

WAR DEPARTMENT

TECHNICAL MANUAL



LATHES

AIR CORPS

LATHES

Prepared under direction of the
 Chief of the Air Corps

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SECTION I

NOMENCLATURE AND MAINTENANCE

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1. **General.**—*a.* The lathe is principally used for removing material from the internal or external portion of straight or tapered cylindrical articles. Facing or radial turning is also performed with the lathe, and by use of the proper attachments and accessories, threads of various pitches may be cut, radii turned, and cylinders, etc., of irregular outline machined. The removal of material is accomplished by the use of cutting knives, known as tool bits, which are ground to the proper shapes for various operations.

b. Lathes for general shop work may be divided into two classes: engine lathes and toolroom lathes. The toolroom lathe is ordinarily more accurately constructed and is provided with more attachments than the engine lathe. Therefore, work of a better class and of a more complete nature may be accomplished on the toolroom lathe.

c. Lathes are made in various sizes, the size being determined by the diameter of work that can be swung in it and by the over-all length of the bed. The swing is measured in inches and the bed is measured in feet.

2. Nomenclature.—The lathe is composed of five essential features: bed, headstock, tailstock, carriage, and feeding and threading mechanisms. (See fig. 1.)

a. The bed is the main body of the lathe upon which are machined the ribbed portions known as ways. These ways afford alinement and bearing surface for the headstock, carriage, and tailstock.

b. The headstock is made up of the headstock casting, main spindle and bearings, necessary mechanism for obtaining various spindle speeds, and a series of gears used to transmit motion from the spindle to the feeding or thread-cutting mechanism.

c. The tailstock is mounted on the ways and is designed to be clamped at any point on the bed. It is provided with a sliding spindle operated by a handwheel. The tail spindle is also fitted with a center called the “dead” center. The tailstock may be adjusted laterally (toward or away from the operator) by means of adjusting screws.

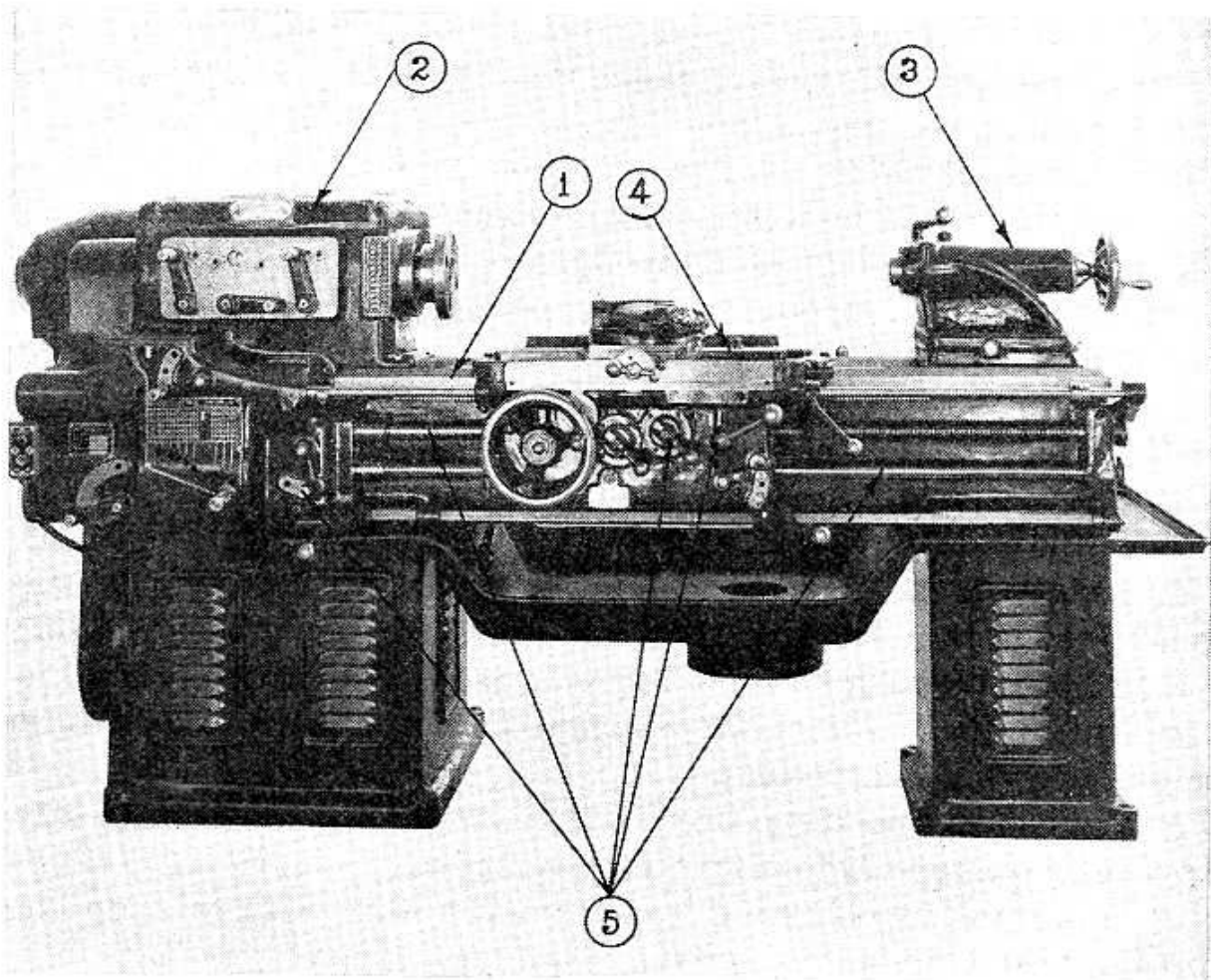
d. The carriage consists of the saddle, which can be made to slide along the ways by hand or power feed, and the apron fastened to the saddle at the front of the bed. The function of the carriage is to carry the cutting tool. To the saddle is fitted the cross slide which may be caused to move by hand or power feed at 90° to the axis of the lathe. On the cross slide is mounted the compound rest which can be swiveled and clamped at any angle. On its upper side is a T-slot which carries the tool post. The carriage is moved along the ways by means of a spool gear traveling in a rack at the front of the bed. The apron contains the gears and clutches used to transmit motion from the feed rod or lead screw to the carriage.

e. The feeding and threading mechanisms are power fed from the spindle by means of a gear train. All modern lathes are provided with a quick change gear box so that various feeds may be obtained easily and quickly. Power is transmitted through the feed rod to the carriage in normal cutting and from the lead screw to the carriage in threading.

3. Care and maintenance.—*a.* In order that a lathe may operate efficiently it must be properly mounted and adjusted. Primarily, the lathe must be set and maintained in a level position. It should be mounted on a solid concrete foundation, if possible; however, it may

be mounted on a substantial wood floor, in which case it may be necessary to brace the floor securely from below to prevent sagging.

b. If the lathe is not level it will not rest evenly on all four legs, and the weight of the lathe will cause the lathe bed to be twisted, throwing the headstock out of alinement with the V-ways of the bed, causing it to turn and bore taper. There are several approved methods of leveling and securing a lathe. Leveling screws, shims, or



1. Bed.
2. Headstock.
3. Tailstock.
4. Carriage.
5. Feeding and threading mechanism.

FIGURE 1.—Toolroom lathe.

hardwood wedges may be used under the feet, adjusting them so that the bed is level in both longitudinal and lateral positions. A precision level that is at least 12 inches long and sufficiently sensitive to show a distinct movement of the bubble when a 0.003-inch shim is placed under one end may be used in leveling the lathe. A check must be made across the lathe bed at both the headstock and tailstock end. A lathe should be anchored to the floor by means of lag

screws and the leveling rechecked after the screws have been drawn down.

c. The proper adjustment of the various clutches, bearings, and mating members of the lathe are most important in the production of accurate work. Some of the common adjustments are listed here in the order of the frequency that they will probably occur:

- (1) Gibs on cross feed, compound, and carriage.
- (2) Longitude and cross feed clutches.
- (3) Thrust bearing on lathe spindle.
- (4) Headstock motor drive clutch.
- (5) Spindle bearings.
- (6) Thrust collar on lathe lead screw.

d. Keeping the lathe well oiled will greatly influence its operating efficiency as well as its life. Only a good grade of machine oil, equal in quality to SAE No. 10, should be used and all bearings and bearing surfaces oiled regularly. The bearings should always be oiled progressively so that none will be omitted. When oiling the sliding surfaces, such as the ways, cross slide, etc., it is best to rub the oil in with the hands so as to make sure that the oil is well distributed. It is not necessary to use an excess of oil, a few drops being sufficient.

4. Safety measures.—The following safety measures will help to keep the lathe in working order and prevent injury to the operator:

- a.* Do not operate a machine before it has been thoroughly oiled.
- b.* Unless familiar with the machine, do not attempt to operate it before receiving instructions.
- c.* Try out all operating levers and cranks and place them in safe or neutral positions before starting the motor.
- d.* If a crank or operating lever does not work with ease, do not force it. Find out what is wrong.
- e.* Do not oil the machine while it is running.
- f.* Do not leave safety guards off gears, belting, etc.
- g.* Do not hammer on the lathe.
- h.* Do not lay hard or heavy objects, such as files, chucks, etc., on the ways.
- i.* Do not let dirt, shavings, oil, or refuse accumulate about the lathe.
- j.* Do not work without proper light.
- k.* Do not "slam" the clutch lever in and out of engagement; ease it in and out.
- l.* When screwing chucks on and off the spindle, support them in such a manner that they will not drop onto the ways and cause damage to the machine.

- m.* Do not use power to apply any chuck or driving plate.
- n.* Do not leave a machine when it is running. Maintain a position enabling instant control of the operating levers.
- o.* Do not leave a machine in a dirty condition. Upon completion of a job or at the end of a day, clean the machine and see that the tools are in good shape and in their proper places. Keep the machine in working order and, if anything is wrong, report it to the proper person.
- p.* Do not form the habit of carrying on idle conversation with a fellow workman. If conversation is necessary, shut off the machine.
- q.* Keep the hands away from revolving work.
- r.* Do not work in loose clothing and keep sleeves rolled up to the elbows.
- s.* Do not allow boxes, pieces of stock, or other objects that might be tripped over to lie on the floor around the lathe.
- t.* Do not handle chips or shavings with the bare hands; they may be hot or have razor-sharp edges.
- u.* Do not attempt to lift heavy articles alone. Get a helper or use a crane.
- v.* Do not leave the chuck wrench in the chuck.
- w.* Do not fail to report an injury and have it treated immediately.
- x.* Keep dirty and oily rags or waste in metal containers until disposed of. If they are left in a pile exposed to the atmosphere, a fire may be started due to spontaneous combustion.

SECTION II

CUTTING TOOLS, SPEEDS, AND LUBRICANTS

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5. General.—In order to machine materials efficiently it is necessary to have the correct type of tool, with a keen cutting edge, well supported, and set at the proper height.

6. Cutting tools.—*a.* Primarily, cutting tools may be considered as wedges which are forced into the material to cause compression with a resultant rupture or plastic flow of the material. This rupture or plastic flow is usually called cutting. If the wedge is of thin section, it will cut more easily, but will not have the strength to resist the load applied when machining steel or other hard and

tenacious metals. This wedge will show the best results when its angle is approximately 61° for the machining of soft steels. For the harder materials this angle is increased to give the cutting edge support.

b. In order for the tool bit to cut effectively, the side and end are ground so as to leave a projecting edge. This is known as side and end relief. If the amount of relief is not sufficient, the tool bit has a tendency to rub against the work, causing excessive heat and leaving a surface of rough appearance. If the amount of relief is too great, the cutting edge will be weak and will break due to insufficient support.

c. The top of the tool bit should slope away from the cutting edge so that the tool bit may be forced into the metal with less resistance, and the chip of metal being removed will not be so greatly distorted, thus reducing the power required. This sloping of the top of the tool bit is known as rake. Figure 2 illustrates the various angles ground on a tool bit and gives the proper nomenclature involved.

d. A table of tool bit angles for various materials is given below:

Material	Side relief	Front relief	Back rake	Side rake
	<i>Degrees</i>	<i>Degrees</i>	<i>Degrees</i>	<i>Degrees</i>
Low carbon steel.....	12	8	$16\frac{1}{2}$	18
Medium carbon steel.....	10	8	12	14
High carbon steel.....	10	8	8	12
Cast iron.....	10	8	5	12
Stainless steel.....	12	10	$16\frac{1}{2}$	10
Copper.....	14	12	$16\frac{1}{2}$	20
Bronze.....	10	8	0	0
Brass.....	10	8	0	0
Aluminum.....	12	8	35	15
Monel.....	15	13	8	14
Silicon bronze.....	10	10	10	6

e. For the simple removal of metal it is best to have a large radius at the cutting edge of the tool bit. This shape distributes the cutting pressures and also gives more surface through which to radiate heat. It will wear better and last longer than a tool that is pointed or has sharp corners, although it is sometimes necessary to use a tool that is pointed for machining operations, such as squaring a shoulder, cutting a thread, etc. When using this type of tool care must be exercised due to its inherent weakness.

f. Beyond proper rake and relief there are no definite rules to govern the shape of cutting tools. They may be square, pointed, of small or large radii, or of irregular shape, and for certain classes of work the cutting edge may be shaped to fit gages of various kinds (fig. 3).

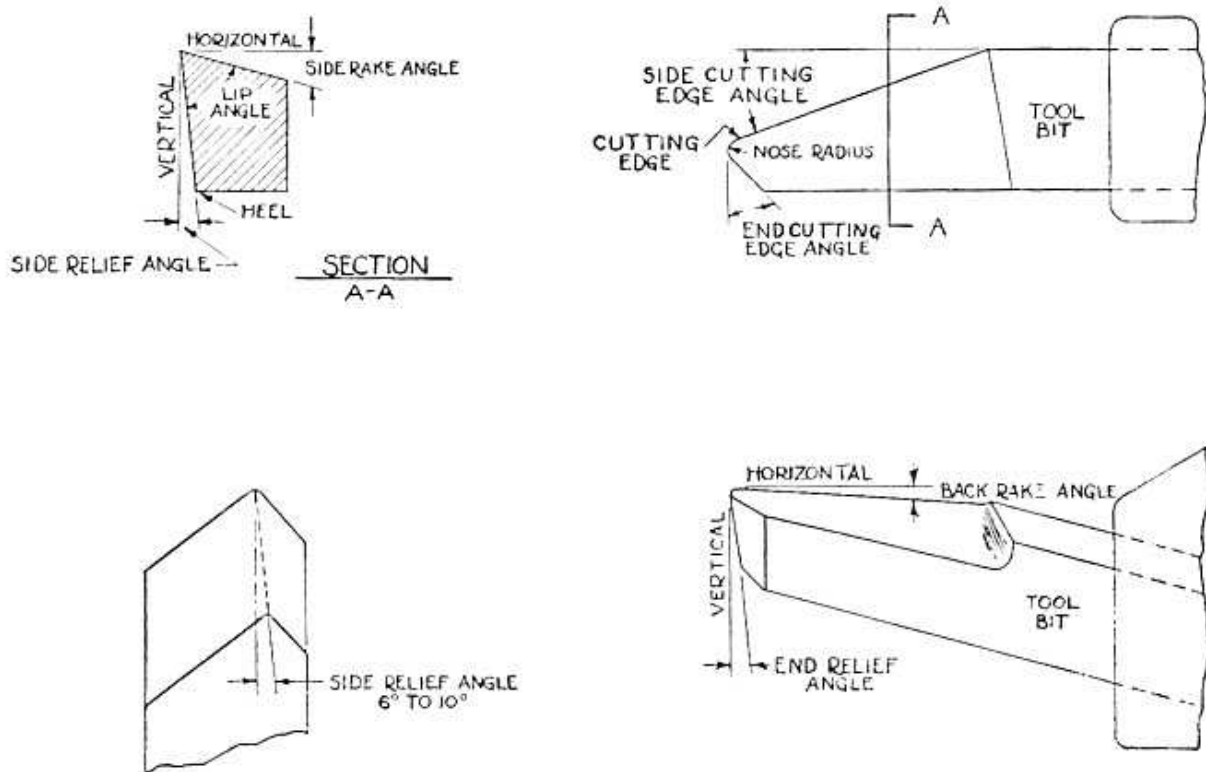


FIGURE 2.—Tool bit nomenclature.

Tools which are shaped to fit gages are generally known as “forming tools” and can be used to advantage when making knobs, balls, machine handles, radius grooves, etc.

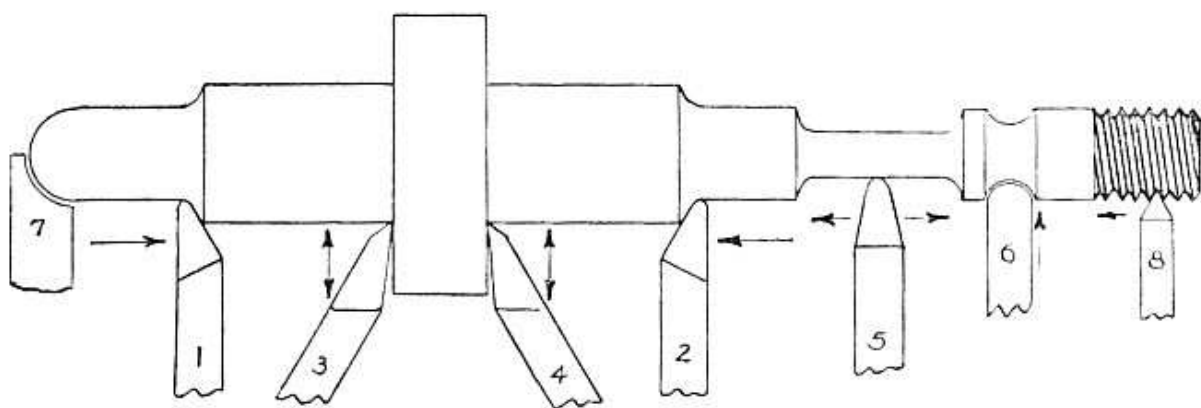


FIGURE 3.—General tool bit forms.

g. The ordinary means of shaping cutting tools is by the use of grinding wheels. The wet grinder is preferred and should be used with a heavy flood of water so there is no danger of drawing the temper from the tool as it is ground. If a dry wheel is used, the tool bit should

be cooled frequently by dipping it in water. It is also necessary to see that the wheel is dressed properly, the grinding pressure is not too heavy, and the tool bit is not held against the wheel too long without being cooled. The relief and rake surfaces of the finished tool should be clean and smooth and should not have a number of facets. Considerable practice is necessary before this can be accomplished by the average person. The cutting edge should be sharp and keen and can be greatly improved by hand stoning the tool after grinding, with a hard, medium grain stone. This is not a remedy for a tool that has become dulled in use (in which case it should be reground), but is for the purpose of improving its condition after it has been ground on the grinding wheel.

h. The majority of tool bits used at this time are of high speed steel and are considerably more efficient than the carbon steel tools. They are capable of retaining their hardness at higher temperatures and therefore can be used at higher speeds. In view of the numerous steels used in the manufacture of cutting and turning tools, it is difficult to give a definite rule for their selection. Steels for this purpose may be generally classed as carbon steel and high speed steel and are marketed under various trade names, such as Rex A, Rex AA, Rex AAA, Super Dreadnaught, Dreadnaught, etc., in the high speed steel class, and Ketos, Black Diamond, Crescent, Sanderson, etc., in the carbon steel class. Generally, high speed steels are an alloy of tungsten with various proportions of chromium and vanadium. When selecting steel for the manufacture of tools, the cutting speed must be considered. For low speed turning and for hand tools, such as taps, reamers, chisels, and punches, carbon steel gives satisfactory results and is more economical. For high speeds the high speed steels should be used.

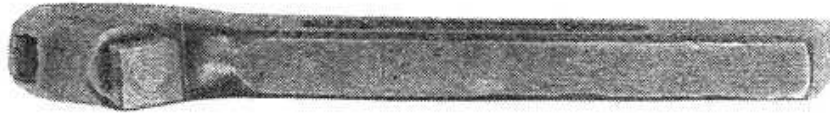
7. Tool holders.—There has been a gradual decline in the use of hand forged tools for lathe work. These have been replaced by tool bit holders of various types. Many varieties of holders are on the market and care should be used in their selection, so that proper tool efficiency may be obtained. Tool bits are available in different sizes to fit the various holders and are furnished hardened and cut to standard lengths. Tool holders for the average line of lathe work are described as follows:

a. The straight, right, or left hand turning tool holders (fig. 4) are used for the majority of external turning and machine operations.

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① Left hand.

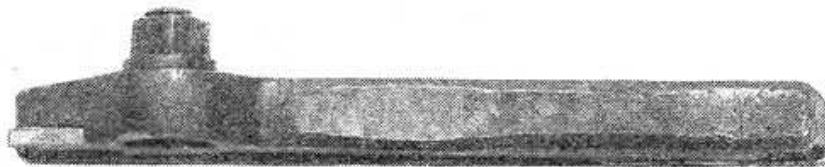


② Straight.

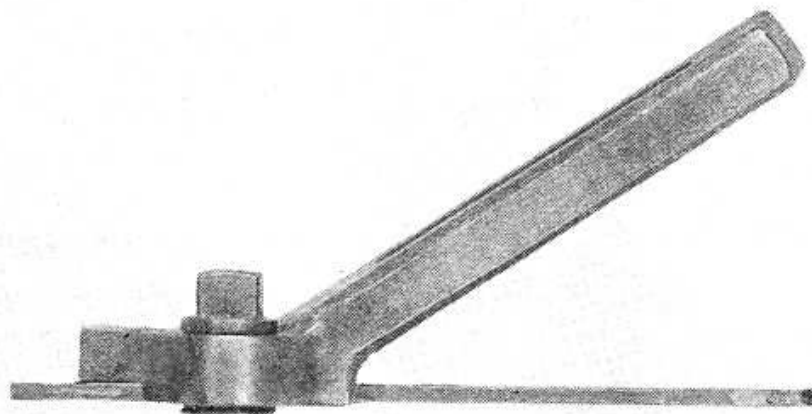


③ Right hand.

FIGURE 4.—Turning tool holders.



① Straight.



② Offset.

FIGURE 5.—Cutting-off tool holder.

b. The cutting-off tool holder (fig. 5) is made either offset or straight. It is shaped to hold flat, thin-sectioned tool bits and is used to separate pieces in the lathe.

c. The boring tool holders (fig. 6) are standardized commercial types. Boring tool holders can be locally manufactured by slotting the ends of rods and brazing high speed tool bits in these slots. Another

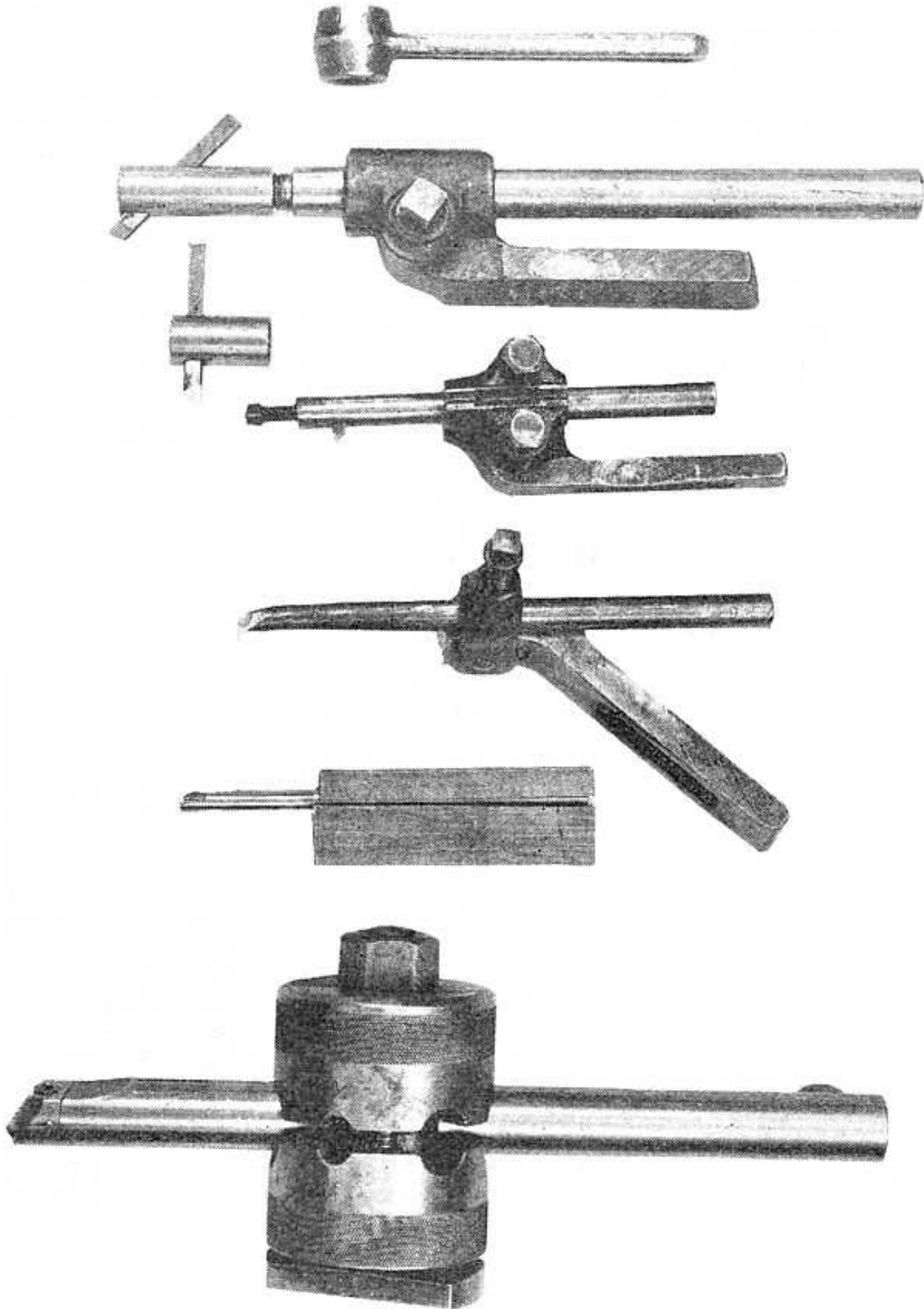


FIGURE 6. Boring tool holders.

way of making boring tool holders is to broach a hole in a bar or rod of proper size to hold the tool bit. A set screw or other suitable device is used for holding the tool bit firmly in place.

d. Form threading tools (fig. 7) have the thread form and proper relief ground on them by the manufacturer and therefore remain true to form and of correct angle, if the sharpening is done on the

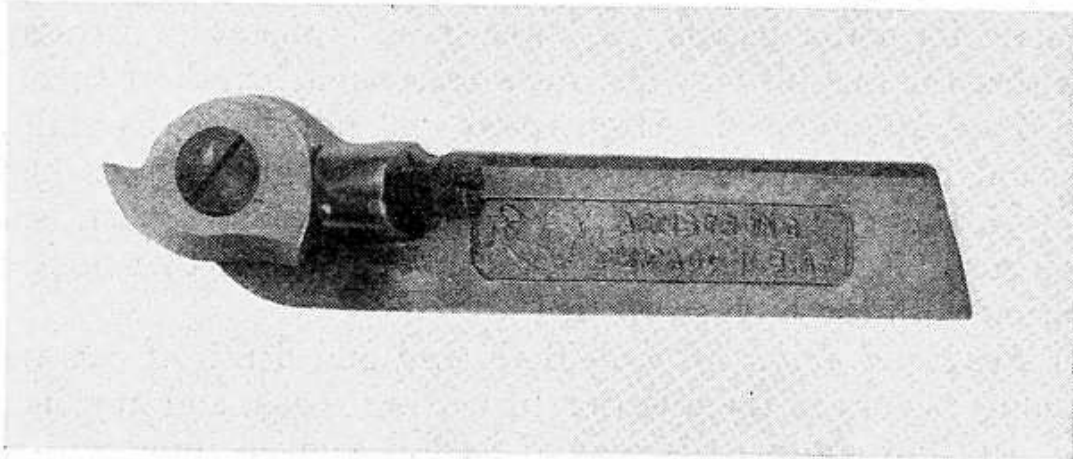


FIGURE 7.—Form threading tool.

top edge only. This type of form threading tool insures better fitting threads and saves much grinding time.

e. The knurling tool holder (fig. 8) has a revolving head containing three pairs of knurls. It is used for rolling depressions into the surface of work both for decorative purposes and to furnish a better grip on the handles of various tools. Figure 48 shows the three

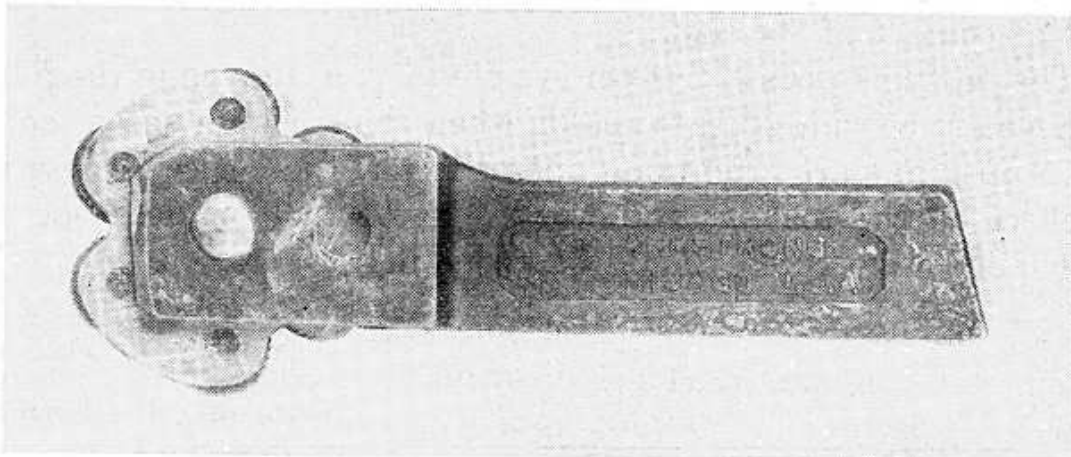


FIGURE 8.—Knurling tool holder.

grades of knurl rolls and illustrates the pattern that each set makes.

8. Cutting speeds and feeds.—*a.* In order to machine metals successfully, careful attention must be given to the speed at which the work revolves and the distance the tool advances during each revolution. These are known as “cutting speeds and feeds.” Cutting speed, which is usually given in feet per minute, is equal to

the number of feet, at the outside surface of the material, that pass the tool bit point in 1 minute.

b. There are five factors that should be considered in regulating the cutting speed:

(1) *Hardness of metal being cut.*—Hard metals require a lower cutting speed than softer metals, because they are cut with a tool having a blunt angle which will heat more rapidly than the sharper edge used for softer metals. A lower speed is therefore necessary in order that the tool bit may last for a reasonable length of time.

(2) *Tool bit material.*—High speed tool bits have the ability to withstand high temperatures, and therefore higher speeds may be used with this type of tool bit. The usual procedure, when using a carbon steel bit, is to reduce the speed to one-half of that used when operating with the high speed tool.

(3) *Feed and depth of cut.*—Both feed and depth of cut are determining factors in the selection of cutting speed, and any increase in the depth of cut or coarseness of feed at a given speed will result in a proportional increase in heat generated. Heat is one of the main considerations in tool bit life.

(4) *Diameter and length of work.*—When the diameter of the work is small and its length is great enough to set up vibrations due to speed (thereby causing poor finish), it is necessary to reduce the cutting speed.

(5) *Lubricant.*—The cutting speed can be increased about 40 percent if a large stream of lubricant is directed upon the chip at the point of contact of the tool.

c. The cutting speeds in feet per minute (f. p. m.) given in the following table are considered safe speeds when using a high speed tool bit. It is proper to start machining operations at these speeds, observing the effect on the tool bit and work. If the tool bit does not wear satisfactorily the speed should be reduced.

Kind of metal	Feet per minute (turning)	Feet per minute (threading)
Low carbon steel.....	80 to 100.....	35
Medium carbon steel.....	60 to 80.....	25
High carbon tool steel.....	50 to 75.....	20
Bronze.....	80 to 100.....	25
Cast iron.....	50 to 80.....	25
Soft yellow brass.....	150 to 200.....	50
Aluminum.....	200 to 300.....	50
Monel metal.....	100 to 120.....	35
Stainless steel.....	40 to 50.....	15

To use the above speeds on the lathe, they must be transposed to revolutions per minute of the lathe spindle by the following formula:

$$\frac{\text{f. p. m.}}{0.2618 \times \text{work diameter}} = \text{r. p. m.}$$

d. Feed, or the distance the tool advances during each revolution, controls to a certain extent the speed at which the metal is removed and finish produced. For the roughing cut (fast removal of stock), it is ordinarily advisable to use a comparatively shallow cut and a coarse feed.

(1) For example, in the case of a 14-inch by 6-foot lathe, using a tool bit of the proper size and shape, a depth of cut of $\frac{1}{4}$ inch and a feed of 0.030 inch can be utilized for the fast removal of stock on short work of large diameter. A depth of 0.010 inch and feed of 0.005 inch or less might be considered a finishing cut for best results, assuming that the set-up and machining conditions are of the best.

(2) The correct depth of cut in relation to the feed depends upon the kind, size, and type of machine tool and tool bit, as well as the nature of the work being machined. A depth of cut of 1 inch and feed of 0.125 inch for some classes of work on the large turning lathes would not be excessive, while a cut of 0.125 inch and a feed of 0.004 inch might be considered heavy cutting for work of a fragile nature on some of the smaller bench lathes.

9. Cutting lubricants.—*a.* The major function of a cutting oil or compound, as applied to lathe work, is to help carry off the heat developed in separating the chip from the work and thereby prevent a dangerous rise in temperature through the accumulation of such heat. Minor functions of the cutting compound are to lubricate the chip as it slides over the tool, improve the finish of the work, guard against rusting, and wash away the chips from the cutting area.

b. In production operations the practice is to flood the work with the cutting lubricant in order to obtain the full benefit of its action. In the average shop where cutting compounds are used only for finishing and the more delicate operations, it is general practice merely to apply lubricant when actually required.

NOTE.—Lubricating oils should never be used as cutting oils nor should cutting oils be used as bearing lubricants.

c. The most common cutting lubricants with types of metals for which they may be used are given below:

(1) Pure lard oil is one of the most efficient cutting oils available, but due to its cost the undiluted oil is not generally recommended. A water emulsion, which is a good economical cutting compound for machine work, can be made by mixing one part of lard oil with four

parts water, and adding sufficient sal soda to cause the mixture to emulsify. The amount of sal soda generally required is 1 ounce to each gallon of mixture. This compound is recommended when machining steels of the low and medium carbon groups.

(2) Pure turpentine or turpentine mixtures are used when machining hard and refractory steel or chilled iron.

(3) Kerosene is used when machining aluminum and aluminum alloys.

(4) Cast iron is generally machined dry. However, to obtain better finish when threading or reaming, it is advisable to use water to which sufficient sal soda has been added to prevent rusting.

(5) Brass is generally machined dry, although in some operations it may be necessary to use a cutting oil to obtain satisfactory results. A water and lard oil emulsion is recommended in this case.

(6) Mineral oil, lard oil, or paraffin oil is used when a lubricant is necessary in machining copper.

(7) Stainless steel and monel metal require a compound made up of white lead and lard oil.

SECTION III

APPLICATION OF MEASURING INSTRUMENTS

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10. General.—*a.* In order that correct sizes may be maintained, parts duplicated, and various pieces accurately mated, an assortment of measuring and calibrating instruments is required for machine work. Some of these are direct reading, while others are used to transfer the size of one part to another. The graduations and calibration of all good direct-reading measuring instruments must be accurate and reliable. If they vary, the parts made in one shop would not be interchangeable with like parts made and measured in another shop. The majority of the tool manufacturers have their “master” measuring tools conform, as near as possible, to specific dimensions maintained by the Bureau of Standards. This is done by sending the tools, gages, etc., to the Bureau of Standards at regular intervals to have them certified as to accuracy.

b. The most simple direct-reading measuring tool used by the machinist is the steel rule.

(1) The standard graduations on this rule are subdivisions of $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, and $\frac{1}{64}$ inch. Rules with metric graduations are also used, and their divisions and subdivisions are in decimal parts of the meter.

(2) Steel rules may be obtained in numerous lengths, widths, thicknesses, and types of graduations. These graduations are either stamped or etched on the cheap rules and are not considered accurate. The graduations on the better class of rules are cut and may be considered accurate. A person with normal eyesight should be able to measure within 0.005 inch, plus or minus, with a good rule in a well-lighted shop.

(3) Rules are used at the lathe for measuring lengths and diameters; also for setting calipers, dividers, etc.

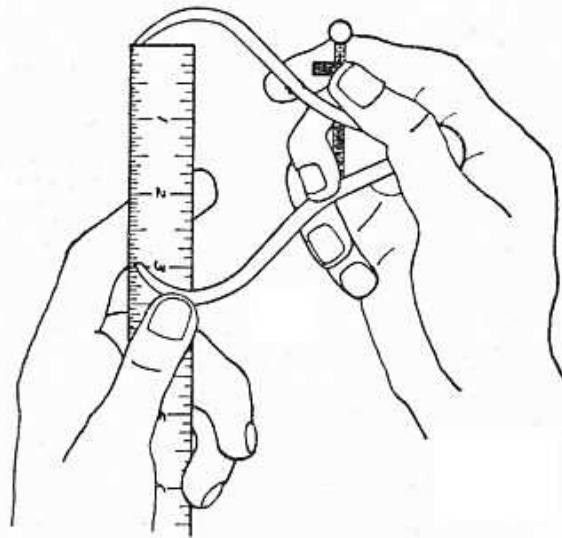


FIGURE 9.—Setting outside caliper.

11. Calipers.—*a.* Both inside and outside calipers are used at the lathe for the measurement of internal and external diameters. Since they are not a direct measuring tool, their use is limited to the transfer of one size to another. The size of calipers is designated by the length of the leg from point to hinge in inches. Several designs are in general use, such as the screw adjusting, firm joint, transfer joint, and quick adjusting screw types. The calipers should be light, rigid, have good balance, and true, smooth measuring points if good results are to be expected. Calipers are generally set to a rule or some other standard gage, and the dimension thus obtained is transferred to the work.

b. When setting the outside calipers, one leg is hooked over the end of the scale and the other is set to the desired dimension (fig. 9). When measuring a cylinder with the outside caliper, the caliper must

be held at right angles to the axis of the cylinder and moved gently back and forth across its diameter to arrive at an accurate measurement (fig 10).

c. When setting the inside calipers to the rule the end of the rule should be set squarely against a flat, metal surface. One leg of the calipers is placed on this surface and against the rule and the

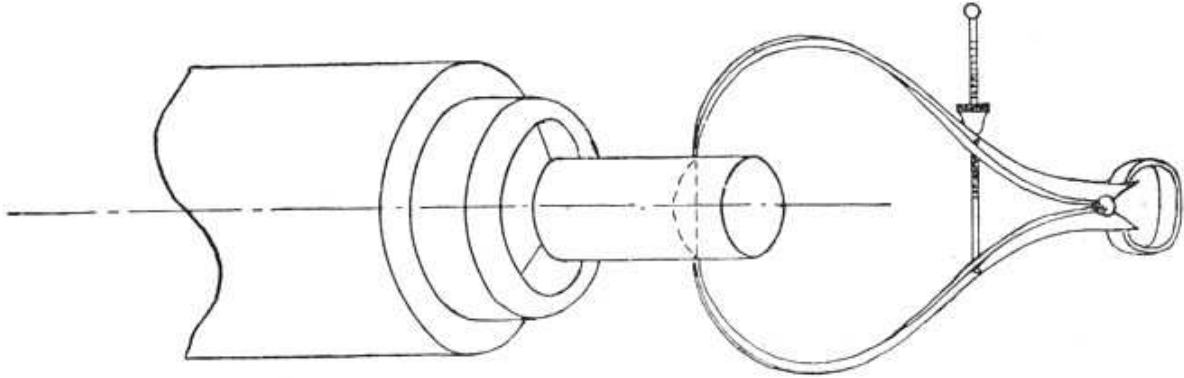


FIGURE 10.—Using outside caliper.

other leg extended to the reading desired (fig. 11). To measure inside diameters, the caliper is held square across the diameter of the hole and the caliper points moved, as shown in figure 12, while the adjustment is made.

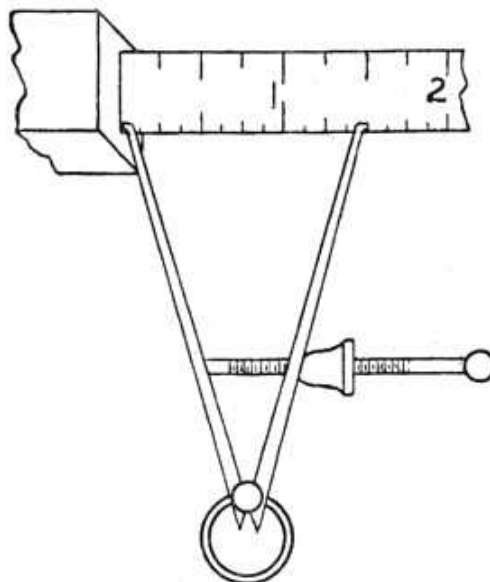


FIGURE 11.—Setting inside caliper.

d. Screw thread calipers have legs that are bent and dressed to a wedge shape to fit into the thread. Measurements made with screw thread calipers are usually transfer measurements from a finished screw thread to a like thread being cut.

e. The hermaphrodite caliper, which has one leg hooked like the ordinary caliper and the other pointed like a divider leg, is used for

the scribing of lines on work. To set to the proper dimension, the curved caliper leg is hooked over the end of the rule and the pointed leg adjusted to the desired dimension (fig. 13).

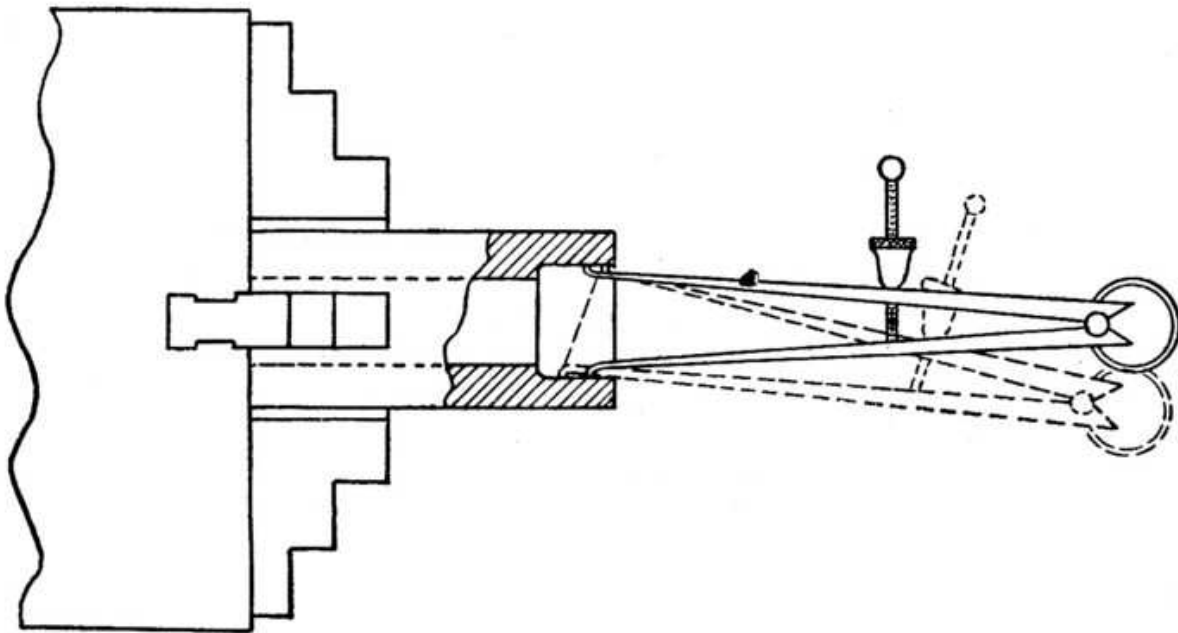


FIGURE 12.—Using inside caliper.

f. The vernier caliper is a beam caliper with jaws at right angle to the beam and is used for taking either inside or outside measurements. This caliper is fitted with a vernier scale which permits measurements to within 0.001 inch and is illustrated in figure 14 ①. There are two

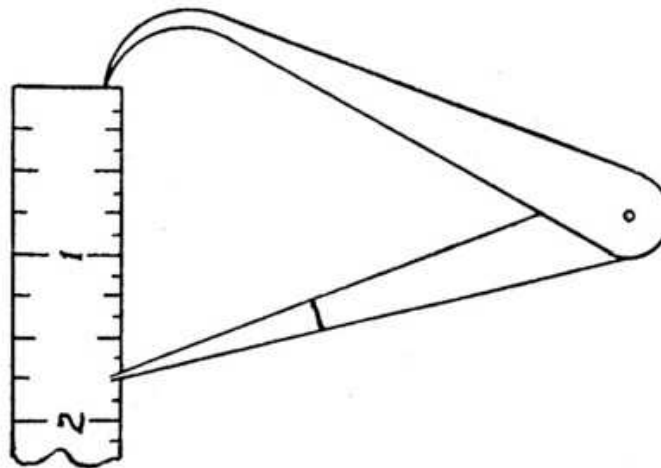


FIGURE 13.—Setting hermaphrodite caliper.

leading systems of graduation used on vernier calipers. The beam scale of one type is divided into $\frac{1}{50}$, $\frac{1}{10}$, $\frac{1}{2}$ inch, etc., the smallest divisions being equal to 0.020 inch. Twenty divisions on the vernier

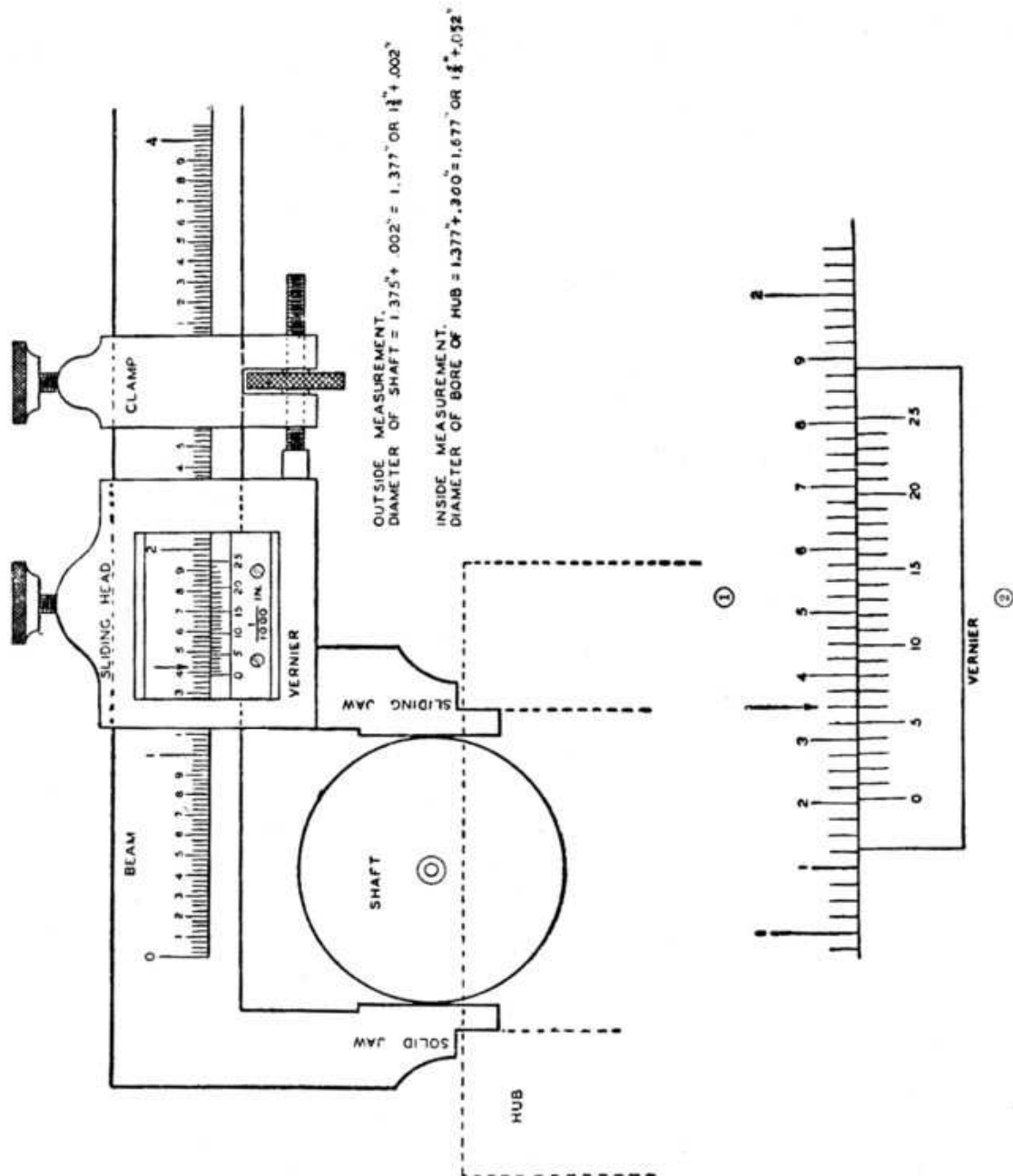


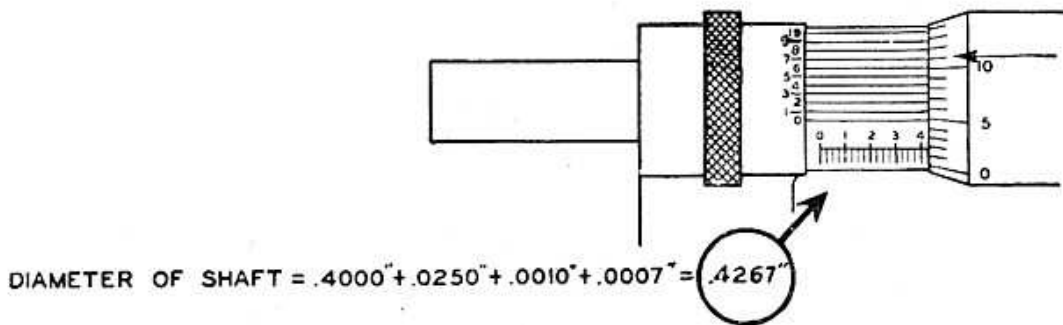
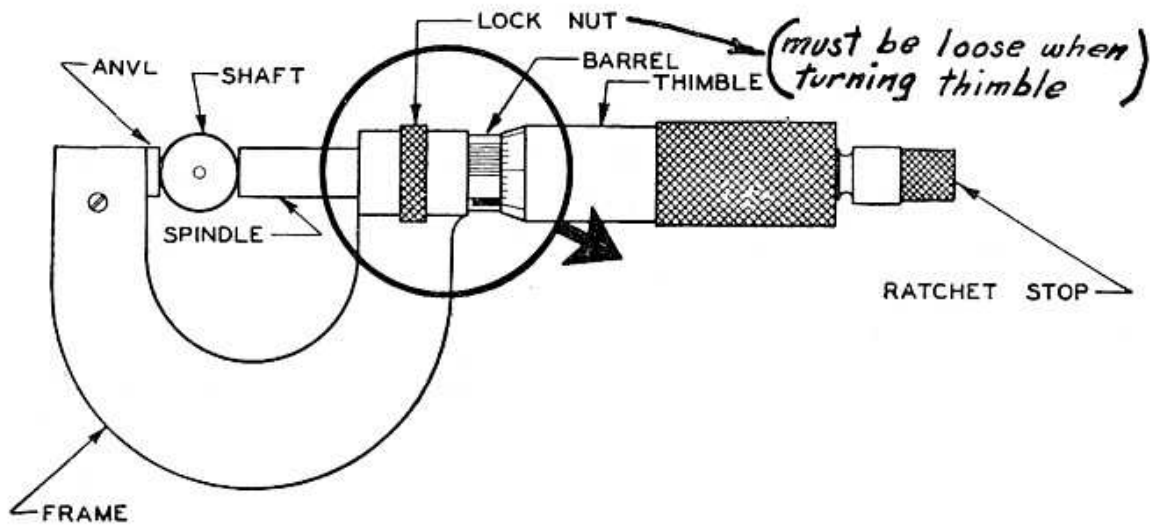
FIGURE 14.—Details of vernier caliper.

equal 19 of the smallest divisions on the scale. The difference between a division on the vernier and one on the scale (smallest divisions being meant in both cases) is, therefore, for this instrument, $\frac{1}{20}$ times $\frac{1}{50}$ (0.05×0.02) which equals 0.001 inch. On the other type of caliper the smallest scale divisions equal 0.025 ($\frac{1}{40}$) inch, and 25 divisions on the vernier equal 24 on the scale, the difference being $\frac{1}{25}$ times $\frac{1}{40}$ (0.04×0.025) which equals 0.001. On the bar of the instrument is a scale which is divided into inches and numbered 0, 1, 2, etc. Each inch division is again divided into 10 parts, and each tenth part is divided into 4 additional parts, making 40 divisions to the inch. On the sliding jaw is a scale divided into 25 parts, numbered 0, 5, 10, 15, 20, 25. This is known as a vernier, and 25 parts on the vernier

correspond in extreme length with 24 parts or twenty-four fortieths of an inch on the bar. Consequently each division on the vernier is smaller than each division on the bar by one-thousandth part of an inch. If the sliding jaw of the caliper is pushed up to the solid jaw so that the line marked 0 on the vernier corresponds to that marked 0 on the bar, the next two lines to the right will differ from each other by one-thousandth of an inch, and the difference will continue to increase (one-thousandth of an inch for each division) until they again correspond at the line marked 25 on the vernier. To read the distance when the caliper is open, commence by noting how many inches, tenths, and parts of tenths the zero point on the vernier has been moved from the zero point on the bar. Then count upon the vernier the number of divisions, until one is found that coincides with the one on the bar, which will be the number of thousandths to be added to the distance read off on the bar. The best way of expressing the value of the divisions on the bar is to call the tenths, one-hundred thousandths (0.100), and the fourths of tenths, or fortieths, twenty-five thousandths (0.025). For example, the vernier shown in figure 14 ② has been moved to the right one and two-tenths divisions (1.200 inch) as indicated by the bar, and the sixth line on the vernier coincides with a line on the bar, thus making six-thousandths (0.006) to be added to the reading from the scale, which would make the total reading one and two-hundred and six thousandths (1.206) inches. American verniers have scales on opposite sides of the beam for taking inside and outside readings directly. In making inside measurements with the 12-inch English vernier, three-tenths (0.300) of an inch should be added to the apparent reading on the vernier side for the space occupied by the caliper points.

g. The micrometer caliper is made in various styles and sizes depending upon the purpose for which it is to be used. The most common types are the outside, the inside, and the outside thread micrometers. This tool is used where close precision is required, being capable of taking measurements to within 0.0001 inch. It consists of a frame, an anvil, or fixed measuring point, a spindle which has a thread cut 40 to the inch on the portion inside the sleeve or barrel, and the thimble which goes outside the sleeve and turns the spindle. One turn of the screw moves the spindle $\frac{1}{40}$ (0.025) inch, and the marks on the sleeve show the number of turns the screw is moved. Every fourth graduation is marked 1, 2, 3, etc., representing tenths of an inch and as each mark is 0.025 inch, the first four mean 0.025 times 4 or 0.100 inch. The thimble has a beveled edge divided into 25 parts and numbered 0, 5, 10, 15, 20, and back to 0. Each of these means $\frac{1}{25}$ of a turn or $\frac{1}{25}$ of $\frac{1}{40}$,

which equals $\frac{1}{1000}$ inch. To read, simply multiply the marks on the barrel by 25 and add the graduations on the edge of the thimble. A typical micrometer is illustrated in figure 15 ①.



②

FIGURE 15.—Details of micrometer caliper.

(1) Some micrometers have a vernier scale on the frame in addition to the regular graduations so that measurements within 0.0001 inch can be taken. This arrangement is shown in figure 15 ②. Micrometers of this type read as follows: first, determine the number of thousandths, as with the ordinary micrometer; then find a line on the vernier scale that exactly coincides with one on the thimble. The number of this line represents the number of ten-thousandths to be added to the number of thousandths contained on the regular graduations. The relation between the graduation of the vernier and those of the thimble is as follows: the vernier has ten divisions which occupy the same space as nine divisions on the thimble. The difference between the width of a vernier division and one on the thimble is equal to one-tenth of the space on the thimble. Therefore, a movement of the thimble—equal to the difference between the vernier and the thimble graduation—represents 0.0001 inch.

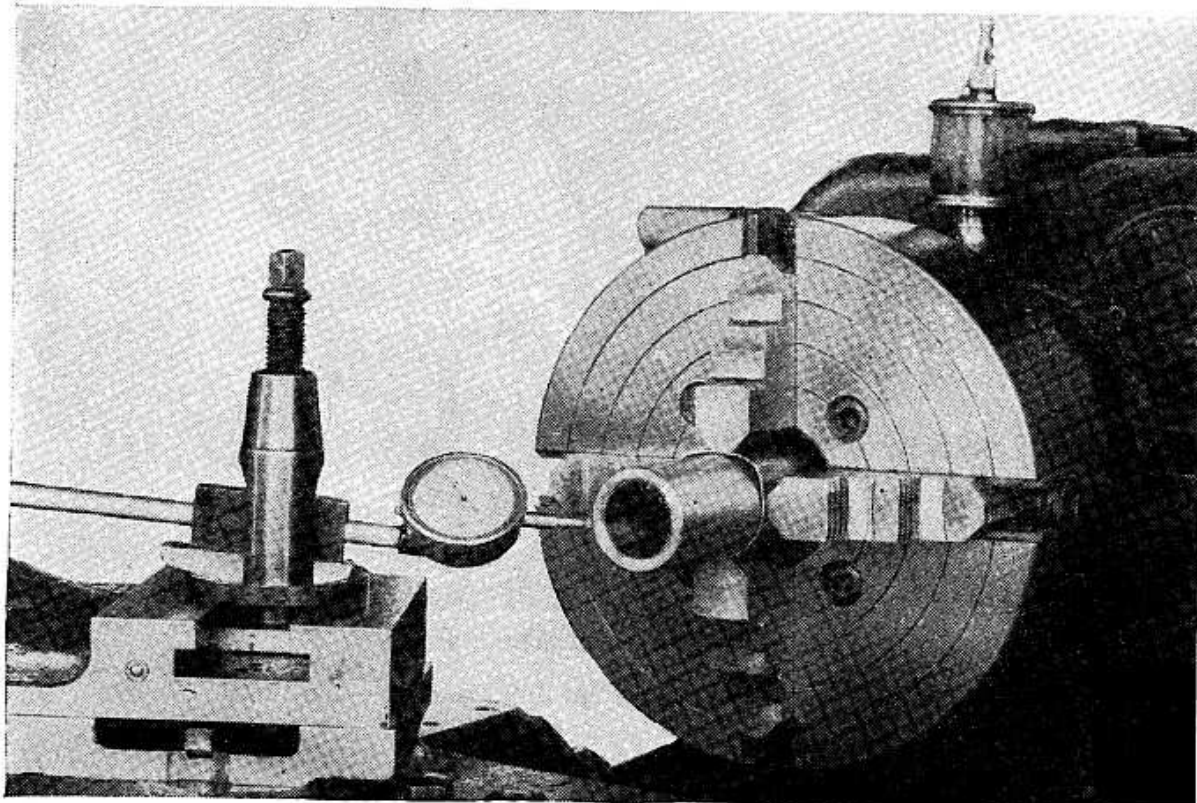
(2) Thread micrometer calipers are used for measuring the pitch diameter of threads. The anvil and the end of the spindle are ground to an included angle corresponding to the included angle of the thread to be measured. Each thread micrometer has an average range of 5 pitches, i. e., one micrometer will measure threads from 8 to 13, another from 14 to 20, and so on. The spindle has a travel of 1 inch as in the ordinary outside micrometer caliper.

(3) Inside micrometer calipers are for taking inside measurements. This micrometer has a travel of $\frac{1}{2}$ inch. Rods of various lengths make up the set. The graduations and readings are the same as for the outside micrometer.

12. Test indicators.—*a.* Test indicators are for the accurate testing of revolving work. Both the fulcrum lever and dial types are used in the average shop.

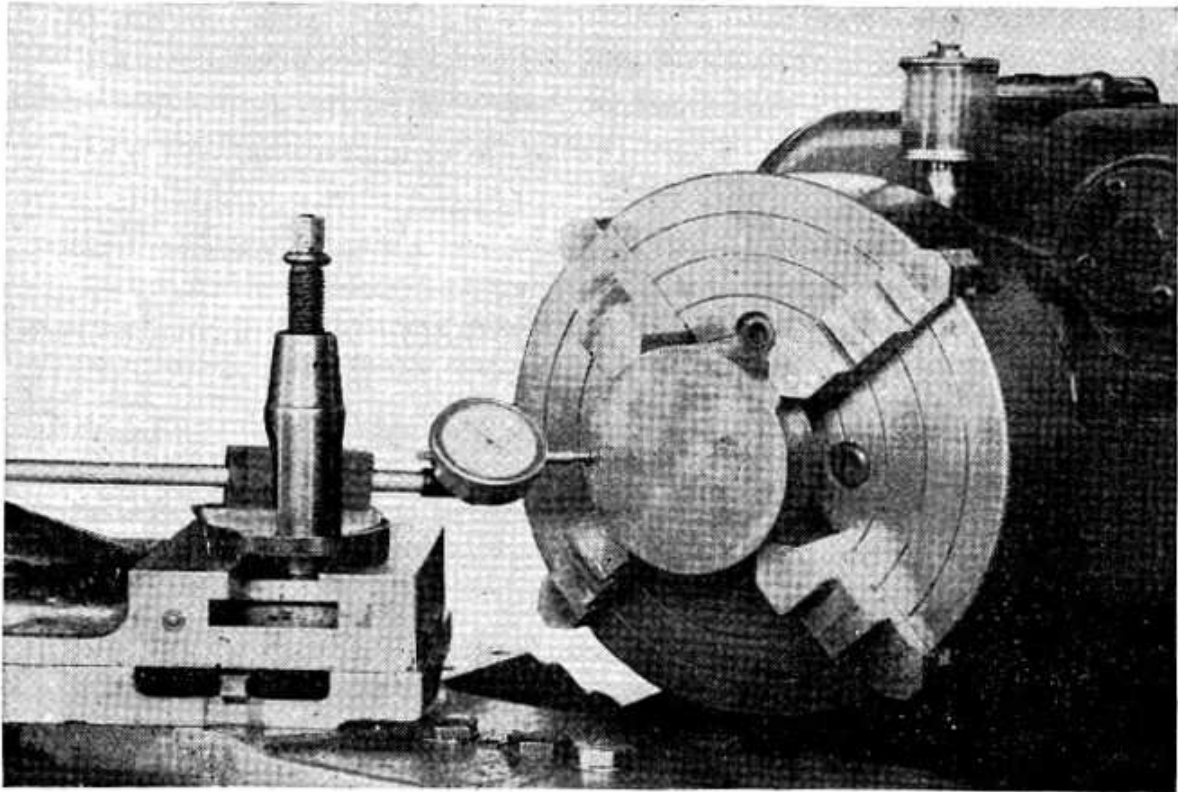
(1) The fulcrum lever type is mounted on a frame which may be held in the lathe tool post. When in use the short end of the lever is placed against the revolving part and the movement of the long end may be easily noted. The fulcrum ratio of the lever is ordinarily about 50 to 1.

(2) The dial test indicator consists of a case containing a series of reduction gears through which any motion from a plunger, protruding from the case, is increased so as to be easily detected on a dial. Figure 16 illustrates typical applications of the dial test indicator.

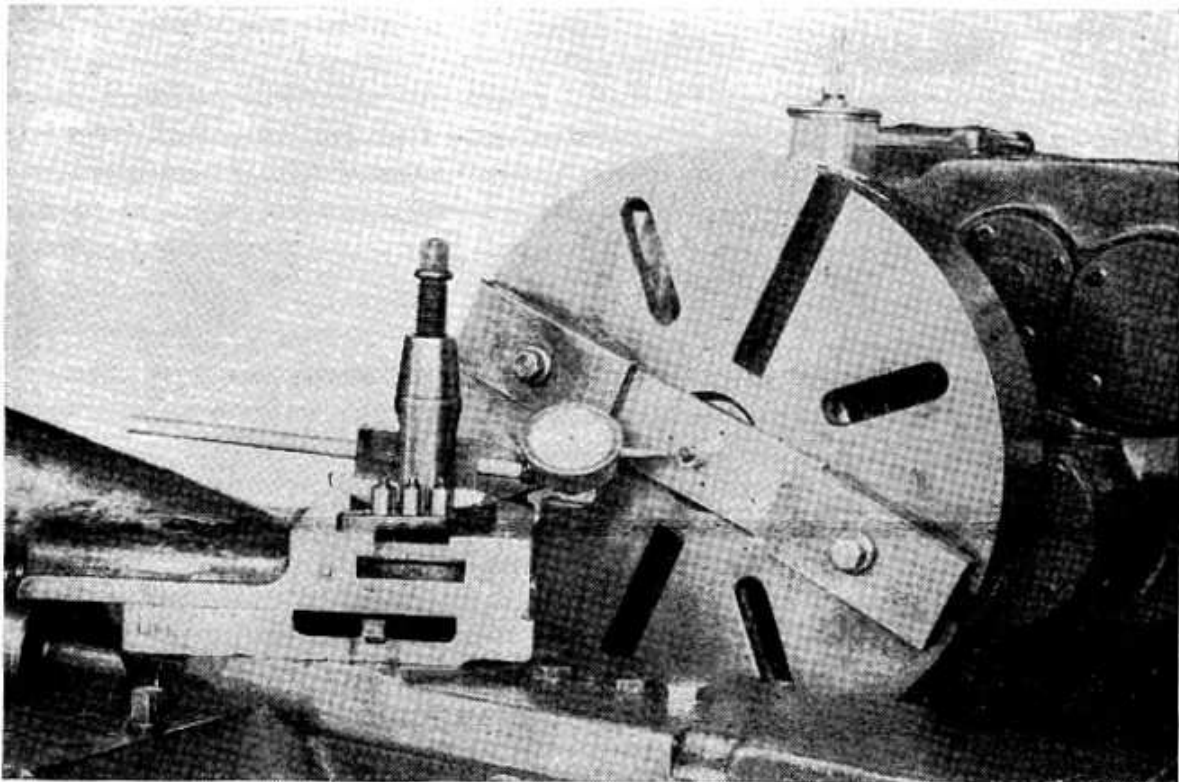


① Alinement of bushing.

FIGURE 16.—Test indicator applied to lathe work.



⊙ Alinement of work face.



⊙ Alinement of tool makers' buttons

FIGURE 16.—Test indicator applied to lathe work—Continued.

b. The levers and dials of indicators are ordinarily calibrated to 0.001 inch; however, indicators calibrated to 0.0001 inch are also available for delicate precision work.

c. Test indicators are used for rechucking operations, testing revolving centers, and with a test bar for alining centers. They may also be used for testing work that is held between centers as shown in figure 40 ③.

13. Gages.—Gages are standards of measurements. They are made in a variety of types, for checking the size of external and internal surfaces, and also for the measurement of lengths.

a. The plug gage is probably the most common type for checking the size of bores, both straight and tapered. It consists of a cylindrical body of the shape and size desired with a handle attached for holding it when in use.

b. Straight rods with the ends hardened and ground to a desired radius, known as standard measuring rods, are used for making internal measurements.

c. Standard reference disks which are flat, circular pieces of hardened and ground metal are also used for some styles of gaging.

d. The Johanson type gage blocks are generally used for the checking and setting of other measuring tools. These gages are rectangular blocks of steel, hardened, ground, and lapped to extremely close limits. Other gages in ordinary use are the snap gage, ring gage, and thread gage.

e. When checking curves and radii, flat sheet metal pieces, shaped to the correct curvature, are used. When the curves or radii are standard measurements, they are known as gages; if not, they are known as templates.

14. Buttons.—*a.* In machine work it is often necessary to have two or more holes accurately located in relation to each other or position correctly in relation to the edge of the plate. Tool makers' buttons, which are small, hollow, accurately made cylinders, may be

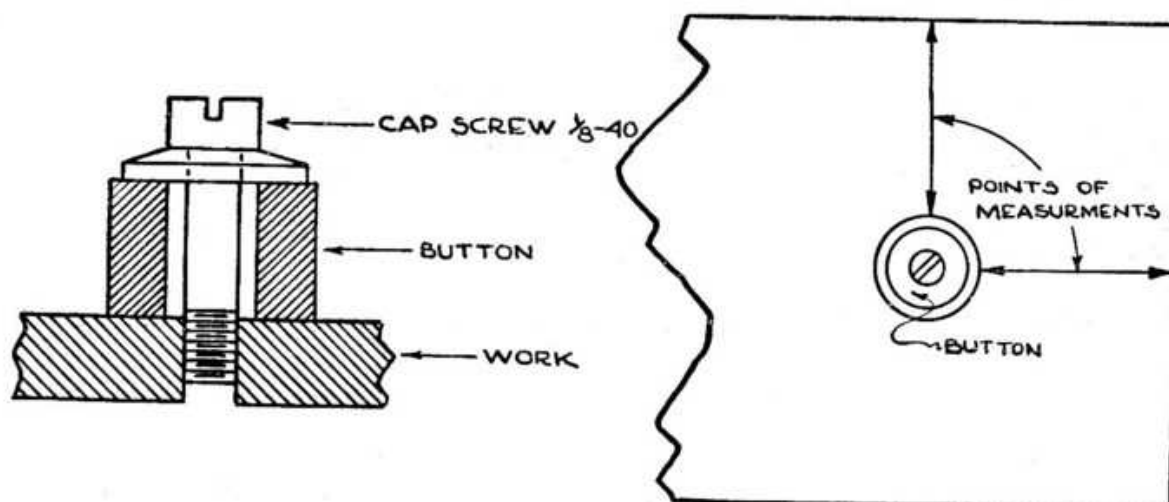


FIGURE 17.—Alinement with tool makers' button.

used for this purpose. They are usually furnished in sets of four, with retaining screws to hold them in place while in use, and their application is illustrated in figure 17.

b. As an example of the use of tool makers' buttons, the following procedure is outlined:

By means of a pair of dividers and other necessary tools, locate the holes to be bored, then drill and tap them for the retaining screws. Put the buttons in place, and with the screws sufficiently tight to hold the buttons shift them around until they are accurately located, then tighten the screws so as to hold them from further movement. Mount the work in the lathe and true the work to the button, by use of an indicator, then remove the button that has been indicated, leaving the work accurately positioned and ready for boring.

SECTION IV

HOLDING WORK

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15. General.—Lathe work is held either in chucks on face plates or between centers and may be supported by such attachments as the center and follower rests.

16. Chucks.—A great amount of lathe work involves the use of chucks, and the following description includes the ones which apply to general machine shop operations:

a. Independent chucks are used more than any other type for general lathe work due to the fact that they will take work of practically any shape, have great holding power, and can be adjusted very accurately (fig. 18).

(1) In mounting this chuck or any attachment that screws on the lathe spindle, the threads and bearing surfaces of both the spindle and the chuck should be cleaned and oiled. In cleaning these threads a spring thread cleaner (fig. 19) is very desirable.

(2) To aline work in the independent chuck, it is placed between the chuck jaws and adjusted to approximate central position by the use of the concentric rings on the chuck face. When this is

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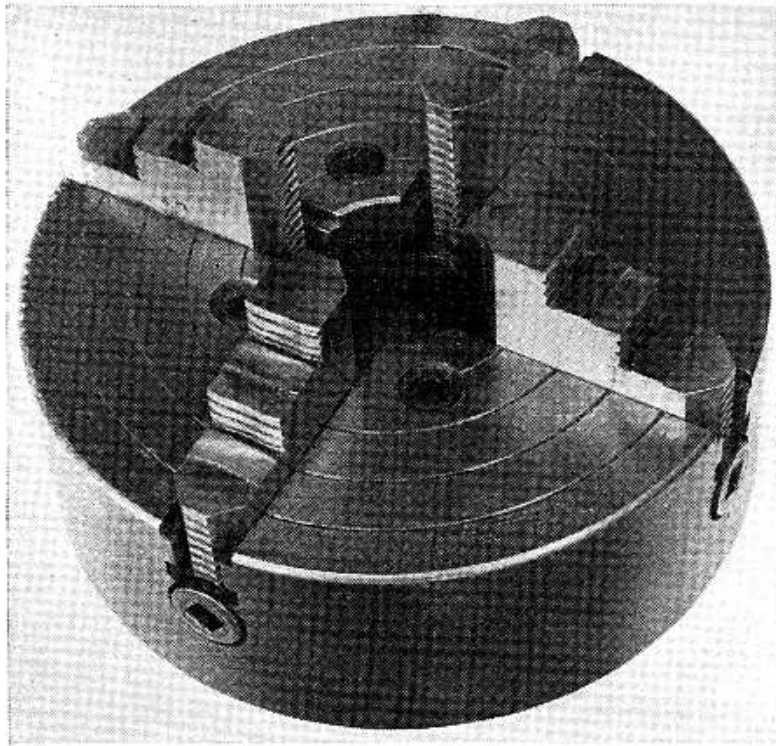


FIGURE 18.—Four-jaw independent chuck.

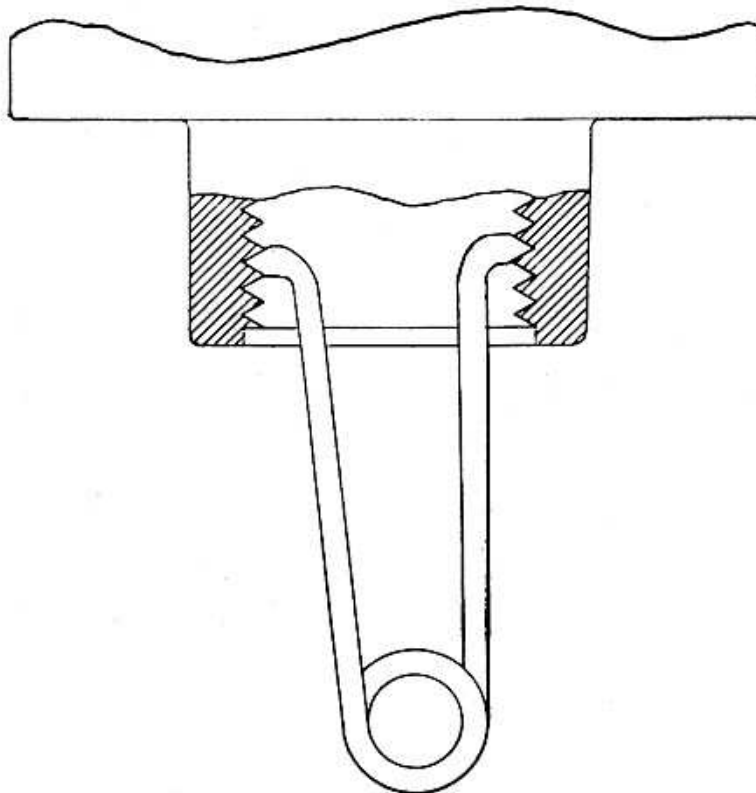


FIGURE 19.—Spring thread cleaner.

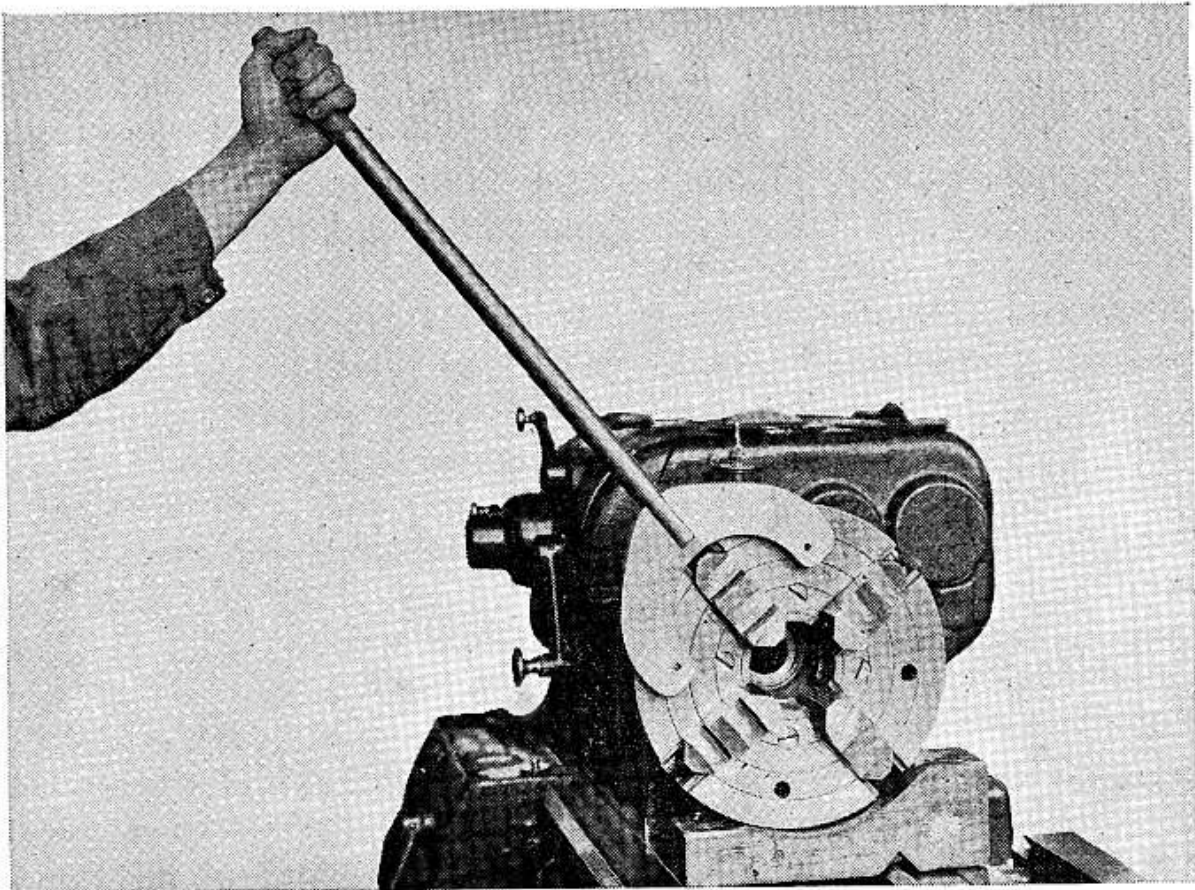
done the work is revolved and a piece of chalk held lightly against it until a mark shows. The spindle of the lathe is then stopped, and the jaw or jaws opposite the chalk mark are loosened while the jaws on the chalk-marked side are tightened. This operation is

repeated until the desired accuracy is attained. Before cutting, all chuck jaws must be tight.

(3) When centering smooth-surfaced work to a high degree of accuracy, a test indicator may be used. To do this the indicator is placed on the lathe with the indicator point in contact with the surface to be aligned (fig. 16). The chuck is then rotated by hand, and the concentricity is shown by the indicator pointer movement. Adjustment may be made on the jaws until the desired accuracy is attained.

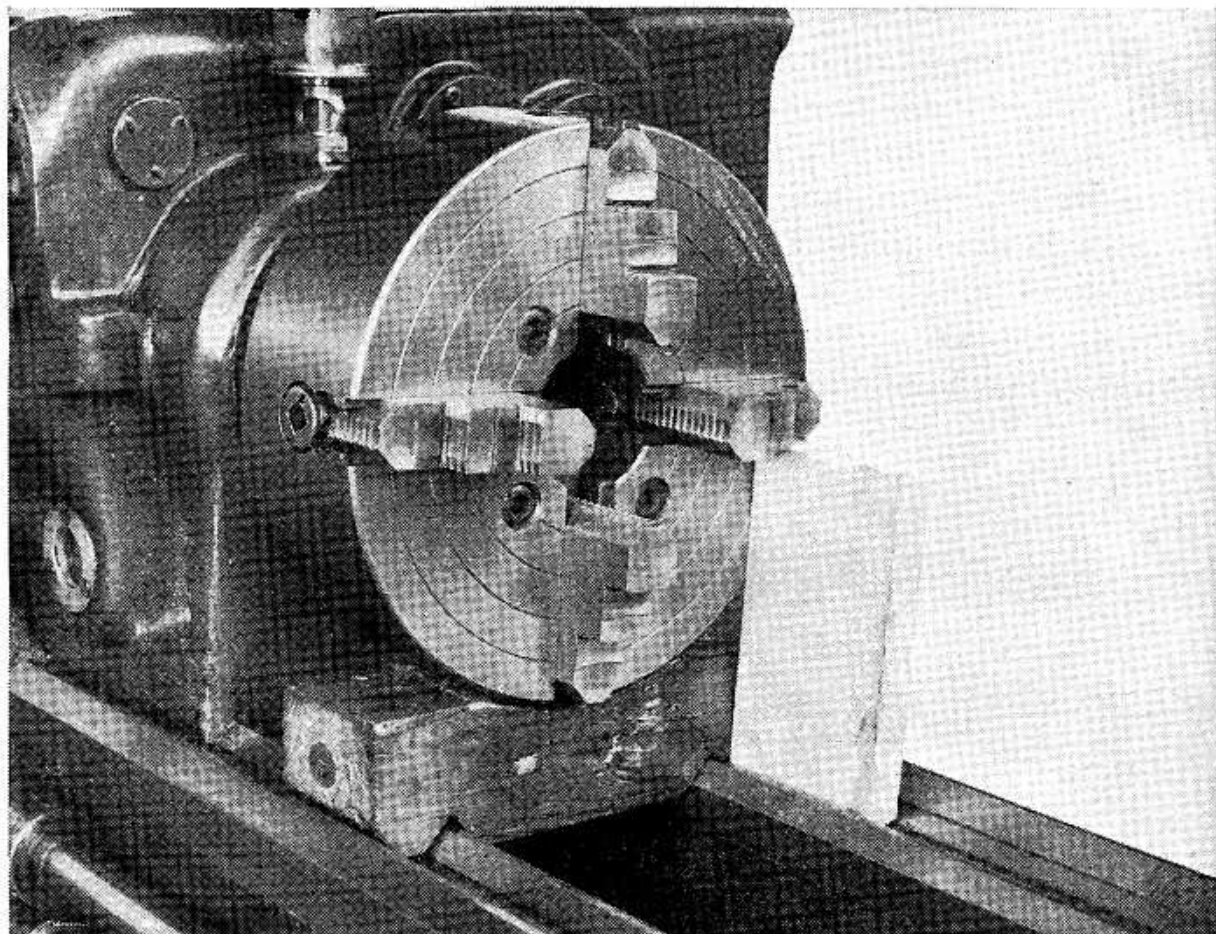
(4) To remove chucks or face plates that are screwed on the lathe spindle, a chuck-removing wrench should be used, although if not available a block of wood placed between the ways of the lathe and one chuck jaw is satisfactory if the lathe spindle is placed in reverse and started in low gear (fig. 20). *Caution:* A wood plate should always be placed on the lathe bed below the chuck during this operation to protect both chuck and lathe from damage.

b. The universal chuck is used in holding round and hexagonal work and can be adjusted to centralize the work quickly. Two sets of jaws are usually required on a universal chuck; one set for internal work and one set for external work (fig. 21).



① By means of a chuck wrench.

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② By means of a wood block.

FIGURE 20.—Removing chuck from lathe spindle.

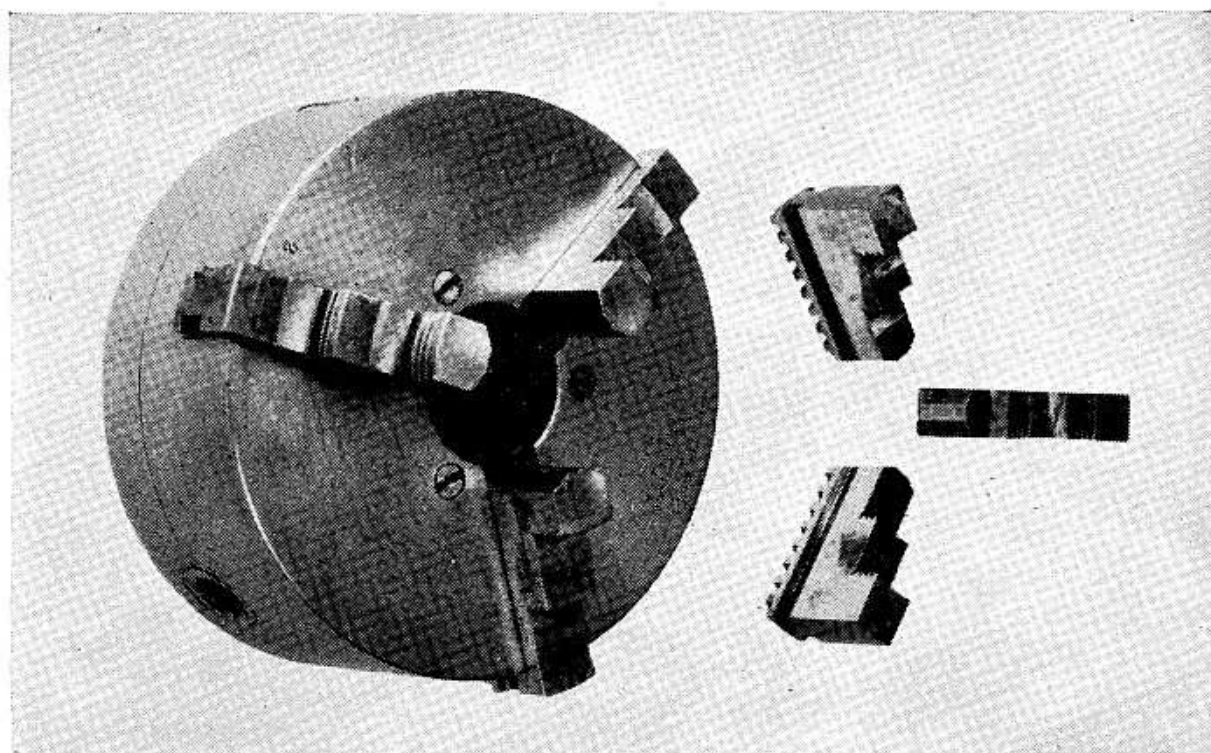


FIGURE 21.—Three-jaw universal chuck.

c. Collet chucks are small, accurately made chucks of the split shell type. They are used to hold work that has smooth, round, external surfaces and should be used only for light machining operations on work that fits them accurately. Collets may also be obtained for holding square, hexagonal, and octagonal work. As shown in figure 22 the collet (A) is held in a special adapter (B) which is fitted into the lathe spindle. The collet is clamped onto work by action of the threaded draw bar (C) which is operated through the spindle by the hand wheel (D).

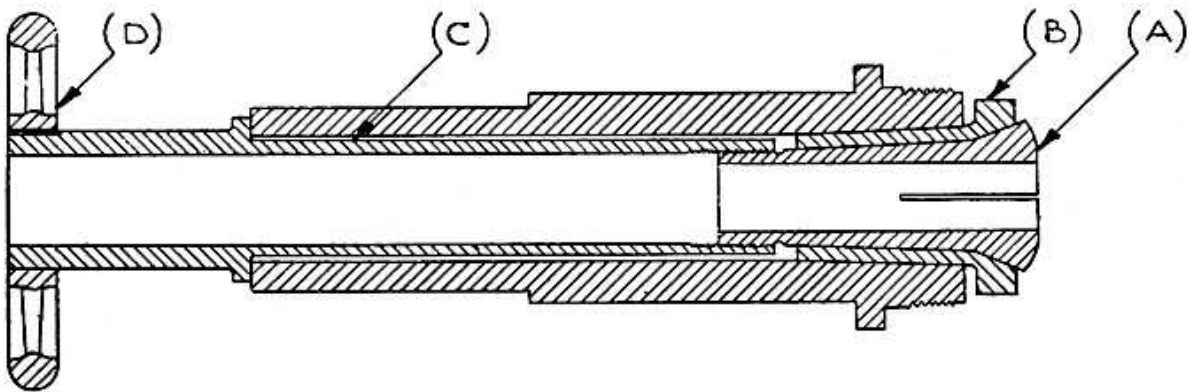
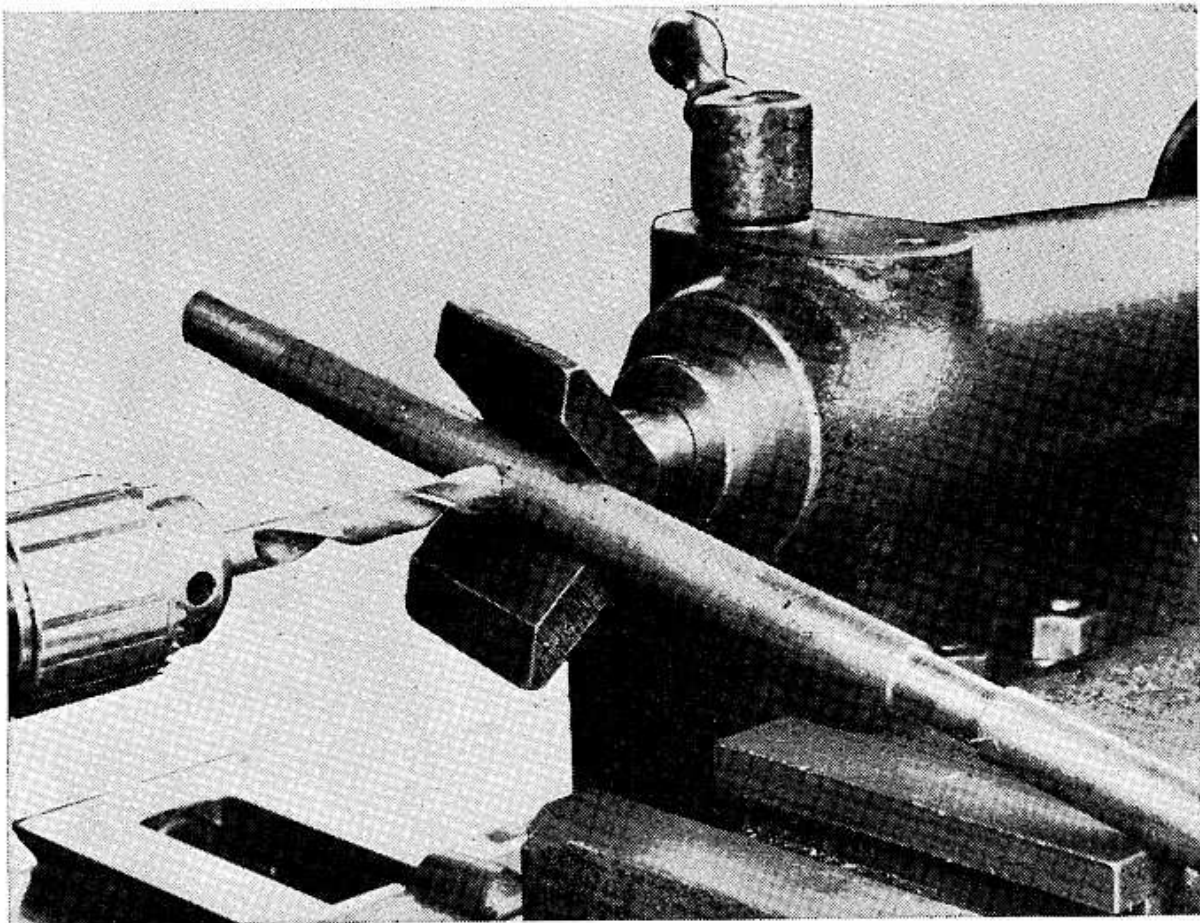
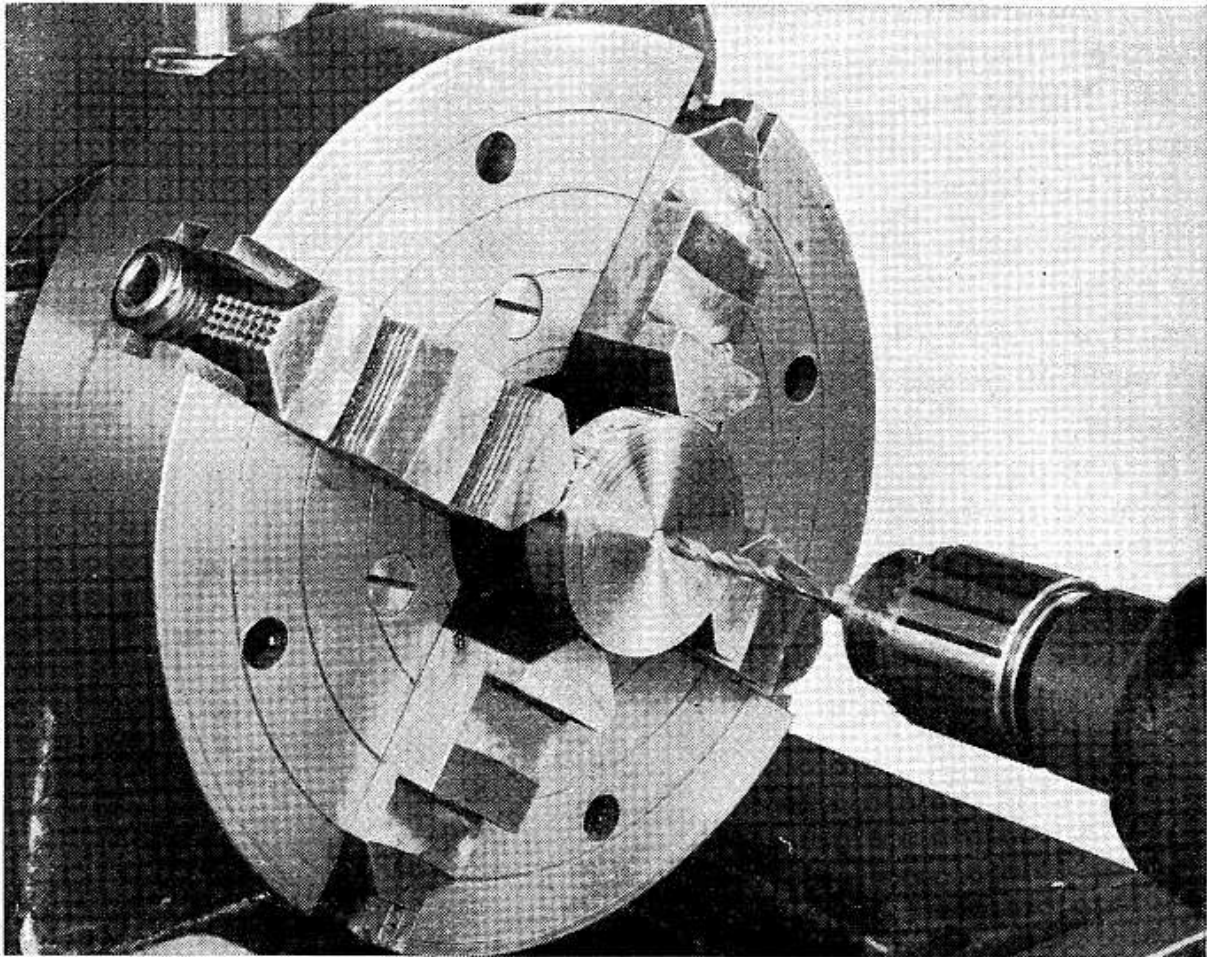


FIGURE 22.—Collet chuck assembly.



① Mounted in headstock spindle.



© Mounted in tailstock spindle.

FIGURE 23.—Application of drill chuck.

d. The combination chuck is made with either three or four jaws which can be moved either independently or in unison.

e. The magnetic chuck holds the work against its face by magnetic force. It is generally used when machining thin, flat sections.

f. The drill chuck is a small universal chuck that can be mounted in either the headstock or tailstock spindle and is used to hold drills, reamers, etc., as well as work of small diameter (fig. 23).

17. Face plates.—*a. Description.*—The face plate is a flat, round plate provided with T-slots and is especially valuable in machining holes that are to be accurately located in thin work. It screws onto the lathe spindle and is used for holding work to be machined. Angle plates may be bolted to the face plate and the work mounted thereon. (See fig. 24.)

b. Use.—(1) The accuracy of the bearing surface of a face plate is most important. Any unevenness of this surface should be removed by taking a facing cut.

(2) Care should be exercised in clamping work to the face plate so that neither the work nor the face plate will be sprung.

(3) To eliminate any spring or vibration caused by having work offset on the face plate, balance weights may be used (fig. 24).

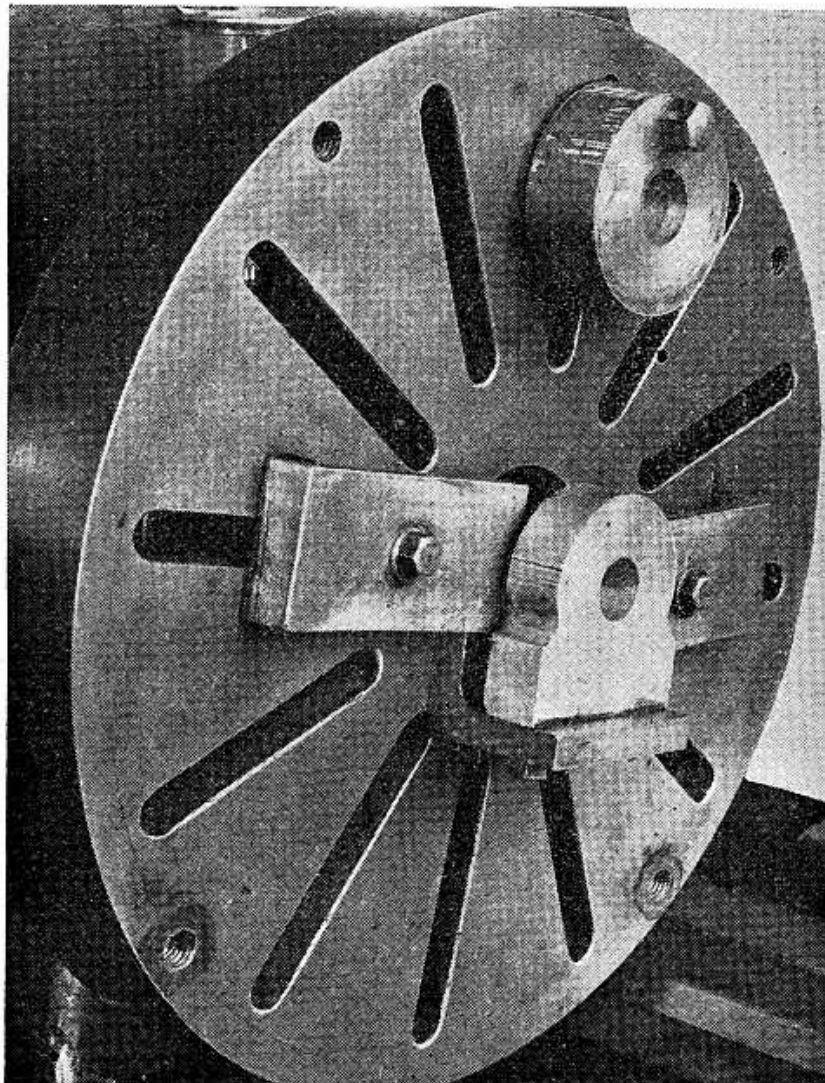
(4) Paper placed between the face plate and the work when the set-up is made will reduce the possibility of slippage.

18. Centers.—The various types of centers (fig. 25) have many applications in general lathe work and are briefly described as follows:

a. The standard plain or male centers are the most common and are used in pairs to support work that has center holes drilled in its ends.

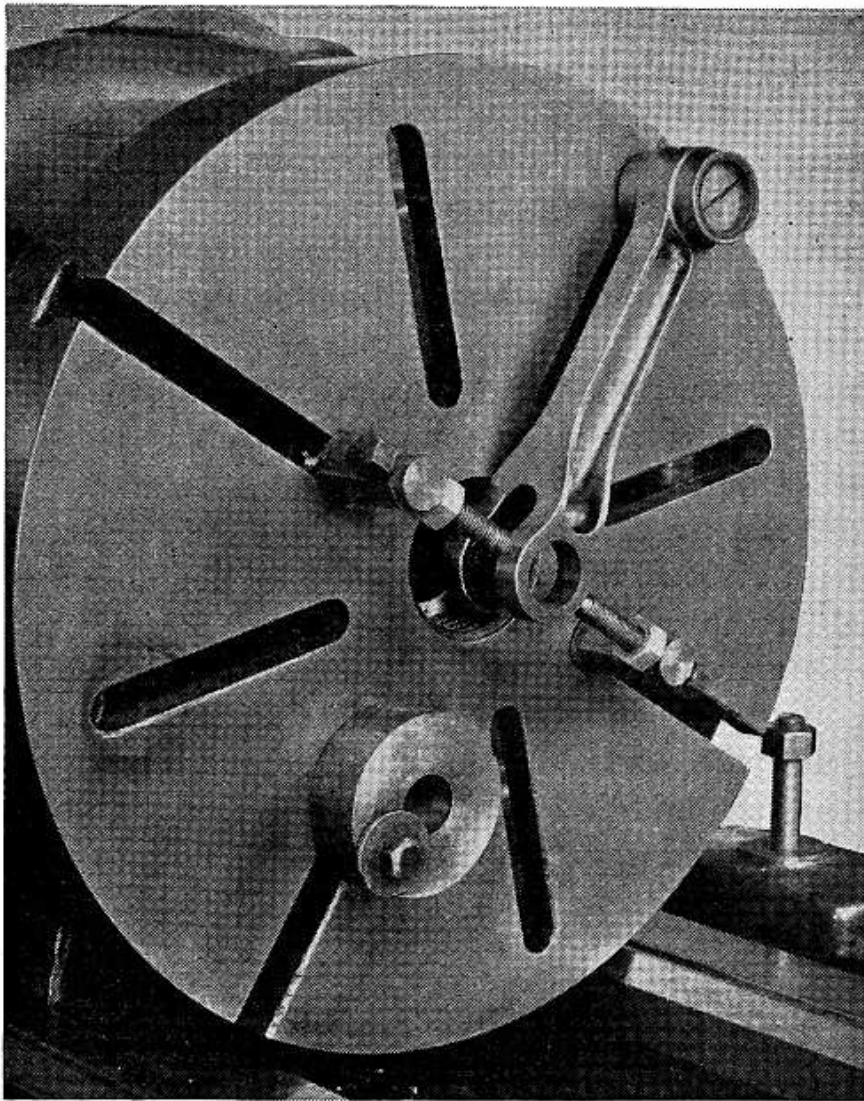
b. The pipe center has a conical point which revolves on a bearing. It is used for holding pipe, tubing, etc.

c. The self driving or square center has a point made in the shape of a pyramid. It is used on small work where a light complete cut from end to end is desired without interference from a driving dog. The shape of the center hole in the work is made to correspond to the driving center.



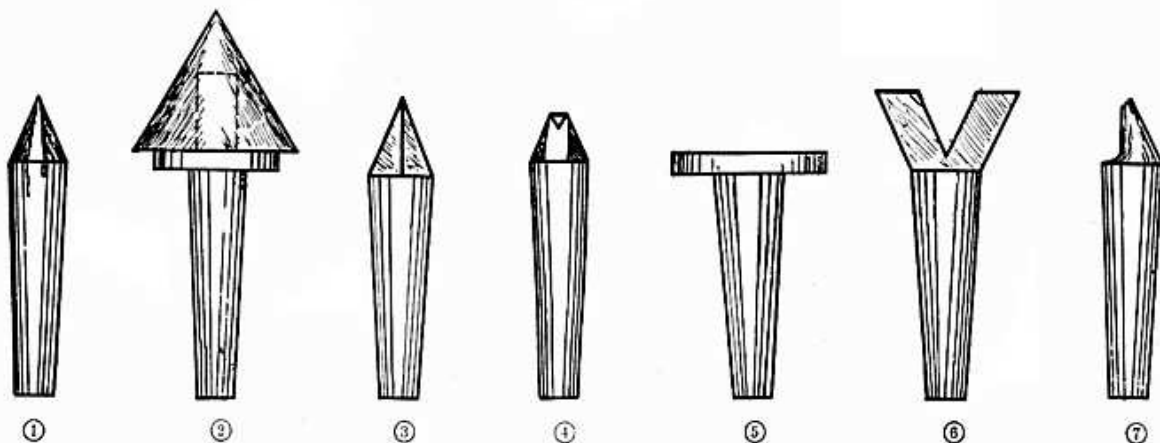
① Boring offset bearing.

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② Boring connecting rod.

FIGURE 24.—Typical face plate set-ups using balance weights.



- ① Standard male.
- ② Pipe.
- ③ Self driving.
- ④ Female.
- ⑤ Drill pad.
- ⑥ Crotch.
- ⑦ Half.

FIGURE 25.—Various types of lathe centers.

d. The female center is conically bored at the tip and used to support work that is pointed on the end.

e. The drill pad center is used to drill flat stock in the lathe and is an ordinary center shank, terminating in a disk or pad, against which the work is held by friction.

f. The crotch center is used to hold round work at right angles to its axis, for such operations as drilling or reaming the wrist pin hole in a piston.

g. The half center is a plain center having a portion of the 60° end cut away. It is used for completely facing the ends of work held between centers.

19. Mandrels.—*a.* The purpose of the mandrel is to hold work that has been previously bored or reamed so that its outside surface may be machined in relation to that bore or ream.

(1) The standard mandrel (fig. 26) is generally made of tool steel, hardened and ground on the surface that supports the work. This surface is usually tapered 0.008 inch per foot, and the average or standard size is near the middle of the bearing surface. This taper allows the work to be pressed tightly upon the bearing surface or the mandrel where it is held by friction.

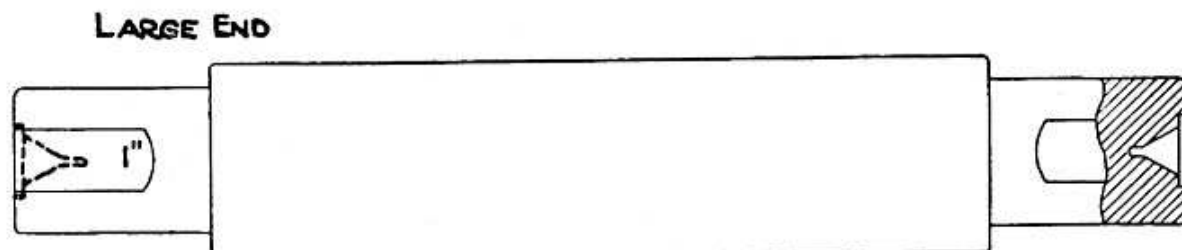


FIGURE 26.—Solid mandrel.

(*a*) Mandrels that operate on lathe centers should have center holes as large as possible to provide ample bearing surface.

(*b*) The mandrel should always be lubricated before work is pressed upon it to prevent galling.

(*c*) The size of a mandrel is usually marked on the large end.

(2) The expansion mandrel is used to hold work that is reamed or bored to nonstandard sizes. Figure 27 ① shows an expansion mandrel composed of two parts, consisting of an inner arbor which has a taper of approximately $\frac{1}{16}$ inch for each inch of length and an outer split shell that is tapered to fit the arbor. The split shell is placed in the work and the tapered arbor forced into the shell, causing it to expand the necessary amount. Expanding-jaw mandrels are also in common use and are similar in construction to expansion reamers. A mandrel of this type is illustrated in figure 27 ②.

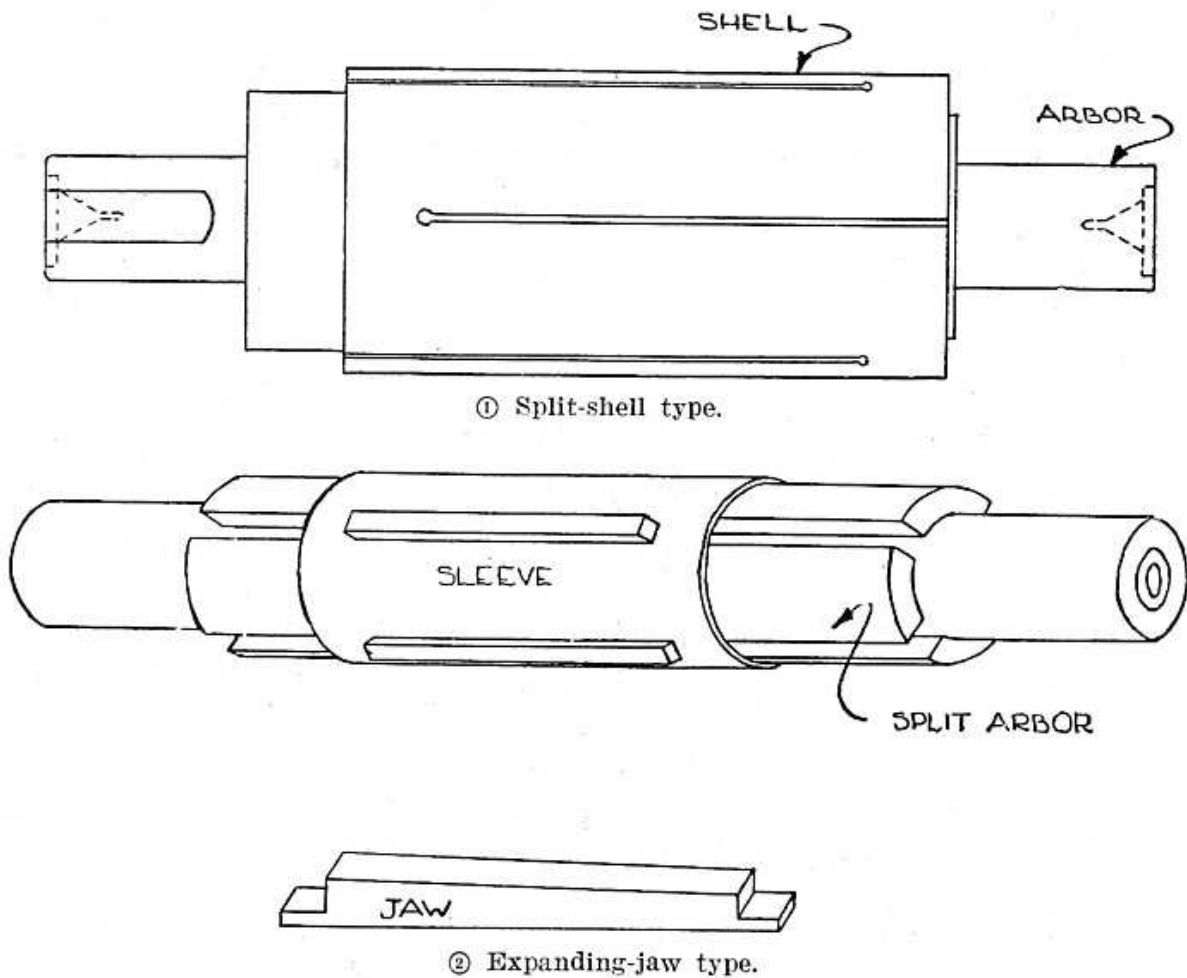


FIGURE 27.—Expansion mandrels.

(3) The nut mandrel (fig. 28) is a mandrel that is threaded to a shoulder at one end. Nuts are screwed onto the threaded portion until flush with the shoulder and held in this manner so that they may be machined in proper relation to their threaded bore.

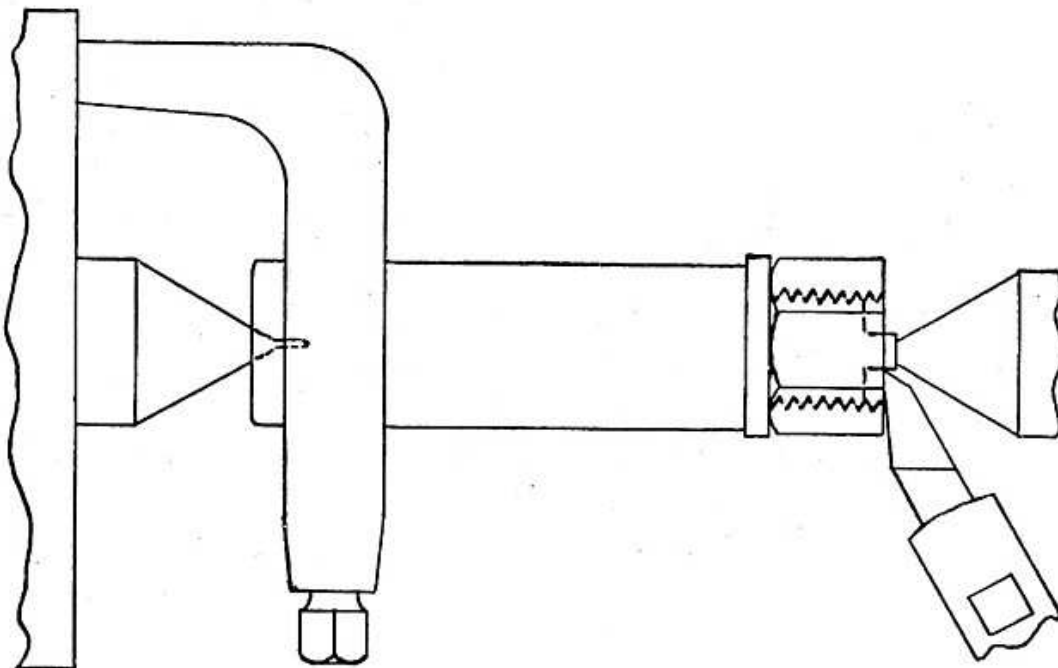


FIGURE 28.—Application of nut mandrel.

(4) The eccentric mandrel (fig. 29) has two or more center holes at each end. One pair is located in the center of the mandrel and the other pair a predetermined distance off center. By mounting the mandrel between the offset centers, the outside diameter of work may be machined eccentric to its bore.

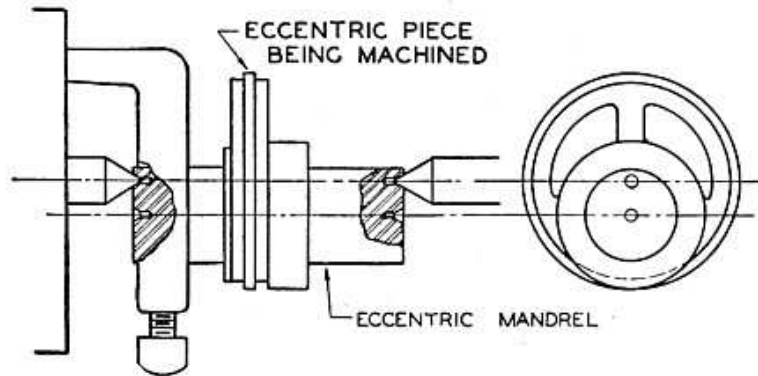


FIGURE 29.—Application of eccentric mandrel.

b. The gang mandrel (fig. 30) is used for holding several duplicate pieces such as gear blanks. The pieces are held tightly against a shoulder by means of a nut at the tailstock end.

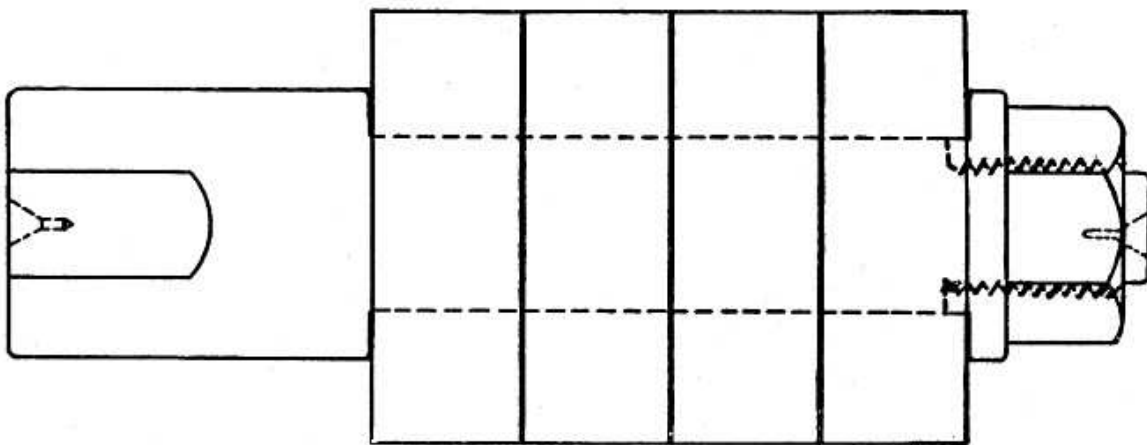


FIGURE 30.—Application of gang mandrel.

c. Special mandrels (fig. 31) which are held in chucks may be made locally when a mandrel of the proper size or shape is not available. Mandrels of this type may also be made for special applications, such as the holding of a tapered sleeve upon its internal taper or the machining of nuts which are not bored completely through.

20. Center rest.—a. This attachment (fig. 32) consists of a frame carrying three adjustable jaws and is used to support work that may spring or distort while being machined.

b. The center rest may be used to an advantage on work held either in the chuck or between centers. It is, however, necessary first to ma-

chine a concentric bearing surface on the work at the point at which the jaws are to be applied. After the work has been mounted and the center rest clamped firmly to the lathe bed, the jaws must be carefully adjusted to this surface and locked in position by means of the attached set screws.

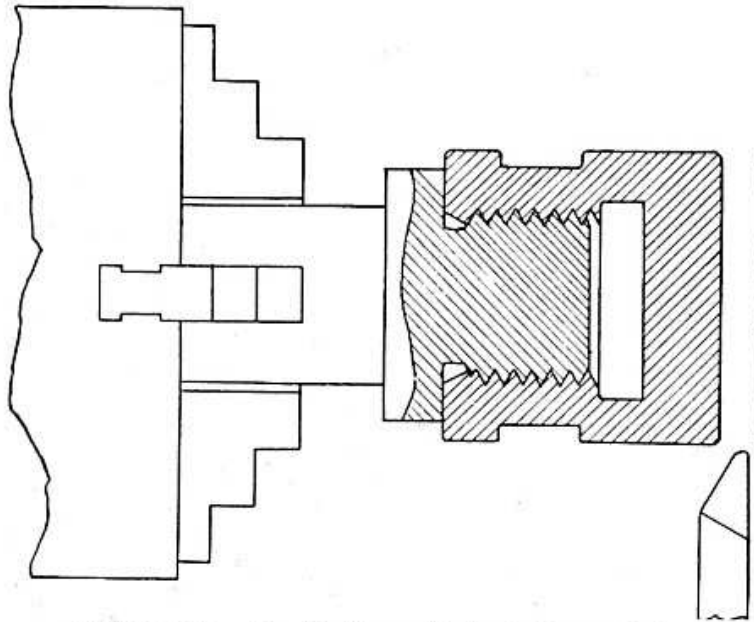


FIGURE 31.—Application of chucked mandrel.

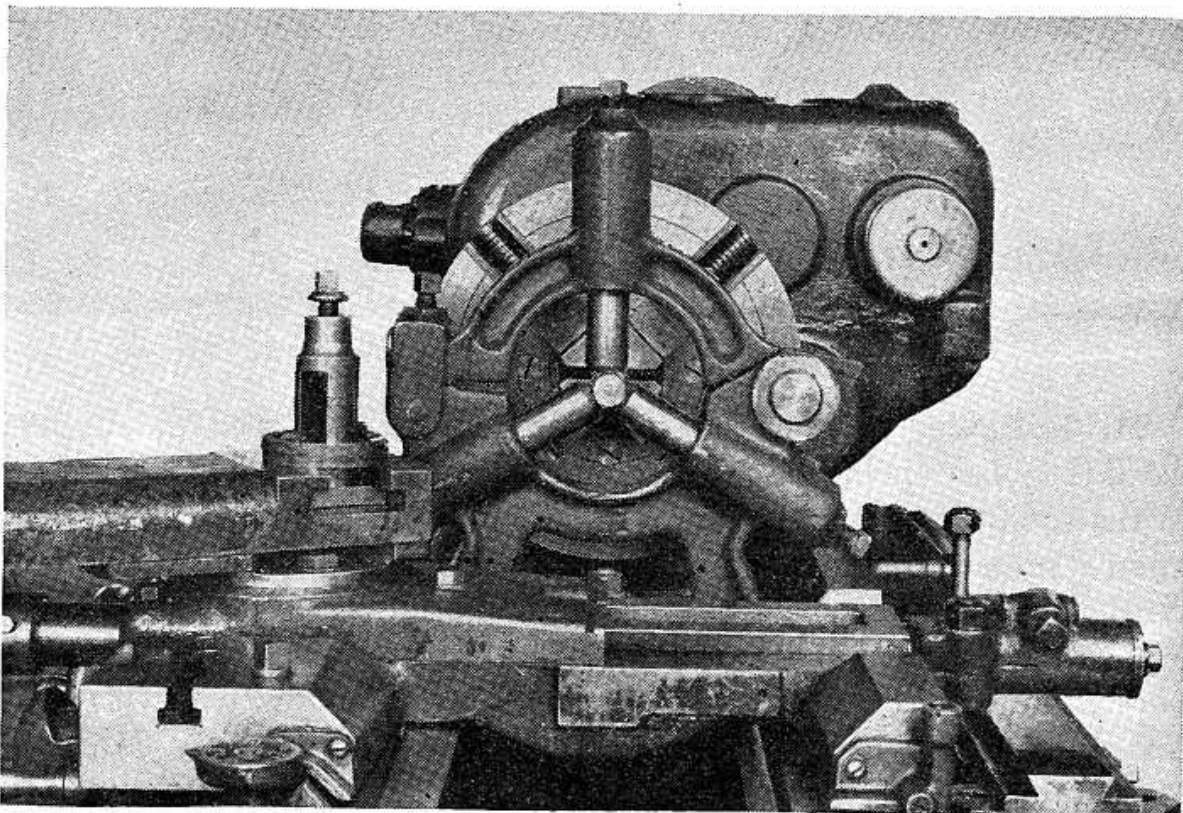


FIGURE 32.—Application of center rest.

(1) An overarm is provided on the center rest so that work may be removed and replaced without disturbing the jaw adjustment. This feature also allows the machining of duplicate pieces.

(2) To prevent marring of work which has ground surfaces, the use of copper shim stock between the center rest jaws and the work is advisable.

(3) Center rest bearing surfaces must be kept lubricated with a mixture such as white lead and lubricating oil to prevent scoring.

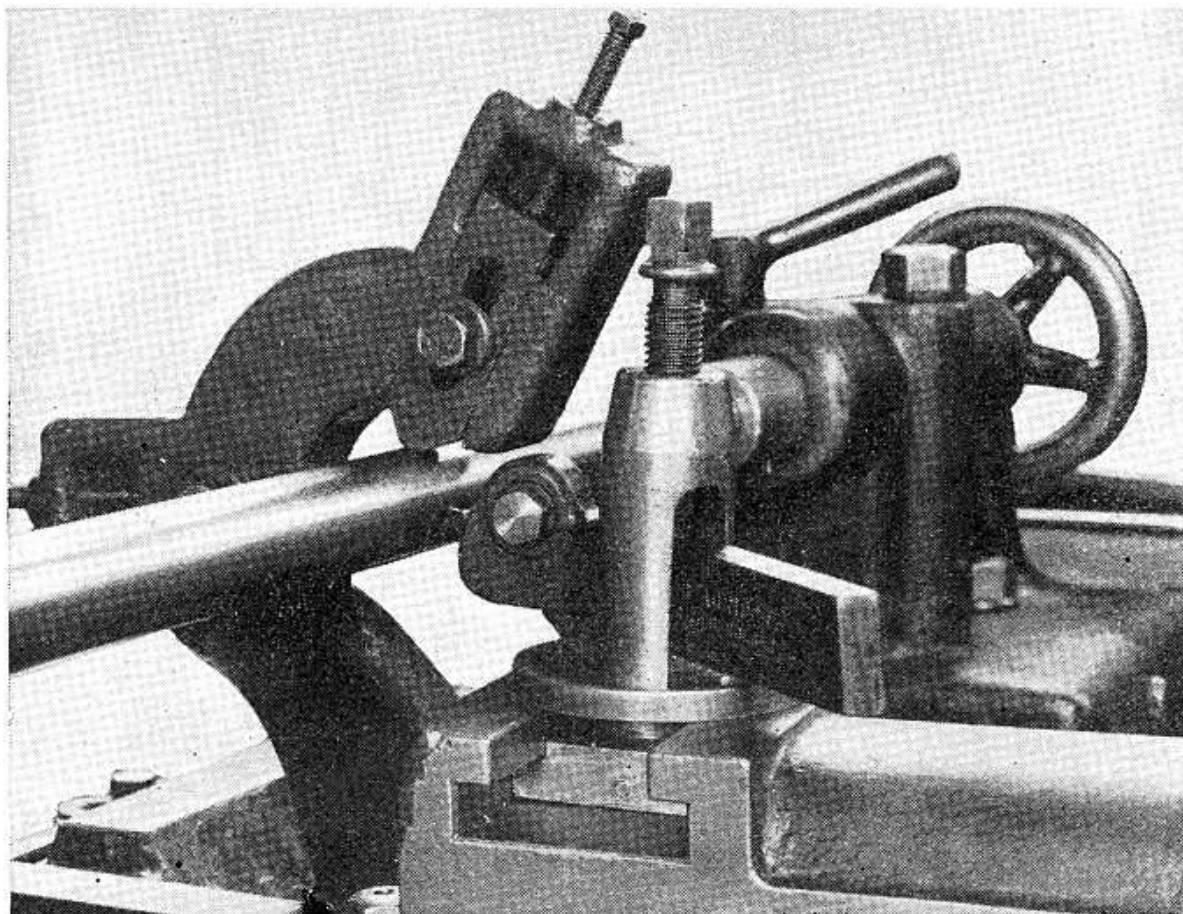


FIGURE 33.—Application of follower rest.

21. Follower rest.—The follower rest is also used to support work that may spring or distort while being machined. It is clamped to the saddle of the lathe, and the two jaws are adjusted and locked upon a surface of the work which has previously been cut. The tool is usually mounted a short distance to the left of the follower rest jaws, and as the carriage and tool move along the work the rest gives support almost directly behind the cut (fig. 33). A follower rest is essential in threading long work of small diameter and is very useful in many other similar operations.