PRACTICAL HINTS

FOR

DRAUGHTSMEN.

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PREFACE.

THE leading object of this treatise is to explain various modes of representation which are in many cases better than the precise ones of projection; for mechanical drawings often convey false impressions by too close adherence to the truth, and become obscure by being too exact.

All working plans are made for the purpose of showing what is to be done, and should exhibit the maker's knowledge, not of the refinements of theory, but of the requirements of practice. They are to a considerable extent beyond the jurisdiction of the rigid laws of descriptive geometry, and to that extent they lie within the domain ruled by plain common-sense. This fact is often not duly impressed upon the mind of the student; which is unfortunate, because no one thing is more fatal to practical efficiency than the strict formalism which subordinates the end to the means, allows no exercise of discretion, and binds the draughtsman to the observance at all times of inflexible rules.

It is hoped that the reader will escape such thraldom in either constructing drawings to scale or making sketches; both of which are illustrated by a number of practical examples of approved methods.

The addition of the chapter on drawing instruments is justified by the fact that in most treatises upon drawing, mere descriptions or illustrations are given, with nothing to guide the novice in distinguishing the good from the bad; and also by the reception of numerous letters of inquiry, from those desirous of information upon this very important and much-neglected matter.

C. W. MACCORD.

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PRACTICAL HINTS FOR DRAUGHTSMEN.

CHAPTER I.

WORKING DRAWINGS DEFINED. RULES OF PROJECTION DEFIED. CLEARNESS AND CERTAINTY THE ESSENTIAL REQUISITES. ILLUSTRATIVE EXAMPLES.

1. **Mechanical Drawings** are made in the main according to the principles of projection, which constitute a part of the science of descriptive geometry; but even a perfect acquaintance with that science will not of necessity or of itself make its possessor an efficient practical draughtsman, no matter how skilful he may also be in the manipulation of the instruments.

The object of working drawings is, *to show the workman what to make and how to make it*, which they should do in a distinct and unmistakable manner. And it is amply proved by experience, that drawings may be in themselves absolutely correct, and fail nevertheless to accomplish this object. The meaning may be there; but if it is not clearly and forcibly expressed, the work is radically bad, though never so finely executed.

Other things being equal, he is the most valuable man in the drawing office who can with the least outlay of time and labor produce such work as will enable the construction to be carried forward with certainty and dispatch. To this end his drawings must be easily read and well arranged; it will not suffice, as many suppose, that they be correct as studies of projection. It is well that the draughtsman should be master of the principles of his science, but in the practice of his art he should not be their slave; perspicuity is as important as accuracy, and judicious defiance of rigid rules will often result in a gain in this respect as well as in a saving of time.

2. It is mainly to such irregularities that the following pages are devoted; supposing the reader to be already familiar with the laws of projection, it is proposed to show how and when those laws may be broken with impunity.

This cannot be done wholly by laying down specific instructions; it would be difficult if not impracticable so to classify exceptions as to deduce from them rules that would cover the whole ground, or be of universal application. New devices and new combinations are continually arising, special features of which may require special treatment, and there is constant occasion for the exercise of judgment and ingenuity.

The general plan adopted therefore is, to illustrate the matter by a number of examples selected from practice, explaining in each case the particulars in which it violates the strict canons by which so many submit to be fettered, and showing the advantages thereby secured.

3. For the guidance of the workman, there are required *detail drawings*, showing the construction of the different parts, and a *general plan*, showing these parts assembled, or put together.

If a machine is to be manufactured by the quantity, with interchangeable parts, a separate drawing is usually made of each individual piece, large or small, with all the dimensions accurately marked in figures. And the idea is to some extent prevalent that this is always necessary, and that the draughtsman's work is not complete without it.

But the term detail drawing is also used in another sense. Suppose the case of a constructing engineer designing the machinery for a steamship. He must furnish to the building shop, certainly, drawings from which the engines can be made as he plans them, but in his detail sheets he need not dissect so minutely as above indicated. A drawing, for instance, of the connecting rod, showing it keyed together as when in place, is as properly a detail drawing as though the shank, brasses, gibs, keys, straps, bolts and set-screws were disconnected and scattered broadcast over the paper. It is indeed a better working drawing, since with a fraction of the labor it explains more, showing both how the different pieces are made and how they are related to each other and fitted together.

4. It is in this broader sense that we use the expression *detail* drawings, as distinguished from what might more accurately be called the *detached* drawings mentioned above. The former are always necessary, whether the others are required or not; he who can make them can always make the others on occasion; and the more skilfully he can make them,—the greater his ability to *condense*, and to reduce the number of sheets,—the more efficient will he be, and the more expeditiously can he "put work in hand" in cases of emergency. They are in effect both "general" and "detail" drawings for the members of the machine, and are all that the designer need furnish to the constructor, who is at liberty to follow his own judgment as to further subdivision.

5. General plans, as above stated, are intended to show how the various parts of the machine are arranged and put together as a whole.

They are too often made upon the assumption that in each view it is necessary to introduce every piece that would be visible, partially or wholly, in the corresponding view of the machine itself. The effect is sometimes more confusing than explanatory, and in the majority of cases a great many minor details can be omitted not only without detriment, but with a great gain in perspicuity. This is more especially true as to bolts and nuts—the fastenings must of necessity be shown in the detail drawings, and usually a repetition of them is worse than useless.

6. No rule can be laid down as to how many views should be made, or what views they should be; these points must be decided by common-sense and good judgment, aided by experience. But there can be no greater mistake than the too common deduction from a study of projections, that a front view, an end view and a top view are always required and always sufficient. No pains should be spared to make drawings clear, and the meaning unmistakable: this must be done at any cost, but all beyond that is superfluous and a waste of time. If one view will answer the purpose, so much the better; but if a dozen are necessary, they must be made. Before sending out a sheet, let the draughtsman satisfy himself that the representations and annotations are such that by following them *the workman can make what is intended, and cannot make anything else;* then, and not until then, his working drawing is complete; and in a practical sense correct, no matter how numerous or flagrant the violations of theoretical formality.

7. As before intimated, it is not easy to frame a definite code of laws for guidance in breaking those of another code; because the circumstances which justify the breaking of any one may vary in different cases. But it is possible to indicate some, at least, of the articles of that code, the ignoring of which is likely to be most frequently recommended. Among these are the following:

(1) That all the things shown in any drawing must be represented in all the different views, as preserving the same absolute and relative positions.

(2) That everything visible in one view of a drawing, must also be shown in every other view.

(3) That in sectional views the cutting plane should be parallel to the paper.

(4) That everything should be shown in section, through which the cutting plane in a sectional view would pass if indefinitely extended.

(5) That everything beyond a cutting plane should be shown.

8. And in opposition to these in their order, the following general principles may be enunciated:

(1) That in each separate view, whatever is shown at all should be represented in the most explanatory manner.

(2) That which is not explanatory in any one view may be omitted therefrom, if sufficiently defined in other views.

(3) The proper position of a cutting plane is that by which the most information can be clearly given.

(4) It is not necessary to show in section everything which might be divided by a cutting plane.

(5) Whatever lies beyond a cutting plane may be omitted when no necessary information would be conveyed by its representation.

9. In what follows, no attempt has been made to observe the above order in arranging the illustrative examples. That could not well be done, for the reason that in many of them more than one of these principles is involved, as well as others of less moment not here enumerated. They are accordingly given, rather in the order of the relative importance of the special methods of representation which are recommended.

And these, it is proper to say, are such as have not only received the sanction of the highest authorities, but have stood the test of trial and of use; for they have been continuously employed, during years of practice, in the preparation of drawings from which machinery to the value of many millions has been constructed.

PRACTICAL APPLICATIONS OF THE FOREGOING PRINCIPLES.

EXAMPLE I.

10. We select as the first subject for illustration, an upright cylinder fitted with a cover. A vertical section of both, and a top view of the cover, are given in Fig. 1.

Let it be noted, first, that in the top view the *bolt-holes* only are shown, the nuts being omitted.

The section is by the plane *ab* through the axis; which passes through a bolt at *d* on the right, and midway between the bolts *c* and *e* on the left.

But it is to be noted, secondly, that the sections of both cylinder and cover are made continuous, as though there were no bolts, and the bolts themselves are then dotted in; and, thirdly, that on each side, the centre line of the bolt is placed *at its actual distance from the edge of the flange.*

11. One important precept is here illustrated, an exception to which is very rarely met with, viz.: *The continuity of masses of metal should not be broken for the purpose of showing fastenings.*

In this example, the conveying of the idea of the construction as a whole depends more upon showing at a glance the thickness and the breadth of each flange, than upon any other one thing.

The cylinder and the cover must be fastened together, and the bolts are made for that purpose; but being subordinate, they should not be made unduly prominent.

A very common and very faulty method of drawing the sectional view in such cases is shown at *A*, upon which the makers insist, because, they say, the bolt lies in the plane of the section.

But the effect is very much as though the bolt thus brought into notice were the important feature, and the cylinder and its cover made chiefly for the purpose of using it. Still worse, two little portions of the flanges are thus isolated, like islands lying off a headland, and the main idea is neither as clearly nor as forcibly expressed as it is in the method recommended, while the labor is greater.

Again, it is very common to see the *nuts* carefully drawn in the top view; and projected to their corresponding positions in the side view, as also shown in *A*. The whole of this is a sinful waste of time. If the kind of bolt, its size, its true position in the flange, and the form of the nut, are shown in the section, there is no use of showing the projections of the nuts beyond the plane of the section; and if the number and arrangement of the bolt-holes is shown in the top view, there is no use of drawing the nuts.

12. A vast amount of time and labor are in many cases worse than wasted in just such apparently small items as these; and we wish to impress upon the reader this maxim, *that each view should be made to tell all it can, but nothing should be put in it which does not tell something worth knowing.*

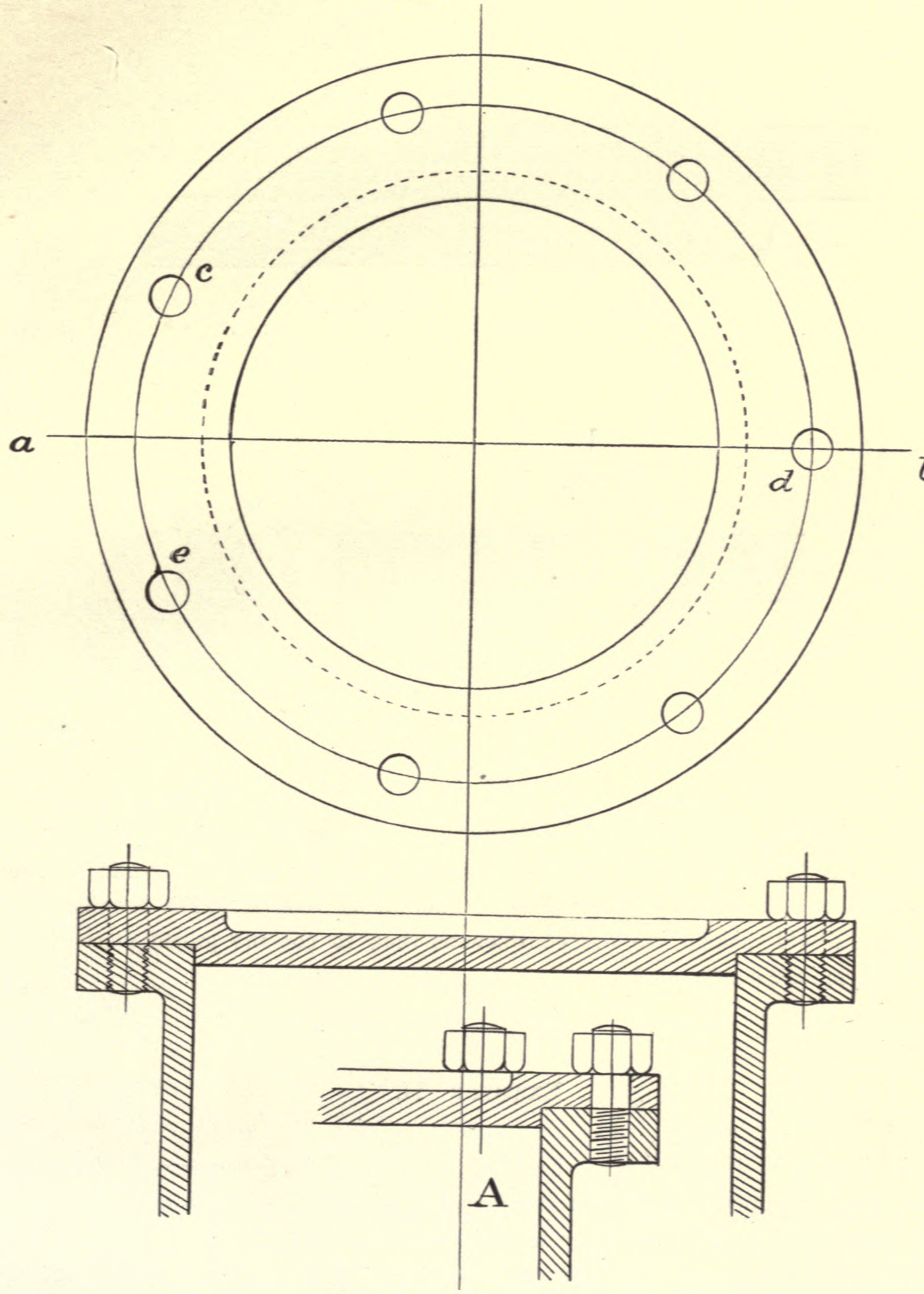

FIG. 1.

Another illustration of the disadvantage of giving too great prominence to the fastenings is given in Fig. 2, which shows one arrangement of a double-riveted joint between two sheets of wrought-iron. If the rivets are shown in full, each sheet is cut into three detached parts in the sectional view, and the extent of the lap, which is the feature of prime importance, instead of being made to catch the eye at the first glance, is thrown quite into the shade, and requires a little mental arithmetic for its full realization.

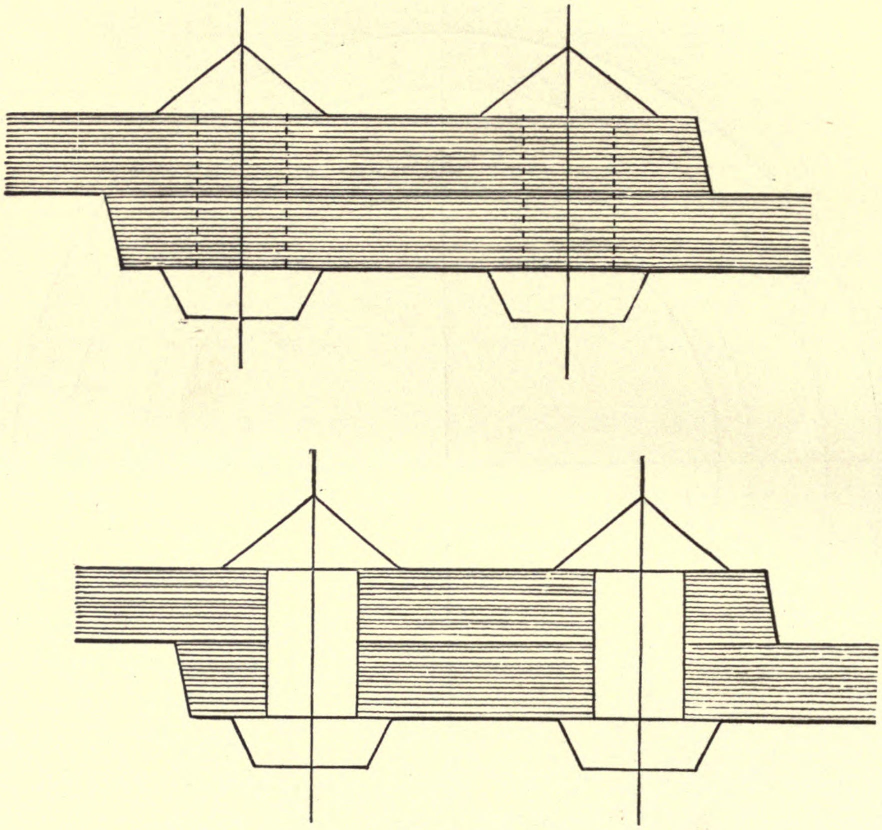

FIG. 2.

It must also be recollected that in studying a drawing, the designer himself will find it greatly to his advantage if the relative proportions of the parts are made as conspicuous as possible: and in the representation of bolted or riveted joints nothing could be devised which would make them *less* conspicuous than to cut the joined pieces into little bits, in the style here condemned.

EXAMPLE II.

13. In Fig. 3 is shown a vertical cylindrical box, divided transversely for a part of its depth by a web upon which are formed two hubs, through which bolt-holes pass, and provided with four lugs perforated for holding-down bolts.

In the top view the lugs are disposed diagonally with reference to the main centre lines; this being the position which the piece is to occupy when in place. In order to show the true diameter and thickness of the cylinder in the section, the cutting plane should pass through *ab*: in that case it would also cut the dividing web.

And too often the position is meekly accepted, the web cut through and the outlines

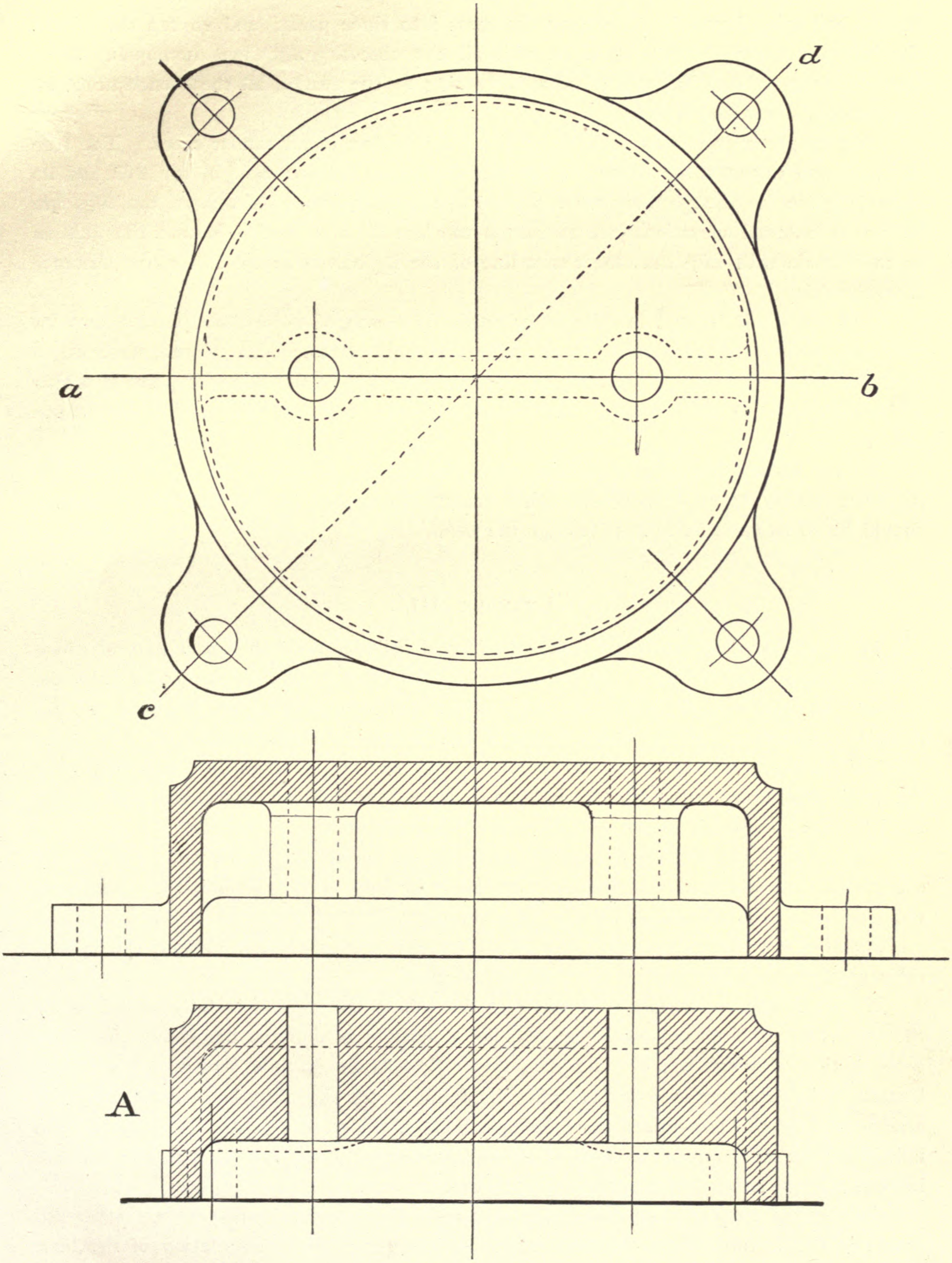

FIG. 3.

of the bolt-holes drawn in, separating the mass into three parts; and to cap the climax the lugs are projected and dotted in, with all the obscurity attendant thereupon. As a good specimen of bad judgment, and as a warning to the reader, all these enormities are represented in section *A*.

The proper course is to back the bull off the bridge, in all similar cases. The true diameter and thickness *are* shown in the section, but an outside view of the web and its hubs is given, as though they were beyond the cutting plane. Moreover, the lugs are shown in external elevation, just as though the line *cd* were turned around the axis so as to coincide with *ab*; thus the centre line of the lug-bolt is shown at its true distance from the axis.

And the result is, that in spite of, or rather by reason of, these discrepancies between the views considered as studies of projection, a much clearer idea of the structure is conveyed by the sectional view, while the relative positions of the different parts is shown in the top view, so that with the two before him the workman cannot find an excuse for an error.

It may be stated as a general rule, then, that *a web parallel to the paper should not be shown in section*, even though a plane cutting other parts which must be so shown, should be so situated as to pass through the web.

Example III.

14. Fig. 4 represents a portion of a horizontal cylinder upon the lower part of which is cast a supporting bracket. This bracket consists of a foot-plate, connected with the cylinder by two vertical webs at right angles to each other. At the end of the cylinder a hub *H* is formed, which is drilled and tapped for a drain-cock.

This example illustrates, as did the preceding one, the maxim just laid down, for the vertical plane *xy* really cuts through both the hub *H* and the longitudinal web of the bracket;—but neither is shown as being cut, in the longitudinal section.

The form of the foot-plate, and the positions of the holding-down bolts, are clearly shown by a horizontal section through *ab*, placed directly under the bracket. Similarly, the form of the hub is shown by a section through *cd*.

Again, the transverse cutting plane *wz* is so situated as actually to split the central cross web, which accordingly is *not* drawn in section.

Notice is also to be taken of the fact that since the hub *H* is fully explained by the two views of it above mentioned, it is not dotted in behind the bracket in the transverse section, although the cylinder flange is. This flange is thus shown, not so much because it is necessary in order to define its form, as for the purpose of exhibiting the arrangement of the bolt-holes; there being a bolt on the vertical centre line, opposite the hub, the hole for it must be tapped, as indicated by dotting *two* circles, one for the bottom and the other for the top of the thread.

This being an important consideration, and a thing which could not be otherwise shown in these views, affords another reason for omitting the representation of the hub, which if introduced here would obscure this bolt-hole by the confused mass of dotted lines.

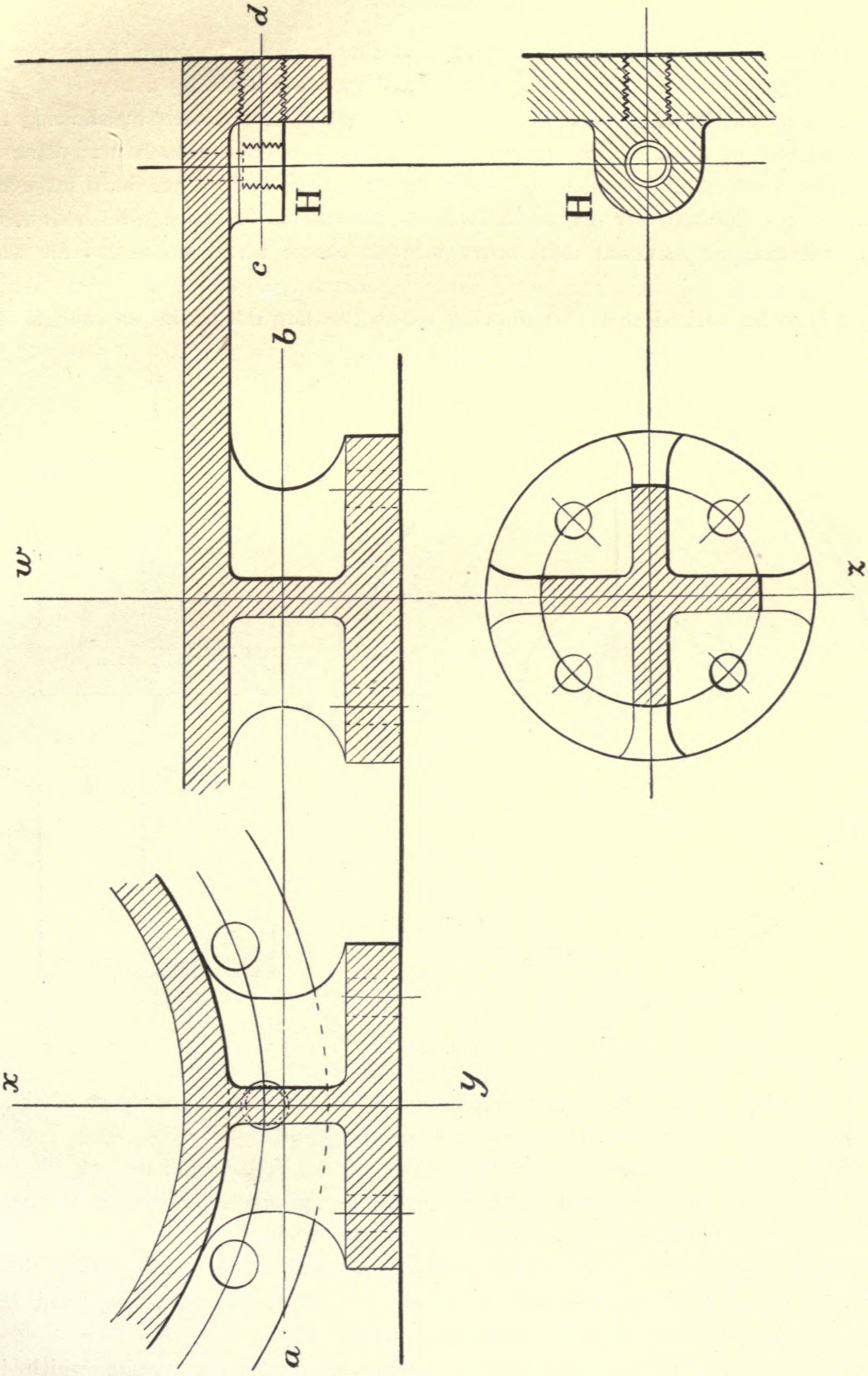

FIG. 4.

Example IV.

15. The next illustration, Fig. 5, is that of a simple pulley or drum, consisting of a rim connected with the hub by a web, and secured upon the shaft by a key.

In the end view, the shaft and key are brought out most distinctly by showing them in section, as though cut off flush with the end of the hub by the transverse plane *ab*.

The other view is in the main a section by the plane *xy*. The shaft, however, is not shown as cut through, nor do we think it ever would be unless it were hollow, as is sometimes the case, or possessed some other peculiar feature which would call for such a course.

But it is to be noticed that this drawing shows the key dotted in as though it lay

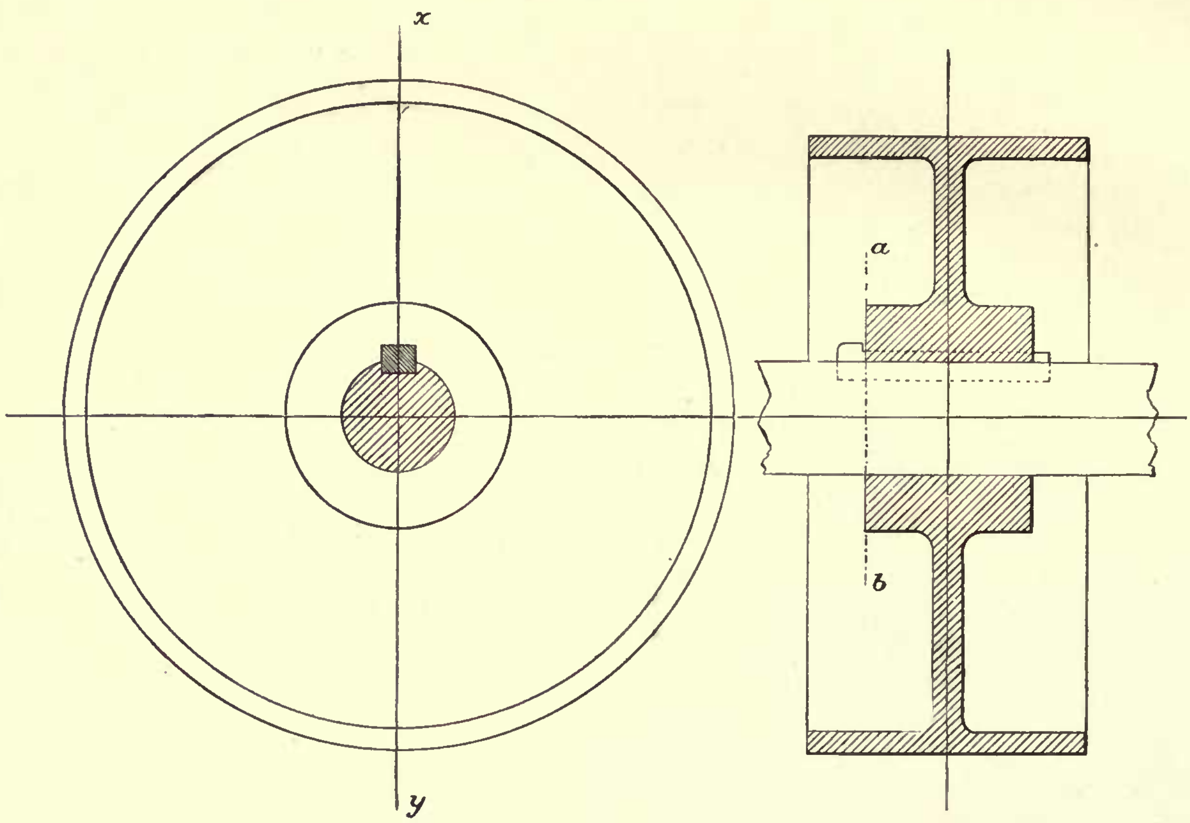

Fig. 5.

beyond the cutting plane. A very common fault is, to draw the upper part of the key, which is outside the shaft, in full, as well as the shaft itself.

In that case the sectioning of the upper half of the hub terminates at the upper outline of the key; and the effect is that the whole appears lop-sided, as though the hub were eccentric, or thinner on one side than on the other.

It may be urged that this can lead to no error, since all is explained by the end view. The truth of this argument we freely admit; but there can be no good reason why that false impression should be conveyed by either view.

And we shall have occasion to illustrate in other examples the maxim, which is of no small moment sometimes, that *if a thing be symmetrical, it should be represented as symmetrical in every view if possible.*

EXAMPLE V.

16. Fig. 6 shows two hand-wheels, one having four straight arms, the other three curved ones.

It is particularly to be noticed that the longitudinal section is the same for both, and if *xy* be regarded as the cutting plane, it does not represent the appearance of either. But it does show exactly what the workman wants to know, viz., the forms of the sections of the rim and of the hub, the thickness of the arms at the hub and at the rim, and the sizes of the side fillets at the ends of the arms. In the case of the wheel with the three curved arms, a true section by the plane *xy* would show the upper side of the rim and of the hub with an unsightly and unsymmetrical excrescence, which, if not unintelligible as well, would at best convey no information except that the

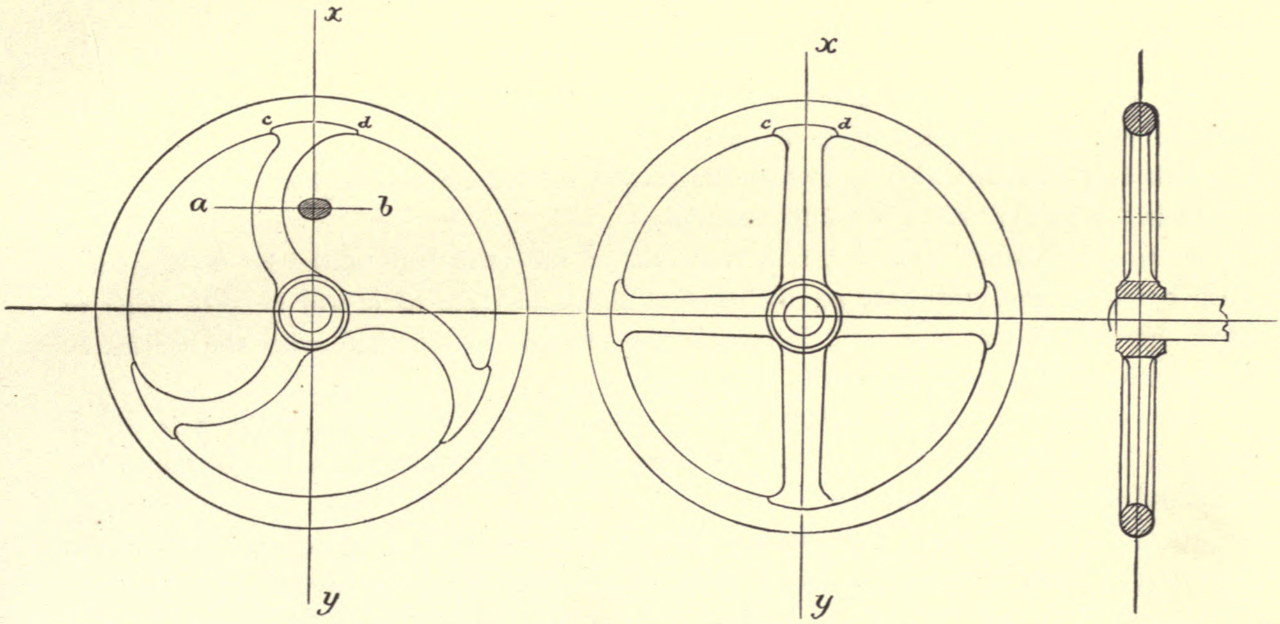

FIG. 6.

draughtsman knew how to make the section: and the same may be said of the foreshortened projection of the lower arm and its junction with the rim.

In the case of the other wheel, a true section by the plane *xy* would at first glance convey the impression that hub and rim were joined by a continuous web. Closer study would rectify the error if the outlines of the hub and the rim were completed by dotted lines: still, that is not a good reason for making a drawing which can possibly convey such an idea, when it is easier to make one which can not.

17. The form of the arms is explained by making a transverse section of one of them, as by the plane *ab*; this section should, as shown, be drawn at one side of the arm, and not directly upon it, as is sometimes done; a device apparently founded on the idea of "revolving the cutting plane about its trace into the plane of projection," but a very ineligible one: for it has precisely the appearance which would and should be presented if the arm had a piece cast upon it, projecting from the front side—such a piece could not be more effectively brought into notice than by sectioning it.

The fact that the arms, by reason of their thickness, do not join the rim entirely on the inner circumference, but encroach upon its breadth, is indicated in the front views by the curves *cd.*

These, it is to be observed, are not curves of *intersection* properly so called, but indicate the lines of tangency of the fillets formed at the ends of the arms and the surface of the rim.

Strictly, then, they are imaginary lines, and some worshippers of the Correct insist that they ought not to be drawn. But such evidences of things not seen will often define most clearly the substance of things hoped for: and when they will it may be as well to let them. In the present instance, and in others which will be met with subsequently, it is beyond dispute that the introduction of these imaginary lines, if drawn finely, is fully warranted by the service they render in making the drawing intelligible.

Example VI.

18. Fig. 7 represents a crank, crank-pin, and a portion of a shaft, including a journal between two collars formed upon the shaft.

This is introduced here in further illustration of the use of imaginary lines, as being a case in which they are absolutely essential.

It is a well-known fact that if a crank-pin of the form here shown be made with a sharp corner at the inner face *ab*, like that at the outer face *cd*, it will be very liable to break there; and that the same is true if the junction of the shaft with the collars be made sharp, even if the angle be a right angle.

The liability to accident is very greatly reduced by rounding out, or, as it is called, "filleting," these angles, as shown in the drawing, the vertical lines being joined to the horizontal ones by quarter-circles.

If, as often happens, circumstances prevent the use of a long journal, it becomes necessary, in order to secure as much cylindrical bearing surface as possible, to make the fillets as small as may be; and very small ones are far better than none at all.

In such a case, especially if the drawing be on a small scale, the very existence of the fillet might be overlooked, were the line of tangency not drawn in. This renders such an oversight impossible, no matter how fine the line; and the finer it is the better the drawing will look.

Tastes differ in regard to the question whether this addition improves the appearance of a drawing; but the draughtsman whose experience includes the breaking of a shaft in consequence of its omission, will thereafter vote in the affirmative: the safe side is always the most comfortable.

It may then be stated that in general, though the rule has exceptions, *the fillet lines should be drawn in outside views of surfaces of revolution.*

This crank is shown as secured to the shaft by two keys, the positions of which are shown in the end view, which also defines the cross-section of the keys. The side view can convey no further information except as to the length of the keys; and this is as well done by showing only one of them, while it is clearer to place it in that view at the top of the shaft, which is accordingly done.

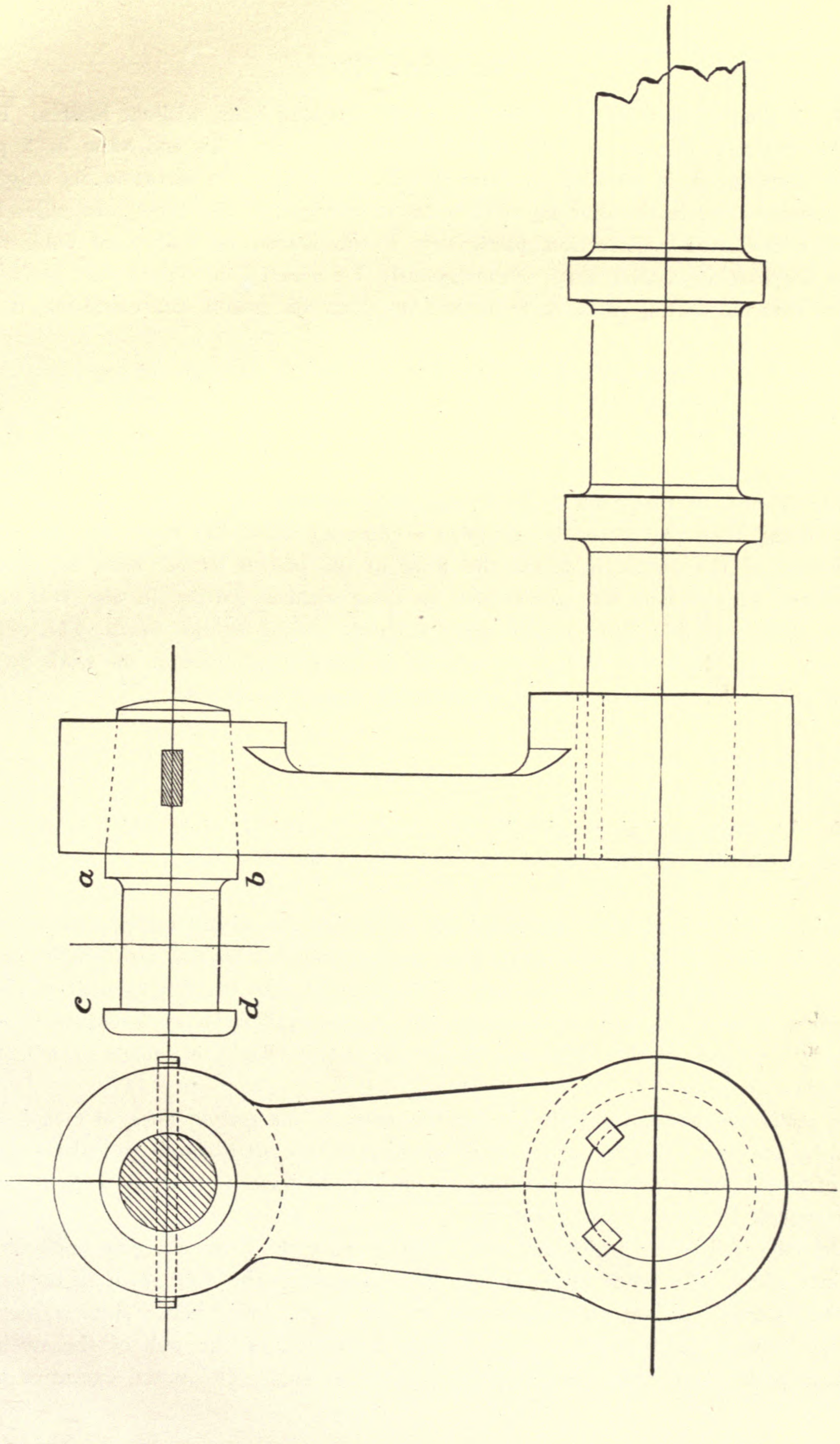

Fig. 7.

Example VII.

19. A simple pillow-block, consisting of bed, cap, and bolts, without brasses. Fig. 8.

This example illustrates chiefly the selection of views. An end view of a pillow-block is often made, in addition to those given: but if it be in elevation, its only effect is to consume time in the drawing office without saving it in the shop. In pillow-blocks of more complicated construction, particularly if the brasses be hollow, or babbitted, or both, *a longitudinal section* may advantageously be added; in which case it is to be observed that the dotting in of parts beyond the plane of section, and concealed, is better omitted.

In the present instance, the side and the top view are all that are required. And in the latter, only the bed is shown; the cap and the bolts are removed.

It is sufficiently indicated by the lines in the side view, that the form of the cap corresponds to that of the top of the bed; and the bolts, with their heads and nuts, are fully defined in that view. By leaving these things out in the top view, we not only save the time that would be occupied in drawing them, but make the view clearer: as the form of the pocket in which the head of the bolt is buried, must be dotted in at any rate, which could not consistently be done without dotting in also the head of the bolt, and over this again would come the full outline of the nut. The effect, as a moment's consideration will show, would be to confuse this part of the work by superposition of lines. *Judicious omission is preferable to correct superfluity.*

Example VIII.

20. An ornamental air-vessel, with an opening in the top, into which is screwed the plug *P*. This plug is itself bored out and tapped for the insertion of the pipes *T*, *T*. Fig. 9.

This exhibits a legitimate expedient for combining the advantages of a sectional view and an elevation. The general appearance and proportions of the air-chamber are best shown by an outside view, but the form of the interior, and the arrangement of the plug and pipes, if merely dotted in, would not be as distinctly seen as if drawn in section. The body and neck of the vessel are round; the bottom flange is square, as indicated by the shadow lines.

In sectioning over an outside view in this manner, the section lines, or cross-hatching, *should be full, and not dotted or broken;* the effect of this last is simply to make a confused mass of dots, while the effect which sectioning should have is that of a light tint, not heavy enough to overpower the outlines.

Dotted parallel lines which are close together have in all cases a very unpleasing and indistinct effect. In order to avoid this in representing the tube *T*, it is to be noted that the external outlines only are shown, except at the lower part. Here a section of the pipe is made, *in full lines*, just as though a portion of the wall of the air-chamber had been broken out, thus permitting the pipe to be seen. The actual execution of that

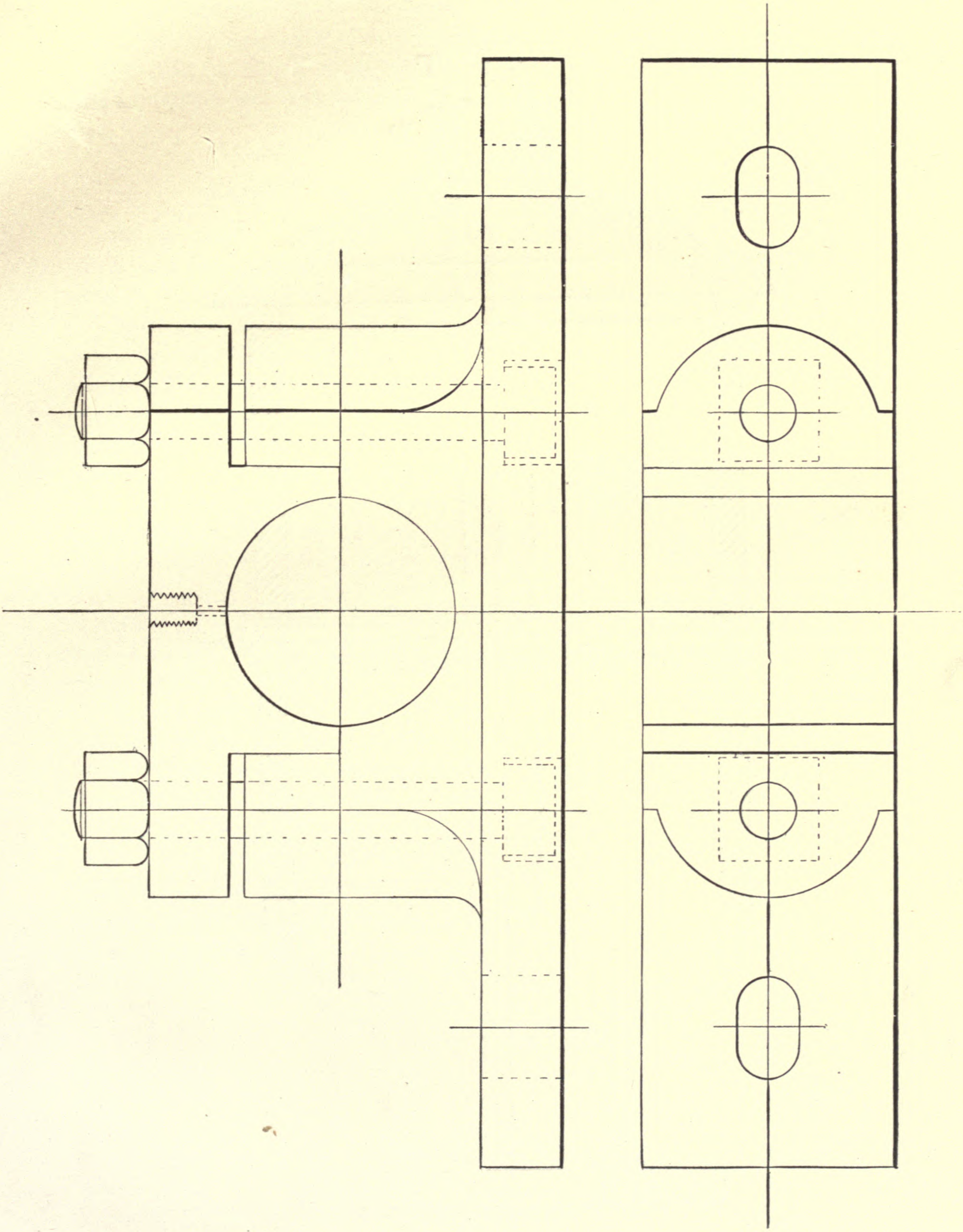

FIG. 8.

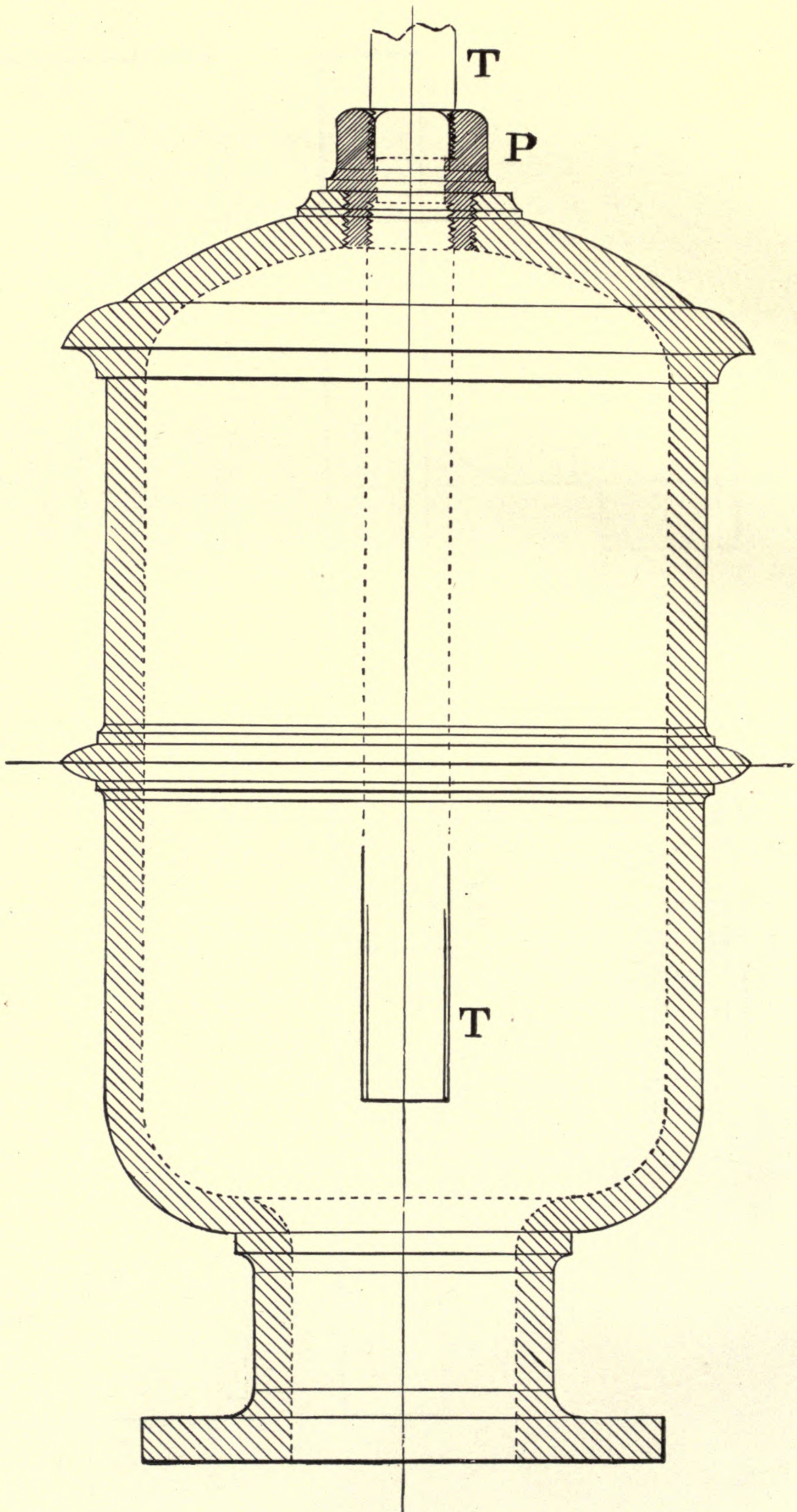

FIG. 9.

process is sometimes shown, by making a broken line representing the fracture; but in such cases as this, it would merely be hideous without any compensating advantage.

EXAMPLE IX.

21. A vertical shaft, Fig. 10, upon which is pinned a collar *C*, supporting a piece *B* which turns freely on the shaft.

This again illustrates the advantage sometimes gained by sectioning over an outside view. Both *B* and *C* are of such form that outside views of them are needed, or at least best suited to the circumstances. But an outside view *only* of these three pieces in place would be ambiguous, since it would appear exactly the same were *B* and *C* made in one piece. This ambiguity is entirely removed by sectioning over the outlines, which nevertheless explain the outward forms just as clearly as if it were not done.

A very common but very objectionable practice in such cases as this is to make an end view also, showing all the pieces in place: with the result of showing nothing clearly. The only reasonable method is to make an end view of each piece by itself, as in the figure: though in the case of the collar, *C*, it may be rather an advantage than otherwise to show the shaft within it, if, as is here done, it be drawn in section.

And in general, it is to be recollected, the fact that in one view a number of parts are shown as put together is not a sufficient, and often is not even a good, reason for preserving that arrangement in other views,—*in which they should be separated if that shows them more clearly.*

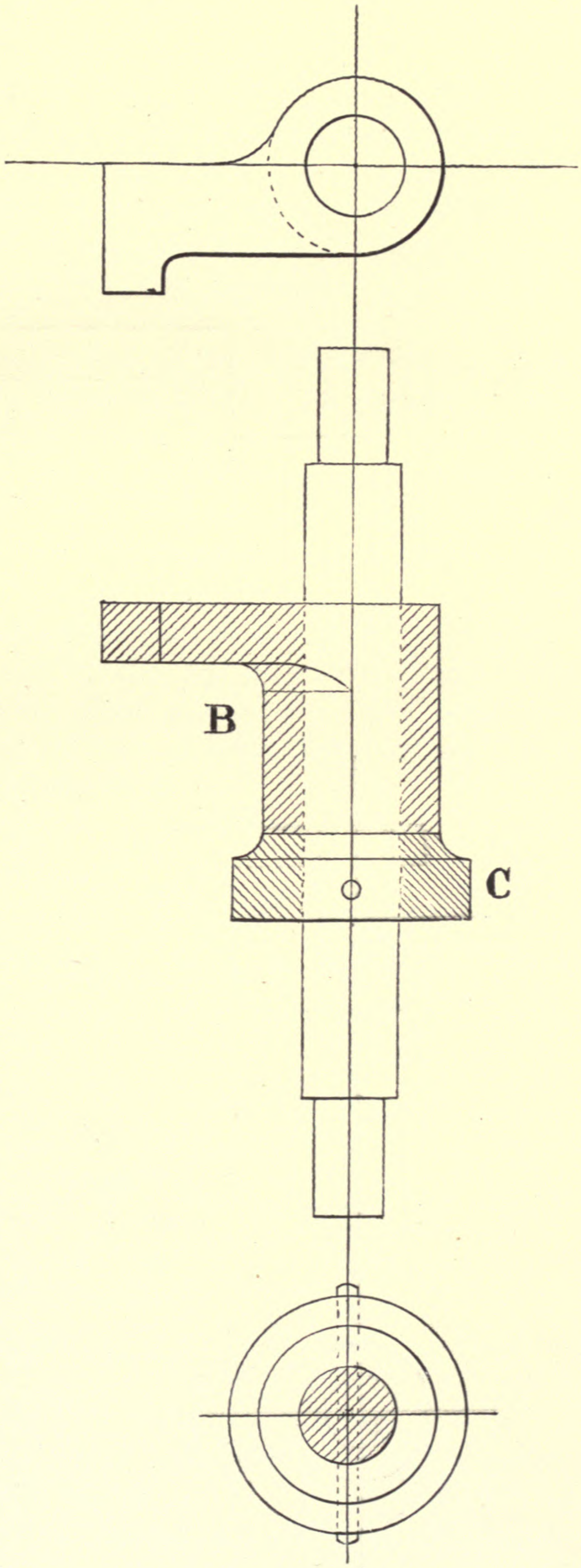

FIG. 10.

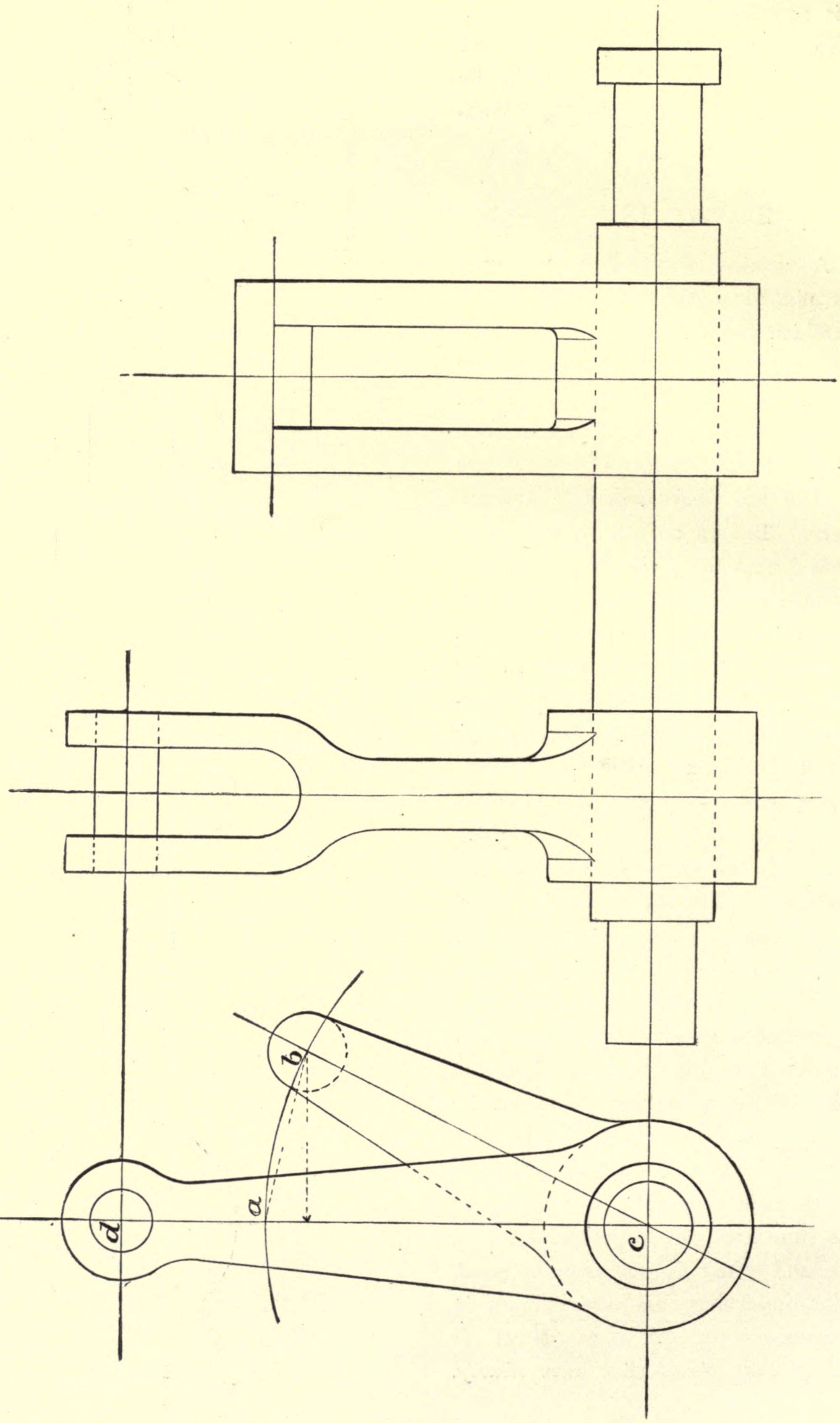

Fig. 11.

EXAMPLE X.

22. A rock-shaft, with two levers which are not in line with each other, is shown in Fig. 11.

This combination differs from the preceding in the particular, that no confusion is caused by superposition of lines in the end view, although the parts are there shown as put together; which indeed is necessary in order to define the relative position of the two levers.

This is best done, as shown, by placing one of them so that its centre line is vertical, as *cd*; the side view of that one will then correspond to it as a true projection. The centre line of the other lever is drawn in the end view at the correct angle with that of the first; which angle is best defined on the drawing by describing an arc, *ab*, through the centre of the second pin, about *c*, the axis of the rock-shaft, and marking in figures either the length of the chord *ab*, or else the *offset*, or horizontal distance of *b* from *cd*, or both.

But in the side view the formation of this second lever is best shown, not by projecting it in its inclined position, but by drawing it as though it also were vertical. *Thus the true dimensions are seen in both views;* which is essentially more explanatory than it is to exhibit the same relative position of parts in both views, whenever, as is the case here, some parts would thereby be foreshortened.

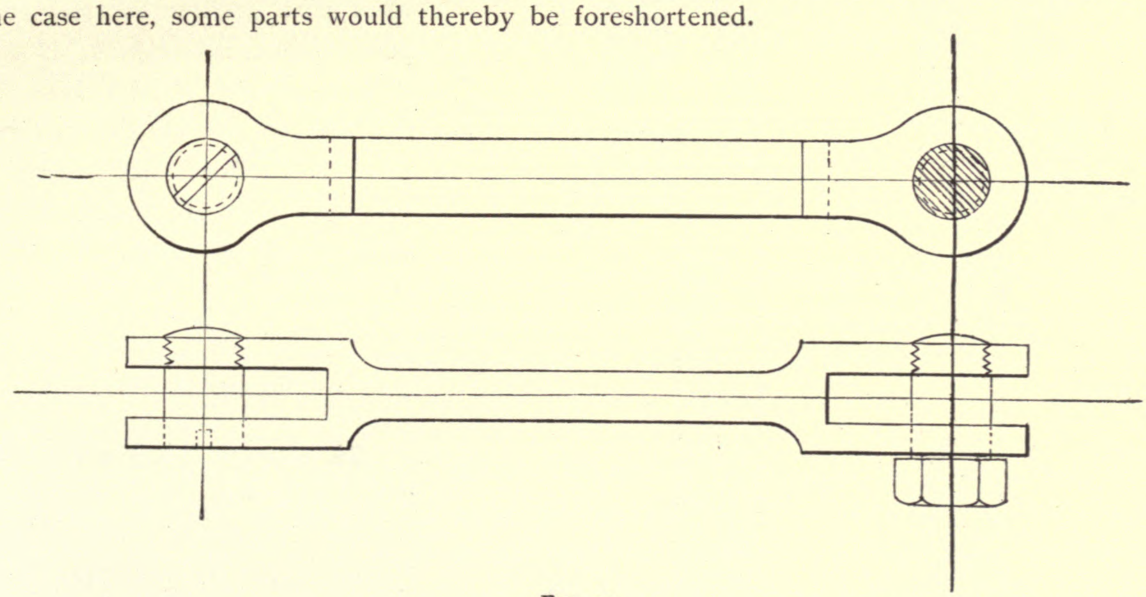

FIG. 12.

EXAMPLE XI.

23. A simple link with a jaw at each end, Fig. 12. The pin at one end is slotted for a screw-driver, that at the other end being a tap-bolt.

The tap-bolt being intended solely to serve the purpose of a pin, must neither bind the jaw nor be liable to work loose. Its head must therefore not touch the outside of the jaw, and accordingly, in the side view, it is limited by a line *just far enough from the jaw to show daylight between them.* And that it may stay in place, the thread *bottoms*, just as in the case of a standing bolt; as shown by the abrupt termination

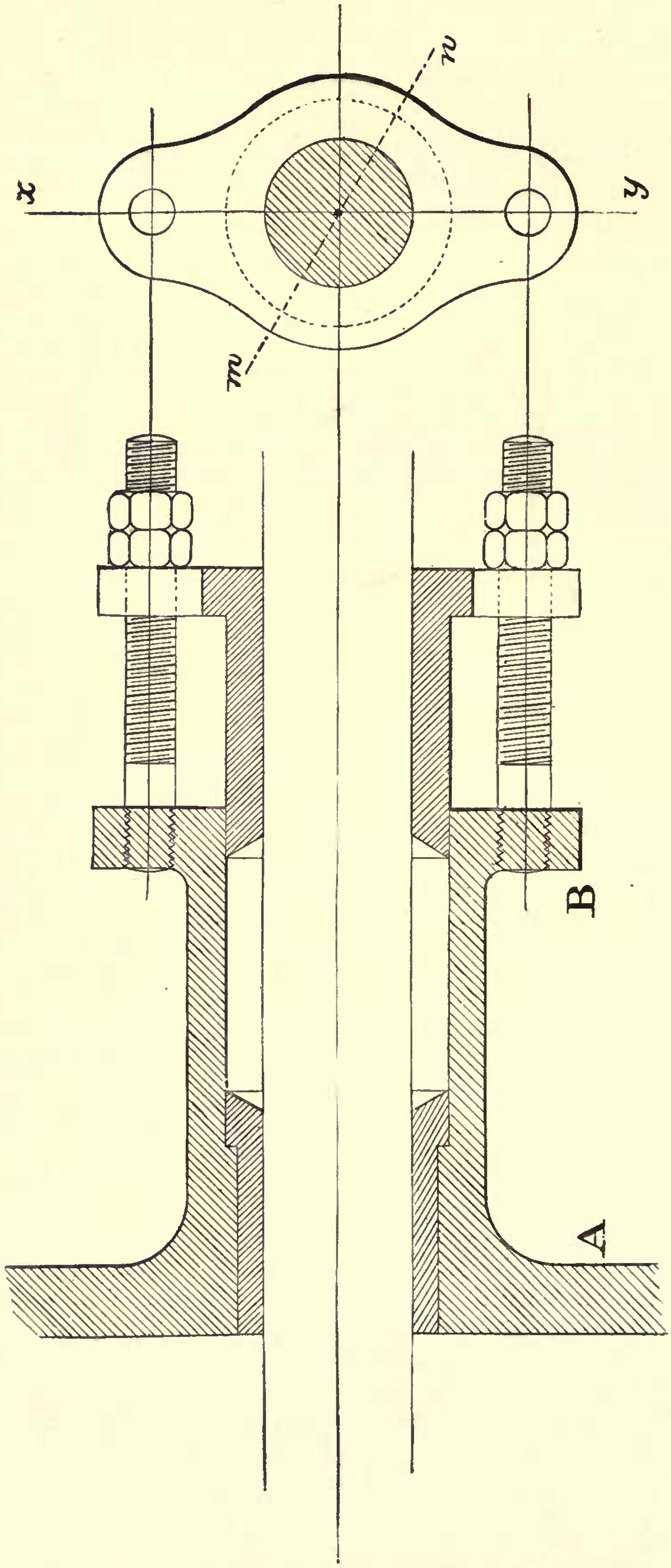

Fig. 13.

of the thread at the face of the jaw. The hexagonal form of the head being fully shown in the side view, the pin is best shown in the other view in section, as though cut off flush with the jaw.

The other pin also must be screwed in till the thread bottoms: in the side view the true size of the slot is shown; that is to say, the slot is supposed to be *perpendicular to the paper*, as it always should be, for the simple reason that it thus shows more clearly what is intended. In the other view it should be placed in whatever position will make it most conspicuous. Just what that position is, may depend upon circumstances; if possible to avoid it, the sides of the slot should not be parallel to either centre line,—and in this case they are drawn at an angle of 45° to each.

Example XII.

24. A stuffing-box, with gland and bolts, Fig. 13. This stuffing-box is cast as part of the cylinder-head *A*, and has a circular flange *B*, in which are fixed two standing bolts, which pass through lugs formed on the gland.

This drawing is made on principles in direct opposition to those of strict projection. In the first place, the cylinder-head and the stuffing-box itself are shown in complete section, the standing bolts being drawn as in Ex. I.

Now, if a true section were made by the plane *xy* through the gland, (which is too often perpetrated,) no one could tell, by looking at that section, but that the gland itself had a large circular flange, as well as the stuffing-box, which might very easily be, and often is, the case. But here, the gland is furnished only with two lugs, which toward the centre spread out and merge into a stiffening ring, or narrow flange, formed at the outer end of the gland.

That this may be distinctly kept in view even while examining the sectional drawing, the lug is there shown in elevation, while the body of the gland is shown as though a section by the plane mn were turned about the axis into the plane of the paper.

And it should be shown in the same way exactly, whether the bolts are actually on the vertical line or not; the required position of the gland being shown in the end view.

Example XIII.

25. A valve and valve-seat for a water-pump, Fig. 14. The valve consists of an india-rubber disk into which is sprung a central eyelet of brass, bored out to slide freely on a sleeve which supports the valve-guard that limits the lift of the valve; the whole being held in place by a bolt passing through the sleeve and guard, and also through the central hub of the seat.

We have here another case in which the sectional view is constructed, not to exhibit a knowledge of projections, but to convey information by any means which will do it clearly.

The valve-seat is a grating, circular in outline and having a central hub from which arms radiate, as shown in the top view, where everything relating to the thickness and arrangement of the arms, the form and dimensions of the openings, etc., is made evident at a glance.

A second glance makes it equally evident that the regular proceeding dictated by the laws of projection, that is by making a vertical section through the plane xy, would make the other view very unsatisfactory and actually misleading: nor in fact is there any one plane which can be so passed as to render a true section by it very explanatory.

Accordingly, the sectional view is constructed as follows: the bolt is first drawn with the flat side of the square head parallel to the paper; the exterior lines of the hub are then drawn, so as to show its true diameter, next the inside and outside lines of the central ring of the grating, in which the inner arms terminate, then the inside line of the outer ring; thus the outer part only of this view is a "correct" section, such as is insisted on by extreme advocates of order and system. But *it tells its story*, and tells it more truly than it can be told by calvinistic observance of the letter of the law. The end justifies the means.

It is so obvious from these two views that the rubber valve is round, and also the eyelet and the sleeve, that it would be ridiculous to make end views of those pieces in a working drawing. A top view of the guard would be necessary—which is not here given, as the object of the illustration is simply to call attention to the manner in which the sectional view is constructed.

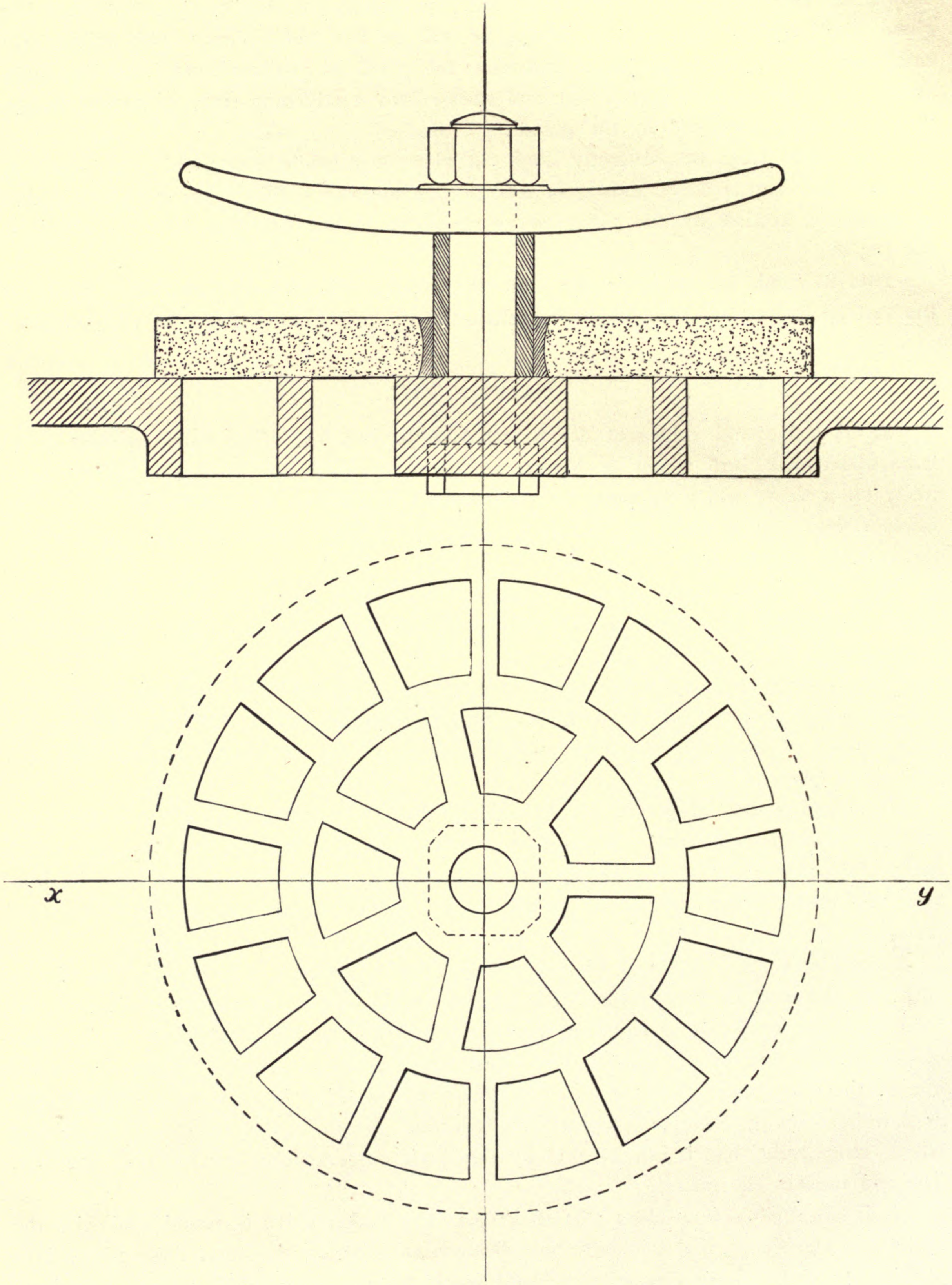

Fig. 14.

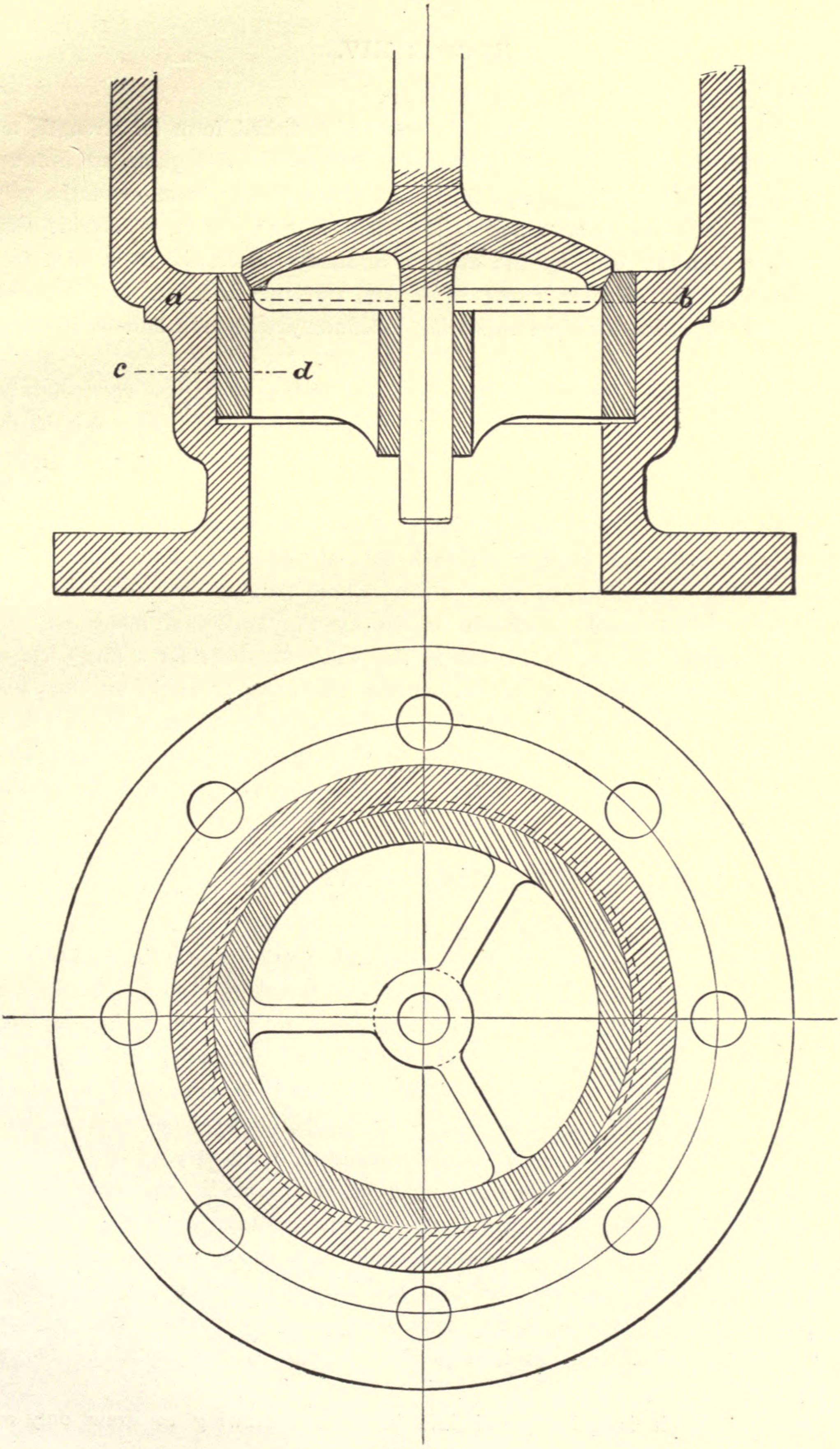

FIG. 15.

Example XIV.

26. Fig. 15. A poppet valve and valve-seat.

The valve, supposed to be of brass, is made of a dished form for strength, and cast in one piece with the stem, the lower part of which serves as a guide to insure correct seating when the valve closes. Large fillets are shown at the junction of the valve with the stem both above and below: and as the stem is best shown in outside view, thus indicating its cylindrical form by the absence of shadow lines, the fillet lines are drawn in. The body of the valve is shown in section, and the cross-hatching is continued a little way upon the stem, merely terminating indefinitely without a line of fracture being shown.

The valve-seat, also of brass, consists of a cylindrical, or rather very slightly tapering ring, tightly driven into the neck of the cast-iron valve-chamber. Within the ring, and forming one piece with it, is a spider of several arms, supporting a central hub through which the lower part of the valve-stem slides freely as a guide. This seat is also shown in section, the two sides being drawn as symmetrical, an outside view of one arm of the spider being made on each side of the centre line, without regard to the actual number or position of these arms. These particulars are defined in the top view, in which the valve-seat is shown as cut by the horizontal plane *ab*. But this plane is not extended to cut the metal of the valve-chamber; for a much clearer idea of the general proportions is given by cutting the cast-iron neck by the plane *cd*. In a shop drawing it would not be obligatory to make this top view at all, since it would practically suffice to write upon the longitudinal section the instructions about the spider, thus: "Three arms, $\frac{3}{8}''$ thick," and also the number of bolts in the lower flange of the chamber.

Example XV.

27. Drawing of Spur-Wheels. Fig. 16.

A spur-wheel if very small may be made by cutting teeth in a simple disk of metal, as in the change-wheels of engine lathes. But large wheels usually consist of an outer rim on which the teeth are cut, connected to the central hub by arms or a web. In general structure then they closely resemble the pulley and the hand-wheel, illustrated in Examples IV and V; like them they are best represented by an end view and a longitudinal section, and, as explained in relation to them, this section should be made so as of itself to convey the impression of symmetry.

In order to this, the rim should always be shown as if cut between two teeth, and the hub as if cut between two arms, if there be any, as in the figure, without regard to the number or relative positions, which are shown in the end view. In the larger of the wheels in Fig. 16, the hub has an external flange, and the rim an internal one; to which the ribs of the arms are joined by fillets. The section at *b b* shows the form of the arm, as in Fig. 6, and thus the structure of the whole is fully defined.

If time presses, it is quite permissible in a shop drawing to draw only a few of the teeth, as in the figure; this defines the contour, and for the rest it is sufficient to draw the pitch circle and the outline of the blank, and to mark in figures the number of teeth required.

28. The smaller wheel is introduced for the purpose of showing how two wheels in gear with each other are best represented in section. If cut by a single plane, which

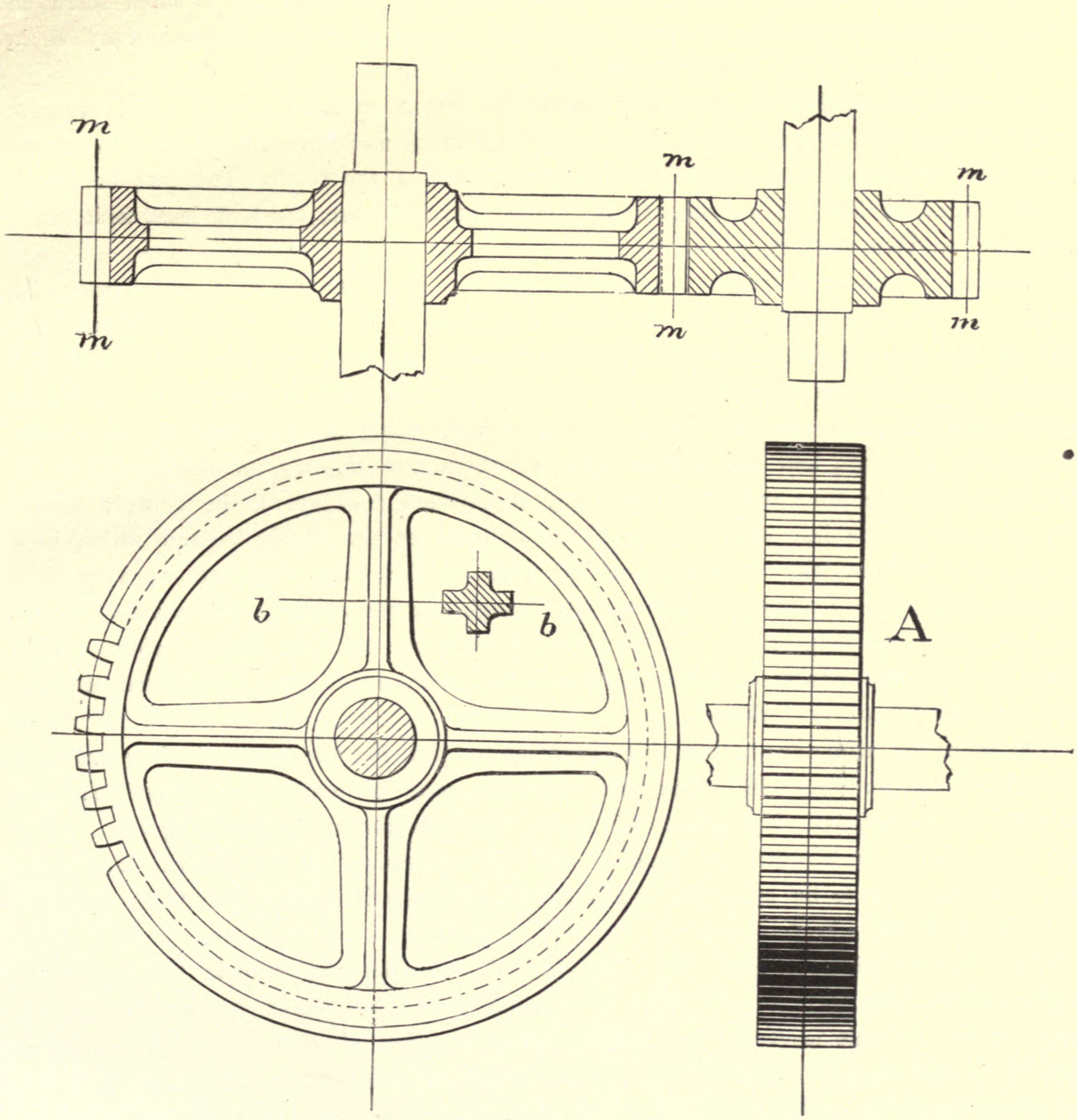

FIG. 16.

would pass through a tooth of one and a space of the other, the effect is indistinct and misleading. Instead of this, each is cut through a space, and the tooth of one is thus placed in front of a tooth of the other; the top of this latter tooth is therefore dotted, but the bottom of the space is shown in a full line, thus making the clearance obvious at a glance; and the junction of face and flank is indicated by drawing the hair lines *m m*, which are the outlines of the pitch cylinders.

The side view of a spur-wheel in elevation is very seldom introduced in a detail drawing, as the longitudinal section usually answers every purpose as well if not better, and is in any case necessary in addition to the outside view if the latter be made for any reason. Still it is occasionally desirable, and in a general drawing it may be necessary: so that a few words in regard to it are appropriate.

And it is to be stated, that there is no one thing, unless it be a small screw, in which the labor of making a correct projection is so absolutely thrown away as in such an outside view of a spur-wheel.

It is utterly ineffective, and it is hardly too much to say that the more accurate it is, the less will it look like a wheel; it will convey no impression of roundness, and very little of the existence even, let alone the forms, of the teeth. This last, indeed, is of little account, but the drawing, to be of any practical use, must at least look round and give an idea that there *are* teeth.

29. The manner in which this may be effected is shown at *A* in the figure. Beginning at the side from which the light is supposed to come, lines are drawn parallel to the axis, at first as if for shading a cylinder as large as the blank: when this has been carried a small distance, the tops of the teeth are indicated by drawing a double line for each, the line away from the light being made a shadow line. The breadth of the tops, and the spaces between them, are slightly increased as they approach the centre line, and again gradually diminished as they recede from it toward the position of the line of shade upon the cylinder of the blank, beyond which it is useless to continue the indication of the tops of the teeth, unless for a very little distance; and the remainder is finished as though merely shading the cylinder. Some practice, and good judgment, are required to produce the most satisfactory effect in any given case, as the treatment must vary in detail according to the size of the teeth as well as the size of the wheel.

It is to be understood that this operation is not for the purpose of *representing* the wheel, in the sense in which that word is used in general, and particularly in treating of projections. No attempt is made to make the lines indicating the tops of the teeth agree in number or position with the contours shown in the end view; and the whole is to be explicitly considered as an *indication* only, and not in any sense a drawing, of the wheel.

If occasion arises to show the side view of two wheels in gear in this manner, a slight modification is necessary, since the cylinders of the blanks are not tangent to each other; on this account, the above-described shading of that one whose engaging side is toward the light should begin at a distance from the axis equal to the radius of the *pitch circle*. This wheel should be first completed, and the other one afterward treated in the same manner: by which the encroachment of one upon the other due to the meshing of the teeth will be indicated in a manner which will make it intelligible without reference to the other view.

Example XVI.

30. Drawing of Bevel Wheels. Fig. 17.

The sectional view shows two bevel wheels in gear, the smaller one cut out of the solid, the larger one of sufficient size to require the web, which connects the rim with the hub, to be stiffened by ribs. If the wheel were larger, the connection would be by means of arms—in regard to the drawing of which the same methods would be followed as in the case of spur-wheels and pulleys.

The form of the tooth is in this case shown, not in the end view of the wheel, where it would appear foreshortened, but by making a drawing by itself of each end of the tooth, as *m*, *n*. This being done, the section itself would suffice for a working drawing if the wheel be solid or have a web only: and on a pinch it would answer when, as in this case, ribs are added, if definite instructions be noted on the section, as for example "Four radial ribs, ½″ thick;" for the shape of the rib is defined in the sectional view.

If arms are used, an end view is necessary, and the section of an arm should also be given as in Figs. 6 and 16. In no case is it *necessary* in the end view to show the teeth, a drawing of the blank only being required in order to make the wheel: but of course the work looks more complete if the teeth be drawn.

In making the section, the rim should be cut between two teeth; and the hub between two arms or ribs, as the case may be, as previously explained. And in this sectional view *the pitch cones should always be shown*, being drawn like the centre lines, either hair-lines if in black, or a very little heavier if in red ink or other distinguishing color.

31. In a working drawing, it is not advisable to draw the inner ends of the teeth, which are actually visible on the farther half of the wheel; for they would be foreshortened, and what is of more consequence, would rather diminish than increase the clearness of the drawing: in a general plan it may, however, be desirable thus to complete a wheel which may be shown in section, particularly if other objects beyond are partially concealed by it.

In regard to a side *elevation* of a bevel wheel, it is to be noted that since the forms of the teeth are actually shown, although foreshortened, a true projection not only does convey a correct impression, but nothing else will: with this mitigation, however, of the labor of making it, that it is not necessary to be rigidly precise in determining the contours of the ends of the teeth.

The preceding remark, it is to be understood, relates to the *representation* of the wheel in outside view. In many cases an *indication* will suffice, which is much less difficult to make, consisting of the frustum of the pitch cone, limited at the outer end by that of the normal cone, as shown at *A*. But this is open to the objection, which in particular cases may have some weight, that it is an exact representation of conical friction gearing.

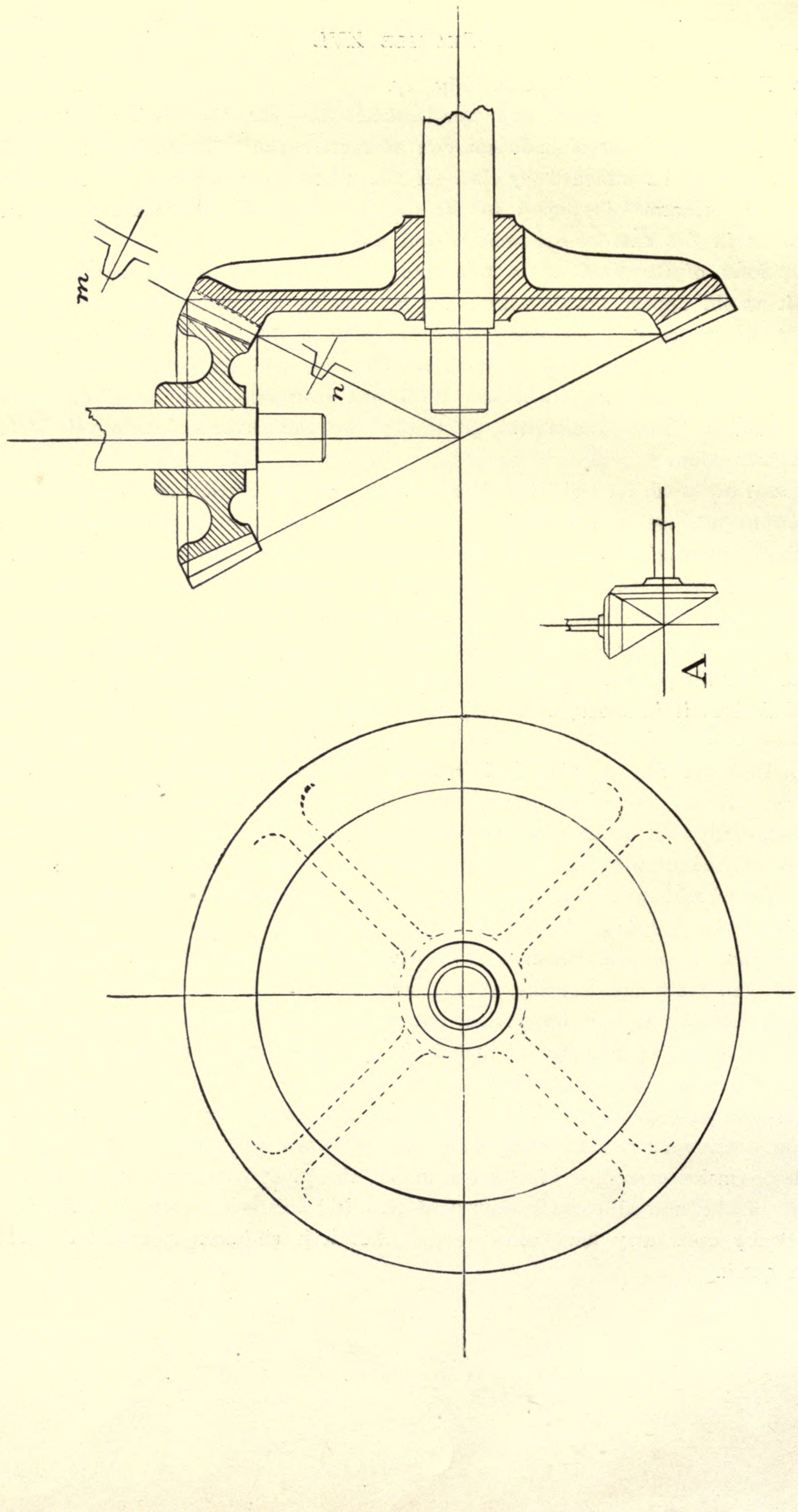

Fig. 17.

Example XVII.

32. Drawing of a worm and wheel. Fig. 18.

A worm-wheel, like a spur-wheel, is cut out of the solid if small, and if larger has arms or a web to connect the rim and the hub: and its longitudinal section is accordingly drawn in a similar manner, the rim being always cut between two teeth and the hub between two arms.

But in making the section of the rim, we have here a new state of affairs owing to the twist of the teeth: a plane through the axis would cut the teeth obliquely, making a very confusing representation. Consequently the drawing is made just as though the rim were sawn across along a line drawn in the middle of the space, making a twisting cut.

In connection with this section of the wheel, an end view of the screw is given, the correct distance between the centre lines being laid down as when in gear, as shown on the right in the figure. The screw is not shown in section in this view, but the spindle may be cut off in front of the screw, as shown; the engaging tooth of the wheel being thus concealed, is dotted in.

An end view of the wheel is of course needed; but in a working drawing this may in the main be a drawing of the blank, the required number of teeth being marked in figures, and the teeth themselves being shown only so far as to include those which engage with the screw, and one or two more on each side. In showing these teeth, the preferable method is to make a section of the rim by the plane *xy*, drawing in the contours of the teeth as thus determined, and also the parts of them which lie beyond the plane of section: these last should be true projections, but if there be a central web, it should not be shown as cut, and indeed even when there are arms, it is as well to show the inside line of the rim in full, and draw the arms as though they were beyond the cutting plane.

33. The side view of the screw should be a true projection and accurately drawn. This will of course hide a part of some of the sectioned teeth; and in order to give fuller and more exact information, there should also be given, as at *A*, a section of the screw, in which the pitch line of the rack thus formed is drawn, and the central section of the wheel should be repeated, drawing it as in gear with that rack; with an arc of its pitch circle also.

The above suffices for a shop drawing from which the worm gear is to be made. In a general plan, it will often suffice to make the side view of the wheel in section; but hardly so with the end view, and in many cases it is necessary to show both views in elevation.

Then there is nothing for it but to face the guns and carry the battery: as in the case of the bevel wheels, a drawing in projection is necessary to convey any reasonably good idea, if the scale be not very small: though as no measurements are to be taken from it, extreme precision in constructing the curves is not essential. On a very small scale, it may be admissible to make a mere indication by drawing

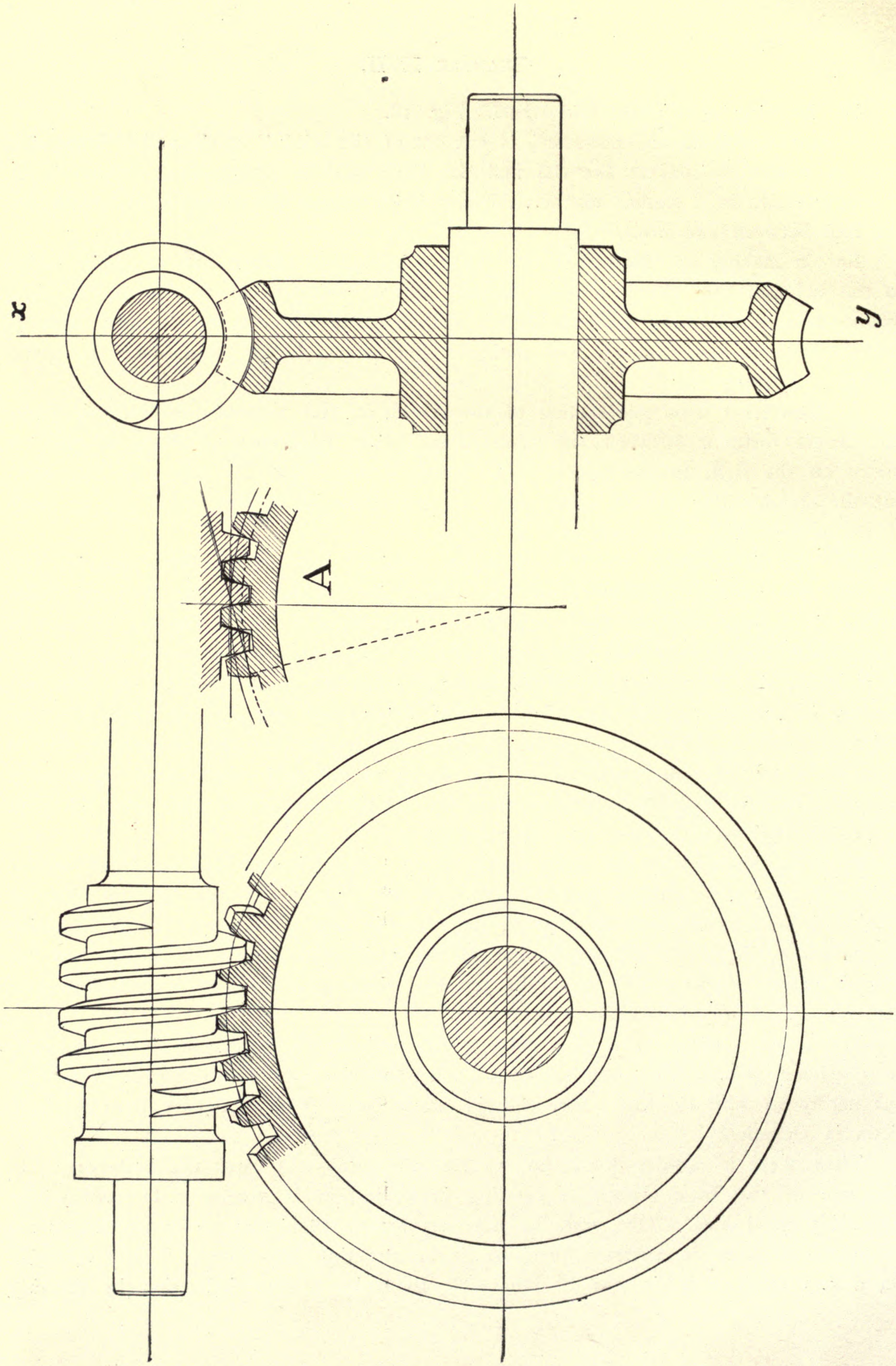

Fig. 18.

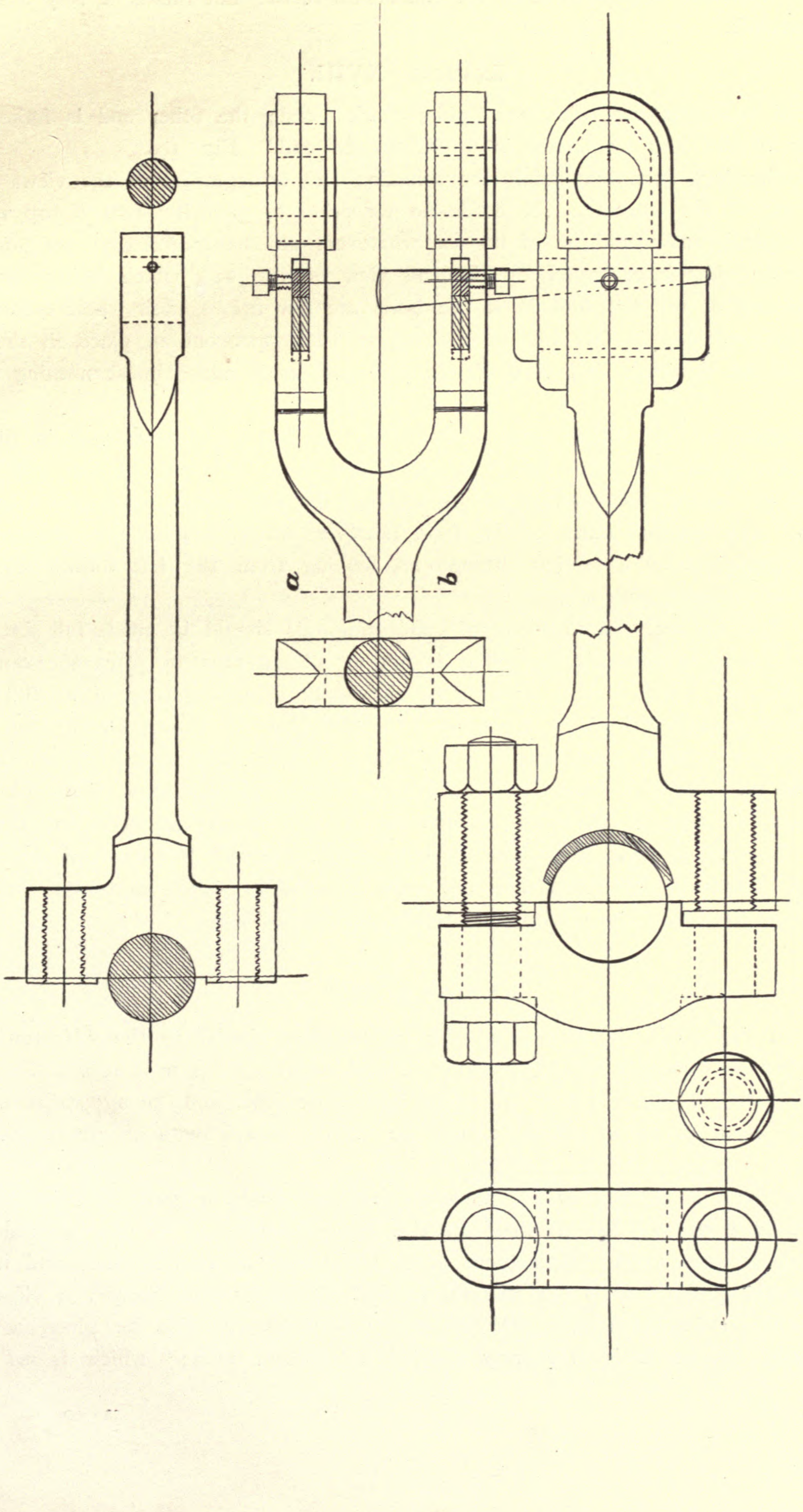

FIG. 19.

the pitch cylinders only, with lines for the helical teeth: but this is a very unsatisfactory makeshift.

Example XVIII.

34. A connecting-rod, with one "pillow-block" end; the other end is forked, and each arm of the fork terminates in a "strap and end." Fig. 19.

This drawing illustrates mainly the selection and arrangement of the views needed for the use of the workman. It needs no reflection to perceive that a top view of the pillow-block end would be of no use whatever; all the information not contained in the front view is conveyed by the end view of the cap, which being *from* the left, is placed *at* the left, and in it the bolts are not drawn, their whole construction being fully explained in fact by the drawing of the upper one in place, in the front view: still the detached end view of one is added, as it adds almost nothing to the labor.

In regard to the forked end, a front view is just as important as in the case of the pillow-block end; but here an end view would be very obscure and of no assistance in reading the drawing or in making the rod, which absolutely requires a top view. The peculiar finish of the fork, however, where it joins the round shank, is better explained by a section through *ab*, looking from the left toward the right, which is accordingly added.

35. Such drawings of the *ends* of connecting-rods should be made full size, or on as large a scale as convenient; but it is not at all necessary to place the centres at the full distance apart: still, a drawing of the shank being requisite, of its full length and in true proportion, this is made on a smaller scale as shown above; the circles for the pins are drawn, upon whatever scale may be admissible, at the correct distance apart: the two ends of the shank are then reduced to the same scale, placed in their proper relations to these circles, and the contour of the shank is completed, all the paraphernalia of caps, straps, brasses, etc., being omitted. If the shank be turned, as is very commonly the case, only one view is needed: which of course should be drawn upon the same sheet with the details of the ends.

Example XIX.

36. In Fig. 20 is shown a part of a combination, similar to the "Horton Lathe Chuck," but in this case having its axis vertical when set up in place.

This casting is formed with ribs on the upper side, and facing strips on the lower, the arrangement of which cannot be clearly shown without direct views of each side.

When there is nothing to the contrary, it is no doubt a good idea to represent an object in even a detail drawing, in the same position as in the general plan. Now there are many who think there never is anything to prevent this; and in such a case as the present, it is not unusual to find the piece thus shown: a view from above is of course given, and easily read; — but there will also be given a "view from below," or, as it is frequently labelled, a "bottom plan;" which is *not* easily

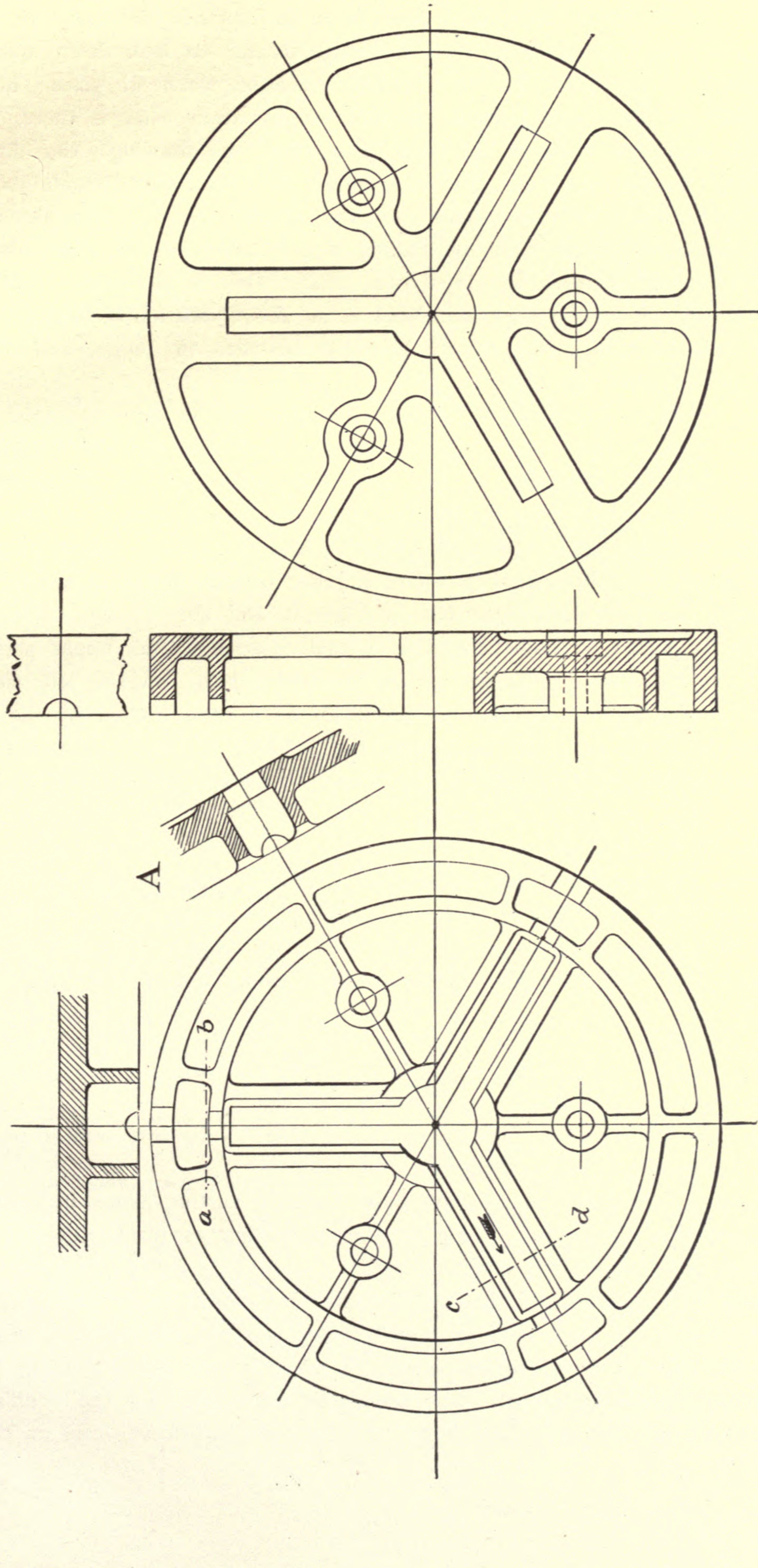

FIG. 20.

read, for the simple reason that it is seen from an unusual direction. In examining a detached piece of any machine, it is perfectly natural to look down upon it from above, especially if the piece has a horizontal position when in place: but nobody ever gets under it and looks upward, in order to ascertain what is there, if he can help it. This ought to be kept in mind in making the drawing; the draughtsman does not stand on his own head, and he should not ask other people to stand on theirs. The top view is, naturally and correctly, placed over the side view; and the difficulty is sometimes gotten over by making a new side view in which the piece is inverted, and drawing another top view over that. This is decidedly better than to place it under the first side view and label it as above mentioned, but still it is not always very easy to realize the correct relations between the upper and lower parts when drawings are thus arranged.

37. The advisable expedient is to place the piece on its side and draw it in that position; then a view of the parts on the left placed at the left, and a view of those on the right placed at the right, of the view first made, will be readily understood. Just as though the drawing first mentioned were the south front of a house, and the other two the west and east fronts respectively. And that is the course here adopted: the axis is placed in a horizontal position, and the central view is a section made in accordance with the principles illustrated in Figs. 21 and 22.

Over this is placed an outside view of a small portion of the upper part, in order to define clearly the semicircular groove in the outer flange on the left side of the casting. Above the view at the left is given so much of a section by the plane *ab*; looking downward, as is necessary to explain the relation of the small radial ribs thus cut, to the surrounding parts; and this also shows the semicircular groove in the inner flange.

This groove is also seen in the section at *A*, which is made by the plane *cd*, and seen from the direction indicated by the arrow. It may be said that this section could have been put nearer to its plane by drawing it on the other side of the large view—which is true; but if that were done the arrow ought to be reversed and the section looked at in the opposite direction, which would not be so clear nor so explanatory.

Example XX.

38. Fig. 21 exhibits the Slide-valve, Valve-chest, Valve-seat and a part of the Cylinder of a horizontal steam-engine.

This example illustrates the advantage of selecting cutting planes in such a way as to show clearly what is desired; using in the same view as many different planes as may be found necessary or convenient.

The longitudinal section of the cylinder and valve-chest is by the plane *ab*; but that of the valve is by the plane *cd*, which evidently shows its structure more clearly.

In the top view, the valve-chest is cut by a horizontal plane through the centre of the valve-stem and steam-pipe. But the valve and stem, and the stuffing-box, as well as the bolts, are omitted. The bolts pass through half-sleeves cast on the outside

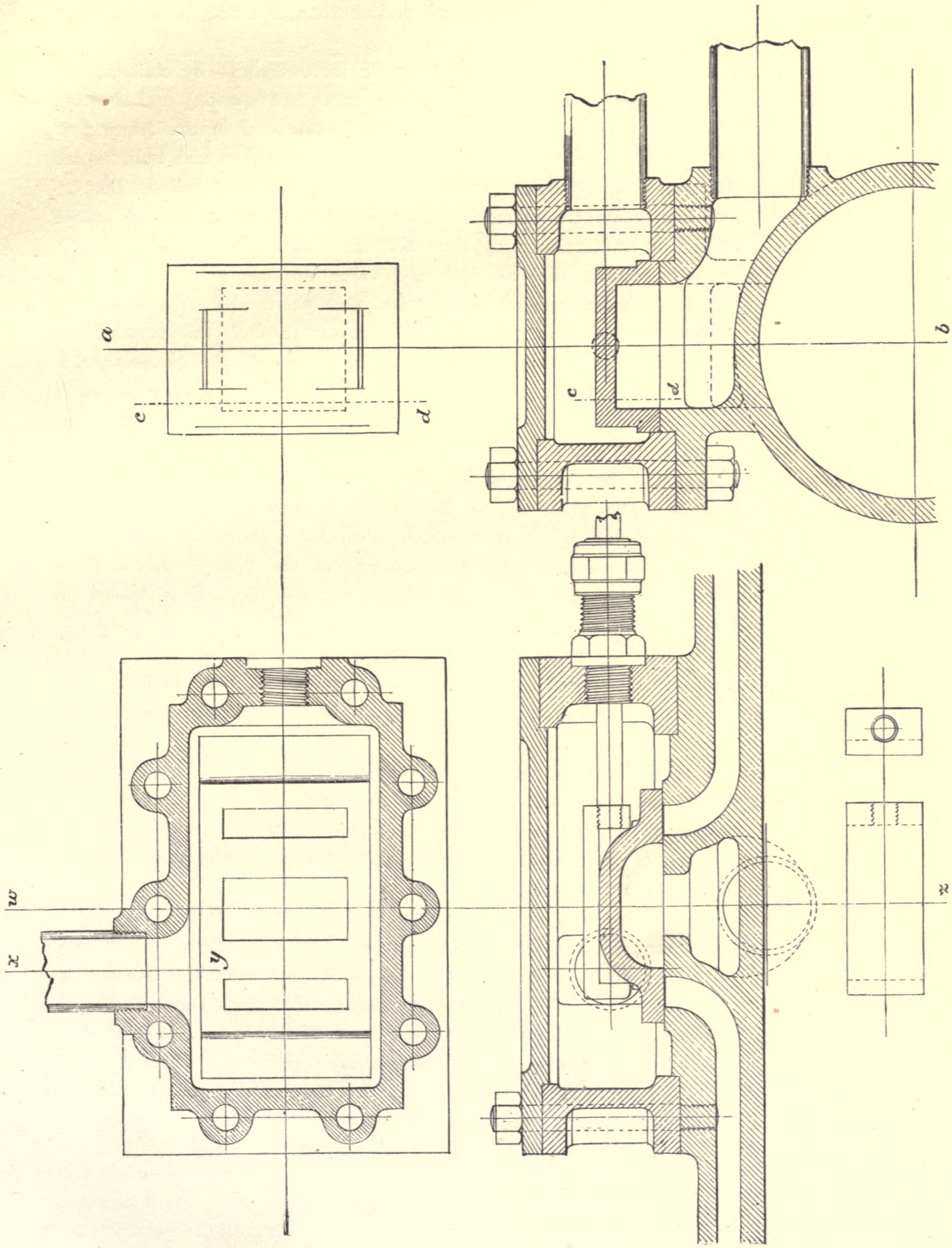

FIG. 21.

of the wall of the chest, and this drawing is much clearer than it would be if the bolts were shown in section.

The relation of the chest to the valve-seat is made more distinct by omitting the valve (of which a detached top view is given over the transverse section), and showing the seat with its ports. But this last would of course be repeated in the drawing of the cylinder, (in which the valve-chest would be removed,) exhibiting the hubs which must be provided for the standing bolts at the end of the chest, as well as the exhaust opening. These last items are therefore omitted in this drawing, the seat alone being all that is needed in connection with the valve and chest.

39. In the transverse section, the cylinder and valve are cut by the plane wz through the centre of the exhaust port and pipe. But this plane, obviously, would cut the valve-chest in a very unsatisfactory manner, for it passes through the axes of the two central bolts. Therefore, the plane xy through the centre of the steam-pipe is chosen instead. Nevertheless, the middle bolt on the right-hand side is dotted in; for it must somehow and somewhere be shown that a standing bolt must be used in this position also; and it can be shown nowhere else so well as here. Nor does this in the least confuse the drawing, for the outline of this bolt coincides exactly with that of one beyond the cutting plane. The plane xy, in the present instance, passes between two bolts on the left-hand side of the steam-chest, which is therefore shown as also cut by this plane in the transverse section, so that the main wall of the chest is shown in its true relation to its flanges, the half-sleeve surrounding the bolt beyond is shown in outside view, and the bolt itself is dotted in.

Thus in each of the two lower sections, two different cutting planes are employed; and had a bolt chanced to lie opposite the steam-pipe, there would have been no hesitation in cutting the left-hand side of the chest by a third transverse plane which should *not* pass through the axis of that bolt.

The advantage in respect to compactness, by adopting the methods here explained, is self-evident, as all the sections made use of are necessary. Nor is there a point left in doubt, with the single exception of the arrangement of the interior of the stuffing-box; in a plan on a practical scale, this would be dotted in, and made distinct by sectioning over the outlines, as in Figs. 27 and 28.

40. It is not pretended that the above examples include all the infractions of the laws of projection, or departures from the methods of descriptive geometry, which may be found useful. But though it is hoped that they include a sufficient number to be of practical service, the writer still more strongly desires that they may prove suggestive of others, and that the reader, freeing himself from the trammels of precedent and prejudice, may make rapid progress toward the highest efficiency: which it is as vain to expect of the rigid formalist, as it is to look for the healthy growth and full development of a bark-bound tree.

CHAPTER II.

ON THE REPRESENTATION OF BOLTS, NUTS, SCREWS, AND RIVETS.

1. In every working drawing, it is essential that the fastenings, such as bolts, screws, and rivets, should be as clearly indicated as any other detail.

But it does not follow that they need be drawn with the same degree of precision. For in every machine-shop a system of some kind is adopted, in which the diameter of a bolt determines the number of threads per inch, as well as the sizes of the head and the nut. So that in respect to these particulars it does not matter whether the drawing be made in exact accordance with the standard or not; and much time may be saved by adopting the following methods of representation:

2. Bolt-heads and nuts are usually either square or hexagonal; and it is clearly a convenience, in making the wrenches, to have the side of the square, and the breadth or "short diameter" of the hexagon, of sizes that can be readily set off by the scales in common use. Consequently in the case of the hexagon, the "long diameter," or distance from corner to corner, will involve an awkward decimal. This is of no consequence in making the nut, but would be very inconvenient in making the drawing: for the side view of a bolt should *invariably* be such that there is no possibility of doubt or error as to the shape of either the head or the nut; if square the *short* diameter, if hexagonal the *long* diameter, should be parallel to the paper.

3. Calling the diameter of the bolt unity, the proportions given below will be found very convenient in practice, being simple and easily remembered.

Side of Square	Nut,	$1\frac{3}{4}$;	Depth,	1.
" " "	Head,	$1\frac{1}{2}$;	"	$\frac{3}{4}$.
Long Diam. Hex.	Nut,	2;	"	1.
" " "	Head,	$1\frac{3}{4}$;	"	$\frac{7}{8}$.

It is only in very massive machinery that bolts used as fastenings are over $1\frac{1}{4}$ inches in diameter: up to that size, the proportions just given do not differ materially from the standards in general use, and the saving of time effected by employing them is sufficient in many cases to be of very considerable importance. Tables for the U. S. and the Whitworth Standard systems may be found in the Appendix.

4. Through Bolts.—Fig. 22 shows two pieces of metal secured together by what is called a *through bolt*, with hexagonal head and nut.

The bearing side of the nut has its corners rounded off, since otherwise the sharp edges and angles would scrape and catch upon any inequalities on the surface against which it bears, thus possibly preventing the bolt from binding: for a contrary reason the corners of the head are not rounded off on the bearing side, though on the other side they may be as a matter of taste in respect to appearance.

Now as to the manner in which this rounding off is represented. The point *b* is first located, either by describing about *c* an arc with radius *cd*, or drawing with the 60° triangle a line through *c* at an angle of 30° with the centre line; then a horizontal through *b* locates the points *a, e, f*: by trial and error the bow-pen is set to draw an arc through *a* and *b*, tangent to the lower side of the nut, and with this radius the four arcs shown are drawn.

Be it understood that this process does not represent precisely the effect of turning off the end of the nut in the form of part of a sphere, which will be discussed farther on. But it answers perfectly the practical end in view, which is to indicate that the corners are by some means to be prevented from scraping.

The bolt projects very slightly above the top of the nut. This is shown by two vertical

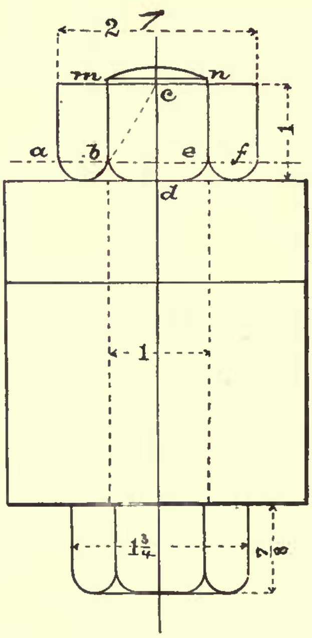

FIG. 22.

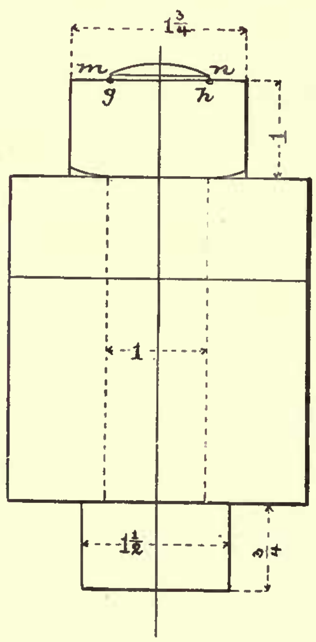

FIG. 23.

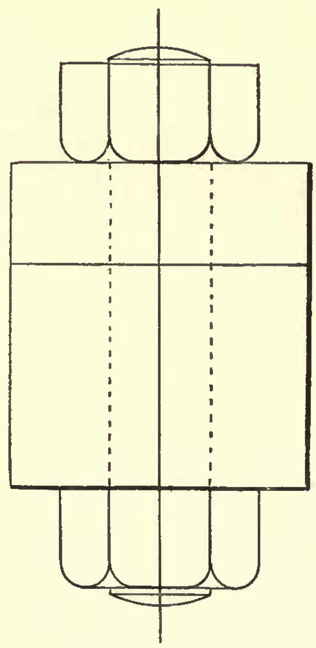

FIG. 24.

lines, just long enough to "show daylight" between the top of the nut and the horizontal line *mn*, no attempt being made to represent the screw-thread: and finally the top of the bolt is finished off by a circular arc about centre *d*.

5. In Fig. 23 we have a through bolt with square head and nut: the corners of the nut are in this case shown as rounded off by two arcs about centres *g* and *h*, with a radius equal to the depth of the nut.

And in Fig. 24 is shown a through bolt with a nut at each end, which is sometimes made necessary by an obstacle that prevents a headed bolt of the requisite length from being put in place.

In this case it is hardly necessary to say that only the nut which is ordinarily to be removed, should have the bearing side rounded off, the other one being reversed, since in unscrewing the upper nut it is rather desirable than otherwise that the lower one should not turn.

6. Tap-bolts.—The *tap-bolt*, Fig. 25, is a bolt with a solid head; it passes through the upper piece, and is screwed into the lower one; the whole bolt being turned by the wrench applied to the head, of which the corners are therefore rounded off on the bearing side.

It is necessary here to indicate the thread, which is done by simply drawing the "Vs" as in making a section of the screw. This is executed by first drawing lightly, in pencil only, two guiding lines on each side, for the tops and bottoms of the threads, making the depth of the thread about $\frac{1}{8}$ the diameter of the bolt; after which the sloping lines are to be drawn at once in ink, using a common steel writing-pen with a fine point. The Vs need not be measured, but are to be drawn free-hand, making a light up-stroke and a heavy down-stroke to represent a shadow-line on the section thus indicated; but it is not material which side of the V is made heavy. This work should be done as regularly and evenly as possible, the angle of the Vs as nearly 60° as may be; and in order to avoid the natural tendency to round the angles, care must be taken to lift the pen entirely off the paper at the end of each stroke.

The thread must extend above the face *rs*, to a distance of, say, $\frac{1}{4}$ the diameter of the

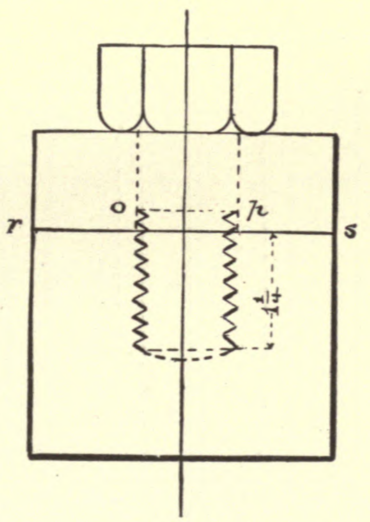

Fig. 25.

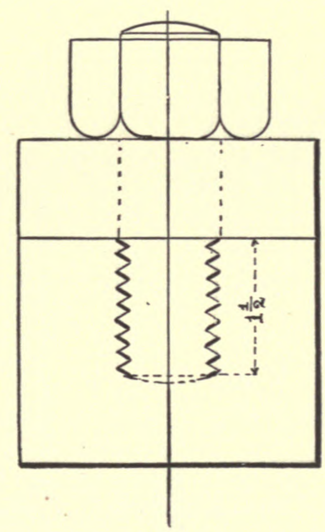

Fig. 26.

bolt, and attention is called to this circumstance by a dotted line *op*: and the lower end of the bolt is finished by a transverse line and a circular arc of radius equal to the diameter.

7. Standing Bolts.—A *standing bolt*, or "stud" as it is sometimes called, is firmly screwed into one of the two pieces to be connected, and remains permanently fixed; the other piece being held down by a nut on the upper end of the bolt, as in Fig. 26. The thread on the lower end is indicated exactly as in the case of the tap-bolt, with this important exception, viz., that this thread of the standing bolt *must terminate exactly at the face* of the lower piece.

This is because it is never intended to come out, and it is therefore screwed in so as to make the thread "bottom" or "jam," thus fixing it so firmly that it will not work loose when the nut is put on or taken off; and the length of this lower thread should when practicable be made equal to $1\frac{1}{2}$ diameters.

8. Key-bolts.—In circumstances which make it undesirable to use either of the fastenings above described, the *key-bolt*, Fig. 27, is sometimes employed.

The thickness of the key should be $\frac{1}{4}$ the diameter of the bolt, its breadth $1\frac{1}{4}$ diameters, and the bolt should extend beyond the key to a distance equal to $\frac{3}{4}$ the diameter. The slot should of course be a trifle larger than the key in each direction; that is to say, "an easy fit" only is required; but it is unnecessary to indicate this by double lines in the drawing: and it makes the construction much more distinct to show the key in section, as in the figure.

The above remarks relate, be it noted, only to the representation of fastenings *in place*, that is, in connection with the pieces which they hold together: and it is proper to call

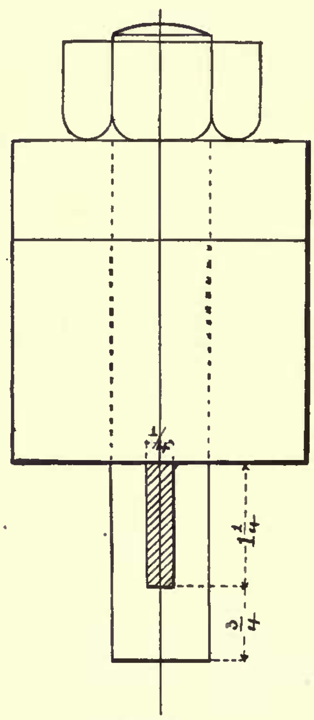

FIG. 27.

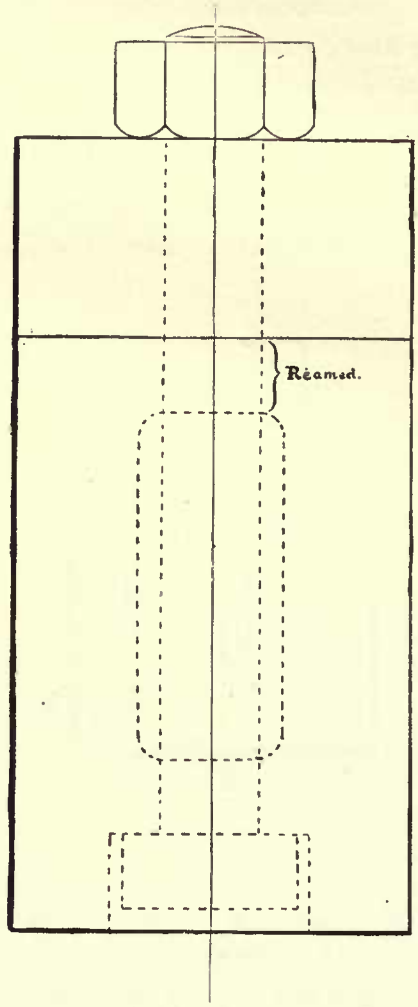

FIG. 28.

attention here to one or two points in reference to the preceding illustrations, and some of those which follow.

1. The holes *not* tapped, through which a bolt passes, are drilled or cored a little larger than the bolt. But it is not necessary in a connected plan to indicate this, (with an exception to be explained presently,) since the double lines would confuse the drawing, without any advantage. The outline of the *bolt* is drawn, and its diameter in all cases marked in figures; it is then the part of the machinist to make the hole *for a bolt of that size.*

2. The holes which *are* tapped must of course be made a little deeper than the length of the entering part of the bolt. But again, confusion would arise from showing this, and the drawing of the bolt being made, it is the mechanic's duty to make the hole deep enough for it.

If separate drawings are made of the parts to be bolted together, the holes are *there* to be laid out of the size and depth actually required.

3. In order that a nut may "draw" or "bind," the bolt must be threaded for a distance a little greater than the depth of the nut.

This being perfectly well understood, and implied by the very existence of the nut, the thread need not be indicated in a connected plan. If detail drawings of the bolts are made, the thread must there be shown, in a manner which will be illustrated farther on.

10. The exceptional case alluded to in the preceding section is illustrated in Fig. 28. The bolt being of considerable length, the hole is "chambered" for some distance to a diameter much greater than that of the bolt. This chambering is therefore shown in the drawing—as is also the "pocket" or recess formed when occasion requires for burying the head of the bolt. In order to secure alignment the upper part of the bolt-hole is often reamed so as just to permit the bolt (which, however, need not be turned) to pass through: this must be noted on the drawing, as in the figure.

11. The reader must not be surprised if he is solemnly assured by many that the hex-

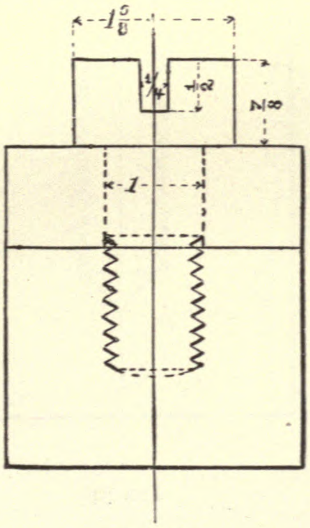

FIG. 29.

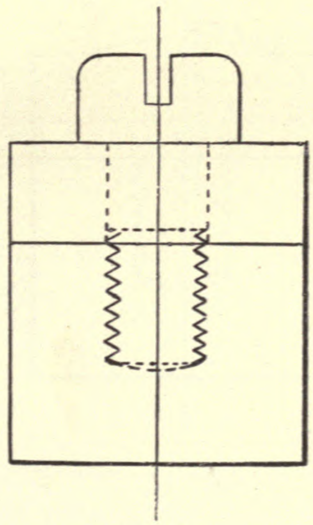

FIG. 30.

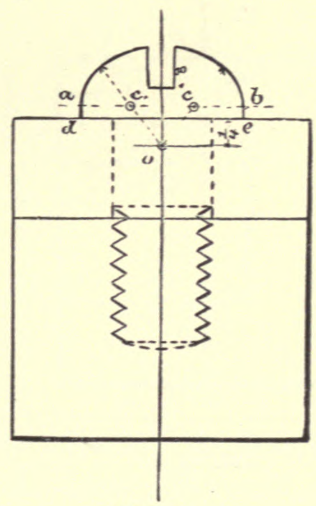

FIG. 31.

agonal nuts and heads herein shown are all wrong side up, and that in machinery making any pretension to finish, the corners of the *top* instead of the bottom should be rounded off. Also that the method above described of preventing the lower corners from scraping is not the right method, but that this object ought to be accomplished by turning the lower side so as to form a very thin cylindrical collar of a diameter equal to the inscribed circle of the hexagon. This is merely a matter of taste; and neither style has any practical advantage over the other.

12. Screw-driver Heads.—Bolts with round heads, slotted for the application of a screw-driver, are rarely used in heavy work, but those of small size, called "machine screws," are extensively employed in lighter constructions. Even in that case, they should be correctly represented; and they are occasionally met with up to $1\frac{1}{4}$ inches in diameter; most frequently when the head must be countersunk.

Suitable proportions are shown in Fig. 29; calling the diameter of the bolt 1, as usual that of the cylindrical head is $1\frac{5}{8}$, its depth $\frac{7}{8}$, the slot being $\frac{1}{4}$ wide and $\frac{1}{2}$ deep.

By rounding off the top corners with a radius of $\frac{1}{4}$, as in Fig. 30, we have the "fillister-headed" machine screw, the smaller sizes of which are largely used in model work and light mechanism of a similar kind. The heads of these small screws are also sometimes made of a hemispherical form. But if made *exactly* so, the effect is unpleasing, and a preferable contour is given in Fig. 31. The diameter of the head is $1\frac{5}{8}$, and the sides *da*, *eb*, are vertical for a distance of $\frac{1}{8}$. From centres *c c* on *ab* two circular arcs are drawn with a radius of $\frac{1}{2}$, and these are joined by an arc about a centre *o* on the centre line, lying $\frac{1}{4}$ below the bottom of the head: the slot is $\frac{1}{4}$ wide and $\frac{3}{8}$ deep.

13. By counterboring the piece against which it bears, the cylindrical head shown in Fig. 29 may be partially buried—or even entirely if that piece be thick enough. If it be not thick enough, and it be desirable nevertheless to make "flush work," the conical head, Fig. 32, is

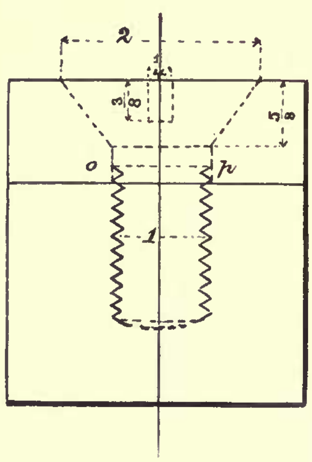

FIG. 32.

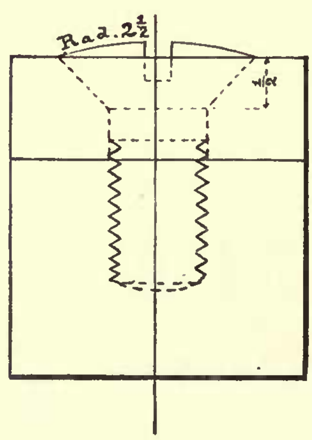

FIG. 33.

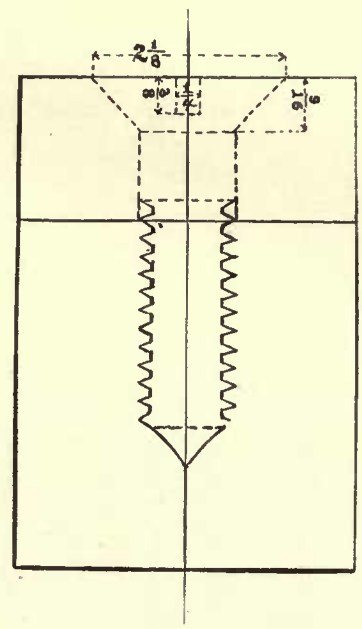

FIG. 34.

used. The larger diameter is 2, depth of frustum $\frac{5}{8}$, slot $\frac{1}{4}$ wide and $\frac{3}{8}$ deep. If not required to be absolutely flush, the depth of the frustum may be made $\frac{1}{2}$, as in Fig. 33, and the top of the head finished off with a circular arc having a radius of $2\frac{1}{2}$, the size of the slot remaining unchanged.

14. Wood-screws.—The angle of the Vs, in representing the wood-screw, Fig. 34, should be less than 60°, say about 45°, and the threads separated by a small distance at the bottom. The "gimlet point" is indicated by finishing the end of the screw with two concave arcs as shown; the slope of the conical head is 45°, the depth $\frac{9}{16}$ of the diameter of the screw; the slot $\frac{1}{4}$ wide and $\frac{3}{8}$ deep. These dimensions are larger than those found in many of the screws in market, a very common defect in which is a slot too small to give sufficient bearing surface, the result being that the edges yield and the slot quickly becomes useless; a most vexatious experience familiar to all.

15. Detail Drawings of Screws.—In many machine-shops it is customary to make, for any engine or machine in hand, a "bolt sheet," showing all the different kinds and sizes of bolts, nuts, screws, etc., required, with the number of each.

A good practical method of indicating the screw-thread is shown in Fig. 35: the exterior outline of the bolt being drawn in ink, the guiding lines for the bottoms of the threads are lightly pencilled; but instead of drawing the Vs, the threads are indicated by a series of parallel lines, alternately long and short, properly inclined as required by the pitch. The inclination is very readily determined as shown at the right of the figure; the section *ebc* of a single thread being drawn with the 60° triangle, then since the root on one side of the bolt is opposite the crest on the other, *ca* is drawn "square across," and *ab* is the desired slope. Setting the triangle by this line, then, the parallels are drawn at once in ink, the spacing being done by the eye, as in sectioning. Since the crests of the threads cast shadows, the *long* lines should be made heavy; which is best done by going again over each with the pen, as soon as it is drawn.

16. This is a purely conventional way of indicating a screw-thread; it is not, and does not pretend to be, a *drawing* of it in any proper sense; but it answers the purpose in view just as well as the most accurate representation.

Moreover, at a little distance a drawing of a small screw thus made actually looks like a screw, whether it is like it or not—much more so than it would be likely to were

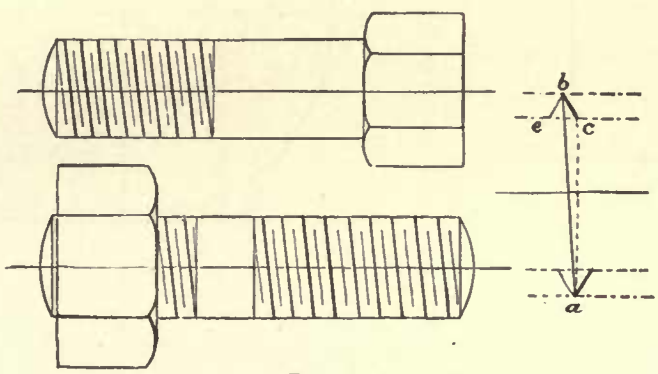

FIG. 35.

the Vs drawn with the triangle, especially if the pitch be fine; in which case the most painful accuracy in the use of the instruments is necessary to avoid variations in the diameter, which are always conspicuous even if small, and utterly ruinous to the effect: whereas trifling errors in the spacing of the parallel lines do not force themselves upon the attention to anything like the same extent.

17. If the bolt is very large, the above modes of representing it in full-size drawings are not eligible. It is, however, very rarely that one is used of such dimensions as to make it worth while to construct an exact projection of it, introducing all the details of the flattening of the crest at the top and the groove at the bottom, the helical curves of the thread, etc. As a compromise between this and the preceding processes, that shown in Fig. 36 may be used with good effect.

This consists in laying out the section of a "full sharp" V-threaded screw, which is carefully inked in with the aid of the 60° triangle, after which the tops of the threads are joined by one series of parallels (made heavy, as being shadow-lines), and the bottoms by another series, which of course have a slightly different inclination.

It is, certainly, possible that a bolt may be required, in very massive machinery, so large that it may be desirable to show the outline in this manner even in a plan where the bolt is drawn "in place." But this should not be done if the pitch be much if any less than half an inch, or the effect will be merely that of a mass of dots; and far less distinct, while much more laborious, than that of the method first described.

18. Exact Drawing of a Nut.—On the other hand, if the nut be very large, it may be worth while to represent precisely the effect of turning it off to a spherical form at the end.

Let the axis of the hexagonal prism, and the dotted great circle of the sphere whose centre is *c* in Fig. 37, lie in the plane of the paper, *LL* representing a plane perpendicular to the axis. Then all the edges of the prism pierce the sphere at the same distance

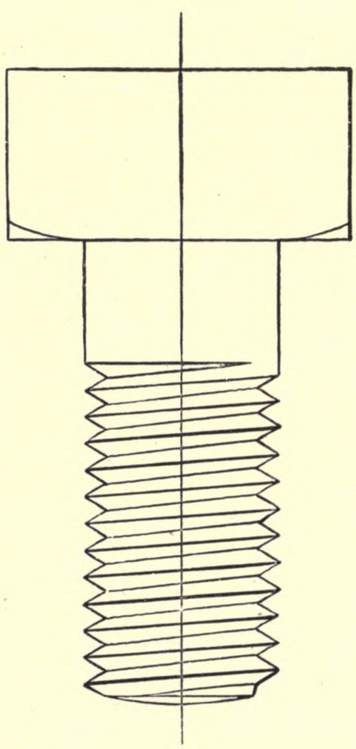

Fig. 36.

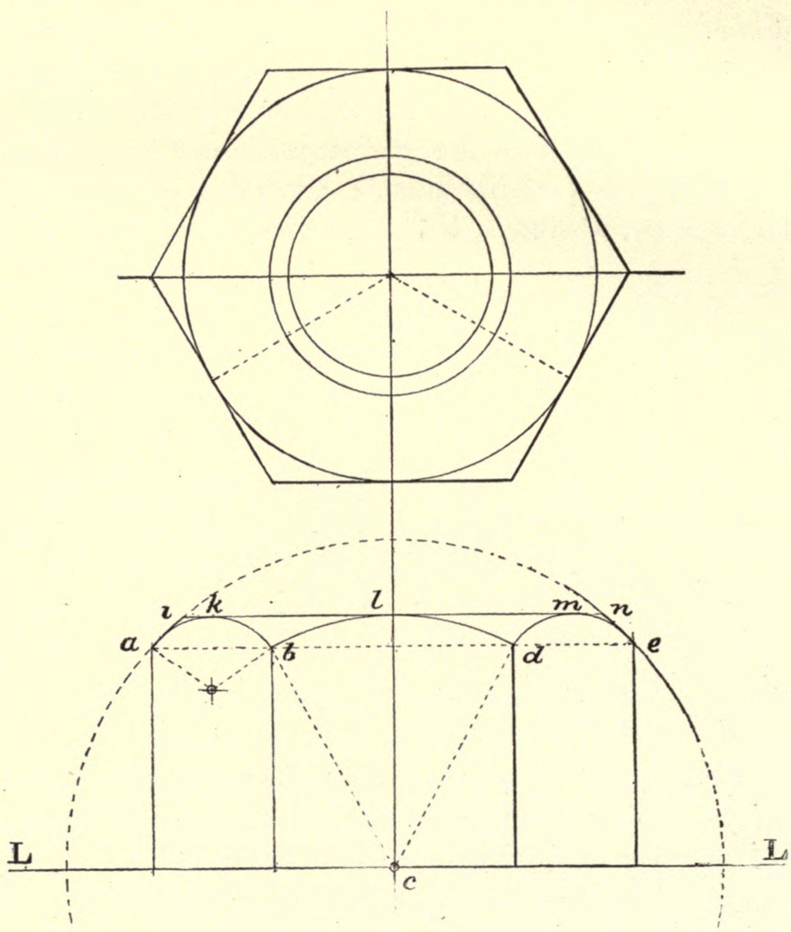

Fig. 37.

from *LL*, to which therefore *abde* will be parallel. The front face of the prism cuts from the sphere a small circle, of which the arc *bld*, whose centre is *c*, will be visible, and since this face is parallel to the paper, this arc will be seen in its true form.

Equal circles will be cut from the sphere by the other visible faces; but since these faces are inclined to the paper, the arcs *akb*, *dme*, will, strictly, appear as parts of ellipses, the middle points *k*, *m*, of these arcs being the extremities of the major axes. The distance of these points from *LL* will of course be equal to *cl*; therefore if the nut be finished, as is usual, by a transverse plane through *l*, it will suffice in practice to draw through that point the horizontal line *in*, and to draw *akb* as a circular arc tangent to *in*; finding the centre by trial and error. Thus it is seen that the short-hand representation adopted in the working drawing differs from this exact construction only in the omission of the portions *aik*, *enm*, and the substitution of two arcs of a shorter radius for the flatter arc *bld:* but these apparent trifles will be found to effect a material saving of time and trouble where many nuts of the same size are to be drawn.

19. Rivets.—By the use of the hand-hammer, the form given to the outer head of a rivet is approximately conical; and it may be represented in either of the two ways shown in Fig. 38, the diameter of the base of the cone being, in each, twice that of the rivet, which is taken as unity.

The one on the left is more readily drawn, the head being an exact cone whose altitude is $\frac{3}{4}$. The one on the right is a stronger form, bounded by two circular arcs, each struck with a radius of $1\frac{3}{4}$ about a centre on the opposite side of the outline of the body of the rivet; thus, the arc *ab* is described about *c* as a centre. The lower, or

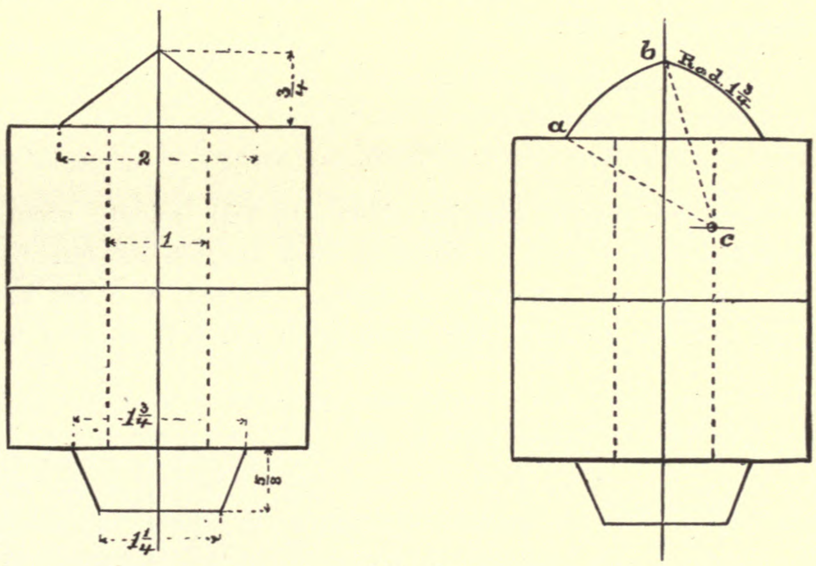

FIG. 38.

original, head of the rivet is in the form of a truncated cone, the larger diameter being $1\frac{3}{4}$, the smaller diameter $1\frac{1}{4}$, and the depth $\frac{5}{8}$.

20. If a die (sometimes called a "snap" or a "button-set") is used instead of the hand-hammer, the "cup-head" thus formed may be represented as shown on the left in Fig. 39. This is not a complete hemisphere, its diameter on the flat face being $1\frac{3}{4}$, and the centre of the curve being $\frac{1}{4}$ below the face.

In machine-riveting the finish may be the same at both ends, as shown on the right in the same figure; and of course a round-headed rivet may be riveted over with the hand-hammer if desired.

21. Countersunk Rivets may be made "dead flush," as shown in the left in Fig. 40, or finished with a slightly convex surface, as shown on the right; the latter being preferable when circumstances admit. In either case, the depth of the countersink is $\frac{1}{2}$, its larger diameter $1\frac{3}{4}$; and the second one has, in addition to the cone thus formed, a projecting spherical swell of which the radius is $2\frac{1}{2}$.

22. It is to be kept in mind, that this chapter relates to the representation and indication of things in the execution of which it is not essential, nor expected, that the mechanic shall be governed by the precise dimensions of the drawing. And in like manner, it is not essential that in adopting the proportions herein suggested, the draughts-

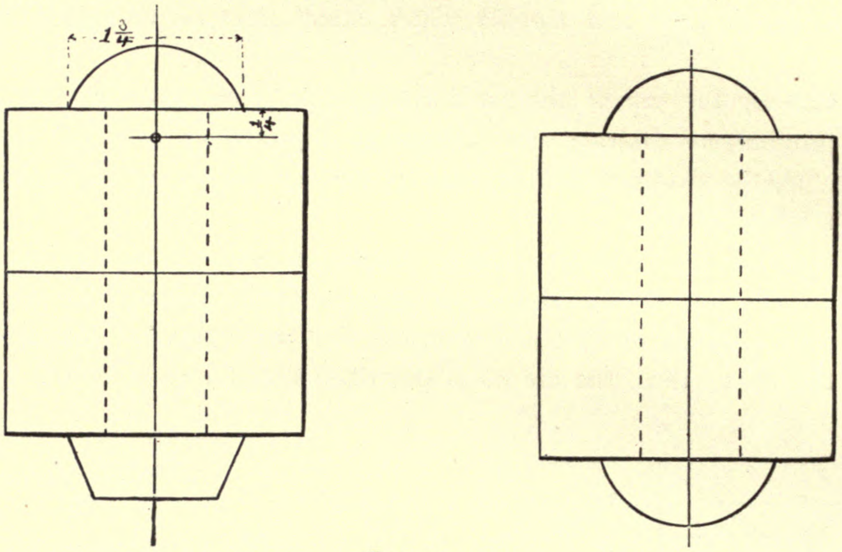

FIG. 39.

man should be over-scrupulous in carrying them out with minute accuracy; common-sense should be exercised in respect to rejecting such insignificant fractions as would in some cases result from a rigid adherence to them. Indeed, it is not advised to make computations at all in these matters: the *diameter* of the bolt or rivet being accurately

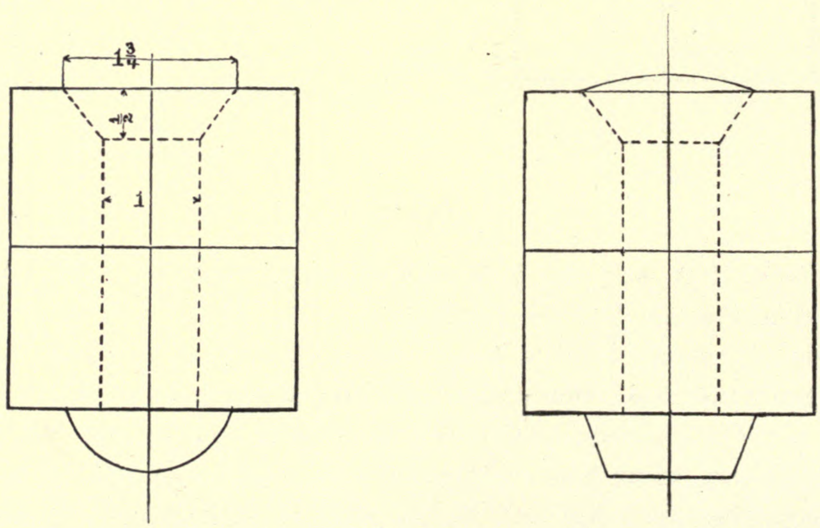

FIG. 40.

set out, the fractions of that magnitude used in laying out the other parts can, with a very little practice, be at once taken up with the compasses, by the eye, with all the precision needed for the purpose of making working plans.

CHAPTER III.

ON FREE-HAND SKETCHING.

Sketching in Proportion.—Its Utility in Designing.—Sketching from Measurement.—Methods of Practising.—Practical Suggestions and Examples.

1. It is supposed by some, that deft handling of instruments of precision alone is required of the mechanical draughtsman. This, however, is an error; no matter how expert he may be in the execution of working plans by rule and compass, the measure of his accomplishments is not yet full if he lack the ability to make good free-hand sketches.

To the designer of a new machine of any degree of complexity, a fair degree of skill in this direction is absolutely essential. He may have the clearest possible conception of the relations of the parts and of the general arrangement of the whole, but without some visible record of that conception, to which reference can be made from time to time, he cannot proceed with any certainty of success in the elaboration of the details. This record is in the nature of a sketch, though not necessarily wholly free-hand Sometimes certain absolute dimensions are assigned as a basis, such for example as the bore and the stroke in a steam-engine.

Or again, definite movements must be provided for, and their elements reduced to settled proportions, as a preliminary; the resulting diagram forming the skeleton of the proposed structure. In either case some use of scale and instruments is of course proper, not to say necessary; but the filling out of this skeleton into the complete body is largely dependent upon free-hand work.

2. Usually this dependence is direct, the designer at once sketching in the general arrangement, for the sake of having something before him as a guide in subsequent operations; and his sketch-plan serves him as the clay serves the sculptor, being subject to erasures and alterations as the development of his scheme may suggest or demand.

In simple cases, however, he may proceed, without this, to construct the details, adding them successively to his skeleton drawing, as each is completed. But whether this be done or not, these details are but the individual figures in the group, and each can be finished with greater ease and certainty in the marble if first modelled in the clay. In designing them, the problems are less comprehensive, but their nature is the same; the skeleton plan indicates certain pins, which must be connected by a link; it locates certain journals, and these must be supported by a frame with suitable bearings; it gives the positions of certain orifices, which are to be joined by pipes with valves; and so on in endless variety of condition and requirement. One of these problems seldom admits of a single absolute solution, which must be accepted to the exclusion of all others. Sometimes tentative methods are necessarily adopted; and in most cases there is a choice of ways and means, so that a judicious selection can be made only by comparison: in either event the utility of reasonably accurate sketches is self-evident, and from the nature of things it is equally apparent that they can be made most advantageously with the free hand, whether for the use of the maker only, or for submission to the inspection and decision of another.

3. But before attaining to the position of a designer, the draughtsman will in the usual course of events be confronted with circumstances in which such sketching is indispensable. Machines will break down; and it is very frequently necessary to replace a broken piece in the absence of the drawing from which it was made. Or a drawing may be lost after a piece is finished, and a new one is required. If the part in question be small and portable, it might be brought into the drawing-office, and the measurements as taken off be set out at once by scale; but in general this is not practicable, and a sketch must be made and the object measured wherever it may happen to be.

Again, in the case of machines already built, additions or alterations, often called for, require accurate definition of all surroundings, in order that the new parts may go properly into place and action, without interfering with the old ones; and such changes must frequently be made elsewhere than in the original constructing shop, so that the working drawings are inaccessible. It devolves upon the draughtsman to obtain the requisite data as a basis of operations, and his first services are to be rendered, not with his drawing apparatus, but with the mechanic's callipers, squares and rules, wherewith he makes the measurements to be noted on a free-hand sketch. And he who can do this well,—who can be relied on to make no oversights or mistakes, but to return to the office with a clear, distinct, and accurately figured sketch, so that the work may be proceeded with in perfect confidence, is the fortunate possessor of a most valuable qualification.

4. It is advantageous if there be much of this kind of practice, for it is of threefold utility. Not only are the sketches directly made use of for their special purposes, but in the very process of making them and the necessary measurements, the habit of close observation is cultivated, and, in addition, impressions of relative if not of absolute dimensions insensibly fix themselves in the mind, and what may be called a sense of proportion is developed, which to the designer is of the greatest value. For in planning, it is perfectly clear that those sketches are the best which most closely resemble the drawings when finally worked out, since the latter must embody the results of calculations based upon the known properties of materials and the conditions that must be fulfilled. And in making them, the free hand is guided in unconscious conformity with the results of experience and with unwritten deductions from successful practice, just as the style of a writer is influenced without his knowledge by the books he has read; and the more extensive and varied the store of precedents, the better is it likely to be guided. And be it understood, that this acquisition does not make the designer a copyist, any more than a wide range of reading makes a plagiarist of an author; but the one is more likely to put his original conceptions into good practical forms, and the other to put his original thoughts into terse and telling words.

5. In "sketching from measurement," the dimensions are always given in figures; so that the scale drawing must be like the object, whether the sketch is or not. Whence some make the inference, and what is worse they act upon it too, that care with the lines is useless if only the figures are right; and are content with records so rude that no one else can read them, and they themselves cannot do it after a short time has elapsed. They tacitly assume that he who makes the sketch is also to make the scale drawing, and to do it immediately; neither of which is by any means always the case,—and even if it were, this course is simply throwing away an opportunity of improvement.

It is not the intention that any reader hereof shall make so gross an error. Nothing but the most extreme urgency can excuse such slovenly work, and in all ordinary cases there is time to do it at least fairly well. A good sketch is a permanent record, and either the maker or any one else should be able to work from it at any time: and no draughtsman who desires to improve will permit himself to make one which will not pass this test.

6. The power to sketch new details in good mechanical proportion, previously mentioned as so valuable to the designer, may be greatly increased by practice. And the following naturally suggest themselves as lines in which such practice may be followed to advantage.

1. *Making free-hand copies of working drawings.*

The benefit of this is evident from the fact already stated, that the object in planning is to make sketches which shall serve as guides in making the scale drawings. It need hardly be said that in thus copying, the proportions should be preserved as closely as possible, but the scale may be advantageously varied.

2. *Making sketches from memory.*

This will be found a most beneficial exercise, either for the student or the professional draughtsman. The former may take any good detail drawing, and after careful examination and study of its various parts and their dimensions, subsequently make sketches as nearly in correct proportion as he can, without referenee to the original. The latter may do the same in relation to any plans upon which he may be engaged during the day. The dimensions should be written in and verified by subsequent comparison with the original.

3. *Sketching from the object without measuring.*

This affords the best of training for both eye and hand. It is to be understood that working sketches, not perspective representations, are to be made. If the object, which may be any detail of machinery that happens to be accessible, is small, it is excellent practice to make the sketch as nearly of the exact size as possible: *and after it is completed,* to go over it with a scale and see how close the approximation is. If the piece be large, the sketch should be reduced, and subsequently tested in a similar manner; in doing this, the scale of reduction is determined by comparing the magnitude of some leading part in the sketch, as for instance the diameter of a journal, with its actual size: other parts ought of course to be found reduced in the same ratio.

7. This last must not be confounded with the ordinary operation of "sketching from measurement," previously spoken of, although in some respects similar. It is to be regarded as an exercise pure and simple, and its object would be defeated were the measurements taken beforehand; nor is rapidity, at least in the beginning, a special desideratum, although ultimately it is a point of some consequence. Whereas in the other case time is usually an important item, and a material saving in this respect may often be made by taking some of the leading dimensions before beginning the sketch; besides, the main object here is to obtain a record of the measurements, which must be figured in, clearly and without the possibility of erroneous interpretation. This is absolutely indispensable; if it can be done, and the sketch still have all parts in correct proportion, so much the better. But this is not always the case, and, as will be explained presently, advantages may often be gained by purposely sketching out of proportion, which also the draughtsman should know how and when to do. Such liberties, it is needless to say, are wholly out of the question in the practice of the preceding exercise.

PRACTICAL SUGGESTIONS.

8. It will have been gathered from the foregoing, that in general a good sketch is equivalent to a working drawing made with the free hand instead of by the aid of instruments: with the one as with the other, the object is to show what to do and how to do it, and neither is perfect if in any particular there is a deficiency or a doubt. But experience proves that one may be quite competent to make a drawing of any mechanical detail from a figured sketch, and yet fail to produce a satisfactory sketch if the piece itself be placed before him. Just as with everything else, practice is necessary in order to do this with facility; written instructions could hardly be made to cover every contingency, but still some hints may be useful to the novice, and enable him to avoid many errors unfortunately too common. The causes of such failures are various; but one of the most prominent is a misconception of what is wanted.

Beginners are very apt to think that an *exact duplicate* is to be made of what they are required to sketch, and to expend much labor in measuring minutiæ of no real importance; such for instance as variations in the thickness of rough castings or unfinished forgings, which are unavoidable, and deviations from symmetry without apparent reason, which may be due to inaccurate workmanship. Such precise duplication is rarely required. In making any part of a machine from a working drawing, in ordinary cases special accuracy is necessary in regard to certain dimensions on account of their relation to other parts, while in many particulars slight deviations from the drawing may be of trifling moment.

The object, then, is usually gained if the *original drawing* can be reproduced from the sketch, and the making of the latter is greatly facilitated by a proper distinction between essentials and non-essentials.

9. Another source of difficulty is the fact that the centre lines, which in the drawing are before the eye and often furnish a key to the laying out of much of the work, do not exist in the finished piece. Consequently the beginner is apt either to forget them, or, by measuring from rough surfaces, or similar unreliable methods, to fail in securing data from which they can be laid down in correct relation to each other or to some definite base line. In making the drawing, the very first step is to locate these centre lines; and so in making the sketch, their positions should be determined at once, and other measurements made in reference to them. This very often results in proving with practical certainty that parts which actually are not symmetrical about these lines were intended to be so, the observed irregularities being due to errors of workmanship or to accidental causes, such as shifting of cores or prints, unequal contraction of castings, and the like: in which case the labor of measuring such deviations is saved, while the sketch itself is all the better.

10. Another oversight consists in omitting to verify measurements by comparison or otherwise, to make sure that all agree with each other. It is very often impossible to take a necessary dimension directly, and it must be reached in a roundabout manner, by making several different ones and then adding some and subtracting others. This being done for this specific purpose; it may also occur that in measuring other parts, a second set of figures is obtained by manipulation with which the same dimension can be ascertained. Now, it is very disagreeable, on attempting to work from the sketch, to find these results at variance with each other: this should be found out before, and the error corrected. And it hardly need be added that care should always be taken to see that the sum of a number of consecutive dimensions is equal to the actual total as determined by measurement.

11. In regard to the number of dimensions to be taken, there are errors of redundance as well as of deficiency. Beginners not only, but occasionally those of considerable experience, will sometimes cover a sketch with superfluous figures, and sometimes they do not put down enough. Of the two, the former is preferable, as being on the safe side, always provided that there are no discrepancies; it is better to waste the time required to make a dozen useless measurements, than to run the risk of omitting one that may prove essential—for an opportunity may not offer to do the work over again, and if a figure be lacking it is tolerably certain to be among the first ones wanted in laying out the drawing.

12. The novice is often at a loss to decide what views ought to be sketched, and how they should be arranged in relation to each other.

This matter is determined precisely as in the case of the original working drawings; the sketches are complete only when they contain all the data which are requisite in laying out a drawing from which new pieces could be made with the certainty that they could be substituted for those measured.

And be it observed that the evils of a slavish observance of the laws of projection, great enough in making drawings, are still more pronounced in the making of sketches. All that has been said in regard to the former applies with added emphasis to the matter now under consideration: by following the suggestions contained in the preceding chapters, sketches may be kept free from a vast amount of useless rubbish, the introduction of which is a sinful waste of valuable time.

13. As previously remarked, this matter cannot well be reduced to the form of abstract rules of procedure. Two or three general principles, however, may be deduced from what has been set forth, which apply in nearly all cases.

(1) Special care is requisite in measuring those portions of any detached pieces which are fitted to other parts of the machine.

(2) Centre lines and lines of symmetry, when such exist, should be carefully located.

(3) All measurements should be made from centre lines or faced surfaces when possible.

(4) Measurements should be verified by comparison, and all discrepancies corrected.

14. It is very desirable that sketches from measurement should be reasonably compact; and by skilful management it will be found practicable to make distinctly figured and complete free-hand records of even massive machinery on the pages of a pocket note-book.

It is not, however, to be supposed that this can be accomplished if all parts are drawn in due proportion and upon the same scale. Nor is it imperative that anything approaching to this should be attempted; if it can be done, as has already been stated, it is well to do it; but if not, such liberties may be taken with the proportions as circumstances may dictate.

This can best be made clear by example, as no general rules can be laid down for this either: and the following figures, which are *fac-similes* of fair free-hand sketches, are given with the view of illustrating to some extent not only what may be done in this respect, but some other points previously alluded to, as well as one or two which have not been mentioned.

SKETCH NO. 1.

15. In Fig. 41 is shown a valve-stem for a large engine, with a circular collar fitted to a conical portion of the stem near the middle: both ends are threaded and provided with nuts.

In such a case as this, the diameter may be exaggerated and the length contracted; as otherwise the sketch would be inconveniently long, or else so narrow that the figures could

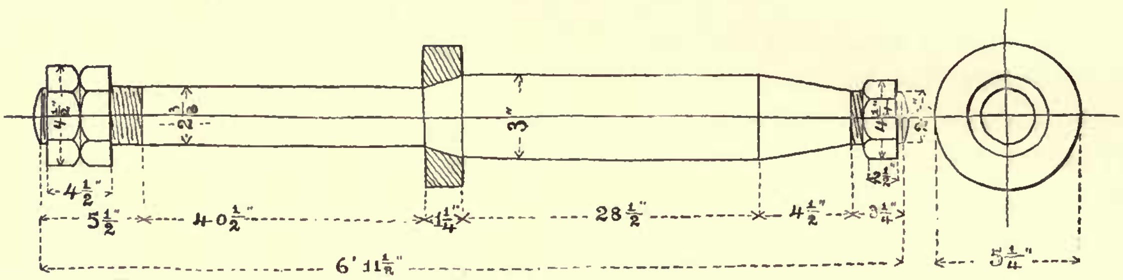

FIG. 41.

not be distinctly written in. This is equivalent to drawing the lengths by one scale and the breadths by another, a familiar expedient in topographical work. But here it is not necessary to preserve the proportions which actually exist between the different parts into which the total length is divided.

The collar is shown in section in its proper place, and an end view of it is also given at the right. The valve-stem being turned, and the nuts hexagonal, no other view of either is necessary.

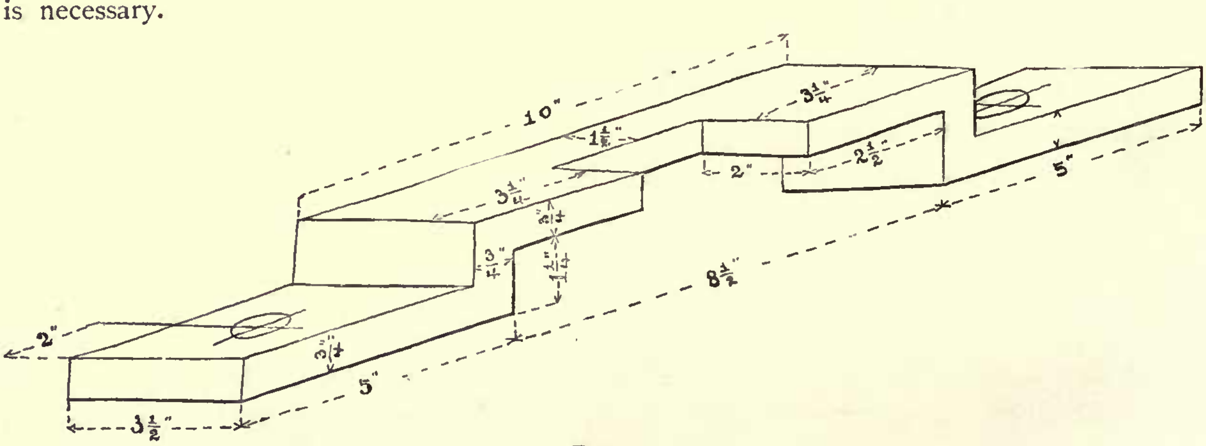

FIG. 42.

SKETCH NO. 2.

16. A simple bridge-piece, of rectangular section, with a notch cut in one side of the raised part, and a bolt-hole in each end, is shown in Fig. 42.

This is a case in which a single view is sufficient, when drawn in oblique projection, or what is known as "cavalier perspective." It is not properly perspective, however, as the oblique lines, representing those lines of the object which are in space perpendicular to the plane of the paper, are parallel instead of convergent.

This method is often extremely convenient, when applied as in this case to objects bounded by lines and planes at right angles to each other.

It conveys the meaning very clearly, and the drawing may be worked from directly, since, all the oblique lines being parallel, and those which are equal always appearing equal, they may be set off in their true lengths when a scale is used, and the actual dimensions may with perfect propriety be written on a sketch thus made.

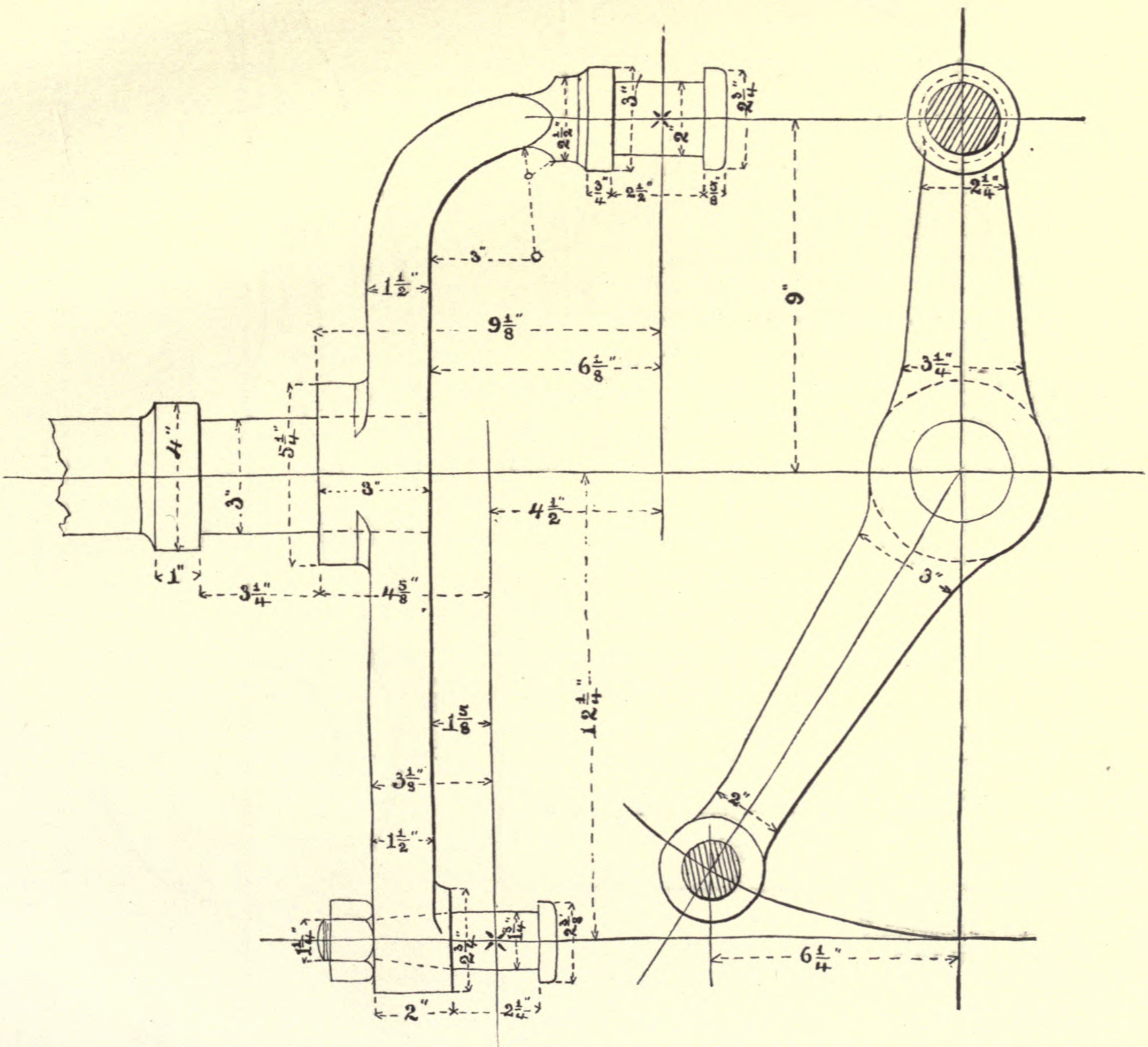

FIG. 43.

SKETCH NO. 3.

17. A lever, of which the two arms make an obtuse angle, and one is bent at right angles, so that its pin is parallel to the shaft, is shown in Fig. 43.

Two views suffice to define the construction of this somewhat crooked piece, so that no questions need be asked.

In the end view on the right, the bent arm is placed with its centre line vertical; the other arm is shown in its true length and position, and both pins are drawn in section, thus

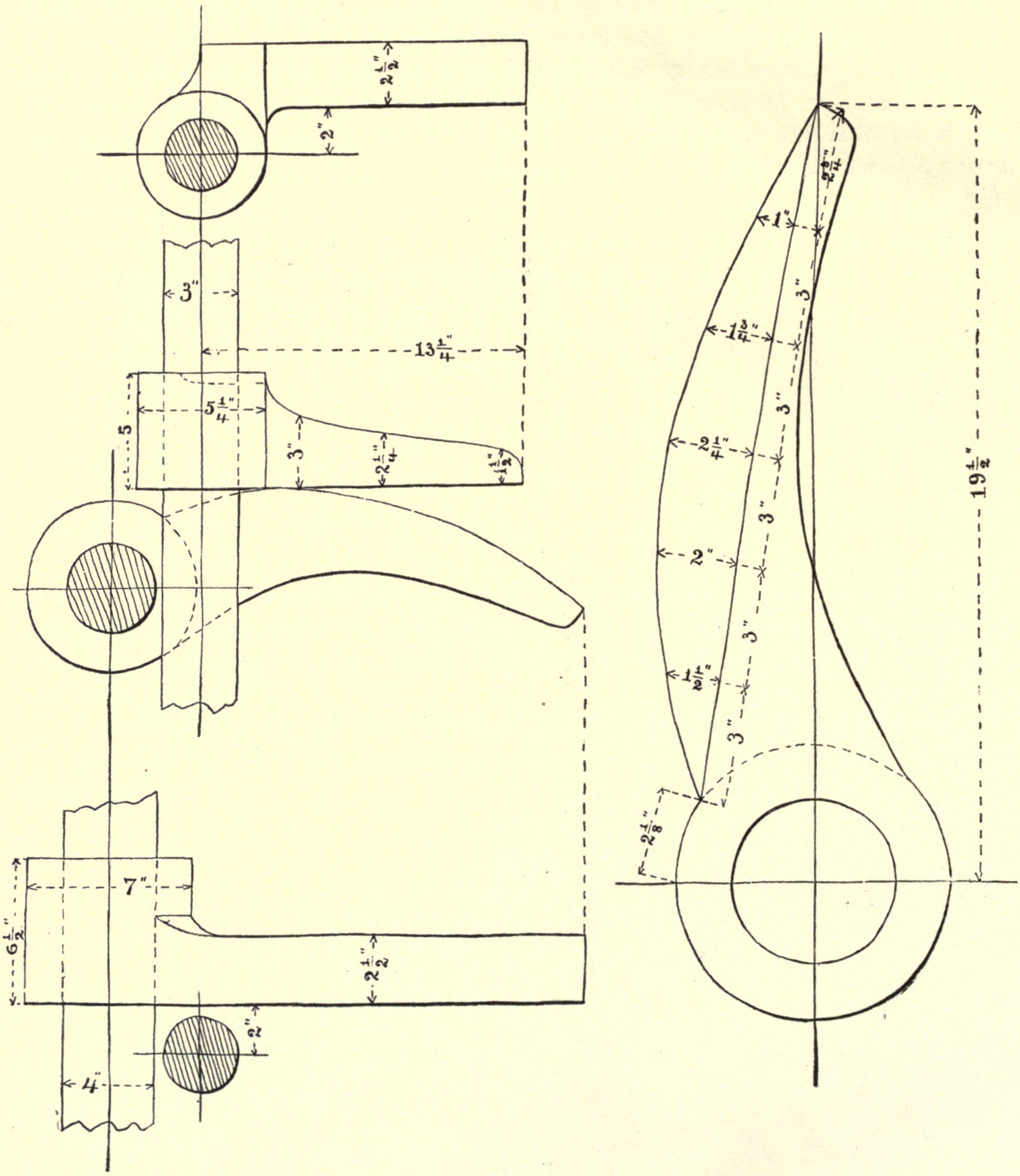

FIG. 44.

avoiding the necessity of showing the outward collars and dotting the pins. This last item is more important than it perhaps seems, as the pins are the more prominent parts, and by thus making them conspicuous the whole is rendered more clear and striking.

In the side view, the inclined lever is not projected in its true position, but *is shown in its true length*, just as though in the end view its centre line were also vertical.

Particular attention is called to the circumstance that in this view vertical centre lines are drawn through the middle points of the lengths of the pins; and the distance of these from each other, and of each from the face of the central hub of the lever, are given.

These vertical lines locate the planes of rotation, and their positions in drawings of other parts of the machine which are connected with these pins must obviously agree with those here shown.

Sketch No. 4.

18. In Fig. 44 are shown a "lifting toe," and its cam or "wiper," such as are used in the valve gear of the common beam-engine.

On the left there is sketched a side view of these two pieces, with a portion of the lifting rod to which the toe is attached. Above this is a top view of the toe, the lifting rod being given in section as though cut off above the toe. Below it is shown a top view of the wiper, a section of the lifting rod being also placed in its proper position relatively to the wiper, a part of whose rock-shaft is likewise given: a section of the latter is seen in the side view.

The form of the curved face of the wiper is important; and in order to define it with precision, an enlarged sketch of it is made on the right. In this, a chord of the curved acting face is drawn, and the "offsets," or perpendicular distances from this chord to the curve, are given at definite intervals.

This chord at one extremity cuts the outer circumference of the hub of the wiper: and in order to define the angle at which the wiper is placed, a line is drawn from the other extremity of the chord through the centre of the shaft; also a perpendicular to this line, passing through the centre and cutting the circumference, in another point: and the distance from this last point to the first-mentioned extremity of the chord is figured in.

Sketch No. 5.

19. The subject of this sketch is the cross-head of a steam-engine, formed of a transverse piece forged on the piston-rod, which is also shown in Fig. 45.

Two views are in this case also made to serve all purposes. In the side view the length of the piston-rod is contracted, it being quite needless to show it in due proportion to the other parts. And while the idea of the general contour of the cross-head is reasonably well indicated, no attempt has been made to preserve the relative sizes, which are sketched so as to accommodate the figuring, upon which everything ultimately depends in making a drawing to scale.

In the end view, the piston-rod is shown in section, and so also is a part of the upper end of the cross-head, the lower part being drawn in elevation. Here, again, everything is made subservient to the easy and clear introduction of the figures, and to the keeping of the whole sketch within due limits as to size.

Sketch No. 6.

20. In Fig. 46 is shown a pillow-block, or bracket, of a somewhat peculiar form, the cap being inclined at an angle of 45° to the horizontal.

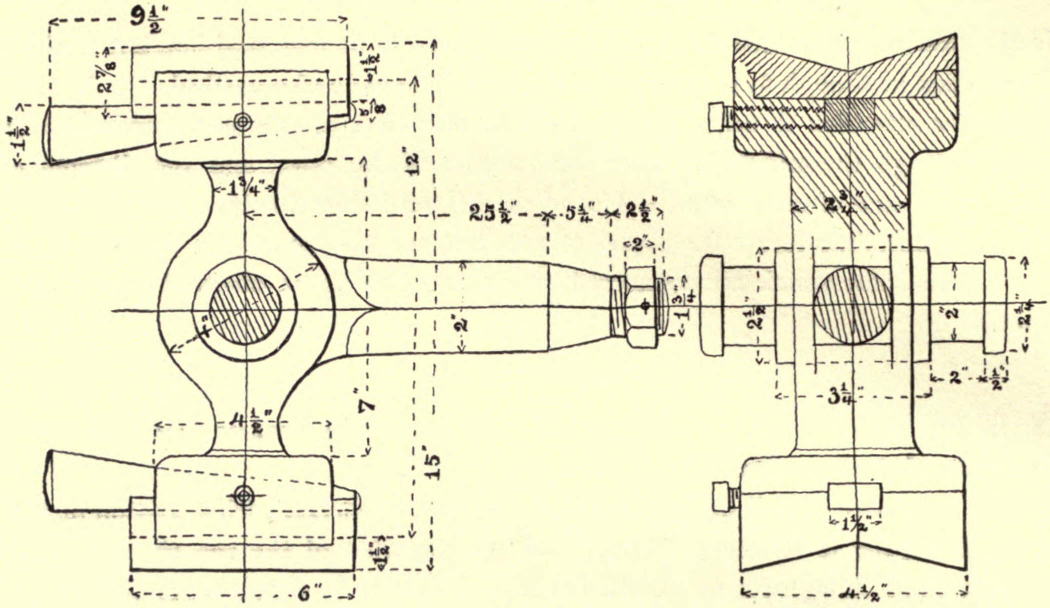

FIG. 45.

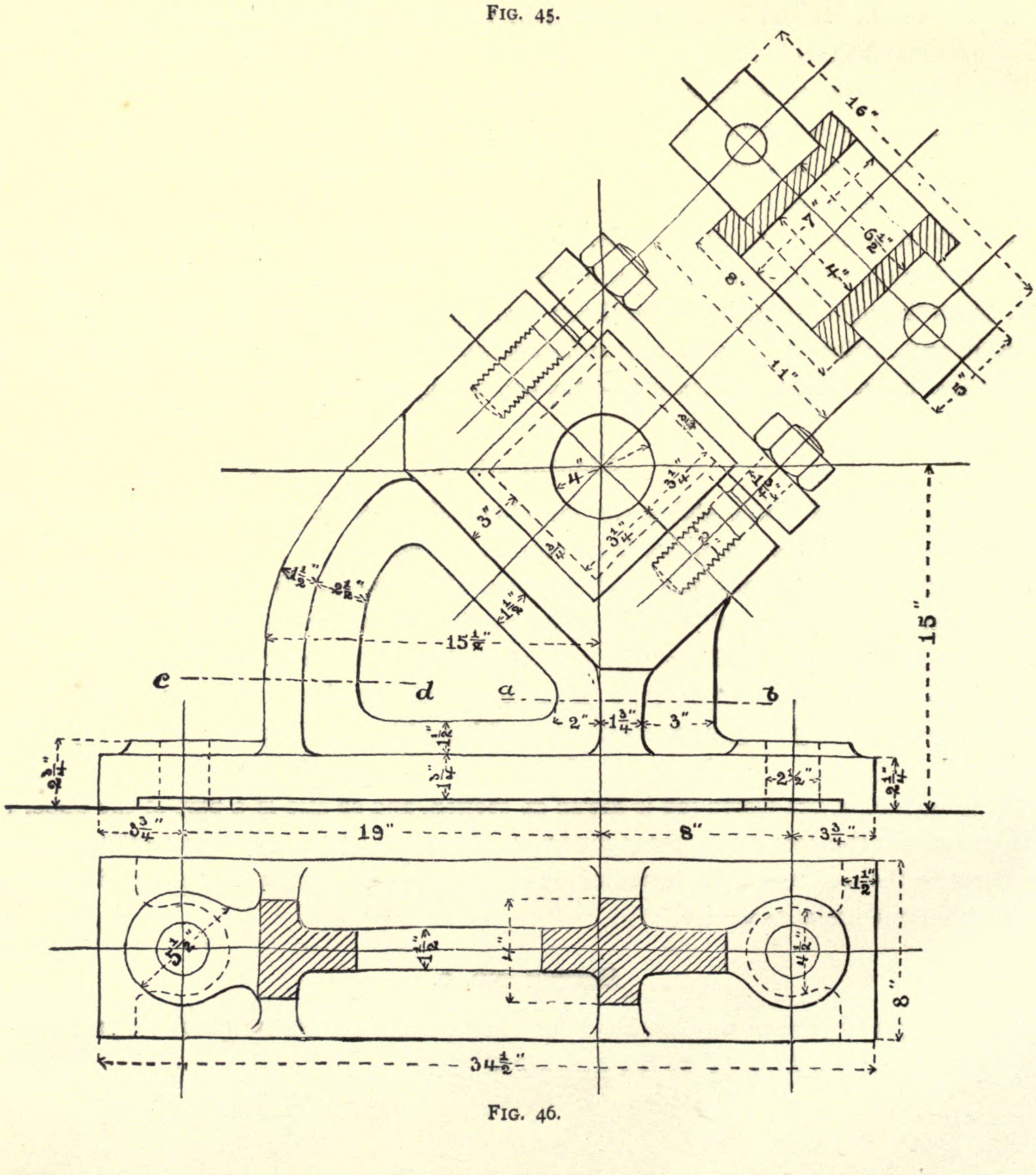

FIG. 46.

In such a case as this, it is at once apparent that while the front view is in the highest degree explanatory, a view from either the right, the left, or above, would be not only troublesome to sketch, but of very little service in the way of imparting information, if it were made.

But drawing a centre line perpendicular to the cap, it is equally clear that a direct view of the bearing from the upper side, in the direction of that line, will convey all that is lacking as to the construction of the brasses and the solid metal by which they are surrounded; the cap may be omitted, if, as is usual and as here supposed, its outline be the same as that of the bearing. This view is made more distinct by supposing the upper brass to be removed, and showing a section of the lower one, as though a film had been planed off its upper face.

The centre lines of the bolts are drawn and the distance between them given: which is sufficient, as when there is no indication to the contrary, it is always understood that they are equidistant from the main centre line; and the same holds true in regard to other dimensions, such as the breadth of the bearing, the diameter of the bore, the width of the brasses: when practicable, the whole should be given, as in this illustration, and not the halves, or distances from the centre line.

21. But when, as in the side view, the main centre line (in this case the vertical one) is not a line of symmetry for all parts, then the unequal distances from it to those lines which it is necessary to locate should be given: as for instance the centre lines of the holding-down bolts.

Now, the base of this bracket being horizontal, a top view of it is essential. But in order to avoid the introduction of a foreshortened view of the bearing, cap, etc., the upper part is cut off, by the two horizontal planes *ab*, *cd;* and then looking perpendicularly down upon what is left, a perfectly clear idea is gained of the structure of the supporting ribs and of the whole arrangement of the base, the facing strips on the bottom being dotted in. From this faced surface the vertical distance to the centre line of the shaft is measured.

In sketching such an arrangement as this, there is no reason for deviating from the true proportions as they actually exist, since all the parts are so compact that there is no necessity to reduce any one of them for the sake of economizing space, nor is there any for enlarging others in order to make the figures clear.

Opportunities of this nature should always be improved for the purpose of gaining practice and skill in accurate free-hand drawing, and as much care taken as time will permit to sketch in proportion, for reasons already explained.

Sketch No. 7.

23. In Fig. 47 are shown all the sketches necessary for the barrel of an air-pump for a marine engine provided with surface condensers.

This is very different from the preceding subject in respect to the possibility of sketching in proportion; the diameter and the length being so great, as compared with the thickness of the metal, the breadth of the flanges, and the sizes of the bolts, that any attempt to show the whole in correct relations would be preposterous.

Therefore the effort is not made. A longitudinal section is absolutely necessary, and the thickness of metal in different parts, as well as the joints and fastenings, must be clearly shown.

Now, the barrel of the pump is round, and it has a curved nozzle or discharge-pipe, of rectangular section, on one side near the top. The bore of the pump, and the number and

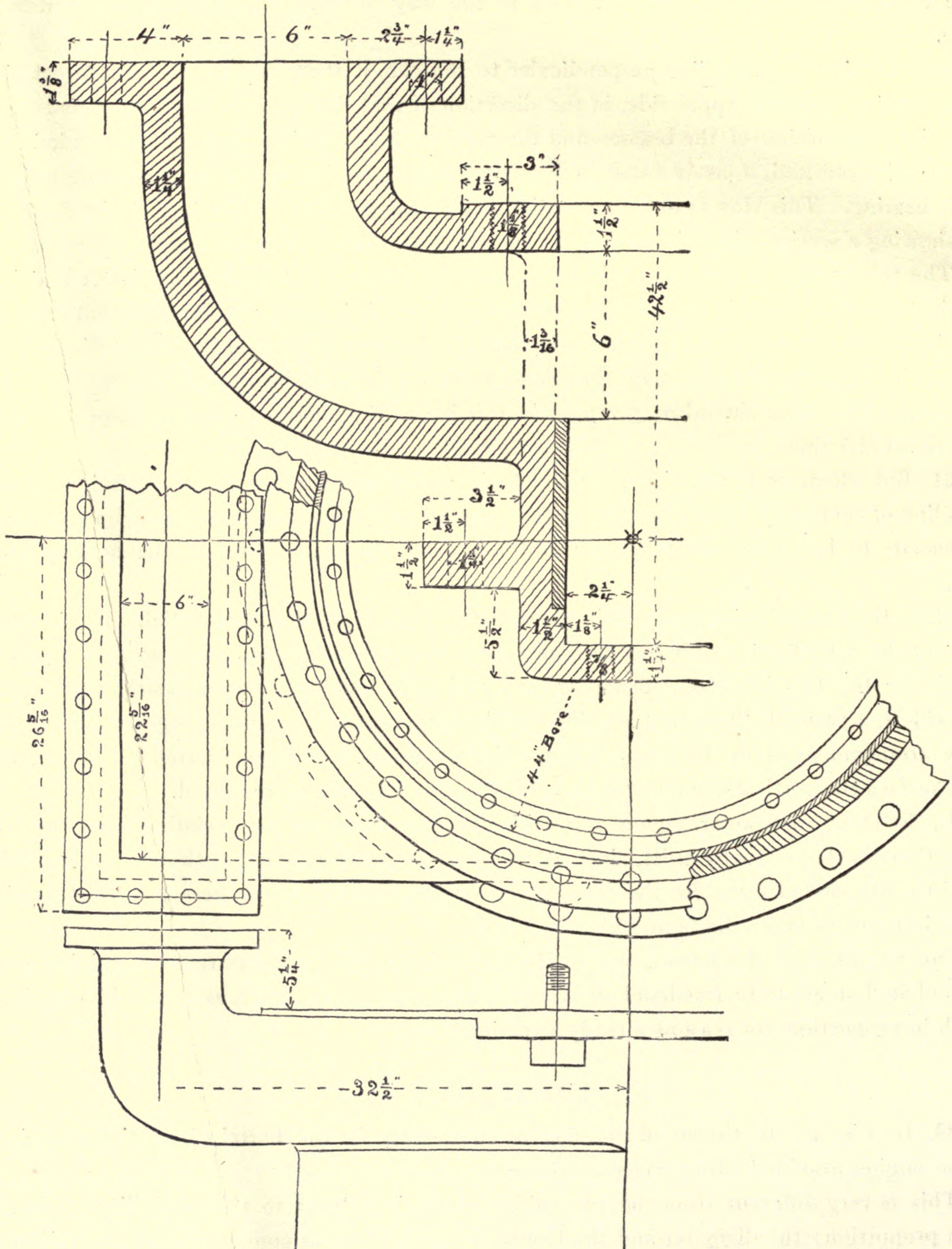

FIG. 47.

arrangement of the bolts in the flanges, are fully indicated by making a top view of a little more than one quadrant, with a little more than a half of the rectangular discharge-pipe just mentioned. This view is sketched on a small scale in the lower part of Fig. 47: or rather the central part, for below this top view is given an outside view of the upper part of the barrel, including the upper flange and the discharge-pipe; showing clearly that this last extends only to the main centre line, and also exhibiting a hub which must be provided for one of the standing bolts, which comes directly over the side wall of the nozzle.

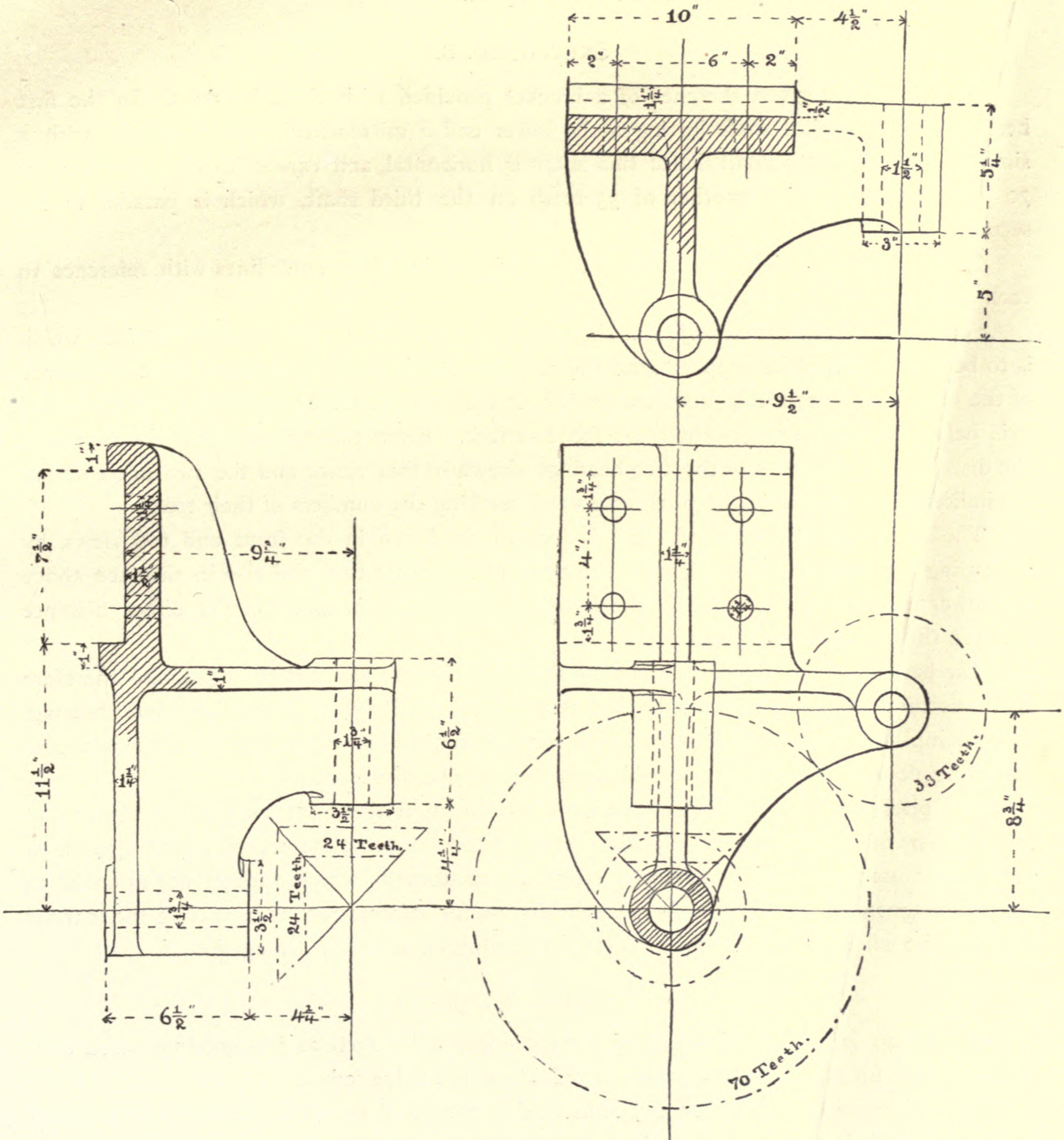

FIG. 48.

Above these is made a sketch on a much larger scale, being a section by the plane *ab*; but a section only of that side on which the discharge-pipe is placed: the form of the section of the opposite side, in so far as it is unlike this one, is indicated by continuing the side wall of the barrel, above the lower side of the nozzle, in a peculiar style of dotted line, consisting of alternating dashes and dots.

In making this sectional sketch, all the flanges and bolts are indicated, and the dimensions written in: the length is contracted, in order to save in height; and thus the whole is fully recorded within very reasonable limits of space.

Sketch No. 8.

In Fig. 48 are given sketches of a bracket provided with three bearings. In the first bearing runs a vertical shaft having at its lower end a mitre-wheel, which engages with a similar wheel on the second shaft; this shaft is horizontal, and carries also a spur-wheel of 70 teeth, engaging with another of 33 teeth on the third shaft, which is parallel to the second.

This example specially illustrates the necessity of locating centre lines with reference to each other and to faced surfaces.

As clearly shown in the side view at the left, this bracket has a faced bearing surface, which is to be bolted against its support; and the first step should be to measure the exact distance of the vertical axis from this face: the second, to measure the distance of the lower horizontal axis below the lower edge of the same faced surface. From these centre lines are measured the distances to the faces of the two bearings shown in that view; and the two mitre-wheels are indicated by dotting in the pitch cones and marking the numbers of their teeth.

The centre line of the third shaft is located, as shown in the front and top views, by measuring its distance to the right of the plane of the other two, and also its distance above the lower horizontal axis, a good check being to measure in addition the direct distance between the two horizontal axes.

The bearing of this third shaft is fully shown in the two views at the right, and therefore is not dotted in, in making the side view at the left; similarly, the lower horizontal bearing, being completely defined in the two lower views, is omitted in the top view: it being a general principle to avoid dotted lines whenever they can be dispensed with.

The pitch circles of the two spur-wheels are shown in the front view at the right: and the numbers of teeth being noted, this sketch contains a complete record of the system of gear-wheels used, so far as the velocity ratios are concerned: which, though not essential to the completeness of the bracket, is, nevertheless, useful information, as indicating the manner in which the wheels, which would be sketched separately, are to be arranged.

Sketch No. 9.

In Fig. 49 are shown sketches of a "stationary link" such as is sometimes used as a reversing gear for steam-engines, with the link-block and valve-rod.

This link consists of a slotted arc, connected by means of two short standards to a curved back-piece which is extended into a lever, and secured, by means of a hub formed upon it, to a supporting spindle. The forms of the arc and the back-piece are clearly shown in the upper view at the left: the supporting spindle and the standards are shown in the side view, at the right, where, however, the lever is not dotted in, as it would present a confused and confusing mass of dotted lines.

In order to show this lever and its pin, a top view is given below, in which the back-piece

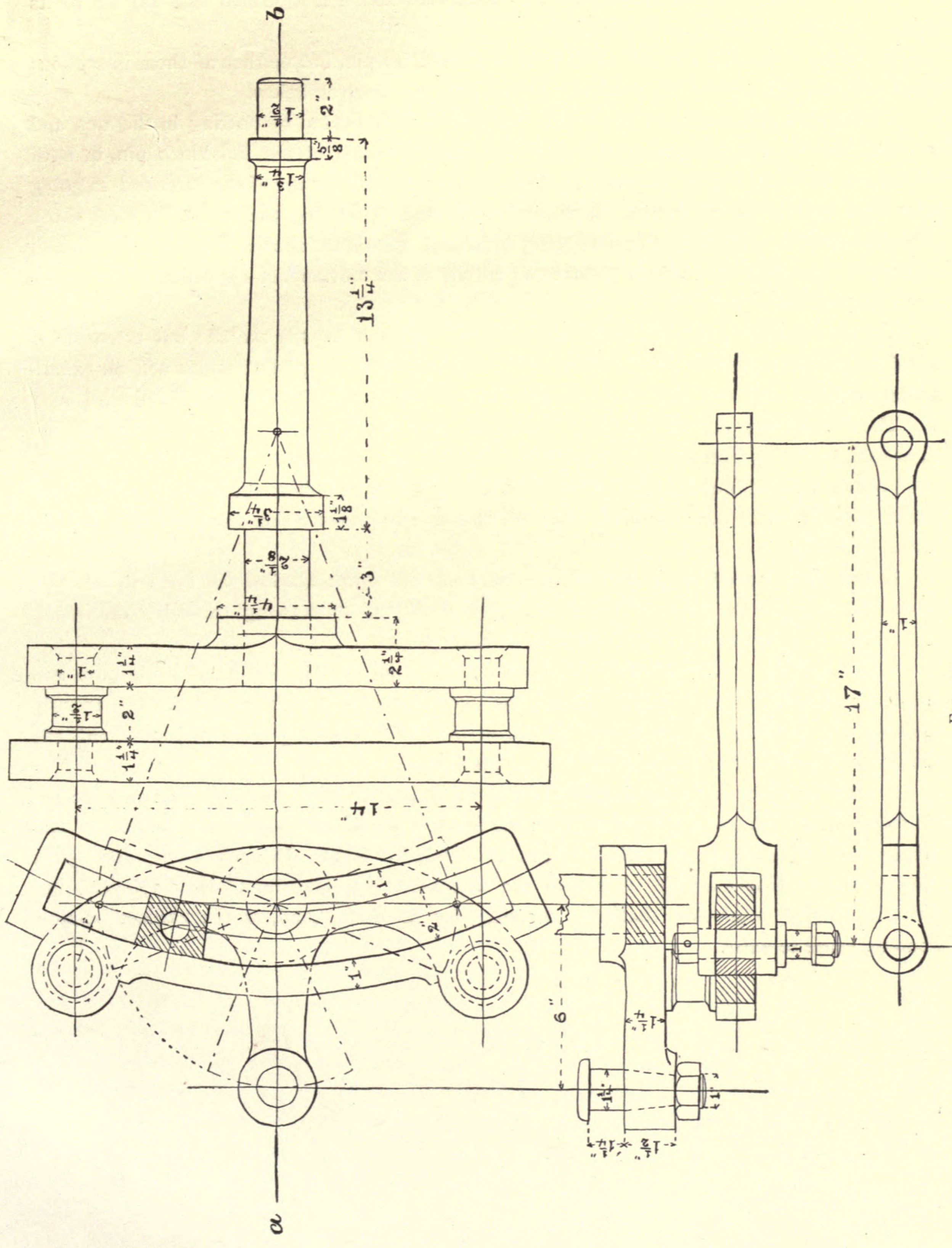

FIG. 49.

is cut off, not through the centre, but *above the hub.* The link itself, however, is cut by the horizontal plane *a b*, in this top view; so also is the link-block, which is here supposed to be in its central position, although in the front view above it is pushed half way up to its highest position for the sake of perspicuity.

In the top view also the valve-rod is shown, with its pin, but neither of them in section: and finally, a front view of the valve-rod without the pin is given below.

The angular movement of the lever and the link is indicated by dotting in the arcs, and the radii limiting the extreme positions of the lever-pin, and of the link-block pin, in both the lowest and the highest positions. Also the angular movement of the valve-rod in going from "full ahead" to "full back" is similarly indicated by dotting the centre lines for those two positions, the centres of the pins being indicated by minute circles: and thus the sketch conveys a very clear idea of the nature and extent of the movements for which the arrangement is designed.

The dimensions of all the smaller details are not given in this sketch; but attention is called to the arrangement and location of the figures which are given; which will on examination be found sufficient for laying out the link and the principal pieces connected with it.

These few examples will serve to illustrate some of the most important points to be observed in making sketches of details, the nature of the expedients which may be resorted to on occasion for abbreviating the work and saving space, as well as the style in which they can be executed with the free hand when the object is to preserve the due proportions of the parts.

It is to be understood also, that the methods of representation set forth in the two preceding chapters are just as applicable in sketching as in drawing to scale, and many useful hints may be found in the illustrations there given.

In conclusion it may be well to observe, that while skill in free-hand work pure and simple is a most valuable accomplishment, the acquirement of which cannot be too strongly advised; yet the inference must not be drawn that in "sketching from measurement" the size of instruments is under all circumstances prohibited.

It often happens that time is of the utmost consequence, and measurements and records are required in such haste that he who makes them, if not already an expert, cannot in conscience avail himself of the task to train his unskilled hand. In such event, although a scale cannot well be used, the ruler and the compasses may and should be employed: but with the mental resolution that the necessity for so doing shall, at the earliest possible moment, cease to exist.

CHAPTER IV.

DRAWING INSTRUMENTS AND MATERIALS.

1. A great number of appliances can be packed into a case of instruments, if it is only large enough; and a whole treatise might be devoted to an explanation of them. Many of those found in the more expensive cases, though each has ostensibly a purpose, are in fact of pecuniary value only, and of no practical use whatever; notwithstanding which they are very often given such prominence even in works upon drawing as to imply that their possession is desirable. It is proposed here to describe only those instruments which are essential for the ordinary, and sufficient for the extraordinary, occasions of the mechanical draughtsman; and to add some hints as to their selection, for the guidance of those whose judgment has not been trained by experience, because the difference between a good article and one which is radically bad often lies not in the quality or finish, but in points which might be easily overlooked by any one not an expert in its use.

In this as in many other matters true economy consists in procuring the best. There is a vast amount of "cheap" trash in the shops, and he who is wise will leave it there. If he has but a limited sum at command, his best course is, not to buy a "complete set" of inferior quality, but to purchase only what is absolutely indispensable at the time, and add to his stock subsequently as opportunity permits.

The English, French, Swiss, and German instruments have each their distinguishing characteristics of *style*, in regard to the beauty of which tastes differ; but this is not a thing of material consequence. But there are features which are; and instruments of whatever make should possess certain qualities in order to give perfect satisfaction in use. Some of those mentioned are almost always excessively heavy, and this is not good; every piece should be as light as is consistent with the necessary stiffness and freedom from springing. The illustrations that follow represent instruments of the English pattern, but lighter than those of English make are usually found; the exact proportions having been determined by experiment, the weight being gradually reduced until the present limit was reached. They are of American manufacture, and in every respect equal to any in the world.

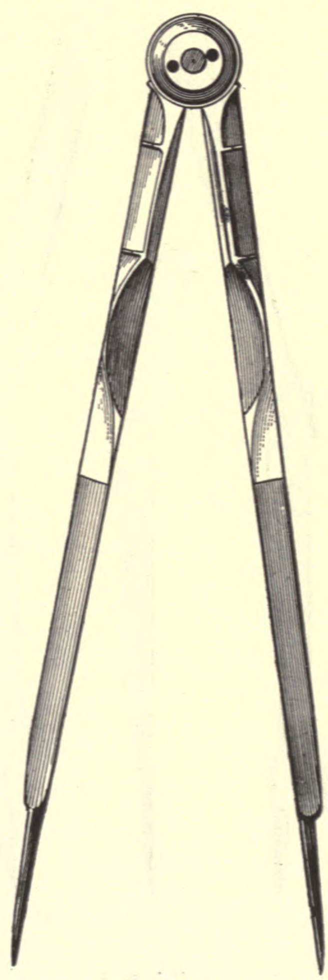

FIG. 50.

2. The Dividers.—Beginning with the "case instruments," the first thing on the list is a pair of dividers, Fig. 50. The construction of this is too familiar to require explanation. The lower part of the leg is of fine steel, the upper part preferably of German silver. The body of the leg is of triangular form, but for half an inch at the lower end is made round, forming what is known as the English needle-point. The points should close fairly together; they should be as sharp as needles, and *kept* so: their use is not to act as a nut-pick, a drill, or a reamer, as sometimes erroneously supposed, but to make the finest of visible holes *in the surface only* of the paper.

The value of the instrument depends upon the perfection of the joint. This should be so accurately fitted as to move with uniform ease through the whole range of its motion; if it goes easily in one place and sticks in another, or if in either opening or closing from any position the legs resist at first and yield with a start, the instrument is a poor one, let the maker be who he may.

The best form of joint is that shown in the figure, and known as the "double sector joint," the upper part of one leg being provided with two thin leaves of steel, fitting into two slots in the other leg. This requires the best of workmanship, but a good joint of this kind will last indefinitely, and its use is a constant pleasure.

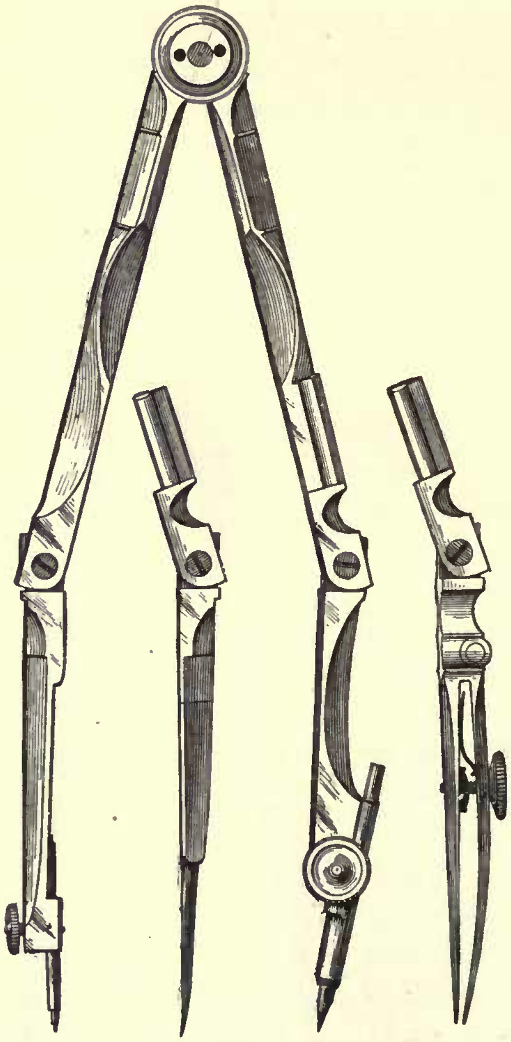

FIG. 51.

In selecting, the joint should be tested as in using; it should retain any position without the least "shakiness," but move with such ease that it can be opened to its full range with the fingers of one hand only, and adjusted, or set to any given measurement, with perfect facility in the same manner.

The most convenient length for ordinary use is about five inches, and a pair of this size should form a part of every set of instruments: if there be another pair, a length of from three and one half to four inches will be found very convenient when making drawings on a small scale.

3. The Compasses.—As above stated, the dividers are used for setting off measurements by pricking the surface of the paper; they are never used for describing circles. The instrument for this purpose is a pair of compasses, Fig. 51. The form and construction are the same as in the dividers, except that one leg is jointed, and the other leg is fitted with three "shifting points," viz., a plain leg, a pen, and a pencil-holder, each of which is also provided with a joint.

These joints are necessary in order that each leg when in use, or at least the lower part of it, may be placed as nearly vertical as possible.

A great many are to be found with joints only in the shifting pieces, the other leg being rigid like that of the dividers; these, too, have their proper place, and that place is in the show-case of the dealer's shop.

The principal joint (that uniting the legs) is made the same as in the dividers, and the same tests should be applied to it in selecting; the joints in the leg and shifting pieces are also best made double, two leaves of steel fitting between three of German silver; they should move with uniformity throughout, but rather less easily than the main joint: they are more liable to disarrangement in handling, and nothing is more vexatious than compasses which are "weak in the knees."

4. **The Needle-point** with which the permanent leg of the compasses is provided should be most carefully scrutinized. The point itself is separate from the leg, and consists merely of a piece of finely tempered steel wire, which should be quite thick, tapering to a point like that of the dividers at one end; at the lower end a square shoulder is formed, with a very fine and sharp point projecting below it. This point only should enter the paper, and the object of the shoulder is to support the weight of the instrument. Hence the shoulder should be as broad as the diameter of the wire will leave it; and on no account should the lower end of the wire be chamfered or tapered, as it too often is.

The needle-point enters a cylindrical socket in the lower end of the leg of the compasses, and is secured by a set-screw. It should enter this socket with a snug sliding fit, without side shake, and be of such length that the set-screw shall bear against the cylindrical and not against the tapered part.

There is another form of needle-point, in which a socket or a clamp is arranged to hold a common needle; which is mentioned only to warn the reader against it as being in most cases worse than none at all, and in the remainder very little better.

5. The best mode of securing the shifting points in place is by means of the "bayonet joint," which is shown in the figure. The lower end of the short leg to which they are fitted is first drilled to form a short cylindrical socket, and this socket is then sawed through for a short distance, on the outside, allowing a small amount of spring.

The upper end of each shifting point is turned cylindrically to fit the socket, and provided with a feather on the outside, which enters the split above mentioned, being very slightly tapered to secure a tight and reliable fit. This is far more neat, compact, and convenient in use, than the more common device of a binding screw to hold the shifting pieces in place.

If the latter is used, the socket and the neck which enters it should be square in section, and should fit without side shake before the binding screw is tightened; also, let the purchaser see to it that the screws are long enough, and have heads of liberal size.

6. **The Shifting Points** are three in number, as previously stated, viz.: a plain leg, a pen, and a pencil-holder.

The plain leg is formed like that of the dividers, and like it terminates in an English needle-point. When this piece is used, the movable needle-point of the permanent leg may be reversed, when the whole becomes another pair of dividers, which is sometimes very convenient.

The pen is formed of two blades of steel, through one of which an adjusting screw passes, which is tapped into the other; the whole being precisely like the drawing pen to be more fully described presently, and subject to the same scrutiny and criticism in selecting.

The pencil-holder is in the form of a clamp, consisting of a small tube, which is either a part of the lower piece of this joint, or if made of steel, brazed to it on the outside, at a small inclination as shown. Both tube and supporting piece are split longitudinally, and a binding screw on the side gives the requisite pressure.

This piece should be most carefully scrutinized, as there are many makers who seem to think that, no matter what the proportions or arrangement, a clamp is a clamp, and one as good as another; and so it is *not.*

In the first place, the tube should be accurately drilled, so that a Faber "instrument lead" may *fit* it, and thus receive uniform pressure at every part of the tube when screwed up.

In the second place, in order to produce this uniform pressure, the binding screw should be placed *opposite the middle of the length of the tube.*

In the third place, that the lead may be held with sufficient firmness, the tube should be *from one half to three fourths of an inch in length,* according to the size of the instrument.

In the fourth place, the lower end of the tube, when the compasses are closed, should be *at least five sixteenths of an inch above the lower end of the needle-point socket on the permanent leg.* Thus the lead will project about three eighths of an inch below the tube; which is necessary in order to sharpen it properly.

In the fifth place, the head of the binding screw should stand well out from the bearing surface, be of liberal size and thickness, and well milled on the edges. And the same is true of all binding screws employed.

7. The above form of pencil-holder is beyond question and beyond comparison the best form. There is another, in which the end of the split tube is made conical, and compressed by screwing over it a tube correspondingly tapered internally. The whole is precisely the same device as that used for securing the movable leads in wood or ivory holders for writing; which purpose it answers admirably. But its application to a pair of compasses is the climax of misdirected ingenuity, and mention is made of it for the sole purpose of cautioning the reader against it. The pencil is to be trimmed to an edge, which must be tangent to the arc to be drawn; and after trimming it is usually a little too short, and requires to be drawn out. With the clamp first described, this adjustment can be readily made, nor is there any danger of disturbing it in tightening the binding screw. But with the device here deprecated, the lead is almost sure to be pushed in, and what is worse, turned partially around; so that in spite of its neat and plausible appearance, it is practically as bad an arrangement as could be adopted.

Another useless piece of furniture is ordinarily added to the compasses. This is the "lengthening bar;" which is a bar of metal, one end fitted to enter the socket of the short leg, the other furnished with a similar socket, to receive the pen or pencil. The object is to increase the range and permit large circles to be drawn: a good object, but a bad expedient. For with this addition the instrument is apt to spring unless excessively heavy: a beam compass is much better.

8. The compasses, if there be but one pair in the case, will be best adapted for general use if about five and a half inches in length. If larger they are too heavy, since in order to prevent springing the weight must be increased in a more rapid ratio than the length.

Smaller ones are extremely serviceable: and a pair of four inches in length, made upon exactly the same lines, will soon come to be highly prized by the possessor; being more convenient than the larger ones for drawing circles a little beyond the range of the spring-bows, and for general use in making drawings on a small scale.

9. The Drawing Pen.—This instrument, as shown in Fig. 52, consists merely of two rather stiff blades of steel, formed out of one piece. Their elasticity keeps them apart, the distance being adjusted by means of the screw, which passes through one blade and is tapped into the other.

This is the best form, although its first cost is least. Many pens are made with the outer blade hinged to the inner one, the two being kept apart by a spring. The ostensible advantage is the facility of cleaning them: which is no real advantage, because there is no difficulty in cleaning the others. The jointed pens cost more, and are not as good; because the least wear will permit a sliding movement of one blade over the other, which renders their action uncertain.

The inner edge of the blade into which the screw is tapped should be straight, and in line with the axis: the outer blade should be so curved, as in the figure, that the two shall approach each other most rapidly toward the point. The object is to have a reasonable quantity of ink retained there, so that it will not evaporate too quickly, as it would if the film were thin. The blades should be comparatively broad, and well rounded, at the points, as then they will not wear so rapidly, and will remain longer in condition to make smooth lines, than if they taper to a narrow point. In selecting, they should always be tested to see that they are properly set, and have no tendency to cut or to scratch the paper. The case should contain at least two, and preferably three, pens of different sizes, the smaller being used for the finer lines.

Fig. 52.

With proper care and usage, the pen will remain for a long time in good working order. It should be held as nearly vertical as possible, that the blades, when they do wear, may wear "square across." For wear they will, and occasionally require to be reset: and if by habitually inclining the pen the blades are thus worn off obliquely, the film of ink in contact with the paper will be bounded by converging instead of parallel lines, and when this is the case to any appreciable extent the line drawn will be no longer smooth and even, but ragged and rough. The sharpening, or "setting," is effected by means of a small fine oilstone, and the secret of success is best learned from the instrument-maker. If the draughtsman in constant employment cannot sharpen his own pens, it is a good plan to have an extra set of them, that he may always have those serviceable which are in use.

10. The Spring-bows. For the smallest work there must be smaller instruments: and the "spring-bows," Figs. 53, 54, and 55, are adapted to the drawing of very small circles, and the subdivision and setting off of minute distances. The legs of these, instead of being jointed together, are formed of one piece of steel, the elasticity keeping them apart, and the radius being adjusted by means of a screw pivoted to one leg, passing through a hole in the other, and provided with a milled thumb-nut. The hole in the outer leg must be large enough to accommodate the motion of the screw as the angle of the legs varies, and on the outside should be of spherical form, the bearing end of the thumb-nut being correspondingly convex, in the manner of a ball-and-socket joint.

In all these little instruments, the degree of stiffness of the spring is of paramount importance. A very common fault is the making of the legs too thin at the top, the result being a tendency to tremble, and a consequent variation of the radius, often even under the slight pressure required to draw a firm clean line with them. If there be the slightest indication of such weakness at any part of the range, the piece should be peremptorily rejected; it is better that the spring be a little too stiff; but there is not much latitude in that direction either, for too powerful a spring causes the screw and nut to

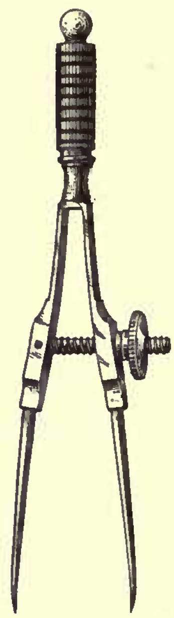

FIG. 53.

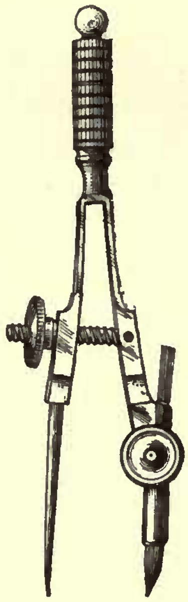

FIG. 54.

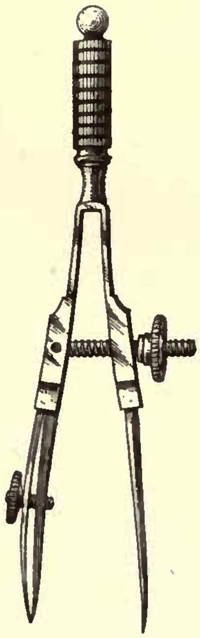

FIG. 55.

wear out rapidly, and renders the adjustment difficult. All these instruments are manipulated by means of a small handle at the top, preferably of cylindrical form, and made of metal very finely milled to give a firm hold.

11. The "spacing divider," as it is often called, Fig. 53, consists merely of two plain points; these should be as sharp as steel can be made, *and kept so;* and capable of being screwed up so that the extremities will meet.

The "bow-pencil," Fig. 54, has one leg formed into a clamp for a Faber instrument lead, exactly like that of the compasses. The tube of this clamp *should not be less than three eighths of an inch long;* and the other leg should extend at least the same distance below the lower end of the tube.

Another most important test is the following: Put into the clamp a lead truly sharpened to a conical point, or, better, a wire of the same size thus tapered, and close the instrument. These two points *should come exactly together;* if they do not, the piece is not worth accepting as a gift, unless on condition that the recipient may in turn present it to a rival. In other words, the axis of the tube should lie in a plane passing through the supporting point (or centre of the circle to be drawn) and the axis of the handles.

The most serious fault is to have the tube inclined to that plane; and the next to that to have the clamp come foul of the opposite leg on closing the instrument. The former renders it difficult to draw a circle at all; the latter renders it impossible to draw the smallest ones: both are very common, but neither is excusable.

To do the best work with this instrument, the lead must be carefully trimmed to a clean *edge*, rounded like the point of the drawing pen, and concave on the inner side as in the figure; it must also be as carefully adjusted so as to lie with this edge tangent to the circle, and to be of just the right length. All of which can best be done with the form of clamp here recommended.

The bow-pen, Fig. 55, has one leg formed into a pen, which is exactly similar in form to the drawing pen, Fig. 52. The peculiar curvature of the outer blade, to which attention was called in (**9**), is most important in this small bow, because when set to a very small radius, the pen cannot be cleaned and refilled easily without opening the legs; and when a large number of such little circles of the same radius are to be drawn, it makes a great difference in time whether this operation must be repeated once in five minutes or once in ten.

The bow-pen should be carefully tested by trial, to see that the plane of the edge of the pen is tangent to the circle; and also to see that when closed the opposite leg shall *touch* the inside of the pen, *and that at the middle of the breadth of the blade.*

The supporting point should project a very little beyond the end of the pen or the pencil, so as just to puncture the surface of the paper: and it should be possible with either pencil or pen to draw a circle of one thirtieth of an inch in diameter, or even less.

12. The form of spring-bow above described is recommended as being the lightest and most convenient. One material feature, affecting the convenience, remains to be noted, viz.: *the adjusting screw is pivoted to the pen or pencil leg, and the thumb-nut bears against the opposite leg.* This is of especial consequence in the smaller sizes, and more important in the bow-pencil than in the bow-pen. But it is far preferable to the contrary arrangement, adopted by many makers. For in that arrangement the thumb-nut is in the way of the pencil, unless the adjusting screw is too high up or the pencil-clamp too low down or too short—and very often all these faults exist at once; and again, in drawing several small circles without lifting the bow from the paper, the instrument being held on the centre by the index-finger resting on the top of the handle, the thumb and middle finger are used in changing the radius; so that if the nut is over the pen or pencil the work is obscured by them.

13. If there be but one set of bows, a very convenient size is one inch and three quarters in length, from the crotch of the spring to the point. If there be two sets, the smaller may be one inch and five eighths, the other two inches, in length. They are to be had much larger than this; but are not to be recommended, as too wide a range makes the adjustment tedious; besides, those larger ones are not suited for very small work, and anything beyond the range of the size first mentioned can readily be drawn with the compasses.

These spring-bows, it is to be observed, may be and often are provided with needle-points: and if there be two sets, the larger ones may advantageously be thus fitted; or at least the ones with the pen and the pencil. The advantage is most obvious in the case of the pen bow, owing to the necessity of some adjustment due to the gradual shortening of the pen by wear. But in respect to the wearing of a hole in the paper when many circles are drawn about the same centre, the advantage is more fancied than real, if the operator handles his instruments as lightly as he should. And in drawing very small circles the needle-point is rather in the way: but if it be preferred, by all means let the *shouldered* needle-point be chosen, and made precisely like that described in (4). Except of course in the case of the spacing divider, which must have tapered points if it has any.

14. Jointed Bows.—The above are the *essential* instruments; if additional facilities for drawing circles are desired, a jointed bow-pen and bow-pencil, Figs. 56 and 57, may be added,

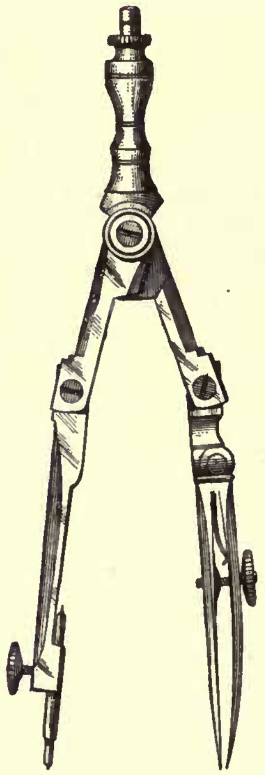

Fig. 56.

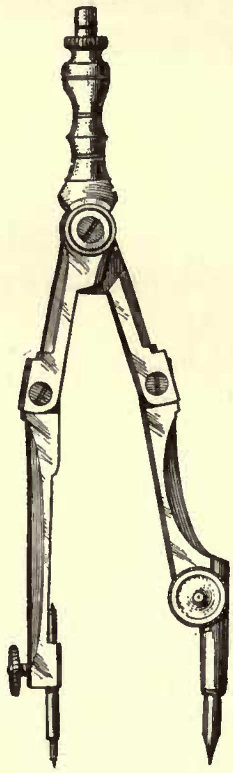

Fig. 57.

and are in many emergencies very useful. They are exactly similar in construction to the compasses, (double-jointed throughout,) with the addition of a handle at the top, a jaw at the lower end of which embraces the main joint of the instrument. Thus these bows are manipulated like those before described, by merely twirling the handle between the thumb and finger.

Bows of this kind should not be more than about two and a half inches in length from the point to the centre of the main joint; for if much longer, they cannot be well controlled by the handle at the top.

And it may be added, that the mere existence of such a handle, for any reason, upon larger compasses or dividers, is a nuisance. It forms a necessary part of the Alteneder joint, which for that very reason is not recommended; it is a very good joint, but not in any particular better than an equally well-made double one, and this excrescence makes it very objectionable for any but the smaller instruments, like those just described.

15. The Beam-compass.—For setting off distances too great for the dividers, and for describing circles of radii beyond the range of the ordinary compasses, the instrument shown in Fig. 58 is used.

This consists essentially of two German silver sockets, *A* and *C*, which slide freely on a wooden bar, or "beam," *B*. The socket *A* has on top a binding screw, *E*, for securing it at any position on the beam; the point of the screw pressing not directly against the wood, but upon a metal tongue fixed inside the socket, which distributes the pressure and protects the beam.

On the bottom of the socket is a cylindrical hub, *O*, drilled to receive the shank of a plain point, *D*, or a needle-point, as the case may be, and fitted with a binding screw to hold the point in place.

The other socket, *C*, also has a clamping screw, *I*, similar to *E*, but on the lower side

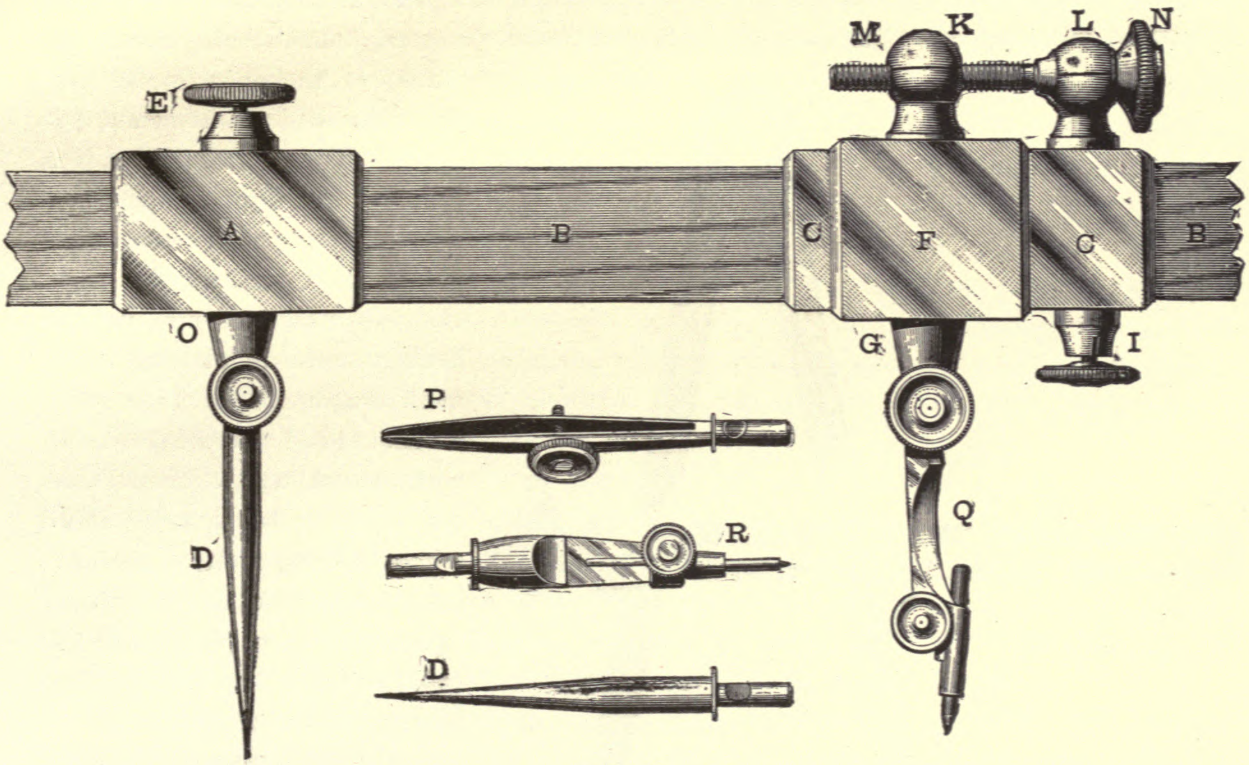

FIG. 58

instead of the upper. It also carries a fixed stud, *L*, which forms a bearing for a journal turned on the prolongation of the screw *M*, operated by the milled head *N*.

The nut for this screw is the stud *K*, fixed on the socket *F*, which is accurately fitted to slide on *C*, and is provided below with a hub, *G*, arranged like *O* for carrying a movable point, a pencil or a pen. Thus when *C* is clamped to the beam after setting the instrument as nearly as may be by the hand, the precise adjustment is completed by turning the milled head *N*.

16. This is recommended as the most convenient form of beam-compass for general use. It will be noted that as *both* sockets slide on the beam, it is easy to keep the instrument in balance, which cannot be done if, as in some forms, one socket is fixed at the end of the bar. And also that, in this arrangement, the whole adjustment can be effected without lifting the instrument off the paper: the beam is naturally supported by the second and third fingers of each hand, and without removing this support, the screws *E*, *I*, and *N* can be manipulated with perfect ease by the thumb and first finger. Thus with a two-foot beam, any number of circles, varying from four inches to four feet in diameter, can be drawn without moving the needle-point from the centre, and without removing the hands from the most convenient position in handling the instrument.

17. There are two arrangements often found in beam-compasses of different designs, either one of which would be worse than the other, if that were possible. The first consists in having the sockets open at the top, the binding screws being placed on the side; so that they do not require a special beam, but may be clamped on any flat ruler; and they drop off that ruler every time the clamps are loosened to adjust them. The other consists in making the pen or pencil carrier the vertical arm of a bent lever, the fine adjustment being effected by means of a vertical screw acting to raise or lower the horizontal arm: probably the worst adaptation of wrong means to the right end ever contrived by any human being, unless the device of the open socket may share that bad pre-eminence.

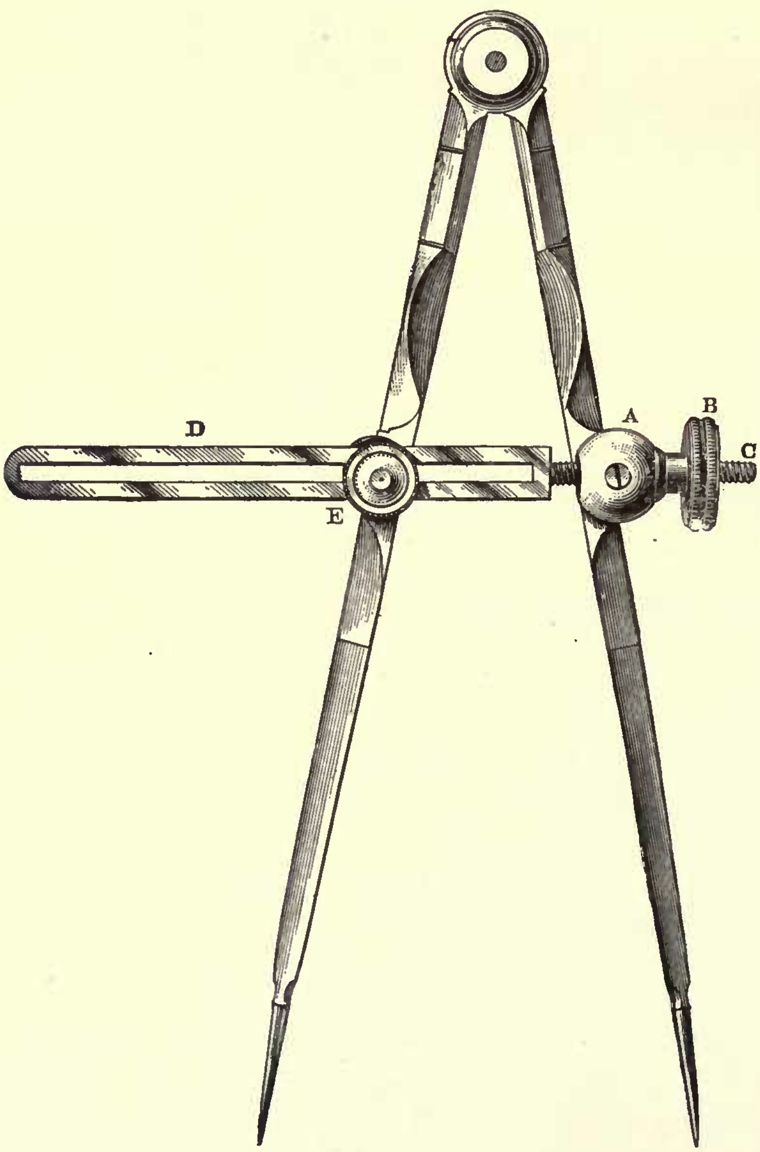

Fig. 59.

18. The "furniture," as it is called, of the beam-compass consists of two plain solid steel points, D, D, used merely in setting off measurements, and especially useful in plotting movement diagrams on a large scale; a shouldered needle-point, R, which should be of liberal diameter in the body, so as to afford a good bearing surface; a pen, P, of the same form as the drawing pens; and a pencil-holder, Q, the construction of the clamp being like that before described.

A beam-compass like that shown in the figure, the sockets being fitted to slide easily on a satin-wood bar of rectangular section, five eighths of an inch wide and five sixteenths thick, is large enough for all ordinary work. In addition to this, one of which the bar is three eighths wide and half as thick, with or without the slow-motion screw for adjusting it, is an exceedingly convenient thing to have; being preferable to the jointed compasses, particularly in inking in, when the circles are so large as to be near the limit of the range of the latter.

19. Dividers with Tangent-screw.—This instrument, Fig. 59, is to be classed among the draughtsman's luxuries. It is not very often wanted, but when the occasion does come, it is wanted very much: as for instance in laying out a wheel whose number of teeth is 31, or 67, or any large prime. There is in such cases, as every expert knows, no practical escape from the operation of setting the dividers to the chord, and "stepping this distance off" around the pitch circle. And if the pitch is too great for the spacing divider, Fig. 53, the instrument here shown is invaluable.

It consists essentially of a pair of dividers made much heavier than the plain ones, to one leg of which is pivoted the ball *A*, so as to turn freely. An adjusting screw, *C*, is formed on the end of a slotted steel bar, *D*, and passes through the thumb-nut *B*, which is extended into a journal whose bearing is in the ball *A*; "end shake" is prevented by a set-screw with conical point, which enters a triangular groove in the journal. The other leg of the instrument has a hub projecting from its face, upon which the bar *D* rests; and into this hub is tapped a binding screw, *E*, which passes through the slot. When this screw is loosened, the dividers are manipulated like the ordinary ones, and set as nearly as possible to the right measurement; the screw *E* is then tightened, and the adjustment completed by turning the nut *B* in one direction or the other as may be required.

20. By means of this attachment, the dividers can not only be adjusted with the utmost accuracy and facility, but they will stay so: and this last consideration is often very important, as the slightest accident, such as may happen to the most careful operator, either "alters the set" of the common dividers, or, what is almost as bad, leaves it uncertain whether it has done so or not.

The immense superiority of this device to the common and cheaper one of the "hair-spring" and screw is too evident to require demonstration. The hair dividers are not only liable to accidental derangement through a movement of the legs at the joint, but unless the spring is uncommonly stiff, and the manipulator unusually certain of hand, the spacing with it is subject to variations due to springing of the adjustable leg; far more so than the small spacing divider, on account of the greater length.

21. As previously stated, a great many other instruments are often put into the larger cases, and there is a pleasing delusion that they make the outfit more complete. Among these, in addition to the hair dividers, may be mentioned proportional compasses, "wholes and halves," bows and compasses with reversible points, "railroad" or double pens, dotting wheels, metal squares, triangles of small size and unknown angles, sectors, broad ivory scales with the sides covered with lines and figures like those of Gunter, rectangular protractors, three-legged compasses, three-bladed pens, parallel rulers and opisometers.

In this list there is not an item of any value to the mechanical draughtsman, and hardly one of practical use to anybody else; some of the articles are very expensive, and none of them will, by any service rendered, pay interest on the first cost. Probably the one most absurdly overrated is the proportional compass, which is a brazen impostor, and the use of it is a waste of time.

22. The Drawing Board.—The best material for the drawing board is clear, well-seasoned, straight-grained white pine, free from knots and from turpentine. If the board be too large to be made of a single piece, the requisite breadth is made up of two or more pieces by simply matching and gluing the edges, without tongues or grooves.

In order to prevent the board from warping, two battens of hard wood are fitted into dovetailed grooves across the back; these should be fitted accurately, so as to require to be driven in, but on no account should they be glued in. The object is to allow the board to expand or contract as it will, sliding slightly on the battens, and no fastening must interfere with this freedom. In order to weaken the board transversely, and thus lessen its power to warp, the back is run lengthwise over a circular saw, thus cutting a series of slits half through its thickness, from a half to three quarters of an inch apart, as shown in Fig. 60, which represents a drawing board such as above described.

If the board be a large one, it may advantageously be not only weakened but lightened by planing a series of grooves in the back, instead of merely slitting it; these may be three quarters of an inch wide, and the ribs left between them of the same breadth, making the section of the board appear as shown at *A*. The battens for large boards may also be more easily fitted if made in two pieces, as at *B*, which should be both glued

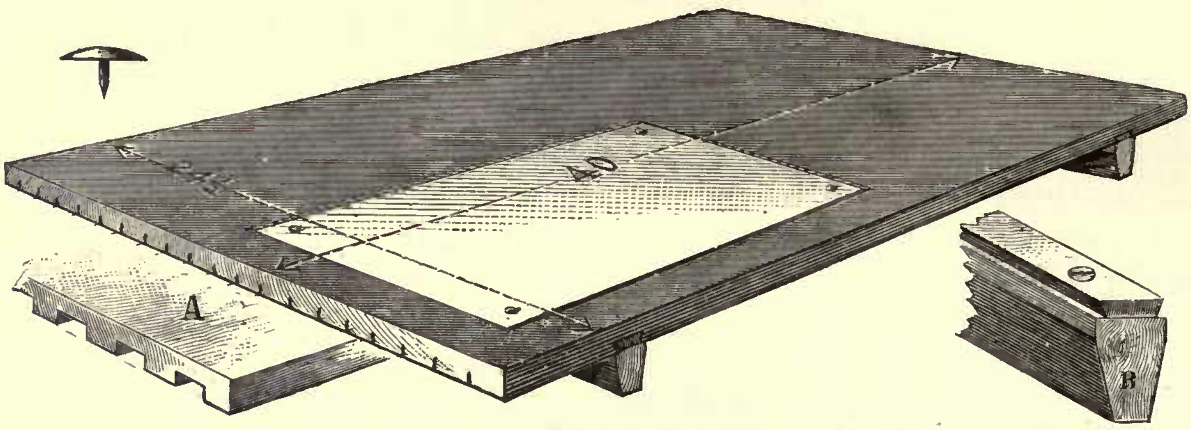

Fig. 60.

and screwed together: the upper strip, which slides into the dovetail groove, should always be of ash, cherry, or similar hard wood, but the lower and larger piece may be of pine. The ends and edges of the drawing board should be *planed* true and smooth, and its upper surface sand-papered. But no oil, paint, varnish, or polish of any kind should be applied to any part of it.

The above is believed to be the best construction possible for a board made entirely of wood: and even if an iron frame were to be used, substantially the same principles should be adhered to in making the wooden centre. This is mentioned here, because it must be admitted that the most minute precision can be attained only by the use of metal straight-edges and squares, including the edges of the drawing board and both stock and blade of the T-square. But for the ordinary purposes of the mechanical draughtsman a sufficient degree of accuracy can be secured by using wood instead of metal.

23. The T-square.—Two forms of this important instrument are shown in Fig. 61, one with a fixed, the other with a movable, blade. In the first the blade is usually secured to the side of the stock by gluing, as well as by the screws shown. But, however it is fastened, let it be noted that it is not let into the stock, or head, but simply laid over it: thus when in use, the upper side of the stock is flush with the face of the paper. This allows the triangle to slide past the edge of the paper, at the left, instead of being arrested by the inside of the stock as when the blade is let into it.

The same construction is adhered to in the other form, the blade in that case being held in any desired position by *two* binding screws. The inner one of these is fixed in the stock, and passes through a hole in the blade, thus serving as the centre of rotation when the milled nut is loosened. The other one has a round head below the stock, and a portion of the neck of the screw is fitted to slide in a circular slot in the stock itself, whose centre is the first screw: it then passes through another hole in the blade and is fitted above with a milled head like the other one. Thus the blade is easily set at any

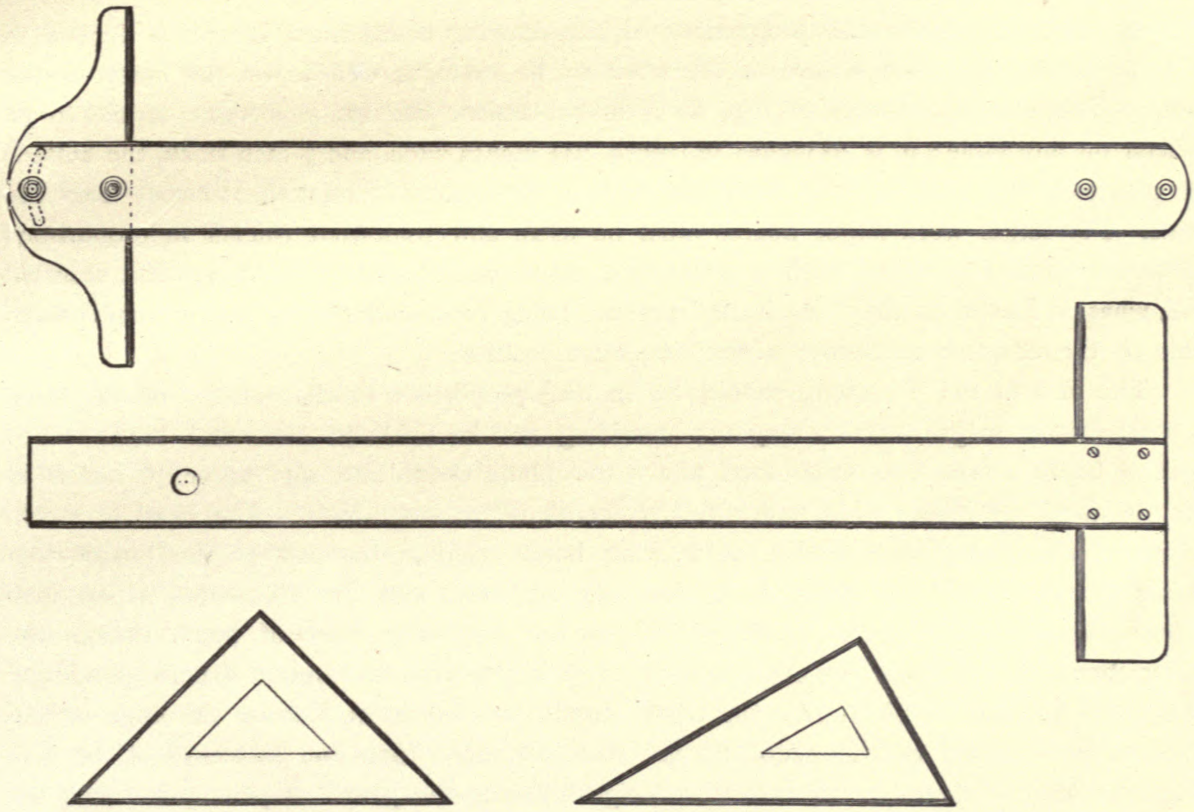

FIG. 61.

angle, and, what is most important, *it can be set firmly;* and this is due to the use of *two screws*. In many styles of "swivelling heads," as they are called, but one screw is used, and the strength of a Samson will not suffice to fix the blade with the requisite firmness. This forms a very excellent square; two correspondingly placed holes for the screws should be made at the other end of the blade, and all these four should be bushed with brass: thus the blade can be reversed in the case of injury to the upper edge, and also detached and used as a simple ruler.

The blade should be made of wood which is fine-grained and hard. If of a single piece, probably satin-wood is equal if not superior to any for large blades, though solid ebony is used for very small ones. But a blade of any size may be made with ebony edges, and such blades are the best of all; the well-defined contrast between the paper and the ruler materially lessens the strain on the eyes, and the grain of the ebony itself is admirably adapted to the purpose. Such are the ones shown in the figure; the body of the blade may in this construction be made of any wood that pleases the fancy;

satin-wood and mahogany are very suitable. The finish that can be given to these, without any application in the nature of varnish, is sufficient for practical uses; though the beauty is enhanced by "French polishing," and also the liability to become soiled by adhering dust is diminished, and they are more readily cleaned. But on no account should any instruments of wood be "finished in oil," as they sometimes are: which is worse than no finish at all. Hard rubber is sometimes used for blades; but unless for what might be called miniature instruments it cannot be recommended, being too flexible and too brittle for those of any size.

24. The dimensions and proportions of the drawing board must of course depend to a great extent upon the nature of the work to be done, as well as on the fancy of the user. The one represented in Fig. 60 is of convenient size for a portable article, to be placed on any table; it is 40 inches in length, $24\frac{1}{2}$ inches wide, and $\frac{3}{4}$ inch thick, the battens of ash, one inch wide by one inch and a half deep, placed about three inches from the ends. For larger work larger boards must be used, and somewhat thicker in proportion: these are usually provided with a permanent stand, which should be strong and substantial, what is known as the "saw-buck" pattern being commendable for rigidity, and preferable to the common substitute of two separate trestles.

The size of the T-square should be in due proportion to that of the board, being a little less in length, that it may not overhang and be liable to accidental blows. For such a board as the one mentioned above the blade should be, say, 34 or 36 inches in length, about $2\frac{1}{4}$ inches wide, and a full sixteenth of an inch thick. The head, or stock, which is also faced with ebony, as wearing better against the end of the board than softer woods, should be about 10 inches long, $2\frac{1}{2}$ wide, and five sixteenths of an inch thick: this relates of course to the plain, not the swivelling, form of head, though the latter should be of about the same length. For larger work the square is correspondingly larger and thicker: in which case the edges should be chamfered, because the edge of any ruler is inconvenient and unreliable in use if much more than one sixteenth of an inch thick, (at most it should never exceed one eighth,) since the pencil or pen must touch the *upper* corner only. The thickness of the blade should always be such that it can be lifted from the board easily by means of the stock held in the left hand only; if too thin for this, it is too weak.

25. Tests of Drawing Board and T-square.—The T-square is used by holding the stock against either the left-hand end, or the lower side, of the drawing board; the former position is for drawing horizontal, the latter for drawing vertical, lines. When used in either position, all the lines drawn by it should be straight, and also parallel. The first condition requires the blade of the T-square to be straight; the second requires that both the inside edge of the stock, and the end and edge of the drawing board, should be straight. This part of the problem then consists in the testing of straight-edges; which is done by taking two of them, and applying one to the other, observing carefully whether any light can be seen between them: if this is the case at any position while one slides along the other, it is evidence of a fault. But even if it does not happen, the question is not perfectly settled, because each may be faulty, but the convexity of one may fit the concavity of the other. Both should then be separately tried by a third: if no defects be thus found, the presumption is that all three are correct.

This is the only test that need be applied to the T-square. It is a very common superstition that one with a fixed head is worthless if the stock and blade be not exactly at right angles. In fact this is of no consequence whatever except for the sake of appearance: if it were, the use of a movable blade would be very circumscribed; and it is not easy to see what gave rise to this false idea. Because in using the square, first against the end, then against the side, of the board, the two sets of lines thus drawn should be perpendicular to each other. And this requires simply that the lower left-hand corner of the board shall be *true;* that is, that the left end and lower side shall be at right angles; though the corners of the board are preferably slightly rounded off, as being thus less liable to injury. It therefore makes no difference, if the board has its "working corner" a true right angle, whether the head of the square be thus accurate or not.

Now, in order to test the squareness of this corner of the board, it is necessary first to have a good T-square; with this draw a vertical and a horizontal line, intersecting near the centre; describe a circle about the intersection: if the four parts into which the circumference is cut prove on careful measurement to be equal, the corner of the board is square. If all four corners are true, so much the better; but the one mentioned should be made so in every case, while the others are of less consequence.

26. The Triangles, or Set-squares.—These are among the most serviceable appliances used in drawing, and are seldom out of the hands of the expert. They consist merely of two right-angled triangles, the one having two angles of 45°, the other having one angle of 60° and one of 30°, as shown in Fig. 61. They are to be found in great variety of material and of style; some being made of a single piece of wood, others of hard rubber, some of metal, and they can be had of glass. For ordinary practical use the choice lies between those of hard rubber and those of wood, framed as shown in the figure; those of a single piece of wood are not at all to be relied on, but the framed ones are, if thoroughly seasoned. As in the case of the T-square, the best are those with ebony edges, the main frame being of mahogany or satin-wood.

A pair of triangles, or one triangle and any straight-edge, is the best parallel ruler that can be found. For this particular purpose, it would not matter what the actual angles were; but the facility of drawing short vertical lines by placing a triangle against the T-square without moving the latter from the horizontal position, at once suggests the advisability of having one angle of 90° in each, which also enables the operator to draw two lines perpendicular to each other through any point and in any position. And the frequent recurrence of lines at angles of 30°, 45°, and 60° with the horizontal or with the vertical, in mechanical constructions, is a sufficient reason for the adoption of those values in the triangles for common use; though for special purposes other values may occasionally be required. The draughtsman should have one pair of triangles measuring ten or twelve inches on the longest side; and another pair of six or seven inches will be found very convenient. These if of hard rubber will be about one sixteenth of an inch thick; if framed of wood, somewhat thicker.

27. Tests of Triangles.—To test the right angle, place the T-square horizontally, and draw a vertical line with the triangle, placing its base against the upper edge and its hypothenuse sloping to the left. Then reverse the triangle, making the hypothenuse slope to the right, but keeping the base in contact with the square. Then a vertical line drawn by the same edge as before, should coincide exactly with the one first drawn.

To test the angles of 45°, draw a vertical and a horizontal line through the centre of a circle whose radius is a little less than the short side of the triangle. Place the T-square horizontally, its upper edge a little below the centre of the circle, and against this edge place the hypothenuse of the triangle. Draw first a radius by one side of the triangle, sloping one way, then slide the instrument along and draw another radius by the other edge, sloping the other way. Each of these radii should bisect exactly the quadrant which it cuts.

Another method is to draw the circle of a diameter a little less than the hypothenuse, divide it into quadrants by the vertical and horizontal line as before; then placing the T-square with its upper edge a little below the lowest point of the circumference, place a short leg of the triangle against it, and draw a diameter sloping one way by the hypothenuse. Then use the other short leg as a base without turning the triangle over, and draw another diameter sloping the other way: these two diameters should also bisect the quadrants, and moreover should coincide exactly with two other diameters similarly drawn, but with the other surface of the triangle in contact with the paper.

To test the angles of 60° and 30°, draw the circle, cut into quadrants by the vertical and horizontal lines, as before; and, applying the short leg of the triangle to the horizontal edge of the T-square, draw a diameter by the hypothenuse. The chords of the arcs thus determined, measured from the extremities of the horizontal diameter, should each be exactly equal to the radius. Still keeping the same surface in contact with the paper, apply the long leg to the T-square and draw another diameter; the chords of the arcs measured from the extremities of this diameter to those of the vertical one should also be exactly equal to the radius. And the same should be true also when the other surface of the triangle is placed on the paper and the same process repeated.

28. Abstractly, of course, the short legs of the 45° triangle ought to be equal to each other, and the shorter leg of the 60° triangle should be one half the hypothenuse; but no reliance can be placed on a test depending upon those properties, for practically it is almost impossible to make the angles rigorously sharp, and quite so to keep them in that condition; which is of no consequence whatever, since a line is never drawn by either side quite to the extremity. But the inclinations of the sides to each other should be as exact as it is possible to have them made; for then these little implements, in connection with the T-square and a true-cornered drawing board, enable the draughtsman with the utmost facility to divide the circle into four, six, eight, or twelve parts as may be desired, and to draw with equal ease the inscribed or circumscribed equilateral triangle, square, hexagon, and octagon.

29. Sweeps, or Irregular Curves.—The mechanical draughtsman frequently has to deal with curves which are not circular. In many cases these can be made up of approximating circular arcs: but in others this expedient cannot conveniently be employed. Even when it can ultimately be used to advantage, it is often much better to draw the line accurately in pencil through the points which are determined by construction according to the given law of the curve, than to attempt at once to find the circular arcs which can be substituted for it.

For practical purposes, in general work, no mechanical contrivance for drawing curves by continuous motion, such for instance as an elliptograph, is of service to an extent anything like proportionate to its cost. Such contingencies as these are best provided against by the possession of a selection of curved rulers, or *sweeps* as they are technically called. The forms of these should, in general, conform to some mathematical law, according to which the curvature varies with regularity: and

FIG. 62.

the dimensions must be in accordance with the scale of the work in hand. For instance, there are to be had sets of ellipses and of hyperbolas, of varying eccentricities, and parabolas on different scales; and these are in many cases of great use. There are also to be had "French curves," "scrolls," or "universal curves" without number and without value. In these last, the radius of curvature almost always changes abruptly at various points, which destroys their regularity and their utility in drawing curves not similarly characterized.

In Fig. 62 are shown the contours of a number of what are known as the "Copenhagen Ship Curves;" which, though originally intended for the use of naval architects, have, with the addition of one or two logarithmic spirals, been found of most material use in the drawing of machinery: they are here reduced to about one half of the actual size. In a great many cases these are of use in inking in arcs of circles of a few degrees only in length; especially when these are tangent to two other lines, as much time is saved by using the drawing pen thus guided, instead of adjusting the inking point of the compasses, to say nothing of the greater facility in making the joinings of the lines neat and smooth.

Fig. 63 shows a selection of larger curves from the same set as the others: not merely of greater size, but of greater radii of curvature, or in other words flatter. These in particular have been found of great utility in the laying out of screw-propellers; and are shown on a scale of about one third of the actual size. The very best material

FIG. 63.

for these articles is hard rubber; and all those here shown, as well as the whole set of "Copenhagen" curves, and some of English origin specially adapted for the drawing of the "lines" of vessels, are now to be had of this substance, which is so far superior to wood of any kind as to be in the end much cheaper.

30. The Scale.—The draughtsman's scale is a piece of metal, wood, or ivory, one edge of which is divided into inches, and these again are subdivided into halves, fourths, eighths, and sixteenths. This is called the full-size scale, and is used in laying out drawings of the actual size of the objects represented.

The scale is thus graduated, to correspond with the scales and folding rules used by the workman; this unit and this system being in use throughout the country. The merits, if there are any, of the metric system of measures, and the advantages, real or fancied, of the decimal system of subdivision, are foreign to the question; what is used in the shop must be used in the drawing office, and that definitely settles the matter.

Working drawings are preferably and usually made "full size," unless they would thereby be either too large or too small to be conveniently worked from. In that case they must be made upon a smaller or a larger scale; that is to say, an inch must be represented by a distance less or greater than an actual inch, and its multiples or submultiples are of course reduced or enlarged in the same proportion: the result being the same as if a full-size drawing were made of a smaller or a larger object.

31. Now, reduced or enlarged drawings can be made with the aid of only the scale above mentioned. If, for instance, a "quarter-size" drawing is wanted, each dimension of the object is divided by four, and the quotient set off with the full-size scale. This, however, is not expeditious, by reason of the amount of mental arithmetic involved; it is very easy to divide by four, but the operation soon becomes monotonous and vexatious by repetition. And this repetition can be wholly avoided by the simple expedient of dividing the scale itself by four at the outset; then with this contracted scale the measurements of the actual dimensions are set off, without dividing them.

Thus, the quarter-size scale is formed by taking three inches to represent one foot; this three-inch space being divided into twelve equal parts, each of them represents one inch; and these are subdivided, like the actual inches on the full-size scale, into halves, fourths, and eighths.

In like manner, *any* distance may be selected to represent a foot, and a similar scale constructed by dividing it into twelve parts, and subdividing them as before. Such scales are usually designated by specifically stating the distance taken to represent one foot; as, for example, "3 inches to the foot," "1½ inches to the foot," "½ inch to the foot," etc.; which for brevity's sake are colloquially called the 3-inch scale, the 1½-inch scale, the ½-inch scale, and so on.

32. One of the most convenient forms of scales is shown in Fig. 64. The graduations extend to the very edge, and when the scale lies upon its side they are thus

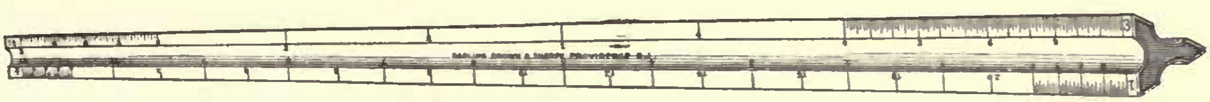

FIG. 64.

brought into direct contact with the paper, so that measurements may be set off directly, using either a pencil or a needle as may be desired. This is a very important feature; no work can be executed with any reasonable degree of rapidity if the measurements are taken from the scale, and set off, with the dividers or compasses; which should be done only in case of necessity. Again, operations are much facilitated in many cases by laying the scale against the upper edge of the T-square, and thus pushing it along until the edge reaches the line along which distances are to be set off: and the triangular scale lends itself readily to this mode of using it.

The peculiar formation of this instrument allows a number of different scales to be cut upon its various edges. This, to be sure, is not an unmixed advantage, as among so many it is not always easy on the instant to find the one wanted, and were it not for the bulk and the expense, it would perhaps be more convenient in many instances to have but one or two scales, upon one edge only. This would necessitate the use of a number of separate instruments, and the inconvenience thus caused, as well as the increased expense of material, prevent these separate scales from being placed on the market in any form more substantial than that of printed strips of paper. These are not very durable, but they possess one commendable feature, that of expanding and contracting as the moisture of the air varies, pretty nearly in the same ratio as the paper upon which the drawing is made.

33. These triangular scales are made both of metal and of wood. The former are not solid, but made of drawn brass tubing, with closed ends, nickelled with a dull finish. They are thus very light, and possess the advantages of not being liable to warp, or crack, or chip at the edges; nor are they subject to variations due to moisture like those of wood. On the other hand, they are more trying to the eyes, the graduations not being so strongly in contrast with the surface; and thus far they are not to be had over one foot long.

This is long enough for some purposes, of course; but in general practice in machine drawing, there are so many measurements of more than one foot to be laid off, that a longer one is almost a necessity, if facility and speed are of account.

Those of boxwood are to be had both 18 and 24 inches in length: of these the former is more convenient under average circumstances. It is, besides, of considerably less first cost, and it is much easier to find a perfect one; and when good at the beginning, it is more likely to remain good; for the difficulty of finding a piece of wood which will not check or warp sooner or later, increases very rapidly with the length.

34. The edges of these instruments are usually divided to scales of $\frac{3}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{3}{4}$, $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 3 inches to the foot, and the remaining edge has the full-size scale above mentioned: some have a 4-inch and a 2-inch scale upon one edge, instead of the $\frac{3}{16}$ and $\frac{3}{32}$ scales; but neither one of these four is very frequently made use of.

In selecting, the purchaser should see that the wood is free from veins or streaks, be careful to note that it is as nearly straight as possible (absolute perfection in this respect is hardly to be expected of wood), and above all things that the graduations are *fine* and clean-cut. This last they are almost sure to be if the maker be one of reputation, and there are those whose names are of themselves a guarantee of accuracy; but, on the other hand, scales of this popular form are to be found upon which the lines are very coarsely cut: this is a fatal defect, and all such should be rejected, no matter how good they may be in other particulars; the mere fact of being stamped "U. S. Standard" is not alone sufficient, but the graduations of the smallest scales, such as the $\frac{3}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, and $\frac{1}{4}$, should bear close scrutiny with a magnifying glass without revealing irregularity of divisions or blurring of lines.

MATERIALS AND MISCELLANEOUS ARTICLES.

35. Drawing Paper.—In order to do good work, the draughtsman should be provided with good materials as well as good instruments. For fine work in ink, Whatman's hot-pressed paper is no doubt superior to any other, for making both detail and general drawings of machinery.

It is to be noted that the thickness of this paper varies with the size of the sheet; and the size known as "double elephant" (27 by 40 inches) has a body and substance peculiarly well adapted for these purposes. It may also be stated that this is as large a sheet as ought to be used, unless for very particular reasons. Anything larger than this is inconvenient to handle as a working drawing in the shop; and with a judicious selection of the scales, it is large enough for the details of the most massive machinery. Occasions will arise, as in making plans of vessels, etc., in which these dimensions must be exceeded; but it is usually in length only, a wider drawing being seldom called for.

Where drawings are to be at once sent into the shop and worked from, without tracing, a cheaper paper may be desired. In this case the article known as "Duplex" paper, a Manila paper of a fine creamy tint, serves an excellent purpose. It takes ink fairly well, and for drawing in pencil only, is better than Whatman's; it is to be had of a size very nearly the same as the double elephant.

36. But of whatever make or quality, the paper should be procured in sheets, and *kept flat*, if it is expected to do even tolerable work.

With a mistaken idea of economy, paper is sometimes procured in huge rolls, and cut off as required. If every piece is "damp-stretched" before using, this may answer; but that costs more in time than is saved in the purchase. If, on the other hand, it is merely pinned down as usual, no one can draw upon it as well or as rapidly as he can upon a flat sheet lying smoothly on the board.

The best course is to procure a considerable quantity at a time; if it must be rolled for transportation, let the roll be as large as possible, and as soon as may be, put the whole into a drawer of suitable size, that the weight may act to make it flat again and keep it so. The larger the stock laid in, the better; for whatever the reason may be, good paper improves by age.

37. It seems not to be as generally known as it might be, that for many purposes common writing paper is admirably adapted. Not, to be sure, for making working drawings; but for fine diagrams, and for illustrative drawings, it is perhaps better than any other. The best is the heaviest linen "ledger" paper, which has not only a surface upon which the finest ink lines can be drawn, but sufficient body to permit erasures to be made, still leaving the paper in condition to take the ink without spreading. And thinner writing papers answer exceedingly well for making tracings.

38. Pencils.—It is universally conceded that in all the essential qualities of a good drawing pencil, those made by Faber are unsurpassed. They are to be had of different degrees of excellence as well as of hardness; the "Siberian" are the best. Those marked HHHH are, as regards hardness, most suitable for general use, as if softer, they do not make a fine enough line nor keep long enough in good trim, and if harder, the lines are not so easily erased as is desirable. But for making the very finest work, where there is reasonable certainty that little if any erasing will be necessary, the HHHHHH grade may be used to good advantage.

And this last grade should always be the one chosen for the "instrument leads," already mentioned in connection with the compasses and pencil bows: as there is, apparently, a difference between the gradings of these leads and of those used in the pencils, and these will be found none too hard.

39. Rubber, Ink Eraser, etc.—The rubber for erasing pencil marks should effect that object without soiling the paper; which neither the pure gum (or virgin rubber) nor the black rubber will do. Neither ought the rubber itself to become soiled in the operation; the best is that known as "velvet" rubber, which has some substance incorporated with it of such nature that the whole wears off quite rapidly in use, the acting surface remaining clean and fresh.

For erasing ink lines, Faber's "ink eraser" is the best article to use. The use of a knife or other steel instrument should be sparingly indulged in; the edge should be very keen, and the convex portion only should be applied to the paper, so as to *scrape* its surface, and that very lightly: the use of the point of a knife to *scratch* out a line is a barbarism. The ink eraser recommended is similar to the velvet rubber, with a larger admixture of pumice stone, which, used without sufficient force or speed to heat the paper, removes the ink and polishes the surface: which if then rubbed lightly with an ivory paper folder, will be in good condition to receive ink again. Thus with due care, corrections and alterations can be made so neatly as to escape any but the closest scrutiny.

For removing light marks of the pencil, and for cleaning the paper if dusty or otherwise soiled, a very useful article is now furnished, called rubber sponge. It is most excellent when new, but in some way hardens, and gradually becomes useless, with age. Equally good for the same purpose is the crumb of stale wheat bread; it should be broken into small bits and well rubbed, or rolled, into the surface of the paper, thus forming numberless little pellets, to which the dust adheres.

40. Ink.—Ordinary writing ink is wholly unsuitable for mechanical drawing; it rapidly corrodes the pens, and acts chemically upon the paper, making neat erasure almost impossible. For this purpose, then, India ink alone is used; it consists wholly of carbon and some adhesive substance, so that it merely lies on the surface of the paper without "biting in."

The best is of Chinese manufacture, and comes in sticks or cakes of various sizes and forms; this is to be simply rubbed up with water to any desired density. This labor of preparation, slight as it is, is to some persons a great bugbear; and in response to their demands various "liquid India inks" are offered for sale; the bottles, when properly cleaned, are good: which is more than can be said of the contents.

The Chinese inks vary greatly in quality and in price; but it does not always happen that the most expensive is the best. That for line drawings should be comparatively soft, while that to be used for tinting with the brush should be quite hard; but both must be free from grit. In selecting, wet the end of the finger, and rub the ink upon it; that for line work only should in a very few seconds produce a dense black spot, and without any rough or gritty feeling; when dry the spot should have a brilliant lustre, and a dull or cloudy appearance should cause it to be rejected. It may also be noted that the better grades of this ink have, when wet, an odor of musk.

Further, the ink should be tested as to its adhesive power. Draw a broad black line with it, wait until perfectly dry, then apply the rubber vigorously, as if erasing pencil marks. The brilliance of the line may be impaired, but it should remain black and continuous; if it does not, the ink lacks adhesiveness, and is not suited for the purpose.

41. The preceding relates to black ink, which forms a perfect emulsion, and deposits no sediment, merely becoming more viscid as it evaporates. There are also Chinese inks of different colors, but they cannot be recommended, as the coloring matters, though very brilliant, are also very heavy, and do not remain well in suspension. It is therefore quite difficult to keep the same tone or shade in drawing a number of lines consecutively. For making lines in color, then, the draughtsman cannot do better than to use the cakes of water colors furnished for artists. Preference should be given to those which are most soluble, such as Prussian Blue, Carmine, Scarlet Lake, Indian Yellow, etc.: they are used exactly like the India ink; and like it are not corrosive, which all the colored writing fluids are, and they should not be used with instruments of any value.

42. In preparing the ink for tinting with the brush, the stick should never be dipped into the water, but merely rubbed upon the wetted finger, which again is rubbed upon the bottom of the saucer of water. This is for the purpose of preventing any speck or flake of the solid ink, which is quite friable, from eventually lodging in the brush. It also serves a good purpose in avoiding the immersion of the stick of ink, which becoming soaked and soft, is still more apt to crack and scale off. And there is no doubt that even for line work, the above is the *best* process. But it is undeniably tedious; and it is not absolutely necessary to the execution of even the finest work. For this purpose it is admissible to rub the ink directly in the water; but the solution, or emulsion, should afterward be carefully rubbed with the finger until it is certain that there are no bits of solid ink remaining, for if one of these gets into the pen, as it is tolerably sure to do, it will be found that no time has been gained by neglecting the precaution here insisted on. And dust is nearly as bad; so that the saucer should be kept covered after the ink is mixed: the saucers which come in nests, each being a cover to the one below, are very convenient, as are also those provided with glass plate covers.

Neither the India ink nor the colors should be wetted more than absolutely necessary in mixing, and they should be wiped dry with soft paper, at once, to prevent the absorption of water, which tends to disintegrate them.

The blades of the drawing pen being moistened by breathing between them, the ink is introduced by means of a common steel writing pen which has not been used with any writing fluid, and should be kept for this purpose exclusively.

The ink will look black in the saucer, when in fact it is not as dense as it should be. The test is to draw a broad black line with one stroke of the drawing pen: this when dry should be absolutely black; if it be grayish or brownish, the ink is not thick enough. It will of course become thicker by evaporation as the work progresses; hence care should be taken to prepare a comparatively large quantity at the outset; in diluting it afterward if necessary, water should be added a few drops at a time, and the whole rubbed with the finger after each addition. And the same process should be adopted in again mixing ink which has dried in the saucer when set aside, which is perfectly good for line work; but for tinting the saucer should be washed out and fresh ink prepared.

43. Drawing Pins, or Thumb-tacks.—For all ordinary purposes, particularly for working drawings, the paper should merely be secured to the board by a "drawing-pin" at each corner, as shown in Fig. 60: being placed as near to the lower left-hand corner as possible. As a matter of course, the paper will expand and contract to some extent on account of variations in the moisture of the air: for which an allowance dictated by experience must be made in using the scale, unless the latter itself be of paper. But the errors due to this cause are less than those which arise when a "stretched" sheet is cut loose; upon which the paper contracts, and that not only to a variable and uncertain extent, but not always evenly; so that lines which ought to be straight are sometimes quite the reverse.

The form of these drawing pins is shown in Fig. 60: the heads are slightly *convex*, not bevelled, and the pins are *cylindrical* with tapered points; and not wholly conical. They are so inexpensive that none but the best should be used; these are made by *screwing* a steel pin into a German-silver head: cheaper ones have the pin riveted into the head, and the riveting if slight may yield under the pressure of the thumb, causing serious injury.

44. Damp-stretching.—For making line-drawings in the nature of pictures, it is sometimes desirable to have the sheet stretched, as it undoubtedly gives a smoother surface than can be obtained in any other way; and for tinting, if the surface be of any size, it is indispensable. The operation of "damp-stretching" consists essentially in wetting the back of the paper and gluing or pasting down the edges while thus expanded; but to do this neatly requires some little care and skill: attention to the following directions will, however, be likely to ensure success.

1. Chamfer the edges. To do this, lay the sheet, face up, on the board, and with a ruler and a very sharp knife, cut just through the surface, about a quarter of an inch from each edge. The strips thus partially severed are now to be *torn* off, taking care to pull downward and away from the sheet. Thus the edges will be left sharp, thin, and at the back slightly roughened, which will cause the paste to hold better.

2. The paper still lying face up, fold over each edge, say three eighths of an inch for a double elephant sheet, and for different sizes in proportion.

3. Turn the paper face downward, and wet the back thoroughly, leaving the folded edges dry. Water may be poured on the middle of the sheet, but toward the corners the sponge must be used, in order to have all parts equally wet. Allow the paper to soak until the whole is perfectly limp; then take off the surface water with the sponge.

4. Turn the paper again face upward, lay a sheet of thin soft wrapping paper upon it, and rub with an old linen handkerchief *from the centre outward*, with considerable force, to press out the wrinkles. Lay strips of paper an inch wide under the folded edges, to prevent accidental smearing of paste upon the face of the sheet.

5. The best adhesive preparation is *dextrine*; mixed up with water, not into a liquid, but into a thick glutinous mass; with which the edges are to be well covered. If it should happen to become too dry in any part before the edge is turned down and secured, it is only necessary to wet it slightly; and after the paper is cut loose, the remaining edges can be readily removed and the board cleaned, by liberal sponging.

6. Apply the dextrine first to only about one third the length of the sheet, *in the middle of one side.* Turn down that portion, lay a strip of clean paper over it, and rub hard with an ivory paper folder or something similar; it is well also to put a thumb-tack at each end of the part thus treated. Then proceed in like manner with *the middle part of the opposite side:* take next the middle of one end, then the part opposite to that;

and leave the corners to the last, completing them in any order that is most convenient.

7. In removing a stretched sheet from the board, cut first *one side*, and next *one end*. If two opposite sides or ends are cut in succession, the sheet is very likely to have a corner torn off by the contraction of the paper when the first transverse cut is made.

45. Mounted Paper.—It is rarely that mechanical drawings are subjected to usage requiring them to be "mounted" on linen, as maps frequently are. But no map or drawing should be mounted on linen after it is made; for that operation involves a second wetting, with a nearly absolute certainty of distortion upon drying. Ready-mounted paper should be used; this may be stretched as above explained, that is by dampening, and then fixing the edges to the board. But let it be observed, that in this case the *face* must be wetted, as the application of water to the back would loosen the linen and ruin the sheet; also that, owing to the weight of the material, glue should be used instead of dextrine. If the greatest accuracy in the finished work is required, the sheet should be stretched only for the purpose of making it smooth, and it then should be cut loose, and merely fastened with large thumb-tacks while the drawing is in progress.

46. Tracing Cloth.—This is used for making copies of drawings which may be employed either to work from directly, or for reproducing the original by the "blue-print" or other heliographic process. In the latter case *all* the lines should be black; in the former, colors may be used for centre lines and to distinguish one material from another. A good coat of clear shellac varnish should be applied before the tracing is sent into the shop.

In selection, Hobson's choice is substantially that now offered the purchaser; the manufacture being apparently a monopoly, the result being the production of but one quality, which might perhaps be called good were it not immeasurably inferior to that formerly furnished; an article fifty per cent better, though no higher in price, than any now to be had.

By reason of this depreciation, there is great liability to the mishap of having the ink strike through the coating and spread in the meshes of the cloth; the ink must be pretty thick, the pen in good condition and lightly used; but no precaution will ensure the operator against this most annoying accident, which never ought to occur.

47. Tracing Paper.—Of this article there are fortunately several varieties to be found, and most of them of excellent quality; it is to be had in sheets of various sizes, and also in rolls. And it is to be said that its perfect flexibility prevents any injurious effect from keeping it rolled, even on a small roller; when spread over the drawing it will lie flat, without curling.

Some of the tracing papers are white, others of a yellow tint; so far as the quality, and the ease of drawing upon them, are concerned, there seems to be little difference; but the former are to be preferred if it be intended to make blue-prints.

Among the best and strongest of these varieties are those known as "parchment tracing-paper," and "parchment process tracing-paper;" the latter is remarkably heavy and tough, the former thinner but of similar toughness, and both are exceedingly smooth and fine in surface. There is, however, one variety, known as "vegetable parchment," against which the purchaser should be warned. It is unusually clear,—so clear indeed that it is not easy to tell which lines have been traced and which have not; but it does not take ink perfectly, and it expands and contracts so much with apparently no provocation at all, that it is next to impossible to make a tracing which tallies with the original.

As before mentioned, some of the thin writing papers are excellent for making small tracings. And what is known as "bond paper" can also be used to good advantage, if the lines of the original are not too fine—it is not so transparent as the regular tracing papers, but is much stronger and more durable.

ON THE USE AND CARE OF INSTRUMENTS.

48. The Compasses.—In striking a circle with a pair of compasses, the uninstructed novice is very apt to take hold of the instruments by the legs, thinking that they are thus more securely held. This habit once formed is difficult to abandon, like other bad habits; at the very beginning, therefore, the tyro should accustom himself to the correct manipulation, and to handle the compasses by the joint alone, using only the thumb and the first two fingers.

Begin the circle at the lowest point, holding the joint of the compasses between the thumb and the middle finger, the index finger resting lightly against the left side of the joint. Turn the compasses *with* the clock, describing the left half of the circumference by rolling the joint between the thumb and second finger; that finger can go no farther, but its place is then easily and naturally taken by the first finger, and the joint is rolled between it and the thumb until the circle is completed, by one continuous motion. This requires a little practice, but the trick of it once acquired is never forgotten, and the instrument is at all times under perfect control, with no danger of altering the radius. The action will be readily understood by the aid of Figs. 65 and 66. In setting the compasses to draw a circle of given diameter, it is not enough simply to open the legs to the required radius, for it seldom happens that this can be done with exactness; two short arcs should be struck, on opposite sides of the centre, and the scale applied to see that the *diameter* is correct: this should not be done on the drawing, but on a separate piece of paper.

In order to make a line of uniform thickness, the pen must be used with uniform pressure; and this should be the lightest practicable. If the pen is *new*, that is, just sharpened, the merest touch is sufficient, so that instead of bearing down, the operator should rather support part of the weight of the compasses.

The fact that a variation in the pressure makes a difference in the breadth of the mark with either pencil or pen, is made use of in putting in shadow lines. The marking point is put in motion before touching the paper, the pressure gradually increased towards the part where the greatest thickness of line is required, then gradually diminished, and taken off the paper while still in motion; the whole action being analogous to the use of a writing pen in shading letters and flourishes.

The two legs of the compasses should always be kept in a *vertical plane*, and the marking point as well as the needle-point, perpendicular to the paper.

Some draughtsmen have a vicious way of holding the compasses so that both legs lean over, in the direction in which they are moving: an excellent way to ream out a conical hole at the centre of the circle, and to spoil the pen at the same time.

94. The Dividers.—These should be handled in the same manner as the compasses;

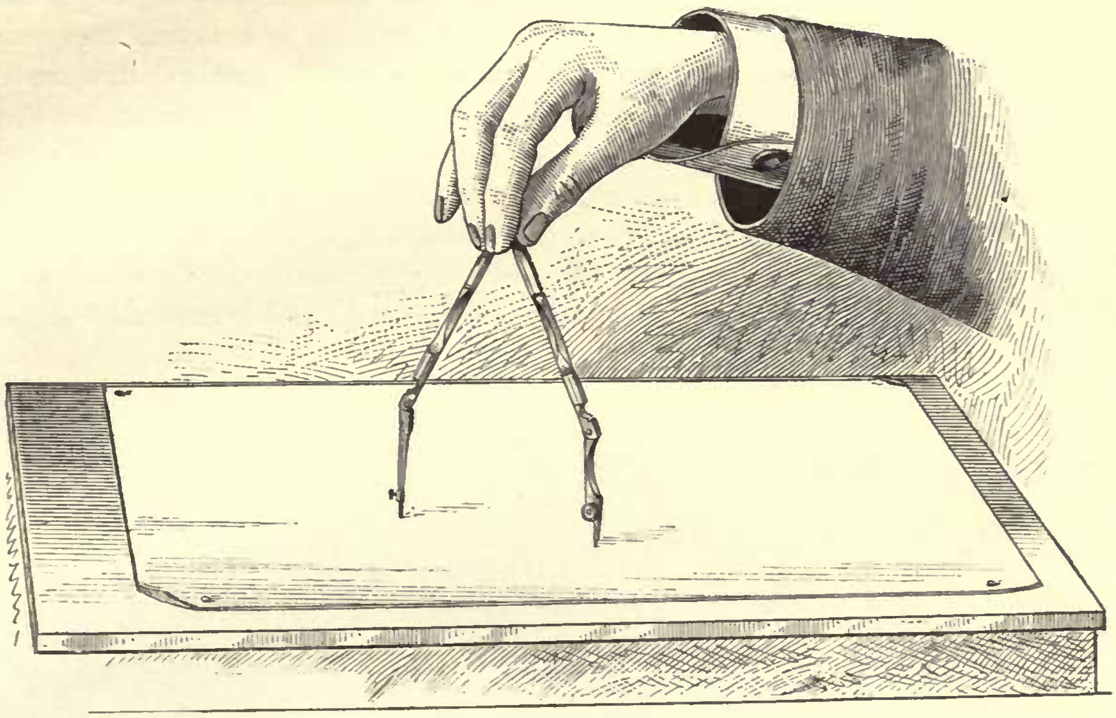

Fig. 65.

that is to say, they should be held by the joint only, and not by the legs; which last is not only awkward to a degree, but is very liable to derange the adjustment. In "stepping off" a measurement repeatedly along a line, or around a circle, they should not be

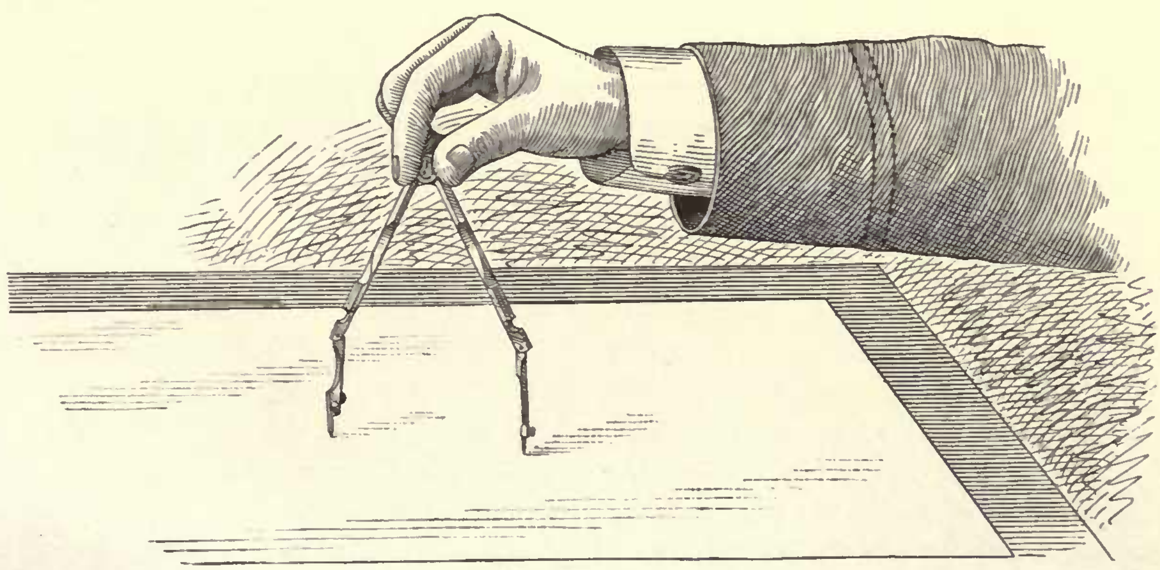

Fig. 66.

lifted entirely off the paper, but first one point and then the other is taken as a centre, and the instrument is manipulated as if describing a series of semicircles, the rotations being alternately with and against the clock. Thus it is never required to shift the dividers in the hand, which would be unavoidable were the attempt made to turn them over and over in the same direction. And the same is true in handling the spacing divider, which is the only one of the bow instruments requiring mention here.

50. The Drawing Pen.—This is held by the thumb and first two fingers; the third and fourth fingers resting lightly on the ruler, steady the hand and control the pressure, or at least aid in keeping it uniform, which is necessary in order to draw an even line. It has already been stated that if properly set, the pen will do its best work when held *upright;* as in Fig. 67. If it be not, then it may be necessary to incline it slightly, the top being a little in advance; but this should be avoided if possible.

It is sometimes desired to draw a very broad line, as for instance in making a border around a picture. In such a case the attempt should not be made to cover the whole stripe with ink at once; but, ruling a series of parallel lines close together,

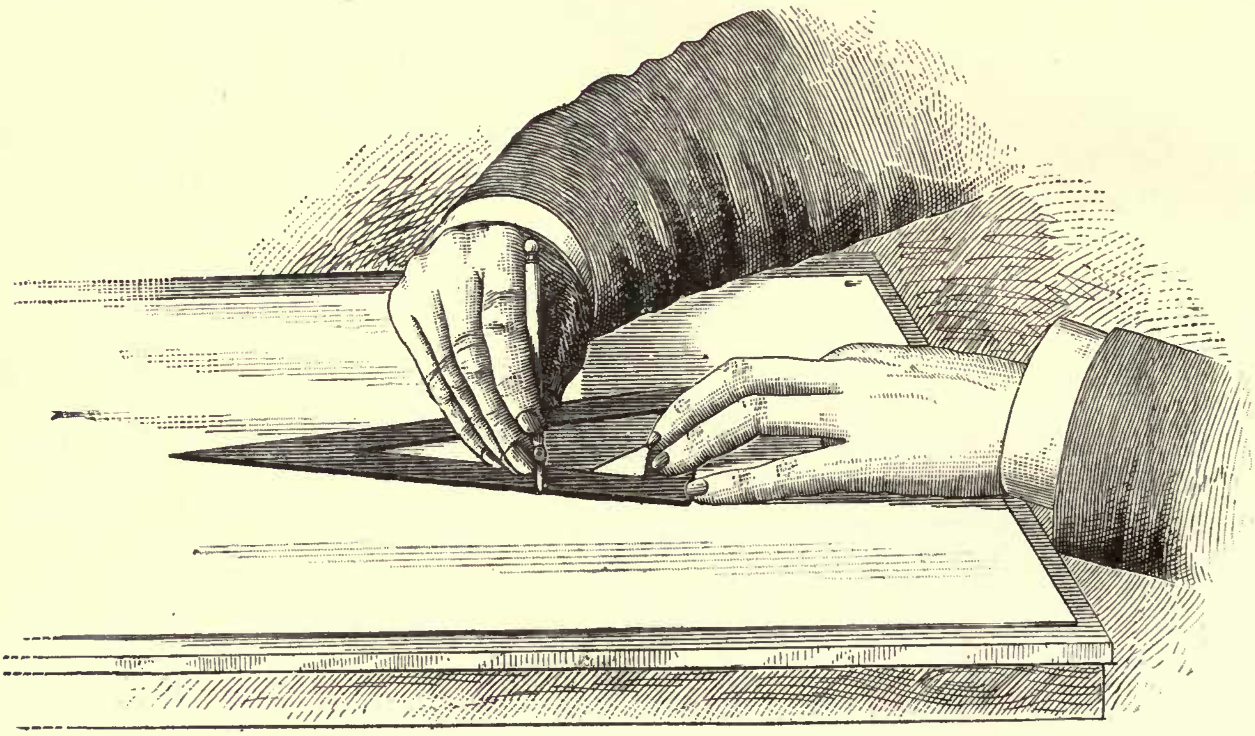

FIG. 67.

each as thick as the pen will draw conveniently, wait till these are perfectly dry, and then draw another series overlapping them and thus filling in the spaces.

It is imperatively necessary to keep the blades of all the pens *clean* both inside and out, if the best results are to be attained. While using them, the ink should never be allowed to become too thick; at the first sign of this, pass a strip of paper, folded once or twice, between the blades, and refill the pen. And the ink should not be allowed to *dry* in the pen under any circumstances; on laying one down, even for a short time, it should be cleaned. For this purpose, a bit of paper, folded so as to require some pressure to pass it between the blades from screw to tip, answers best; the blades will spring apart, but their elasticity keeps the paper in contact with the inner surfaces. This should be repeated until no more ink is seen on the paper even if it be moistened.

Neglect of this is the real cause of much bad work for which the pen is wrongfully blamed; it is unreasonable to expect a blade thickly encrusted with ink to make good lines, yet in careless hands the indurated deposit is frequently found thick enough to interfere with the adjustment. And this must be attended to with special care when colored lines are to be drawn, as a very little India ink will ruin the brilliance of any other color.

The adjusting screws of the pen blades are apt to rust if care be not taken to prevent it, which is easily done by the occasional application of a drop of oil. And indeed the like attention should be given to all the screws of all the instruments.

51. The T-square is held against the left-hand end or the lower side of the drawing board, with the left hand. The board should be so placed as to receive the light from the upper left-hand corner; and horizontal lines are drawn by the *upper edge* of the square, never by the lower edge, and drawn from left to right, the pencil being held and handled precisely like the pen, as described in the preceding section. Vertical lines are to be drawn by the *left-hand edge* of the T-square or the triangle, as the case may be, the hand moving always *away from the body*, and never toward it.

Of course it is to be understood that, particularly in inking in, the operator is at liberty to turn the board around, into any position that may be most convenient: the lines in that case will be drawn by that edge of the square or ruler which is toward the light.

It need hardly be added, that the pen or pencil is guided by the *upper corner* of the edge of the ruler in use, so that the line drawn does not coincide with the line of contact between the ruler and the paper, but is separated from it by a distinct line of "daylight." Some care is therefore requisite to keep the marking instrument always vertical, as variations in its position will make the line wavy instead of straight.

52. The Triangles.—What has been happily called "a fluent use of the triangles" is as important to the draughtsman as ready speech to an orator: and there are bad as well as good ways of using them.

It has been pointed out that no dependence can be placed upon the *corners* of the triangle, which are sure to be soon rounded off by use if not so to begin with. Yet it is not uncommon to see the attempt made to draw a perpendicular to a given line at a given point upon it, by placing one of the short legs in exact coincidence with the line, the right angle in exact coincidence with the point, and then marking with the pencil along the other leg; and the sight would be exasperating were it not melancholy.

If one triangle be held stationary, and the other moved along so that its hypothenuse slides on one of the sides of the first, a series of parallels can be drawn by one leg, and another series, at right angles to the first, by the other leg. And by grasping the two sides which are in contact, it is as easy to move both triangles at once in adjusting them, as either one alone: when adjusted, one is held still by the pressure of the left hand; the thumb and little finger suffice, leaving the other fingers free to move and hold the other triangle as desired.

In the case mentioned, then, a correct manipulation would be to set one leg of the moving triangle by the given line, and then sliding it along, to draw the required line by the other leg through the given point.

Another and in general a preferable method is to set the *hypothenuse* of the movable triangle by the given line, one leg being in contact with the fixed one: the former is then shifted so as to bring the other leg in contact, and the perpendicular drawn by the hypothenuse, which will now be at right angles to its first position.

53. It is to be particularly observed, that in "setting" a triangle, T-square, or any ruler by a given line, no attempt is made to bring its edge into actual *coincidence* with that line; it is to be so placed that the given line could be redrawn, or produced if required, by the edge in question; which will therefore be separated from the line itself by a small, uniformly wide, space of white paper, technically called "daylight." So also in setting a ruler to draw a line through two given points, through a given point in a given direction, through a given point and tangent to a given curve, tangent to two curves, or tangent to a given curve and in a given direction: in all these cases the accuracy of the adjustment depends upon the certainty with which the eye can judge of the equality of the minute distances measuring the "daylight" at different points, and this certainty is practically absolute.

Fig. 68.

A single illustration will suffice to show the utility of a pair of reliable triangles. Let it be required to draw a right line tangent to two given circles, and to find the points of contact. This can be done by a geometrical process, but much more readily thus: taking the two triangles together, set the hypothenuse of one to draw the tangent, hold the other one still, turn the first so as to bring the other leg in contact, then slide it along and draw lines by its hypothenuse through the two centres to cut the circumferences: the result will be practically more to be depended on than that of a geometrical construction.

54. The Curved Rulers.—These are used, as has been explained, for drawing curves through points determined by construction. In using them, they are "set" so that some part of the ruler in hand shall enable the operator to draw a portion of his line; the edge not passing through, but being equidistant from, so many of the given points as may be.

Now in order to make sure not only of a good joining, but of proper alignment in producing the curve, this precaution must be carefully observed; that in setting the new sweep, it must be so adjusted as to agree with a part of the line already drawn. Otherwise, the eye is very likely to be deceived, and the new part of the line is apt not to be tangent to the first part; the result being painfully evident in the form of a "hump" or "broken back."

55. The Pencil.—For the operations of mechanical drawing, the pencil should be sharpened, not to a round point, but to an edge; not a square edge like that of a chisel, but rather like a duck's bill; rounded off at the end, as shown in Fig. 68; and the flat side is held against the ruler, precisely as the drawing pen is held.

By trimming the pencil in this way, fine clean lines can be drawn with it much longer than if it were cut to a conical point. Some make use of fine sand or emery paper to bring the pencil to an edge; others prefer a file; but a sharp knife is better than either. The instrument leads are trimmed in a similar manner, as has already been stated; and so set in the clamp as to have the edge run in the direction of the circumference to be drawn.

The draughtsman should be as sparing as possible in the use of the pencil; the lines should be fine, because the ink does not run as well if there be much superfluous pencil lead on the surface of the paper; and the pencil line should not extend beyond the limit of the proposed ink line if it can be avoided.

It is just as easy to leave out a line as to rub it out, nay, easier; and no unnecessary ones should be even pencilled in. Lines that are to be dotted in ink ought always to be dotted in pencil, lest the fact that they are to be dotted be forgotten when the pen is taken in hand. In short, the pencil drawing should look as nearly like the ink drawing as possible; the advantage is readily seen when it is considered that if time presses, tracings must often be made from the pencil drawing direct. If this be intended, the pencilling should be heavier than if the sheet is to be finished in ink.

56. The Scale.—The scale should never be used as a ruler, for which it is neither intended nor well fitted. It should be used only for setting off measurements on the drawing, and for measuring distances. Its utility for either purpose depends upon the perfection of its edges, and the accuracy and fineness of the graduation; and nothing should be done which tends to injure either.

In either measuring or setting off distances, the scale should be applied directly to the drawing, and in the latter operation, the points should be marked with either a needle, or a finely sharpened pencil, which latter is in general the better instrument.

The compasses and dividers should be applied to the surface of the scale only in urgent cases: in setting the compasses to a radius, the best way is to lay the scale on the paper and adjust the instrument by the edge, thus avoiding the scratching and defacing of the graduations by the needle-point.

In setting off a number of consecutive measurements along a line, as A, B, C, D, etc., it is perhaps more *convenient* to set off first A, then to move the scale and lay off B, then from the third point to set off C, and so on, since in each case only one distance requires attention. But since there is a probable error in each independent operation, and at least an even chance that these errors will accumulate instead of balancing, this is not an advisable method.

The proper way is to keep the scale stationary; then from zero set off in succession the distances A, $A+B$, $A+B+C$, $A+B+C+D$, and so on to the end, or as far as the length of the scale will permit. In this way it is ensured that the whole as laid off will be equal to the sum of all its parts, which it might not prove to be if the first mode of operation were adopted.

57. General Remarks.—It is hardly necessary to suggest to any one, certainly not to him who has made his outfit pay for itself, that good care of all instruments will be found profitable: neglect and improper usage will soon ruin a set which if treated as it should be would do good service for two generations of draughtsmen. It is not enough to see that the pens are always clean and in good order; the needle-points and the points of the dividers are necessarily extremely sharp, and therefore the more likely to be broken by careless handling. If this happens, no attempt should be made to use them until they are resharpened: but it is better to prevent it. When not in use, the instruments should be replaced in the case, if there be one; if not, a piece of cork is a good protection to the points of dividers and the blades of pens.

In order to do good work, the paper must be kept clean: and there should be always at hand either a soft feather duster, an old linen handkerchief, or the like, with which to remove not only dust, but more particularly the *detritus* left after using the rubber: a particle of either in the pen is sure to cause annoyance, if not to spoil the lines.

But in spite of all care, dust or dirt will eventually adhere to the wooden instruments; if this be allowed to go on to any great extent, it will be impossible to keep the paper from being soiled by the sliding over it of the squares and triangles, though they be ever so carefully brushed. It is well to know, then, that this closely adhering dirt, as also ink-stains and the like, may be removed without injuring the articles in the least by vigorous rubbing with a cloth *slightly* dampened: much water is not good, but the result of using a little in this way is surprising to one who has not seen it tried.

APPENDIX.

THE proportions of bolts, nuts, threads, and bolt-heads, according to the Sellers system, adopted as the U. S. standard, are given in the first of the annexed tables.

In this system the thread of the screw is of the V form, with its surfaces inclined at an angle of 60°, and with the angles cut off at the top and filled in at the bottom to the extent of one eighth of the depth of the V-thread each, so that the depth of the thread is three fourths that of the full V form. Or it may be defined by saying that the breadth of the flat, at the top of the thread and also at the bottom of the groove, is one eighth of the pitch.

Let $D =$ outside diameter of belt,

$P =$ pitch of thread.

Then the other dimensions given in the tables are calculated by the following formulæ, viz.:

$P = 0.24\sqrt{D + 0.625} - 0.175$;

Number of threads per inch, ... $\frac{1}{P}$;

Depth of thread, ... $0.65P$;

Diameter inside of thread, ... $D - 1.3P$;

Short diameter of head and nut, hexagonal or square, . . $\frac{3}{2}D + \frac{1}{8}''$;

Depth of nut, ... D;

Depth of head, ... $\frac{3}{4}D + \frac{1}{16}''$.

The number of threads per inch, as determined by these formulæ, is in practice so far modified as to use the nearest convenient aliquot part of a unit.

U. S. STANDARD SYSTEM.

Diameter of Bolt.	Threads per Inch.	Dimensions of Nut. Long Diameter. Hexagonal.	Dimensions of Nut. Long Diameter. Square.	Dimensions of Nut. Short Diameter.	Dimensions of Nut. Depth.	Dimensions of Head. Long Diameter. Hexagonal.	Dimensions of Head. Long Diameter. Square.	Dimensions of Head. Short Diameter.	Dimensions of Head. Depth.
1/4	20	9/16	23/32	1/2	1/4	9/16	23/32	1/2	1/4
5/16	18	11/16	27/32	19/32	5/16	11/16	27/32	19/32	19/64
3/8	16	25/32	31/32	11/16	3/8	25/32	31/32	11/16	11/32
7/16	14	29/32	1 3/32	25/32	7/16	29/32	1 3/32	25/32	25/64
1/2	13	1	1 1/4	7/8	1/2	1	1 1/4	7/8	7/16
9/16	12	1 1/8	1 3/8	31/32	9/16	1 1/8	1 3/8	31/32	31/64
5/8	11	1 7/32	1 1/2	1 1/16	5/8	1 7/32	1 1/2	1 1/16	17/32
3/4	10	1 7/16	1 3/4	1 1/4	3/4	1 7/16	1 3/4	1 1/4	5/8
7/8	9	1 21/32	2 1/32	1 7/16	7/8	1 21/32	2 1/32	1 7/16	23/32

U. S. STANDARD SYSTEM—*Continued.*

Diameter of Bolt.	Threads per Inch.	Dimensions of Nut.				Dimensions of Head.			
		Long Diameter.		Short Diameter.	Depth.	Long Diameter.		Short Diameter.	Depth.
		Hexagonal.	Square.			Hexagonal.	Square.		
1	8	$1\frac{7}{8}$	$2\frac{5}{16}$	$1\frac{5}{8}$	1	$1\frac{7}{8}$	$2\frac{5}{16}$	$1\frac{5}{8}$	$\frac{13}{16}$
$1\frac{1}{8}$	7	$2\frac{3}{32}$	$2\frac{9}{16}$	$1\frac{13}{16}$	$1\frac{1}{8}$	$2\frac{3}{32}$	$2\frac{9}{16}$	$1\frac{13}{16}$	$\frac{29}{32}$
$1\frac{1}{4}$	7	$2\frac{5}{16}$	$2\frac{27}{32}$	2	$1\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{27}{32}$	2	1
$1\frac{3}{8}$	6	$2\frac{17}{32}$	$3\frac{3}{32}$	$2\frac{3}{16}$	$1\frac{3}{8}$	$2\frac{17}{32}$	$3\frac{3}{32}$	$2\frac{3}{16}$	$1\frac{3}{32}$
$1\frac{1}{2}$	6	$2\frac{3}{4}$	$3\frac{11}{32}$	$2\frac{3}{8}$	$1\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{11}{32}$	$2\frac{3}{8}$	$1\frac{3}{16}$
$1\frac{5}{8}$	$5\frac{1}{2}$	$2\frac{31}{32}$	$3\frac{5}{8}$	$2\frac{9}{16}$	$1\frac{5}{8}$	$2\frac{31}{32}$	$3\frac{5}{8}$	$2\frac{9}{16}$	$1\frac{9}{32}$
$1\frac{3}{4}$	5	$3\frac{3}{16}$	$3\frac{7}{8}$	$2\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{3}{16}$	$3\frac{7}{8}$	$2\frac{3}{4}$	$1\frac{3}{8}$
$1\frac{7}{8}$	5	$3\frac{13}{32}$	$4\frac{5}{32}$	$2\frac{15}{16}$	$1\frac{7}{8}$	$3\frac{13}{32}$	$4\frac{5}{32}$	$2\frac{15}{16}$	$1\frac{15}{32}$
2	$4\frac{1}{4}$	$3\frac{19}{32}$	$4\frac{13}{32}$	$3\frac{1}{8}$	2	$3\frac{19}{32}$	$4\frac{13}{32}$	$3\frac{1}{8}$	$1\frac{9}{16}$
$2\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{32}$	$4\frac{15}{16}$	$3\frac{1}{2}$	$2\frac{1}{4}$	$4\frac{1}{32}$	$4\frac{15}{16}$	$3\frac{1}{2}$	$1\frac{3}{4}$
$2\frac{1}{2}$	4	$4\frac{15}{32}$	$5\frac{15}{32}$	$3\frac{7}{8}$	$2\frac{1}{2}$	$4\frac{15}{32}$	$5\frac{15}{32}$	$3\frac{7}{8}$	$1\frac{15}{16}$
$2\frac{3}{4}$	4	$4\frac{29}{32}$	6	$4\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{29}{32}$	6	$4\frac{1}{4}$	$2\frac{1}{8}$
3	$3\frac{1}{2}$	$5\frac{11}{32}$	$6\frac{17}{32}$	$4\frac{5}{8}$	3	$5\frac{11}{32}$	$6\frac{17}{32}$	$4\frac{5}{8}$	$2\frac{5}{16}$
$3\frac{1}{4}$	$3\frac{1}{2}$	$5\frac{25}{32}$	$7\frac{1}{16}$	5	$3\frac{1}{4}$	$5\frac{25}{32}$	$7\frac{1}{16}$	5	$2\frac{1}{2}$
$3\frac{1}{2}$	$3\frac{1}{4}$	$6\frac{7}{32}$	$7\frac{19}{32}$	$5\frac{3}{8}$	$3\frac{1}{2}$	$6\frac{7}{32}$	$7\frac{19}{32}$	$5\frac{3}{8}$	$2\frac{11}{16}$
$3\frac{3}{4}$	3	$6\frac{5}{8}$	$8\frac{1}{8}$	$5\frac{3}{4}$	$3\frac{3}{4}$	$6\frac{5}{8}$	$8\frac{1}{8}$	$5\frac{3}{4}$	$2\frac{7}{8}$
4	3	$7\frac{1}{16}$	$8\frac{21}{32}$	$6\frac{1}{8}$	4	$7\frac{1}{16}$	$8\frac{21}{32}$	$6\frac{1}{8}$	$3\frac{1}{16}$
$4\frac{1}{4}$	$2\frac{7}{8}$	$7\frac{1}{2}$	$9\frac{3}{16}$	$6\frac{1}{2}$	$4\frac{1}{4}$	$7\frac{1}{2}$	$9\frac{3}{16}$	$6\frac{1}{2}$	$3\frac{1}{4}$
$4\frac{1}{2}$	$2\frac{3}{4}$	$7\frac{15}{16}$	$9\frac{23}{32}$	$6\frac{7}{8}$	$4\frac{1}{2}$	$7\frac{15}{16}$	$9\frac{23}{32}$	$6\frac{7}{8}$	$3\frac{7}{16}$
$4\frac{3}{4}$	$2\frac{5}{8}$	$8\frac{3}{8}$	$10\frac{1}{4}$	$7\frac{1}{4}$	$4\frac{3}{4}$	$8\frac{3}{8}$	$10\frac{1}{4}$	$7\frac{1}{4}$	$3\frac{5}{8}$
5	$2\frac{1}{2}$	$8\frac{13}{16}$	$10\frac{25}{32}$	$7\frac{5}{8}$	5	$8\frac{13}{16}$	$10\frac{25}{32}$	$7\frac{5}{8}$	$3\frac{13}{16}$
$5\frac{1}{4}$	$2\frac{1}{2}$	$9\frac{1}{4}$	$11\frac{5}{16}$	8	$5\frac{1}{4}$	$9\frac{1}{4}$	$11\frac{5}{16}$	8	4
$5\frac{1}{2}$	$2\frac{3}{8}$	$9\frac{11}{16}$	$11\frac{27}{32}$	$8\frac{3}{8}$	$5\frac{1}{2}$	$9\frac{11}{16}$	$11\frac{27}{32}$	$8\frac{3}{8}$	$4\frac{3}{16}$
$5\frac{3}{4}$	$2\frac{3}{8}$	$10\frac{3}{32}$	$12\frac{3}{8}$	$8\frac{3}{4}$	$5\frac{3}{4}$	$10\frac{3}{32}$	$12\frac{3}{8}$	$8\frac{3}{4}$	$4\frac{3}{8}$
6	$2\frac{1}{4}$	$10\frac{17}{32}$	$12\frac{29}{32}$	$9\frac{1}{8}$	6	$10\frac{17}{32}$	$12\frac{29}{32}$	$9\frac{1}{8}$	$4\frac{9}{16}$

The Whitworth system, which is extensively used in England, differs from the Sellers system chiefly in the form of the thread; this is of a V form, with the surfaces inclined to each other at an angle of 55° instead of 60°. The tops of the threads and the bottoms of the grooves are *rounded off* with arcs of equal radii, of such magnitude as to reduce the depth of the thread to two thirds that of the original V. The following formulæ give close approximations to the dimensions in the second table:

$P = 0.08D + 0.04$;

Number of threads per inch, ... $\frac{1}{P}$;

Diameter inside of thread, ... $0.9D - 0.05$;

Short diameter of head and nut, hexagonal or square, . . $1.5D + 0.18$;

Depth of nut, ... D.

WHITWORTH SYSTEM.

Diameter of Bolt.	Threads per Inch.	Short Diameter, Head and Nut.	Depth.		Diameter of Bolts.	Threads per Inch.	Short Diameter, Head and Nut.	Depth.	
			Nut.	Head.				Nut.	Head.
$\frac{1}{4}$	20	$\frac{33}{64}$	$\frac{1}{4}$	$\frac{7}{32}$	$1\frac{3}{8}$	6	$2\frac{7}{32}$	$1\frac{3}{8}$	$1\frac{13}{64}$
$\frac{5}{16}$	18	$\frac{19}{32}$	$\frac{5}{16}$	$\frac{17}{64}$	$1\frac{1}{2}$	6	$2\frac{13}{32}$	$1\frac{1}{2}$	$1\frac{5}{16}$
$\frac{3}{8}$	16	$\frac{45}{64}$	$\frac{3}{8}$	$\frac{21}{64}$	$1\frac{5}{8}$	5	$2\frac{37}{64}$	$1\frac{5}{8}$	$1\frac{27}{64}$
$\frac{7}{16}$	14	$\frac{53}{64}$	$\frac{7}{16}$	$\frac{3}{8}$	$1\frac{3}{4}$	5	$2\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{17}{32}$
$\frac{1}{2}$	12	$\frac{29}{32}$	$\frac{1}{2}$	$\frac{7}{16}$	$1\frac{7}{8}$	$4\frac{1}{2}$	$3\frac{1}{16}$	$1\frac{7}{8}$	$1\frac{41}{64}$
$\frac{5}{8}$	11	$1\frac{3}{32}$	$\frac{5}{8}$	$\frac{35}{64}$	2	$4\frac{1}{2}$	$3\frac{5}{32}$	2	$1\frac{3}{4}$
$\frac{3}{4}$	10	$1\frac{19}{64}$	$\frac{3}{4}$	$\frac{21}{32}$	$2\frac{1}{4}$	4	$3\frac{35}{64}$	$2\frac{1}{4}$	$1\frac{31}{32}$
$\frac{7}{8}$	9	$1\frac{31}{64}$	$\frac{7}{8}$	$\frac{49}{64}$	$2\frac{1}{2}$	4	$3\frac{57}{64}$	$2\frac{1}{2}$	$2\frac{3}{16}$
1	8	$1\frac{43}{64}$	1	$\frac{7}{8}$	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{3}{16}$	$2\frac{3}{4}$	$2\frac{13}{32}$
$1\frac{1}{8}$	7	$1\frac{55}{64}$	$1\frac{1}{8}$	$\frac{63}{64}$	3	$3\frac{1}{2}$	$4\frac{17}{32}$	3	$2\frac{5}{8}$
$1\frac{1}{4}$	7	$2\frac{3}{64}$	$1\frac{1}{4}$	$1\frac{3}{32}$					

The third table gives data relating to standard pipe-threads, in drawing which the following instructions are to be observed:

The tube is tapered on the outside as far as the perfect threads extend; back of those are two threads, perfect at the bottom but imperfect at the top: the bottoms of all these lie in a line parallel to the outside taper. Beyond these, again, are four threads, imperfect at both top and bottom: the manner of drawing these is essentially arbitrary.

The angle of the thread is 60°, rounded off at top and bottom alike, so as to leave a depth of $\frac{4}{5}$ the pitch.

STANDARD DIMENSIONS OF WROUGHT-IRON WELDED TUBES.

Diameter of Tube.			Thickness of Metal.	Screwed Ends.	
Nominal Inside.	Actual Inside.	Actual Outside.		Number of Threads per Inch.	Length of Perfect Screw.
Inches.	Inches.	Inches.	Inch.	No.	Inch.
$\frac{1}{8}$	0.270	0.405	0.068	27	0.19
$\frac{1}{4}$	0.364	0.540	0.088	18	0.29
$\frac{3}{8}$	0.494	0.675	0.091	18	0.30
$\frac{1}{2}$	0.623	0.840	0.109	14	0.39
$\frac{3}{4}$	0.824	1.050	0.113	14	0.40
1	1.048	1.315	0.134	$11\frac{1}{2}$	0.51
$1\frac{1}{4}$	1.380	1.660	0.140	$11\frac{1}{2}$	0.54
$1\frac{1}{2}$	1.610	1.900	0.145	$11\frac{1}{2}$	0.55
2	2.067	2.375	0.154	$11\frac{1}{2}$	0.58
$2\frac{1}{2}$	2.468	2.875	0.204	8	0.89
3	3.067	3.500	0.217	8	0.95
$3\frac{1}{2}$	3.548	4.000	0.226	8	1.00
4	4.026	4.500	0.237	8	1.05
$4\frac{1}{2}$	4.508	5.000	0.246	8	1.10
5	5.045	5.563	0.259	8	1.16
6	6.065	6.625	0.280	8	1.26
7	7.023	7.625	0.301	8	1.36
8	7.982	8.625	0.322	8	1.46
9	9.000	9.688	0.344	8	1.57
10	10.019	10.750	0.366	8	1.68

Taper of conical tube-ends, 1 in 32 to axis of tube.

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