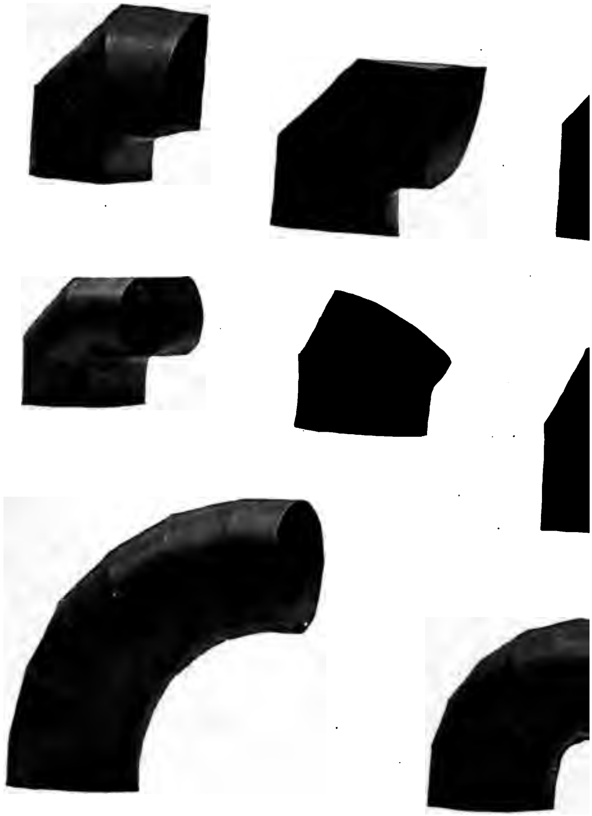
ELBOW PATTERNS

FOR

ALL FORMS OF PIPE



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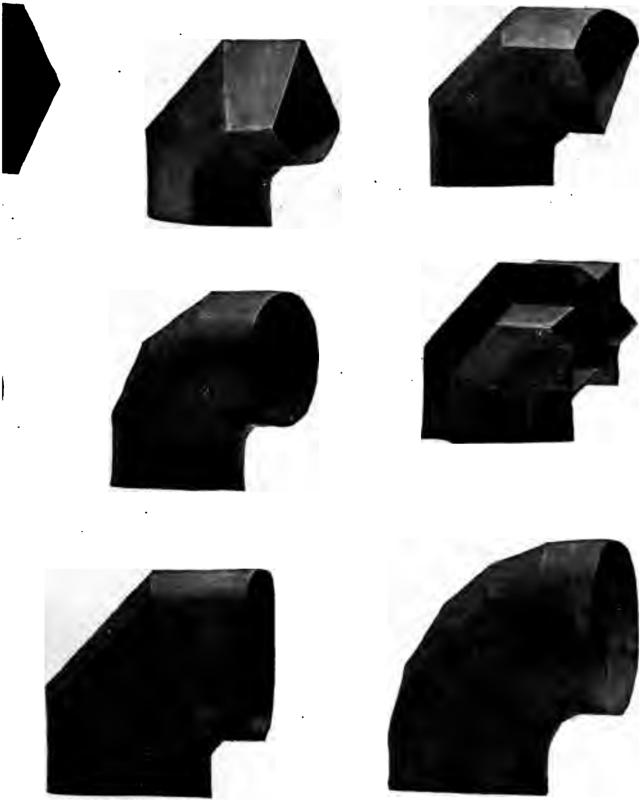

: used in Elbows.

ELBOW PATTERNS

FOR

ALL FORMS OF PIPE

A TREATISE UPON THE ELBOW PATTERN EXPLAINING THE MOST SIMPLE AND ACCURATE METHODS FOR OBTAINING THE PATTERNS FOR ELBOWS IN ALL FORMS OF PIPE MADE FROM SHEET METAL

WITH USEFUL MATHEMATICAL RULES AND TABLES

SECOND EDITION, ENLARGED

BY

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PREFACE

THE importance of a quick and accurate method of securing patterns for elbows, has induced the writer to lay before the Sheet Metal Worker in the following pages, methods which may be employed in securing the patterns for elbows of any angle or number of pieces in all forms of pipe. Methods are here pointed out which admit of the least display, and the greatest accuracy, without that study of geometrical work usually recommended.

In other words, if we possess a pair of compasses and straightedge, we can produce patterns for elbows in round pipe of any size, angle, or number of pieces. With very little additional attention, we are enabled to produce the patterns for elbows of all forms of pipe with the greatest accuracy and in the least possible time, which is an important factor in these days of sharp competition.

F. S. K.

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ELBOW PATTERNS

PART I

AN ANALYSIS OF THE FORMS INVOLVED IN PRODUCING THE PATTERNS FOR ELBOWS IN ROUND PIPE

FIG. 1 illustrates a four pieced 90 degree elbow, and upon reducing this to its simplest form, we find it contains three elbows at an angle of 30 degrees. When it is stated that it contains three elbows at an angle of 30 degrees, it should be remembered that the term 30 degrees is to an extent shop phraseology, since angles are measured by the position the two lines of which they are formed occupy as radii of a circle. This places what is usually termed 30 degrees at 150 degrees, unless the axis of one arm of said angle or elbow is presumed to be parallel to a right line in space, then will the axis of the second arm be at an angle of 30 degrees to said right line. The writer has in this work, used the usual shop term, or the number of degrees the elbow varies from a right line.

While the illustration Fig. 1, shows only an

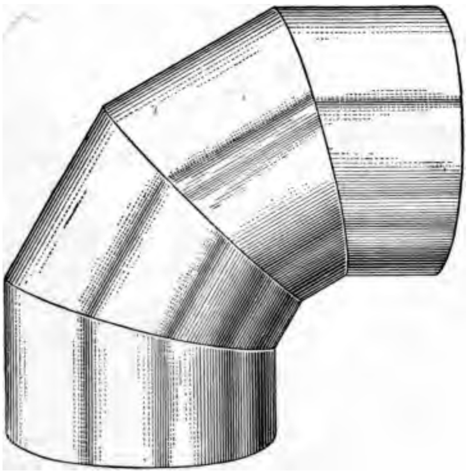


Fig. 1.—Illustrating a four-pieced square elbow, which when reduced to its simplest form contains three elbows at an angle of 30 degrees.

elbow of four pieces at an assumed angle of 90 degrees, the reader can readily conceive how the above principles may be adapted to elbows of any angle or number of pieces. In every case, the required number of component elbows is dependent upon the required number of pieces, the angle of which is also dependent upon the required angle of the finished elbow. For example, let it be presumed that an elbow is required to be made in three pieces at an angle of 72 degrees, we then have two component elbows at an angle of 36 degrees: and had the specification called for this elbow in five pieces, then four component elbows at an angle of 18 degrees would have been required.

Thus in every instance, we may deduct one from the number of pieces required in the finished elbow, then will the remainder represent the number of component elbows required: and by dividing the specified angle in degrees of the finished elbow, by the number representing the component elbows, we find the required angle of each component. As an example, let it be presumed that an elbow is required to be made in six pieces at an angle of 80 degrees, the mathematical solution would appear thus— $80° \div (6-1) = 16°$.

A graphical solution may be arrived at by the use of our compasses and straightedge as shown at Fig. 2, by drawing an indefinite right line as *a b*, and from any point on this line as center as at *c*, describe an arc of convenient radius.

Presuming the bevel to have been set to the required angle of the finished elbow, (in this instance 80 degrees) place it in position as shown, i.e., one arm parallel to line *a b*, with vertex of

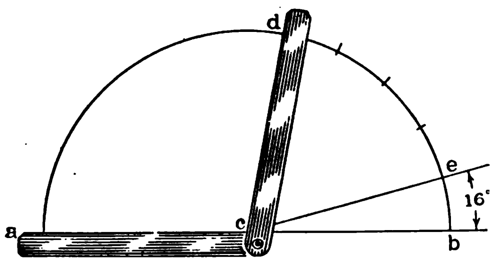


FIG. 2.—Showing a graphical method of obtaining the angle of the component elbow.

angle at point *c*, when point *d* may be located. Upon dividing the arc *b d*, into one less number of equal parts than pieces required in the finished elbow, the point *e* is established in the first division from *b*: and by drawing a line from point *c*, intersecting point *e*, the required angle of the component elbow is shown at *a c e*, i.e., 16 degrees.

From what has been shown, it is evident that the use of the protractor will greatly facilitate the work, but it is by no means necessary. It is also evident that when called upon to produce the patterns for an elbow of any angle, or number of pieces beyond two, we have only to secure the curved line upon which one piece of the component elbow is cut, and duplicate for the whole. Therefore the important factor to be determined is, at what angle to the base of a right cylinder must a plane be presumed to cut its curved surface to produce a line, whose development upon a flat surface will constitute the curved line of the required pattern: presuming the diameter of said cylinder is equal to the diameter of pipe for which the elbow is to be made.

The above statement is exemplified in the so-called adjustable elbow, inasmuch as its sections may be so revolved as to form either a piece of straight pipe, or an elbow, whose angle is dependent upon the number of sections, together with the angle each section is cut to its axis.

Fig. 3 illustrates an adjustable square elbow, made in four pieces which have been so revolved as to form a piece of straight pipe, and as each section is cut at the same angle to its axis, when we determine the angle of one, we know the angle of all.

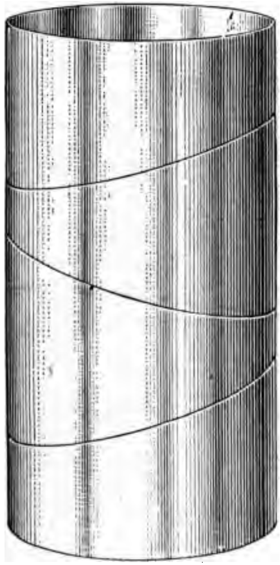


FIG. 3.—Illustrating an adjustable square elbow with sections so revolved as to form a piece of straight pipe.

If we presume to remove two sections and revolve them so that their shortest portions intersect, we form a simple elbow made of two pieces, at an angle of 30 degrees, which is one of the three components of the whole elbow, and to produce the patterns for this, we must

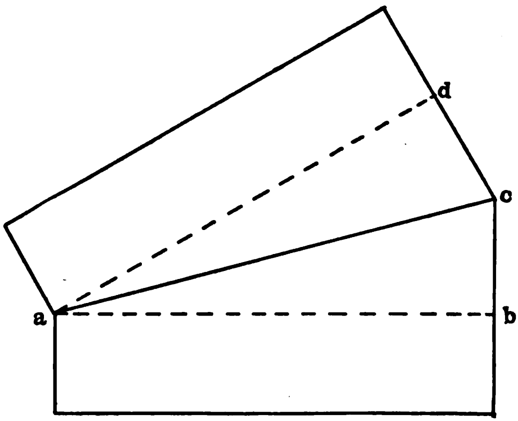


FIG. 4.—Showing elevation of simple or component elbow.

determine how much longer should each piece be at the heel than at the throat. This can be determined by bisecting the angle: as for example, the angle is said to be 30 degrees, and upon bisecting same, we obtain 15 degrees as the inclination of section line to bases of cylinders when placed in elevation as shown at Fig. 4.

Portions of said elevation are right angled triangles as shown at *a b c,* and *a d c*: the bases of which are equal in length to the diameter of pipe for which the elbow is to be made, with perpendiculars equal to the altitude of the required heels. We may construct such a triangle independently, since it is possible to obtain the length of the perpendicular, when the magnitude of two angles and the length of base are known, thereby avoiding the necessity of producing a complete elevation.

PART II

PATTERNS FOR ELBOWS IN ROUND PIPE

FROM what has been demonstrated in Part I. we may deduct the following Rules to obtain the altitude of heel for elbows of any size, angle, or number of pieces.

RULE 1.—*Divide the required angle of the finished elbow by a number which is one less than the number of pieces required, then will the quotient be the required angle of the component elbow.*

RULE 2.—*Divide the required angle of a simple, or component elbow by two, then will the quotient represent the angle of the hypothenuse to the base of a right angled triangle, whose perpendicular will furnish the altitude of heel, providing its base is equal in length to diameter of pipe for which the elbow is to be made.*

To illustrate the application of the above Rules, let it be presumed that the patterns are

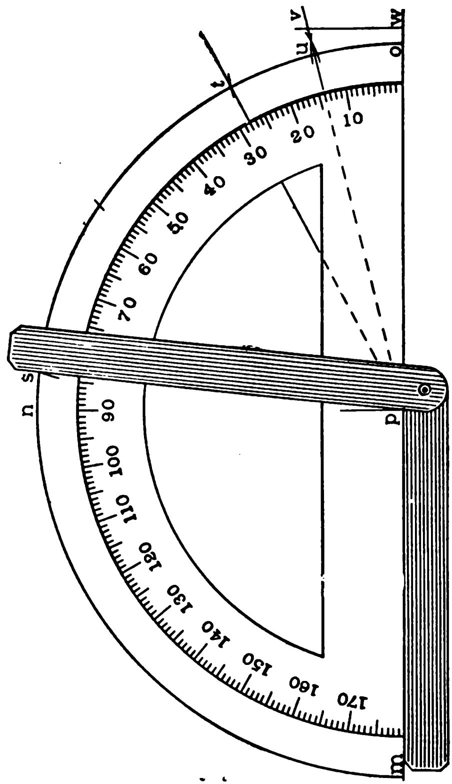


FIG. 5—Illustrating methods of obtaining the altitude of heel for elbows of any angle, or number of pieces.

required for an elbow to be made in four pieces, for a 12 inch pipe, of a given angle to which the bevel has been set.

In using the protractor, we may place the bevel in a position as shown at Fig. 5, when we find the angle to read 84 degrees: then by Rule 1, the angle of the component elbow is found to be 28 degrees, after which we apply Rule 2, and find the inclination of section line to be 14 degrees.

If we use the graphical method, we may look upon the arc *m n o* Fig. 5, as the arc of convenient radius, (spoken of in connection with Fig. 2, Part I) which has been described from point *p* as center. With bevel in position as shown, point *s* is located, when we apply Rule 1 to the use of our compasses in dividing are *s o,* thereby locating point *t.* Rule 2 may be applied to arc *t o* to locate point *u,* and upon drawing line *p u,* it will be noted that we secure identical results, i.e., we note that line *p u* makes an angle of 14 degrees to line *p o.*

Upon making base line *p w* equal in length to diameter of pipe for which the elbow is to be made, (12 inch) and erecting a perpendicular as *w v* Fig. 5, by measuring same, we find the necessary altitude of heel to be 3 inches for the required elbow, i.e., an elbow for 12 inch pipe, to be made in four pieces, at an angle of 84 degrees.

As has been shown, Fig. 5, the required inclination of section line has been found to be at an angle of 14 degrees to the base line *p o*,

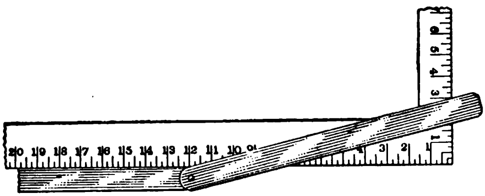


FIG. 6.—Illustrating method of obtaining the altitude of heel by the use of the steel square.

and with the bevel set to that angle, we may, if we choose employ the steel square to determine the altitude of heel, as shown Fig. 6, which needs little explanation to enable the reader to note that we secure the same result, i.e., an altitude of 3 inches.

By placing one arm of the bevel in contact with the blade, and with vertex of angle at the mark indicating the diameter of pipe for which the elbow is to be made: the second arm of bevel will be found to intersect the 3 inch mark upon the tongue of the square as shown.

To produce the curved line upon which the pattern is cut, we may employ either of two methods hereinafter shown, and designated as *First,* and *Second.* The First method is one which may be followed with the least number of tools, and satisfactory results secured in the shortest possible time.

First method of producing the curved line upon which an elbow pattern is cut

Upon turning attention to Fig. 7, the reader will note the representation of a piece of sheet metal at A, B, C, D, from which it may be assumed an elbow is to be made: i.e., it may be assumed that the elbow is for a pipe of a given size, and that this piece of sheet metal is of correct length, with seams added.

At any required distance from edge C D, a line may be drawn as E E. With compasses set to a distance equal to *one-half* the required altitude of heel, (found as previously explained) place one point at points E. and locate points F, with points F as centers, and F E as radius, describe

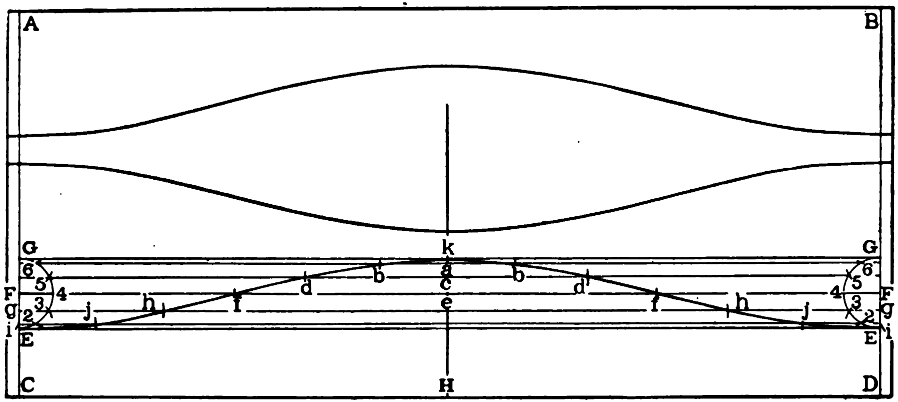


FIG. 7.—Illustrating the method of obtaining the curved line upon which an elbow pattern is cut.

the semi-circles as shown, thus locating points G when lines F F, and G G may be drawn. Without changing adjustment of compasses, and using points E as centers, describe the small arcs as at 3. With points G as centers, describe arcs as at 5, and with points 4 as centers, describe arcs as shown at 2 and 6, thus dividing each semi-circle into six equal parts, when lines are drawn as 2 2, 3 3, etc. Bisect C D as at H, and draw the perpendicular H *k*. With compasses so adjusted as to divide the line G *k* into six equal parts, place one point at *a*, and mark points *b b*. From point *c*, step two spaces each way, marking the points *d d*: from point *e*, step three spaces each way, and mark points *f f*. To shorten the work we may now step two spaces from points *g*, thus locating points *h h*, and one space from points *i* locates points *j j*, thus securing points *k b d f h j i*, through which the curved line may be traced.

Upon cutting this piece, i.e., C E *k* E D, a pattern is secured which may be duplicated for the required number of pieces as shown.

The accuracy of the foregoing method may perhaps be questioned for the reason that the circumference of the pipe is divided into so few parts. It may be stated that such criticism is justified from a scientific standpoint: however this may be overcome in a practical way when cutting the pattern, if it is remembered that the points secured are in correct positions, but the straight lines usually drawn between those points are not correct, inasmuch as they should be more or less curved. Therefore if the shears are swung between points so as to cut a curved instead of a straight line, a very little practice will overcome this objection to a great extent. However the second method may be employed to secure any degree of accuracy.

Second method of producing the curved line upon which an elbow pattern is cut

The inclination of section line as shown at 1 *a,* Fig. 8, may be determined by any method previously explained. In Fig. 8, a graphical solution has been arrived at by employing the arc of convenient radius in the following manner.

Draw an indefinite right line as A B, and from any point as center as at 1, draw an arc of convenient radius as shown at *b c f.* Set the bevel to the required angle of the finished elbow

(84 degrees in this instance) and place it in position as shown at Fig. 2, Part I, thus locating point *c*. By Rule 1, (presuming the elbow is to be made in four pieces) point *d* is located. By

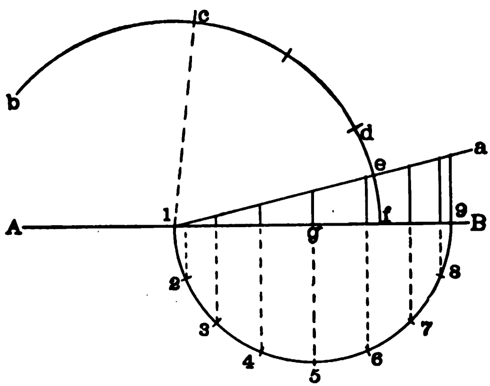


FIG. 8.—Showing the plan and elevation of a sufficient portion of the elbow to supply all measurements required to complete the pattern.

Rule 2, locate point *e*, through which the line 1 *a* is drawn, thereby determining the inclination of that line to A B.

With the compasses set to a distance equal to *one-half* of the diameter of the pipe for which

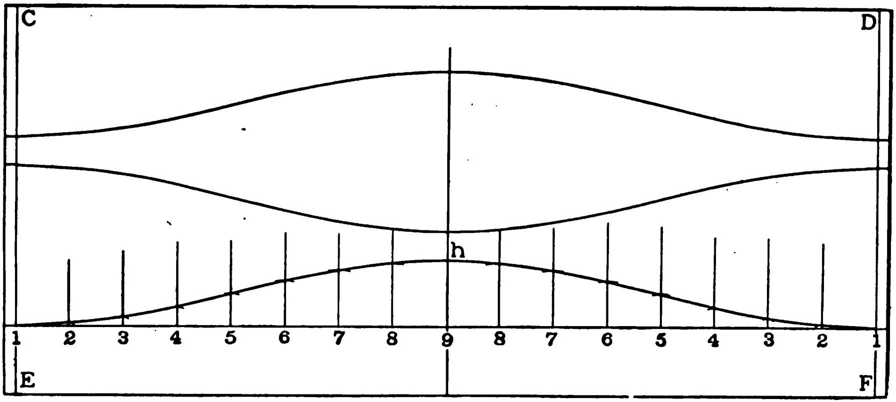


FIG. 9.—Showing the patterns for an elbow to be made in four pieces, at an angle of 84 degrees, with seams at throat and heel.

the elbow is to be made, place one point at 1 and locate point *g*. Without altering adjustment of compasses, with point *g* as center draw the semi-circle 1 5 9. Divide the semi-circle 1 5 9 into any desired number of equal parts as at 1 2 3 4 etc., and draw right lines from said points of division perpendicular to line A B to intersect line 1 *a* as shown. Thus the plan and elevation of a sufficient portion of the elbow has been drawn, together with a number of right lines presumed to be upon its surface, furnishing all necessary measurements required to complete the pattern, i.e., for an elbow to be made in four pieces, at an angle of 84 degrees.

Select a piece of material whose length is equal to the circumference of the pipe for which the elbow is to be made, or double the length of semi-circle 1 5 9, Fig. 8, as shown at C D E F, Fig. 9, with seams added. At a suitable distance from the edge E F, draw a line as 1 1 and bisect it as at point 9. From point 9, draw a perpendicular line as shown by 9 *h* prolonged. Divide lines 1 9 into the same number of equal parts as the semi-circle 1 5 9, Fig. 8, has been divided into, and from these points of division, draw perpendicular lines as shown at 2 3 4 5, etc. By the use of the

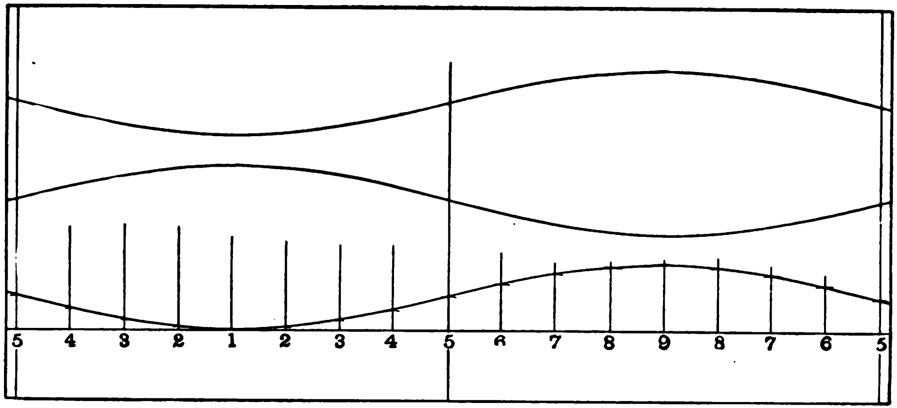


Fig. 10.—Showing the patterns for an elbow to be made in four pieces, at an angle of 84 degrees, with seams at the side.

compasses, transfer lengths of lines found between lines I B and I *a,* Fig. 8, to lines of similar numbers from I I, Fig. 9, thus locating points through which the curved line of the pattern is traced as shown.

When the piece I *h* I E F is cut, it may be revolved or reversed and used as a pattern for tracing the remaining curved lines as shown.

Fig. 10 illustrates the different assignment of numbers to the lines when the seams are required upon the side, instead of at the throat and heel, which is the only difference in producing such patterns. Numbers can be so arranged as to locate the seam upon any one of the lines, which are in reality, elements of the cylindrical surface of which the elbow is composed.

In many branches of sheet metal work, the length of each piece in the throat is a matter of convenience, there being no special importance attached to it, further than to make it sufficiently long to be handled in the making up: or perhaps short enough to economize in the matter of material. However in some branches, a specified radius of throat is demanded, in which case the elbow is often made in a considerable number of pieces.

To secure the length of each piece in the throat for an elbow of any required radius

Draw an indefinite right line as *a b*, Fig. 11, and from any convenient point upon this line as

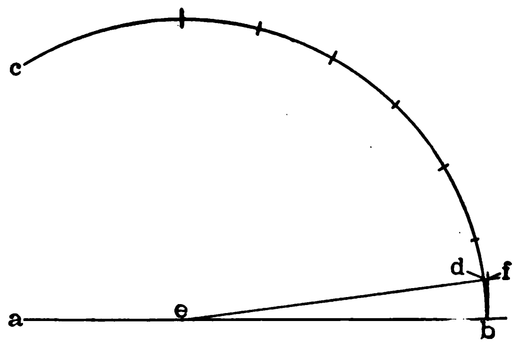


FIG. 11.—Illustrating a graphical method of determining the length of each piece in the throat, for an elbow of any required radius.

center, describe an arc whose radius is equal to the radius of the required elbow, as *c d b*. Locate by Rules 1 and 2 a line which will be at the proper angle to line *a b* to represent the section line for an elbow of the same angle and number of pieces, as shown by line *c d* Fig. 11, where it has been presumed that an elbow was required to be made in seven pieces, at an angle of 90 degrees, thus locating line *d c* at an angle of 7½ degrees to line *a b*. From point *b*, draw a line perpendicular to line *a b*, which intersects line *d e* at the point *f*, then will the length of line *b f* equal *one-half* the length of each piece in the throat for an elbow of the required radius and number of pieces, regardless of size. The necessary allowance for seams must be added to the above measurements.

In making elbows, it is sometimes found there is a variation in the angle, i.e., the finished product will not answer true to name. The cause for this is usually found in the fact that the edges have not been turned the same width at the throat as at the heel, a variation often found when machines of the older type are used. Patterns are usually developed on the presumption that the seam will be the same width throughout, and if found this is not accomplished, the section line may be so adjusted as to overcome it. In elbows of two pieces the difference will be slight, but as the number of pieces is increased, this variation increases to a point where it must be remedied.

PART III

PATTERNS FOR ELBOWS IN PIPE OF ANY FORM

METHODS of securing the patterns for elbows in forms of pipe other than round, differ in no essential respect, since in every instance the same inclination of section line will prevail for elbows of the same angle, or number of pieces, regardless of the form of pipe for which it is to be made. The difference is simply in that portion of the diagram which represents the form of pipe. This must, in every instance, be a true representation of the form of pipe for which the elbow is required, or what is usually termed, a cross-section of it, unless said form consists of two equal and opposite parts, in which case, either part will fulfill every requirement, since it may be duplicated for the other.

In forms whose diameters are not constant, it becomes somewhat difficult to designate which way the elbow is to turn: as for example, it may be required to make a square elbow in oblong

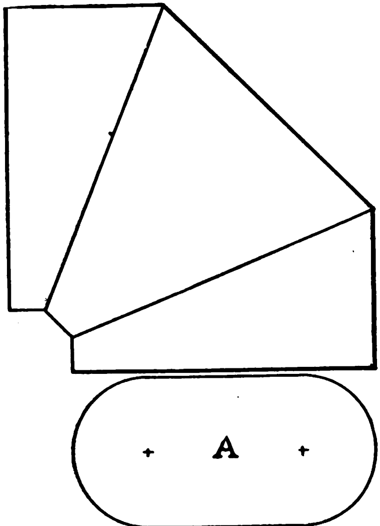


Fig. 12.

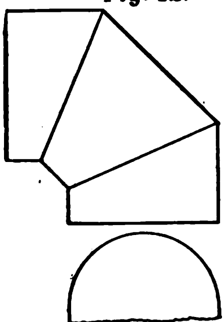


Fig. 13.

FIGS. 12 and 13.—Showing a method of designating which way an elbow is to turn.

pipe, when the question arises, Which way is the elbow to turn? This is perhaps best answered by the use of simple diagrams as shown at Figs. 12 and 13.

Figs. 12 and 13 may be looked upon as the representations of elbows, and the oblong diagram at A as the form of pipe. The same methods are employed for each, although the finished patterns show some variation in appearance: therefore diagrams are herein shown to illustrate the development of each.

To secure the patterns for an elbow in oblong pipe, turning parallel to the plane of the major axis of said pipe, as shown at Fig. 12

The diagrams are drawn in the same general manner as previously explained, and shown at Fig. 14, where the graphical method has been employed to determine the inclination of section-line, presuming the elbow is to be made in three pieces, and at an angle of 90 degrees. For example, the indefinite right line 1 9 is drawn, and from any point upon this line as center as at 1, describe the arc of convenient radius as *b d f*.

Upon applying the bevel as shown at Fig. 5, Part I, point *c* is located. By Rule 1 we find point *d*, and by Rule 2 locate point *e* through which the section-line 1 *a* is drawn. As shown

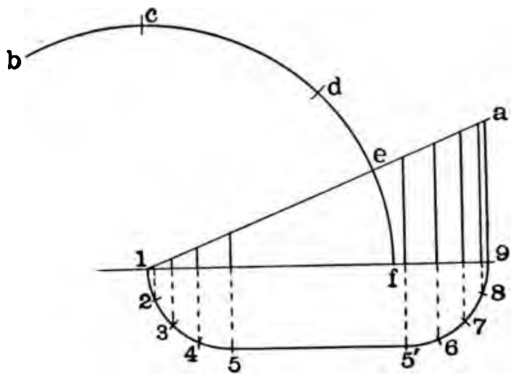


FIG. 14.—Showing diagram from which lengths of lines are secured.

at Fig. 12, the pipe is required to turn parallel to the plane of its major axis, therefore in Fig. 14 its representation, or a necessary portion of it is placed with its longest diameter parallel to the base of triangle 1 *a* 9. Divide the curved portions of the diagram which represent the form of pipe, into a number of equal parts as at 1 2 3 4, etc.

Draw lines from said points of division, perpendicular to the base of triangle, intersecting its hypothenuse as shown, thus establishing lengths of lines to be transferred to the material upon which the pattern is to be developed. Upon this piece of material, which is understood to be equal in length to the circumference of pipe, draw a line as 1 1, Fig. 15 at any required distance from one edge.

Locate points upon this line at the same relative distance from each other as found upon the diagram representing the form of pipe in Fig. 14, remembering that this diagram represents *one-half* the pipe only, and must be duplicated to complete the whole circumference, and that there must be allowance made for seams, as shown, Fig. 15.

From said points draw indefinite right lines perpendicular to 1 1. Transfer distances as found upon triangle 1 *a* 9, in lines 1 2 3 4, etc., Fig. 14, between their intersection with line 1 *a* and 1 9, to lines of similar numbers upon the material from which it is proposed to cut the pattern, setting off said distances from line 1 1,

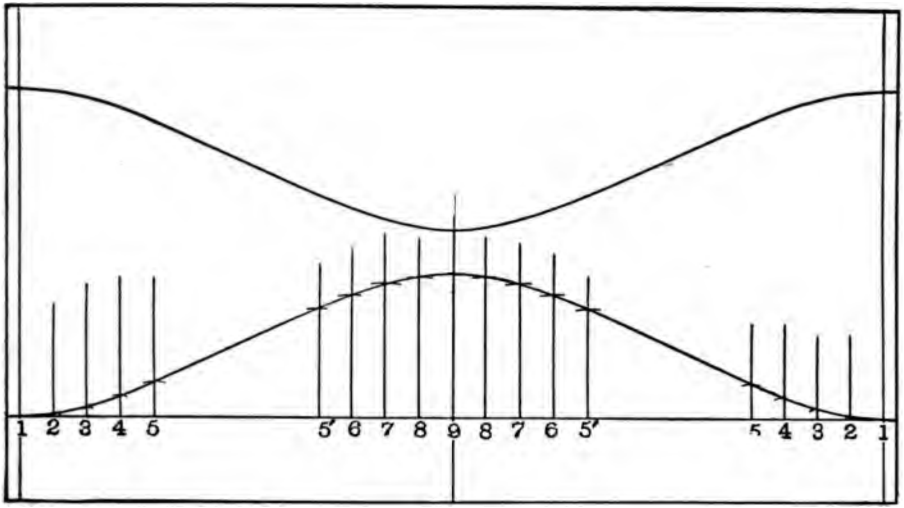


FIG. 15.—Showing patterns for an elbow in oblong pipe, as illustrated at Fig. 12.

thus locating points through which the curved line is traced. Cut the material upon this line, thereby securing a piece which is used for a pattern in tracing the additional curved line as shown, to complete the patterns for an elbow as above specified.

To secure the patterns for an elbow in oblong pipe, when it is required to turn said pipe parallel to the plane of its minor axis as illustrated at Fig. 13

By comparing Figs. 14 and 16, the reader will note that the only variation in determining the lengths of lines, is in the position of that portion of the diagram which represents the form of pipe. In Fig. 16, it has been so revolved as to place its short diameter parallel to the base line of triangle.

The inclination of the hypothenuse of said triangle to the base line *a b* is established when the necessary inclination of section line is determined, in precisely the same manner as previously explained, which in this example is 22½ degrees, since it is assumed that the patterns are required for an elbow to be made in three pieces, at an angle of 90 degrees.

Upon placing the diagram which represents the form of pipe, or a suitable portion of it, in a position as shown at Fig. 16, divide the curved

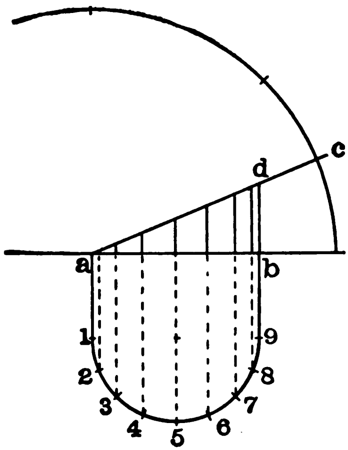


FIG. 16.—Showing diagram from which lengths of lines are secured.

portion into a number of equal parts. From said points of division, draw lines perpendicular to line *a b* intersecting line *a c*, then will that portion of those lines contained within the triangle represent lengths to be transferred to the sheet upon which the pattern is to be developed.

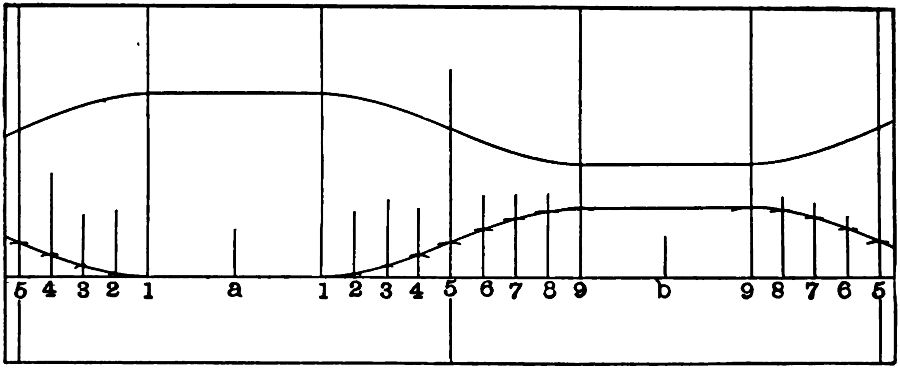


FIG. 17.—Showing patterns for an elbow in oblong pipe, as illustrated at Fig. 13.

Upon the piece of material from which the elbow is to be made, whose length is equal to the circumference of the pipe, with the necessary allowance for seams added, draw a line at any desired distance from one edge, as shown by line 5 5, Fig. 17.

Locate points upon line 5 5, at the same relative distance from each other as found on that portion of the diagram representing the form of pipe in Fig. 16, remembering that, as shown in Fig. 16, it represents only *one-half* the circumference of the pipe, which must be duplicated for the other half. Points located upon line 5 5, Fig. 17, have in this instance been so numbered as to place the seam at the side, which is perhaps the best position for an elbow of this class. From said points draw indefinite right lines, perpendicular to line 5 5. Transfer distances as found upon triangle *a d b,* in lines 1 2 3 4, etc., to lines of the same number upon the material, thus locating points through which the curved line of the pattern is traced. Cut the material upon this line, and reverse or revolve the piece to trace the additional line, as shown at Fig. 17.

To secure the patterns for an elbow in elliptical pipe, when it is required to turn said pipe parallel to the plane of its major axis.

In the development of patterns for elbows in elliptical pipe, the reader should experience little difficulty, providing he has secured an understanding of what has been previously discussed. The main difficulty is perhaps in one's inability to describe a proper form of section.

The writer has made it a practice, when called upon to produce the patterns for elbows in elliptical pipe, to make a templet, with its major and minor axis marked upon it.* By the aid of this templet the production of elbow patterns for elliptical pipe becomes as simple as any previously discussed.

In Fig. 18, the necessary inclination of section line has been determined by the graphical method as follows: Draw the indefinite right line *a* 11, and from point 1 as center with any convenient radius, describe an arc as *b c d f*.. Place the bevel in position as shown at Fig. 5, Part I, thus locating point *c*. By Rule 1, point *d* is located,

* Methods of describing the ellipse will be found in the Appendix.

and by Rule 2, locate point *c*, through which the line 1 *c g* is drawn, thereby establishing the inclination of section line when the elbow is to be made in six pieces, and at an angle of 90 degrees.

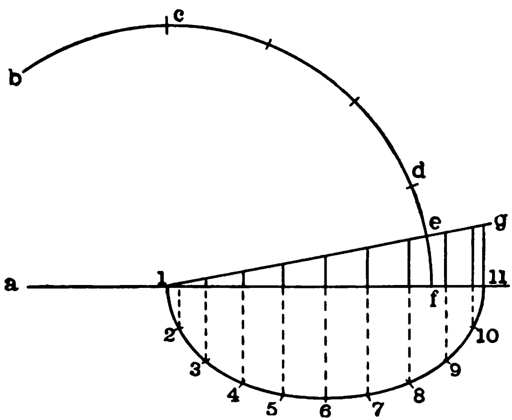


FIG. 18.—Showing diagram from which lengths of lines are secured.

(Variation of angle, or the number of pieces, have been fully discussed in the foregoing pages.) Place the semi-form of pipe in position as shown by line 1 6 11, Fig. 18, and divide this curved line into a number of equal parts as shown

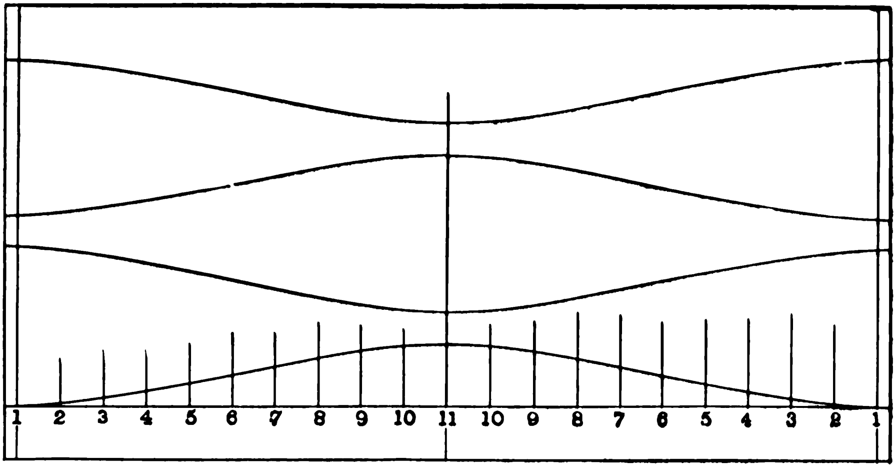


FIG. 19.—Showing patterns for an elbow in elliptical pipe, to be made in six pieces, at an angle of 90 degrees, turning parallel to the plane of its major axis.

at points 1 2 3 4, etc. From said points of division draw right lines perpendicular to line *a* 11, to intersect line 1 *g*, then will those lines between lines 1 11, and 1 *g*, furnish the necessary lengths to be transferred.

Upon a piece of material whose length is equal to the circumference of pipe, (with seams added) for which the elbow is to be made, draw a line as 1 1, Fig. 19 at any required distance from one edge.

Locate points upon line 1 1, at the same relative distance from each other as shown in points 1 2 3 4, etc., Fig. 18.

Erect perpendiculars as shown, upon which set off distances from line 1 1, as found in lines shown between lines 1 11, and 1 *g*, Fig. 18 upon lines of a similar number in Fig. 19, thus locating points through which the curved line is traced, and duplicated to complete the pattern, as shown.

To secure the patterns for an elbow in elliptical pipe, when it is required to turn said pipe parallel to the plane of its minor axis

In the development of patterns for elbows as above described, the reader will note, upon turning attention to Figs. 20 and 21, that the only variation from the one last discussed, is in the position the semi-form of pipe occupies as regards the base of triangle from which the true lengths of lines are secured.

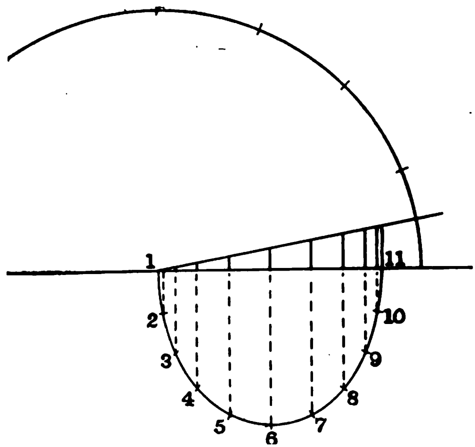


FIG. 20.—Showing diagram from which lengths of lines are secured.

Figs. 20 and 21 show the necessary diagrams to secure the patterns when it is required to turn the pipe parallel to the plane of its minor axis, and as will be noted, the minor axis of the

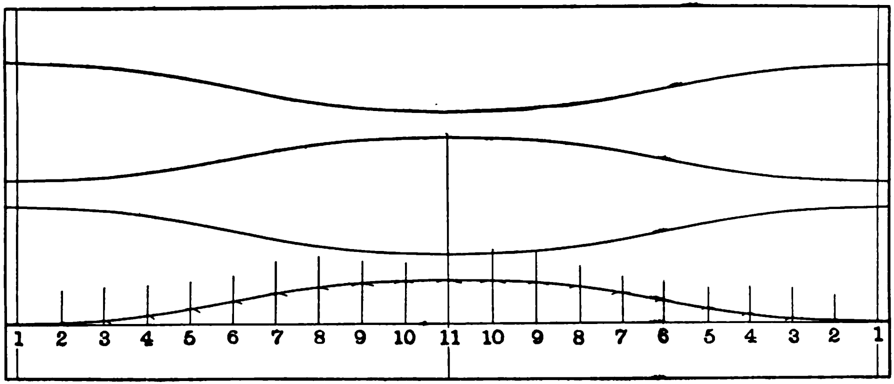


FIG. 21.—Showing patterns for an elbow in elliptical pipe, to be made in six pieces, at an angle of 90 degrees, turning parallel to the plane of its minor axis.

We may introduce any number of right lines upon Fig. 23, as *a d*, or *e f*, and presume those lines to be the plans of additional planes, thus enabling us to locate a plane from its plan,

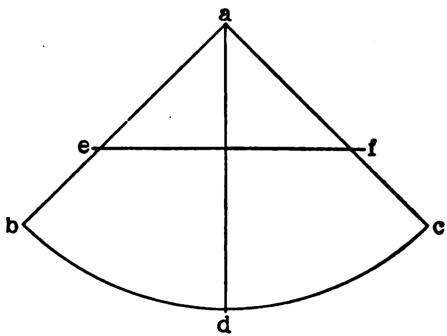


FIG. 23.—Showing cross-section, or plan of pipe.

parallel to which the elbow is to turn. With this determined, we have the key to the necessary position of the diagram representing the form of pipe, as regards the base of triangle from which the true lengths of lines are secured. In the following demonstrations will be found three examples of obtaining the patterns for elbows in a form of pipe as shown at Fig. 23, to be made in three pieces, and at an angle of 90 degrees. The variation is in the way the elbow is to turn. Figs. 24 and 25 illustrate the method

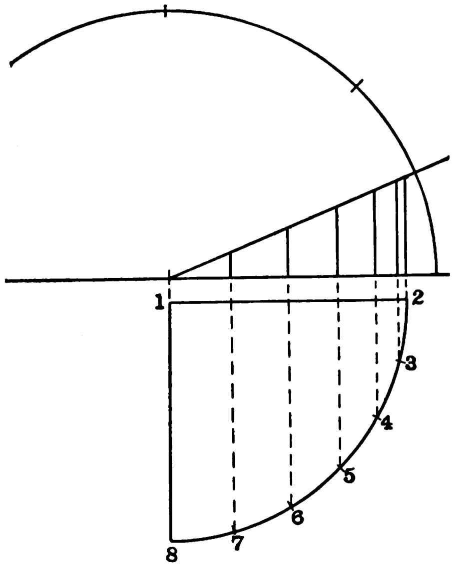


FIG. 24.—Illustrating method of securing the true lengths of lines.

of securing the lengths of lines, and transferring same to the material from which the elbow is to be made, when it is required to turn the pipe

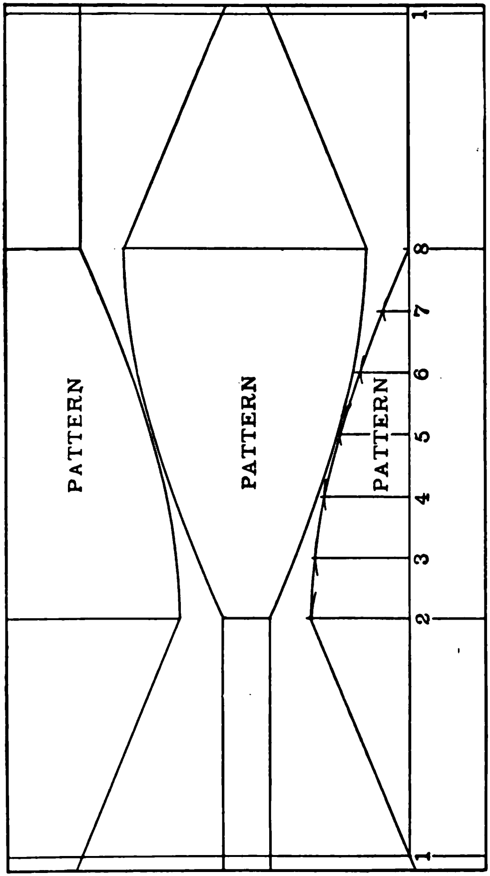


FIG. 25.—Showing patterns for an elbow in a pipe whose cross-section is a quadrantal triangle.

parallel to the plane of one of its sides, or that side represented in plan by line *a c*, Fig. 23.

Upon examination of Fig. 24, it will be noted that the side of the diagram representing the form of pipe, designated as *a c*, Fig. 23, has been placed parallel to the base line of triangle, Fig. 24.

Since the method of obtaining the necessary inclination of section line has been discussed to some length, and, as has been previously stated, the inclination is dependent solely upon the required angle, together with the number of pieces, it would seem that further discussion upon that point would be needless repetition.

It will be noted that the curved portion of the diagram representing the form of pipe, has been divided into a number of equal parts as 2 3 4 5, etc., Fig. 24, and that the vertice of the angle as at 1, has also been given a number. From these numbered points lines have been drawn, perpendicular to the base line of triangle, thereby securing true lengths of lines to be transferred in the usual manner.

Upon turning attention to Fig. 25, the reader will note that the line 1 1, has been drawn at a convenient distance from one edge of the piece of material from which the elbow is to be made, and points located upon that line at the same relative distance from each other as found upon the diagram representing the form of pipe Fig. 24. From points 1 2 3 4, etc., Fig. 25, perpendicular lines are drawn as shown, upon which lengths are set off as found in Fig. 24, thereby locating points through which the irregular line is traced to complete one piece of the required pattern, when said line may be duplicated as shown, for the whole.

A position of the diagram representing the form of pipe as shown in Fig. 24, places the heel at point 2. Had it been required to place the heel upon side 1 8, that diagram would have been reversed thereby placing point 1 in the position now occupied by point 2. Similar principles will also apply to the following example.

Fig. 26 shows the necessary diagrams when it is required to turn this pipe parallel to a plane whose position is indicated by the line *a d,* Fig. 23. Fig. 27, shows the patterns for the elbow to be made in three pieces, and at an angle of 90 degrees.

By comparing Figs. 24 and 26, it will be noted that the cross-section of pipe has been so revolved in Fig. 26 as to place a line upon that diagram as 1 5, which corresponds with *a d* Fig. 23, parallel to the base line of triangle. This is the

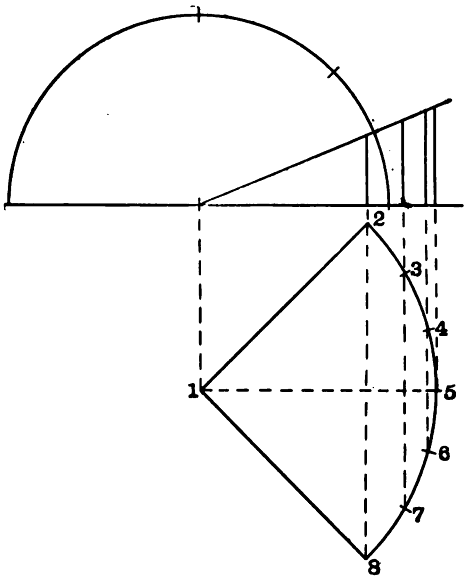


Fig. 26.—Illustrating method of securing the true lengths of lines.

only change in the operation of developing the patterns as shown at Fig. 27.

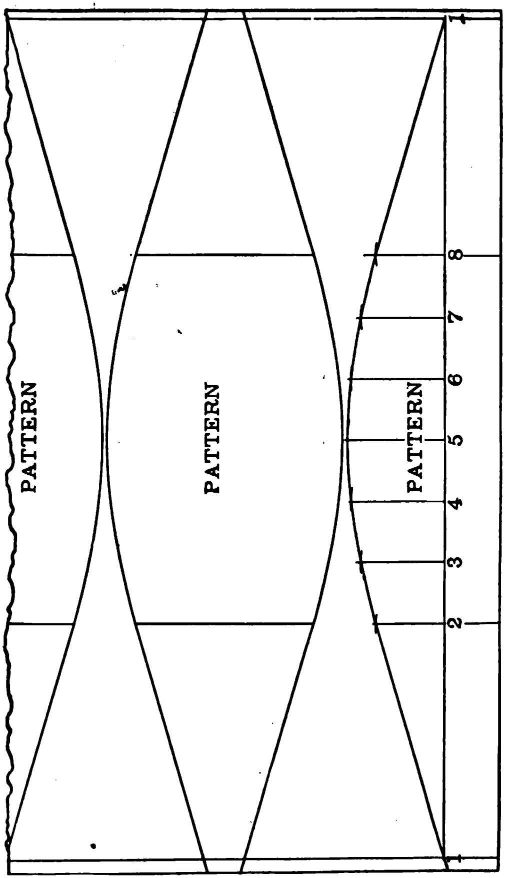


FIG. 27.—Showing patterns for an elbow in a pipe whose cross-section is a quadrantal triangle.

In Fig. 28, it has been presumed that the patterns are required to turn the pipe parallel to a plane whose position is indicated by line *e f*, Fig. 23.

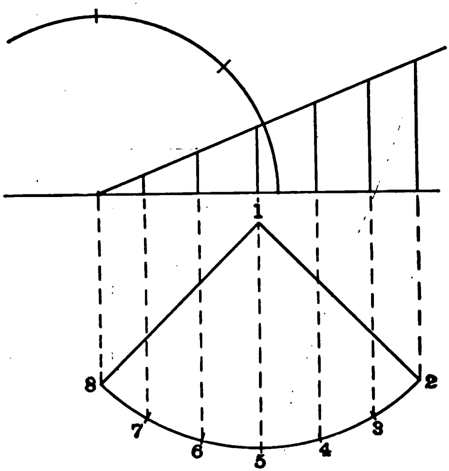


FIG. 28.—Illustrating method of securing the true lengths of lines.

Therefore in Fig. 28, the cross-section has been so revolved as to place a line corresponding to *e f*, Fig. 23 parallel to base line of triangle, thereby securing the patterns as shown at Fig. 29.

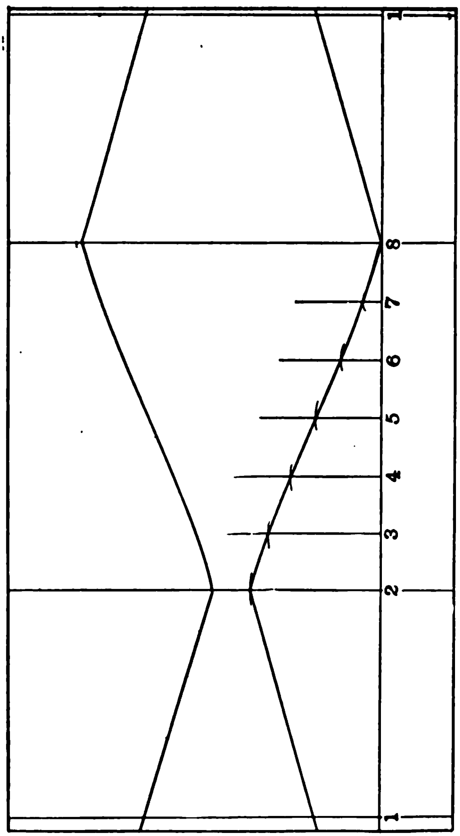


FIG. 20.—Showing patterns for an elbow in a pipe whose cross-section is a quadrantal triangle.

Fig. 30, shows the necessary diagrams to secure the patterns for an elbow in a form of pipe whose cross-section resembles a six pointed star.

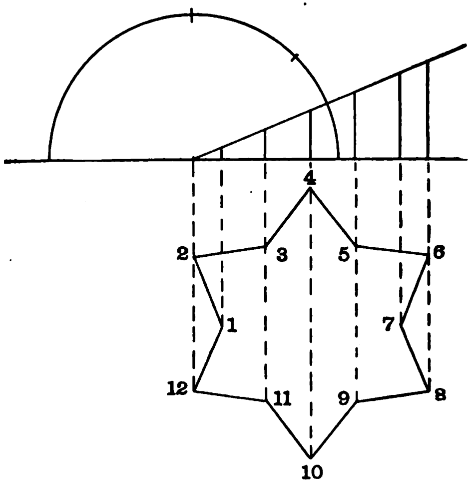


FIG. 30.—Illustrating method of securing the true lengths of lines.

Here, as will be noted, the vertice of each angle has been looked upon as the points of division, or the plans of lines presumed to be upon said pipe, and numbered in the usual manner.

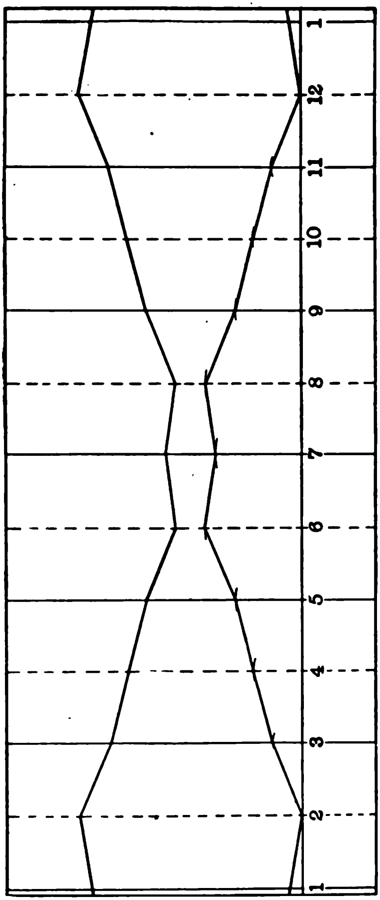


FIG. 31.—Showing patterns for an elbow in a pipe whose cross-section resembles a six-pointed star.

These numbered points are now treated precisely as in the foregoing examples, to secure the patterns as shown at Fig. 31, although the lines become somewhat involved in Fig. 30.

The portion of the diagram representing the form of pipe in Fig. 30 places the heel at points 6 and 8. Should the reader be of an inquisitive turn of mind, he is advised to develop a pattern after revolving that diagram in a manner so as to place points 2 and 8 in a line parallel to the base line of triangle, when he will have had an opportunity to observe more than could be written in pages, since practice and the consequent observations are important factors in self instruction.

PART IV

PATTERNS FOR RIVETED ELBOWS TO BE MADE FROM HEAVY IRON

When the riveted elbow is demanded, the pattern cutter encounters a problem which calls for considerable accuracy. The rivet holes should be punched in the material while flat, and in proper positions to coincide when the elbow is assembled, thus it becomes necessary to consider the thickness of the material.

If an elbow is to be made from No. 20 iron or lighter, the difference between the inside and outside diameters is negligible. On the other hand, as the thickness of the material increases, the difference between these diameters increases. When the material is No. 10 iron, that difference is approximately 1/4 inch. As an example, we may presume that a round collar is girded with a steel tape and found to be 113 inches. We note from the circumference table, page 78, that the diameter is very close to 36 inches. Some error exists here since our tape which surrounds the collar is a circle whose diameter is one thickness of the tape more than the collar proper.

We may cut a strip of No. 10 iron for the purpose of making a collar, and make that strip 113 inches in length from center to center of rivet holes. From the circumference table on page 78, we have noted that the diameter of a 36 inch circle is approximately 113 inches, therefore we would in a crude way expect our collar to come to a 36 inch circle. However, if we measure this, we find an outside diameter of 36⅛ inches, and an inside diameter of 35⅞ inches approximately. From the above it will be noted that there must be allowances made for inside and outside diameters when using heavy materials.

Allowances which Should be Made.

When each joint of pipe (round, elliptical or oblong) is made with a large and small end, an allowance of from six to seven thicknesses of the material is required, regardless of the size. For example, upon referring to the table, page 85, we note that No. 10 iron is 9/64 of an inch in thickness, thereby requiring an allowance of from 54 to 63/64 of an inch.

If we return to the collar spoken of above, and presume that an inside diameter is required, we would multiply one thickness of the material by 3.14, and add this product to the 113 inches. Thus, a collar with an inside diameter of 36 inches made from No. 10 iron should be cut approximately 113 7/16 inches from center to center of holes. Had an outside diameter been required, we would have deducted 7/16 of an inch from 113, thereby making the required length of the collar 112 9/16 inches approximately. It is found in practice that the iron as it comes to the mechanic is not always the exact thickness given in tables, however the thicknesses given here are for illustrative purposes only.

Having explained the necessary allowances to be made when working heavy material into pipe and elbows, we should also consider the method of making slips. From the lighter materials up to, and including No. 10, we may perhaps make our pipe and elbows with a large and small end,

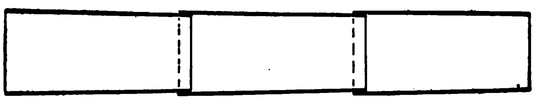


FIG. 32.—Illustrating the connection of joints which have a large and small end.

as illustrated at Fig. 32. In some instances, it may be desirable to make alternate joints equal in diameters to the large and small ends as shown at Fig. 33. This method becomes more desirable

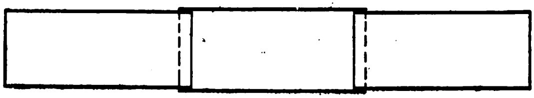


FIG. 33.—Illustrating the connection of joints when made in two diameters.

as the thickness of the material increases. For example, with No. 18 iron ⅜ of an inch is very nearly correct for a slip, thus the distortion of the cylindrical form is slight. On the other hand, should the material be ¼ inch thick, then the taper would be very close 1¾ inches. This is prohibitive, since so much taper would distort what should be a cylindrical form to an extent which can not be ignored. Each joint would then become in reality the frustum of a cone. Therefore with the heavier materials, it would seem better to follow the example of the boiler maker and make our joints of constant diameters and of two sizes.

Spacing for Rivet Holes where Joints are to be Connected.

As illustrated at Fig. 34, rivets which pass through the ends of the joints where connected

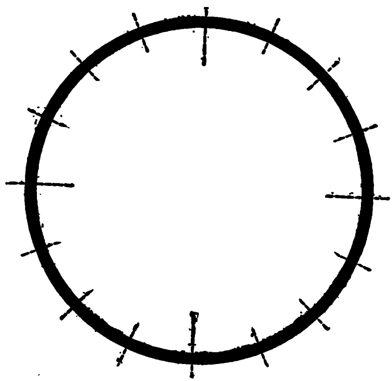


FIG. 34.—Showing the relative position of rivet holes in the large and small ends of joints where connected

may be conceived as being in radial lines from the center. Therefore each circumference is usually divided into the same number of equal parts. For example, we may presume to have a joint of 36 inch pipe to be made from No. 10 iron. As has been explained, this gives us two lengths to be divided, i.e., the circumferences of the large and small ends, the variation of which is, in this instance approximately 7/8 of an inch. It is usually desirable to have the number of connecting holes divisible by four, therefore we divide those lengths into four parts, then subdivide each part to suit the desired number of rivets in the connection.

It should be remembered that the variation in the sizes which the large and small ends should be made is wholly dependent upon the thickness of the material used for round, elliptical or oblong pipe, regardless of size. Rivet holes at the ends of joints where connected are spaced proportionately in round or elliptical pipe. In oblong pipe, a section of which is shown at Fig.

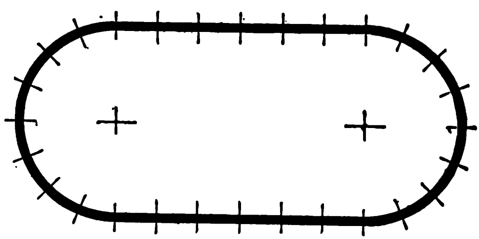


Fig. 35.—Showing the relative position of rivet holes in the large and small ends of joints in oblong pipe.

35, the curved portions are spaced proportionately, with the straight sides spaced equally as will be noted upon examination of Fig. 35.

To Develop the Patterns.

The development of the patterns for the riveted elbow to be made from heavy material differs in no essential respect from methods shown in the earlier pages of this work. On the other hand, some modifications can be made to suit existing conditions. This explanation will be devoted to securing the patterns for a square elbow in 36 inch round pipe, to be made in five pieces, from No. 10 iron. Since changes in the gauges of material, the sizes of pipe, or the angle of the elbow simply changes dimensions, not the principles involved, the student should have little difficulty in applying those methods to elbows of various sizes, angles, number of pieces and gauges of material.

Presuming, as stated above, that a 36 inch elbow in round pipe is required, to be made from No. 10 iron, in five pieces and with a specified radius of throat of 18 inches, we may proceed somewhat as follows: In any convenient position draw an indefinite right line as *A B,* Fig. 36.

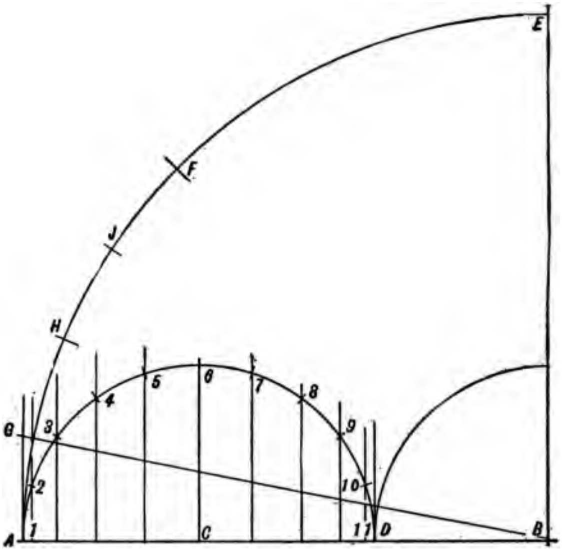


FIG. 36.—Diagrams necessary to secure the true length of lines to be transferred to the pattern.

From some point along this line as at *C*, draw a semi-circle to represent a semi-plan of the 36 inch round pipe, as *1 6 11* as shown.

It may be here explained that if a 36 inch inside diameter is required, this semi-circle should be increased one thickness of the iron above the required diameter, i.e., it should be made 36⅛ inches. From point *D* along the line *D B* set off a distance equal to the required radius of the elbow at the throat as at *B*. With point *B* as center and *D B* as radius, describe an arc as shown. With trummels set to a radius equal to the distance from *B* to *1*, and with point *B* as center, describe the large arc as also shown. From point *B* draw a line as *B E* perpendicular to line *A B*. Divide the arc *1 E* into two equal parts as at *F*. Since the elbow is to be made in five pieces, we divide the arc *1 F* into four equal parts as at *G H* and *J*. Upon drawing the line *G B* we have the inclination of the miter cut for all sections of the elbow.

Since we may best locate our rivet holes along elements of the cylindrical form it may be well to determine the number required in each mitered seam, then divide the semi-circle representing the cylinder into a number of parts which is divisible without remainder by the number of rivets required. For example, should 8 or 16 rivets be required, we may divide the semi-circle into 8 parts, should 10 or 20 rivets be required we could then divide the semi-circle into 10 parts, and so on for any required number. It is presumed in this example that 20 rivets are required in each mitered seam, and the same number at the ends of the elbow where it is to be connected to the straight pipe, therefore points upon the semi-circle are located as shown. Lines drawn through those points of division perpendicular to *A B* as shown, then supply all necessary measurements for locating points upon the curved line of the pattern.

Since accuracy and simplicity are elements which should be considered, the author recommends that a pattern for one-half of one end section including the necessary rivet holes, as shown at Fig. 37 be cut from some light mate-

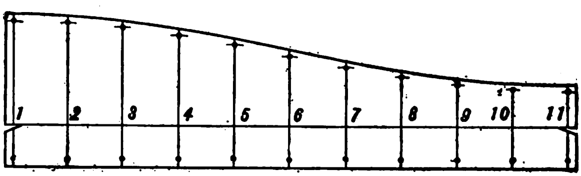


FIG. 37.—A Pattern cut from light material.

rial. Here as will be noted, lengths of lines supplied at Fig. 36, are transferred to similarly designated lines of the pattern. Rivet holes are

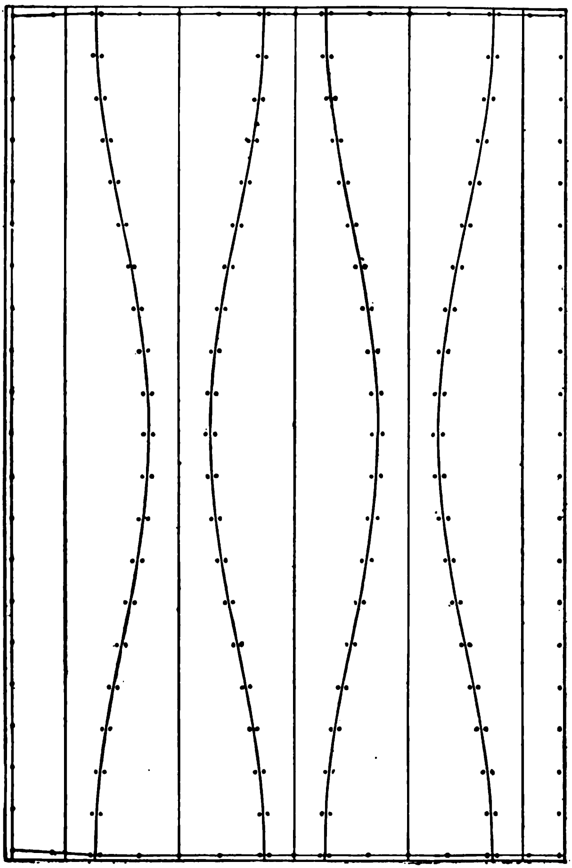


FIG. 38.—The Pattern for an elbow to be riveted.

considered as points in the curved line of the pattern, and the necessary lap added. This lap cannot be too small, on the other hand it should not be too large as an increased width adds to the difficulty of assembling the elbow. A margin of one-half inch from center of rivet holes usually gives very satisfactory results.

Presuming that a pattern as shown at Fig. 37 has been cut from light material, we may test its accuracy by placing it upon a flat surface and marking the curved line and holes. Upon reversing it, the curved line and holes should coincide in their order. Finding our pattern correct, we now proceed to reverse and revolve it upon the material from which the elbow is to be made, to secure results as shown in a reduced scale at Fig. 38. This process is substantially the same as was explained in Part 2.

Distortion Caused by Taper at the Small End.

A constant diameter of the elbow is maintained except at the small end shown at Fig. 38. Here as will be noted, the circumference has been decreased the necessary amount for a slip, and rivet holes placed accordingly. This causes some distortion, however, if we can secure a length of 8 inches or more, this may be ignored. Two longitudinal seams in this section will, with a portion of the taper in each, still further reduce the distortion.

In some instances, one is called upon for an elbow with a relatively short small end, in which case, providing the elbow must be assembled with the laps all one way, a somewhat serious problem is encountered. The required taper forces this section into a far from normal condition. To overcome this, we may employ slightly different methods which are hereinafter explained.

The student's attention is directed to the fact that *G A D*, Fig. 36, can be conceived as being an elevation of a portion of the elbow at its extremities, also one-half of each intermediate section of which there are three in this example. Any length added below the line *A D* is simply an added length of pipe, and has no direct influence upon the elbow. On the other hand, this length must be preserved as one-half of each intermediate section to maintain the specified radius of throat. A change in the length of the intermediate sections will not change the angle, however it will change the distance in which the elbow turns. Some attention to the earlier pages of this work, and an examination of Figs. 36, 37 and 38 should give the student a clear understanding of the problem now before us.

A Substitute Method.

The author's attention has many times been called to a substitute method wherein taper is introduced into each section. While this method proves quite satisfactory, it distorts the whole elbow to some extent, and the sections must be assembled in the same order as cut from the material. Some mention will be made of it, and allow the operator to judge for himself. In examples where unusually short small ends are called for, some advantage may be gained, as the difference in circumference between any two connecting sections is then slight.

When diagrams are drawn for the purpose of determining the lengths of lines to be transferred to the pattern, those diagrams are usually made upon the presumption that the elbow has a constant diameter. When we taper the elbow our diagrams are then somewhat in error. However when confronted with two evils, we may consistently choose the least.

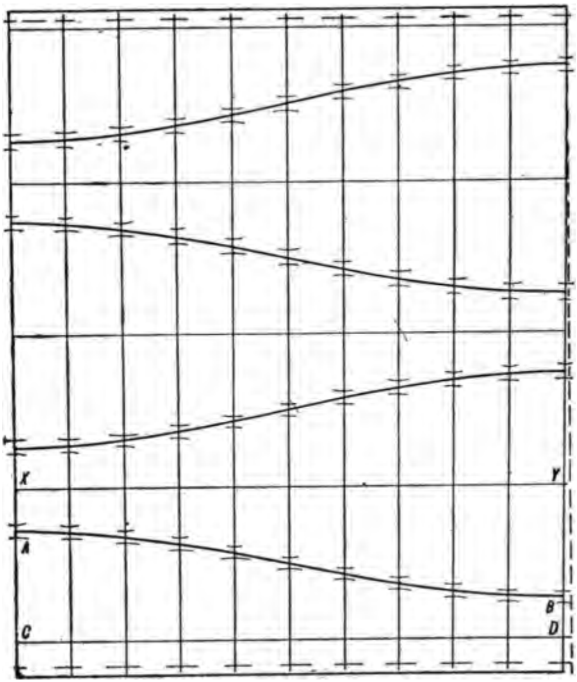


FIG. 39.—The semi-pattern for an elbow to be riveted.

Fig. 39 shows the semi-pattern for substantially the same elbow as previously explained. Here, as will be noted, the large and small ends have been established upon a suitable portion of the material, and rivet holes located at each of these ends. Lines are then drawn between corresponding rivet holes previously located at the large and small ends as shown, which compare in a measure with the usual equidistant parallel lines. At a suitable distance from the small end, a line is drawn which may be presumed to be the line *1 11*, Fig. 36. Points in the curved line, or the rivet-holes are located in precisely the same manner as has been previously explained.

Having developed the pattern as shown at *A B C D* Fig. 39, which is in this instance, the small end of the elbow, we must now develop the patterns for the remaining sections. To accomplish this we locate lines as *X Y* Fig. 39 at the required distance from *C D* to allow the setting off of distances above and below those lines as was set off above *C D*.

Some study of the construction lines shown in Fig. 39, and a comparison of measurements found in that diagram with those found in Fig. 36, should enable the student to complete his pattern as shown. We must locate each point or rivet hole, since no two are at the same distance from each other. Here, far more spacing is called for with a consequent loss of accuracy, however, satisfactory results are often secured.

Assembling the Elbow.

When the pattern is developed as above explained, the elbow is usually assembled with laps all one way, as from left to right, Fig. 32. The ends of the sections which go inside are drawn in at the heel somewhat more than the angle at which the sections meet, and gradually reduced to the center of the throat. The ends of the sections which go outside are drawn out at the throat slightly more than the angle at which the sections join, and gradually diminished to the center of the heel. To preserve the relative distance between the rivet holes we should draw one section in the same amount as we draw out the other. Since our sections where connected are normally the same circumference, one must be drawn in to average one-half the thickness of the material, while the other is drawn out a similar amount. Should the connections be somewhat overdrawn, the rivets will draw them into position, when the edges may be dressed up.

Considerable difference in appearance is noted in elbows assembled by different mechanics. Some skill is demanded, and with this very pleasing results are obtained.

Elbows in Extremely Heavy Material.

When the material is thicker than No. 10, no doubt—more satisfactory results will be obtained by making the sections of two diameters, the variation being sufficient for one to pass inside the other, or that variation necessary for a large and small end. We may then develop our patterns as shown at Figs. 36 and 37 for each size. We should then draw the semi-circles to represent each size in separate positions, and divide each into the same number of parts, then proceed with each size as with an elbow whose sections are of one diameter. It should be remembered that if we begin with a section of small diameter, the next should be a large one, and so on for the full number. Each large section acts as a sleeve to connect the small ones each side of it. In this way no drawing is required at the ends of the sections except to change the direction where those sections lap.

Spacing for Rivet Holes.

A very simple appliance for spacing rivet holes is shown at Fig. 40. Rivets in long seams are usually spaced at a constant distance, i.e., at a specified distance from center to center. This distance is sometimes known as the pitch of the rivets.

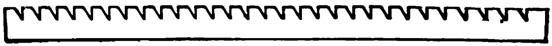


FIG. 40.—An appliance for locating rivet holes.

The appliance shown at Fig. 40 is simply a strip of light material in which notches have been cut at a constant distance from each other to suit the required pitch of rivets. If this notching has been accurately done, we have a gauge from which rivets may be located along a straight line with far more accuracy than by the use of compasses.

APPENDIX

THE CIRCLE

A CIRCLE is a plane figure bounded by a curve, all points of which are equally distant from a point within called the Center. The Circle includes a greater area than any other form of equal perimeter, i.e., equal length of outline.

The curve which bounds the circle is called the Circumference, and any portion of it is called an Arc.

A Chord is a straight line which joins any two points on the circumference, as *a b*, or *c d*, Fig. 32.

When a chord passes through the center as *c e d*, Fig. 32, it has its greatest length, and is called the Diameter.

A Radius is the length of a straight line drawn from the center to the circumference, as *c e* or *e d*, Fig. 32, and is equal to one-half the diameter.

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. For most purposes it is sufficient to take 3.1416, and in many cases 3.14, or approximately $\frac{22}{7}$, which is a convenient vulgar fraction, the error being about one part in two thousand.

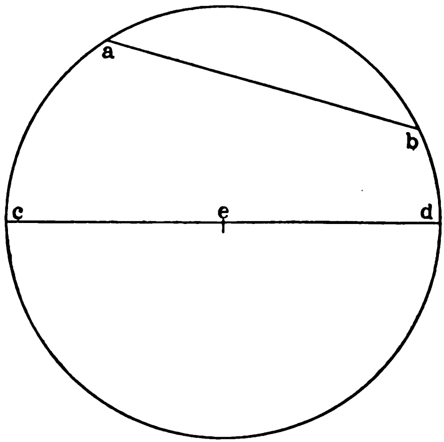


FIG. 32.

To find the circumference of a circle, multiply its diameter by 3.14, or if vulgar fractions are preferred, multiply the diameter by $\frac{22}{7}$. The table here appended will obviate those calculations many times.

To secure the approximate circumference of a circle by a graphical method

Describe a circle of the required diameter as shown at Fig. 33. By the use of the steel square,

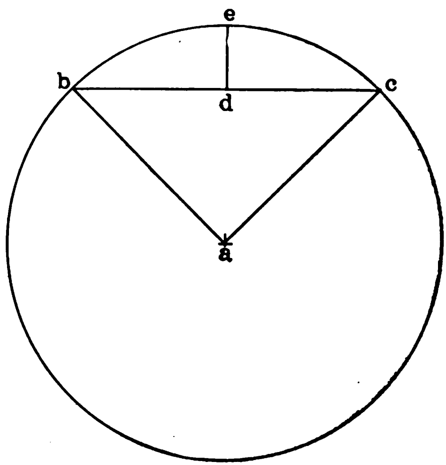


FIG. 33.

draw radial lines from the center of circle at right angles to each other as *b a*, and *a c*. From the intersections of said lines with the circle as at *b* and *c*, draw the line *b c*. From the center of line *b c*, as at *d*, draw the perpendicular line *d e*. Multiplying the diameter of circle by three, and adding the length of line *e d*, will determine the circumference close enough for all practical purposes, or perhaps within six one-hundredths of an inch for a 12 inch circle. The area of circles are to each other as the square of their diameter, thus the area of a 20 inch circle is equal to four 10 inch.

To find the area of a circle, multipy the square of its diameter by .7854.

Areas and Circumferences of Circles

To find the circumference of a circle whose diameter involves the smaller fractions of an inch, take the circumference as found for the full number of inches, and add the circumference of the fraction as given. For example, let it be presumed that the circumference of a 22⅝ inch circle is required.

We find from the table, the circumference of a 22 inch circle to be 69.1152, and the circumference of a ⅝ inch to be 1.9635, which we add to 69.1152 thus finding the circumference of a 22⅝ inch circle to be 71.0787 inches.

Diam.	Circum.	Area.	Diam.	Circum.	Area.
1/64	.0491	.0002	7½	23.5620	44.1787
1/32	.0982	.0008	8	25.1328	50.2656
1/16	.1963	.0031	8½	26.7036	56.7451
1/8	.3927	.0123	9	28.2744	63.6174
3/16	.5890	.0276	9½	29.8452	70.8823
1/4	.7854	.0491	10	31.4160	78.540
5/16	.9817	.0767	10½	32.9868	86.590
3/8	1.1781	.1104	11	34.5576	95.033
7/16	1.3744	.1503	11½	36.1284	103.869
1/2	1.5708	.1963	12	37.6992	113.098
9/16	1.7671	.2485	12½	39.2700	122.719
5/8	1.9635	.3068	13	40.8408	132.733
11/16	2.1598	.3712	13½	42.4116	143.139
3/4	2.3562	.4418	14	43.9824	153.938
13/16	2.5525	.5185	14½	45.5532	165.130
7/8	2.7489	.6013	15	47.1240	176.715
15/16	2.9452	.6903	15½	48.6948	188.692
1	3.1416	.7854	16	50.2656	201.062
1½	4.7124	1.7671	16½	51.8364	213.825
2	6.2832	3.1416	17	53.4027	226.981
2½	7.8540	4.9087	17½	54.9780	240.529
3	9.4248	7.0686	18	56.5488	254.470
3½	10.9956	9.6211	18½	58.1196	268.803
4	12.5664	12.5664	19	59.6904	283.529
4½	14.1372	15.9043	19½	61.2612	298.648
5	15.7080	19.6350	20	62.8320	314.160
5½	17.2788	23.7583	20½	64.4028	330.064
6	18.8496	28.2744	21	65.9736	346.361
6½	20.4204	33.1831	21½	67.5444	363.051
7	21.9912	38.4846	22	69.1152	380.134

Diam.	Circum.	Area.	Diam.	Circum.	Area.
22½	70.6860	397.609	37½	117.810	1104.469
23	72.2568	415.477	38	119.381	1134.118
23½	73.8276	433.737	38½	120.925	1164.159
24	75.3984	452.390	39	122.512	1194.593
24½	76.9692	471.436	39½	124.093	1225.420
25	78.5400	490.875	40	125.664	1256.640
25½	80.1108	510.706	40½	127.235	1288.250
26	81.6816	530.930	41	128.806	1320.260
26½	83.2524	551.547	41½	130.376	1352.660
27	84.8232	572.557	42	131.947	1385.450
27½	86.3940	593.959	42½	133.518	1418.630
28	87.9648	615.754	43	135.089	1452.200
28½	89.5356	637.941	43½	136.660	1486.170
29	91.1064	660.521	44	138.230	1520.53
29½	92.6772	683.494	44½	139.801	1555.29
30	94.2480	706.860	45	141.372	1590.43
30½	95.8188	730.618	45½	142.943	1625.97
31	97.3896	754.769	46	144.514	1661.91
31½	98.9604	779.313	46½	146.084	1698.23
32	100.5312	804.250	47	147.655	1734.95
32½	102.1020	829.579	47½	149.226	1772.06
33	103.673	855.301	48	150.797	1809.56
33½	105.244	881.415	48½	152.368	1847.46
34	106.814	907.922	49	153.938	1885.75
34½	108.385	934.822	49½	155.509	1924.43
35	109.956	962.115	50	157.080	1963.50
35½	111.527	989.800	50½	158.651	2002.97
36	113.098	1017.878	51	160.222	2042.83
36½	114.668	1046.349	51½	161.729	2038.08
37	116.239	1075.213	52	163.363	2123.72

Diam.	Circum.	Area.	Diam.	Circum.	Area.
52½	164.934	2164.76	62½	196.350	3067.97
53	166.505	2206.19	63	197.921	3117.25
53½	168.076	2248.01	63½	119.492	3166.93
54	169.646	2290.23	64	201.062	3217.00
54½	171.217	2332.83	64½	202.633	3267.46
55	172.788	2375.83	65	204.204	3318.31
55½	174.359	2419.23	65½	205.775	3369.56
56	175.930	2463.01	66	207.346	3421.20
56½	177.500	2507.19	66½	208.916	3473.24
57	179.071	2551.76	67	210.487	3525.66
57½	180.642	2596.73	67½	212.058	3578.48
58	182.213	2642.09	68	213.629	3631.69
58½	183.784	2687.84	68½	215.200	3685.29
59	185.354	2733.98	69	216.770	3739.29
59½	186.925	2780.51	69½	218.341	3793.68
60	188.496	2827.44	70	219.912	3848.46
60½	190.067	2874.76	70½	221.483	3903.63
61	191.638	2922.47	71	223.054	3959.20
61½	193.208	2970.58	71½	224.624	4015.16
62	194.779	3019.08	72	226.195	4071.51

The Ellipse

The Ellipse is a curve in which the sum of the distances of each point from two fixed points called the Foci, is equal to a given line.

The straight line drawn through the foci and terminated by the curve as at A B, Fig. 34, is called the Major, or Transverse axis, and the middle of that line as at E, is the Center of the ellipse.

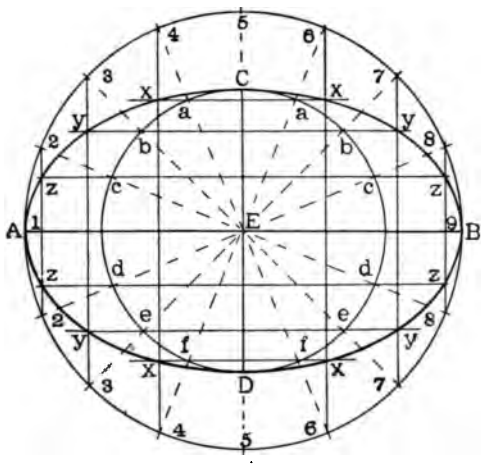


FIG. 34.—Illustrating a method of describing an ellipse.

The straight line drawn through the center at right angles to the major axis, and terminated by the curve as at C D, is called the Minor or Conjugate axis.

To draw an ellipse in given dimensions

Draw the two diameters as A B, and C D, Fig. 34 at right angles to each other intersecting at their centers as at E. With point E as center, describe two circles, one with radius E A, and one with radius E C, as shown. Divide each quarter of the large circle into the same number of equal parts as at 1 2 3 4, etc., and draw lines from center E to intersect these points, thus dividing the small circle into the same number of equal parts as at *a b c d e* and *f*. Connect similar numbered points upon the large circle with vertical lines, and through the similar lettered points upon the small circle draw horizontal lines. The intersections of said lines as at *x y z*, are points in an ellipse whose dimensions have been specified in lines A B and C D.

To draw an approximate ellipse

Draw the two diameters A B, and C D. Fig. 35, at right angles to each other, and intersecting at their centers as at E. Locate point *a* at a distance from A equal to C D, and divide line *a* B into three equal parts as at 1 2 3. Locate points *b b* at a distance from E equal to *a* 2. From points *b b* as centers, with compasses set to a distance equal to *b b*, describe arcs intersecting each other

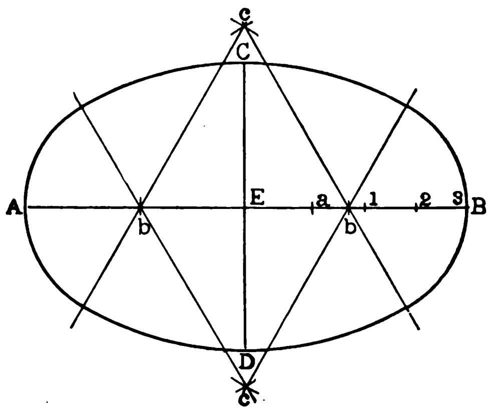


FIG. 35—Illustrating the method of describing an approximate ellipse.

as at point *c c*. From points *c c* draw right lines through points *b b*. From points *c c* as centers, and C C or *c* D as radius, describe arcs intersecting lines *c b* produced. From points *b*, with *b* A or *b* B as radius, draw arcs meeting those previously drawn, which completes the figure as shown.

This is sometimes called a false ellipse, since strictly speaking, no part of an elliptical curve is a part of a circle, however, this figure closely approximates the ellipse, and is to be preferred in some cases.

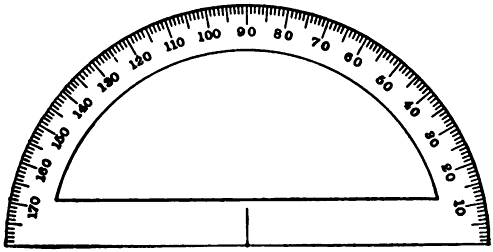
To determine the circumference of an ellipse

Multiply the sum of the semi-major and semi-minor axes by 3.1416. As for example, find the circumference of an elipse whose diameters are 8 and 12 inches. The solution arrived at would be as follows: $4+6\times3.1416=31.416$.

To find the area of an ellipse, multiply the length of the major axis by the length of the minor axis, and this product by .7854.

The Protractor

The Protractor is an instrument for measuring, or laying off angles, consisting usually of a graduated arc, or circle. The protractor as found in the cheaper grades is commonly divided to one degree, although in some instances it is found divided to one-half degree.



Protractor.

The more expensive grades have a vernier which reads to five minutes, or one-twelfth of a degree.

UNITED STATES STANDARD GAUGE AND WEIGHTS OF SHEET STEEL

As given by the manufacturer

Number of Gauge.	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Weight per Square Foot in Ounces Avoirdupois.	Weight per Square Foot in Pounds Avoirdupois.
0000000	1/2	.5	320	20.00
000000	15/32	.46875	300	18.75
00000	7/16	.4375	280	17.50
0000	13/32	.40625	260	16.25
000	3/8	.375	240	15
00	11/32	.34375	220	13.75
0	5/16	.3125	200	12.50
1	9/32	.28125	180	11.25
2	17/64	.265625	170	10.625
3	1/4	.25	160	10
4	15/64	.234375	150	9.375
5	7/32	.21875	140	8.75
6	13/64	.203125	130	8.125
7	3/16	.1875	120	7.5
8	11/64	.171875	110	6.875
9	5/32	.15625	100	6.25
10	9/64	.140625	90	5.625
11	1/8	.125	80	5
12	7/64	.109375	70	4.375
13	3/32	.09375	60	3.75
14	5/64	.078125	50	3.125

UNITED STATES STANDARD GAUGE AND WEIGHTS OF SHEET STEEL—*Continued*

Number of Gauge.	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Weight per Square Foot in Ounces Avoirdupois.	Weight per Square Foot in Pounds Avoirdupois.
15	9/128	.0703125	45	2.8125
16	1/16	.0625	40	2.5
17	9/160	.05625	36	2.25
18	1/20	.05	32	2
19	7/160	.04375	28	1.75
20	3/80	.0375	24	1.50
21	11/320	.034375	22	1.375
22	1/32	.03125	20	1.25
23	9/320	.028125	18	1.125
24	1/40	.025	16	1
25	7/320	.021875	14	.875
26	3/160	.01875	12	.75
27	11/940	.0171875	11	.6875
28	1/64	.015625	10	.625
29	9/640	.0140625	9	.5625
30	1/80	.0125	8	.5
31	7/640	.0109375	7	.4375
32	13/1280	.01015625	6½	.40625
33	3/320	.009375	6	.375
34	11/1280	.00859375	5½	.34375
35	5/640	.0078125	5	.3125
36	9/1280	.00703125	4½	.28125
37	17/2560	.006640625	4¼	.265625
38	1/160	.00625	4	.25

WEIGHT PER SQUARE FOOT OF GALVANIZED SHEETS

As given by the manufacturer

Number.	Pounds.	Number.	Pounds.	Number.	Pounds.
12	4.53	20	1.65	27	.843
14	3.28	22	1.40	28	.781
16	2.65	24	1.15	29	.718
18	2.15	26	.90	30	.65

THE METRIC SYSTEM

Measures of length

The metric system having been legalized by the United States Government, no doubt a distinct advantage would be gained by its more general use.

In all mathematical calculations involving length, area, or volume, decimal fractions are more easily computed than vulgar fractions, in which we become involved when using feet and inches. To suit convenience, either for very large or very small measurements other units have to be derived from these by taking definite fractions, or multiples of them.

There is no doubt that with the system universally in vogue, it is most convenient to take each smaller unit as one-tenth of the one above, and each larger unit as ten times the one below. This is done in the metric system, as shown by the following tables.

THE METRIC SYSTEM

Measures of Length

10 milli-meters	1 centi-meter	=	0.3937	inches
10 centi-meters	1 deci-meter	=	3.937	inches
10 deci-meters	1 meter	=	39.37	inches
10 meters	1 deca-meter	=	393.7	inches
10 deca-meters	1 hecto-meter	=	328 feet	1 inch
10 hecto-meters	1 kilo-meter	=	3280 feet	10 inches

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