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Jigs and Fixtures

By EINAR MORIN

PART III

BORING, PLANING AND MILLING FIXTURES

SECOND EDITION

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JIGS AND FIXTURES—PART III

CHAPTER IX

PRINCIPLES OF BORING JIGS*

Boring jigs are as commonly used as drill jigs, in interchangeable manufacturing, and the requirements placed on drill jigs apply in most respects to boring jigs. Boring jigs are generally used for machining holes where accuracy of alignment and size are particularly essential, and also for holes of large sizes where drilling would be out of the question. Two or more holes in the same line are also, as a rule, finished with the aid of boring jigs.

The boring operation is performed by boring bars having inserted cutters of various kinds, and boring jigs are almost always used in connection with this kind of boring tool, although boring operations may be satisfactorily accomplished with three or four lipped drills and reamers. The reamers may be made solid, although most frequently shell reamers mounted on a bar and guided by bushings are used. The majority of holes produced in boring jigs, whether drilled or bored out, are required to be of such accuracy that they are reamed out in the last operation.

The boring bars are usually guided by two bushings, one on each side of the bored hole, and located as close as possible to each end of the hole being bored. The bar is rotated and simultaneously fed through the work, or the work with its jig is fed over the rotating bar. Boring jigs may be used either in regular boring lathes, in horizontal boring and drilling machines, or in radial drills.

The jig body is made either in one solid piece or composed of several members, the same as in drill jigs. The strain on boring jigs is usually heavy, which necessitates a very rigidly designed body with ribbed and braced walls and members, so as to allow the least possible spring. As boring jigs when in operation must be securely fastened to the machine table, means must also be provided in convenient and accessible places for clamping the jig without appreciably springing it.

The places in the jig where the bushings are located should be provided with plenty of metal so as to give the bushings a substantial bearing in the jig body. Smaller jigs should be provided with a tongue or lip on the surface which is clamped to the machine table; this permits the operator to quickly locate the jig in the right position. As an alternative, finished lugs locating against a parallel or square may be provided. It is frequently advantageous to have small sized boring jigs provided with feet so that they can be used on a

* MACHINERY, January, 1909.

regular drill press table in cases where holes to be bored out are to be opened up with a drill piercing the solid metal. It is both easier and cheaper to do this rough drilling in a drill press.

The guide bushings, of the same type as the bushings for drill jigs, are made either of cast iron or steel and ground to fit the boring bar, which is also ground. The bars are made of machine steel and should be made as heavy as possible, in order to prevent them from bending or springing too much should there be a heavier cut on one side than on the other. The bushings should be made rather long to insure good bearing.

The most common type of boring jig for small and medium size work is shown in Fig. 109. In this engraving, *A* represents the work which is held down by straps or clamps. In many instances when the work is provided with bolt and screw holes before being bored, these holes are used for clamping the work to the jig. In some cases

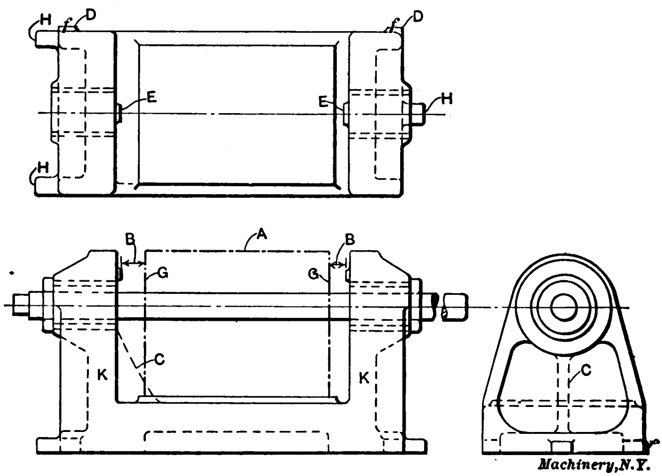


Fig. 109. General Outline of Simple Boring Jig

it is important that the work be attached to the jig in the same way as it is fastened to its component part in the machine for which it is made, and also that it be located in a similar way. If the work is located by V-slides when in use on the machine, it is preferable to locate it by V's in the jig. In other cases the locating arrangement for the work in the machine where it is to be used may be a tongue, a key, a dowel pin, a finished pad, etc. The same arrangement would then be used for locating it in the jig. In Fig. 109 enough clearance is left at *B*, at both ends, to allow for variations in the casting and to provide space for the chips; also, if the hole is to be reamed out, and the reamer be too large to go through the lining bushing, then the space left provides room for inserting the reamer and mounting it on the bar. In nearly all cases of boring, a facing operation of the bosses in the work has also to be carried out and provisions must be made in the jig to permit the insertion of facing tools.

A great deal of metal may be saved in designing heavy jigs by removing superfluous metal from those parts where it does not materially add to the strength of the jig. In Fig. 109, for instance, the jig can be cored out in the bottom and in the side standards as indicated without weakening the jig to any appreciable extent. The rib *C* may be added when necessary, and when it does not interfere with the work to be finished in the jig. It will be seen that extended bosses are carried out to provide long bearings for the bushings. The bosses may be made tapering, as shown, providing practically the same stiffness as a cylindrical boss containing considerable more metal. They must be given a rather liberal diameter, as they may not always be placed exactly correct on the pattern, and consequently be a little out of center in the casting. Finished bosses should be located at suitable places to facilitate the laying out and the making of the jig,

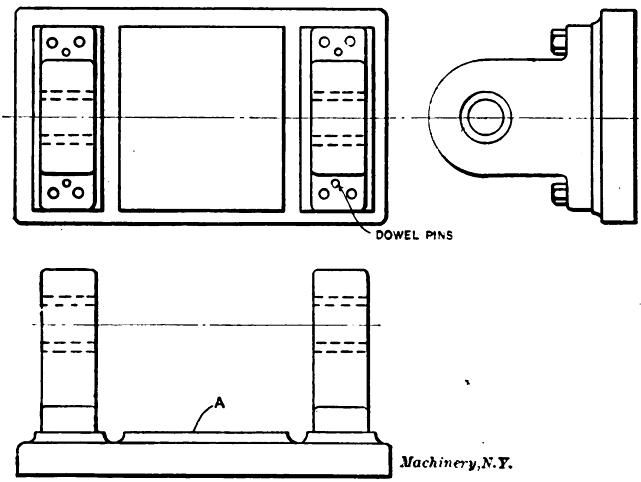


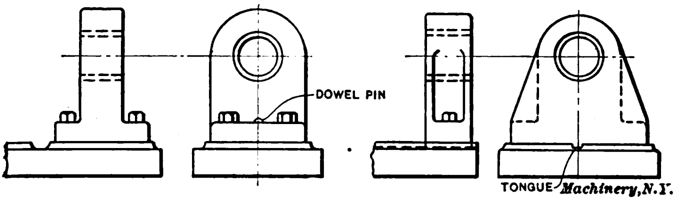
Fig. 110. Boring Jig with Base Separate from Side Standards

as shown at *D* in Fig. 109. The finished faces of these bosses are also of advantage when locating the jig against a parallel, when it is not provided with a tongue for locating purposes.

In some cases bosses are placed where measurements may be taken from the finished face to certain faces of the work, in which case the finished bosses, of course, must stand in a certain relation to the locating point; such bosses are indicated at *E*, from which measurements *B* can be taken to surfaces *G* on the work. The three lugs *H* are provided for clamping purposes, the jig being clamped in three places only to avoid unnecessary springing action. If the jig is in constant use, it would be advisable to have special clamping arrangements as component parts of the jig for clamping it to the table, thereby avoiding loss of time in finding suitable clamps.

The walls or standards *K* of large jigs of this type are frequently made in loose pieces and secured and dowelled in place as shown in

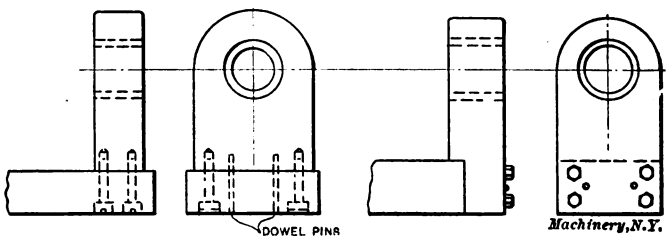
Figs. 110 to 114. In such a case the most important thing is to fasten these members firmly to the base, preventing shifting by tongues, keys, or dowels. It is evident that when the standards are made loose, as in Fig. 110, it is easier to finish the pad *A* of the base, and this is of importance, particularly when difficult locating arrangements are planed or milled in the base; the pattern-maker's and the molder's work is also simplified. As a rule the standards are screwed to the base permanently and then the bushing holes are bored. In some cases, however, it may be easier to first bore the hole in a loose part.



Figs. 111 and 112. Different Methods for Securing and Locating the Uprights on Base-plate of Boring Jig

and then attach it to the main body. Such an instance is shown in Fig. 115. It is easier to locate the bracket with the bushing *B* by working from the finished hole in connection with other important holes or locating means, than it would be to first screw the bracket in place and then expect to be able to locate the hole to be bored exactly in the center of the hub of the bracket.

When boring jigs are designed for machine parts of a similar design but of different dimensions, arrangements are often made to make one jig take various sizes. In such a case one or both standards may have



Figs. 113 and 114. Alternative Methods of Fastening Uprights to Jig Base

to be moved, and extra pads are provided on the face as illustrated in Fig. 116. This shifting of the standards will take care of different lengths of work. Should the work differ in height, a blocking piece *B* may be made as indicated in the same illustration. Sometimes special loose brackets may be more suitable for replacing the regular standards for shorter work. If there is a long distance between two bearings of the work, a third standard may be placed in between the two outside ones, if the design of the bored work permits, as shown in Fig. 117; this may then be used for shorter work together with one of the end standards. In Fig. 118 is shown another adjustable boring jig. Here the jig consists of two parts *A* mounted on a common base-plate or large table provided with T-slots. The work *B* is located between the standards. A number of different standards suitable for different pieces of work may be used on the same base-

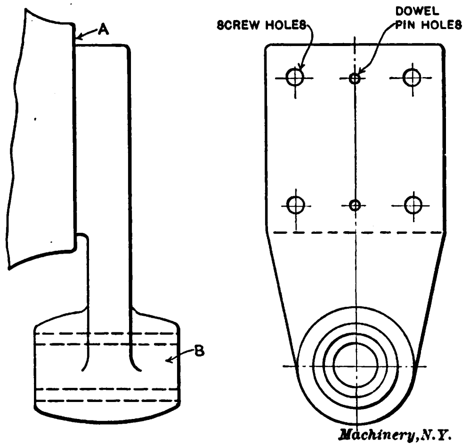


Fig. 115. A Case where the Bushing Hole is Bored Previous to Locating and Fastening Bracket on Jig Body

plate. The jigs or standards are held down on the base-plate by screws or bolts, and generally located by a tongue entering the upper part of the T-slots.

In the examples thus far given the work has been located on the jig, but it is apparent that boring jigs are frequently made which are

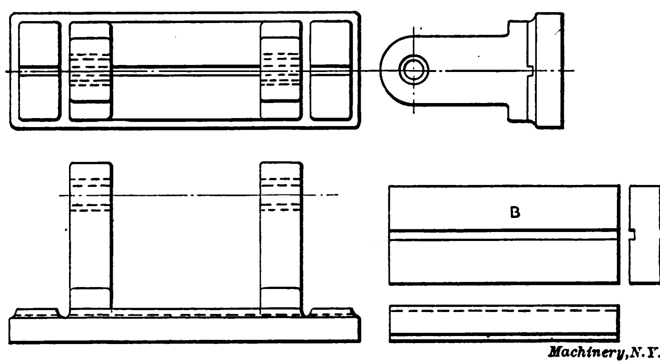


Fig. 116. Jig Adjustable for Different Sizes of the Same Class of Work

located and supported on the work. Fig. 119 shows such a jig. The work *A*, which in this case represents some kind of a machine bed, has two holes bored through the walls *B* and *C*. This jig may guide the bar properly if there be but one guide bushing at *E*, but it is better if it can be arranged to carry down the jig member *D* as indicated to give support for the bar near the wall *B*. It may sometimes be more convenient to have two separate jigs located from the same surfaces on the top or sides. In other cases it may be better to have the members *D* and *E* screwed in place instead of being solid with *F*,

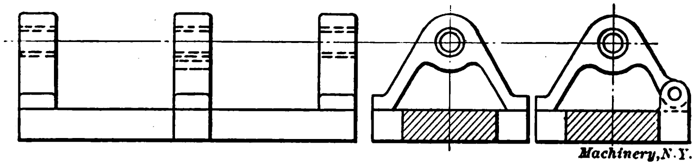


Fig. 117. Boring Jig with Removable Bearing in the Center, Adapting it to Different Sizes of Work of Similar Character

and in some cases adjustable. Of course, these variations in design depend on the conditions involved, but the principles remain the same. The jig or jigs are held to the machine on which they are used by clamping arrangements of suitable type.

The type of boring jigs described above supports the bar in two or

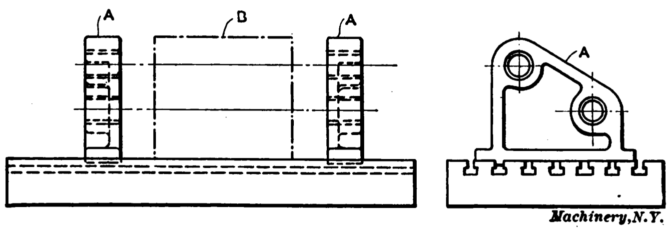


Fig. 118. Universal Base-plate for Standards of Various Descriptions for Different Classes of Work

more places, and the cutting tools are placed at certain predetermined distances from the ends of the bars, depending on the shape and size of the work. Sometimes it may prove necessary, however, to have a cutting tool inserted just at the end of the bar. For example, a boring jig may consist of simply one bracket as shown in Fig. 120. A very

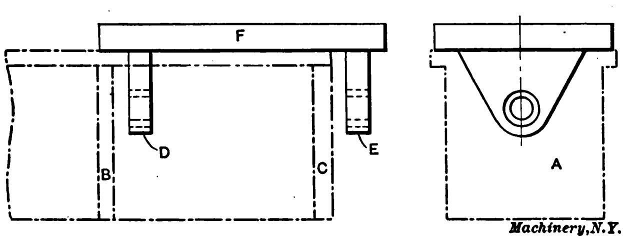
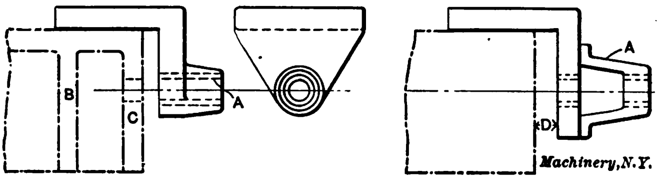


Fig. 119. A Case where the Jig is Located on and Supported by the Work

long bearing *A* is then provided so as to guide the bar true. The arrangement shown in Fig. 121 is sometimes used to insure a long bearing for the bar. A special bracket *A* is mounted on the jig and bored out at the same time as the jig proper is machined. This provides, in effect, two bearings. In these cases bars with a cutting tool at the end are used. The reasons for using the kind of boring jig illustrated in Figs. 120 and 121 are several; in Fig. 120, for instance, there is a wall *B* immediately back of the wall *C* in which the hole is to be



Figs. 120 and 121. Examples of Guiding Arrangements where no Support is Obtainable on One Side of Hole to be Bored

bored. Other obstacles may be in the way to prevent placing a bearing on one side of the hole to be finished. Instead of having a space *D* between the jig and the work, as shown in Fig. 121, the jig can oftentimes be brought up close to the work and clamped to it from the bushing side. A combination between this latter type of jig with

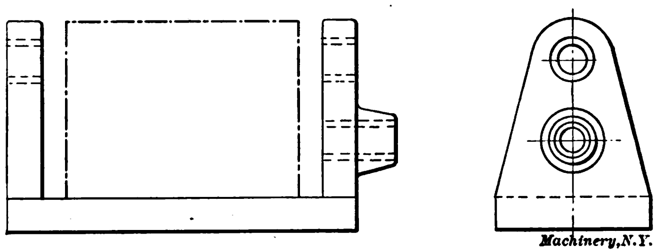


Fig. 122. Boring Jig in which One Bar has Single and One Double Bearing

but one bearing for the bar, and the type previously described with two bearings, is shown in Fig. 122.

Each of the different holes in boring jigs has, of course, its own outfit of boring bars, reamers, and facing tools. In making the jig it must be considered whether it will be used continuously and what

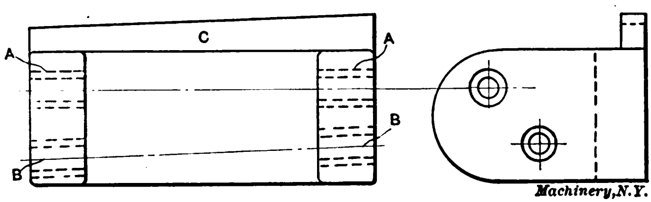


Fig. 123. Boring Jig for Boring Holes Placed at an Angle to Each Other

degree of accuracy will be required. When extreme accuracy is required there should be a bar provided with cutting tools for each operation to be performed. It is cheaper, of course, to use the same bar as far as possible for different operations and, ordinarily, satisfactory results are obtained in this way. It is desirable to have bushings fitting each bar, but often this expense can be reduced by using the same bushings for bars having the same diameter.

It sometimes happens that one or more holes form an angle with the axis of other holes in the work to be bored. In the jig shown in Fig. 123 the bushings *A* guide one bar for boring one hole and the bushings *B* the bar for boring another hole, the axis of which is at

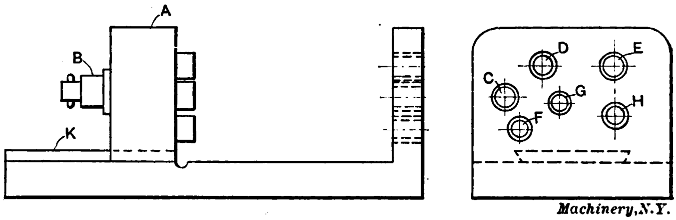


Fig. 124. Principle of Multiple Bar Boring Jig

an angle with the axis of the first hole in the horizontal plane. Then an angle plate *C* can be made in such a manner that if the jig is placed with the tapered side of plate *C* against a parallel, the hole *B* will be parallel with the spindle. This arrangement may not be necessary when universal joints are used between the spindle and the bar. If a hole is out of line in the vertical plane, a similar arrangement as

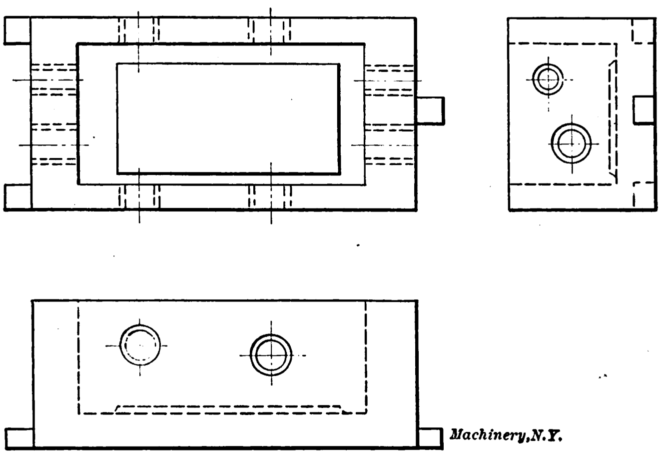


Fig. 125. Jig for Boring Holes through Work both from Sides and Ends

that used for drill jigs, and previously described in Part II, can be used.

As a rule but one hole is bored out at a time owing to the fact that machines for boring generally have but one spindle. Several holes, however, could be bored out in a large size multiple spindle drill, in which case the jigs naturally ought to be designed somewhat stronger. Another method of designing jigs for boring two or more holes at the same time is illustrated in Fig. 124, the outlines only being shown in this illustration. *A* is a gear box containing the main driving gear which is mounted on a shaft *B* which in turn is driven by the spindle of the machine. The gear on shaft *B* drives the gears and shafts connected with the boring bars passing through the bushings *C*, *D*, *E*, *F*, *G*, and *H*. The gears are proportioned according to the speed required for each bar, which in turn is determined by the sizes of the holes. The housing or gear box *A* slides on a dove-tail slide *K*. A particularly good fit is provided, and the gear box can be fed along in relation to the work either by table or spindle feed. If boring operations are to be performed in two directions, a jig on the lines indicated in Fig. 125 is designed. This jig may be mounted on a special revolving table permitting the work and the jig to be turned and indexed so as to save resetting and readjusting the work and jig when once placed in position on the machine.

The outline given above of boring jigs illustrates only the fundamental principles involved, it being considered more important to state the fundamental principles in this connection than to describe complicated designs of tools in which the application of such principles may be more or less obscure or hidden.

CHAPTER X

BORING JIG DESIGNS*

In the previous chapter the fundamental principles of boring jigs were outlined. In the present chapter a number of applications of these principles to boring jigs that have been designed for shop use will be shown.

In Fig. 126 are shown two views of a small jig supported directly on the work to be bored. This jig is used for boring out a cross-slide carriage, and is located on the work by the dove-tail slide and held in place by the two set-screws *A*. The two bushings *B* are driven into the solid part of the jig and the two corresponding bushings *C* are placed in the loose leaf *D* which is removed when the jig is placed in position on, or removed from, the work. The two set-screws *A* do not

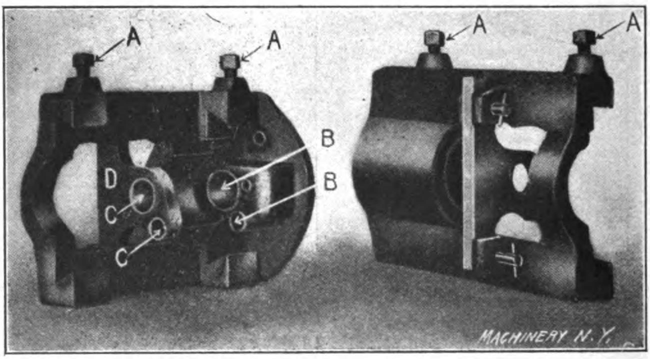


Fig. 126. Example of Small Boring Jig, with Removable Leaf for Holding Guide Bushings

bear directly on the side of the carriage, but are provided with brass or steel shoes as shown in Fig. 127, where *E* is the shoe. The leaf *D* cannot be attached permanently to the jig and simply swung out of the way when the jig is located on the work, because it could not be swung in place after the jig is applied on account of the small clearance in the cross-slide carriage. The leaf is therefore made loose, which is an objectionable feature, but lugs have been carried up on the casting on both sides of the leaf as shown, to give good support; these lugs are carefully finished to fit the leaf, and the latter is located and held in place by ground plugs.

In Fig. 128 is shown a boring jig which receives the work *A* between two uprights. The work in this case is the tail-stock of a lathe where two holes *B* and *C* are to be bored out. The bottom surface of the tail-stock is finished before boring, and is located on the finished

* MACHINERY, February, 1909.

bottom of the jig by means of a key and keyway. The keyway is cut in the jig and is a little wider than the key in the work. and the set-screws *D* bring the key against one side of the keyway, that side being in accurate relation to the hole *B* to be bored in the tail-stock. Longitudinally the work is located by a stop pin, against which it is brought

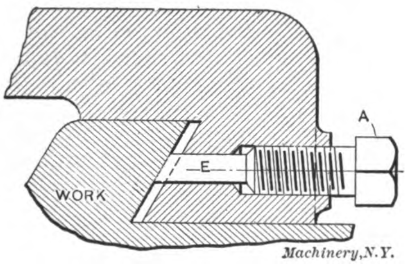


Fig. 127. Means for Holding Work against Locating Side of Dove-tail Slide of Boring Jig in Fig. 126

up by a set-screw from the opposite side. The tail-stock is held to the jig by bolts *E* exactly as it is held on the lathe bed.

The placing of the set-screws *D* at different heights is one of the features of the jig; this makes it possible for the jig to take tail-stocks of various heights for different sizes of lathes, raising blocks being used for the smaller sizes. The raising blocks are located exactly as the tail-stock itself, so that the work placed on them will come in the same relative position to the uprights of the jig whether

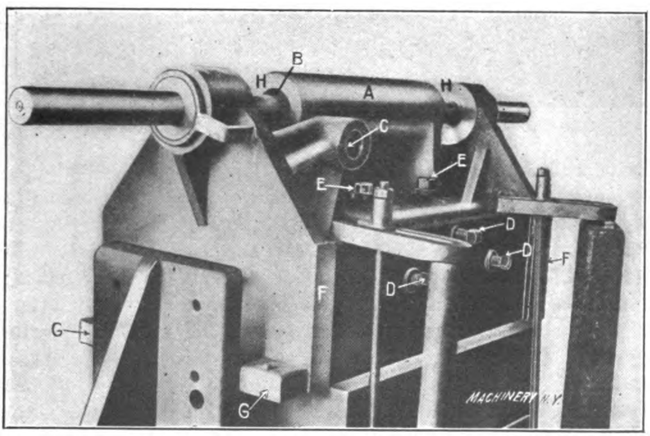


Fig. 128. Common Type of Medium Size Boring Jig

the work rests directly on the jig bottom or on the raising pieces. The two finished strips *F* are provided for facilitating the making of the jig, and the lugs *G* for the clamping down of the jig to the boring machine. The jig, however, can also be clamped to the boring machine table as shown in the illustration. At *H* is a liberal clearance between the work and jig, allowing ample room for the inserting of facing cutters, reamers, and boring tools. Ribs are provided for strengthening the jig, as shown.

The half-tone Fig. 129 shows a large size boring jig made from a solid casting. In this case the work to be bored out is the head of a lathe. It is located and clamped to the jig in a way similar to that mentioned in the case of the tail-stock; clamping it to the jig in the same way that it is fastened to the lathe bed insures that the effects of possible spring will be less noticeable. Opinions differ as to whether it is good practice to make up a jig of the size shown in one piece, the distance between the standards *A* and *B* being from four to five feet, or whether it would be better to make loose members located on a base-plate as shown in Fig. 130. The writer advocates the making of one piece jigs of as large sizes as possible, because, with loose members as shown in Fig. 130, there is no assurance that the standards are located

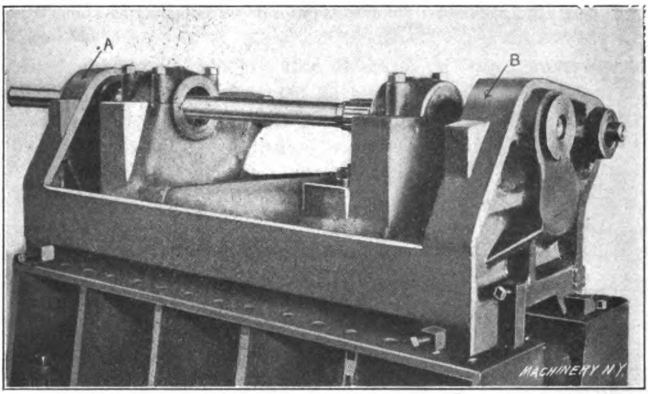


Fig. 129. Large Size Boring Jig made from a Solid Casting

correctly in relation to each other or to the work to be bored, and it involves more or less work to get the jig in order. The jig in Fig. 129 does not need to be as heavy as would be inferred from the illustration, because a large portion of the bottom can be cored out.

The boring jig illustrated in Fig. 130 consists of four parts; the upright members *A*, *B*, and *C*, and the base-plate *D*, which latter may be used for all jigs of similar construction. This type of boring jig is used only for very large work. In the case illustrated large lathe heads are to be bored. The work is located on the base-plate between the two members *A* and *C*. The member *B* is only used when the distance between *A* and *C* is very long, so that an auxiliary support for the boring bar is required, or when some obstacle prevents the bar from passing through the work from one of the outside members to the other. As a rule these members are located on the base-plate by a tongue fitting into one of the slots as shown at *E*. The members are brought as close as possible to the work, sufficient space, of course, being permitted for the cutting tools to be inserted. The standards are cored out and ribbed and lugs provided so as to give the bearing bushings long and substantial support. Good results will be obtained with this type of jigs provided they are carefully set up on the base-plate. At *F* in the member *B* is shown a boss; this is provided with a tapped hole for a hook or eye-bolt for facilitating the moving of the jig

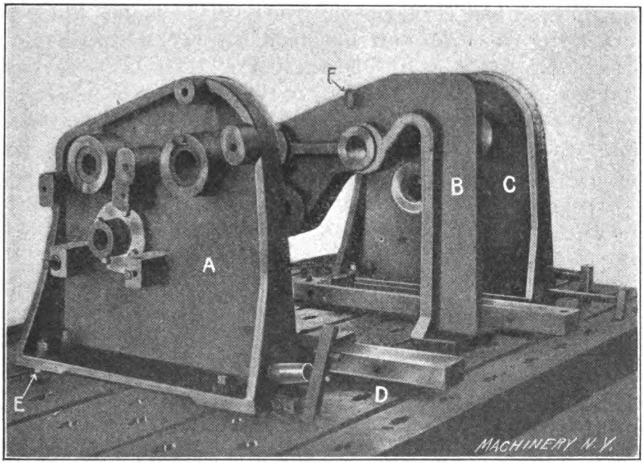


Fig. 130. Boring Jig Consisting of Base-plate and Separate Removable Uprights carrying the Guide Bushings

member by an overhead crane. The other members have tapped holes on the top for the same purpose.

The jigs in Figs. 126, 128, and 129 are ordinarily used on boring lathes, but the one shown in Fig. 130 may also be used in combination

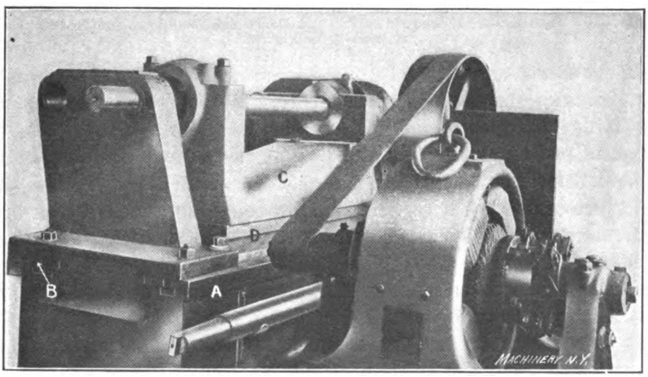


Fig. 131. Boring Jig with Portable Drive

with a portable driving and feeding arrangement, one type of which is shown in Fig. 132. The lugs and finished bosses on the side of jig member *A*, which do not carry bushings, are used for connection to this drive and feed mechanism.

Fig. 131 shows a boring jig of the loose member type provided with motor drive for the boring bars. The members are mounted on the base *A*, located by the tongue *B*, and clamped down by T-bolts. The work *C*, a lathe head, is placed on the extension piece *D*. The boring bar is driven from the motor by means of a worm and worm-wheel, the bar being fed along as shown in Fig. 132. In this engraving, *A* represents the work, *B* and *C* the jig members, *D* the motor which is belt-connected to the pulley *E*, which, in turn, through a worm-shaft *F* and the worm-wheel *W*, drives the boring bar *G*; this latter is keyed to, but at the same time is a sliding fit in, the worm-wheel. The bar is fed forward by the feed-screw *H* which passes through the stationary nut *J* fastened to the base-plate. The motion of the screw is actuated from the bar itself through a train of gears. The gear *K* is keyed to the screw and driven by the gear *L* which is mounted on the same stud as the star-wheel *M* which is turned by the pin *N* attached to the connecting head *O*; this latter rotates with the boring bar, but the

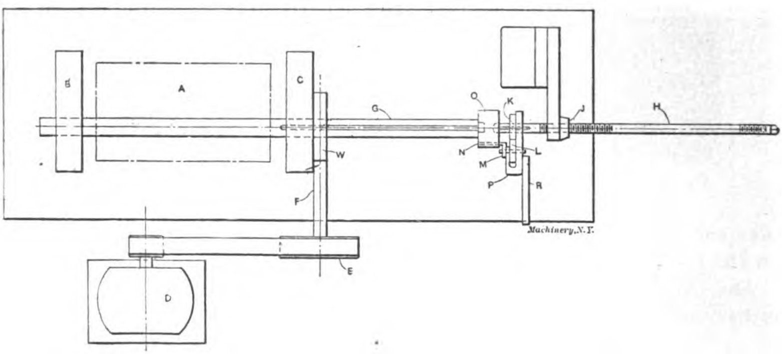


Fig. 132. Outline of Arrangement of the Drive and Feed of the Boring Bar of the Jig in Fig. 131

screw *H* is a free-running fit in *O*, and simply has a thrust washer at its end to take the feed thrust. More or less feed can be arranged for by using more than one pin in the connecting head. The pin or pins can be pulled back when the feed is not required. The gears and star-wheel are mounted in the bracket *P* which follows the bar and which is prevented from turning by the rod *R* fastened to the bracket. The bar can be pushed back by using a wrench or crank at the end of the feed-screw.

The feed arrangement shown has proved very serviceable and reliable. A separate and portable drive, of the type indicated, is quite necessary for large boring jigs as there are few machines large enough in the ordinary shop to handle such heavy work.

In Fig. 133 is shown a boring jig for boring out the top frame *A* of radial drills. The design of the jig is simple but effective; the hole *B* is parallel with the finished side *C* of the jig and is bored out after the jig has been brought up square against a parallel and strapped to the machine table. The hole *D* is bored at an angle with the hole *B*, and the setting of the jig for the boring out of this hole is facilitated by providing a wedge-shaped piece *E* of such an angle that the jig will be set in the proper position when moved up against the wedge. If universal joints are used for connecting the boring bar with the driving spindle, the setting of the work at an angle could be omitted, although it is preferable even when using universal joints to have the boring

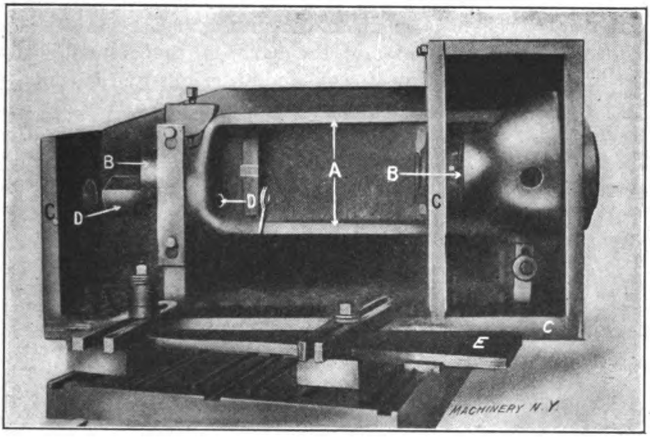


Fig. 133. Wedge-piece for Aligning Work for Boring Holes with the Axes at an Angle

bars as nearly as possible in line with the spindle. This eliminates a great deal of the eccentric stress, especially when taking a heavy cut with coarse feed.

Boring operations are sometimes carried out using parts of the machine itself as guiding means for the boring bars, and in some

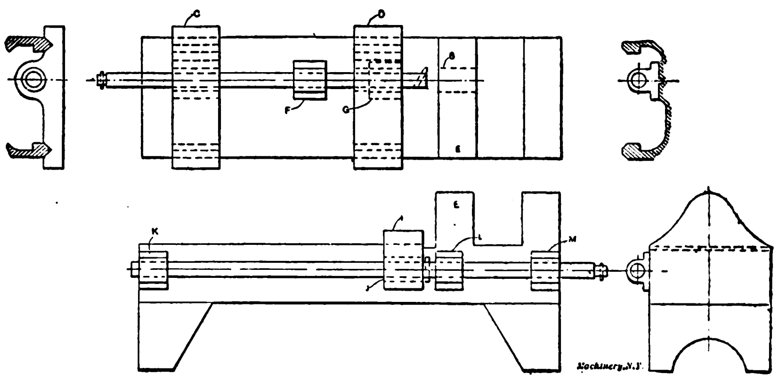


Fig. 134. Examples of Boring where Parts of the Machine being Built are Used as Guiding Means

instances it is very essential that boring operations be performed in this way in order to obtain perfect alignment. In Fig. 134 is shown a line engraving of a machine bed with the head-stock solid with the bed. In the top view is shown a method for boring out a hole at *B* by the use of two jigs *C* and *D* which are located on the V's of the machine and held down by hook bolts. If the hole *B* only passes through the part *E* of the head this would be the preferable way of boring it. In some instances, however, the hole *B* may be required to be in alignment with the holes in a carriage or in a bracket as at *F* and *G*. These holes, of course, can then be used to great advantage as guiding means. Should the holes be too large to fit the boring bar, cast-iron bushings can be made to fit the holes and the bar. In the elevation and end view of Fig. 134 is shown how a cross-slide carriage and apron *I*, which has a hole *J* in line with the holes in bearings *K*, *L*, and *M*, and travels between *K* and *L*, can be bored out by using the brackets *K*, *L*, and *M* to guide the boring bar. By keying the traveling part *I* close to the bracket during the boring operation, as illustrated, accurate results will be obtained. It is evident that two of the bearings could be bored out by using the finished bearing and the traveling part *I* as guiding

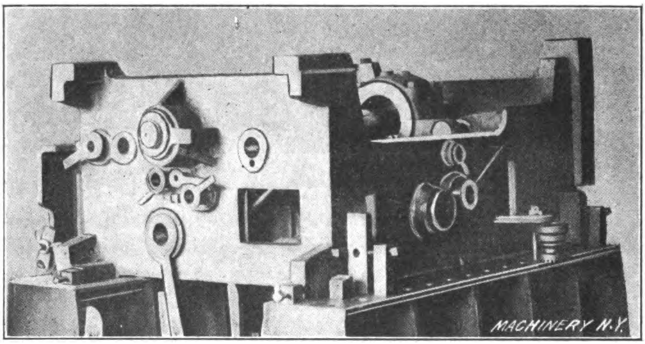


Fig. 135. Combined Drilling and Boring Jig Used with a Horizontal Drilling and Boring Machine

means. Arrangements of this kind usually save expensive tools, and often give better results.

Combination Drill and Boring Jig

Jigs for performing both drilling and boring operations are frequently used to great advantage. In designing such jigs, however, judgment must be shown so that combination jigs will not be employed when the operations can be more easily performed in two separate jigs. Sometimes it is advisable to have a jig for the boring alone, and then to use the bored holes for locating the work in a separate drill jig. In other cases it may be better to do the drilling first and locate the work for the boring operations from the drilled holes. The designer should decide which method would be preferable, considering, in the first place, the factors of the time required and the accuracy of the work. To give any definite rules for this work is not possible; but it may be said that combination jigs should be used only when the drilled and bored holes have nearly the same diameters. When the holes are of widely different diameters two jigs are preferable. If a few screw-holes of small diameter for holding a collar or bracket, for instance, located around a large bored hole, were to be drilled with the same jig used for the large hole, the jig, when used on a small drill press, would be entirely too heavy to manipulate. It is likely that in such a case a small separate drill jig could be attached directly to the work. In other cases, however, it will prove a distinct saving to combine the boring and drilling jig in one.

In Figs. 135 and 136 is shown a combination drill and boring jig of large size. The work *A* in Fig. 136 is a head-stock for a lathe with a

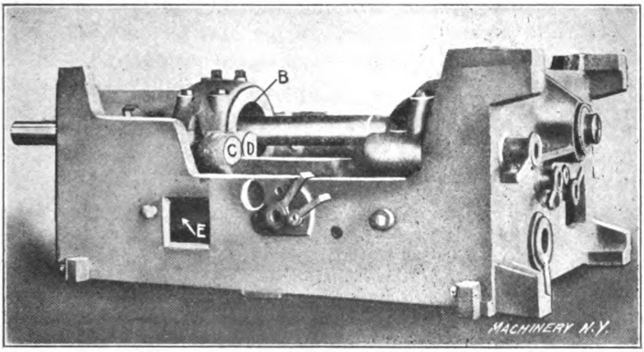


Fig. 136. Another View of the Jig in Fig. 135. Note that Holes are Drilled or Bored from All Sides

number of holes to be drilled. The large holes *B* at both ends of the head-stock are cored as usual, and allow the boring bar to enter for taking the roughing cut. The holes at *C* and *D* are opened up by drills previous to the boring operation. As there is considerable distance between the end of the head-stock and the uprights of the jig, long bushings are used to give the tools a good bearing close to the work. Both the drilling and boring operations may be performed on a horizontal boring and drilling machine. As the horizontal boring and drilling machines usually have adjustments in all directions, the only moving of the jig necessary is to turn it around for drilling the holes on the opposite sides.

CHAPTER XI

BORING, REAMING AND FACING TOOLS*

More or less elaborate tools or sets of tools are required for the various boring operations performed with or without boring jigs. These tools comprise boring, reaming and facing bars, boring and facing cutters, solid or shell reamers, boring and facing heads, bushings, stops, drills, collets, and knuckle or universal joints.

Boring Bars

The general requirements of a boring-bar are that it must be as heavy and rigid as possible, straight, and ground concentric, and a good running fit in the bushings. When the bar has been turned and once ground to the right size, it should never be put in a lathe and filed, or emery cloth used on it. Boring bars are made from machine steel and are not hardened. Sometimes small bars are made from tool steel and hardened, in order to give them additional stiffness. Shanks for reamers, and facing bars, should be made in the same way as boring bars, but if possible, should be even stiffer.

The most common type of boring bar is shown in Fig. 137, the cutter *A* being located about at the middle of the bar, and the bar being guided at both ends by bushings *B* and *C*. The bar is provided with a taper shank at *D*, fitting the spindle of the machine or a collet connected with a knuckle joint. It is quite common practice to turn down the end of the bar, as shown in Fig. 138, to fit a knuckle joint or the collet shown in Fig. 141. Sometimes, of course, the bar can be left full size, as shown in Fig. 139, and sometimes the end is even made larger than the bar, by forcing on a collar, as shown in Fig. 140, in order that the end may fit the driving collet. A key is passed through the end of the bar for driving it; this key fits in the slot *A* in the collet shown in Fig. 141.

The bar shown in Fig. 137 can also be used for facing purposes, the cutter *A* being taken out, and a facing cutter inserted. The same bar can also be used for a special shell reamer, when this has a straight hole, the reamer being held to the bar by a taper pin, as shown in Fig. 142. Standard shell reamers have a taper hole, and for these, the bar must be turned with a taper part, as shown in Fig. 143, where the part *A* is turned up to the largest size possible (generally 1/32 or 1/16 inch under the diameter of the reamer); part *B*, being turned to fit the taper hole in the shell reamer, is left long enough to permit the reamer being pressed up tight without touching the shoulder *D*. As a rule, the taper part is so dimensioned that ⅛ inch will be left at *E*, between the shoulder of the bar and the back of the shell reamer, when this is forced up as far as possible. The reamer is driven by keys or pins entering in a slot cut across the end of the reamer. The

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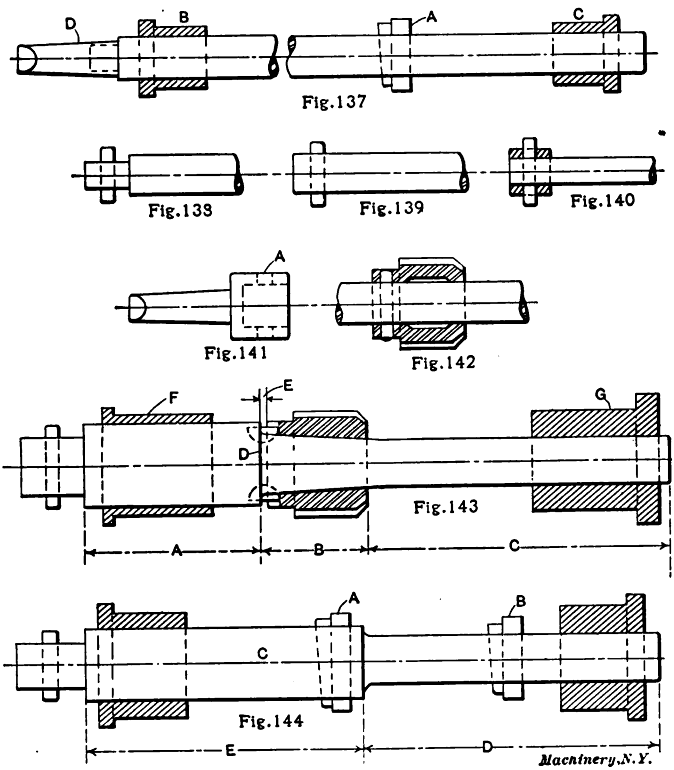
* MACHINERY, March, 1909.

part *C* of the bar is turned down to some standard size, just below the size of the small end of the taper hole in the reamer. The bushings *F* and *G* may be made with the same outside diameter, fitting the same size lining bushings in the jig, their inside bearings being made to fit the large and small diameters of the bar.

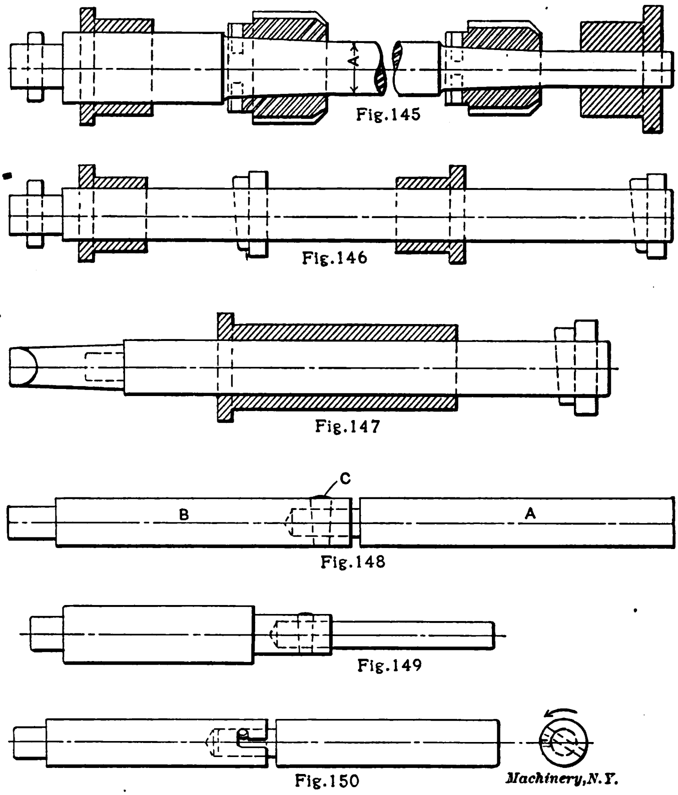
A boring bar used for boring out two holes of different sizes may be made as shown in Fig. 144; *A* and *B* are the cutters for the two holes, and part of the bar *C* is turned down for a length *D*, to fit the small hole. The part *E* can then be made of as large diameter as



Figs. 137 to 144. Boring Bars of Different Types

permissible for boring out the hole for which tool *A* is used. By making the bar in this way, a more rigid construction is possible than if the part *E* were turned down to the smaller diameter required by the hole bored by cutter *B*. There may be more than two holes of different sizes in succession,and then the bars may have a greater number of steps; if there is but a slight difference in the sizes of the holes to be bored out, it hardly pays to turn down steps on the bar. The stepped bar may also be used for facing bars. While these small matters may seem unimportant and elementary, they must be taken into consideration when designing a set of expensive tools for boring jigs which are to be in constant use.

Reamer bars used for reaming out two or more holes simultaneously may be made as shown in Fig. 145, providing the diameter *A* is large enough for turning the taper portion for another shell reamer of smaller size. Should the diameter be too small to permit this, an extension can be provided, or a separate bar used for the smaller reamer. The principle of stepped bars can be applied also in cases



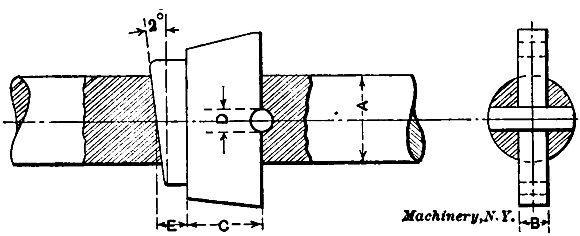
Figs. 145 to 150. Other Designs of Boring Bars

where the cutters are placed as illustrated in Fig. 146. Here one boring cutter or facing tool is placed at one end, the bar still being guided by two bushings.

A boring, facing, and reamer bar used almost as commonly as the one already described, is illustrated in Fig. 147. The principal features of this bar are that the cutting tool is always located at the end of the bar, opposite where it is driven, and that there is but one bushing for guiding. This bushing should be as long as possible to give a good bearing and prevent the bar from wabbling. Sometimes, as illustrated in Fig. 121, the jig is made with two bearings which, however, are on the same side of the cutter, and a comparatively short distance apart.

Sometimes a bar must be made in two parts. The reason may be that one solid bar would be too long to permit its being pushed into the jig from one side. Another reason may be that the cutting tools are too large to pass through some intermediate hole. The two parts of the bar may be connected with a taper pin, as shown in Fig. 148, the end of bar *A* being a sliding or driving fit in the hole in section *B*. This bar should be ground after the two parts are assembled, so that they will run exactly true with each other. A stepped bar made up of two sections is shown in Fig. 149. In Fig. 150, another method of connecting the two sections is shown; when this method is used the two bars can be put together and taken apart very rapidly.

TABLE X. BORING AND FACING CUTTERS

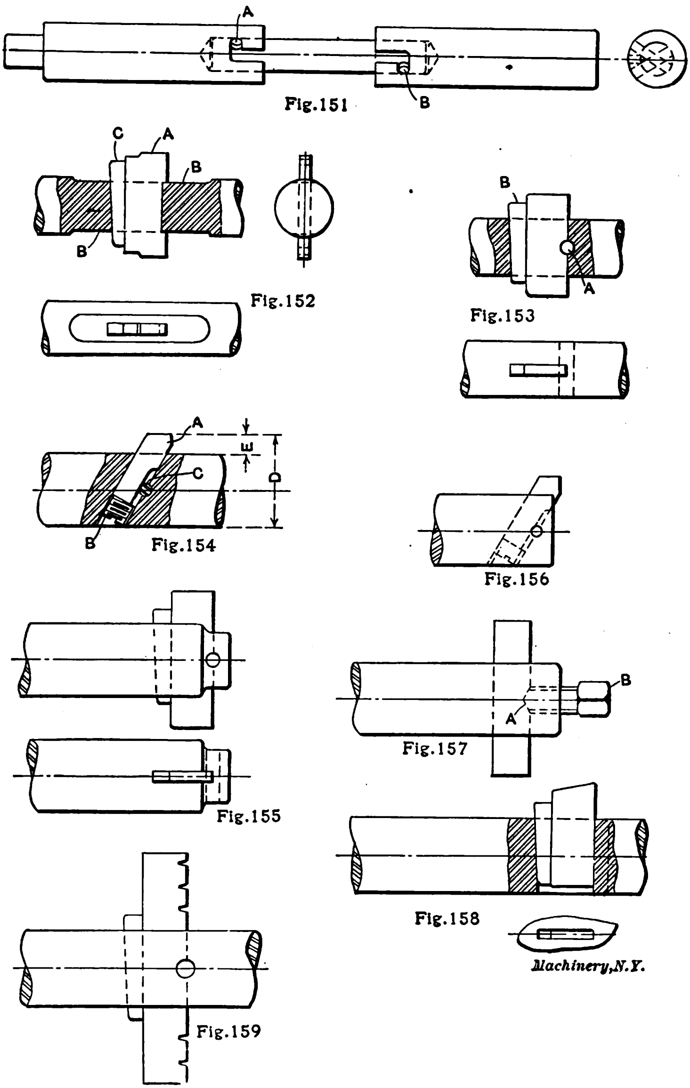


A	B	C	D	E
$\frac{3}{4}$ to $\frac{15}{16}$	$\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{1}{4}$
1 to $1\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{1}{4}$
$1\frac{1}{2}$ to $2\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
$2\frac{1}{2}$ to 3	$\frac{1}{2}$	1	$\frac{1}{4}$	$\frac{5}{16}$
$3\frac{1}{8}$ and larger	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$

This method can also be used to connect two bars by a separate piece, as shown in Fig. 151, the two sections being bored out to fit the intermediate piece, which has two pins *A* and *B* driven into it, and transmitting the motion from one section of the bar to the other, as indicated. It is evident that two bearings would hardly be sufficient for this class of boring bars. When these bars are used, three or more bearings should be provided. This type of bar, however, is not used to a very great extent.

Cutters for Boring Bars

The cutters used in boring bars vary widely. The cutter *A*, Fig. 152, is commonly used. It cuts with both ends, and is centered by the two flats *B*, milled or filed on the bar; a slot is provided in the cutter, which fits these flats of the bar. After the cutter has been put in place, it is tightened by the key *C*, and is turned to the correct diameter required, and then hardened. A more modern arrangement is shown in Fig. 153. The cutter here is a plain rectangular piece of steel, cutting with both ends. It is centered by the pin *A*, which is driven into a hole drilled so that one-half of it passes through the slot in the cutter. As in the former case, the cutter is turned down to the



Figs. 151 to 159. Different Types of Cutters and Methods of Fastening

right diameter when in place. It is tightened down by the key *B*. This way of locating the cutter centrally has proved very satisfactory. In Table X are given dimensions of cutters for different bar diameters.

Facing cutters may be located and held in place in the same way.

They are longer than boring cutters, being intended to finish a boss or seat around a hole, but otherwise they are made to about the same dimensions.

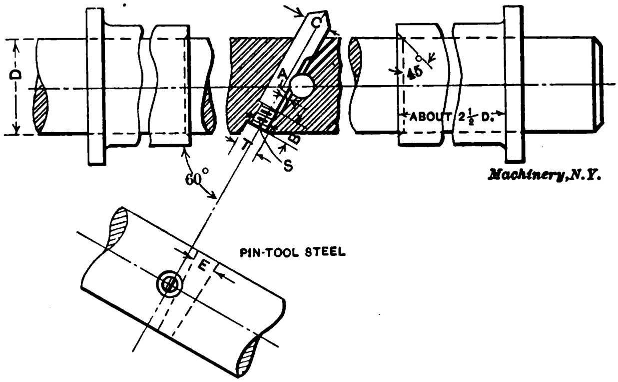
Single-ended boring cutters, as shown in Fig. 154, are used to a great extent, and it is claimed that they give a more perfect hole. The illustration shows a common way of securing the tool; the cutter *A*, which is made of drill rod or other round tool steel stock, fits a hole bored at an angle of sixty degrees with the axis of the bar, and is adjusted by the headless set-screw *B*. When adjusted, the cutter is held rigidly in place by the pin *C* provided on one side with a flat tapering portion, which fits against the flatted side of the cutter, as shown in the engraving. This cutter is very easily set by taking a measurement *D* with a micrometer. Subtract from the dimension *D* the diameter of the bar, thereby obtaining dimension *E*. Now add *E* to *D*, thereby obtaining the diameter of the hole which will be cut. The screw may have to be adjusted a few times, to obtain the desired result. Table XI gives dimensions for this kind of cutters, and also for screws and pins used with them. The two kinds of cutters referred to may also be used on the ends of the bars, as shown in Figs. 155 and 156. The cutter of the type shown in Fig. 153 may be held in either of the two ways shown in Fig. 155 and Fig. 157. In the latter case, the cutter is spotted at *A*, and held by a pointed screw *B*. This method, however, does not always insure very accurate results. The simplest kind of single-ended cutter, and the manner in which it is held is shown in Fig. 158. It may be used in any kind of bar, and with ordinary care, good results may be obtained even with this simple tool. The variations possible are many, and the examples shown simply indicate the most common practice.

Facing cutters may be made similar to boring tools, or they may be made with teeth, like end milling cutters, as illustrated in Fig. 161. In this engraving, one of the cutters *A* cuts with both sides, while the cutter *B* cuts with one side only. The bar is provided with a slot and with notches for locating and holding in place the various cutters, as shown at *C*. A pin *D* is driven into the cutter, and enters the notch, thus driving the tool. The cutters can also be held on the bar by taper pins, but the putting in place and the removal of the cutters would then be much slower.

Different cutters are commonly used for roughing and finishing. To make it easier to remove the metal with the roughing cutter, it may be made with every other tooth beveled in opposite directions, as shown in Fig. 160, where *A* is one tooth beveled toward the center, and *B* the next tooth beveled outward. Using a cutter of this kind will produce a surface as indicated at *C*, which must be faced square by a finishing cutter.

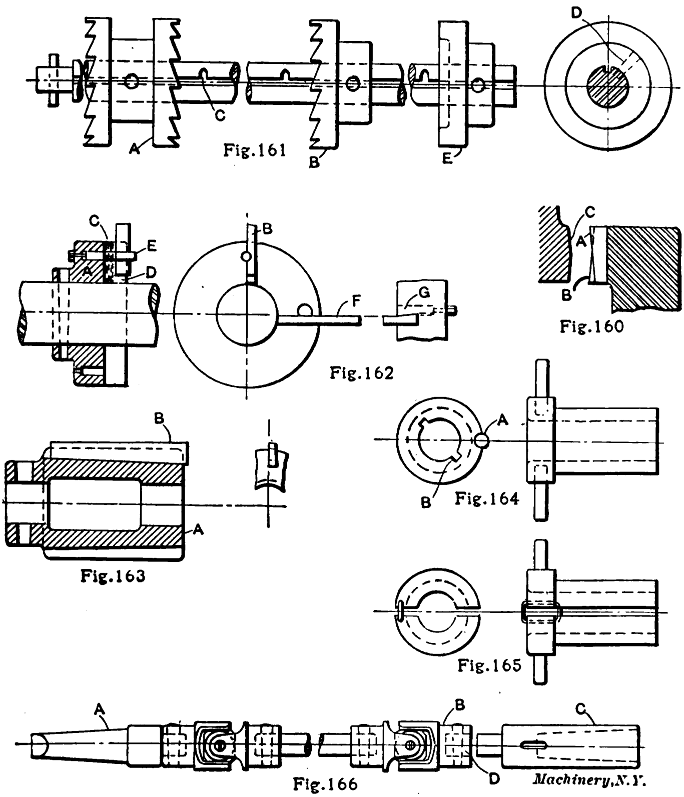
In order to face the work to correct dimensions, stops are sometimes provided which strike against some finished surface on the jig which stands in a given relation to the finished surface on the work and the cutting edge of the facing cutter. Such a stop may be made as shown at *E* in Fig. 161, and be held and located in the same way

TABLE XI. BORING-BAR CUTTERS



D	C	E	A	S	T	B
Diameter of Bar.	Diameter of Cutter.	Diameter of Pin.	Depth of Milled Down Part.	Diameter of Screw.	Diameter of Counter-bore.	Length of Thread.
3/8	1/8	1/16	1/64	1/16	1/8	5/64
7/16	1/8	3/32	1/64	1/16	1/8	5/64
1/2	1/8	3/32	1/64	1/16	1/8	5/64
9/16	1/8	1/8	1/32	1/8	5/32	1/8
5/8	3/16	1/8	1/32	1/8	5/32	1/8
11/16	3/16	5/32	1/32	1/8	3/16	5/32
3/4	3/16	5/32	1/32	1/8	3/16	5/32
13/16	1/4	5/32	1/32	3/16	1/4	3/16
7/8	1/4	5/32	1/32	3/16	1/4	3/16
15/16	1/4	3/16	1/32	3/16	1/4	1/4
1	1/4	3/16	1/32	3/16	1/4	1/4
1 1/8	5/16	7/32	1/32	1/4	5/16	5/16
1 1/4	5/16	1/4	3/64	1/4	5/16	5/16
1 3/8	3/8	1/4	3/64	1/4	5/16	5/16
1 1/2	3/8	9/32	3/64	5/16	3/8	3/8
1 5/8	7/16	5/16	3/64	5/16	3/8	3/8
1 3/4	7/16	5/16	3/64	3/8	7/16	1/2
1 7/8	1/2	11/32	1/16	3/8	7/16	1/2
2	1/2	3/8	1/16	7/16	1/2	9/16
2 1/8	9/16	13/32	1/16	7/16	1/2	9/16
2 1/4	9/16	13/32	1/16	1/2	9/16	5/8
2 3/8	5/8	7/16	5/64	1/2	9/16	5/8
2 1/2	5/8	15/32	5/64	9/16	5/8	11/16
2 5/8	11/16	1/2	5/64	9/16	5/8	11/16
2 3/4	11/16	1/2	5/64	5/8	11/16	3/4
2 7/8	3/4	17/32	3/32	5/8	3/4	7/8
3	3/4	9/16	3/32	5/8	3/4	7/8

as the facing cutter. The stops are made of machine steel, case-hardened, and ground on the bearing surface. When facing up a wide surface with an inserted blade facing tool, it is often the practice to cut small notches in the blade, as shown in Fig. 159, the cutting edges on the one end overlapping the notches on the other. Very often the holes to be bored are too large to permit cutters, such as previously described, being used, and then it is necessary to provide the boring bars with a boring head. A simple boring head is illustrated in Fig. 162, in which *A* is the head held on the bar by a taper pin; *B* is a boring tool which fits in a slot in the head, and which can be adjusted out and in by the screw *C*, passing through the shoe *D* which, in turn, fits the slot, and against which the cutter is located, as illustrated. The cutter and shoe are held by the bolt *E*. The bolt is milled flat on one side so that a hook is formed for binding the cutter

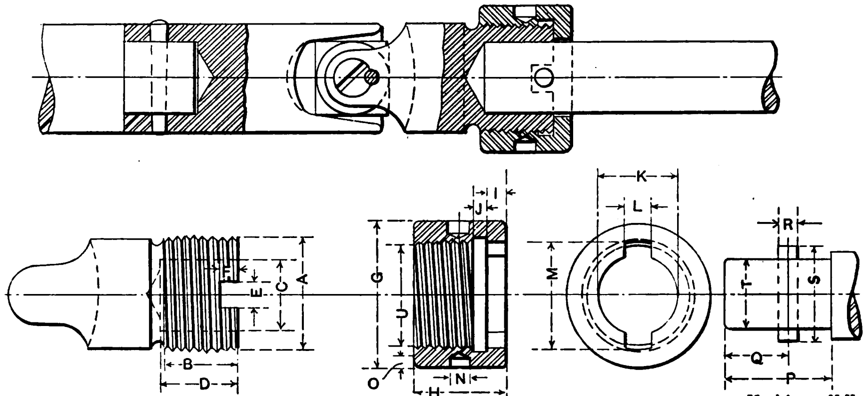


Figs. 160 to 166. Facing Tools, Boring Heads, Boring Jig Bushings, and Universal Joints for Driving Boring Bars

and shoe. Two or more cutters may be used in these boring heads. At *F*, in Fig. 162, is shown a facing tool used in the same head as the boring tool. No adjusting shoe is necessary in this case, as the facing cutter bears directly against the bottom of the slot in the head, and against the boring bar, and is held by a bolt *G*, milled with a tapering flat on one side, which wedges the cutter into its seat. More complicated boring heads are provided with a small slide for adjusting the tools; some are made similar to the box tools used in turret lathes.

The reamers most commonly used in connection with boring jigs

TABLE XII. BORING-BAR COUPLINGS



Machinery, N.Y.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U, Bore.	Threads per inch.	Used for Bars.
$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{5}{32}$	1	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{17}{32}$	$\frac{3}{16}$	$\frac{11}{16}$	$\frac{9}{64}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{21}{32}$	0.499	0.6610	16	$\frac{3}{8}$ to $\frac{1}{2}$
1	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{4}$	$\frac{7}{32}$	$1\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{21}{32}$	$\frac{1}{4}$	$\frac{15}{16}$	$\frac{11}{64}$	$\frac{5}{32}$	$\frac{7}{8}$	$\frac{15}{32}$	$\frac{3}{16}$	$\frac{7}{8}$	0.624	0.9110	16	$\frac{1}{2}$ to $\frac{3}{4}$
$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{16}$	$\frac{9}{32}$	$1\frac{5}{8}$	$\frac{13}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{25}{32}$	$\frac{5}{16}$	$1\frac{5}{32}$	$\frac{13}{64}$	$\frac{5}{32}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{16}$	0.749	1.1615	12	$\frac{3}{4}$ to 1
$1\frac{1}{2}$	$\frac{13}{16}$	1	$\frac{7}{8}$	$\frac{7}{16}$	$\frac{13}{32}$	2	$1\frac{1}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$1\frac{1}{32}$	$\frac{7}{16}$	$1\frac{13}{32}$	$\frac{15}{64}$	$\frac{7}{32}$	$1\frac{3}{8}$	$\frac{11}{16}$	$\frac{3}{8}$	$1\frac{5}{16}$	0.999	1.4115	12	1 to $1\frac{1}{2}$
$2\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$\frac{9}{16}$	$\frac{17}{32}$	3	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$1\frac{17}{32}$	$\frac{9}{16}$	$2\frac{3}{8}$	$\frac{19}{64}$	$\frac{7}{32}$	$1\frac{7}{8}$	$1\frac{1}{8}$	$\frac{1}{2}$	$2\frac{1}{4}$	1.4985	2.4115	12	$1\frac{1}{2}$ to 2
3	$\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{3}{4}$	$\frac{11}{16}$	$\frac{21}{32}$	$3\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	$1\frac{29}{32}$	$\frac{11}{16}$	$2\frac{7}{8}$	$\frac{21}{64}$	$\frac{7}{32}$	$2\frac{5}{16}$	$1\frac{7}{16}$	$\frac{5}{8}$	$2\frac{3}{4}$	1.8735	2.9115	12	2 and over

are shell reamers of standard make. Many concerns have been in the habit of making their own shell reamers with inserted blades, designed about as shown in Fig. 163; *A* is a machine steel body, and *B* a tool steel blade, which is made tapered as shown, and driven into place. When the blades are inserted in the body, the reamer is ground. The reamer can be re-ground when dull, and kept to standard size, by forcing up the blades along the taper. The bodies of very large inserted blade reamers are made of cast iron.

Bushings for Boring Jigs

Lining bushings for boring jigs are made of machine steel, casehardened and ground, and the loose bushings also are often made of machine steel. They may, however, be made with equal success from cast iron, which wears well, and has less tendency to stick to the steel bar. The bushings for boring jigs may be made with facilities for removal, similar to those previously described in Chapter II, of Part I. In Fig. 164 is shown a bushing having two pins driven into the head, to facilitate removal, and the pin *A* over which the half-round slot in the edge of the head fits, prevents the bushing from turning. Slots, as shown at *B*, are sometimes provided to permit cutting tools to pass through.

In places where it is impossible to put in bushings before the bar is put in, or over the end of the bar after it is put in, a bushing made in two halves can be used, as illustrated in Fig. 165. The writer has seen this kind of bushing in use in the Pratt & Whitney Co.'s shops, where it probably was originated, and it worked very well. The two halves are held together by a wire passing through the head flanges at one side as indicated. A bushing of this type can be put right over the bar at any place, and pushed into the lining bushing.

Knuckle Joints

When boring bars are provided with a standard taper shank, this may be put directly into the spindle of the machine, but in that case the jig must be lined up very accurately with the spindle, and this sometimes takes more time than is permissible. It is better to use knuckle or universal joints for connecting the live spindle with the boring bar. These are constructed as indicated in Fig. 166, and are made in different sizes, for the different sized bars for which they are used. The shank *A* fits into the machine spindle. The end of the knuckle joint *B* is provided with a hole *D* into which fits the end of the collet *C*, which in turn, takes the shank of the boring bar. The hole *D* may also take the end of the boring bars directly. The method of driving the bar from the knuckle joint may be either by a taper pin as shown in Fig. 166, or by the means shown in the engraving in Table XII, where dimensions are given for a coupling of good construction, connecting boring bar and knuckle joint.

CHAPTER XII

PLANING AND MILLING FIXTURES*

Fixtures for planing and milling are as essential for interchangeable manufacturing as are drilling and boring jigs. Fixtures of this kind serve primarily the purpose of locating and holding the work, but they are often provided with setting pieces or templets which are made either in one part with the fixture or separate; the cutting tools are set to these setting pieces so that the work is always machined in a certain relation to the locating means on the fixture itself.

When more than one milling operation is to be performed on the same piece, it is often possible to use the same fixture for the various operations, but it may be, in some cases, of advantage to make up a fixture for each different operation. The designer must in this case be guided by the number of pieces that are to be machined, and the advantages as regards rapidity of handling and operation that may be gained by having special fixtures for every operation, even though the operations may be such as to permit the same fixture to be used, with or without slight changes.

The strength of fixtures should be governed by the kind of operation to be carried out on the work while in the fixture, whether planing, milling, slotting, etc., and how much stock is to be removed. A milling fixture, as a rule, must be made stronger than a planing fixture, because a milling cutter, as a rule, takes a heavier cut than a planing tool.

The principles which have been previously explained in this treatise for drill jigs govern the locating means of milling fixtures, and clamping devices of the same general type are described and illustrated in Chapter IV, are used, except that they are usually made heavier than when used for drill jigs and planing fixtures. On account of the irregular form of the work and the necessity for clearing the cutting tools, the clamps of milling and planing fixtures must often have irregular shapes.

An important factor, on which too much stress cannot be placed, is the necessity of having sufficient clearance for the cutting tools so that they will not interfere with some part of the fixture and clamping devices, and also that the fixtures, when located on the platen or machine table, will not interfere with any part of the machine, when the table is fed one way or another. As a rule, milling and planing fixtures are provided with a tongue or key in the base, for locating them on the machine table. Suitable lugs should also be provided for clamping the fixture to the platen.

One of the very simplest types of fixture is illustrated in Fig. 167; work being planed is very commonly located and held by the means indicated, and for taking light cuts in the milling machine such an

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* MACHINERY, April, 1909.

appliance may also be used. In this case, the planer platen *A* forms part of the fixture, and the work *B*, located on the platen, is held up against the bar *C*, which is held down by bolts, and located by a tongue as shown. The lugs and lug-screws shown with the spurs *D* hold the work up against the bar, and press it flat against the table. Instead of using the loose spurs *D* between the screws and the work, it is sometimes possible to let the screws bear directly on the work, in which case the screws should pass through the lugs at an angle with the top of the table, as shown in Fig. 173. The arrangement in Fig. 167 may or may not properly be considered a fixture, but it illustrates the

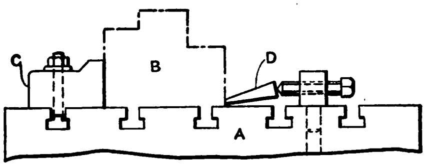

Fig.167

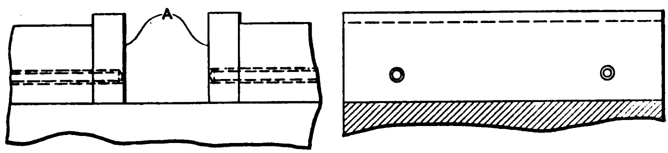

Fig.168

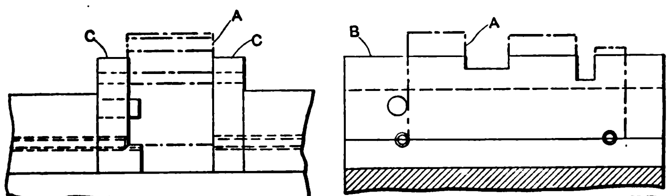

Fig.169

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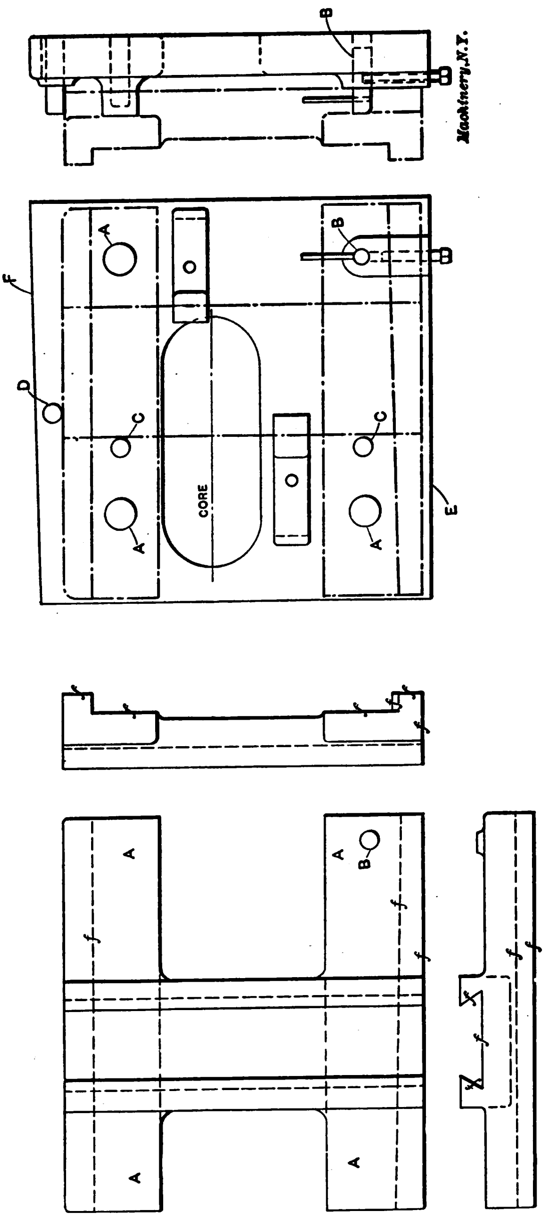
Fig. 167. Principles of Fixtures as shown by Common Method of Clamping Work on the Planer. Fig. 168. The Common Milling Machine Vise, an Example of Adjustable Fixture of Wide Range. Fig. 169. Vise with False Jaws shaped to the Form of the Work by the Cutting Tools themselves

principles of a fixture, as it locates and clamps the work in the simplest manner.

The most commonly used fixture for planing, shaping and milling is the vise. Standard vises are indispensable in planer or milling machine work, and by slight changes they can be used for a large variety of smaller pieces. In Fig. 168 are shown the regular vise jaws *A* of a standard vise. These jaws are often replaced by false jaws, which may be fitted with locating pins and seats, and held to the vise the same as the regular jaws. They are usually left soft, and often the milling cutter is permitted to cut out the jaw to the same shape as required for the work, as shown in Fig. 169. Vises with false vise jaws are especially adapted for milling operations, but vises are not usually employed for long work, special fixtures then being commonly



Figs. 170 and 171. Lathe Carriage and Fixture for Rough Planing Ways

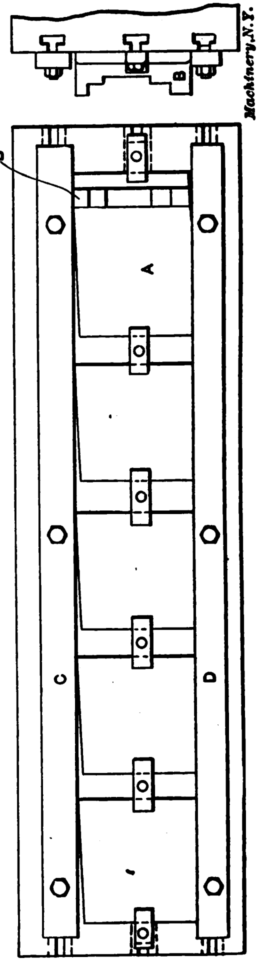


Fig. 172. "String" of Fixtures on the Platen of a Planer

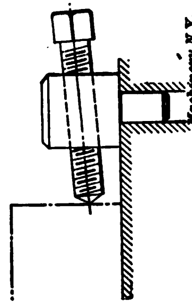


Fig. 173. Clamping Work by Means of Pointed Screw

made. While it is difficult to lay down specific principles for the designing of milling and planing fixtures, it may be said that for most kinds of plain work, finished in the planer, the fixture shown in Fig. 167 is quite satisfactory. When pieces of a more complicated nature are to be machined, particularly in the milling machine, more complicated fixtures will be required.

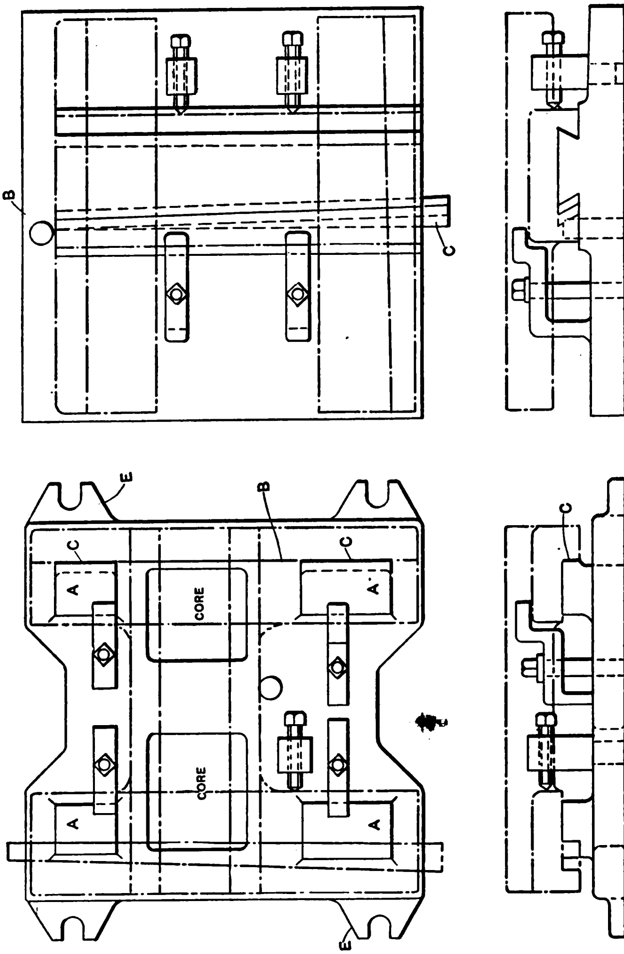
Assume that a set of planing fixtures for the piece shown in Fig. 170 is required. The work is a slide or carriage for a lathe. The finishing marks given on a number of the surfaces indicate where the work is to be finished. The piece comes from the foundry. In the first place, it must be considered from which sides to locate, and how to locate and hold the work without springing it, and in what order the operations should be performed to best advantage. Fig. 171 shows a fixture for roughing out the ways on the bottom. The slide is located on three fixed locating points *A* and the sliding point *B*. This latter is adjustable in order to enable cutting the metal in the slide as nearly as possible to uniform thickness. Sometimes, if the parts *A*, Fig. 170, bevel toward the ends, lugs *B* may be added; these can then be finished and used for locating purposes. The carriage, as shown in Fig. 171, is further located against the pins *C* in order to insure that the cross-slide of the carriage will be square with the bottom ways. The slide is brought up sidewise against the pin *D*, and then clamped down in convenient places, the clamps being placed as near the bearing points as possible to avoid springing. The reason for not having the locating point *D* on the opposite side, is that this side must be finished at the same setting; this side, being the front side of the carriage, is finished for receiving an apron.

The sides *E* and *F* of the fixture may be finished in a certain relation to the locating points and each other, and the side *E* may be made perfectly square with the locating points, so that when it is brought up against a parallel on the machine table, the ways of the machined piece will be square with the ends. The side *F* may be finished on the same taper as required in one way of the work for a taper gib.

The fixture for the next operation is shown in Fig. 174. This fixture is made to receive the carriage and locate it by the now rough-finished ways; in this fixture the cross-slide dove-tail in the work is planed. The slide rests on four finished pads *A*, and the straight side *B* of the ways in the slide is brought up against the finished surfaces *C*. If no other part is available for clamping the fixture on the machine table, lugs *E* are added. If there are no tapering surfaces, the fixture can be located on the machine table by a tongue, as already mentioned, or by placing a finished side against a parallel. The slide or dove-tail is now roughed out and it is usually sufficiently accurate practice to finish it in the same setting, especially as slides must always be scraped and fitted to suit the machine on which they are to be used.

The next operation would be performed in the fixture illustrated in Fig. 175. The carriage is here located by the dove-tail and by the pin *B*, and held by a gib *C*, or by straps and screws, as shown. It will be noticed that with the given design, the straps and screws must be removed each time a new piece is inserted, which is an undesirable feature of the fixture. If parts *A* in Fig. 170 project out too far, so that a light finishing cut would cause springing, they are supported by sliding points or other adjustable locating means.

If the dove-tail in the slide had simply been rough-finished in the fixture Fig. 174, the finishing operation of the bottom ways could



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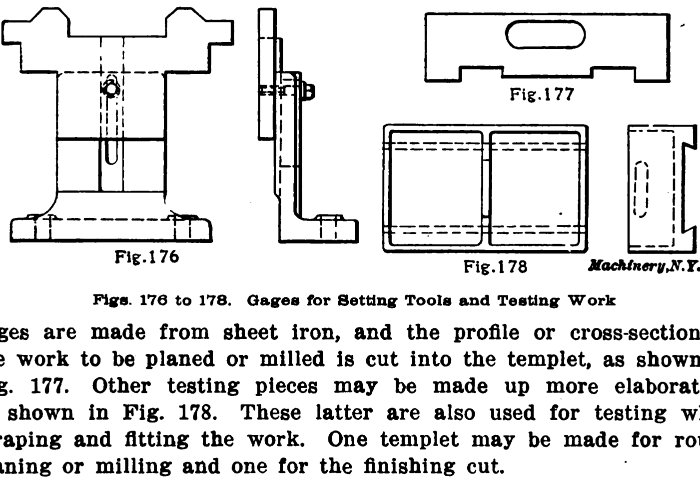
Figs. 174 and 175. Fixtures for Planing the Dove-tail Slide and for Finish Planing the Ways of Carriage in Fig. 170

have been done as just described in the fixture in Fig. 175, and then, after having finished the bottom ways in this fixture, the work could again have been located in the fixture Fig. 174, and the dove-tail finished; this procedure might insure more accurate work in some cases.

In the case just described, the work requires three different fixtures to be completed. The number of fixtures to use in each case is entirely dependent upon the nature of the work. When there is a large amount of work of the same kind to be done, several fixtures of the same type are made up for the same piece, and when in use these fixtures are placed in a "string" on the table of the machine, as shown in Fig. 172. Each strap holds down two of the jigs, one on each side of the bolt through the strap. The first one of the fixtures, *A*, is provided with a templet *B*, to which the tool may be set. The fixtures are located against the bars *C* and *D*, alternately, depending upon whether the straight or tapered side of the slide planed in these fixtures is being finished.

Templets are often made up separately and are used to determine the machining of both larger and smaller work. A templet may even be made adjustable, as shown in Fig. 176. This templet may be fastened to the machine table either in front or behind the work and the tool set to it, and is used when planing machine beds. Other templets or gages are made for testing the planing. They may not properly be considered as parts of the fixtures, but are usually designed and made at the same time as the fixtures are completed. These



Figs. 176 to 178. Gages for Setting Tools and Testing Work

gages are made from sheet iron, and the profile or cross-section of the work to be planed or milled is cut into the templet, as shown in Fig. 177. Other testing pieces may be made up more elaborately, as shown in Fig. 178. These latter are also used for testing when scraping and fitting the work. One templet may be made for rough planing or milling and one for the finishing cut.

A milling fixture of a type commonly used is illustrated in Fig. 179. The work *A* is supposed to be milled on both sides simultaneously. It is located on the fixture base *B*, and is held up against the half V-shaped piece *C*, which is stationary and held to the base by screws; the clamping is done by a clamp *D*, which is guided at *E* as indicated, so that it has a tendency to hold the work down well. Both the clamp and the corresponding piece *C* are thinner than the work, so as to allow the straddle milling cutters to pass over the fixture without interference.

In Fig. 180 is illustrated a simple fixture which may be used for both milling and planing. Two pieces are machined at the same setting in this fixture, and are located against the finished seats *A* and *B*, which latter acts both as a seat and as a stop. Another seat like *B* on the opposite side is not visible in the illustration. As the work to be done is of a rough character, sliding points provided at *C* give an adjustable support. The work is clamped by the pointed screws *D*. The tool is set by the lug *E*, which is cast solid with the fixture and which has its top finished to the required height.

It is often advantageous to perform milling operations after the boring and drilling has been done on the work, and then some finished hole may be used for locating the work. An example of this is shown in Fig. 181 where the work *A* is located by an arbor *B* passing through the finish-bored hole in the work, and resting on two V-blocks planed out in the fixture as shown. Two straps *C* hold the arbor down in the V-blocks. The work is further located against the screws *D*,

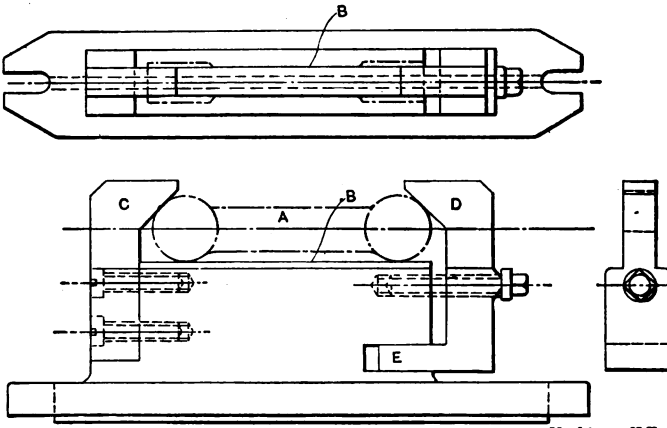


Fig. 179. A Typical Milling Fixture

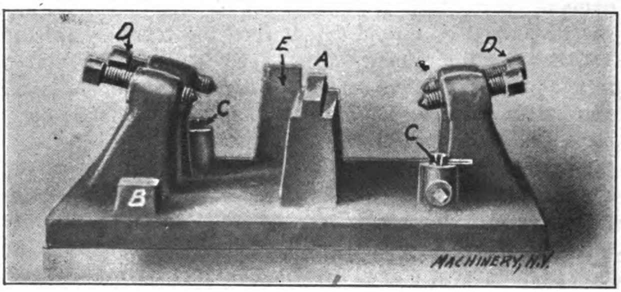


Fig. 180. Simple Type of Milling Fixture

which are adjustable so that the work may be held level. The clamping screw *E* holds the work against the screws *D*.

It is sometimes advantageous to make fixtures for holding work in the lathe. Suppose that a piece to be finished has the appearance shown in Fig. 182. The dove-tail *A* is finished, and the circular seat *B* is to be turned afterward so that the center of the seat will come in a certain relation to the dove-tail and a certain distance from the end. This operation can be carried out as shown in Fig. 183, by placing parallels *A* on the face-plate *B* of the lathe. These parallels will serve as locating means, and straps *C* hold down the work. If it is required that the seat be in exact relation to the dove-tail, two rollers *D* may be used against which the slide is located; the angle of the dove-tail and the diameter of the rollers are calculated so that the work can be very carefully located.

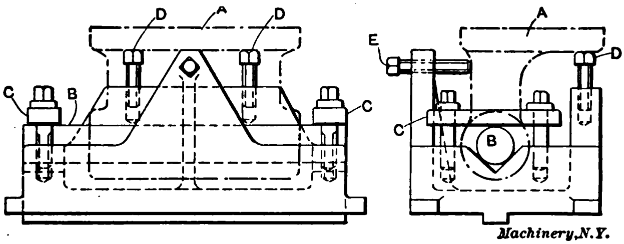
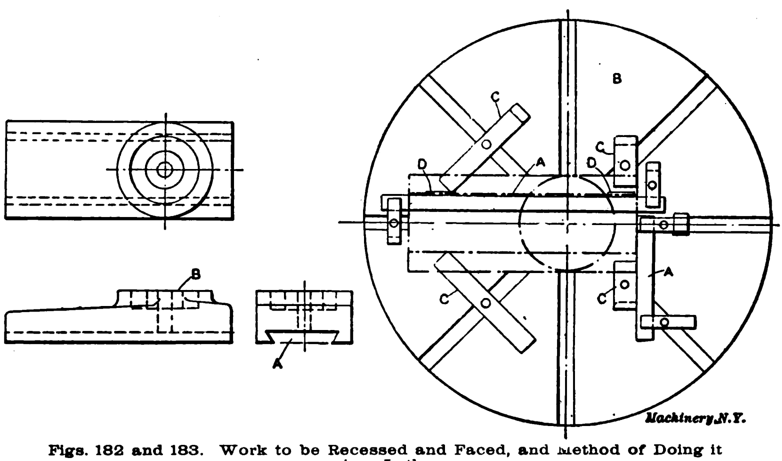


Fig. 181. Milling Fixture in which Work is Located from a Previously Bored Hole

The work may be turned out properly by this means by a careful man, but there are always chances of moving the parallels and it is a slow operation. If a simple fixture like the one illustrated in Fig. 184 is used, an apprentice can do the work correctly, provided he knows how to run a lathe. The work *A* is located by a dove-tail in a manner similar to that in which it will later be located on the machine on which it is to be used. It is held against the dove-tail in the fixture



Figs. 182 and 183. Work to be Recessed and Faced, and Method of Doing it in a Lathe

by screws *B* and clamped down on its seat by straps *C*. The pin *D* locates the work in the other direction, and the fixture itself is located on the face-plate by the boss *E*; as this boss has a perfect fit in a recess turned out in the face-plate, it must, by necessity, run true. Slots may be provided for locating the fixture on the face-plate and driving keys inserted at *F*. A sufficiently large lug *G* may be provided for counter-balancing.

It is always of advantage to try to locate work in fixtures in the same manner as it is located on the machine in which it is to be used

Indexing Fixtures

A number of fixtures for performing various operations are fitted with indexing devices, so that accurate machining at predetermined places in the work may be carried out in the shortest possible time. A simple indexing fixture is shown in Fig. 185. The work is mounted on a disk *A*, which turns in the bearing hole *B* bored out in the knee or angle iron *C*, which is located and fastened on the machine table. The disk *A* is indexed, and held in the right position by a pin *D*, which fits into a finished hole in the angle iron and also into one of the holes in the disk. The disk *A* is clamped against the knee *C* by a screw and washer *E* while taking the cut. When the main parts of this fixture are made of cast iron it is sometimes the practice to put lining

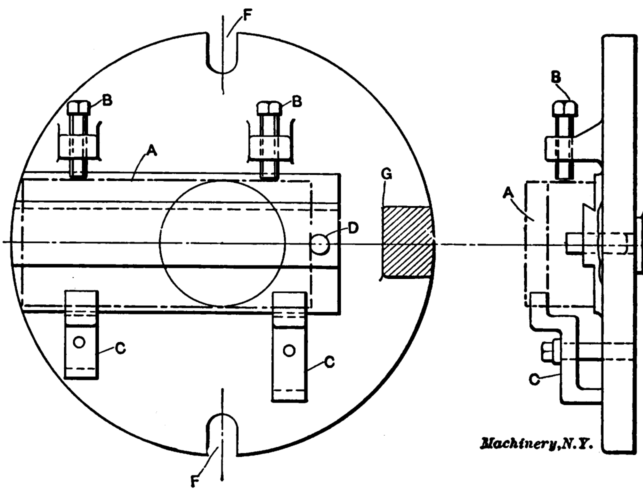


Fig. 184. Fixture for Recessing Work shown in Fig. 182

bushings of tool steel in the indexing holes to prevent them from being worn out too rapidly by the continual removal and insertion of plug *D*. This is a very simple indexing fixture, but a great deal of work can be finished without more elaborate arrangements. By adding a plate *F*, screwed to the top of the knee, and fitted with a drill bushing as indicated, radial drilling operations may be performed in the same device.

In Fig. 186 is shown a similar indexing fixture somewhat modified. The work is located and held on the rotating disk *A*, which is fitted in place in the bracket or body *C*, so as to have no play. The round plunger *B* is beveled on the end, and fits the slots in the circumference of the disk. A spiral spring pushes the plunger into place. The plunger is guided by a pin in an oblong slot, so as not to turn around. Sometimes the plunger may be made square or with a rectangular section, and fit a slot which may be shaped to this form. This latter method is more expensive and does not give better satisfaction than the plunger with the round body.

A large variation of methods for indexing are in use, employing pawls, levers, springs and safety-locking devices, which sometimes may be necessary. Indexing fixtures, however, designed according to the

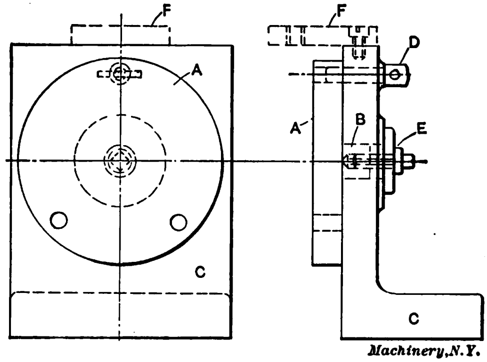


Fig. 185. Simple Type of Indexing Fixture

simple principles laid down above, will give as good service as many complicated arrangements. These indexing devices are used in cases where the standard indexing heads would not be suitable, and for many classes of work are equally efficient.

Conclusion

In a large shop with a great number of jigs and fixtures, it is quite difficult to keep them in proper order, and to have them so indexed

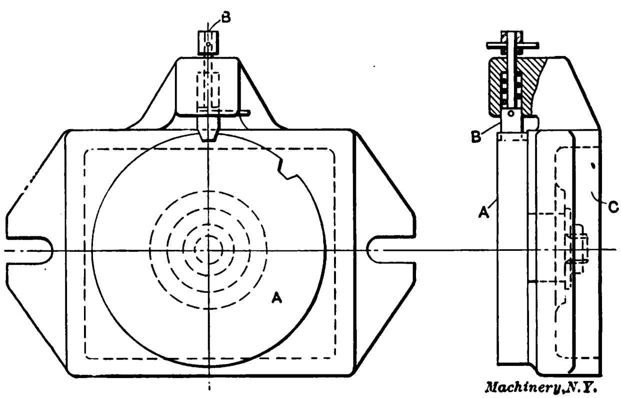


Fig. 186. Another Type of Indexing Fixture

and classified as to be able to find the required fixture at a moment's notice. It is unquestionably the best way to permit each department to have a storing place for all its own jigs and fixtures, more especially so if there is a store-room for other tools in each department. The jigs or fixtures are given out to the operators in exchange for checks, and before they are returned they should be carefully cleaned and the finished surfaces greased to prevent rusting. Before returning the check to the workman, the tool-room clerk should look over the fixture to see that no loose parts are missing, and no parts broken, and also that all loose pieces are tied together and attached to the jig body. The tools are placed on shelves partitioned off and numbered and an index is kept, showing at a glance the location of the tools for different operations. A copy of the index should be in the possession of the foreman, and also of the tool-room clerk, and should give the piece number of the work to be done in the jig, the number of the jig itself, and its place in the racks.

When arranging and storing the jigs, the lighter jigs are placed on the top shelves and the heavier further down. This not only permits a lighter construction of the storing shelves, but also makes it more convenient for the attendant to put the jigs and fixtures in place. If possible, jigs used for the same machine, or the same type of machines, should be in the same section of the rack, as this, to a certain extent, facilitates getting out jigs for the same work. When a jig or fixture needs repairing, it should be sent at once to the tool-making department, even if it is not to be used immediately.

In some trade journals there has been a great deal of paper wasted discussing what position a tool and jig designer really occupies,—whether he should be considered a designer with a designer's salary, or simply a draftsman, and of other topics of similar nature. The fact remains, however, that a progressive manufacturing plant, in order to have suitable and efficient tools devised, requires a man who possesses in the first place, good shop experience, in the second place, sound practical judgment, and in the third place, a fundamental knowledge of theoretical mechanical principles.

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No. 40. Fly-Wheels.—Their Purpose, Calculation and Design.

No. 41. Jigs and Fixtures, Part I.—Principles of Jig and Fixture Design; Drill and Boring Jig Bushings; Locating Points; Clamping Devices.

No. 42. Jigs and Fixtures, Part II.—Open and Closed Drill Jigs.

No. 43. Jigs and Fixtures, Part III.—Boring and Milling Fixtures.

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