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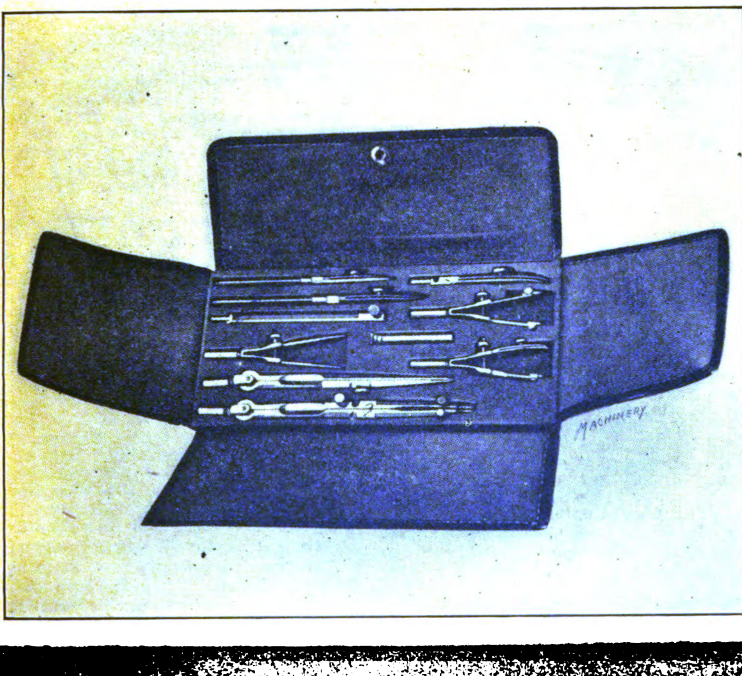
MECHANICAL DRAWING

BY OSCAR E. PERRIGO

PART IV—CAM DESIGN—DRAFTING-ROOM METHODS AND SYSTEMS



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NUMBER 88

MECHANICAL DRAWING

By Oscar E. Perrigo

Second Edition

PART IV

CAM DESIGN—DRAFTING-ROOM METHODS AND SYSTEMS

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CHAPTER I

DESIGNING AND DRAWING CAMS

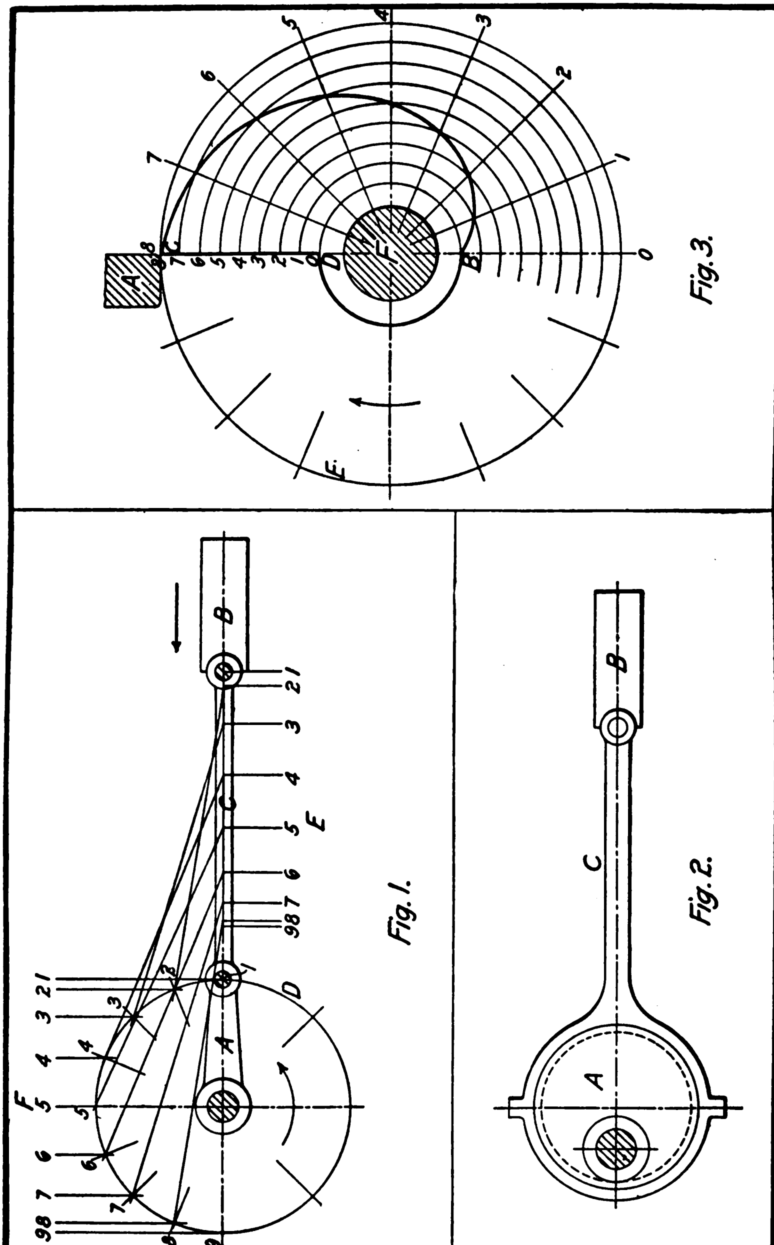
Producing Reciprocating Motions

The power which drives machines is ordinarily transmitted through the medium of belts and gears. The pulleys for the belts and the gears may be said to represent *circular* motion. This circular motion is the primary motion received by a machine; but while the circular motion is used in practically every machine built, there are numerous other kinds of motion which we must produce in order to perform the various mechanical operations required. In this chapter we are particularly concerned with *reciprocating* motion, or the motion of a certain part back and forth; and as we already have circular motion, the problem is to convert circular motion into reciprocating motion. This is done in the planer by means of a toothed rack and gear. It is frequently accomplished by a crank, or its nearly related device, the eccentric. There is a very marked difference, however, in the motion, according to the method by which it is produced. The motion produced by the rack and gear is one of constant and regular speed throughout the stroke, while the motion produced by the crank or the eccentric is one of constantly varying speed.

This is shown in the diagram Fig. 1, exhibiting the motion produced by a crank. The crank *A* is attached to the sliding piece *B* by the connecting rod *C* pivoted at each end. The circle *D* represents the path of the crank-pin, and is divided into 16 equal parts for the purpose of explanation. The crank, revolving in the direction of the arrow, will successively pass the points 1, 2, 3, etc., to 9, drawing the block *B* (in the direction of the arrow) to similarly numbered points at *E*. Owing to the fact that the crank *A* travels in a circle, these points will be comparatively close together at the beginning of the stroke, and become continually further apart until the middle of the stroke at 5 is reached, after which they will become nearer together until the half revolution of the crank is completed at 9. This variation indicates the continual variation of speed, as is further proved by the varying distances between the vertical lines drawn upward from the points in the circle at *F*. The action of the eccentric, shown in Fig. 2, is identical with that of the crank. The eccentric *A*, operating the sliding block *B* through the medium of the eccentric strap *C*, is a device that may be applied at any point on a shaft without weakening it by forming a crank upon it.

The cam is a mechanical device by means of which it is possible to produce a reciprocating motion of either constant speed or varying speed, according to the design of the cam.

In Fig. 3 is shown the method of drawing a simple cam, such as



Figs. 1 to 3. Crank Motion. Eccentric and Uniform Motion Cam would be used in a stamp mill or for a similar purpose. The object in this case is to raise the vertical sliding bar *A* with a constant speed from the point *B* on the cam until the latter has made one-half a revolution, to the position shown, when, as the point *C* passes from under the bar *A*, the latter drops to the point *D*. As the cam continues to revolve in the direction of the arrow, the operation is repeated.

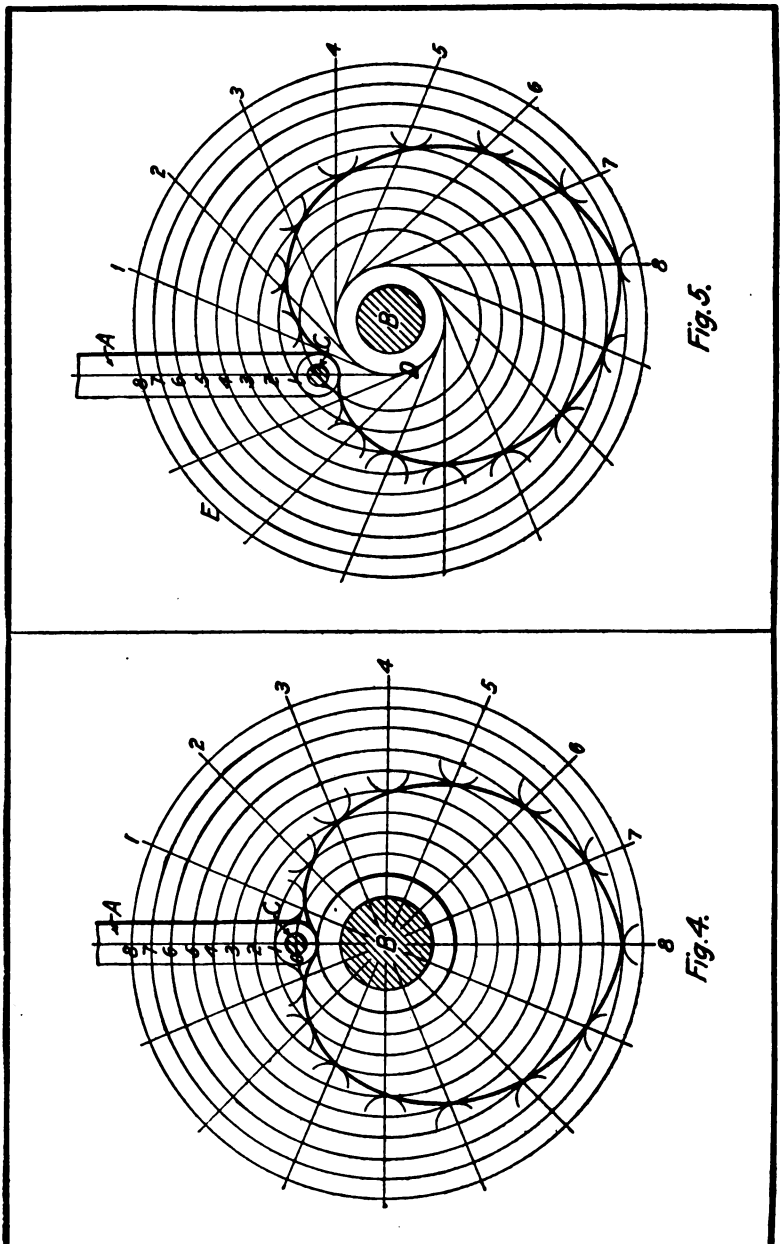
As the motion is to be confined to one-half the circle *E*, we divide that portion into 8 equal parts, and draw radial lines through each of these points, and number them as shown. The stroke or movement of the bar *A* is from *C* to *D*. We devide this distance into 8 equal parts, numbering them as shown. Through these points we draw circles with *F* as center. Beginning from *B* we mark the intersection of the radial line 1 with the circle 1, then the intersection of the radial line 2 and circle 2, and so on to the point 8. Through these points of intersection, and with the aid of an irregular curve, we draw the curve forming the contour of the cam, as shown.

It will be noticed that in this case the sliding bar *A* is raised during one-half of a revolution of the cam, and then drops and rests during the other half of a revolution. If it is desired to have the sliding bar *A* commence its rise as soon as it has fallen, the curve of the cam will begin at *D* instead of *B*. This will give a more gradual rise of the sliding bar, but eliminate the rest.

Design of a "Heart" Cam

The cam shown in Fig. 4 is usually called a "heart" cam, on account of its form. In the cam in Fig. 3 the office of the cam was simply to raise the sliding bar, which fell suddenly by its own weight. In the heart cam the movement required is a gradual and constant rise, and a similar downward movement. In this case a friction roller is introduced. It is used in nearly all cams to reduce friction to a minimum.

In drawing this cam the circle representing the shaft *B* is first drawn; then the circle of the hub. The friction roller *C* is laid out in the position it is to occupy when at its lowest point, or the point nearest the center of the shaft. Then the upper limit of the movement of the sliding bar *A* is determined, and marked as at 8. The distance between the upper and lower limits of the movement is divided into any convenient number of equal parts, in this case 8, and numbered from the bottom upward as shown. Through the points thus located circles are drawn. The outer circle is then divided into twice the number of equal parts, or 16, one-half of this number representing the rise and one-half the fall of the contour of the cam. Radial lines are drawn through these points and numbered as shown. The points of intersection of like numbered radial lines and circles are then marked as before. Now, with the dividers set to the radius of the friction roller *C*, and with these marked intersections as centers, we draw the semi-circles shown. By the aid of an irregular curve we draw a curved line just touching these semi-circles, thus giving the contour of the cam.



Figs. 4 and 5. Design of Uniform Motion Cams

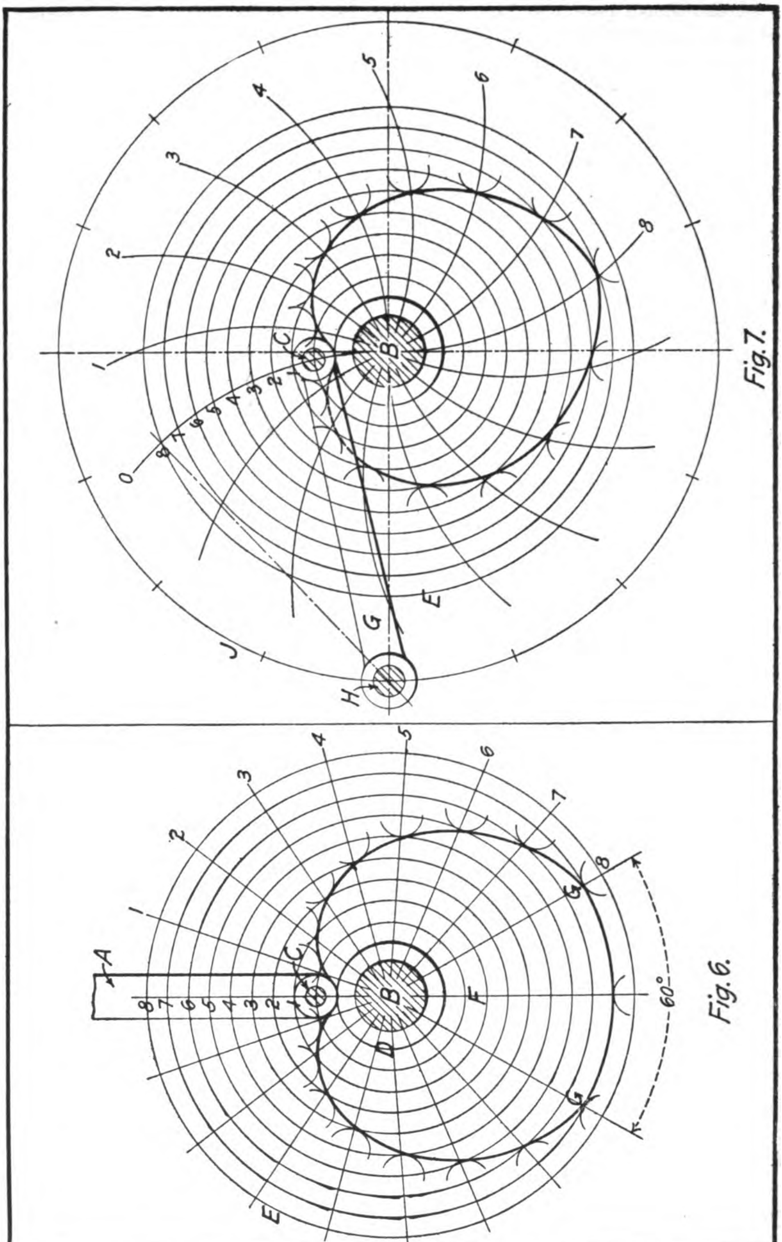
In the above case the line of motion of the sliding bar *A* is directly toward the center of the shaft *B*. It happens sometimes that the sliding bar must be placed to one side of the center, but the same reciprocal movements are required as before. Such a case is shown in Fig. 5. In this case, the shaft circle is first drawn and the center line of the sliding bar *A* laid out. The circle for the friction roller is drawn, and from its center the limit of the movement, or "stroke," is laid out, divided, and numbered, as before. Circles are drawn through the division points. With the dividers set at the distance from the center line of the shaft to the center line of the sliding bar *A*, the circle *D* is drawn. The circle *E* is divided into twice as many equal parts as that of the stroke of the sliding bar *A*, and the points numbered as shown. Instead of drawing radial lines through these points, the lines must be tangent to the circle *D*, because of the changed position of the line of motion of the sliding bar *A* in relation to the center of the shaft *B*. The tangent lines having been drawn as shown, the remaining work is done in a manner similar to that of Fig. 4.

The Heart Cam with a Rest Period

In the cams shown in Figs. 4 and 5 the movement of the sliding bar was required to be a gradual rise followed by a gradual fall. It is sometimes the case that the sliding bar, having arrived at its highest point, is required to "rest" there for a certain part of the revolution of the cam, and then to gradually descend. Such a case is shown in Fig. 6. The rest is to be through an arc of 60 degrees or one-sixth of the circle, the remaining portion to be equally divided between the rise and fall of the sliding bar. The shaft and friction roller circles are drawn and the stroke of the sliding bar is laid out, as before. Upon the circle *E*, 30 degrees are laid out on each side of the center line *F*, and radial lines drawn through these points (*G*). The remaining portions of the circle each way from the points *G* to *C* are divided into the same number of equal parts as the stroke. The contour of the cam for the 60 degrees from *G* to *G* is the arc of the circle. The portions on each side from *C* to *G* are drawn in a manner similar to that in the previous examples.

Cams with Pivoted Followers

Heretofore the movements of the friction roller and the piece to which it is pivoted have been in a straight line. It often happens, however, that the friction roller is pivoted at the end of a lever, as shown in Fig. 7. The lever *G* is pivoted at *H*, which point is so located that an arc described by the movement of the center of the friction roller *C* will pass through the center of the cam shaft *B*. To provide for these changed conditions the construction lines intersecting the circles in the former examples now become circular arcs with a radius equal to *CH*. To draw these, we first describe the circle *J*, with *B* as a center and *CH* as the radius. This circle is divided into any convenient number of equal parts, in this case 16, beginning at *H*. From the points thus located, as centers, and with the radius *CH*, draw succes-



Figs. 6 and 7. Other Forms of Uniform Motion Cams

sively the arcs 0, 1, 2, 3, etc. Using the intersections of these arcs with the circles drawn as in the previous examples we proceed in the same manner as before to draw the semi-circles and lay out the contour of the cam.

Cam to Produce Compound Motions

In the cam shown in Fig. 6, the movement produced is a gradual rise, a rest, and a gradual fall. Frequently a combination of several of these movements is required during one revolution of the cam. Such a case is shown in Fig. 8. It is customary in designing cams of this kind to define the different movements by a given number of degrees, 360 degrees forming a complete revolution.

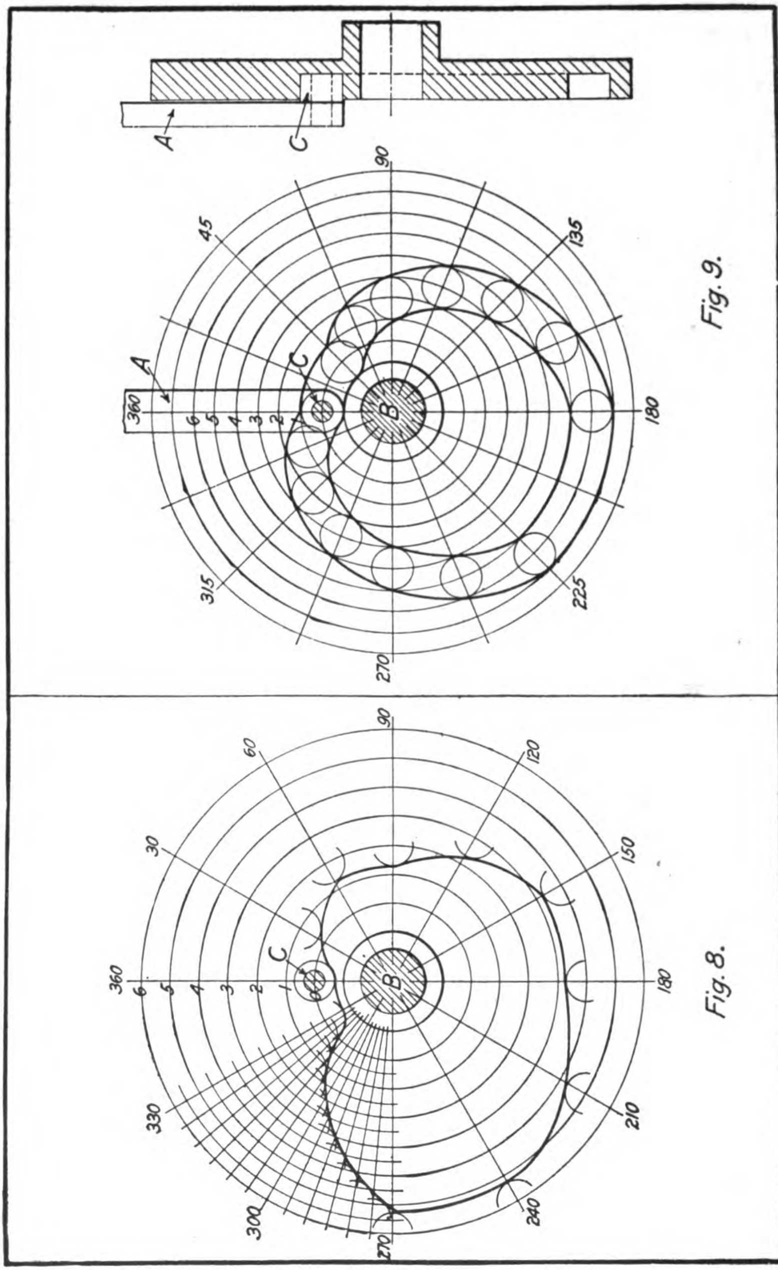
To design this cam the shaft *B* and friction roller *C* are laid out as before. Then the stroke is determined, as from the center of the friction roller to 6. A circle is drawn through the point 6 and divided into such number of parts as the design of the cam may require. In this case the motions of the follower are as follows, beginning at the position of the friction roller as shown:

1. To rise 2 spaces in 60 degrees.
2. To rest during 30 degrees.
3. To rise 2 spaces in 60 degrees.
4. To rest during 30 degrees.
5. To rise 2 spaces in 60 degrees.
6. To rest during 30 degrees.
7. To return to original position in 60 degrees.
8. To rest during 30 degrees.

As these periods of the full revolution are all either 30 or 60 degrees, the circle is divided into 12 parts of 30 degrees each, and the division points marked in degrees commencing at the top. Radial lines are drawn through these points. Circles are drawn through the division points 0, 1, 2, etc., in the stroke line. Now proceed in a similar manner as in the previous example, remembering that all parts of the cam producing rests are arcs of a circle whose center is the center of the cam shaft. These periods of rest occur between 60 and 90, 150 and 180, 240 and 270, and 330 and 360 degrees. The portion between 270 and 330 degrees, for the gradual descent of the friction roller, is divided into 12 spaces and radial lines drawn. Intermediate circles are drawn between the six original ones to correspond to these 12 radial lines. Thus, a very accurate contour may be laid out. In the practical designing of cams it should be remembered that the greater the number of radial lines and circles, the more accurate will be the contour of the cam.

Face Cams and Cam Grooves

Thus far the friction roller has rested upon the irregularly formed edge of the cam. This condition necessitates the weight of a sliding block or the use of a spring to hold the friction roller in contact with the cam surface. This is not always either practicable or desirable. To obviate this condition, cam grooves, slots, or races are formed in



Figs. 8 and 9. Design of Irregular Motion Cam and of Face Cam

the face of the cam disk, as shown in Fig. 9. A vertical section is shown at the right, giving an idea of the cam groove. In drawing a cam of this kind we proceed as in the former examples, except that instead of drawing semi-circles of the same radius as the friction roller, we draw the entire circle, and make it very slightly larger than the friction roller. We also draw the contour of the cam slot both inside and outside of these cicles. In this case it will be noticed that the large construction circle (representing also the diameter of the cam disk) is divided into periods of 45 degrees each, as there are two rests of 45 degrees each; the remainder of the circle, 270 degrees, is divided equally between the period of rise and fall, each being 135 degrees.

Cylindrical Cams

The examples so far have all been either edge cams, that is, cams formed of a disk upon whose edge is formed the cam track; or similar disks in whose face is cut a cam groove or track of the proper form and wide enough to accommodate the friction roller. We now come to those cams in which the cam groove is formed in the surface of a cylinder. In Fig. 10 is shown an end and side elevation of a characteristic form of such a cam, containing two grooves. In laying out such a cam we first determine its diameter and draw the shaft hole, hub and outer diameter as shown respectively at *A*, *B*, and *C*. The circle *C* is divided in this case into 12 spaces of 30 degrees each, and numbered as shown.

To determine the form of the cam groove we must develop the surface of the cylinder, or in other words, we must make a drawing on a piece of paper that would be exactly sufficient to cover the cylinder when wrapped around it. This development of the cylinder is shown in Fig. 11. It is divided into spaces of 30 degrees, and numbered the same as similar points around the cylinder. Horizontal lines are drawn for determining the location of the roller at various stages in its movement. The completed cam is shown at the right in Fig. 10.

Referring to the first cam groove at *D*, the requirements are a movement to the right of 3 spaces, during 60 degrees, beginning at the 120-degree graduation, and a similar movement to the left, the remainder of the revolution being rest. The method of drawing this cam is readily understood from Fig. 11. The second cam groove *E* is more complicated. This requires:

Beginning at the 30-degree graduation, a movement to the right of 3 spaces, in 60 degrees.

A rest of 60 degrees.

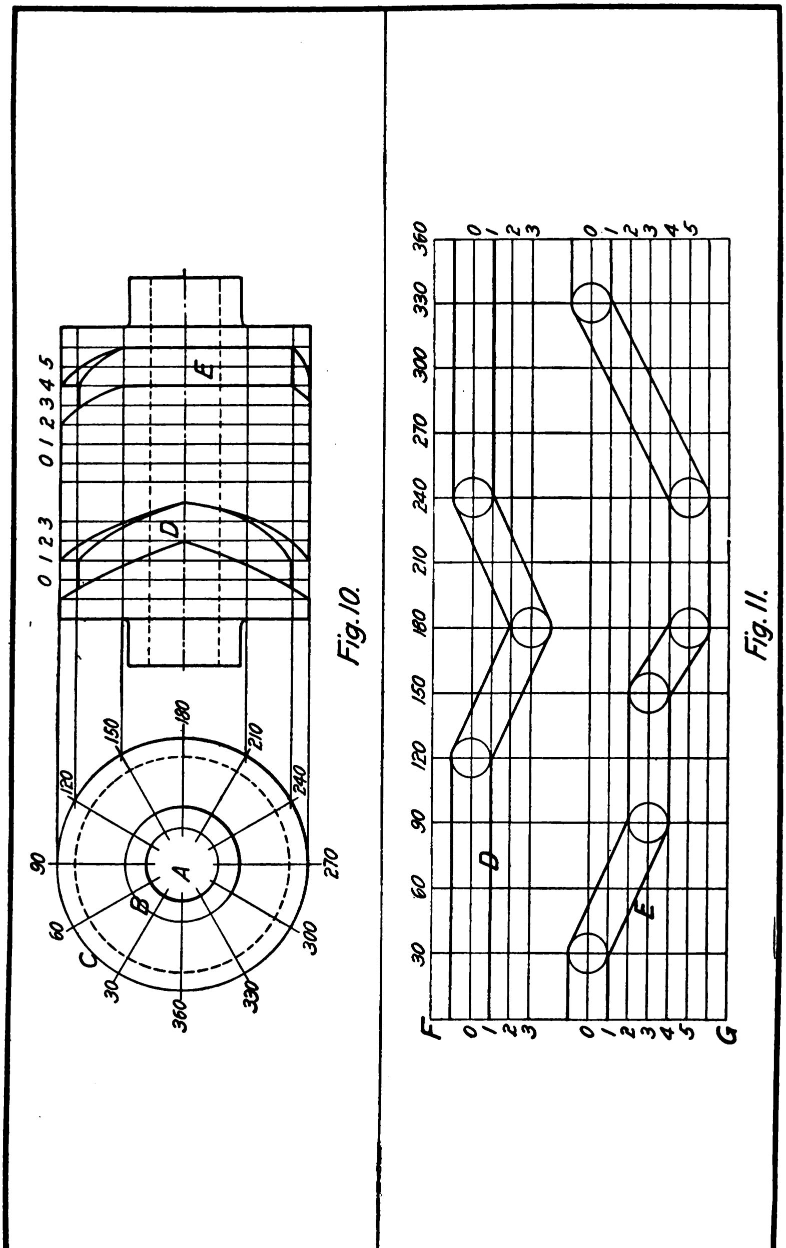
A movement to the right of 2 spaces, in 30 degrees.

A rest of 60 degrees.

A movement to the left of 5 spaces, in 90 degrees.

A rest of 60 degrees.

The plotting of this groove is, however, comparatively simple when laid out in this manner. If we were to take the piece of paper on which the development is thus drawn and wrap it around the cylinder



Figs. 10 and 11. Design of Cylindrical Cams

shown, the cam grooves would appear exactly as they are represented in Fig. 10. To determine the different points of the cam groove on this cylinder we make its length equal to the width *FG* of the development diagram in Fig. 11, and draw vertical lines across it as shown, numbering them 1, 2, 3, etc. Then by projecting lines from the various points in the outer circle *C* (Fig. 10) we obtain points for the contour of the grooves.

This cam is adapted for use with a sliding bar, to which is pivoted a friction roller, or an arm carrying the roller. In the latter case, if the lever is short or its movement passes through a greater arc than 20 degrees, it may be necessary to modify the construction lines as shown in Fig. 7. Ordinarily such a movement is arranged to be partly above and partly below the center line and the variations are so slight as not to require attention.

Cylindrical cams are sometimes made upon the projecting ends of a hollow cylinder, which is so shaped as to form a cam track, the friction roller being held in contact with it by means of a spring or weight. Cams are formed upon the outer surface of cylinders by attaching to it strips of steel of such a form and in such positions as to produce the required motions, as for example the cam drum of an automatic screw machine. There are a great many varieties and modifications of cam forms, and often many combinations of several forms in the same cam, but in nearly all cases they consist of some combination of the several simple forms just shown, so that with these forms thoroughly understood, we may be able to make such combination of them as a given case may require. For a more thorough treatise on cam design and cam action, see MACHINERY's Reference Series No. 9, "Designing and Cutting Cams."

CHAPTER II

GENERAL METHODS OF DRAWING, TRACING AND BLUE-PRINTING*

In the present chapter are given practical examples of miscellaneous general drawing, of such a nature as the draftsman may encounter at any time. These examples are: A floor plan of a portion of a manufacturing plant; a machine foundation built of brick and stone; and a complete drawing of a casehardening and annealing furnace. These are selected purposely because of being different from the strictly machine drawing heretofore treated in this course, so as to broaden the scope of the work as much as possible. These drawings are taken from those used in practical construction work. In addition to this, the necessary instructions for making tracings from drawings are given in this chapter, as well as for making blue-prints.

In making drawings of the examples given, the work should be made upon large sheets, so as to produce clear and open work; better work can be done in this way, and it is always advisable to use as large a scale as practicable. In order to afford ample practical use of the drawing instruments, these drawings should be fully inked in. The necessity for practice of this nature is, at this stage, greater than for the study of an undue amount of printed text.

Floor Plan

Fig. 12 shows a plan made for the purpose of locating the machines in a pattern shop, and the pattern racks or shelving system in the pattern storage loft. Lay out first the walls of the building, spacing the windows and doors as on the drawing. Then lay out the racks and other features of the pattern storage. Next, lay out the stairs and lockers in the pattern shop; then the benches and stock closet, with its shelves. Locate the various machines, taking the measurements from the side walls and being careful as to the form and dimensions of the space occupied by each machine. Use shade lines as explained in Part III of this treatise, and be careful to make the lettering clear and regular. To do this, make a pencil line at the top and bottom of every line of lettering.

Case-hardening and Annealing Furnace

Study carefully the six different views of this drawing, and endeavor to understand thoroughly what each view means and why it is necessary, and what purpose it serves in enabling the workmen to build the furnace. The three views given in Figs. 13, 14, and 15, representing the exterior appearance of the front and rear end and one side, give a good idea of the general appearance. The side opposite to the one shown in Fig. 14 is plain, having no door; consequently, a view of

*See also MACHINERY'S Reference Book No. 2: "Drafting-room Practice."

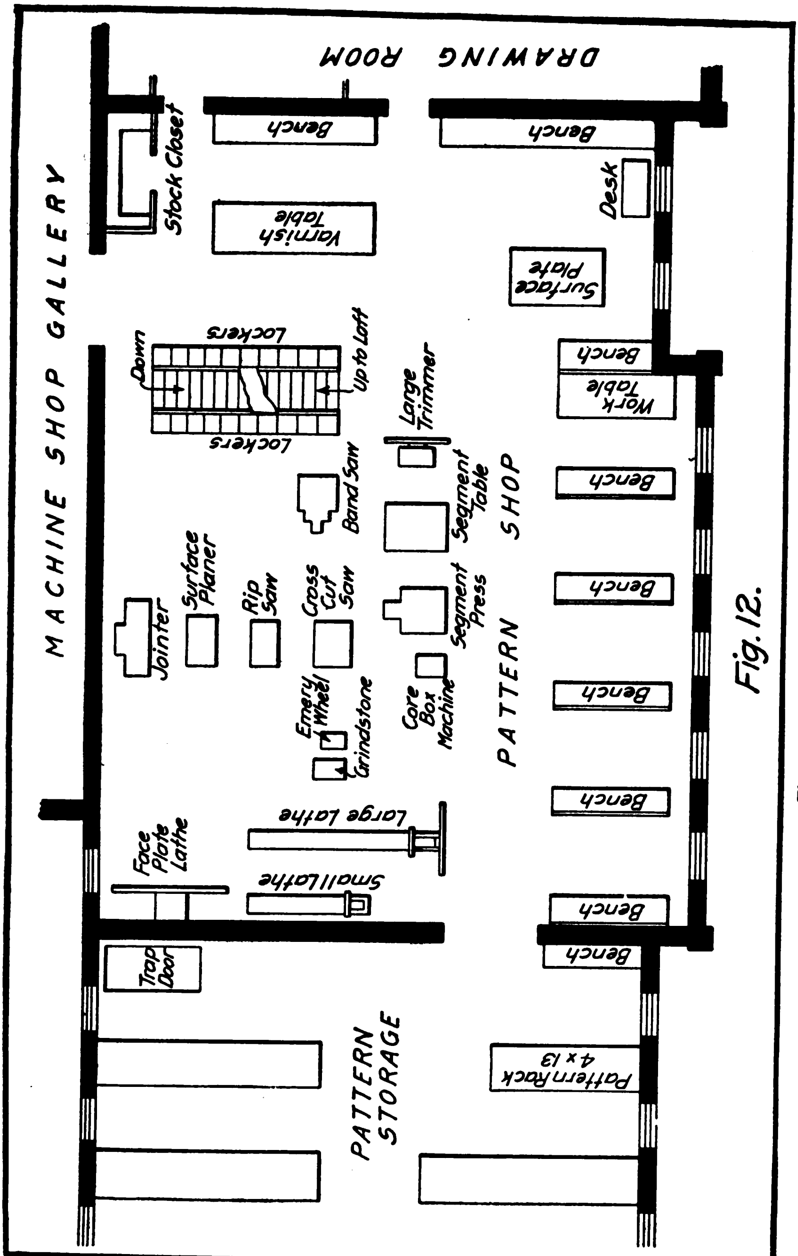


Fig. 12. Floor Plan of Pattern Shop

it is not needed. Figs. 16, 17, and 18 are sectional views which show the methods of construction. Such brickwork as is covered by diagonal sectional lining is of fire-brick, or fire-tile. Brickwork not so sectioned is of ordinary hard, red brick.

The reference letters used and their significance are as follows: *A*, fire-box; *B*, top of the bridge wall; *C*, heating space for the annealing pots; *D*, ash-pit; *E*, fire-brick tiles forming the floor of the annealing chamber, placed one-half inch apart, and supported by a central wall *M; F*, firebrick arch over the fire-box and annealing chamber; *G*, blast pipe; *H*, fire-door; *J*, ash-pit door; *K*, rear door of the annealing chamber; *L*, rear door of the ash-pit; *M*, rear end of central supporting wall of the fire-brick tiles *E; N*, door to annealing chamber; *P*, the removable fire-proof plug, by the removal of which the condition of the annealing space may be examined.

The entire brickwork is held firmly clamped by means of cast-iron vertical binder bars whose lower ends are firmly set in the foundation and whose upper ends are rigidly secured by tie-rods as shown. In drawing the end elevations and cross-sections, lay out the vertical center lines first and lay off the horizontal distances each way from them.

The sections (Figs. 16, 17 and 18) should be drawn first, and the elevations laid out from the dimensions of these, as the method of construction is the more important subject. Wherever dimensions appear, be careful to lay out the lines to the measurements given, and write in the dimensions as shown. The drawing may be made to a scale of ¾ inch = 1 foot. If the student has no scale of three-quarters of an inch to the foot, it may be mentioned that an ordinary rule graduated in sixteenths of an inch can readily be used, as each sixteenth on the rule will represent an inch on the drawing. Much care will be necessary in making this drawing, particularly on the smaller detail parts. The student is advised to take all the time necessary to make as good a drawing as he can.

Planer Foundation

To design and build an efficient foundation for a large planer is usually a difficult piece of work and calls for good judgment as to the weight to be sustained, the character of the ground on which the foundation is to be built, and the convenience of operating the machine after it is in position ready for work. The drawing here represented is from a design by the author, and has proved successful. Therefore, it is a strictly practical example.

In drawing this foundation the vertical, longitudinal section, Fig. 19, is first laid out, beginning with the drawing of the side elevation of the planer *A*, itself, which is shown in outline only, adding circles for the pulleys and gears which extend below the base line of the machine. The brick piers are next drawn, and then the stone foundation upon which they rest. The brickwork sectioned by diagonal lines is so drawn to show that it is in section, while the remaining portions, as well as the stone work is shown in elevation without being sectioned.

The stairs *B*, leading to the pit beneath the planer, are of wood. The cylindrical supporting columns *C*, are of cast iron. All the shading of the stone work and the markings representing earth, should be put in with ink, to resemble, as nearly as possible, that shown. The plan, Fig. 20, is next drawn, first laying out a center line from which to take the measurements for the different widths of the foundation.

It is best to locate the plan on the drawing directly under the longitudinal section, as this will permit of projecting construction lines downward from Fig. 19 to Fig. 20 for a great many of the desired points, and thus save time in taking measurements, and decrease the liability to errors. A convenient scale to which to make this drawing is ⅜ inch = 1 foot, and the student is reminded that the scale of three-eighths of an inch to the foot may be measured on an ordinary scale of sixteenths, since each sixteenth represents two inches, or 32 actual inches equal one inch on the scale.

If the student desires, this drawing may also be made to twice the scale mentioned, that is to a scale of three-quarters of an inch to the foot. This will render the work somewhat easier to lay out.

Making Tracings

Tracings for use in producing blue-prints are made upon tracing paper or tracing cloth, according to whether they are intended to be for permanent or for temporary use. It is true that there are tracing papers, such as bond paper, vellum or parchment paper, etc., that are strong enough to stand considerable hard usage, but for nearly all classes of permanent tracings, cloth is the more reliable material.

If a tracing is to be made from a drawing, it is not necessary to ink it in, unless the detailed work upon it is very fine and complicated. If the drawing paper has a sufficient grain to take pencil marks readily, the lines to be traced may be made with a 2H pencil, and will be found quite clear enough to be seen through either tracing cloth or paper. The ordinary tracing cloth used by mechanical draftsmen has one "dull" side and one smooth or glossy side. For mechanical drawing the glossy side is used for the ink lines. Architectural draftsmen nearly always use the dull side.

The tracing cloth is stretched smoothly over the drawing and fastened with thumb-tacks. A small quantity of pulverized chalk is sprinkled over the surface and rubbed carefully over every part that is to be drawn upon, by the use of a dry cloth, or preferably a piece of chamois skin, after which it is carefully wiped off. The purpose of this application is to absorb the slight trace of grease from the glossy surface, which would prevent the ink from flowing freely. If the dull side of the cloth is to be drawn upon, this treatment is unnecessary.

The work of drawing ink lines upon the tracing cloth or paper is performed the same as in inking-in a drawing on paper. That is:

1. Ink all center lines.
2. Ink all small circles.
3. Ink all large circles and circular arcs.

4. Ink all straight lines.
5. Ink all lines requiring the use of an irregular curve.
6. Ink all section lining.
7. Ink all shading or shade lines that have not been completed.
8. Ink all dimension lines.
9. Write in all dimensions.
10. Do the lettering, including the title, notes, special directions, etc.

The lines should in all cases be heavy enough to show a clean, white line on a blue-print made from the tracing. Shade lines should ordinarily be about three times the width of the other outlines. Center lines and dimension lines should be only wide enough to show on the blue-print, or usually about half as wide as the light lines of the outlines of the pieces. If the tracing is very large and there are a number of different views upon it, each view or small group of parts should be inked in before another section of the tracing is worked upon, because tracing cloth or paper is very sensitive to changes of temperature and moisture, which will throw the lines out of place if left but a few hours.

It should be remembered that drawing ink flows much more readily on tracing cloth than on drawing paper, and care in the work must be taken accordingly. Ink also dries slower on a tracing than on a drawing, and more care will be required to avoid blots. As erasures are much more difficult to make on a tracing than on a drawing, mistakes, and the overrunning of lines, should be carefully avoided. Finally, care must be used to avoid all moisture on the surface of the tracing. A drop of water causes an ugly blotch which will usually destroy ink lines and nearly always cause a defect in the blue-print.

Blue-printing

It was formerly the custom to make paper tracings and shellac these to thin boards for shop use. The discovery of the blue-printing process revolutionized this method. In blue-printing, the tracing is used in a manner similar to that of the negative in making photographic prints, except that the tracing is a "positive", and the blue-prints are negatives, although the blue-prints are not "left-handed", as is the case with a photographic negative.

For the purpose of blue-printing, frames, usually made upon practically the same plan as the photographic printing frames, are used. In these the tracing is placed with its face next to the glass, and the sensitized paper behind it, the two being held in contact by a felt covered back board, retained in place by springs or some similar means. Being thus prepared, the frame is turned with the face toward the sun for a few minutes, the time depending on the strength or intensity of the light. The exposed paper is then removed and quickly immersed in cold water and thoroughly washed, and then hung up and dried.

The sensitizing solution applied to paper for making it sensitive to light is prepared as follows:

SOLUTION A

Red Prussiate of Potash......................	5 ounces
Water	1 quart

SOLUTION B

Ammonia-citrate of Iron......................	8 ounces
Water	1 quart

These solutions should be separately mixed and thoroughly filtered. The sensitizing solution is prepared by mixing, in a dark room, equal parts of solutions *A* and *B*. The paper should be coated and dried in a dark room. A soft brush or sponge may be used for the purpose. Usually blue-print paper is purchased in rolls, prepared and ready for use. It should be carefully protected from the light until properly exposed in the blue-print frame.

The action of the process of blue-printing is as follows: Before the paper is exposed to the light it is of a pale and somewhat greenish yellow. In this condition, if a piece is placed in water the solution would readily wash off, leaving the paper white. The sensitive coating is therefore soluble in water. When exposed to the light, the coating is by a chemical change rendered insoluble. This change takes place in all parts of the paper exposed to the light. The ink lines protect some parts from the chemical change produced by the light. Therefore, when the exposed paper is washed, the portions protected by the ink lines wash out white, and all other portions are changed to a blue color by the action of the light. The shade of color produced depends upon the time of exposure and the brightness or intensity of the light.

When a large number of blue-prints are to be made, printing machines are used, in which the sensitized paper and the tracings are wound around a slowly revolving cylinder, during the revolution of which they are exposed to the light of electric lamps. The exposure is thus made at a great saving of time and labor. Blue-prints are sometimes sent into the shop as they come from the drying process, but usually they are mounted upon thick straw board, binder's board, or thin boards of wood, and sometimes on thin sheet iron. In issuing them from the drafting room they are charged to the department to which they are sent, and credited when they are returned. Thus the location of every print is positively known.

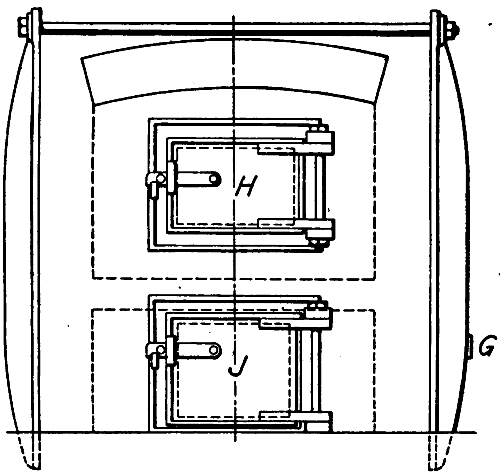
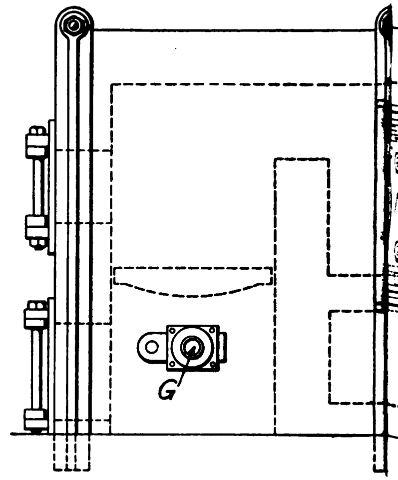


Fig. 13. Front Elevation



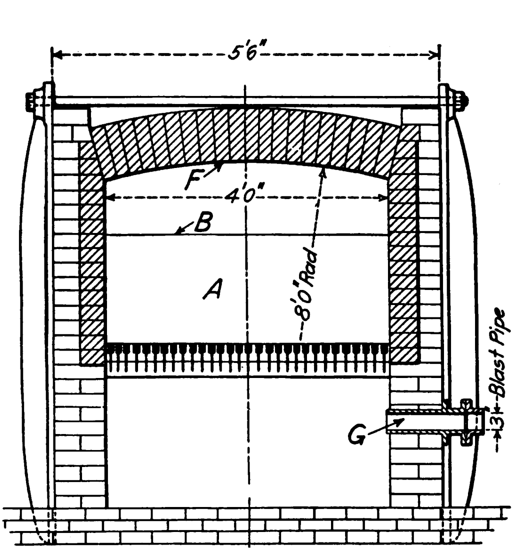


Fig. 16. Section Through Firebox, etc.

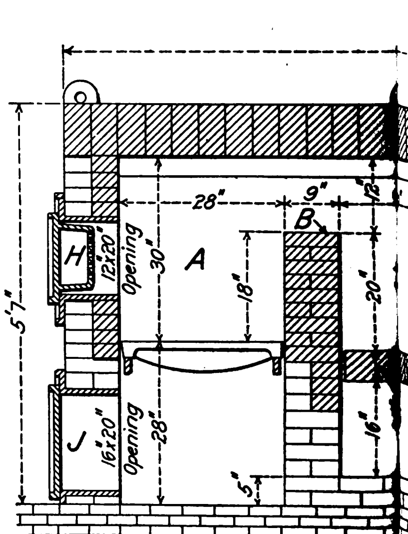
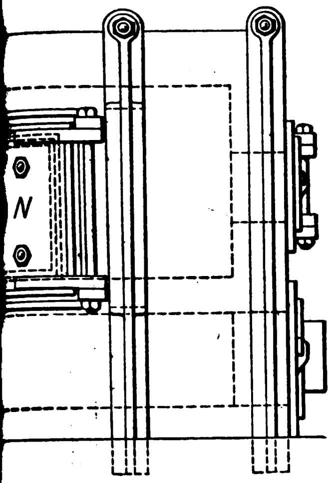


Fig. 17. L

Figs. 13 to



vation.

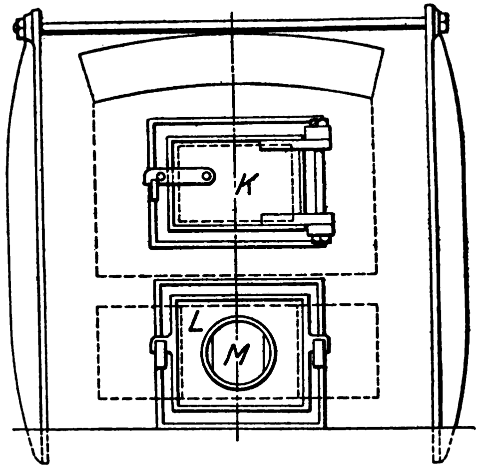
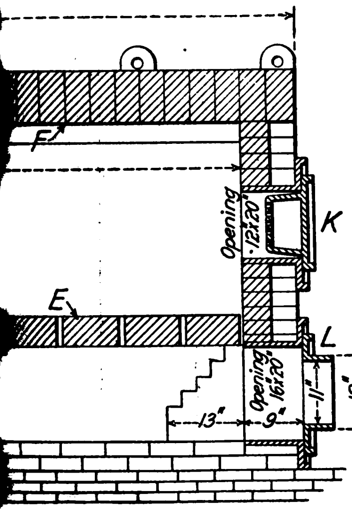


Fig. 15. Rear Elevation.



Section.

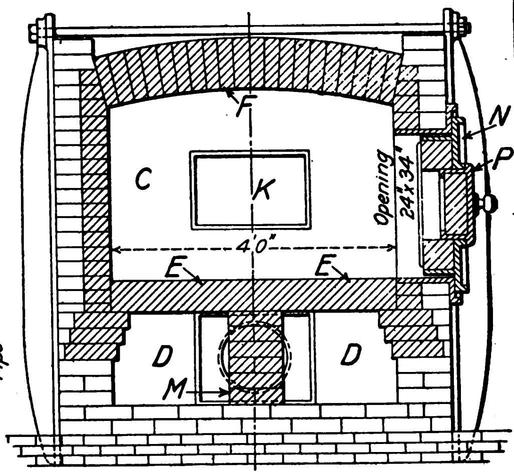


Fig. 18. Section Through Heating Chamber.

Furnace

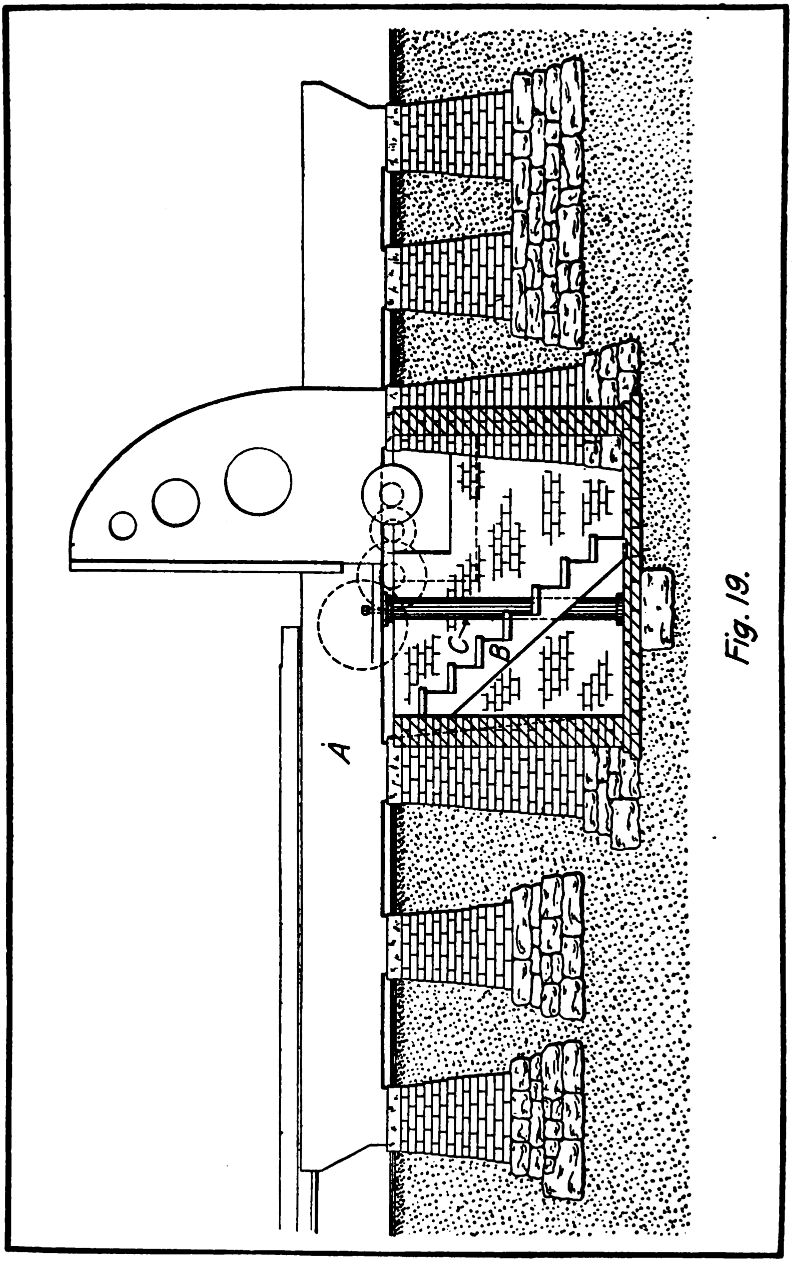


Fig. 19. Elevation of Planer Foundation

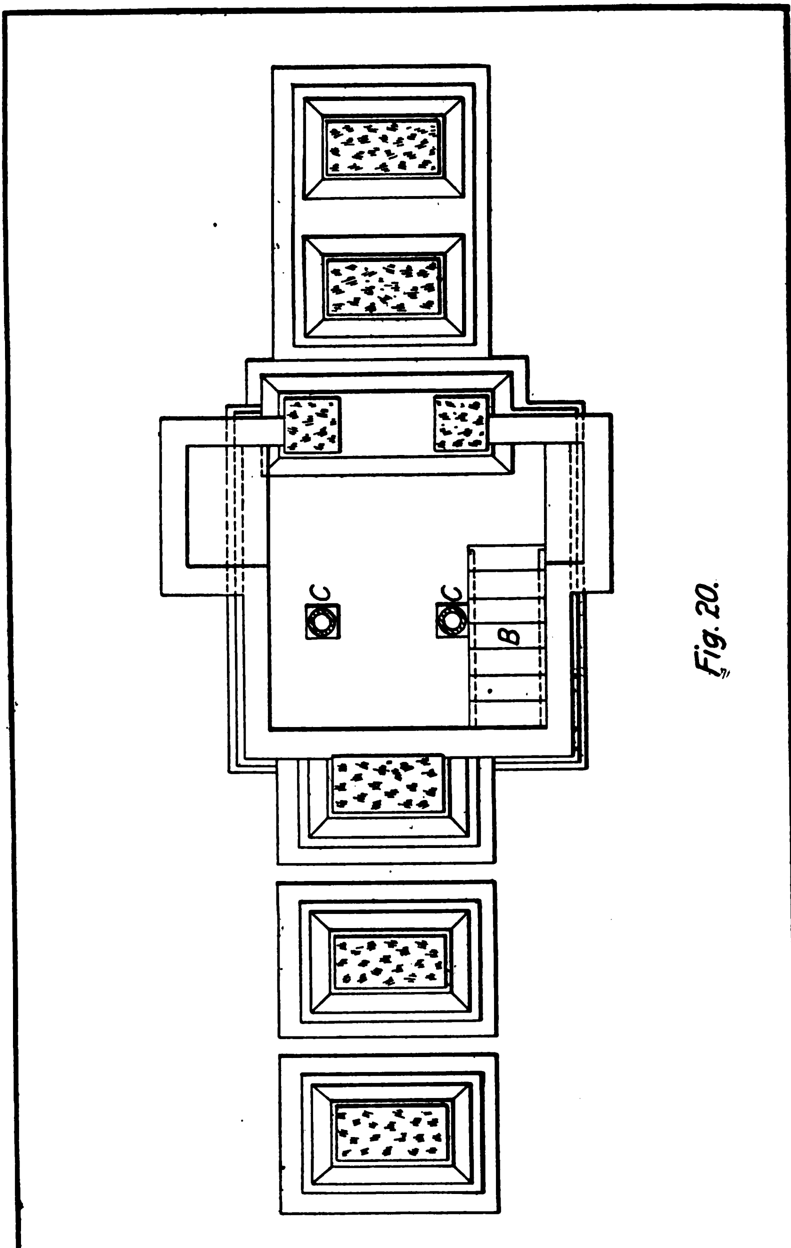


Fig. 20. Plan of Planer Foundation

CHAPTER III

DRAWING MATERIALS

In producing good mechanical drawings, much depends upon the materials used, particularly the quality of paper upon which the drawing is made. It should not be inferred from this that the most expensive materials should be used, but, rather, the most appropriate and suitable materials for the particular work to be done. Mechanical drawings are usually, though by no means always, made on paper. Various kinds of card board, bristol board, cloth in the form of tracing cloth, celluloid, isinglass, parchment, etc., are also used. Many drawings, particularly for forgings, were formerly made on pine board slightly coated with shellac varnish, a coat of this varnish over the drawing preventing its obliteration. Paper tracings were also mounted on boards with shellac. With the discovery of the process of blue-printing, these and a number of other methods of making drawings were discarded on account of the rapidity and economy of producing copies by this new process.

There are a great many kinds and qualities of drawing paper manufactured to suit the great variety of uses to which it is put, since each different kind or class of drawings can best be made on certain kinds of paper adapted to it. In former years drawing paper was mostly made in sheets, of certain arbitrary sizes, those in most common use being as follows: Medium, 17 by 22 inches; Imperial, 22 by 30 inches; and Double Elephant, 27 by 40 inches. The best quality, marked "Whatman," is still used when an extra good quality is wanted. The thickness of this paper varies according to the dimensions of the sheet; that is, the larger the sheet, the thicker it is. Two different surfaces are furnished: smooth, or "hot pressed" (marked HP), and rough, or "cold pressed" (marked CP), the latter having a considerably roughened or "grain" surface. There are many other kinds and qualities of drawing paper of all grades, sizes and prices, and of both foreign and domestic manufacture, which are used for mechanical drawing. However, drawing paper in sheets is used to a much greater extent in schools and by artists and other free-hand draftsmen than by mechanical draftsmen. The reasons for this are that very large sizes of sheets are seldom required by the former classes of draftsmen, that paper in sheets is more conveniently stored in drawers than if it is in the form of rolls; and that it is more easily procured in small quantities.

There are a variety of colors, or rather tints, or shades of drawing paper from clear white to buff, grey, terra cotta, and the natural manila tints. While the artists uses those tints which best suit the character of the work, the mechanical draftsman is governed by questions of utility. Pure white paper is not usually as agreeable to the eye-sight as paper having a slight cream or ecru tint. A slight tint shows the effect of dust less than pure white, and it is not so easily soiled. When soiled by being worked upon for a considerable length of time, it is usually easier to clean and put in a presentable condition.

On account of the variety of sizes of sheets needed by the mechanical draftsman, paper manufactured in rolls is usually preferred, as sheets of any desired dimensions may be readily cut from the roll. In many cases quite large construction drawings are required, which necessitate sheets as large as 4 feet wide and 8 to 12 feet in length. For ordinary shop drawings it has come to be regarded as good practice to adopt standard sizes for the sheets or drawings, making the standard sheet, say, 24 by 36 inches, and sub-dividing this into half-sheets, 18 by 24 inches; quarter-sheets, 12 by 18 inches; and eighths or "sketching" sheets, 9 by 12 inches. If a sheet larger than 24 by 36 inches is needed, a "double sheet," 36 by 48 inches, is used. Sheets larger than this will only be used for construction drawings, and no regular dimensions are fixed, although the usual width of continuous or roll drawing paper, 48 inches, determines the width. Roll drawing paper can be procured, however, in other widths, these being 30, 36, 38, 40, 42, 56, 58, and 62 inches. These rolls contain from 10 yards of the finer and more expensive grades of paper, to 24 and 50 yards for medium grades, and for the cheaper grades the rolls are sold by the gross weight, in quantities of 50, 100 and 150 pounds.

In the case of paper sold in sheets the prices are fixed at so much per sheet, or per quire of 24 sheets. Occasionally the price is given per ream of 480 sheets. If sold in rolls of so many yards, the price is fixed by the yard; if sold by the weight, at so much per pound for whatever the roll may weigh, as the rolls will vary somewhat from the standard weight. Continuous or roll drawing paper is made in almost as great a variety of quality, thickness and tints as that which comes in sheets. Usually, however, such drawing paper is either of pure manila and of the natural color, or of a mixture of manila and other materials, and slightly tinted, the tints running toward buff and terra cotta.

The surface of manila paper is made either very smooth and glossy or with a slight grain. As the smooth finish is made by running it between heated calender rolls it does not usually lie flat upon the drawing board, but has a tendency to buckle or rise up in numerous places. A smooth surface manila paper is, therefore, not nearly as convenient for doing the pencil work of a drawing as that having a slight "grain" or roughness. There is a tendency of the pencil to slide over the surface without making a distinct line, unless the pressure applied to it is considerable, or the pencil is considerably softer than those which the draftsman is in the habit of using. Of course, the point of a soft pencil wears away much faster than a hard one, and, therefore, requires more attention to keep it in proper condition. Another difficulty is that the smooth surface is liable to either stain or become rough under the action of the erasing rubber. It is, however, a very strong paper, and its price is moderate. Manila drawing paper with a rough or "grain" surface is well adapted to either pen or pencil work, and works well under the erasing rubber. The slight tint of the surface is an advantage to the eye-sight of the draftsman. It is generally purchased in rolls.

Eggshell drawing paper is one of the best papers made for drawings. It withstands a good deal of hard usage while being made and much rough usage afterwards. While it is made in sheets of the usual sizes, it is more often obtained in continuous rolls. On account of the high price of this paper, these rolls usually contain only 10 yards each. The surface of this paper, as its name indicates, somewhat resembles the surface of an eggshell, except that the small depressions forming the grain are deeper and quite pronounced. The surface is very hard and takes either pencil or ink readily, and will stand almost any amount of rubbing with the erasing rubber.

Mounted drawing paper is drawing paper strengthened by being mounted on cloth, or having a backing cloth pasted to it. This process is usually confined to the more expensive kinds of white and slightly tinted drawing papers, and generally to those in large sheets or rolls. Such paper is used for maps and plans that are intended to withstand much handling and very hard usage. Mounted drawing paper is only occasionally used for mechanical drawings.

German drawing papers are usually of good quality and are sold at a reasonable price. They have a good hard surface capable of standing hard usage under the rubber, and are made in all the usual sizes.

Weston's linen ledger papers are made in the usual drawing paper sizes and have a fine surface for both pen and pencil work. They are sold at a medium price. White linen ledger paper is very useful for making fine line drawings in ink, particularly of small machine parts, or of assembled groups of parts, or small machines.

For many kinds of mechanical drawings, particularly of the smaller sizes, a white paper is desirable. At the present time many drawings are made in pencil only, and tracings in ink are made from them without "inking in" the original drawing. This is a matter of economy, and a white paper is necessary to obtain good contrast between the pencil and the surface of the paper when tracing. White writing paper, selected for its fine surface, is well adapted to fine pencil and pen work. For many purposes it answers quite as well as linen ledger paper, and is much more economical.

Bristol boards are a high quality of card board, made by pasting several sheets of high grade linen paper together so as to form the thickness required. After pasting, they are subjected to a very heavy pressure, and present a very smooth surface for ink work. The thickness of bristol boards is indicated by the number of sheets pasted together to form the "board." Hence, they are called 2-sheet, 3-sheet, 4-sheet and 5-sheet, the latter being the thickest usually made. The 3-sheet bristol board is specified by the United States Patent Office as the proper material on which to make all patent drawings. For many years the Reynold's bristol boards have been recognized as first class, and they should be used for all fine work.

Thus far all the drawing papers mentioned have been those with absolutely plain, blank surfaces. There is, however, a large class of drawing papers on which preliminary lines in two directions, at right angles to each other, are ruled as a valuable aid to the draftsman in laying out his work. These are known as cross-section papers. Strictly speaking, cross-section paper is that in which the horizontal and vertical ruling is spaced at the same distance apart, there being, for example, eight or ten lines to the inch. When this ruling is so made that the horizontal spaces of the ruling are much less than the vertical, it is properly called profile paper. In this case the vertical ruling is 20, 25 or 30 to the inch. Cross-section paper is used for making sketches, diagrams, etc., and for free-hand work; the ruling is of great assistance in properly proportioning the parts. It is also largely used in the plotting of graphic charts and similar work. It is nearly always white.

Profile paper is used by civil engineers for representing the profile or cross-section of grades, cuts, embankments, excavations and the like. This paper is made in sheets 16 by 20 and 17 by 22 inches, and also in continuous rolls. For the use of railway surveyors, the profile paper is made in continuous strips, folded between covers in book form; these books are called profile books.

The principal feature of ordinary tracing paper (thin, transparent paper), is its cheapness. However, it is very useful for temporary work, or when there is to be very little handling of the tracing. So-called "onionskin" paper is much used for tracings. While not as transparent as ordinary tracing paper, it is much stronger.

Parchment paper may be used as a drawing paper. The entire work of the drawing, both pencil and pen work, may be done on it, and the drawing may then be used the same as an ordinary tracing for producing blue-prints or brown-prints. By the use of this paper only one drawing is made, instead of a drawing and tracing as with the usual methods.

Tracing cloth is largely used for regular tracings that must be handled and used a great deal. It is made of finely woven and very smooth cloth, coated with a preparation of Canada balsam for the purpose of giving it the fine surface for the use of the pen, and also rendering it transparent. One side is very smooth and glossy while the opposite side has a dull finish. This peculiarity is known as "dull back"; the tracing cloth can be purchased with a gloss surface on both sides if desired. It is possible to use it for a preliminary pencil drawing, to be afterwards inked in, by working upon the dull side, although this is not usually practiced except for simple work in which comparatively few lines are needed. Tracing cloth is nearly always sold in continuous rolls, 24 yards long and of 30, 36 and 42 inches wide. That marked "Imperial" is usually considered the best.

Drawing Ink

The principal, and at present almost the only ink used by the mechanical draftsman, is a good quality of black India ink. Occasionally a good, permanent blue ink is used, but since the introduction of the process of blue-printing, nearly all mechanical drawings show only black and red lines, with a strong tendency to omit even the red for center lines. Exhibition drawings may require a variety of tints and colors, but this method is at the present time confined rather to architectural than strictly mechanical drawings. At the present time excellent grades of specially made liquid India ink may be purchased in bottles, so that the former annoyance and loss of time of "rubbing up" the ink is avoided.

General Considerations in Selecting Drawing Paper

In selecting a suitable paper for a certain work there are several requirements which should be kept in mind, and which may be enumerated as follows: Manila paper should be used for large construction drawings; linen ledger paper for fine design work on small parts, etc.; the paper should be of such a tint as to be agreeable to the eyes of the draftsman; it should be possible to readily stretch the paper so that it lies perfectly flat on the drawing board. Where much pencil work is to be done, as in designing, the paper must stand the frequent use of the erasing rubber, and it must take pencil lines readily, even if a pencil as hard as 6H is used. If the drawing is to be finished in ink, the quality of the paper must be such as to take ink readily, without wrinkling where the ink lines are made. The thickness and texture of the paper should be even and uniform over the entire surface. A good drawing paper should be of such a surface as not to absorb liquids too readily, and not to repel them at all. If the surface is repellant, inks or colors are liable to rise up in small blotches on parts of the ink line and leave an insufficient quantity of ink to make a good line at other points. While all these qualities will not be likely to be found in any one paper, a paper should be selected embodying as many of them as possible.

In selecting a proper medium for tracing, the draftsman must be guided by the conditions of the work. These conditions will ordinarily be as follows: For temporary drawings, and when but a few blue-prints are to be made, ordinary tracing paper will be used; if the tracing is to be used for a large number of blue-prints, or for permanent use as a record, it should be made on good tracing cloth. If a drawing as well as a tracing is wanted quickly, or if the drawing is to be of a comparatively temporary nature, parchment paper may be used if considerable pencil work with the usual erasures are expected.

CHAPTER IV

A DRAFTING-ROOM SYSTEM

When we refer to the drafting-room and its routine, we necessarily include not only the work of making drawings, but the general work of the mechanical engineering department as well. The drafting-room is properly regarded as the initial department of the manufacturing plant, since it is here that all manufacturing operations are planned, and the systematic methods of work are laid out, developed and brought into shape for the practical work of the shop. Here all this work of planning is recorded by means of drawings, tracings, blue-prints, shop operation sheets, lists of materials, and other similar records. The success of the manufacturing operations and their economical administration depends not a little upon this department, and the manner in which its part of the work is performed. Hence, it is one of the most important departments of the entire plant.

Drafting-room Requirements

The drafting-room department should always be located on a second, or some higher floor, so as to be away from the dust and noise of the ground-floor, and better situated in regard to light. When possible, its principal windows should be in a northerly direction so as to avoid direct sunlight, and, hence, avoid the use of curtains at the windows as much as possible. The walls may be sheathed up to the height of the drawing tables, and above this the walls, and also the ceiling, should be finished in white, hard plaster, coated with kalsomine or oil paint. Window curtains should be white, or nearly so, and where necessary for shutting out direct sunlight, there should be two curtains at each window, one hung at the top and drawing down, and the other hung at the bottom so as to be drawn up. This is very convenient in protecting a drawing near the window, and at the same time not shutting off the light from the center of the room.

Artificial lighting should be by electricity. Incandescent lamps are suspended from the ceiling and fitted with porcelain reflectors so shaped as to diffuse the light over the drawing table. This is the most economical and satisfactory method. The present requirements of a complete drafting-room include a dark-room fitted up for photographic purposes, and a blue-printing room, the latter frequently situated on the roof so as to secure ample light. Large establishments are usually provided with electric blue-printing machines.

If possible, there should be a fire-proof vault in which original drawings, tracings and valuable records may be safely kept, and to which they are returned each night before closing time. The drafting-room should be so arranged that the work of making drawings, particularly those involving designing, should be separated as much as possible from the clerical work, such as making, keeping and filing records, etc.

A Drafting-room System

If there is any department in the modern manufacturing plant where a well formulated, efficient and smooth working system is necessary, it is in the drafting-room—right at the beginning of the work of manufacturing. This is the initial department, from which new designs and plans originate, and from which they should always have the advantage of a fair start, unencumbered by complex conditions and the defects that such conditions are very liable to produce. Therefore, the various regulations and forms necessary for a simple, but efficient system of handling the work and of keeping the necessary records will be described, step by step, so as to be readily understood and memorized.

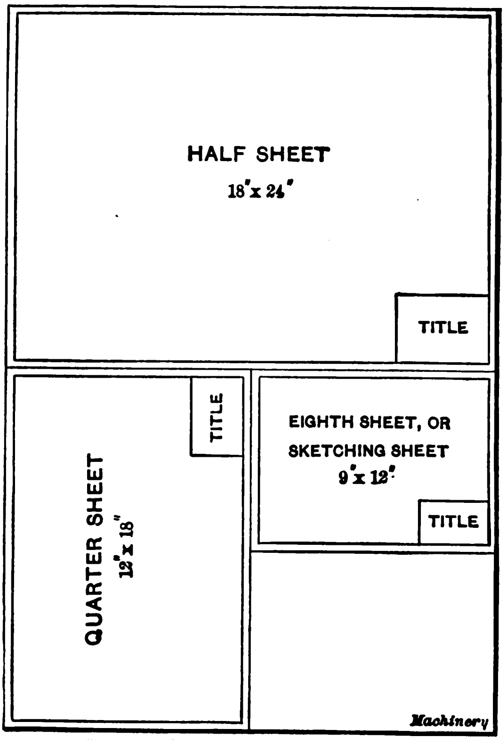


Fig. 21. Sizes of Sheets for Drawings

Sizes of Sheets for Drawings

While the paper required for construction drawings is frequently continuous or roll paper from 36 to 42 inches wide, and of whatever length may be needed, it is quite essential that the working drawings, from which tracings and blue-prints are made for use in the shop, should be of certain regular sizes. The working drawings are thus much more convenient to make, to handle, to properly store, to issue to the manufacturing departments, and to use. A good size for the "standard sheet" is 24 by 36 inches. This is divided into a "half-sheet", 18 by 24 inches; a "quarter-sheet", 12 by 18 inches; and an "eighth-sheet", sometimes called a "sketching sheet", 9 by 12 inches. The method of dividing the sheet, and locating the margin line and the title is shown in Fig. 21.

The dimensions of the standard sheet are determined by two conditions. First, it is a convenient size and of good proportions. Second, drawing paper, tracing cloth and blue-print paper can always be had in rolls 24 and 36 inches wide. Either of these widths will readily cut to this size sheet with no waste.

Margins and Titles

All sheets should have a margin of one-half inch on all four sides. This is indicated by a single ink line of the same width as the ordinary lines on the drawing. All of the work of the drawing must be within this line. The title of the drawing is to be in the extreme lower right-hand corner of the sheet, inside the margin line and surrounded by a similar single line. This line should enclose a space of from

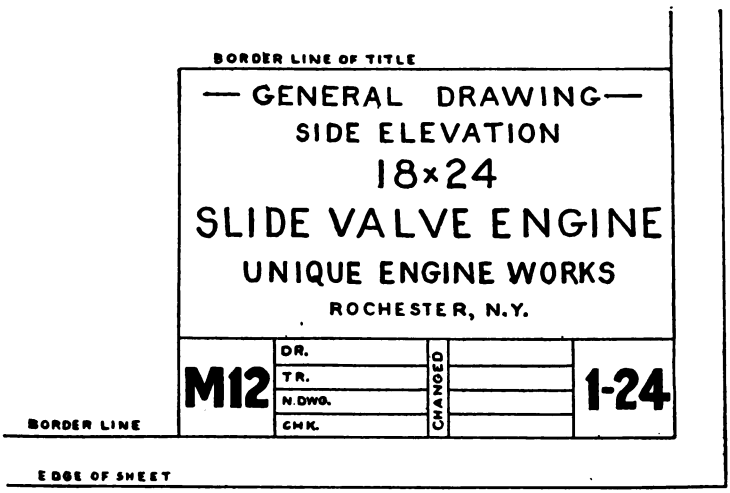


Fig. 22. Sample of Complete Title

two to three inches high and from four to five inches wide. It should contain (see Fig. 22):

1. The statement as to whether it is a "construction", "general", or "detail" drawing.
2. If a general drawing, the name of the particular view, as "side elevation", "plan", etc. If a detail drawing, the name of the part or group of parts represented.
3. Any distinguishing dimensions of the machine of which it represents parts, as "18 × 24", relating to the size of an engine.
4. The name of the machine to which the parts belong.
5. The name and location of the plant in which the drawing is made.
6. The "machine symbol" (at the left), and the "sheet numbers" (at the right).
7. Between the machine symbol on the left, and the sheet numbers at the right, a ruled and divided space for filling in the dates when drawn, traced, checked, changed, etc., and the initials of the draftsmen performing these several portions of the work.

A sample of the complete title is shown in Fig. 22.

The Selection of Drawing Paper, Etc.

The general characteristics of drawing paper have been dealt with in Chapter III of this treatise. Except in cases where a great deal of hard usage, particularly in making and erasing lines, construction drawings, especially when large sheets are required, are made on a good quality of slightly rough, but hard surfaced, manila paper. If much fine work is required, a similar quality of strong, white, or very slightly tinted paper is used, 36 inches wide, and the length of the sheet made in multiples of 24 inches, so that the drawing may be folded to the standard size of 24 by 36 inches. When a wider sheet is required, 48-inch paper is used. In this case the length of the sheet is in multiples of 36 inches, so as to be folded to standard size. For standard sized sheets a good quality of hard surfaced, white paper is desirable, as pencil lines show distinctly on the surface, rendering tracing easy without the extra work of inking in the drawing.

Parchment drawing and tracing paper is useful in many cases, as the pencil work of laying out may be done directly upon this paper, the lines being afterwards inked in and the blue-prints made from it. It is not suitable for the regular permanent tracings on account of its liability to crack, which renders it of no further use. The thinner kinds of tracing paper are suitable only for the most temporary use.

For mailing purposes, blue-print paper may be quite thin, so as to avoid excessive postage. For regular shop work the paper should be thick and strong, and the prints mounted upon strong and thick cardboard, such as is used for covers by book-binders.

Machine Symbols

A simple system of machine symbols is very necessary, not only for use in the drafting room, but also in the pattern shop, foundry and machine shop. The system outlined below is prepared with this in view, and consists in adopting a letter of the alphabet to represent each machine, as for instance, in a line of lathes:

A. 12-inch Engine Lathe,
B. 16-inch Engine Lathe,
C. 20-inch Engine Lathe,

and so on to the end of the alphabet, omitting the letters I and O as they are easily confused with the figures 1 and 0; and also omitting the letter X, as the pattern shop often uses this letter on patterns to indicate the changes made on them.

If there are more machines than we have available letters for, we may double the letters, as AA, BB, etc., placed close together. Different letters may be combined in a similar manner if desired. If a regular machine, as a planer, 36 inches wide and represented by the letter J, is built on a special order calling for a width of 40 inches, the parts necessary for this change would have the letter J-K as the symbol, as K represents a 40-inch planer. The hyphen is introduced to indicate that two machines are involved in the designation.

The various parts may be numbered in groups according to the material of which they are composed. For instance: Cast-iron parts from 1 to 499; malleable-iron parts from 500 to 599; steel castings, from 600 to 699; and so on for brass, bronze, iron and steel forgings, etc. These numbers will be used on detail drawings, lists of parts, shop operation sheets, index cards, patterns, etc., as well as on the parts

LIST OF PARTS Date________

Machine Name________ Size______ No.______ Symbol______

CASTINGS. Material________________

Part No.	Part Name	Number Wanted	Weight, each	Date Ordered	Order Completed

Machinery

Fig. 23. List of Parts, as arranged for Castings

themselves. Thus every machine has its distinctive symbol and every part its individual number, which should not be changed. These symbols and numbers are used in all departments of the plant. On drawings the part number should be written within a small circle so

LIST OF PARTS Date________

Machine Name________ Size______ No.______ Symbol______

BAR STOCK PARTS.

Part No.	Part Name	Length, One Piece	Number Wanted	Material	Form of Section	Total Length

Machinery

Fig. 24. List of Parts made from Bar Stock

as to distinguish it from figures used as dimensions, or for any similar purpose.

Lists of Parts

There should be accurate lists of all component parts of all machines for which drawings are made. The parts should be classified according to the material of which they are made, and the different classes arranged on separate sheets. Fig. 23 shows one of these sheets arranged for castings, the material being written in. The same form, with the word "forgings" instead of "castings," is suitable for all kinds of forgings by specifying the material.

Fig. 24 shows the form used for parts made from bar stock, the columns being specially arranged for this purpose. The sheets for a list of purchased parts, that is, parts which are purchased in a com-

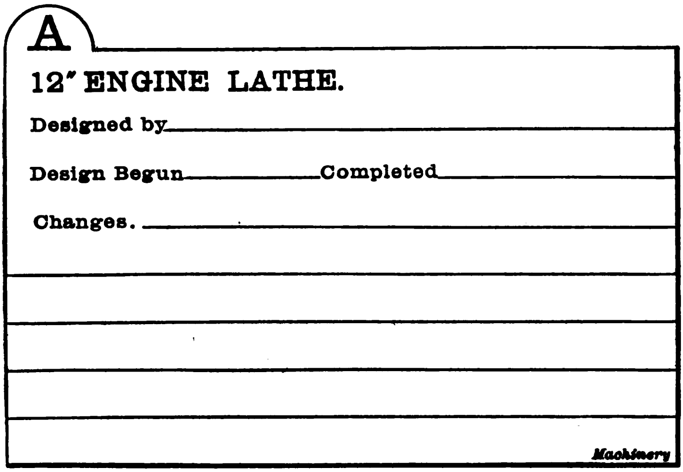


Fig. 25. Index Card for Drawings

plete form, as bolts, nuts, screws and many similar articles, should be arranged in a similar manner. These part lists may be traced and blue-printed, but when the machines are a regular product from year

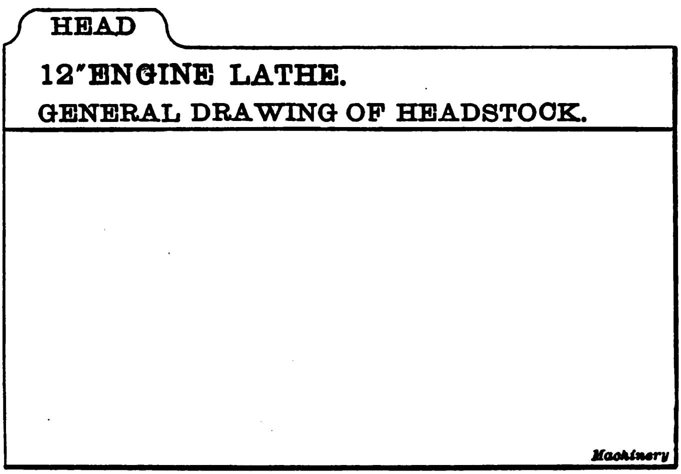


Fig. 26. Index Card for Drawings

to year, they should be printed with type, as there will be many of them required, not only in the drafting-room, but in all other departments. From these part lists, orders for material, lists of material, and all similar records will be compiled.

A card index should be kept of all drawings, tracings, blue-prints, etc., produced and handled by the department. The method of arranging these cards should be as follows:

General guide cards, Fig. 25, made of blue color, bear the machine symbol. Secondary guide cards, Fig. 26, of salmon color, bear the name of the various groups of parts. Ordinary filing cards, Fig. 27, of white color, each bear the name of a drawing, with such explanatory matter as may be necessary. A set of these filing cards should be made for drawings, another set for tracings, and a third set for blue-prints. The set representing blue-prints will, of course, be used much more than either of the others.

In some plants the location of blue-prints, their issue to the shop and their return to the drafting-room, is accounted for by the use of two

GENERAL DRAWING OF HEADSTOCK.
Machine________ Size________ Symbol________

Designed by________ Date________

Changes________

Remarks________

Machinery

Fig. 27. Index Card for Drawings

filing drawers, one labeled "Drafting-room", and the other "Shop", the cards being transferred from the one to the other as may be necessary. A better plan, particularly in a large plant, is to use a transfer card, as shown in Fig. 29, upon which an entry is made of the department number, date of issue, and date of return, by the use of rubber stamps. There must be a card for each blue-print, and when the spaces on it are filled by entries it is laid aside, and a new card put in its place.

Storage and Care of Drawings

A very complete case for storing drawings, rolls of paper, etc., is shown in Fig. 28. The drawers are of different sizes to accommodate standard and half-sheet drawings, as well as a supply of drawing paper and tracing material. Usually each drawer is devoted to the drawings of a single machine, the name and symbol of which appears on a label attached to it. Above the table surface covering the drawers are two cases for holding rolls of paper of different widths and qualities, tracing cloth, etc. Doors hinged at the top exclude dust and afford convenient access to the rolls.

In cutting paper into sheets, the end of the paper is brought down

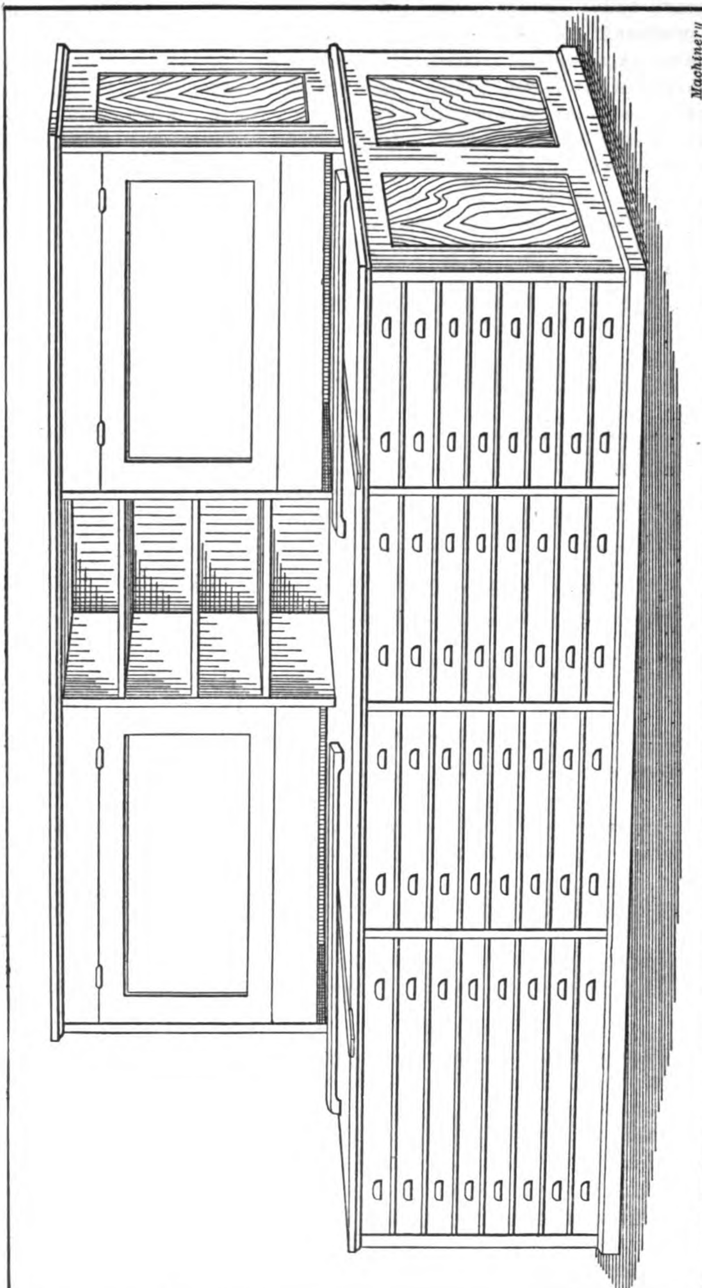


Fig. 28. Filing Cabinet for Drawings

at the back of the case and out under the guide bar shown, and along a sliding scale of inches let into the table top, by which any desired length or width of sheet is measured. The sheet may then be cut off with a knife guided by the guide bar. Similar cases of drawers should be provided for holding blue-prints previous to mounting, except that the case should be much higher, as no roll paper storage space is needed. Mounted blue-prints can best be stored by placing them on edge, on shelves, having vertical divisions for the different lots, or those belonging to different machines.

Orders for the Drafting-room

In the regular routine of the plant, orders for work in the drafting-room will be determined by the copy of the general manager's order

12" ENGINE LATHE. GENERAL DRAWING OF HEADSTOCK.					
DEPT.	ISSUED	RETURNED	DEPT.	ISSUED	RETURNED
					Machinery

Fig. 29. Index Card for Drawings

to the head of the manufacturing departments, a copy of which is first sent to the chief draftsman or mechanical engineer, as the case may be. With this authority, the head of the drafting-room has drawings, tracings and blue-prints made, or issues from his files such blue-prints, lists of material, etc., as he already may have applying to the work. In some establishments the general manager's order goes direct to the factory manager, or superintendent, and from his office a department order is sent to the mechanical engineer, or chief draftsman, for such drawings to be made or issued as may be needed. In any event there should be a complete file of all general orders kept in the drafting-room, to enable the official in charge of it to keep in close touch with all work going on in the plant. Requisitions for supplies, and many similar matters, should be handled in the drafting-room in the same manner as in any of the other departments of the plant, and in accordance with the general system for such work.

While there are many individual conditions in the drafting-rooms of different plants which require changes or additions to the system herein outlined, this general plan will be found both simple and efficient for all necessary purposes, as all of its provisions have been carefully tried out under practical manufacturing conditions. Additional information relating to drafting-room systems and drafting-room work may be obtained by studying MACHINERY'S Reference Series No. 2, "Drafting-room Practice"; No. 8, "Working Drawings and Drafting-room Kinks"; and No. 33, "Systems and Practice of the Drafting-room."

OUTLINE OF A COURSE IN SHOP AND DRAFTING-ROOM MATHEMATICS, MECHANICS, MACHINE DESIGN AND SHOP PRACTICE

Any intelligent man engaged in mechanical work can acquire a well-rounded mechanical education by using as a guide in his studies the outline of the course in mechanical subjects given below. The course is laid out so as to make it possible for a man of little or no education to go ahead, beginning wherever he finds that his needs begin. The course is made up of units so that it may be followed either from beginning to end; or the reader may choose any specific subject which may be of especial importance to him.

Preliminary Course in Arithmetic

JIG SHEETS 1A TO 5A:—Whole Numbers: Addition, Subtraction, Multiplication, Division, and Factoring.

JIG SHEETS 6A TO 15A:—Common Fractions and Decimal Fractions.

Shop Calculations

Reference Series No. 18. SHOP ARITHMETIC FOR THE MACHINIST.

Reference Series No. 52. ADVANCED SHOP ARITHMETIC FOR THE MACHINIST.

Reference Series No. 53. USE OF LOGARITHMIC TABLES.

Reference Series Nos. 54 and 55. SOLUTION OF TRIANGLES.

Data Sheet Series No. 16. MATHEMATICAL TABLES. A book for general reference.

Drafting-room Practice

Reference Series No. 2. DRAFTING-ROOM PRACTICE.

Reference Series No. 8. WORKING DRAWINGS AND DRAFTING-ROOM KINKS.

Reference Series No. 33. SYSTEMS AND PRACTICE OF THE DRAFTING-ROOM.

General Shop Practice

Reference Series No. 10. EXAMPLES OF MACHINE SHOP PRACTICE.

Reference Series No. 7. LATHE AND PLANER TOOLS.

Reference Series No. 25. DEEP HOLE DRILLING.

Reference Series No. 38. GRINDING AND GRINDING MACHINES.

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Data Sheet Series No. 1. SCREW THREADS. Tables relating to all the standard systems.

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Data Sheet Series Nos. 10 and 11. MACHINE TOOL OPERATION. Tables relating to the operation of lathes, screw machines, milling machines, etc.

Reference Series Nos. 50 and 51. PRINCIPLES AND PRACTICE OF ASSEMBLING MACHINE TOOLS.

Reference Series No. 57. METAL SPINNING.

Jigs and Fixtures

Reference Series Nos. 41, 42 and 43. JIGS AND FIXTURES.

Reference Series No. 3. DRILL JIGS.

Reference Series No. 4. MILLING FIXTURES.

Punch and Die Work

Reference Series No. 6. PUNCH AND DIE WORK.

Reference Series No. 13. BLANKING DIES.

Reference Series No. 26. MODERN PUNCH AND DIE CONSTRUCTION.

Tool Making

Reference Series No 64. GAGE MAKING AND LAPPING.

Reference Series No. 21. MEASURING TOOLS.

Reference Series No. 31. SCREW THREAD TOOLS AND GAGES.

Data Sheet Series No. 3. TAPS AND THREADING DIES.

Data Sheet Series No. 4. REAMERS, SOCKETS, DRILLS, AND MILLING CUTTERS.

Hardening and Tempering

Reference Series No. 46. HARDENING AND TEMPERING.

Reference Series No. 63. HEAT TREATMENT OF STEEL.

Blacksmith Shop Practice and Drop Forging

Reference Series No. 44. MACHINE BLACKSMITHING.

Reference Series No. 61. BLACKSMITH SHOP PRACTICE.

Reference Series No. 45. DROP FORGING.

Automobile Construction

Reference Series No. 59. MACHINES, TOOLS AND METHODS OF AUTOMOBILE MANUFACTURE.

Reference Series No. 60. CONSTRUCTION AND MANUFACTURE OF AUTOMOBILES.

Theoretical Mechanics

Reference Series No. 5. FIRST PRINCIPLES OF THEORETICAL MECHANICS.

Reference Series No. 19. USE OF FORMULAS IN MECHANICS.

Gearing

Reference Series No. 15. SPUR GEARING.

Reference Series No. 37. BEVEL GEARING.

Reference Series No. 1. WORM GEARING.

Reference Series No. 20. SPIRAL GEARING.

Data Sheet Series No. 5. SPUR GEARING. General reference book containing tables and formulas.

Data Sheet Series No. 6. BEVEL, SPIRAL AND WORM GEARING. General reference book containing tables and formulas.

General Machine Design

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Reference Series No. 56. BALL BEARINGS.

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Reference Series No. 49. GIRDERS FOR ELECTRIC OVERHEAD CRANES.

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Data Sheet Series No. 13. BOILERS AND CHIMNEYS.

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