A PRACTICAL COURSE IN MECHANICAL DRAWING

FOX & THOMAS

D. VAN NOSTRAND COMPANY.

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IN

MECHANICAL DRAWING

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PREFACE.

The object of this work is to provide a simple, practical course of progressive lessons in Mechanical Drawing. It will be noticed that all instructions are given in connection with a special, concrete exercise, instead of being presented in an abstract and general manner; furthermore, the didactic principle of " one thing at a time " has been followed as much as possible.

No practical draughtsman will criticise us for not starting with the traditional geometric problems that, from time immemorial, have adorned the introductory pages of " Manuals of Mechanical Drawing." We have reason to believe that the average student does not appreciate the beauty and use of Euclid's Geometry and Monge's Descriptive Geometry, if these subjects are introduced *before* their bearing and practical application are understood. We reserve the introduction of such scientific work for a second part, hoping thereby to arouse an interest in advanced problems that necessitate strictly mathematical constructions.

The subject is best taught with the use of models, instead of sketches and pictorial illustrations. A glance through the book will convince the teacher that a set of models corresponding to the exercises can be easily procured. The result of the instruction will then be real instead of imaginary, since the student knows absolutely what his drawings represent, and need not rely on an untrained imagination.

This course is peculiarly adapted to the needs of High-schools, Schools for Apprentices, and young Mechanics. The exercises are elementary and progressive in character. There is no striving after effect; all thinking teachers deplore the tendency towards "exhibition-work" of any kind; the danger in the case of mechanical drawing is the greatest of all. The student is taught to copy a magnificently tinted, complicated drawing in a faithful, photographic style; and, lo, the populace stand open-mouthed before a work of "art" of absolutely no educational value. Ask the skillful draughtsman of a marine-triple-expansion-steam-engine to make a working sketch of the piston rod and see what he invents!

The figures in this book are intended to show what an average draughtsman should be able to accomplish. No unusual skill or finish is claimed for these illustrations; their very imperfections are such as to encourage the student, since he feels that he can certainly do at least as well as the designer. We trust that after he has faithfully worked through the series of exercises prescribed, the pupil will find that he can make sketches from any actual piece of machinery, and also that he will be able to "read" and understand an ordinary mechanical drawing.

We take this opportunity to express our thanks for cuts furnished by Lexington Gear Works, Schwencke, Kirk & Co., F. W. Devoe, C. T. Raynolds Co. and Keuffel & Esser.

College of the City of New York, W. F.
November, 1898. C. W. T.

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INTRODUCTION.

A *working drawing* must give all the necessary information to the workman, if it is to be of any practical use in the shop. The form of the object to be constructed, as well as the dimensions, must be shown in an unmistakable manner. Sometimes rigid laws, and in other cases conventional rules, must be obeyed in order that the resulting drawing can be easily "read" or understood.

It is evident that in deciding as to the different methods to be employed certain conditions are imposed; the method which fulfills the greatest number of these conditions and in the best manner, would naturally be the one adopted. A few of these are the following: parallel lines are to be shown parallel; dimensions of lines in the drawing should correspond in some definite ratio to the real dimensions in space; angles between lines should be represented true to nature; the details of construction and the interior also must be distinctly shown.

An ordinary perspective drawing is not available for this work, since it shows the object as it appears to the eye with all the distortions of form and changed relative dimensions. We find, however, that, as the point of view is moved further and further away from the object, these distortions are gradually decreased. Thus, if far enough away, the eye would perceive the right angles of the front face of a cube, for example, as right angles, and the front face itself as a square, and the other edges as parallel lines.

Let us now imagine a clear pane of glass to be placed in front of the cube, and let us trace the outline and edges of the cube on that pane as they *would* appear to an eye very far away. Rays of light from every point of the cube to the distant eye are practically parallel to each other, and the points where they pierce the pane of glass, form the image or tracing of the cube beyond. Fig. 1 shows the cube as viewed at an angle by an eye placed far away, *above* the level of the cube and to the *right*. If we now suppose the eye to move down and to the front of the object, the rays of vision will become perpendicular to the pane of glass, and the top and the side of the cube will shrink in size until, when at last the eye is in front, they disappear altogether and Fig. 2 is the result.

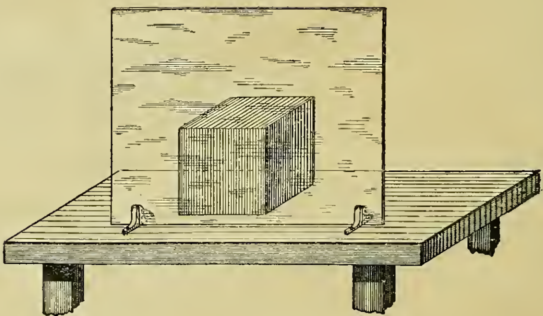

FIG. 1.

Fig. 1 is a so-called parallel perspective of the cube. The top and side are evidently distorted, while the edges, though parallel to each other, may or may not be equal in length to the lines bounding the front face, depending on the obliquity of the view. This method of drawing is useful in bringing out the solidity of an object, and in giving [illegible] idea concerning the relative dimensions of some of the lines. The inforı .ion imparted is, however, not absolute. Thus, in the case of Fig. 1, the block represented may be a solid in which the sides, top and bottom are *inclined* to the front face, and are not at right angles to it, as in the cube. We shall employ this method of representation (parallel perspective) as an auxiliary to ~nable the student to imagine the solids to be drawn.

Fig. 2 gives the manner usually employed. We may imagine the eye sighting along each perpendicular edge

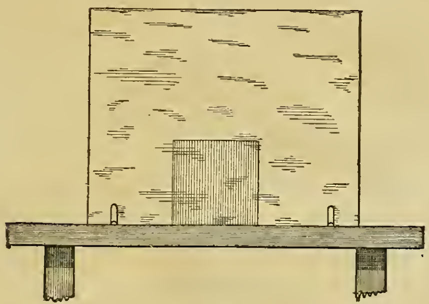

FIG. 2.

and tracing the lines on the transparent pane as the eye moves, keeping always directly in front of the edges drawn. The result will then be the same as if the view were taken from a very distant point. This drawing alone (Fig. 2) is, however, not sufficient: it gives only two dimensions of the solid. To obtain the third dimension, another direct view of the cube is traced on a transparent plane placed perpendicularly to the pane in front of the object. This second view may be either from the top, nom below, from the right or from the left, and is taken sighting in a manner like the one described above. In a working drawing these views are th... d on the same sheet of paper in proper corresponding positions. Usually two of the views taken suffice to show the form and proportions: in complicated pieces of machinery, however, three and even more views are necessary to give the information required. The planes on which the tracing is supposed to be done are placed at right angles to each other, and the tracings are then properly arranged on the same sheet of paper.

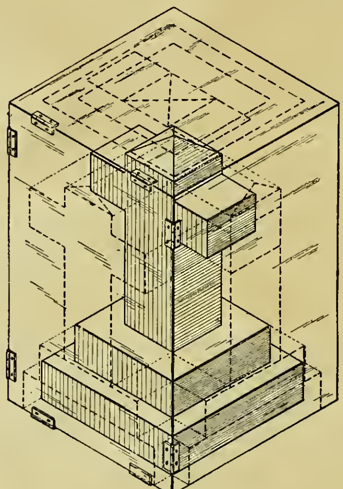

FIG. 3.

Fig. 3 shows a glass box in which the solid is supposed to be placed; the views are shown traced on the panes, the lines of sight being in every case at right angles to the pane taken. The view on the front plate is called the front-view or elevation, and shows the front of the object in its natural upright position; the top plane giv th top-view or plan; the right and the left sides show respectively the right and left side-views or end-elevations; the bottom carries the bottom-view or view from the bottom upward.

Fig. 4 illustrates the proper grouping of the drawings. The hinges marked in Fig. 3 indicate the manner in

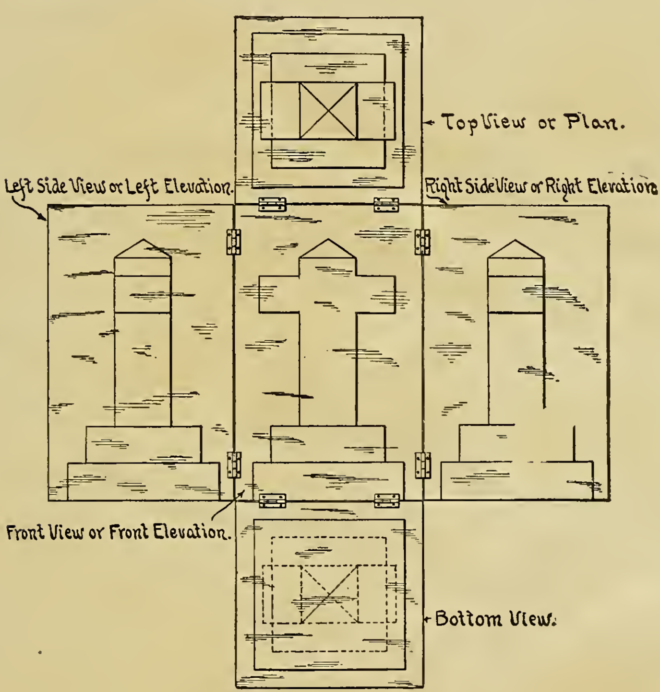

FIG. 4.

which the various plates are swung forward into the plane in front of the object. The front view is placed in the center, and each of the other views is placed to that side of the elevation *from* which it is taken.

USE OF T-SQUARE, TRIANGLES AND RULING-PEN.

EXERCISE 1.

Draw the front-view, top-view and right-side-view of the object shown in Figs. 3 and 4, making the lines about four times as long as in Fig. 4. It need hardly be said that the box, the panes, and the hinges are not to be drawn.

Special Instructions: The student is advised to procure a drawing-board, 12″ x 17″, an 18″ T-square, two triangles, 45°, and 60° and 30°, and thumbtacks. Special drawing paper is to be used for this work, and a hard pencil, No. 5 or No. 6 or grade VH, is needed for the purpose of producing a faint sketch that can easily be erased after the drawing has been inked in. The exercises in this book are designed so as to go on paper 10″ x 14″, leaving a margin of at least ½″ on three sides, and a special margin of 1″ on the left side for the purpose of binding the set.

Figs. 5 and 6 illustrate the position of the T-square for drawing horizontal lines; perpendiculars to these horizontals are made by means of the triangles as shown. Parallel horizontal lines are constructed by simply shifting the T-square, the head of the same being in contact with the left-hand edge of the board. In a similar manner, perpendiculars are passed through points by si. sliding the triangle along the T-square until it is in proper position, as shown in Figs. 7 and 8.

An ordinary u. may be used for the present in measuring off distances, as required.

The spacing of the views is chiefly a matter of artistic judgment. All that can be said in regard to this matter is that the views must not be too far apart, because they

FIG. 5.

then appear to be independent of one another, and it , difficult to trace corresponding parts. Further- .oo small a space must also be avoided, because . the views are merged together and do not appear separate and distinct. It is also evident that large drawings will require larger spaces than small ones. From ½″ to 1″ is the amount that may be allowed in making the exercises described in this book.

It is often desirable to show edges that are not directly visible. This is done by means of so-called dotted lines, which are really formed of short dashes.

FIG. 6.

These indicate that a certain edge or line would appear in that position if the object were transparent enough. The bottom view in Fig. 4 illustrates this conventional method of representing hidden edges.

After the drawing has been sketched in pencil, it is to be "inked in." The drawing-pen, and the proper manner of holding it, are shown in Figs. 5 to 8. The India ink used is somewhat different from the ordinary writing fluids; it can be obtained prepared and ready for use, or may be rubbed up from a stick of Chinese ink. A quill, or an ordinary writing-pen, is employed to transfer the

FIG. 7.

ink to the space between the blades of the drawing-pen. The outside of these blades must be kept clean and free from ink to prevent blotting. The desired thickness of the line is obtained by tightening the little thumb-screw, bringing the points of the blades the required distance apart. Try your pen on a separate slip of paper, before applying it to the drawing. Like any other tools, drawing instruments must be kept clean, and should be wiped off before the ink has a chance to dry. As regards the quality of the instruments, they should be the best that the student is able to procure.

Erase all pencil lines with a soft rubber, that does not mar the ink-lines.

Fig. 8.

EXERCISE 2.

Draw the plan and the elevation of the following objects:

a. A square prism, 2″ x 2″ x 3″;

b. A square pyramid, 2″ x 2″ x 3″ high;

c. A wedge (triangular prism), rectangular base 1½″ x 3″; height, 2½″.

Special Instructions: The elevation represents the object in its natural position. Thus, the prism should be placed in an upright position, the front face (2″ x 3″) appearing as a rectangle in full size; similarly the plan will show a square whose side is 2″. The pyramid, in a like manner, is best placed on the square base: the [illegible] then be a square with the diagonals to represent the slanting edges. It will be noticed that these edges are foreshortened in both views, and therefore their actual length cannot be determined directly from the drawing; if the altitude or height of the pyramid and half the diagonal in the square plan are laid off perpendicularly to each other, then the line (hypothenuse) completing the right-angled triangle will give the length of the slanting edges.

From the dimensions given, the elevation and the plan of the wedge can be readily found. The former will be a rectangle, 3″ x 2½″, but does not show the true size of the slanting front face; the wedge-line appears as a line drawn across the rectangular plan (3″ x 1½″), which gives the true size of the base only. If desired, the dimensions of the slanting lines can be found by a construction similar to the one described in connection with the pyramid. Instead of the rectangular elevation, a view from the triangular end may be substituted; the result will then be a drawing showing more clearly the form of the wedge.

DIMENSION-LINES.

EXERCISE 3.

Draw three views (front-view, side-view, and plan) each of Fig. 9 and Fig. 10.* Mark the dimensions on the drawing!

SPECIAL INSTRUCTIONS: Auxiliary lines are used to show dimensions. These are thin, long-dashed lines

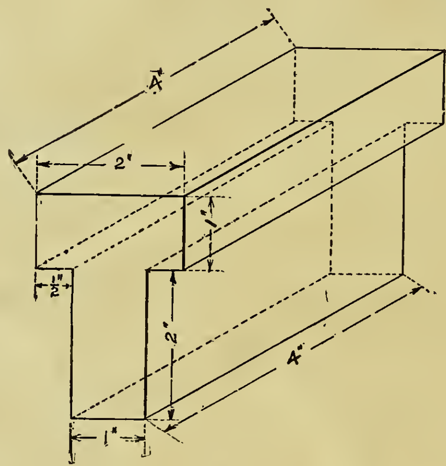

FIG. 9.

drawn near and parallel to the distances the size of which is to be given. The ends of the dimension lines are shown to correspond to the proper points by short cross lines;

*NOTE: Fig. 10 is a so-called Isometric drawing.

they are also marked with arrowheads, drawn free-hand with an ordinary writing-pen. In a space left open near the middle of the dimension-line the figure indicating the length is marked. These figures are best placed so as to read along the dimension lines, and from the bottom or from the right-hand side, for horizontals and verticals respectively. The inch (marked ″) is usually taken as the unit.*

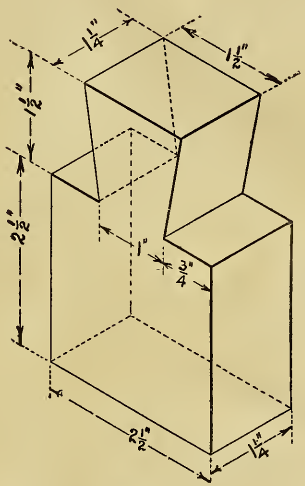

FIG. 10.

The sketches shown in Figs. 9 and 10 are intended to take the place of models; they indicate the solid form of the object to be drawn.

The dimensions should be marked on every working drawing; hence the student is expected to "figure" every exercise following.

*Several forms of these figures are given in Fig. 50.

DRAWING TO SCALE.

EXERCISE 4.

Draw the three views required for the bench shown in Fig. 11. Scale: ¼" = 1".

SPECIAL INSTRUCTIONS: Since it is rarely practicable to make the dimensions of a drawing the same as those of the object itself, the method of drawing to scale has been

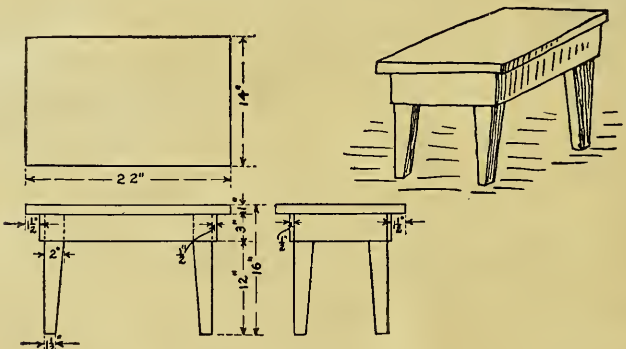

FIG 11.

invented. The relative proportions of the parts are correctly shown, while the actual dimensions are obtained by using a reduced unit. Thus, in this drawing each ¼" stands for 1" on the object; and if we construct a rule on which the quarter-inches are marked in the order of numbers as the inches on the inch-rule, it can be used directly to lay off required distances on our drawing. The student is advised to buy a special scale-rule, at least 12″ long, and divided to several different scales on various sides. A good scale is the triangular scale, shown Fig. 12, giving different divisions on the six sides and in the grooves. These correspond to 3/32″, 1/8″, 3/16″, 1/4″, 3/8″, 1/2″, 3/4″, 1″, 1 1/2″, 3″, 12″, to the foot, yielding reductions as follows: 1/128, 1/96, 1/64, 1/48, 1/32, 1/24, 1/16, 1/12, 1/8, 1/4, and 1.

The 1/2″ to the foot can be used as a 1/2″ scale, the inch being then subdivided into twelfths instead of eighths and sixteenths as usual.

FIG. 12.

The scale may also be given simply as an abstract fraction, or again as a certain number of inches or fractions of an inch to the foot. Thus, the scale 1/4″ = 1″ may be called scale 1/4, or scale 3″ = 1′. In every case the scale of the drawing should be marked on it. If for some reason or other an unusual scale is taken, a few dimensions should be marked off on a separate line, as exemplified in maps.

The student's attention is called to the special manner of figuring small dimensions: the arrow-heads may be turned the other way, as for the dimension 1 1/2″; or else the figure may be placed outside altogether, as for 1/2″. (See Fig. 11.)

The form of the bench is shown in the free-hand perspective sketch.

EXERCISE 5.

Construct a complete working drawing from the free-hand perspective sketch of the box shown in Fig. 13. Scale 1″ = 1′ (1 ft.).

SPECIAL INSTRUCTIONS: A rough sketch is very often given to a draughtsman, from which he is required to construct a complete and accurate drawing. In order to accustom the student to such work, he should be required to develop and copy drawings without paying

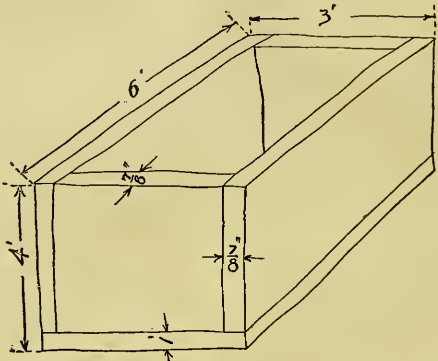

FIG. 13.

the slightest attention to faulty outline, wrong proportions, or other mistakes in the original before him. He should also practice sketching free-hand and marking dimensions in a clear and unmistakable manner; for that purpose actual models or pieces of machinery are necessary, from which the draughtsman first makes a rough dimensioned sketch, and then works out the finished drawing.

The student must decide for himself what views are necessary for the *complete* drawing.

CENTER LINES.

EXERCISE 6.*

Front-view and bottom-view of a pin, shown in Figs. 14 and 15. Full size.

SPECIAL INSTRUCTIONS: The center of the circle is to be marked by the intersection of two lines, called center-lines. One of these is drawn *through* the two

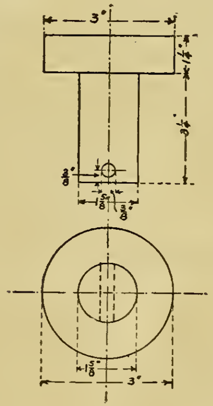

FIG. 14.

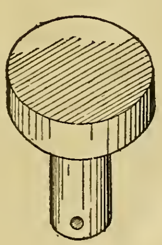

FIG. 15.

views, and shows that they belong together; the other is at right angles to the former and marks the center of the circle. In order to distinguish them from the other lines of

* NOTE: Exercises 6 and 7 are designed to be drawn on the same sheet.

the drawing, they are composed of alternate long and short dashes, and are usually extended indefinitely *beyond* the outlines of the views, and in no case terminate on the outline or at any particular points. The center-line is

FIG. 16.

drawn in every case as an axis of symmetry, and dimensions are laid off from it in both directions. These distances are best marked on the front-view, because there the diameters appear as straight lines.

The small circle shown in the elevation is one view of a hole drilled through the shank of the pin. The center of this hole must also be marked by the intersection of two perpendicular center-lines. The distance of the center

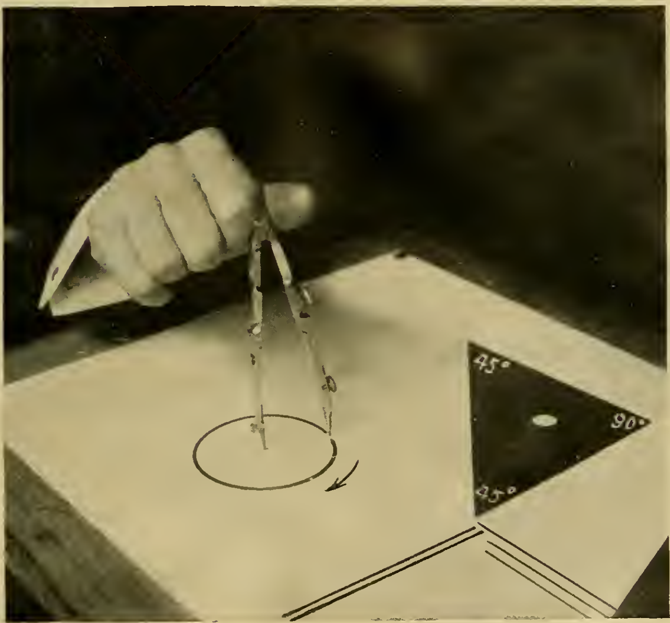

FIG. 17.

from the end of the pin should likewise be noted on the drawing.

The "compass" and the proper position for it are illustrated in Fig. 16. The pen-point should be nearly perpendicular to the paper; the starting position should be such that the entire circle can be swept with one continuous stroke by moving the thumb forward and around without shifting the hold on the compass. (Fig. 17.) A circle that has been drawn in several instalments is never as smooth and perfect as one finished with one sweep.

The student has probably learned from experience that drawing-pens do not require any pressure to cause the ink to flow from the instrument to the paper.

USE OF DIVIDERS.

EXERCISE 7.

Three views of ink-pot shown Fig. 18. Full Size. Mark dimensions!

SPECIAL INSTRUCTIONS: The center-line being drawn and the center marked in the plan, draw the circle in

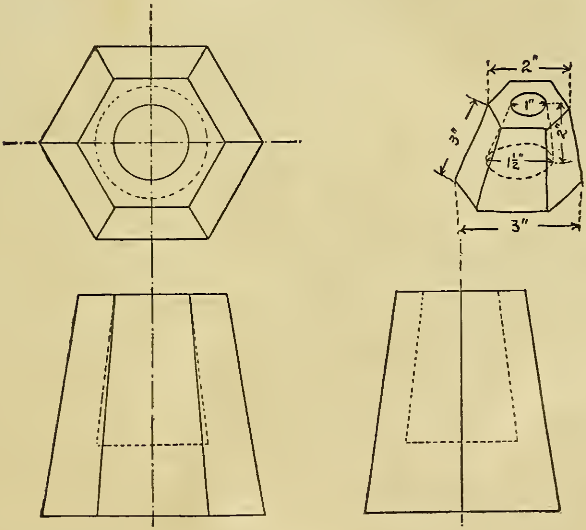

FIG. 18.

which the regular hexagon is to be inscribed. A pair of "dividers" is the instrument best adapted for "stepping off" equal distances. The side of the hexagon is theoretically equal to the radius of the circle ; but if we apply that principle in the present case we may discover an error

Fig. 19.

owing to spring of the dividers, or to inequalities in the board or on the paper. Figs. 19, 20, and 21, show the motion of the points of the dividers in stepping off equal distances along a straight or a curved line. If the distance is too small, we must separate the legs of the dividers by a distance equal to one-sixth of the remainder left over, after stepping six times. If, on the contrary, the side of

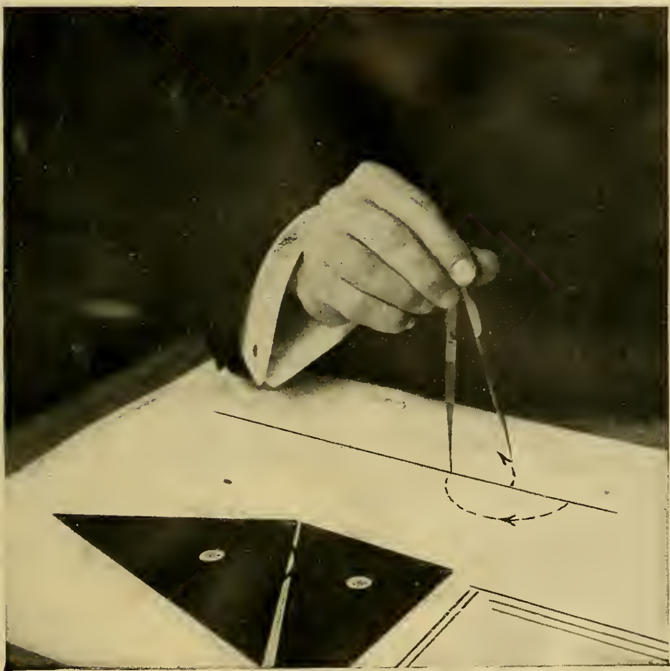

FIG. 20.

the hexagon is too great, it must be decreased by one-sixth of the surplus or distance overstepped. Three successive trials should, in any case, be sufficient to divide the circle into six or any other number of parts. A similar use of the dividers enables the draughtsman to divide a straight or a curved distance into any number of equal parts.

Two views would have been sufficient in this case: the plan and that view which shows three faces, and not

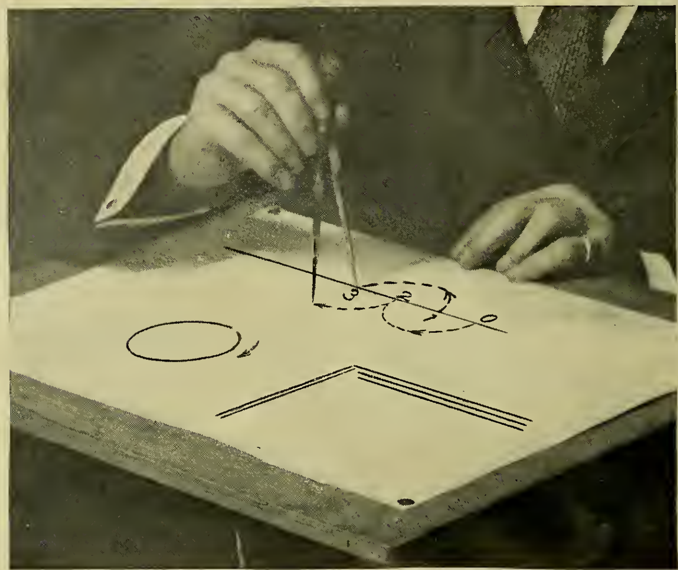

FIG. 21.

the one showing only two. The extreme lines of the elevation then represent edges, and not faces; and the middle face, at least, is drawn in true width, while both faces in the other view appear fore-shortened.

The free-hand view gives the necessary dimensions.

USE OF BOWPEN.

EXERCISE 8.

Two views of the angle-patch,* 12″ long, indicated in the rough sketch, Fig. 22. Scale: ½″=1″.

Exercises 8 and 9 may be drawn on the same plate.

SPECIAL INSTRUCTIONS: The center of every one of the rivet holes should be marked distinctly by the intersection of short lines, perpendicular to each other, and drawn in the main directions, viz.: horizontal and vertical.

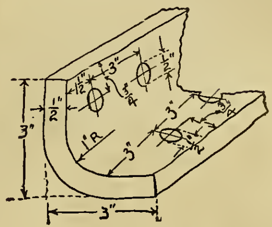

FIG. 22.

A smaller compass, called bowpen, may be necessary for inking in small circles. (Fig. 23.) This instrument is certainly more convenient and more accurate for this work than an ordinary compass.

The angle is formed by two straight lines tangent to a quadrant of a circle at its ends. It will be found best to

* Only part of the patch is shown; the rest is supposed to be continued in the same manner.

ink the curve first, and *then* the straight lines, because better tangency will be attained. This rule should be applied in every case where straight lines and curves are to be drawn tangent to each other.

The two views taken in this case can hardly be called elevation and plan, or front- and top-view. It is better to place them next to each other, as a front- and a side-elevation, the latter being viewed from the open or concave face of the angle. A third view may be considered necessary to show the position, the form, and the spacing of the holes in the other flange of the angle ; yet with the

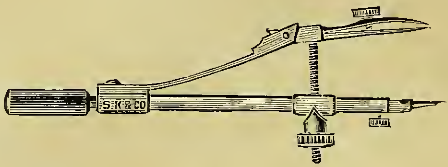

FIG. 23.

center-lines and the distances marked, these holes can be accurately located in the two views taken.

The radius of the quadrant can be indicated in a way similar to that shown in the sketch (Fig. 22): an arrow, starting from the center and ending on the circumference, carries the inscription 1″R.

EXERCISE 9.

Two views of the face-wheel. Fig. 24, full size.

SPECIAL INSTRUCTIONS : It will be noticed that the small circles, representing in plan the projections from the face of the plate, are arranged around the center of the disk. Instead of a straight center-line, a center-circle is drawn, marking the positions of these smaller circles ; the short lines intersecting the center-circle mark the centers, and are drawn pointing to the center of the

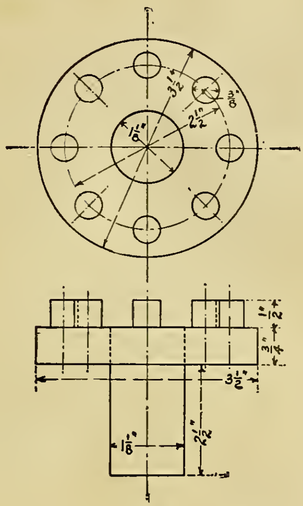

Fig. 24.

plate. The diameter of this center-circle is shown on an *inclined* line passing through the center, and finished off with arrow-heads at the circumference of the circle ; the figure is marked *beyond* the center.

SECTIONS.

EXERCISE 10.

a. Two views of a cylindrical pipe; scale, **1″=1″**.
b. Three views of a box and cover; scale, 1″=1″.

Special Instructions: Fig. 25 gives the two views of the pipe. On consideration, however, it is observed that the information imparted by these views is

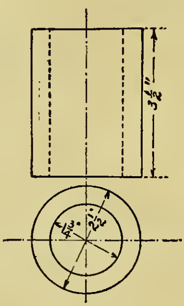

Fig. 25.

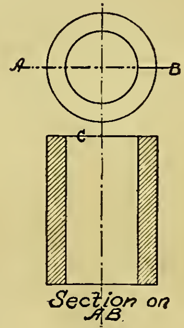

Fig. 26.

not definite. We cannot tell from the drawing whether the inner circle and the dotted lines correspond to a *plug* filling the hollow, or merely to the *hollow* itself. In the former case, we might mark that fact by lettering the word, "plug," but in the latter case a more direct, conventional way is employed.

If we were to saw the pipe in half, as indicated in Fig. 27, we notice that we are cutting the material in the walls of the pipe only; if there were a plug, we should be cutting it also. If we now show the circular view with the saw in place, we get the plan represented in Fig. 26. The center-line made up of dashes alternating with two dots (or rather two shorter dashes) is called the plane of section and shows the manner in which the saw is supposed to cut. We now suppose that the front half is removed and the interior will be displayed as well as the surfaces made by the cutting plane. The dotted lines in Fig. 25 are replaced by lines in full, Fig. 26, and the plane sur-

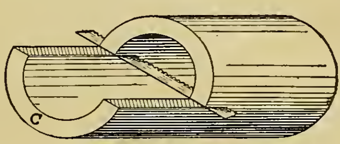

FIG. 27.

faces are "sectioned," that is, covered with parallel lines. The lettering "AB" and "Section on AB," is customary though not absolutely necessary.

The section-lines are best drawn by sliding the 45° triangle along the T-square, giving an inclination of 45° with the center-lines. The thickness of the section-lines should be somewhat less than that of the outline, while the distance apart should not be less than about 1/32″. The student is cautioned against careless sectioning, and should rather stop short of the outline, than cross it in a ragged manner.

The cylindrical box (b) to be drawn is shown only in "longitudinal section"* in Fig. 28. The other views required are an outside elevation and the plan. The line C, Fig. 28, represents the upper edge of the hollow in the back-ground. The lines marked C in Figs. 26 and 27 show a similar construction.

Notice that the sectioning in the box proper is in a different direction from that in the cover. This is done in order to show that these two pieces are separate.

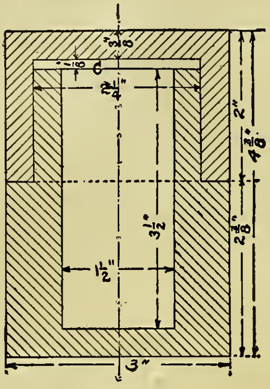

FIG. 28.

EXERCISE 11.

Fig. 29 represents a parallel perspective view of one-half of a "stuffing-box and gland." The student is to draw a sectional elevation and a plan. Scale: 3″ = 1 ft.

SPECIAL INSTRUCTIONS: As indicated in the perspective figure by the change of direction of the section-lines, the object contains four separate pieces. In the sectional view, therefore, a similar method must be employed to distinguish the various pieces from each other.

* The distinction between longitudinal section and cross section is apparent.

No two draughtsmen would probably agree as to the direction and spacing of the section-lines. We advise the student to choose the 45° inclination, whenever possible, and also to keep the same spacing between the lines. Thus in the figure shown, even contiguous pieces are sectioned in a similar manner, and the difference between the parts is shown by breaking the sectioning at the dividing lines,

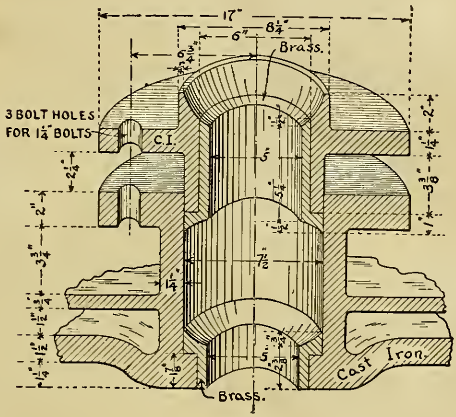

Fig 29

taking care that the section lines are not continuous across the two pieces. In exceptional cases, 30° or 60° inclination may be chosen.

The fact that the small pieces are to be made of brass, while the rest of the device is to be cast iron, may be indicated, as in the figure, by means of proper inscriptions. The word "brass" is placed outside of the piece, because the space is too small for a neat inscription; the name "cast iron" on the other hand, is printed right on the parts as shown, in a space left in the sectioning.

Some draughtsmen advocate special forms of sectioning for different materials, such as, for example, is used by Unwin in his book on Machine Design, illustrated on p. 16 of that work: alternate thick and thin lines for wrought iron, alternate full and dashed lines for brass, dashed lines for steel, etc. No uniform and standard method has yet been definitely adopted; if, therefore, any one desires to use this plan, sample squares, illustrating the different shading, should be marked on the drawing, with the names of the materials represented. (See Standard Sections, Fig. 89.)

EXERCISE 12.

a. **Cross-section and elevation of Phenix column, Fig. 30; Scale: 1½" = 1'.**

b. **Sectional front-view, and plan of the two brasses, Fig. 31. (Fig. 32 illustrates the perspective.) Scale: ½.**

Special Instructions: The Phenix column is built up of a number of flanged strips, fastened together by bolts or rivets. For the sake of simplicity, these fastenings are merely suggested in the drawing, as well as the holes through which they pass. The cross-section alone suffices in this case, if properly marked. The vertical view should be drawn by the student, because it presents the problem of correctly placing the vertical lines.

Large surfaces need not be covered entirely with section-lines, while small ones may be filled in in black. This is illustrated in the drawings of the bushings, where the narrow black spaces represent sections of the white metal used. Water colors, instead of section-lines, are sometimes used to cover a cut surface with a tint, definite colors being employed to distinguish the materials. This method is, of course, not applicable if the drawings are to be reproduced photographically, as, for instance, in blue-printing.

Attention is called to the line CD in the elevation; being made up of alternate one long dash and two short dashes, it indicates a plane of section. The view next to

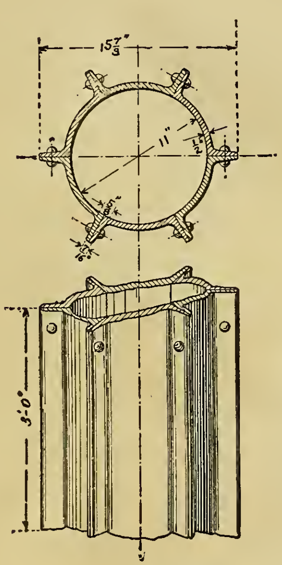

FIG. 30.

it does not show any section-lines, because no metal is cut by the plane CD, which passes between the two parts or brasses.

In the elevation only one brass is sectioned, since the object is symmetrical, and the other half would simply be a repetition. The lines AOB show that one-half of the right-hand brass is cut away. The front-elevation is thus a combined outside and sectional view.

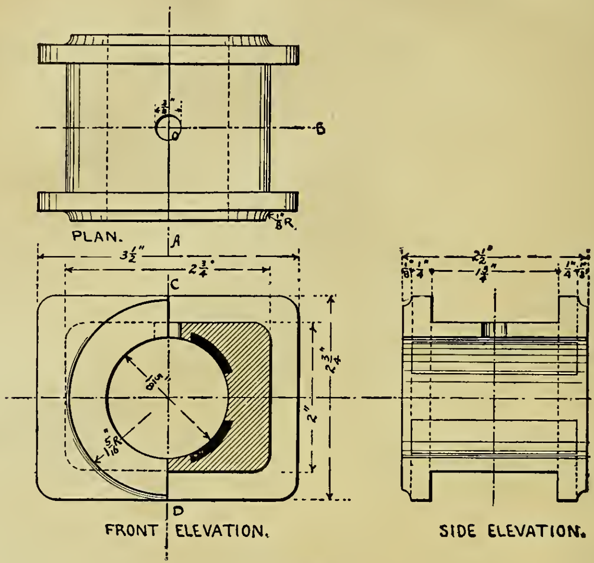

Fig. 31.

Figs. 30 and 31 are partly shaded to help the student to imagine these objects. The principles involved are explained in the following pages.

SHADING.

EXERCISE 13.

Copy the Figs. 33–36. Full size.

Special Instructions: Some of the outlines are drawn heavier than the others, so as to give an appearance of solidity. The conventional rule prescribes the

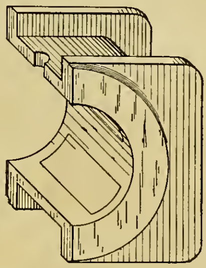

Fig. 32.

"shading" of the lower and the right-hand edges of all solid portions, supposed to project from the paper. It follows, therefore, that the outlines of holes and depressions are shaded along the upper and the left-hand edges. The draughtsman finds it most convenient to have the light fall on his work from over his left shoulder; hence the drawing also is supposed to be viewed in the same light. Thus shadows will be formed to the right and below each projecting part.

In Figs. 33 and 35, a section is not necessary because the shading of the plan shows that the openings are not plugged or filled. The lines separating adjoining pieces are not shaded if the surfaces are "flush" or continuous, because then no shadows can be cast by them. There-

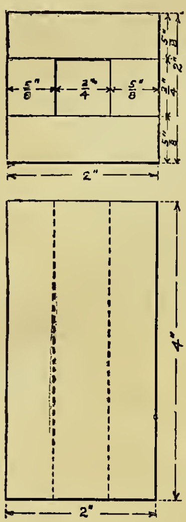

Fig. 33.

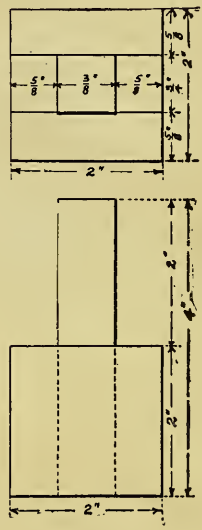

Fig. 34.

fore, if the inner square, Fig. 33, or the inner circles, Fig. 35, were not shaded, we should conclude that the holes were filled.

The thickness of the shade-lines should be about double that of the light lines.* In shading circles, first draw the entire circle with the pen-compass, obtaining a

* The thickness added for the purpose of shading is usually placed to the right and below the unshaded line.

single thickness all around; then, without changing the radius, shift the pin-point down and to the right of the real center by a distance equal to the thickness of the line, and draw over the *half* of the circle to be shaded. The thickest part will then be to the southeast (or northwest in the case of holes) of the center, while the shading will terminate at the northeast and southwest points.

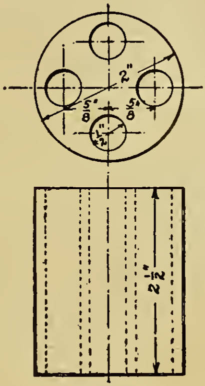

FIG. 35.

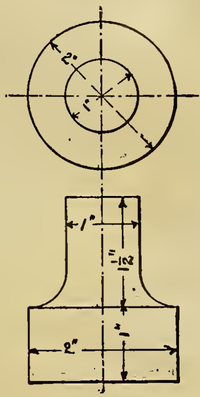

FIG. 36.

It is customary to shade the right-hand edge of the cylinder, although the correctness of this can be disputed; similarly the shading of the *entire* line representing the base of the cylinder, in the elevation, can be criticised. As with all conventional methods, the draughtsman should be allowed some license, especially if, as in this case, he improves a drawing which, if constructed in accordance with the strict rules of shades and shadows, would appear strange.

The fillet-curves or quadrants in Fig. 36 should be considered portions of circles bounding holes; the left-hand one will, therefore, remain light, while the one on the other side is partially shaded. Do not forget to draw these curves *before* drawing the straight lines tangent to them.

EXERCISE 14.

Eye-bar shown in Fig. 37. Full size. (Exercise 15 may go on the same plate.)

SPECIAL INSTRUCTIONS : The shading of the surfaces is sometimes resorted to for the purpose of emphasizing

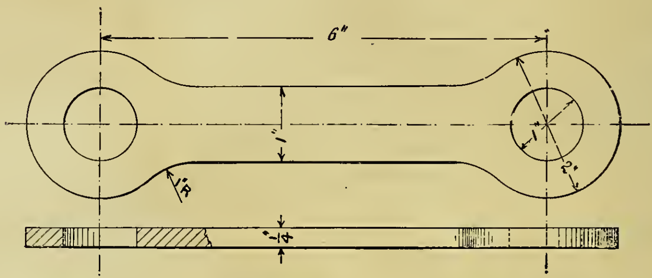

FIG 37.

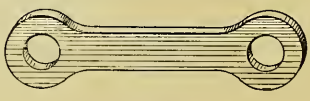

FIG. 38.

certain features. This shading should never be done free-hand. The lines are drawn parallel to each other, and to the elements of the surface ; they increase in thickness and proximity towards a point corresponding to the southeast portion with respect to the center or axis. The curvature of the fillets is also similarly represented. At the left end, a partial section is taken and the semi-cylindrical hollow is shown shaded, the darkest portion being at the left-hand edge.

The irregular line representing the fracture is drawn free-hand, with a writing pen, and indicates that the section is only partial, since it is unnecessary to extend the sectioning across the entire bar.

EXERCISE 15.

Figs. 39 and 40 illustrate two forms of rivets, showing a section of the plates riveted. Draw these figures with the shading as shown. The perspective sketches, Figs. 41 and 42, will help the student to understand the mechanical drawing.

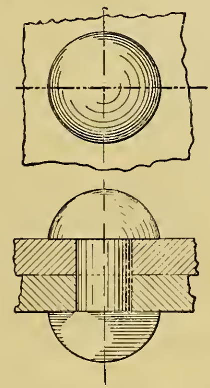

FIG. 39.

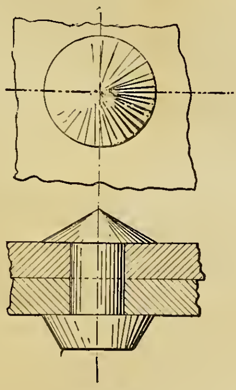

FIG. 40.

SPECIAL INSTRUCTIONS: Similar effects may be produced in various ways: thus the plan of Fig. 39 may be shaded by means of straight lines, in a manner similar to the shading of the head in the elevation. The lightest portion should always be that turned towards the imaginary source of light, above and behind the left shoulder of the observer; *i. e.*, in front of the upper, left-hand corner of the sheet.

In shading the elevation of a cone, Fig. 40, the slanting lines are best drawn *not* convergent to the apex, so as to avoid a blotch near that point.

The section is taken through the central axis of the hole, and the uncut rivet is supposed to be placed into position. This is the almost universal practice in repre-

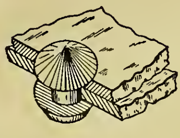

Fig. 41.

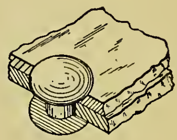

Fig. 12.

senting cylindrical pieces fitting into corresponding cavities: the cylindrical piece itself is supposed to remain uncut by the section-plane.

Make the drawings twice the size of Figs. 39 and 40.

EXERCISE 16.

a. Two views of the journal, Fig. 43, shaded; full size.

b. Two views of the handle, Fig. 44, shaded; full size.

Special Instructions: The shading that the student is asked to do in this exercise would rarely be applied in practice. Patent-office drawings, and drawings for books, trade-catalogues, and advertisements, however, require a certain skill in mechanical shading that should be acquired by every draughtsman.

In the journal, Fig. 43, the curved shading-lines in the fillets run into the straight lines on the cylindrical parts; from a circular quadrant at the edges, these curves should change into parts of ellipses, gradually increasing in eccentricity until they become straight lines on the center line. They may, however, be drawn as arcs of circles with increasing radii, the centers of these arcs being on the perpendicular line through the center of the quadrant at the edge.

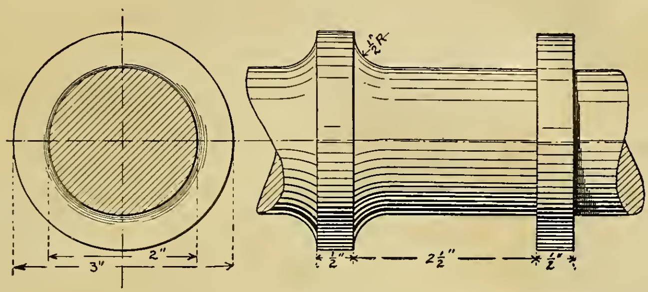

FIG. 43.

Fig. 44 is somewhat difficult to shade, owing to the irregular curved outline. In this case, the shading can be done more effectively if it is first pencilled free-hand;

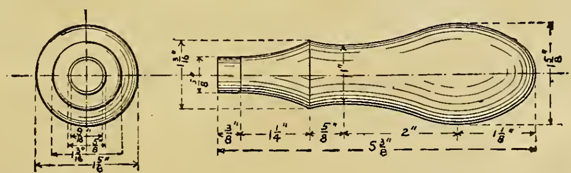

FIG. 44.

"sweeps" are then fitted as nearly as possible for inking. These sweeps are made of rubber or box-wood, and can be obtained in an almost endless variety of forms. Fig. 45 shows a number of these sweeps, as illustrated in trade-catalogues. They are used like an ordinary straight-edge to guide the ruling-pen in drawing a curve that cannot be traced with the compass.

Attention is called to the free-hand curve representing the broken ends of the shaft, Fig. 43.

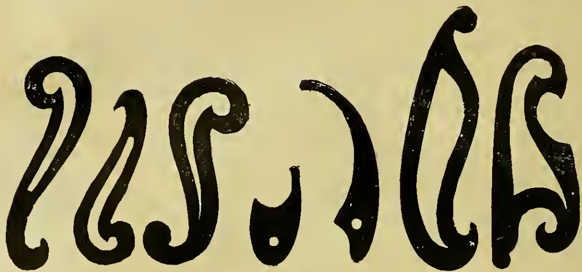

FIG 45.

EXERCISE 17.

a. Two views of the key, Fig. 46, shaded. Full size.
b. " " " pin, Fig. 47, " " "
c. " " " bracket, Fig. 48. Scale, ½. Shade.
d. " " " cylinder-head, Fig. 49, shaded. Scale, ⅛.

SPECIAL INSTRUCTIONS: The following conventional rules are usually observed:

Parallel equi-distant lines of the same thickness indicate a *flat* surface, facing the observer. Straight (Figs. 46 and 48) or circular (Fig. 49) lines may be used, depending on the outline.

A surface in the light appears darker the further it is removed from the eye. This is also illustrated in Figs. 46, 48 and 49, where the shading lines are drawn further apart or finer on the nearer surfaces.

A surface inclined to the light, but still receiving light, is drawn darker as the inclination of the rays

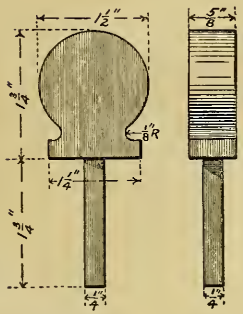

Fig. 46.

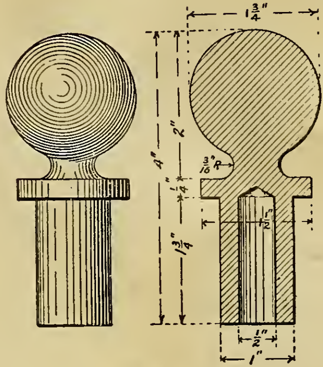

Fig. 47.

decreases; the high light is placed where these rays are perpendicular to the surface. (See shading of cylinders and sphere, Fig. 47.)

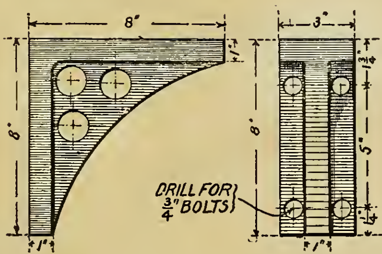

Fig. 48.

A surface in the shade, *i. e.*, turned away from the light, is shaded lighter as it recedes from the eye. (See shading of cylinders and sphere in Fig. 47 and others.)

A shadow is rarely shown in a mechanical drawing, as it tends to obscure the details of the work. If used at all, it should be the darkest part of the drawing.

Additional streaks of light are sometimes introduced in the shaded parts, to represent reflections from the surface, if it is polished. These additional high lights are very effective, especially in the shading of polished disks, as in Fig. 49.

Attention is called to the dimension 2′-4″ marked in Fig. 49; as the mechanic uses the two-feet rule, all

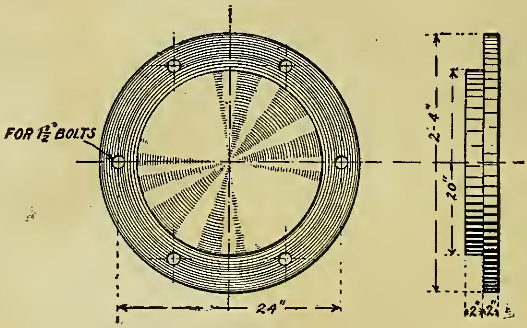

Fig. 49.

dimensions above 24″ should be marked in feet and inches.

The shading of the globular part, Fig. 47, is obtained by means of concentric circles around the high-light point as center. This point may be found by means of a rigid geometrical construction; it will, however, suffice to place it approximately as follows: In the circle representing the front-view of the sphere draw a diameter, making an angle of 45° with the vertical center-line; the high-light point, or point at which the light strikes the surface of the globe at right angles, will be found on that line, at a distance of a little more than 1/5 of the diameter (more exactly 3/14) from the upper, left-hand end of the diameter drawn.

A study of illustrations in catalogues and mechanical journals, together with close observations on the effects of light and shade in reality, will teach the student a great deal more than lectures on the subject. Considerable practice will of course be needed to attain special dexterity. The student is advised to practice shading on the exercises preceding Number 13; Fig. 31 is thus shown shaded in part.

LETTERING.

Lettering and figuring are by no means unimportant parts of a drawing; many a careful work is spoiled by carelessness in this respect. A little practice and a few precautions will enable the student to become fairly proficient in free-hand lettering. Certain styles of ruled letters are used for the main titles, while free-hand printing and figuring is adopted for minor inscriptions.

EXERCISE 18.

Ruled letters illustrated in lines 1-5 inclusive, Fig 50. Complete the various alphabets indicated.

Special Instructions: In every case, draw two or three parallel lines in pencil, for the proper lining up of the letters; the letters themselves are also drawn in pencil before being inked in; the pencil guide-lines should, of course, be erased after the letters are inked in.

The first two lines show an alphabet that may be constructed almost exclusively with T-square and triangles, using perpendiculars. The ratio of the height to the width may be varied, and different effects will be produced. In a like manner, slanting of the letters, either forward or backward, may be preferred in some cases. The objection to this style is the identity of A and R, D and O, U and V.

By introducing short oblique lines, 45°, to cut off the corners, the type shown in the fourth line may be obtained;

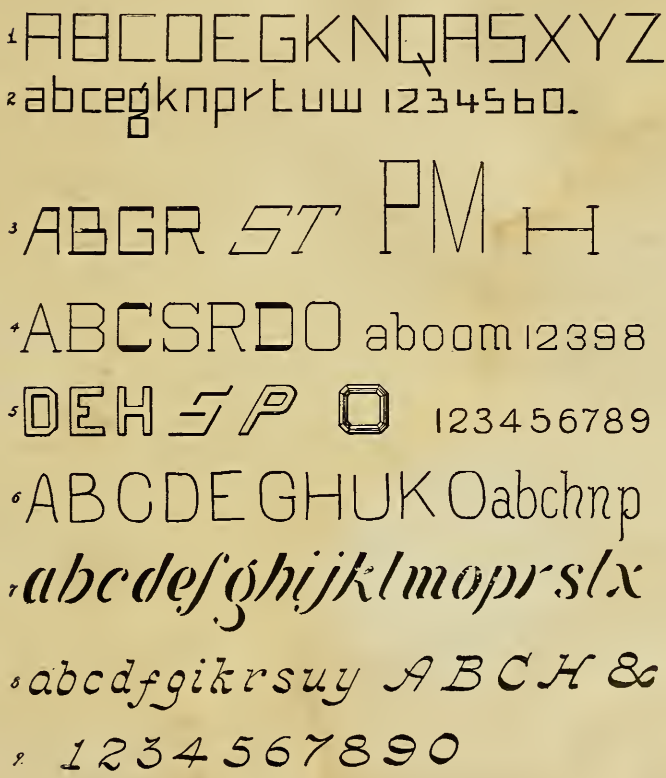

Fig. 50.

this may be still further modified by substituting quadrants of circles for the 45° lines. Similar alphabets, broad or high, vertical or oblique, are easily developed.

By substituting double lines for the single lines shown in the previous alphabets, the letters may be made to appear in relief, as if they were carved out. Shading the outline as in an ordinary mechanical drawing (see Exercise 13) will enhance the effect. Different examples are given in line five of the figure.

Line three illustrates the introduction of short bars at the ends of long lines. By shading only the horizontal lines, good effects may be produced. The use of complicated, shaded letters is questionable. They require considerable time and labor, and very often prove too ornamental for an ordinary mechanical drawing. The styles described above can be made sufficiently impressive and appropriate for any mechanical drawing. If the student likes the work, he may try his hand at the other types illustrated in the figure.

EXERCISE 19.

Free-hand lettering illustrated in lines 6, 7, 8 and 9.

Special Instructions: The draughtsman should not forget to rule his guide-lines. The work can be inked at once, a writing pen with a fine point being used. If the letters are shaded, the hair lines may be omitted altogether, since the eye can supply them very readily and with good effect. The inclined style seems to be more convenient. Simple ornaments may be added, if they do not appear too laborious and heavy.

The French "round writing" is extremely useful, on account of the rapidity with which it can be produced, as well as on account of its clear-cut, legible appearance. Special stub-pens are used; special copy-books for practice are the best means for attaining a proficiency in this work. (Fig. 51.)

EXERCISE 20.

Letter the plates containing exercises 1–17. Mark the name of the object, the date, the name of the draughtsman, the scale of the drawing, and other particulars that were not introduced before.

Special Instructions: Rule the pencil guide-lines in every case! Avoid making the lettering too prominent; your name, especially, should be marked in a

Fig. 51.

modest manner. The position for the principal lettering will depend on the open spaces left by the general arrangement of the drawings. Do not underscore any words! The space between letters of the same word may equal the width of the letter D, while the space between words may be double that width. In order to place lettering symmetrically, start with the middle letter of the inscription, and work in both directions.*

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* For an excellent and easy method of lettering see "Lettering for Draughtsmen, Engineers, and Students," by Chas. W. Reinhart. (D. Van Nostrand Co.)

SCREWS.

The screw-thread cut on a bolt causes it to move in the direction of its axis, as it is turned around the axis, the part into which it fits being called the nut. If, on the contrary, the bolt remains stationary, the turning of the nut will cause the same to move along the bolt.

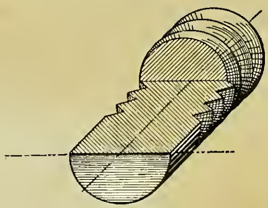


FIG. 52.

If we place a finger on any point of the thread and follow the ridge around, we find that as we pass around the axis, we also move lengthwise along the bolt. A section of the bolt (Fig. 52) through the axis, shows the thread to be almost triangular. The sides of the triangle being inclined 60° to each other. The grooves between the threads are also triangular. The apex of the triangle, if followed around the bolt, will be seen to correspond to the ridge of the thread, while the bottom of the groove forms a similar curve (helix) around the axis.

As we take a front view of the screw, we observe the ridge and bottom lines as *curves*, sloping upward on the bolt, disappearing at the right, and re-appearing at the left. In moving along the ridge from the left-hand extremity of one of these visible portions to the right-hand end, the displacement parallel to the axis will be equal to that which takes place on shifting along the back or hidden portion from right to left.

If, therefore, we lay off distances on the extreme left edge, equal to the axial travel for each complete turn, we shall obtain the positions of the ridge-points at the left.

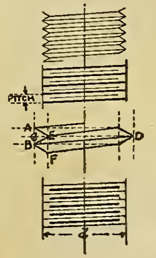


Fig. 53.

This distance is called the pitch of the screw. (Fig. 53, A–B.) Now draw perpendiculars across the axis, through two consecutive ridge-points, A and B; the thread will then bring the ridge on the right *half-way* between these two lines, to point D.

Instead of drawing the sinusoidal curve from ridge-point on the left to the one just found on the right, it is usually sufficient in practice to draw *straight* sloping lines, the difference being hardly discernible. The other ridge-lines are then simply drawn through the left-hand points, parallel to this first line, BD. The bottom of the thread is represented by similar straight lines ; the bottom points are found by constructing the section-triangle, sloping the two sides from the ridge-points. The upper portion of Fig. 53 shows a thread drawn in this manner.

The simplest conventional method of representing screw threads is shown in the lower portion of Fig. 53. First draw the two parallel lines at a distance apart equal to the diameter of the screw. This given diameter refers to outside extreme measurements. Next find from tables the standard number of threads per inch corresponding to that diameter ; the pitch will equal the fraction of an inch obtained by dividing one inch by the number of threads per inch. Lay off this pitch $\left(=\frac{1''}{\text{no. threads per in.}}\right)$ along the left-hand line. Through a point, C, half-way between any two consecutive points, A and B, draw a pencil-line across and mark its intersection, D, with the right-hand line. The line BD gives the proper slope for the ridge. On AB as base, construct the triangle AEB, sloping AE and BE 30° up and 30° down, respectively, getting the point E.* A pencil-line through E, parallel to the axis, gives the limiting line of the bottom of the thread on the left, while a line equally distant from the center-line will give the same depth on the right. Mark points similar to E, as F, etc.

Set your triangle so that one edge is on the line BD, and place a straight-edge touching one of the other sides of the triangle ! Sliding this triangle along the straight-edge, we are able to draw at once, in ink, parallel sloping lines limited by the outer and inner bounding lines of the screw, the ridges passing through points similar to A and B, while the bottom lines correspond to points like E.

* Use the 30° and 60° triangle with the T-square.

Ink in the extreme lines, parallel to the axis, and erase all pencil marks! The lower part of Fig. 53 shows the finished appearance of this thread. There is a difference of opinion as to the shading of the thread-lines, some draughtsmen drawing the long lines heavier, and others, the short lines. The majority in practice seem to favor the latter method, shading the bottom-lines.

Notice that the right-hand extremities of the shorter lines are placed exactly opposite the left-hand ends of the longer lines. This brings the shorter lines below the proper position, half-way between the long ridge-lines. This inaccuracy need not be considered in practice;

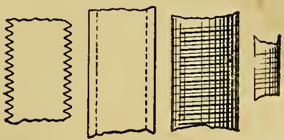


FIG. 54.

indeed, the bottom lines are usually gauged by the eye, without measurement, and are drawn as near the middle as possible.

If the diameter of the drawing of the screw warrants it, the limiting straight lines are replaced by a serrated outline, as shown in the upper portion of Fig. 53. In small drawings, on the other hand, the sloping lines may be omitted, the zig-zag being sketched in free-hand with an ordinary writing pen; again, some draw the outer and inner lines only, without the sloping lines across; shading may be used to enhance the effect. (Fig. 54.) In very small screws it may be sufficient to draw the outer lines and the long sloping lines, thus disregarding the bottom of the thread altogether.

"Right-handed" threads are easily distinguished from "left-handed" ones. In the latter case, if the front-view is placed with the axis vertical, then the thread-lines will slope up towards the left instead of the right. (Fig. 55.) The other part of this figure shows what is called a double thread; there are two separate

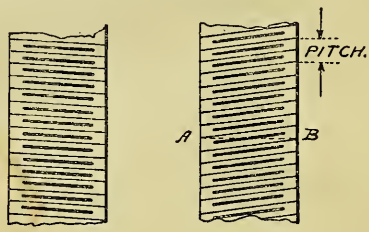


Fig. 55.

ridge-lines and bottom lines, the ends of successive visible portions being exactly opposite to each other, as A and B; the pitch will equal the axial distance between *alternate* threads.

If a right-handed screw be turned around its axis in the direction of motion of the hands of a clock, it will move into the nut; to produce a similar effect with a left-handed screw, the rotation must be "counter-clock-wise" instead of "clock-wise."

EXERCISE 21.

Two views of a 2″ bolt, round head and hexagonal nut; standard size. Also add side-view of nut, and section of nut, showing interior; also views of a square nut, fitting the 2″ bolt. Full size.

Special Instructions: Fig. 56 shows a bolt similar to the one required. The thread is not represented as it passes through the nut; neither is it shown in the portion of the screw extending beyond the nut. The majority of draughtsmen are opposed to dotting hidden threads; hence these lines are usually omitted; or, again, in some special cases they are draw in full as if they were visible. A dotted thread would certainly tend to confuse the drawing without being of any use in explaining the construction of the work. For similar reasons the end sticking out beyond the nut need not be shown as a thread,

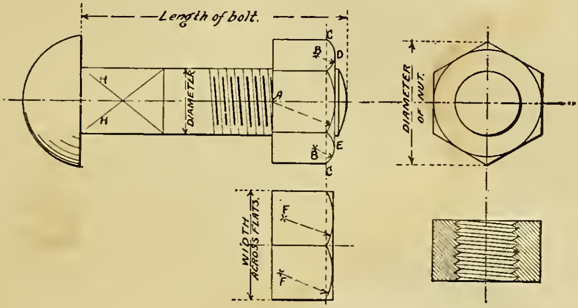


Fig. 56.

since the fact that a screw-bolt is intended is sufficiently indicated by the rest of the design.

In the sectional view of the nut, the thread lines that appear correspond to the *back* of the screw, and, therefore, they slope in the opposite direction as compared with the slope of the lines in the screw itself. The "chamfering" of the nut is produced by turning off the sharp edges of the prism; the chamfer-lines, thus produced, are usually arcs of a circle. The side-surfaces of the nut are fore-shortened in the view and hence the circular chamfer-lines do not appear as circular arcs, but as portions of ellipses ; a sufficiently accurate representation is, however, obtained by making them circular. All these chamfer-arcs are tangent to the top-line and are, of course, equal in height, their ends being on the same level. The method of constructing the views of the chamfered hexagonal nut are indicated in the figure. In the front-elevation three faces are shown, while only two appear in the side-view ; since the extreme lines in the latter view correspond to faces of the prismatic nut, the chamfer-lines of these faces are seen as straight lines, extending to the top-line, just as in the other view. The size of the wrench-opening required is indicated by the width across the flats, shown in the side-elevation. This distance is, of course, less than the distance across the angles of the hexagon. The radii indicated in the figure are not to be inked in. The point A is the center of the middle arc ; the radius being equal to the depth of the nut. The centers B, B, are found by passing an arc of a circle through the points C, and tangent to the line D, E. The centers F, F, in the side view are determined in a similar manner.

The length of bolts is always taken as the distance under the head to the point. The diagonals H, H, are used in a conventional way to denote that the bolt is square in section at that portion ; this is to prevent rotation when the nut is tightened.

The square nut is also chamfered, and the chamfer-lines are arcs of circles. Here, also, the side-lines should extend to the top, on account of the chamfer cut on the side-face. If the nut were represented with edge towards the observer, two faces would appear fore-shortened. On account of the confusion that might arise if only two views of the nut are given, it is customary to show three faces of the hexagonal nut in the elevation, and only one of the square nut; in any case, a closer inspection of the views showing two faces brings out the distinction between the two forms of nuts. (Fig. 57.)

As explained in a previous exercise, it is better to construct the plan first. The circle tangent to the outline of the nut corresponds to the circle produced by the

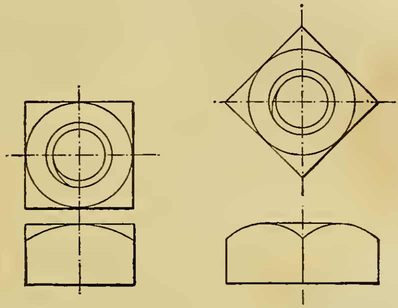


Fig. 57.

chamfer. Some draughtsmen insist on dotting in the smaller circle inside of the outer circle of the bolt, to represent the bottom of the thread in the plan; this refinement is hardly necessary.

By reference to tables furnished in any trade-catalogue, we find that a 2″ bolt has 4½ threads per inch. The dimensions of the head and nuts will vary for different makes; a good average value will be 3⅝″ diameter and 1 9/16″ depth for the head, 3⅝″ diameter and 1 15/16″ depth for the hexagonal nut, and 4 27/64″ diameter and 1 15/16″ depth for the square nut. The diameter is taken "across corners."

EXERCISE 22.

Oil-cup and cover, shown in perspective, Fig. 58 ; detailed views ; full size. (Same plate as Ex. 23.)

SPECIAL INSTRUCTIONS : In deciding as to the views that are required, we notice that an axial section is necessary to show the interior. The knurling of the rim of

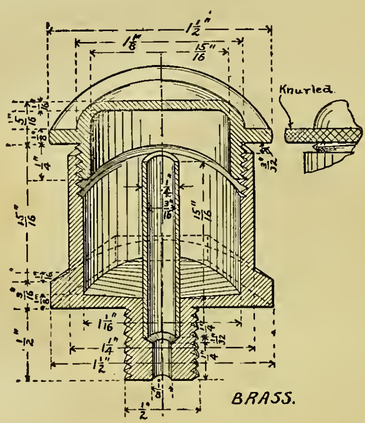


FIG. 58.

the cap may be shown in an outside-view, or else the wood " knurled " may be printed on the drawing. The plan should show that the body of the cup is cylindrical, and should also give some information concerning the small tube inside.

We therefore advise the following views : Sectional front-view ; top-view with the greater portion of the cap supposed to be removed ; and side-view of the cap only.

The thread is of the same character as on the bolt, and is represented in the same way. The pitch depends on the diameter and is also found in the tables, owing to the fact that standard taps and dies are used to prepare the hole and the thread respectively. A taper is usually given to the screwed nipple; but it is doubtful whether this fact is of sufficient importance to warrant its being shown in the drawing.

The cap should not be screwed down tightly; some thread should appear on the box below the cap, and some on the part of the cover beyond the box. The knurling need not be drawn with great precision; lines crossing each other as indicated in the figure will convey this information.

The student is reminded that he must change the direction of the sectioning lines for the different pieces.

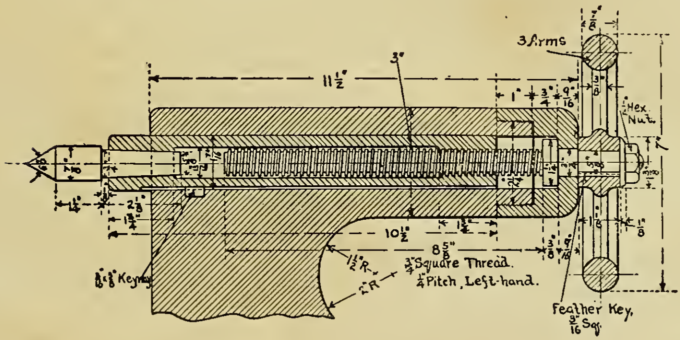


FIG. 59.

EXERCISE 23.*

Square-threaded screw, used in tailstock of a lathe; show hand-wheel and a portion of the stock. Fig. 59. Scale: ½.

SPECIAL INSTRUCTIONS: A section of a square-thread screw is shown in Fig. 60. It will be noticed that the hollows are taken the same in size as the projections, or, in other words, the sides of the squares are equal to one-

* Same plate as Ex. 22.

half the pitch ; for a single-thread screw the hollows on one side (B) are, therefore, exactly opposite the projections (A) on the other.

The sloping lines are drawn straight, their real curvature being disregarded. If the screw is small, the bottom-lines need not be shown, and if very small, the threads

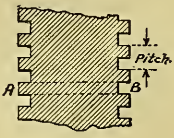


FIG. 60.

are marked only on the right half of the screw. Fig. 61 shows the different ways of drawing the square thread.

This screw is used chiefly for transmitting motion. In the present example it is made left-handed, so that right-handed turning of the hand-wheel should force the loose "center" outward.

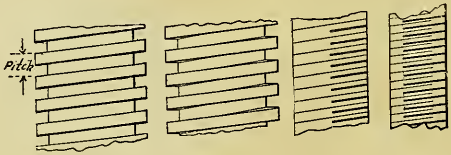


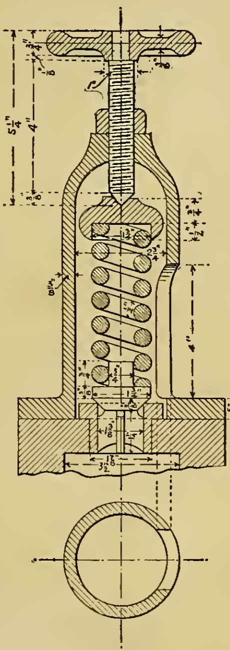
FIG. 61.

Other forms of threads are sometimes employed, but they are of little importance; any one able to draw the triangular thread and the square thread will find no difficulty in making representations of any other form, such as the trapezoidal, the buttress, and the knuckle threads.

Attention is called to the sectional view of the hand-wheel. The cutting plane is always supposed to cut the rim and the hub only, not the arms.

EXERCISE 24.

Relief-valve for steam-cylinder. Fig. 62. The valve-plug proper is held against the seat by the tension of a coiled spring; this tension may be increased or otherwise adjusted by means of a hand-screw pressing against the other end of the spring. Scale: ½. A longitudinal section and an outside elevation will show everything; hence the plan is not required.



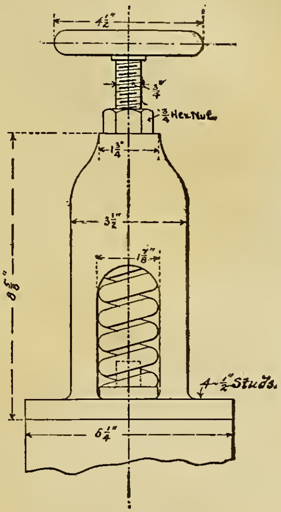


FIG. 62.

FIG. 63.

SPECIAL INSTRUCTIONS: The coiled spring is not drawn by means of curved sloping lines, but, as in the screw-thread, straight lines are used. The spring really forms a thread, which is, however, not wound on a cylinder; hence a portion of the back is visible between the front parts of the thread. The cross-sections of the convolutions of the coil must be placed like the ridges in the screw; *i. e.*, those on one side opposite the spaces on the other side. The pitch will depend on the distance allowed for the spring.

The curves of the contour may be struck with the compasses as tangent circular arcs; as the special outline is of no great importance, the centers of these arcs need

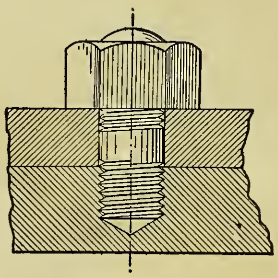


FIG. 64.

not be marked. The hole cut into the side for the escape of the steam shows in the profile-view as two lines set back towards the axis. The reason for this is apparent. To get the amount of this recession accurately would require the view given in Fig. 63, at the lower left-hand corner.

The valve-plug itself is not sectioned, in accordance with a law stated previously.

The "studs" called for in the drawing are not represented, and need not be shown, since a mistake is not possible. Fig. 64 illustrates a "stud" or "standingbolt." This is a bolt without a head, threaded at both ends, and screwed into one of the pieces to be connected. Properly speaking, in this lower portion, in which the bolt "stands," the thread should "bottom," *i. e.*, the thread should not extend beyond the limits of the tapped hole. The plate that is bound down and held by the nut is drilled, but not tapped, a fact shown in the figure by the straight lines outside of the zig-zag lines.

COG-WHEELS.

EXERCISE 25.

Represent to scale and in a conventional manner, a 10″ wheel gearing with a 5″ wheel, the diametral pitch being 7.

SPECIAL INSTRUCTIONS: The 10″ and 5″ refer to the diameters of the "pitch" circles. These are imaginary circles tangent to each other. The teeth or cogs project beyond the pitch-circle by a distance called the addendum; the dedendum is the working depth of the teeth, inside of the pitch-circle; the clearance is the remaining depth to the base of the cogs. The total depth, measured radially, is thus seen to be equal to the sum of the addendum, dedendum, and clearance.

The term diametral pitch denotes the number of teeth for each inch of diameter. Thus, in this case, the 10″ wheel has 7x10=70 teeth, while the 5″ wheel has 7x5 = 35 teeth. In order that two wheels should gear, they must have the same pitch, because then the distances from the middle of one tooth to the middle of the next one, measured along the pitch circles, will be equal in the two wheels. This distance is called the circular pitch, and is evidently the circumference of the pitch-circle divided by the number of teeth. The circumference is equal to π times the diameter, while the number of teeth equals the diametral pitch times the diameter; therefore the circular pitch is found by dividing π by the diametral pitch, since the diameter is cancelled by the division.

The addenda and dedenda are usually equal in the two wheels to the length of diameter per tooth; *i. e.*, to the diameter divided by the number of teeth, or what amounts to the same thing, to one inch divided by the diametral pitch. The clearance prevents the teeth of each wheel from scraping the bottom of the space in the other wheel. It varies in amount for different makes from $\frac{.157''}{\text{diam. pitch}}$ to $\frac{.125''}{\text{diam. pitch.}}$

The profiles of the teeth are portions of cycloids or of involutes of circles; they may, however, be represented by means of arcs of circles.

The space between the teeth is also made a little wider at the pitch-circle than the cogs themselves, by an amount called "backlash."

Fig. 65 illustrates the different portions of the cogs, and gives their names.

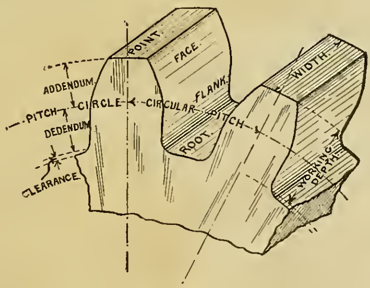


Fig. 65.

In our drawing we shall make the addendum and dedendum each $\frac{1}{7}''$, the clearance $\frac{1}{56}''$, and the tooth and space equal; the profiles can be drawn as circular arcs with a constant radius.

Place the centers A and B, Fig. 66, $(10'' + 5'') \div 2 = 7\frac{1}{2}''$ apart, measured to scale; the two dotted pitch-circles are tangent to each other at the point C on the center-line AB. The circumference of the pitch-circle A is to be divided into 70 parts, each of which is to be further subdivided into two. By trial, step off the circumference with the dividers into 10 parts at first, and then subdivide one of these parts into 7. Lay off a few of these in both directions from C. The other wheel has the same circu-

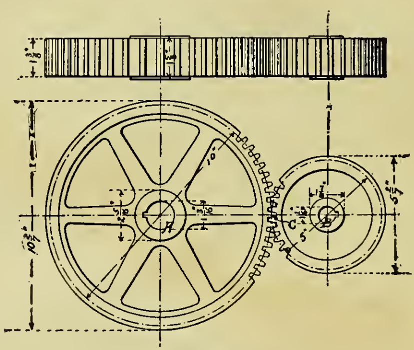


FIG. 66.

lar pitch; but, since it has a shorter radius and therefore greater curvature, the distance between the points of the dividers should be a trifle less. As only a few teeth need be shown on each wheel, this correction may be disregarded.

Fig. 67 shows on a larger scale a good method of drawing the profiles of the cogs. Lay off CD equal to the addendum $\frac{1}{7}''$ and EC equal to the depth remaining, $\frac{9}{56}''$; the circles through D and E, from center A, are drawn in pencil, giving respectively the point-circle and the root-circle, limiting the teeth. Lay off from C the distances CF = FG = GH etc., equal to the circular pitch, which is 1/70 of the circumference in the given case. Place the point K at a distance from G equal to ¼ GH, the circular

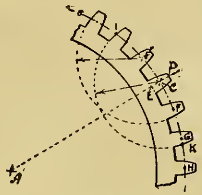


FIG. 67.

pitch. Set the bowpen for the radius = CK = 2¼ times the pitch, and, with the center successively at F, G, H, etc., strike off the arcs as shown. The points and the roots or bottoms of the spaces are then inked in from the center, A, of the wheel. In drawing the cogs on the other wheel, use the same radius for the profile.*

Fig. 66 shows the complete drawing. Where the teeth are not represented, the blank wheel-disks, showing the dotted addendum or point-circle, give the necessary information in a conventional way.

The edge-view of the wheels show transverse lines that might be spaced accurately if the cogs were drawn all around the wheels. Nothing would be gained by such unnecessary accuracy, since only the thickness of the wheel is determined from that view. Approximate lining may be done as follows: Draw two transverse lines in the middle of the view and at a distance apart equal to the width of the tooth at the point; pairs of lines are then

* The radius chosen for the profiles will not give a well-shaped tooth in every case; the draughtsman must decide by trial what radius to take.

drawn on each side of the middle pair to correspond to the teeth next on each side, the distances showing the pitch. As we proceed further away from the middle, both the distances between the point-lines and the spaces between teeth decrease constantly, the latter being, however, always greater than the others next to them. At the extremes, furthest away from the middle, they are shown quite close, but still distinct. The lines that correspond to the base of the teeth are *not* shown, as they would tend to confuse the drawing without adding any new information. A good effect is produced by drawing the right-hand edges heavier, as shown in Fig. 66.

Fig. 68 gives another conventional way of representing gears. This is readily understood without any further explanation.

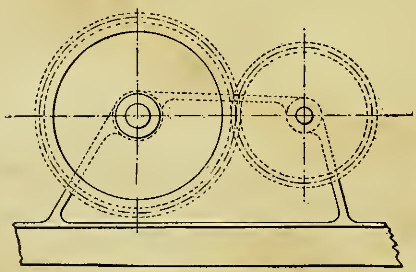


Fig. 68.

EXERCISE 26.

Rack and Pinion. Diametral pitch = 6; 15 teeth on the pinion; full size. (Same plate as Ex. 27.)

Special Instructions: The rack is simply a portion of a cog-wheel whose diameter is infinitely great. The pitch-circle of the pinion is tangent to the straight pitch-line of the rack. The distance measured on the pitch-line of the rack from center to center of consecutive spaces (or cogs) must be the same as the circular pitch on the pinion. This latter is equal to 3.1416″ divided by 6, the diametral pitch, or .5236″; hence this distance must be laid off on the pitch-line of the rack.

The pitch-diameter of the pinion must be $15/6'' = 2\frac{1}{2}''$; the addendum $= 1/6''$; the outside diameter $= 2\frac{1}{2}'' + 2/6'' = 2\frac{5}{6}''$; the whole depth of the tooth $= 2/6 + .157/6 = .3595''$. The other dimensions are taken from stock-sizes of gear-wheels. (Fig. 69.)

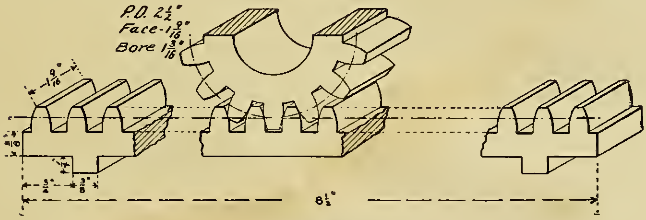


Fig. 69.

The circumference of the pitch-circle is $2.5'' \times 3.1416 = 7.854''$. The rack is 8½″ long, so that the pinion may make one complete revolution in shifting the rack each way.

Strike off the profiles with circular arcs as before! The two views required are: the front-view, showing the gears meshing, and a sectional side-view (or top-view), giving the form of the body of the pinion. Since the number of teeth is odd, the section must pass through one tooth; this fact is, however, not usually represented, and the section is shown as if the cutting plane passed through the middle of a space.

EXERCISE 27.*

Worm and worm-wheel. Single thread, right-handed; lead=.314″; diameter of the worm = 2″; number of teeth=55. Full Size.

SPECIAL INSTRUCTIONS: Each revolution of the screw or worm moves the pinion or wheel forward one cog, if there is only one thread; this advance is called the lead. It follows, therefore, that the pitch of the pinion must be equal to the lead of the worm, and the diametral pitch will equal $3.14''/.314'' = 10$. Since there are 55 cogs on the wheel, great reduction of speed is obtained.

The diameter of the pitch-circle of the pinion $= 55/10'' = 5\frac{1}{2}''$; addendum $= 1/10''$; pitch-diameter of the worm $= 2'' - .2'' = 1.8''$; therefore the distance between the axis of the worm and the axis of the wheel must be $\frac{1.8''}{2} + \frac{5.5''}{2} = 3.65''$, because the two pitch-circles must be tangent to each other in the middle section. The diameter of the wheel at the "throat" is $5.5'' + .2'' = 5.7''$, and the whole depth of the cogs $= 2.157/10'' = .2157''$.

The "face" of the wheel is made ¾ of the diameter of the worm, or $1\frac{1}{2}''$ in this case. The other proportions may be taken from Fig. 70.

Fig. 71 is a perspective sketch of a worm-gear.

Since the exterior view of the cogs of the pinion and of the convolutions of the worm is of little importance, it will be found more convenient to draw two sectional views: one passing through the axis of the wheel and perpendicular to the worm-axis, the other through the axis of the worm and perpendicular to the wheel-axis. The latter view resembles the profile of the rack and pinion. The

* Same plate as Exercise 26.

section of the worm-thread is usually bounded by straight lines, so that the worm is really a screw with a triangular or rather trapezoidal thread, in which the sides slope 15°. The other sectional view is drawn as if it passed through spaces and cut neither thread nor cog; it shows the hollowed edge of the teeth, the width of the "face" and the particular form of the body and hub of the pinion.

A little reflection will convince the student that the

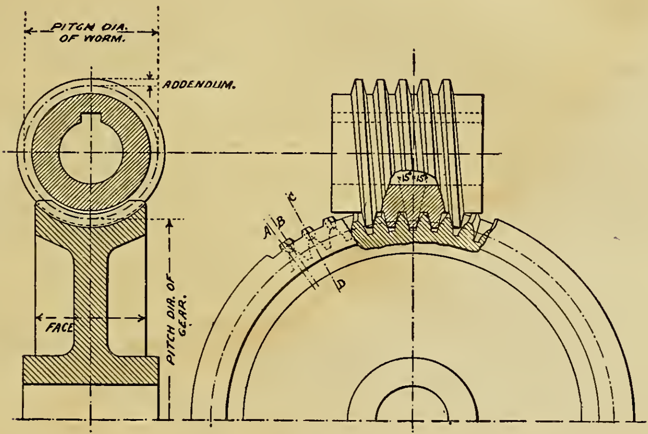


Fig. 70.

ordinary spur-wheel would have to be modified in order to gear with a worm; thus the spaces and teeth can no longer run perpendicularly across the edge of the wheel, but must be curved and slanted at an angle, so as to hug the helical turns of the worm.

In Fig. 70 only a portion of the gearing device is shown in section; the rest, in outside view, is drawn in a manner similar to that employed in representing screws and ordinary cog-wheels. The fore-shortened sides (AB) of the sloping and hollowed teeth of the pinion appear about ¼ of the lead in width.* Care should be taken to

Fig. 71.

pass the median profile (CD) through the middle points of this width.

The entire circular view need not be shown.

* The wheel embraces about 90° or one-quarter of the circumference of the worm, and, hence, the teeth are in contact with a quarter turn of the thread.

EXERCISE 28.

Bevel and pinion gear; shafts at right angles to each other; largest pitch-diameters, 8″ and 4″; 2 pitch; face=1½″.

SPECIAL INSTRUCTIONS: The cogs of bevel wheels (Fig. 72) are cut on cones instead of cylinders, as in the ordinary spur-wheel. The pitch-circles corresponded to imaginary pitch-cylinders, that were in rolling contact

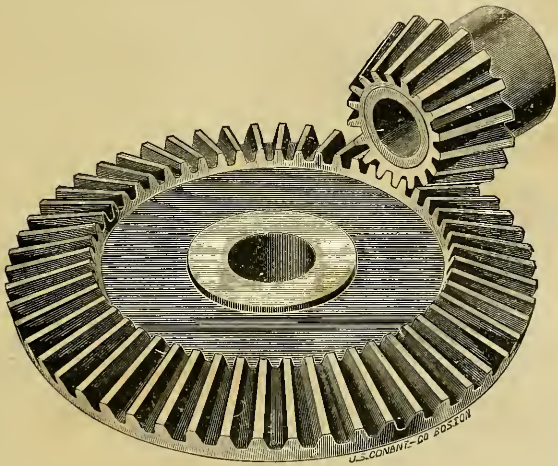


FIG. 72.

with each other; these are now replaced by pitch-cones, in which the largest diameter is called the pitch-diameter.

Fig. 73 shows the simplest conventional method of representation. The conical pitch-surfaces are shown in the two views, the "face" being the slant height of the frustums. The dotted prolongations of the extreme elements, AO, BO, and CO, indicate that O is the common apex of the two pitch-cones. The pitch and the diameters being marked, the number and proportions of the teeth are readily determined.

The holes in the gears, as well as the special size of the hub and the form of the body (whether plain, webbed or armed), may be indicated in the figure.

Figure 74 is somewhat more explicit than the previous illustration. The "back-cones," ADB and AEC are merely suggested, the lines ED, BD, CE being perpendicular to AO, OB, OC, respectively. AOC and AOB

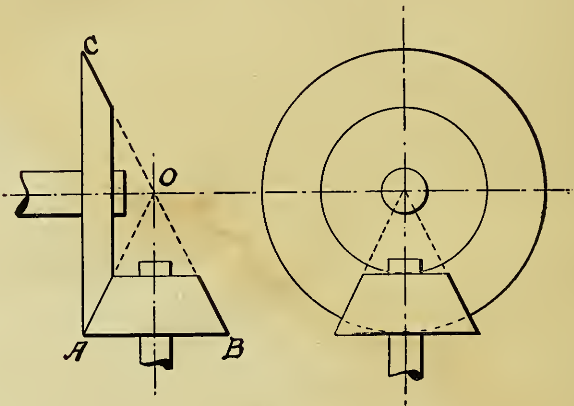


FIG. 73.

are the pitch-cones. The addenda portions of the teeth are omitted, and the gears appear as if they were cut down to the pitch-cones. The radial lines in the circular view simply suggest the teeth in the crudest ma... ...d are spaced approximately. Notice the shading of the right-hand and lower edges, in a manner similar to that shown in Fig. 66.

Fig. 75 is more elaborate. The sectional view appeals most strongly to the practical man, since it shows all construction details, and also the depth of the teeth, ab = cd. The cogs themselves are supposed to be uncut by the section plane.

AB and AC are still the pitch-diameters; CEA and ADB the "back-cones"; Aa = Ad = addendum = $\frac{1}{2}''$; ac = db = clearance = $\cdot 157/2'' = .0785''$. The heavy dash-lines FG and HI represent conventionally the broken edge-lines of the cogs in the background.

The other view given in Fig. 75 affords excellent

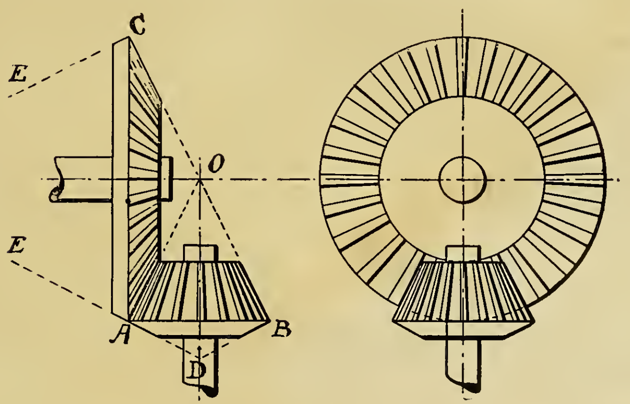


Fig. 74.

practice for spacing and drawing numerous short lines. The outlines of the teeth may be constructed as in the spur-wh[illegible]s. All the "point-lines" and "base-lines" [illegible] on cones whose common apex is at O, are drawn radially from O′ as a center. The fore-shortened depth F′K′ on the inner cone is easily obtained by viewing FK from the side, as indicated by the dashed lines shown in the figure.

Two methods of fastening the wheels to shafts are illustrated: the pinion is held by a "key" or wedge, while the gear is bound by a "set-screw." It should also be noticed that the shafts passing through the holes in the gears are not sectioned.

NOTE ON GEARS IN GENERAL: Ordinary spur-wheels transform rotation around one axis into rotation around another and parallel one. The axes of the bevel-gears intersect and are usually at right angles to each other;

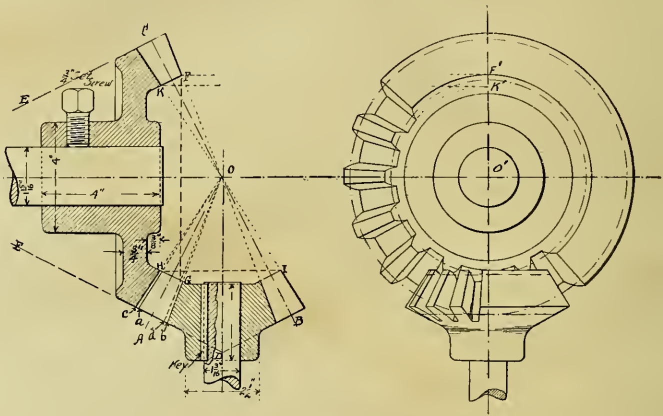


FIG. 75.

while the axes of the worm and its pinion do not intersect, but are also perpendicular to each other.

The discussion of the relative velocities of the wheels and the design of the proper form of the cogs does not come within the province of this book.

Gears, like bolts and screws, have been standardized so that a careful detail drawing is only required when new designs are introduced. Then the problem becomes a very difficult one, and presupposes for its solution a knowledge of the laws of kinematics.

READING OF DRAWINGS.

The draughtsman should be able to understand a drawing; he must see the object in his mind's eye; he must trace out the lines corresponding to each other in the various views; he must appreciate all the dimensions as well as the forms.

The following exercises are given as a substitute for reading and deciphering drawings.

EXERCISE 29.

Copy Fig. 76, showing main shaft of a steam-engine; scale: 1/8. Analyze and explain the construction and form of the shaft.

SPECIAL INSTRUCTIONS: The cross-section is represented in a break in the view shown; the shaft is circular

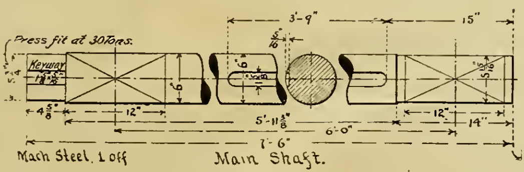


FIG. 76.

in section, and a rectangular groove, slot, or "key-way" is cut a distance of 3′ 9″. The shaft is turned cylindrical to different diameters at the different portions as indicated.

The key-way at the left end is marked $1\frac{5}{8}'' \times \frac{5}{16}''$; the latter dimension is evidently the depth of the slot.

The diagonal lines shown near each end are used conventionally to indicate the place for the bearings or supports of a shaft. The distance between the centers of these journals (6′ 0″) is marked because it is customary to measure between centers rather than between the ends of symmetrical parts.

The length, 5′ 11⅜″, is figured separately because it shows a portion of the shaft turned to the same diameter. It will be noticed that the dimension "over all" is given; this is important since it suggests to the workman the entire length of the piece without obliging him to perform the arithmetical calculation himself. The draughtsman must, of course, be careful in marking this "over all" dimension, making sure that it tallies with the detailed figures.

"Press fit" indicates the accuracy required in turning that portion. "Machine steel," of course, gives the material to be used. "1 off" means that only one such piece is required for a single machine.

EXERCISE 30.

Figs. 77, 78, and 79 show the construction of a piston, piston-rod and packing-rings of a steam-engine. Draw an outside elevation of the piston and rod together; also a sectional view on the plane marked "A," perpendicular to the rod and along the face of one ring, not cutting the latter!

Special Instructions: The views suggested are evidently practice-drawings only, and would not be used for a working drawing. In making them the student must understand the views shown.

The rod is easily seen to be round from the section placed between the imaginary breaks. The different lengths and diameters are also evident. The screw-thread

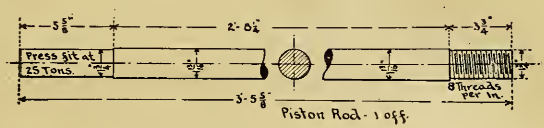


FIG. 77.

extends a distance of 3¾″ on a diameter ot 1¾″, the pitch being marked because it is not standard for that diameter.

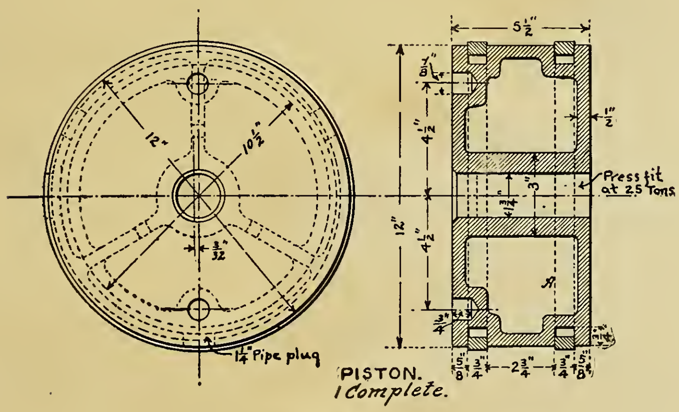


FIG. 78.

The other end of the rod fits into the 1¾″ hole through the piston, and should be turned to "press fit."

The piston is, of course, cylindrical, 12″ diameter and

5½″ thick. The section shows that it is cast hollow, while the other view indicates three webs dividing the hollow interior into three spaces. The part marked "1¼″ pipe plug" is supposed to fill a hole left for core-prints in casting the piece; two other marks placed similarly with reference to the other hollows are for the same purpose.

Two holes, ⅞″ diameter and ¾″ deep, are bored into

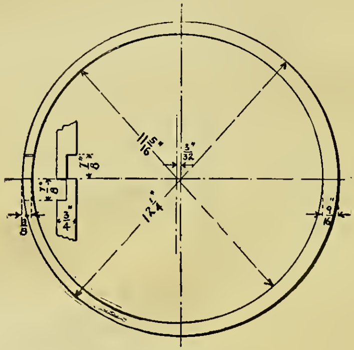


FIG 79.

the end of the piston on opposite sides of the center and 4½″ away; as seen from the end-view, the parts where these holes are bored are made thicker for some distance around, no special dimensions being given.

The hole for the rod is provided with a countersink; the part of the rod that fits into that hole is ⅛″ longer than the thickness of the piston; this ⅛″ is forced down to fill the countersink.

Two grooves, $\frac{3}{4}''$ wide and $\frac{5}{8}''$ from each end, are cut into the piston to a depth of $\frac{3}{4}''$; the $10\frac{1}{2}''$ circle shows the bottom of these grooves. The metal behind these grooves is strengthened to an amount that can be judged from the drawing.

The "packing rings" are shown in the detail drawing (Fig. 79) better than by a section or by dotted lines. The outer $12\frac{1}{4}''$ circle and the inner $11\frac{5}{16}''$ circle are struck from centers $\frac{3}{32}''$ apart, the outer circle being placed concentric with the piston in Fig. 78. The ring is thus $\frac{3}{8}''$ at the thinnest part, and $\frac{9}{16}''$ at the thickest. At the former a half-lap cut is made, extending a distance of $\frac{7}{8}''$. (As the rings are sprung into position in the grooves and are then forced into the $12''$ cylinder, the half-lap will close up a distance of about $3.1416''/4 = .785''$, reducing the open circle diameter $12\frac{1}{4}''$ to a diameter $12''$). Only one ring is represented, dotted in the circular view of Fig. 78, to avoid a confusion of lines; the other ring would be placed with the joint on the opposite side of the piston, so as to diminish the leakage of steam.

"2 off" means that two of these rings are to be made from this detail sketch. Similar phrases are sometimes used to denote the same thing: thus, "one of this," "one like this," "one a set," are such instructions.

Attention is called to the position in which the packing ring is placed so as to give a good view; in the section-view the joint of one ring is shown dotted, the other ring being cut off with the front portion of the piston. The section-plane passes through one of the webs, but the metal of the web is not represented in section, because such cross-hatching would obscure the view.

The outside elevation is omitted, since nothing new would be shown by it.

EXERCISE 31.

Fig. 80 gives outside and sectional views of a connecting rod. Make special detail views of the various parts, marking all dimensions!

SPECIAL INSTRUCTIONS: Figs. 81–86 give these details in parallel perspective; the student should not copy these views, but should show plan and elevations of all the parts.

In order to understand the drawing let us consider one end at a time, beginning with the cross-head end (left). We notice, first, that there are several pieces held together; to take them apart we must first take out the so-called "cotter" and "gib" (Fig. 81). The taper marked applies to one side each of the cotter and the gib. Next we slip off the U-shaped "strap" (Fig. 82) being careful, in our drawing, to place the holes for the cotter and gib at the proper distance from the ends. The box (Fig. 83) consists of two "brasses," provided with flanges; the front view shows that they do not touch, the space being left for adjustment.

The rod proper (Fig. 84) fits against the box and presses the same against the cross-head pin, when the wedges are tightened; clearance spaces, left between the cotter and the strap, and also between the gib and the rod, are clearly indicated in the elevation; hence the hole through the rod should be carefully placed at the right distance from the end of the rod.

The right-hand end fits over the crank-pin. The brasses on that side (Fig. 85) are kept in position by a wedge (Fig. 86) pressing with its tapering side against an equally tapered surface in the box-end of the rod, while its other surface is forced against the left-hand side

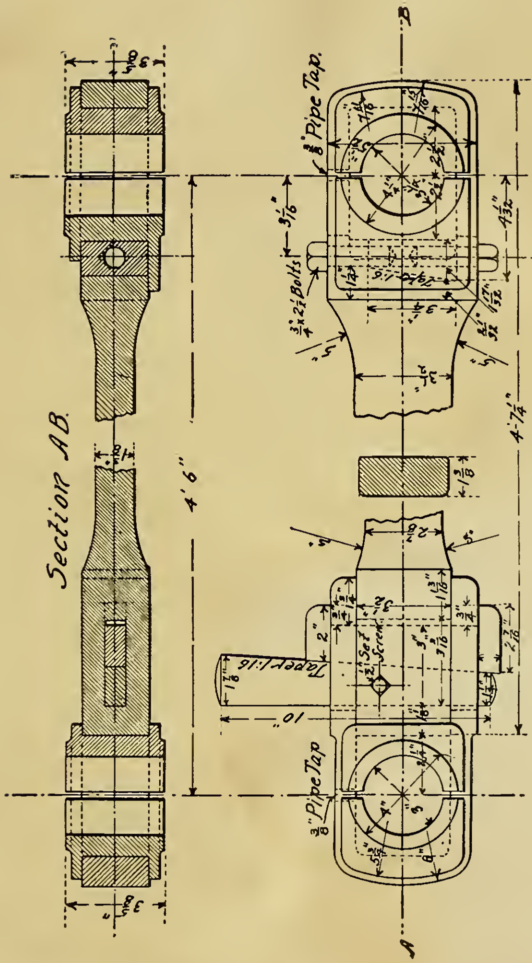


Fig. 80.

of the brass. This wedge contains a tapped hole, into which screw the bolts used for tightening the device.

The left-hand brass on this end should be studied,

FIG. 81.

because it is designed so as to slip into the box-space in the rod; hence the dimensions of the flange on one side

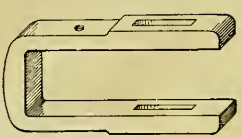


FIG. 82.

are small enough to allow it to enter after the other brass and the crank-pin are in place; the wedge must also be

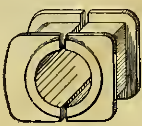


FIG. 83.

placed against the brass before it is introduced into the box-space of the rod. If the two tap-bolts are now passed through the holes in the rod and are screwed into the wedge, the latter is tightened and presses the brasses against the crank-pin.

The rod itself (Fig. 84) is rectangular in section, the

Fig. 84.

larger dimension increasing from 2⅞″ at the left, gradually to 3½″ at the right, the thickness remaining constant. The ends of the rod must correspond exactly to

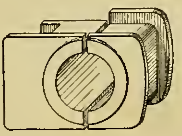


Fig. 85.

the size of the strap, the brasses, and the wedge. The ½″ screw hole in the side is for a set-screw to "lock" the cotter in any position, by pressing against it. Places

Fig. 86.

with "pipe tap" marked are intended for the reception of oil-cups. Attention is called to the form of the holes through which the tightening bolts pass in the crank-end of the rod; they are not circular, but are bounded by two straight lines and two semicircles. This is necessary to allow for the adjustment required.

The length of the rod, technically speaking, is the distance between the centers of the cross-head pin and crank-pin respectively; in the drawing this length is shown by the distance from the center of the circle formed by the brasses at one end to the center of the circle at the other end.

The original drawing shown (Fig. 80) is called the "assembled," "general," or "connected" view, while the drawings of the parts are designated "details." "F all over" means that all the surfaces are to be machine-finished to the size marked. If only some of the surfaces are to be finished, then mark "F" or "X" on them. (The "X" mentioned is really a corruption of the letter "f.")

MISCELLANEOUS.

In the following chapter, additional instructions are given without illustration in any given case ; the student will at this stage of his work be able to appreciate the few hints and regulations summarized below.

VIEWS : In choosing the views to be taken, give preference to what may be called the natural positions, thus avoiding oblique and inverted views, and queer sections! Draw only as many views as are necessary to represent all the particulars of form and size !

In a symmetrical drawing two views may be easily combined into one : half may be shown in section and half in outside view. The center-line (dash and dot) remains as the boundary line between the two parts, or else an irregular line, sketched free-hand, may be introduced somewhat to one side of the center-line. Thus, the piston shown in Fig. 78 could be represented in that manner, half only being in section.

Let your drawings be clean, clear and concise ! If many particulars and dimensions are to be marked, it is better to make separate detail drawings than to attempt to crowd everything into a complicated general drawing.

Parts of the same machine that are intended to be made in different departments of a shop are usually detailed on separate sheets. Thus, the cast iron work is shown separately for the pattern-maker, who makes his own allowances for shrinkage and the like; the forge-sheet is designed for the blacksmith, and often the necessary additions are made by the draughtsman for fitting and finishing. Of course it is worth while to mark very distinctly any special instructions to the mechanic who is to work from the drawing.

DIMENSIONS: The dimensioning of a drawing is next in importance to the proper representation of the shape of the object; considerable attention should therefore be paid to this branch of the work.

1. The figures should be plain and easily read at a glance; they should not be too small or hidden in out of the way places.

2. The best place for the dimensions is outside of the drawing proper.

3. Place no dimensions on the center-lines, and none on the lines of the drawing itself!

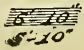
4. Mark the chief dimensions in the general view; repeat important dimensions in the different views!

5. Group the dimensions! That is, place together dimensions pertaining to the same part!

6. The dimension "over all" should be marked conspicuously!

7. If the distance required is not properly shown to scale in the drawing, and if it is decided that it is not worth while to change the whole design, you may mark the proper dimension as follows: "Make 5″." This means that the distance is to be 5″ irrespective of the size drawn.

If the design is changed and certain dimensions are to be altered, it is best to cross over the old figures without blurring them and to mark underneath the new and corrected dimensions.



8. In describing dimensions, take the following order: *a*, width; *b*, thickness; *c*, length.

METHOD: In drawing thick lines, hold the pen in the proper position and be especially careful to clean the outside of the pen, if you wish to prevent blotting!

Where accurate construction is required, all shade-lines should be omitted.

In no case should the draughtsman use the corners of the triangles or the ends of a scale, because they are sure to be worn off and hence inaccurate.

It will be found extremely expeditious to perform in groups all operations that require the same setting of an instrument; thus, a series of equal circles and arcs should be drawn together; lines having the same thickness, lines running in parallel directions, curves of similar forms, figures and letters, should all be inked together, wherever possible.

COLORED INKS: Before blue-prints were introduced, it was customary to confine the use of black ink to the lines representing edges on the object itself, to the figures, the arrow-heads, and to the lettered instructions; red ink was used for center-lines and dimension-lines and offset-lines; blue ink also had a special function in some drawing rooms. If colored ink is used, the distinction between full, dashed, dotted and composite lines need not be observed so rigorously.

SPECIAL PRACTICE: It is impossible to give any particular instructions that are recognized in all drawing-rooms. Each factory is a law unto itself, and hence we find diversions of many kinds. Thus full lines, long dashes, very short dashes, dashes and dots are used indiscriminately for dimension-lines, offset-lines, center-lines, hidden line~ · different methods of representing material by special sectioning are employed (vid. Fig. 87, recommended to the Am. Soc. of Mech. Engineers, but not adopted) ; views are arranged contrary to the rules laid down in these pages ; special short-cuts and conventions are used.

The intelligent draughtsman should have no difficulty in adapting himself to what is considered the best prac-

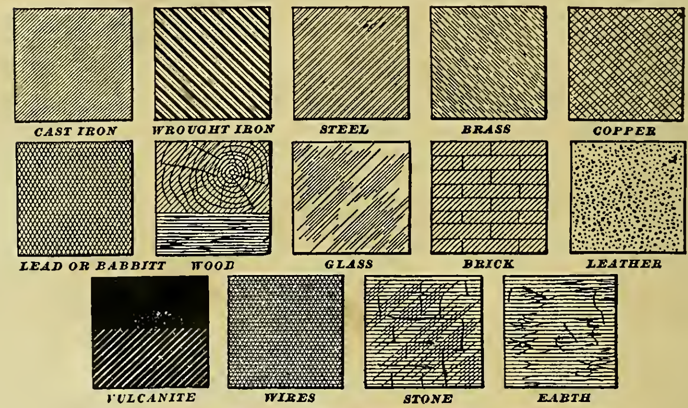


FIG. 87.

tice in his immediate surroundings. It is hardly worth while to temporize concerning these minor details, inasmuch as unanimity of practice, no matter how desirable, will not be possible until *all* the technical schools and *all* the technical societies decide on some definite standards.

LETTERING : Lettered instructions are often clearer than an elaboration of detail ; e. g., the words "knurling" or "tapped" are more explicit than the correct drawing.

The name of the whole machine, as well as that of the special part, should be marked on each sheet. The name or initials of the draughtsman and the date are likewise important. The date of any alteration made should also be recorded.

TRACING : The drawing is to be inked on the tracing cloth or tracing paper ; and, therefore, the sketch on the ordinary paper need not be finished in ink. The smooth side of the cloth is preferable, but takes the ink badly unless rubbed with powdered chalk.

The sensitive paper can to-day be bought so cheaply that it is not worth the draughtsman's while to prepare it himself. An exposure of from 5 to 15 minutes suffices, and a good wash in clean water " fixes " the drawing. The blue-print usually distorts the proportions, since the paper contracts unequally.

ADDITIONAL INSTRUMENTS : The instrument market is well supplied with a variety of instruments, some of which are extremely useful, while others are chiefly ornamental. A reference to the trade catalogues will be found instructive. A few of the more important drawing tools are enumerated below :

The *Beam Compass* is a straight rod to which are attached separate pin, pencil and pen points ; it is used for drawing circles of a radius too large to be spanned by the ordinary compass. Extension pieces fastened in the latter instrument to lengthen its span are a very awkward, heavy and inaccurate device.

The *proportional dividers* are extremely useful to the copyist in enlarging or reducing drawings ; the draughtsman proper, however, has little use for them.

The *protractor* can be replaced by a table of slopes and tangents.

The *prick-point* is excellent for very accurate work; the points to be marked are pricked into the paper, and a small circle is pencilled around each to help to identify the point.

The use of *sponge-rubbers* is advised for cleaning an inked drawing.

The *double triangle*, the *tetrangle* (four-sided), are modifications of the ordinary triangles, and have the advantage of giving a greater variety of inclinations and angles.

Section-liners are made in various forms, to insure an accurate spacing of the lines used for sectioning. A good substitute may be improvised by driving nails into a wood rule at a distance apart a little greater than the side of the triangle. By alternately sliding the rule on the T-square, or straight-edge, and of the triangle on the rule, equal spacing is obtained.

INDEX.

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Barrus. Boiler Tests: Embracing the results of one hundred and thirty-seven evaporative tests, made on seventy-one boilers, conducted by the author. 8vo. Boston, 1895. $5.00

Colyer. A Treatise on the Working and Management of Steam Boilers and Engines. Shaftings, Gear, and Machinery. 2d edition, revised and enlarged. 12mo. London, 1892. $1.50

Courtney. The Boiler Maker's Assistant in Drawing, Templating, and Calculating Boiler Work and Tank Work, with rules for the Evaporative Power and the Horse Power of Steam Boilers, and the Proportions of Safety Valves, and Useful Tables of Rivet Joints of Circles, Weights of Metals, etc. Revised and edited by D. K. Clark, C.E. Illustrated. London, 1898. (Weale's Series.) $0.80

The Boiler Maker's Ready Reckoner. With examples of Practical Geometry and Templating, for the Use of Platers' Smiths, and Riveters. Revised and edited by D. K. Clark. 3d edition. London, 1890. (Weale's Series.) $1.60

Davis. A Treatise on Steam-Boiler Incrustation, and Methods for Preventing Corrosion and the Formation of Scale; also a Complete List of all American Patents issued by the Government of the United States from 1790 to July 1, 1884, for Compounds and Mechanical Devices for Purifying Water, and for Preventing the Incrustation of Steam Boilers. 65 engravings. 8vo. Philadelphia, 1884. $2.00

Foley, Nelson. The Mechanical Engineer's Reference Book for Machine and Boiler Construction, in two parts. Part I., General Engineering Data. Part II., Boiler Construction. With 51 Plates and numerous illustrations specially drawn for this work. Folio, half mor. London, 1895. $25.00

Horner. Plating and Boiler Making. A Practical Handbook for Workshop Operation, including an Appendix of tables by A Foreman Pattern Maker. 338 illustrations. 12mo. London, 1895. $3.00

Hutton. Steam Boiler Construction: A Practical Handbook for Engineers, Boiler Makers, and Steam Users. With upwards of 300 illustrations. 3d edition. 8vo. London, 1898. $6.00

Munro. Steam Boilers: Their Defects, Management, and Construction. 2d edition enlarged, with numerous illustrations and tables. 12mo. London, 1892. $1.50

Roper. The Steam Boiler: Its Care and Management. With instructions for increasing the Efficiency and Economy, and insuring the Durability and Longevity of all classes of Steam Boilers, Stationary, Locomotive, Marine, and Portable. With Hints and Suggestions and Advice to Engineers, Firemen, and Owners of Steam Boilers. 4th edition, revised. 12mo, tuck, mor. Philadelphia, 1897. $2.00

—— **Use and Abuse of the Steam Boiler.** Illustrated. 11th edition. 12mo, mor. tucks. Philadelphia, 1897. $2.00

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Rowan. On Boiler Incrustation and Corrosion. New edition, revised and enlarged by F. E. Idell. 16mo, boards. New York, 1895. $0.50

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Thurston. Manual of Steam Boilers: Their Designs, Construction, and Operation. For Technical Schools and Engineers. 183 engravings in text. 6th edition, 8vo. New York, 1898. $5.00

—— **Steam Boiler Explosions.** In Theory and Practice. Illustrated. 2d edition, 12mo. New York, 1888. $1.50

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Goodeve. On Gas Engines: with Appendix describing a Recent Engine with Tube Igniter. 12mo. London, 1887. $1.00

Robinson. Gas and Petroleum Engines. A Practical treatise on the internal combustion engine. With numerous illustrations. 8vo. London, 1890. [Reprinting.]

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Anderson. On the Conversion of Heat into Work. A Practical Handbook on Heat Engines. 3d edition. Illustrated. 12mo. London, 1893. $2.25

Box. Treatise on Heat as Applied to the Useful Arts, for the use of Engineers, Architects, etc. 8th edition. 12mo. London, 1895. $5.00

Larden. A School Course on Heat. Illus. 12mo. London, 1894. $2.00

McCulloch. Elementary Treatise on the Mechanical Theory of Heat and its application to Air and Steam Engine. 8vo. New York, 1876. $3.50

Maxwell. Theory of Heat. New edition, with Corrections and Additions by Lord Rayleigh, Sec. R. S. Illustrated. 12mo. New York, 1897. $1.50

Peabody. Thermodynamics of the Steam Engine and other Heat Engines. 8vo. New York, 1898. $5.00

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Towne. **A Treatise on Cranes,** descriptive particularly of those designed and built by the Yale and Towne Manufacturing Company, owning and operating the Western Crane Company, including also a description of light hoisting machinery as built by the same makers. 8vo. New York, 1883. $1.00

Weisbach and Hermann. **The Mechanics of Hoisting Machinery,** including Accumulators, Excavators, and Pile-drivers. A Text-book for Technical Schools and a guide for Practical Engineers. Authorized translation from the second German edition by Karl P. Dahlstrom. 177 illustrations. 8vo. New York, 1893. $3.75

ICE-MAKING MACHINES.

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