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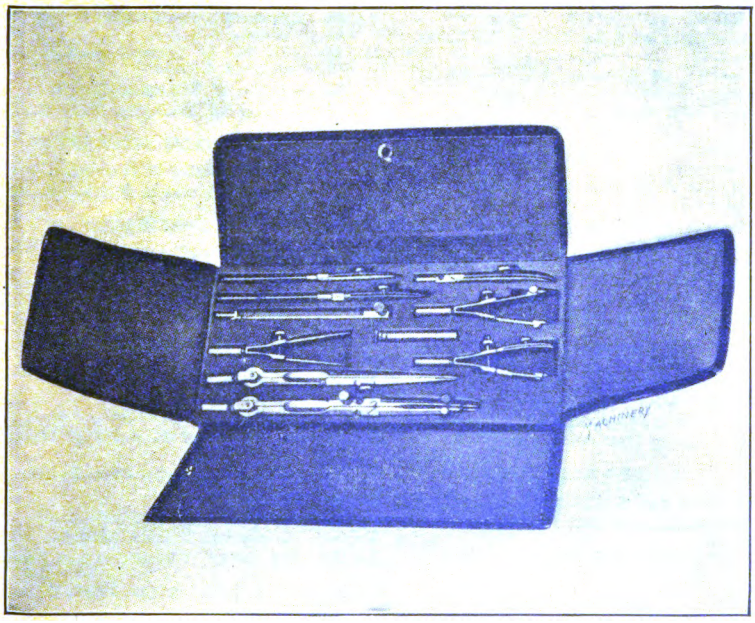
MECHANICAL DRAWING

BY OSCAR E. PERRIGO

PART II—ORTHOGRAPHIC PROJECTION—LETTERING



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NUMBER 86

MECHANICAL DRAWING

By OSCAR E. PERRIGO

PART II

ORTHOGRAPHIC PROJECTION LETTERING

THIRD EDITION

CONTENTS

CHAPTER I

ORTHOGRAPHIC PROJECTION

In Part I of this treatise (MACHINERY'S Reference Series No. 85), the principles of such portions of the elements of geometry as are necessary and useful in mechanical drawing, have been dealt with. Thus far all of the figures represented have been in one plane, this plane being, for instance, the surface of the paper upon which they have been drawn. In the following the study of the representation of solid figures will be taken up. Solid figures or solids extend in three directions. They have length, breadth and height. This leads us into the subject of *orthographic projection*. By the term orthographic projection we mean the drawing of objects in such a manner that they are represented or "pictured" on two or more planes, which are at right angles to each other. In other words, the object is so represented that we may see two or more sides or faces of the object.

In mechanical drawing we frequently represent three sides of an object, and sometimes even a greater number, the idea being to show as many of its various faces as may be necessary to illustrate clearly its form and construction. For this purpose sections on different planes and angles, and various interior views of complicated portions of the mechanism, are frequently drawn, as will be shown later. For our present purpose, however, we will confine our attention to comparatively simple and familiar forms, for the purpose of teaching the principles without distracting the mind by complex forms of construction. Unusual technical terms will be avoided as far as is practical, and all the necessary explanations will be made plain, simple, and concise, so that they may be readily understood by those who have not had the advantage of technical education.

In referring to the various views of a piece we use the term "elevation" for those showing vertical faces; hence, "end elevation", "front elevation", "rear elevation",' etc. The view of the top of a piece we usually call a "plan" or "plan view", and a view of the under side, a "bottom view." In addition to these views there are "interior views", and "sections", each term being qualified by various descriptive words, forming such terms as "cross-section", "longitudinal section", "section on the line *AB*", etc.

Practical Problems in Projection

A number of problems, illustrating the methods of projection, are given in the following. The problems are numbered consecutively, and form a continuation of the problems presented in Part I. Each problem is illustrated in the accompanying plates, the numbers of which are also a continuation from Part I of this treatise.

In working out the problems, pencil lines only need be used. It will be better to defer the use of ink lines until later, when with more practice, greater facility in the use of the drawing instruments has been acquired. The geometrical principles upon which the work is based is the important part of the subject at this stage, and it is not well to further complicate it by premature refinements of the practice of drawing. The problems should be worked out several times so as to fix their basic principles in the mind. They should be drawn to such a scale that each will cover a space of, at least, 6 by 8 inches. Thin white drawing paper will be suitable for this work. A 4H drawing pencil will be the proper grade to use. If desired, the outlines of the different views may be afterwards made more distinct by the use of a 2H drawing pencil, or a No. 2 commercial pencil. The T-square and the angles should be used for making these drawings. Determine as nearly as possible where a line should be before making it. Avoid the use of the erasing rubber as much as possible. Excessive use of the eraser is a bad habit and indicates either a careless workman or an inefficient thinker.

Problem 50. This problem is one of the most simple and common cases of projection. It is required to represent on the drawing a short cylinder, such as a piece of round steel, squared up on the ends.

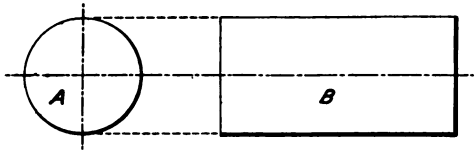
The end elevation at *A* is a circle which shows not only the form, but the diameter of the piece. The view at *B* is a side elevation and shows not only the diameter, but the length of the piece. Such a piece requires but two dimensions, diameter and length. The end elevation could, therefore, be dispensed with, if the dimensions were given on the side elevation, and the fact that the piece is round indicated in some manner. In this and the following problems dotted "construction" lines are used, so as to more clearly show the connecting lines between the several views. By construction lines is meant such pencil lines as are necessary in laying out different views, but which are erased after the drawing is inked in.

Problem 51. In this problem the piece represented is cut from a square instead of from a round bar. As in the previous problem, the view *A* is an end elevation and *B* a side elevation. The object represented being a square bar, a center line is not necessary. In this case the end elevation shows thickness and width as well as the form of the bar, while the side elevation shows only its height or thickness and its length. The end elevation at *A* is, therefore, necessary.

Problem 52. In this problem the piece represented is of hexagonal form. A center line is necessary in this case. The end elevation shows the form and the "short diameter," or as usually expressed, the distance "across flats", while the side elevation, as in the former examples, shows the length. Both views also show the "long diameter" or dimension over opposite corners of the hexagon. The side elevation shows by horizontal lines the corners or angles of the hexagonal form. Other forms of bars having the same form or cross-section throughout their entire length may be represented in a similar manner.

Problem 53. In this problem the piece to be represented has not the

Problem 50.



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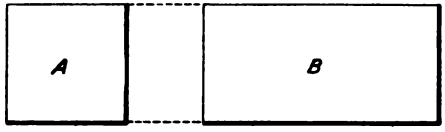

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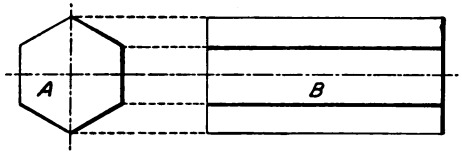

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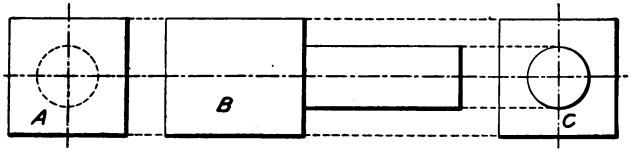

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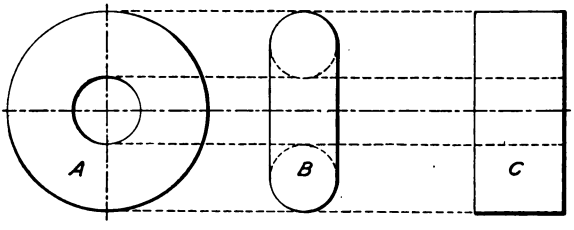


Plate XV. Problems 50 to 54

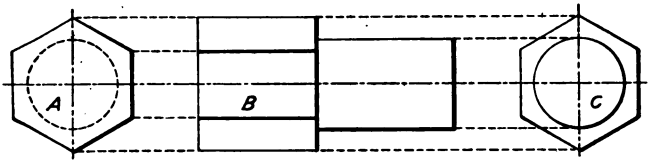
same form throughout its entire length. One portion of the square bar has been turned down, or forged, to a cylindrical form. While the side elevation shown at *B* indicates the length of each portion and the whole length, and the diameter of the round and the side of the square part, it does not show the form. Hence, we must make use of end elevations. The end elevation *A* shows the square form of the larger part. The end elevation *C* shows, in full lines, the cylindrical part also. It also shows that the centers of both the square and the cylindrical parts are the same; in other words, that the cylindrical part is in the center of the square part. At *A* this is also shown by the dotted circle which shows that the cylindrical part lies beyond and is hidden from view. While the elevation at *A* is not absolutely required, it renders the reading of the drawing easier, and the ease and certainty with which a drawing can be read are its most valuable features.

Problem 54. In this problem a circular ring, made from a round rod is to be represented. The form or cross-section of the rod of which it is made is quite as important as that it is a circular ring. At *A* is shown the front elevation, which gives the outside diameter and the diameter of the opening, or inside diameter; but the form is not shown. The edge view or elevation at *B* is necessary to show this. The full line shows the contour of the outside of the ring, but the dotted half-circles are necessary to show that the rod of which the ring is made is completely round rather than flat on the inside, as it might be if the dotted lines were omitted. The edge view at *C* is introduced to show that the front elevation at *A* would as readily represent a ring made of square rod as one made of round rod. Therefore, in such a case two views are required. If the cross-section is irregular, a sectional view might be necessary.

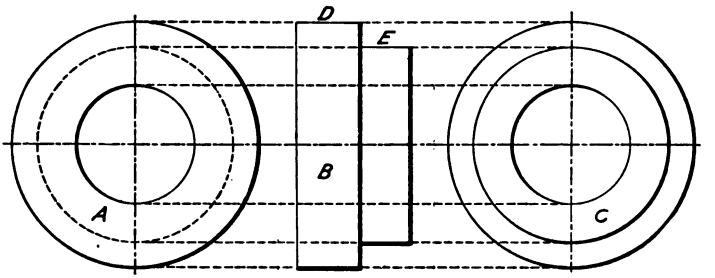
Problem 55. This case is somewhat similar to that shown in Problem 53, and one which frequently occurs in practical work. In this case a hexagonal rod has been turned down, or forged, to a cylindrical form. The different lengths are shown in the front elevation at *B*, but the forms of each part are shown at *A*. The third view at *C* offers additional opportunities for applying dimension lines. (The question of dimension lines will be dealt with later.) In drawing these elevations, center lines should always be used, and they should be drawn carefully, so that the intersection of these lines is the correct center.

Problem 56. In this problem a reducing bushing, fitting the interior of two different diameters of pipes, is to be represented. The circular form, the outside diameter, and the diameter of the hole is readily shown at *A*, but the edge view at *B* is necessary to show the form, thickness, and the length of the two parts *D* and *E*. In case there are to be rounded corners, or a fillet at the junction of the two parts, this view is the proper place to show this. The third view, at *C*, is introduced to more clearly show the form of the part *E*, although this is, in practice, considered as sufficiently represented by the dotted circle at *A*. Like in the former example, however, a second elevation renders the drawing more easily understood. In pieces of greater complication,

Problem 55.



Problem 56.



Problem 57.

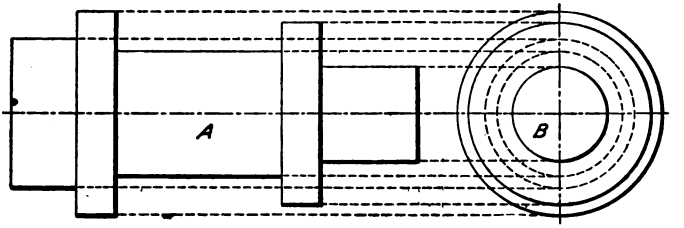


Plate XVI. Problems 55 to 57

it will be found more necessary to show views of each side (as those at *A* and *C*), as some parts of the form may not be circular, as for instance, a flattened side, a keyway, or any similar special form, that it would be necessary to show.

Problem 57. In this problem a piece with a number of different dimensions is shown, there being five different diameters to be represented. All the diameters and the lengths may be properly shown in the front elevation at *A*, but this view gives no indication of the form of the cross-sections. Under certain practical conditions some of these might be cylindrical, some square, and some hexagonal or octagonal. The end view determines the cross-sectional shape. In some cases, in order to show pieces of this class correctly and conveniently, it might be necessary to show a second elevation of the end, or a cross-section of one or more parts, in order to insure correct understanding of what is required.

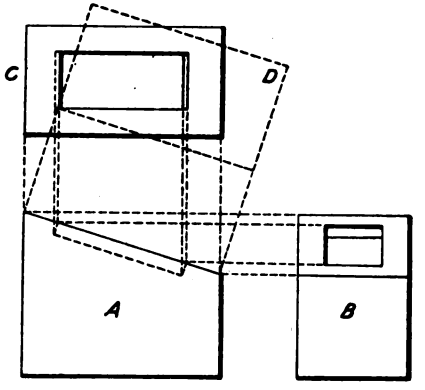
Objects Requiring to be Represented by Plan and Bottom Views

In all the foregoing cases we have shown pieces of such form that the several views representing them have been upon a common center line, and, therefore, comparatively easy to lay out. We will next consider pieces of such forms that plan and bottom views must be adopted in order to show adequately the forms of the several sides or faces. Careful attention should be given to these more or less elementary examples, since much more complicated ones presented later are based upon the same principles.

Problem 58. A square block having an inclined and recessed top is to be shown. As its width, length, height and the form of the recess are to be shown, three views will be necessary. At *A* is shown a side elevation which gives the width and height, and also shows the angle of inclination of the top. The dotted line shows that there is a depression in the top, but only shows its depth, not its form. At *B* is a front elevation which shows the length of the piece, and also shows the width of the depression in the top. The plan at *C* shows the form of the depression in the top, but will not show accurately its length, for the reason that the top surface is at an angle to this view. Such a view as that at *C* may often be necessary, although a view drawn at right angles to the inclined surface, as shown in dotted lines at *D*, rather than vertically above it, would in this case more clearly and accurately show what is intended. By this method all distances are shown in their normal or natural length, and there is no liability to make mistakes, if they are measured with a graduated scale.

Problem 59. The piece here represented is of a considerably more varied contour than the last, and four views are necessary to show it properly. Its particular features are the step-like form of one side, the curved form of the top, and a circular recess in the bottom. The side elevation *A* shows the step-like form and the length and height. By the line *E*, near the top, some change of contour is indicated, but the form is not shown. The dotted lines at the base also indicate an opening and give its depth, but do not show its form. The side eleva-

Problem 58.



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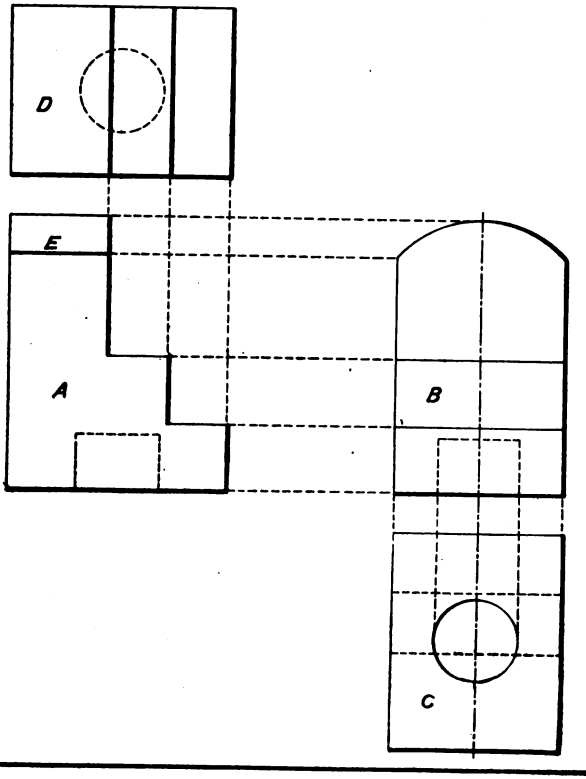


Plate XVII. Problems 58 and 59

tion at *B* shows the width and the curved form at the top, but does not add any information as to the form of the bottom opening. Therefore, we draw the bottom view at *C*, by which we are able to show that the bottom opening is circular. The plan, or view at the top at *D*, shows that the step-like forms run straight across the piece. (This is also indicated by the dotted lines at *C*.) The views at *C* and *D* are located nearest to the side they represent of the two principal views *A* and *B*, as this renders the drawing more easily and accurately understood. This point is one of first importance.

Representing Objects in Inclined Position

We have, so far, considered only the projection of objects in vertical or horizontal positions. The drawing of these views, projecting construction lines from one view to the next, was found to be comparatively simple. In actual practice, however, we are always liable to find objects, such as machine parts or portions of machine parts, that stand at various angles to the principal parts, and therefore, are not parallel to a plane at right angles to the line of sight. We will, therefore, proceed to the consideration of the accurate representation of objects in various inclined positions, so as to be prepared to properly represent them in mechanical drawings.

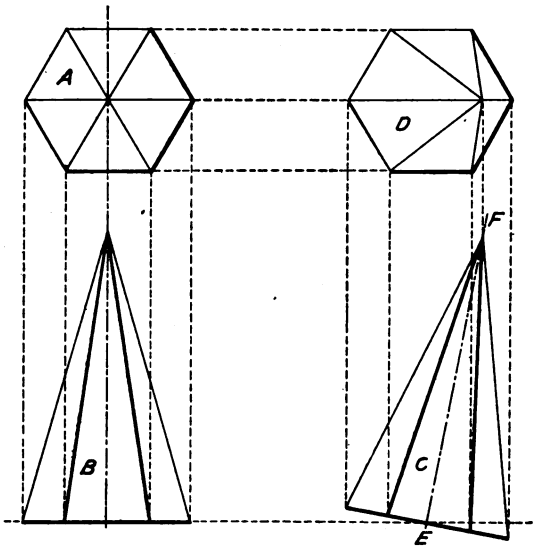
Problem 60. A plan and elevation of a hexagonal pyramid is given. An inclined projection of the hexagonal pyramid, as shown to the right, is to be drawn.

At *A* is a plan of the hexagonal pyramid, and directly beneath it is a front elevation, the vertical dotted construction lines giving the principal points for the side lines from the base to the apex. At *C* the same pyramid is drawn in an inclined position, drawing first the inclined base and then the center line *EF* at right angles to it, after which the side lines are drawn as before, the height, or altitude, of the pyramid being set off on the center line from the base, the same as in the view at *B*. At *D* the plan of the inclined pyramid is drawn, the required working points being found by vertical construction lines drawn upwards from the various points of the pyramid, as shown, and intersecting horizontal lines from corresponding points in the plan view at *A*. It will be noticed that while the hexagon at *A* could be readily laid out by first drawing a circle and then describing the regular hexagon around it, by the use of the 30- and 60-degree angle, the hexagon shown in the plan at *D* is not regular, and its angles differ more or less from those at *A*, owing to the inclined position of the pyramid in the front elevation. This variation or distortion of angles and of curved contours occurs in representing all objects in an inclined position, and should be anticipated. Sometimes the variation is so slight as to make comparatively little difference, while in other cases the variation is so important as to require extreme care and accuracy in the making of the drawing.

Problem 61. To draw a hexagonal prism in an inclined position.

As before, we will first represent the prism in a vertical position so as to get the true form of its cross-section, or upper and lower

Problem 60.



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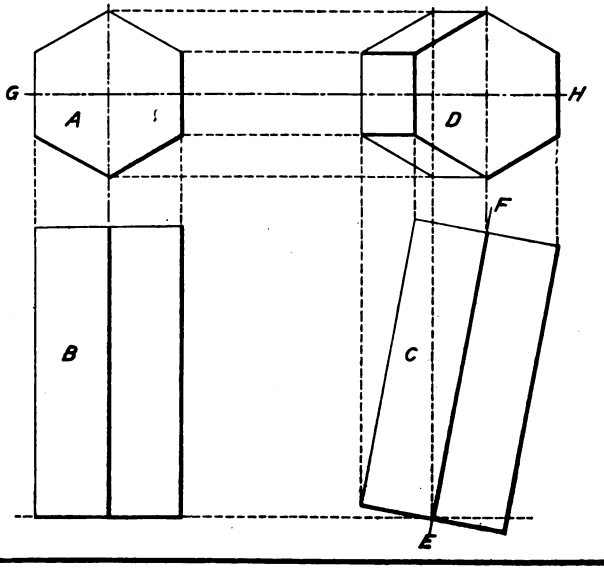


Plate XVIII. Problems 60 and 61

ends. Therefore, draw the hexagon at *A* as before, and from the points in this view draw construction lines downward to give the points required for the front elevation at *B*. The inclined view at *C* is a true copy of the view at *B*, and is drawn as in the previous problem, the center line *EF* being at right angles with the base, the position of which determines the inclination. As before, the points necessary for drawing the plan at *D* are obtained by vertical construction lines rising from points of the front elevation at *C* and intersecting horizontal lines from corresponding points in the plan view *A*. The lines showing the sides of the prism at *D* will, of course, be horizontal (parallel to the center line *GH*). The completed view will be a perfect representation of the inclined prism as seen from above.

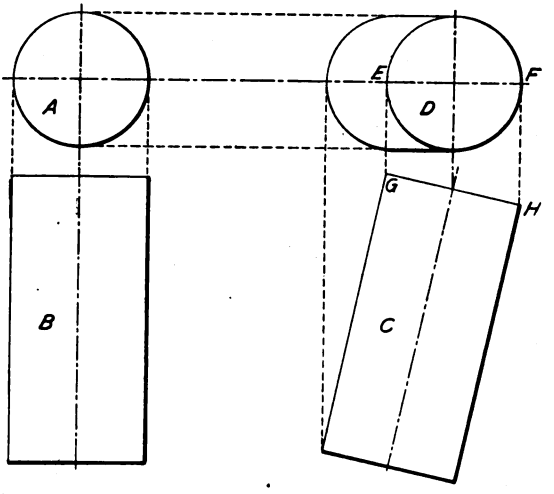
Problem 62. To draw a cylinder in an inclined position.

In this problem we proceed in the same manner as in the last, by drawing the plan at *A*, which is a circle; then draw the lines showing the elevation of the cylinder at *B*, which is represented by a rectangle. The cylinder is then drawn at *C*, in an inclined position, and construction lines are drawn as indicated for obtaining the plan at *D*, which consists of a portion of an approximate circle representing the base and a circle representing the top, the two being connected by horizontal lines representing the sides, and completing the plan. It should be observed that the ends of the cylinder here shown will not be exact circles, owing to the inclined surfaces represented. The greater this inclination, the more the circle will be flattened into an ellipse. In this case it approaches the circle so closely that the dividers may be used in describing it. If the inclination is great, an ellipse should be drawn by the methods explained in Part I of this treatise, the greater or major axis being the actual diameter of the cylinder, and the shorter or minor axis being the distance *EF*, as detemined by the construction lines from points *G* and *H*.

Problem 63. In this problem a cylinder is shown in an inclined position, somewhat in the same manner as in Problem 62, but the inclined cylinder is shown in the side elevation *B*, and as we view it at *D* it is inclined toward us so that its top surface appears as an ellipse whose contour it is required to ascertain and lay out with accuracy.

The inclined center line *KL* is first drawn, then the horizontal center line *MN*, and with the intersection of these as a center, the circle *A* representing the top surface of the cylinder is described. Parallel with the inclined center line *KL*, draw the sides of the inclined cylinder *B*, and at right angles to the sides draw the lines of the top and bottom. Upon the horizontal center line *MN* describe a circle at *C*, of the same diameter as at *A*, and through its center draw the vertical center line *OP*. Then draw the side lines of the cylinder at *D*. From points *E* and *F* project horizontal lines, giving the transverse axis of the ellipse representing the top of the cylinder *D*. The correct form of this ellipse is determined as follows: Draw the inclined line *GH* at right angles to the inclined center line *KL* of the cylinder *B*. Divide circles *A* and *C* into any convenient number of equal parts (in this

Problem 62.



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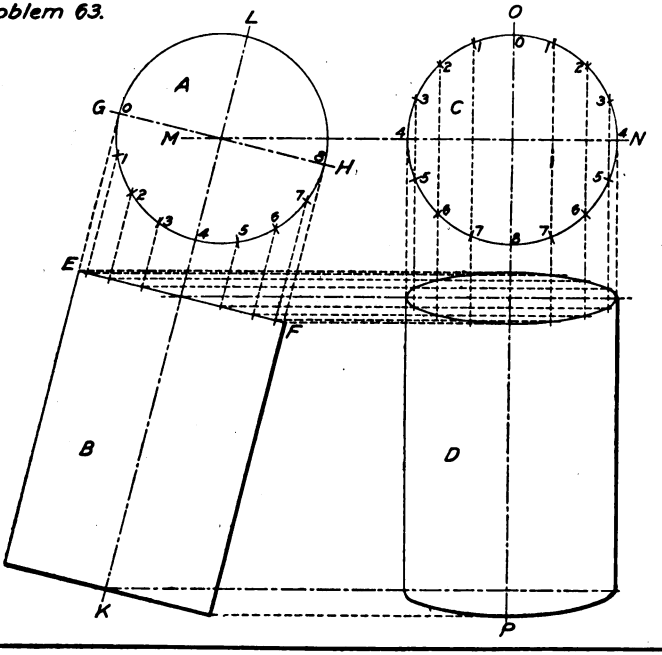


Plate XIX. Problems 62 and 63

case sixteen), and number the division points as shown. From these points on the circle *A* draw inclined lines (parallel to the center line *KL*), intersecting the top line *EF* of the cylinder *B*. From the points on the circle *C* draw vertical lines downwards across the upper face of the cylinder *D*. From the points of intersection of the inclined lines from the points on the circle *A* with the line *EF*, draw horizontal lines intersecting the vertical lines drawn from the points on the circle *C*. The intersections of the lines of corresponding number will be points on the required ellipse. The outline of the ellipse may then be drawn by the aid of an irregular curve. The elliptic curve at the bottom of the cylinder *D* is the same as the lower half of the one just described, and may be easily copied from it.

Problem 64. To project the three faces of the cube shown in perspective at *A*. The different faces are indicated respectively by a circle, a square, and a diagonal cross, so as to distinguish them in the several views.

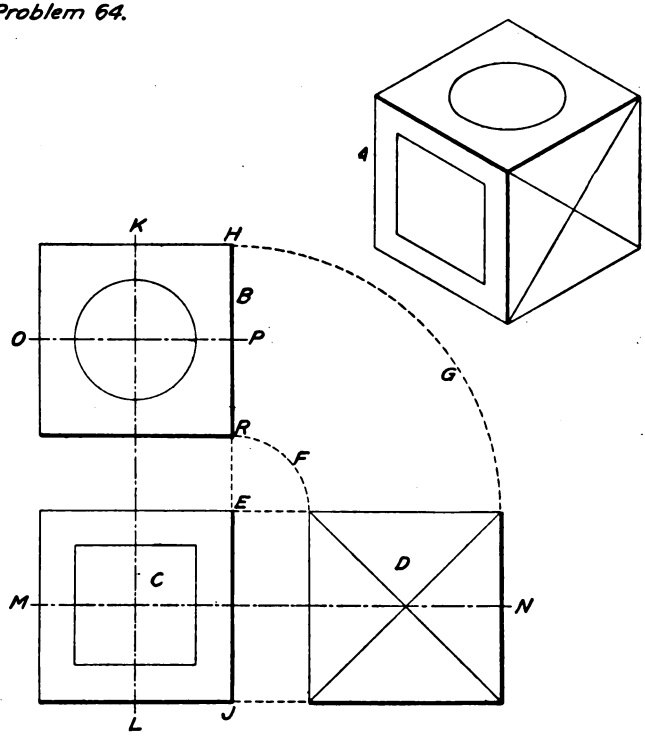
First draw the center lines *KL*, *MN*, and *OP*. Then draw the plan at *B*, marking it by the circle as shown. Beneath this draw the front elevation at *C*, projecting by construction lines from *B*, and within it draw the distinguishing square, as shown. With the corner *E* of the front elevation as center, and with a radius equal to the distance from *E* to *R*, describe the arc *F*, and with a radius equal to the distance from *E* to *H*, describe the arc *G*. These will give the width of the side elevation at *D*. From the front elevation at *C* project horizontal construction lines from *E* and *J*, giving the height of the side elevation at *D*. Complete the view by drawing the diagonal distinguishing lines. The object of this method of locating and laying out the three views is to show in a graphic manner how the dimensions of the object in the several views are obtained.

Problem 65. To represent in plan and two elevations the forged strap shown in perspective at *A*. This is an ordinary "holding-down" strap, such as is used on a planer or a milling machine, with two bolt holes located near the ends.

Draw a horizontal center line *EF*, upon which the bolt holes are to be located, and lay out the width and length of the strap. Draw vertical center lines *GH* and *KL* to locate the bolt holes, and describe the circles showing the holes, as shown in view *B*. This view is the plan. Beneath this draw the front elevation *C*, showing the thickness, and by the aid of construction lines projected downwards from the plan *B*, show the bolt holes by dotted lines. At the right of the plan *B*, and by construction lines projected from it, draw the end elevation as at *D*, indicating the bolt holes by dotted lines as before. This is the usual manner of drawing and arranging the views for nearly all objects of this character.

Problem 66. To represent a plan and elevation of the block shown in perspective at *A*, when placed in an inclined position. The two faces and top are differently marked so as to distinguish them in the different views to be drawn.

Problem 64.



Problem 65.

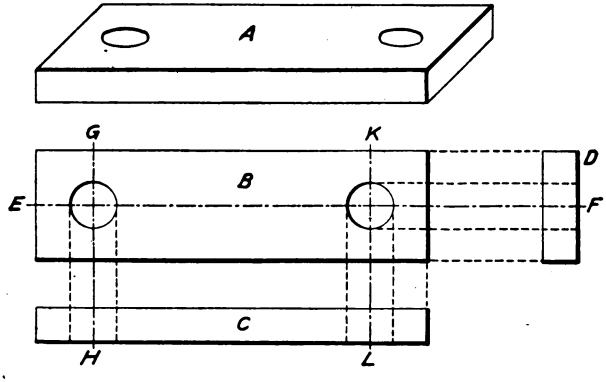


Plate XX. Problems 64 and 65

Draw the vertical center line *DE*, the inclined center line *FG*, and the horizontal center line *HK*. Draw a front elevation of the object at *B*, in an inclined position as shown by the center line *FG*. Indicate by dotted lines the depressed circle on the top and the cross at the right of the perspective view at *A*. From the various points on the top and side of the inclined view *B* project construction lines upward, giving the positions for the lines of the plan at *C*. From the horizontal center line *HK*, lay out the width of the plan, and lay out the circle and the cross from the vertically projected construction lines as shown. It should be noticed that the projection of the circle becomes an ellipse in the plan view *C*, owing to the inclined face of the object in the elevation *B*. The vertical arms of the cross also will appear much narrower than the horizontal ones.

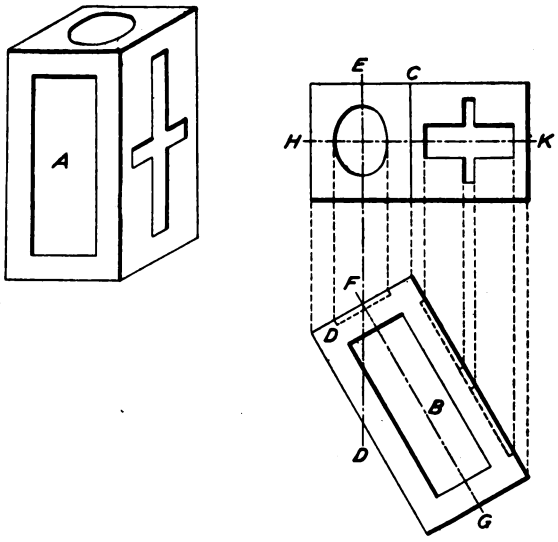
Problem 67. To represent the same object as shown in Problem 66, but in a position somewhat less inclined from the horizontal. Refer to the perspective view in Problem 66, at *A*.

Draw the vertical center line *CD*, the inclined center line *GH*, and the horizontal center line *EF*. Draw the inclined front elevation at *A*, showing the depressed figure of the cross upon the upper side, and the circle at the end, by dotted lines as in the last problem. Upon the center lines *CD* and *EF* as a basis, draw the plan *B*, determining the various points by construction lines drawn upward from similar points in the front elevation at *A*. Complete the drawing in a similar manner to that in Problem 66, laying out the ellipse at the left and the cross at the right, noting that as the inclination of the block shown at *A* is different from that shown in the last problem, these figures will appear in different proportions.

Problem 68. To represent in plan, front elevation, and side elevation, the die block shown in perspective at *A*. This piece is a close approach to a regular machine part, the more complicated points of construction being omitted so as to simplify it, as it is intended to teach the principles of accurate projection only. It should be noticed that in the perspective view at *A* the dimensions from front to rear cannot be measured, as they become foreshortened by being drawn in perspective, while the dimensions at the front, being in a plane at right angles to the line of sight, and those shown in the view beneath, are the normal and actual dimensions.

Draw the vertical center line *GH* and horizontal center line *KL* for the plan as shown at *B*, the vertical line being continued downward to serve also as a center line for the front elevation at *C*. Upon these as a basis draw the plan view substantially as shown, assuming the necessary dimensions for the width. Draw the front elevation at *C*, projecting construction lines downward from the plan at *B* for determining the various points required, and taking the vertical distances from the front of the perspective view at *A*. While some of the heights shown in the perspective view cannot be accurately measured, they will be quite sufficient for present purposes, and may be assumed to be as shown at *C*. The front elevation at *C* being completed, the center *E* is assumed at any convenient point on the vertical construc-

Problem 66.



Problem 67.

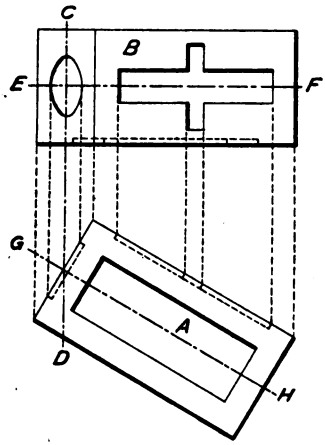


Plate XXI. Problems 66 and 67

tion line, and the arc *F* is described, continuing the center line from a horizontal to a vertical direction and locating vertical center line *NO*, which will be the center line of the side elevation at *D*. In a similar manner the other arcs from the center *E* are described down to line *EM*, carrying the construction lines to the side elevation at *D*. thus obtaining from the plan at *B* the necessary points for the drawing of this elevation.

The method of transferring dimensions by circular arcs is here used to graphically illustrate this procedure. Dimensions can be transferred with a great degree of accuracy in this way, if the work is carefully done. The general principles here set forth will be found very useful in practice, and should be thoroughly mastered. It should be remembered that by transferring construction points and dimensions as above described, we eliminate entirely the occasions for error that are always present when dimensions are measured and set off from a graduated scale.

Conic Sections and Intersecting Surfaces

The practical phase of the work of representing the sections of cones, cylinders and other solids is an important branch of the work of the draftsman. Cones, in their strict geometrical sense, are not often encountered in practical work, but parts of cones are very common and must often be represented with considerable accuracy. All of the practical problems relating to conic sections and intersecting surfaces in general, are based upon the elementary forms and methods of representation which have been previously explained, and for the sake of simplicity have been reduced to the plainest and most easily comprehended form.

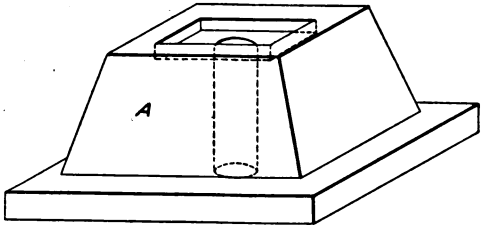
Problem 69. It is required to represent in a plan view, the appearance of the frustum of a cone when it is cut by a plane at a given angle to its axis.

Let *ABC* be the given cone, which is cut by the plane *DE*. Draw the circle *FG* of a diameter equal to the base *BC* of the given cone. Divide this circle into any number of equal parts, in this case twenty-four, number the points as shown, and draw radial lines through each of the points on the lower half of the circle. From the intersection of these radial lines with the circle, draw vertical lines intersecting the base-line *BC* of the cone *ABC* at *1*. *2*, *3*, etc. From the points *1*, *2*, *3*, etc., on the base-line, draw converging lines to the apex *A* of the cone, intersecting the plane *DE*. Through these intersections draw vertical lines intersecting the radial lines in the plan view. The points of intersection will be points on the required curve representing a plan of the top of the frustum of the given cone. This curve is then drawn by the aid of an irregular curve.

Problem 70. It is required to represent the plan view and side elevation of a cone when cut by a plane parallel to one of its sides.

Let *ABC* be the given cone, which is cut by the plane *DE*, parallel to *AC*. Draw the circle *FG*, divide it, and draw radial lines as in Problem 69. Proceed to determine the points on the curve within the

Problem 68.



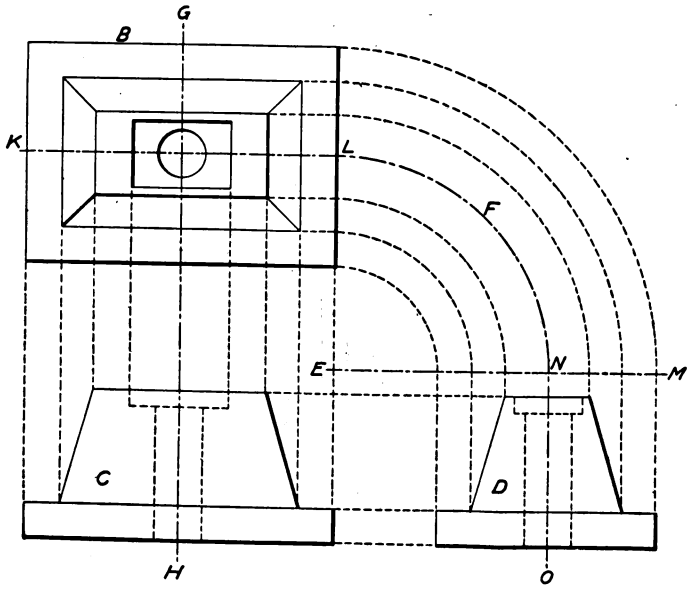


Plate XXII. Problem 68

Problem 69.

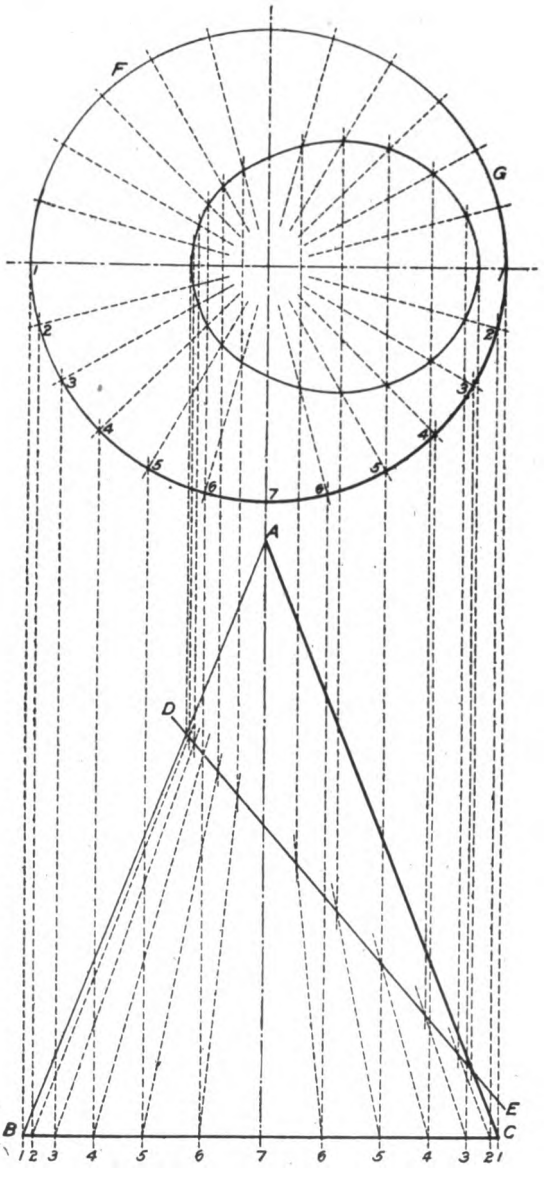


Plate XXIII. Problem 69

Problem 70.

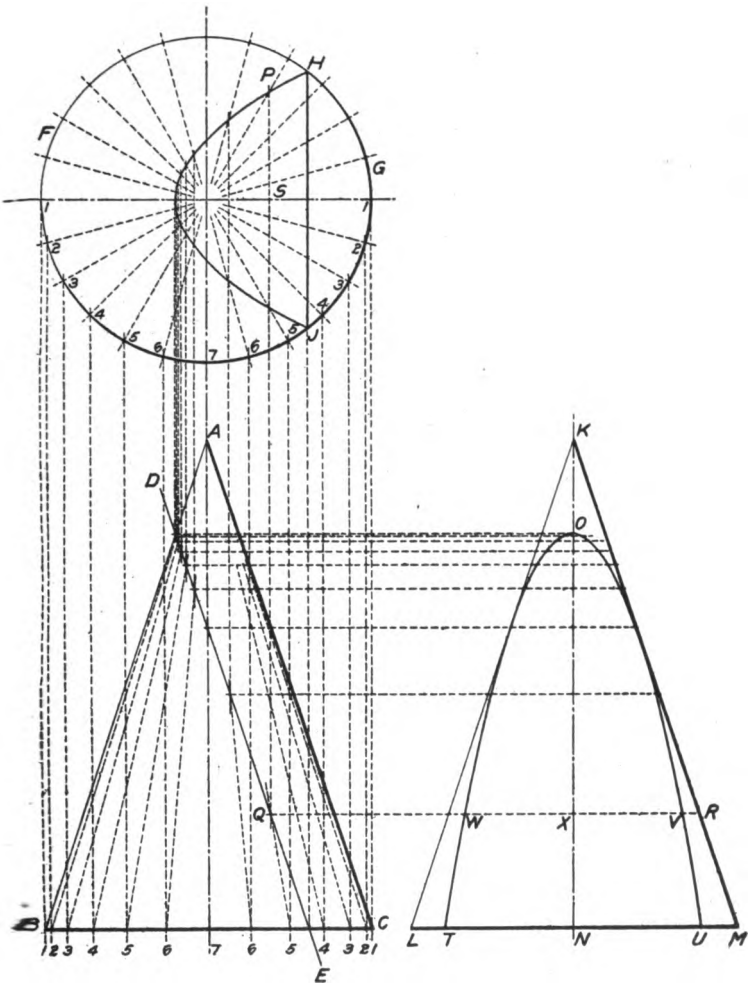


Plate XXIV. Problem 70

circle *FG*, in the same manner as in the previous problem, and draw the outline with the aid of an irregular curve. The straight line *JH* completing this figure is located by drawing a vertical line upward from the point *E* on the base-line of the cone. Draw the cone *KLM* of the same dimensions as the cone *ABC*. From the intersections of the diverging lines from *A* with the plane *DE*, draw horizontal lines across the cone *KLM*. Upon the vertical lines, intersecting the radial lines in the circle *FG*, obtain distances, which, set off on each side of the vertical center line *KN*, will give points on the curve *TOU*. For instance: From the intersection of the line *PQ* with the plane *DE*, draw the horizontal line *QR*. Take the distance *SP* in the dividers and set off the distance *XV* and *XW*. In like manner set off the proper distances on all horizontal lines; then draw the required form by the aid of an irregular curve.

Problem 71. It is required to represent the side elevation of a cone when cut by a plane parallel to its axis.

Let *ABC* be the given cone, which is cut by the plane *DE*. Draw the circle *FG*, divide it, and draw radial lines as before. Proceed as in Problem 69 to determine points on the base-line, and draw converging lines to the apex at *A*. Draw the cone *KLM*, of the same dimensions as the cone *ABC*. Through the points of intersection of the lines from *A* with the plane *DE*, draw horizontal lines across the cone *KLM*. Draw the line *HJ* in prolongation of the line *DE*. From the center line *NO*, take the distances to the intersections of each of the radial lines, along the line *HJ*, and set them off from the center line *KP* of the cone *KLM*. as in Problem 70, thus obtaining curve *RTS*.

Problem 72. It is required to represent in plan and elevation a given cone intersected by a cylinder placed at right angles to its center line.

Let *ABC* be the given cone intersected by the cylinder *DE*. Draw the cone *ABC* on the vertical center line *AF* as shown, and the cylinder *DE* on the horizontal center line *GH*. Draw the cone *JKL* of the same dimensions as the cone *ABC*, and also the circle *DE* on the center line *GH*, representing the end of the given cylinder. Above the cone *ABC* draw the circle *MN*, representing the base of the given cone. At the right of this draw the circle *OP* representing the end of the given cylinder. Divide one-half of each of the circles *DE* and *OP* into any number of equal parts, in this case eight, as shown. Draw horizontal lines from these points on the circle *DE* across the given cone; and from those on the circle *OP* across the circle *MN*. Determine the points *1*, *2*. *3*, etc., in the required intersecting curve in the following manner: On the horizontal line *1*, in the given cone *ABC*, set the dividers to the distance from the center line *AF* to the intersection with the right-hand side line of the cone. With this distance as a radius, and with *Q* in the plan above as a center, mark the point *1*. With a radius equal to the distance from the center line *AF* to the point *2* on the given cone, mark the point *2* on the plan. Repeat this for all the other distances of the series until the points *1*, *2*, *3*, etc., are determined in the plan view. From these points draw the required contour with the aid of an irregular curve.

Problem 71.

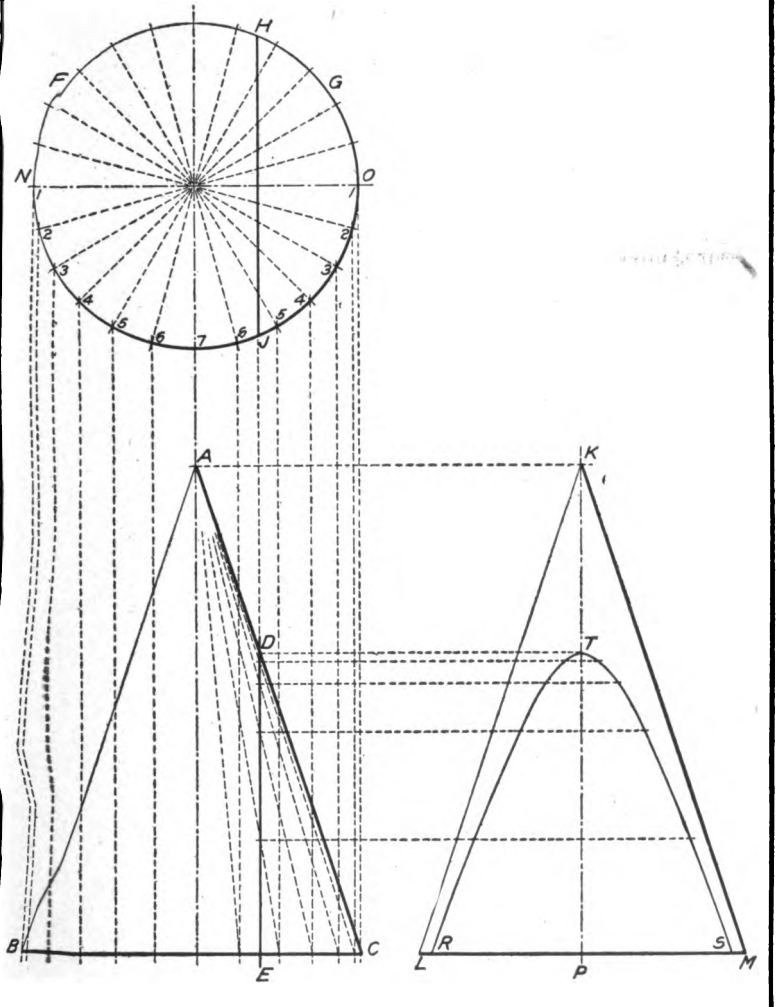


Plate XXV. Problem 71

From the points *1*, *2*, *3*, etc., on the plan, draw vertical lines down to the given cone, intersecting the horizontal lines from the points *1*, *2*, *3*, etc., on the circle *DE*, and giving the points of the required curve on the elevation *ABC*, which shows the line of intersection between the surface of the given cone and the given cylinder. This line may then be drawn by the aid of an irregular curve. The principles of this problem are applicable to a large number of cases where sheet metal, and a similar class of work, is involved.

Problem 73. It is required to develop (lay out on a plane) the surfaces of two cylinders of equal diameter joining each other at right angles, as a pipe elbow.

Draw the side elevation as at *ABDEFC*, including the center lines of both cylinders. Draw the circle *L* representing the end of the vertical cylinder. Divide this circle in any number of equal parts, in this case twelve. Draw the radial lines as shown. Through the intersections of the radial lines with the circle *L*, draw vertical lines upward, intersecting the inclined line *CD* at the junction of the two cylinders. Draw a base-line *JK* and set off upon it a distance equal to the circumference of the cylinders. The diameter multiplied by 3.1416 will give this dimension. Divide this distance into as many spaces as there are divisions of circle *L* (in this case twelve). Erect vertical lines at each of these points on the line *JK*. From the base-line *JK* (from each end), set off successively the distances on the lines *1*, *2*, *3*, etc., from the base-line *EF* to the inclined line *CD*. The points thus obtained are points on the required curve, and *JKMNO* is the development of each of the cylindrical surfaces given. With an irregular curve trace the line through these points, which will be the curve required.

Problem 74. It is required to develop the surface of the central section of the three-piece elbow shown.

The elbow is shown at *ABDEGHFC*. Bisect the angle formed by the lines *CD* and *EF*. Draw the circle *JK* and divide it in any number of equal parts, in this case twelve. Draw radial lines through these points. From the intersections of these radial lines with the circle *JK*, draw vertical lines upward intersecting the inclined line *EF*. From these intersections draw lines parallel to the lines *DE* and *CF* and intersecting the line *CD*. Draw the center line *NO* and set off upon it a distance equal to the circumference of the cylinder, the surface of which is to be developed. Divide this line in twelve parts, and erect vertical lines as in Problem 73. Take successively from the center line *LM* the distances to the line *EF* (or *CD*) on the lines *1*, *2*, *3*, etc., and set them off above and below the center line *NO*. The points thus obtained are points on the required development curve, which may then be drawn by the aid of an irregular curve. Upon the principles described in this problem and the one immediately preceding it, a great many of the practical problems of sheet metal work may be readily solved.

Problem 75. It is required to develop the surface of a smaller cylinder intersecting a larger cylinder at right angles.

Problem 72.

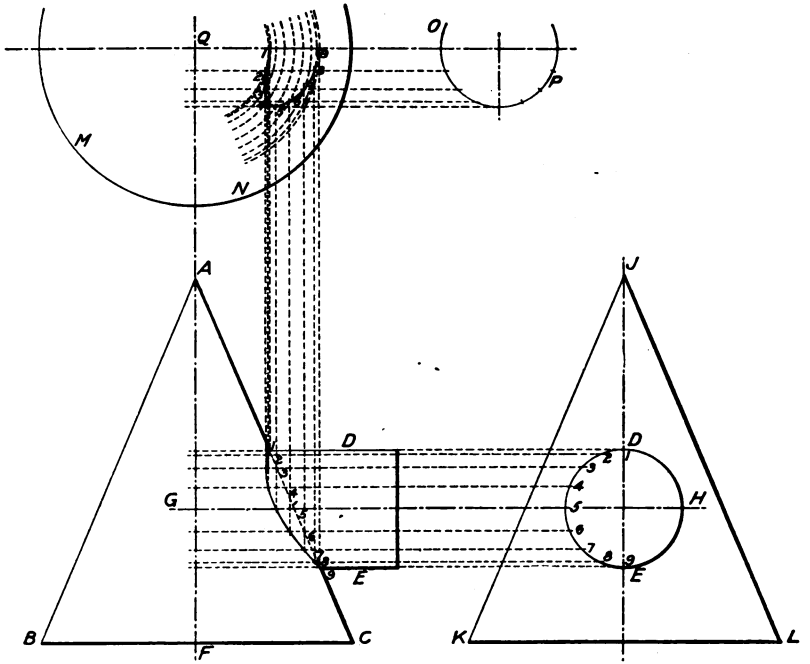
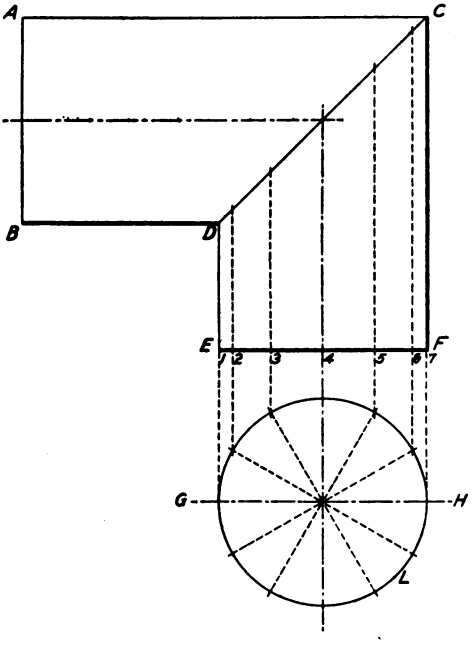


Plate XXVI. Problem 72

Problem 73.



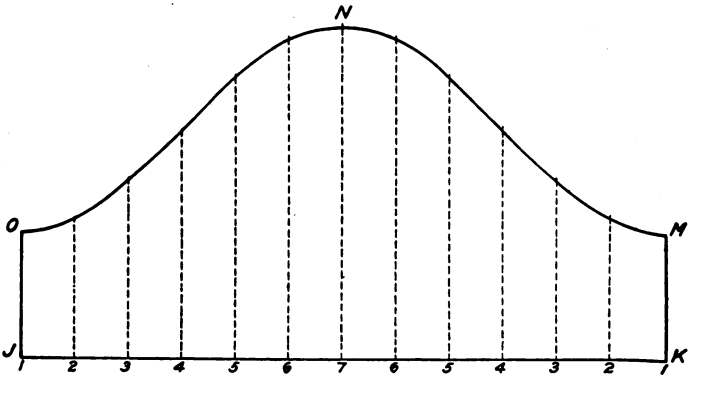
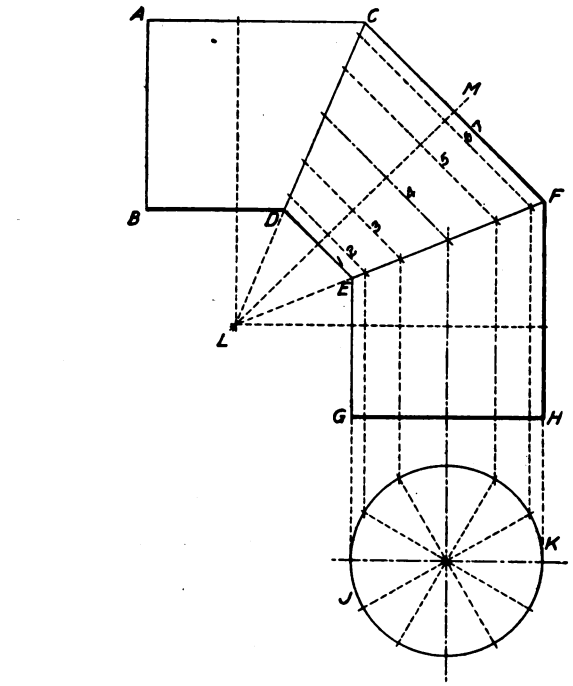


Plate XXVII. Problem 73

Problem 74.



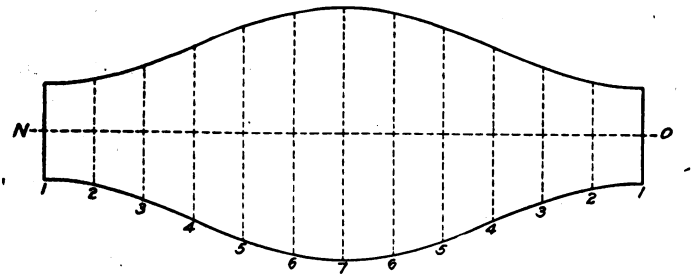


Plate XXVIII. Problem 74

Draw the front elevation of the two cylinders as at *ABDFEC*. At the right draw a side elevation, representing the smaller cylinder by the circle *LM*. Under the first elevation draw the end view of the larger cylinder as the circle *NO*, and the elevation of the smaller cylinder at *PQVX*. Divide the circle *LM* into any number of equal parts, in this case twelve, and draw radial lines intersecting the circle. Draw horizontal lines through these intersections and across the smaller cylinder *EF*. Draw vertical lines to the horizontal line *HK*, from whence they are prolonged by arcs, from *Y* as a center, to the vertical line *YG*, and again prolonged by horizontal lines across the smaller cylinder at *PQVX*, intersecting the circle *NO*. From these intersections draw vertical lines intersecting the horizontal lines on the smaller cylinder at *EFUT*. These intersections will give points on the intersection curve *TU*, which may be drawn by the aid of an irregular curve. Draw the base-line *RS* and set off upon it the circumference of the circle *LM*. Divide this in the required number of equal parts, and erect perpendiculars *1*, *2*, *3*, etc. On these lines set off the distances on the lines *1*, *2*, *3*, etc., from line *EF* to curve *TU*. The points thus determined are points on the required development curve, which may be drawn by the aid of an irregular curve.

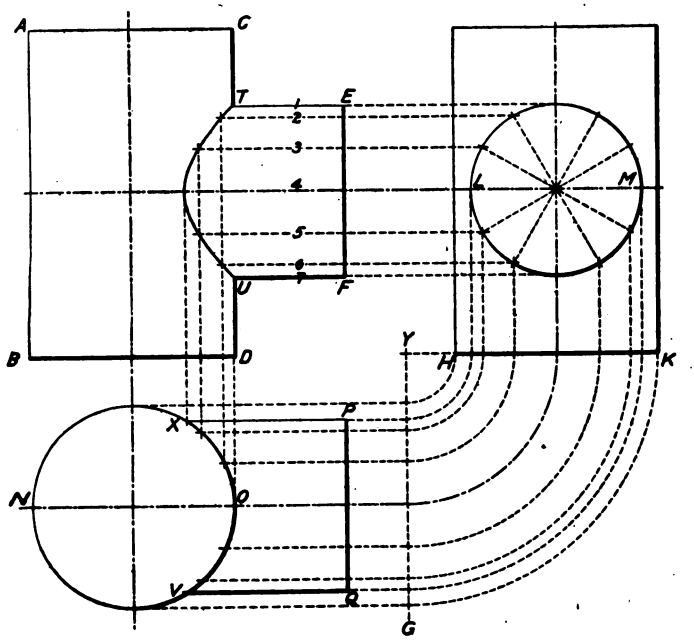
Problem 76. It is required to develop the surface of a smaller cylinder intersecting a larger one at an angle of 60 degrees with its axis.

Draw a front elevation of the two cylinders upon center lines at an angle of 60 degrees, as shown. Draw the circles *GH* and *JK* as end views of the two cylinders. Divide the circle *GH* as in previous problems, and draw lines from the intersections over the smaller cylinder at *EF*. At right angles to the axis of the cylinder *EF* draw lines to the inclined line *LM*. Prolong these lines by arcs to the line *NO*, and from thence draw horizontal lines across the smaller cylinder at *PQ*, and intersecting the circle *JK*. From the intersections of these lines with the circle *JK* draw vertical lines intersecting those from the circle *GH*. The intersections are points on the intersection curve *RS*, which may be laid out by the aid of an irregular curve. The end of the smaller cylinder at *PQ* will appear neither as a straight line as at *EF*, nor as a circle as at *GH*, but as an ellipse whose width or transverse axis will be determined by vertical lines drawn through the points *E* and *F*. Draw the base-line *TU*, divide it, and draw vertical lines as in the previous problems. Take the lengths of the lines *1*, *2*, *3*, etc., from line *EF* to curve *RS*, and set off these distances from the base line *TU*. The points thus determined are points on the required development curve, which may then be drawn with the aid of an irregular curve.

Problem 77. It is required to develop the surface of the frustum of a cone.

Draw the given cone *ABC*, cut by the plane *DE*, forming the frustum *BCED*. Beneath the cone draw the circle *FG* representing its base. Divide this into any convenient number of equal parts, in this case

Problem 75.



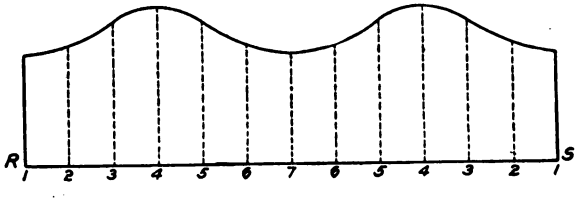


Plate XXIX. Problem 75

Problem 76.

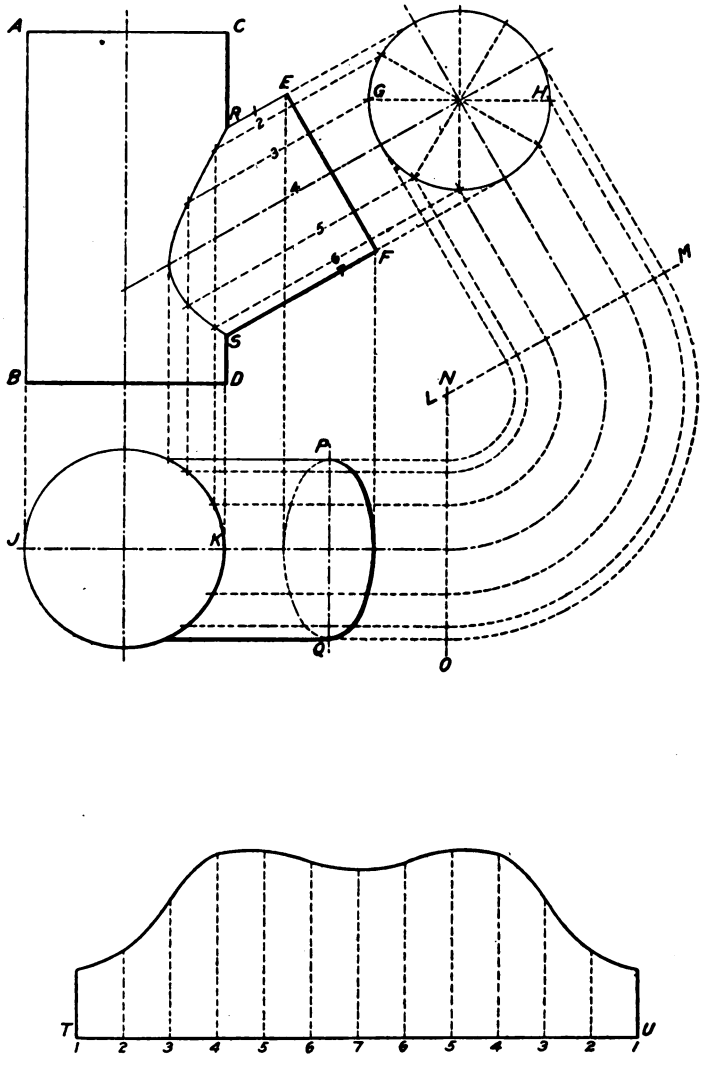


Plate XXX. Problem 76

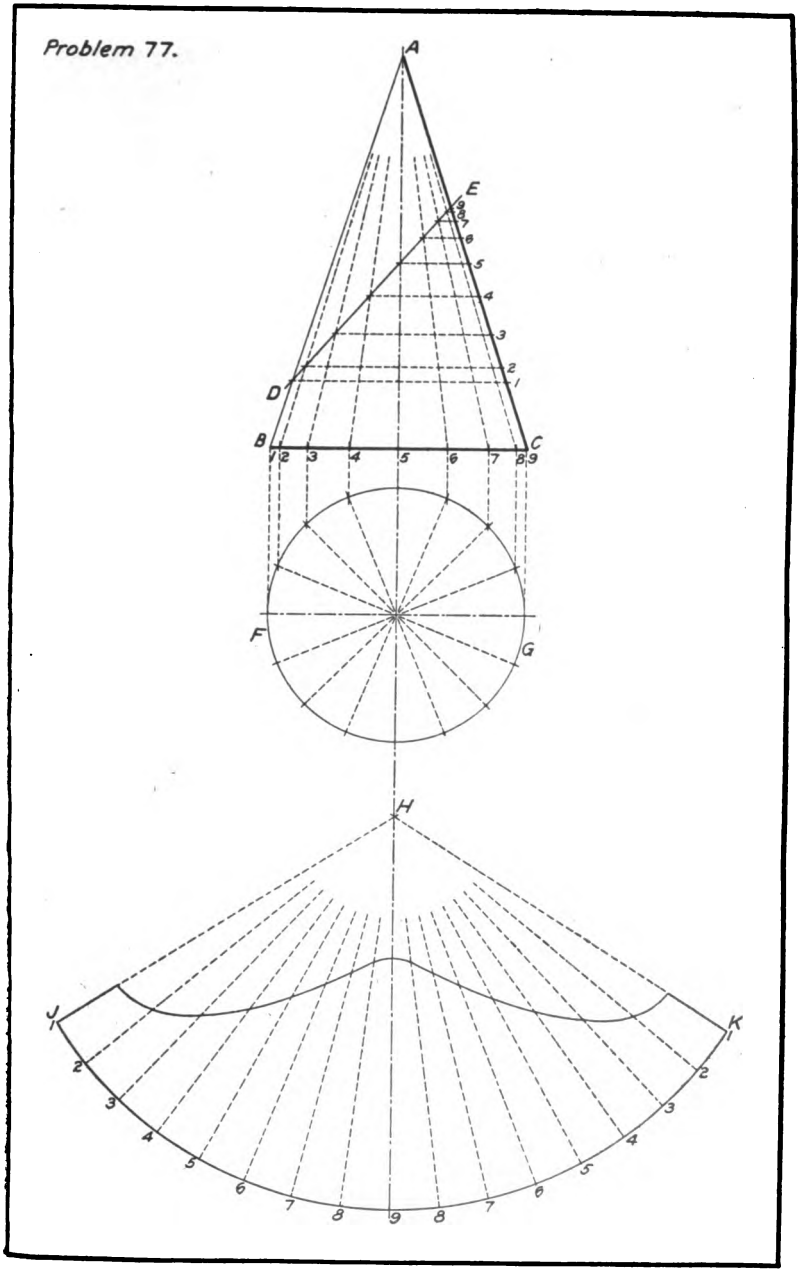


Plate XXXI. Problem 77

sixteen, and draw radial lines through these points. Project lines intersecting the base-line *BC*, and draw converging lines from these intersections to the apex *A*, as in Problem 69. With *H* as a center and with the length *AB* of the side of the cone as a radius, draw the arc *JK*. On this set off the circumference (determined as before) of the base of the cone, and divide the arc in the same number of equal spaces as the circle *FG*. Draw radial lines from the center *H* to each of the points on the arc *JK*. Transfer the distances from the base *BC* to the plane *DE* on the converging lines *1*, *2*, *3*, etc., onto the line *AC*, on which they are shown in their natural length. Then set off the distances *C1*, *C2*, etc., successively on the radial lines at *JK*. This will give the required development curve which may then be drawn with the aid of an irregular curve.

The problems presented in this chapter should be carefully and thoroughly studied. No problem should be passed over until it has been carefully worked out several times, and the principles upon which it is based are fully understood. To fail to be able to readily and accurately solve problems of this character is to acknowledge a deficiency of training that is inexcusable even in a young draftsman. The examples represented are specially selected as being those which will be found the most useful in actual practice.

CHAPTER II

LETTERING

In the actual practice of the mechanical draftsman, it is essential that he produce a neat, clean and workmanlike drawing. It is also necessary that all the lines be carefully made, and that they are of the proper width, that they meet each other without falling short or running over the line where they should terminate, etc. But when all this has been done, the drawing will always present an unattractive appearance if the lettering has been carelessly arranged or is poorly made. In former years the lettering on mechanical drawings was frequently remarkable for its ornamental design and execution, and there was little effort made to standardize it or to simplify its design. In recent years this has been greatly changed, and the question of utility, that is, the absolute certainty of the meaning of every figure, sign, symbol and letter is deemed most essential. Hence the requirements in relation to lettering on drawings are rigidly fixed. Among these requirements, the following are the most important:

1. All figures and all lettering must be plain, legible and absolutely unmistakable.
2. The terminals of all dimension lines must be plainly indicated by arrow points.
3. Titles must be expressed in the fewest practicable number of words. These titles usually give the following information:
   a. The class of machine represented by the drawing.
   b. The dimension, or similar special designation of the machine.
   c. The part of the machine represented.
   d. The view shown, as plan, side elevation, etc.
   e. The name of the manufacturer.
   f. The date when the drawing was completed.

   In addition, there are other quite necessary data which will be mentioned later.
4. The size of the lettering used should be in proportion to the importance of the words, that is, the largest will be the name or class of the machine; then its dimension or special designation, etc.
5. If a style of letter of more ornamental form than plain "block" or Gothic is adopted, but one line of it should be used, and that should be for the largest and most important line.

Styles of Lettering Used

The two most important styles of lettering used are *Gothic* and *Italic*. The former is used because it is plain, readily formed, and therefore suitable for the larger lettering; the latter is used for the smaller lettering because the form of the letters resemble those used in writing, and may therefore be quickly and easily made. In the

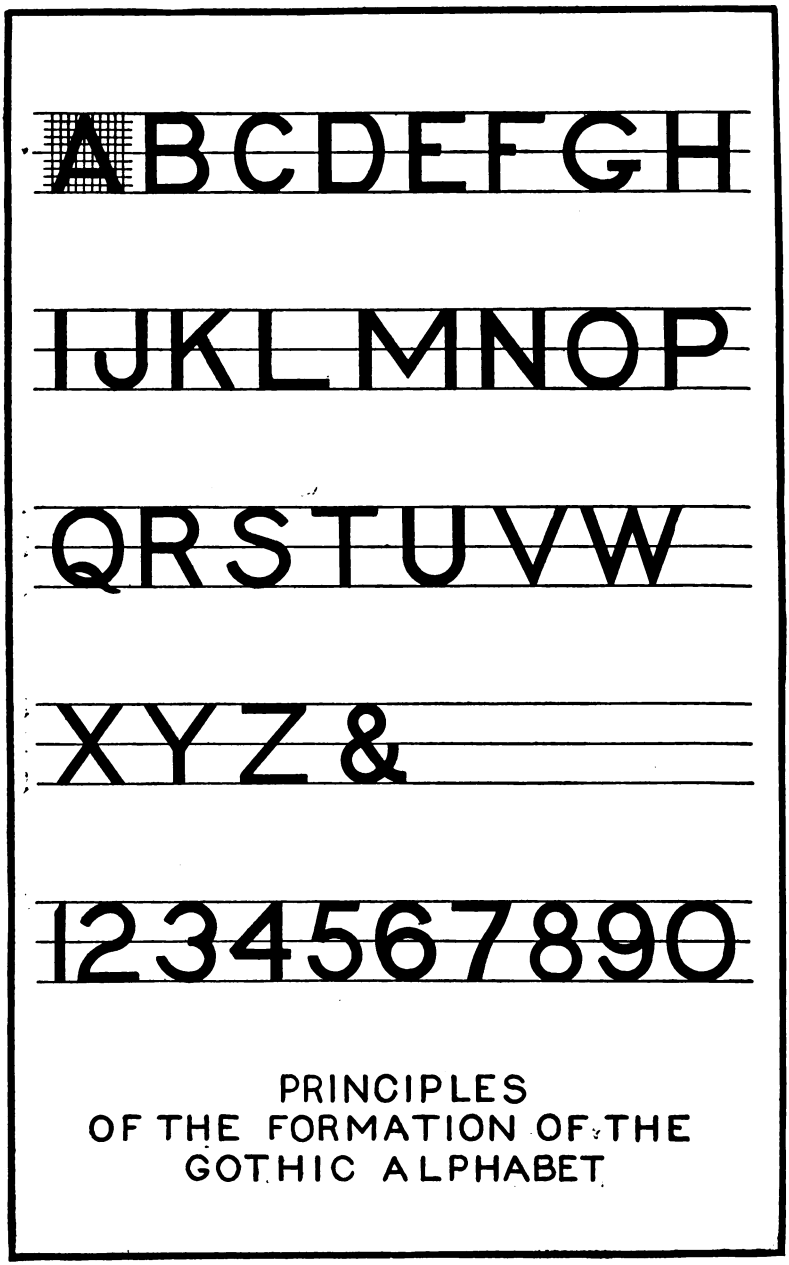

ABCDEFGH
IJKLMNOP
QRSTUVW
XYZ&
1234567890
PRINCIPLES
OF THE FORMATION OF THE
GOTHIC ALPHABET

Plate XXXII

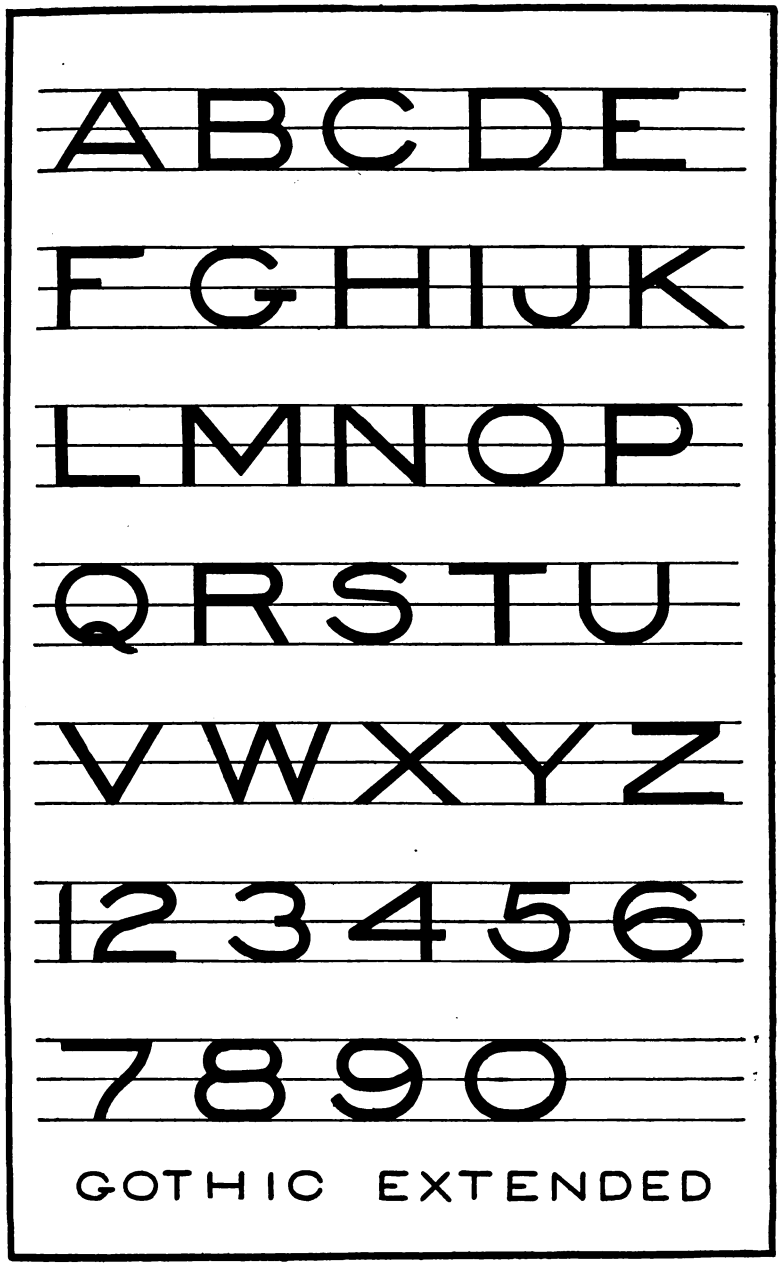


Plate XXXIII

Plates 32 to 37 inclusive is given a series of different sizes of the Gothic letter, and also a sample of what is known as the "Draftsman's Italics," largely used on drawings.

Size of Letters to be Used

On a very large drawing it may be necessary to use lettering as large as three-eighths of an inch high, but ordinarily letters a quarter of an inch high will be as large as need be used, except when giving machine numbers or symbols as described in the following. The other sizes usually employed are three-sixteenths and one-eighth inch high. Occasionally Gothic letters three-thirty-seconds of an inch high are needed. These sizes relate particularly to Gothic letters. Draftsmen's Italic letters are generally one-eighth inch high. In some drafting rooms they are made five-thirty-seconds inch high, which is a good size. In all cases these dimensions are given as the height of the capital letters, and do not include that portion of the small letters reaching below the line.

The Form and Proportions of Letters of the Gothic Alphabet

Plate 32 gives the normal proportions of the Gothic alphabet on a large scale. This alphabet should be drawn on profile paper ruled vertically and horizontally with twenty spaces to the inch. These spaces are used as units of measurement. The height of the letters is half an inch or ten spaces. The widths of the letters vary with the form of the letter and are as follows:

The letter I is two spaces.

The letter J is seven spaces.

The letters B, C, D, E, F, H, K, L, N, P, R, S, T, U, V, X, and Z are eight spaces.

The letters A, G, O, Q, and Y are nine spaces.

The letter M is twelve spaces.

The letter W is thirteen spaces.

The distance between the letters is three spaces. The distance between the words is ten spaces.

For ordinary purposes the following proportions are sometimes used:

The letter I is two spaces.

The letters M and W are twelve spaces.

All the other letters are eight spaces.

The figures have the following widths:

Figure 1 is two spaces.

All the other figures are eight spaces.

The width of the lines forming the letters are two spaces.

In drawing the letters of the Gothic alphabet, first determine the height and draw horizontal lines for the top and bottom of the letters. The distance between these lines is then divided into 10 spaces. In forming the letters it should be noted that the top portion of such letters as B, E and S, and the figures 2, 3, 5, and 8 should be slightly narrower at the top than at the bottom. It should also be observed that the center bar of the letters B, E and F, should be above

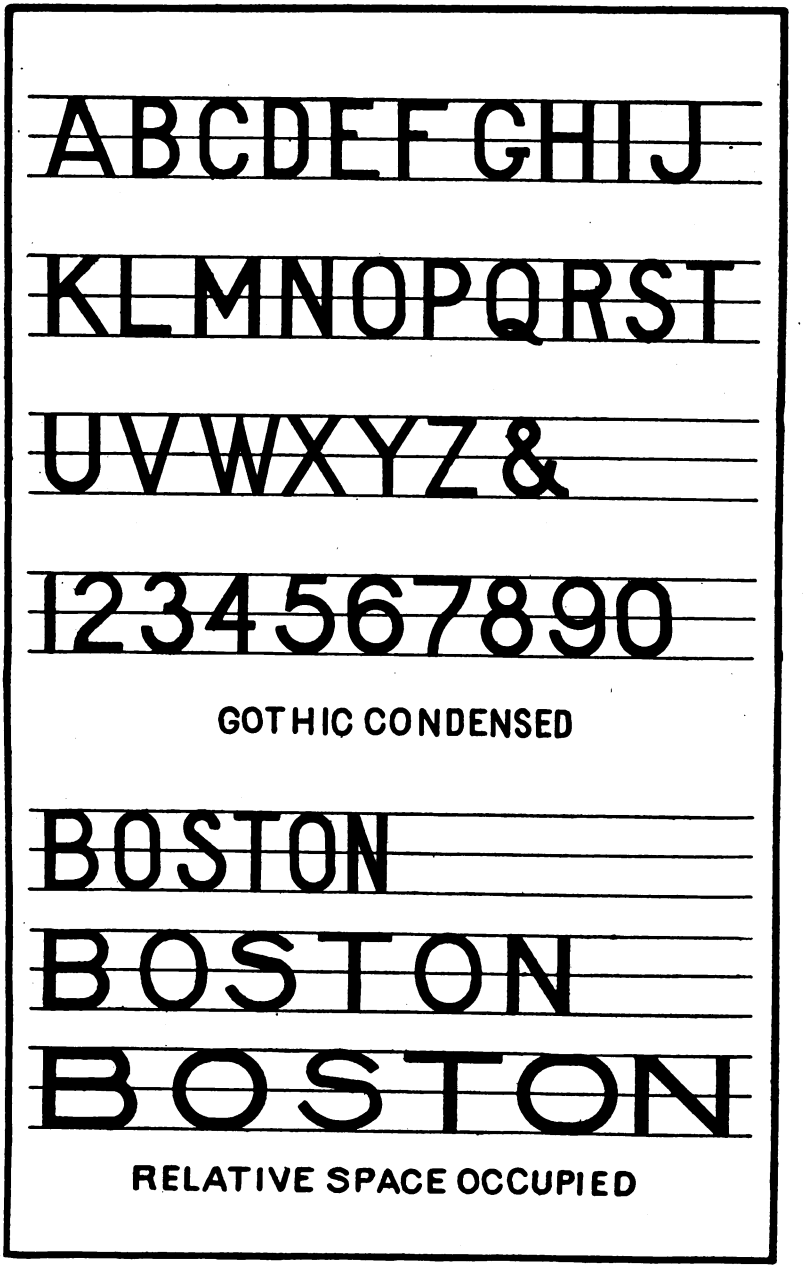

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ&
1234567890
GOTHIC CONDENSED
BOSTON
BOSTON
BOSTON
RELATIVE SPACE OCCUPIED

Plate XXXIV

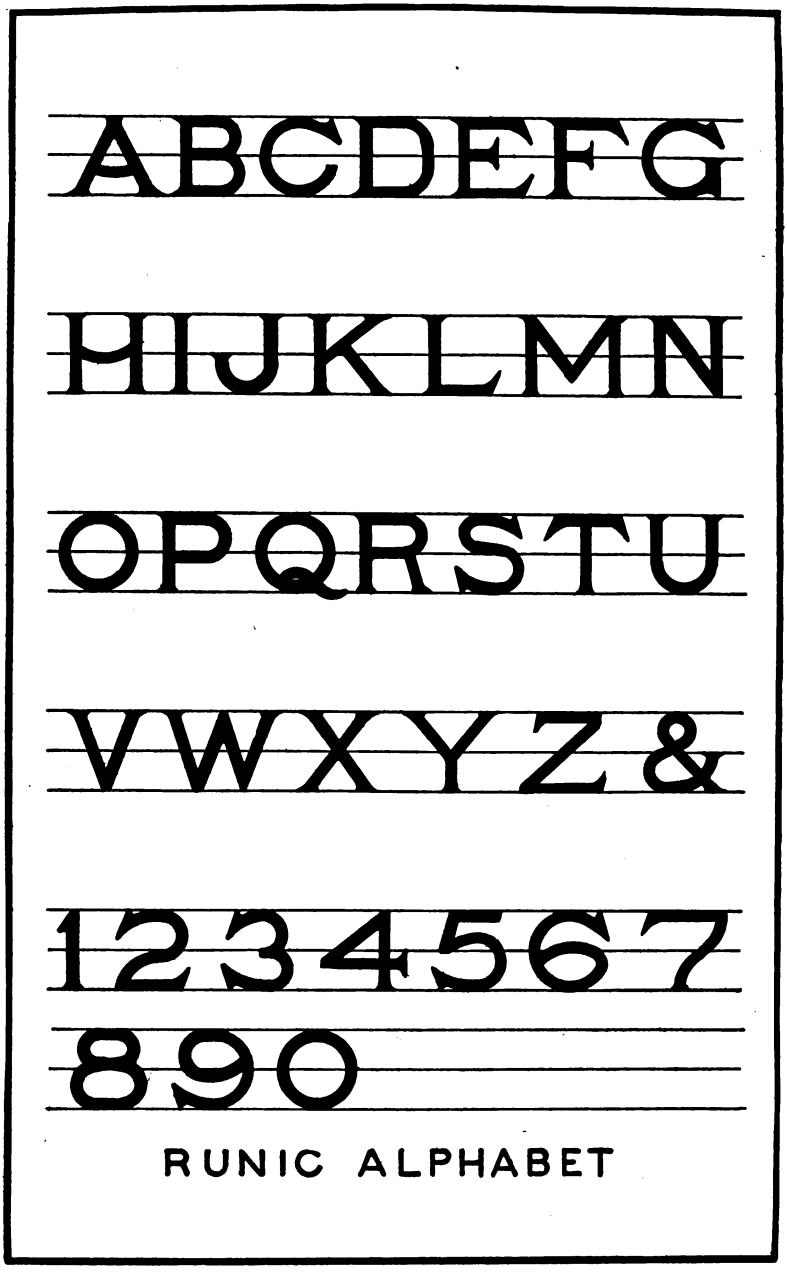


Plate XXXV

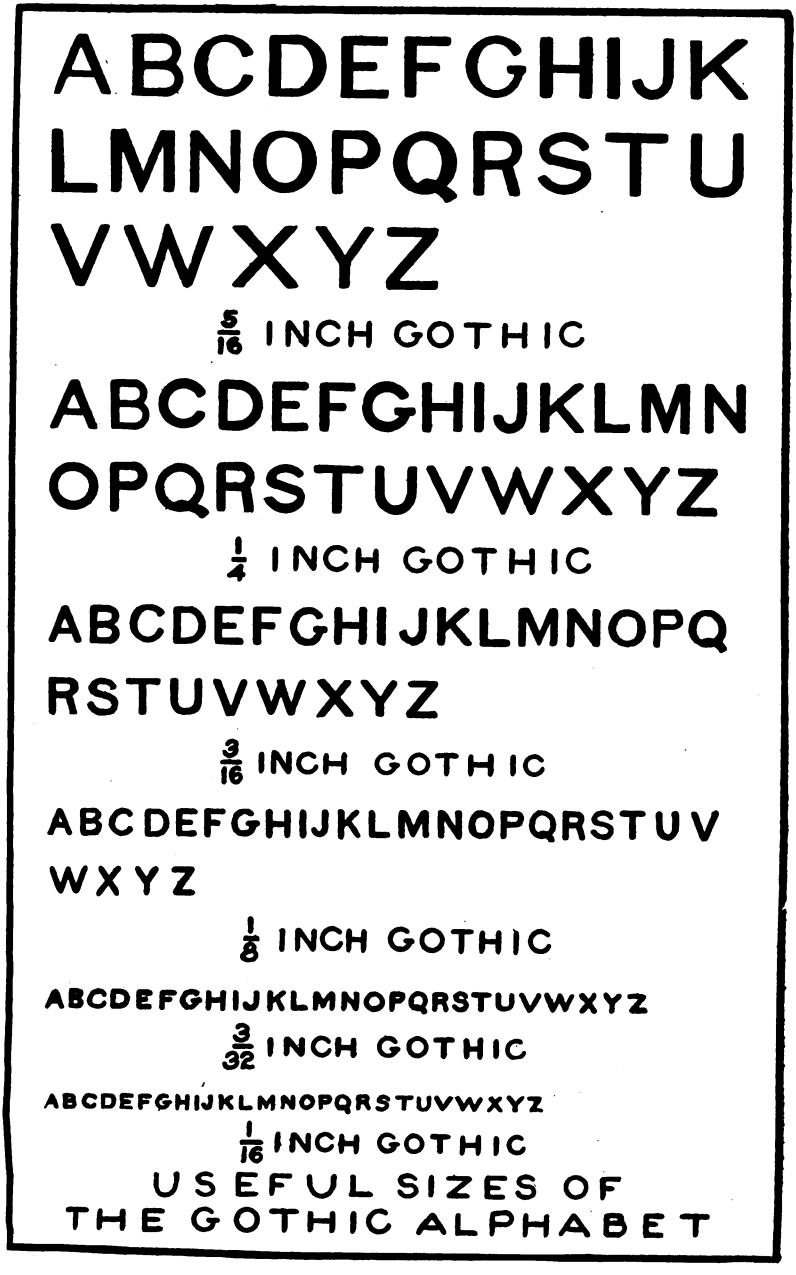

ABCDEFGHIJK
LMNOPQRSTU
VWXYZ
5/16 INCH GOTHIC
ABCDEFGHIJKLMN
OPQRSTUVWXYZ
1/4 INCH GOTHIC
ABCDEFGHIJKLMNOPQ
RSTUVWXYZ
3/16 INCH GOTHIC
ABCDEFGHIJKLMNOPQRSTUV
WXYZ
1/8 INCH GOTHIC
ABCDEFGHIJKLMNOPQRSTUVWXYZ
3/32 INCH GOTHIC
ABCDEFGHIJKLMNOPQRSTUVWXYZ
1/16 INCH GOTHIC
USEFUL SIZES OF
THE GOTHIC ALPHABET

Plate XXXVI

the center, while that on the letter A and the figure 4 is below the center; and that the base point of the figure 7 is eactly under the center of the top bar. A careful study of the peculiarities of the different letters will be found very helpful in the proper drawing of them.

When it is required to add to the boldness of a line of Gothic letters, and the space will admit, the "extended" form may be used. The alphabet and figures of this form are shown on Plate 33. In proportioning these letters, add 50 per cent to the width of all letters except the letter I, and to all the figures except the figure 1. Otherwise draw them the same as the normal form of Gothic letters.

The Gothic condensed alphabet is shown on the upper portion of Plate 34. It is used when there is not sufficient room in the line for the normal Gothic letters as shown on Plate 32. The width of these letters is two-thirds of the width of the normal Gothic letters, excepting the letter I and the figure 1, which remain as in the normal Gothic.

The Runic alphabet, sometimes called Celtic, is well adapted for use where it is desired to introduce some degree of ornamentation into a prominent line of lettering. This alphabet is shown in Plate 35. It may be drawn by widening the normal Gothic letter from one to two spaces, and adding triangular points as shown. The figures are ornamented in a similar manner.

In Plate 36 the various sizes of Gothic alphabets suitable for use on mechanical drawings are shown, full size, and beneath each sample alphabet is given its height. These are given so that the general appearance of the different sizes may be observed for the purpose of judging of the proper size to use for a given purpose.

The Draftsman's Italic Alphabet

In the previous examples the capital letters only have been used. In the case of Italic letters we use both capital letters and the small or "lower case" letters. This style, particularly in the case of the small letters, the use of which greatly predominates, is extremely useful because it resembles the written alphabet, and consequently is more readily and quickly made than the more rigid and exact forms of the Gothic capital letters. In this style of lettering, Plate 37, a line should be drawn for the top and bottom of the capital letters, representing the height of the letters. The distance between these lines is divided into five spaces, of which the lower three spaces are occupied by the small letters. The b, f, h, k, and l will however reach the top line, while the top of d and t will be one space lower. The g, j, p, q, and y will extend two spaces below the bottom line. In the preliminary practice of writing this alphabet a line should be drawn to limit this distance.

As good lettering is often one of the more difficult accomplishments of the draftsman, it is necessary to practice the various alphabets diligently, drawing them again and again until good work can be done. While a correct knowledge of the formation of all the letters of the alphabet and all the figures is very necessary, the drawing of all

Plate XXXVII

— DETAILS —

CROSS HEAD

18 × 24

SLIDE VALVE ENGINE

UNIQUE ENGINE WORKS

ROCHESTER, N.Y.

M12	DR. J.P. 5-6-09	CHK. B.J.K. 5-8-09	5-24
	TR. L.H.B. 5-10-09	CHG. H.B.M. 7-10-09	
	N. DWG.	CHG.	

TITLE FOR DETAIL DRAWING

— GENERAL DRAWING —

SIDE ELEVATION

18 × 24

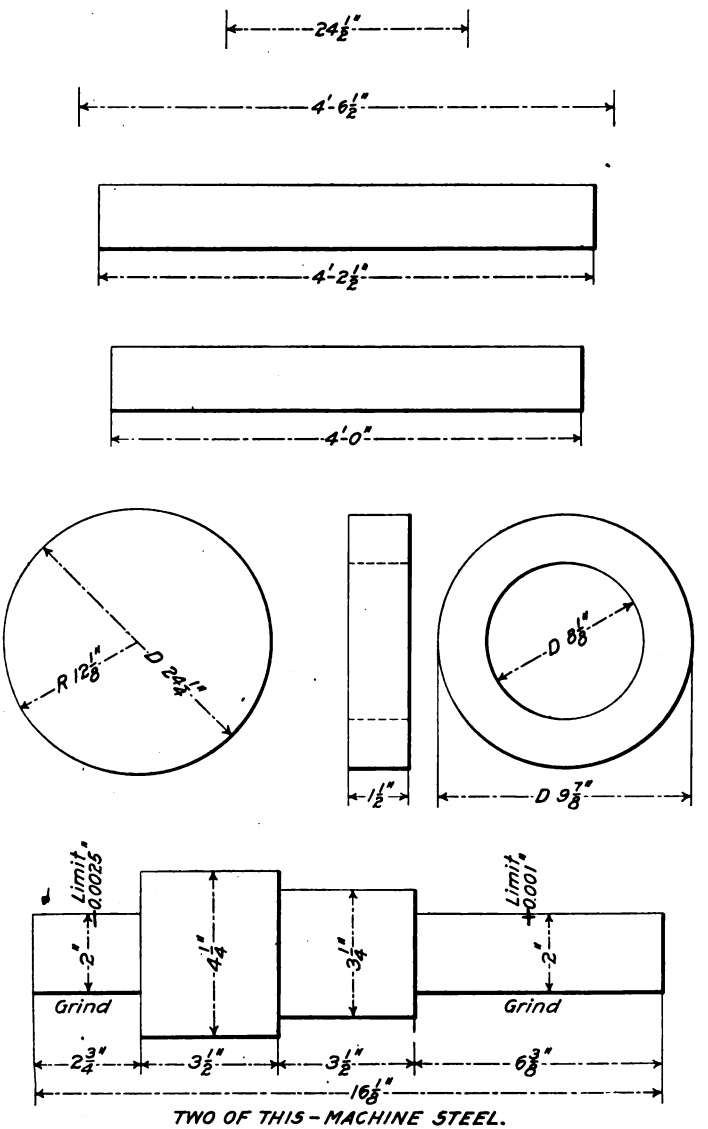
SLIDE VALVE ENGINE

UNIQUE ENGINE WORKS

ROCHESTER, N.Y.

M12	DR.	CHK.	1-24
	TR.	CHG.	
	N. DWG.	CHG.	

Plate XXXVIII



TWO OF THIS - MACHINE STEEL.

Note: Turn parts to be ground 0.005" large.

Plate XXXIX

the alphabets shown in the plates would be very tedious. It is, therefore, deemed best, as well as most practical, to have the examples of work consist of titles for drawings made up of several lines of various sizes of letters drawn with the pencil only, and other samples drawn with pen and ink. The straight lines should be made with the aid of the T-square and angle. Examples of this kind are given on Plate 38. These samples should be copied, and in addition to them original designs of titles for drawings should be made.

Dimension Lines and Figures

On Plate 39 are given numerous examples of the method of writing in dimensions; very careful attention should be given to this matter. Dimension lines are composed of a series of dots and dashes, and their terminals should always be distinctly and accurately marked by arrow points as shown. There should always be a dash between figures representing feet and those representing inches as shown in the second and third examples on the plate. If a dimension is given in even feet there being no inches, this is best shown by a cipher, as in the fourth example: 4'—0". The figures representing diameter are preceded by "D.," or "Dia.," and those giving a radius by "R.," or "Rad." In the last example all the dimensions of the piece are given as they should appear in a drawing. Two parts of the shaft shown are to be finished by grinding, which is indicated by the word "Grind." A note shows the size to which they are to be turned preparatory to this process, while above the piece is given the allowable limit permitted in the grinding, that for the part to the left being — 0.0025 inch, which indicates that it may be small (minus) to the extent of two-and-a-half-thousandths inch. In the other case, + 0.001, indicates that the diameter may be one-thousandth inch large. It will be noticed that in a line under this drawing it is specified that two of these shafts are wanted, and that they are to be of machine steel.

Titles for Mechanical Drawings

The proper selection of lettering, and a correct arrangement is very important. Hence, two examples of titles are given on Plate 38. In the title shown in the upper part, the heavy faced mark in the lower left-hand corner, M12, is called the "machine symbol," each class or type of machine being indicated by a letter, as M, and each different size of this particular class by a number, as 12.

In the lower right-hand corner the figures 5-24 indicate that this is sheet 5, and that there are 24 sheets in the complete set. These are called the "sheet numbers." These machine symbols and sheet numbers are useful in quickly selecting the sheet required from a drawer full of drawings. The abbreviation DR. means drawn. The initials of the draftsman's name and the date follow. The abbreviation CHK. means checked, indicating that the dimensions have been checked by the draftsman whose initials are given and on the date marked. TR. means traced, and CHG, changed; N. DWG. signifies new drawing.

No. 67. Boilers.
No. 68. Boiler Furnaces and Chimneys.
No. 69. Feed Water Appliances.
No. 70. Steam Engines.
No. 71. Steam Turbines.
No. 72. Pumps, Condensers, Steam and Water Piping.

LOCOMOTIVE DESIGN AND RAILWAY SHOP PRACTICE

No. 27. Locomotive Design, Part I.
No. 28. Locomotive Design, Part II.
No. 29. Locomotive Design, Part III.
No. 30. Locomotive Design, Part IV.
No. 79. Locomotive Building. — Main and Side Rods.
No. 80. Locomotive Building. — Wheels; Axles; Driving Boxes.
No. 81. Locomotive Building. — Cylinders and Frames.
No. 82. Locomotive Building.—Valve Motion.
No. 83. Locomotive Building.—Boiler Shop Practice.
No. 84. Locomotive Building.—Erecting.
No. 90. Railway Repair Shop Practice.

ELECTRICITY—DYNAMOS AND MOTORS

No. 34. Care and Repair of Dynamos and Motors.
No. 73. Principles and Applications of Electricity. —Static Electricity; Electrical Measurements; Batteries.
No. 74. Principles and Applications of Electricity. —Magnetism; Electro-Magnetism; Electro-Plating.
No. 75. Principles and Applications of Electricity. —Dynamos; Motors; Electric Railways.
No. 76. Principles and Applications of Electricity. —Telegraph and Telephone.
No. 77. Principles and Applications of Electricity. —Electric Lighting.
No. 78. Principles and Applications of Electricity. —Transmission of Power.
No 115. Electric Motor Drive for Machine Tools.

HEATING AND VENTILATION

No. 39. Fans, Ventilation and Heating.
No. 66. Heating and Ventilation of Shops and Offices.

IRON AND STEEL

No. 36. Iron and Steel.
No. 62. Hardness and Durability Testing of Metals.
No. 117. High-speed and Carbon Tool Steel.
No. 118. Alloy Steels.

FORGING

No. 44. Machine Blacksmithing.
No. 45. Drop Forging.
No. 61. Blacksmith Shop Practice.
No. 113. Bolt, Nut and Rivet Forging.
No. 114. Machine Forging.
No. 119. Cold Heading.

MECHANICAL DRAWING AND DRAFTING-ROOM PRACTICE

No. 2. Drafting-Room Practice.
No. 8. Working Drawings and Drafting-Room Kinks.
No. 33. Systems and Practice of the Drafting-Room.
No. 85. Mechanical Drawing.—Geometrical Problems.
No. 86. Mechanical Drawing.—Projection.
No. 87. Mechanical Drawing.—Machine Details.
No. 88. Mechanical Drawing.—Machine Details.

DIE-CASTING

No. 108. Die-Casting Machines.
No. 109. Die-Casting, Dies and Methods.

MISCELLANEOUS

No. 35. Tables and Formulas for Shop and Drafting-Room.
No. 110. Extrusion of Metals.

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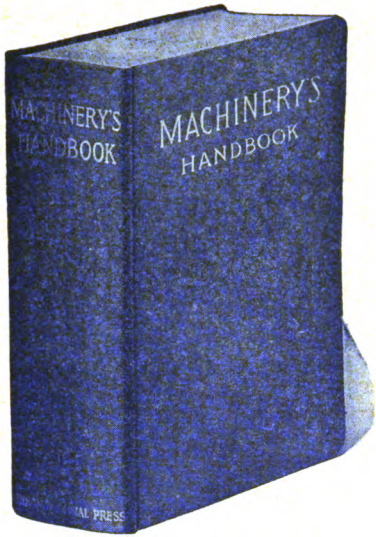

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