The aviation maintenance technician (AMT) spends a major portion of each day using a wide variety of hand tools to accomplish maintenance tasks. This chapter contains an overview of some of the hand tools an AMT can expect to use. An AMT encounters many special tools as their experience widens; large transport category aircraft have different maintenance tasks from those of a light airplane, and special hand tools are often required when working on complex aircraft.

This chapter outlines the basic knowledge required in using the most common hand tools and measuring instruments used in aircraft repair work. This information, however, cannot replace sound judgment on the part of the individual, nor additional training as the need arises. There are many times when ingenuity and resourcefulness can supplement the basic rules. Sound knowledge is required of these basic rules and of the situations in which they apply. The use of tools may vary, but good practices for safety, care, and storage of tools remain the same.

General Purpose Tools

Hammers and Mallets

Figure 9-1 shows some of the hammers that the aviation mechanic may be required to use. Metal head hammers are usually sized according to the weight of the head without the handle.

Occasionally it is necessary to use a soft-faced hammer, which has a striking surface made of wood, brass, lead, rawhide, hard rubber, or plastic. These hammers are intended for use in forming soft metals and striking surfaces that are easily damaged. Soft-faced hammers should not be used for striking punch heads, bolts, or nails, as using one in this fashion will quickly ruin this type of hammer.

A mallet is a hammer-like tool with a head made of hickory, rawhide, or rubber. It is handy for shaping thin metal parts without causing creases or dents with abrupt corners. Always use a wooden mallet when pounding a wood chisel or a gouge.

When using a hammer or mallet, choose the one best suited for the job. Ensure that the handle is tight. When striking a blow with the hammer, use the forearm as an extension of the handle. Swing the hammer by bending the elbow, not the wrist. Always strike the work squarely with the full face of the hammer. When striking a metal tool with a metal hammer, the use of safety glasses or goggles is strongly encouraged.

Always keep the faces of hammers and mallets smooth and free from dents, chips, or gouges to prevent marring the work.

Screwdrivers

The screwdriver can be classified by its shape, type of blade, and blade length. It is made for only one pur-

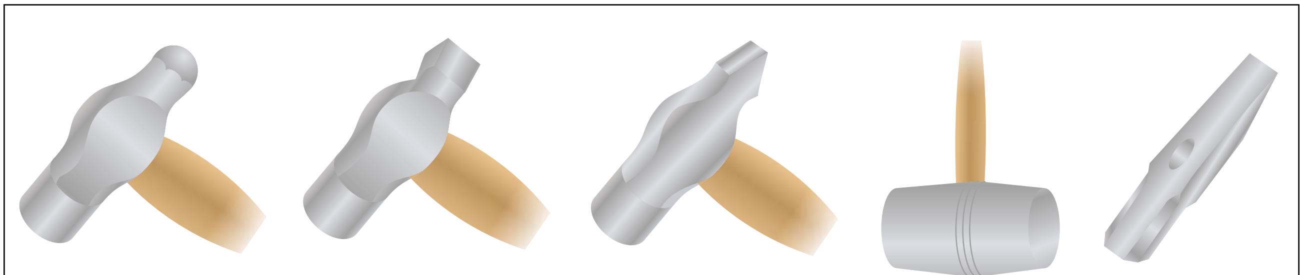

Figure 9-1. Hammers.

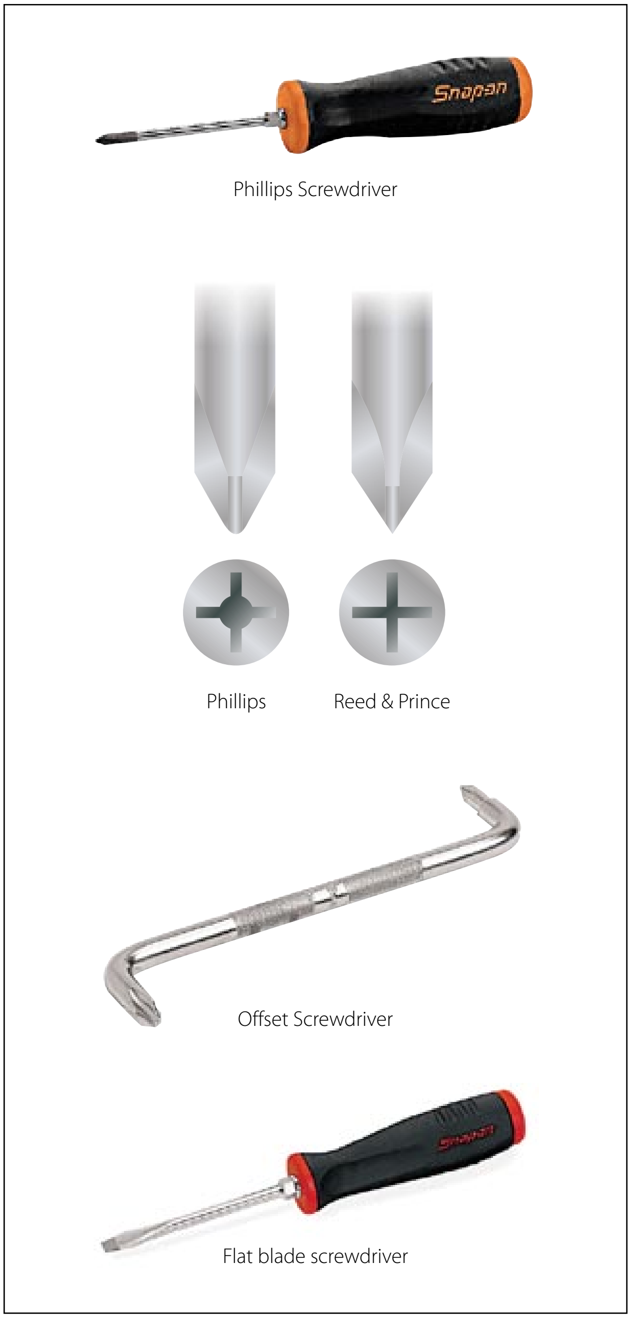

Figure 9-2. Typical screwdrivers.

pose, i.e., for loosening or tightening screws or screw head bolts. Figure 9-2 shows several different types of screwdrivers. When using the common screwdriver, select the largest screwdriver whose blade will make a good fit in the screw that is to be turned.

A common screwdriver must fill at least 75 percent of the screw slot. If the screwdriver is the wrong size, it cuts and burrs the screw slot, making it worthless. The damage may be so severe that the use of screw extractor may be required. A screwdriver with the wrong size blade may slip and damage adjacent parts of the structure.

The common screwdriver is used only where slotted head screws or fasteners are found on aircraft. An example of a fastener that requires the use of a common screwdriver is the camlock style fastener that is used to secure the cowling on some aircraft.

The two types of recessed head screws in common use are the Phillips and the Reed & Prince.

Both the Phillips and Reed & Prince recessed heads are optional on several types of screws. As shown in Figure 9-2, the Reed & Prince recessed head forms a perfect cross. The screwdriver used with this screw is pointed on the end. Since the Phillips screw has a slightly larger center in the cross, the Phillips screwdriver is blunt on the end. The Phillips screwdriver is not interchangeable with the Reed & Prince. The use of the wrong type screwdriver results in mutilation of the screwdriver and the screw head. When turning a recessed head screw, use only the proper recessed head screwdriver of the correct size. The most common crosspoint screwdrivers are the Number 1 and Number 2 Phillips.

An offset screwdriver may be used when vertical space is limited. Offset screwdrivers are constructed with both ends bent 90° to the shank handle. By using alternate ends, most screws can be seated or loosened even when the swinging space is limited. Offset screwdrivers are made for both standard and recessed head screws. Ratcheting right angle screwdrivers are also available, and often prove to be indispensable when working in close quarters.

A screwdriver should not be used for chiseling or prying. Do not use a screwdriver to check an electric circuit since an electric arc will burn the tip and make it useless. In some cases, an electric arc may fuse the blade to the unit being checked, creating a short circuit.

When using a screwdriver on a small part, always hold the part in the vise or rest it on a workbench. Do not hold the part in the hand, as the screwdriver may slip and cause serious personal injury.

Replaceable tip screwdrivers, commonly referred to as "10 in 1" screwdrivers, allow for the quick changing of a screwdriver tip, and economical replacement of the tip when it becomes worn. A wide variety of screwdriver tips, including flat, crosspoint (Phillips and Reed & Prince), Torx and square drive tips are available for use with the handles. [Figure 9-3]

The cordless hand-held power screwdriver has replaced most automatic or spiral screwdrivers for the removal of multiple screws from an airframe. Care must be

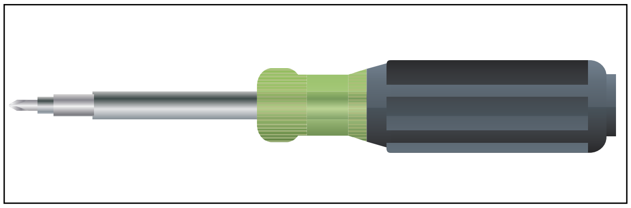

Figure 9-3. Replaceable tip screwdriver.

exercised when using a power screwdriver; if the slip clutch is set for too high a setting when installing a screw, the screwdriver tip will slip and rotate on top of the screw head, damaging it. The screw should be started by hand, to avoid driving the screw into the nut or nutplate in a cross-threaded manner. To avoid damaging the slot or receptacle in the head of the screw, the use of cordless power drills fitted with a removable tip driver to remove or install screws is not recommended, as the drill does not have a slip-clutch installed.

Pliers and Plier-Type Cutting Tools

As shown in Figure 9-4, the pliers used most frequently in aircraft repair work are the diagonal, needlenose, and duckbill. The size of pliers indicates their overall length, usually ranging from 5 to 12 inches.

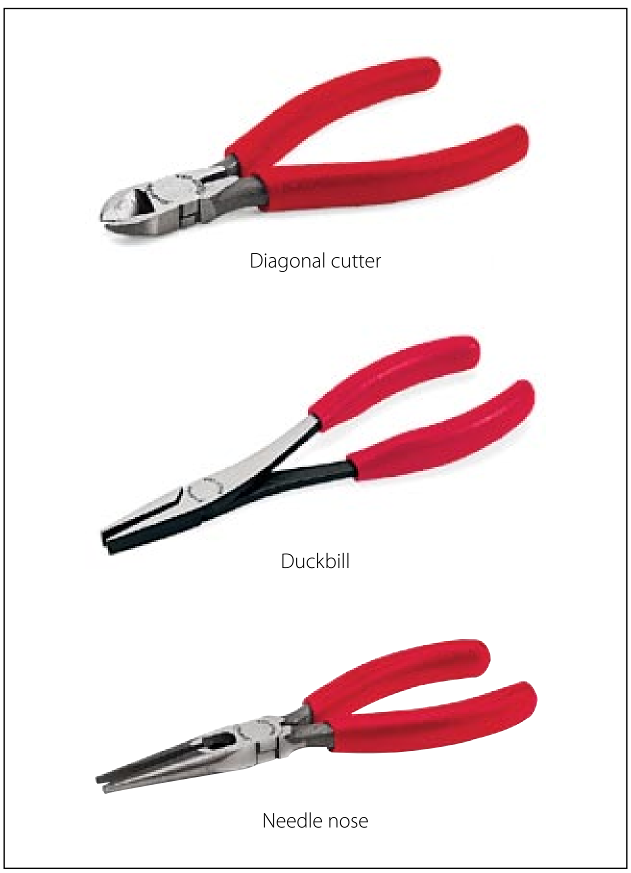

Figure 9-4. Pliers.

Roundnose pliers are used to crimp metal. They are not made for heavy work because too much pressure will spring the jaws, which are often wrapped to prevent scarring the metal.

Needlenose pliers have half round jaws of varying lengths. They are used to hold objects and make adjustments in tight places.

Duckbill pliers resemble a "duck's bill" in that the jaws are thin, flat, and shaped like a duck's bill. They are used exclusively for twisting safety wire.

Diagonal pliers are usually referred to as diagonals or "dikes." The diagonal is a short-jawed cutter with a blade set at a slight angle on each jaw. This tool can be used to cut wire, rivets, small screws, and cotter pins, besides being practically indispensable in removing or installing safety wire. The duckbill pliers and the diagonal cutting pliers are used extensively in aviation for the job of safety wiring.

Two important rules for using pliers are:

1. Do not make pliers work beyond their capacity. The long-nosed variety is especially delicate. It is easy to spring or break them, or nick the edges. If this occurs, they are practically useless.
2. Do not use pliers to turn nuts. In just a few seconds, a pair of pliers can damage a nut more than years of service.

Punches

Punches are used to locate centers for drawing circles, to start holes for drilling, to punch holes in sheet metal, to transfer location of holes in patterns, and to remove damaged rivets, pins or bolts.

Solid or hollow punches are the two types generally used. Solid punches are classified according to the shape of their points. Figure 9-5 shows several types of punches.

Prick punches are used to place reference marks on metal. This punch is often used to transfer dimensions from a paper pattern directly on the metal. To do this, first place the paper pattern directly on the metal. Then go over the outline of the pattern with the prick punch, tapping it lightly with a small hammer and making slight indentations on the metal at the major points on the drawing. These indentations can then be used as reference marks for cutting the metal. A prick punch should never be struck a heavy blow with a hammer because it may bend the punch or cause excessive damage to the material being worked.

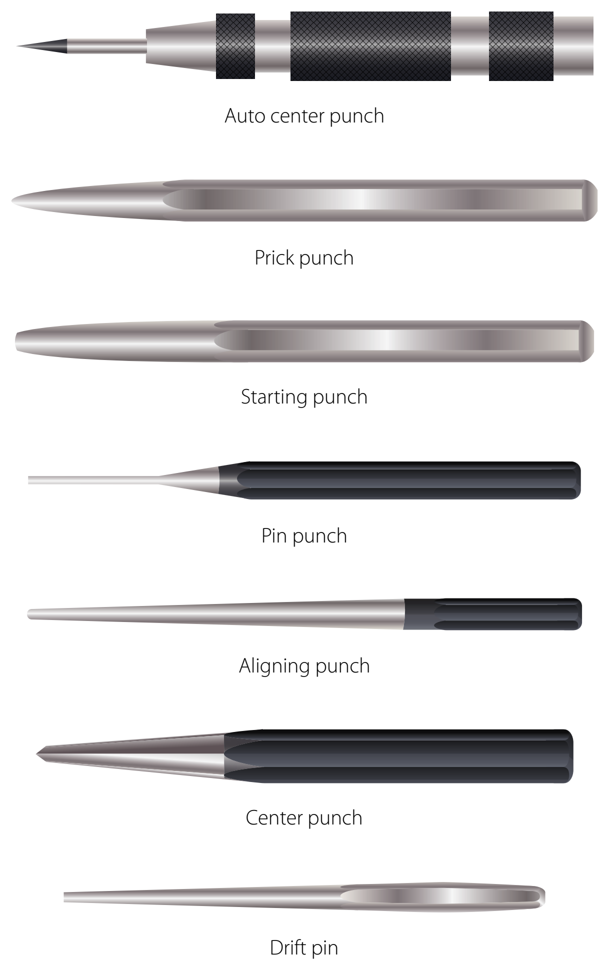

Figure 9-5. Punches.

Large indentations in metal, which are necessary to start a twist drill, are made with a center punch. It should never be struck with enough force to dimple the material around the indentation or to cause the metal to protrude through the other side of the sheet. A center punch has a heavier body than a prick punch and is ground to a point with an angle of about 60°.

The drive punch, which is often called a tapered punch, is used for driving out damaged rivets, pins, and bolts that sometimes bind in holes. The drive punch is therefore made with a flat face instead of a point. The size of the punch is determined by the width of the face, which is usually $\frac{1}{8}$ inch to $\frac{1}{4}$ inch.

Pin punches, often called drift punches, are similar to drive punches and are used for the same purposes. The difference between the two is that the sides of a drive punch taper all the way to the face while the pin punch has a straight shank. Pin punches are sized by the diameter of the face, in thirty-seconds of an inch, and range from $\frac{1}{16}$ to $\frac{3}{8}$ inch in diameter.

In general practice, a pin or bolt which is to be driven out is usually started and driven with a drive punch until the sides of the punch touch the side of the hole. A pin punch is then used to drive the pin or bolt the rest of the way out of the hole. Stubborn pins may be started by placing a thin piece of scrap copper, brass, or aluminum directly against the pin and then striking it with a hammer until the pin begins to move.

Never use a prick punch or center punch to remove objects from holes because the point of the punch will spread the object and cause it to bind even more.

The transfer punch is usually about 4 inches long. It has a point that tapers, and then turns straight for a short distance in order to fit a drill locating hole in a template. The tip has a point similar to that of a prick punch. As its name implies, the transfer punch is used to transfer the location of holes through the template or pattern to the material.

Wrenches

The wrenches most often used in aircraft maintenance are classified as open-end, box-end, socket, adjustable, ratcheting and special wrenches. The Allen wrench, although seldom used, is required on one special type of recessed screw. One of the most widely used metals for making wrenches is chrome-vanadium steel. Wrenches made of this metal are almost unbreakable. Solid, nonadjustable wrenches with open parallel jaws on one or both ends are known as open-end wrenches. These wrenches may have their jaws parallel to the handle or at an angle up to 90°; most are set at an angle of 15°. The wrenches are designed to fit a nut, bolt head, or other object, which makes it possible to exert a turning action.

Box-end wrenches are popular tools because of their usefulness in close quarters. They are called box wrenches since they box, or completely surround, the nut or bolt head. Practically all well-manufactured box-end wrenches are made with 12 points so they can be used in places having as little as 15° swing. In Figure 9-6, point A on the illustrated double broached hexagon wrench is nearer the centerline of the head and the wrench handle than point B, and also the centerline of nut C. If the wrench is inverted and installed on nut C, point A will be centered over side "Y" instead of side "X." The centerline of the handle will now be in the dotted line position. It is by reversing (turning the

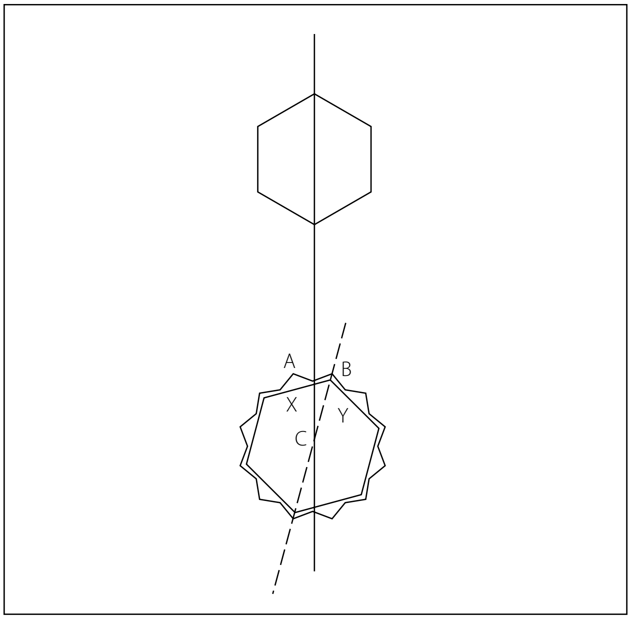

Figure 9-6. Box-end wrench use.

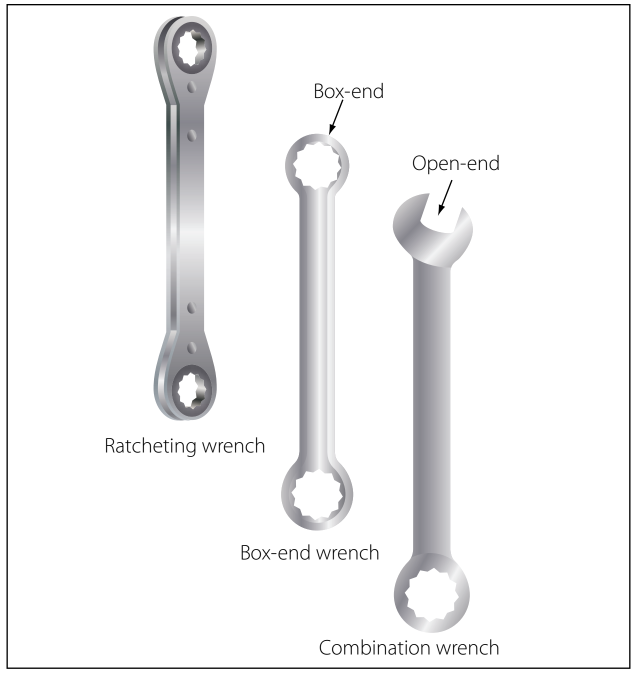

Figure 9-7. Box-end and combination wrenches.

wrench over) the position of the wrench that a 15° arc may be made with the wrench handle.

Although box-end wrenches are ideal to break loose tight nuts or pull tight nuts tighter, time is lost turning the nut off the bolt once the nut is broken loose. Only when there is sufficient clearance to rotate the wrench in a complete circle can this tedious process be avoided.

After a tight nut is broken loose, it can be completely backed off or unscrewed more quickly with an open-end than with a box-end wrench. In this case, a combination wrench can be used; it has a box end on one end and an open-end wrench of the same size on the other.

Another option for removing a nut from a bolt is the ratcheting box-end wrench, which can be swung back and forth to remove the nut or bolt. The box-end, combination, and ratcheting wrenches are shown in Figure 9-7.

A socket wrench is made of two parts: (1) the socket, which is placed over the top of a nut or bolt head, and (2) a handle, which is attached to the socket. Many types of handles, extensions, and attachments are available to make it possible to use socket wrenches in almost any location or position. Sockets are made with either fixed or detachable handles. Socket wrenches with fixed handles are usually furnished as an accessory to a machine. They have either a four, six, or twelve-sided recess to fit a nut or bolt head that needs regular adjustment.

Sockets with detachable handles usually come in sets and fit several types of handles, such as the T, ratchet, screwdriver grip, and speed handle. Socket wrench handles have a square lug on one end that fits into a square recess in the socket head. The two parts are held together by a light spring-loaded poppet. Two types of sockets, a set of handles, and an extension bar are shown in Figure 9-8.

The adjustable wrench is a handy utility tool that has smooth jaws and is designed as an open-end wrench. One jaw is fixed, but the other may be moved by a thumbscrew or spiral screwworm adjustment in the handle. The width of the jaws may be varied from 0 to $\frac{1}{2}$ inch or more. The angle of the opening to the handle is $22\frac{1}{2}$ degrees on an adjustable wrench. One adjustable wrench does the work of several open-end wrenches. Although versatile, they are not intended to replace the standard open-end, box-end, or socket wrenches. When using any adjustable wrench, always exert the pull on the side of the handle attached to the fixed jaw of the wrench. To minimize the possibility or rounding off the fastener, use care to fit the wrench to the bolt or nut to be turned.

Special Wrenches

The category of special wrenches includes the crowfoot, flare nut, spanner, torque, and Allen wrenches. [Figures 9-9 and 9-10]

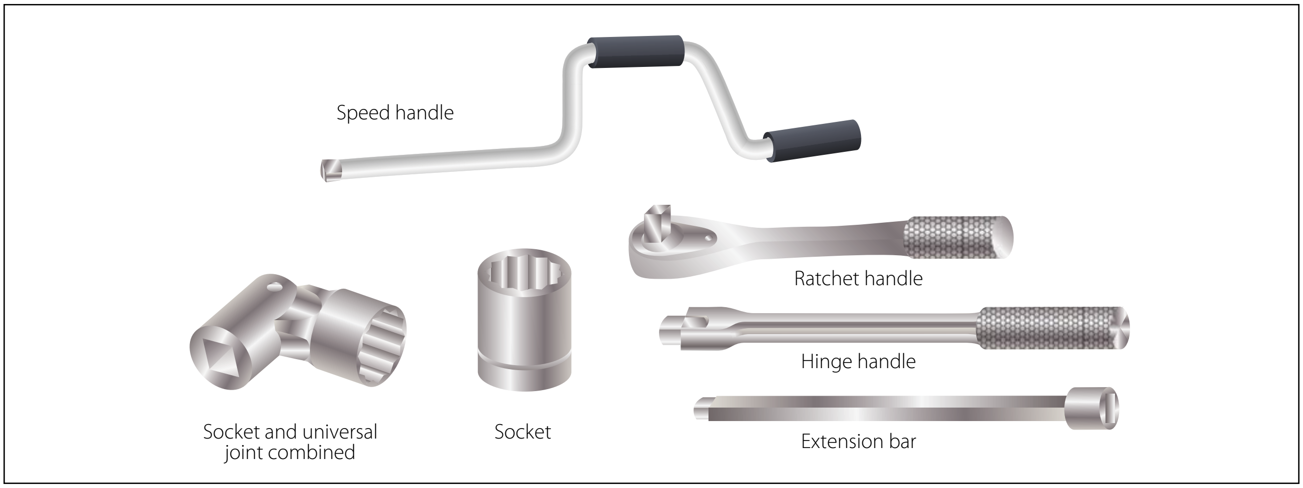

Figure 9-8. Socket wrench set.

The crowfoot wrench is normally used when accessing nuts that must be removed from studs or bolt that cannot be accessed using other tools.

The flare nut wrench has the appearance of a box-end wrench that has been cut open on one end. This opening allows the wrench to be used on the B-nut of a fuel, hydraulic, or oxygen line. Since it mounts using the standard square adapter, like the crowfoot wrench, it can be used in conjunction with a torque wrench.

The hook spanner is for a round nut with a series of notches cut in the outer edge. This wrench has a curved arm with a hook on the end that fits into one of the

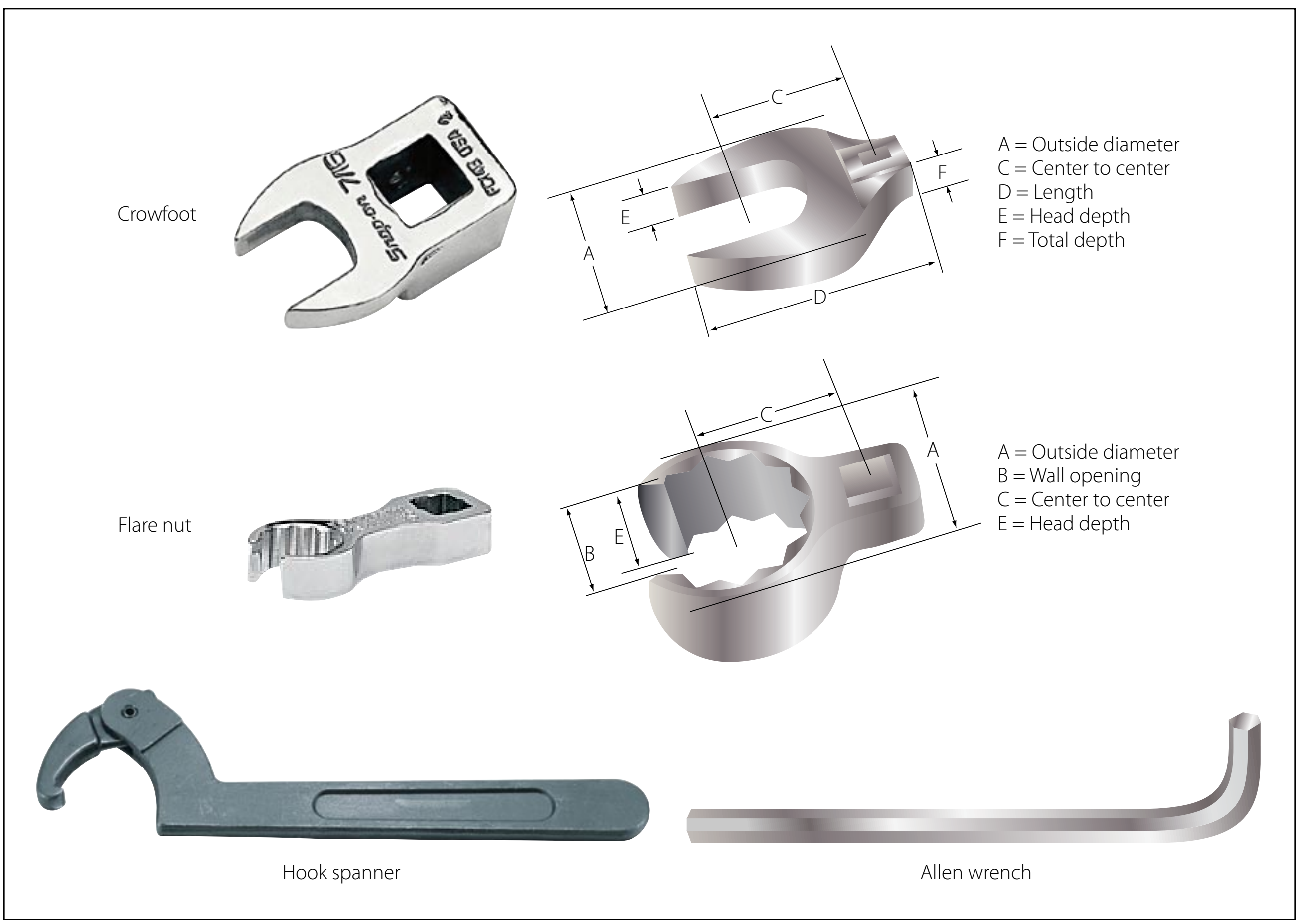

Figure 9-9. Special wrenches.

notches on the nut. The hook is placed in one of these notches with the handle pointing in the direction the nut is to be turned.

Some hook spanner wrenches are adjustable and will fit nuts of various diameters. U-shaped hook spanners have two lugs on the face of the wrench to fit notches cut in the face of the nut or screw plug. End spanners resemble a socket wrench, but have a series of lugs that fit into corresponding notches in a nut or plug. Pin spanners have a pin in place of a lug, and the pin fits into a round hole in the edge of a nut. Face pin spanners are similar to the U-shaped hook spanners except that they have pins instead of lugs.

Most headless setscrews are the hex-head Allen type and must be installed and removed with an Allen wrench. Allen wrenches are six-sided bars in the shape of an L, or they can be hex-shaped bars mounted in adapters for use with hand ratchets. They range in size from $\frac{3}{64}$ to $\frac{1}{2}$ inch and fit into a hexagonal recess in the setscrew.

Torque Wrench

There are times when definite pressure must be applied to a nut or bolt as it is installed. In such cases a torque wrench must be used. The torque wrench is a precision tool consisting of a torque indicating handle and appropriate adapter or attachments. It measures the amount of turning or twisting force applied to a nut, bolt, or screw.

Before each use, the torque wrench should be visually inspected for damage. If a bent pointer, cracked or broken glass (dial type), or signs of rough handling are found, the wrench must be tested. Torque wrenches must be tested at periodic intervals to ensure accuracy.

Commonly used torque wrenches include the deflecting beam (not shown), dial indicating, micrometer, and electronic setting types. [Figure 9-10]

When using the deflecting beam and the dial indicating torque wrenches, the torque is read visually on a dial or scale mounted on the handle of the wrench. The micrometer setting torque wrench is preset to the desired torque. When this torque is reached, the operator notices a sharp impulse or breakaway "click." For additional information on the installation of fasteners requiring the use of a torque wrench, refer to "Installation of Nuts, Washers, and Bolts" located in chapter 5.

Figure 9-10. Torque wrenches.

Strap Wrenches

The strap wrench can prove to be an invaluable tool for the AMT. By their very nature, aircraft components such as tubing, pipes, small fittings, and round or irregularly shaped components are built to be as light as possible, while still retaining enough strength to function properly. The misuse of pliers or other gripping tools can quickly damage these parts. If it is necessary to grip a part to hold it in place, or to rotate it to facilitate removal, consider using a strap wrench that uses a plastic covered fabric strap to grip the part. [Figure 9-11]

Figure 9-11. Strap wrench.

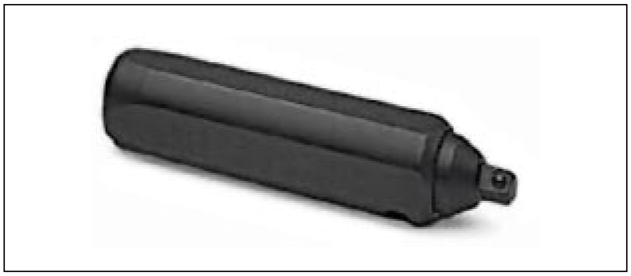

Figure 9-12. Impact driver.

Impact Drivers

In certain applications, the use of an impact driver may be required. Struck with a mallet, the impact driver uses cam action to impart a high amount of torque in a sharp impact to break loose a stubborn fastener. The drive portion of the impact driver can accept a number of different drive bits and sockets. The use of special bits and sockets specifically manufactured for use with an impact driver is required. [Figure 9-12]

Metal Cutting Tools

Hand Snips

There are several kinds of hand snips, each of which serves a different purpose. Straight, curved, hawksbill, and aviation snips are in common use. Straight snips are used for cutting straight lines when the distance is not great enough to use a squaring shear and for cutting the outside of a curve. The other types are used for cutting the inside of curves or radii. Snips should never be used to cut heavy sheet metal. [Figure 9-13]

Figure 9-13. Typical snips.

Aviation snips are designed especially for cutting heat-treated aluminum alloy and stainless steel. They are also adaptable for enlarging small holes. The blades have small teeth on the cutting edges and are shaped for cutting very small circles and irregular outlines. The handles are the compound leverage type, making it possible to cut material as thick as 0.051 inch. Aviation snips are available in two types, those which cut from right to left and those which cut from left to right.

Unlike the hacksaw, snips do not remove any material when the cut is made, but minute fractures often occur along the cut. Therefore, cuts should be made about $\frac{1}{32}$ inch from the layout line and finished by hand filing down to the line.

Hacksaws

The common hacksaw has a blade, a frame, and a handle. The handle can be obtained in two styles: pistol grip and straight. [Figure 9-14]

Hacksaw blades have holes in both ends; they are mounted on pins attached to the frame. When installing a blade in a hacksaw frame, mount the blade with the teeth pointing forward, away from the handle.

Blades are made of high-grade tool steel or tungsten steel and are available in sizes from 6 to 16 inches in length. The 10-inch blade is most commonly used. There are two types, the all-hard blade and the flexible blade. In flexible blades, only the teeth are hardened.

Selection of the best blade for the job involves finding the right type and pitch. An all-hard blade is best for sawing brass, tool steel, cast iron, and heavy cross-section materials. A flexible blade is usually best for sawing hollow shapes and metals having a thin cross section.

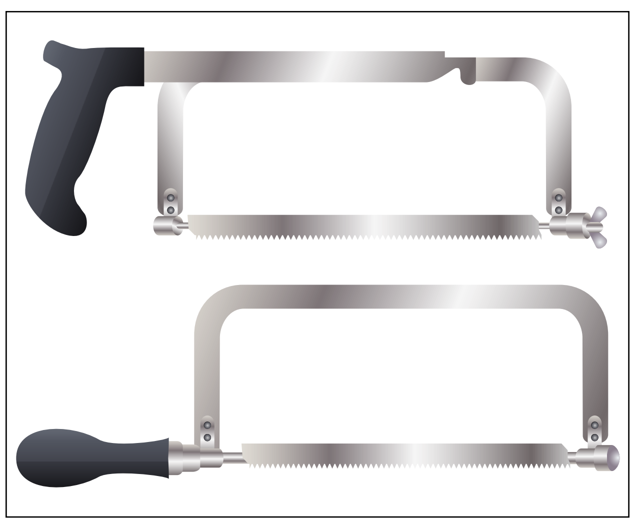

Figure 9-14. Hacksaws.

The pitch of a blade indicates the number of teeth per inch. Pitches of 14, 18, 24, and 32 teeth per inch are available. A blade with 14 teeth per inch is preferred when cutting machine steel, cold rolled steel, or structural steel. A blade with 18 teeth per inch is preferred for solid stock aluminum, bearing metal, tool steel, and cast iron. Use a blade with 24 teeth per inch when cutting thick-walled tubing, pipe, brass, copper, channel, and angle iron. Use the 32 teeth per inch blade for cutting thin-walled tubing and sheet metal. When using a hacksaw, observe the following procedures:

1. Select an appropriate saw blade for the job.
2. Assemble the blade in the frame so that the cutting edge of the teeth points away from the handle.
3. Adjust tension of the blade in the frame to prevent the saw from buckling and drifting.
4. Clamp the work in the vise in such a way that will provide as much bearing surface as possible and will engage the greatest number of teeth.
5. Indicate the starting point by nicking the surface with the edge of a file to break any sharp corner that might strip the teeth. This mark will also aid in starting the saw at the proper place.
6. Hold the saw at an angle that will keep at least two teeth in contact with the work at all times. Start the cut with a light, steady, forward stroke just outside the cutting line. At the end of the stroke, relieve the pressure and draw the blade back. (The cut is made on the forward stroke.)
7. After the first few strokes, make each stroke as long as the hacksaw frame will allow. This will prevent the blade from overheating. Apply just enough pressure on the forward stroke to cause each tooth to remove a small amount of metal. The strokes should be long and steady with a speed not more than 40 to 50 strokes per minute.
8. After completing the cut, remove chips from the blade, loosen tension on the blade, and return the hacksaw to its proper place.

Chisels

A chisel is a hard steel cutting tool that can be used for cutting and chipping any metal softer than the chisel itself. It can be used in restricted areas and for such work as shearing rivets, or splitting seized or damaged nuts from bolts. [Figure 9-15]

The size of a flat cold chisel is determined by the width of the cutting edge. Lengths will vary, but chisels are seldom under 5 inches or over 8 inches long.

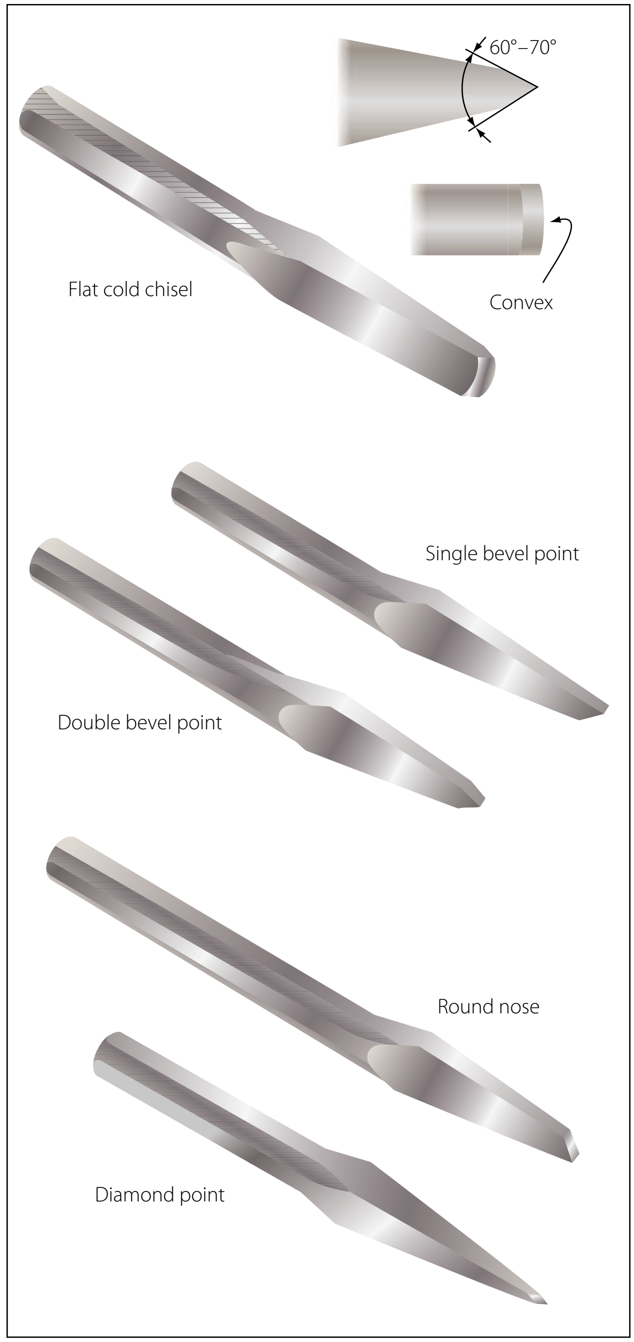

Figure 9-15. Chisels.

Chisels are usually made of eight-sided tool steel bar stock, carefully hardened and tempered. Since the cutting edge is slightly convex, the center portion receives the greatest shock when cutting, and the weaker corners are protected. The cutting angle should be 60° to 70° for general use, such as for cutting wire, strap iron, or small bars and rods.

When using a chisel, hold it firmly in one hand. With the other hand, strike the chisel head squarely with a ball peen hammer.

When cutting square corners or slots, a special cold chisel called a cape chisel should be used. It is like a flat chisel except the cutting edge is very narrow. It has the same cutting angle and is held and used in the same manner as any other chisel.

Rounded or semicircular grooves and corners that have fillets should be cut with a roundnose chisel. This chisel is also used to re-center a drill that has moved away from its intended center.

The diamond point chisel is tapered square at the cutting end, and then ground at an angle to provide the sharp diamond point. It is used for cutting B-grooves and inside sharp angles.

Files

Most files are made of high-grade tool steels that are hardened and tempered. Files are manufactured in a variety of shapes and sizes. They are known either by the cross section, the general shape, or by their particular use. The cuts of files must be considered when selecting them for various types of work and materials.

Files are used to square ends, file rounded corners, remove burrs and slivers from metal, straighten uneven edges, file holes and slots, and smooth rough edges.

Files have three distinguishing features: (1) their length, measured exclusive of the tang [Figure 9-16]; (2) their kind or name, which has reference to the relative coarseness of the teeth; and (3) their cut.

Files are usually made in two types of cuts: single cut and double cut. The single cut file has a single row of teeth extending across the face at an angle of 65° to 85° with the length of the file. The size of the cuts depends on the coarseness of the file. The double cut file has two rows of teeth that cross each other. For general work, the angle of the first row is 40° to 45°. The first row is generally referred to as "overcut," and the second row as "upcut;" the upcut is somewhat finer and not as deep as the overcut.

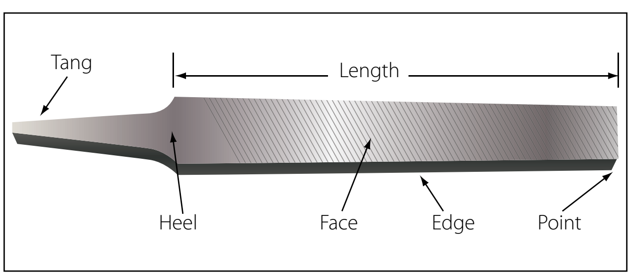

Figure 9-16. Hand file.

Files — Care and Use

Files and rasps are catalogued in three ways:

- *Length.* Measuring from the tip to the heel of the file. The tang is never included in the length.
- *Shape.* Refers to the physical configuration of the file (circular, rectangular, or triangular or a variation thereof).
- *Cut.* Refers to both the character of the teeth or the coarseness — rough, coarse, and bastard for use on heavier classes of work and second cut, smooth and dead smooth for finishing work.

Most Commonly Used Files [Figure 9-17]

Hand files — These are parallel in width and tapered in thickness. They have one safe edge (smooth edge) which permits filing in corners, and on other work where a safe edge is required. Hand files are double cut and used principally for finishing flat surfaces and similar work.

Flat files — These files are slightly tapered toward the point in both width and thickness. They cut on both edges as well as on the sides. They are the most common files in use. Flat files are double cut on both sides and single cut on both edges.

Mill files — These are usually tapered slightly in thickness and in width for about one-third of their length. The teeth are ordinarily single cut. These files are used for drawfiling and to some extent for filing soft metals.

Square files — These files may be tapered or blunt and are double cut. They are used principally for filing slots and key seats, and for surface filing.

Round or rattail files — These are circular in cross section and may be either tapered or blunt and single or double cut. They are used principally for filing circular openings or concave surfaces.

Triangular and three square files — These files are triangular in cross section. Triangular files are single cut and are used for filing the gullet between saw teeth. Three square files, which are double cut, may be used for filing internal angles, clearing out corners, and filing taps and cutters.

Half-round files — These files cut on both the flat and round sides. They may be single or double cut. Their shape permits them to be used where other files would be unsatisfactory.

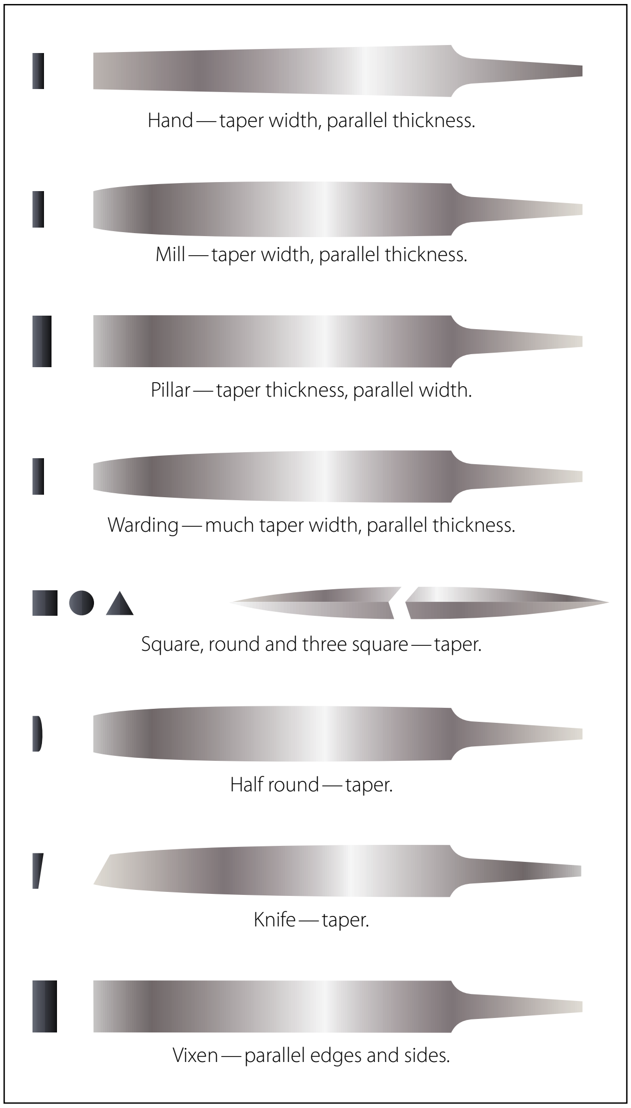

Figure 9-17. Types of files.

Lead float files—These are especially designed for use on soft metals. They are single cut and are made in various lengths.

Warding file—Rectangular in section and tapers to narrow point in width. This file is used for narrow space filing where other files cannot be used.

Knife file—Knife blade section. This file is used by tool and die makers on work having acute angles.

Wood file—Same section as flat and half-round files. This file has coarser teeth and is especially adaptable for use on wood.

Vixen (curved-tooth files)—Curved-tooth files are especially designed for rapid filing and smooth finish on soft metals and wood. The regular cut is adapted for tough work on cast iron, soft steel, copper, brass, aluminum, wood, slate, marble, fiber, rubber, and so forth. The fine cut gives excellent results on steel, cast iron, phosphor bronze, white brass, and all hard metals. The smooth cut is used where the amount of material to be removed is very slight, but where a superior finish is desired.

The following methods are recommended for using files:

1. *Crossfiling.* Before attempting to use a file, place a handle on the tang of the file. This is essential for proper guiding and safe use. In moving the file endwise across the work (commonly known as crossfiling), grasp the handle so that its end fits into and against the fleshy part of the palm with the thumb lying along the top of the handle in a lengthwise direction. Grasp the end of the file between the thumb and first two fingers. To prevent undue wear of the file, relieve the pressure during the return stroke.
2. *Drawfiling.* A file is sometimes used by grasping it at each end, crosswise to the work, then moving it lengthwise with the work. When done properly, work may be finished somewhat finer than when crossfiling with the same file. In drawfiling, the teeth of the file produce a shearing effect. To accomplish this shearing effect, the angle at which the file is held with respect to its line of movement varies with different files, depending on the angle at which the teeth are cut. Pressure should be relieved during the backstroke.
3. *Rounding corners.* The method used in filing a rounded surface depends upon its width and the radius of the rounded surface. If the surface is narrow or only a portion of a surface is to be rounded, start the forward stroke of the file with the point of the file inclined downward at approximately a 45° angle. Using a rocking chair motion, finish the stroke with the heel of the file near the curved surface. This method allows use of the full length of the file.
4. *Removing burred or slivered edges.* Practically every cutting operation on sheet metal produces burrs or slivers. These must be removed to avoid personal injury and to prevent scratching and marring of parts to be assembled. Burrs and slivers will prevent parts from fitting properly and should always be removed from the work as a matter of habit.

Lathe filing requires that the file be held against the work revolving in the lathe. The file should not be held rigid or stationary but should be stroked constantly with a slight gliding or lateral motion along the work. A standard mill file may be used for this operation, but the long angle lathe file provides a much cleaner shearing and self-clearing action. Use a file with "safe" edges to protect work with shoulders from being marred.

Care of Files

There are several precautions that any good craftsman will take in caring for files.

1. Choose the right file for the material and work to be performed.
2. Keep all files racked and separated so they do not bear against each other.
3. Keep the files in a dry place—rust will corrode the teeth points, dulling the file.
4. Keep files clean. Tap the end of the file against the bench after every few strokes, to loosen and clear the filings. Use the file card to keep files clean—a dirty file is a dull file. A dirty file can also contaminate different metals when the same file is used on multiple metal surfaces.

Particles of metal collect between the teeth of a file and may make deep scratches in the material being filed. When these particles of metal are lodged too firmly between the teeth and cannot be removed by tapping the edge of the file, remove them with a file card or wire brush. Draw the brush across the file so that the bristles pass down the gullet between the teeth. [Figure 9-18]

Drills

There are generally four types of portable drills used in aviation for holding and turning twist drills. Holes ¼ inch in diameter and under can be drilled using a hand drill. This drill is commonly called an "egg beater." The breast drill is designed to hold larger size twist drills than the hand drill. In addition, a breastplate is affixed at the upper end of the drill to permit the use of body weight to increase the cutting power of the drill. Electric and pneumatic power drills are available in various shapes and sizes to satisfy almost any requirement.

Figure 9-18. File card.

Pneumatic drills are preferred for use around flammable materials, since sparks from an electric drill are a fire or explosion hazard.

Twist Drills

A twist drill is a pointed tool that is rotated to cut holes in material. It is made of a cylindrical hardened steel bar having spiral flutes (grooves) running the length of the body, and a conical point with cutting edges formed by the ends of the flutes.

Twist drills are made of carbon steel or high-speed alloy steel. Carbon steel twist drills are satisfactory for the general run of work and are relatively inexpensive. The more expensive high-speed twist drills are used for the tough materials such as stainless steels. Twist drills have from one to four spiral flutes. Drills with two flutes are used for most drilling; those with three or four flutes are used principally to follow smaller drills or to enlarge holes.

The principal parts of a twist drill are the shank, the body, and the heel. [Figure 9-19] The drill shank is the end that fits into the chuck of a hand or power drill. The two shank shapes most commonly used in hand drills are the straight shank and the square or bit stock shank. The straight shank generally is used in hand, breast, and portable electric or pneumatic drills; the square shank is made to fit into a carpenter's brace. Tapered shanks generally are used in machine shop drill presses. [Figure 9-20]

The metal column forming the core of the drill is the body. The body clearance area lies just back of the margin; it is slightly smaller in diameter than the margin, to reduce the friction between the drill and the sides of the hole. The angle at which the drill point is ground is the lip clearance angle. On standard drills used to cut steel and cast iron, the angle should be 59° from the axis of the drill. For faster drilling of soft materials, sharper angles are used.

The diameter of a twist drill may be given in one of three ways: (1) by fractions, (2) letters, or (3) numbers. Fractionally, they are classified by sixteenths of an inch (from 1⁄16 to 3½ inch), by thirty-seconds (from 1⁄32 to 2½ inch), or by sixty-fourths (from 1⁄64 to 1¼ inch). For a more exact measurement, a letter system is used with decimal equivalents: A (0.234 inch) to Z (0.413 inch). The number system of classification is

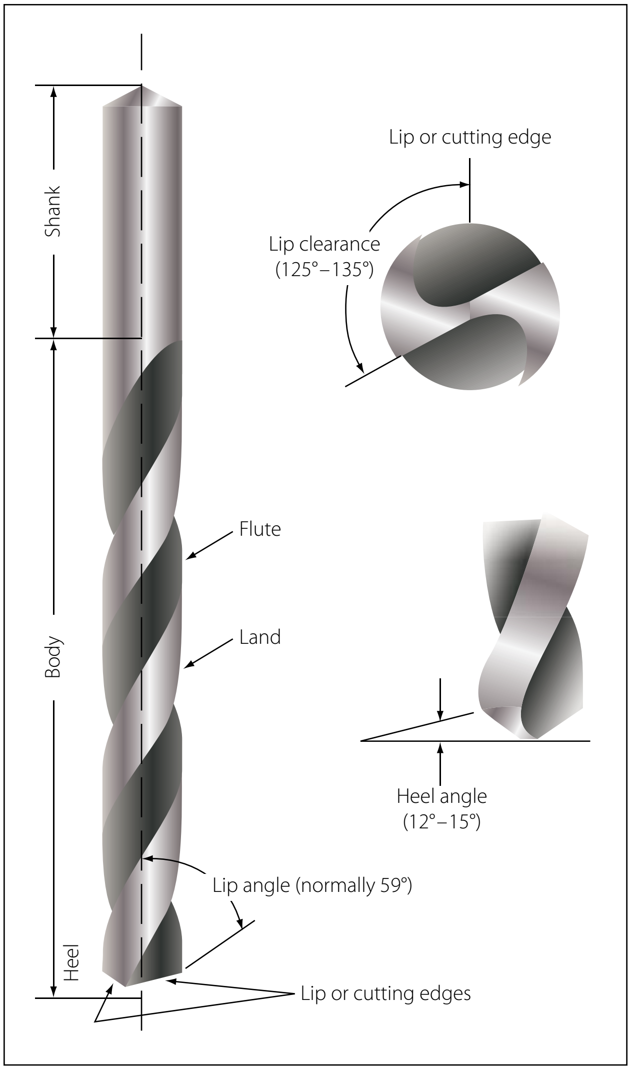

Figure 9-19. Twist drill.

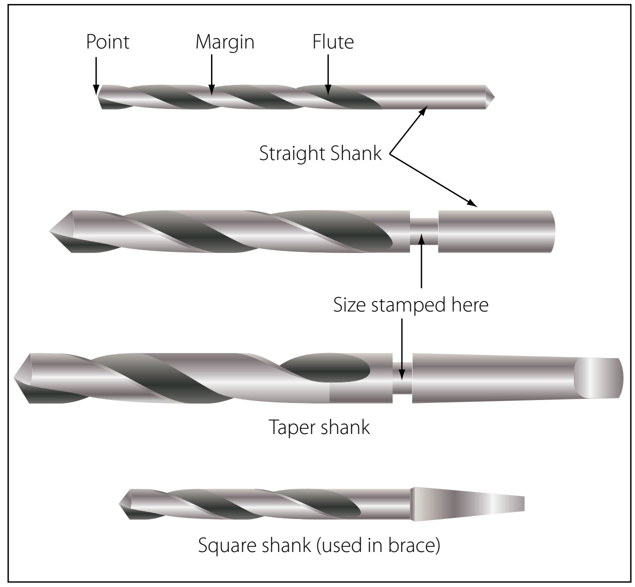

Figure 9-20. Drill types.

most accurate: No. 80 (0.0314 inch) to No. 1 (0.228 inch). Drill sizes and their decimal equivalents are shown in Figure 9-21.

The twist drill should be sharpened at the first sign of dullness. For most drilling, a twist drill with a cutting angle of 118° (59° on either side of center) will be sufficient; however, when drilling soft metals, a cutting angle of 90° may be more efficient.

Typical procedures for sharpening drills are as follows: [Figure 9-22]

1. Adjust the grinder tool rest to a convenient height for resting the back of the hand while grinding.
2. Hold the drill between the thumb and index finger of the right or left hand. Grasp the body of the drill near the shank with the other hand.
3. Place the hand on the tool rest with the centerline of the drill making a 59° angle with the cutting face of the grinding wheel. Lower the shank end of the drill slightly.
4. Slowly place the cutting edge of the drill against the grinding wheel. Gradually lower the shank of the drill as you twist the drill in a clockwise direction. Maintain pressure against the grinding surface only until you reach the heel of the drill.
5. Check the results of grinding with a gauge to determine whether or not the lips are the same length and at a 59° angle.

Alternatively, there are commercially available twist drill grinders available, as well as attachments for bench grinders which will ensure consistent, even sharpening of twist drills.

Reamers

Reamers are used to smooth and enlarge holes to exact size. Hand reamers have square end shanks so that they can be turned with a tap wrench or similar handle. The various types of reamers are illustrated in Figure 9-23.

A hole that is to be reamed to exact size must be drilled about 0.003 to 0.007 inch undersize. A cut that removes more than 0.007 inch places too much load on the reamer and should not be attempted.

Reamers are made of either carbon tool steel or high-speed steel. The cutting blades of a high-speed steel reamer lose their original keenness sooner than those

Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number
.1	.0039			—	.0410		59	2.2	.0866			—	.1470		26
.15	.0059			1.05	.0413			2.25	.0885			3.75	.1476		
.2	.0079			—	.0420		58	—	.0890		43	—	.1495		25
.25	.0098			—	.0430		57	2.3	.0905			3.8	.1496		
.3	.0118			1.1	.0433			2.35	.0925			—	.1520		24
—	.0135		80	1.15	.0452			—	.0935		42	3.9	.1535		
.35	.0138			—	.0465		56	2.38	.0937	3/32	—	—	.1540		23
—	.0145		79	1.19	.0469	3/64	—	2.4	.0945			3.97	.1562	5/32	—
.39	.0156	1/64	—	1.2	.0472			—	.0960		41	—	.1570		22
.4	.0157			1.25	.0492			2.45	.0964			4.0	.1575		
—	.0160		78	1.3	.0512			—	.0980		40	—	.1590		21
.45	.0177			—	.0520		55	2.5	.0984			—	.1610		20
—	.0180		77	1.35	.0531			—	.0995		39	4.1	.1614		
.5	.0197			—	.0550		54	—	.1015		38	4.2	.1654		
—	.0200		76	1.4	.0551			2.6	.1024			—	.1660		19
—	.0210		75	1.45	.0570			—	.1040		37	4.25	.1673		
.55	.0217			1.5	.0591			2.7	.1063			4.3	.1693		
—	.0225		74	—	.0595		53	—	.1065		36	—	.1695		18
.6	.0236			1.55	.0610			2.75	.1082			4.37	.1719	11/64	—
—	.0240		73	1.59	.0625	1/16	—	2.78	.1094	7/64	—	—	.1730		17
—	.0250		72	1.6	.0629			-	.1100		35	4.4	.1732		
.65	.0256			—	.0635		52	2.8	.1102			—	.1770		16
—	.0260		71	1.65	.0649			—	.1110		34	4.5	.1771		
—	.0280		70	1.7	.0669			—	.1130		33	—	.1800		15
.7	.0276			—	.0670		51	2.9	.1141			4.6	.1811		
—	.0292		69	1.75	.0689			—	.1160		32	—	.1820		14
.75	.0295			—	0.700		50	3.0	.1181			4.7	.1850		13
—	.0310		68	1.8	.0709			—	.1200		31	4.75	.1870		
.79	.0312	1/32	—	1.85	.0728			3.1	.1220			4.76	.1875	3/16	—
.8	.0315			—	.0730		49	3.18	.1250	1/8	—	4.8	.1890		12
—	.0320		67	1.9	.0748			3.2	.1260			—	1910		11
—	.0330		66	—	.0760		48	3.25	.1279			4.9	.1929		
.85	.0335			1.95	.0767			—	.1285		30	—	.1935		10
—	.0350		65	1.98	.0781	5/64	—	3.3	.1299			—	.1960		9
.9	.0354			—	.0785		47	3.4	.1338			5.0	.1968		
—	.0360		64	2.0	.0787			—	.1360		29	—	.1990		8
—	.0370		63	2.05	.0807			3.5	.1378			5.1	.2008		
.95	.0374			—	.0810		46	—	.1405		28	—	.2010		7
—	.0380		62	—	.0820		45	3.57	.1406	9/64		5.16	.2031	13/64	—
—	.0390		61	2.1	.0827			3.6	.1417			—	.2040		6
1.0	.0394			2.15	.0846			—	.1440		27	5.2	.2047		
—	.0400		60	—	.0860		44	3.7	.1457		—	—	.2055		5

Figure 9-21. Drill sizes.

Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number	Millimeter	Decimal Equivalent	Fractional	Number
5.25	.2067			7.25	.2854			9.5	.3740			16.5	.6496		
5.3	.2086			7.3	.2874			9.53	.3750	3/8	—	16.67	.6562	21/32	
—	.2090		4	—	2900		L	—	.3770		V	17.0	.6693		
5.4	.2126			7.4	.2913			9.6	.3780			17.06	.6719	43/64	
—	.2130			—	.2950		M	9.7	.3819			17.46	.6875	11/16	
5.5	.2165			7.5	.2953			9.75	.3838			17.5	.6890		
5.56	.2187	1/32	—	7.54	.2968	19/64	—	9.8	.3858			17.86	.7031	45/64	
5.6	.2205			7.6	.2992			—	.3860		W	18.0	7087		
—	.2210		2	—	.3020		N	9.9	.3898			18.26	.7187	23/32	
5.7	.2244			7.7	.3031			9.92	.3906	25/64	—	18.5	.7283		
5.75	.2263			7.75	.3051			10.0	.3937			18.65	.7344	47/64	
—	.2280		1	7.8	.3071				.3970		X	19.0	.7480		
5.8	.2283			7.9	.3110			—	.4040		Y	19.05	7500	3/4	
5.9	.2323			7.94	.3125	5/16	—	10.32	.4062	13/32	—	19.45	.7656	49/64	
—	.2340		A	8.0	.3150			—	.4130		Z	19.5	.7677		
5.95	.2344	15/64	—	—	.3160		O	10.5	.4134			19.84	.7812	25/32	
6.0	.2362			8.1	.3189			10.72	.4219	27/64		20.0	7874		
—	.2380		B	8.2	.3228			11.0	.4330			20.24	.7969	51/64	
6.1	.2401			—	.3230		P	11.11	.4375	7/16		20.5	.8071		
—	.2420		C	8.25	.3248			11.5	.4528			20.64	.8125	13/16	
6.2	.2441			8.3	.3268			11.51	.4531	29/64		21.0	.8268		
6.25	.2460		D	8.33	.3281	21/64	—	11.91	.4687	15/32		21.03	.8281	53/64	
6.3	.2480			8.4	.3307			12.0	.4724			21.43	.8437	27/32	
6.35	.2500	1/4	E	—	.3320		Q	12.30	.4843	31/64		21.5	.8465		
6.4	.2520			8.5	.3346			12.5	.4921			21.83	.8594	55/64	
6.5	.2559			8.6	.3386			12.7	.5000	1/2		22.0	.8661		
—	.2570		F	—	.3390		R	13.0	.5118			22.23	.8750	7/8	
6.6	.2598			8.7	.3425			13.10	.5156	33/64		22.5	.8858		
—	.2610		G	8.73	.3437	11/32	—	13.49	.5312	17/32		22.62	.8906	57/64	
6.7	.2638			8.75	.3445			13.5	.5315			23.0	.9055		
6.75	.2657	17/64	—	8.8	.3465			13.89	.5469	35/64		23.02	.9062	29/32	
6.75	.2657			—	.3480		S	14.0	.5512			23.42	.9219	59/64	
—	.2660		H	8.9	.3504			14.29	.5625	9/16		23.5	.9252		
6.8	.2677			9.0	.3543			14.5	.5709			23.81	.9375	15/16	
6.9	.2716			—	.3580		T	14.68	.5781	37/64		24.0	.9449		
—	.2720		I	9.1	.3583			15.0	.5906			24.21	.9531	61/64	
7.0	.2756			9.13	.3594	23/64	—	15.08	.5937	19/32		24.5	.9646		
—	.2770		J	9.2	.3622			15.48	.6094	39/32		24.61	.9687	31/32	
7.1	.2795			9.25	.3641			15.5	.6102			25.0	.9843		
—	.2811		K	9.3	.3661			15.88	.6250	5/8		25.03	.9844	63/64	
7.14	.2812	9/32	—	—	.3680		U	16.0	.6299			25.4	1.0000	1	
7.2	.2835			9.4	.3701			16.27	.6406	41/64					

Figure 9-21. Drill sizes (continued).

of a carbon steel reamer; however, after the first super keenness is gone, they are still serviceable. The high-speed reamer usually lasts much longer than the carbon steel type.

Reamer blades are hardened to the point of being brittle and must be handled carefully to avoid chipping them. When reaming a hole, rotate the reamer in the cutting direction only. Do not back a reamer out of a hole by rotating it opposite the cutting direction. Turn the reamer steadily and evenly to prevent chattering, or marking and scoring of the hole walls.

Reamers are available in any standard size. The straight fluted reamer is less expensive than the spiral fluted reamer, but the spiral type has less tendency to chatter. Both types are tapered for a short distance back of the end to aid in starting. Bottoming reamers have no taper and are used to complete the reaming of blind holes.

For general use, an expansion reamer is the most practical. This type is furnished in standard sizes from $\frac{1}{4}$ inch to 1 inch, increasing in diameter by $\frac{1}{32}$-inch increments.

Taper reamers, both hand and machine operated, are used to smooth and true taper holes and recesses.

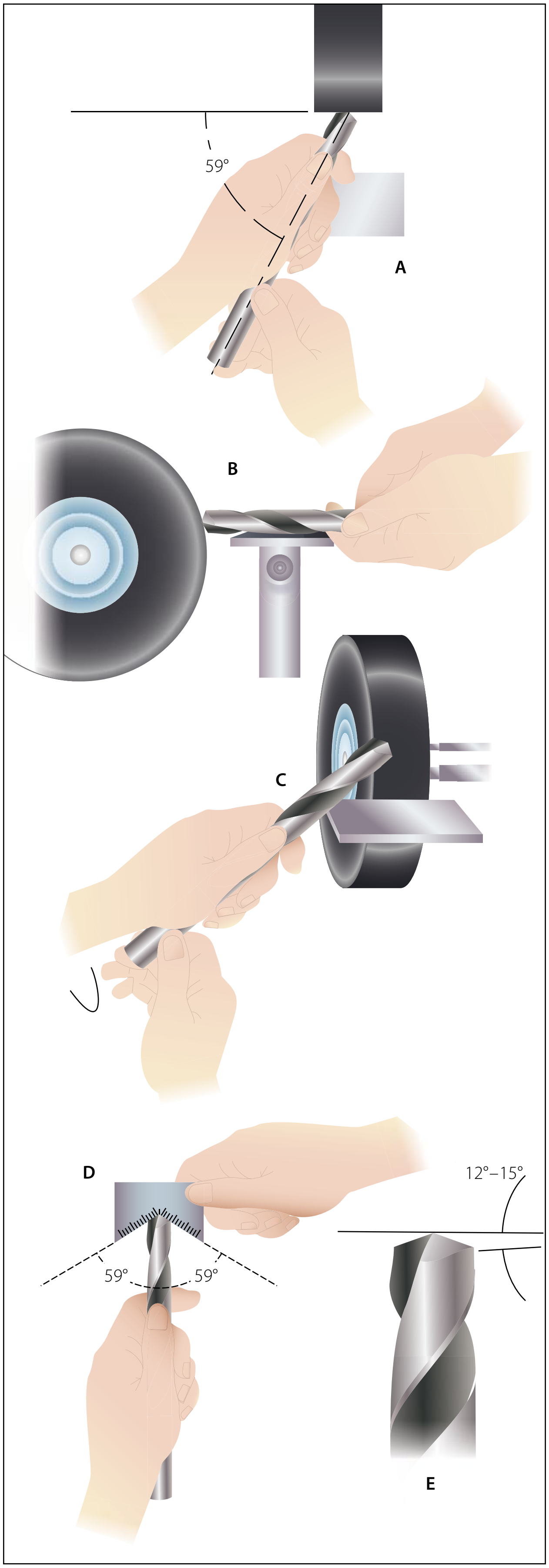

Figure 9-22. Drill sharpening procedures.

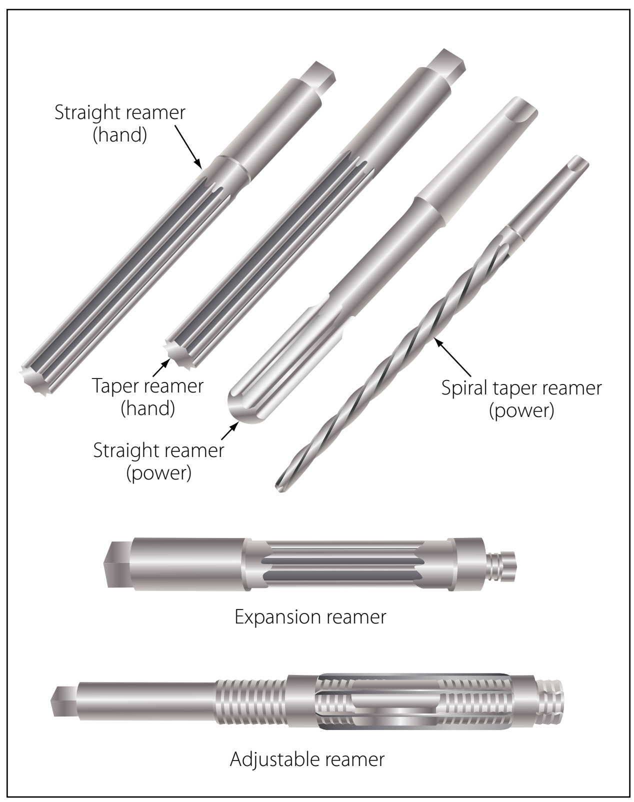

Figure 9-23. Reamers.

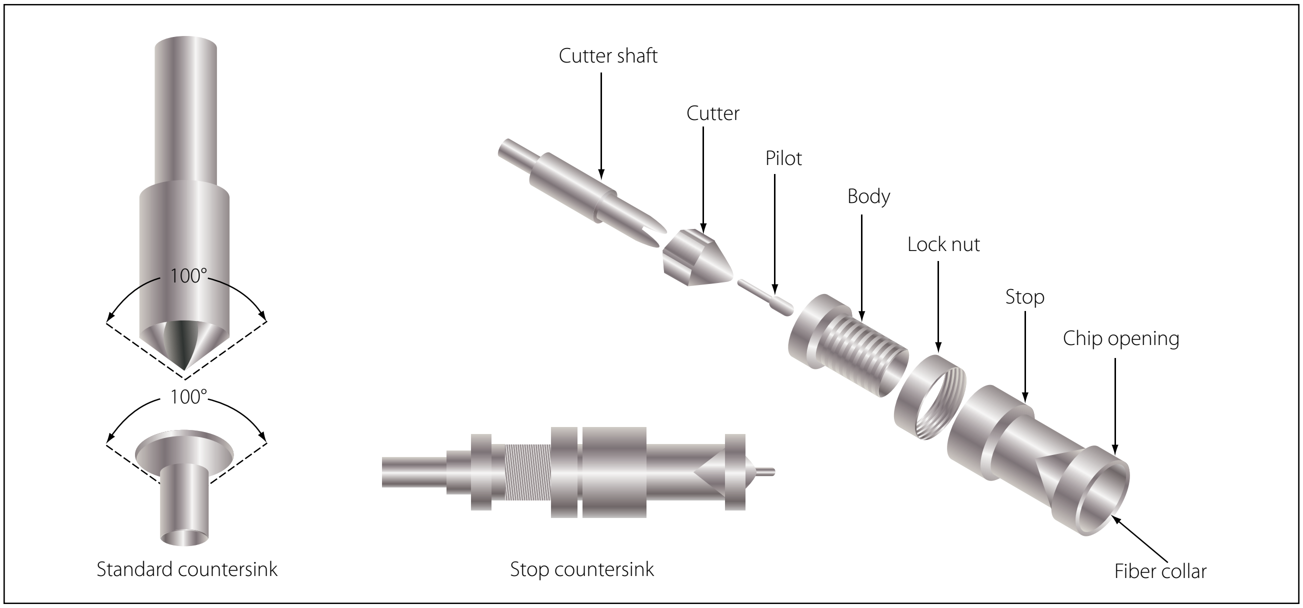

Figure 9-24. Countersinks.

Countersink

A countersink is a tool that cuts a cone shaped depression around the hole to allow a rivet or screw to set flush with the surface of the material. Countersinks are made with various angles to correspond to the various angles of the countersunk rivet and screwheads. The angle of the standard countersink shown in Figure 9-24 is 100°.

Special stop countersinks are available. Stop countersinks are adjustable to any desired depth, and the cutters are interchangeable so that holes of various countersunk angles may be made. Some stop countersinks have a micrometer set arrangement (in increments of 0.001 inch) for adjusting the cutting depths. [Figure 9-24]

When using a countersink, care must be taken not to remove an excessive amount of material, since this reduces the strength of flush joints.

Taps and Dies

A tap is used to cut threads on the inside of a hole, while a die is for cutting external threads on round stock. They are made of hard tempered steel and ground to an exact size. There are four types of threads that can be cut with standard taps and dies. They are: National Coarse, National Fine, National Extra Fine, and National Pipe.

Hand taps are usually provided in sets of three taps for each diameter and thread series. Each set contains a taper tap, a plug tap, and a bottoming tap. The taps in a set are identical in diameter and cross section; the only difference is the amount of taper. [Figure 9-25]

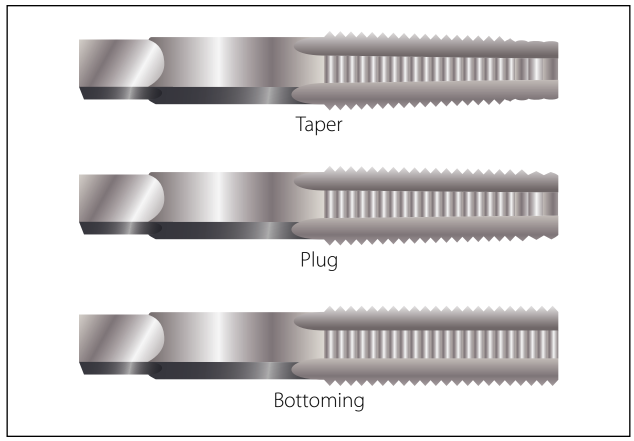

Figure 9-25. Hand taps.

The taper tap is used to begin the tapping process, because it is tapered back for 6 to 7 threads. This tap cuts a complete thread when it is cutting above the taper. It is the only tap needed when tapping holes that extend through thin sections. The plug tap supplements the taper tap for tapping holes in thick stock.

The bottoming tap is not tapered. It is used to cut full threads to the bottom of a blind hole.

Dies may be classified as adjustable round split die and plain round split die. The adjustable split die has an adjusting screw that can be tightened so that the die is

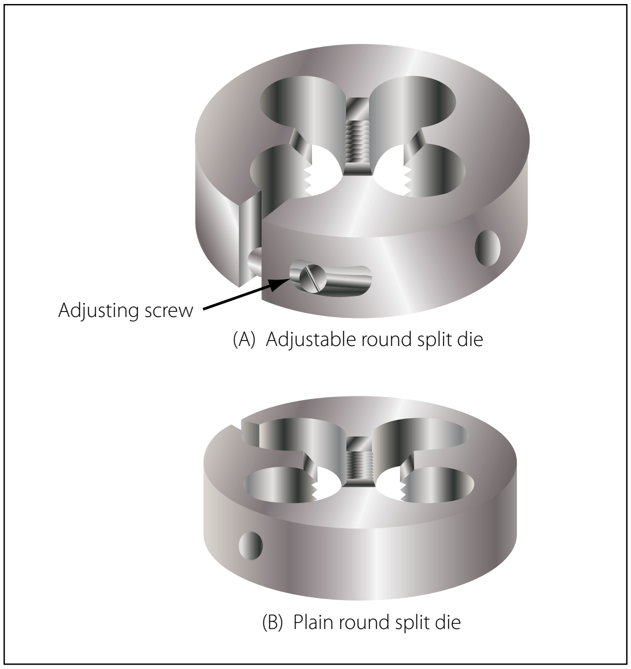

Figure 9-26. Types of dies.

spread slightly. By adjusting the die, the diameter and fit of the thread can be controlled. [Figure 9-26]

Solid dies are not adjustable; therefore, a variety of thread fits cannot be obtained with this type. There are many types of wrenches for turning taps, as well as turning dies. The T-handle, the adjustable tap wrench, and the diestock for round split dies shown in Figure 9-27 are a few of the more common types.

Information on thread sizes, fits, types, and so forth, is shown in Figures 9-28, 9-29, and 9-30.

Layout and Measuring Tools

Layout and measuring devices are precision tools. They are carefully machined, accurately marked and, in many cases, are made up of very delicate parts. When using these tools, be careful not to drop, bend, or scratch them. The finished product will be no more accurate than the measurements or the layout; therefore, it is very important to understand how to read, use, and care for these tools.

Rules

Rules are made of steel and are either rigid or flexible. The flexible steel rule will bend, but it should not be bent intentionally as it may be broken rather easily. In aircraft work, the unit of measure most commonly used is the inch. The inch may be divided into smaller parts by means of either common or decimal fraction divisions.

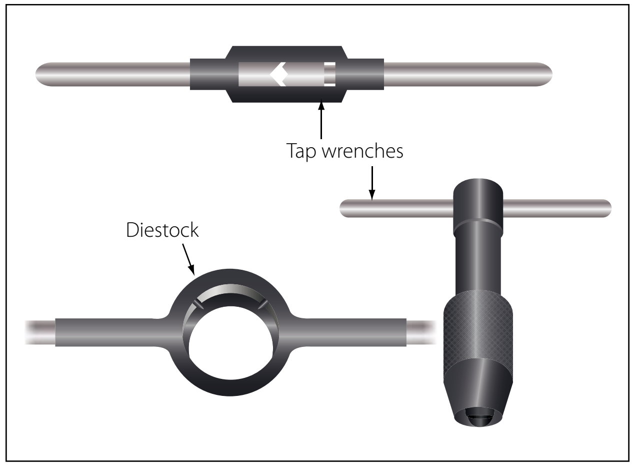

Figure 9-27. Diestock and tap wrenches.

The fractional divisions for an inch are found by dividing the inch into equal parts: halves ($\frac{1}{2}$), quarters ($\frac{1}{4}$), eighths ($\frac{1}{8}$), sixteenths ($\frac{1}{16}$), thirty-seconds ($\frac{1}{32}$), and sixty-fourths ($\frac{1}{64}$).

The fractions of an inch may be expressed in decimals, called decimal equivalents of an inch; for example, $\frac{1}{8}$ inch is expressed as 0.0125 (one hundred twenty-five ten-thousandths of an inch).

Rules are manufactured in two basic styles—those divided or marked in common fractions and those divided or marked in decimals or divisions of one one-hundredth of an inch. A rule may be used either as a measuring tool or as a straightedge. [Figure 9-31]

Combination Sets

The combination set, as its name implies, is a tool that has several uses. It can be used for the same purposes as an ordinary tri-square, but it differs from the tri-square in that the head slides along the blade and can be clamped at any desired place. Combined with the square or stock head are a level and scriber. The head slides in a central groove on the blade or scale, which can be used separately as a rule. [Figure 9-32]

The spirit level in the stock head makes it convenient to square a piece of material with a surface and at the same time tell whether one or the other is plumb or level. The head can be used alone as a simple level.

The combination of square head and blade can also be used as a marking gauge to scribe lines at a 45° angle, as a depth gauge, or as a height gauge. A convenient scriber is held frictionally in the head by a small brass bushing.

National Coarse Thread Series Medium Fit Class 3 (NC)					National Fine Thread Series Medium Fit Class 3 (NF)				
Size and Threads	Diameter of body for thread	Body Drill	Tap Drill		Size and Threads	Diameter of body for thread	Body Drill	Tap Drill	
			Preferred diameter of hole	Nearest standard drill size				Preferred diameter of hole	Nearest standard drill size
					0-80	.060	52	.0472	3⁄64″
1-64	.073	47	.0575	#53	1-72	.073	47	.0591	#53
2-56	.086	42	.0682	#51	2-64	.086	42	.0700	#50
3-48	.099	37	.078	5⁄64	3-56	.099	37	.0810	#46
4-40	.112	31	.0866	#44	4-48	.112	31	.0911	#42
5-40	.125	29	.0995	#39	5-44	.125	25	1024	#38
6-32	.138	27	.1063	#36	6-40	.138	27	.113	#33
8-32	.164	18	.1324	#29	8-36	.164	18	.136	#29
10-24	.190	10	.1472	#26	10-32	.190	10	.159	#21
12-24	.216	2	.1732	#17	12-28	.216	2	.180	#15
1⁄4-20	.250	1⁄4	.1990	#8	1⁄4-28	.250	F	.213	#3
5⁄16-18	.3125	5⁄16	.2559	#F	5⁄16-24	.3125	5⁄16	.2703	I
3⁄8-16	.375	3⁄8	.3110	5⁄16"	3⁄8-24	.375	3⁄8	.332	Q
7⁄16-14	.4375	7⁄16	.3642	U	7⁄16-20	.4375	7⁄16	.386	W
1⁄2-13	.500	1⁄2	.4219	27⁄64"	1⁄2-20	.500	1⁄2	.449	7⁄16"
9⁄16-12	.5625	9⁄16	.4776	31⁄64"	9⁄16-18	.5625	9⁄16	.506	1⁄2"
5⁄8-11	.625	5⁄8	.5315	17⁄64"	5⁄8-18	.625	5⁄8	.568	9⁄16"
3⁄4-10	.750	3⁄4	.6480	41⁄64"	3⁄4-16	.750	3⁄4	.6688	11⁄16"
7⁄8-9	.875	7⁄8	.7307	49⁄64"	7⁄8-14	.875	7⁄8	.7822	51⁄64"
1-8	1.000	1.0	.8376	7⁄8"	1-14	1.000	1.0	.9072	49⁄64"

Figure 9-28. American (National) screw thread sizes.

Nominal size (inches)	Number of threads per inch	Pitch Diameter		Size and Threads		Pipe o.d. (inches)	Depth of thread (inches)	Tap drill for pipe threads	
		A (inches)	B (inches)	L2 (inches)	L1 (inches)			Minor diameter small end of pipe	Size drill
1⁄8	27	.36351	.37476	.2638	.180	.405	.02963	.33388	R
1⁄4	18	.47739	.48989	.4018	.200	.540	.04444	.43294	7⁄16
3⁄8	18	.61201	.62701	.4078	.240	.675	.04444	.56757	37⁄64
1⁄2	14	.75843	.77843	.5337	.320	.840	.05714	.70129	23⁄32
3⁄4	14	.96768	.98887	.5457	.339	1.050	.5714	.91054	59⁄64
1	11 1⁄2	1.21363	1.23863	.6828	.400	1.315	.06957	1.14407	1 5⁄32
1 1⁄4	11 1⁄2	1.55713	1.58338	.7068	.420	1.660	.06957	1.48757	1 1⁄2
1 1⁄2	11 1⁄2	1.79609	1.82234	.7235	.420	1.900	.06957	1.72652	1 47⁄64
2	11 1⁄2	2.26902	2.29627	.7565	.436	2.375	.06957	2.19946	1 7⁄32
2 1⁄2	8	2.71953	2.76216	1.1375	.682	2.875	.10000	2.61953	2 5⁄8
3	8	3.34062	3.8850	1.2000	.766	3.500	.10000	3.24063	3 1⁄4
3 1⁄2	8	3.83750	3.88881	1.2500	.821	4.000	.10000	3.73750	3 3⁄4
4	8	4.33438	4.38712	1.3000	.844	4.500	.10000	4.23438	4 1⁄4

Figure 9-29. American (National) pipe thread dimensions and tap drill sizes.

Diameter of drill	Soft metals 300 F.P.M.	Plastic and hard rubber 200 F.P.M.	Annealed cast iron 140 F.P.M.	Mild steel 100 F.P.M.	Malleable iron 90 F.P.M.	Hard cast iron 80 F.P.M.	Tool or hard steel 60 F.P.M.	Alloy steel cast steel 40 F.P.M.
1/16 (No. 53 – 80)	18320	12217	8554	6111	5500	4889	3667	2445
3/32 (No. 42 – 52)	12212	8142	5702	4071	3666	3258	2442	1649
1/8 (No. 31 – 41)	9160	6112	4278	3056	2750	2445	1833	1222
5/32 (No. 23 – 30)	7328	4888	3420	2444	2198	1954	1465	977
3/16 (No. 13 – 22)	6106	4075	2852	2037	1833	1630	1222	815
7/32 (No. 1 – 12)	5234	3490	444	1745	1575	1396	1047	698
1/4 (A – F)	4575	3055	2139	1527	1375	1222	917	611
9/32 (G – K)	4071	2715	1900	1356	1222	1084	814	542
9/16 (L, M, N)	3660	2445	1711	1222	1100	978	7333	489
11/32 (O – R)	3330	2220	1554	1110	1000	888	666	444
3/8 (S, T, U)	3050	2037	1426	1018	917	815	611	407
13/32 (V – Z)	2818	1878	1316	939	846	752	563	376
7/16	2614	1746	1222	873	786	698	524	349
15/32	2442	1628	1140	814	732	652	488	326
1/2	2287	1528	1070	764	688	611	458	306
9/16	2035	1357	950	678	611	543	407	271
3/8	1830	1222	856	611	550	489	367	244
11/16	1665	1110	777	555	500	444	333	222
3/4	1525	1018	713	509	458	407	306	204

Figure 9-30. Drill speeds.

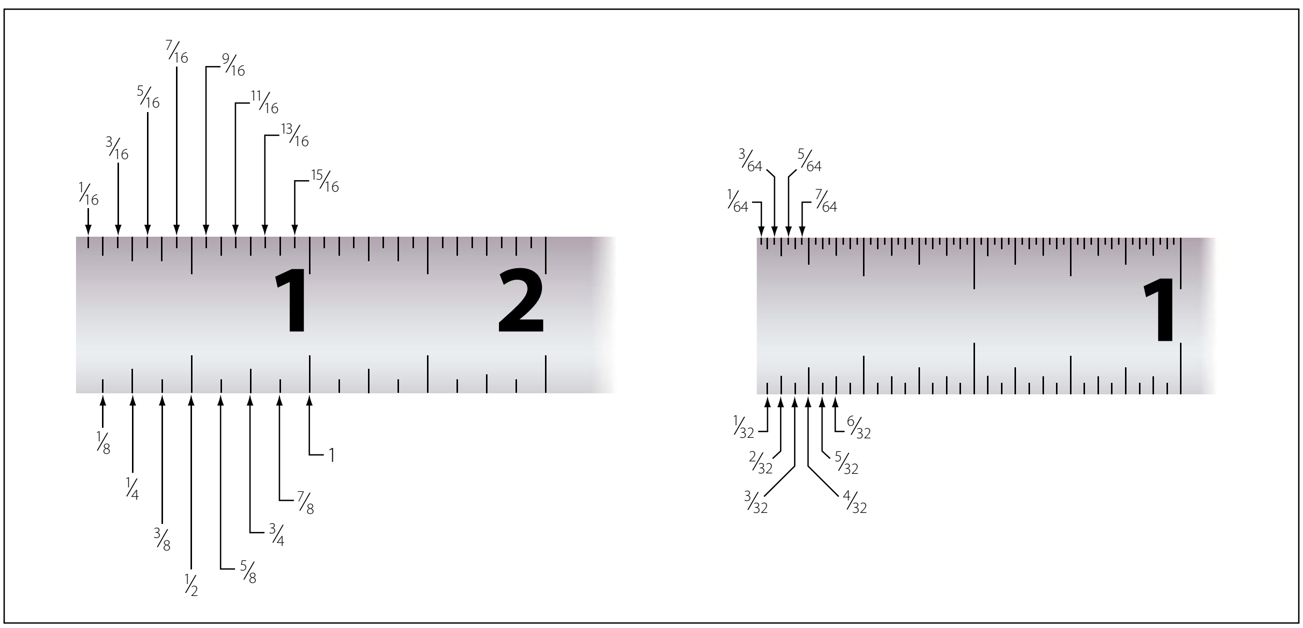

Figure 9-31. Rules.

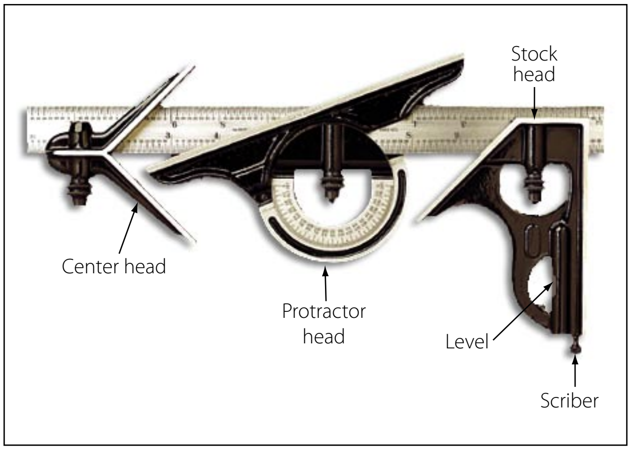

Figure 9-32. Combination set.

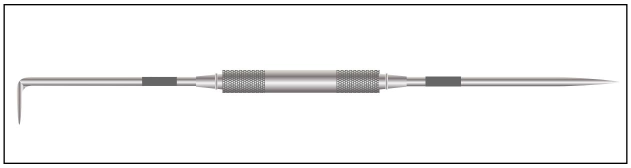

Figure 9-33. Scriber.

The center head is used to find the center of shafts or other cylindrical work. The protractor head can be used to check angles and also may be set at any desired angle to draw lines.

Scriber

The scriber is designed to serve the aviation mechanic in the same way a pencil or pen serves a writer. In general, it is used to scribe or mark lines on metal surfaces. The scriber is made of tool steel, 4 to 12 inches long, and has two needle pointed ends. One end is bent at a 90° angle for reaching and marking through holes. [Figure 9-33]

Before using a scriber, always inspect the points for sharpness. Be sure the straightedge is flat on the metal and in position for scribing. Tilt the scriber slightly in the direction toward which it will be moved, holding it like a pencil. Keep the scriber's point close to the guiding edge of the straightedge. The scribed line should be heavy enough to be visible, but no deeper than necessary to serve its purpose.

Dividers and Pencil Compasses

Dividers and pencil compasses have two legs joined at the top by a pivot. They are used to scribe circles and arcs and for transferring measurements from the rule to the work.

Pencil compasses have one leg tapered to a needle point; the other leg has a pencil or pencil lead inserted. Dividers have both legs tapered to needle points.

When using pencil compasses or dividers, the following procedures are suggested:

1. Inspect the points to make sure they are sharp.
2. To set the dividers or compasses, hold them with the point of one leg in the graduations on the rule. Turn the adjustment nut with the thumb and forefinger; adjust the dividers or compasses until the point of the other leg rests on the graduation of the rule that gives the required measurement.
3. To draw an arc or circle with either the pencil compasses or dividers, hold the thumb attachment on the top with the thumb and forefinger. With pressure exerted on both legs, swing the compass in a clockwise direction and draw the desired arc or circle.
4. The tendency for the legs to slip is avoided by inclining the compasses or dividers in the direction in which they are being rotated. In working on metals, the dividers are used only to scribe arcs or circles that will later be removed by cutting. All other arcs or circles are drawn with pencil compasses to avoid scratching the material.
5. On paper layouts, the pencil compasses are used for describing arcs and circles. Dividers should be used to transfer critical measurements because they are more accurate than a pencil compass.

Calipers

Calipers are used for measuring diameters and distances or for comparing distances and sizes. The three common types of calipers are inside, outside, and hermaphrodite calipers, such as gear tool calipers. [Figure 9-34]

Outside calipers are used for measuring outside dimensions — for example, the diameter of a piece of round stock. Inside calipers have outward curved legs for measuring inside diameters, such as diameters of holes, the distance between two surfaces, the width of slots, and other similar jobs. A hermaphrodite caliper is generally used as a marking gauge in layout work. It should not be used for precision measurement.

Micrometer Calipers

There are four types of micrometer calipers, each designed for a specific use: outside micrometer, inside micrometer, depth micrometer, and thread micrometer.

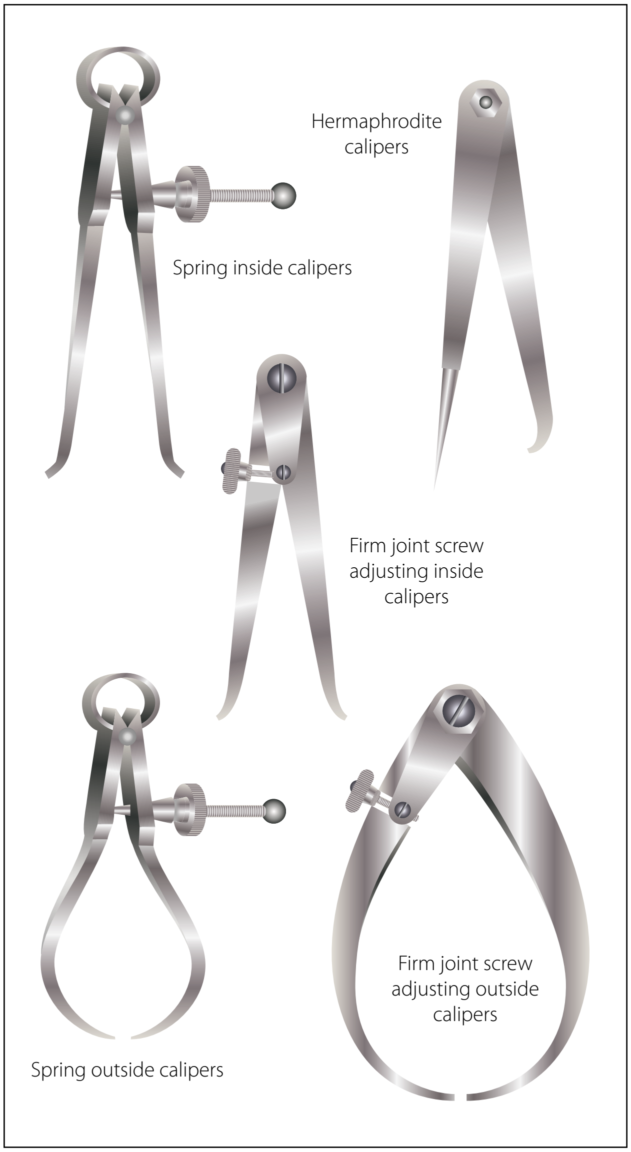

Figure 9-34. Calipers.

Figure 9-35. Outside micrometers.

Micrometers are available in a variety of sizes, either 0 to ½ inch, 0 to 1 inch, 1 to 2 inch, 2 to 3 inch, 3 to 4 inch, 4 to 5 inch, or 5 to 6 inch sizes. In addition to the micrometer inscribed with the measurement markings, micrometers equipped with electronic digital liquid crystal display (LCD) readouts are also in common use.

The AMT will use the outside micrometer more often than any other type. It may be used to measure the outside dimensions of shafts, thickness of sheet metal stock, the diameter of drills, and for many other applications. [Figure 9-35]

The smallest measurement which can be made with the use of the steel rule is one sixty-fourth of an inch in common fractions, and one one-hundredth of an inch in decimal fractions. To measure more closely than this (in thousandths and ten-thousandths of an inch), a micrometer is used. If a dimension given in a common fraction is to be measured with the micrometer, the fraction must be converted to its decimal equivalent.

All four types of micrometers are read in the same way. The method of reading an outside micrometer is discussed later in this chapter.

Micrometer Parts

The fixed parts of a micrometer are the frame, barrel, and anvil. The movable parts of a micrometer are the thimble and spindle. The thimble rotates the spindle which moves in the threaded portion inside the barrel. Turning the thimble provides an opening between the anvil and the end of the spindle where the work is measured. The size of the work is indicated by the graduations on the barrel and thimble. [Figure 9-36]

Reading a Micrometer

The lines on the barrel marked 1, 2, 3, 4, and so forth, indicate measurements of tenths, or 0.100 inch, 0.200 inch, 0.300 inch, 0.400 inch, respectively. [Figure 9-37]

Each of the sections between the tenths divisions (between 1, 2, 3, 4, and so forth) is divided into four parts of 0.025 inch each. One complete revolution of the thimble (from zero on the thimble around to the same zero) moves it one of these divisions (0.025 inch) along the barrel.

The bevel edge of the thimble is divided into 25 equal parts. Each of these parts represents one twenty-fifth of the distance the thimble travels along the barrel in moving from one of the 0.025 inch divisions to another. Thus, each division on the thimble represents one one-thousandth (0.001) of an inch.

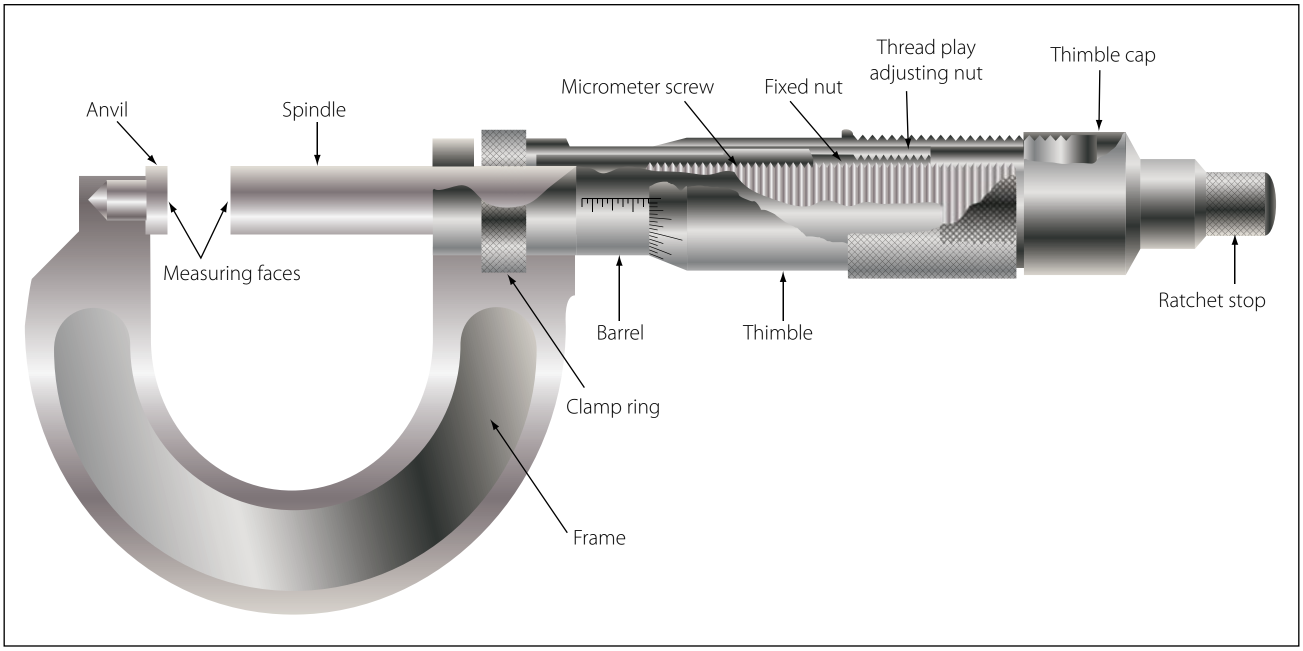

Figure 9-36. Outside micrometer parts.

These divisions are marked for convenience at every five spaces by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the spindle (having made one revolution) has moved 0.025 inch.

The micrometer is read by first noting the last visible figure on the horizontal line of the barrel representing tenths of an inch. Add to this the length of barrel between the thimble and the previously noted number. (This is found by multiplying the number of graduations by 0.025 inch.) Add to this the number of divisions on the bevel edge of the thimble that coincides with the line of the graduation. The total of the three figures equals the measurement. (Figure 9-38 shows several sample readings.)

Vernier Scale

Some micrometers are equipped with a vernier scale that makes it possible to directly read the fraction of a division that is indicated on the thimble scale. Typical examples of the vernier scale as it applies to the micrometer are shown in Figure 9-39.

All three scales on a micrometer are not fully visible without turning the micrometer, but the examples shown in Figure 9-38 are drawn as though the barrel and thimble of the micrometer were laid out flat so that all three scales can be seen at the same time. The barrel scale is the lower horizontal scale, the thimble scale is vertical on the right, and the long horizontal lines (0 through 9 and 0) make up the vernier scale.

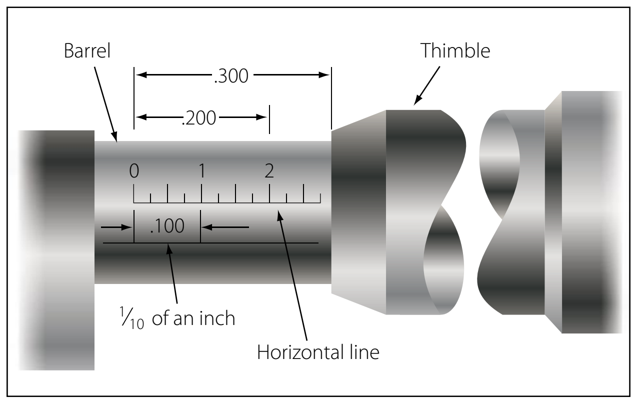

Figure 9-37. Micrometer measurements.

In reading a micrometer, an excellent way to remember the relative scale values is to remember that the 0.025 inch barrel scale graduations are established by the lead screw (40 threads per inch). Next, the thimble graduations divide the 0.025 inch into 25 parts, each equal to 0.001 inch. Then, the vernier graduations divide the 0.001 inch into 10 equal parts, each equal to 0.0001 inch. Remembering the values of the various scale graduations, the barrel scale reading is noted. The thimble scale reading is added to it; then the vernier scale reading is added to get the final reading. The vernier scale line to be read is always the one aligned exactly with any thimble graduation.

In the first example in Figure 9-39, the barrel reads 0.275 inch and the thimble reads more than 0.019 inch. The number 1 graduation on the thimble is aligned

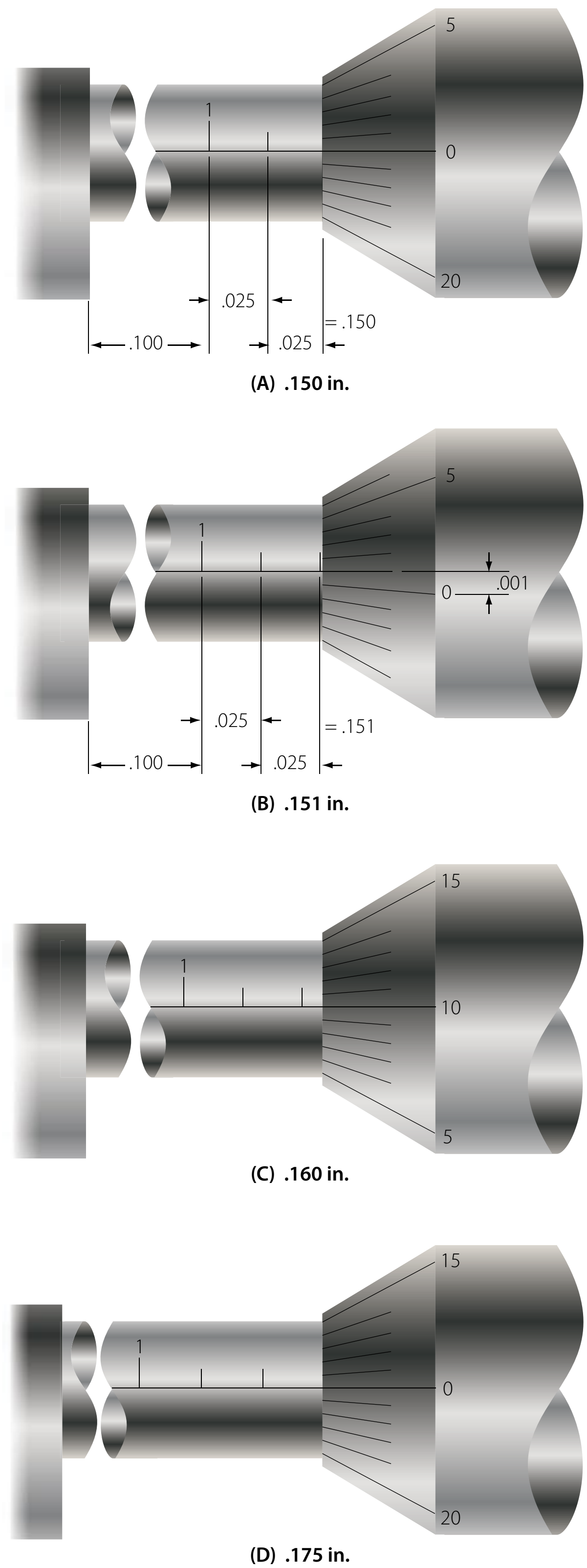

Figure 9-38. Reading a micrometer.

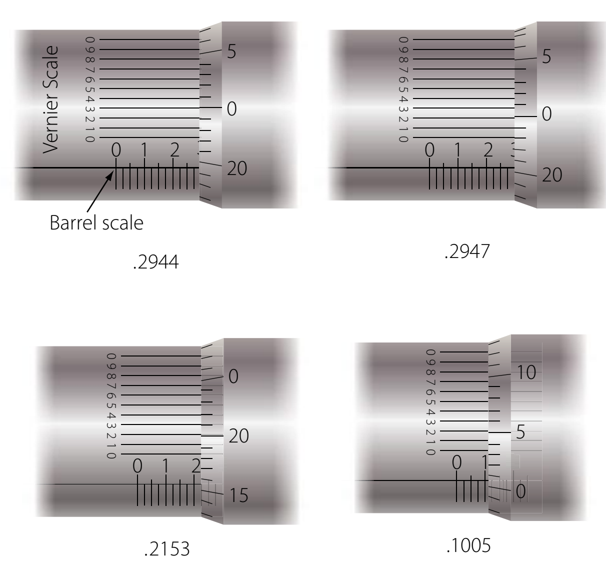

Figure 9-39. Vernier scale readings.

exactly with the number 4 graduation on the vernier scale. Thus, the final reading is 0.2944 inch.

In the second example in Figure 9-39, the barrel reads 0.275 inch, and the thimble reads more than 0.019 inch and less than 0.020 inch. On the vernier scale, the number 7 graduation coincides with a line on the thimble. This means that the thimble reading would be 0.0197 inch. Adding this to the barrel reading of 0.275 inch gives a total measurement of 0.2947 inch.

The third and fourth examples in Figure 9-39 are additional readings that would require use of the vernier scale for accurate readings to ten-thousandths of an inch.

Using a Micrometer

The micrometer must be handled carefully. If it is dropped, its accuracy may be permanently affected. Continually sliding work between the anvil and spindle may wear the surfaces. If the spindle is tightened too much, the frame may be sprung permanently and inaccurate readings will result.

To measure a piece of work with the micrometer, hold the frame of the micrometer in the palm of the hand with the little finger or third finger, whichever is more convenient. This allows the thumb and forefinger to be free to revolve the thimble for adjustment.

A variation of the micrometer is the dial indicator, which measures variations in a surface by using an accurately machined probe mechanically linked to a

Figure 9-40. Dial Indicator.

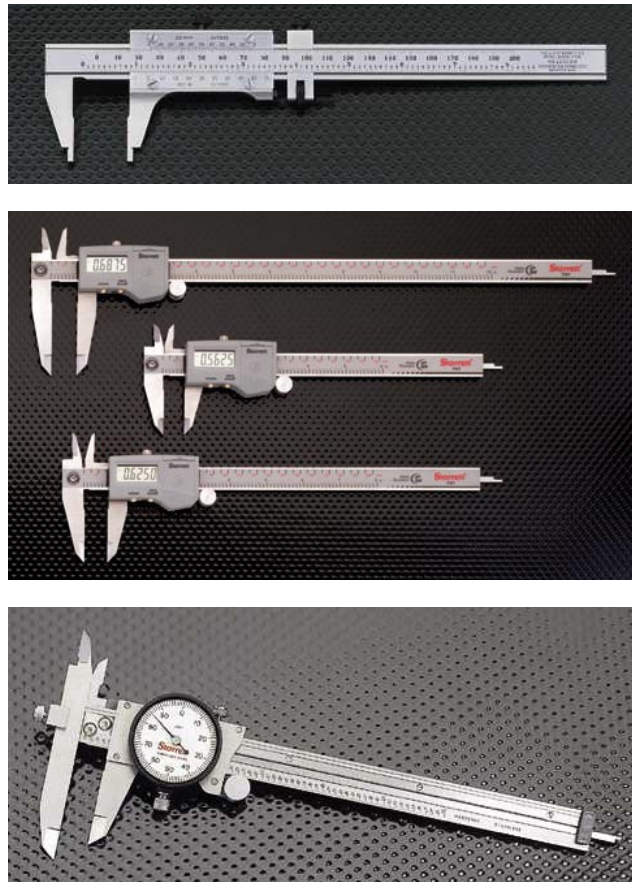

Figure 9-41. Electronic and dial indicator slide calipers.

circular hand whose movement indicates thousandths of an inch, or is displayed on a liquid crystal display (LCD) screen. [Figure 9-40]

A typical example would be using a dial indicator to measure the amount of runout, or bend, in a shaft. If a bend is suspected, the part can be rotated while resting between a pair of machined V-blocks. A dial indicator is then clamped to a machine table stand, and the probe of the indicator is positioned so it lightly contacts the surface. The outer portion of the dial is then rotated until the needle is pointed at zero. The part is then rotated, and the amount of bend, or runout, is displayed on the dial as the needle fluctuates. The total amount of the fluctuation is the runout.

Another common use for the dial indicator is to check for a warp in a rotating component such as a brake disc. In some cases, this can be done with the brake disc installed on the airplane, with the base clamped to a stationary portion of the structure.

In either case, it is imperative that the dial indicator be securely fastened so that movement of the indicator itself induces no errors in measurement.

Slide Calipers

Often used to measure the length of an object, the slide caliper provides greater accuracy than the ruler. It can, by virtue of its specially formed jaws, measure both inside and outside dimensions. As the tool's name implies, the slide caliper jaw is slid along a graduated scale, and its jaws then contact the inside or outside of the object to be measured. The measurement is then read on the scale located on the body of the caliper, or on the LCD screen. [Figure 9-41]

Some slide calipers also contain a depth gauge for measuring the depth of blind holes.