PRACTICAL
SHEET METAL WORK
AND
DEMONSTRATED PATTERNS

A COMPREHENSIVE TREATISE IN SEVERAL VOLUMES ON

SHOP AND OUTSIDE PRACTICE AND PATTERN DRAFTING

VOLUME XII
SPECIAL PROBLEMS

COMPILED FROM THE

METAL WORKER

PLUMBER AND STEAM FITTER

EDITED BY

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PREFACE

THE final sorting and selecting of the material for the eleven volumes of the series of books, PRACTICAL SHEET METAL WORK AND DEMONSTRATED PATTERNS, left a collection of various pattern problems, practical articles, kinks and the like from which to choose for this last volume—XII. The majority of this collection, and it might be said the most valuable ones, are pattern problems of an unusual nature; hence the title, "SPECIAL PROBLEMS." Inasmuch as their very existence proves conclusively that the pattern draftsman is daily confronted with complicated problems, it was decided to use them for the book. Though no particular problem herein may exactly coincide with some problem which may be encountered, there is no doubt that a perusal of the book (and of course the other volumes too) will give a trained draftsman sufficient inspiration to enable him to solve his particular problem. To the student of pattern drafting no better discipline can be had than the studying of their intricate problems, especially the one on page 130. In short, it is firmly believed by the editor and the publisher that this series is an invaluable one to everyone who has to do with sheet metal work, and further that the various books comprising the series have never been equaled in the character of instructive matter they contain for the sheet metal worker.

In the respective prefaces to the preceding volumes, the source of the material for the series was told. It may, however, be again stated that through the generosity of METAL WORKER it was possible to compile these books. Needless to say, as it is a well-known fact, that journal has the services of experts in the various fields it represents and accordingly it would seem no further recommendation is necessary for the series PRACTICAL SHEET METAL WORK AND DEMONSTRATED PATTERNS.

In conclusion it is desirable to say that the publisher here expresses appreciation and thanks to METAL WORKER and the known contributors of the articles included in Volume XII; namely, George W. Kittredge and William Neubecker.

J. HENRY TESCHMACHER, JR.

CONTENTS

Practical Sheet Metal Work and Demonstrated Patterns

PATTERN FOR TAPERING PIPE INTERSECTING TWO CYLINDERS

This deals with a method of obtaining the pattern for a tapering pipe joining two cylindrical pipes, placed in position shown in Fig. 1. In this, B is the plan of the vertical pipe, shown in elevation by B^1, and C the plan of the tapering pipe, shown in elevation by C^1. D in the plan shows the inclined pipe, shown in elevation by D^1. E is the true pitch of the pipe on F H in plan. The pattern cut at the intersection L in elevation is not developed; for it, the reader is referred to Problem 156 in "The New Metal Worker Pattern Book."

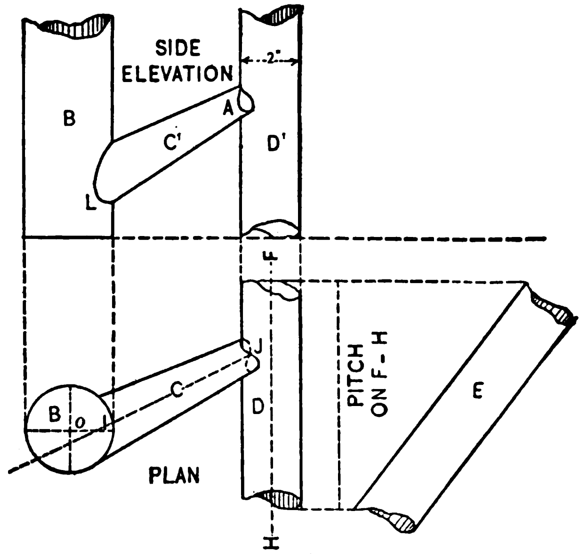


Fig. 1. Sketch of the Problem

The pattern for the cut A in elevation will be obtained as shown in Fig. 2, in which A B C shows the part plan view of the vertical pipe shown in elevation by E F G H. Referring to the plan in Fig. 1, it will be seen that the axis I J of the tapering pipe does not pass through the center of the circle O. Therefore, when drawing the plan in Fig. 2 assume that O in plan in Fig. 1 is the pivot, and turn C and D so that the axis I J of the tapering pipe will be a horizontal line, as has been done in Fig. 2, in which 4 R, the axis of the tapering pipe, lies horizontally. Through the center D draw D B. At the required distance below D B draw the axis of the cone or tapering pipe indefinitely, as 4 R.

Now draw the plan of the inclined pipe in its proper position and angle, making the length from 5′ to 5″ at pleasure, as shown by 5′ 5″ 1″ 1′. Draw the profile

J, which divide into equal spaces, as shown from 1 to 8. From these parallel to 5′ 5″ draw lines intersecting the ends of the pipe in plan, as shown by similar figures, 1′ to 8′ and 1″ to 8″.

Parallel to 1′ 1″ draw K L, which represents the line of the floor, at right angles to which and from L draw L M of the required hight desired, so that a line drawn from M to K will be the desired angle. Now take a tracing of the profile J and place it as shown by J^1, giving the circle a one-quarter turn so that the line 3 7 in the profile J will be at right angles to K M, as shown. Through the point 7 parallel to K M draw 7 7, which intersect with lines drawn at right angles to K L from 1′ and 1″ in plan, thus obtaining the lines 3 7 and 3 7 in the true angle, as shown. Through the small figures in the profile J^1 draw lines parallel to K M intersecting the vertical ends K 7 and M 7 at 1 to 7 at top and bottom. Then will K 7 7 M be the true angle on 7′ 7″ in plan.

The axis of the cone 4 R intersects the circle in plan at 2. From 2 at right angles to 4 R draw a line into the elevation, as shown by 2 2^x, the point 2^x in elevation being established at pleasure. From 2^x, at its proper angle to G F of the vertical pipe, draw the line 2^x S. Then with the apex S as center and S 2^x as radius describe the arc 2^x 4^x. Set the dividers equal to the distance that the tapering pipe is to have at its base, and using 2^x as center intersect the arc 4^x, as shown. From 4^x draw a line to S and another from 2^x to 4^x. Place the profile T in its proper position. From the center U draw a line to S, intersecting the circle at 1. Extending the line downward until it intersects the circle at 3, draw 2 4, thus dividing the circle into four equal spaces. At right angles to 2 4 in T, and from points 1 to 4, draw lines intersecting the base line 2^x 4^x at 2^x, 1^x, 3^x, 4^x. From the intersections 3^x, 1^x and 4^x drop lines into the plan, as shown by 4^x 4, 1^x 1 and 3^x 3. Now take the distances from U to 3 and U to 1 in the profile T and place them as shown in plan from U^1 to 3 and U^1 to 1 on the line drawn from 1^x and 3^x in elevation. Trace an ellipse through points 1, 2, 3 and 4 in plan, and draw lines from 1 and 3 to the apex R, which completes the plan and elevation for the tapering pipe.

The miter lines in plan and elevation of the tapering pipe joining the vertical pipe and the pattern for same should be obtained by the rule shown in Problem 156 in "The New Metal Worker Pattern Book."

The next step is to obtain an elevation of the inclined pipe. From the intersections 1′ to 8′ carry lines upward to the elevation (partly shown). Now, measuring from K in the true angle, obtain the various hights to 1 to 8, and place them on lines having similar numbers in elevation, measuring from E N, thus obtaining the points of intersection 1 to 8. Trace through these points the ellipse O. In precisely the same manner obtain the ellipse P. Now connect similarly numbered points in the sections O and P, as shown.

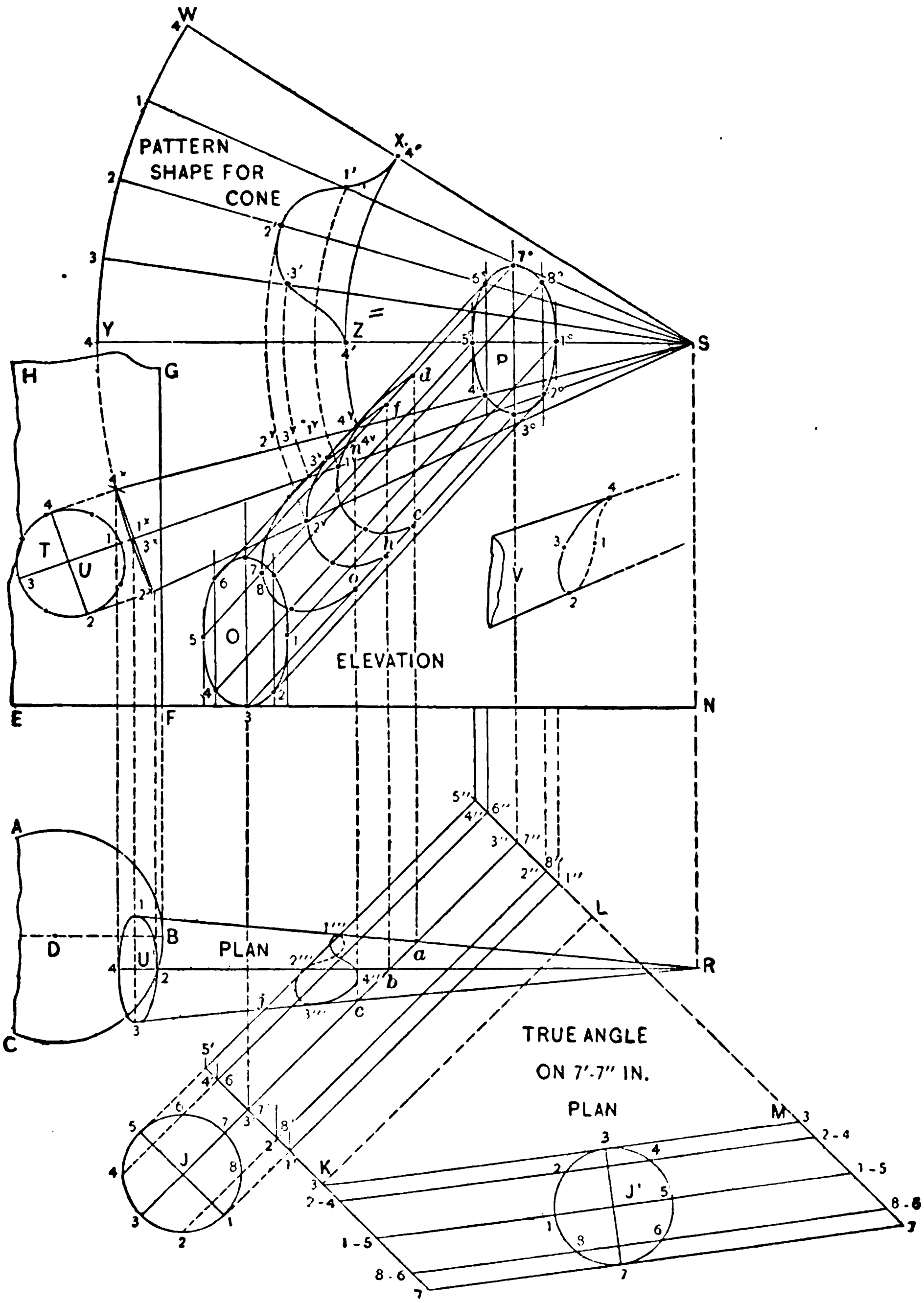


Fig. 2. Plan, Elevation, True Angle, Sections and Pattern

It will next be necessary to obtain sections in the elevation of the inclined pipe on the lines 1 R, 4 2 R and 3 R of the tapering pipe in plan, where they cross the inclined pipe $5'$ $5''$ $1''$ $1'$. At right angles to 4 R and from the intersections where the line 1 R intersects the lines $5'$ $5''$, $4'$ $4''$, $6'$ $6''$, and $3'$ $7'$, $3''$ $7''$, of the inclined pipe, carry lines upward (partly shown) intersecting lines of similar numbers in elevation. Trace a line through the points, then will *d e* be the section on R 1 in plan. Where S 1, the vertical projection of the line, the horizontal projection of which is R 1, intersects *d e*, establish 1^v 1^v. In similar manner locate 4^v, 2^v and 3^v.

If a line was traced through the intersections 1^v, 2^v, 3^v and 4^v it would look as shown in diagram V. If for any reason it was desired to obtain the miter line in plan between the tapering and inclined pipe, then at right angles to E N in elevation and from intersections 1^v, 2^v, 3^v and 4^v drop lines intersecting cone lines having similar numbers in plan, as shown by $1'''$, $2'''$, $3'''$ and $4'''$.

For the pattern for the tapering pipe proceed as follows: At right angles to the axis of the cone U S in elevation, and from intersections 4^v, 1^v, 3^v and 2^v, draw lines intersecting the side of the cone 4^x S at 4^y, 1^y, 3^y and 2^y. With S as center and with radius equal to S 4^x describe the arc 4^x W. Draw any radial line, as Y S, and setting the dividers equal to one of the spaces in the profile T step off spaces on the arc Y W, as shown. From these draw radial lines to S. Now, using S as center and with radii equal to S 4^y, S 1^y, S 3^y and S 2^y, describe arcs, thus obtaining the intersections $4'$, $3'$, $2'$, $1'$ and $4'$. Trace a line through the points thus obtained, then will X $2'$ Z be the miter cut on the tapering pipe.

The opening in the pattern for the round inclined pipe would be obtained by projecting the miter line to the oblique elevation and developing as for an ordinary T.

PATTERNS FOR A HELICAL TAPERING PIPE

One of the inquiries received was to be shown how to develop the patterns for a tapering helical pipe, and, as an illustration of the idea, a small picture was sent of a blast furnace which is reproduced in Fig. 3, in which the arrow indicates what is known as the "'down comer.'' In this picture the pipe is seen to descend first vertically to an elbow, whence it falls spirally around the body of the furnace. Careful inspection of the pipe seems to indicate that one or two sections or joints of the pipe only are made tapering. For the purpose of more fully demonstrating the principle involved, however, the spiral pipe has been given in the diagrams a continuous and uniform taper throughout its entire course, from which it can easily be seen how to vary the method to suit a pipe with an irregular taper.

The construction of an elevation of the spiral from which the exact angle of the elbows can be obtained will be the first thing sought. The conditions for accomplishing this in its entirety will, however, be found very unusual when it is discovered that such a view cannot be completed until a correct view of each and every joint of the pipe has been constructed in which is to be found every detail necessary to the development of its pattern. The work is best begun by the construction of a plan and elevation of the axis of the pipe—that is, the axial lines of the several joints, it being understood that the diameter of the furnace body, the diameter of the helical pipe at its upper and its lower end, the hight of the fall, its circumferential length on the plan and the number of pieces required are all given.

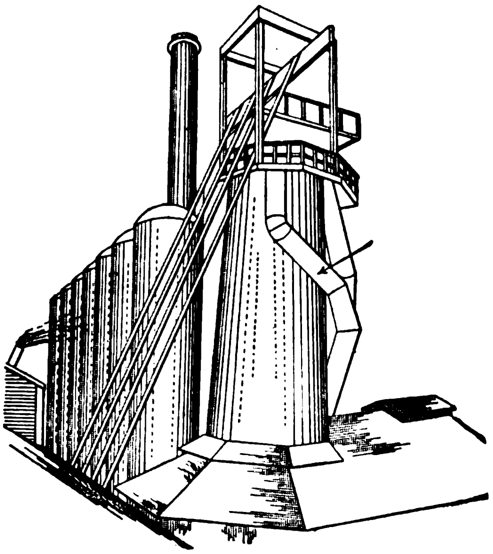


Fig. 3. Tapering Down Comer of a Blast Furnace

Therefore draw first the plan of the furnace body as shown by *a b c* of the plan in Fig. 4, the center of which is at *d*. Upon the supposition that the helical pipe is to extend through half a circle in the plan, extend the center line of the plan in either direction, and set off on the same at one side (the left) the diameter of the smaller end of the pipe as shown by *c f*, and at the other side the diameter of the larger end as shown by *g h*, making such allowances from *a* to *e* and from *c* to *g* as will allow the several pieces of the pipe to clear the furnace body at their middle portions, the said pieces appearing in the plan as tangents to a circle. Here occurs the first instance in which extreme accuracy cannot be insured, since these allowances can be only approximated or obtained by experiment. Bisect *e f* and *g h*, obtaining the points 1 and 6. Then bisect the distance 1 6, obtaining the point *i*, from which a semicircle may be drawn from 1 to 6 as shown. It being granted that the angle of the fall of the pipe is to be uniform in every piece, and that it is to be made in five joints or pieces, divide the circle just drawn in the plan into five equal spaces as shown by the figures 2, 3, 4 and 5, and through each of these points draw a line of indefinite length toward the center *i*, as shown outside the circle *a b c*.

The diameter of the pipe at its upper and lower ends having been indicated by *e f* and *g h*, uniformity in its taper may be obtained by the construction of a diagram of diameters as shown above the right of the plan, in which the diameter of the inner circle is equal to *e f* and and that of the outer circle is equal to *g h*. If the space between these two circles be divided into five equal parts and circles drawn through the points of division, the intermediate circles may be assumed as the respective sizes of the pipe at the points 2, 3, 4 and 5 of the plan, and their diameters may be set off respectively on the radial lines previously drawn through the points just mentioned (half on each side as shown), and the points so found connected, thus forming the broken lines from *e* to *g* and *f* to *h*. It must be understood that this drawing does not constitute an accurate plan of the pipe for several reasons, its purpose being primarily to bring the sides of the pipe into the desired juxtaposition with the sides of the furnace body. When this matter has been satisfactorily adjusted, lines connecting the points 1 and 2, 2 and 3, etc., will then form an accurate plan of the axes of the several pieces, from which an elevation must be projected as shown above.

In the construction of the elevation of the helix the uniformity of its fall is maintained by drawing any vertical line, as G H, making it equal to the desired hight of the fall and dividing it into the same number of equal spaces as were used in dividing the plan, in this case 5, as shown by the figures 1′ to 6′. Lines drawn horizontally from the points 1′, 2′, 3′, etc., to intersect vertical lines erected from points of corresponding number in the plan, as shown by 1″, 2″, 3″, etc., will locate the central points of the several miters in the elevation, and the lines 1″ 2″, 2″ 3″, 3″ 4″, etc., will be the axial lines of the several pieces.

If from any cause it becomes necessary that the position of the points 2, 3, 4, etc., of the plan and 2′, 3′, 4′, etc., of the elevation should be arbitrarily fixed, the result would no doubt be such that every section of the helical axis would then stand at a different angle to the horizon. Such a condition would not vary the method of solution as given below, but would require an extra degree of care in determining the angles and locating the throats of the several miters.

In the subsequent operations of obtaining correct views of the several pieces from which the patterns can be developed, it is necessary that the axis of each piece shall first be brought into or parallel to the plane of the view in the elevation. This is accomplished by turning the plan into such a position on the drawing board that the axis of the piece under consideration shall be squarely in front—that is, shall lie horizontally across the board before the projection of the points into the elevation is made. In the plan as drawn the piece D, the axis of which is the line 3 4, conforms to this requirement. The result of this is that the line 3″ 4″ of the elevation is in the plane of the view and therefore represents the true length of the axis of piece D.

As the possibility of making the sides of the helical pipe parallel instead of tapering, was referred to, it may be stated here that in either case the operations as described up to this point, and, in fact, to the point wherein a correct and complete projection of a given piece is found, are the same. Beyond this it becomes, in the case of the pipe of uniform diameter, simply a question of miter cutting, but if the pipe be tapering, the pattern can best be obtained by means of triangulation. In either case the two great points of the problem are the finding of the correct angle between any two adjacent pieces and the relative distance, on the circumference of the pipe, between the throat points of the miters at the two ends of any piece, for upon this latter feature depends the pitch or fall of the spiral. Otherwise the intended spiral would be the same as a pieced elbow, all arms lying in one plane.

To be more specific, the positions of the throats are determined by the angle made by the axes of the two adjacent pieces as measured upon a plane at right angles to the axis of piece under consideration. A view or section in such a plane can be obtained by extending the axial line 3″ 4″ in either direction upon which any point, as *n*, may be assumed as the center of an end view. By extending 3 4, the corresponding line of the plan in both directions, it is discovered that the points 2 and 5 are back of the line 3 4—that is, back of a vertical plane represented by the line 3 4, a distance equal to *j* 2 or *k* 5. Therefore set off from point *n*, on 3″ 4″ extended, a distance equal to *j* 2 or *k* 5 as shown by the point *m* and through *m* draw a line at right angles as shown, representing a vertical plane. Lines projected from 2″ and 5″ of the elevation, parallel to 3″ 4″, to intersect the line through *m*, as shown at 2‴ and 5‴, will determine the angle between the axes of the two pieces adjacent to piece D. If now two circles the diameters of which are respectively equal to those marked 3 and 4 in the diagram of diameters be described from *n* as a center, their intersection with the lines *n* 2‴ and *n* 5‴, as shown at 3^a and 4^a, will represent the circumferential distance between the throat points at the two ends of piece D. In the case of a helical axis having an irregular fall, as before mentioned, the distances *j* 2 and *k* 5 would most likely be unequal, with the result that two points would be set off near *m* instead of one, when the line from point 2″ would fall into the line through one of the points, while the line from 3″ would fall into the line drawn through the other, and the points 2‴ and 5‴ would be thus located.

To obtain a view in the plane of the axes of the two pieces 3″ 4″ and 4″ 5″, which will give the true angle between them, first draw any line parallel to the axis 3″ 4″ and conveniently near, into which project lines from points 3″ and 4″ at right angles to this axis as shown at *r* and *s*. On *r s* extended at any convenient point as *n'* place a duplicate of the section at *n* so turned as to bring the line *n* 5‴ at right angles to *r s n'* as shown by *n'* 5ᵃ, which line will then represent a horizontal plane with reference to the view about to be constructed about the axis *r s*. The point 5″ of the elevation may now be located in this plane by the projection

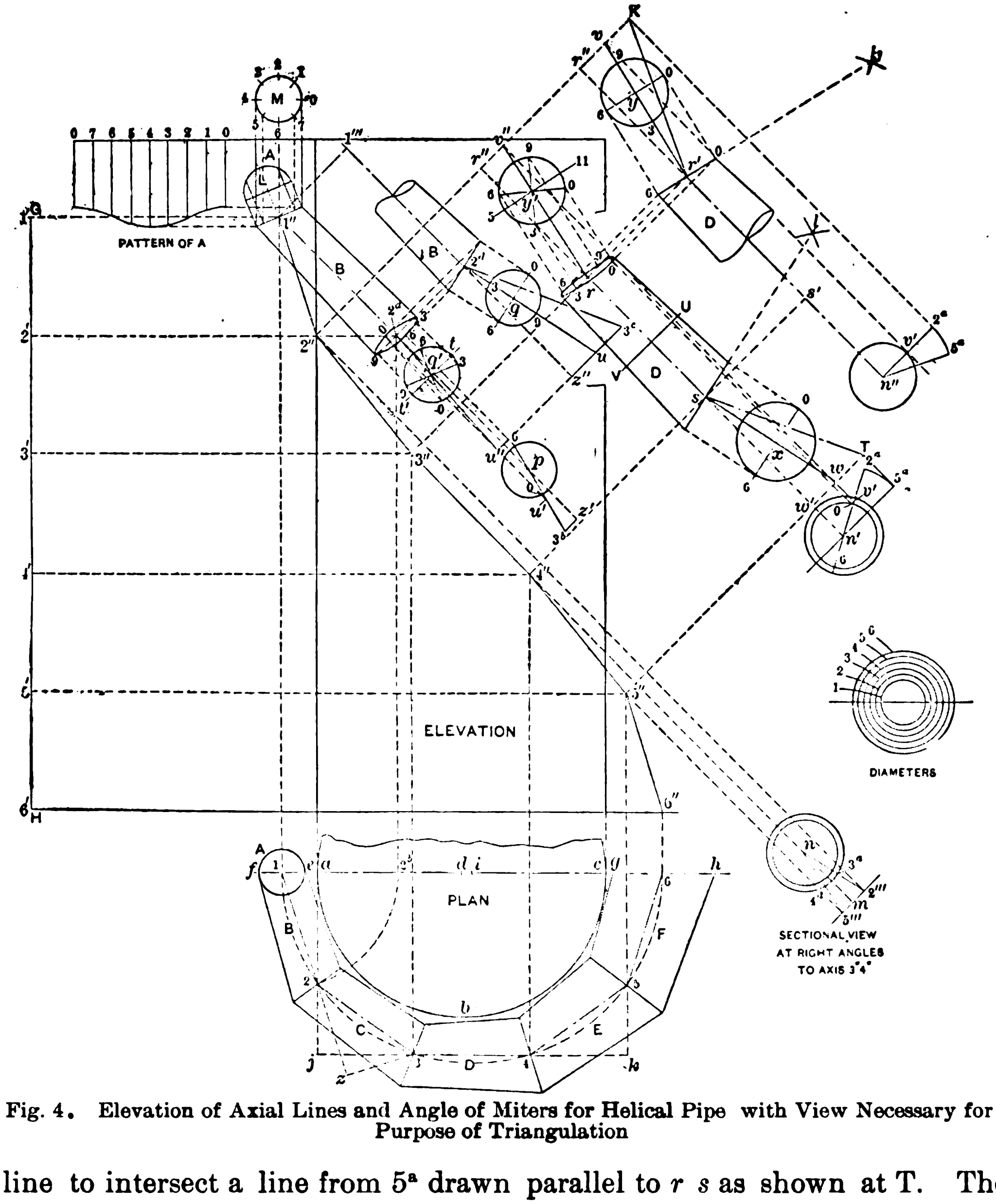


Fig. 4. Elevation of Axial Lines and Angle of Miters for Helical Pipe with View Necessary for Purpose of Triangulation

of a line to intersect a line from 5ᵃ drawn parallel to *r s* as shown at T. Then a line drawn from T to *s* will represent in this view the axis of the piece 4″ 5″ (which is shown at E of the plan), and the angle T *s r* will be the true angle of the miter. To obtain the miter line, or line representing the miter plane, the bisecting of this angle is only necessary, which can be most easily done by drawing from *r* and T as centers with any radius greater than *r s*, two arcs intersecting each other as shown at *l*. A line drawn from *l* through point *s* will then represent the desired miter plane.

This operation will have to be repeated with the axis 2″ 3″ to obtain the angle of the miter plane at the upper end of piece 3″ 4″. Since the axis 2″ 3″ does not lie in the same plane as that of the miter before shown, an additional view will have to be constructed, this time bringing the line *n*″ 2ª of the section at right angles to the axial line, all as shown still beyond the view just obtained, which for convenience may be termed an auxiliary view or projection. In this view *r*′ *s*′ is the axis obtained by continuing the lines previously drawn from 3″ and 4″, and a line is projected from 2ª of the section to meet a line from 2″ as shown at K, when K *r*′ *s*′ is the true angle of the upper miter, which is bisected as before by the arcs crossing at J, and J *r*′ represents the miter plane.

Thus far the procedure was entirely by using the axes only of the several pieces. Before attempting the construction of such an elevation of any piece as may be used in developing its pattern, the nature of its profile or cross section must be considered. In the sections thus far shown the circle has been made use of merely as representing a true section. From this point in the solution of the problem, however, two courses are open to the draftsman, one of which may be termed the truly mathematical course, while the other offers an expedient whereby some labor may be saved. According to the first, a cross section of any piece on a plane at right angles to its axis, as for instance, that indicated by the line V U, is assumed naturally to be a circle, whence it follows that whether the piece be tapering or cylindrical, the sections on the miter planes must be elliptical, because they are oblique to the axis. According to the second course, it may be assumed that the section on the miter plane is a circle which conversely can exist only when the right or normal section (V U) of a piece is elliptical. Since the operations of triangulation impose no conditions upon the shapes of the two bases or ends of what are frequently termed transition pieces, by adopting the second course, the development of the ellipses mentioned in the first course is avoided, and also that of a right section mentioned in the latter course, since such section will serve no purpose. It may be remarked that the flattening of the pipe into an elliptical section at V U will cause very little change in its appearance, except the angle between any two pieces be made more acute than shown, as would be the case if the pipe passing around a semicircular plan were made in three or four pieces instead of five.

Having now determined the shape of the piece at its ends or miters, it now remains to complete such a view as will show the correct relative position of all points in both miters, such a view being required in the operations of triangulation in order that the exact lengths of all the elements of the surface, both primary and secondary, may be determined. In the case of the pipe of uniform diameter, the pattern would be obtained conjointly from the two views last obtained by setting off two stretchouts of the profile on a line at right angles to the axial lines *r s* and *r′ s′*, as toward J, taking care to place the point 0 of the upper stretchout at a distance from 0 of the lower stretchout, equal to that from 3^a to 4^a of profile *n*, the profiles at both ends being of course the same diameter. This will bring the throat points at the opposite ends of the piece in proper relation to each other in the pattern, thus insuring the proper twist of the spiral, after which points from profile *n″* will be projected to the miter line at *r′*, and thence into the measuring lines of the upper stretchout, while points from profile *n′* will be carried to the miter line at *s*, and thence into the lower stretchout.

In constructing the view for the purpose of triangulation above mentioned, it becomes necessary on account of different positions of the miter planes at the two ends to make a projection from points on the miter line at one end as at *r′* of the auxiliary view into the other or principal view, so as to obtain at *r* the correct position of the upper miter plane in its twisted position, thus bringing into that view all that is necessary for the purposes of triangulation. In order, first, that the points in the circumferences of both miter planes may be located upon the miter lines passing through *s* and *r′*, it is necessary that their profiles should be so placed that their centers are on lines normal to those miter planes at their centers. Therefore, draw *r′*, *v* and *s w* at right angles, respectively, to those miter lines, and from any convenient points on them as *y* and *x* as centers, draw the profiles as shown. Lines drawn through those centers parallel respectively to the miter lines which they represent, will locate the points at the throat and the heel, as shown at 0 and 6 in both profiles.

To place a duplicate of the profile *y* in correct relation to the end of the principal view, so that the oblique view of the upper end or miter plane shown at *r* may be obtained by means of intersections from points on both profiles will perhaps be found the most difficult part of the entire problem. It can be accomplished by first obtaining the position of the line *r′ v* in the other view, as shown at *r v″*. In the rotation of this piece of pipe upon its axis, referred to above, it will be seen that, since the line 2″ K is at right angles to its axis, this line will represent a plane in which the points K and *v* would describe circles of which the point r'', shown in both views, is the center. As explained above, the auxiliary view is a view in the plane shown by n'' 2^a of the profile n'', or by n $2'''$ of the profile n, and that the other or principal view is in the plane of n $5'''$ of the profile n, the plane of the view being shown in every case by the line drawn through the adjacent profile at right angles to the axis of rotation. Therefore, to transfer the point v from one view to the other first carry a line from v, parallel to the axis, to cut the line n'' 2^a, as shown at v', then transfer this point to the corresponding line of the profile n', as shown by v', and carry it thence by a line parallel to the axis to cut the line 2″ K, as shown at v''. The line v'' r will then show the correct position of the line in question, upon which any point, as y', may be assumed as the center of the profile. The positions of the throat and heel in the miter may now be obtained by projecting lines from points 0 and 6 of profile n', parallel to the axis, to intersect lines drawn at right angles to the axis from 0 and 6 on the miter line r', which are obtained from profile y, as shown at 0 and 6 near r. These points may now be carried parallel to r v'' to cut the circumference of the profile y', as shown at 0 and 6. The profiles y and y' may now be spaced into the same number of equal spaces and the other points projected and intersected as explained in regard to the points 0 and 6, and as shown by 0, 3, 6 and 9, near r, the intermediate points being omitted on account of the necessarily small scale of the diagram. On account of the acuteness of the angle of intersection of the lines 0 0 and 6 6 with the profile y', there is great chance of error. As a means of verification it should be noted that the angle made by the intersection of the line 0 6 with the line 5 11 of profile y' should be equal to the angle made at n by the lines n $2'''$ and n $5'''$ of the first profile, this being the amount of rotation between the principal and the auxiliary view of this piece of the spiral pipe.

In reference to the statement made at the beginning regarding the difficulty of making a correct elevation and plan, it will now be seen how it is possible to make projections from the points obtained in the miters, as shown at r and s, back toward 3″ and 4″, to obtain a true front elevation, and, further, to extend those methods to also complete the plan. But as these operations are not essential to the development of the patterns they need not be described.

With the elevation of a piece completed as explained, the method of triangulating its surface will require some explanation since some unusual conditions occur. For this purpose in Fig. 5 is shown a view of the piece to a scale sufficiently larger to permit of points omitted in Fig. 4 being clearly shown. In this drawing the points of division in the profiles of both ends and the method of triangulation are fully shown, but the miter line at r' of the auxiliary elevation of Fig. 4, from which projections are made to obtain the oblique view of the end r, is here omitted to make room for the diagrams of sections, with the hope that its use, though only partially shown, was there fully explained. Before beginning the construction of either diagram, it must be noted that as the result of the preceding operations the points of division at the two ends of the piece do not come numerically opposite, as they should be placed when conditions permit. In the latter arrangement points of like number at opposite ends are joined to form the primary elements, shown by the solid lines of the elevation, while points at one end are joined with those of the next higher number at the opposite end to form the secondary elements, shown by dotted lines. The method usually employed in obtaining the true lengths of the elements, in pieces of this general shape, is that of assuming a plane passing through the axis of the pipe as a base from which to measure hights at the two ends. Such a plane is, of course, parallel to the plane of the view and may be supposed to be the surface of the paper, one-half of the solid thus bisected being above the surface of the paper and one-half below. This plane is represented in the profile at the right by the line 0 x 6 and in that at the left by the line R y' S, both lines being at right angles to lines normal to the center of the miter planes, as explained above.

This method has been employed in diagram of secondary elements, which is constructed as follows: Draw any line, as T V, representing the plane of bisection, and at T erect a perpendicular, upon which set off the hight of all the points in the profile x as measured at right angles to the line 0 6. The distances of points below the bisecting line being equal to those above, three points on the perpendicular at T will thus represent all the hights in this profile, placing to each point all the numbers represented. From T, on T V, set off the lengths of all the secondary elements as measured on the elevation, placing the number of the point at the left end of the line, at the points as located, and at each point erect a perpendicular making its hight equal to that of corresponding number in the profile y' as measured above or below the bisecting line R S, all as shown above V in the diagram. It is advisable to repeat the numbers, as the several points are located at their proper hights, so that no mistake can be made in connecting these points properly with those on the perpendicular at T. Lines drawn from points on T to points at the left end corresponding with numbers connected in the elevation will then give the true lengths of the secondary elements.

Careful inspection of the profile y' will show that the point 11 at that end of the piece comes very nearly opposite point 0 at the right end, and therefore that each point at the left will be just as nearly opposite to the point next higher in number at the right end. Being thus practically opposite, points at the left may be joined with those at the right in the following order to form the primary elements: 11 with 0, 0 with 1, 1 with 2, etc. Each primary being also practically in a plane with the axis of the pipe, the diagram for obtaining the true lengths of the primary elements may be very simply constructed by using the axis of the pipe as a base of the sections. The diagram thus becomes a series of radial sections folded or rotated into one plane, of which X Y is the base line. Therefore project lines at right angles to X Y from all points in both ends of the piece, cutting X Y and extending somewhat beyond. Since all the points in the miter at the small end are practically equidistant from the axis, draw a line across the perpendiculars at a distance from Y equal to the radius of the profile y', as shown at a, numbering the points of intersection with a to correspond with the points from which they are derived. For like reason draw the line b across the perpendiculars near X at a distance from X equal to the radius of profile x, numbering each point as before and as shown by the small figures. As all of the elements in this diagram would, if drawn, be practically one line, it is better to use the diagram without the line, simply finding the length of the element wanted by means of the figures at its ends as given on the elevation.

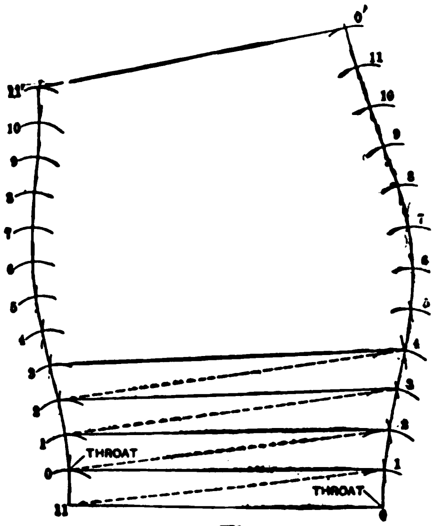


Fig. 6

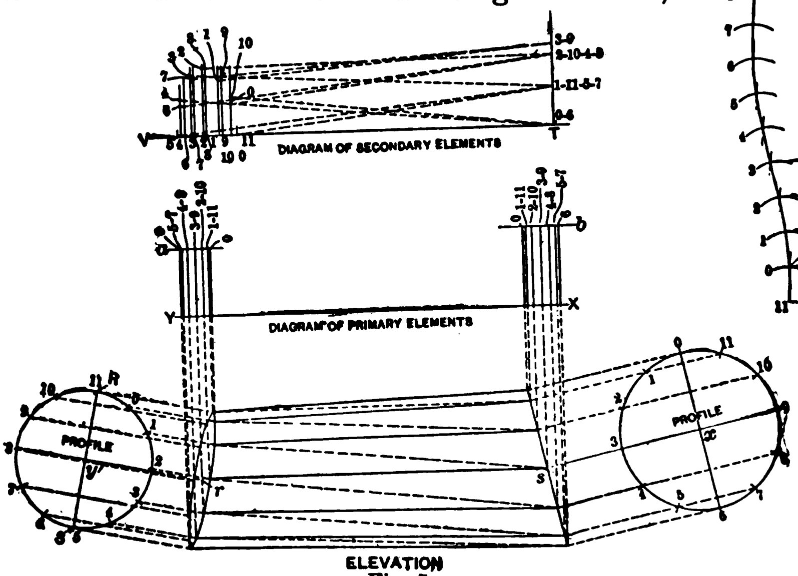


Fig. 5
Enlarged View of Middle Piece, Showing Method of Triangulation and Pattern

With the lengths of all the elements now obtained, the method of developing the pattern does not differ from that explained in these books in connection with many similar cases and need not, therefore, be explained in detail. But on account of the unusual manner in which the numbers occur, it will be advisable to adopt some system of coupling the numbers whereby error may be avoided. Thus in beginning the pattern a line equal in length to 11 0, the first primary element is set off, when it will be noticed that the first secondary element is drawn from 11 at the left to 1 at the right end in the elevation and that it is set off from a point at the left in the pattern, so as to determine, in combination with the space 0 1 of profile x, the position of a point at the right which is two numbers higher; also that the following primary element is set off from a point at the right to locate, in combination with 11 0 of profile y', a point at the left which is one number lower. It will therefore be a great help to arrange the figures, by reference to the elevation, in the form shown in the two accompanying tables, in which the two numbers used to designate each element are coupled and placed in the order to be used as indicated by the words left and right:

TABLE OF NUMBERS TO BE JOINED FOR ELEMENTS

Primary				Secondary			
Right	Left	Right	Left	Left	Right	Left	Right
0	11	7	6	11	1	5	7
1	0	8	7	0	2	6	8
2	1	9	8	1	3	7	9
3	2	10	9	2	4	8	10
4	3	11	10	3	5	9	11
5	4	0	11	4	6	10	0
6	5						

The several elements can thus be taken from the diagrams by number as wanted and checked off the table as used. When the pattern has been completed, as shown in Fig. 6, the points marked 0 at the opposite sides will be the throat points in the two miters and will meet the points numbered 0 in miters of the adjacent pieces.

In proceeding with the work it will be necessary to repeat these operations as described for each of the pieces except for piece B. Since this piece miters with piece A at 1″ of the elevation at a sharp angle, the miter plane of its upper end is necessarily an ellipse. This makes the piece B a transition from an ellipse at one end to a perfect circle at the other. In beginning the work on this piece, its axis is brought into the plane of the view by carrying the point 2 of the plan around 1 as a center to 2^b on the center line of the plan, and projecting this point into the elevation to intersect the line from 2″, or 2′, as shown at 2^d. The axis of piece A being vertical, the position of the miter plane is found by bisecting the angle, as before explained and as shown at 1″.

The piece A being cylindrical instead of tapering, its pattern is obtained in the usual manner from points on its profile M, as shown at the left, and the points obtained on the miter line at 1″ in the operation are used in constructing the elliptical section L in the usual manner. The position of the miter plane at the upper end of piece B being thus fixed, and being also shown in the profile, it becomes necessary to obtain a view of the miter plane at its lower end, as seen in the plane of its axis. This is accomplished, as before, by means of an auxiliary elevation shown at B′, thus duplicating the operation performed at the upper end of piece D. At p is shown an end view of the lower part of piece B, in which $p\ z'$ is equal to $z\ 3$ of the plan and $z'\ 3^b$ equal to $m\ 5'''$, because the twist is the same at all the miters of the spiral from 2″ down. $2^d\ z''$ is equal to $s\ w'$ and $z''\ 3^c$ is equal to $p\ 3^b$. Thus $2^d\ 3^c$, the axis of piece 3, is brought into the same plane with $2^d\ 1'''$, the axis of piece B, when the angle at 2^d is bisected, giving the position of the miter plane of the auxiliary elevation. $2^d\ u$ is drawn normal to the miter plane on which is placed the profile q, of which 0 is the throat. Point u is transferred to a corresponding position on $p\ 3^b$, as shown by u', and carried parallel to the axis of B to intersect $3^c\ z''$ extended at u'', when the line $u''\ 2^d$ will represent the position of the normal in the principal elevation. On this last named line, from any convenient point as center, as q', draw a duplicate of profile q. Now from points 0 and 6 of profile p project lines to intersect lines from the throat and heel of the miter at 2^d, as shown at 0 and 6, near 2^d, and carry these points back to profile q', parallel to the normal 2^d, u'', cutting that profile, as shown at the points bearing the same numbers. With the throat and heel of the miter thus located on the two profiles q and q', the remaining points of division are easily found and the intersections made in an exactly similar manner to that explained above in regard to the profiles y and y', thus completing the elevation with respect to showing the lower miter plane in the twisted position necessary to produce the desired miter at 2″ of the elevation. In following the points down from profile M it will be noted that the throat of the upper miter will fall at t on the profile q', thus showing that the circumferential distance between the throat points at the two ends of the piece is more than 90 degrees; and further, that the line $t\ t'$ of profile q' represents the bisecting plane from which to measure hights in obtaining the diagrams of elements, all as explained in Fig. 5.

PATTERN FOR A FOUR-PRONGED FORK

Probably the best method to pursue in developing the pattern of this nature, to bring the ends of the several prongs to the required shape is to first cut a disc of

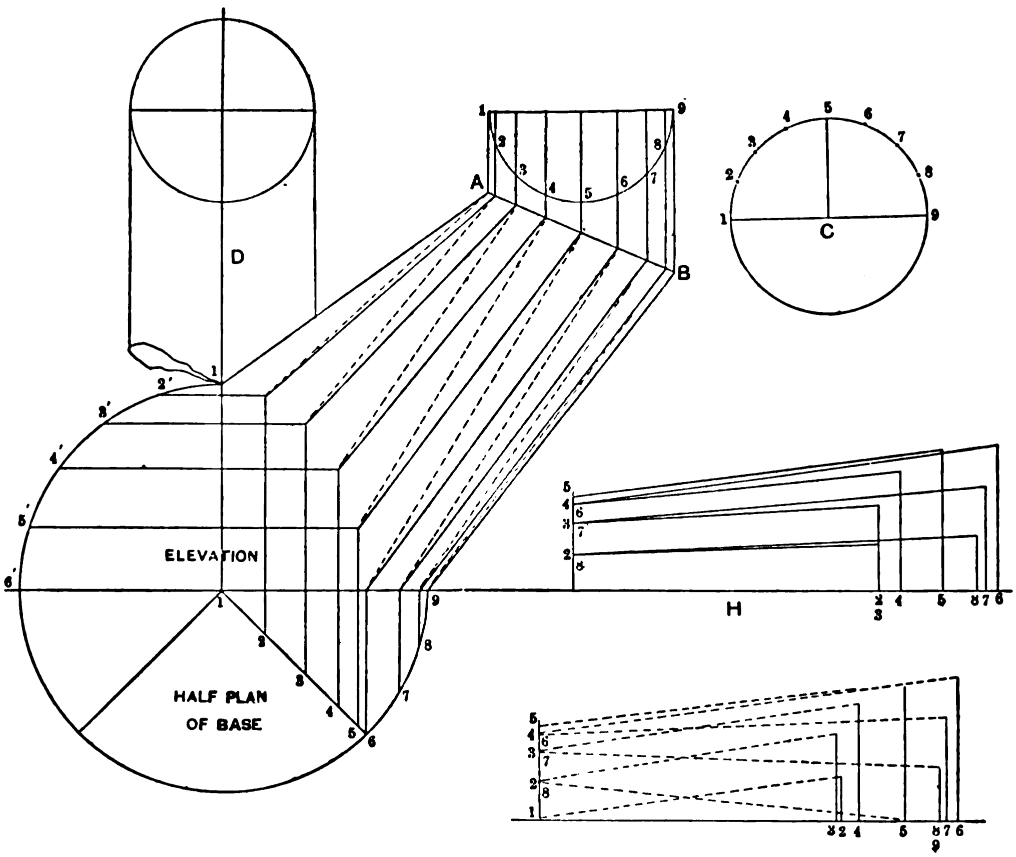


Fig. 7. An Obvious Solution of the Problem

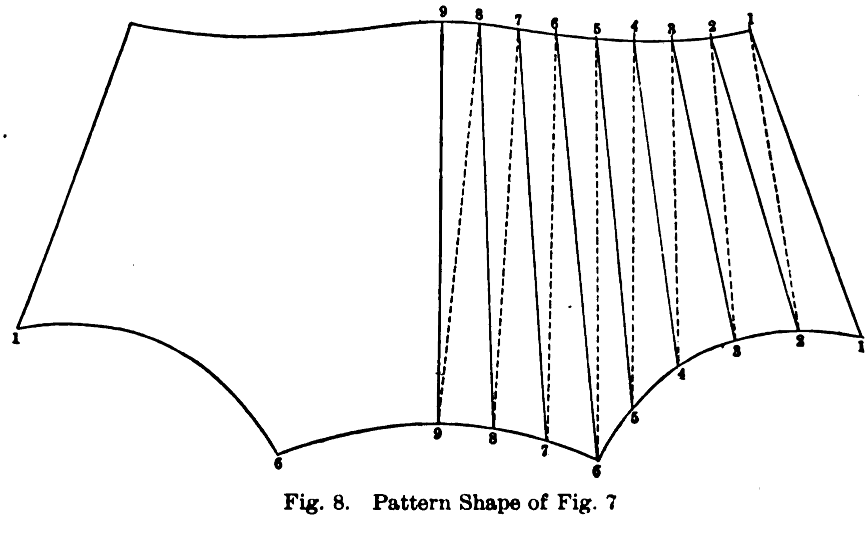


Fig. 8. Pattern Shape of Fig. 7

metal to the exact diameter of the plan of the large pipe, and then to bend two pieces of wire so as to form exact semicircles of the same diameter as the disc.

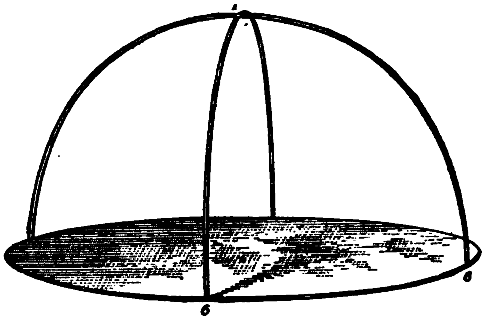


Fig. 9. Templet to Show the Shape of the Large Ends of the Prongs

The two wires, being crossed and fastened at right angles in the middle, may now have their ends soldered to the edge of the disc at four equi-distant points, when the templet thus formed will appear as in Fig. 9. Four spaces will thus be provided to receive the four prongs of the fork; and when the three points of one of the prongs indicated by 1, 6 of the pattern in Fig. 8 have been drawn apart till they reach the three angles of one of the openings of the templet the curves 1 6, 6 6 and 6 1 of the pattern must coincide with the corresponding curves of the templet, because in developing the pattern they have been made equal thereto. When the prong has been thus formed it will appear as in Fig. 10.

The extra or fourth prong of the model, has been formed to its proper shape and its lines found to exactly coincide with such a templet and its angles of inclination to conform to that given in Fig. 7.

In applying the methods described in Problem 208 of "The New Metal Worker Pattern Book" to forks having a greater number of prongs than three, the method of establishing the joint line between adjacent prongs demands careful consideration. That the general section of the several prongs or branches, whatever be their number, should be as nearly round as possible throughout their course is quite a natural idea. In fact, the simplest solution to the problem that might suggest itself, before going into detail, is that of bringing together a number of prongs of a general conical form, by placing them radially about a common center and then cutting away as much of their sides as is necessary to form a miter joint between them, after the manner of a miter between cylindrical pipes. A miter formed between radial prongs cylindrical in shape would obviously result in a joint line greatly differing from the quarter circle 1 6′ of the elevation in Fig. 7, as will be shown. The methods

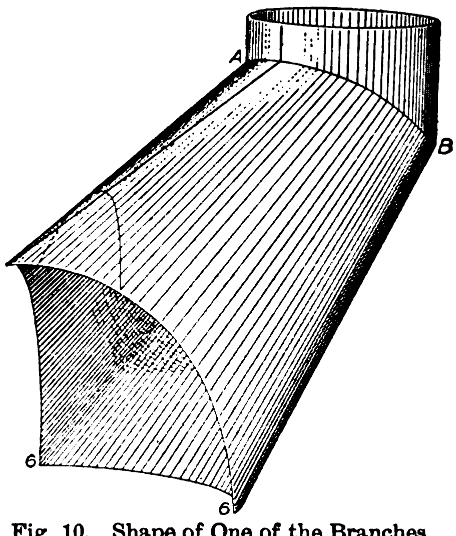


Fig. 10. Shape of One of the Branches of a Four-Pronged Fork

prescribed in Problem 208 can without doubt be extended to include any number of prongs and still satisfy the demands of capacity, since there is no technical reason for the large end of a prong, in the case of a four-pronged fork, having a greater capacity than one-fourth of that of the end of the large pipe.

Let it be supposed, for instance, that six prongs or branches are required. A templet constructed similarly to that shown in Fig. 9 to represent the junction of six branches would then have six arcs or wires descending from the apex 1 to six equi-distant points on the perimeter of the disc, when it will appear that while the sides of the openings still remain quarter circles as before, their lower arcs or outlines will be only sixths of a circle, thus narrowing the openings; and further that the openings would become narrower and more slot like as their number is increased, which would, if this method be adhered to, result in a corresponding flattening of the sides of the branches.

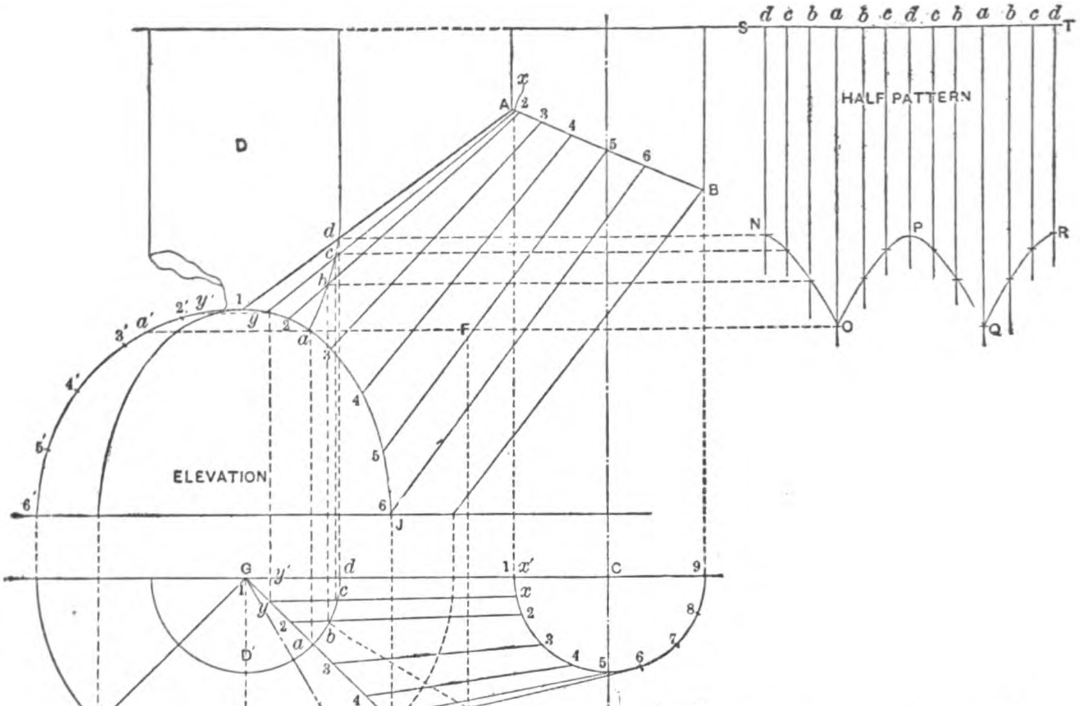
The operations of triangulation in their simplest form consist in developing the shape of a surface which when properly formed will constitute the side walls to inclose a space between two dissimilar and arbitrary forms the outlines of which can be properly termed the basis of the solid figure. Inasmuch as triangulation renders possible the use of arbitrary forms as bases, it thereby opens up the way to a great chance of error when it becomes necessary, as in the present case, to work to forms which are assumed instead of those which are the result of some other operation included in the solution of the problem. In the present case one base only is given in full, that shown by A B of Fig. 7. The other given base, the end of the large pipe, must be divided into as many equal arcs as there are branches required. On the above supposition that six are required, the sixth of the large circle can form only a part of the base of the larger end of a branch which must obviously also unite in part with the adjacent branches. In assuming any particular shape of outline as the remaining part of the required base the draftsman should be able to form a correct idea at the outset of what the result obtained therefrom will be; to see in his mind's eye, at least approximately, the shape of the resulting form in its entirety. This is an accomplishment that can scarcely be taught in books. It must be developed by exercise, by indulging the imagination, and by storing up a fund of knowledge which is the result of experience.

To maintain the rotundity therefore of the several branches at their junction with each other, a plan should first be drawn upon which the desired number of branches or prongs are shown, and each branch should be drawn with a taper approximately equal to that shown in its elevation. Fig. 11 gives the essential features of the parts. The plan of an additional prong is also shown in dotted lines, its axial line being placed at an angle of 60 degrees from that of the other (as when six prongs are required), from which it will be seen that the sides of the prongs intersect each other at a point E, which is outside the circle of the large pipe. If a line be erected from E of the plan to intersect any line in the elevation of the prong which may be supposed to represent its greatest width, as for instance the line 5 5, it will be seen that the joint line between the prongs in the elevation must pass through this intersection, F, and must therefore be a much fuller curve than that originally assumed by the quarter circle 1 6′ in the elevation, Fig. 7. If the prongs of the fork were perfect cones or cylinders in form their lines could then be prolonged to the miter plane and the joint line developed in the usual manner, but since the form is irregular the draftsman is thrown upon his general knowledge of intersections to draw or design such a line as will pass from 1 through F to the point J of the elevation, Fig. 11.

The problem of a fork having any number of prongs can also be solved by constituting each branch a section of a perfect cone and extending its sides to intersect as they may with the miter planes 1 6 of the plan, and also with the sides of the large pipe, which would result in producing a mitered end on the large pipe.

To make this more interesting it is shown how to obtain the miter on the end of a small pipe to fit down over the intersection of the four prongs, as shown at D, Fig. 7, as well as the shape of the part to be cut from the pattern of the prong to form, when all are put together, the round hole to fit the mitered end of the pipe D. The first step is to draw a perfect plan of the prong, which shall include at least one set of the lines used in the elevation for the purpose of triangulation, all as shown in Fig. 11. Extend the center line of the short pipe above A B to cut the center line of the plan, as shown at C. From C, as center, describe the plan of the pipe to correspond with that above A B in Fig. 7, and divide it into the same number of spaces, as shown by the small figures. The points on 1 6 of the elevation and 1 6 of the plan are made duplicates of corresponding lines of Fig. 7. Now connect points of corresponding number in the plan, as shown by 2 2, 3 3, etc., thus obtaining lines upon the plan which exactly correspond with the solid lines in the elevation of the prong.

Now from G of the plan, as center, describe the plan of the central pipe D, as shown at D, cutting the several lines in the plan of the prong, as shown at *a* *b* and *d*. From these points erect lines into the elevation to cut lines of corresponding number, as shown by the same letters in that view. Should additional points be required in the miter, as for instance, in the space *b* *d*, bisect the spaces 1 2 of the plan C, and also of the line 1 6 in the plan D′, as shown at *x* and *y*, respectively, and connect these points by the line crossing the plan D′ at *c*. Project points *x* and *y* into the elevation, as shown, draw *x y* of that view and erect a line from *c* of the plan to intersect line *x y* of the elevation, thus giving the additional point *c* in the elevation of the required miter.



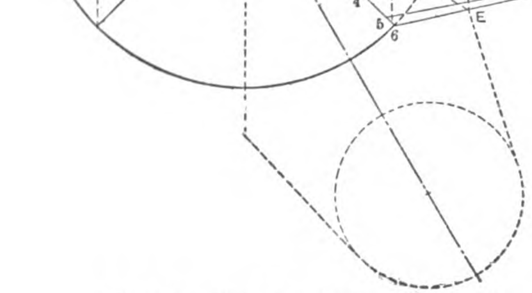


Fig. 11. Obtaining Pattern of Pipe D

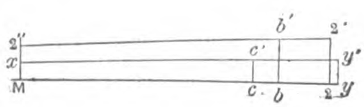


Fig. 12. Obtaining Points for Pattern, Fig. 13

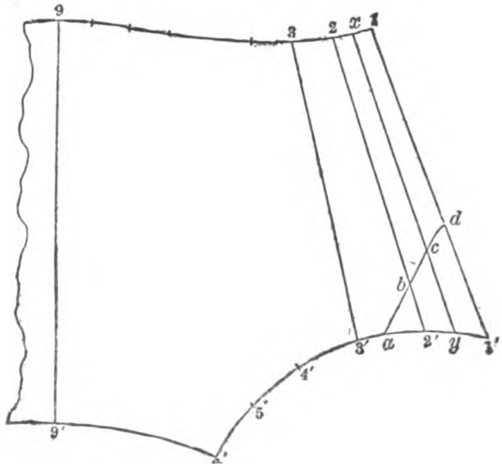


Fig. 13. Half Pattern of Prong, Showing Cut for Pipe D

The stretchout of the pipe D may now be taken from the several spaces between the points *a*, *b*, *c* and *d* on the plan D′ and set off on any line, as S T, drawn at right angles to the elevation, repeating the same as many times as is necessary to constitute the complete stretchout of the pipe, remembering that since the spaces in

D′ are unequal it will be necessary to reverse their order in each alternate group, all as shown on S T, which is sufficient for a half pattern. Lines from the points *a*, *b*, *c*, *d* of the elevation may now be projected into the measuring lines of the stretchout, all as shown by dotted lines, thus developing the required pattern of D, one-half of which is shown by S, N, O, Q, R, T.

To obtain the pattern of the hole or in other words, the shape of the portion to be cut from the pattern of the prong, so that it shall meet the mitered end of pipe D, it will be necessary to set off the distances *y c* and 2 *b* of the plan Fig. 11, upon the base line of the diagram H, of Fig. 7, from which the true lengths of the solid lines of the elevation were obtained. Since, however, only one of the lines of this diagram is used, while an additional line, *x y*, has been introduced into the elevation, this operation is shown separately in Fig. 12, in which points 2″ and 2 and lines connecting them are duplicates of corresponding parts of diagram H of Fig. 7. In Fig. 12 M 2″ and M *y* are respectively equal to 2 2 and *x y* of the elevation, Fig. 11. Now from *y* of Fig. 12 set off on *y* M the distance *y c*, equal to *y c* of the elevation, Fig. 11; and from 2″ on 2″ M the distance 2″ *b*′, equal to 2 *b* of the elevation. At *y* erect a line *y y*′, equal to *y y*′ of the plan, Fig. 11, and at M make M *x* equal to *x x*′ of the plan. Draw *y*′ *x* of Fig. 12, and from *c* erect a line cutting the same at *c*′; then from *y* of the pattern, Fig. 13, set off on *y x* the distance *y*′ *c*′ of Fig. 12, and also make 2′ *b* of the pattern equal to 2′ *b*′ of Fig. 12.

The distance 1′ *d* of the pattern is of course equal to 1 *d* of the elevation, while the position of the point *a* of the pattern is obtained by first projecting the point *a* of the elevation to the profile of the joint line 1 6′ at the left, as shown thereon at *a*′, when its distance from either adjacent point may be set off from the corresponding point on the line 1′ 6′ of the pattern. A line traced through the points *a*, *b*, *c* and *d* of the pattern will show the shape of the piece (*a d* 1′) to be cut from the pattern to insure a miter with the pattern of the pipe D. The position of point *y* upon the pattern is obtained by a projection to the the left from *y* of the elevation to line 1 6′, as shown at *y*′, etc., all as explained in regard to point *a*, while the position of *x* must be obtained by measurement from an adjacent point on a true section on A B, if such section is developed or on the miter pattern of the connecting piece, as explained above. Its position on the plan C of Fig. 11 is, however, sufficiently accurate to serve the present purpose.

An inspection of the pattern of the pipe D, as shown in Fig. 11, will now show that its shape corroborates the statement above made with reference to the triangular shape of the large end of the prong, as shown in Figs. 9 add 10. Since the prong is nearly round at A B of Figs. 7, 10 and 11, and quite angular at point 1, its shape at *d* of Figs. 10 and 11, which is about one-third of the way up from point 1, can easily be conceived to be that shown at P of the pattern in Fig. 11.

SQUARE TO ROUND TWISTED ELBOW PATTERNS

In this solution it is well to state that the principles as here outlined are applicable to any number of pieces and for this example a four-piece elbow was taken. This is a 90-deg. elbow twisting from square to round as shown by the perspective Fig. 14.

In Fig. 15 let I II III IV represent the side elevation of the four-piece twisted elbow with an angle of 90 deg. as shown, the miter or joint lines *a b*, *c d* and *e f* being drawn toward the center H°. The two end pieces of the patterns will be developed by parallel lines and the two middle pieces by triangulation.

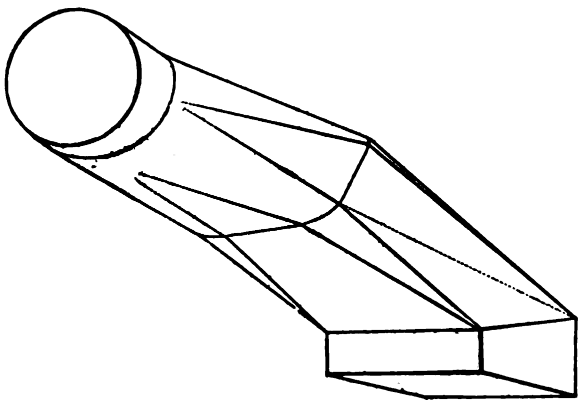


Fig. 14. Model of the Completed Twisted Elbow

In this case assume that the miter lines *a b*, *c d* and *e f* remain fixed lines, representing the miter planes when the elbow is viewed from the side. From these planes the miter lines shown in the front elevation are then projected. By using this method of establishing straight lines in the side elevation as the miter planes considerable time is saved when developing the patterns, because no true angles need be found, and the various operations in projections needed in connection with the true angles can be dispensed with.

Having drawn the side elevation of the elbow, bisect the miter lines 1 5, 6 11 and 12 13 and obtain the points 3, B and C respectively. Through these points draw the center line of the elbow shown by the heavy dotted line from A to D. Extend the line 3 A indefinitely to the left, upon which establish the point A^3 representing the center of the round pipe. Using A 1 or A 5 in the side elevation as radius and A^3 as center, draw the circle 1 3 5 3′ representing the front view of the upper piece of the elbow marked I in the side elevation, when it is twisted and turned toward the reader.

From the center A^3 draw a vertical line until it intersects the line D H° extended from the side elevation at J. At pleasure establish the distance J D° in the front elevation, which in this case has been made equal to J A^3. As the elbow has two pieces between the top and bottom pieces, as shown in the side ele-

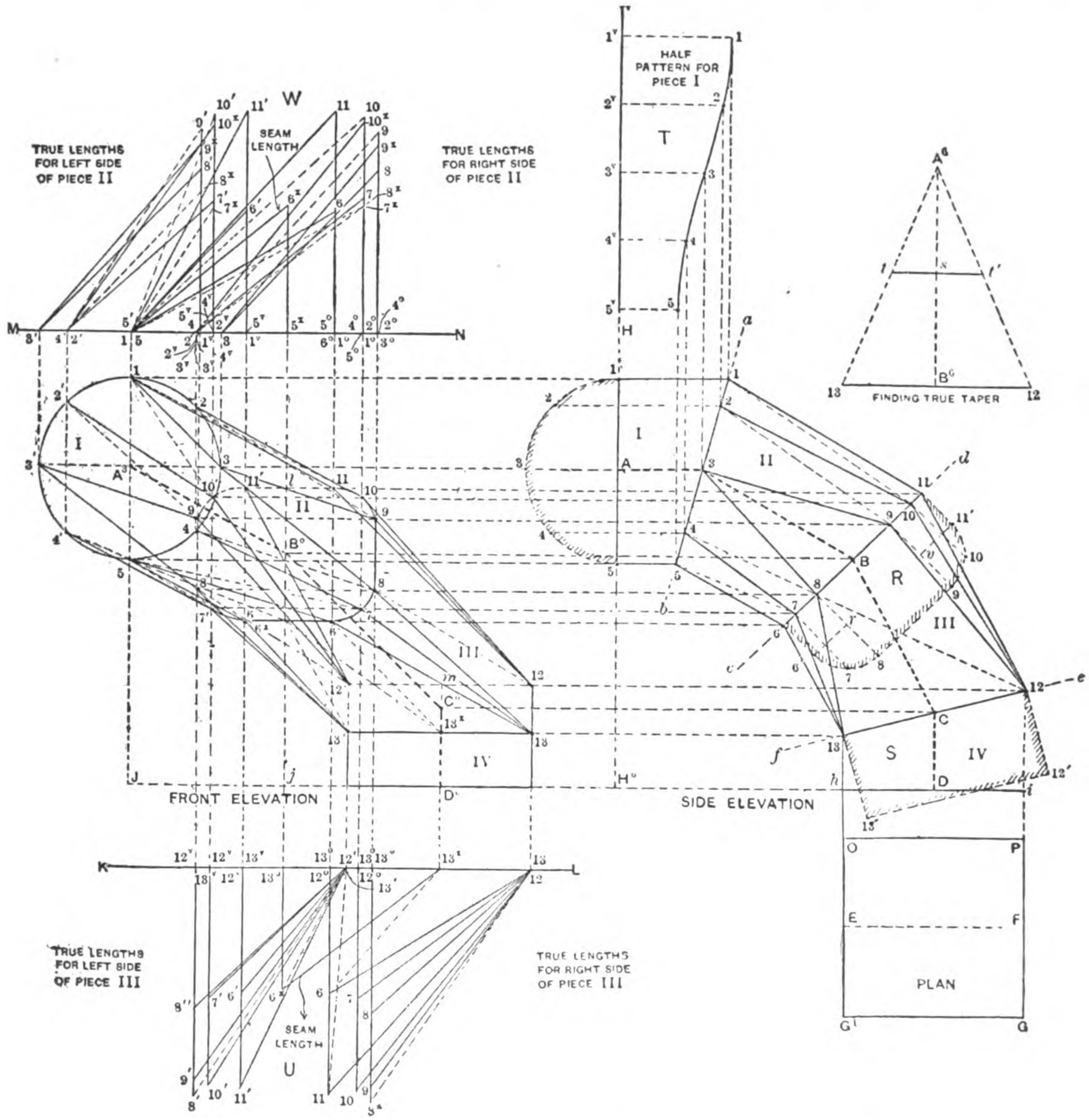


Fig. 15. Elevations, Plan, Diagram of Triangles, Pattern and True Taper

vation, divide the space between J and D° in the front elevation in two parts as shown by *j*, and from *j* and D° erect vertical lines until they intersect horizontal lines drawn from B and C in the side elevation at B° and C° respectively in the front elevation. Trace the heavy dotted line as shown from A^3 to B° to C° to

D° which represents the center line of the elbow in the front elevation shown by similar letters. A 3 B C and D in the side elevation.

Whatever number of pieces are contained in the elbow between the top and bottom pieces in the side elevation, that number should be divided between J and D° in the front elevation, so as to establish the center line of the elbow in that view. Thus if a six-pieced elbow is used, the space between J and D° would be divided in four parts, which is the number of spaces contained between the top and bottom pieces.

With A in the side elevation as center, and A 1 as radius draw the semicircle shown, which divide into an equal number of spaces, in this case four as shown from 1 to 5. In similar manner divide the circle I in the front elevation in similar number of spaces as shown from 1 to 3 to 5 to 3′ to 1. This semisection 1 3 5 in the side elevation represents the half profile for piece I of the elbow. Below the line *h i* of piece number IV draw the section of the square pipe as shown by O P G G^1, which represents the profile for piece IV.

As the pieces I and IV will be developed by parallel lines, these two patterns will be laid out first. Extend the line 5 1 as shown by H I, upon which place the girth of the semi-section of the round pipe, as shown by the small figures 1^v to 5^v. At right angles to H I through the small figures draw lines, which intersect by lines drawn parallel to H I from similar numbered intersections on the miter line *a b*, which were previously obtained by drawing lines at right angles to 1 5 from the small figures in the semicircle. A line is traced through points thus obtained as shown by the small figures 1 to 5 in T. Then will 1^v 1 5 5^v be the half pattern for piece number I.

For the half pattern for piece number IV, take the girth of the half-square section F P O E, and place it upon the horizontal line A^2 B^2, as shown by F° P° O° E°, and through these points erect perpendicular lines to A^2 B^2 as shown. Measuring from the line *h i* in the side elevation, take the hights to points 12 and 13 on the miter line *f e* and place them in the pattern on corresponding lines measuring in each instance from the line A^2 B^2, obtaining the points 12, 12′, 13′, 13 respectively. Trace a line through points thus obtained. Then will E°, 13, 12, F° be the half pattern desired.

The next step is to obtain the true sections on the miter lines *e f* and *c d*. No true section need be found on the miter line *a b* because the piece I lies in a horizontal line, so that when the miter line *a b* is viewed from the front it will show a true circle as indicated by I in the front elevation. If, however, the piece I in the side elevation were other than in a horizontal position, the front view of the miter would show an elliptical shape and would be obtained in a manner similar to that which will be explained in connection with obtaining the front view of the miter line 6 11 in the side elevation.

As the elbow runs from square to round, a proportional taper must be found between the square end of piece IV and the round end of piece I. This taper from the square end to the round end is shown by 3, 9, 12, 13, 8, 3 in the side elevation and is found as follows: Draw a vertical line of any length as A^6 B^6, at right angles to which draw the line 12 13, making B^6 12 and B^6 13 equal to the miter lines C 12 and C 13 respectively. From 12 and 13 in the true taper, draw lines to the apex A^6. The elbow having two middle pieces, divide the line A^6 B^6 in two parts as shown by *s*, through which draw the horizontal line cutting the sides of the triangle at *t* and *t′*. Then *s t* or *s t′* is placed from B to 8 and B to 9 in the side elevation and lines drawn from 3 to 9 to 12 and from 3 to 8 to 13.

As the pipe is a true square at one end, this same taper applies to the top and bottom of the elbow as well as the sides. This taper along the bottom and top of the elbow is shown in the front elevation and is projected to that view as will be described. The true taper being known the true section on the miter line *c d* is found as follows: At right angles to *c d* from points 6, 8, 9 and 11 erect perpendicular lines, making the distances 6 6′ and 11 11′ equal to *s t* in the true taper and the distances 8 8 and 9 9 in the side elevation equal to the full width *t t′* in the true taper. From 6′ and 11′ in the side elevation, parallel to *c d*, draw lines intersecting the lines 8 8 and 9 9 at *r* and *v* respectively. Using *r* and *v* as centers, with a radius equal to *r* 6′, or *v* 11′, draw the quarter circles shown by 6′, 8 and 11′, 9 respectively. Then will 6, 6′, 8, 9, 11′, 11 be the half true section on the miter line *c d*.

To find the true section on the miter line *f e*, draw lines from points 12 and 13 at right angles to *f e*, as shown by 12, 12′ and 13, 13′ both equal to the half width of the square pipe shown by O E or P F in plan. Draw a line from 12′ to 13′. Then will 12, 13, 13′, 12′ be the half true section on the miter line *f e*.

As the quarter section A 1 3 of piece I is divided into two equal spaces, divide the quarter circles in the half section on *c d*, also each into two parts as shown by points 7 and 10, from which points at right angles to *c d* draw lines intersecting the miter line *c d* at 7 and 10 respectively. Connect the various points on the miter lines *a b*, *c d* and *e f* as follows: Draw lines from 4 to 7 to 13; from 3 to 8 to 13; from 3 to 9 to 12; from 2 to 10 to 12; also dotted lines from 5 to 7, 4 to 8, 2 to 9 and 1 to 10. These lines represent the bases of the triangles which will be constructed later on.

The next step is to draw a correct view of the front elevation, showing the true position of the miter lines *c d* and *e f* in the side elevation. Therefore, from points 12 and 13 on the joint line *f e* in the side elevation draw horizontal lines in the front elevation, indefinitely as shown. Extend the center line D° C° in the front elevation as shown by D° *m*. Measuring from this line *m* D°, set off the distances *m* 12, *m* 12′, 13^x 13 and 13^x 13′ equal to the half width of the square pipe shown by D *h* or D *i* in the side elevation. Draw lines from 12 to 13 to 13′ to 12′ to 12, which represents the front view of the miter line 12 13 in the side elevation.

In a similar manner from points 7, 8, 9 and 10, on the miter line *c d* in the side elevation draw horizontal lines to the front elevation indefinitely as shown, and through the intersection B° extend the line *j* B° as B° *l*. Measuring from the line *c d* in the side elevation, take the various distances to points 6′, 7, 8, 9, 10 and 11′ and place them in the front elevation on similar lines previously drawn, on either side of the center line *l* 6^x, thus obtaining the points of intersections from 6 to 11 on the right and from 6′ to 11′ on the left. A line traced through these points as shown will be the miter line in the front elevation on the line 6 11 in the side. Connect the various points in the front elevation as follows: 6, 7 and 8 to 13; 9, 10 and 11 to 12; 6′, 7′ and 8′ to 13′ and 9′, 10′ and 11′ to 12′, which is similar to the connections shown in piece III in the side elevation. Connect the various points in piece II in the front elevation by drawing solid lines from 1 to 11, 2 to 10, 3 to 9, 3 to 8, 4 to 7, 5 to 6; 5 to 6′, 4′ to 7′, 3′ to 8′; 3′ to 9′, 3′ to 10′ and 1 to 11′. Also draw dotted lines from 1 to 10, 2 to 9; 4 to 8, 5 to 7; 5 to 7′, 4′ to 8′; 2′ to 9′ and 1 to 10′, which represent similar connections shown in piece II in the side elevation.

As the seam will be placed in the throat of the elbow, bisect 6 6′ and 13 13′ in the front elevation as shown respectively by 6^x and 13^x and draw the seam line 5 to 6^x to 13^x as shown. The horizontal distances between the various points shown in the miter lines in the front elevation represent the altitudes of triangles, which must now be constructed as follows: Through the various intersections in the lower and center miter lines in the front elevation, drop vertical lines indefinitely as shown. In a similar manner through the various intersections in the center miter line, as well as through the points in the profile of the upper arm, erect vertical lines indefinitely, as also shown. At pleasure, below the front elevation, draw a horizontal line as K L, and in a similar manner above the front elevation draw another horizontal line as M N. To find the true lengths of the lines shown in piece III in both front and side elevation take the various distances from 13 to 6, 13 to 7 and 13 to 8 in the side elevation and place them on lines dropped from points 6, 7, 8, 6′, 7′ and 8′ in the miter line in the front elevation, measuring in each instance from and below the line K L, as shown respectively from 13° to 6, 13° to 7, 13° to 8, also from 13^{v} to 8″, 13^{v} to 7′ and 13^{v} to 6′. At right angles to K L from points 13 and 13′ in the miter line, drop lines intersecting the line K L at 13 and 13′ respectively, and from the point 13 just obtained in diagram U, draw lines to 6, 7 and 8, and from 13′ draw lines to 6′, 7′ and 8″. These lines represent the true lengths of lines shown by similar numbers in piece III in the side or front elevation.

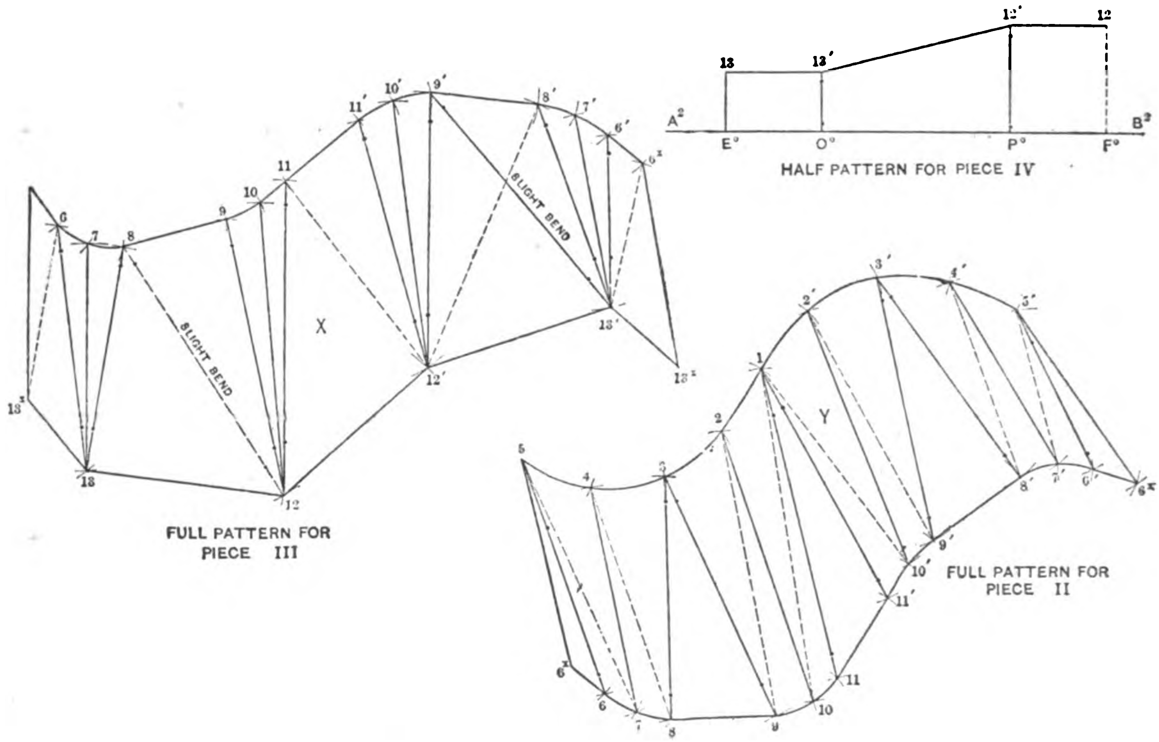


Fig. 16. Patterns for the Various Parts

In a similar manner take the various distances in piece III in the side elevation, from 12 to 9, 12 to 10 and 12 to 11, and place them on lines dropped from 9, 10 and 11, also from 9′, 10′ and 11′ in the miter line in the front elevation, measuring in each instance below the line K L, as shown respectively from 12° to 9, 12° to 10 and 12° to 11, also from 12^{v} to 9′, 12^{v} to 10′ and 12^{v} to 11′, and draw the slant lines from 9, 10 and 11 to point 12, and from points 9′, 10′ and 11′ to point 12′, both points 12 and 12′ being upon the line K L, having been previously obtained by lines dropped from points 12 and 12′ respectively in the miter line in the front elevation. These slant lines just drawn in diagram U then represent the true lengths of similar numbered lines shown in piece III in the front or side elevation. Further procedure would be to find the true length of the dotted line shown from 8 to 12 in piece III in the side elevation, accordingly the distance from 8 to 12 is taken and setting it off on lines dropped from 8 and 8′ in the miter line in the front elevation, as shown respectively from 12° to 8^{a} and from 12^{v} to 8′ and draw lines from 8′ to 12′ and from 8^{a} to 12, which represents the true length of similar numbered lines shown from 8′ to 12′ and 8 to 12 in the front elevaion.

Before the patterns for the flat surface 11, 11′, 12′, 12 in piece III in the front elevation can be obtained, the true length on the dotted line drawn from 11 to 12′ must first be ascertained, by taking the distance from 11 to 12 in the side elevation and placing it as shown from 12° to 11 in diagram U and drawing a line from 11 to 12′. This slant line then shows the true length of the line 11, 12′ in the front elevation.

And, in a similar manner before the pattern for the flat surface 6′, 6, 13, 13′ shown in piece III in the front elevation can be obtained, the true lengths of the seam line 6^{x}, 13^{x}, and lines drawn from 6 to $13^{x\prime}$, and 6 to 13^{x} must first be ascertained as follows: Take the distance from 6 to 13 in the side elevation and place it in diagram U, as shown, respectively, from 13^{a} to 6^{x}, 13^{v} to 6′ and 13° to 6, and draw slant lines from 6^{x} to 13^{x}, 6′ to 13′ and 6 to 13^{x}, representing, respectively, the true lengths of lines shown by similar numbers in piece III in the front elevation.

Possessing all the necessary data by the methods explained in the foregoing, the operation now is to obtain the true lengths of the various lines shown in piece II in the side elevation. From the various intersections 1, 2, 3, 4, 5, 4′, 3′, 2′ in the circle shown in the front elevation, lines are erected until they intersect the line M N as shown by similar figures. Take next the various distances of 5 6, 4 7 and 3 8 in the side elevation and place them upon lines drawn from points 6, 7 and 8, also points 6′, 7′ and 8′ in the miter line in the front elevation, measuring from the line M N in diagram W, as shown, respectively, from 5° to 6, 4° to 7 and 3° to 8, also from 5^{v} to 6′, 4^{v} to 7′ and 3^{v} to 8′ and draw slant lines from 6 to 5, 7 to 4 and 8 to 3, also from 6′ to 5, 7′ to 4′ and 8′ to 3′. These lines represent the true lengths of lines having similar numbers in piece II in the elevations.

Again take the distances of 3 9, 2 10 and 1 11 in piece II in the side elevation, and place them, measuring from the line M N, upon lines drawn from points 9, 10 and 11, also 9′, 10′ and 11′ in the miter line in the front elevation as shown, respectively, by the distances from 3° to 9^x, 2° to 10^x and 1° to 11, also from 3^v to 9^x, 2^v to 10^x and 1^v to 11′, and draw slant lines from 9^x to 3, 10^x to 2 and 11 to 1, also from 9^x to 3′, 10^x to 2′ and 11′ to 1, which show the true lengths of similar numbered lines in piece II. Having carefully followed the aforesaid instruction, watching particularly the secondary indices, finally take the length of the dotted lines in the side elevation, from 5 to 7, 4 to 8, 2 to 9 and 1 to 10 and place them, measuring from the line M N, upon lines drawn from points 7, 8, 9 and 10, also points 7′, 8′, 9′ and 10′ in the miter line in the front elevation, as shown by the distances 5° to 7^x, 4° to 8^x, 2° to 9 and 1° to 10, also from 5^v to 7^x, 4^v to 8^x, 2^v to 9′ and 1^v to 10′, and draw slant lines from 7^x to 5, 8^x to 4, 9 to 2 and 10 to 1, also from 7^x to 5′, 8^x to 4′, 9′ to 2′ and 10′ to 1, which lines show the true distance of similar numbered lines in the front or side elevation.

As the seam line is shown by 5 6^x in piece II in the front elevation, to find this true length take the distance of 5 6 in the side elevation and place it on the line erected from 6^x in the front elevation, as shown in diagram W, from 5^x to 6^x and draw a slant line from 6^x to 5, which is the true length desired. All of the true lengths having been found, the patterns are now in order. To develop the pattern for piece II proceed as follows: Take the distance of 5 6^x in diagram W and place it upon the line drawn in Y as shown by 5 6^x. With 6 6′ in the semi-section R in the side elevation as radius and 6^x in Y as center, draw the arc 6, which intersect by an arc struck from 5 as center and 5 6 in W as radius. Again with 6′ 7 in the semi-section R in the side elevation as radius and 6 in Y as center, describe the arc 7, which intersect by an arc struck from 5 as center and 5 7^x in the diagram W as radius. Now using the division 5 4 in the miter cut in the half pattern T as radius and 5 in the pattern Y as center, draw the arc 4, which intersect by an arc struck from 7 as center and 7 4 in diagram W as radius.

Proceed in this manner, using alternately, first the divisions in the semi-profile R in the side elevation, then the proper true length in diagram W; the divisions along the miter cut in T, then the proper length slant line in W until the line 1 11 in pattern Y has been obtained. Then with a radius equal to twice the distance of 11 11′ in the semi-section R in the side elevation, and 11 in pattern Y as center, describe the arc 11′ and draw a line from 11′ to 1. Now again proceed as before, using alternately, first the divisions of the proper number in the semi-section R, then the proper true length in the diagram W; the proper division along the miter cut in T, then the proper true length in W, until the line 5′

6′ in pattern Y has been obtained. Then using 6 6′ in the semi-section R as radius, and 6′ in the pattern Y as center, describe the arc 6^x, which intersect by an arc struck from 5′ as center and 5 6^x in W as radius. A line traced through points thus obtained in the pattern Y, as shown from 5 to 1 to 5′ to 6^x to 11′ to 11 to 6^x to 5, will be the pattern for piece II of the elbow, to which edges must be allowed for seaming purpose.

For the pattern for piece number III, Fig. 16, draw any line as 6^x 13^x in X equal in length to the seam length 6^x 13^x in diagram U. In this case, instead of using the divisions in the semi-sections R in the side elevation as radius, use the divisions along the lower cut 6^x to 6^x of the pattern Y, which were previously taken from R, and therefore are the same. Then with 6^x 6 in Y as radius and 6^x in X as center, draw the arc 6, which intersect by an arc struck from 13^x as center and 13^x 6 in diagram U as radius. With 13 13′ in the semi-section S or 13 13′ in the half pattern for piece IV as radius and 13^x in the pattern X as center, describe the arc 13, which intersect by an arc struck from 6 as center, and 6 13 in diagram U as radius. With radii equal to 13 7 and 13 8 in diagram U, and 13 in the pattern X as center, describe the arcs 7 and 8. Set the dividers equal to the spaces 6 7 and 7 8 in Y and step from arc 6 to arc 7 to arc 8 in X. Now with 13′ 12′ in either the semi-section S or the half pattern for piece IV as radius, and 13 in the pattern X as center, describe the arc 12, which intersect by an arc struck from 8 as center and 8^a 12 in diagram U as radius.

Proceed in this manner, using alternately, first the divisions along the lower cut of pattern Y, then the proper slant line in diagram U, until the line 11 12 in pattern X has been drawn. Then take as a radius, twice the distance of 12 12′ in diagram S in the side elevation, or the distance of P G in the plan, which is the same and with 12 in X as center describe the arc 12′, which intersect by an arc struck from 11 as center and 11 12′ in diagram U as radius. Now proceed as before, using alternately, first the divisions in the lower cut of the pattern Y, then the proper slant line in diagram U; the divisions in the semi-section S or the half pattern for piece IV, both divisions being similar, then again the proper slant line in diagram U, until the line 6^x 13^x in the pattern X has been obtained, which must be similar to the seam line on the opposite end of the pattern.

A line traced through points thus obtained as shown from 6^x to 6 to 11 to 11 to 6′ to 6^x to 13^x to 13′ to 12′ to 12 to 13 to 13^x to 6^x, will be the pattern for piece III, Fig. 16, of the twisted elbow. Laps must be allowed on the pattern for seaming purposes. In forming up pattern for piece III, Fig. 16, slight bends must be made along 8 12 and 9′ 13′ as indicated on the pattern.

PATTERNS FOR TRANSITION PIECE INTERSECTING CONE

The following instructions are for the proper method of laying out the patterns for a separator involving its intersection by a transition piece, changing from round to a rhomboid, the sides of which run parallel to the top and sides of the main funnel or cone.

Referring to the accompanying diagrams, Fig. 17, let A B represent the center line of the funnel or cone and C D E F the elevation. At a point below the elevation in its proper relative position with G on the center line as center, draw the plan H J and L M, representing respectively the sections through C D and E F of the elevation. In its proper position draw the rhomboid shown in elevation by 1 2 4 5. This represents the elevation of the transition piece where it intersects the cone. Draw also the circle *a c e g* in its proper position, which represents a section of the transition piece at the outer end indicated by *c g* in plan.

The first step is to find the miter line showing the line of intersection between the rhomboid and funnel in plan. To do this draw horizontal planes through 1 2 and 4 5 in elevation; also establish another plane between 1 and 5, as shown by 3 6.

In practice, more planes must be employed to obtain an accurate pattern, but only three planes are used in this case, to show the principles employed.

Extend the planes 2 1, 3 6 and 4 5 until they intersect the side of the cone C F at 1′ 2′, 3′ 6′ and 4′ 5′, from which intersections vertical lines are drawn to the plan intersecting the horizontal line *i j* drawn through the center, G in plan, as shown by similar numbers. Then using G as center, with radii equal to G1′, 3′ and 4′, draw the circles shown, which represent the various planes in plan. Now from the intersections 1, 2, 3, 4, 5 and 6 in the rhomboid in elevation, drop perpendicular lines in the plan, intersecting similar numbered planes, as shown by similar numbers, through which trace the miter line as shown. Establish at its proper distance from the center line *i j*, the line *c g*, upon which obtain the intersections, *c*, *g*, *c*, *d*, *b a e*, *h f* and *g*, by dropping perpendiculars from similar lettered intersections in the circle in elevation, all as shown by the dotted lines.

Now connect the various points in the rhomboid and circle both in plan and elevation as follows: Connect 1 and 2 to *a*; 5 and 4 to *e*; 5, 6 and 1 to C; 4, 3 and 2 to *g*; *h* to 2; *f* to 4; *b* to 1, and *d* to 5.

Then will the lines in plan represent the base lines of triangles which will be constructed in X, with altitudes equal to the various hights between similar numbers and letters in elevation. As 1, 2 and *a* in elevation lie in one plane. then will 1, 2 and *a* in plan show the true pattern for that part. As *e* in elevation lies above the plane 5 4, establish another point between 5 and 4 as shown by 7, and drop a perpendicular line in plan, intersecting the plane 4′ 5′ in plan at 7. Connect

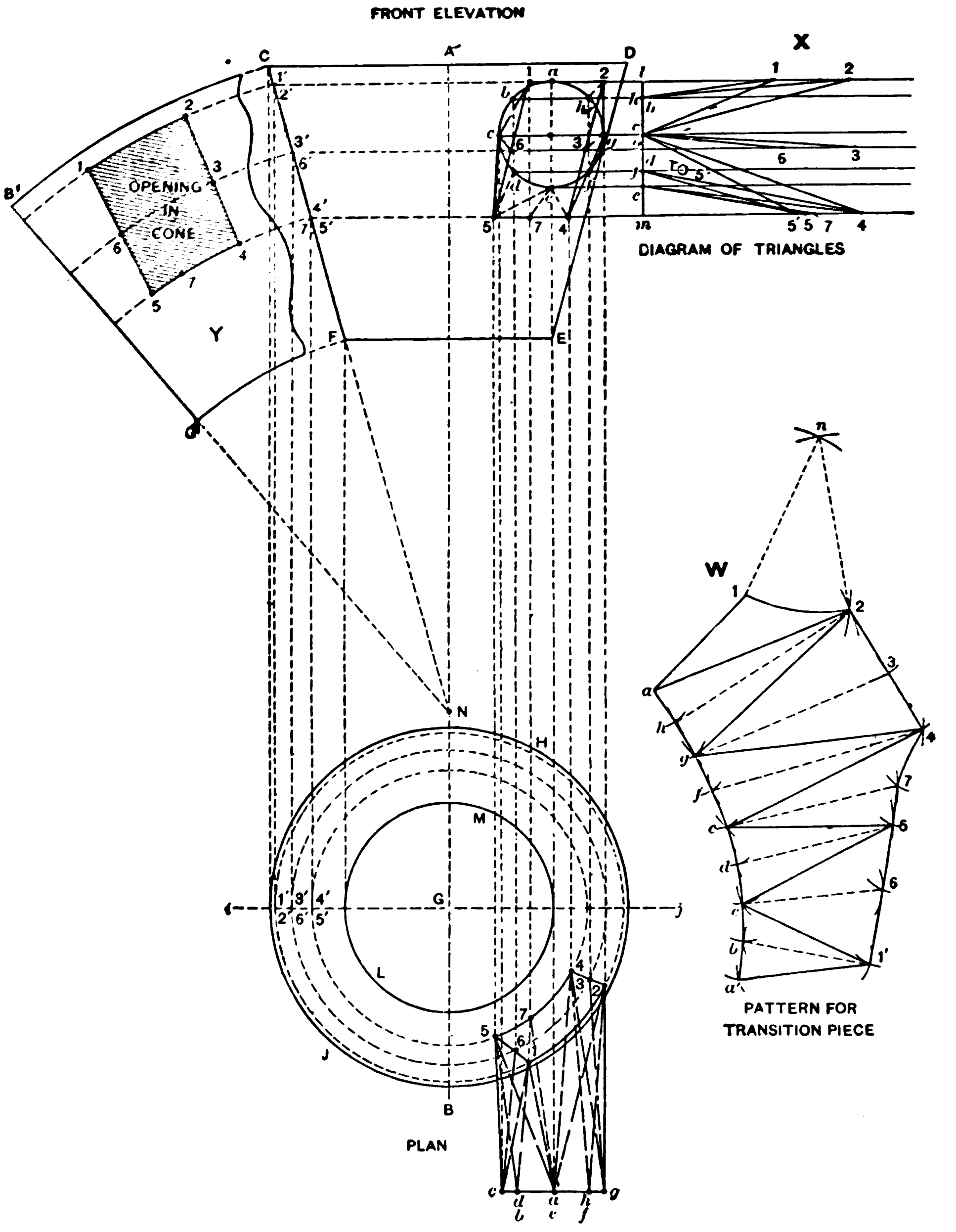


Fig. 17. Complete Process for Obtaining Patterns of Transition Piece Intersecting a Cone

the point 7 to *e*, both in plan and elevation. From the various points in the circle and rhomboid in elevation, draw horizontal lines to the right as shown, perpendicular to which draw the line *l m*.

To obtain the various true lengths of the lines shown in plan, three examples will be given. Thus, to obtain the true lengths of the lines *e* 5 and *e* 4 in elevation, take the distances of *e* 5 and *e* 4 in plan and place them in X, measuring from the line *l m*, as shown by 5 and 4 on the line drawn through 5 7 4 in elevation. From 5 and 4 in X draw lines to where the horizontal line drawn from *e* in elevation intersects the line *l m* at *e*. Then will *e* 4 and *e* 5 in X represent the true length of *e* 4 and *e* 5 in plan or elevation.

Again to obtain the true length of 5 *d* in plan or elevation, take the length of 5 *d* in plan and place it as shown from *m* to 5′ in X, and draw a line from 5′ to *d*, on the line *l m*, being the intersection where the horizontal line drawn through *d* in elevation intersects *l m*. Then will *d* 5′ be the true length of *d* 5 in plan or elevation. In this manner all of the true lengths are obtained.

Before laying out the pattern for the transition piece, the opening in the funnel or cone is first developed as follows: Extend C F of the cone until it intersects the center line A B at N. Then using N as center and radii equal to N C, N 1′, N 3′, N 4′ and N F, draw arcs as shown. At pleasure draw any radial line as B^1 G^1 N. Now measuring from the line B G in plan, step off along the arcs to points 1 6 and 5, and place these distances along similar arcs in the pattern Y, measuring in each instance from the line B^1 G^1, thus obtaining the points 5 6 and 1 in the pattern.

Again measuring from the line B G in plan, step off along the various arcs to points 2, 3, 4 and 7 and place them in Y, stepping off on similar numbered arcs, measuring in each instance from the line B^1 G^1, and obtaining points 2, 3, 4 and 7. Trace a line through points thus obtained, shown shaded, which will be the opening to be cut into the cone pattern, and also furnishes part of the measurements used when developing the transition pattern.

For the pattern for the transition piece proceed as follows: Draw any line *a* 1 in W equal to *a* 1 in plan. With *a* 2 in plan as radius, and *a* in W as center, draw the arc 2, which intersect by an arc struck from 1 as center and 1 2 in plan as radius. Using G 1 or G 2 in plan as radius and 1 and 2 in W as centers, draw arcs intersecting each other in *n*, which use as a center, and with similar radius, describe the arc 1 2.

Thus it will be seen that 1 2 *a* in W is simply a reproduction of 1 2 *a* in plan, because 1 2 *a* lies in the same horizontal plane in elevation, and that the curve 1 2 in W will equal the curve 1 2 in Y. With *a h* in the circle in elevation as radius, and *a* in W as center, draw the arc *h*, which intersect by an arc, struck from 2 as center, with radius equal to 2 *h* in X as radius. Again using *h g* in the circle in elevation as radius, and *h* in W as center, describe the arc *g*, which intersect by an arc, struck from 2 as center and 2 *g* in X as radius. Now with 2 3 in the opening in cone Y as radius, and 2 in W as center, draw the arc 3, which intersect by an arc struck from *g* as center and *g* 3 in X as radius. Again using 3 4 in Y as radius and 3 in W as center, describe the arc 4, which intersect by an arc struck from *g* as center and *g* 4 in X as radius.

Proceed in this manner, using alternately, first the divisions in the circle in elevation, then the true lengths in X. The divisions in the pattern for opening in Y, then again the proper true length in X, until the last line, *a'* 1' in W has been obtained, similar to *a* 1. Thus the divisions in the pattern for the transition piece, which are numbered, are obtained from the spaces in Y; while the divisions in W, which are lettered, are obtained from the spaces in the circle in elevation, while the true lengths in W are obtained from similar numbered and lettered lengths in X.

A line traced through points of intersections thus obtained in W, will be the pattern for the transition piece, joining the opening in cone Y.

INTERSECTION OF HOPPER AND A PIECED ELBOW

This problem is: Given a flaring article, the base of which is elliptical and the top round, intersecting a pieced elbow. Required to find the line of intersection and the patterns, the dimensions are: A three-pieced elbow 36 inches in diameter, the throat of which was struck by an 18-inch radius, while the lower side of the elbow is intersected by a hopper, the top of which is an ellipse 24×42 inches and the base a circle 22 inches in diameter. The hight of the hopper is to be 30 inches, measuring from the lowest point of the elbow. In this case the hopper is seen to cross one miter line of the elbow. Whether the number of miter lines crossed be more than that shown, the principles governing the developments remain the same.

First draw the plan of the three-pieced elbow in the usual manner, as shown in Fig. 18 by A B C D E F G H. At right angles to B C construct a part elevation of the elbow, as shown by P R R' P', letting P R represent the top line of the elbow. In the required position in the plan draw the elliptical base of the hopper, 1 3 5 7, which represents a true section on the plane P R in elevation. Also, in the plan draw the circle 1' 3' 5' 7', which represents the circular base, or end, of the hopper on a plane parallel to P R in elevation. As 1 1' in plan lies at right angles to B C, extend the line 1 1' into the elevation, and measuring from the line P R, make T X the required hight of the hopper, and from X draw a line parallel to P R. Through the center of the plan of the elbow draw the dotted line I J, which represents the highest point in the rounded surface of the elbow. Tangent to the ellipse and circle draw the line 6 6′, extending it until it intersects 1 1′ at *b*. Divide the ellipse from 1 to 6 into any desired number of spaces, as shown by 2, 3, 4 and 5, from which points draw lines to the apex *b*, intersecting the opposite half of the ellipse at 7, 8, 9 and 10 and the circle at 1′, 2′, 3′, 4′, 5′, 6′, 7′, 8′, 9′ and 10′. Then will these lines represent the planes of the various sections, which will be constructed to determine how far in each the hopper will be extended beyond the elliptical base before cutting into the elbow, all of which is necessary before any pattern can be developed. Now, from the various points 1 to 10 on the ellipse in plan erect lines at right angles to B C into the elevation, intersecting the line P R, respectively, from 1 to 10. In similar manner from the various points of intersections 1′ to 10′ in the circle in plan erect lines at right angles to B C, intersecting the line X 5′ in elevation, as shown from 1′ to 10′.

Parallel to E D in plan draw the line L M, and with K on the center line I J extended, as center, describe the part section of the elbow, as shown by N, *a*′, O, being careful to have *a*′ of the circle tangent to L M. The line L M will therefore correspond with P R of the elevation, both lines representing the plane of the elliptical base in their respective views. Now, to obtain the sections on the various planes indicated in plan proceed as follows: Extend the line 1′ 1 in plan until it intersects the center line I J of the elbow at *a*. From the intersections *a* and 1 draw lines parallel to B C, until they intersect the miter line F C, from which drop vertical lines on to the section N O, as shown by *a*′ and 1″. Now, take the spaces between points *a*, 1 and 1′ in plan and set them off on a horizontal line in the diagram S, as shown by *a* 1 1′. From 1′ erect the perpendicular 1′ X, equal to the hight T X in elevation. From 1 in S draw the perpendicular line 1 1″, equal to the distance measured from the line L M to 1″ in section. As the plane *a* 1′ in plan lies at right angles to B C, draw from *a* in S the perpendicular *a* K, equal to the radius K *m*′ in section. Then using K as center and K *a* as radius, describe the arc *a b*, which will pass through 1″, as shown. Now, draw a line from X through 1 until it intersects the curve *a b* at 1°. As the line *a* 1′ in S is tangent to the highest point of the elbow, corresponding with P R of the elevation, the plane of the ellipse, then will the distance from 1 to 1° show the amount that the line 1′ 1 in plan and elevation must be extended to meet the surface of the elbow in that section. To obtain this point of intersection in plan take the horizontal distance between points 1 and 1° in S and set it off from 1 on the line 1′ 1 in plan, thus obtaining the point 1°. To obtain this point in elevation take the vertical distance between the points 1 and 1° in S, and measuring from and perpendicular to the line P R in elevation, set it off on the line 1′ 1 extended, thus obtaining the point of intersection 1°.

Since the method of constructing the sections on the several plane lines before mentioned is exactly the same in each case (the difference in result being due entirely to difference in the relative positions of the several points) it will not be necessary to describe each in detail. The method of obtaining the section on the line 2 10′ of the plan is clearly shown at V, at the left in Fig. 18, while that on the line 3 9′ is shown above at U, and need not be described inasmuch as a full description of the method of obtaining the section on the line 4 8′ is considered necessary. The reason for this is that the line 4 8′ crosses the miter line F C of the pieced elbow, and in that respect possesses a feature not a part of the sections previously obtained. The section on this line should be first completed as though no miter line existed and it was intersecting the piece B C F G extended.

Therefore extend the plane 8′ 4 until it cuts G F extended at *o*, and also the bottom line E D of the elbow at *h*, and from *i* extend a line parallel to G F, intersecting 8 *o* at *j*′. The point *i* was assumed at convenience in developing the section 3 9′ simply to get an additional point in the curve *a c b* of the section U, and shown at *i*′. It is used again in this section for a similar reason. From the several points on *o* 8 in plan draw lines parallel to G F until they cut the miter line F C, from which intersections drop vertical lines, cutting the section N O at *m*′, *i*′, *e*′, *d*′, 4‴ and 8″. Set off the divisions on *o* 8′ on the horizontal line in W, as shown by *o*, *j*, 4, *e*, *d*, 4′, 8 and 8′. From the points 4′ and 8′ erect the vertical lines 4′ X and 8′ X equal in hight to T X in elevation. From the points *o*, *j*, *e*, *d*, 4′, 8 drop vertical lines making *o m*′, *j*, *i*′ *e e*′, 4′ 4‴, and 8 8″, equal respectively to similar distances measured from the line L M to points *m*′, *i*, *e*, 4‴ and 8″ in section N O. As *d* in plan represents the highest point, then *d* in W is in correct position in the section. Through the points *m*′, *i*′, *e*′ *d*′ 4‴, 8″ draw the curved line *m*′ *b*, and draw lines X 4 and X 8 intersecting the arc *m*′ *b* at 4ˣ and 8°, respectively. Now take the horizontal distance between the points 4 and 4ˣ and set it off on the proper plane line in plan, measuring from the point 4, thus locating the point 4ˣ. Draw a curved line in plan from 2 through 3° and 4ˣ, which will cross the miter line F C at A°. From A° drop a line into the section N O, intersecting it at Aˣ. From A° in plan, at right angles to B C, erect a line into the elevation intersecting R P at A, and from A set off the distance A A° equal

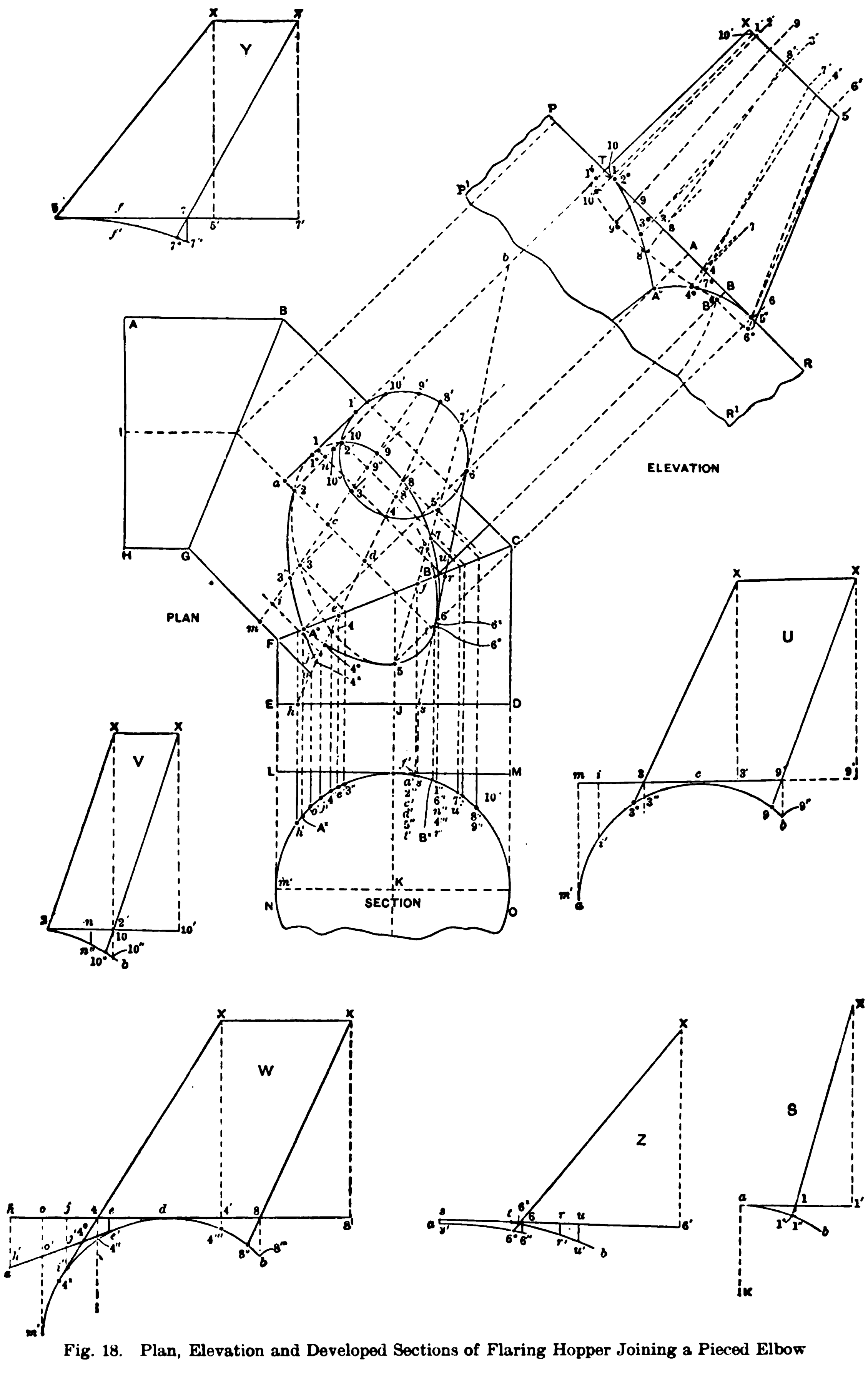


Fig. 18. Plan, Elevation and Developed Sections of Flaring Hopper Joining a Pieced Elbow

to the distance from A^x to the line L M in the section N O. Then will A° in elevation represent the position of the point A° of the plan. The next step is to find the intersection of the plane 8′ 4 with the portion of the elbow shown by F E D C. Therefore, in addition to the spaces on the horizontal line in W, set off from *o* the distance *o h* in plan, as shown. From *o*, *h* and 4 drop vertical lines, as shown, making *h h′*, *o o′*, *j j′* and 4 4″ equal to distances measured from L M in section to points *h′*, *o′*, *j′* and 4″ in N O. Through the points *h′*, *o′*, *j′* and 4″ draw the curve *a d*, which will intersect the line X 4^x at 4°. To obtain in plan the position of points 4° and 8° take the horizontal distances between the points 4 4° and 8 8° in W and set them off in plan on the line 8′ *h*, measuring respectively from the points 4 and 8, thus locating the points 4° and 8°. For their positions in elevation take the vertical distances in W, between the points 4 and 4° and 8 and 8°, and set them off respectively on the lines 4′ 4 and 8′ 8 extended in elevation, measuring perpendicularly from the line P R, thus locating the points 4° and 8°.

For the section on the plane 7′ 5 in plan, proceed as follows: From the point 7, parallel to B C, draw a line intersecting the miter line F C, from which point, including the points 5 and *f*, drop vertical lines intersecting the section N O at 7″, *f′* and 5. Now take distances between the points 5, *f*, 7, 5′ and 7′ in plan and set them off on the horizontal line in Y, as shown by 5, *f*, 7, 5′ and 7′. From the points 5′ and 7′ erect the perpendiculars 5′ X and 7′ X, equal to T X in elevation, and from the points *f* and 7 in Y drop vertical lines, making *f f′* and 7 7″, equal to the distances measured from the line L M to points *f′* and 7″ in the section N O. Through the points 5, *f′* and 7′ draw the arc shown. Draw X 5 and X 7, extending X 7 to intersect the arc 7°. Then will 5 X X 7° be the required section on the line 5 7′ of the plan. As point 5 is at the highest point of the curve in the plan its position in the elevation will be on the line P R in elevation, its position thereon being obtained by erecting from 5 in plan a line at right angles to B C. Now take the horizontal distance between the points 7 and 7° in Y and set it off on the line 7′ 5 in plan measuring from the point 7, thus locating the point 7°. In similar manner take the vertical distance between the points 7 and 7° in Y and set it off in elevation on the line 7′ 7 extended, measuring from and at right angles to the line P R, as shown by 7°.

As the plane 6′ 6 in the plan crosses the miter line F C, it will again be necessary to find at what point between 6 and 7 the line of intersection between the hopper and the pipe will cross the miter line F C. This point is shown by B°, and is obtained as follows: First consider this plane as intersecting the continuation of the middle piece of the elbow B C. Extend the center line of the elbow, also the lines drawn through 4′ and 7, parallel to B C, until they intersect the plane line 6′ 6 at points *t*, *r* and *u*, and from their intersections with F C drop lines to N O as before. Take the various divisions *t*, 6, *r*, *u* and 6′ in plan and set them off, as shown by *t*, 6, *r*, *u* and 6′ on the horizontal line in Z. From that point 6′ erect the line 6′ X, equal in hight to T X in elevation. From the points *r* and *u* in Z drop vertical lines, making *r r*′ and *u u*′, equal respectively to similar distances measured from the line L M to points *r*′ and *u*′ in the section N O. As *t* in plan represents the highest point of the elbow, then will *t* in Z be the correct position in the section. Through the points *t*, *r*′ *u*′ draw the curved line *t b*, and draw a line from X through 6, intersecting the arc *t b* at 6^{x}. Take the horizontal distance between the points 6 and 6^{x}, and set it off in plan on the line 6′ 6, measuring from the point 6, thus locating the point 6^{x}, as shown. Draw a curve line through 7° and 6^{x}, which will cross the miter line F C at B°, the point desired. The full curve begins at point 1° and passes through 10°, 9°, 8°, etc., to 6^{x}. From B° drop a line into the section N O, intersecting it at B^{x}. From B° in the plan, at right angles to B C erect a line into the elevation, intersecting R P at B, then from B set off the distance B B°, equal to the distance measured from the line L M to B^{x} in N O. Then will B° in elevation represent the position of the point B° on the miter line. The next step is to find the intersection of the plane 6′ 6 in plan with that part of the elbow shown by F E D C. Therefore extend the line 6′ 6 in the plan until it intersects E D at *s*. From *s* drop a vertical line into the section intersecting N O at *s*. Set off the distance *t s* in plan on 6′ *t*, extended as shown at *s* in Z. From *s* and 6 drop vertical lines, making *s s*′ and 6 6″, equal to distances measured from the line L M to points *s* and 6″ in the section N O. Through the points *s*′ and 6″ in Z draw the curve *a c*, which will intersect the line X 6, extended at 6° To obtain this point in plan take the horizontal distance between the points 6 and 6° and set it off in plan on the line 6′ 6, measuring from the point 6, as shown. For the same point in elevation, take the vertical distance between the points 6 and 6° in Z and set it off on the line 6′ 6 extended, measuring from and perpendicular to the line P R in elevation, thus locating the point 6° in the view. The full curve in the plan above referred to may then be extended through 6° to 5 and on through 4° to A°. That portion of it lying beyond the hopper is shown dotted. This line is also similarly traced in the elevation, as shown. Then will this line represent the intersection of the hopper with the elbows in plan, and the true distances between the points, to be subsequently obtained, will form the bases of the triangles, which must be constructed in developing the pattern of the hopper by the usual operations of triangulation. It is evident that these distances cannot be measured on the plan, because of the curved section of the pieces composing the elbows. The simplest method of obtaining the correct distances between the several points in the line of intersection is by developing the patterns for the several portions of the

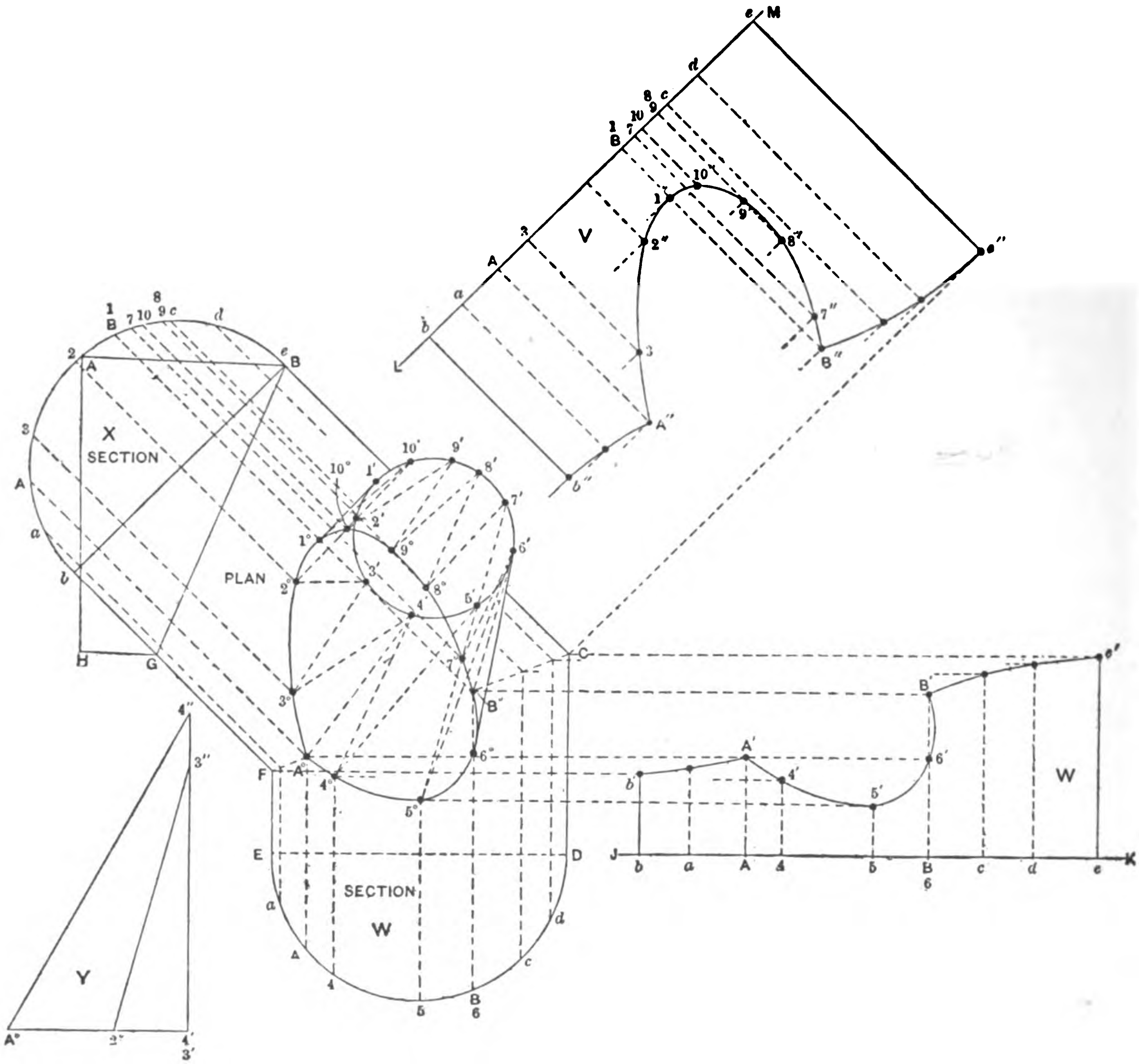


Fig. 19. Development of the Elbow Where Intersected by the Hopper

elbow. For this purpose Fig. 19 is therefore presented, in which A B C D E F G H and the various points of intersection 1°, 2°, 3°, A°, 4°, 5°, 6°, B°, 7°, 8° 9° and 10°, also the points of intersections on the circle 1′ to 10′, are reproductions of parts bearing similar letters and figures in Fig. 18. For the pattern for one-half of the lower piece of the elbow proceed as follows: Draw its half section

W on the line E D, as shown by E 5 D, and from the various points of intersections A°, 4°, 5°, 6° and B° drop lines intersecting W, as shown. Establish at pleasure the points *a*, *d* and c, and from them erect lines cutting the miter line F C, as shown. Extend E D, as shown, by J K, upon which place the stretchout of W, using the spaces contained therein, as shown, and from the several points erect lines at right angles to J K, which intersect by lines drawn at right angles to C D from points of similar number in plan. Trace a line through points thus obtained, then will *b* *b*′ A′ 5′ B′ *e*′ *e* be the pattern for the half of the lower part of the elbow, to intersect with a portion of the hopper. Thus the various distances between point A′, 4′, 5′, 6′ and B′ are the true distances between similarly numbered points in plan. For the pattern for the center part of the elbow, draw the half section X in line with the center part, as shown, and from the various points on the miter line F C and the points 7°, 8°, 9°, 10°, 1°, 2° and 3° draw lines parallel to B C, intersecting the half section X, as shown. At right angles to B C draw any line, as L M, upon which place the stretchout of all of the spaces contained in the half section X, as shown by similar letters and figures, and through the points thus obtained draw lines at right angles to L M, which intersect with lines drawn at right angles to B C from points of similar number in plan. Trace a line through points thus obtained, as shown by *b*″, A″, 10″, B″ and *e*″, which will represent the miter cut to join the lower piece and also the opening to be cut into same to admit the remaining portion of the hopper. Thus the various distances between the points A″, 3″, 2″, 1″, 10″, 9″, 8″, 7″ and B″ are the true distances between similar numbered points in plan.

The method of triangulating the body of the hopper is shown by the dotted lines connecting points of similar number in the two bases and the dotted lines drawn between. The altitudes of the triangles must be obtained from the elevation in Fig. 18, as shown in the diagram Y of Fig. 19, showing one pair of triangles, which may be identified by the reference letters and figures. With the several points in the elliptical base of the hopper determined, those of the circular base given and the method of obtaining the hypotenuses of the triangles indicated, those who are famılar with the usual operations of triangulation will find no difficulty in developing the pattern.

PATTERNS FOR BRANCH INTERSECTING SIDE OF ELBOW

A problem was submitted involving a connection, as shown in Fig. 20, in which A B in the end view represents a branch pipe intersecting the side of a five-pieced elbow, as shown in the side view by C, the branch having the same diameter as the elbow.

In this connection it may be proper to say that the miter line *a b c* in the end view in sketch does not represent the true line of intersection between the branch and elbow; and as this intersecting line is not necessary in the development of the patterns, the method of projecting this miter line will be omitted in the drawings, which are given in Fig. 21, as all that is required is the side elevation of the elbow.

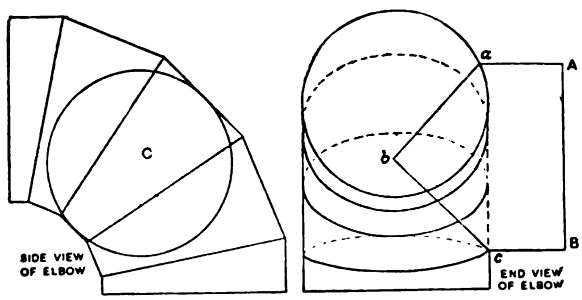


Fig. 20. Sketch of Submitted Problem

Let C D E F represent the side elevation of the five-pieced elbow, and A the section of the elbow on the line E F. Divide A into any convenient number of spaces, in this case from 1 to 7 to 1. Through these points erect vertical lines until they intersect the first miter line as shown. From these intersections, parallel to the sides of the lower piece S, draw lines to the second miter line, from which points, parallel to the sides of piece B, lines are drawn to the third miter line and continued in this manner until the line C D has been intersected.

As the branch is to come directly over the middle piece of the elbow, draw a center line through the middle piece B as shown by 1 7, and where it crosses the center line 4 4 at X becomes the center point with which to strike the profile of the branch B. This profile will intersect the various lines at points numbered 1 to 7 on both sides as shown. Where the profile B crosses the miter line at *a*, establish another line in elevation as well as in plan as shown in both views by the letter *a*.

Establish at pleasure the length of the branch 1 H and 7 J. Extend H J as H K and obtain the pattern for the branch as follows: Take the stretchout of the profile of the branch B in elevation from 1 to 7 to 1, including the point *a*, being careful to measure each space separately, as they are all unequal, and place it as shown by similar letters and figures on J K. From these points erect perpendiculars to J K and intersect them by horizontal lines drawn parallel to H K from similar numbered and lettered intersections on the lower half of the profile A. Trace a line through points thus obtained, then will 1 *c d e* 1 be the full pattern for the branch B, with seam at 1 in side elevation.

As the branch comes directly in the center of the three pieces of the elbow, then the pattern for the lower piece S will also answer for the upper piece S. At right angles to the side of the lower piece S draw the line N P, upon which place the girth of the profile A, including the point *a* between 5 and 6, as shown by similar numbers on N P. Through these points, at right angles to N P, draw perpendiculars, which intersect by lines drawn parallel to N P from the various intersections on the miter line T R at the bottom and U 2 *a* V at the top. A line traced through points thus obtained, as shown by *m*, *n*, *o*, *r*, *s*, *t*, *u*, will be the pattern for the pieces marked S in elevation.

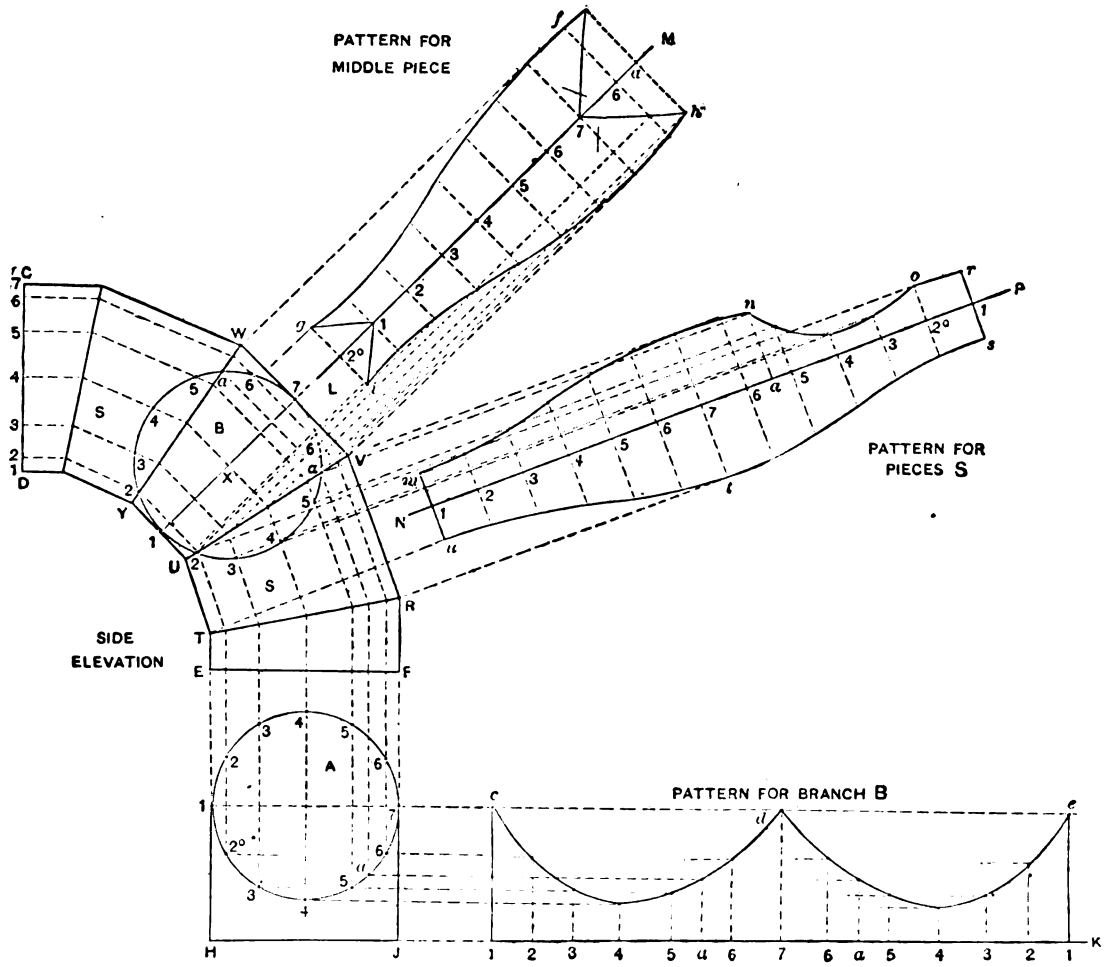


Fig. 21. Elevation, Sections and Patterns for Branch Intersecting Side of Elbow

For the pattern for the middle piece it will only be necessary to take the girth from 2° to 1 to 7 to *a* in the profile A and place it on the line L M, drawn at right angles to the middle piece of the elbow in elevation. Through the various points on L M draw perpendiculars which intersect by lines drawn parallel to L M from the various intersections on the miter lines 2 U V *a* and 2 Y W *a*. A line traced through points thus obtained, as shown by 1, *g*, *f*, 7, *h*, *i*, will be the pattern for the middle piece. Laps must be allowed on the elbow pieces for seaming and on the branch for riveting.

PATTERNS FOR ELBOW MITERING AGAINST SOFFIT OF WINDING CHUTE

The following is a method of developing the patterns for an elbow mitering against the soffit of a winding chute. The drawings show a plan and elevation representing each of the four sides of the article in question, a portion of which are reproduced in Fig. 22 of the accompanying diagrams, while Fig. 23 is a perspective of the article in question. The rear and one of the side elevations are omitted in Fig. 22, for the reason that they show nothing not given in the other views.

The elevations being projected from the plan necessarily have their tops turned toward the same, but as the side view is in this case the one most useful in obtaining the patterns, the drawings are turned on the page so that this view occupies an erect position.

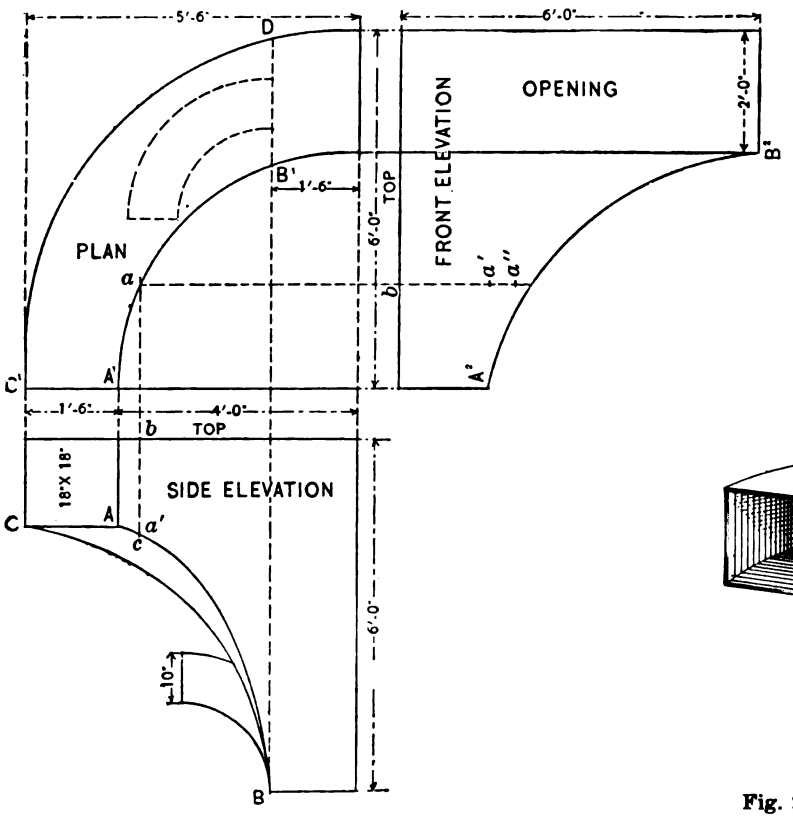


Fig. 22. Sketch to Give an Idea of Problem

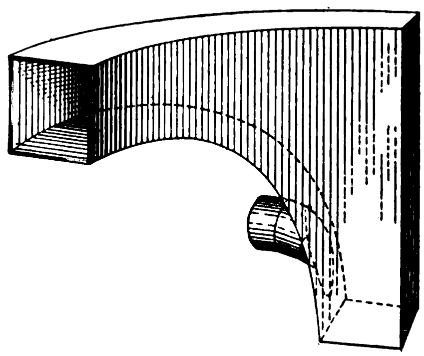


Fig. 23. Perspective View of Article Shown in Fig. 22

The drawing of Fig. 22 is not correct and as the operation of projecting correctly the several elevations from the plan and one given elevation is of prime importance in the solution of many problems, the method by which the several elevations may be made to correspond in every particular is briefly given. If the curve A B of the side elevation in Fig. 22 is accepted as correct, it must first be divided into convenient spaces and lines from the several points of divisions dropped vertically upon the corresponding line A^1 B^1 of the plan. If a front elevation is desired, lines must now be carried from the several points on A^1 B^1 toward the front of the plan indefinitely—that is, at right angles to the first set of lines drawn—upon which the hights of the several points on A B must be set off from any horizontal line, as the line of the top. A line traced through the points thus obtained in the front elevation will then exactly correspond with A B of the side elevation. The line obtained by the foregoing process from A B would be very much different from the line A^2 B^2 already drawn in front elevation, as will presently be shown.

While only one view, when corrected, is necessary in obtaining the pattern, the above operation will greatly assist in completing the design, from the fact that neither elevation will in the present case present such outlines as will be apparent to the eye in the finished article. For instance, if any point, as *a*, be assumed upon the inner curve of the plan somewhere near the 18 × 18 inch opening and lines be projected therefrom in both the elevations, as shown dotted in Fig. 22, it will be discovered that the intersection with A B of the side elevation at a' is much nearer the top line or point *b* than is the intersection a'' of the front elevation as drawn, the difference being there shown by a' a''. This is because the sides of that portion of the chute near the 18-inch opening are very oblique to the plane of the side view, and therefore do not present the outlines of the soffit as they really are; in other words, the point a' is much further back of A than it appears, while those portions of the curve nearer the larger 6-foot opening are more correctly shown in the side view, and for the same reason would, if correctly drawn, be correspondingly distorted in the front view. It then becomes apparent that the outline in one or the other, or perhaps in both views, is wrong, and that as a matter either of design or of utility, as the case may be, the view from which the patterns are to be obtained, in this case the side view, should be so corrected as to produce the desired result. That is, if a line drawn through points A^2 and a' of the front elevation (not shown) be considered as having the proper pitch or slant, then the line from A to B, passing through a' of side elevation, may be assumed as correct; but if such pitch, when shown in the front view, be not deemed sufficient, then a point somewhere below a' of the elevations, as *c* or a'', must be assumed and the curve A B so drawn as to pass through it.

To assist the reader in forming a correct idea of the figure under consideration Fig. 23 shows a perspective view of the same as it would appear if made approximately from the plan and side elevation shown in Fig. 22, from which the inclination of the soffit at all parts of its course may be seen.

Before the operations of the pattern development can be begun one other matter must be determined—viz., the exact nature of the soffit or curved surface forming the bottom (and in its lower part the back) of the chute. This surface, as shown in plan by A^1 B^1 D C^1 and in the side elevation by A B C, is similar to the soffit of an arch in a circular wall. In Problems 214 to 217, inclusive, of the "New Metal Worker Pattern Book" surfaces of this character are treated, from which the reader may derive much benefit by comparison of methods. In the treatment of this surface, in view of subsequent operations, the pattern cutter, as in many other instances, is called upon to choose between the method which adheres strictly to the drawings as given him, and thereby leads him into intricate complications, and a course which is very much simpler and more practicable, though not following out the design to the letter. Since it is against this surface that the elbow, partially outlined in Fig. 22, is required to miter, and since the pattern for such a surface can only be developed by triangulation, it will be seen that the several triangles into which its surface is divided by the operation of obtaining its patterns are all small planes, each slanting at a different angle, and that to obtain with accuracy the intersections of the different pieces of the elbow with the several triangular planes which may lie in the path or course of each would involve much labor. There is no limit to the intersections which it is possible to obtain if necessary, so long as the surfaces or figures involved and their relative positions can be geometrically defined. Such operations would no doubt be more interesting and instructive than practicable. In view, then, of the above mentioned conditions, so far as obtaining the patterns is concerned, the intersection of the elbow can be greatly simplified by considering the soffit as a portion of a somewhat cylindrical surface, having a profile A B of the side view, Fig. 22, thus doing away with the line C B. At all events, if a single line be used from B to a point above where the 10-inch elbow enters, the further outline may then be allowed to deviate to the point C, as shown in Fig. 25, if it is desirable to adhere to the original character of the design as given in the side view of Fig. 22. This arrangement reduces the intersection of the elbow with the curved soffit, shown in detail in Fig. 26, to a problem in miter cutting so simple as to scarcely require demonstration; and if, as above mentioned, the single line A B be adopted as the profile of the soffit, the same may be said of the remainder of the work.

The method of obtaining the pattern of the soffit upon this supposition is shown upon the plan of Fig. 24. Since that portion of the pattern corresponding to C A of the profile, which is horizontal, must be the same as shown in the plan, the remaining portion of the profile A B is divided into any convenient number of equal spaces, as shown by the figures 1 to 7 at the right, and a stretchout of the same, beginning at A^1, is set off on C^1 A^1 of the plan, extended as shown by A^1 E. Lines from the several points on A B are then carried upward to intersect with the

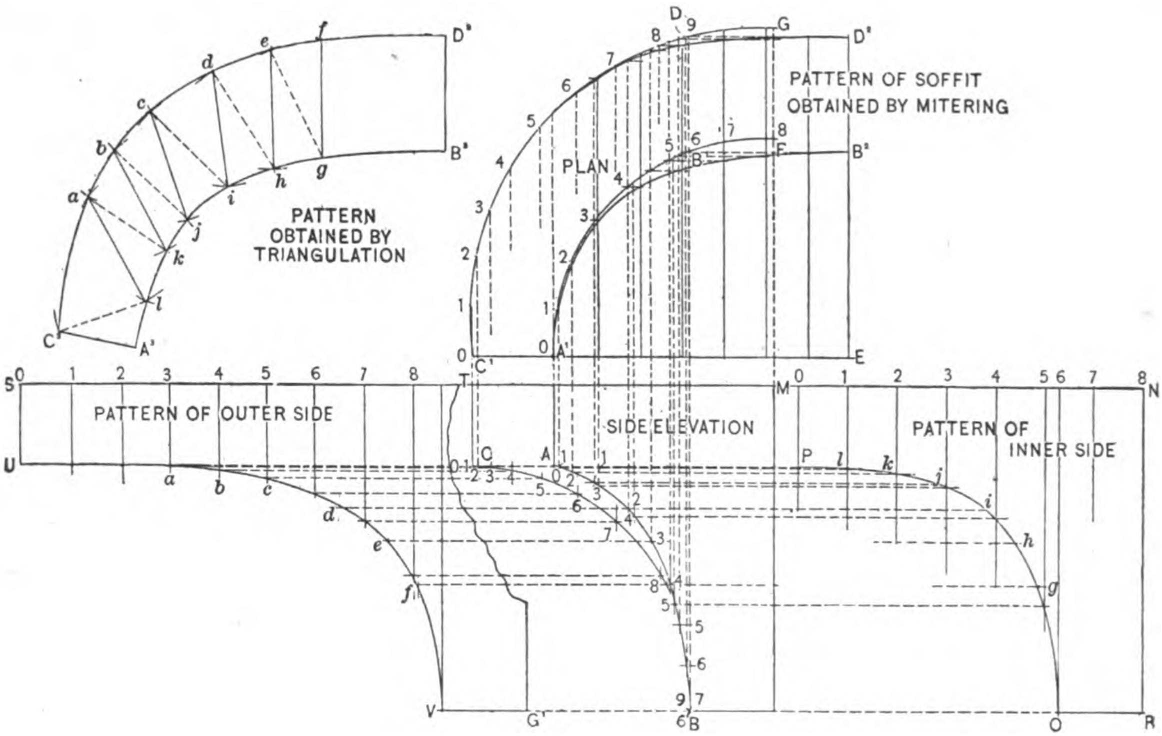


Fig. 24. Process for Obtaining Patterns of Chute

outlines of the sides A^1 B^1 and C^1 D of the plan, from which points of intersection lines are carried into the measuring lines of corresponding number of the stretchout in the usual manner. Then will A^1 B^2 D^2 C^1 be the pattern of a soffit of which C A B is the profile. That portion of the pattern corresponding to C A of the profile, being horizontal, is obviously the same as C^1 A^1 *c* of the plan itself, to which the remaining portion corresponding to A B of the profile, is added, as above described. The intersections are not numbered on the sides of the plan to avoid confusion with another set of numbers on each, which will be used in obtaining the patterns of the sides.

If, however, it is desirable, as before described, to adopt the line C B as drawn in Fig. 25 as the further outline of the soffit, the pattern must be obtained by triangulation. As its sides must correspond in length, respectively, with the lower edges of the two side pieces of the chute, it will be most convenient to develop the patterns for the side pieces first.

Therefore divide A^1 F of Fig. 24, the plan of the inner side, into any convenient number of equal spaces, as shown by the small figures 1 to 8, and set off a stretchout of the same on the top line of the elevation, extended as shown by M N, and draw the usual measuring lines. From the several points on A^1 F drop lines, cutting the line A B of the side, as shown by the small figures on the left of A B, and from the several points of intersection carry lines horizontally, cutting measuring lines of corresponding numbers, and trace a line through the several intersections as shown by P Q R. Then will P Q R N M be the pattern for the inner side. It will be noted that a line from point B of the side must be projected onto the plan, where it is designated as 6. It must then be correspondingly located on M N, so as to determine the position of point Q of the pattern. The pattern for the outer side is obtained in exactly the same manner by dividing its profile or plan C^1 G into spaces, which are set off on the line S T for a stretchout. Lines from the points on C^1 G are then dropped into the line C B of the side view and are carried thence into the measuring lines, all as shown at the left in Fig. 24. The line C A B may be used instead of C B if the mitered pattern above obtained is to be used. The reader is referred to Problem 48 of the "New Metal Worker Pattern Book," in which a subject of similar nature is treated.

The triangulation of the soffit piece is shown in Fig. 25, but the pattern as obtained therefrom is shown in the upper part of Fig. 24 at the left. Since from the nature of the design there is no view in which the full length of its sides can be given, any method of dividing them into spaces may be adopted which is most convenient. The line A B of Fig. 25 is therefore first divided by the points *j*, *i*, *h* and *g* into equal spaces down to the point *g*, which corresponds with the point 4 of the first division of A B, Fig. 24, used in obtaining the first or mitered pattern of soffit, and which also represents the point of deviation between the line of the inner side B A of the soffit and that of the outer side B C. On account of the coincidence of the two lines from B up to this point it is evident that the two patterns must be alike for the same distance, therefore in beginning the triangulated pattern first transfer a duplicate of that portion of the mitered pattern from the measuring line 4 of the stretchout A^1 E of Fig. 24 to the end B^2 D^2 to any convenient position, as shown by *f* *g* B^3 D^3 at the left.

Now erect lines from points in A B of Fig. 25 to cut line A^1 B^2 of plan, after which it will appear that a very long space occurs from A^1 to point *j* of the plan. This space may be further divided by points *k* and *l*, and lines from these points of division carried back to the side view and correspondingly lettered, as shown. From the several points *g* to *l* of the side view carry lines horizontally across, cutting the outer line C B at points *a* to *f*, and from these points erect lines, cutting the outer line of the plan C^1 D^1, as shown by corresponding letters. Connect points on the inner with those on the outer line of the plan with solid lines corresponding with those just drawn across the side view, as *f g*, *e h*, etc., and divide the spaces so obtained by means of dotted lines drawn through the shorter diagonal of each, as *e g*, *d h*, etc. In determining the true lengths of the sides of the several triangles into which the plan of the soffit has thus been divided it will be seen that the lengths of the solid lines and of the dotted line C^1 *l* may be taken directly from the plan as given, because they represent the horizontal lines

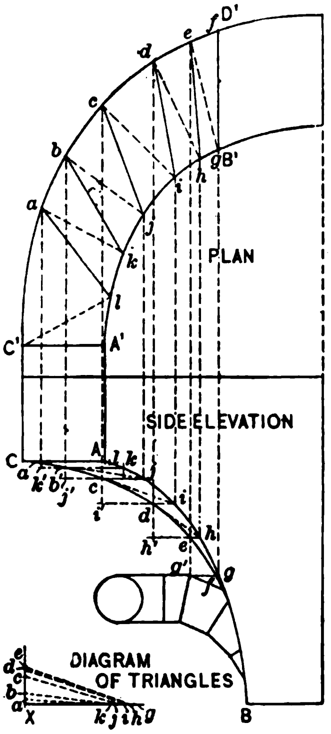


Fig. 25

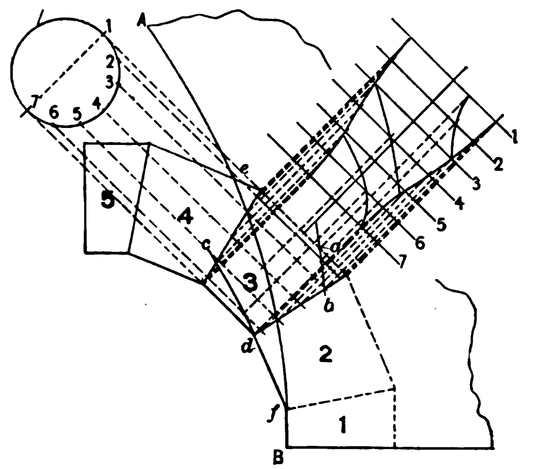


Fig. 26

Process for Obtaining Patterns of Elbow

of the side view, but that the true length of the dotted lines must be obtained by constructing a diagram of triangles, as shown below in Fig. 25. Therefore, from each of the various points *g*, *h*, *i*, etc., on the line A B draw a horizontal line to a point directly below the next higher point on the line C B, from which drop a perpendicular. Then will the several perpendiculars *g′ e*, *h′ d* etc., be the altitudes of the right angled triangles of the diagram, of which the dotted lines will be the bases.

In constructing the diagram of triangles the several hights X *a*, X *b*, X *c*, etc., are made equal to *k′ a*, *j′ b*, *i c*, etc., of the side elevation, while the bases X *k*, X *j*, X *i* are made equal to the dotted lines *a k*, *b j*, *c i*, etc., of the plan. The several hypotenuses *a k*, *b j*, *c i*, etc., of the diagram will then be the true lengths of the dotted lines of corresponding letters in the plan.

In order to find the true lengths of the spaces *a b*, *b c*, etc., of the outer side and *l k*, *k i*, etc., of the inner side it will be necessary to find points exactly corresponding to them on the outlines or miters, U V and P Q of the patterns of the side pieces previously obtained in Fig. 24. Therefore from the points 1, 2, 3 and 4 as numbered on the right of A B of Fig. 24, which correspond exactly with points *j*, *i*, *h* and *g* of A B, Fig. 25, project lines in either direction, cutting the lines U V and P Q of the patterns, as shown, and lettered to correspond respectively with the points on C B and A B of Fig. 25. Then will the spaces *g h*, *h i*, etc., and *f e*, *e d*, etc., be the correct lengths of the spaces bearing corresponding letters of the plan, Fig. 25.

To complete the pattern as shown in the upper left hand corner of Fig. 24, of which the portion *g f* D^3 B^3 has already been obtained as described above, take first the distance *e f* of the pattern of side just below, and from *f* of pattern as center describe a small arc near *e*, which intersect with another arc the center of which is *g* of the pattern and the radius of which is *g e* of the diagram of triangles in Fig. 25, thus locating the point *e*. In the same manner, with radii respectively equal to the spaces *g n* of the pattern of the inner side and *e n* of the plan in Fig. 25, describe arcs intersecting at *h*. So continue, using the spaces upon the pattern of the outer side piece for distances on the outer side of the pattern and those from the pattern of inside piece for distances on inner side of pattern; also lengths from plan in Fig. 25, for distances on the solid lines across the pattern and lengths from the hypotenuses of the diagram of triangles for distances on the dotted lines of the pattern, all as shown. Having carefully followed the foregoing instructions, lines traced through the intersections of arcs, as shown by A^3 *g* and C^3 *f*, will complete the pattern. That portion of the curve from C^3 to *a* of the pattern may be transferred from the corresponding arc of the plan, since the surface of the soffit at that part is practically horizontal and therefore correctly shown in the plan, a fortunate saving of tedious triangulating.

The intersection of the elbow with the cylindrical surface at B *g* of Fig. 25 is shown somewhat enlarged in Fig. 26. The elbow, as if completed, is there drawn in five pieces, but any number of pieces desired can be used. As will be seen, piece 1 is entirely eliminated by the intersection, while pieces 2, 3 and 4 miter against the surface of the soffit. The operation of developing the pattern of piece 3 is first shown as though it were an entire piece. The intersections of the miter line A B with pieces 2 and 4 have been transferred to corresponding points on piece 3, as shown at *a b* and *c d*, so that the operation of developing the patterns for the three pieces is performed at once, a half pattern of all the pieces being shown, from which the full pattern for each piece may be traced, making the joint either at the throat or at the back, as described. As should be readily understood, these operations can be performed while transferring the patterns to the sheet metal. The stretchout is obtained from a profile of the elbow placed in line with piece 3 of the elevation, and the subsequent operations are so fully shown in Fig. 26 as to require no further demonstration.

The length of the opening in A B to receive the elbow is equal to *e f* and its stretchout may be taken from the points of intersection on A B for piece 3, to which is added above that of *a b* for piece 4 and below that of *c d* for piece 2. The width of the opening at the several points is equal to that of the profile on lines of corresponding number. Naturally, said opening would be drawn in its correct position on the pattern for the soffit of the chute.

PATTERNS FOR INTERSECTION BETWEEN CYLINDER AND TRANSITION PIECE

The following deals with the method of obtaining the patterns for the intersection between a cylinder and transition piece, as is shown in Fig. 27. A B C D E F in Fig. 28 represents the front elevation, and G H I J the section in plan on the line F C in elevation and K L M N in plan the horizontal projection of the section on the line E D in elevation.

Through the center O in plan draw the two diameters G I and H J at right angles to each other. Draw the lines of transition N to J to M to I to L to H to K to G to N. From the front elevation construct one-half of the side elevation as follows: Draw the center line B^1 G^1, as shown, and take a tracing of the half plan G N M I O J and place it, as shown, opposite the center line B^1 G^1 by G^1 N^1 M^1 I^1 O^1 J^1, placing the line G^1 I^1 on the center line B^1 G^1, as shown. From the points F, D and E in front elevation project lines to the left. Extend the line N^1 M^1 in plan, intersecting the lines drawn from E and D at N^2 and M^2, respectively. From J^1 in plan parallel to the center line draw a line intersecting the line drawn from F at 6. Extend 6 A^1 and draw lines from 6 to M^2 to N^2 to 6. Then will A^1 B^1 E^1 N^2 M^2 6 A^1 be the one-half side elevation. The reader should

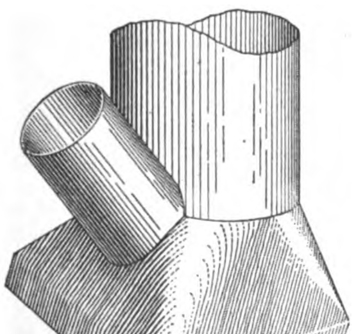


Fig. 27. Perspective View of Cylinders and Transition Piece

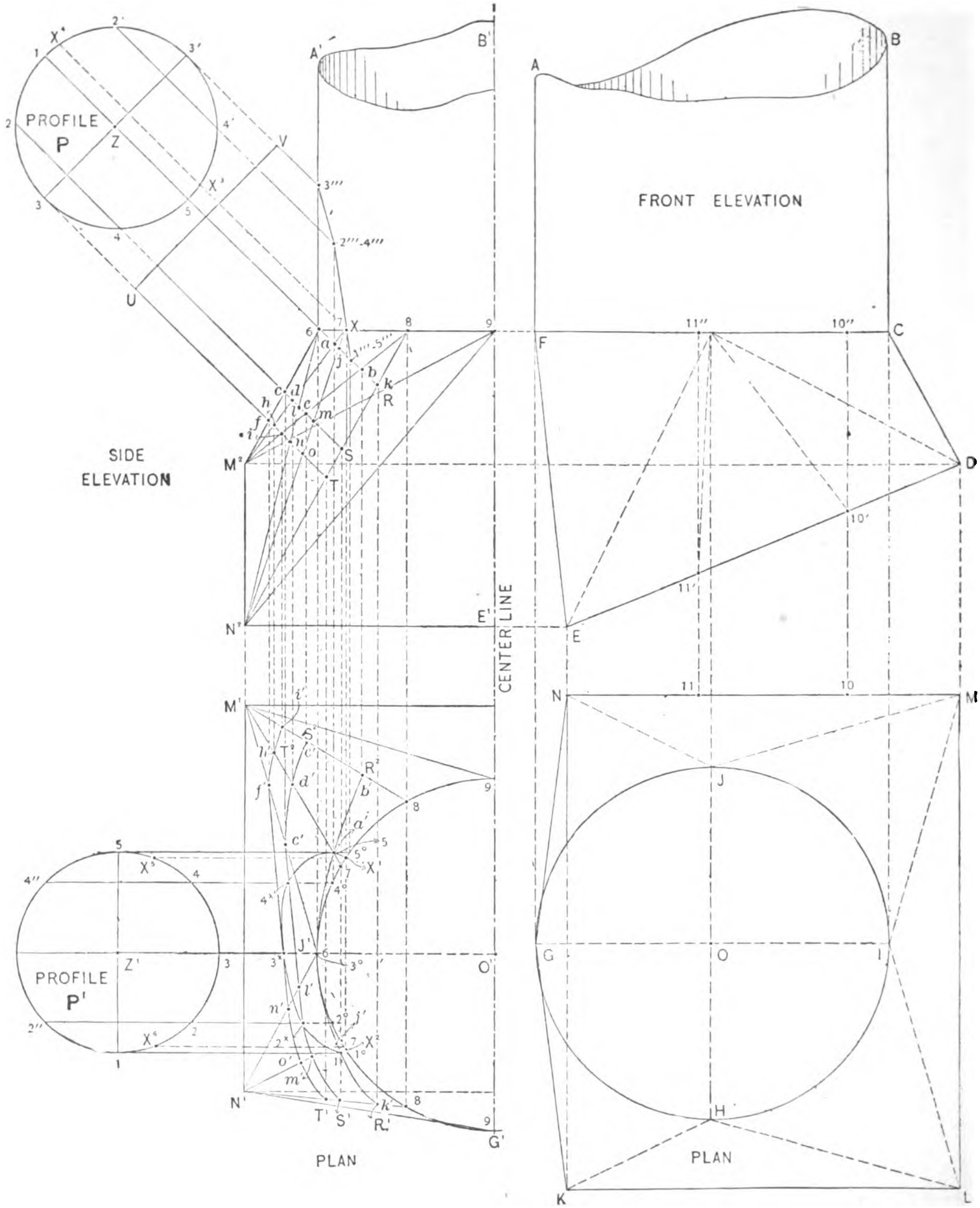


Fig. 28. Procedure for Obtaining the Miter Lines

understand that the point N^2 is the lowest point of the transition piece and is represented in plan by N^1, while M^2 in elevation is the highest point and is represented in plan by M^1.

The first step is to obtain the radial lines in both plan and elevation of the partial scalene cones. Divide the two quarter circles I^1 J^1 and J^1 G^1 in plan both into the same number of equal parts, as shown by the small figures 6, 7, 8 and 9 on both sides. From these points draw radial lines toward the apexes N^1 and M^1, respectively. Parallel to the center line B^1 G^1 and from 6, 7, 8 and 9 erect lines intersecting 6 9 in side elevation at 6, 7, 8 and 9. From these figures draw radial lines to the apex M^2, and from similar figures to the apex N^2.

From any desired point, as 6 in the side elevation, at its proper angle, draw the center line of the branch pipe, as shown by 6 1. With Z as center describe the profile P. Then through Z at right angles to 1 6 draw the diameter 3 3′. Divide the profile P into any number of equal parts, as shown by 1 2 3 4 5 4′ 3′ 2′. Parallel to 3 3′ draw at pleasure the line U V.

It will be noticed that the upper part of the pipe from X^3 to X^4, points which will be established later, intersects the vertical round pipe, while the lower part of the inclined pipe, X^3 3 X^4, intersects the transition piece. Before obtaining the intersection or miter line between part of the inclined pipe and the transition piece horizontal sections must be obtained in plan. Assume that the inclined pipe will not cut any deeper than to the radial lines 8 N^2 and 8 M^2 in side elevation. Then at right angles to U V and from the small figures in the profile P draw lines intersecting the radial lines 6, 7 and 8 in 6 9 M^2 and 6, 7 and 8 in 6 9 N^2, as shown by R, S and T. Thus the lines drawn from 1 5, 2 4 and 3 in the profile P intersect the radial lines in 6 M^2 8 at 6, *a*, *b*; *c*, *d*, *e*; and *f*, *h*, *i*, respectively, while similar lines intersect the radial lines in 6 N^2 8 at 6, *j*, *k*; *l*, *m*, S; and *n*, *o*, T, respectively.

From the intersections 6, *c*, *f* on the radial line 6 M^2 in side elevation drop lines intersecting the radial line 6 M^1 in plan at 6, *c*′ and *f*′, respectively. Then from the intersections *a*, *d* and *h* on the radial line 7 M^2 in elevation drop lines intersecting the radial line 7 M^1 in plan at *a*′ *d*′, and *h*′. Finally from the intersections *b*, *e* and *i* on the radial line 8 M^2 in elevation drop lines intersecting the radial line 8 M^1 in plan at *b*′, *e*′ and *i*′. From the intersections 6, *l* and *n* on the radial line 6 N^2 in elevation drop lines intersecting the radial line 6 N^1 in plan at 6, *l*′ and *n*′. Then from the intersections *j*, *m* and *o* on the radial line 7 N^2 in elevation drop lines intersecting the radial line 7 N^1 in plan at *j*′, *m*′ and o′. Finally from the intersections R, S and T on the radial line 8 N^2 in elevation drop lines intersecting the radial line 8 N^1 in plan at R^1, S^1 and T^1.

Now through the points of intersections i', h', f, n', o' and T^1 draw the section line T^1 T^2, which will represent the horizontal section on the line f T in elevation. In similar manner in plan through the intersections e', d', c' l', m' and S^1 draw the section line S^1 S^2, which will represent the horizontal section on the line c S in elevation. Finally, through the intersections in plan b', a', 6, j and k' draw the section line R^1 R^2, which represents the horizontal section on 6 R in elevation.

In the desired position in plan next draw the center line of the inclined pipe, as shown by J^1 3″. With any point as Z^1, as center, describe a duplicate of the profile P in elevation, as shown by P^1. Divide the profile P^1 into the same number of spaces as the profile P. As the points 3′ and 3 in the profile P represent the top and bottom of the inclined pipe respectively, then must the points 3 and 3″ in the profile P^1 be placed in the position shown, so that if the circle was turned on the line 1 5 the points 3 and 3″ will represent the top and bottom respectively of the inclined pipe in plan.

Parallel to 3″ 3 in plan and from the small figures in the profile P^1 draw lines intersecting similar section lines in plan, as follows: As the point 3 in the profile P in elevation cuts the section line T, then must the point 3 in the profile P^1 in plan intersect the section line T^1 T^2, as shown by 3^x. Then as the points 2 and 4 in the profile P in elevation intersect the section line S, then must the points 2 and 4 in the profile P^1 in plan intersect the section line S^1 S^2, as shown by 2^x and 4^x. Finally, as the points 1 and 5 in elevation intersect the section line R, then must the points 1 and 5 in the profile P^1 in plan intersect the section line R^1 R^2 in plan, as shown by 1^x and 5^x.

It will now be necessary to find the point of intersection between the inclined pipe in elevation and the joint line 6 9 of the transition piece. Therefore, at right angles to 1 5 in plan and from points 1, 2″, 3″, 4″ and 5 draw lines intersecting the semicircle 1^1 J^1 G^1 at 1°, 2°, 3°, 4° and 5°, respectively. From these intersections and parallel to the center line erect lines intersecting lines having similar numbers drawn from the points 1, 2′, 3′, 4′ and 5 in elevation in profile P at right angles to 3 3′, thus obtaining the intersections 3‴ 2‴, 4‴ and 1‴ 5‴. Trace a line through points thus obtained, as shown from 1‴ to 3‴, intersecting the joint line 6 9 at X. From X at right angles to U V draw a line intersecting the profile P at X^3 and X^4. Now, from X at right angles to 6 9 drop a line intersecting the half circle in plan at X^1 and X^2. From these two points at right angles to the center line draw lines intersecting the profile P^1 at N^5 and X^6, which will give the same location as similar points in the profile P. Through the points in plan X^1, 5^x, 4^x, 3^x, 2^x 1^x and X^2 draw the miter line.

The next step is to obtain the miter line in elevation between the inclined pipe and transition piece. To avoid a confusion of lines, which would otherwise occur, a tracing is made in Fig. 29 of the plan and elevation in Fig. 28. In Fig. 29, from the various points of intersections in the miter line in plan, X^1 3^x X^2, erect lines parallel to the center line, intersecting lines drawn from similar numbers in the profile P at right angles to U V, thus obtaining the points X, 1, 2, 3, 4 and 5 in elevation. Trace a line through points thus obtained; then will 3′ X 3 X 3′ be the miter line between the inclined pipe, the transition piece and the main pipe.

For the pattern for the inclined pipe proceed as follows: On the line V U extended, as U D, place the stretchout of the profile P, introducing the extra points X and X, as shown. At right angles to D U and from X and X and the small figures draw lines, which intersect with lines drawn from points having similar numbers in the miter line 3′ X 3 parallel to U V. A line traced through points thus obtained, shown by T L H F W K, will be the pattern for the cylinder branch, with the seam at V 3′ in elevation.

For the pattern for the opening, to be cut into the main pipe A B C X 3′ to receive part of the branch pipe, draw at right angles to the center line any line, as A^1 B^1, upon which place the stretchout of that portion of the plan in Fig. 28 which is intersected from points in the profile P^1, as shown by X^2 2° 3° 4° X^1. These are shown by similar figures on A^1 B^1 in Fig. 29. At right angles to A^1 B^1 and from the small figures draw lines, which intersect with lines drawn from points having similar figures in 3′ X in elevation at right angles to the center line. A line traced through these points, as shown by C^1 D^1 E^1, will be the required cut.

Only one-half of the pattern for the transition piece will be developed, as both halves are symmetrical, but diagrams of triangles must first be constructed as follows: In Fig. 30 draw any horizontal line, as & A, upon which place the various lengths M 9, M 8, M 7 and M 6 in plan in Fig. 29 as shown by & 9, & 8, 7 & and 6 & on & A in Fig 30. At right angles to & A erect & M, equal to & C in elevation in Fig. 29. Then from the points 6 9 and 7 8 draw lines to M in Fig. 30, which will represent the true lengths on similar lines in plan in Fig. 29.

In similar manner draw any horizontal line, as E A in Fig. 31, upon which place the various lengths N 6, N 7, N 8 and N 9 in plan in Fig. 29, as shown by E 6, E 7, E 8 and E 9 on E A in Fig. 31. At right angles to E A draw E N, equal to E C in elevation in Fig. 29. Then from 6, 7, 8 and 9 in Fig. 31 draw lines to N, which will represent the true lengths on similar lines in plan in Fig. 29.

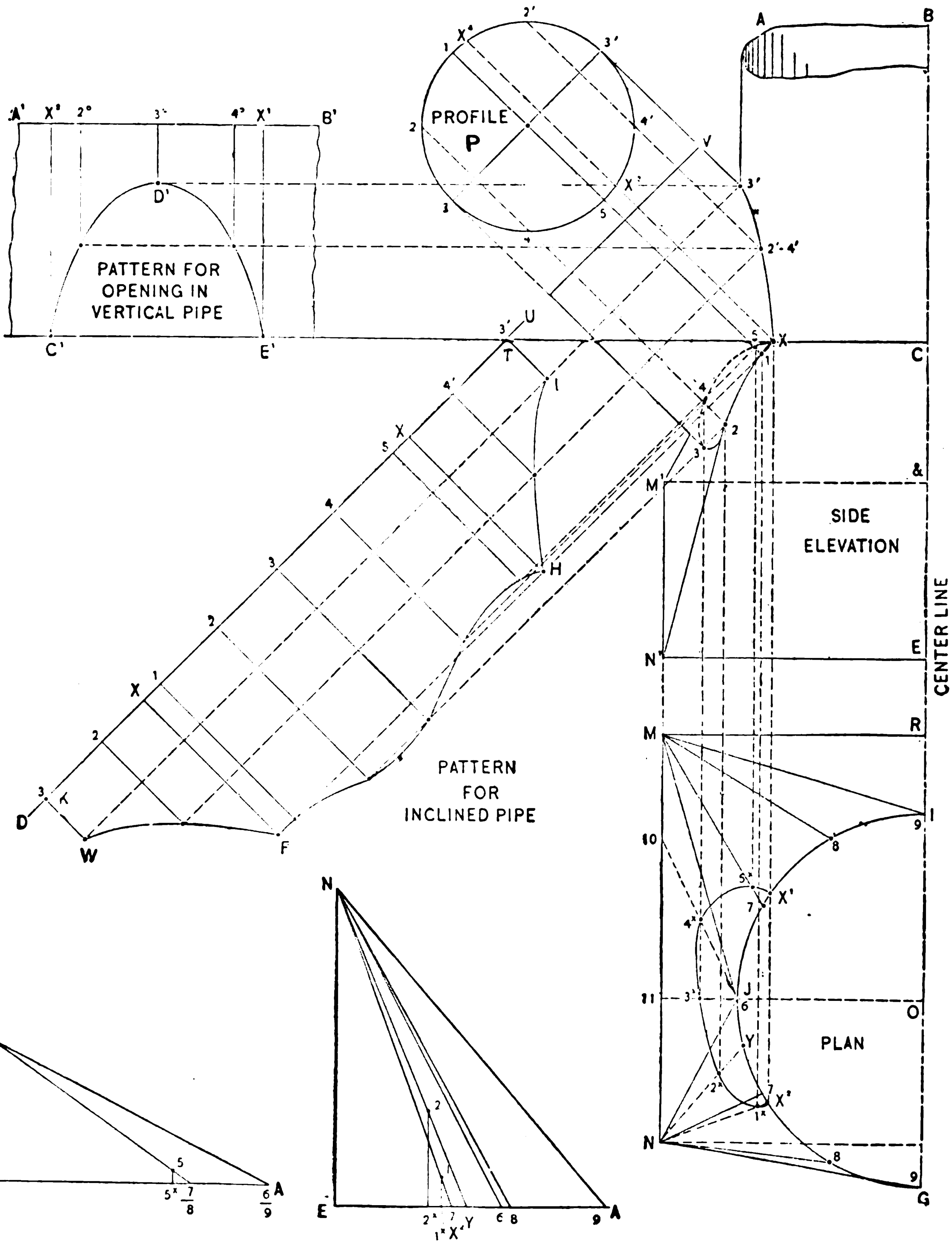


Fig. 31 Fig. 30 Fig. 29

Procedure for Obtaining Diagrams of Triangles and Patterns

For the pattern for the transition piece draw in Fig. 32 horizontal line N M, equal to E D in front elevation in Fig. 28; then using M 6 in Fig. 30 as radius and M in Fig. 32 as center describe the arc 6, which intersect by an arc struck from N as center and N 6 in Fig. 31 as radius. Draw a line from N to 6 to M in Fig. 32. Now, with N as center and radii equal to N 7, N 8 and N 9 in Fig. 31, describe the arcs N 7, N 8 and N 9 in Fig. 32. Now set the dividers equal to the spaces into which the half plan I J G in Fig. 29 is divided, and, starting from 6 in Fig. 32, step from one arc to another, thus obtaining the intersections 7, 8 and 9. Draw a line from 9 to N. Now, with 9 as center and E F in the front elevation in Fig. 28 as radius, describe the arc S in Fig. 32, which intersect by an arc struck from N as center and N S in plan in Fig. 29 as radius. Draw a line from 9 to S to N in Fig. 32 and trace a line from 9 to 6. With radii equal to M 7, M 8 and M 6-9 in Fig. 30 and M in Fig. 32 as center describe the arcs 7′, 8′ and 9′. Set the dividers equal to one of the spaces in the half plan I J G in Fig. 29, and, starting from the point 6 in Fig. 32, step from one arc to another, thus obtaining the points 7′, 8′ and 9. Draw a line from 9′ to M. Now, with M R in plan in Fig. 29 as radius and M in Fig. 32 as center, describe the arc R, which intersect by an arc struck from 9′ as center and C D in front elevation in Fig. 28 as radius. Draw a line from M to R to 9′ in Fig. 32 and trace a line from 9′ to 6. Then will 9 6 9′ R M N S be the half pattern for the transition piece.

For the pattern for the opening to be cut into the transition piece proceed as follows: As the point of intersection 5^x in the miter line in plan in Fig. 29 intersects the radial line 7 M, then take the distance from M to 5^x and place it in Fig. 30 on the line & A from & to 5^x. From 5^x erect a perpendicular line intersecting the slant line M 7 at 5. Take the distance from M to 5 and place it on the line M 7′ in Fig. 32 from M to 5, as shown. Now through the points of intersections in the miter line in plan in Fig. 29, 1^x and 2^x, draw lines to the apex N, extending them until they intersect the half circle at X^2 and Y, respectively. Take the distances of N X^2 and N Y and place them on the line E A in Fig 31 from E to X^2 and E to Y, respectively, and draw lines from X^2 to N and Y to N, which will represent the true distances on similar lines in plan in Fig. 29. Now take the distances from N to 1^x and N to 2^x and place them from E to 1^x and 2^x, respectively, in Fig. 31. From 1^x and 2^x erect perpendicular lines intersecting the hypotenuses X^2 N and Y N at points 1 and 2, respectively, as shown. Take the distance from 6 to Y and 7 to X^2 in plan in Fig. 29 and place it, as shown, from 6 to Y and 7 to X^2, respectively, in pattern in Fig. 32. From the points Y and X^2 draw lines toward the apex N. Then with N 1 and N 2 in Fig. 31 as radii and N in Fig. 32 as center intersect the radial lines X^2 N and Y N at 1 and 2, respectively. Through the intersections 3^x and 4^x in the miter lines in plan in Fig. 29 draw lines to the point 6, extending them and intersecting the line M N at points 11 and 10, respectively. Take the distances from N to 11 to 10 to M and place them in the plan in Fig. 28, as shown from N to 11 to 10 to M. At right angles to N M draw the lines 11 11″ and 10 10″, intersecting F C and E D in front elevation at 11″ 10″ and 11′ 10′, respectively.

It will now be necessary to construct an extra set of triangles on 10 6 and 11 6 in plan in Fig. 29. In Fig. 33 draw any horizontal line, as A B, upon which place the lengths of 6 10 and 6 11 in plan in Fig. 29, as shown by 10 10′ and 11 11′, respectively, in Fig. 33. At right angles to A B and from 11′ and 10′ draw 11′ 6 and 10′ 6, equal in hight to 11′ 11″ and 10′ 10″, respectively, in front elevation in Fig. 28. Draw lines from 6 to 11 and 6 to 10 in Fig. 33, which will represent the true distances on similar lines in plan in Fig. 29. Now take the distances 11 3^x and 10 4^x in plan in Fig. 29

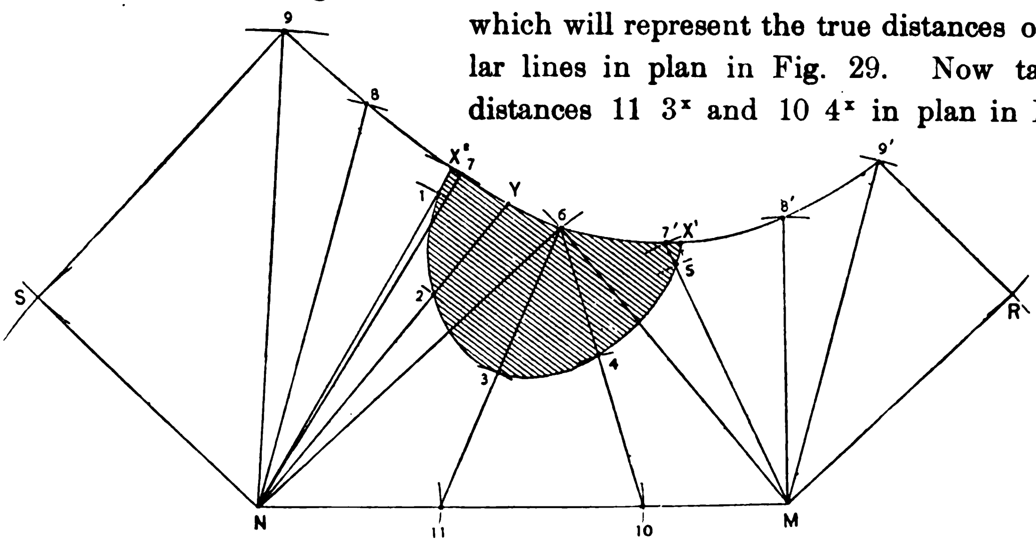


Fig. 32. Pattern of Transition Piece Showing Opening

and place them in Fig. 33 on the line A B, as shown from 11 to 3^x and 10 to 4^x, respectively. From 3^x and 4^x erect lines intersecting the slant lines 6 11 and 6 10 at 3 and 4. Take the distances in front elevation in Fig. 28 from E to 11′ to 10′ to D and place them in Fig. 32 from N to 11 to 10 to M, as shown. From 10 to 11 draw lines to the point 6. Then take

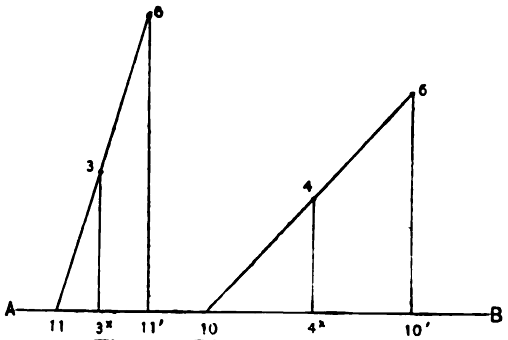


Fig. 33. Diagram of Triangles

the lengths from 11 to 3 and 10 to 4 in Fig. 33 and place them in Fig. 32 from 11 to 3 and 10 to 4, respectively, as shown. Take the distances from 7 to X^1

and 7 to X^2 in plan in Fig. 33 and place them, as shown, from 7 to X^2 and 7′ to X^1 in Fig. 32 respectively. Through the points of intersections X^2, 1, 2, 3, 4, 5 and X^1 trace a line, as shown. Then will the shaded portion be the part to be cut out of the transition piece to receive the inclined pipe.

PATTERN FOR TRANSITION PIECE OF PECULIAR FORM

It may be stated that in this, as, in fact, in all cases where more than one view of an object is required, "getting the correct views"—that is, the question of drawing—is of the utmost importance. A sufficient number of views which correspond with each other in every respect must be obtained before the patterns can be

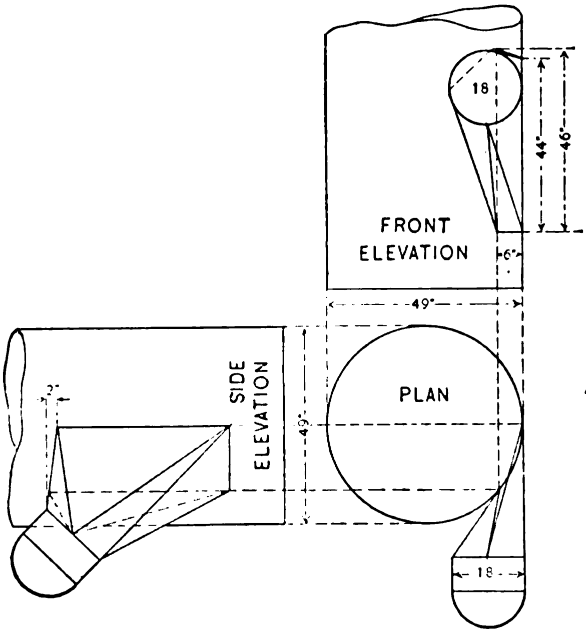


Fig. 34. A Sketch of the Problem

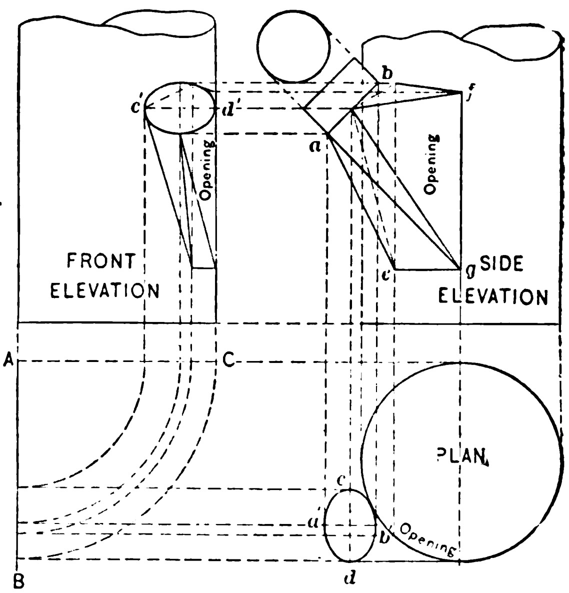


Fig. 35. Method of Projecting the Side Elevation from the Other Views

developed. The drawings which are shown to a reduced scale in Fig. 34, are in the preliminary work correctly projected. The 18-inch opening, however, in the front elevation should show elliptical, and the same may be said of this opening as it appears in the plan.

In Fig. 35 is shown another method of projecting the several views, from an inspection of which the method of arriving at the widths of the ellipses will be seen. Since the side elevation is, in this case, the principal one, the plan should first bè drawn in such a position that the side of which the elevation is required will be turned toward the bottom of the paper, after which lines are carried upward from its several points, as shown at the right in Fig. 35. With the plan and one elevation complete, the other elevation should be obtained by projections from both the other views. Although in this case the other or front elevation is not necessary so far as obtaining the patterns is concerned, it is here explained, since the method of obtaining it may be readily applied in numerous other instances.

The front elevation may, of course, be obtained by projecting it from the plan at right angles to the other elevation, as it is in Fig. 34; but if obtained by horizontal projections from the front elevation, as shown at the left in Fig. 35, the relative hights of the corresponding parts are more easily seen and obtained, as will be presently shown. This course will require either the drawing of another plan turned one-quarter around (that is, with its front toward the bottom of the paper), or the obtaining of the lateral widths by some other method. They may be obtained either by measurements made vertically across the plan and transferred to the front elevation, or by projection from the plan in the following manner, as shown in Fig. 35. Lines from the several points of the plan are carried horizontally to the left until they intersect a vertical line, A B, drawn at any convenient point, and are then carried around a quarter circle, the center of which, A, is taken at convenience on A B. Having thus reached the horizontal line A C, they are continued upward into the front elevation, as shown. In the construction of the drawings now, the lines *a b* of the side elevation and *c d* of the plan are each made equal to the full width of the small pipe (18 inches), the line *c d* being projected from the middle point of *a b*. Lines from *a* and *b* are now projected to cut the center line of the pipe in plan at *a'* and *b'*, thus giving the correct width of the ellipse in plan. Lines from *c* and *d* of the plan are also carried into the front elevation by the course above described, where they cut the horizontal line from the center of *a b*, as shown at *c'* and *d'*, giving the length of the ellipse, while lines from *a* and *b* are carried this time horizontally to the front elevation, to cut the center line of the pipe brought from *a' b'* of the plan, thus giving the correct width of the ellipse in the front elevation.

Lines drawn from *b* to *f* and from *a* to *e* will complete the general outline of the transition piece. The position of the lines diverging from *g* will be determined in the subsequent process of triangulation.

A transition piece forming a connection between a round and a rectangular opening, under ordinary conditions, consists of four plane triangles and four quarter cones, more or less oblique, according to circumstances. The great difference, however, between the case under consideration and that of an ordinary transition piece lies in the fact that what in the present case has been called a rectangular opening is, in fact, only rectangular as it appears in elevation. Since it is an opening in the side of a large cylinder, its ends are curved to the radius of the cylinder, and, furthermore, the position of the smaller pipe is found to be so very oblique with reference to the opening that, should an attempt be made to tri-

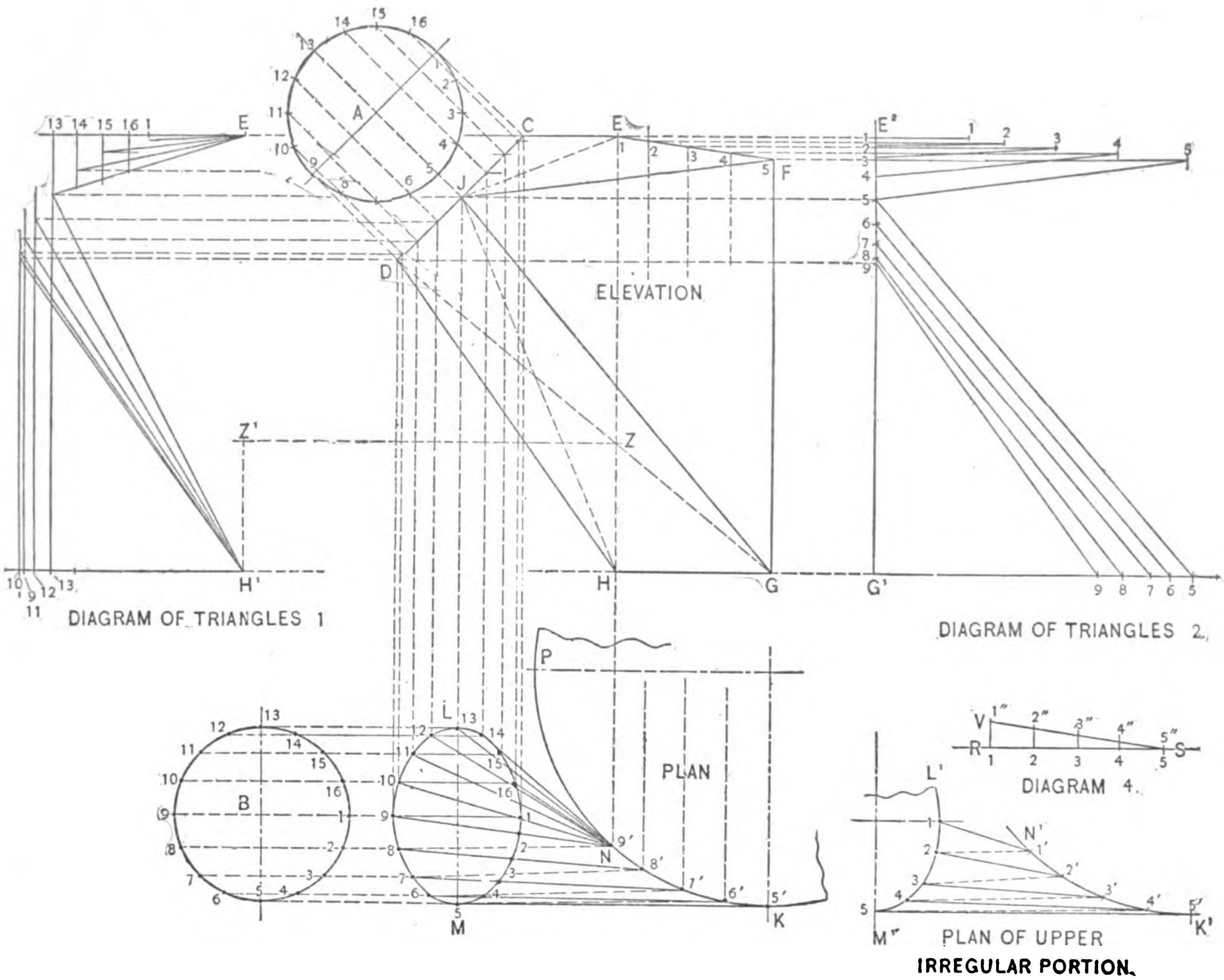


Fig. 36. Elevation and Plan of Transition Piece with Diagrams of Triangles Showing Method of Triangulation

angulate it according to the above subdivision, the curve of the cylinder would cut into the sides of two of the cones. This will be seen by reference to Fig. 36, in which E F G H shows to an enlarged scale the opening *b f g h* of Fig. 35, while D C, with its profile, A, corresponds with *a b* of the latter figure. In the plan the curve P K of the large cylinder has been drawn with a slightly shorter radius, comparatively, than in Fig. 35, so as to avoid confusion of lines.

A correct projection of the opening of the 18-inch pipe, as shown at L M of the plan, must be obtained before the work of triangulation can be begun, which can be done in the following manner: First draw a profile of this opening in line with L M, as shown at B, and divide both profiles, A and B, into the same number of equal spaces, as shown by the small figures, being careful that point 1, the highest point of the opening, is correspondingly located in both, as shown. From the several points in profile A project lines at right angles to C D, cutting the same as shown. Now, from the several points in profile B project lines at right angles to L M indefinitely, which intersect with lines of corresponding number dropped vertically from the points previously obtained on D C. A line traced through the points of intersection, as shown by the corresponding small figures in L M, will give the required view of the opening in plan.

It will now be seen that the triangulation of the transition piece can be most conveniently accomplished by first dividing the circular opening into four equal parts, by the points 1, 5, 9 and 13 of profiles A and B, with a view of making each quarter the base of an oblique cone with an apex at the nearest angle of the large, or so-called rectangular, opening. Thus, that quarter between points 1 and 13 will form the base of a quarter cone, the apex of which is at E of the elevation or N of the plan, while that quarter from 13 to 9 will be the base of a cone the apex of which is at H of the elevation and which appears also at N of the plan. These two conical surfaces are connected by the plane triangle shown by J E H of the elevation and by L N of the plan, all these parts or elements forming what may be termed the back of the transition piece. If now it be attempted to carry out this method in the treatment of the front part, the quarter 1 5 would be taken as the base of a quarter cone the apex of which is at F of the elevation, and the cone would be shown by points 1, 5, K of the plan; but if a line be drawn from 1 to K of the plan (not shown), it will be cut by the circle P N K of the large cylinder somewhere near the point N, thus mutilating this conical portion, as above mentioned. The same may be said of the fourth conical surface, which would be shown by 9 5 K of the plan. It will therefore be better to consider that portion of the transition piece from 1 to 5 at its round end to E F of the elevation at the other end, as one irregular piece or element of the whole; and likewise that portion from 5 to 9 at the round end to G H at the large end as another similar element, thus leaving the large plane triangle J F G of the front side to complete the pattern.

With this separation of the transition piece into its elementary parts the operations of triangulation may be completed as follows: First draw lines from points 9, 10, 11, etc., to 1 of L M, to the point N of the plan. These lines will represent the horizontal distances of points 9 to 13 from H of the elevation, and of points 13 to 1 from point E, and will be used as the bases of a series of right angled triangles, the hypotenuses of which, when obtained, will be the true distances between points of corresponding number on the finished article.

The triangles for the conical portion, the apex of which is at E, may most easily be obtained by extending E C of the elevation in either direction, as shown at the left of A, upon which set off from any point, as E^1, the lengths of the several lines in the corresponding quarter of the plan just drawn to point N, as shown by E^1 13, E^1 14, etc. Now, from the several points 13, 14, 15, etc., thus obtained, drop perpendiculars, which intersect by horizontal lines drawn from points of corresponding number on J C, previously obtained from profile A. Lines drawn from the several points of intersection to E^1, as shown, will be the required hypotenuses. The triangles for the lower conical portion may be obtained in a similar manner by using an extension of H G as the base. The lengths of the lines N 9, N 10, etc., of the plan are set off from any point, as H^1, as shown by the small figures 9 to 13, from which perpendiculars are erected and intersected by horizontal lines projected from points of corresponding number on D J. Lines drawn from the several points of intersection to H^1 will be the required hypotenuses for the lower cone.

To triangulate the lower irregular element above described, the line N K of the plan must first be divided into as many equal spaces as either quarter in the front half of L M—that is, into four spaces—as shown by the points 6′, 7′ and 8′ between N K or 5′ 9′ of the plan. Solid lines may now be drawn between points of corresponding number on L M and N K, and dotted lines from points 5, 6, 7 and 8 on L M, respectively, to points 6′, 7′ 8′ and 9′ on N K.

The triangulation of the upper irregular piece is accomplished in exactly the same manner, and to avoid a confusion of lines its plan is shown at the right of the main plan, of which its curved lines are duplicates. The points in N^1 K^1 are numbered from 1′ to 5′ to correspond with those in the adjacent quarter of L^1 M^1. The several solid lines here shown together with those previously obtained on the main plan form the bases of the triangles in the diagram at the right of the elevation, while the triangles to be formed upon the several dotted lines of the plans are shown in a separate diagram in Fig. 37.

Since E F of the front elevation is an oblique line it will be necessary, in constructing a diagram of triangles for the upper irregular element of the transition piece, to project lines horizontally from each of the points on E F indefinitely to the right, as shown in diagram of triangles 2, upon which the lengths of the several solid lines of corresponding number of the plan are set off from the intersection of a common perpendicular E^2 G^1, thus locating points 1 to 5, shown at the right of E^2. Horizontal lines are now projected from points on J C as obtained from profile A, cutting E^2 G^1, as shown by the small figures. Lines drawn from these points of intersection to points of corresponding number at the right will give the hypotenuses for the solid triangles. Diagram 3 should properly be constructed at the right of diagram 2, the points on E^3 G^2 being obtained by a continuation of the projections from the elevation used in obtaining the points on E^2 G^1, but for lack of space it is shown separately in Fig. 37. The hypotenuses in Fig. 37 are drawn between numbers corresponding with those of the dotted lines of the two plans, as from 2 to 1, 3 to 2 and 5 to 6, 6 to 7, etc.

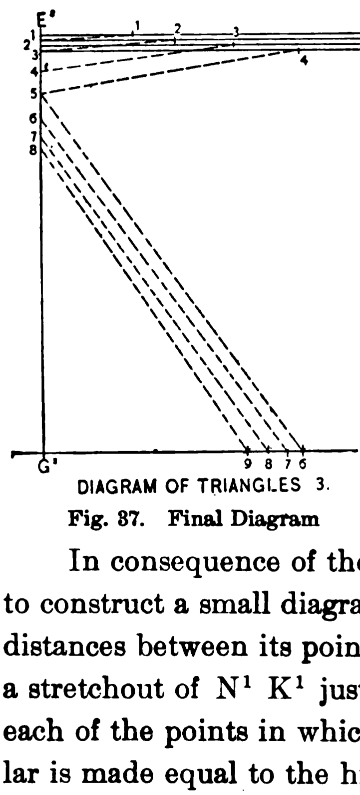


Fig. 37. Final Diagram

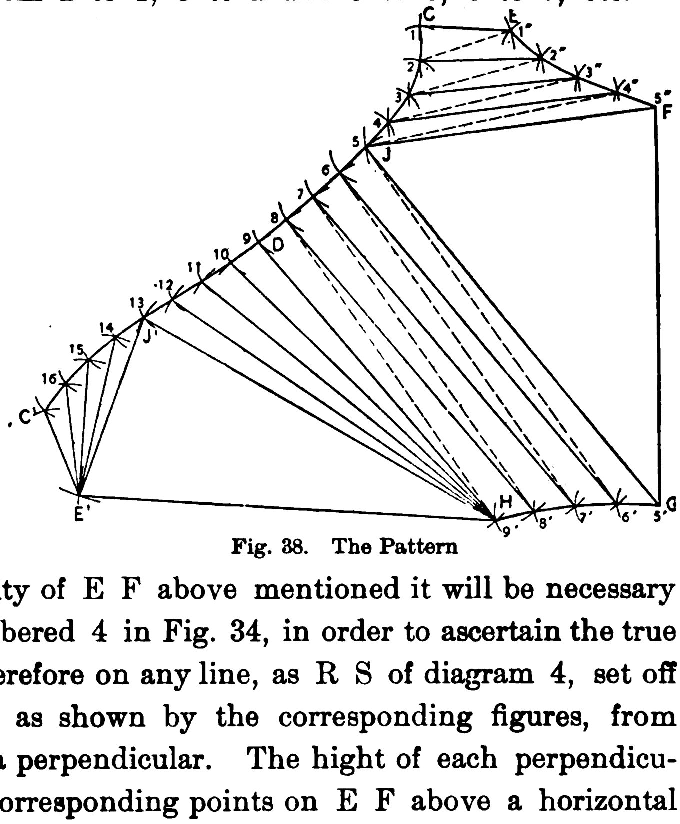


Fig. 38. The Pattern

In consequence of the obliquity of E F above mentioned it will be necessary to construct a small diagram, numbered 4 in Fig. 34, in order to ascertain the true distances between its points. Therefore on any line, as R S of diagram 4, set off a stretchout of N^1 K^1 just below, as shown by the corresponding figures, from each of the points in which erect a perpendicular. The hight of each perpendicular is made equal to the hight of corresponding points on E F above a horizontal line drawn from F but not shown, or is obtained from the projection of those points on E^2 G^1, as above described, and as also shown at T of diagram 3.

For convenience in laying out the pattern from the various dimensions now obtained it will be considered that the joint is to be made upon the line C E of the elevation; although the size of the piece will require several joints, the positions of which can most easily be determined after the pattern is developed as a whole. Therefore construct first the triangle J F G of the pattern, Fig. 38, which is an exact duplicate of the triangle designated by the same letters in the elevation, Fig. 36. Now, with 5 4 of diagram 3, Fig. 37, as a radius and J of the pattern as center describe a short arc near 4″ of the pattern, which intersect with another arc the radius of which is 5″ 4″ of diagram 4, thus locating point 4″ of the pattern. With a radius equal to 4 4 of diagram 2 and from 4″ of the pattern as center describe a short arc, which intersect with another arc drawn from point J (5) of the pattern as center and with a radius equal to 5 4 of profile A, thus locating the position of point 4 of the pattern. Continue this operation, using the spaces of profile A in numerical order, as shown, for the side J C of the pattern, and those of V S of diagram 4 for the side F E, while the measurements across are taken alternately from the upper parts of diagrams 3 and 2, all as shown.

The lower irregular element of the transition piece may now be added to the pattern in exactly the same manner as above described for the upper part, beginning with J G of the pattern as a base, and using the lengths of the dotted hypotenuses from the lower part of diagram 3 with the distances from N K of the plan as radii to develop that part of the pattern from G to H, and the hypotenuses from the lower part of diagram 2 with the corresponding spaces on profile A as radii to develop that pattern from J to D, all as shown by the corresponding figures in the several views mentioned.

The lower conical element of the pattern may now be added by first describing arcs from H of the pattern as center with radii equal to the lengths of the several lines converging at H^1 of diagram 1, after which the spaces from 9 to 13 of profile A may be set off from D (9) of the pattern upon the several arcs, measuring or stepping from one arc to the next in numerical order, thus developing the line from D to J^1. The large triangle forming the back of the transition piece, shown by J E H of the elevation, may next be added in the following manner: From J^1 of the pattern as center, with a radius equal to E^1 13 of diagram 1, describe a short arc, and intersect the same with another arc, the radius of which is equal to H E of the elevation, thus locating the point E^1 of the pattern. The upper conical element is finally added, using as radii the lengths of lines converging at E^2 in the upper part of diagram 1 with the spaces from 13 to 1 of profile A, all as shown from J^1 to C^1. Lines traced through the several intersections of arcs from C to C^1, from E to F and from G to H will complete the pattern

PATTERN FOR A SPOUT HOPPER

Problems of this nature must be solved by triangulation, the principles of which, in cases of this kind, are explained in Problems 176, 180 and 182, of "The New

Metal Worker Pattern Book." Such pieces are termed transition pieces because, being usually made to form an intermediate joint or section between two pipes of different plans or profiles, they form a transition from one form to the other, and the principles involved in obtaining the pattern of any such piece are applicable to any other of that class.

If in making the joint at the bottom the vertical pipe is cut off square, the lower base of the transition piece will, of course, be a simple circle, but if it is cut off by an oblique plane, making the angle with the inclined and with the vertical portions approximately equal, as in an ordinary elbow, then a little more preliminary work will have to be done before the work of triangulation can be begun. In that case the ellipse produced by cutting the round pipe obliquely will have to be first developed.

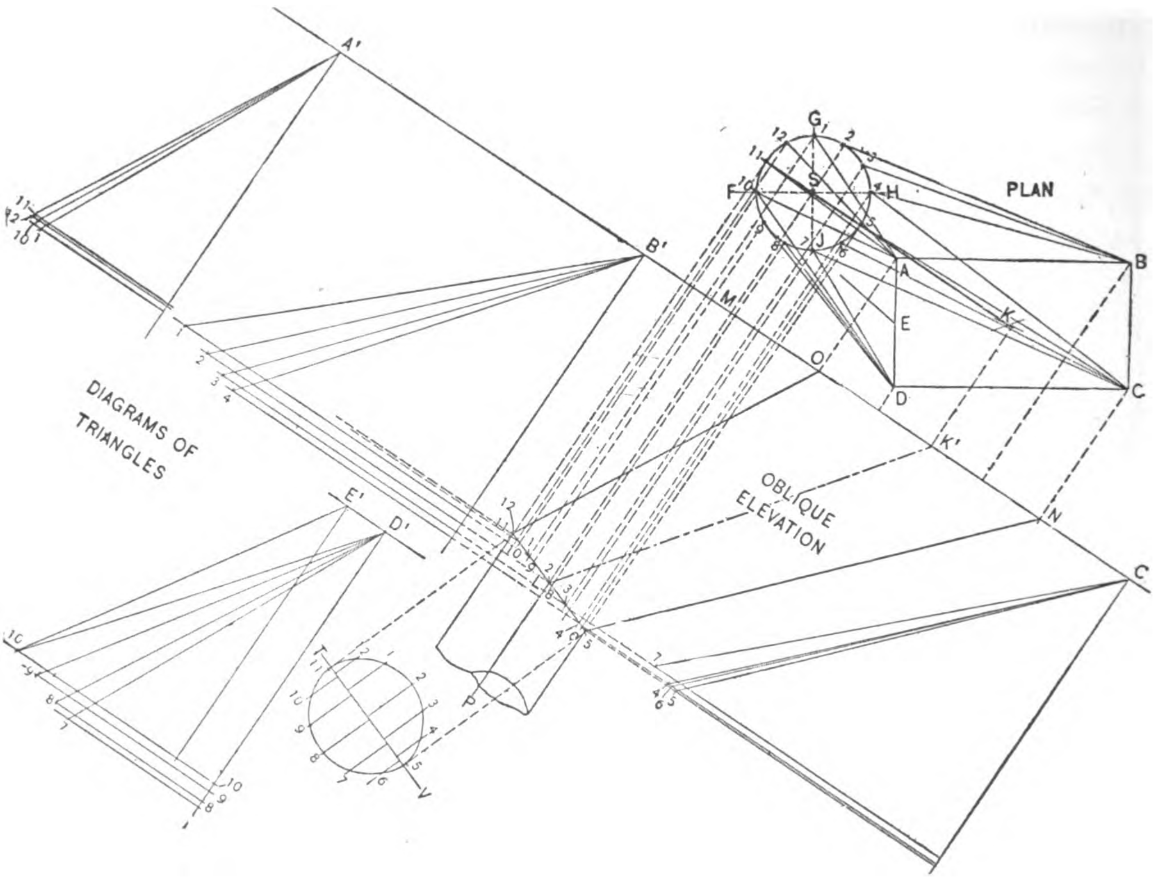


Fig. 39. Plan of Hopper, Indicating the Manner in which the Oblique Elevation and Diagrams of Triangles are Obtained

In Fig. 39 of the diagrams, A B C D represents a plan of the upper rectangular end of the hopper, while F G H J shows the relative position of the vertical pipe with which its lower end is to miter. The proper way to obtain the correct angle of the miter between the hopper and the vertical pipe is to first construct an oblique elevation on a plane parallel to a line joining the centers of the two ends or bases in plan. Therefore, find the center of A B C D, as shown at K, and draw a line from K through the center of the round pipe shown heavy on the plan. Now, at any convenient position below the plan draw a line, as M N, parallel to the heavy line, and from each of the points A, B, C, D and K drop lines at right angles to M N, cutting the same, as shown. Also drop a similar line from the center of the round pipe of indefinite length, upon which set off from M N the required vertical hight of the hopper, as shown by M L, and draw L K^1. The angle K^1 L P will then be the correct angle between the vertical pipe and the hopper, and the miter line may now be drawn through L, so as to bisect this angle, just as though both arms of the miter were to be of the same profile. The lines of the sides of the pipe may now be projected from the plan, as shown, and from their intersections with the miter line, lines are drawn to the points O and N, corresponding to the angles A and C of the rectangle. This completes the general outlines of the elevation.

In completing the plan and determining the method of triangulation the plan of the round pipe must first be divided into quarters by the lines F H and G J, each quarter of which will form the base of a quarter cone the apex of which is at the corresponding corner of the rectangle. Thus, F G S is the base of one quarter of an oblique or scalene cone, the apex of which is at A, while G H S is a quarter of a different scalene cone, having its apex at B. In like manner J S H C and F S J D are the two remaining cones, each of the four differing from the others in the amount of its obliquity or slant. Between the envelopes or outer coverings of these four quarter cones four plane triangles exist, the bases of which are the four sides of the rectangular base and the vertices of which are at the points G, H, J and F; as A G B, B H C, etc. The triangles which form the sides of the transition piece may be said to be inverted with reference to the cones, the envelopes of which form the angles or rounded corners of the same.

Now, divide each quarter of the plan of the round pipe into any convenient number of equal spaces, as shown by the small figures, and draw lines from the points of division in each quarter to the corresponding apex, as shown. These lines represent in plan the division of each conical surface into three plane triangles, and the true lengths of these lines may be obtained by using them as the base of a series of right angled triangles, the hypotenuses of which when found will be the true distances as measured between corresponding points of the finished article. These triangles may be most easily constructed by projecting the hights from the oblique elevation, as shown at eace side of the same, one group being made for each of the four cones to avoid confusion of lines. First drop lines from all of the points of division in F G H J parallel to M L, cutting the miter line drawn through L, and from the points on the miter line thus obtained draw horizontal lines (parallel to M N) indefinitely to each of the diagrams, as shown. From any points, as A^1, B^1, etc., on M N extended, draw perpendiculars, as shown, cutting the horizontal lines just drawn, and from their intersections with the perpendiculars set off on each the length of corresponding line of the plan. Thus, upon the lines drawn from points 1, 2, 3 and 4 on the miter line set off on each from the perpendicular B^1 the lengths 1 B, 2 B, etc., of the plan, as shown in the diagram, and finally draw 1 B^1, 2 B^1, etc., which distances will be the true distances across the pattern.

Had the vertical pipe been cut off square at L instead of obliquely the lengths of the several lines of the plan would have been set off from their respective perpendiculars upon a single line drawn through L, forming the bases of the several diagrams of triangles, and the hypotenuses drawn as before. In that case also the measurements for the lower edge of the pattern could have been taken directly from the spaces on plan F G H J. But since the oblique section necessarily has a longer perimeter than a right section, a true section on the miter line through L must be obtained.

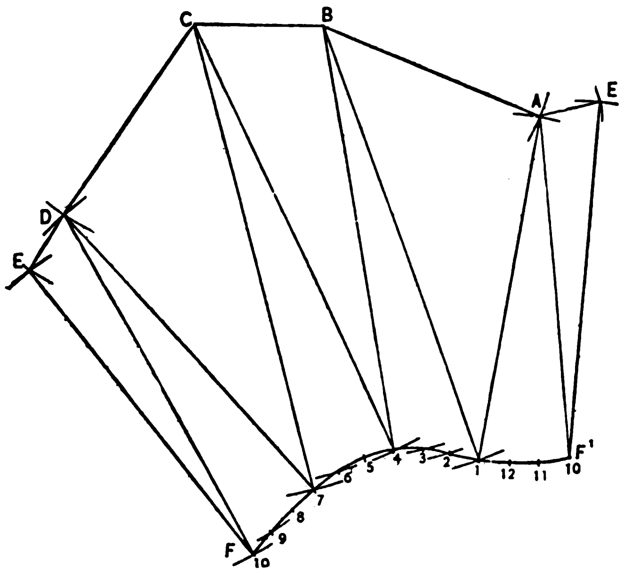


Fig. 40. The Pattern

To develop the section on the miter line first draw any line, as T V, parallel thereto, and from the several points on the miter line drop lines at right angles to T V, cutting the same, and extend them to one side or the other of T V to correspond with the lines of the plan F G H J with reference to the heavy center line. The lengths of the several lines are then made equal to corresponding lines of the plan, when a line traced through the several points thus obtained will give the required section.

To develop the pattern it is simply necessary to combine the dimensions now obtained, those of the elliptical section forming one side of the pattern and those of the plan of the rectangular base forming the other, while the distances across the pattern are taken from the diagrams of triangles. This part of the work will be very briefly described, because many patterns of this class have been given in these books, and all patterns obtained by triangulation are developed in the same general manner after the preliminary dimensions have been obtained. The pattern may be begun with either of the large intermediate triangles, as that shown by B H C of the plan. First draw C B of the pattern, equal to C B of the plan; then with B^1 4 of the diagram of triangles as radius and C of the pattern as center describe a small arc, which intersect with another arc drawn from B of the pattern as center with a radius equal to B^1 4 of the diagrams, thus locating the point 4 of the pattern. The three adjacent triangles on either side of C B 4 have their apexes at C and B of the pattern. Therefore, from C of the pattern as center describe three arcs the radii of which are respectively C^1 5, C^1 6 and C^1 7 of the diagrams. Now, from 4 of the pattern as center describe a small arc with a radius equal to 4 5 of the section T V, cutting arc 5, and from the point 5 thus obtained in the pattern describe a small arc with a radius equal to 5 6 of the section T V, cutting arc 6, and establishing the point 6 of the pattern. In the same manner the point 7 of this group is obtained and also 3, 2 and 1 of the group on the other side of C B 4, the disances of which from B of the pattern are equal to B^1 3, B^1 2 and B^1 1 of the diagrams. The large intermediate triangles corresponding to the sides C D and B A of the plan are next constructed in the same manner as C B 4, after which the two conical surfaces the centers of which are at D and A of the pattern are described in the same manner as those centering at C and B, and the pattern is completed by the addition on either side of one-half of the triangle corresponding to A F B of the plan, the joint being made on the line E F.

PATTERNS FOR SHIP'S VENTILATOR OCTAGON IN SECTION

This article explains how to develop the patterns for a ship's funnel or ventilator made from lateral pieces, similar to the perspective view shown in Fig. 41. First draw the outline of the side elevation as shown in Fig. 42 by 1, 6, 19, 24, and divide at pleasure the heel and throat lines of the ventilator into any number of equal spaces, in this case five on the heel, as shown by 2, 3, 4, 5 and 6, and five in the throat, as shown by 20, 21, 22, 23 and 24. Connect these points, as shown from 2 to 23, 3 to 22, 4 to 21 and 5 to 20. These lines represent a series of planes on which true sections must be found. Knowing these true sections, assume that each section as 1, 2, 23, 24; 2, 3, 22, 23; 3, 4, 21, 22; 4, 5, 20, 21; 5, 6, 19, 20 in the side elevation is a transition piece, with the various semi-profiles on either end. The true section on the line 1 24 in the side elevation in Fig. 42 is shown drawn in its proper position by C D E F 24, 13, 12 and 1. Through the center of this section draw the two diameters as shown, and directly in the center of these two lines draw the true octagon G H I J 19, 18, 7, 6, which represents the true section on the line 6 19 in the side elevation. In practice it is only necessary to draw the half sections.

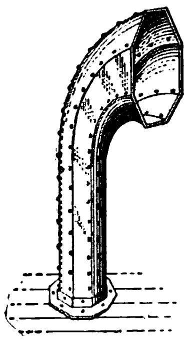


Fig. 41 Perspective of Ventilator

Now draw lines from the corners 1 to 6, 12 to 7, 13 to 18 and 24 to 19. Bisect each one of the planes in the side elevation, as shown by *a b c d e* and *f*. Take the distances from *b* to 2, *c* to 3, *d* to 4 and *e* to 5 and place them on the center line A° E° in the sections, measuring from and above the center point *h* and draw horizontal lines until they intersect the line 1 6 at 2, 3, 4 and 5 respectively. In a similar manner take the distances in the side elevation from *b* to 23, *c* to 22, *d* to 21 and *e* to 20 and place them on the center line A° E° measuring from and below the point *h*, and draw horizontal lines until they intersect the line 19 24, at 23, 22, 21 and 20 respectively.

Before the widths through the center points *b c d* and *e* in elevation can be found, a one-half vertical section through *a f* in elevation must be found as follows: At pleasure draw any vertical line alongside of the side elevation as shown by A^1 B^1 and from the various intersections *a b c d e* and *f* draw horizontal lines intersecting the vertical line A^1 B^1 as shown. Take the distances from *h* to *a* *h* to *f* in the sections, and place them as shown respectively by A^1 *a* and B^1 *f* in the vertical section. At pleasure draw the curved line from *a* to *f*, intersecting the horizontal lines previously drawn at *b c d* and *e*. These points, when measured horizontally to the center line A^1 B^1, give the true semi-widths through similar lettered points in the side elevation.

Measuring from the center line A^1 B^1 take the various distances to points *b c d* and *e* and place them in the sections, measuring from the center point *h*, as shown by *b c d* and *e*. Through these points at right angles to *h a* draw lines intersecting the line 12, 7 from 11 to 8 and intersecting the line 13, 18, from 14 to 17 respectively. From the various points on the line 12, 7, connect lines to the points on the line 1, 6. In a similar manner from the various points on the line 13, 18, connect lines to points on the line 24, 19. This diagram of sections then represents a series of 6 sections on the 6 planes shown in the side elevation by similar numbers.

The next step is to obtain the miter lines 7 12 and 13 18 in the side elevation. These are obtained by taking the distances in the diagram of sections from *b* to 11, *c* to 10, *d* to 9 and *e* to 8 and placing them on the planes in the side eleva-

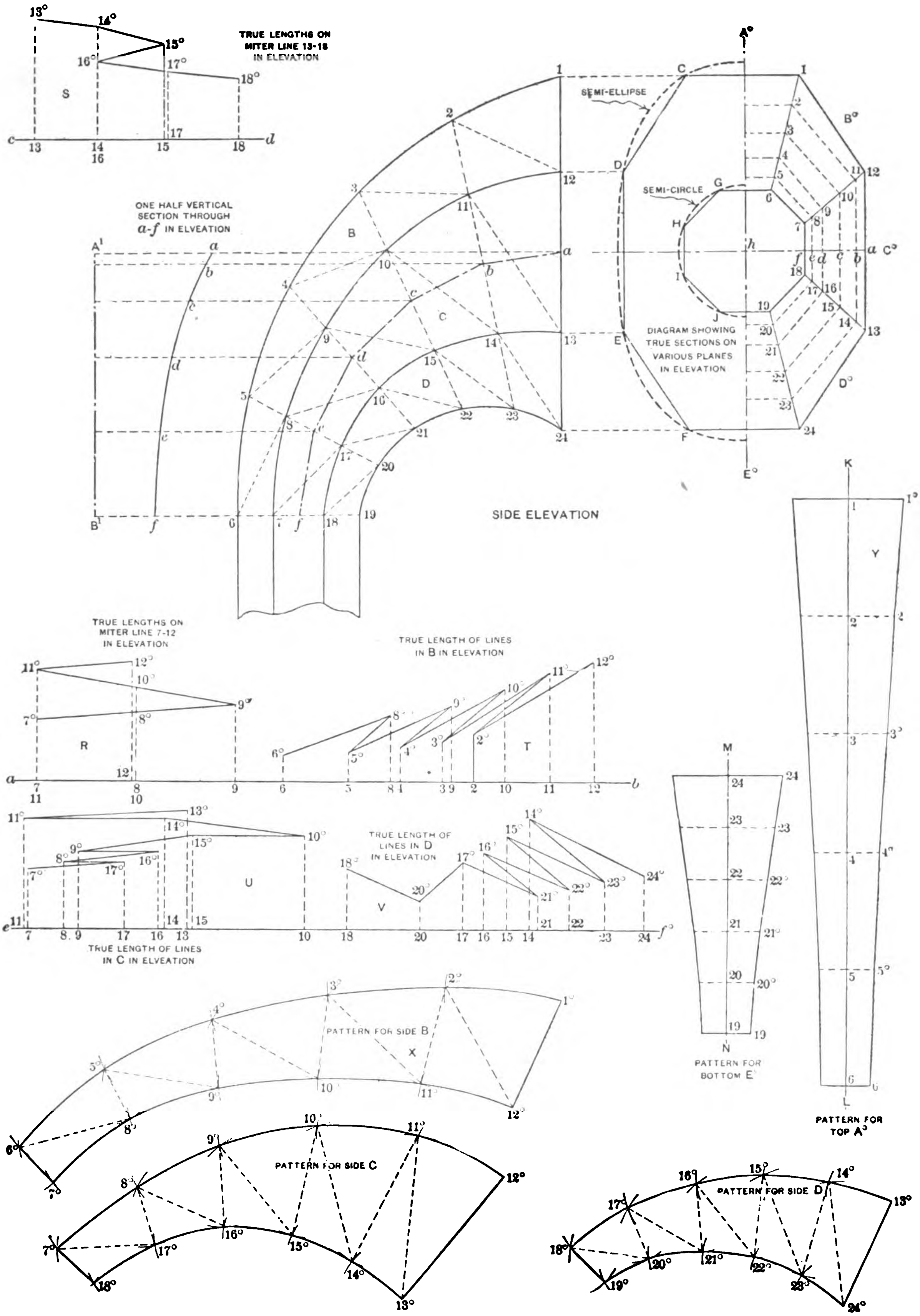


Fig. 42. Complete Process for Obtaining Patterns

tion from *b* to 11, *c* to 10, *d* to 9 and *e* to 8 and tracing a curved line as shown from 7 to 12. In a similar manner take the distances in the diagram of sections, from *b* to 14, *c* to 15, *d* to 16 and *e* to 17 and place them in the side elevation as shown from *b* to 14, *c* to 15, *d* to 16 and *e* to 17 and trace a curved line from 13 to 18. This completes the side elevation of the ventilator.

Draw the diagonal connecting lines in the side elevation as shown from 2 to 12, 3 to 11, 4 to 10, etc., until the last line 14 to 24 is drawn. The various solid and dotted lines in the elevation must then be considered as bases of sections the altitudes of which are found in the various horizontal distances in the diagram of sections to the right of the center line A° E. The true length of the curve 1 6 in the elevation on its miter line will be found when the pattern for the top is developed, while the true length of the curve 19 24 on its miter line will be found when the bottom pattern is laid out.

To obtain the pattern for the top of the ventilator marked A° in the diagram of sections proceed as follows: Take the girth of the outer curve 1 to 6 in the side elevation, and place it on the vertical line K L as shown by similar numbers, through which points, at right angles to K L, draw lines indefinitely. Measuring from the center line A° E° in the diagram of sections take the various distances to points 1, 2, 3, 4, 5 and 6 and place them on similar numbered lines in the pattern for top, measuring on either side of the center line K L. A line traced through points thus obtained will be the pattern for the top of the ventilator and the miter cut shown from 1° to 6° will give the true edge line of the upper curve of the lateral piece B in the side elevation.

To obtain the pattern for the bottom of the ventilator, take the girth of the lower curve 19 24 in the side elevation and place it on the line M N as shown by similar numbers, through which draw the usual measuring lines. Measuring from the line A° E° in the diagram of sections, take the various distances to 19, 20, 21, 22, 23 and 24 and place them on similar lines in the pattern for the bottom, measuring on either side of the center line M N. A line traced through the various intersections will be the pattern for the bottom marked E° in the diagram of sections and the miter cut 19° 24° in the pattern for bottom will be the true edge line of the lower curve of the lateral piece marked D in the side elevation.

To obtain the true lengths on the miter line 7 12 in the side elevation, take the distances from 7 to 8, 8 to 9, 9 to 10, 10 to 11 and 11 to 12 and place them on any horizontal line as *a b*, as shown from 7 to 8, 8 to 9, 9 to 10, 10 to 11 and 11 to 12. It will be noticed that the lengths are placed backward and forward over one another, so as to take up little space. At right angles to *a b* through the various points 7 to 12 erect perpendiculars as shown, making them equal to the horizontal distances in the diagram of sections, measuring in each instance from the line A° E° to points 7, 8, 9, 10, 11, and 12 respectively. For example, to make this perfectly clear, the distance of 7 8 in the side elevation has been placed on the line *a b* as shown from 7 to 8 in R. From points 7 and 8 in R perpendiculars are erected as 7 7° and 8 8°, equal respectively to the horizontal distances measured from the line A° E° in the diagram of sections to points 7 and 8. The distance from 7° to 8° in R then represents the true length of the line 7 8 in the side elevation. In precisely the same manner obtain the true lengths of the miter line 13 18 in elevation, as shown in the diagram S, by similar numbers on the line *c d*, the various hights in S are obtained from the horizontal projections measured from the line A° E° to similar numbers in the diagram of sections.

To obtain the true lengths in the lateral side B in the side elevation, take the various distances from 12 to 2, 2 to 11, 11 to 3, 3 to 10, 10 to 4, 4 to 9, 9 to 5, 5 to 8 and 8 to 6 and place them on the line *a b* in T, as shown by similar numbers, placing one distance over another as from 12 to 2, 2 to 11, 11 to 3, etc., so as to save space. From the various points vertical lines are erected, equal to the horizontal distances in the diagram of sections, when measured from the center line A° E° to similar numbers. For example, to find the true length of 4 10 in B in the side elevation, take this distance and place it as shown by 4 10 in T, from which points erect the perpendiculars 4 4° and 10 10°, equal respectively to the horizontal distances measured from the line A° E° in the diagram of sections to points 4 and 10. The distance 4° 10° in T then becomes the true length of similar numbered line in the side elevation. In this manner all the true lengths in B are obtained.

The true lengths in the lateral pieces C and D in the side elevation are obtained in a similar manner as shown by similar numbers on the line *e f*° in the diagrams U and V respectively. The true lengths having all been obtained, the patterns may now be laid out.

To obtain the pattern for the lateral piece shown by B in the side elevation or B° in the diagram of sections proceed as follows: Take the distance from 1 to 12 in the diagram of sections and place it on any line as 1° 12° in the pattern for side B, which will hereafter be called X. With 1° 2° in the pattern Y as radius, and 1° in X as center, describe the arc 2° which intersect by an arc struck from 12° as center, with 12° 2° in the true lengths in T as radius. With a radius equal to 12° 11° in R, and 12° in X as center, describe the arc 11°, which intersect by an arc struck from 2° as center and 11° 2° in T as radius. Proceed in this manner, using alternately first the divisions in the miter cut in Y, then the true length of the proper number in T; the true length of the proper line in R, then the true length of the proper number in T; the true length of the proper line in R, then the proper length from T, until the last line 6° 7° in X has been obtained, which is taken from 6 7 in the diagram of sections. A line traced through points thus obtained as shown from 1° to 6° to 7° to 12° in X will be the pattern for the two sides marked B in the side elevation.

When obtaining the pattern for the side C, the outer edge lines from 7° to 12° in C are obtained from similar numbers in the pattern X, while the lower edge lines 13° to 18° in pattern for side C are obtained from the true lengths in diagram S and the lengths of the connecting diagonal lines in the pattern for side C are obtained from the true lengths in diagram U. The edge lines from 13° to 18° in the pattern for the side D are obtained from similar numbers in the pattern for C. The edge lines from 19° to 24° in the pattern for side D are obtained from similar numbers in the miter cut in the pattern for the bottom E°, while the lengths of the diagonal connecting lines in the pattern for the side D are obtained from the true lengths in the diagram V. In both the patterns C and D the lengths of 12° 13° and 7° 18° in the former, and 13° 24° and 18° 19° in the latter, are obtained respectively from lines having similar numbers in the sides C° and D° in the diagram of sections.

Laps must be allowed for wiring at the mouth as well as for riveting the lateral pieces together, and if it is desired that the ventilator be made from round to elliptical, then the various patterns can be raised by means of the raising hammer to the desired shape, as is shown by the dotted lines in the diagram of sections.

PATTERN FOR A DIAMOND BOSS

The following deals with the method of how to obtain the pattern for the diamond boss shown in Fig. 43. B D shows part of the can, F E the diameter of the faucet and T U the extreme length of the boss. Directly below the elevation is the plan view of the boss, as shown by G C U J. Draw G U and C J. From K, as a center, draw the circle L S P N, representing the section on F E. Draw the diagonals T O and R M. As the four sides are alike it will only be necessary to develop the pattern for C S P U. Therefore divide the quadrant S P into four equal spaces, as shown by S 1, R 2 and P. In similar manner divide the profile of the can C U in elevation into equal spaces, as shown by C, 3, 4 and

U, and from these points drop lines intersecting C U in plan at C, 3, 4 and U. Draw lines from C to 1 and R; from R to 3, 4 and U, and from U to 2 and P. Then will these lines represent the bases of triangles which will be constructed with altitudes equal to various hights in elevation.

The reader should bear in mind that all the spaces contained in the circle in plan are on F E in elevation, while all the spaces contained in the side of the boss C U in plan are C U in elevation. Extend F E as F U^1, and from the various points C, 3, 4 and U in elevation draw horizontal lines, as shown. Take the various distances in plan as C S, C 1 and C R, and place them on F U^1, as shown by C S, C 1 and C R. From C erect C C^1, intersecting the line drawn from C in elevation. Draw lines from C^1 to S, 1 and R, which lines are the true lengths on similar numbers in plan. At any point, as R on the line F U^1, erect R R^1, cutting the line drawn from U in elevation. Take the various distances in plan from R to 3, R to 4 and R to U and place them in the diagram of triangles, measuring in each instance from the line R R^1 to similar numbered lines, as shown by 3, 4 and U, from which points draw lines to R. In similar

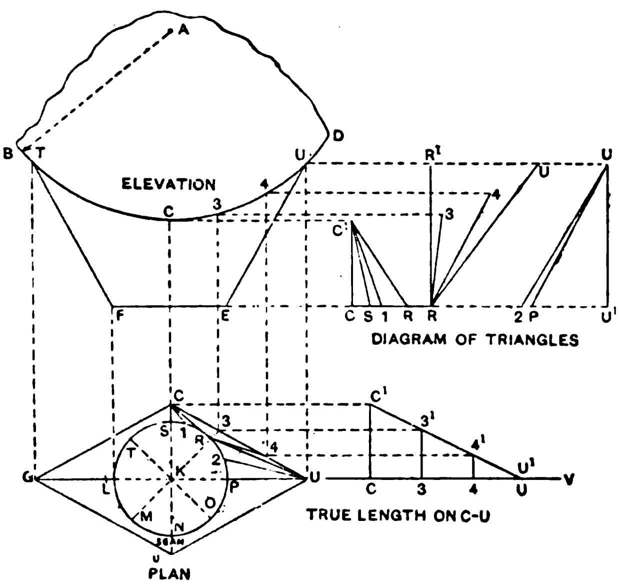


Fig. 43. Preliminary Work

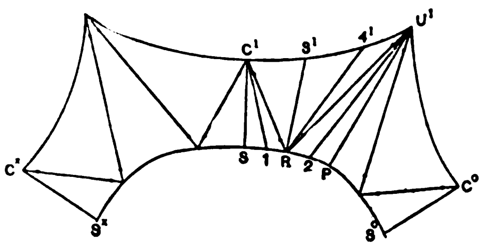


Fig. 44. The Full Pattern

manner erect U^1 U and set off U^1 P and U^1 2, equal in length to U P and U 2 in plan. Then draw lines in the diagram of triangles, as shown, from 2 and P to U. This completes the triangles necessary for the development of the pattern.

The next step is to obtain the true length on C U in elevation, for which proceed as follows: Extend G U in plan as C U, upon which place the stretchout of C U in elevation, as shown by similar figures on U V. From C, 3, 4 and U on U V erect lines which intersect by horizontal lines drawn from C, 3, 4 and U in plan, resulting in the intersections C^1, 3^1, 4^1 and U^1. Connect these points, obtaining the true length on C U in elevation.

For the pattern draw any line, as C^1 S, in Fig. 44, equal to C^1 S in the diagram of triangles in Fig. 43. With radii equal to C^1 1 and C^1 R and C^1 in Fig. 44 as center, describe the arcs 1 and R. Set the dividers equal to the spaces in S R in plan in Fig. 43, and, starting from point S in Fig. 44, step from S to arc 1 to arc R and draw lines from 1 and R to C^1. With radii equal to R 3, R 4 and R U in the diagram of triangles in Fig. 43 and R in Fig. 44 as center, describe the arcs 3^1, 4^1 and U^1. Set the dividers equal to the various spaces C 3, 3 4 and 4 U in plan in Fig. 43, and, starting from C^1 in Fig. 44, step to arc 3^1, 4 and U^1, respectively, and draw lines from these points to R. Finally, with radii equal to U 2 and U P in the diagram in Fig. 43 and U^1 in Fig. 44 as center, describe the arcs 2 and P, which intersect by lengths obtained from the divisions in R P in plan in Fig. 43. Draw lines from 2 and P to U^1 in Fig. 44. Then C^1 U^1 P R S is the one-quarter pattern. If the pattern is desired in two parts trace opposite the line U^1 P, as shown by $C°$ $S°$. If the boss is desired in one piece, with a seam at J N in plan in Fig. 43, trace the half in Fig. 44 opposite C^1 S, as shown.

PATTERN FOR A GARBAGE CHUTE

The following is the method of developing the pattern, in one piece, with seam on S T, having the square and round bodies in one piece, of what is termed a garbage chute. The square opening is to have a lid.

In connection with this problem, it must be said that while the pattern can be in one piece, another seam is necessary as at A′ 4″. Only the manner of obtaining the net pattern is exemplified. The allowing of laps for seams and method of joining the round collars and the making of the lid are governed by the gauge of material and the mode of manufacture. The lid pattern is simply a rectangular piece large enough to cover the 9×12-in. opening.

The procedure is as follows: Draw a 9-in. circle W to represent the pipe in plan. As the square body will be 9 in. wide, extend lines from the side of the circle. Project lines upward from the circle to be the sides in elevation of round body. From the center point o′ on the line S 4′ with the 45-deg. triangle draw the line O′ B′ indefinitely. Placing the triangle opposite to the position it had when drawing line O′ B′, move the triangle along till a point as A′ is 12 in. from B′ and outside the side line 4′ 4″ of the round body. It is understood, of course, that the design of this square body is a matter of choice, guided only by the requirement that design must permit of being made in one part. Connect point A′ with 4″ and point B′ with 4′, thereby completing the elevation. Drop lines from B′ and A′ to the plan and connect points B and C with O; also points A and D with 4, giving the plan.

Divide circumference of circle into equal parts as shown, and project these points to the elevation. The next step is to ascertain the true length of lines, as B 1, A 7, etc. Therefore project lines to the side as indicated from points 4″ and A′ and from B′ and 4′. Place points B″, X, A″ and Y on the line from X and Y, place the distances in plan as B 1, A 7, etc. Connecting in diagram M and P with points B″ and A″ gives the true lengths of the lines.

For the pattern draw any line as 4 B of Fig. 46, of a length equal to 4″ B″ of diagram M, Fig. 45. On the compasses take the distances in plan B C and from B of the pattern draw an arc. Swing line B 4 to this arc, which gives point B′. With points B and B′ as centers and the compass set to diagram M, strike small arcs, and on these arcs with the bow dividers adjusted to the space 0 1 of the plan step the stretchout of the profile W. The distances O B and 8 B′ was taken from 0′ B′ of the elevation.

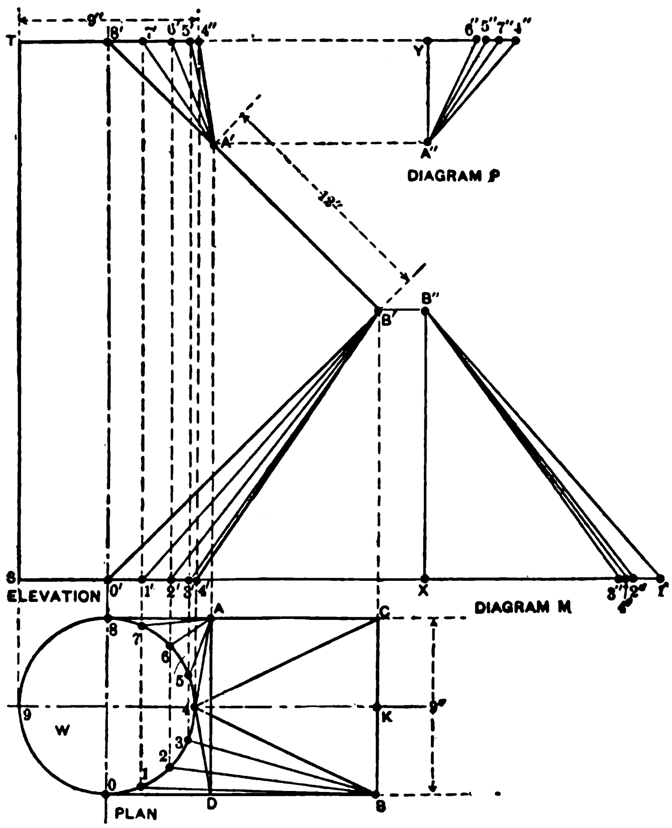


Fig. 45. Method of Obtaining Measurements for Patterns

With compasses set to B′ 8′ of the elevation and from points B and B′ strike small arcs. From 0 and 8 on these arcs place the distance 0′ 8′ of the elevation, giving in the pattern a duplicate of 0′ B′ 8′ of the elevation.

At right angle to the lines 0 0 and 8 8 draw lines on which are stepped the stretchout of profile W from 0 to 9, which can be accomplished in this case by using the space 0 1 four times.

From points 0′ and 8′ on lines 8 B′ and B 0, place the distances 8′ A′ of the elevation. With these points A and A as centers and compass set to diagram P strike arcs on which are stepped the distance 0 1 of profile W. From

4' and 4' draw arcs, taking the distance 4" A' of the elevation. From A and A, with the dividers spanning B K of the plan, prick the space on the arcs

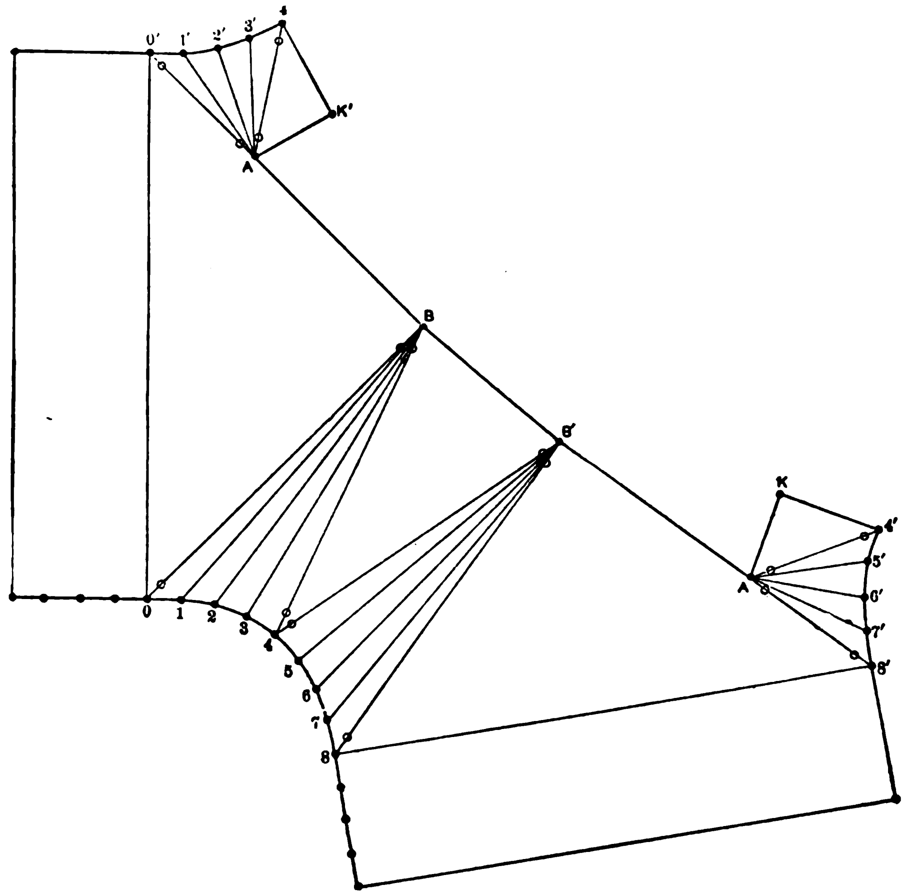


Fig. 46. Pattern for the Garbage Chute

obtaining points K and K'. This now is the pattern in one piece of the required article.

PATTERN FOR A CONCAVE SPIRAL CONVEYOR

The helical slide problem is of great interest to pattern cutters, and the following tells how to obtain the patterns for a concave so-called spiral conveyor when the center shaft is 8 in. in diameter as shown in the finished view in the accompanying illustration, Fig. 47 and the spiral conveyor has a projection of 18 in. with the surface concave upward as shown, with a vertical ledge 6 in. high. The hight of one revolution indicated by A has not been given, which can, however, be any desired measurement.

In this connection it is proper to say that the various lines of curvatures in the spiral represent various sections through a solid, and therefore only an approximate pattern can be developed, which will require some considerable skill with the stretching hammer to bring it to the desired shape. As the diameter from outer to outer edge of the conveyor measures 3 ft. 8 in., it is advisable to make a small model of clay, taking in, say, one-eighth of a revolution of the helix, and from this clay model make a female die of plaster paris. This plaster paris model is given a coat of shellac, when it can be sent to the foundry and an iron model cast, or if sufficient scrap zinc is at hand a die can be cast from zinc. After having the iron die made a male die is cast of lead.

Then, using the lead die as the base and the iron die as the top, the various pieces can be stamped, using a hard piece of a wooden slat to lay over the iron die, while a small sledge furnishes the stamping power. While this method is crude, it answers the purpose when the job is small.

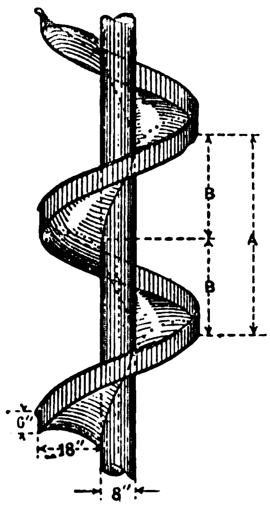


Fig. 47. View of finished Concave Conveyor

Of course where a considerable number of revolutions are needed, the work can be done more cheaply and accurately by sending measurements to any sheet metal stamping concern who will furnish estimates and guarantee an accurate fit along joints and intersections.

Assuming that the job is small and that it is desired to hammer up this work by hand in short sections, with the 6-in. vertical ledge in long sections, the method of obtaining the approximate pattern for the helix and the accurate pattern for the ledge is as follows:

Using A in plan as center, Fig. 48, describe the 8-in. circle, make the distance from 8 to 8′ 18 in., and with A as center and A 8′ as radius describe the outer circle. Divide the outer semi-circle in equal spaces (the closer the spaces the more accurate the pattern), in this case 8, as shown from 0′ to 8′, from which points draw radial lines to the center A, cutting the inner circle, as shown, from 0 to 8.

Draw the elevation of the center shaft as shown, and parallel to it draw any line as B C. As only a one-half revolution of the spiral will be shown in elevation, set off on B C, a distance 0 8, which will be equal to the hight of the desired half revolution, such as indicated by B in the finished view. As the semi-circle in plan has been divided into eight parts, then also divide the half revolution 0 8 on the line B C into eight equal spaces as shown.

From these points 0 to 8 at right angles to B C draw horizontal lines as shown, which intersect by lines drawn vertically from points 0 to 8 in the plan of the shaft. Trace a line through these intersections, as shown from D to E,

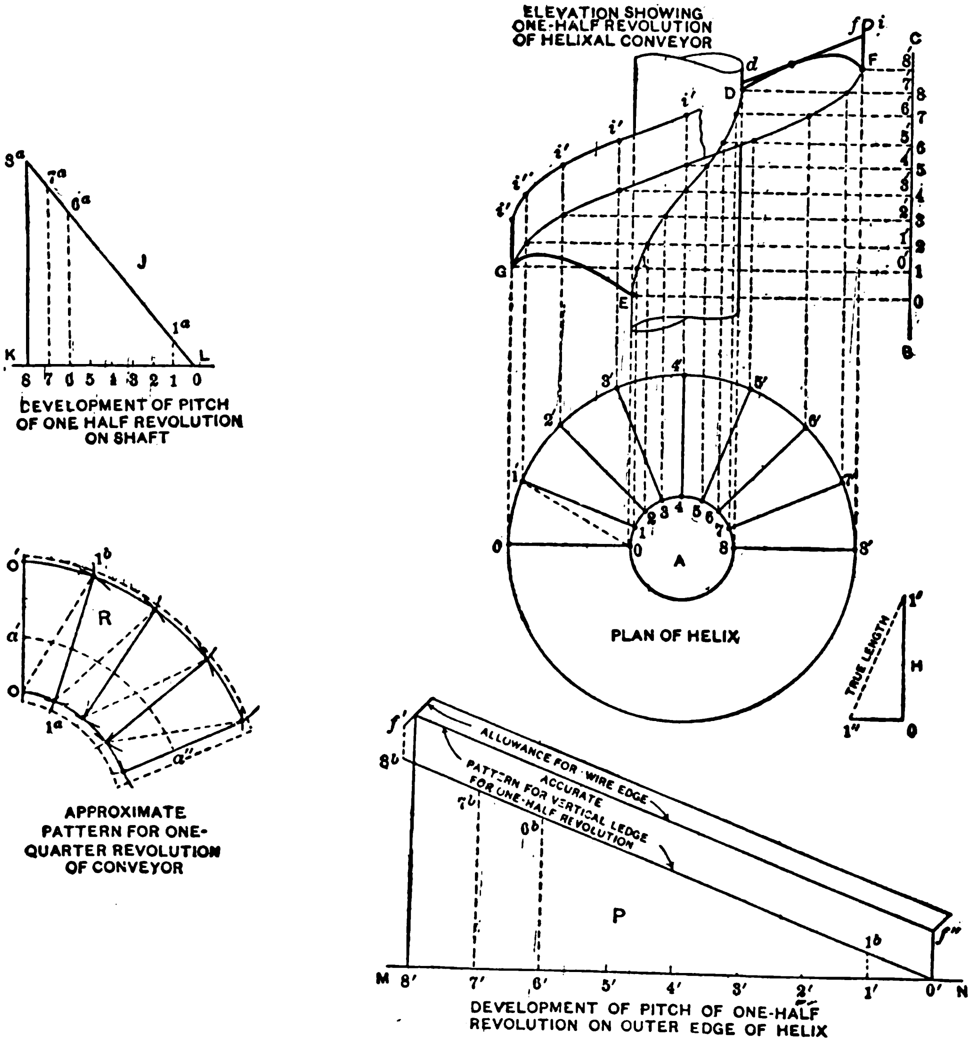


Fig. 48. Details of Pattern for a Concave Spiral Conveyor

which will, as can be seen, indicate the intersecting joint between the shaft and helix. Continuing further, from D draw the profile of the conveyor as shown from D to F to *i*.

From F draw a horizontal line, cutting the line B C at 8′, and from 8′ set off on the line C B the eight divisions from 8′ to 0′, equal to the divisions from 8 to 0, also on C B. At right angles to C B from points 0′ to 8′ draw horizontal lines, intersecting vertical lines erected from 0′ to 8′ in plan. A line traced from F to G will show the outer edge of the helix in elevation along the lower edge of the ledge at F. If the hight from F to *i* is set off on the vertical lines just erected from the plan, as from G to *i*′, and as indicated by the point *i*′, they will give the upper line of the wired edge of the ledge in elevation. These helical lines just obtained are not necessary so far as the pattern is concerned, but are shown here, so that in case, which is seldom in practice, it becomes necessary to make a completed view, as shown in the illustration, the method of projection will be understood.

As this concave helical surface is, in a measure, similar to a curved molding, a line must be averaged through the profile D F, which will give the proper flare and the proper girth or amount of material to make up the mold or concave D F. In drawing the averaged line or flare no rule can be given, as the nature of the mold must determine the pitch of the line *d f*. In this case the pitch or averaged line has been drawn as shown by *d f*, touching the mold at *a*. Measuring from *a*, obtain the girth of *a* D and *a* F, and place it as shown respectively by *a d* and *a f*.

In developing the approximate pattern, triangulation will be employed; therefore the length of *d f* in elevation shows the true length of the solid line shown in plan. The true length to opposite points in plan, as from 0 to 1′, must now be found by taking the distance of 0 to 1′ in plan and placing it in diagram H, as shown from 0 to 1′; from 0 erect the perpendicular 0 1″, equal to the vertical hight 0 1′ or two spaces on the line B C in elevation. A line drawn from 1′ to 1″ in H will be the true length of the dotted line in plan.

The next step is to find the true pitch of the one-half revolution of the helix around the shaft. On any horizontal line, as K L in diagram J, place the girth of the small semi-circle in plan, as shown by similar numbers on K L, at right angles to which, from point 8, erect the perpendicular 8, 8^a, equal to 0 8 on the line B C. Draw a line from 8^a to 0 in diagram J and from point 1 erect the perpendicular, cutting the pitch line at 1^a. 0 1^a then gives the true length of one of the spaces against the shaft in elevation as E to 1. In diagram J perpendiculars have also been drawn from points 6 and 7, giving the intersections 6^a and 7^a and shows that but one space is necessary, as they are all equal to 1^a 0.

The true length along the outer edge of the helix from F to G in elevation must now be found as follows: Upon any horizontal line as M N in diagram P, place the girth of the large semi-circle in plan (which represents the plan view of this outer helical edge), as shown by similar numbers from 0′ to 8′ on M N. From 8′ at right angles to M N erect the line 8′ 8^b equal to 0′ 8′ on the line B C in elevation. Draw a line from 8^b to 0′ in diagram P, and from points 1′, 6′ or 7′ on the line M N erect perpendiculars, cutting the pitch line 8^b 0′ at 1^b, 6^b or 7^b. Any one of these spaces will give the true distance of the spaces along the outer edge line of the spiral F G in elevation.

From this diagram P, the pattern for the vertical ledge for a one-half revolution can be obtained. Simply take the hight from F to *i* in elevation and place it on the two perpendiculars erected from 0′ and 8^b in diagram P, as shown by *f″* and *f′* respectively. Draw a line from *f′* to *f″*, and allow an edge for wiring as shown. Then *f′* 8^b 0′ *f″* is the desired pattern.

The approximate pattern for the concave spiral is developed as follows: Take the distance from *d* to *f* in elevation and place it in diagram R on the vertical line from 0 to 0′. Now, with radius equal to 0′ 1^b in diagram P, and 0′ in diagram R as center, describe an arc, which intersect by an arc, struck from 0 as center and 1′ 1″ in diagram H as radius. Now, with 0 1^a in diagram J as radius, and 0 in the pattern R as center, describe an arc, which intersect by another arc, struck from 1^b as center and 0 0′ in R as radius. Trace a line through points thus obtained, then will 0′ 1^b 1^a 0 be the pattern for one part or one-sixteenth of a full revolution shown in plan by 0′ 1′ 1 0.

In the pattern R four of these parts have been joined, thus giving an approximate pattern for a one-fourth revolution of the helical slide. As previously explained, it depends upon the diameter and shape of the conveyor to determine in how many sections the full revolution will be made up. The development obtained in diagram J is also used to obtain the intersecting line D E in elevation, by rolling up K L to an 8-in. semi-circle and placing 8 8^a vertically against the shaft, and scribing a line on the shaft, along 8^a 0 of diagram J. The line then obtained as shown from D E in elevation forms a guide line when hammering the short sections or stamping the one-eighth revolutions. If M N in diagram P is rolled up to a semi-circle (in this case to 3 ft. 8 in. diameter) the slant line 0′ 8^b will show the true edge line, indicated by F G in elevation, after which the outer edge of the conveyor can be trimmed if made by hand. The vertical ledge pattern is first wired, then rolled up in the rollers to the proper diameter, placing the ends 8^b *f′* or *f′* 0′ parallel to the lines of the rollers when rolling.

PATTERN FOR CANOPY IN A PARABOLIC REFLECTOR

This is a problem of a canopy having an elliptical base in which dimensions are given. The small end of the canopy is to fit the hole in the side of a parabolic reflector made by the intersection of a 2 1-16 in. circular cutter. To obtain the pattern for the canopy, the following interesting study of the problem has been made.

In the left half of the elevation of the accompanying illustrations, Fig. 49, the outlines are given of the submitted diagram, that is, the curve A B, the line A C, the position and size of the intersecting circular cutter, marked "profile of cylinder" and the included outline of the canopy. To the original drawing was appended the statement that the base of the canopy is an ellipse $2\frac{3}{8}$x$4\frac{3}{4}$ in. The diagram was carefully drawn to full size, but for convenience it is here reproduced to a scale of two-thirds its size, so that the full length of any dimension can be determined by adding to the same one-half itself.

As the parabolic curve is employed as the profile of reflectors, it is inferred that the curve A B of the diagram is one-half the profile of a concave reflector, and that the purpose of the canopy, which is placed within the reflector, is to carry away the gases or heat of a flame or other source of light placed immediately below it and in the optical focus of the reflector. Under these conditions the axial line A C of the reflector would no doubt, when in use, occupy a horizontal position, in which case the left side of the drawing would then represent the top. For convenience in representation and description the position shown has been taken.

Since the profile of a concave reflector is necessarily the same in all directions from its axis, its surface is such as would be generated by the curve B A by revolving the figure B A C about the line A C as an axis. The volume thus generated would be geometrically termed a solid of revolution. Considered as such it belongs to a class of figures termed conoids, from their somewhat conical shape, which figures have special names according to the character of the curves of their profiles.

The reference to the circular cutter leads one to suppose that the opening in the side of the reflector is made by mechanical means, as by the passing of a milling tool in a straight line across one side, cutting into the reflector to the depth shown by that part of the circle which lies inside the curve A B. In this respect the action of the cutter upon the reflector becomes, geometrically speaking, the intersection of a conoid by a cylinder. The development of the shape of the opening in the conoid, then forms the first requirement of the problem. This having been accomplished the second operation is the construction of a canopy, one end of which shall fit this opening, while the other end is an ellipse of the dimensions given above. In this respect the canopy is simply what, in ordinary pattern work, would be termed a transition piece, in shape somewhat resembling the frustum of a cone the axis of which is at right angles to the axis of the conoid, and the pattern must be developed by the methods of triangulation.

The curve A B—that is, any parabolic curve—may be extended indefinitely, but for the purpose of representation it has been terminated at B, drawing the horizontal line B D, representing a base of the conoid. In constructing a plan of the several parts, first carry lines from the points B and A to intersect the center line of the plan immediately above at B^1 and A^1, and from A^1 as center draw the

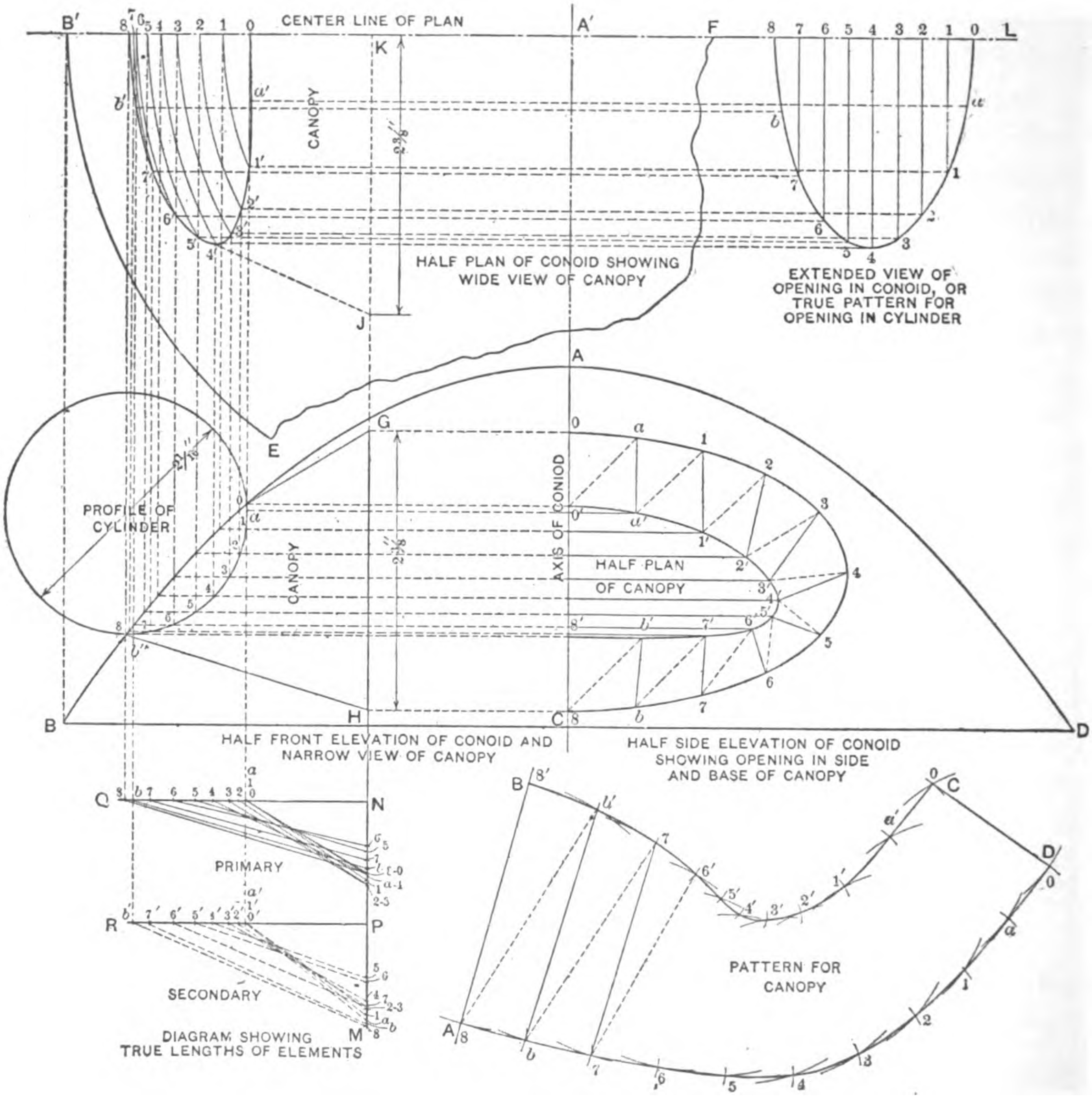


Fig. 49. Pattern for a Canopy in a Parabolic Mirror Involving the Intersection of a Cylinder and a Conoidal Surface

arc B^1 E, which will represent a portion of the circumference of the base, while the broken line E F will include in the half plan a sufficient portion of the conoid to show the hole made by the intersection of the cylinder or cutter.

The first part of the operation will consist in locating the points of penetration. In the revolution of the figure A B C on its axis, A C, previously referred to, it will be seen that each point in the curve A B will describe a circle. Divide that portion of the profile of the cylinder which passes inside the curve A B into any convenient number of equal spaces, as shown by the small figures, 0 to 8. Horizontal lines drawn through each one of these points crossing the elevation and continued to intersect that portion of the curve A B, lying between the points 0 and 8, will represent in the elevation the lines of a certain number of horizontal sections or circular planes, the positions of which in the plan it will be necessary to find. These positions may be determined by projecting lines from each of the intersections on A B, between 0 and 8, to the center line B^1 A^1 of the plan above, as shown by the small figures. These sections may be completed in the plan by describing circles through each one of these points on B^1 A^1 from the point A^1 as center. Portions of the circles only are shown in the plan, which are produced only far enough to receive the necessary intersections.

Project lines upward into the plan to intersect circles of corresponding number. Thus, a line erected from point 1 of the elevation will intersect the circle marked 1 in the plan at point 1′. Lines from points 2, 3, etc., on the profile of the cylinder will intersect circles of corresponding number at 2′, 3′, etc., of the plan. A line traced through these points of intersection will then give the true plan of the opening made in the side of the conoid by the circular cutter referred to.

The lines 8 H G O of the elevation represent the side or narrow view of the canopy as given in the problem and referred to above. As it was explained that the elliptical base of the canopy is $2\frac{3}{8} \times 4\frac{3}{4}$ in., if desired, in the problem one-half the wide view of the canopy may now be constructed by continuing the line G H into the plan and setting off thereon from the center line one-half the long diameter of the ellipse, $2\frac{3}{8}$ in., as shown by the line K J, drawing a line from J tangent to the curve of the opening just developed in the plan, which it touches near point 4′. This view of the canopy, the outlines of which are shown dotted, being beneath the shell of the reflector as viewed from above, is not absolutely necessary in obtaining the pattern, but will assist the eye in forming an accurate conception of the relative positions of the several parts.

What may be termed a plan of the ellipse is shown at the right in the elevation by the curve designated by the small figures 0 to 8 at the right of the center line A C. It is scarcely necessary to refer to the method of describing this curve, since it is required to be a true ellipse, and may therefore be described by any regular method for drawing an ellipse. For the purpose of completing a view from which the pattern for the canopy can be obtained, it will be necessary to obtain in connection with this a correct plan or view of the opening in its correct relation to the elliptical base. To do this carry lines from each of the points 1, 2, 3, etc., on the profile of the cylinder to the right, crossing the center line A C and extending them indefinitely. The position of each one of the numbered points in this curve will be derived from the plan of the opening previously obtained above by measuring the distance of each point from the center line B^1 A^1 of the plan and setting off the same distances on horizontal lines of corresponding number, measuring from the center line A C to the right as shown by the points marked 1′, 2′, 3′, etc., in this view.

While the curve B A D, with the base line B D, gives a general elevation of a conoid, that portion of the elevation to the left of the center line A C may for convenience be termed a front elevation of the conoid, and that portion to the right of the center line may represent a side elevation of the same as viewed from the left, or, in other words, as looking from the left through the opening in the side of the conoid, showing what may be termed a plan of the canopy, and is, therefore, a projection in a vertical plane at right angles to that of the view shown at the left.

Having now completed the plan and elevation of the opening in the conoidal surface, the second part of the problem is reached, viz.: developing the pattern for canopy, and the view just completed and termed its plan will be the most suitable view for this purpose. The plan view of the opening in the conoid, as developed from the points upon the profile of the cylinder, contains eight spaces, but as the result of the intersections the space from 0 to 1′ and the space from 7′ to 8′ are very much greater than the other spaces along this. It will, therefore, be advisable to divide each of these spaces into two equal or nearly equal parts. Owing to the peculiar character of this opening neither one of the views thus far obtained shows a full view of both these parts of the opening. That part of the curve from 8′ to 7′ of the plan is more fully shown in the plan of the conoid above the elevation from 8 to 7, and may be there divided into approximately equal spaces by the point *b*′ as shown, and the position on this point *b*′ may be transferred to the plan of the canopy in the same manner as previously described for the other points—that is, by measuring its distance from the line B^1 A^1 and setting the same distance off from line A C on a corresponding line in the plan of the canopy, which has been obtained by first dropping a line from the point *b* in the plan above to cut the profile A B of the elevation, as shown at *b*″, and carried thence into the plan of the canopy at the right. That portion of the curve from 0 to 1′ in the plan of the canopy is fully shown in the plan, and may be divided in that view into equal spaces as shown by the point *a*′.

The result of these operations is to give 10 spaces upon the outline of the opening forming the top of the canopy.

Divide the elliptical base into 10 equal spaces as shown by small figures and the letters *a* and *b*. To avoid confusion in the operations of triangulation it will be advisable to number these points to correspond with those opposite in the plan of the top as shown. The triangulation may then be shown in this plan by first connecting points of like numbers or letters by the solid lines *a′ a*, 1′ 1, 2′ 2, etc., as shown. This divides the surface of the canopy into a number of four-sided figures, which figures may be further divided into triangles by simply drawing diagonals, as shown by the dotted lines *a* 0′, 1 *a′*, 2 1′, etc. As is usual in these operations these four-sided figures are irregular in shape, and it is advisable for accuracy's sake to employ the shorter of the two diagonals and, if possible, to maintain the same order or direction throughout the course. In this case the diagonals were drawn from each figure on the ellipse to the next higher figure on the upper outline. This course, it will be seen, when continued beyond the points 6 6′ will necessitate drawing the diagonal the longer way. The order can be changed at this point if necessary, but is apt to cause confusion, and if the difference is not too great it is usually advisable not to reverse the order.

Two further operations are now necessary before the correct lengths of the various measurements indicated on the plan of the canopy can be obtained. First, a correct development of the opening in the side of the conoid (represented by the inner line of the plan of the canopy) must be obtained as a means of obtaining the correct stretchout of the pattern along its upper edge. This is shown in the small diagram at the right of the general plan, and is obtained by setting off on the center line B^1 A^1 of that view extended, as shown toward L, a correct stretchout of that portion of the cylinder indicated by the points 0 to 8, all as shown by the points 0 to 8 in the diagram referred to and designated as an extended view of the opening in the conoid. From each of the points on the line A′ L drop perpendiculars, as shown, and intersect them with lines carried horizontally from each of the points in the previously obtained plan of the opening in the conoid, as shown. The resulting curve 0, *a*, 1, 2, etc., will be the correct stretchout for what may be termed the upper edge of the pattern of the canopy. This would constitute a true pattern for the opening in the side of the cylinder were it necessary to obtain such a pattern.

As a means now of obtaining the correct lengths of the several solid and dotted lines drawn across the plan of the canopy it will be necessary, in the second place, to construct two diagrams, as shown immediately below the canopy at the left of the drawing. For this purpose extend the line G H downward, as shown, toward M, and at any convenient points, as N and P, draw the lines N Q and P R at right angles, as shown. From each of the points on the profile of the cylinder from 0 to 8 drop lines cutting these two perpendiculars, as shown by the small figures on each and partially indicated by dotted lines. From the point N on the line N M set off the lengths of the several solid lines of the plan of the canopy, as shown by the distances N *a*, N 1, N 2, N 3, etc., as shown by the small figures. By joining points in the line N M with those of corresponding number in the line N Q, the several oblique lines there shown will be the correct lengths of the primary elements. For obtaining the true lengths of the secondary elements set off from the point P on the line P M the lengths of the several dotted lines of the plan, representing the secondary elements in that view, making the distance P *a*, P 1, P 2, etc., equal to the distances *a* 0′, 1 *a*′, 2 1′, etc., of the plan, being careful that the designating figure on P M corresponds with that end of the line which intersects the base of the canopy. In this diagram the points on the line P M must be connected with points on the line P R, correspondingly with the connections made by the dotted lines of the plan, thus *a*′ on P M is connected to point 0 on P R, 1′ on P M is connected with *a*′ on P R, 2′ on P M is connected with 1′ on P R, etc. These lines shown dotted in the drawing will then represent the correct lengths of the secondary elements.

All the means necessary to develop the pattern for the canopy have been obtained, which may be accomplished in the following manner: Upon any convenient line, as A B, set off the distance 8 8 in the diagram of the primary elements, as shown by points 8 8′ in the pattern. From 8 of the pattern as center, with a radius equal to 8 *b*′ of the diagram of secondary elements, describe a small arc near *b*′ of the pattern, which intersect with a small arc drawn from 8′ of the pattern as center, with a radius equal to 8 *b* of the extended view of the opening, thus obtaining the point *b*′ of the pattern. With this point *b*′ as a center, with a radius equal in length to the line *b* *b* of the diagram of primary elements, describe an arc near *b*, which intersect with another arc drawn from 8 of the pattern as a center, with a radius equal to 8 *b* in the plan of the canopy, thus locating the point *b* of the pattern. Continue this operation using the lengths of the secondary elements in connection with the distances upon the extended view of the opening to determine the points on the upper edge of the pattern, and the lengths of the primary elements in connection with the spaces on the base of the canopy to determine the location of the points on the base of the pattern, until the points 0 0 have been reached, all as shown. Curves traced through the points successively obtained, as shown by B C and A D, will give the required pattern.

PATTERNS FOR SPIRAL INSIDE A CONE

To produce the pattern of a spiral on the inside of a cone revolving around a shaft, such as those used on the inside of a dust collector, to settle and draw the dust down to the receiver, proceed as follows :

As the various lines of curvature in the spiral represent various sections through a solid, only an approximately correct pattern can be obtained, the edges of which must be stretched with the stretching hammer to obtain the proper curvature, as shown by the elevation in the accompanying illustration, Fig. 50, similar to the thread of a screw.

The first step is to draw the plan and elevation as follows: Let A 3^v 7^v represent the elevation of the cone, and B C D E the shaft, the plans of both the cone and shaft being shown below. In this case it is assumed that the spiral is to make two revolutions in the vertical hight from 1 to 1 in elevation, although the same principles apply to any number of revolutions in a given hight.

Divide the plan of the cone into any desired number of equal spaces, in this case eight, bearing in mind, however, that the greater number of spaces employed the more nearly accurate will be the pattern. Number the various points in the plan of the cone from 1 to 8, from which points draw radial lines to the center A°, intersecting and dividing the plan of the shaft, also from 1 to 8. As the plan is divided into eight parts and there are to be two revolutions in the elevation, divide the vertical hight 1 1 in elevation into 2×8 or 16 parts, from 1 to 1° to 1, from which draw horizontal lines in the cone and intersect these by vertical lines erected from similar numbers in the plan of the shaft. A line traced through these intersections, from 1^x 1^t to 1^v will show the line of the spiral around the shaft. From the intersections in the plan of the cone, erect vertical lines intersecting the base of the cone in elevation from 1^v to 8^v, from which points radial lines are drawn to the center A, intersecting similar numbered horizontal lines. A line traced through these points of intersections by 1^x, 7^x, 3^x, 1^t, 7^t, 3^t, 1^v will be the line of the spiral around the inside of the cone, making two revolutions. This completes the elevation of the spiral which, however, is not necessary in the development of the pattern and may be omitted in practical work.

The plan of the spiral will be necessary, in the development of the pattern, and is obtained as follows: As the elevation contains 16 spaces, divide the line from 3^a to 3^b in plan into 16 parts, as shown by the small dots, and using A° as center and the distances to the various dots as radii describe circles which intersect the various radial lines in rotation at 1 2 3 4 5 6 7 8 1° 2° 3° 4° 5° 6° 7° 8° and 1, through which the spiral curve of the two revolutions are drawn. Draw

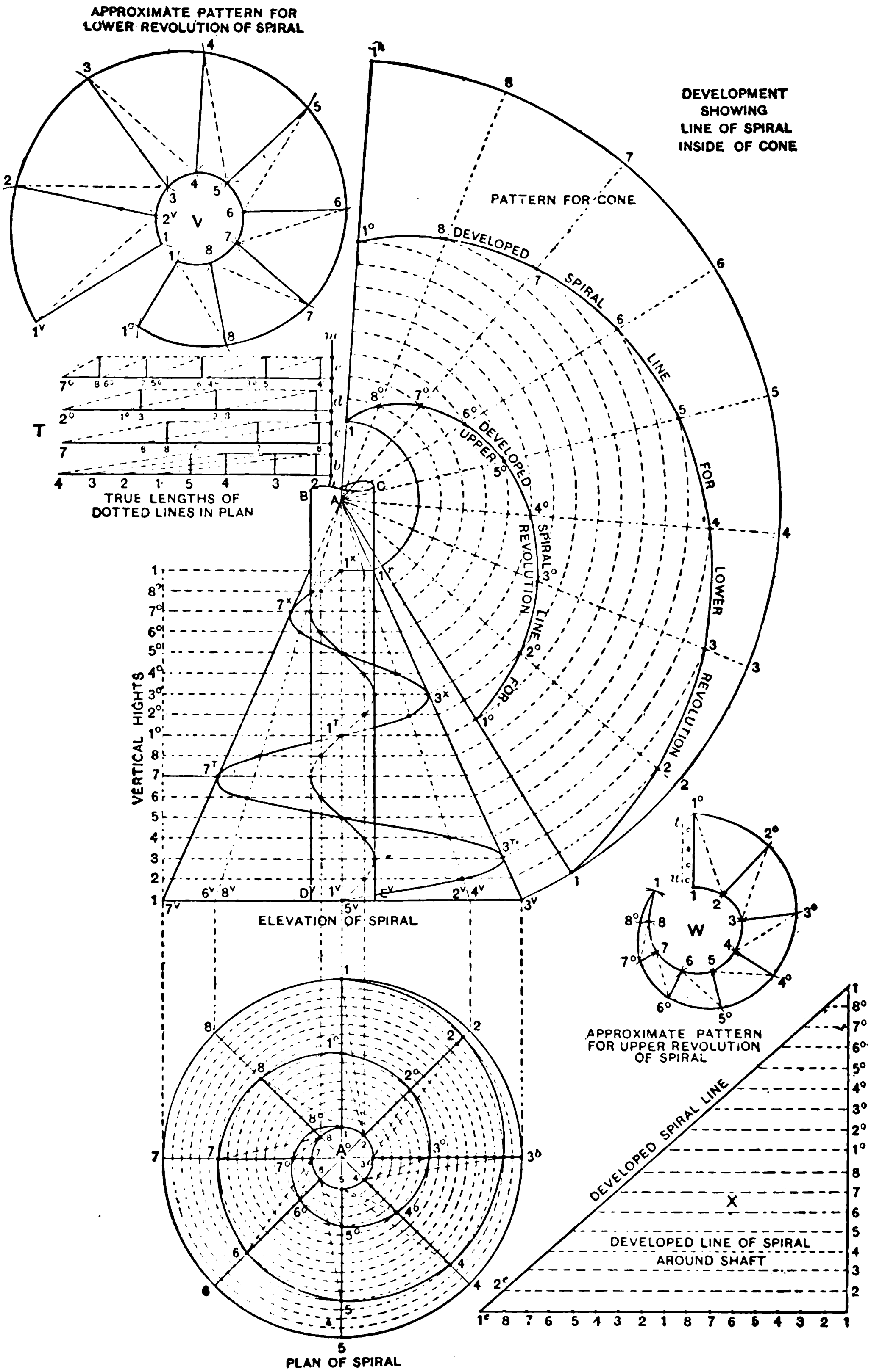


Fig. 50. Complete Procedure for Obtaining Patterns

the solid lines in the plan of the spiral which show their true lengths and carefully note how the dotted lines are drawn for the upper and lower revolution. Taking the space between 7 and 8 as an example, a dotted line is drawn from 8 to 7° for that space in the upper revolution, while a dotted line is drawn from 8 to 7 for the lower revolution, and so on until the last line from 2 to 1 is drawn. As the pattern will be developed by triangulation, then will these dotted lines in plan represent the bases of triangles, which will be constructed in T; the altitude of each will be equal to either one of the vertical spaces in the elevation which are shown by *b*, *c*, *d* and *e* in T. For example, to obtain the true length of the dotted line 7 8 in plan, take this distance and place it from 7 to 8 in T. From 8 erect a vertical line equal in hight to *c* and draw the slant line to 7, which represents the true length. In this manner are all the true lengths found in T as shown by similar numbers. In practice separate diagrams need not be made for each line, but it is done here to make each step clear. The next step is to find the edge line of the spiral around the shaft, as follows: As the spiral makes two revolutions, place double the girth of the shaft in plan on any horizontal line in X, as shown. From 1 erect the vertical line 1 1 equal to the vertical spaces in elevation, and draw a line from 1 to 1^e, which represents the developed spiral line, which could be rolled around the shaft and marked, thus giving the exact line of the spiral around the shaft in elevation. In X all of the horizontal lines have been carried over to the developed spiral line, which is not necessary in practice, one line being sufficient to give the true edge line as indicated from 1^e to 2^e, in developing the pattern.

The edge line of the spiral on the inside of the cone must now be found as follows: Using A in elevation as center, with radii equal to A 3^v and A 1^r, draw the arcs 1 1^h and 1^r 1, respectively. Set off on the outer arc 1 1^h the girth of the plan of the cone, as shown by similar numbers, and draw radial lines to the apex A. Where the various lines, drawn from the vertical hights on 1 1 in elevation, intersect the side of the cone 1^r 3^v, use these points as radii, and with A as center, describe arcs intersecting similar numbered radial lines in the pattern for cone, as shown by similar numbers. A line traced through these points will give the pattern for the cone, as well as the developed line of the spiral on the inside of the cone, for both revolutions. The pattern for the lower revolution of the spiral is obtained as follows: Take the distance of the solid line 1 1 in plan and place it, as shown by 1^v 1 in V. Now set the dividers equal to 1^e 2^e in X, and using 1 in V as center draw the arc 2^v, which intersect by an arc struck from 1^v as center, with radius equal to the slant line of the triangle 1 2 in T. Now set the dividers equal to the distance 1 2 in the developed spiral line for the lower revolution in Y, and with 1^v in V as center, describe the arc 2. Now with radius equal to the true length of the solid line shown by 2 2 in plan, and 2^v in V as center, intersect the arc 2 as shown. Proceed in this manner until the lower revolution in V and the upper revolution in W are developed. In both patterns the measurements along the inner curves are obtained from 1^e 2^e in X; the true lengths of the dotted lines in the patterns are obtained from the hypotenuse of the proper numbered triangle in T; the measurements along the outer curves in the patterns are obtained from the proper numbered developed spiral lines in Y, while the solid lines in the pattern are taken from the proper solid lines in plan. Thus V and W show, respectively, the patterns for the lower and upper revolutions of the spiral. Laps are allowed for joining, as shown by *t u* in W. As before mentioned the outer and inner edges will require stretching to bring out the proper curvatures in the spiral.

CYLINDER INTERSECTING A CONE

The following method of determining the miter line of this problem will be found to be accurate. Let A B C be the elevation of a right cone, which is intersected at right angles to one of its sides by the cylinder D E F G, which is of less diameter than the cone. Beneath the elevation draw a plan of cone and cylinder, as shown. At the outward end of the cylinder in both plan and elevation draw the profiles, which divide into spaces, as shown in Fig. 51. It is evident that the lines D E and G F intersect the cone respectively where these lines intersect the line A C, or at the points D and G. These points have also been numbered 1′ and 5′ to agree with the numbers in the profile. From the other numbers in the profile in the elevation draw lines parallel with the axis of the cylinder, intersecting A C. Continue these lines until they intersect the center line of the cone at the points 2″, 3″, 4″. From these points draw lines parallel with the base of the cone, intersecting the side A B, as shown.

Next locate the points 1′ and 5′ in the plan. This is done by dropping perpendiculars from these points to the line O X. It is necessary to locate the points 2 and 8 in plan, therefore from the point 2′ in elevation drop a line intersecting O X at 2′ in plan. Transfer the distance 2″ 2‴ in elevation from O 2‴ on the line O A. Then, using O 2′ as the semiminor axis and O 2‴ as the semimajor axis, draw the elliptical arc 2‴ 2′ 2^v, which intersect by lines drawn parallel to O X from the points 2 and 8 in the profile in plan, thus locating the points 2^v 8^v. Locate the points 3^v and 7^v and 4^v and 6^v in the same manner. Connect these

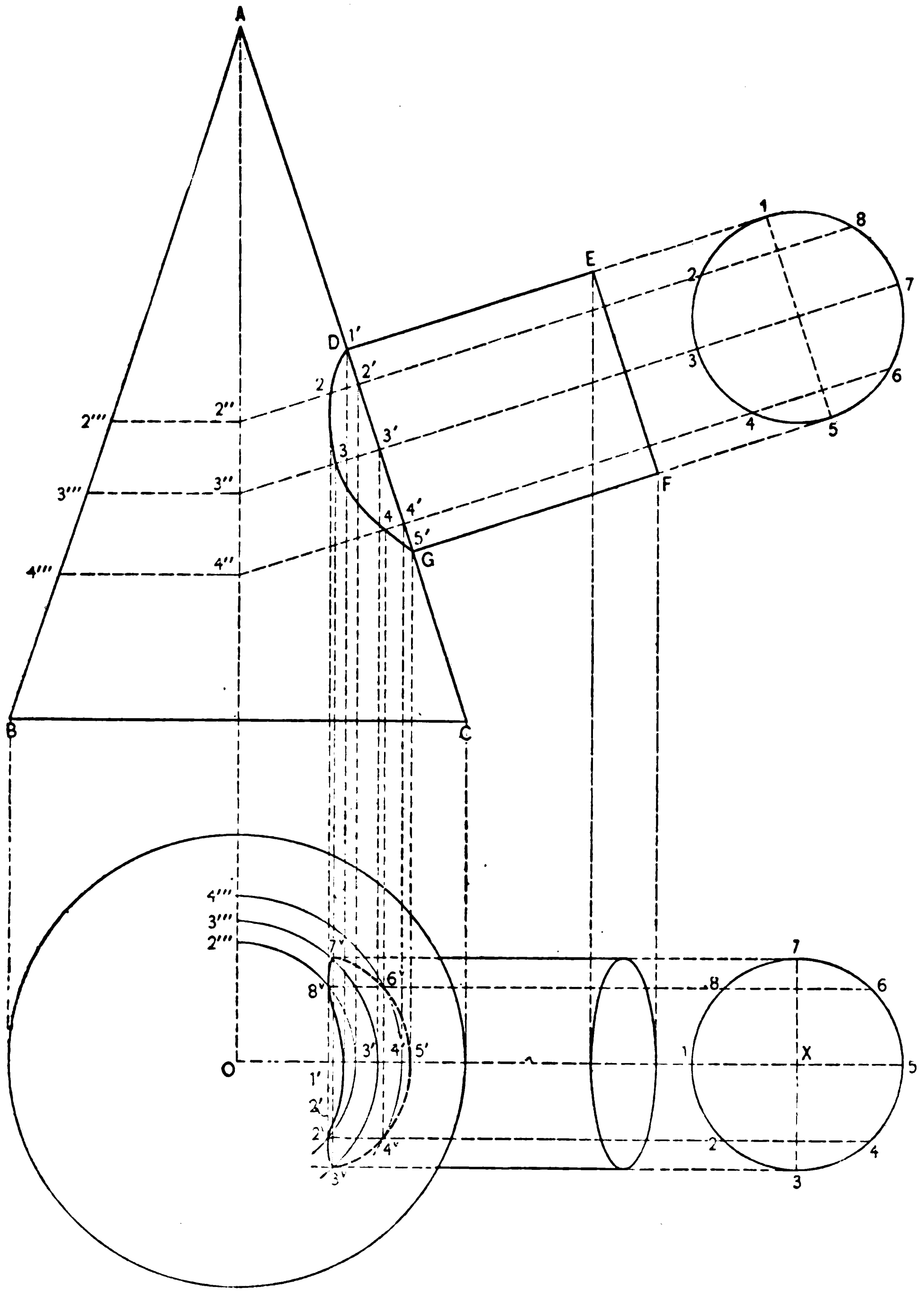


Fig. 51. Plan and Elevation of Cone and Cylinder

points by a curve, thus obtaining the plan of the miter line, as shown. To obtain the location of the points 2^v, 3^v and 4^v in elevation erect lines from these points in plan until they intersect lines drawn from the points in the profile in elevation bearing similar numbers. At these intersections locate the points, as shown by 2^v, 3^v and 4^v. The locations of the points 8^v, 7^v and 6^v are respectively the same as shown by 2^v, 3^v and 4^v. Draw the miter line $1'$ 3^v $5'$, as shown in elevation. The patterns for the cone and for the cylinder may now be obtained by the usual methods.

A CONE INTERSECTED BY A HORIZONTAL CYLINDER

The first step in making the drawing of the object shown in perspective in Fig. 52 is to draw the front elevation of the right cone, as is shown by A B C in Fig. 53 in which A B is the base of the cone and C D the altitude. Next draw the side elevation, as shown by E F G.

To find the line of the axis of the cylinder, produce A B to I, making B I of the required length. At I erect I R perpendicular to A I, making I R equal to the radius of the cylinder. Through R draw a horizontal line, as shown by 3^2 R 3. It is now desired to find the line of the axis in the side elevation. To do this bisect G E F, and where the line of bisection intersects with R 3 is the projection of the center of the cylinder. From K drop the perpendicular K 5, then with a radius equal to K 5 describe the circle 5 7 2; divide this circle into a number of equal parts, as shown by the small figures, locating another point, x, at the point of tangency between the cone and the cylinder. From these points draw horizontal lines intersecting B C and C D, as shown by similar figures. Continue the line I R until it intersects 1 $1'$ at H, then will 5^2 I H 1^2 represent the front elevation of the cylinder.

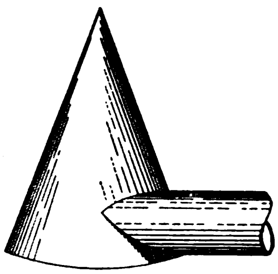


Fig. 52. Perspective View of Cylinder and Cone

To draw the plan directly under D, with O as center and with a radius, O E', equal to D B, draw a circle. From E' on the vertical line O E' lay off E' 5^2, equal to E 5 in the side elevation. Through 5^2 draw a horizontal line to K', on which point with a radius equal to K 5 in the side elevation, draw a circle, as shown, which divide into the same number of parts as was the circle in the side elevation, taking pains to locate the point 1 at 90 degrees to the left of where it is located in the side elevation. Locate the point x at its proper distance between the points 7 and 8, as shown. From these points on the profile draw lines into the plan, as shown. Draw M N directly under H I, then will 3^2 M N 7^2 be the horizontal projection of the cylinder.

To find the miter line between the cone and the cylinder, project onto the horizontal line 0 5′ in plan the points 1′, 2′, x', 3′, 4′ and 5′, in front elevation, as is shown by similar numbers in plan. Through these points, and with O as center, draw arcs, as shown, intersecting the lines bearing similar numbers drawn from the profile K′. At the points where the lines of the same number intersect, locate the points as shown by the numbers 1, 2, 3, 4, 5, 6, 7, x and 8. Trace a curve through these lines, as shown, then will this curve be the plan view of the miter line.

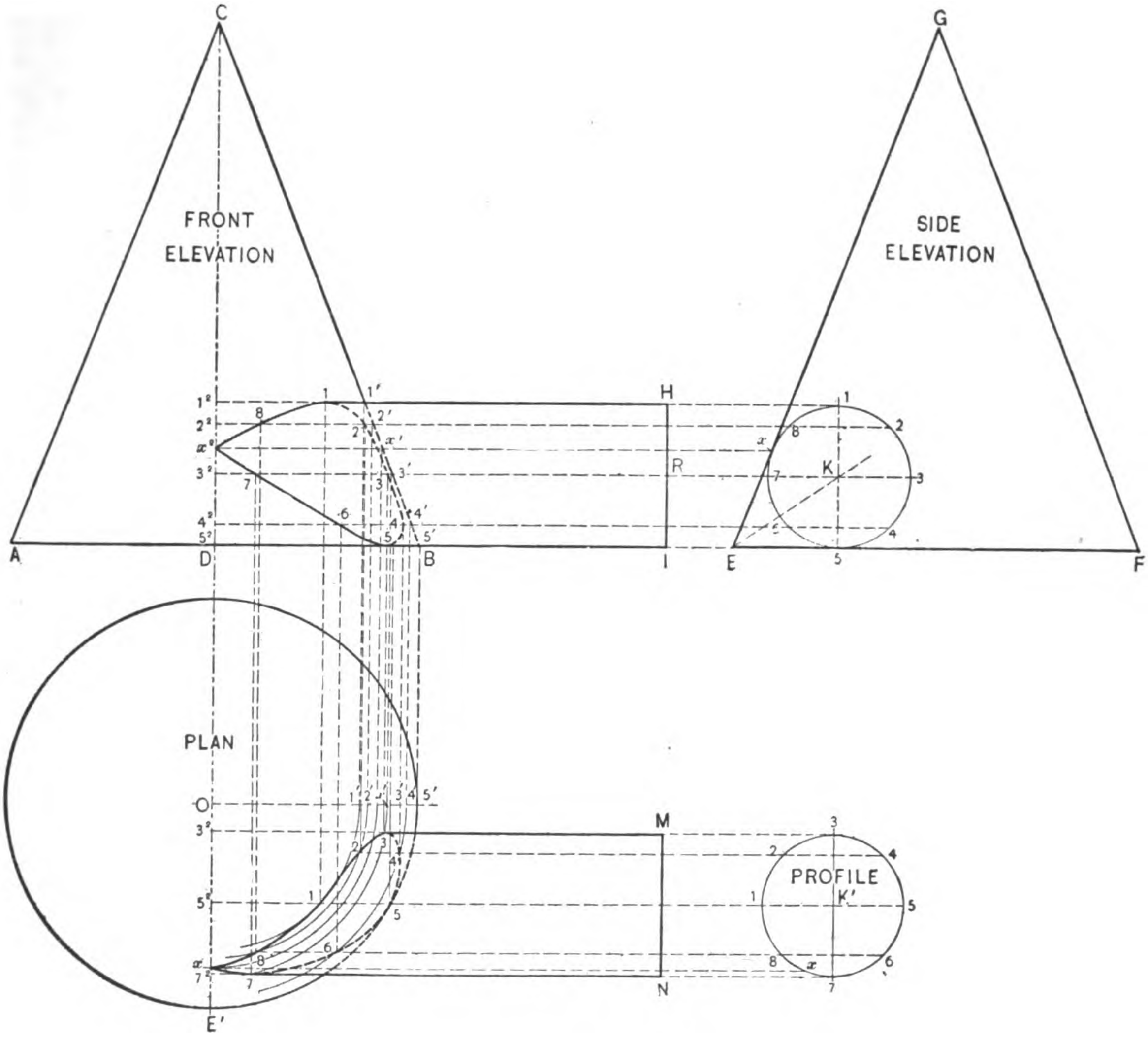
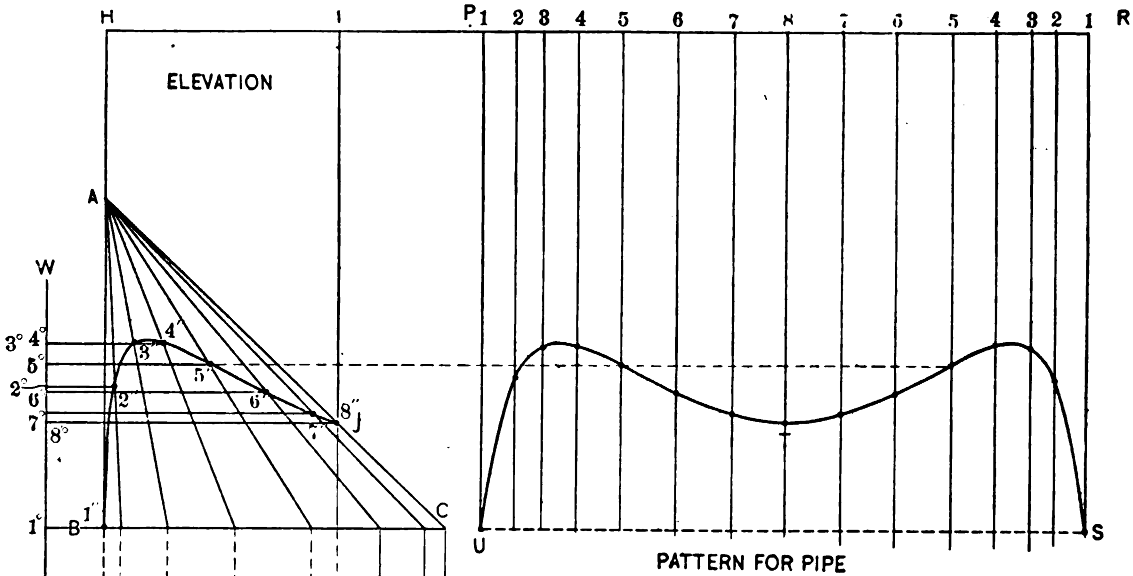


Fig. 58. Determining the Intersecting Lines

To find the elevation of the miter line erect perpendiculars from the point on the miter line just obtained into the elevation. Where these points intersect the horizontal lines drawn from the points in the circle K bearing the same numbers, locate similarly numbered points as shown by 1, 2, 3, 4, 5, 6, 7, *x*, 2 and 8, tracing a curve through these points, then will this curve show the front elevation on the miter line. To develop the patterns for the cylinder and cone, proceed according to the usual methods.

INTERSECTION OF ELLIPTICAL PIPE AND SCALENE CONE

This is a solution of the intersection of an elliptical pipe and a scalene cone, as in Fig. 54, where A B C is the elevation of the scalene cone, and D E F G its



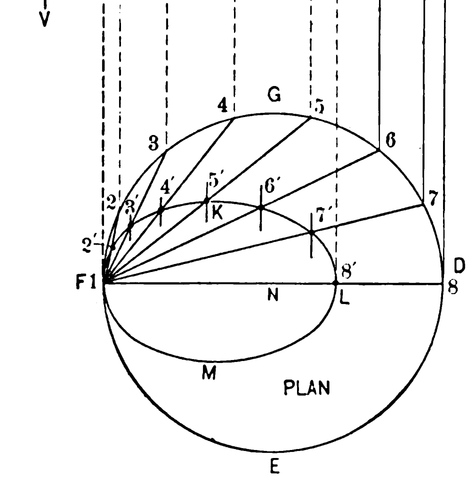


Fig. 54. Method of Obtaining Miter Lines and Pattern

plan, taken on the line B C of the elevation, while H I J B shows the outline of the elliptical pipe placed in plan, as shown by K L M F. To obtain the miter line in elevation between the pipe and cone proceed as follows: Divide one-half of the plan F G D into equal spaces, as shown by the small figures 1 to 8, and draw lines to the apex F in plan, intersecting the half plan of the pipe F K L at points 1, 2′, 3′, 4′, 5′, 6′, 7′ and 8′. At right angles to F D and from points 1 to 8 on F G D erect lines intersecting the base line of the cone in elevation, as shown, from which intersections draw lines to the apex A. Next intersect these radial lines in elevation with others (not shown) draw from the intersections 1, 2′, 3′, 4′, 4′, 5′, 6′, 7′ and 8′ on F K L in plan at right angles to F D, intersecting similar numbered lines in elevation shown by 1″ to 8″. Trace a line, as shown by B J, through points thus obtained, which will show the miter line or intersection between the scalene cone and elliptical pipe. Parallel to A B draw the line V W, upon which place the various hights of the intersections in the miter line B J from points 1″ to 8″ at right angles to A B, as shown from 1° to 8° on V W. This will be used in the diagram of triangles in Fig. 54.

For the pattern for the elliptical pipe draw any line, as P R, in line H I, upon which place the stretch-out of the elliptical section F K L M in plan, being careful to carry each space separately onto the line P R, as shown from 1 to 8 to 1, because the spaces in F K L M in plan are unequal. At right angles to P R and from the small figures draw lines, as shown, which intersect with others (not shown) drawn at right angles to H B in elevation from similar numbered intersections on the miter line B J. Trace a line through points of intersection thus obtained; then will P R S T U be the pattern for the elliptical pipe.

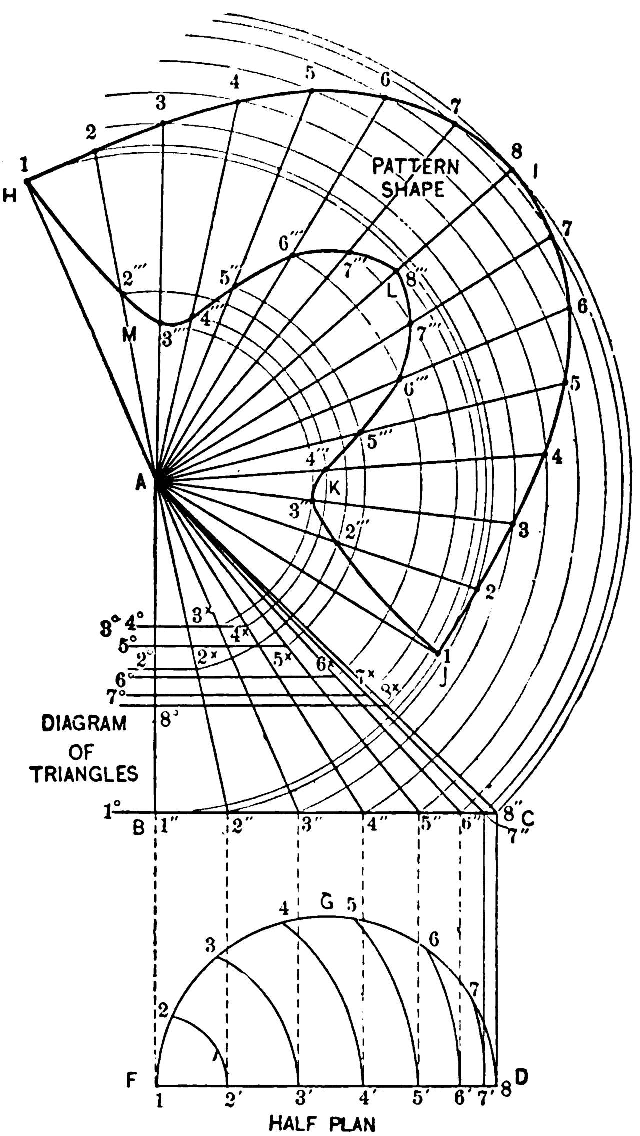


Fig. 55. Method of Obtaining Scalene Cone Pattern

Before obtaining the pattern for the scalene cone it will be necessary to obtain a diagram of triangles from which the pattern is obtained, for which proceed as follows: Let the triangle A B C and the half plan F G D, with the various intersections on same in Fig. 55 be a reproduction of the triangle and half plan having similar letters in Fig. 54. Now, with F as center, Fig. 55, and radii, equal to

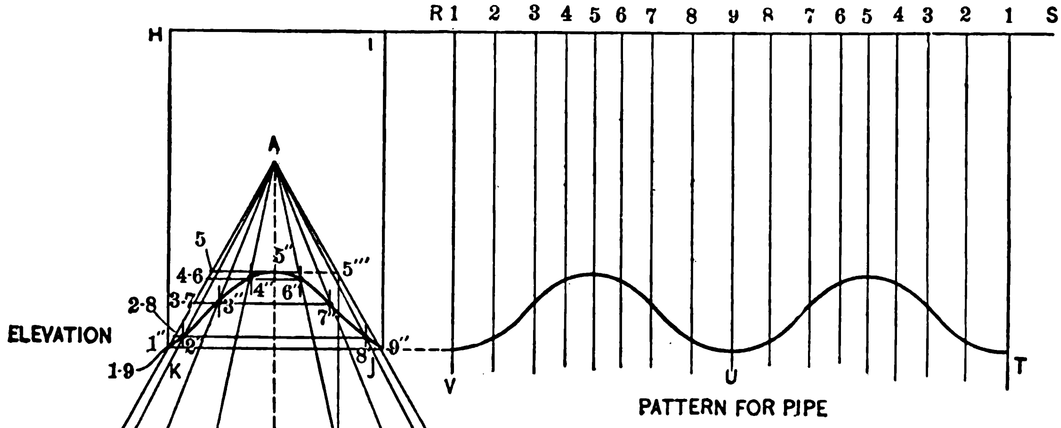
F 2, F 3, F 4, F 5, etc., to F 7, draw arcs intersecting the line F D at points 2′ to 7′. These various lengths represent the base lines of the various triangles which will be constructed by erecting lines at right angles to F D from points 1, 2′, 3′ 4′, 5′, 6′, 7′ and 8, intersecting the base line B C at 1″, 2″, 3″, 4″, 5″, 6″, 7″ and 8″; from these intersections draw lines to the apex A. Take the various hights on V W in elevation, Fig. 54, and place them on the line A B of Fig. 55, placing the point 1° on the point 1″ on the base line B C. Then at right angles to A B and from the various points 1° to 8° draw lines, as shown, intersecting the hypotenuses of triangles having similar numbers, as shown by intersections 2^x to 8^x. With A as center and radii equal to A 1″, A 2″, A 3″, etc., to A 8″, draw arcs, as shown. Now set the dividers equal to the spaces contained in the half plan F G D, and, starting on the arc 1″ at 1, step from one arc to another, or, in other words, starting on the arc 1″ at 1, step to arc 2″, then to 3″, until the point 8 is obtained on arc 8″, which repeat, going backward, until the point 1 on the arc 1″ is obtained. Trace a line, as shown by H I J. Again using A as center and A 2^x, 3^x, 4^x, 5^x, 6^x, 7^x and 8^x as radii, intersect radial lines in pattern drawn from the small figures on H I J to the center A, thus obtaining the intersections 2‴ to 8‴ to 2‴ in pattern. Trace a line, as shown by J K L M H, and H I J K L M H will be the pattern for the scalene cone.

INTERSECTION OF RIGHT CONE AND ELLIPTICAL PIPE

Herein is a solution of a problem based upon the intersection of an elliptical pipe and a right cone, as shown in Fig. 56. Here A B C is the elevation of the cone and D E F G its plan struck from the center P, while H I J K is the outline of the pipe in elevation meeting the cone at J and K, the plan being L M N O. The first step is to obtain the miter line between the cone and pipe. Therefore divide the half plan, F G D, into equal spaces, as indicated by the small figures 1 to 9. From these small figures draw radial lines to the center P, intersecting half of the elliptical pipe L M N at 1′, 2′, 3′, 4′, etc., to 9′. From the intersections 1 to 9 on F G D, and at right angles to F D, draw lines intersecting the base of the cone B C. From these intersections draw lines to the apex A, which intersect with vertical lines (not shown) drawn from intersections having similar numbers on L M N in plan, as shown by 1″, 2″, 3″, 4″, 6″, 7″, 8″ and 9″ in elevation.

To obtain the intersection 5″, use P in plan as center and P O or P 5′ as radius, and strike the arc O 5, intersecting the line F D at 5. At right angles to F D, and from 5, erect the vertical line intersecting the side of the cone A C at 5‴. From 5‴, at right angles to 5‴ 5, draw a line intersecting the radial line 5′ in elevation at 5″. Then through the intersection obtained in elevation trace a line, as shown by K J, which will represent the line of joint or miter between the elliptical pipe and cone.

For the pattern for the pipe, draw any line, as R S, in line with H I of the elevation, and upon the line R S place the stretchout of the elliptical pipe L M



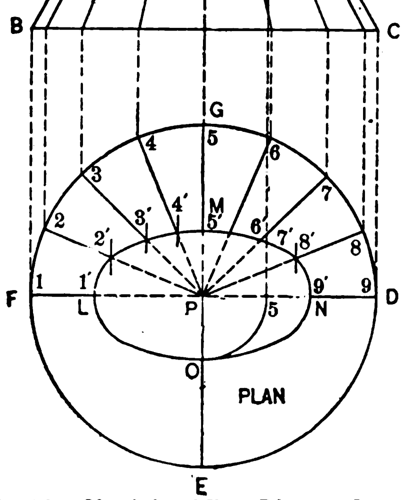


Fig. 56. Obtaining Miter Lines and Pattern for Pipe

N O in plan, being careful to carry each space on L M N separately on R S, as shown by the small figures 1 to 9 to 1. At right angles to R S, and from these figures, draw lines, as shown, which intersect with others (not shown) drawn from intersections having similar numbers on the miter line K J at right angles to A G. A line traced through points thus obtained, as shown by R S T U V, will be the pattern for the elliptical pipe joining the right cone.

For the pattern for the cone proceed as follows: At right angles to A G in elevation, and from the various intersections in the miter line K J, draw lines until they intersect one side of the cone, as A B, as shown by 1 9, 2 8, 3 7, 4 6 and 5. Now, using A B as radius and A in Fig. 57 as center, describe the arc 1 1′, upon which place the stretchout of twice the amount of the half circle in plan,

Fig. 56, as shown from 1 to 9 to 1′ of Fig. 57. From these points draw radial lines to the center A, as shown, and with radii equal to A 1 9, A 2 8, A 3 7, A 4 6, and A 5, and A of Fig. 57 as center, describe arcs intersecting radial lines of similar numbers, as shown. A line traced through the points of intersection

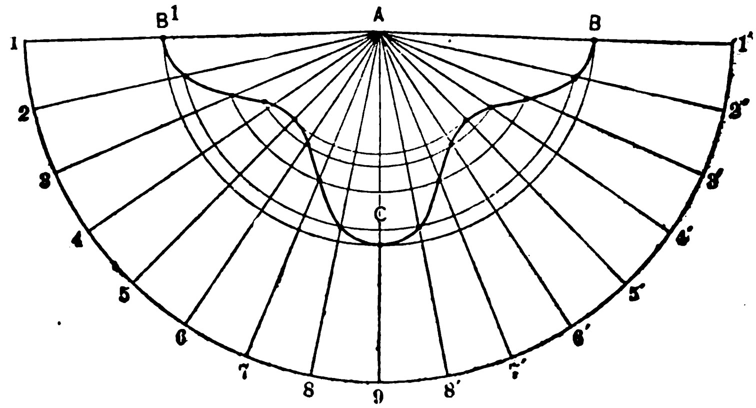


Fig. 57. Obtaining Pattern of Cone

thus obtained, as shown by B C B[1], will be the miter cut joining the elliptical pipe, while 1 B[1] C B 1′ 9 1 will be the pattern shape for the right cone.

PATTERNS FOR INTERSECTING ELLIPTICAL CONES

In Fig. 58 there is presented an interesting problem in intersections. In Fig. 59 is shown an enlarged view, and the method of drawing the plan elevation and miter lines. Let A, B, C, D be the side elevation of the frustum of an oblique cone and E F G H a side view of the frustum of a right elliptical cone. Let O P W S represent the plan view on the lines of base, D C, of the elevation struck from the center V, and K L M N a section of the line G F in elevation, the ellipse being drawn by any convenient method. Extend the lines C B and D A of the elevation until they meet, thus locating the apex J. Divide the plan O P W S into any number of equal spaces as shown by the small figures 8 to 15 and as 15 or W represents the apex of a cone in plan, draw lines from the spaces obtained, O P W S, to 15 or W as shown. At right angles to O W and from the divisions in O P W draw lines upward intersecting the base line D C in elevation at points 8′ to 15′. From these points on the base line P C draw lines to the apex J cutting the line of the upper base A B at points shown from 8″ to 15″. A plan view of the upper base of the frustum A B may be obtained if desired in the following manner: From the intersections 8″ to 15″ and at right angles to D C draw lines (not shown in diagram) intersecting radial lines of similar number in plan, as shown by the small dots. The line T V U W traced through these points will give the required plan.

Extend the lines G H and F E in elevation until they meet in the apex I which will be directly in line with Q, the center of the ellipse K L M N. Divide one-half of this ellipse into equal spaces as shown by the small figures 1 to 7. Through the small figures and at right angles to K M draw lines intersecting the base line G F as shown from 1′ to 7′. From these points draw lines to the apex I, cutting the radial lines in the oblique cone as shown. The next step will be to obtain sections of the oblique cone on the radial line drawn to I. It should be understood that the sections of the oblique cone need be extended only to the line 10′ 10″ in elevation or 10 W in either side of the plan, as they will then be sufficient to obtain the intersection in plan between the elliptical and oblique cones. If, however, the elliptical cone was wider and longer on H E in elevation, thus cutting deeper into the oblique cone, the section lines in plan could be extended as much as required by the same method. To obtain the lines of these sections and plans proceed as

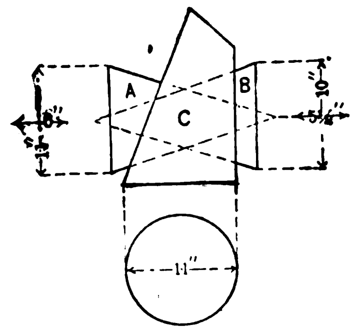


Fig. 58. The Presented Problem

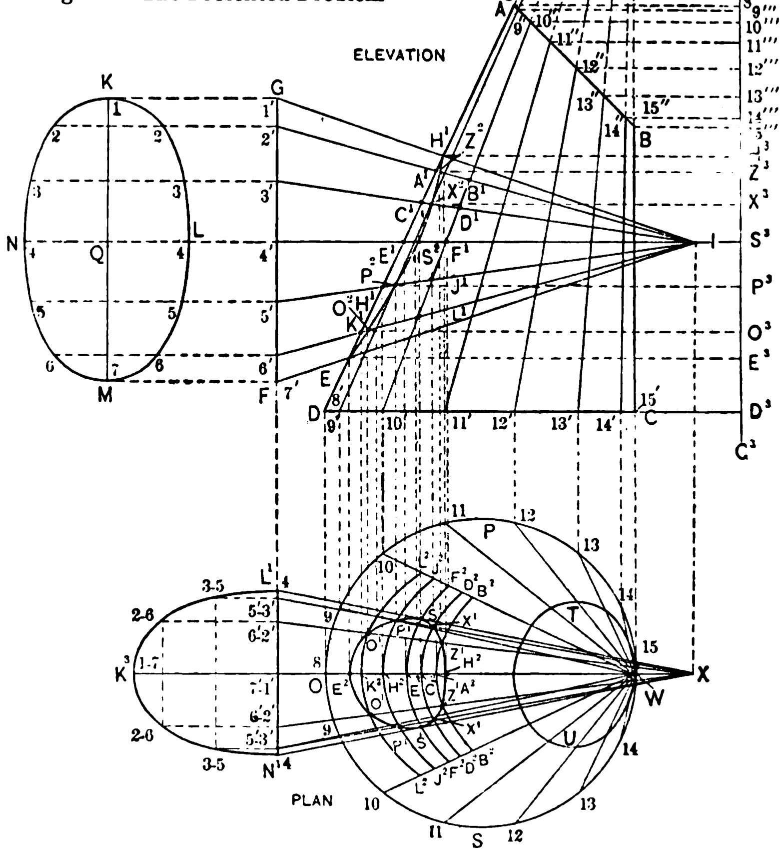


Fig. 59. Procedure for Obtaining Lines of Intersection

follows: As the sides of the elliptical cone G H and F E intersect the side of the oblique cone at H and E, and as the line D A is shown in plan by O V, then at right angles to D C and from the points A^1, C^1, H, H^1 and E^1, E, K^1, drop lines as shown, intersecting O V in plan from E^2 to H^2.

In the same manner from the point where the radial lines 2′ I to 6′ I of the elliptical cone in elevation intersect the radial lines 9′ 9″ and 10′ 10″ of the oblique cone, drop lines intersecting radial lines of similar number in plan, as 10 W and

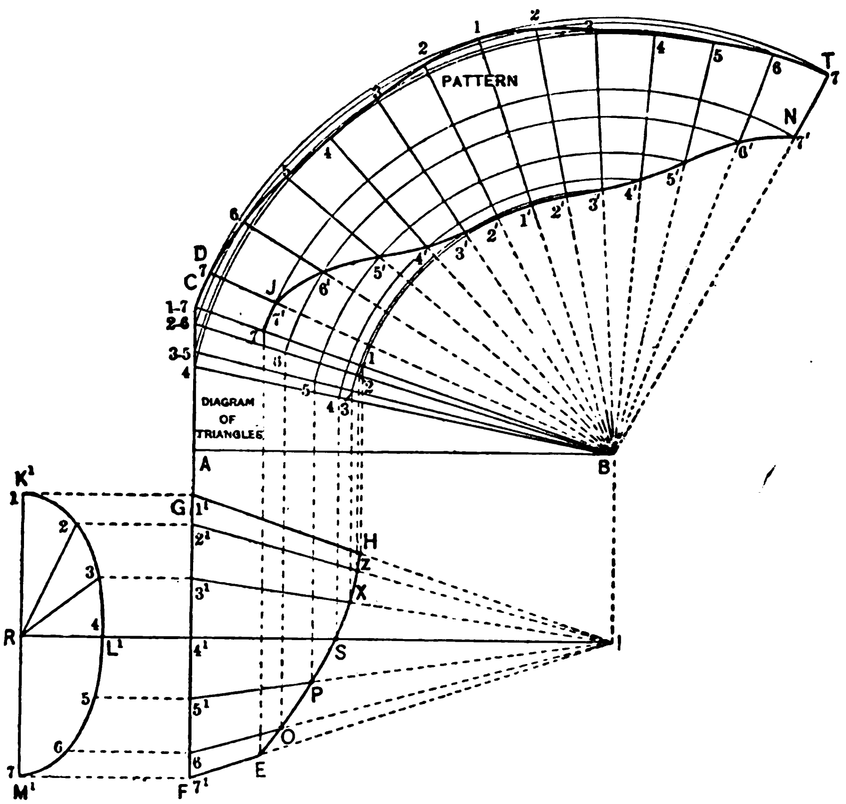


Fig. 60. Procedure for Obtaining Pattern of Right Elliptical Cone

9 W. Trace lines through these intersections as shown; then will the section line L^2 K^2 L^2 represent a plan view of this section K′ L′ of the elevation; also the section lines J^2 H^2 J^2, F^2 E^3 F^2, E^2 C^2 D^2 and B^2 A^2 B^2 will give the plan view of sections taken on the lines J^1 8^1, F^1 E^1, D^1 C^1, B^1, A^1, respectively of the elevation.

Having obtained the section lines and plans the next step is to obtain the intersections of the radial lines of the elliptical cone in plan, so that the miter line between the elliptical and the oblique cone can be obtained in elevation. First obtain this miter line or intersection line in plan as follows: Extend the center line O W in plan either way as shown by K^3 X. At right angles to D C in elevation from the apex I and from the line G F in elevation drop lines intersecting the center line K^3 X in plan at X and 1′ extending the lines to 1′ indefinitely. Take a tracing of the half ellipse in elevation N K L and transfer to the line L^1 N^1 in plan as shown by N^1 K^3 L^1; care being taken to place the point K^3 on the center line as shown. Now from the divisions on the half ellipse in plan (which correspond in spaces and number to those in elevation) and at right angles to L^1 N^1 draw lines intersecting the base line L^1 N^1 at points 5′ 3′ 6′ 2′ and 7′ 1′. From these intersections draw lines to the apex X as shown. As the section line E^1 F^1 in elevation is taken on the radial line 4′ I, then must the corresponding section, F^2 E^2 F^2, in plan be cut by the corresponding radial lines 4 X at the points S^1 S^1.

As the section lines A^1 B^1, C^1 D^1, H^1 J^1 and K^1 L^1 in elevation are taken on the radial lines 2′ I, 3′ I, 5′ I, and 6′ I respectively, then must the section lines of similar letters in plan B^2 A^2 B^2, D^2 C^2 D^2 J^2 H^2 J^2 and L^2 K^2 L^2 be cut by the radial lines 2′ X, 3′ X, 5′ X, 6′ X, on either side of the center lines K^1 X, as shown by the points Z^1, X^1, P^1 and O^1, the points E^2 and H^2 having been previously obtained. Trace a line through these points, when E^2 O^1 P^1 S^1 X^1 Z^1 H^2 will be a half plan of the miter line. The opposite half can be obtained by tracing if desired.

Having obtained this miter line in plan, the next step is to develop the same in elevation. At right angles to K^3 X in plan and from the intersections O^1, P^1, etc. carry lines upward, intersecting corresponding section lines K^1 L^1, H^1 J^1, etc. in elevation as shown by O^2, P^2, S^2, X^2 and Z^2. A line if traced through the points will constitute the miter line in elevation showing the intersection between the elliptical and the oblique cones.

In Fig. 60, E F G H I is a reproduction of E F G H I of Fig. 59 and is carried forward so as to avoid a complication of lines in the development of the pattern for the right elliptical cone. In the Fig. 60, H Z X S P O E is a reproduction of H Z^2 X^2 S^2 P^2 O^2 E of Fig. 59, as is the half elliptical section with the divisions on same a reproduction from Fig. 60. As the apex of a right elliptical cone is directly central over its base, then from the divisions 1, 2, 3 and 4 in the half ellipse Fig. 60, draw lines to the centre R. These lines will then represent the bases of the triangles to be constructed as follows: Parallel to R I draw any line, as A B. At right angles to R I and from points 4′ and I draw lines intersecting A B at A and B. At right angles to A B draw the line A C. Take distances R I, R 2, R 3 and R 4 setting them off on the line A C, measuring in every instance from point A, as shown by the same figures. As the distances

R 5, R 6, and R 7 are equal to R 3, R 2, and R 1, then add these figures as shown on the line A C. From the points on A C draw lines to the apex B; then will A B C represent the diagram of triangles used in the development of the plan. At right angles of R 1 and from the intersections H, Z, X, S, P, O and E on the radial lines draw lines intersecting those of similar numbers in the diagram of triangles as shown by the points 1 to 7.

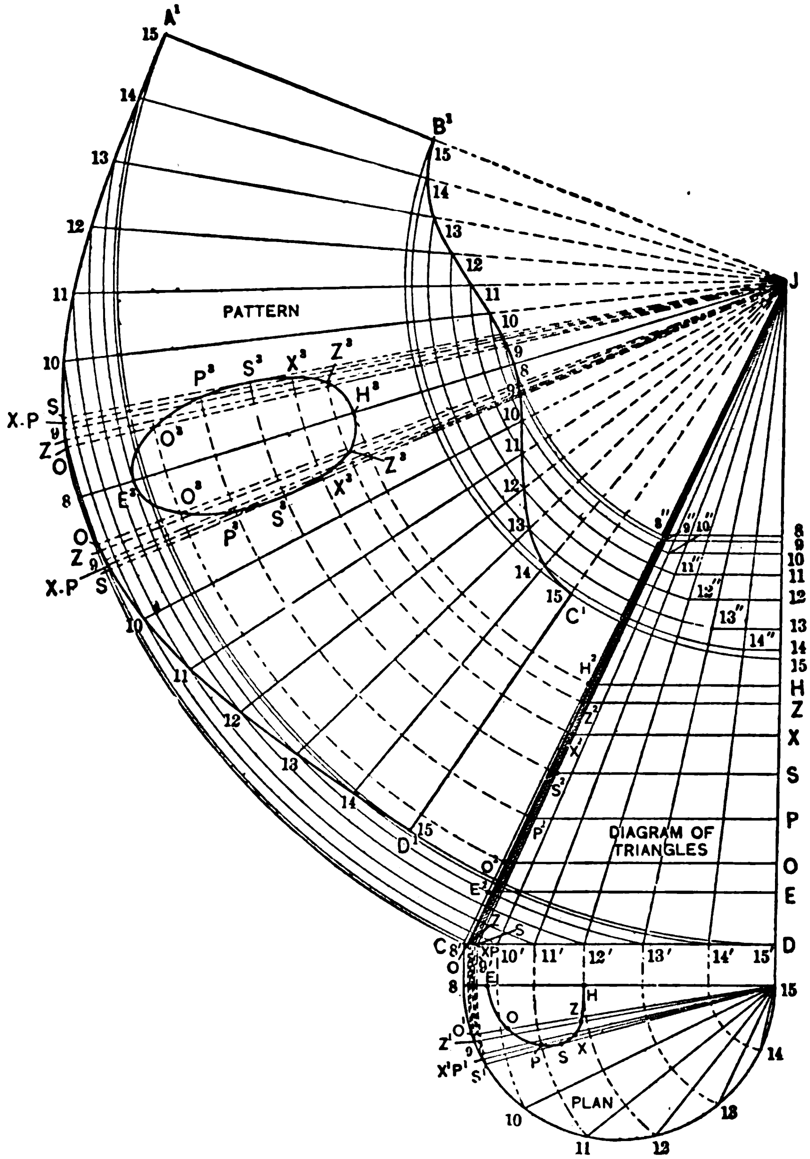


Fig. 61. Procedure for Obtaining Pattern for Oblique Cone

For the pattern proceed as follows: With B in the diagram of triangles as center and with radii B 7, B 6, B 5 and B 4 on the base line A C draw arcs, as shown. In this case the seam is placed at the point 7 at the bottom of the cone. Starting at the point 7 on the arc 7 7, take the distance in the dividers equal to the spaces into which the half ellipse K^1 L^1 M^1 has been divided and step from one arc to another placing the division 6 of the plan on the arc 6 5 of the plan on the arc 5, until all of the divisions necessary to complete the full pattern are obtained. A line traced through the points just obtained as shown from 7 to 7 will be the outline of the base of the pattern. For that portion of the pattern adjoining the oblique cone draw lines from the intersections on the pattern lines 7 7 to the apex B, intersecting arcs of similar numbers struck from the center B, with radii equal to B 1, B 2, B 3, etc. in the diagram of triangles, as shown from 7′ to 7′ of the pattern. Then will D T N J be the pattern for the right elliptical cone to intersect the oblique cone.

In Fig. 61 J D C is a reproduction of J C D of Fig. 59. The half plan 8 12 15 in Fig. 61 is also a reproduction of the lower half plan of Fig 59, as is the miter line H Z X S P O E in Fig. 61 a reproduction of the lower half of the miter line in plan in Fig. 59. To obtain the diagram of triangle with which to develop the pattern proceed as follows: With 15 in plan as the apex or center, and with radii 15 14, 15 13, 15 12, etc. describe arcs intersecting the center line 8 15, as shown. From the intersections thus obtained and at right angles to 8 15 in plan, erect lines intersecting the base lines as C D at 8′, 9′, 10′, etc. From the various intersections on the line C D draw lines to the apex J: then will these lines represent the hypotenuses of the triangles, bases of which are shown by the straight lines of similar numbers in plan. Parallel to J C in Fig. 59 draw the line J^2 C^3. At right angles to J^2 C^3 and from the intersections 8″ to 15″ on the line A B of the oblique cone draw lines intersecting the line J^2 C^3 from 8‴ to 15‴, as shown. In like manner from the intersections on the miter line H S^1 E and from the points J and C^1 draw horizontal lines cutting the line J^2 C^3 at J^2, H^3, Z^3, X^3, S^3, P^3, O^3, E^3 and C^3. Transfer the points from the line J^2 D^3 to the line J D of Fig. 61. At right angles to J D, and from the small figures on same, draw lines intersecting the hypotenuses of similar figures, as shown by 8″ to 14″ of Fig. 61.

For the pattern for the oblique cones proceed as follows: With J in the diagram of triangles as center and radii equal to J 8′, J 9′, J 10′, etc. on the line C D draw arcs indefinitely, as shown. In this case assume that the seam will come at the point 15 in plan. Take the distance in the dividers equal to the spaces into which the plan is divided, and commencing on the arc 15 15 in pattern step from one arc to another, placing the division 14 of the plan on the arc 14 13 of the plan on the arc 13, until all of the divisions necessary to complete the full pattern are obtained. Through the points thus obtained trace a line, as shown, from 15 to 15, which will be the lower pattern cut. For the upper pattern cut, first draw lines from the intersection on the base line of the pattern 15 to 15 toward the apex J, intersecting arcs of similar numbers struck from the center J with radii equal to J 8″, J 9″ or J 10″, etc. in the diagram of triangle, as shown by the intersection from C^1 to B^1. A line traced through these intersections will give the upper cut of the pattern. Then A^1 B^1 C^1 D^1 will be the pattern for the frustum of the oblique cone.

For the shape of the opening to be cut into the oblique cone to admit the elliptical cone proceed as follows: From the center point 15, draw lines through the intersections in the miter lines in plan H S E, continuing them until they intersect the plan of the base at Z^1, X^1, S^1, P^1 and O^1. With 15 in plan as centre and with radii equal to 15 O^1, 15 Z^1, etc. describe arcs intersecting the line 15 8, as shown. At right angles to 15 8 and from intersections just obtained erect lines intersecting the base line C D at O, Z, X, P and S. From these intersections draw lines toward the apex J, to intersect the horizontal lines with similar letters drawn from the points on the J D, as indicated by the dots between H^2 and E^2. Take the distance 8 to O^1 in plan in the dividers and placing one point at 8 in the lower line of pattern, set off the distance on either side toward 9, as shown by O O. In the same manner set off the distance from A to Z^1 of the plan on either side of the point 8 in pattern, as shown by Z Z; finally take the distances 9 to S^1 and 9 to X^1 P^1 in plan and set them off in pattern, measuring on either side from the point 9, as shown by S, X P, on either side of the pattern. From the points S, X P, Z, O, draw lines toward the apex J, which intersect with the arcs of similar letters struck with the apex J as centre, from H^2, Z^2, X^2, S^2, P^2, O^2 and E^2 in the diagram of triangles, as shown in the pattern by H^3, Z^3, X^3, S^3, P^3, O^3 and E^3. A line traced through these points will give the shape of the opening to be cut out of the oblique cone to admit the elliptical cone.

ENVELOPE OF SCALENE CONE WITH FLAT SIDE AND TOP

The subjoined paragraphs tell how to describe the pattern for the frustum of a cone which is flat on one side, the top opening to be perpendicular to the flat side, as shown in Fig. 62, in which A B C D shows the side elevation of the cone, E F G in plan being the section on D C in elevation and struck from the center H, while I J K L is the plan on A B in elevation and is struck from the center M. E G in plan shows the flat side, on the line D A in elevation.

With H in plan as center, complete the full circle of the base, as shown by G N E, and draw the center line in plan N F. Likewise in elevation extend the base line C D, as shown by C O, which intersect with a line drawn from N in plan at right angles to F N, thus obtaining the point O in elevation. From O draw a line to A, extending it indefinitely, as shown by O P. In similar manner extend the line C B until it intersects O P at P. At right angles to N F in plan and from the center H draw a line intersecting the base O C in elevation at R. In similar manner from M, the center of the circle of the top I J K L in plan, erect a line at right angles to N F, intersecting the top line A B in elevation at S. Draw a line through R and S, which must meet the apex P, as shown, thus making P O C a scalene cone. From P at right angles to O C drop a line intersecting the line N F in plan at T, which is the apex in plan of the scalene cone. Now divide the half plan N 4 F into equal spaces, as shown by the small figures 1 to 7; from these small figures draw lines to the apex T in plan, the radial line 6 T intersecting the flat side E G in plan at 6‴. From 6 erect the vertical line intersecting the base line C O in elevation at 6′, from which draw a line to the apex P, intersecting the side A D at 6″.

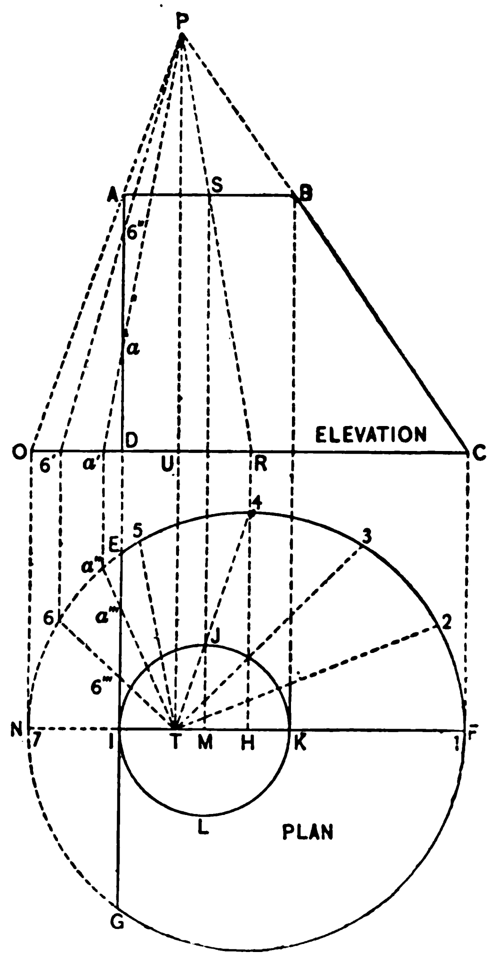


Fig. 62. Completing the Problem as Presented

For convenience, when getting out the pattern for the flat side establish any point, as *a*, on the line A D in elevation. From *a* draw a line to the apex P, extending it downward until it intersects the base line O C at *a*′. From *a*′ at right angles to O C drop a line, intersecting the circle at *a*″, from which draw a line to the apex T in plan, intersecting the flat side E G at *a*‴. All of these points represent the basis of all measurements required for the patterns.

Before obtaining the pattern for the scalene cone, first construct the diagram of triangles shown in Fig. 63, in which 1 T 7 4 is a reproduction of 1 T 7 4 reversed in Fig. 62. Take the various divisions 6 *a*″ E 5 4 3 2 1 and place them as shown by 6 *a* E 5 4 3 2 1 in Fig. 63. From these points draw lines to the apex T in plan. Using T as center and radii equal to T 7, T 6, T *a*, T E, T 5, T 4, T 3 and T 2, draw semicircles, as shown, intersecting the center line 1 7, as shown. From these intersections and at right angles to 7 1 draw lines intersecting any horizontal line, D 1, at points D, 7, 6, *a*, E, 5, 4, 3, 2 and 1. Extend the line T D indefinitely to P, as shown. Take the distance from U to P in Fig. 62 and place it as shown from D to P in Fig. 63. Then from the various intersections on D 1 draw lines to the apex P, as shown. Take the various hights in Fig. 62 from D to *a* to 6″ to A and place them in Fig. 63 on the line D P, as shown from D to *a* to 6 to A. At right angles to D P and from A draw the line A B, which represents the top of the opening.

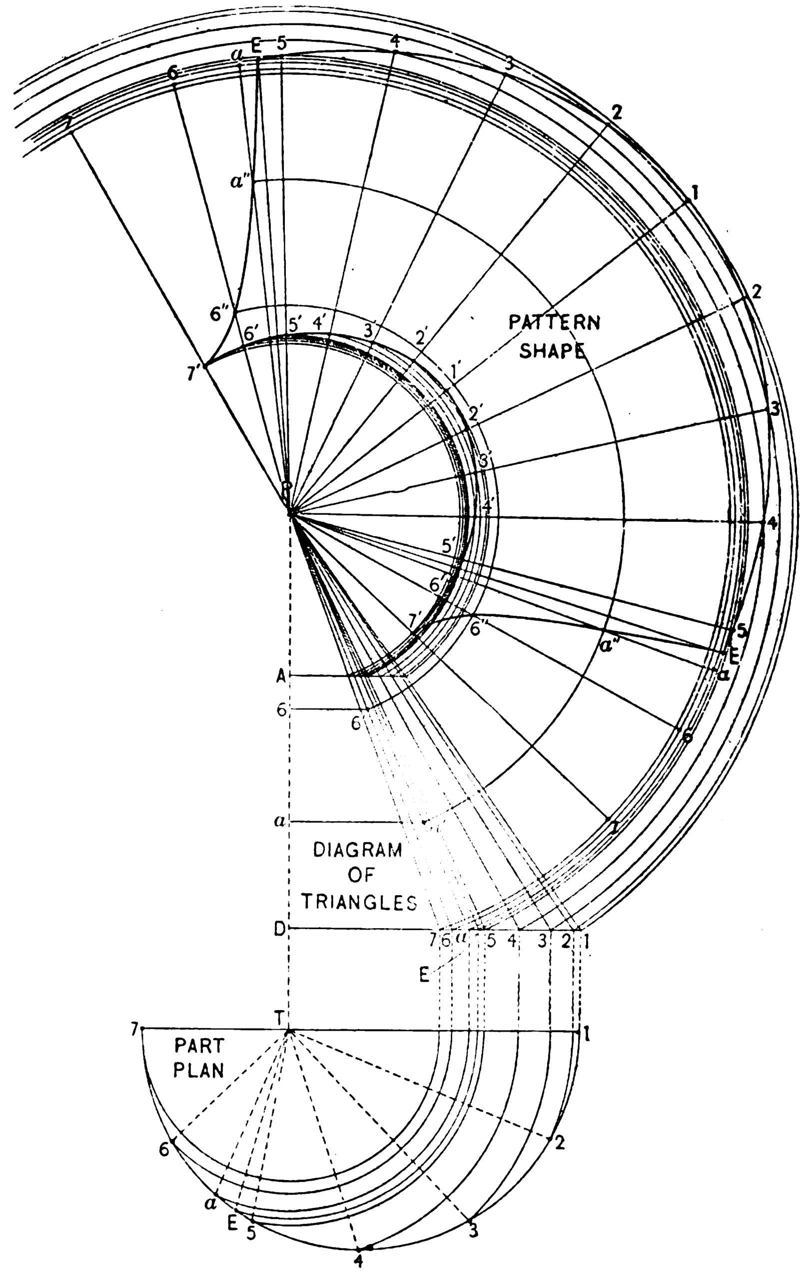


Fig. 63. Obtaining the Diagram of Triangles and Pattern

In similar manner at right angles to D P and from the intersections 6 and *a* draw lines intersecting hypotenuses having similar numbers, as shown by the intersections 6′ and *a*′ respectively. Then will these lines represent the diagram of triangles used in the development of the patterns. For the pattern shape use P as center, and with radii equal to P 7, P 6, *a*, E, 5, 4, 3, 2 and 1, strike arcs indefinitely, as shown. Set the dividers equal to the divisions into which the plan is divided, and starting from the arc 7 step to the arc 6, then to the arc 5, then to 4, 3, 2 and 1, and reverse the operation and step to arcs 2, 3, 4, 5, 6 and 7, as shown. From these points draw lines to the apex P. Next set the dividers equal to the distance 6 *a* in plan, and step from the arc 6 in the pattern to the arc *a*, as shown by *a* on each side. In similar manner take the distance from *a* to E in plan, and step from arc *a* to arc E in pattern on either side. From the points *a* E and E *a* in the pattern draw lines to the apex P. Now with radii equal to P 6 and P *a*′ draw arcs intersecting the radial lines in the pattern drawn from points *a a* and 6 6, thus obtaining the intersections *a*″ *a*″ and 6″ 6″. Finally, with P as center and radii equal to the various numbers 1 to 7 on A B (not shown), draw arcs intersecting radial lines having similar numbers, as shown, thus obtaining the points 7′ to 1′ to 7′. Trace a line through points thus obtained; then will 7′ 6″ *a*″ E 1 E *a*″ 6″ 7′ 1′ 7′ be the pattern shape for the scalene cone.

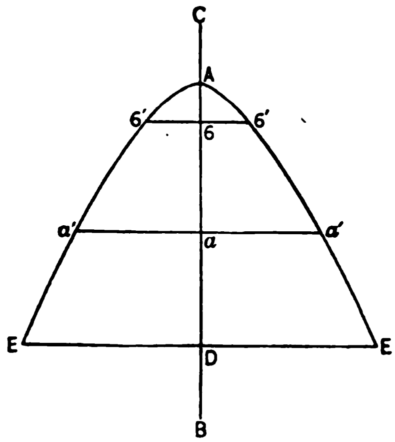


Fig. 64. Pattern of the Vertical Side

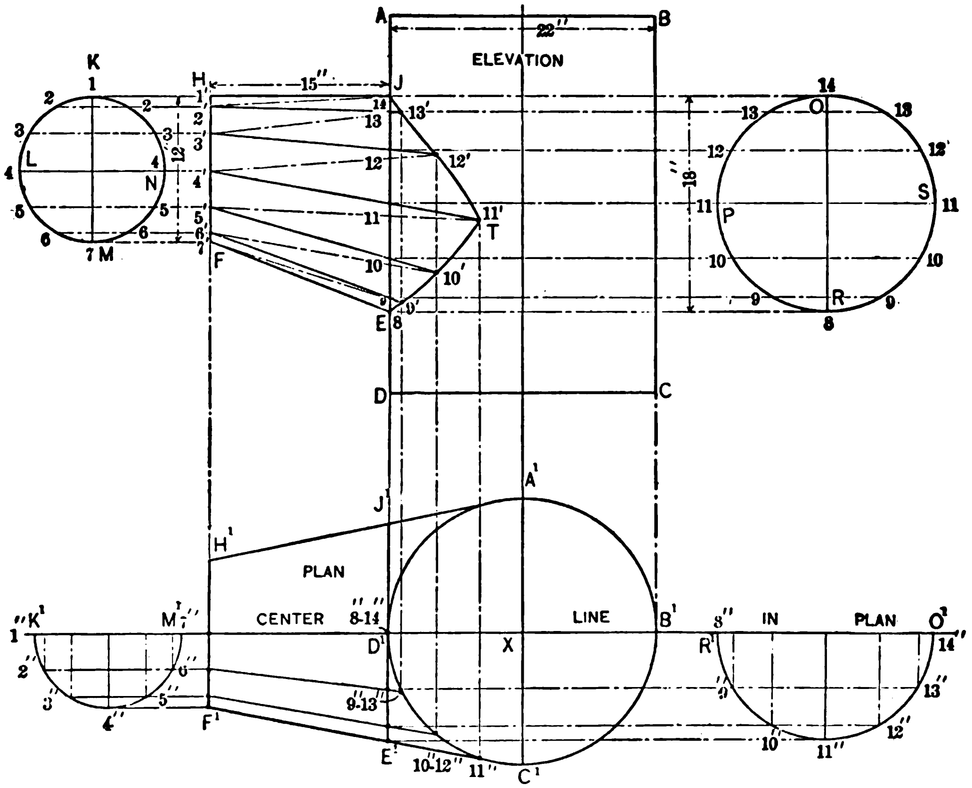
For the pattern for the flat side draw any line, as B C in Fig. 64, upon which place the distances A 6 *a* D, equal to A 6″ *a* D in elevation in Fig. 62. At right angles to B C in Fig. 64 and through the points 6 *a* and D draw lines, as shown. Now, measuring in each instance from the line N F in plan in Fig. 62, take the distances to points 6‴, *a*‴ and E and place them in Fig. 64 on lines having similar letters and figures, measuring in every instance from the line B C on either side, thus obtaining the intersections 6′ 6′, *a*′ *a*′ and E E. A line traced through points thus obtained, as shown by E A E, will be the pattern for the vertical side of the cone.

INTERSECTION OF SCALENE CONE AND CYLINDER

The procedure for obtaining the miter between a scalene cone and a 22 inch cylinder, also the patterns, a sketch of which is shown in Fig. 65 is as follows: Here A B C D represents the 22 inch cylinder and E F H J the scalene cone, the intersection between the cone and cylinder being shown by J T E. The diameter of the cone on the line H F which is shown by K L M N is 12 inches and O P R S shows the diameter of the cone on the line J E which is 18 inches, the length of the horizontal arm H J being 15 inches. Draw the plan of the article, placing it under the elevation in its proper position, as shown by the dotted lines, making A^1 B^1 C^1 D^1 the plan of the cylinder. Through the center point X of the circle in plan draw the center lines K^1 O^1, as shown. On either side of the center line in plan, in their proper positions, as shown by the dotted lines locate

H^1 F^1 equal to 12 inches and J^1 E^1 equal to 18 inches. Draw lines from H^1 to J^1 and F^1 to E^1, extending them until they intersect the 22 inch pipe, as shown. Then will H^1 B^1 represent the plan of the scalene cone and cylinder corresponding to the elevation.

The first step is to obtain the miter line J T E in elevation, for which proceed as follows: Divide the profile K L M N into equal spaces, as shown by the small figures 1, 2, 3, 4, etc. At right angles to K M and through the small figures draw lines intersecting the line H F at $1'$, $2'$, $3'$, etc. as shown. In the



ig. 65. Obtaining the Miter Lines

same manner divide the profile O P R S into the same number of equal spaces as in K L M N, as shown by small figures 8 to 14. At right angles to O R and through the small figures, draw lines intersecting line J E as shown from 8 to 14. Now draw solid lines from $2'$ to $13'$, $3'$ to $12'$, $4'$ to $11'$, $5'$ to $10'$, $6'$ to $9'$, extending the lines indefinitely into the cylinder. Take a tracing of the profile K 4 M in elevation and place it as shown by K^1, $4''$ M^1, in plan, placing the line K^1 M^1 upon the center line in plan, as shown. In the same manner take a tracing of the profile O 11 R in elevation and place it as shown by O^1 $11''$ R^1 in plan, placing the line O^1 R^1 upon the center line in plan. Parallel to K^1 M^1 and through the small figures 2″, 3″, etc. in the half profile draw lines intersecting the line H^1 F^1 as shown. In the same manner, parallel to R^1 O^1 and through the small figures 9″, 10″, 11″, etc., in the half profile draw lines intersecting the lines J^1 E^1 as shown. From the various intersections on the line H^1 F^1 draw lines through the points on J^1 E^1 as shown, continuing them until they intersect the quarter circle D^1 C^1 at 8″ 14″, 9″ 13″ 10″ 12″ and 11″. At right angles to the center line in plan and from the

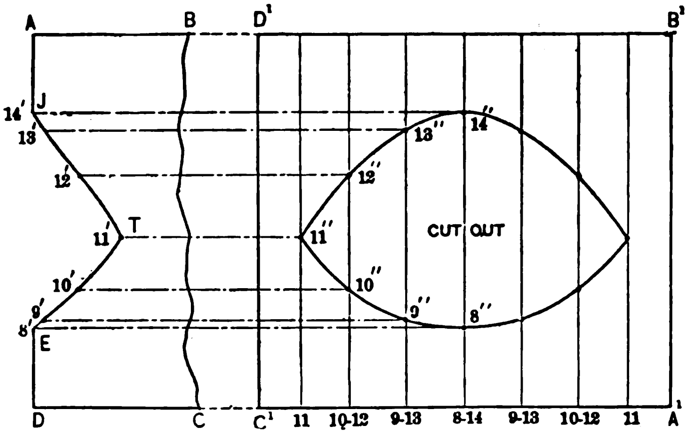


Fig. 66. Pattern of Opening in Cylinder

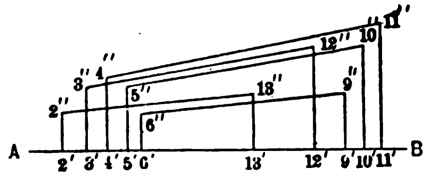


Fig. 67. Diagram of Solid Line Triangles

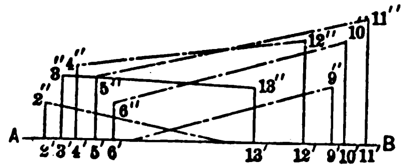


Fig. 68. Diagram of Dotted Line Triangles

intersections on the quarter circle D^1 C^1 carry lines upward intersecting those of similar numbers previously extended into the cylinder, as shown by the points 14′, 13′, 12′, 11′, 10′, 9′ and 8′. A line traced through these points, as shown by J T E will represent the miter line between the scalene cone and cylinder.

The next step is to obtain the opening to be cut into the cylinder. In Fig. 66 let A B C D E J and with the miter line and the various intersections on it be a reproduction, partly broken, of A B C D E J of Fig. 65. On D E of Fig. 66 extended, C^1 A^1, place the stretchout of the half circle in plan, Fig. 65 as shown by the small figures. Now at right angles to C^1 A^1 and through the small figures draw lines, which intersect with those of similar numbers drawn at right angles to A D from the points on the miter line J T E as shown. A line traced through these points from 8″ to 14″ will be the opening to be cut into the cylinder.

The pattern for the scalene cone will be developed by triangulations, and diagrams of sections will be required. Connect points in H F, Fig. 65, with points on the miter line by dotted lines, as shown from 2′ to 14, 3′ to 13′, 4′ to 12′, etc. Draw any horizontal line, as A B in Fig. 67, upon which the various lengths of the solid lines in scalene cone in elevation Fig. 65, as shown by lines of similar numbers A B of Fig. 67: At right angles to A B and from the small figures draw lines, making them equal in hight to vertical lines of similar numbers in the half profile K^1 4″ M^1 and the quarter circle X D^1 C^1 in plan, Fig. 65. From the points thus obtained in Fig. 67 draw slant lines as shown. For example, take the length of the line 4′ 11′ in elevation Fig. 65, and place it as shown by 4′ 11′ on the line A B of Fig. 67. At right angles to A B draw perpendicular lines 4′ 4″ and 11′ 11″ equal in hight, when measuring from the center line in plan of Fig. 65, to 4″ in the profile K^1 M^1 and 11″ in the quarter circle X D^1 C^1. Now draw a line from 4″ to 11″ in Fig. 67, which will be the actual distance on the finished article on the line 4′ 11″ in elevation Fig. 65. Proceed in the same manner for sections on dotted lines. Draw any line in Fig. 68, as A B, upon which place the lengths of the dotted lines in the scalene cone in elevation, Fig. 65, as shown by lines of similar numbers on A B in Fig. 68. At right angles to A B and from the small figures draw lines, making them equal in hight to vertical lines of similar numbers in half profile K^1 4″ M^1 and the quarter circle X D^1 C^1 in plan Fig 65. From the points thus obtained in Fig. 68 draw slant lines as shown. For example, take the length of the line 5′ 11′ in elevation, Fig. 65, and place it as shown by 5′ 11′ on the line A B of Fig. 68. At right angles to A B draw vertical lines 5′ 5″ and 11′ 11″, equal in hight, when measuring from the center line in plan, Fig. 65 to 5″ in the profile K^1 M^1 and to 11″ in the quarter circle X D^1 C^1. Draw a line from 5″ to 11″ in Fig. 68 which will be the actual distance on the finished article on the dotted line 5′ 11′ in elevation Fig. 65.

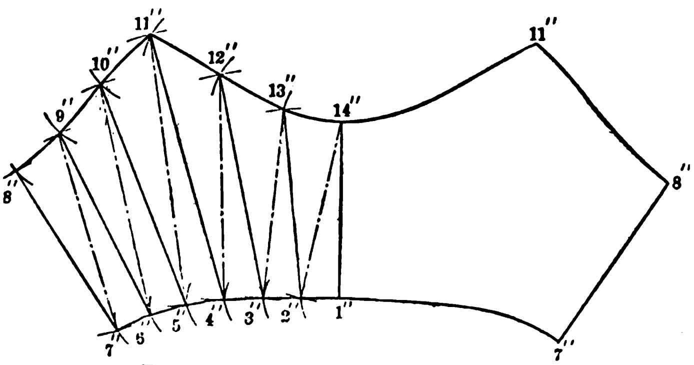


Fig. 69. Full Pattern of Scalene Cone

These are now the diagrams of sections in Fig. 67 and 68, the half profile of the narrow end of the scalene cone K^1 M^1 in plan Fig. 65 and the various divisions in the pattern in Fig. 66, from which to obtain measurements for developing the pattern for the scalene cone, for which proceed as follows: Draw any vertical line, 1″ 14″ of Fig. 69, equal to 1′ 14 or H J in elevation, Fig. 65. With 1″ 2″ in the half profile K^1 M^1 in plan as radius, and 1″ of Fig. 69 as center, describe the arc 2‴. Then, with 14 2″ of Fig. 68 as radius and 14″ of Fig. 69 as center, intersect the arc previously described at 2″. Now with 14″ as center, and 14″, 13″ of the pattern,

Fig. 66, as radius, describe the arc 13″ in Fig. 69. Then with 2″ as center and 2″ 13″ of Fig. 67 as radius, describe an arc intersecting the previous arc 13″ of Fig. 69. Proceed in this manner, using alternately first the spaces in the half profile K^1 M^1 in plan Fig. 65, then the lengths of the dotted lines in Fig. 68, then the spaces in the pattern of Fig 66 and the lengths of the solid slant lines in Fig. 67, until the last line 7″ 8″ of Fig. 69 is obtained equal in length to 7′ 8 or F E in elevation, Fig. 65. Then will 1″ 7″ 8″ 11″ 14″ be the half pattern which can be duplicated, as shown by similar figures to make the whole pattern. Allowance should be made for edges for seaming and riveting.

INTERSECTION OF AN IRREGULAR SCALENE CONE WITH A CYLINDER

The subjoined paragraphs tell how to obtain a pattern for a scalene cone mitering into a cylinder, the under side of the cone being horizontal. The intersection between the cone and outer line of cylinder is to be 22 inches and diameter of the cylinder, 20 inches, as shown in Fig. 70, in which A B C D E F G H is the side view of the article and O P R D^1 E^1 the plan. As C F in elevation is a given width, or 22 inches, and is wider then the diameter of the cylinder, which is 20 inches, the section at the base of the cone becomes an ellipse and therefore constitutes an irregular form and may be constructed as follows: Bisect the width of the cylinder A B or H G by the center line L M. Extend the sides of the cone D C and E F until they meet the center line L M at K and J respectively. Then will K J be the length of the base of the cone and the width of the cylinder that of the base. Parallel to A H draw the line T U, making it equal in length to K J as shown by the dotted lines. Bisect the line T U at the point T^1. Through T^1, and at right angles to T U, draw the line W V, making it equal to the diameter of the cylinder, as shown. Then through the points T, V, U, W draw any oblong figure as shown, which will represent the base of the cone. In the same manner, at right angles to D E, and from points D and E, draw lines, as shown, intersecting the line T U at X and U. Bisect X U at X^1. Then, with X^1 as center and X^1 X or X^1 U as radius, describe the circle X Y U Z which represents the section on line D E in side elevation.

The next step is to obtain the miter line or line of joint shown by C J^1 F in elevation, for which proceed as follows: Divide one half of the outer curve, shown from T to U, into any number of equal spaces as shown by the small figures 1 to

9. In the same manner divide one-half the inner circle into the same number of spaces, as shown from 9 to 17. Draw solid lines from 1 to 17, 2 to 16, 3 to 15, etc., until the last line 8 to 10 is obtained. At right angles to T U and from spaces 1 to 9, draw lines intersecting L M at points 1^1 to 9^1. In the same manner, at right angles to T U and from points 9 to 17, draw lines intersecting D E in elevation at points 9^1 to 17^1. Connect similar points with solid lines, as in section, thus: 1^1 to 17^1, 2^1 to 16^1, etc., until the last line 9^1 to 9^1 is obtained.

Now extend the line S P in plan as shown by S T^1. Upon this line place a duplicate of one-half of the sectional views with the solid lines connecting the same, as shown by T^1 V^1 U^1 Z^1 in plan. At right angles to O R and from the various spaces on the outer curve T^1 V^1 U^1, draw lines intersecting O R, or base of cone in plan, at points 1 to 9. In the same manner, at right angles to D^1 E^1, and from points in the half circle 9 to 17 draw lines intersecting D^1 E^1 at points 9 to 17. Connect similar points with solid lines, as in elevation thus: 1 to 17 and 9 to 9, 2 to 16 and 8 to 10, 3 to 15 and 7 to 11, 4 to 14 and 6 to 12, and 5 to 13, intersecting the circle P R S O at S, A^1, B^1, C^1 and R. Now at right angles to S P and from the various intersections on the quarter circle S R, draw lines upward, intersecting lines in elevation the numbers of which are similar to those in plan, as shown by the points C, F^1, G^1, H^1, J^1, K^1, L^1, M^1, F^1. Trace a line through these points, which will represent the miter line, or line of intersection between the irregular scalene cone and cylinder.

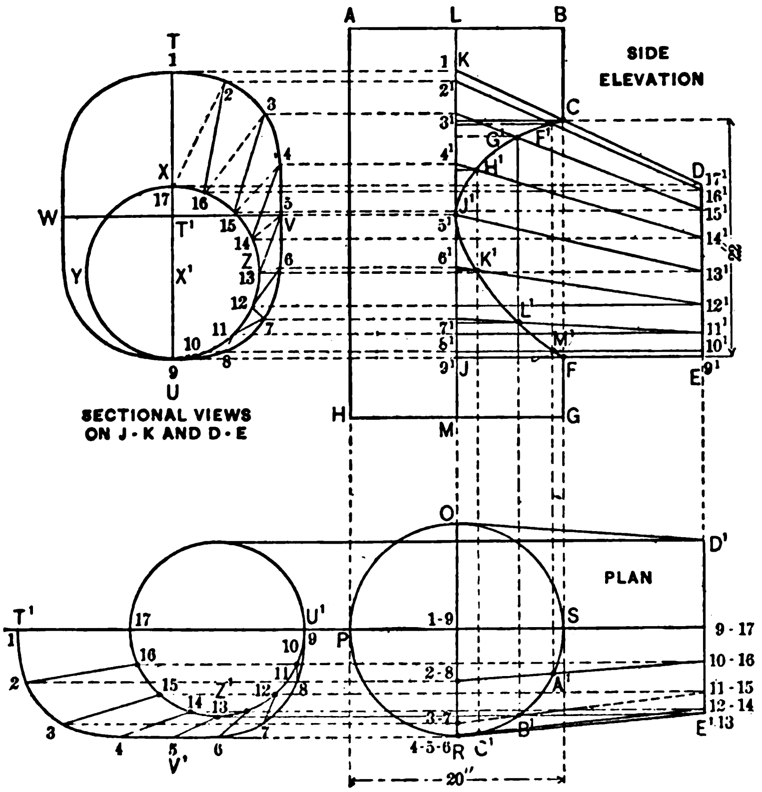


Fig. 70. Procedure for Obtaining Miter Lines

For the pattern of the opening to be cut in the developed cylinder proceed as follows: Duplicate A B C F G H of Fig. 70, as shown by A B C F G H in Fig. 71; also duplicate the plan O P R S with the various intersections, which have been numbered from 1 to 6 as shown. On the line G H extended, as O^1 R^1, place a stretchout of the half circle in plan, transferring each space separately, as shown by R^1 1 2 3 S^1 4 5 6 O^1. At right angles to R^1 O^1, and from the small figures, draw lines, which intersect with those of similar numbers drawn from the miter line C O^1 F at right angles to A H. Trace a line through the various inter-

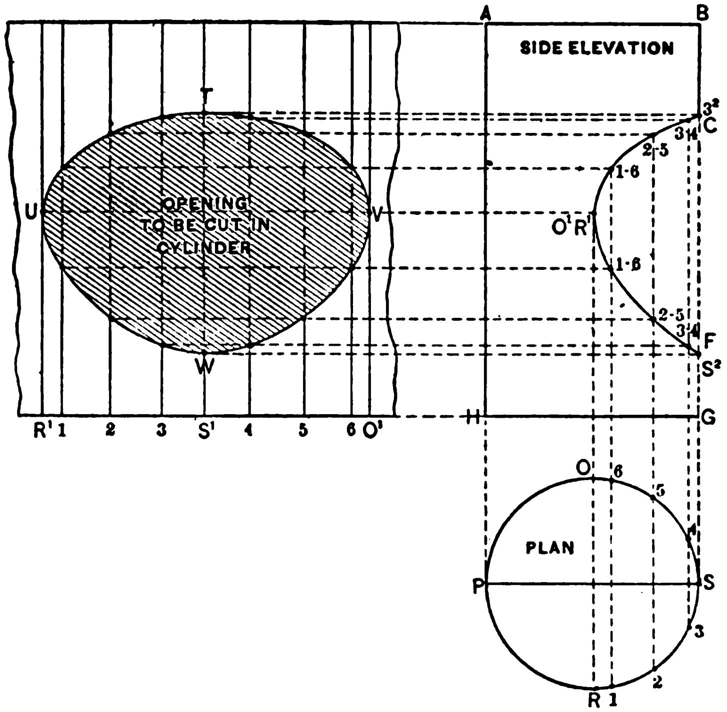


Fig. 71. Procedure for Obtaining Pattern of and Opening in the Cylinder

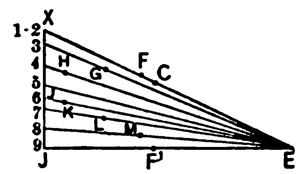


Fig. 72. Diagram of Triangles of Solid Lines

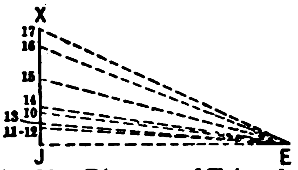


Fig. 73. Diagram of Triangles of Dotted Lines

sections. Then will T U V W be the shape of the opening to be cut into the surface of the developed cylinder.

For the pattern for the irregular scalene cone proceed as follows: From points in the base, Fig. 70, draw dotted lines to the top, as shown from 2 to 17, 3 to 16, 4 to 15, etc., until the last line 9 to 10 is obtained. Draw any horizontal line, as J E in Fig. 72, equal to J E in elevation, Fig. 70. At right angles to J E in Fig. 72 draw the vertical line J X, upon which place the various lengths of the solid lines shown in sectional views Fig. 70, as 17 1, 16 2, etc., measuring in every instance from the point J in Fig. 72, as shown by the small figures 1 to 9. From the small figures draw solid lines to the point E. Then will these solid lines represent the hypotenuse of the triangles, the bases of which are shown in the sectional views, Fig. 70, by solid lines of similar numbers. In the same manner draw any horizontal line, as J E in Fig. 73, equal to J E in Fig. 70. At right angles to J E in Fig. 73 draw the vertical line J X, upon which place the various lengths of the dotted lines shown in sectional views in Fig. 70, as 17 2, 16 3, etc., measuring in every instance from the point J in Fig. 73 as shown by the small figures 10 to 17. From the small figures draw dotted lines to the point E. Then will these dotted lines represent the hypotenuses of the triangles the bases of which are shown in the sectional views in Fig. 70 by dotted lines of similar numbers. Draw any vertical lines 1 17, in Fig. 74 equal in length to 1^1 17^1 of Fig. 70 or 1 E of Fig. 72. Then with 1 2 of the sectional views, Fig. 70, as radius and 1 of Fig. 74 as center, describe the arc 2. Now with 17 E of Fig. 73 as radius and 17 of Fig. 74 as center, describe an arc intersecting the previous arc at 2. Then, with 17 16 of the sectional views of Fig. 70, as radius and 17 of Fig. 74 as center, describe the arc 16, which intersect by another arc struck from 2 as center and E 2 of Fig. 72 as radius. Proceed in this manner, using alternately, first, the spaces on the outer curve in the sectional views of Fig. 70, then the hypotenuses of the triangles of Fig. 73, the spaces on the inner curve in the sectional views of Fig. 70, then the hypotenuses of the triangles shown in Fig. 72, until the last line 9 9^1 of Fig. 74, has been obtained. Trace a line through points of intersections thus obtained. Then will 9 9^1 17 1 be the half pattern for the irregular scalene cone shown in the side elevation Fig. 70, by K D E J.

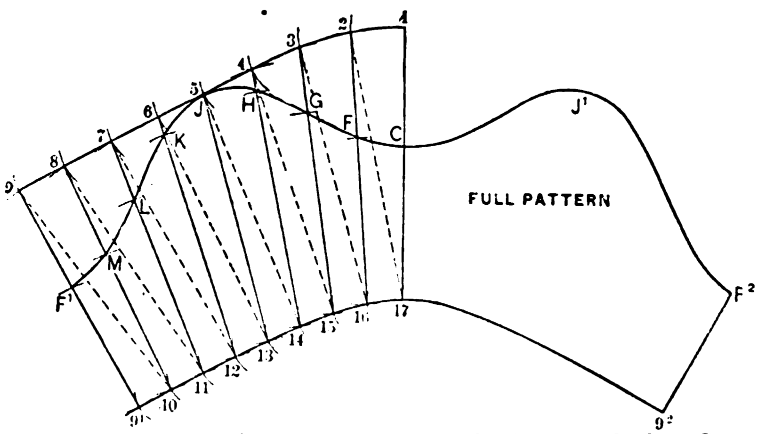


Fig. 74. Procedure for Obtaining Pattern for Irregular Scalene Cone

To obtain the cut or intersection with the cylinder proceed as follows: From the points of intersection C, F^1, G^1, H^1, J^1, K^1, L^1, M^1, F in side elevation Fig. 70, draw horizontal lines at right angles to L M, as shown. Take the distance of these horizontal lines, measuring in each and every instance from the line L M to the intersection on the solid lines, and transfer these lengths on to solid lines of similar numbers shown in Fig. 72, measuring in each and every instance from and at right angles to the line J X, obtaining the points C, F, G, H, J, K, L, M, F^1. On the line 17 1 of Fig. 74, measuring from 17, set off the distance E C of Fig. 72, as shown at C, and from 16 on the line 16 2 set off the distance E F of Fig. 72, locating the point F. In the same manner set off E G of Fig. 72, on the line 15 3 and E H on the line 14 4, etc., proceeding in this manner until the point F^1 in the pattern has been obtained. Trace a line through points thus obtained, as shown. Then will F^1 J C 17 9^1 be the half pattern. Transfer a duplicate opposite the line C 17, as shown. Then will F^1 J C J^1 F^2 9^2 17 9^1 be the full pattern for the irregular scalene cone mitering against the cylinder.

PATTERN FOR AN IRREGULAR BOSS

To cut the pattern for an irregular boss, where the branch pipe is less in diameter than the main pipe, the following has been prepared. The branch, it should be stated, intersects the main at other than a right angle. Proceed as follows:

Let A B C D E F G H in Fig. 75, be the side elevation of the two pipes. At pleasure locate the points 1 and 7, giving the extreme length of the boss at the bottom, also locate the points 8 and 14, giving the horizontal line at the top. From the side elevation construct the end elevation, K representing the section of the main pipe, and 11 11° the top line of the boss. From 11 and 11° draw lines tangent to the circle K at 4 and 4°, respectively. The distance 4 4° and 11 11° represent, respectively, the widths at the bottom and top of the boss.

In line with the branch pipe in the side elevation draw the profile J, which divide into equal parts, as shown by the small figures 8 to 14. From these points parallel to B C draw lines intersecting the top line of the boss as shown by the figures 8 to 14. As any plane cut through a cylinder at other than a right angle produces an ellipse, then the elliptical section must be found through 8 14 in side elevation as follows: From the various intersections 8 to 14 on the top line of the boss draw vertical lines crossing the horizontal line S T in plan as shown. Now measuring from the line 8 14 in the profile J, take the various distances to points 9 to 13 and place them on each side of the line S T in plan on lines drawn from similar numbers measuring in each instance from the line S T. A line traced through points thus obtained will give the true section through the top of the boss, to fit around the cylinder B C D E at the angle shown.

From points 1 and 7 in side elevation project lines to the center line S T in plan, obtaining similar points 1 and 7. From the point 11 in the end elevation draw a vertical line intersecting the line 4 4° at *a*. Take this distance *a* 4 and place it in the plan of the side elevation from 11 to 4 on both sides. Through the

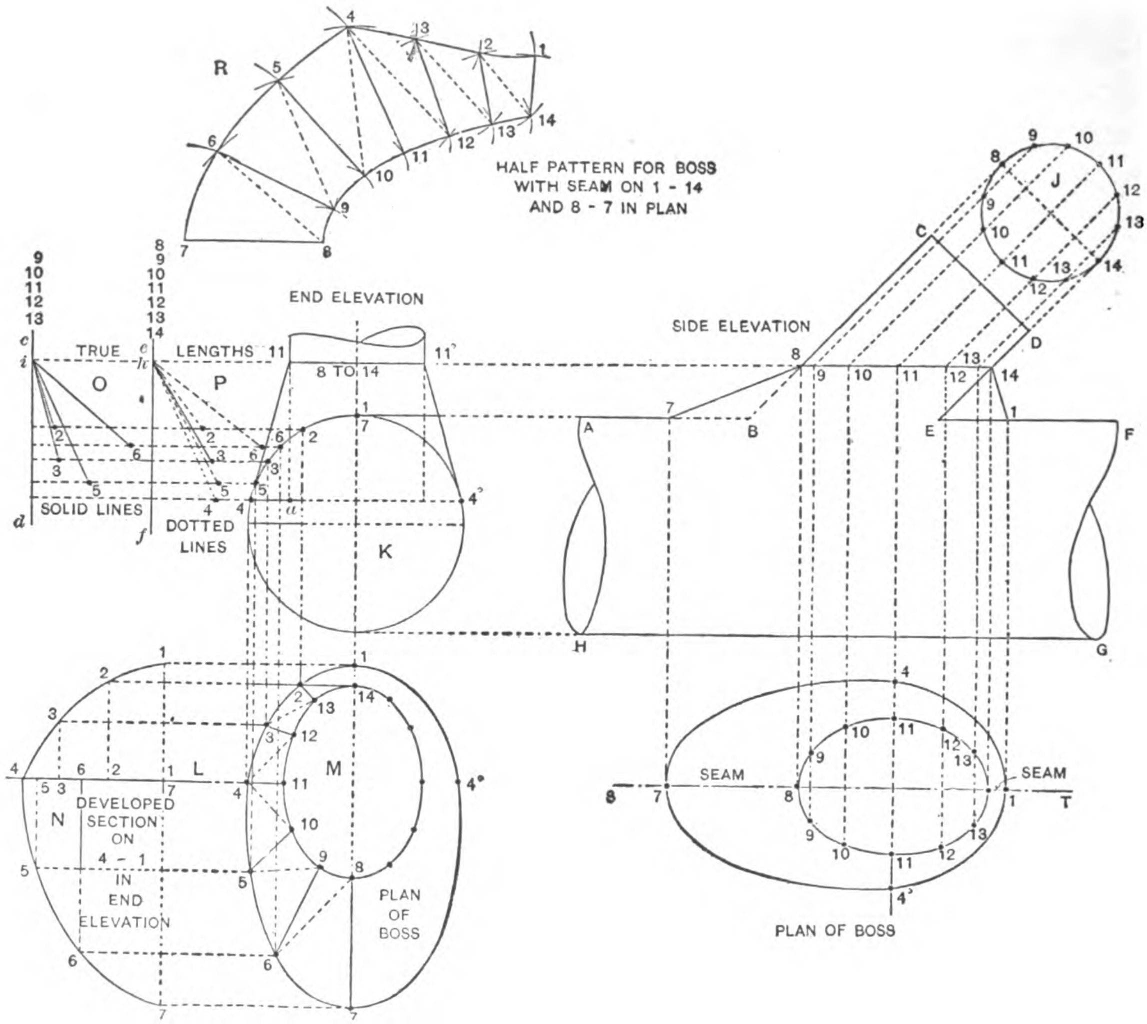


Fig. 75. Complete Process for Obtaining Pattern of the Irregular Boss

points 1 4 7 trace an elliptical figure at pleasure as shown, which will represent the miter line in plan between the boss and main pipe.

Take a tracing of this plan and place it below the end elevation as shown. As both halves opposite the line 1 7 are symmetrical, only one-half of the full pattern will be developed. As one-half of M contains six spaces, then divide one-half of 1 7 also into six spaces as shown from 1 to 7. Draw the solid and dotted lines in the usual manner, and from points 1 to 7 in plan erect perpendiculars until they intersect part of the circle K as shown by points 1 to 7. As all the points from 8 to 14 in plan lie on a horizontal plane, shown by 11 11° in elevation, this line gives their proper hight and is so marked 8 to 14.

The obtaining of true lengths of the solid and dotted lines in plan can be accomplished rapidly by means of the diagrams O and P, the former being the true lengths on the solid lines and the latter the true lengths on the dotted lines. As 1 14 and 7 8 in side elevation and 4 11 in end elevation show the true lengths of these respective lines in plan, they need not be found in diagram O. From the various intersections 2 to 6 on the circle K project horizontal lines to be left as shown, and at pleasure erect two perpendiculars *c d* and *e f*. To obtain the true length of the line 6 9 in plan, take this distance and place it in O on the line drawn from 6 in the circle K, measuring from the line *c d*, and draw the diagonal line from 6 to *i*, *i* representing the upper line of the boss for all points from 8 to 14 in plan.

To obtain the dotted line from 3 to 13 in plan take this distance and set it off on the line drawn from 3 in the circle K measuring from the line *e f*, and draw a line from 3 to *h*; *h* in P representing the upper line of the boss for all points shown in plan from 8 to 14. In this manner obtain all of the solid and dotted lines.

Before the pattern can be developed a true section must be obtained on the curved line from 4 to 1 in K as follows: Take the various distances from 1 7, to 2, to 6, to 3, to 5, to 4 and place them on the horizontal line L 4 in plan, as shown by similar numbers, through which vertical lines are drawn and intersected by horizontal lines drawn from similar numbers 1 to 7 in plan. A line traced through points thus obtained as shown from 1 to 4 to 7 in N will be the developed section.

Assuming that the pattern is to be made in two halves with seam on 7 8 and 14 1 in plan below the side elevation, take the distance 7 8 in side elevation and place it as shown by 7 8 in R. With radius equal to 7 6 in the developed section N, and 7 in R as center, describe the arc 6, which intersect by an arc struck from 8 as center, with a radius equal to *h* 6 in P. With radius equal to 8 9 in plan M and 8 in R as center, describe the arc 9, which intersect by an arc struck from 6 as center and 6 *i* in O as radius. Proceed in this manner in developing the half pattern, noting the direction in which the solid and dotted lines run in plan M, obtaining the length of 4 11 and 1 14 in the pattern R, from 4 11 in end elevation and 1 14 in the side elevation, respectively. Trace a line through intersections thus obtained in R, which will then be the half pattern for the boss.

PATTERNS FOR AN IRREGULAR TEE JOINT

This exemplification treats on laying out an irregular tee joint. The main pipe being 20 in. in diameter, and the branch pipe oval in shape, 20 in. at the top and 40 in. at the intersection, as shown in Fig. 76.

The side and end elevations are given in Fig. 76, showing a 26 in. horizontal pipe being intersected by a branch pipe, the diameter of which at the top is also 20 in., but intersection with the horizontal pipe is 20 in. wide by 40 in. long. This gives an opening which freely allows an in or out flow of air to avoid friction. The principles explained herewith will be found applicable, no matter whether the pipes have similar diameters or not, or whether the branch pipe intersects the main in the center or to one side.

Let A, B, C, D, E, F, 1, 1, A be the side elevation of the tee, F E being 20 in., A 1 20 in. and B 1 40 in. In its proper position draw the end elevation as shown by L, H, J. Then 1, 4, J, K represents the profile on F, E. In its proper position above A 1 in the side elevation draw the plan G; also the plan M above L H in end elevation. From the intersection 4 in end elevation project the horizontal line into the side, meeting a vertical line drawn from the center of the branch at 4, and draw the miter line 1, 4, 1 in side elevation, as shown. Then 1 A 1 4 1 shows the side elevation of a transition piece, which must be developed by triangulation, while the opening in the main pipe can be developed by parallel lines.

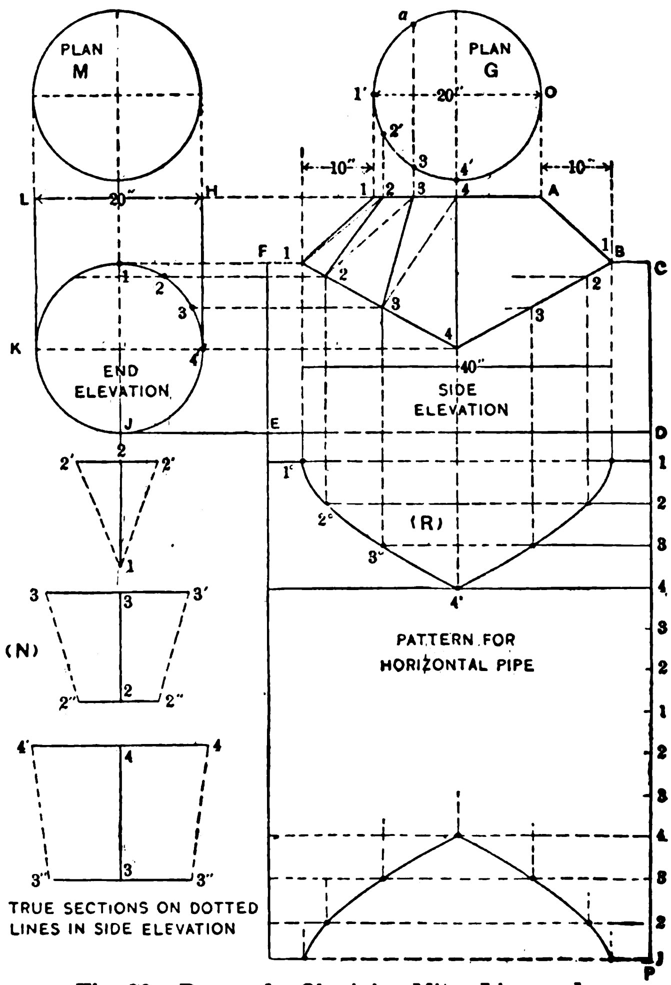


Fig. 76. Process for Obtaining Miter Lines and Pattern of Straight Pipe

As the branch pipe intersects the main directly in the center it will only be necessary to develop the one-quarter pattern, the four quarters being alike. Therefore, divide one-quarter of the main pipe in end elevation into equal spaces, as shown, from 1 to 4, from which horizontal lines are drawn, intersecting the miter line in side elevation, as shown, from 1 to 4 to 1. In similar manner divide one-fourth of the plan G representing the top opening of the branch, also into similar spaces, as in end elevation, as shown from 1′ to 4′, from which perpendicular lines are drawn, cutting 1 A from 1 to 4.

Draw solid lines from 1 to 1, 2 to 2, 3 to 3 and 4 to 4, and dotted lines the shortest way from 1 to 2, 2 to 3 and 3 to 4. These lines then represent the bases of sections the altitudes of which are obtained from the end elevation and from plan G, as will be explained. As the diameter of the plan G and that of the end elevation J are equal, and as the number of spaces in both are alike, the solid lines shown in the transition piece in side elevation will show their true lengths, because the various distances, measured from the center line 1′ O in plan G to the various points 2′ to 4′, will be found similar to the various distances in the end elevation, measuring from the center line J 1 to points 2 to 4.

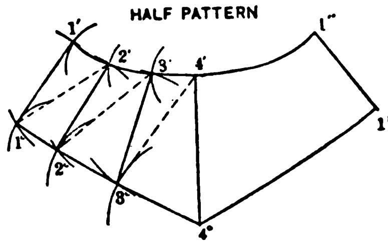


Fig. 77. Process for Obtaining Pattern of Irregular Tee

The true length on the dotted lines 1 2, 2 3 and 3 4 in side elevation are found by taking these distances and placing them on vertical lines in diagram (N), as shown by similar numbers. For example, to find the true length of the line 2 3 in side elevation, place this distance as shown by 2 3 in (N), through which points draw lines indefinitely. As the distance through 3 of the line 1 A in side elevation is equal to 3′ *a* in plan G, take one-half of this, as *a b* or *b* 3′, and place it in (N) on either side of the center line as indicated by 3 3′. In similar manner, as the distance through 2 on the miter line 1 4 in side elevation is equal to *d* 2 in end elevation, then take one-half of this, as *d* 1 of 1 2, and place it on either side of the center line in (N), as shown by 2 2″. Draw the lines 3′ 2″ and 2″ 3′, when 3′ 3′ 2″ 2″ represents the true section on the plane 3 2 in side elevation. In practice only one-half of these sections are required in (N).

The next step is to develop the opening in the main pipe, shown at (R), which will give the true lengths of the miter line and will be used in developing the branch pipe. On the line C D extended draw D P, upon which place the stretchout of the profile J in end elevation, as shown by similar numbers on D P. Through these figures draw the usual measuring lines at right angles to D P, which intersect by lines drawn parallel to D P from similar numbered intersections on the miter line 1 4 1 in side elevation, and resulting in the intersection shown from 1° to 4° in (R). Trace a line through points thus obtained and this will give the pattern for the horizontal pipe, with a seam along C F in side elevation.

The pattern for the branch is now laid out by taking the distance of 4 4 in side elevation and placing it on the vertical line in Fig. 77 as shown by 4′ 4°. With radius equal to 4° 3° in the pattern (R) and 4° as center, describe the arc 3°, which intersect by an arc struck from 4′, in Fig. 77, as center, and 4′ 3″, in diagram (N) in Fig. 76, as radius. Now with 4′ 3′ in plan G as radius and 4′ in Fig. 77 as center, describe the arc 3′, which intersect by an arc struck from 3°, as center, and the solid line 3 3 in the side elevation in Fig. 76 as radius. Proceed in this manner, using alternately first the divisions in the miter cut (R), then the true lengths in (N), and the divisions in the plan G, and then the true lengths shown by the solid lines in side elevation. Through points thus obtained in Fig. 77 trace the line 4′ to 1′ to 1° to 4°, which represents the one-quarter pattern. If the pattern is desired in two part, trace this quarter opposite the line 4′ 4°, as shown by 1″ 1^x, which gives the half pattern with a seam on 1 1 and A 1 in side elevation in Fig. 76.

PROBLEM OF THE PATTERN FOR SPIRAL CONVEYOR

The question has several times been asked, how to cut a pattern for a spiral, such as is used as a conveyor or for the purpose of bolting in a flour mill, or as a conveyor for fertilizing compounds, flax and cotton seed and grains, white lead, concrete and many other materials, and also as a package chute. The question has always been answered by saying that a correct pattern cannot be cut, for the reason that the construction of such a spiral requires more or less stretching of the metal. From the purposes for which it is used it will be seen that when used as conveyors they must be more or less perfect in their curves and construction, according as the material to be conveyed offers more or less resistance.

The curved or twisted surface of such a conveyor is geometrically known as a helicoid, and may be described as a warped surface generated by a line (or some portion of a line) placed at right angles to an axial line, one end of which generating line is kept in contact with the axis, along which it passes at a uniform speed, while the other end of the generating line is revolved about the axis, also at a uniform rate of speed. The outline of the helicoid, or the path traversed by the extreme point of the generating line, is called a helix, and the ratio existing between the two rates of speed for any given length of generating line constitutes what in mechanics is called its pitch. Thus the greater the speed of the generating line along the axis in proportion to the speed of its revolution the greater or higher will be the pitch and distance traveled by the outer end of the line at each revolution. The line at the top or bottom of a screw thread is a helix while the bearing surface (not the cylindrical surface) of a square thread is a helicoid.

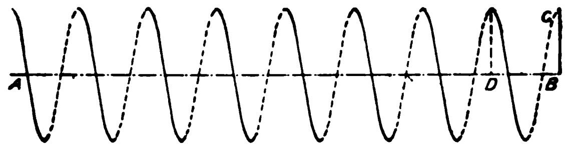


Fig. 78. Spiral or Helix of Low Pitch

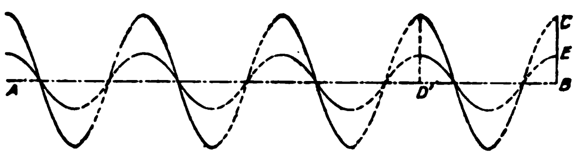


Fig. 79. Outer and Inner Edges of Helicoid of High Pitch

In Figs. 78 and 79 A B are the axes, B C the generating lines, and the spirals shown are the paths traversed by the points C as they revolve about the axes, while B C at the same time moves toward A. In Fig. 78 the line B C has during one revolution traveled the distance B D, while in Fig. 79 it is represented as having traveled twice as far (B D^1), thus producing a spiral or helix of much greater angle of inclination. As intimated above, the inclination of the spiral also depends upon the length of the generating line or distance of the point C from the axis. If another point be assumed upon the generating line nearer the axis than C, as E in Fig. 79, it will be seen that another spiral will be described, with an inclination greater than that described by the point C. The helicoid or surface existing between the two spirals in Fig. 79, or, in other words, the surface generated by the line C E, constitutes in the abstract that which, if executed in metal, would be required to form the essential feature of a spiral conveyor.

A helix may also be described as the line traced upon the surface of a cylinder by a point which is moved at a uniform rate of speed parallel to its axis while the cylinder is being rotated also at a uniform speed. The angle of inclination of a helix may be accurately obtained by constructing a right angle triangle the altitude of which is equal to the distance traversed by the point measured parallel to the axis of the cylinder at one revolution, as B D in Fig. 80 and the base of which is equal to the circumference of the cylinder, the hypotenuse of the triangles showing the required angle. In the triangle X Y Z, in Fig. 80, X Y is equal to the desired longitudinal distance traveled by a point at one revolution of the cylinder, while Y Z is equal to the circumference of the cylinder as taken from the plan above.

The hypotenuse X Z therefore gives the angle of inclination, and at the same time the exact distance measured around the cylinder and along the spiral line from B to D. If such a triangle, the base of which is equal to the circumference of a given cylinder and which altitude is any desired distance, be cut from paper and wrapped around the cylinder, having first placed its altitude parallel to the axis, or, in other words, so that its base shall lie in a perfect circle, the point Z meeting the point Y, as shown at D in Fig. 80, then a true helix may be traced along the hypotenuse upon the surface of the cylinder.

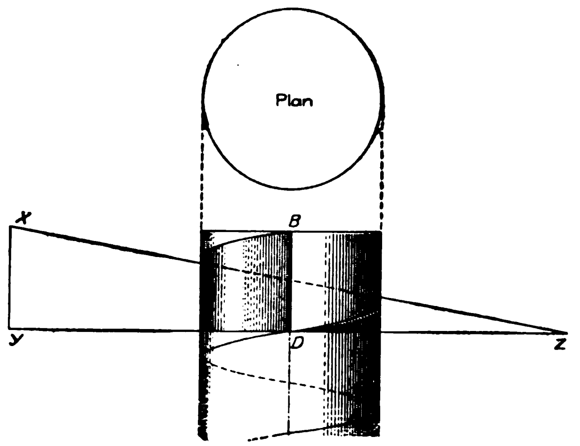


Fig. 80. Obtaining the Inclination and Length of a Helix

In Fig. 81 A B C D is the elevation of a portion of a cylinder or shaft around which it is required to construct a helicoid conveyor, E F being the required outside diameter of the flange, or flight, as that portion of the conveyor is some times termed. A half revolution of the flange is also shown in plan by H I J M L K, and in elevation by D B G E. The method of obtaining a correct elevation of the spiral line in elevation is shown in the left half of the drawing and may be described as follows: Divide one-fourth or one-half a revolution of the desired spiral line in plan into any number of equal spaces, as shown between K and L, also divide the same fraction of the hight of one revolution in the elevation into the same number of equal spaces, as shown by the points *a* to *e* upon the axis, and from these points draw horizontal lines above that portion of the plan similarly divided. From each of the points *b*, *c* and *d* of the plan erect a line cutting that of similar number of the elevation, as shown by the dotted lines. A line traced through the points of intersection, as shown from E to *a*, will give the required line in elevation. Lines drawn from *b*, *c* and *d* to the center P will give points upon other concentric lines of the plan from which to obtain their respective elevations by means of the horizontal lines previously drawn. Thus D *a* is obtained from the points on the arc H I, as shown.

As stated at the outset, the flange cannot be made without a certain amount of stretching of the metal to give it the required twist, which will be more or less according as the angle required is greater or less. If the angle required were lower than that indicated in Fig. 78 it is possible that the metal might be cut in disks (one for each revolution) of the diameter shown in the plan, and forced apart sufficiently with little difficulty. But as the inclination increases the difficulty of construction increases also. In Fig. 81, therefore, an extremely sharp angle has been chosen in order to more clearly show the existing conditions and to make certain differences more apparent. Before these differences can be explained it will

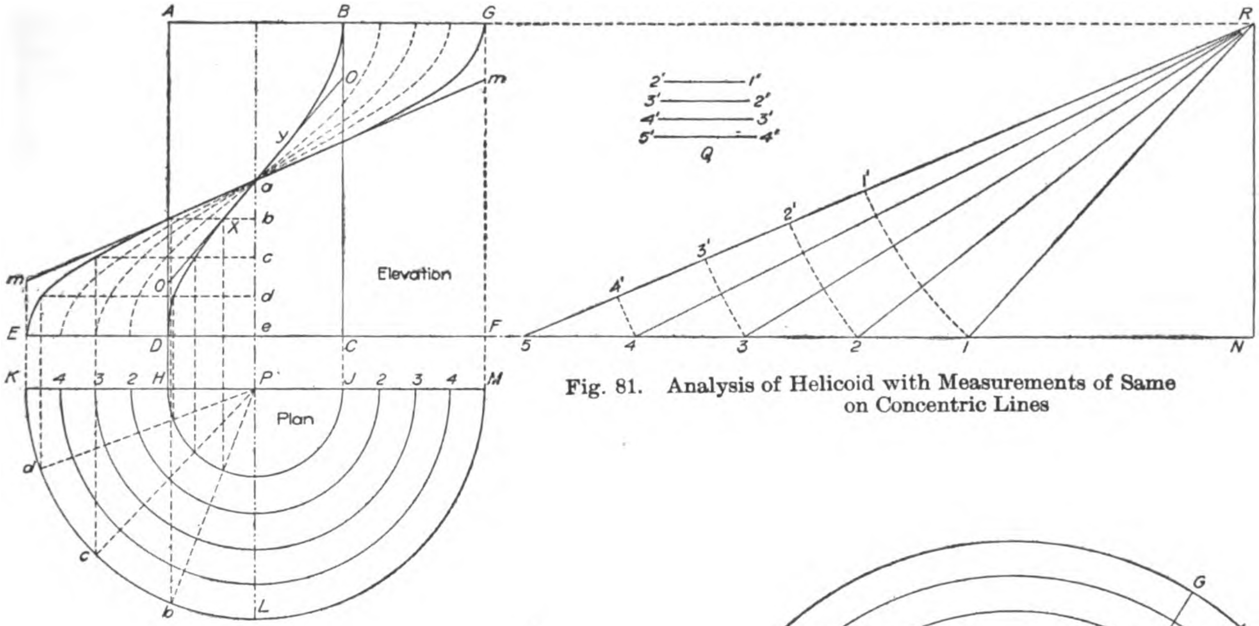


Fig. 81. Analysis of Helicoid with Measurements of Same on Concentric Lines

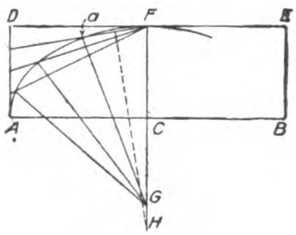


Fig. 82. Method of Obtaining Radius for Inner Side of Blank

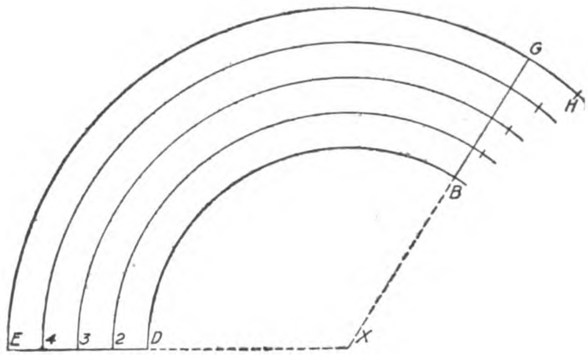


Fig. 83. Pattern for Blank Using Radius Obtained in Fig. 83

be necessary to first understand certain relations existing between circles and their diameters. The circumference of every circle, as is well known, is about three and one-seventh times its diameter. The relation of the diameter to the circumference of a circle cannot be given exactly in figures, but in all computations requiring ordinary accuracy 3.1416 is used as the multiplier of the diameter. The semicircumference H I J is therefore equal to one-half the product of the diameter H J multiplied by 3.1416. In like manner K L M is equal to one-half of 3.1416 times K M; and since the diameter K M is greater than H J by twice the distance J M, the semicircle K L M must be greater than the semicircle H I J by an amount equal to 3.1416 times J M (one-half the difference between the two diameters).

Following this, if K H or J M be divided into any number of equal spaces, and concentric semicircles be drawn, the differences between their circumferences will all be equal, because, as above stated, each difference is the product of 3.1416 by one of the spaces in J M, and the spaces being equal the product must be equal. The distance J M (or H K) having been divided into four equal spaces and the semicircles drawn, the circumference of each with those of H I J and K L M have been set off on the line E F extended, measuring each time from the point N. Thus N 1 is the circumference or stretchout of the line H I J, N 2 is that of the line 2 2, N 3 that of 3 3, etc., showing what has been proved by figures—viz., that the differences are all equal—that is, 1 2, 2 3, 3 4 and 4 5 are all equal. What is true of the set of equally spaced arcs of the plan is equally true of any other similar set of equally spaced arcs including a greater or less number of degrees than the semicircle, provided the arcs are terminated at either end by radii (lines drawn to the center from which they were struck)—that is, their differences would all be equal.

The several dimensions on the line N E having been obtained, the real stretchout on each of the parallel lines of the completed flight, represented in plan by the semicircles and in the elevation by the dotted spiral lines, may be easily obtained by completing the right angled triangle as described in connection with Fig. 80. Therefore erect the perpendicular N R equal in hight to A D and draw the hypotenuses R 1, R 2, etc.; then will R 1 be the correct length of the line D B of the elevation, or H I J of the plan, and R 5 the true length of B G of the elevation, or K L M of the plan. In the same manner R 2, R 3 and R 4 will be the correct stretchouts of the three intermediate parallel lines indicated by 2 2, 3 3 and 4 4 of the plan, and shown dotted in the elevation. A comparison of these distances, R 1, R 2, etc., will now show why a flat pattern for any portion of a flight cannot be cut. With R as a center describe arcs from each of the points 1, 2, etc., bringing all to the line R 5, from which it will be found by measurement that 1′ 2′ is less than 2′ 3′, 2′ 3′ less than 3′ 4′, and it less than 4′ 5′. A comparison of these differences is given at Q, where the short lines correspond in length with spaces of similar number on R 5. Any pattern, therefore, for a blank to form a portion of a flight, supposing it to be drawn to any determined or assumed radius and terminated at each end, as it must be by radial lines, would have to be possessed of stretchouts taken upon equally spaced concentric lines, the differences of which were unequal, a condition which, as shown above, cannot exist in a flat pattern.

In determining the proper radius by which to lay out a blank to be raised or stretched into the required helicoid two methods are open to the mechanic: One is to obtain as nearly correct a curve as possible of the right length or stretchout for the inner side of the pattern, then draw the outside of the blank parallel to it, in width equal to B G or J M, and finish by stretching the outside and intermediate portions with the hammer until they reach the required position, as shown by E G and the parallel dotted lines of Fig. 81. The other method is to reverse the operation, obtaining first the outer curve and work to the inside. An inspection of the elevation will show that both of the spiral curves near where they cross present the appearance of nearly straight lines for a considerable distance. The central or nearly straight portion of the inner spiral D B, for instance, would, if prolonged in either direction, cut the outlines of the cylinder around which it is drawn at the points *o* and *o*; and as any section of a cylinder taken on an oblique plane is an ellipse, it will be seen that that portion of an elliptical section of the shaft taken on the line *o o* and lying between the points *y* and *z* must very nearly approximate the inner curve of the spiral. But as the curve of the spiral is unlike the ellipse, the same at every part, the required portion of the ellipse having been drawn, the approximate radius of that portion can be used in describing the pattern for the required blank.

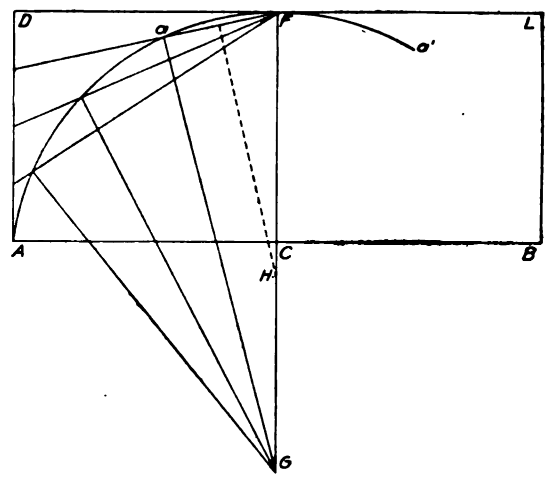


Fig. 84. Method of Obtaining Radius for Outer Side of Blank

This radius can be quite easily obtained as described in Geometrical Problem 78 of the "New Metal Worker Pattern Book," page 66, in the following manner: Draw any line, as A B of Fig. 82, equal in length to *o o* of Fig 81, which bisect at C. At A, B and C erect three perpendiculars, which make equal in hight to I P of Fig. 81, the semi-diameter of the shaft, and draw D F E. Prolong F C, making C G equal to C F. Divide A C into as many equal spaces as sets of centers are desired for drawing the ellipse, in this case four, and divide A D into same number of equal spaces. From points in A D draw lines to point F, and from G draw lines through the points in A C and continue them till they intersect the first set of lines, as shown. Bisect the distance from the first intersection, *a*, to F and from the middle point draw a line at right angles to *a* F and prolong it till it intersects F G (extended if necessary) in H. This will give the radius for that portion of the ellipse from *a* to a^1. It will not be necessary to complete the problem, as the other portions of the ellipse will not be required.

To describe a pattern for a blank, first, with a radius equal to F H of Fig. 82, draw any arc, as D B of Fig. 83, which make equal in length to R 1 of Fig. 81. From the center X draw the radii X D and X B, extending them indefinitely beyond D and B. Upon X D set off the width of the flange, as shown by D E, and draw the arc E G. Then D E G B will be the required pattern for the blank for one-half a revolution of the flight, as shown by the plan in Fig. 81.

The necessary amount of stretching which the blank will require can be found in the following manner: First, divide E D into four equal spaces by the points

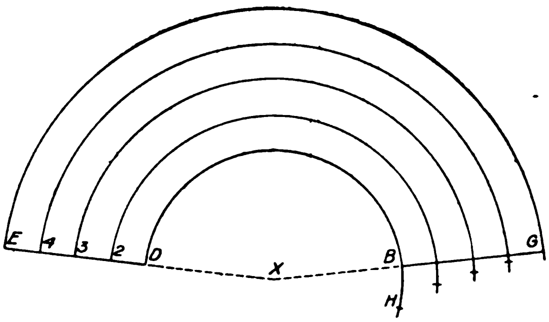


Fig. 85. Pattern for Blank Using Radius Obtained in Fig. 85

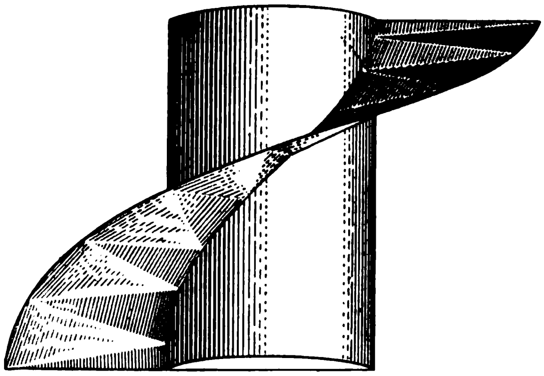


Fig. 86. Portion of Helicoid Obtained by Triangulation

2, 3 and 4, corresponding to those of the plan in Fig. 81, and draw the concentric arcs shown, extending them with the outer arc beyond the line B G. Upon each of these arcs, measuring from E D, set off their required stretchouts as obtained from corresponding hypotenuses in the diagram of Fig. 81. Thus make arc 2 equal in length to R 2 of Fig. 81, arc 3 equal to R 3, arc 4 equal to R 4, and the outer arc equal to R 5. From this it will be seen that the outer arc E G of the blank must when the flange is finished be equal in length to E H; and that in like manner the flange must measure upon each of the intermediate arcs distances greater than those included between the two radii X E and X G by amounts equal to the distances of the several points on them beyond the line B G. The pattern cannot be cut to the points between B and H, but must be cut off on the line B G and stretched as described. If it be required to place a line of any given length so as to be entirely over a shorter line it can only be accomplished by elevating one end more than the other. Thus the stretching of the metal upon any one line or arc gives it the required elevation or inclination as compared with the adjacent arc, which is stretched less or not at all, thus producing the twist.

If it be desirable to adopt the second method referred to above—viz., that of obtaining the outside line of the pattern first—the operation can be performed in exactly the same manner as above described, using the outer spiral of the elevation in Fig. 81 instead of the inner one. Continue its central or nearly straight portion to the outlines of the cylinder in the surface of which it lies, as shown at *m* and *m*, and use the line *m m* as the major axis of a semi-ellipse and proceed as described in the case of line *o o*. This operation is shown in Fig. 84, in which A B is made equal to *m m* and A D equal to L P of Fig. 81. Following this the operation is identical with that described in connection with Fig. 82, and the same reference letters have been used, so that the description may be followed if desired. In obtaining the final result in the latter case, however, the point H is found to fall between C and G, and H F, the radius obtained, is used to describe the outside line E G of the blank shown in Fig. 85. The arc E G of Fig. 85 having been drawn and made equal in length to R 5 of Fig. 81, and the radii E X and G X also drawn, E D is made equal to E D of Fig. 81, and the pattern for the blank completed by drawing the arc D B. The amount of stretching necessary to bring this blank to its required shape may be ascertained by drawing the concentric arcs as in Fig. 83, and extending them with the arc D B beyond the line B G, where the several stretchouts, taken from the diagram in Fig. 81, are indicated by points as before.

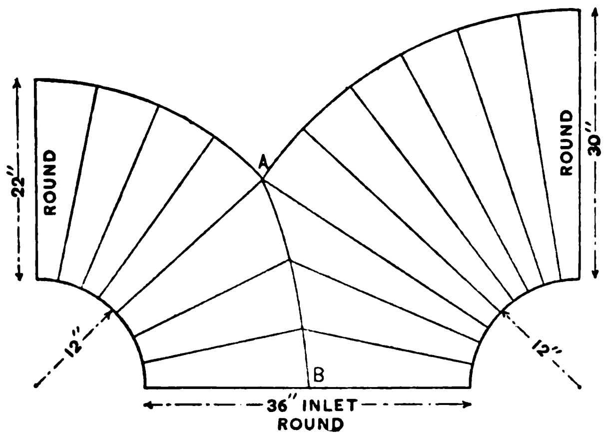
In the case of the blank shown in Fig. 83, which is drawn with the longer radius, the stretching of the metal upon the outer edge shortens or increases its curve until the line B G is elevated and brought into the same vertical plane as the line E D, while in the case of the one shown in Fig. 85, which is drawn with the shorter radius, the stretching of the metal upon the inner edge straightens its curve until the same result is accomplished.

In deciding which of the above methods is to be preferred, the mechanic should be the judge. It is usually considered easier to stretch the metal upon the inner side of a curved strip than upon its outer side, but it is possible and even probable that a middle course would be better than either of those above mentioned. For instance, the line 3 3 or 4 4 of the plan in Fig. 81, or any assumed line, might be made the base of the pattern, in which case the length of the major axis of an ellipse from which to derive its radius could be obtained by using a corresponding spiral line of the elevation the same as D B or E G were used to obtain the line *o o* or *m m*. Such radius having been obtained and the arc drawn, its length would be equal to a corresponding line of the diagram of Fig. 81 measuring from R. The required portions of the width, K H, could be set off on either side of the arc drawn, and the pattern completed by drawing the outer and inner arcs and the radial lines at the ends. Such a blank would then require stretching some on both edges to bring it to the required shape, the amount of which could be obtained as described in connection with Figs. 83 and 85.

Any pattern cutter familiar with the possibilities of triangulation in the treatment of irregular surfaces might reasonably ask if the pattern for a helicoid could not be cut by that method. It is true that a pattern for such a shape could be cut so as to be correct at its inner and at its outer lines; (see pages 78 and 79 of this volume) but, unlike the pattern for an ordinary transition piece, the bends at the several lines crossing the pattern (that is, the sides of the triangles used in obtaining the pattern) would not merge into one general curve, but the pattern would have to be really bent on each line to the exact angle existing between the inclinations of the two spirals between which it is contained. A flight completed by such a method would result in a sort of winding stair, in which the risers assume the angle of the inner spiral B D while the treads lie at the angle of the outer spiral E G of Fig. 81. In Fig. 86 is shown a pictorial sketch of a portion of a triangulated helicoid, from which it will be seen that if so made it would be useless for the purpose for which conveyors are intended; and that if a blank were so cut the metal (of which there is too much through the center) could not be contracted, while a pattern which has the right amount of metal in the center, but too little at the edges, could be stretched to meet the requirements.

IMPORTANCE OF GEOMETRICAL DRAWING TO PATTERN CUTTERS.

In replying to many of the correspondents who have requested solutions to pattern problems, *Metal Worker* has had frequent occasion to refer to the necessity of a more thorough knowledge on the part of the pattern cutter of the principles of geometrical or linear drawing. An inquiry of this class once came to hand in which the correspondent desired to know how to develop the complete patterns of two double pieced elbows as sketched in Figs. 87 and 88, which show what are really two cases of the same problem. In Fig. 87 the two smaller pipes are placed in the same horizontal line at the throat, while in Fig. 88 they are in line on the back. In either case the problem with which the correspondent has to wrestle is one of draftsmanship rather than of pattern cutting. With two carefully completed



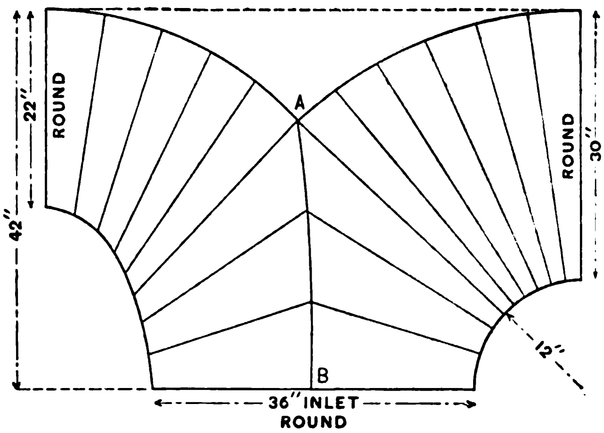


Fig. 87. Reproductions of Original Sketches Accompanying Inquiry Fig. 88.

elevations and a plan of the desired elbows, as specified in either of the above sketches, at hand, no doubt any fairly intelligent pattern cutter would have little difficulty in working out the patterns.

Pattern cutting is simply an adaptation of the principles of linear drawing to the development of sheet metal forms. That particular branch of linear drawing with which the pattern cutter has to deal is properly termed orthographic or right line projection. In accordance with its principles all the points of any one view or elevation are determined with accuracy by means of parallel lines projected from one or more other views (elevations or plans).

Thus the draftsman begins the construction of his principal view from given specifications and proceeds to project therefrom as many other views as possible, or as he finds necessary to arrive at the results desired. In the evolution of such a set of elevations and plans new facts are often brought to light as the work progresses which were unknown at the outset, and which as soon as obtained render their share of assistance in obtaining the final results. Such a course, supplemented by the fund of knowledge which comes with experience on the part of the draftsman, will often accomplish wonders.

This problem furnishes such an excellent opportunity of illustrating the application of the foregoing suggestions that the complete operation of constructing the necessary plans and elevations and of laying out the patterns for the above, as far as necessary, beginning with the conditions as given in Fig. 87 is here consistently undertaken.

The principal view taken from first drawing any horizonal line indefinitely, as C D of Fig. 89, upon which set off at convenience the distance E F equal to 36 inches, the desired diameter of the inlet. From the points E and F set off 12 inches in either direction upon the same line, thus locating the centers G and D, from which the throat curves are to be struck. Erect perpendicular lines from the points G and D indefinitely. From G and D as centers, with a radius of 12 inches, describe arcs from E and F cutting the perpendiculars just drawn in the points M and K. From M and K set off respectively 22 inches and 30 inches upon the vertical lines, obtaining the points N and L. From D as center, with the radius D L, describe an arc, L A, indefinitely; and from G as center with G N as radius, describe another arc, cutting the first one in the point A. This completes the general outline of the side elevation.

Since three pipes of different diameters are to be joined, it is evident that there must be some gradations in the width of this elbow at the various points of its course. It will therefore be necessary to construct a plan or an end view, or perhaps both, upon which to establish such gradations and to measure width when necessary. The plan may be begun at once, and all of the views which is deemed necessary to construct should so far as possible be carried along together, all points in any one view being projected into the other views as soon as obtained. Since both halves of the elbow, when divided by a vertical longitudinal plane, are supposed to be alike, half of the plan or end view will be sufficient for all purposes. Therefore draw C^1 D^1 parallel to C D and at any convenient distance away, as the center line of a plan. From each of the points G, E, F and D drop lines vertically, cutting C^1 D^1 at G^1, E^1, F^1 and D^1, and continue them indefinitely below. Bisect E^1 F^1, obtaining the point B^1, which will become the center from which to describe the semicircle E^1 H F^1, representing the half plan of the inlet or largest pipe.

In drawing the miter line or line representing the junction of the two arms of the elbow, as seen in the side view, and in determining the shape of the opening which it represents as it would appear if seen from either end, the reader will have to be guided by his general knowledge of intersections and the shapes derived therefrom. Were the two pipes of the same diameter throughout their course, and brought or mitered together in the general manner indicated in the drawing, the position of the miter line would result from the simple operation of bringing together two sets of lines emanating from corresponding points in their respective profiles.

If, again, one pipe being larger than the other, both be continued without change of diameter as before through the several pieces composing the elbow, the position of the miter line upon which the two would intersect would be the result of a similar operation. But since the two branches or elbows are required to unite so as to

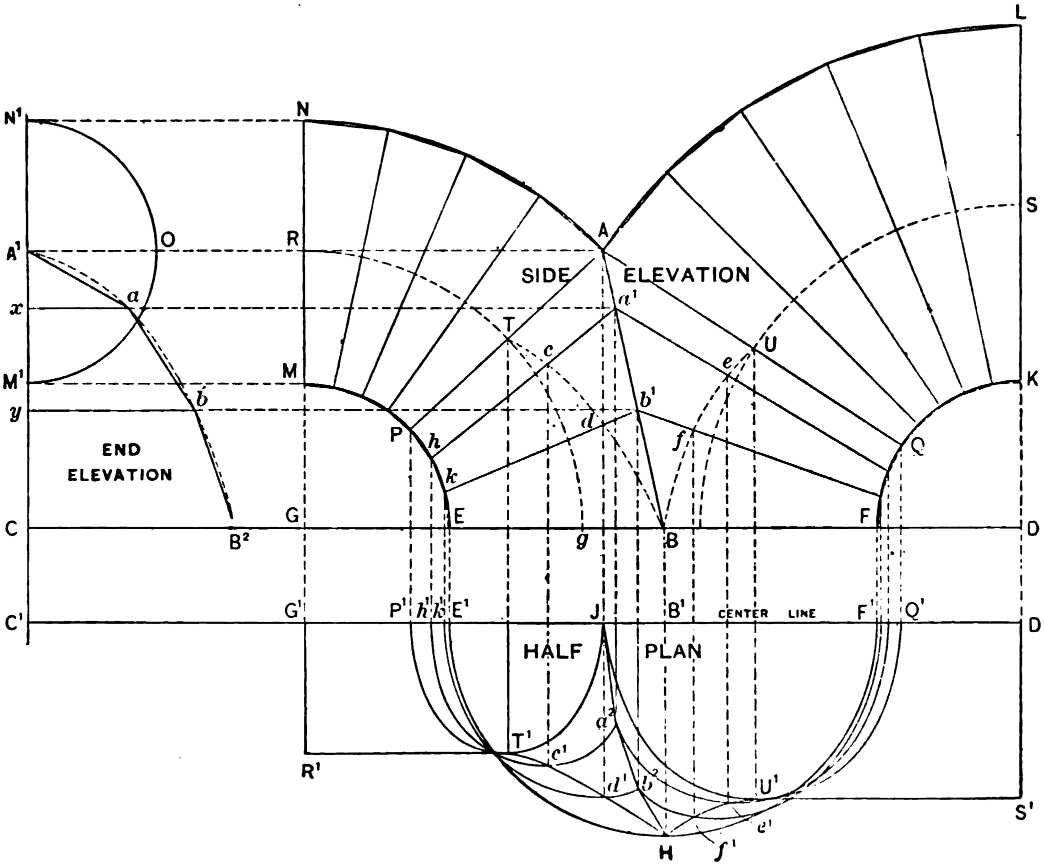


Fig. 89. Complete Drawings of Double Elbow shown in Fig. 87.—One-eighth Full Size

form a third pipe of a specified larger diameter than either, the problem consists in the devising or designing of a transition composed of several pieces which shall begin at A with a junction of the two smaller pipes and finish at E F with a perfect circle representing the larger pipe.

In this part of the work the reader will have an opportunity to exercise the power of his imagination in forming a mental idea of the approximate shapes of the several intermediate pieces necessary to accomplish the transition, working upon the supposition that if he can form an idea of the general shape and dimensions of the several parts he will have little difficulty in placing the different views of them upon paper.

In the failure of his power of mental conception he could be materially aided in his work, should he care to take the trouble, by the construction of a model. An inspection of the drawing, as thus far constructed, will show at once that those portions of the branches from A to N and A to L will be the same as ordinary pieced elbows. Suppose now that these parts have been made in the usual way, and have been placed relatively in the positions which they are to occupy in the finished work. Let the reader now cut out a disk of any material and place the same in the position shown by E F of Fig. 89, then, taking moist clay or molders' sand, proceed to fill in the space E P A Q F between the approaching ends of the elbows and the disk at the base, shaping it so as to meet the curves of the throats at either end and gradually reducing its width or thickness as it rises till it meets the circles at A P and A Q. A model so constructed will give the general shape of the transition, upon which the several pieces of which it is to be constructed must be so outlined that they may be made by simply cutting and bending the metal.

Sooner or later in the solution of every problem in sheet metal work the question of the method of developing the patterns arises. Is it a miter or miters between continuous or parallel forms? Are the pieces portions of regular tapering cones, or are they irregular tapering forms, in which case triangulation must be resorted to? An inspection of the drawing as thus far developed, or of the model if it has been constructed, will show that those parts constituting the transition must be developed by the methods of triangulation, and that therefore their outlines may be drawn arbitrarily in accordance with the judgment of the reader, provided that they are not so drawn as to involve hammering or stretching of the metal.

To proceed then with the drawing in the light of the above conclusions, the miter line A B may be drawn straight from A, the point of least or no width, to B, the point of greatest lateral diameter or width of the united elbows. To be sure, it might be drawn from A to a point to the right or to the left of B if there were any reason for so doing, or it might be drawn with a general curve composed of as many straight lines as there are intersecting pieces on either side, but such a course would only complicate matters to no purpose. The line A B, representing as it does the junction of two pipes while appearing straight in this view must necessarily have a profile when viewed from the end. An idea of the shape which it represents could be obtained by cutting away one portion of the model described above by means of a thin bladed knife or a wire held taut and passed from the point A down through to B, the middle of the disk at the base. To obtain this line without the aid of the model it will become necessary to construct an end view of the junction, as shown at the left in Fig. 89.

The end view is obtained by drawing any vertical line, as C N^1, representing the center line of the proposed view. Project the point A upon this line by means of the dotted horizontal line, as shown at A^1, and from C set off on the

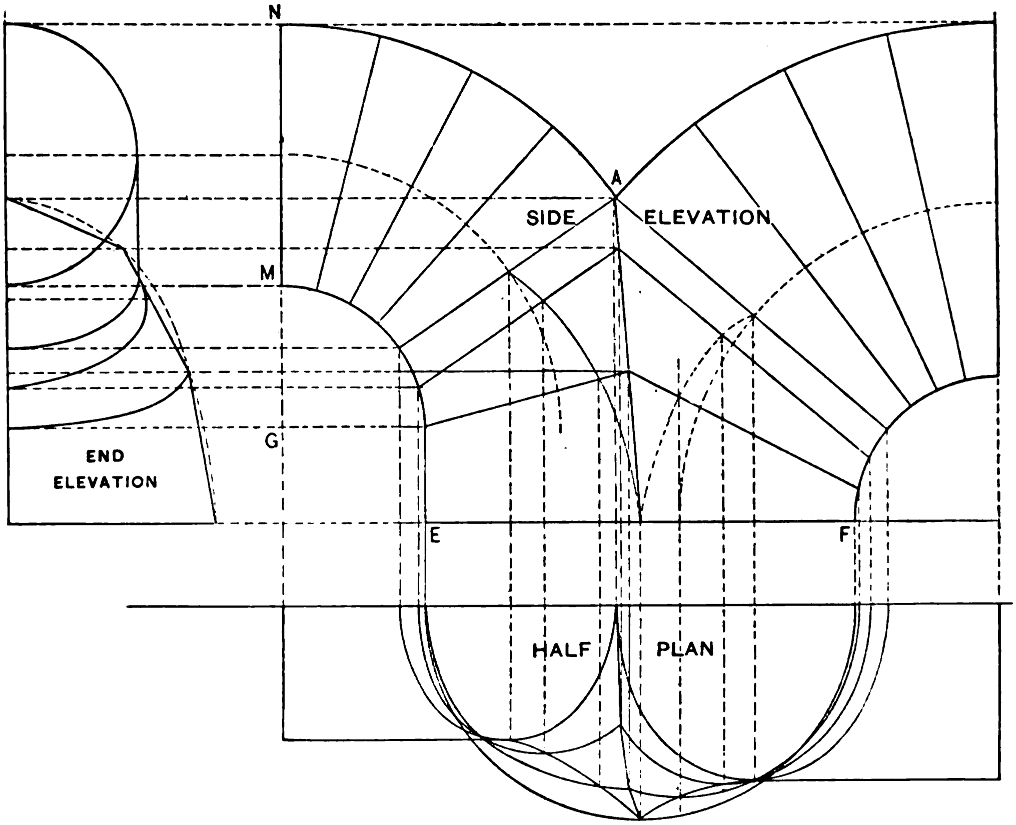


Fig. 90. Completed Drawings of Double Elbow Shown in Fig. 88.—One-eighth Full Size

horizontal base line one-half the width of the largest pipe—that is, make C B^2 equal to 18 inches. A line drawn from A^1 to B^2 will then represent one-half the opening between the two branches of the elbow. This line, so far as the requirements of triangulation are concerned, might be drawn perfectly straight between the two points. But here the knowledge or experience of the reader must be called into play. Any one who has seen two straight pipes mitered together so as to form a Y, or has cut any oblique miter upon a cylinder, knows that the shape of opening so produced is elliptical. It is therefore advisable that the line A^1 B^2 should approximate a quarter ellipse in shape, as shown by the dotted line in the end view.

This end view may be completed as far as desired, making it an elevation of the end nearest which it is drawn. Therefore project the points N and M horizontally from the side elevation to the center line of the end elevation, as shown at N^1 and M^1. Bisect the distance N^1 M^1, locating the point A^1, which by mere accident or coincidence falls at the point representing A of the side elevation. From A^1 as a center describe the semicircle N^1 O M^1, representing one-half the opening at N M to receive the 22-inch pipe. Lines from O toward B^2 may afterwards be drawn to complete this view if found necessary.

The next matter to be determined will be the number of pieces of which the elbows shall be made, and the drawing of the divisions upon the elevations in accordance with the same. The number of pieces will, of course, be determined in accordance with physical requirements; material to be conveyed, friction, etc. Having determined this, first draw lines from A toward G and D, as shown by A P and A Q. The portions A N M P and A L K Q thus become the equivalents of ordinary pieced elbows, and the arcs A N and A L being unequal may each be so divided into equal spaces that the spaces in both shall be approximately alike. Thus it will be seen that if N A be divided into four equal spaces and A L into five, they will be nearly alike in both. From the points of division assumed in N A and A L lines may now be drawn toward G and D to the throat lines, as shown. Connect adjacent points upon the arcs, both of the throats and the backs, by straight lines, thus completing these parts of the side elevation.

In continuing the division to the part forming the junction, the points of division corresponding to those already assumed on the backs of the pieces will have to be established upon the line A B; but as A B represents a curved line it will be better to fix the points of division upon its representative A^1 B^2 of the end elevation. Two points upon A B, dividing it into three spaces, will be found sufficient, since three equal spaces upon each of the remaining portions of the throat lines P E and Q F will result in an approximate equality of spaces in M E and K F respectively. Therefore the points a and b may be so taken upon the curved line A^1 B^2 that the space A^1 a will be the shortest and b B^2 the longest of the three. Connect the adjacent points by straight lines, as shown. By making the spaces shortest where the curve of A^1 B^2 is quickest, or of shortest apparent radius, the resulting broken line will more nearly approach the curved line which it takes the place of than if the spaces had been made equal. The points a and b may now be projected upon the miter line A B of the side elevation, as shown at a^1 and b^1, and straight lines drawn from each to the corresponding points of division upon the arcs P E and Q F.

In the thus completed side elevation the two upper sections of the transition piece lying adjacent to the lines A P and A Q have the appearance of being no wider at their backs than at their throats, but a moment's reflection or a glance at the end elevation will show that the distance of the point a^1 from A is equal to a A^1 of the end view, and that it is therefore greater than the back width of any of the other pieces except those between it and the line E F. One might easily have made the mistake of dividing the line A B of the side elevation into three equal spaces had the end elevation, showing the shape of the section on A B, not been drawn. This liability to error is, in fact, shown in the crude outlines of the original sketches given in Figs. 87 and 88.

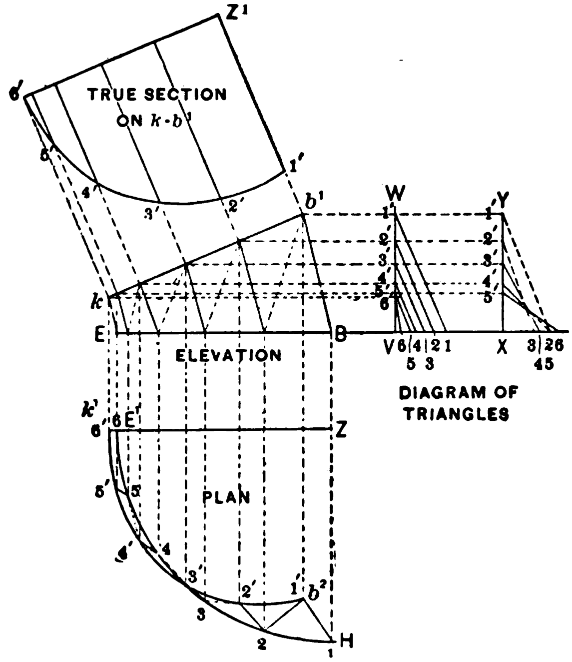


Fig. 91. Elevation, Plan and Section of First Piece, E k b^1 B, in Left Side, Duplicated from Fig. 89, Showing Method of Triangulation.

Attention is now directed to the completion of the plan, upon which must be obtained a view of each of the several miter or joint lines between P A Q and E F, including the line A B. The positions of the points in A B upon the plan are obtained simply by projection and measurement. The point A being upon the longitudinal center may be dropped at once to the center line of the plan, as shown at J. From each of the points a^1 and b^1 also drop lines to the center line, carrying them indefinitely beyond or below. Upon each of these lines respectively set off from the center line the distances a x and b y of the end elevation, as shown by a^2 and b^2. The point B being upon the circumference of the largest pipe may be dropped upon the semicircle representing the same in the plan, as shown at H. Connect the adjacent points obtained in this operation by straight lines; then the broken line J a^2 b^2 H will be the plan of the line A B of the elevation.

No further drawings will, of course, be necessary in obtaining the patterns of those portions between P A Q and the outlets. It will be advisable, however, to represent them in the plan on account of their relationship to the middle and more intricate portion. Therefore drop vertical lines from M and K through the center line of the plan, and make G^1 R^1 and D^1 S^1 respectively equal to the semi-diameters of the outlets M N and K L. From R^1 and S^1 draw lines parallel to G^1 D^1 indefinitely toward the center of the plan.

The next operation will be to obtain upon the plan a projection of the circles P A and A Q. First bisect the lines representing those circles, as shown at T and U. Since T and U represent points of extreme projection or points of greatest transverse diameter, vertical lines may be dropped from them, cutting the lines drawn from R^1 and S^1, as shown at T^1 and U^1; also drop lines from P and Q cutting the center line of the plan at P^1 and Q^1. Then P^1, T^1 and J become three points of a semi-ellipse of which P^1 J is the minor axis; and likewise J, U^1 and Q^1 are three points of a semi-ellipse of which J Q^1 is the minor axis. These semi-ellipses may be drawn upon the plan by raking, by trammel or by any method most convenient which will result in true elliptical curves.

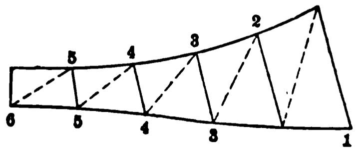


Fig. 92. Half Pattern of Piece Shown in Fig. 91

Having now drawn the plans of the circles constituting the upper and lower sections of the transition portion of the elbow, it remains to fix upon the plan the sections upon the two intermediate joint lines in each side or branch. Inasmuch as the method of triangulation admits of working to assumed outlines, the draftsman is here thrown upon his judgment as to the shape of and the best method of obtaining these sections. This can be accomplished by first establishing the principal points of the curves and then drawing them by eye so as to form in each branch a gradual transition from the circular profile of the small pipe to one-half the circle of the large pipe or inlet. The first points to be determined are those of greatest thickness or transverse diameter in each. The point of greatest transverse diameter in each of the joint lines in the smaller branch pipe is, of course, at the intersection of each with an arc drawn from G as center and with G R as radius, that of P A being at T. This arc continued intersects the line E F at *g*. But as the greatest transverse diameter of E F is at B the points *c* and *d* must be assumed so as to deflect this line at T toward B. Having determined the points of greatest thickness upon these lines the question next arising is: "What shall be the distance across the sections at these points?" This must, of course be determined upon the plan, where T^1 represents the point T, and H the point B. The most reasonable solution to the question seems to be to draw a line in continuation of R^1 T^1, curving it out to reach the point H. The line R^1 T^1 H will then be a plan of R T B of the elevation. Lines dropped vertically from *c* and *d* of the elevation, intersecting this line at c^1 d^1, will then locate the desired points in the plan. Next drop lines from h and k to the center line of the plan, as shown. Then h^1, c^1 and a^2 are three points through which a curve, elliptical in character, must be drawn, establishing a plan of the line $h\ a^1$ of the elevation. In the same manner a like curve drawn through k^1, d^1 and b^2 will answer as a plan of the line $k\ b^1$.

The points and curves in the right half of the plan are obtained by a similar process, which is all shown by the lines of projection and the reference letters.

Should it be desired the projection of all the curves now shown in the plan could be obtained upon the end elevation by a process similar to that just gone through in obtaining the plan, simplified, however, by the fact that no questions of design can there arise, the position of all important points having been already established in drawing the plan. Likewise the projections of the circles represented by the joint lines between A P and N M could be obtained upon both the plan and the end view by the method employed in obtaining the semi-ellipse $P^1\ T^1\ J$ from the line P T A. These operations, however, would only be valuable as a lesson in drawing, as they are in no way necessary to obtaining the patterns, though the reader is advised to do so inasmuch as this is a lesson in drawing.

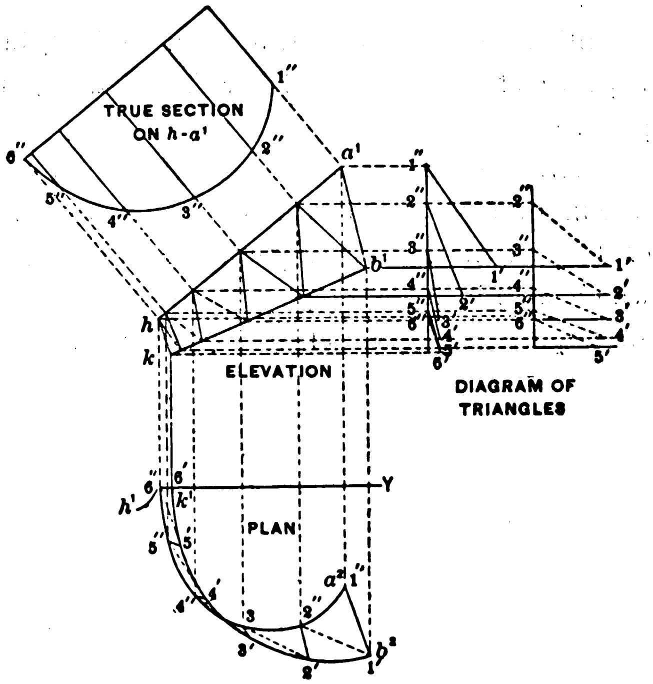


Fig. 93. Elevation, Plan and Section of Second Piece $k\ h\ a^1\ b^1$, in Left Side of Fig. 89, Showing Triangulation

In preparing drawings of the second case, shown in Fig. 88, the methods employed in the foregoing demonstration are equally applicable. The completed drawings of the same are given in Fig. 90, in which corresponding points in the several views are connected by the lines of projection. The conditions of the two cases are so nearly alike that the reader will have no difficulty in applying the demonstration given above to this case. The sketch shown in Fig. 88 differs from that in Fig. 87 principally in the fact that the two outlets are in line at the back, which gives a longer throat line to the smaller pipe than in the former case. The throat proper is confined to a quarter circle the center of which is at G, Fig. 90, as in the former case, the line is then carried vertically to the point E. This keeps that part of the elbow from A to N a regular pieced elbow, as in the former case, and simply modifies the shapes of those pieces lying between A and the line E F. Of course the throat line could be made a continuous curve from E to M if desired, but at the expense of much more labor in obtaining the final pattern.

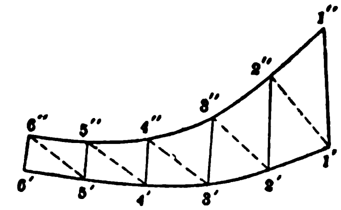


Fig. 94. Half Pattern of Piece Shown in Fig. 93.

The necessary drawings having been completed, it will be advisable before attempting to develop any of the patterns to make separate new drawings, each of which shall include the plan and elevation of one of the pieces, which shall be in all respects duplicates of the outlines already obtained, and placed conveniently near together, thus facilitating the subsequent operations by avoiding the confusion of lines which would result from performing them all upon the one elevation.

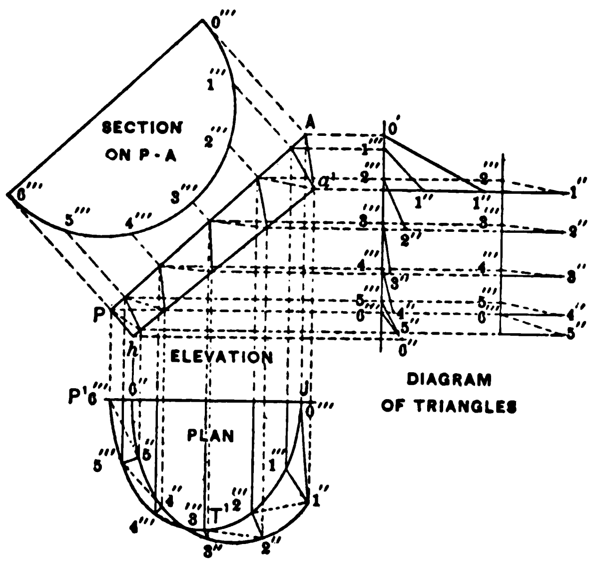


Fig. 95. Elevation, Plan and Section of Third Piece, h P A a^1, in Left Side of Fig. 89 Showing Triangulation

In Fig. 91 is shown a duplicate of the piece E k b^1 B of Fig. 89, there indicated by the same letters, below which is its plan traced from Fig. 89, in which E^1 H is a plan or true section on the line E B of the elevation and k^1 b^2 is a horizontal projection of the line k b as traced from the line bearing the same letters in Fig. 89. Each of these curves constituting the plan of the piece may now be divided into the same number of equal spaces of convenient size, and numbered correspondingly, as shown by the small figures. Points of like number must be connected by solid lines, and the four-sided figures thus produced must be subdivided diagonally by dotted lines, as shown. The triangulation thus produced may be seen to better advantage upon the elevation, the points upon the upper and lower bases being obtained in that view by projection from the corresponding points of the plan, all as shown by the vertical dotted lines.

The true lengths of the several solid and dotted lines thus obtained in both plan and elevation are to be obtained by the method usual in all similar operations—

that is, by considering them as the hypotenuses of triangles the altitudes of which are obtained from the elevation and the bases of which are these lines as they appear on the plan.

This operation is shown in the diagram of triangles at the right, in which the hights of the points in the vertical lines V W and X Y are obtained by projection from the elevation, while the horizontal distances between corresponding points are obtained by measurement from the plan; the hypotenuses being drawn give the true distances across the pattern, which is given in Fig. 92.

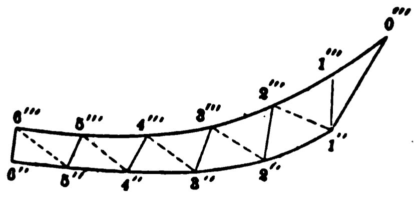


Fig. 96. Half Pattern of Piece Shown in Fig. 95

The lengths of the spaces upon the lower line of the pattern are obtained from E^1 H, the plan of the lower base of this piece. To obtain the lengths of the spaces upon the upper line of the pattern, however, a true section on $k\ b^1$ must be obtained as shown above, since it is evident that distances measured upon the oblique line are greater than the horizontal distances as given upon the plan. This section is obtained by the usual operation of raking from the line of the upper base as given in the plan, viz.: Draw lines from each of the points in $k\ b^1$ at right angles to the same, intersecting the line 6′ Z^1 of the section which is drawn parallel to $k\ b^1$. The distances of the several points in the developed curve from the line 6′ Z^1 are the same as those of corresponding numbers in the plan from the line 6′ Z.

In Fig. 93 is shown the duplicate drawing of the second piece of the left portion of the elbow with its plan, diagram of triangles and the true section of its upper base. In drawing its plan, $k^1\ b^2$, the line of its lower base may be traced and transferred from Fig. 91, with its points as there used, instead of being obtained from the original plan. The true section obtained in Fig. 91 becomes the true profile of the lower base of this piece, therefore the stretchout of the lower side of its pattern, shown in Fig. 94, may be taken from the true section in Fig. 91. The points in $k^1\ b^2$ from which this section was derived are thus located at once in the plan in Fig. 93 by the transferring above alluded to and form the basis of the triangulation. The subsequent work of developing the pattern of this piece is exactly similar to that employed in obtaining the first piece.

In Figs. 95 and 96 are shown the necessary drawings and pattern of the third piece. The true section obtained in Fig. 93 becomes the true lower base of this piece, while the true upper base is a semicircle the diameter of which is A P of Fig 89. While the true projection of this semicircle in the plan, as shown by P^1 T^1 J of Fig. 89, is according to geometrical rules a perfect semi-ellipse, it is better to obtain the same in Fig. 95 by the operation of raking, so dividing the same that the points and spaces used may also be used in connection with those of the lower base $h\ a^1$ for the purpose of triangulation. It will be noticed that one more space has been taken in the upper base of this piece than in the lower on account of its greater length, and that the triangles have been so arranged that the apexes of two come together at the point 1″. By this treatment the triangles so produced are more nearly equilateral, and can therefore be more accurately constructed in the operation of laying out the pattern than if they were very scalene.