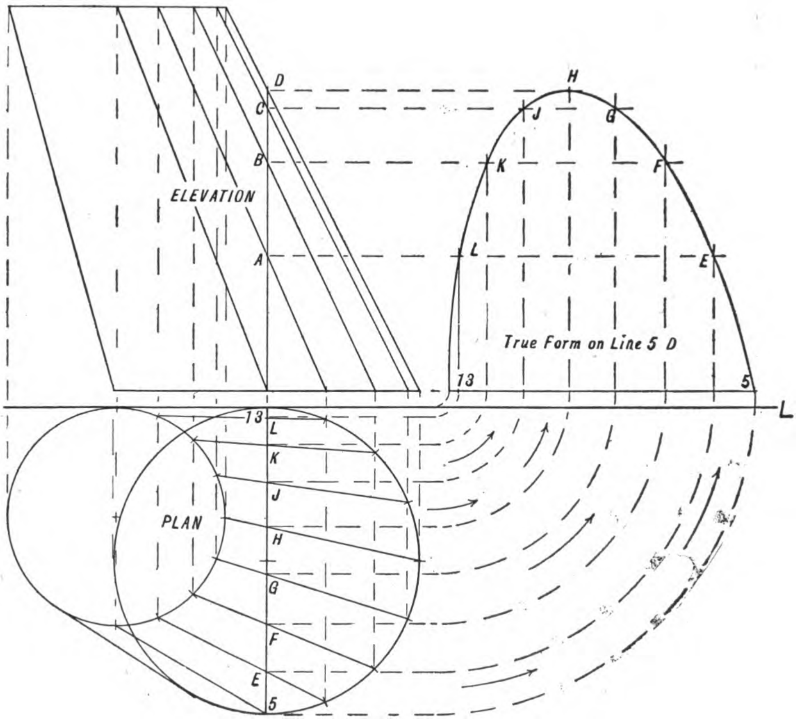


Fig. 105. *Plan, Elevation, and True Form of Section When It is Required That the Fitting Be "Flat on One Side."*

veloped in the same general manner as has been explained for the left hand prong. This is by no means a difficult operation, since the true form in this closely resembles a semi-ellipse whose major diameter is approximately double that of the minor. The author has noted very satisfactory results where this course has been pursued, although it is hardly to be recommended in every instance.

When It Is Required That the Fitting Be "Off Center" or "Flat on One Side."

When it is required that the fitting be "off center" or "flat on one side" the work of developing the pattern is increased, since the object can no longer be divided into equal parts, consequently the surface of the whole object must be developed. In this, as with many other examples, the principles involved are precisely the same; however, there is an increased number of lines to be dealt with, as was explained in the twenty-third chapter. The form of section, or the form at the junction of its prongs becomes far more difficult to approximate, and the methods here recommended are very likely to produce more satisfactory results than could be obtained by first establishing an arbitrary form for the junction of the prongs.

Fig. 105 shows the true form of section of the conical form when said form has been presumed to be cut by a plane represented in plan and elevation by line *5 D*. Here, as will be noted, the circles which represent the upper and lower extremities of the conical form in plan have been drawn tangent to the line *I L*, or a line which is parallel to it. This places one side of the fitting tangent to one plane, or "straight on one side."

It may be here remarked that no absolute rule is intended to be laid down for the development of the pattern for the branched fitting. On the other hand, principles and methods are pointed out which have in past years been found to be of service to those whose work is to design and develop the patterns for various forms of branched fittings.

CHAPTER XXV.

On the Two Pronged Fitting When It Is Required That the Prongs Radiate at a Given Angle to the Main Stem.

Attention will be here directed to methods which may be pursued to secure the patterns for a two pronged fitting whose prongs are required to radiate at a specified

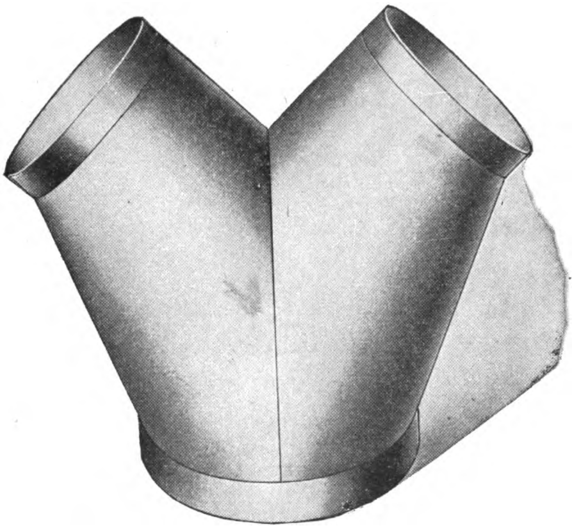


Fig. 106. Photographic View of the Fitting.

angle to the main stem. Fig. 106 illustrates a fitting which conforms to the above specification, and has been presumed to have been constructed by utilizing two prongs whose patterns were discussed in the twenty-fourth chapter.

This mode of procedure will produce very satisfactory results, although we are dependent upon our ability to establish a suitable form at the junction of the prongs. This can be accomplished by pursuing methods as explained in the twenty-fourth chapter. However, that course is not to be recommended in every instance, therefore methods which differ to some extent will be here discussed.

If called upon for the pattern for a fitting as illus-

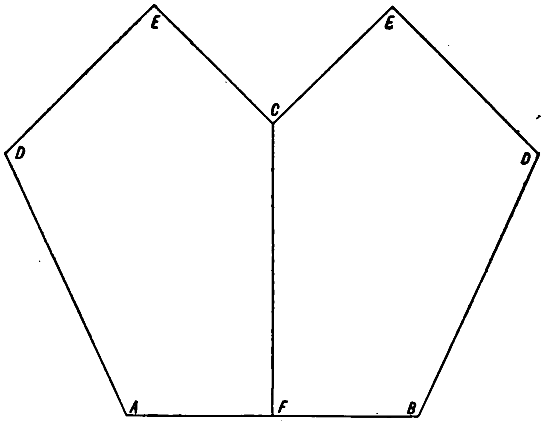


Fig. 107. *An Elevation, or a Section of a Two Pronged Fitting.*

trated at Fig. 106, or one in which the prongs are required to radiate at a specified angle, we may first draw an elevation as shown at Fig. 107, which is a simple diagram and in reality a section of the object. Upon examination of Fig. 107, we note that the line *A B* represents the base of the fitting, or the edge view of a circle whose diameter is equal to the length of that line. In like manner, the lines *D E* are looked upon as representing the diameter of the small collars, while the lines *C E* indicate the angle at which the branches are to radiate from the main stem. The line *C F* represents the length of the fitting at the junction of its prongs.

Since Fig. 107 may be looked upon as an elevation of a fitting whose prongs are equal and "on center," the pattern can be developed for one-half and duplicated for the remaining portion as will be hereinafter discussed. Upon referring to Fig. 108 it will be noted that the diagram *1 9 E E 1* is a duplicate of one-half of Fig. 107, or an elevation of one prong of the fitting shown in elevation or section at that Fig. Since the author is convinced that in the majority of cases it is far better to determine a form for the object at the junction of its prongs from some portion of it, than to establish an arbitrary one, it will be here shown how this may be accomplished if thought more satisfactory by the operator. From the above it is not to be inferred that an arbitrary form cannot be established and results secured by those who have given the subject some attention.

Presuming we have before us an elevation of one prong of the fitting as shown at *1 9 E E 1,* Fig. 108, we note that the line *1 9* represents the diameter of the small collar, and that the line *1 E* represents one-half the diameter of the large collar.

Since the base line of the object is here presumed to be in the line *I L* we may continue the line *9 E* until it intersects the line *I L* as shown at *9 E 9.* In this manner we secure a diagram which may be looked upon as an elevation of an object which has an oblong base and a round top. The major diameter of its base then becomes the length of line *1 9 E 9,* with a minor diameter equal to that of the large collar at the base. A semi-plan of the base is then drawn as shown. A plan of the top is drawn as also shown, and was explained in the last chapter.

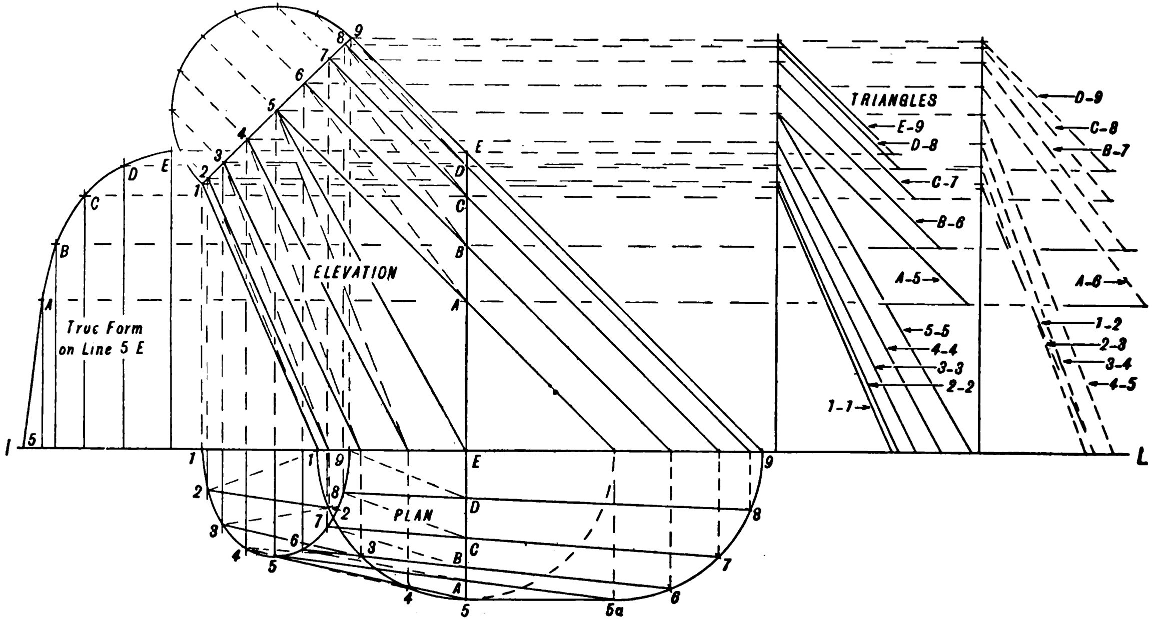


Fig. 108. Diagram Which May Be Employed to Secure the Patterns for a Two Pronged Fitting Whose Prongs Radiate at a Given Angle.

Having drawn the semi-ellipse in plan, which is a plan of the round collar at the top, we have located a number of points in said semi-ellipse which may be looked upon as points of division of the top. We may now divide the arcs in plan which represent the base of the object as shown, and draw lines as *2 2, 3 3, 4 4,* etc. In this manner we complete a semi-plan and elevation of an object, a portion of which will supply one prong of the required fitting when cut away as shown at line *E 5* of the plan, and line *E E* of the elevation. Upon a moment's reflection, we are convinced that there are at least two courses open to us in developing the pattern. One is to develop the semi-pattern for the whole object as shown in elevation and cut away that portion to the right of line *E E,* as was explained in the twenty-second chapter. The second, which is here suggested and explained, is to determine the true form of the object upon line *E E,* and utilize that as the true form of the branch at the junction of its prongs.

The construction lines in Fig. 108 clearly show the method of locating lines in plan and elevation which are the plans and elevations of lines presumed to be upon the surface of the object. Presuming the object to be cut by a plane whose plan and elevation is line *E E 5,* said plane then cuts elements as shown in points *A B C D* and *E.* The plan then supplies in points *5 A B C D* and *E,* distances from each other at which we may draw vertical lines in a convenient position as shown at the true form on line *5 E.* The elevation supplies in points *A B C D* and *E* the distance above the base of the object at which these lines terminate, as at points *A B C D* and *E* of the true form on line *5 E,* thereby establishing the true form of the object on line *5 E E,* Fig. 108.

Having now established the true form of one prong of the fitting at its extremities we may proceed to develop the semi-pattern by first constructing a diagram of triangles as is clearly shown in Fig. 108. As for example, the true length of line *4 4* shown in plan and elevation is found in the hypothenuse of a right angled triangle whose base is equal in length to line *4 4* of the plan, and whose perpendicular is equal to the vertical distance the upper extremity of that line is above the line *I L* in elevation. This line of reasoning applied to all lines shown will enable one to construct his diagram of triangles as shown, or to determine the true length of any line he may select.

Before proceeding with the pattern, it may be well to remind the student that in this example it is presumed that the fitting is to make connection between pipes whose axes are in one plane, or "on center." It will only be necessary to secure the pattern for that portion shown in plan at *1 E 5 5 1,* which may be duplicated to complete the fitting.

The Pattern.

Place upon the plane of development a line as *1 1,* Fig. 109, whose length is found in the diagram of triangles. The true distance between points *1* and *2* at the base of the fitting is found in plan, and the distance at the top of the fitting is one space of the semi-circle which represents a semi-profile of that end. The true distance from *1* at the base to *2* at the top is the length of line *1 2* found in the diagram of triangles. Thus we are enabled to locate point *2* at the top in its correct relative position in the usual manner as shown. Since the work of locating points *2 3 4* and *5* shown in the pattern has been frequently explained in foregoing chapters, a detailed description of that is here omitted.

The true distance between points *5* and *A* at the junction of the prongs is found in the true form on line *5 E,* thereby enabling us to locate line *5 A* of the pattern, Fig. 109.

The remaining lines as *6 B, 7 C, 8 D* and *9 E* are now located in the same general manner as has been explained, thereby completing a semi-pattern as shown, which may be duplicated to complete the object. As

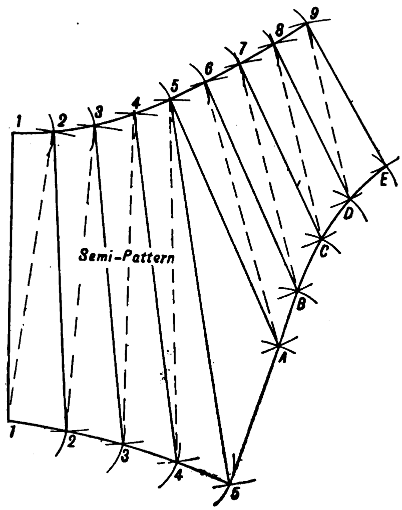


Fig. 109. *Semi-Pattern for a Two Pronged Fitting.*

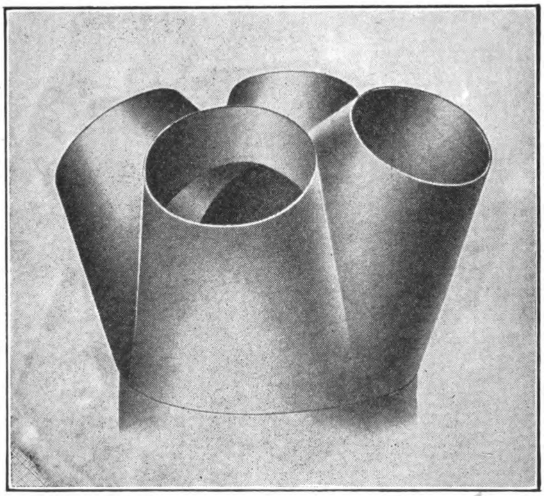
will be noted, this process involves a flat triangular surface upon each side of the prongs as shown in elevation at *A E 5.* This, however, will be found to be of small importance in the finished fitting.

Should the pattern cutter be called upon for a fitting of this class which is "off center," or with all collars tangent to one plane, some attention to foregoing chapters in conjunction with this, should place him in a position to develop its patterns without difficulty.

CHAPTER XXVI.

ON A FITTING WITH ANY NUMBER OF PRONGS.

In foregoing chapters methods have been suggested which enable us to reduce the development of patterns for a two pronged fitting to a comparatively simple operation. Here attention will be directed to the development of patterns for the branched fitting of three or



more prongs by utilizing the same form as was suggested in the last chapter.

For example, a form whose elevation is shown at Fig. 108, Chapter 25, was presumed to be cut away on line *E E*. With Fig. 108 before us it will be noted that the line *E E* is the elevation, and that the line *5 E* is the plan of a plane which cut said form. This plane then passes through the center of the circle which is a plan of the base of the fitting, thereby cutting said circle into two equal parts. If this form had been cut by a combination of planes whose plans included a sector of this circle equal to one-third of it, and properly placed, a portion of the original form could then have been utilized as one prong of a three pronged fitting.

Again, had these cutting planes been located in such positions as to allow their plans to include a sector of the circle which is a plan of the base of the fitting equal to

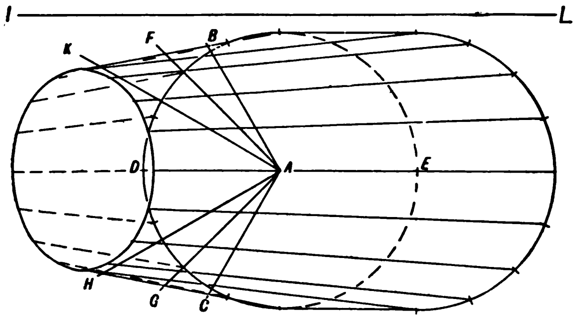


Fig. 110. *The Plan of an Object, a Portion of Which May Be Utilized as One Prong of a Fitting of a Considerable Number of Prongs.*

one-fourth of it, then a portion of the original form could be utilized as one prong of a four pronged fitting, and so on for any reasonable number of prongs.

That we may better understand the above, Fig. 110 has been drawn. This, as will be noted, is a complete plan of an object whose semi-plan and elevation has been shown in Fig. 108, Chapter 25. Here it has been assumed that the circle *C D B E* is a plan of the main stem of the required fitting, and the ellipse is a plan of the small end of one prong. The lines *A B* and *A C* have been drawn at angles of 60 degrees to line *A D,* or 120 degrees from each other, therefore the sector *A C D B* is one-third of the whole circle, and that portion of Fig.

110 to the left of lines *A B* and *A C* may be looked upon as the plan of one prong of a three pronged fitting.

The lines *A F* and *A G* have been drawn at an angle of 45 degrees to line *A D,* or 90 degrees from each other, thereby including a portion of the circle which represents the main stem of the fitting equal to one-fourth of the whole. Thus it will be noted that portions of Fig. 110 to the left of lines *A F* and *A G* may be looked upon as the plan of one prong of a four pronged fitting. By similar reasoning we may look upon that portion of Fig. 110 to the left of lines *A K* and *A H* as the plan of one prong of a six pronged fitting, although in this instance the original object should be made somewhat higher, since the lines *A K* and *A H* approach the ellipse or round collar at the top too closely for satisfactory results.

In this manner we assume those lines radiating from point *A* as *A B, A K,* etc., as the plans of planes which may be employed to cut the original object in such positions as to allow the use of the remaining portions of the object to be used as one prong of a fitting with a considerable number of prongs.

We will now proceed to develop the pattern for a four pronged fitting in accordance with the above analysis of the problem. However, since the line *D E,* Fig. 110, divides that diagram into equal parts, a semi-plan will fulfil every requirement and curtail our work to some extent.

The True Form of Section.

Fig. 111 shows a semi-plan and an elevation similar to that shown in Fig. 108, Chapter 25. Since the line *A G,* Fig. 110, is looked upon as the plan of a plane which cuts elements of the original form, we have only to determine the exact points at which those elements

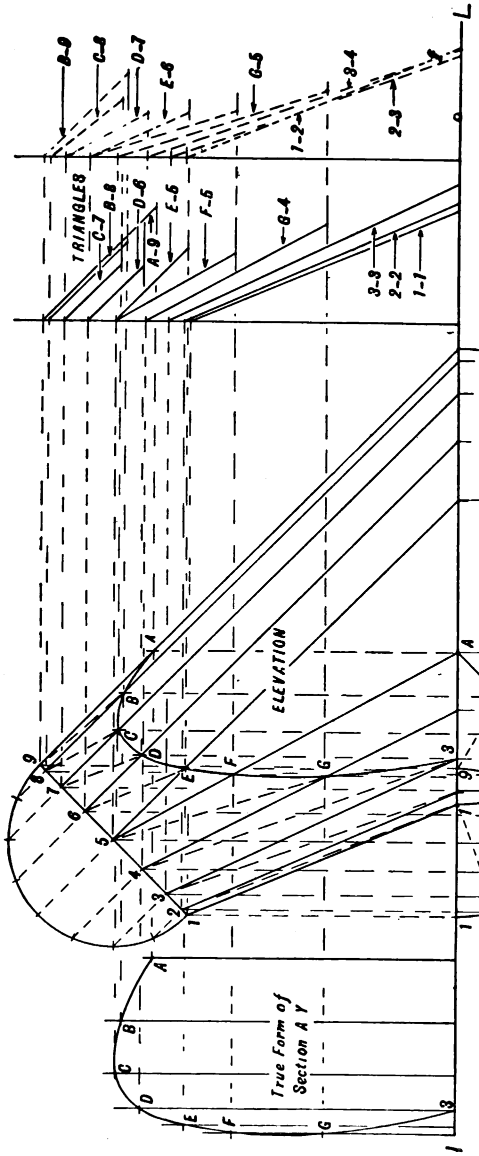


Fig. 111. Semi-Plan, Elevation, and Diagram of Triangles Necessary to Develop the Pattern for a Four Pronged Fitting.

were intersected by said planes to establish the form of the required fitting at the intersection of its prongs. Points as *A B C D E F* and *G* produced by the intersection of line *A Y* with those lines which are elements of the original form are the plans of those points. Vertical lines drawn from points *A B C D,* etc., of that view, then supply us with the exact distance these points are from the horizontal plane, i.e., the distance said points are above the line *I L.*

Thus we may set off along the line *I L* distances as found along the line *A Y,* and erect vertical lines as shown at the true form of section *A Y.* Horizontal lines drawn from points *A B C D,* etc., of the elevation to intersect those lines then supply points through which the line may be traced to secure a true form of section as shown.

TRIANGLES.

The method of drawing the necessary triangles which will supply the true lengths of lines presumed to be upon the surface of the object, and shown in plan and elevation, differs in no essential respect from those methods previously explained. The length of the lines shown in plan is the base, and the difference in hight of the extremities of that line shown in elevation, is the perpendicular. As for example, to determine the true length of the line *8 B* shown in plan, we may draw horizontal lines from the extremities of line *8 B* in elevation as shown, and at any convenient point draw a perpendicular whose length is equal to the distance these lines are from each other. Set off along the lower horizontal line from the above spoken of perpendicular a distance equal to the length of line *8 B* found in the plan. This, as will be noted, supplies points between which a line may be drawn, which is in reality the third side of a right angled triangle which furnishes the true length sought, and shown at *8 B* of the diagram of triangles: Since all other required true lengths will be found in the same general manner, a detailed explanation would seem needless repetition.

It will, no doubt, demand some attention to determine which lines would be intersected by the plane *A Y*.

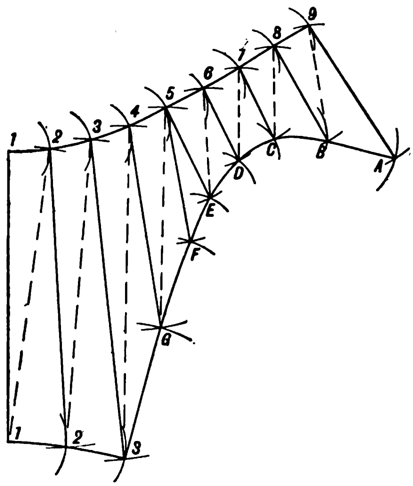


Fig. 112. *Semi-Pattern for One Prong of a Four Pronged Fitting.*

However, the construction lines shown in plan and elevation clearly show them.

The Semi-Pattern for One Prong.

Having now in mind the principles and methods which must be pursued to secure the true length of lines presumed to be upon the surface of the object, we may proceed to draw upon the plane of development those lines in their correct relative positions as shown at Fig. 112. Here, as will be noted, the line *1 1* is drawn whose length is found in the elevation, or diagram of triangles. Point *2* at the top is distant from point *1* equal to the length of one space of the circle which is the true form of the small collar at the top, as shown in Fig. 111. Point *2* at the base of the pattern is distant from point *1* equal to the distance between points *1* and *2* of the large semicircle in plan. The true distance from point *1* at the base of the pattern to point *2* at the top is found in the diagram of triangles. Points *3* of the pattern are located in the same general manner, using measurements as found in Fig. 111.

It will be noted that the intersecting plane *A Y* has produced points *G F E D C B* and *A,* therefore we must refer to the section *A Y* to secure the true distance between said points. It may be explained that the flat triangular piece spoken of in Chapter 25, shows itself in this example at *5 F E.*

Having developed the semi-pattern as shown at Fig. 112, it may be revolved upon line *1 1* and duplicated to complete the pattern for one prong, in this instance of a four pronged fitting. As has been previously explained, the position of the intersecting plane which is presumed to cut the original form, at once determines the number of prongs in the fitting when all are equal.

Unequal Prongs.

We sometimes hear discussions on branched fittings with three or more prongs which are unequal. This at once complicates the work of developing the pattern, although we may proceed along similar lines. Having secured a form for the fitting at the junction of its prongs different formed prongs may be introduced. That is, prongs of different diameters and radiating at different angles. This involves a pattern for each prong. The only thing in common is the form at the junction of the prongs. Examples of this class are usually more in the nature of a stunt than a necessity.

CHAPTER XXVII.

THE RIGHT OR THE SCALENE CONE CONSIDERED IN SECURING THE PATTERNS FOR A BRANCHED FITTING.

In some instances very satisfactory results may be secured by placing one or more branches at the base of the frustum of a right or a scalene cone when a branched fitting is demanded.

The requirements of the fitting at once determine the

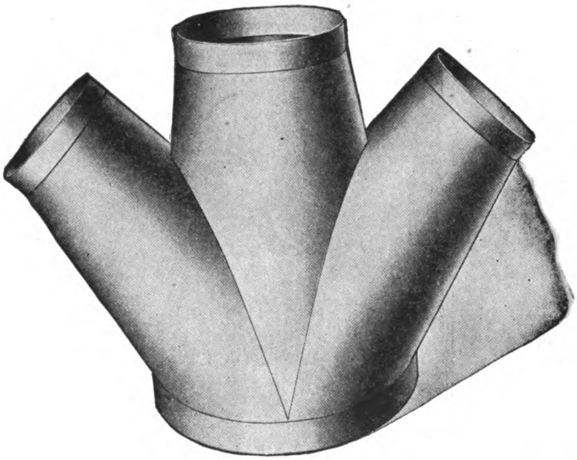


Fig. 113. *A Three Pronged Fitting Where the* **Conical** *Form is Employed in the Main Stem.*

class of a cone which should be employed. If the fitting is to be what is commonly known as "on center," the right cone is employed, and if "off center" or "flat on one side," the scalene cone is utilized as the main stem.

Fig. 113 represents a three pronged fitting whose patterns have been secured by utilizing the frustum of a cone as the main stem.

Properties of the Right Cone.

Some properties of the right cone will be explained before taking up the actual pattern demonstration, since an understanding of the cone is essential to a successful handling of the problem in hand.

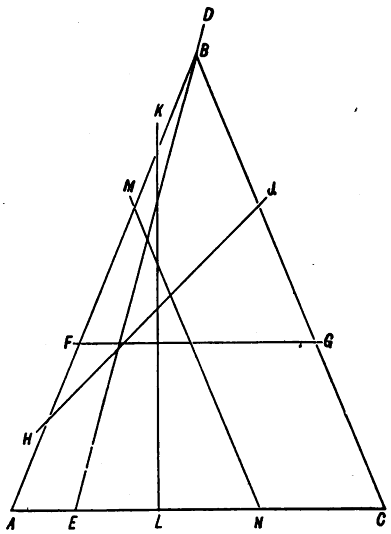


Fig. 114. *An Elevation of a Right Cone and Lines of Section.*

The cone is defined as an object which tapers uniformly from a circular base to a point. If the point lies in the perpendicular from the center of the base, the cone is a right cone, otherwise an oblique or a scalene cone. The right cone may be conceived as being generated by the revolution of a right angle triangle about its perpendicular, therefore may be looked upon as a solid bounded by a conical surface, and a plane which cuts all rectilinear elements of the conical surface. This plane is called its base, and the perpendicular distance from the plane of the base to the vertex is its altitude. A line, real or imaginary, from the center of the base to the vertex is its axis.

In most cases the cone is looked upon as having a circular base, however, this will not always follow, since the base may have a variety of forms. In this demonstration it will be assumed that the cone has a circular base.

The cone with a circular base can be regarded as a pyramid of an infinite number of faces, hence the cone has in general the properties of a pyramid. The true form of section which will be referred to in the following discussion is the form which the cone would present to the intersecting plane when viewed at right angles to it.

Forms Secured from the Right Cone.

Forms secured by cutting the right cone with a circular base are known as conic sections. Fig. 114 has been included for the purpose of conveying to the reader through the medium of the eye, a clear understanding of the positions of cutting planes as spoken of in the following definitions.

Definitions.

1. If a cone be cut by a plane which passes through its vertex and base, as *D E,* Fig. 114, and making any angle with those parts, the true form of its section is an Isosceles Triangle.

2. If a cone be cut by a plane which is parallel to its base as *F G,* Fig. 114, the true form of its section is a Circle.

3. If a cone be cut by a plane which passes through its opposite sides, but not parallel to its base, as *H J,* Fig. 114, the true form of its section is an Ellipse.

4. If a cone be cut by a plane parallel to its axis, but not through it, as *K L,* Fig. 114, its true form of section is a Hyperbola.

5. If a cone be cut by a plane parallel to one of its sides as *M N,* Fig. 114, the true form of its section is a Parabola.

The projection of a cone, the axis of which is perpendicular to the plane of projection, will be a circle, the diameter of which will be equal to the diameter of its base; therefore if a circle be drawn whose diameter is equal to the length of line *A C,* Fig. 114, said circle may be looked upon as a plan of the cone whose elevation is *A B C.*

Some Simple Principles Explained.

Since the representations of conic sections depends upon our ability to represent a given point in plan and elevation, which is presumed to be upon the surface of the cone, some of the more simple principles will be explained.

For an example, we shall presume that *A B C,* Fig. 115, is an elevation of a cone, and that *D* is a given point upon its surface. To locate point *D* in plan we must first have a plan of the cone, as shown in the circle *E F,* when we may draw a line from *B,* the vertex of the cone in elevation, through point *D,* and intersecting the base line in point *G.* This line then becomes a rectilinear element of the conical surface, the plan of which may be secured by letting fall a vertical projector from point *G* to intersect the circle in point *K.* A line drawn as *K H* then becomes a plan of the rectilinear element whose elevation is line *B G*. A vertical projector dropped from point *D* to intersect line *K H*, locates the plan of point *D* as at *M*.

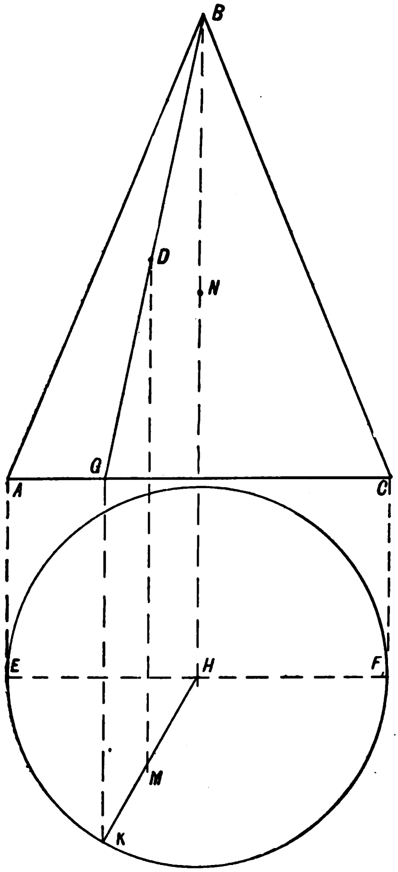


Fig. 115. *The Plan and Elevation of a Right Cone With Points Presumed to Be Upon Its Surface.*

Had the given point *D* been located at or near the center of the cone in elevation as at *N*, its location in plan could not have been found as above described. Therefore it may at times be more desirable to adapt that method which is the most general in application, although it has a greater tendency toward confusion. On the other hand, if we comprehend each method, we may

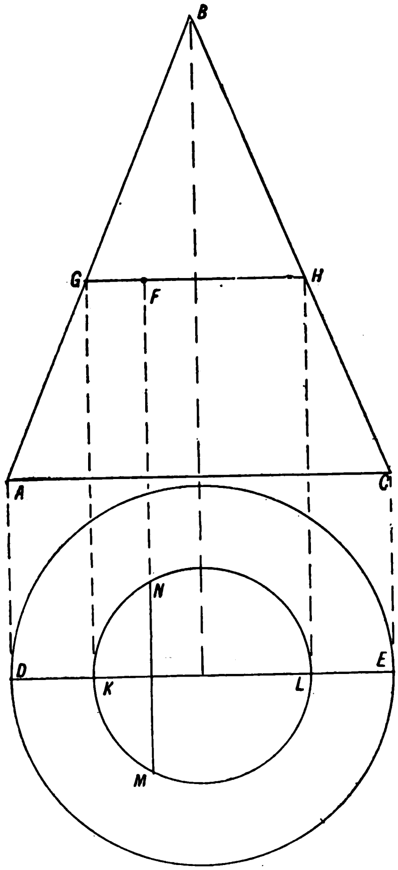


Fig. 116. *The Plan and Elevation of a Right Cone and Its True Form of Section.*

use that which best suits our purpose, therefore it is explained below.

Let *A B C,* Fig. 116, represent the elevation of a cone, and the circle *D E* its plan. If *F* is the given point in elevation, we may find its location in plan as follows: Through point *F* and parallel to the base line of the cone in elevation, draw a line as *G H*. From points *G* and *H* drop vertical projectors to intersect the line *D E* in plan, as at *K* and *L*. Upon drawing a circle as *K L*, we have before us the true form of the cone if cut by a plane whose elevation is the line *G H*. A vertical projector dropped from point *F* to intersect the circle *K L* as at *M*, locates point *F* in plan. Should it become desirable to determine the distance through the cone at point *F*, or the length of a line whose end elevation is at *F*, the length of line *M N* will supply it, presuming said line terminates at the surface of the cone at each side. Upon a moment's reflection, it will be readily understood how these methods may be reversed to locate points in the elevation whose positions are given in plan, providing the vertical hight of the cone is known.

The True Form of the Section of a Cone.

Methods as explained above may be employed to secure the true form of the section of a cone, presuming said cone to be cut by a plane whose elevation is a given line. For example, *A B C*, Fig. 117, is an elevation, and the circle directly beneath it is the plan of a cone. If it be presumed that the true form of section of this cone was required when cut by a plane whose elevation is the line *A D*, we would proceed somewhat as follows: Divide the circle into a number of equal parts as shown, and draw lines from said points of division to the center *E*. Thus we have before us the plan and elevation of the cone, together with the plans of a number of elements of the conical surface. The elevations of said elements are secured by projecting points of the circle as *2 3 4*, etc., to the base line of the cone in elevation. From points thus located along the line *A C* we draw lines to the vertex *B* as shown, thereby locating points as *a b c d,* etc., upon the surface of the cone in elevation. Said points, i.e., *a b c d,* etc., may now be looked upon as the end elevations of lines whose extremities are at the surface of the cone.

In any convenient position draw a line as *G H,* which is parallel to *A B.* From points along line *A D* project lines as shown at *a b c d,* etc. As will be noted, these lines are at a distance from each other along line *G H,* equal to the distance between points along line *A. D.* Thus we have only to determine the length of these lines to locate points through which a line may be traced to show the true form of the cone when cut by a plane whose edge view is line *A D.* These lengths are determined in precisely the same manner as has been explained, and shown at Figs. 115 and 116. If no difficulty has been experienced in determining the true length of a single line presumed to pass through the cone from a given point, no difficulty should be experienced here, since this is simply a number of such examples.

We may, for an example, select point *a* in elevation, where, as will be noted, a vertical projector is dropped to intersect line *2 E* in plan, thereby locating a point in plan as *Y,* whose elevation is *a.* Since the vertical projector from point *2* passes through point *16,* the element *E 16* must be directly back of element *2 E* when shown in elevation. Therefore we may look upon the line *a B* in elevation, as not only the elevation of an element whose plan is *2 E,* but of a similar element whose plan is *16 E.* This applies in all cases where a vertical projector intersects two original points of division of the circle in plan. Thus the vertical projector from point *a* supplies the length of the line whose elevation is *a* in the length of said line between its intersections with lines *2 E* and *16 E,* as shown at *X* and *Y.*

The distance from *O* on the line *1 E* to *X* or *Y* set off from line G H on the line projected from *a,* supplies the

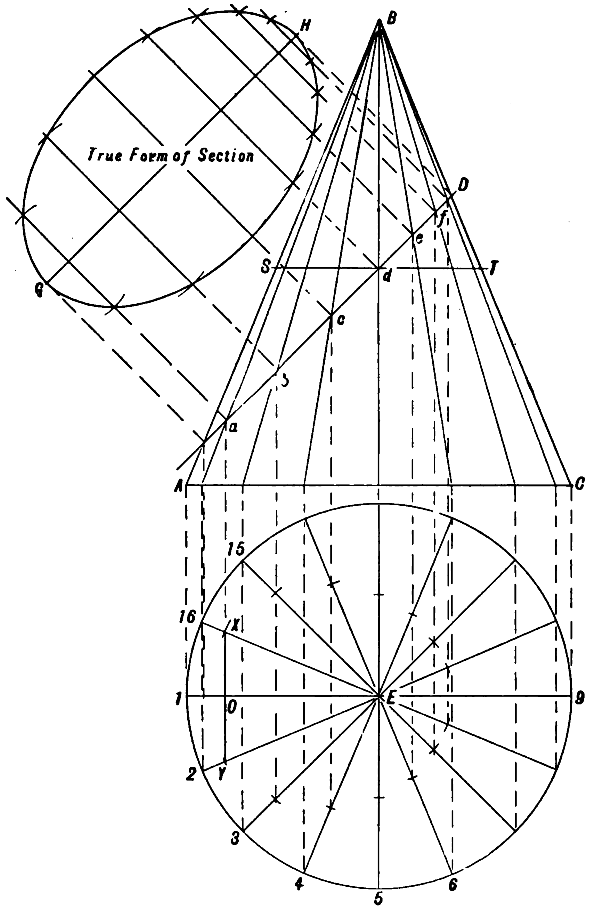


Fig. 117. *The Plan and Elevation of a Right Cone and the True Form of an Oblique Section.*

location of point *a* of the elevation as well as a similar point on the opposite side of the cone.

A similar line of reasoning will enable one to locate points on the side of the cone nearest the eye, as *b c e f* and *g*, together with similar points beyond. Point *d* cannot be located in this manner; however, since the true form of the cone on a plane whose elevation is a horizontal line drawn through point *d* as *S T*, we note that the distance to be set off on each side of line *G H* is that found at *d S* or *d T*.

Some attention to the foregoing should enable the student to find the true form of section of a cone when cut by a plane, regardless of the direction of said plane, providing its location is so taken that its elevation may be represented by a single line, which denotes that said plane is perpendicular to the vertical plane of projection, and at an angle other than a right angle to the horizontal plane only.

A Common Error.

The student is here cautioned against falling into an error which has many times come to the author's notice, and arises from a lack of knowledge of the relative positions of the object and planes of projection. The author has noted instances where the operator was utterly unable to solve his problem for the above reason. It seems a simple matter for one to conceive the object in such positions as to complicate the problem beyond its solution. It should be remembered that our diagrams must be so constructed in examples of this nature, or at least the planes so taken, as to allow the intersecting plane to be perpendicular to one plane of projection. If the original views do not supply this, either planes or the object must be revolved until the above conditions are fulfilled.

In the foregoing considerable space has been devoted to the more elementary work which may be involved when developing the pattern for a fitting as illustrated at Fig. 113. In the following, our work will be confined to a discussion of methods which may be pursued to secure the patterns for the main stem and one branch, since the second branch is but a duplicate, although formed in the opposite direction.

Fig. 118 is a diagram which may be looked upon as an elevation, or a section of a two pronged fitting, wherein the main stem may be considered as a portion of a right cone. For example, the diagram *B F E D C* rep-

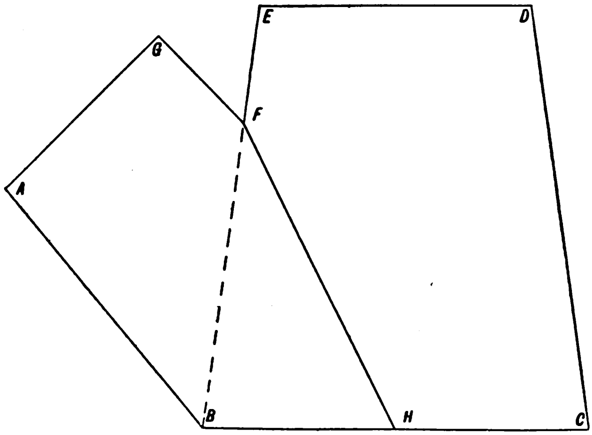


Fig. 118. *The Elevation or Section of a Two Pronged Fitting.*

resents the frustum of a right cone, and the diagram *A G F H B* is an irregular form which constitutes the branch, the two forms being connected on line *F H*. With this in mind, we note that the length of line *A G* represents the diameter of the collar on the branch, and the lengths of lines *E D* and *B C* represent the diameters of the collars or ends of the conical form. To develop the pattern we must have a plan and a somewhat more complete elevation, or at least, we must locate lines presumed to be upon the surface of the object in elevation.

However, since the axes of all collars are here presumed to be in one plane, a semi-plan fulfils every requirement.

On the Development of the Conical Surface With a Slight Taper.

Since the main stem is a conical form, its patterns may be developed without the aid of triangulation. On the other hand, conditions are frequently met with wherein the flare or taper of the frustum of a right cone is so slight that the vertex of the cone, of which the lower part is required, would lie far beyond a reasonable surface upon which our elevation is to be drawn. In examples of this description very satisfactory results can be secured by applying triangulation. Since all rectilinear elements or direct lines are of equal lengths, and all indirect or those usually shown dotted, are also of equal lengths, to develop the surface, it therefore only becomes necessary to determine the true lengths of but two lines which are presumed to be upon the surface of the conical form.

For example, Fig. 119 shows two semi-circles which we may presume to be the semi-plan of the frustum of a right cone, and the distance *1 A* is its vertical hight. The line *1 B* is then the true length of a rectilinear element of the conical surface, or what we have termed, a direct line. The true length of the indirect line *1 2* is shown at *2 B*. One section of the conical surface is shown at *E,* this diagram having been secured by the use of lines shown, as in all examples where triangulation is employed. The diagram shown at *E* duplicated in this instance *16* times, will complete the pattern for the conical form. Some slight inaccuracy may have developed when a pattern has been secured in this manner, although this may usually be corrected without causing any noticeable distortion. All direct lines upon our pattern are looked upon as rectilinear elements of the conical surface.

The Cone and Pyramid Compared.

If we choose the diagram shown at *E,* Fig. 119, may be looked upon as one side of the frustum of a pyramid which has as many sides as parts in the circles which represent the plan of the conical form. Therefore if

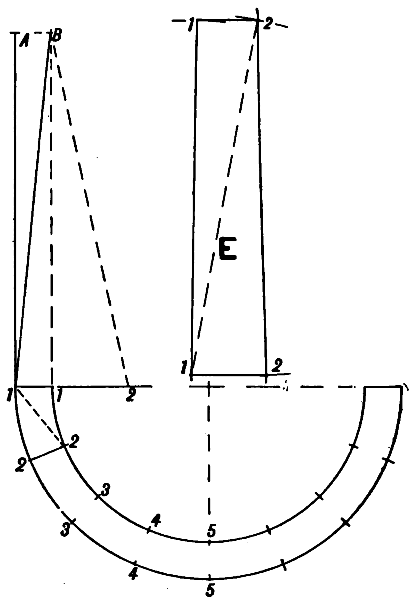


Fig. 119. *The Semi-Plan of the Frustum of a Right Cone and One Section of Its Surface.*

the diagram *E* be revolved about its long side upon the plane of development *16* times, that surface which has been covered by the templet will then very closely approximate that of the conical form.

Upon turning attention to Fig. 120 it will be noted that we have before us a semi-plan and an elevation of a branched fitting, with the true form of an oblique section of the conical portion overlapping the elevation. The semi-circles in plan have been divided into a number of equal parts as at *1 2 3 4,* etc., and lines drawn to connect said points as *1 1, 2 2, 3 3,* etc. These lines are the plans of lines presumed to be upon the surface of the conical form, and upon projecting points as *1 2 3,* etc., to the lines which represent the extremities of the conical form, we locate points between which lines are drawn to secure the elevations of said lines as shown, thereby locating points as *A B C* and *D.*

The curved line *A B C D 5* shown in plan, is the plan of the line *A B C D 5* shown in elevation. Points in this line are located by dropping vertical lines from points *A B C D 5* in elevation to intersect similar elements of the conical form in plan.

Since the work of securing the true form of section of the conical form when cut by a plane has been previously shown in this chapter, the construction lines shown in Fig. 120 should be sufficient to enable the student to determine the true form of the object upon line *A 5* of the elevation, as shown at the true form of section *A 5.*

The semi-ellipse *f g h,* etc., of the plan, is a plan of the round collar whose true form is the profile shown. Lines are drawn as shown in plan and elevation to represent lines presumed to be upon the surface of the branch. With these lines located as shown, the diagram of triangles may be drawn in the usual manner, as also shown.

The Semi-Pattern for the Main Stem.

We may develop the semi-pattern for the main stem

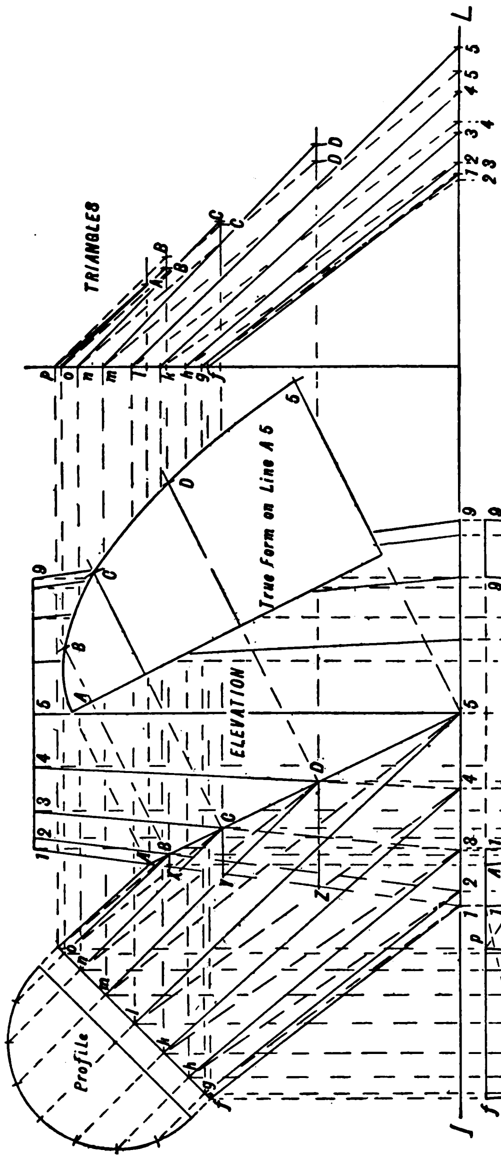


Fig. 120. *Plan, Elevation, True Form of Section and Diagram of Triangles for a Two or Three Pronged Fitting Where the Frustum of a Right Cone Was Utilized as the Main Stem.*

in any manner which secures moderately satisfactory results, and locate lines upon its surface which have been previously located in plan, as shown at Fig. 121. To locate the line upon which the envelope of the conical form should be cut away to receive the branch, we may draw horizontal lines from points *B C* and *D* of the elevation to intersect the line *1 1* of the elevation, as shown at *X Y* and *Z*. Thus we have established distances along the line *1 1* in points *A X Y* and *Z* at which elements of the conical form shall be cut.

For example, the distance *1 A* found in the elevation is transferred to the pattern as *1 A*. The distance *1 X* found in the elevation is transferred to line *2 2* of the pattern, thereby locating points *A* and *B* of the pattern,

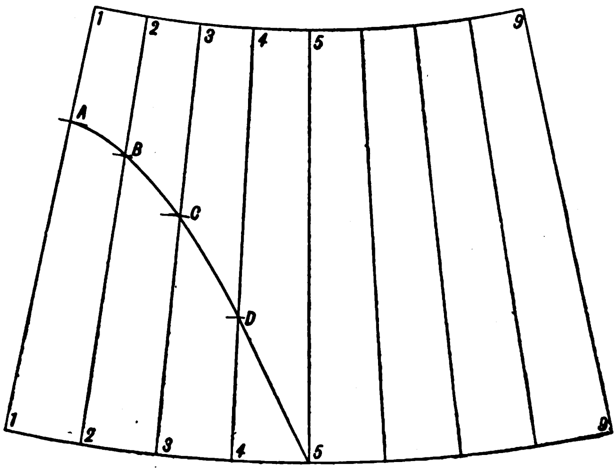


Fig. 121. *The Semi-Pattern for the Main Stem of a Fitting, the Plan and Elevation of Which is Shown at Fig.* 120.

Fig. 121, and so on for all points shown. A line traced through points thus located defines the boundaries of that portion of the semi-pattern for the main stem which is to be cut away to receive the branch.

The semi-pattern for the main stem revolved about the line *1 A* or *9 9* and duplicated, then completes the whole pattern, which in this instance may be formed in either direction, since the fitting is "on center." Had this pattern been designed for a fitting with two prongs which were equal, then that portion of the semi-pattern, Fig. 121, shown at *A 1 5 5* would be the pattern for one-quarter of the main stem.

The Semi-Pattern for the Branch.

That portion of the diagram to the left of lines *A B C D 5* shows in plan and elevation the branch, together with lines presumed to be upon its surface. To de-

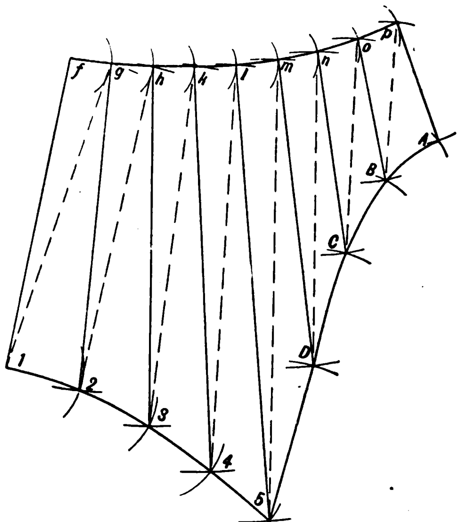


Fig. 122. *Semi-Pattern for the Branch, the Plan and Elevation of Which is Shown at Fig.* 120.

velop the pattern as shown at Fig. 122, is to place upon the plane of development these lines in their correct relative positions. This is an operation which has been too often explained in these pages to require additional discussion, since we have shown in the diagram of triangles

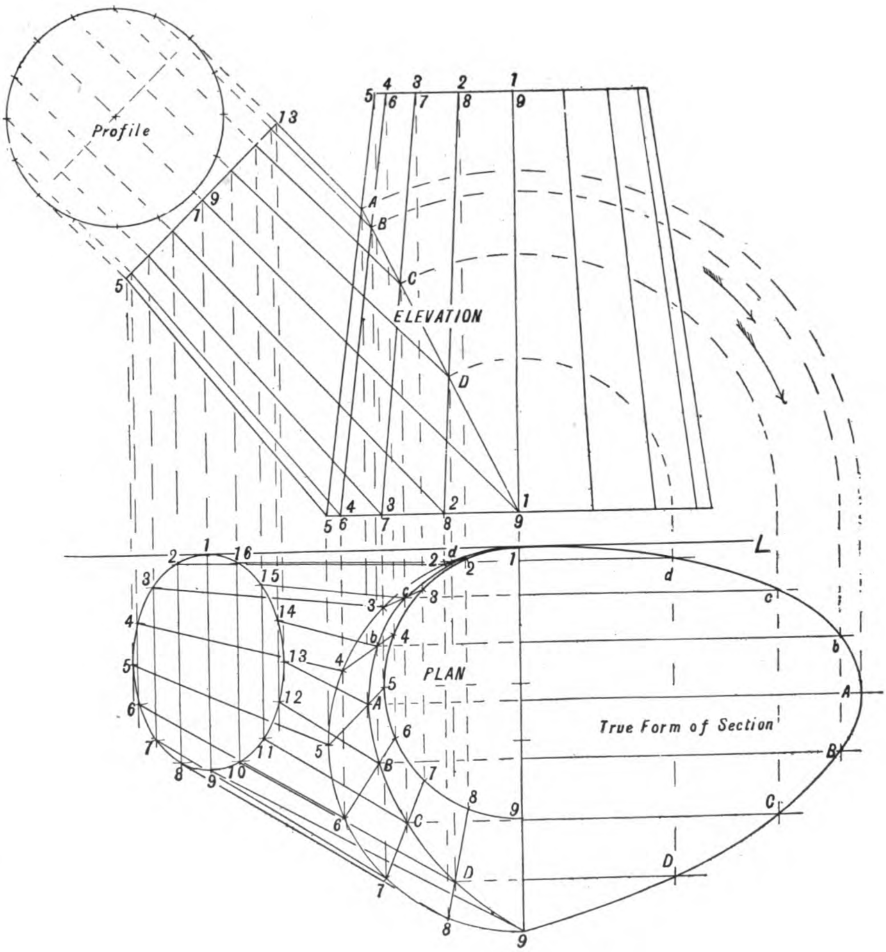


Fig. 123. Plan, Elevation and True Form of Section for a Two or Three Pronged Fitting With One of Its Sides Tangent to One Plane.

the true lengths of said lines. It may be explained that in actual work it would be unnecessary to secure the true form of section, since if the semi-pattern for the main stem is first developed, we then find the true distance between points as *A B C D* and *5*.

When It Is Required That the Fitting Shall Be "Off Center," or Tangent to One Plane.

Should the pattern cutter be called upon for a pattern of this class wherein the specification demands that said fitting shall be "off center," or tangent to one plane, Fig. 123 should now offer all necessary suggestions. As will be noted, Fig. 123 shows a semi-plan and an elevation wherein the above conditions are complied with. The method of determining the true form of section is clearly shown, and beyond the fact that the whole pattern must be developed, it differs in no essential respect from those previously shown, although we are now dealing with an oblique cone for the main stem.

CONCLUDING REMARKS.

The student in sheet metal pattern cutting who has followed this work will have become convinced that a considerable number of pattern demonstrations has been presented. Problems which are of more or less frequent occurrence in the sheet metal shop.

It is not to be expected that a work of this character can be made to embrace all subjects which may come before the operator. However, principles and methods are pointed out which may be employed to secure the patterns for a far greater variety of forms than can be reasonably included in any one volume.

Study is one important factor in securing an understanding of the art of pattern cutting, and must be indulged in by those who wish to become proficient. Pattern cutting is a branch of science which cannot be acquired in a day. There are fundamental principles which must be followed to secure results. A broad understanding of those principles reduces intricate problems to but simple operations.

The author, believing that it is far better to reason than to remember, has in this work pointed out those principles involved in that branch of pattern cutting where triangulation is applied.

An understanding of mechanical or geometrical drawing involves an understanding of the more difficult portions of sheet metal pattern cutting. Those who have had the advantage of securing that understanding, will find this work a series of suggestions. Those who have been denied that advantage, will find a study of mechanical or geometrical drawing a material aid.

Chapters 9 and 10 have been devoted to the fundamental principles of Orthographic Projection, commonly known as mechanical drawing. Diligent application to these will secure surprising results; however, one should hardly expect to find this subject exhaustively treated in a work on pattern cutting.

Practically all problems which demand Triangulation are in close relation. At first sight some appear simple, while others appear complex. The complex example is usually one in which the work in prolonged simply for the reason that a pattern must be developed for each component part of the object for which a pattern is required. Many times the pattern for a component part of a complicated form is as simple of development as many of the so-called simple forms. The trouble experienced by many of our pattern cutters is due solely to their inability to make a proper analysis of the problem in hand, or to their inability to make a correct geometrical representation of the object.

There are two qualifications necessary to make a successful pattern cutter: these are a good understanding of orthographic projection and a good power of conception. The man who possesses these will have little difficulty in his work. We frequently meet a man who has an excellent power of conception, but who has devoted very little time to the study of the underlying principles, relying upon his ability to find an untrodden path by which he could secure his patterns in record time. This often leads him into embarrassing positions. There are underlying principles, an understanding of which is as necessary to the professional pattern cutter as the understanding of his notes is necessary to the professional musician.

He who wishes to excel in the art of sheet metal pattern cutting should devote time to the study of orthographic projection. While this may seem useless work and lost time in the beginning, it will be found that the end amply justifies the means, since he will have placed himself in a far better position to simplify his problems. In proof of the above we may ask: Who would be better prepared to simplify a mathematical problem than an expert mathematician?

He who attempts to develop the patterns for a variety of forms to be constructed of sheet metal without giving the underlying principles some attention is a man groping in the dark. Many such instances have come before the author's notice in his long period of observation.

The author has long been a close student of sheet metal pattern development, and has developed patterns for a great variety of forms which have been made from all gauges of material, from light tin plate to 3/16-inch iron—patterns for fittings which could be placed in the coat pocket, and patterns for fittings the weight of which would exceed a ton. There is no difference in the principles involved, while no doubt a somewhat greater power of conception is required in the larger work, since it is a difficult matter to secure a sufficient surface upon which complete diagrams may be drawn to represent to object upon the required plane.

We may in some instances reduce the required surface by employing a scale drawing, say one-quarter size or 3 inches to one foot. This requires every measurement to be multiplied four times when placed upon the material. It should be understood that any inaccuracy is thus magnified fourfold.

In the lighter stock some inaccuracy may be easily remedied, but in the heavier material this becomes much more troublesome. In forms where the component parts are assembled by double seaming, or by the use of the bench machine, proper allowance can be easily determined. In the heavier work, where holes must be punched in the flat and coincide when the object is assembled, considerable accuracy must be maintained, and the thickness of the material reckoned with in every instance. In practically all examples throughout this work, to avoid confusion, circles have been divided into sixteen parts. This is in no sense a recommendation for the universal use of that number as explained in Chapter IV.

The subject matter included in this work represents an honest endeavor on the part of the writer to place before the mechanic or student, something worthy of attention by those interested in Triangulation as Applied to Sheet Metal Pattern Cutting.

GLOSSARY.

ANGLE.—The point or line on the inner or outer side, where two lines or surfaces meet. In a strict mathematical sense it signifies that relation of lines which is measured by the amount of rotation necessary to make one coincide with the other. This amount is usually expressed in degrees.

ARC.—A part of a circle.

AXIS.—One of the principal lines through the center of a figure or solid, especially the longest or shortest, or a line as to which the figure or solid is symmetrical.

AXES.—Plural of Axis.

BISECT.—To divide into two equal parts.

CENTER.—The middle point of a closed curve or surface; properly a point such that any straight line drawn through it will meet the curve or surface at equal distances on each side of the point.

CHORD.—A straight line connecting the extremities of an arc.

CIRCLE.—A plane figure bounded by a curved line called the circumference, everywhere equally distant from a point within called the center.

CIRCUMFERENCE.—The boundary line of a circle, also of any plane figure that is bounded by a curved line. The boundary line of any space.

CONCEPTION.—The act or process of forming the idea or a notion of a thing, or the idea or notion formed.

CONE.—The cone is an object which tapers uniformly from a circular base to a point. If the point lies in the perpendicular from the center of the base the cone is a right cone, otherwise an oblique or a scalene cone.

CONICAL.—Shaped like a cone; conic.

CONVERGE.—To trend toward one point; to incline and approach nearer together; direct toward a common focus.

CONVERGENT.—Tending to one point; approaching each other as they extend; said of lines.

CROSS-SECTION.—The section of a body at right angles to its length; as the cross-section of a gas pipe.

CUBE.—A solid bounded by six equal squares and having all its angles right angles.

CURVE.—Having a different direction at every point.

CURVILINEAR.—Formed by curved lines.

CYLINDER.—A solid whose curved bounding surface is generated by the motion of a straight line, remaining parallel to itself, around two equal circles in parallel planes, the circle forming the rest of the boundary; called right when the line is at right angles to the planes, oblique when it is not; in the higher geometry, any curved surface generated by the motion of a straight line remaining parallel to itself and constantly intersecting a curve.

DEGREE.—A unit of angular measure, the ninetieth part of a right angle.

DESCRIPTIVE GEOMETRY.—That application of geometry in which the relation of lines and figures are studied on planes.

DESIGNATE.—To cause to be known or recognizable by some mark or sign.

DEVELOP.—To change the form of a surface by bending or unbending without changing its smallest part.

DIAGONAL.—Extending obliquely from corner to corner, a straight line or plane passing from one angle or corner to any angle or corner not adjacent to it.

DIAGRAM.—A figure drawn to aid in demonstrating a geometrical proposition or to illustrate geometrical relations. A mechanical plan or outline.

DIAMETER.—A line through a plane figure or solid, terminated at the boundary thereof; the length of such a line. The term is applied mostly to circular and spherical figures.

DIMENSION.—Any measurable extent or magnitude, as of a line, surface, or solid.

DUPLICATE.—To make an exact copy of; reproduce exactly.

ELEMENT.—A component or essential part, especially a simple part of anything complex.

ELLIPSE.—A plane curve such that the sum of the distances from any point of the curve to two fixed points (called the foci) is a constant.

ELLIPTICAL.—Shaped like an ellipse.

FOCUS.—The point of meeting. The central point.

FRUSTUM.—That which is left of a solid, usually a cone or pyramid, after cutting off the upper part.

GEOMETRY.—The branch of pure mathematics that treats of space and its relation; the science of the mutual relations of points, lines, angles, surfaces, and solids, considered as having no properties but those arising from extension and difference of situation.

GEOMETRICAL.—Of or pertaining to geometry; according to the rules or principles of geometry.

HELICAL.—Pertaining to, shaped like, or following the course of a helix or spiral.

HELICOID.—A surface resembling that of a screw; especially one generated by a straight line, one end of which moves along an axis while the other describes a spiral about it.

HELIX.—A line, wire, or the like, curved into shape such as it would assume if wound in a single layer around a cylinder.

HORIZONTAL.—In the direction or parallel to the horizon; or on a level.

HYPOTHENUSE.—The side of a right angled triangle opposite the right angle.

INTERSECTION.—A place of crossing; the point where two lines or the line in which two surfaces cross each other.

ISOSCELES TRIANGLE.—See Triangle.

LINE.—A line is that which has only one dimension: length, a straight or right line is the shortest length between two points; a broken line is a line composed of different successive straight lines. A curved line is a line no portion of which is straight. The intersection of two lines is a point.

MITER.—The junction of two bodies at an equally divided angle, a piece cut at an angle for mitering, or pieces so cut and joined.

OBLIQUE.—Deviating from the perpendicular or from a direct line by any angle except a right angle; not parallel nor at right angles; neither perpendicular nor horizontal.

OBLIQUE CONE.—See Cone.

OCTAGON.—A plane figure with eight sides and eight angles.

ORTHOGRAPHIC.—Of or pertaining to right lines or angles; drawn or projected by right lines. See Projection.

PARALLEL.—Lying in a plane and not meeting no matter how far produced; said of equidistant straight lines. Lines or surfaces lying in the same direction.

PARALLELOGRAM.—A four-sided plane figure whose opposite sides are parallel.

PERPENDICULAR.—Being at right angles to the plane of the horizon; straight up and down. Meeting a given line or surface at right angles.

PERSPECTIVE.—Delineation of objects as they appear to the eye. Specifically, in mathematics, a branch of projective geometry.

PLAN.—A drawing showing the parts in their proportion as well as relation, as of a building or machine.

PLANE.—A surface such that a straight line joining any two of its points lies wholly in the surface; more precisely a surface which, when turned over, is congruous with itself, however applied. Hence, in common use, any flat or uncurved surface extending uniformly in some one direction.

POINT.—That which has location, but not magnitude.

POLYGON.—A closed figure bounded by straight lines, especially more than four; a figure having many angles.

PROJECTION.—The foot of the perpendicular let fall from a given point to a line or plane, or the straight line forming the feet of perpendiculars thus let fall from the extremities of a straight line, more widely the figure on a fixed plane called the plane of projection. In Orthographic Projection the projecting rays are parallel to each other.

PROJECTOR.—That which projects.

PYRAMID.—A solid bounded by a polygonal plane for its base, and by triangular planes meeting in a point called the vertex.

QUADRILATERAL.—Formed or bounded by four lines; four sided.

RADIATE.—Extending or passing outward from a common focus.

RADII.—Plural of radius.

RADIUS.—A straight line from the center of a circle or sphere to its circumference or surface.

RECTANGLE.—A plane quadrilateral figure having all its angles right angles.

RECTANGULAR.—Having one right angle, or more, being a rectangle.

RECTILINEAR.—Consisting of right lines.

RIGHT ANGLED TRIANGLE.—See Triangle.

ROTATION.—Order of sequence.

SCALENE CONE.—See Cone.

SCENOGRAPHIC.—The art of making drawings in perspective.

SECTION.—A representation, or drawing, showing something, as a building or machine, as it would appear if it were cut by an intersecting plane, and the portion between the observer and the cutting plane removed.

SECTOR.—A part of a circle bounded by two radii and the arc subtended by them.

SPIRAL.—Winding continually as on the surface of a cylinder, or as the thread of a screw; helical.

SQUARE.—A rectangle having equal sides.

TANGENT.—Meeting a line or surface at a point and then leaving without intersection.

TEMPLET.—A pattern usually flat, for shaping something.

TRANSFORM.—To give a different form to; alter in shape.

TRANSITION.—Change from one condition to another.

TRANSITIONAL.—Of or pertaining to transition.

TRIANGLE.—A figure, especially a plane figure bounded by three lines, called sides, and having consequently three angles. Triangles are equilateral and equiangular when all the sides and angles are equal; isosceles when two sides are equal and scalene when no two sides are equal. They are right angled when one of the angles is a right angle, but otherwise oblique angled.

VERTEX.—The extreme point of a figure in a certain direction; especially in a triangle, the point of intersection of its sides. Of a cone or pyramid, the point of intersection of the generating lines or bounding planes respectively.

VERTICAL.—Perpendicular to the plane of the horizon, plumb, upright.

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