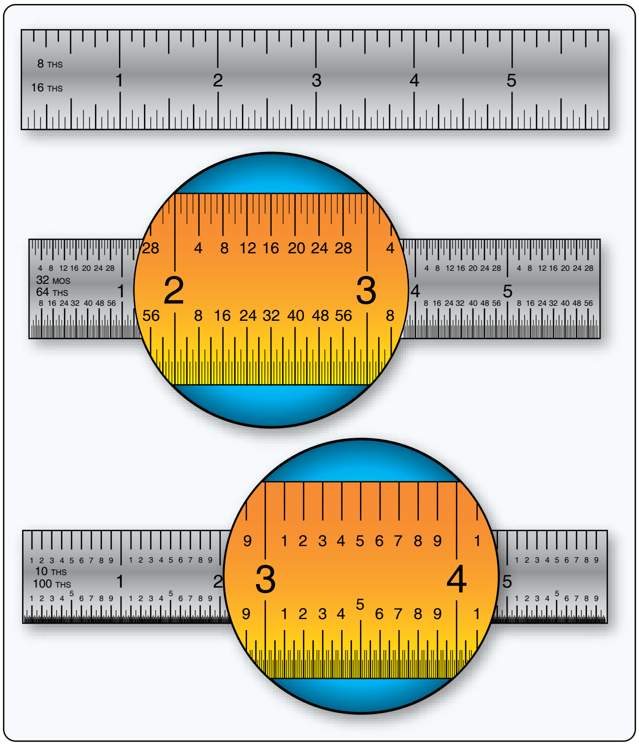


Figure 4-3. *Scales.*

Dividers

Dividers are used to transfer a measurement from a device to a scale to determine its value. Place the sharp points at the locations from which the measurement is to be taken. Then, place the points on a steel machinist's scale, but put one of the points on the 1-inch mark and measure from there. *[Figure 4-5]*

Rivet Spacers

A rivet spacer is used to make a quick and accurate rivet pattern layout on a sheet. On the rivet spacer, there are alignment marks for ½-inch, ¾-inch, 1-inch and 2-inch rivet spacing. *[Figure 4-6]*

Marking Tools

Pens

Fiber-tipped pens are the preferred method of marking lines and hole locations directly on aluminum, because the graphite in a No. 2 pencil can cause corrosion when used on aluminum. Make the layout on the protective membrane if it is still on the material, or mark directly on the material with a fiber-tipped pen, such as a fine-point Sharpie®, or cover the material with masking tape and then mark on the tape.

Scribes

A scribe is a pointed instrument used to mark or score metal to show where it is to be cut. A scribe should only be used when marks will be removed by drilling or cutting because it makes scratches that weaken the material and could cause corrosion. *[Figure 4-7]*

Punches

Punches are usually made of carbon steel that has been hardened and tempered. Generally classified as solid or hollow, punches are designed according to their intended use. A solid punch is a steel rod with various shapes at the end for different uses. For example, it is used to drive bolts out of holes, loosen frozen or tight pins and keys, knock out rivets, pierce holes in a material, etc. The hollow punch is sharp edged and used most often for cutting out blanks. Solid

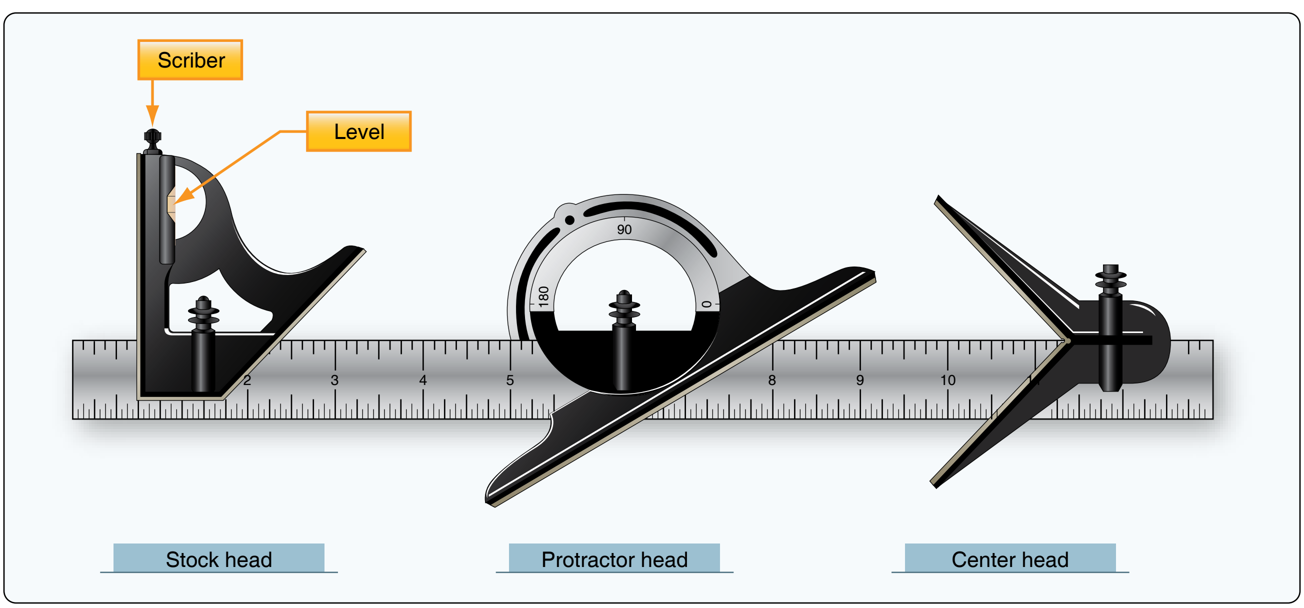


Figure 4-4. *Combination square.*

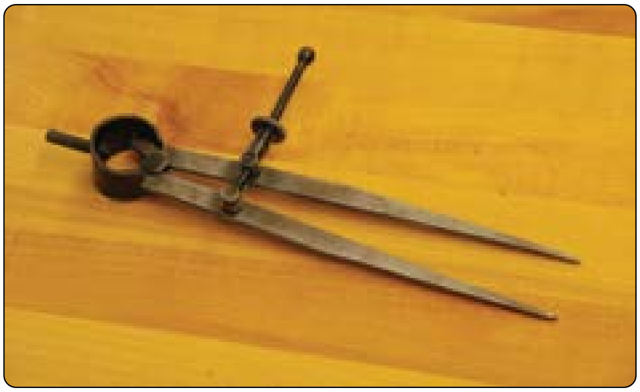


Figure 4-5. *Divider.*

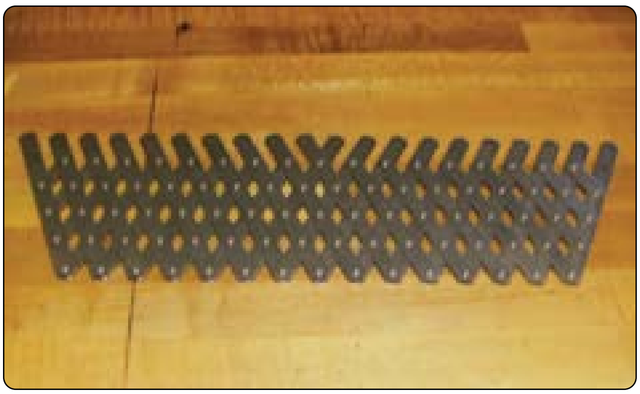


Figure 4-6. *Rivet spacer.*

Figure 4-7. *Scribe.*

punches vary in both size and point design, while hollow punches vary in size.

Prick Punch

A prick punch is primarily used during layout to place reference marks on metal because it produces a small indentation. *[Figure 4-8]* After layout is finished, the indentation is enlarged with a center punch to allow for drilling. The prick punch can also be used to transfer dimensions from a paper pattern directly onto the metal. Take the following precautions when using a prick punch:

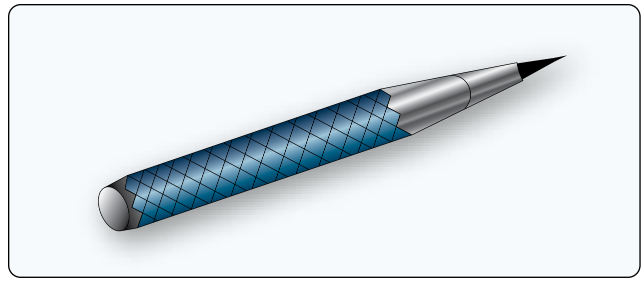


Figure 4-8. *Prick punch.*

- Never strike a prick punch a heavy blow with a hammer because it could bend the punch or cause excessive damage to the item being worked.
- Do not use a prick punch to remove objects from holes because the point of the punch spreads the object and causes it to bind even more.

Center Punch

A center punch is used to make indentations in metal as an aid in drilling. *[Figure 4-9]* These indentations help the drill, which has a tendency to wander on a flat surface, stay on the mark as it goes through the metal. The traditional center punch is used with a hammer, has a heavier body than the prick punch, and has a point ground to an angle of about 60°. Take the following precautions when using a center punch:

- Never strike the center punch with enough force to dimple the item around the indentation or cause the metal to protrude through the other side of the sheet.
- Do not use a center punch to remove objects from holes because the point of the punch spreads the object and causes it to bind even more.

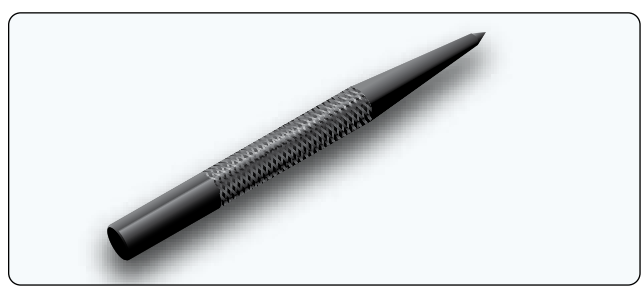


Figure 4-9. *Center punch.*

Automatic Center Punch

The automatic center punch performs the same function as an ordinary center punch, but uses a spring tension mechanism to create a force hard enough to make an indentation without the need for a hammer. The mechanism automatically strikes a blow of the required force when placed where needed and pressed. This punch has an adjustable cap for regulating the stroke; the point can be removed for replacement or sharpening. Never strike an automatic center punch with a hammer. *[Figure 4-10]*

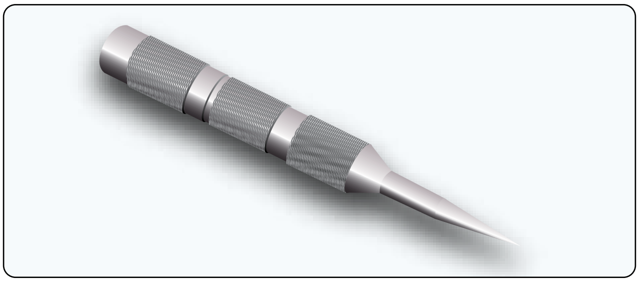


Figure 4-10. *Automatic center punch.*

Transfer Punch

A transfer punch uses a template or existing holes in the structure to mark the locations of new holes. The punch is centered in the old hole over the new sheet and lightly tapped with a mallet. The result should be a mark that serves to locate the hole in the new sheet. *[Figure 4-11]*

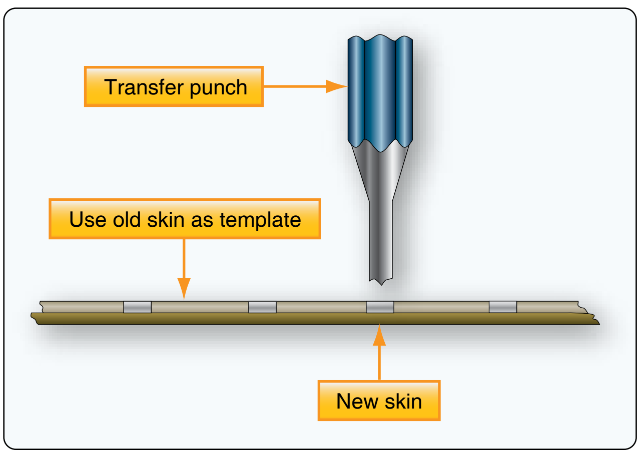


Figure 4-11. *Transfer punch.*

Drive Punch

The drive punch is made with a flat face instead of a point because it is used to drive out damaged rivets, pins, and bolts that sometimes bind in holes. The size of the punch is determined by the width of the face, usually ⅛-inch to ¼-inch. *[Figure 4-12]*

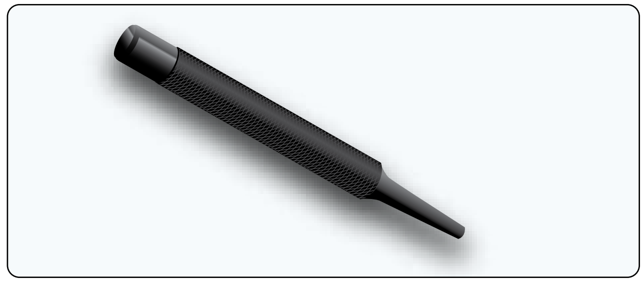


Figure 4-12. *Drive punch.*

Pin Punch

The pin punch typically has a straight shank characterized by a hexagonal body. Pin punch points are sized in 1⁄32-inch increments of an inch and range from 1⁄16-inch to ⅜-inch in diameter. The usual method for driving out a pin or bolt is to start working it out with a drive punch until the shank of the punch is touching the sides of the hole. Then use a pin punch to drive the pin or bolt the rest of the way out of the hole. *[Figure 4-13]*

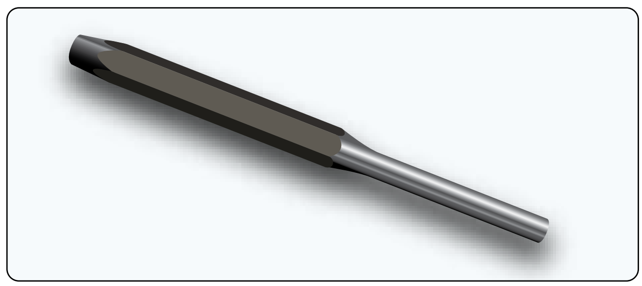


Figure 4-13. *Pin punch.*

Chassis Punch

A chassis punch is used to make holes in sheet metal parts for the installation of instruments and other avionics appliance, as well as lightening holes in ribs and spars. Sized in 1⁄16 of an inch, they are available in sizes from ½ inch to 3 inches. *[Figure 4-14]*

Figure 4-14. *Chassis punch.*

Awl

A pointed tool for marking surfaces or for punching small holes, an awl is used in aircraft maintenance to place scribe marks on metal and plastic surfaces and to align holes, such as in the installation of a deicer boot. *[Figure 4-15]*

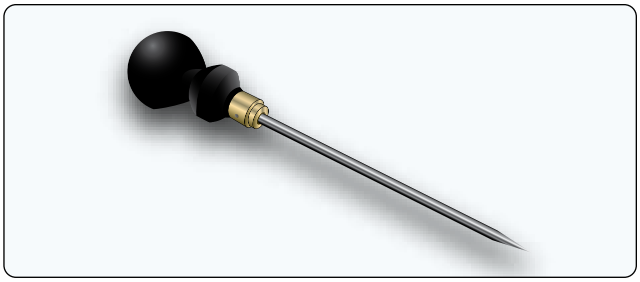


Figure 4-15. *Awl.*

Procedures for one use of an awl:

1. Place the metal to be scribed on a flat surface. Place a ruler or straightedge on the guide marks already measured and placed on the metal.
2. Remove the protective cover from the awl.
3. Hold the straightedge firmly. Hold the awl, as shown in *Figure 4-16*, and scribe a line along the straightedge.
4. Replace the protective cover on the awl.

Hole Duplicator

Available in a variety of sizes and styles, hole duplicators, or hole finders, utilize the old covering as a template to locate and match existing holes in the structure. Holes in a replacement sheet or in a patch must be drilled to match existing holes in the structure and the hole duplicator simplifies this process. *Figure 4-17* illustrates one type of hole duplicator. The peg on the bottom leg of the duplicator fits into the existing rivet hole. To make the hole in the replacement sheet or patch, drill through the bushing on the top leg. If the duplicator is properly made, holes drilled in this manner are in perfect alignment. A separate duplicator must be used for each diameter of rivet.

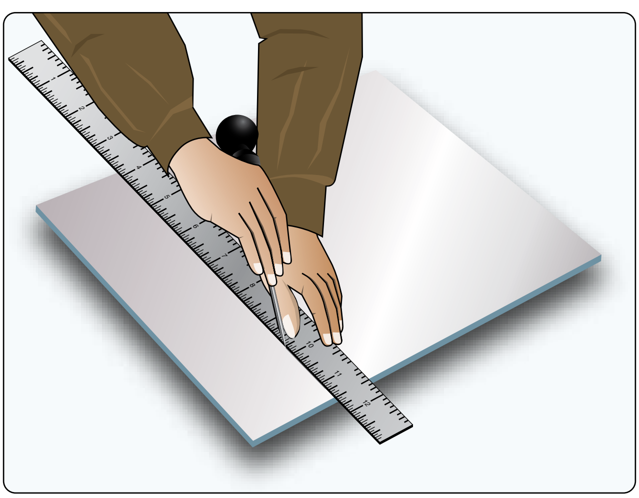


Figure 4-16. *Awl usage.*

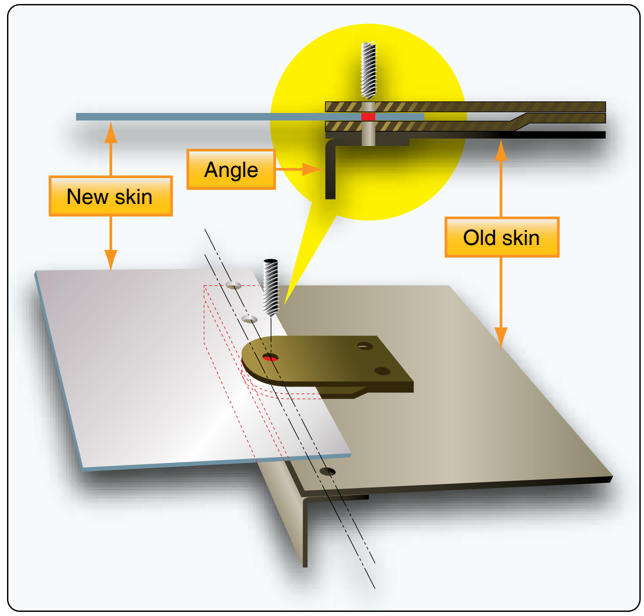


Figure 4-17. *Hole duplicator.*

Cutting Tools

Powered and nonpowered metal cutting tools available to the aviation technician include various types of saws, nibblers, shears, sanders, notchers, and grinders.

Circular-Cutting Saws

The circular-cutting saw cuts with a toothed, steel disc that rotates at high speed. Handheld or table mounted and powered by compressed air, this power saw cuts metal or wood. To prevent the saw from grabbing the metal, keep a firm grip on the saw handle at all times. Check the blade carefully for cracks prior to installation because a cracked blade can fly apart during use, possibly causing serious injury.

Kett Saw

The Kett saw is an electrically operated, portable circular cutting saw that uses blades of various diameters. *[Figure 4-18]* Since the head of this saw can be turned to any desired angle, it is useful for removing damaged sections on a stringer. The advantages of a Kett saw include:

1. Can cut metal up to $^3/_{16}$-inch in thickness.
2. No starting hole is required.
3. A cut can be started anywhere on a sheet of metal.
4. Can cut an inside or outside radius.

Pneumatic Circular-Cutting Saw

The pneumatic circular-cutting saw, useful for cutting out damage, is similar to the Kett saw. *[Figure 4-19]*

Figure 4-18. *Kett saw.*

Figure 4-19. *Pneumatic circular saw.*

Reciprocating Saw

The versatile reciprocating saw achieves cutting action through a push and pull (reciprocating) motion of the blade. This saw can be used right sideup or upside down, a feature that makes it handier than the circular saw for working in tight or awkward spots. A variety of blade types are available for reciprocating saws; blades with finer teeth are used for cutting through metal. The portable, air-powered reciprocating saw uses a standard hacksaw blade and can cut a 360° circle or a square or rectangular hole. Unsuited for fine precision work, this saw is more difficult to control than the pneumatic circular-cutting saw. A reciprocating saw should be used in such a way that at least two teeth of the saw blade are cutting at all times. Avoid applying too much downward pressure on the saw handle because the blade may break. *[Figure 4-20]*

Cut-off Wheel

A cut-off wheel is a thin abrasive disc driven by a high-speed pneumatic die-grinder and used to cut out damage on aircraft skin and stringers. The wheels come in different thicknesses and sizes. *[Figure 4-21]*

Figure 4-20. *Reciprocating saw.*

Figure 4-21. *Die grinder and cut-off wheel.*

Nibblers

Usually powered by compressed air, the nibbler is another tool for cutting sheet metal. Portable nibblers utilize a high speed blanking action (the lower die moves up and down and meets the upper stationary die) to cut the metal. *[Figure 4-22]* The shape of the lower die cuts out small pieces of metal approximately 1⁄16 inch wide.

The cutting speed of the nibbler is controlled by the thickness of the metal being cut. Nibblers satisfactorily cut through sheets of metal with a maximum thickness of 1⁄16 inch. Too

Figure 4-22. *Nibbler.*

much force applied to the metal during the cutting operation clogs the dies (shaped metal), causing them to fail or the motor to overheat. Both electric and hand nibblers are available.

Shop Tools

Due to size, weight, and/or power source, shop tools are usually in a fixed location, and the airframe part to be constructed or repaired is brought to the tool.

Squaring Shear

The squaring shear provides the airframe technician with a convenient means of cutting and squaring sheet metal. Available as a manual, hydraulic, or pneumatic model, this shear consists of a stationary lower blade attached to a bed and a movable upper blade attached to a crosshead. *[Figure 4-23]*

Two squaring fences, consisting of thick strips of metal used for squaring metal sheets, are placed on the bed. One squaring fence is placed on the right side and one on the left to form a 90° angle with the blades. A scale graduated in fractions of an inch is scribed on the bed for ease in placement.

To make a cut with a foot shear, move the upper blade down by placing the foot on the treadle and pushing downward. Once the metal is cut and foot pressure removed, a spring raises the blade and treadle. Hydraulic or pneumatic models utilize remote foot pedals to ensure operator safety.

The squaring shear performs three distinctly different operations:

1. Cutting to a line.
2. Squaring.
3. Multiple cutting to a specific size.

Figure 4-23. *Power squaring shear.*

When cutting to a line, place the sheet on the bed of the shears in front of the cutting blade with the cutting line even with the cutting edge of the bed. To cut the sheet with a foot shear, step on the treadle while holding the sheet securely in place.

Squaring requires several steps. First, one end of the sheet is squared with an edge (the squaring fence is usually used on the edge). Then, the remaining edges are squared by holding one squared end of the sheet against the squaring fence and making the cut, one edge at a time, until all edges have been squared.

When several pieces must be cut to the same dimensions, use the backstop, located on the back of the cutting edge on most squaring shears. The supporting rods are graduated in fractions of an inch and the gauge bar may be set at any point on the rods. Set the gauge bar the desired distance from the cutting blade of the shears and push each piece to be cut against the gauge bar. All the pieces can then be cut to the same dimensions without measuring and marking each one separately.

Foot-operated shears have a maximum metal cutting capacity of 0.063 inch of aluminum alloy. Use powered squaring shears for cutting thicker metals. *[Figure 4-24]*

Figure 4-24. *Foot-operated squaring shear.*

Throatless Shear

Airframe technicians use the throatless shear to cut aluminum sheets up to 0.063 inches. This shear takes its name from the fact that metal can be freely moved around the cutting blade during cutting because the shear lacks a “throat” down which metal must be fed. *[Figure 4-25]* This feature allows great flexibility in what shapes can be cut because the metal can be turned to any angle for straight, curved, and irregular cuts. Also, a sheet of any length can be cut.

A hand lever operates the cutting blade which is the top blade.

Figure 4-25. *Throatless shears.*

Throatless shears made by the Beverly Shear Manufacturing Corporation, called Beverly™ shears, are often used.

Scroll Shears

Scroll shears are used for cutting irregular lines on the inside of a sheet without cutting through to the edge. *[Figure 4-26]* The upper cutting blade is stationary while the lower blade is movable. A handle connected to the lower blade operates the machine.

Rotary Punch Press

Used in the airframe repair shop to punch holes in metal parts, the rotary punch can cut radii in corners, make washers, and perform many other jobs where holes are required. *[Figure 4-27]* The machine is composed of two cylindrical turrets, one mounted over the other and supported by the frame, with both turrets synchronized to rotate together. Index pins, which ensure correct alignment at all times, may be released from their locking position by rotating a lever on the right side of the machine. This action withdraws the index pins from the tapered holes and allows an operator to turn the turrets to any size punch desired.

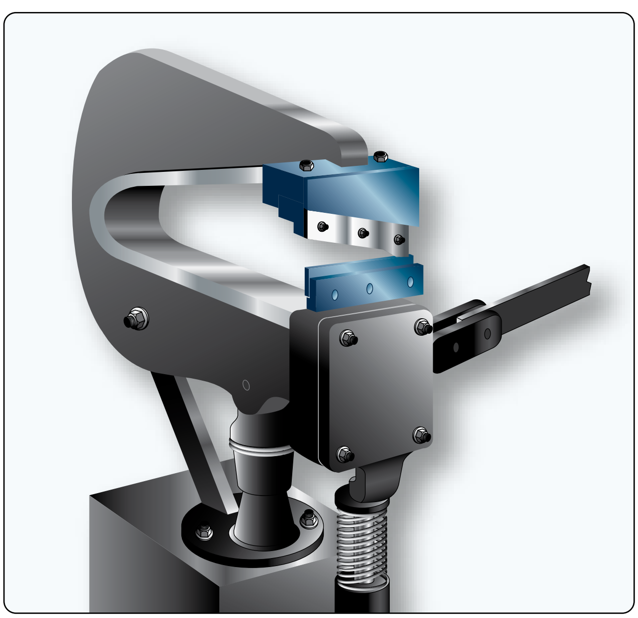


Figure 4-26. *Scroll shears.*

Figure 4-27. *Rotary punch press.*

When rotating the turret to change punches, release the index lever when the desired die is within 1 inch of the ram, and continue to rotate the turret slowly until the top of the punch holder slides into the grooved end of the ram. The tapered index locking pins will then seat themselves in the holes provided and, at the same time, release the mechanical locking device, which prevents punching until the turrets are aligned. To operate the machine, place the metal to be worked between the die and punch. Pull the lever on the top of the machine toward the operator, actuating the pinion shaft, gear segment, toggle link, and the ram, forcing the punch through the metal. When the lever is returned to its original position, the metal is removed from the punch.

The diameter of the punch is stamped on the front of each die holder. Each punch has a point in its center that is placed in the center punch mark to punch the hole in the correct location.

Band Saw

A band saw consists of a toothed metal band coupled to, and continuously driven around, the circumferences of two wheels. It is used to cut aluminum, steel, and composite parts. *[Figure 4-28]* The speed of the band saw and the type and style of the blade depends on the material to be cut. Band saws are often designated to cut one type of material, and if a different material is to be cut, the blade is changed. The speed is controllable and the cutting platform can be tilted to cut angled pieces.

Figure 4-28. *Band saw.*

Disc Sander

Disc sanders have a powered abrasive-covered disc or belt and are used for smoothing or polishing surfaces. The sander unit uses abrasive paper of different grits to trim metal parts. It is much quicker to use a disc sander than to file a part to the correct dimension. The combination disc and belt sander has a vertical belt sander coupled with a disc sander and is often used in a metal shop. *[Figure 4-29]*

Belt Sander

The belt sander uses an endless abrasive belt driven by an electric motor to sand down metal parts much like the disc sander unit. The abrasive paper used on the belt comes in different degrees of grit or coarseness. The belt sander is available as a vertical or horizontal unit. The tension and tracking of the abrasive belt can be adjusted so the belt runs in the middle. *[Figure 4-30]*

Figure 4-29. *Combination disc and belt sander.*

Figure 4-30. *Belt sander.*

Notcher

The notcher is used to cut out metal parts, with some machines capable of shearing, squaring, and trimming metal. *[Figure 4-31]* The notcher consists of a top and bottom die and most often cuts at a 90° angle, although some machines can cut metal into angles up to 180°. Notchers are available in manual and pneumatic models able to cut various thicknesses of mild steel and aluminum. This is an excellent tool for quickly removing corners from sheet metal parts. *[Figure 4-32]*

Wet or Dry Grinder

Grinding machines come in a variety of types and sizes, depending upon the class of work for which they are to be used. Dry and/or wet grinders are found in airframe repair shops. Grinders can be bench or pedestal mounted. A dry grinder usually has a grinding wheel on each end of a shaft

Figure 4-31. *Notcher.*

Figure 4-32. *Power notcher.*

that runs through an electric motor or a pulley operated by a belt. The wet grinder has a pump to supply a flow of water on a single grinding wheel. The water acts as a lubricant for faster grinding while it continuously cools the edge of the metal, reducing the heat produced by material being ground against the wheel. It also washes away any bits of metal or abrasive removed during the grinding operation. The water returns to a tank and can be re-used.

Grinders are used to sharpen knives, tools, and blades as well as grinding steel, metal objects, drill bits, and tools. *Figure 4-33* illustrates a common type bench grinder found in most airframe repair shops. It can be used to dress mushroomed heads on chisels and points on chisels, screwdrivers, and drills, as well as for removing excess metal from work and smoothing metal surfaces.

The bench grinder is generally equipped with one medium-grit and one fine-grit abrasive wheel. The medium-grit wheel is usually used for rough grinding where a considerable quantity of material is to be removed or where a smooth finish is unimportant. The fine-grit wheel is used for sharpening tools and grinding to close limits. It removes metal more slowly, gives the work a smooth finish, and does not generate enough heat to anneal the edges of cutting tools.

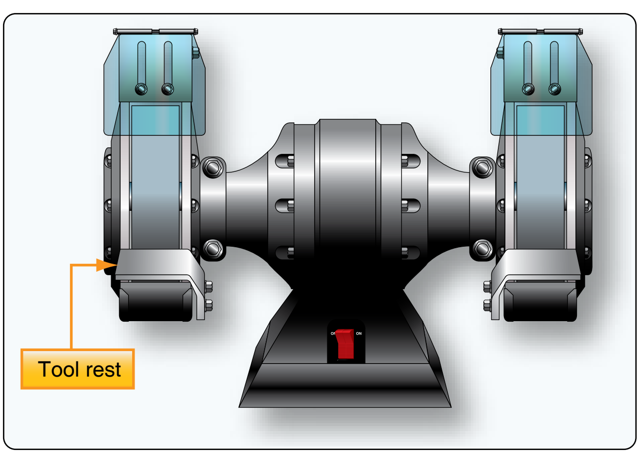


Figure 4-33. *Grinder.*

Before using any type of grinder, ensure that the abrasive wheels are firmly held on the spindles by the flange nuts. An abrasive wheel that comes off or becomes loose could seriously injure the operator in addition to ruining the grinder. A loose tool rest could cause the tool or piece of work to be "grabbed" by the abrasive wheel and cause the operator's hand to come in contact with the wheel, possibly resulting in severe wounds.

Always wear goggles when using a grinder, even if eye shields are attached to the grinder. Goggles should fit firmly against the face and nose. This is the only way to protect the eyes from the fine pieces of steel. Goggles that do not fit properly should be exchanged for ones that do fit. Be sure to check the abrasive wheel for cracks before using the grinder. A cracked abrasive wheel is likely to fly apart when turning at high speeds. Never use a grinder unless it is equipped with wheel guards that are firmly in place.

Grinding Wheels

A grinding wheel is made of a bonded abrasive and provides an efficient way to cut, shape, and finish metals. Available in a wide variety of sizes and numerous shapes, grinding wheels are also used to sharpen knives, drill bits, and many other tools, or to clean and prepare surfaces for painting or plating.

Grinding wheels are removable and a polishing or buffing wheel can be substituted for the abrasive wheel. Silicon carbide and aluminum oxide are the kinds of abrasives used in most grinding wheels. Silicon carbide is the cutting agent for grinding hard, brittle material, such as cast iron. It is also used in grinding aluminum, brass, bronze, and copper. Aluminum oxide is the cutting agent for grinding steel and other metals of high tensile strength.

Hand Cutting Tools

Many types of hand cutting tools are available to cut light gauge sheet metal. Four cutting tools commonly found in the air frame repair shop are straight hand snips, aviation snips, files, and burring tools.

Straight Snips

Straight snips, or sheet metal shears, have straight blades with cutting edges sharpened to an 85° angle. *[Figure 4-34]* Available in sizes ranging from 6 to 14 inches, they cut aluminum up to 1⁄16 of an inch. Straight snips can be used for straight cutting and large curves, but aviation snips are better for cutting circles or arcs.

Figure 4-34. *Straight snips.*

Figure 4-36. *Files.*

Aviation Snips

Aviation snips are used to cut holes, curved parts, round patches, and doublers (a piece of metal placed under a part to make it stiffer) in sheet metal. Aviation snips have colored handles to identify the direction of the cuts: yellow aviation snips cut straight, green aviation snips curve right, and red aviation snips curve left. *[Figure 4-35]*

Files

The file is an important but often overlooked tool used to shape metal by cutting and abrasion. Files have five distinct properties: length, contour, the form in cross section, the kind of teeth, and the fineness of the teeth. Many different types of files are available and the sizes range from 3 to 18 inches. *[Figure 4-36]*

The portion of the file on which the teeth are cut is called the face. The tapered end that fits into the handle is called the tang. The part of the file where the tang begins is the heel. The length of a file is the distance from the point or tip to the heel and does not include the tang. The teeth of the file do the cutting. These teeth are set at an angle across the face of the file. A file with a single row of parallel teeth is called a single-cut file. The teeth are cut at an angle of 65°–85° to the centerline, depending on the intended use of the file. Files that have one row of teeth crossing another row in a crisscross pattern are called double-cut files. The angle of the first set usually is 40°–50° and that of the crossing teeth 70°–80°. Crisscrossing produces a surface that has a very large number of little teeth that slant toward the tip of the file. Each little tooth looks like an end of a diamond point cold chisel.

Figure 4-35. *Aviation snips.*

Files are graded according to the tooth spacing; a coarse file has a small number of large teeth, and a smooth file has a large number of fine teeth. The coarser the teeth, the more metal is removed on each stroke of the file. The terms used to indicate the coarseness or fineness of a file are rough, coarse, bastard, second cut, smooth, and dead smooth, and the file may be either single cut or double cut. Files are further classified according to their shape. Some of the more common types are: flat, triangle, square, half round, and round.

There are several filing techniques. The most common is to remove rough edges and slivers from the finished part before it is installed. Crossfiling is a method used for filing the edges of metal parts that must fit tightly together. Crossfiling involves clamping the metal between two strips of wood and filing the edge of the metal down to a preset line. Draw filing is used when larger surfaces need to be smoothed and squared. It is done by drawing the file over the entire surface of the work.

To protect the teeth of a file, files should be stored separately in a plastic wrap or hung by their handles. Files kept in a toolbox should be wrapped in waxed paper to prevent rust from forming on the teeth. File teeth can be cleaned with a file card.

Die Grinder

A die grinder is a handheld tool that turns a mounted cutoff wheel, rotary file, or sanding disc at high speed. *[Figure 4-37]* Usually powered by compressed air, electric die grinders are also used. Pneumatic die grinders run at

12,000 to 20,000 revolutions per minute (rpm) with the rotational speed controlled by the operator who uses a hand- or foot-operated throttle to vary the volume of compressed air. Available in straight, 45°, and 90° models, the die grinder is excellent for weld breaking, smoothing sharp edges, deburring, porting, and general high-speed polishing, grinding, and cutting.

Figure 4-37. *Die grinder.*

Burring Tool

This type of tool is used to remove a burr from an edge of a sheet or to deburr a hole. *[Figure 4-38]*

Hole Drilling

Drilling holes is a common operation in the airframe repair shop. Once the fundamentals of drills and their uses are learned, drilling holes for rivets and bolts on light metal is not difficult. While a small portable power drill is usually the most practical tool for this common operation in airframe metalwork, sometimes a drill press may prove to be the better piece of equipment for the job.

Portable Power Drills

Portable power drills operate by electricity or compressed air. Pneumatic drill motors are recommended for use on repairs around flammable materials where potential sparks from an electric drill motor might become a fire hazard.

Figure 4-38. *Burring tools.*

When using the portable power drill, hold it firmly with both hands. Before drilling, be sure to place a backup block of wood under the hole to be drilled to add support to the metal structure. The drill bit should be inserted in the chuck and tested for trueness or vibration. This may be visibly checked by running the motor freely. A drill bit that wobbles or is slightly bent should not be used since such a condition causes enlarged holes. The drill should always be held at right angles to the work regardless of the position or curvatures. Tilting the drill at any time when drilling into or withdrawing from the material may cause elongation (egg shape) of the hole. When drilling through sheet metal, small burrs are formed around the edge of the hole. Burrs must be removed to allow rivets or bolts to fit snugly and to prevent scratching. Burrs may be removed with a bearing scraper, a countersink, or a drill bit larger than the hole. If a drill bit or countersink is used, it should be rotated by hand. Always wear safety goggles while drilling.

Pneumatic Drill Motors

Pneumatic drill motors are the most common type of drill motor for aircraft repair work. *[Figure 4-39]* They are lightweight and have sufficient power and good speed control. Drill motors are available in many different sizes and models. Most drill motors used for aircraft sheet metal work are rated at 3,000 rpm, but if drilling deep holes or drilling in hard materials, such as corrosion resistant steel or titanium, a drill motor with more torque and lower rpm should be selected to prevent damage to tools and materials.

Right Angle & 45° Drill Motors

Right angle and 45° drill motors are used for positions that are not accessible with a pistol grip drill motor. Most right angle drill motors use threaded drill bits that are available in several lengths. Heavy-duty right angle drills are equipped with a chuck similar to the pistol grip drill motor. *[Figure 4-40]*

Figure 4-39. *Drill motors.*

Figure 4-40. *Angle drill motors.*

Two Hole

Special drill motors that drill two holes at the same time are used for the installation of nutplates. By drilling two holes at the same time, the distance between the holes is fixed and the holes line up perfectly with the holes in the nutplate. *[Figure 4-41]*

Drill Press

The drill press is a precision machine used for drilling holes that require a high degree of accuracy. It serves as an accurate means of locating and maintaining the direction of a hole that is to be drilled and provides the operator with a feed lever that makes the task of feeding the drill into the work easier. The upright drill press is the most common of the variety of drill presses available. *[Figure 4-42]*

When using a drill press, the height of the drill press table is adjusted to accommodate the height of the part to be drilled. When the height of the part is greater than the distance between the drill and the table, the table is lowered. When the height of the part is less than the distance between the drill and the table, the table is raised.

After the table is properly adjusted, the part is placed on the table and the drill is brought down to aid in positioning the metal so that the hole to be drilled is directly beneath the point of the drill. The part is then clamped to the drill press table to prevent it from slipping during the drilling operation. Parts not properly clamped may bind on the drill and start spinning, causing serious cuts on the operator's arms or body, or loss of fingers or hands. Always make sure the part to be drilled is properly clamped to the drill press table before starting the drilling operation.

Figure 4-41. *Nutplate drill.*

Figure 4-42. *Drill press.*

The degree of accuracy that it is possible to attain when using the drill press depends to a certain extent on the condition of the spindle hole, sleeves, and drill shank. Therefore, special care must be exercised to keep these parts clean and free from nicks, dents, and warpage. Always be sure that the sleeve is securely pressed into the spindle hole. Never insert a broken drill in a sleeve or spindle hole. Be careful never to use the sleeve-clamping vise to remove a drill since this may cause the sleeve to warp.

The drill speed on a drill press is adjustable. Always select the optimum drill speed for the material to be drilled. Technically, the speed of a drill bit means its speed at the circumference, in surface feet per minute (sfm). The recommended speed for drilling aluminum alloy is from 200 to 300 sfm, and for mild steel is 30 to 50 sfm. In practice, this must be converted into rpm for each size drill. Machinist and mechanic handbooks include drill rpm charts or drill rpm may be computed by use of the formula:

$$\frac{CS \times 4}{D} = \text{rpm}$$

CS = The recommended cutting speed in sfm

D = The diameter of the drill bit in inches

Drill Extensions & Adapters

When access to a place where drilling is difficult or impossible with a straight drill motor, various types of drill extensions and adapters are used.

Extension Drill Bits

Extension drill bits are widely used for drilling holes in locations that require reaching through small openings or past projections. These drill bits, which come in 6- to 12-inch lengths, are high speed with spring-tempered shanks. Extension drill bits are ground to a special notched point, which reduces end thrust to a minimum. When using extension drill bits always:

1. Select the shortest drill bit that will do the job. It is easier to control.
2. Check the drill bit for straightness. A bent drill bit makes an oversized hole and may whip, making it difficult to control.
3. Keep the drill bit under control. Extension drills smaller than ¼-inch must be supported by a drill guard made from a piece of tubing or spring to prevent whipping.

Straight Extension

A straight extension for a drill can be made from an ordinary piece of drill rod. The drill bit is attached to the drill rod by shrink fitting, brazing, or silver soldering.

Angle Adapters

Angle adapters can be attached to an electric or pneumatic drill when the location of the hole is inaccessible to a straight drill. Angle adapters have an extended shank fastened to the chuck of the drill. The drill is held in one hand and the adapter in the other to prevent the adapter from spinning around the drill chuck.

Snake Attachment

The snake attachment is a flexible extension used for drilling in places inaccessible to ordinary drills. Available for electric and pneumatic drill motors, its flexibility permits drilling around obstructions with minimum effort. *[Figure 4-43]*

Figure 4-43. *Snake attachment.*

Types of Drill Bits

A wide variety of drill bits including specialty bits for specific jobs are available. *Figure 4-44* illustrates the parts of the drill bit and *Figure 4-45* shows some commonly used drill bits. High speed steel (HSS) drill bits come in short shank or standard length, sometimes called jobbers length. HSS drill bits can withstand temperatures nearing the critical range of 1,400 °F (dark cherry red) without losing their hardness. The industry standard for drilling metal (aluminum, steel, etc.), these drill bits stay sharper longer.

Step Drill Bits

Typically, the procedure for drilling holes larger than ³⁄₁₆ inch in sheet metal is to drill a pilot hole with a No. 40 or No. 30 drill bit and then to oversize with a larger drill bit to the correct size. The step drill combines these two functions into one step. The step drill bit consists of a smaller pilot drill point that drills the initial small hole. When the drill bit is advanced further into the material, the second step of the drill bit enlarges the hole to the desired size.

Step drill bits are designed to drill round holes in most metals,

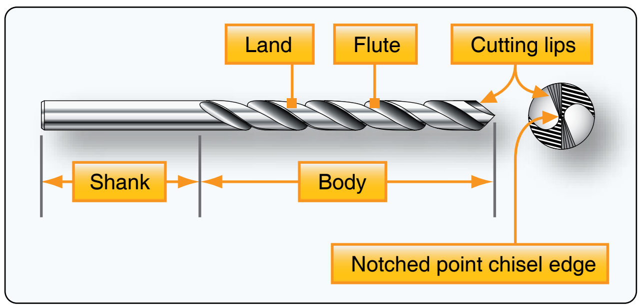


Figure 4-44. *Parts of a drill.*

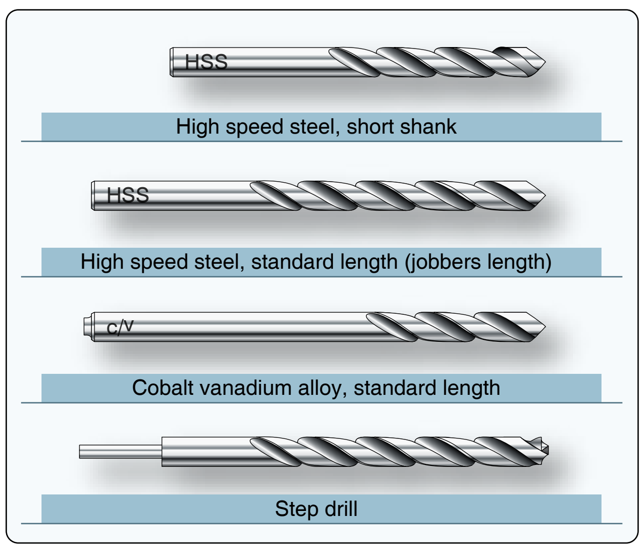


Figure 4-45. *Types of drill bits.*

plastic, and wood. Commonly used in general construction and plumbing, they work best on softer materials, such as plywood, but can be used on very thin sheet metal. Step drill bits can also be used to deburr holes left by other bits.

Cobalt Alloy Drill Bits

Cobalt alloy drill bits are designed for hard, tough metals like corrosion-resistant steel and titanium. It is important for the aircraft technician to note the difference between HSS and cobalt, because HSS drill bits wear out quickly when drilling titanium or stainless. Cobalt drill bits are excellent for drilling titanium or stainless steel, but do not produce a quality hole in aluminum alloys. Cobalt drill bits can be recognized by thicker webs and a taper at the end of the drill shank.

Twist Drill Bits

Easily the most popular drill bit type, the twist drill bit has spiral grooves or flutes running along its working length. *[Figure 4-46]* This drill bit comes in a single-fluted, two-fluted, three-fluted, and four-fluted styles. Single-fluted and two-fluted drill bits (most commonly available) are used for originating holes. Three-fluted and four-fluted drill bits are used interchangeably to enlarge existing holes. Twist drill bits are available in a wide choice of tooling materials and lengths with the variations targeting specific projects.

The standard twist drill bits used for drilling aluminum are made from HSS and have a 135° split point. Drill bits for titanium are made from cobalt vanadium for increased wear resistance.

Drill Bit Sizes

Drill diameters are grouped by three size standards: number, letter, and fractional. The decimal equivalents of standard drill are shown in *Figure 4-47*.

Drill Lubrication

Normal drilling of sheet material does not require lubrication, but lubrication should be provided for all deeper drilling

Figure 4-46. *Twist drill bits.*

Lubricants serve to assist in chip removal, which prolongs drill life and ensures a good finish and dimensional accuracy of the hole. It does not prevent overheating. The use of a lubricant is always a good practice when drilling castings, forgings, or heavy gauge stock. A good lubricant should be thin enough to help in chip removal but thick enough to stick to the drill. For aluminum, titanium, and corrosion-resistant steel, a cetyl alcohol based lubricant is the most satisfactory. Cetyl alcohol is a nontoxic fatty alcohol chemical produced in liquid, paste, and solid forms. The solid stick and block forms quickly liquefy at drilling temperatures. For steel, sulfurized mineral cutting oil is superior. Sulfur has an affinity for steel, which aids in holding the cutting oil in place. In the case of deep drilling, the drill should be withdrawn at intervals to relieve chip packing and to ensure the lubricant reaches the point. As a general rule, if the drill is large or the material hard, use a lubricant.

Reamers

Reamers, used for enlarging holes and finishing them smooth to a required size, are made in many styles. They can be straight or tapered, solid or expansive, and come with straight or helical flutes. *Figure 4-48* illustrates three types of reamers:

1. Three or four fluted production bullet reamers are customarily used where a finer finish and/or size is needed than can be achieved with a standard drill bit.
2. Standard or straight reamer.
3. Piloted reamer, with the end reduced to provide accurate alignment.

The cylindrical parts of most straight reamers are not cutting edges, but merely grooves cut for the full length of the reamer body. These grooves provide a way for chips to escape and a channel for lubricant to reach the cutting edge. Actual cutting is done on the end of the reamer. The cutting edges are normally ground to a bevel of 45° ± 5°.

Reamer flutes are not designed to remove chips like a drill. Do not attempt to withdraw a reamer by turning it in the reverse direction because chips can be forced into the surface, scarring the hole.

Drill Stops

A spring drill stop is a wise investment. *[Figure 4-49]* Properly adjusted, it can prevent excessive drill penetration that might damage underlying structure or injure personnel and prevent the drill chuck from marring the surface. Drill stops can be made from tubing, fiber rod, or hard rubber.

Drill Bushings & Guides

There are several types of tools available that aid in holding the drill perpendicular to the part. They consist of a hardened bushing anchored in a holder. *[Figure 4-50]*

Drill Size	Decimal (Inches)	Drill Size	Decimal (Inches)	Drill Size	Decimal (Inches)	Drill Size	Decimal (Inches)	Drill Size	Decimal (Inches)
80	.0135	50	.0700	22	.1570	G	.2610	31/64	.4844
79	.0145	49	.0730	21	.1590	17/64	.2656	1/2	.5000
1/54	.0156	48	.0760	20	.1610	H	.2660	33/64	.5156
78	.0160	5/64	.0781	19	.1660	I	.2720	17/32	.5312
77	.0180	47	.0785	18	.1695	J	.2770	35/64	.5469
76	.0200	46	.0810	11/64	.1718	K	.2810	9/16	.5625
75	.0210	45	.0820	17	.1730	9/32	.2812	37/64	.5781
74	.0225	44	.0860	16	.1770	L	.2900	19/32	.5937
73	.0240	43	.0890	15	.1800	M	.2950	39/84	.6094
72	.0250	42	.0935	14	.1820	19/64	.2968	5/8	.6250
71	.0260	3/32	.0937	13	.1850	N	.3020	41/64	.6406
70	.0280	41	.0960	3/16	.1875	5/16	.3125	21/32	.6562
69	.0293	40	.0980	12	.1890	O	.3160	43/64	.6719
68	.0310	39	.0995	11	.1910	P	.3230	11/16	.6875
1/32	.0312	38	.1015	10	.1935	21/64	.3281	45/64	.7031
67	.0320	37	.1040	9	.1960	Q	.3320	23/32	.7187
66	.0330	36	.1065	8	.1990	R	.3390	47/64	.7344
65	.0350	7/64	.1093	7	.2010	11/32	.3437	3/4	.7500
64	.0360	35	.1100	13/64	.2031	S	.3480	49/64	.7656
63	.0370	34	.1110	6	.2040	T	.3580	25/32	.7812
62	.0380	33	.1130	5	.2055	23/64	.3593	51/64	.7969
61	.0390	32	.1160	4	.2090	U	.3680	13/16	.8125
60	.0400	31	.1200	3	.2130	3/8	.3750	53/64	.8281
59	.0410	1/8	.1250	7/32	.2187	V	.3770	27/32	.8437
58	.0420	30	.1285	2	.2210	W	.3860	55/64	.8594
57	.0430	29	.1360	1	.2280	25/64	.3906	7/8	.8750
56	.0465	28	.1405	A	.2340	X	.3970	57/64	.8906
3/64	.0468	9/64	.1406	15/64	.2343	Y	.4040	29/32	.9062
55	.0520	27	.1440	B	.2380	13/32	.4062	59/64	.9219
54	.0550	26	.1470	C	.2420	Z	.4130	15/16	.9375
53	.0595	25	.1495	D	.2460	27/64	.4219	61/64	.9531
1/16	.0625	24	.1520	1/4	.2500	7/16	.4375	31/32	.9687
52	.0635	23	.1540	E	.2500	29/64	.4531	63/64	.9844
51	.0670	5/32	.1562	F	.2570	15/32	.4687	1	1.0000

Figure 4-47. *Drill sizes and decimal equivalents.*

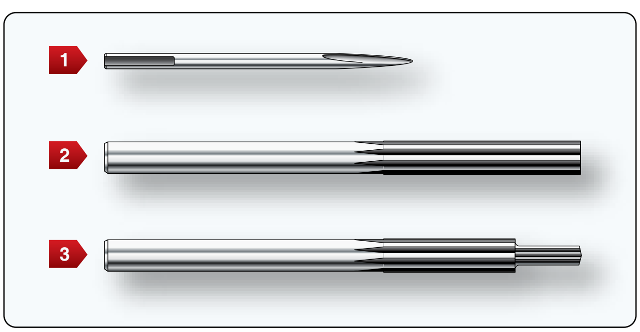


Figure 4-48. *Reamers.*

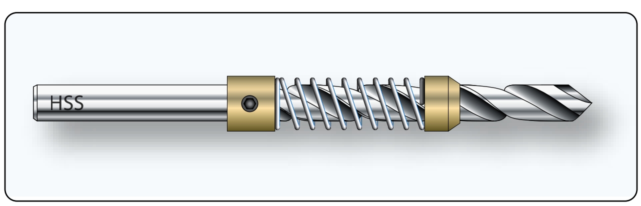


Figure 4-49. *Drill stop.*

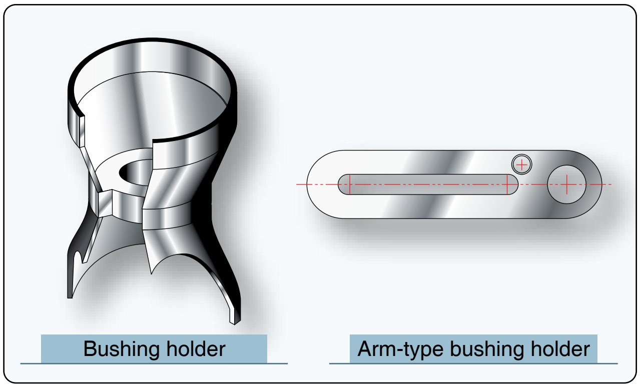


Figure 4-50. *Drill bushings.*

Drill bushing types:

1. Tube—hand-held in an existing hole
2. Commercial—twist lock
3. Commercial—threaded

Drill Bushing Holder Types

There are four types of drill bushing holder:

1. Standard—fine for drilling flat stock or tubing/rod; uses insert-type bushings.
2. Egg cup—improvement on standard tripod base; allows drilling on both flat and curved material; interchangeable bushings allows flexibility. *[Figure 4-51]*
3. Plate—used primarily for interchangeable production components; uses commercial bushings and self-feeding drills.
4. Arm—used when drilling critical structure; can be locked in position; uses interchangeable commercial bushings.

Hole Drilling Techniques

Precise location of drilled holes is sometimes required. When locating holes to close tolerances, accurately located punch marks need to be made. If a punch mark is too small, the chisel edge of the drill bit may bridge it and "walk off" the exact location before starting. If the punch mark is too heavy, it may deform the metal and/or result in a local strain hardening where the drill bit is to start cutting. The best size for a punch mark is about the width of the chisel edge of the drill bit to be used. This holds the drill point in place while starting. The procedure that ensures accurate holes follows: *[Figure 4-52]*

Figure 4-51. *Bushing holder.*

Figure 4-52. *Drilled sheet metal.*

1. Measure and lay out the drill locations carefully and mark with crossed lines.

   Note: The chisel edge is the least efficient operating surface element of the twist drill bit because it does not cut, but actually squeezes or extrudes the work material.
2. Use a sharp prick punch or spring-loaded center punch and magnifying glass to further mark the holes.
3. Seat a properly ground center punch (120°–135°) in the prick punch mark and, holding the center punch perpendicular to the surface, strike a firm square blow with a hammer.
4. Mark each hole with a small drill bit (1⁄16-inch recommended) to check and adjust the location prior to pilot drilling.
5. For holes 3⁄16-inch and larger, pilot drilling is recommended. Select a drill bit equal to the width of the chisel edge of the final drill bit size. Avoid using a pilot drill bit that is too large because it would cause the corners and cutting lips of the final drill bit to be dulled, burned, or chipped. It also contributes to chattering and drill motor stalling. Pilot drill at each mark.
6. Place the drill point at the center of the crossed lines,

perpendicular to the surface, and, with light pressure, start drilling slowly. Stop drilling after a few turns and check to see if the drill bit is starting on the mark. It should be; if not, it is necessary to walk the hole a little by pointing the drill in the direction it should go, and rotating it carefully and intermittently until properly lined up.

7. Enlarge each pilot drilled hole to final size.

Drilling Large Holes

The following technique can be used to drill larger holes. Special tooling has been developed to drill large holes to precise tolerances. *[Figure 4-53]*

1. Pilot drill using a drill bushing. Bushings are sized for ⅛, $^3/_{16}$, or ¼ drill bits.
2. Step drill bits are used to step the hole to approximately $^1/_{64}$-inch smaller than the final hole size. The aligning step diameter matches the pilot drill bit size.
3. Finish ream to size using a step reamer. The aligning step diameter matches the core drill bit size. Reamers should be available for both clearance and interference fit hole sizes.

   Note: Holes can also be enlarged by using a series of step reamers.

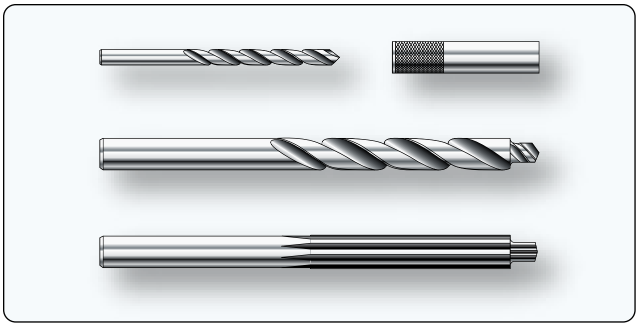


Figure 4-53. *Drilling large holes.*

Figure 4-54. *Chip chaser.*

Chip Chasers

The chip chaser is designed to remove chips and burrs lodged between sheets of metal after drilling holes for riveting. *[Figure 4-54]* Chip chasers have a plastic molded handle and a flexible steel blade with a hook in the end.

Forming Tools

Sheet metal forming dates back to the days of the blacksmith who used a hammer and hot oven to mold metal into the desired form. Today's aircraft technician relies on a wide variety of powered and hand-operated tools to precisely bend and fold sheet metal to achieve the perfect shape. Forming tools include straight line machines, such as the bar folder and press brake, as well as rotary machines, such as the slip roll former. Forming sheet metal requires a variety of tools and equipment (both powered and manual), such as the piccolo former, shrinking and stretching tools, form blocks, and specialized hammers and mallets. *[Figure 4-55]*

Figure 4-55. *Hammer and mallet forming.*

Tempered sheet stock is used in forming operations whenever possible in typical repairs. Forming that is performed in the tempered condition, usually at room temperature, is known as cold-forming. Cold forming eliminates heat treatment and the straightening and checking operations required to remove the warp and twist caused by the heat treating process. Cold-formed sheet metal experiences a phenomenon known as spring-back, which causes the worked piece to spring back slightly when the deforming force is removed. If the material shows signs of cracking during cold forming over small radii, the material should be formed in the annealed condition.

Annealing, the process of toughening steel by gradually heating and cooling it, removes the temper from metal, making it softer and easier to form. Parts containing small radii or compound curvatures must be formed in the annealed condition. After forming, the part is heat treated to a tempered condition before use on the aircraft.

Construction of interchangeable structural and nonstructural parts is achieved by forming flat sheet stock to make channel, angle, zee, and hat section members. Before a sheet metal part is formed, a flat pattern is made to show how much material is required in the bend areas, at what point the sheet must be inserted into the forming tool, or where bend lines are located. Determination of bend lines and bend allowances is discussed in greater detail in the section on layout and forming.

Bar Folding Machine

The bar folder is designed for use in making bends or folds along edges of sheets. *[Figure 4-56]* This machine is best suited for folding small hems, flanges, seams, and edges to be wired. Most bar folders have a capacity for metal up to 22 gauge in thickness and 42 inches in length. Before using the bar folder, several adjustments must be made for thickness of material, width of fold, sharpness of fold, and angle of fold. The adjustment for thickness of material is made by adjusting the screws at each end of the folder. As this adjustment is made, place a piece of metal of the desired thickness in the folder and raise the operating handle until the small roller rests on the cam. Hold the folding blade in this position and adjust the setscrews until the metal is clamped securely and evenly the full length of the folding blade. After the folder has been adjusted, test each end of the machine separately with a small piece of metal by actually folding it.

There are two positive stops on the folder, one for 45° folds or bends and the other for 90° folds or bends. A collar is provided that can be adjusted to any degree of bend within the capacity of the machine.

For forming angles of 45° or 90°, the appropriate stop is moved into place. This allows the handle to be moved forward to the correct angle. For forming other angles, the adjustable collar is used. This is accomplished by loosening the setscrew and setting the stop at the desired angle. After setting the stop, tighten the setscrew and complete the bend. To make the fold, adjust the machine correctly and then insert the metal. The metal goes between the folding blade and the jaw. Hold the metal firmly against the gauge and pull the operating handle toward the body. As the handle is brought forward, the jaw automatically raises and holds the metal until the desired fold is made. When the handle is returned to its original position, the jaw and blade return to their original positions and release the metal.

Cornice Brake

A brake is similar to a bar folder because it is also used for turning or bending the edges of sheet metal. The cornice brake is more useful than the bar folder because its design allows the sheet metal to be folded or formed to pass through the jaws from front to rear without obstruction. *[Figure 4-57]* In contrast, the bar folder can form a bend or edge only as wide as the depth of its jaws. Thus, any bend formed on a bar folder can also be made on the cornice brake.

In making ordinary bends with the cornice brake, the sheet is placed on the bed with the sight line (mark indicating line of bend) directly under the edge of the clamping bar. The clamping bar is then brought down to hold the sheet firmly in place. The stop at the right side of the brake is set for the proper angle or amount of bend and the bending leaf is raised until it strikes the stop. If other bends are to be made, the clamping bar is lifted and the sheet is moved to the correct position for bending.

The bending capacity of a cornice brake is determined by the manufacturer. Standard capacities of this machine are from 12- to 22-gauge sheet metal, and bending lengths are from 3 to 12 feet. The bending capacity of the brake is determined by the bending edge thickness of the various bending leaf bars.

Most metals have a tendency to return to their normal

Figure 4-56. *Bar folder.*

Figure 4-57. *Cornice brake.*

shape—a characteristic known as spring-back. If the cornice brake is set for a 90° bend, the metal bent probably forms an angle of about 87° to 88°. Therefore, if a bend of 90° is desired, set the cornice brake to bend an angle of about 93° to allow for spring-back.

Box & Pan Brake (Finger Brake)

The box and pan brake, often called the finger brake because it is equipped with a series of steel fingers of varying widths, lacks the solid upper jaw of the cornice brake. *[Figure 4-58]* The box and pan brake can be used to do everything that the cornice brake can do, as well as several things the cornice brake cannot do.

The box and pan brake is used to form boxes, pans, and other similar shaped objects. If these shapes were formed on a cornice brake, part of the bend on one side of the box would have to be straightened in order to make the last bend. With a finger brake, simply remove the fingers that are in the way and use only the fingers required to make the bend. The fingers are secured to the upper leaf by thumbscrews. All the fingers not removed for an operation must be securely seated and firmly tightened before the brake is used. The radius of the nose on the clamping fingers is usually rather small and frequently requires nose radius shims to be custom made for the total length of the bend.

Press Brake

Since most cornice brakes and box and pan brakes are limited to a maximum forming capacity of approximately 0.090-inch annealed aluminum, 0.063-inch 7075T6, or 0.063-inch stainless steel, operations that require the forming of thicker and more complex parts use a press brake. *[Figure 4-59]* The press brake is the most common machine tool used to bend sheet metal and applies force via mechanical and/or hydraulic components to shape the sheet metal between the punch and die. Narrow U-channels (especially with long legs) and hat channel stringers can be formed on the press brake by using special gooseneck or offset dies. Special urethane lower dies are useful for forming channels and stringers.

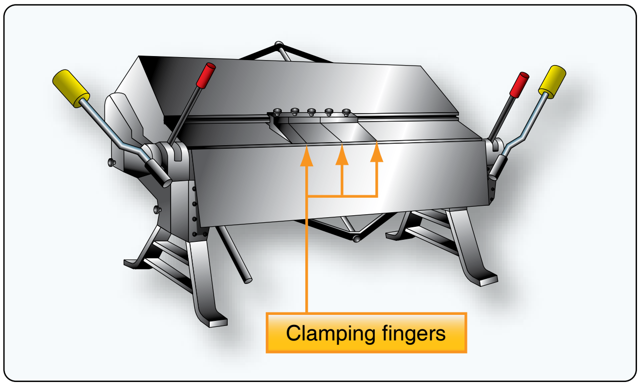


Figure 4-58. *Box and pan brake.*

Figure 4-59. *Press brake.*

Power press brakes can be set up with back stops (some are computer controlled) for high volume production. Press brake operations are usually done manually and require skill and knowledge of safe use.

Slip Roll Former

With the exception of the brake, the slip roll is probably used more than any other machine in the shop. *[Figure 4-60]* This machine is used to form sheets into cylinders or other straight curved surfaces. It consists of right and left end frames with three solid rolls mounted in between. Gears, which are operated by either a hand crank or a power drive, connect the two gripping rolls. These rolls can be adjusted to the thickness of the metal by using the two adjusting screws located on the bottom of each frame. The two most common of these forming machines are the slip roll former and the rotary former. Available in various sizes and capabilities, these machines come in manual or powered versions.

The slip roll former in *Figure 4-60* is manually operated and consists of three rolls, two housings, a base, and a handle. The handle turns the two front rolls through a system of gears enclosed in the housing. The front rolls serve as feeding, or gripping, rolls. The rear roll gives the proper curvature to the work. When the metal is started into the machine, the rolls grip the metal and carry it to the rear roll, which curves it. The desired radius of a bend is obtained by the rear roll. The bend radius of the part can be checked as the forming operation progresses by using a circle board or radius gauge. The gauges can be made by cutting a piece of material to the required finished radius and comparing it to the radius being formed by the rolling operation. On some material, the forming operation must be performed by passing the material through the rolls several times with progressive settings on the forming roll. On most machines, the top roll can be released on one end, permitting the formed sheet to be removed from the machine without distortion.

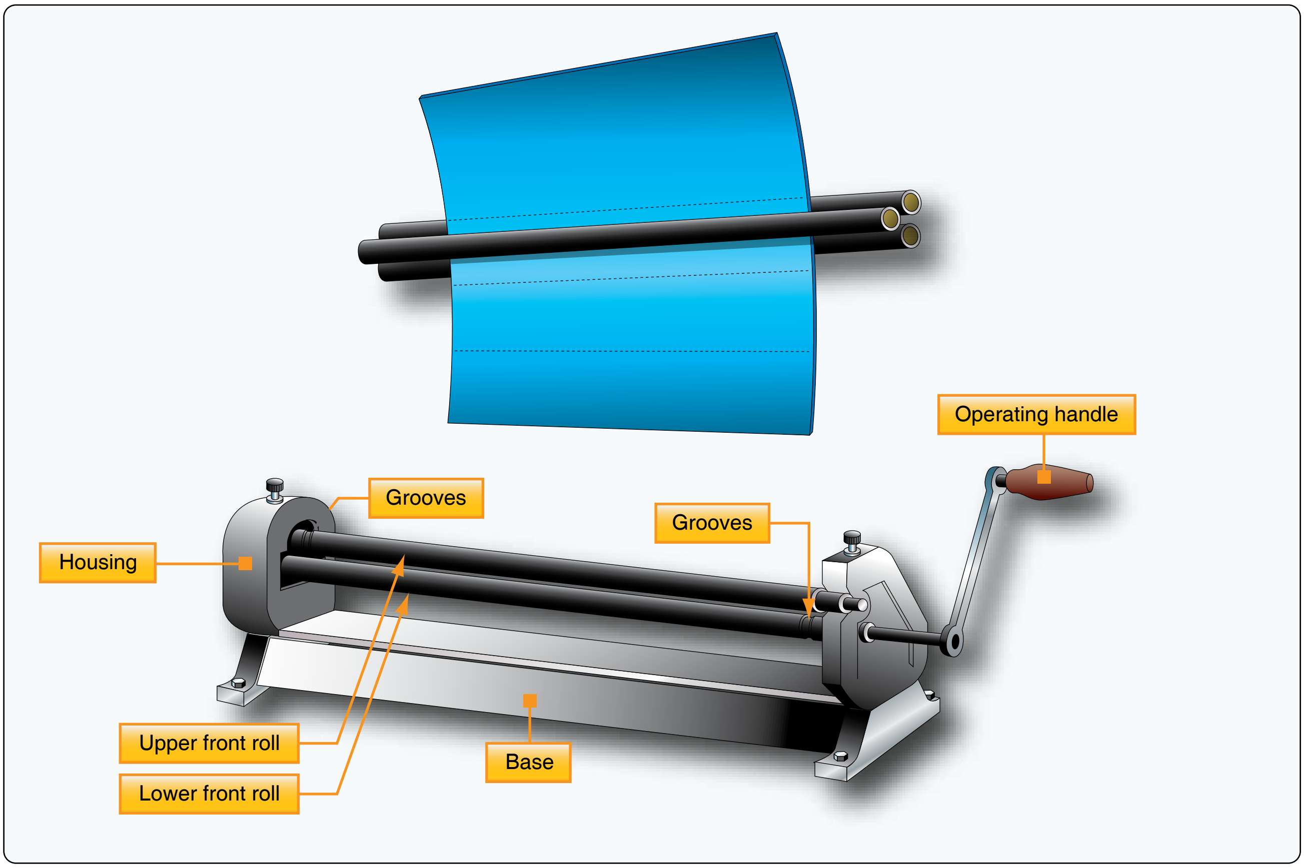


Figure 4-60. *Slip roll former.*

The front and rear rolls are grooved to permit forming of objects that have wired edges. The upper roll is equipped with a release that permits easy removal of the metal after it has been formed. When using the slip roll former, the lower front roll must be raised or lowered before inserting the sheet of metal. If the object has a folded edge, there must be enough clearance between the rolls to prevent flattening the fold. If a metal requiring special care (such as aluminum) is being formed, the rolls must be clean and free of imperfections.

The rear roll must be adjusted to give the proper curvature to the part being formed. There are no gauges that indicate settings for a specific diameter; therefore, trial and error settings must be used to obtain the desired curvature. The metal should be inserted between the rolls from the front of the machine. Start the metal between the rolls by rotating the operating handle in a clockwise direction. A starting edge is formed by holding the operating handle firmly with the right hand and raising the metal with the left hand. The bend of the starting edge is determined by the diameter of the part being formed. If the edge of the part is to be flat or nearly flat, a starting edge should not be formed.

Ensure that fingers and loose clothing are clear of the rolls before the actual forming operation is started. Rotate the operating handle until the metal is partially through the rolls and change the left hand from the front edge of the sheet to the upper edge of the sheet. Then, roll the remainder of the sheet through the machine. If the desired curvature is not obtained, return the metal to its starting position by rotating the handle counterclockwise. Raise or lower the rear roll and roll the metal through the rolls again. Repeat this procedure until the desired curvature is obtained, then release the upper roll and remove the metal. If the part to be formed has a tapered shape, the rear roll should be set so that the rolls are closer together on one end than on the opposite end. The amount of adjustment must be determined by experimentation. If the job being formed has a wired edge, the distance between the upper and lower rolls and the distance between the lower front roll and the rear roll should be slightly greater at the wired end than at the opposite end. *[Figure 4-61]*

Rotary Machine

The rotary machine is used on cylindrical and flat sheet metal to shape the edge or to form a bead along the edge. *[Figure 4-62]* Various shaped rolls can be installed on the rotary machine to perform these operations. The rotary machine works best with thinner annealed materials.

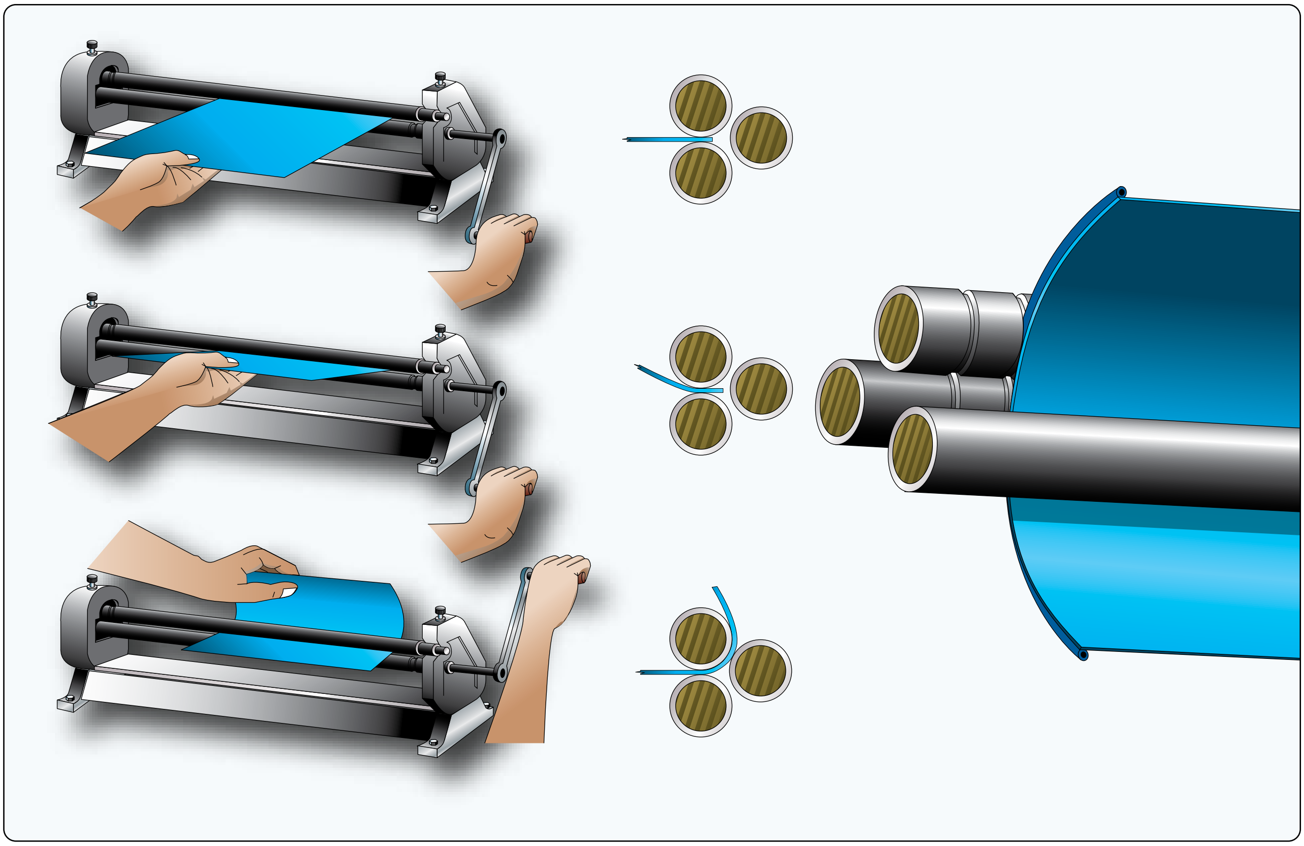


Figure 4-61. *Slip roll operation.*

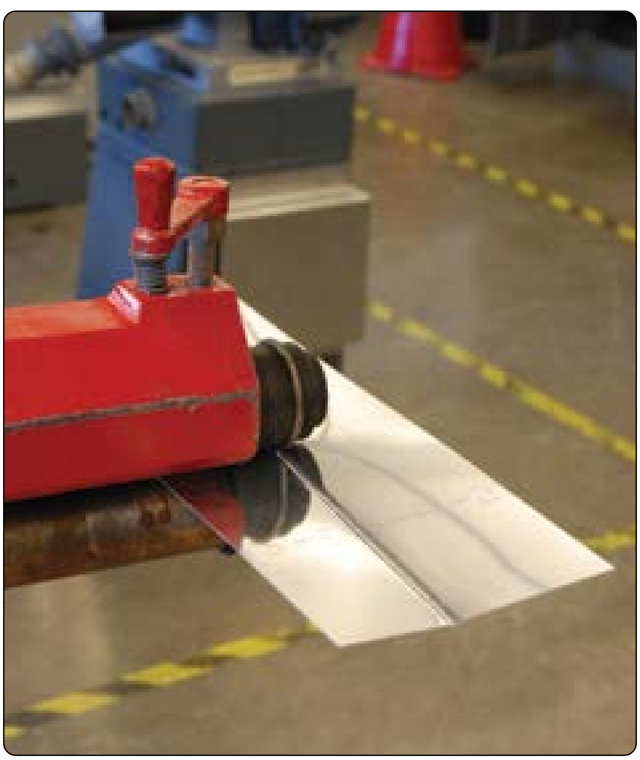


Figure 4-62. *Rotary machine.*

Stretch Forming

In the process of stretch forming, a sheet of metal is shaped by stretching it over a formed block to just beyond the elastic limit where permanent set takes place with a minimum amount of spring-back. To stretch the metal, the sheet is rigidly clamped at two opposite edges in fixed vises. Then, the metal is stretched by moving a ram that carries the form block against the sheet with the pressure from the ram causing the material to stretch and wrap to the contour of the form block.

Stretch forming is normally restricted to relatively large parts with large radii of curvature and shallow depth, such as contoured skin. Uniform contoured parts produced at a faster speed give stretch forming an advantage over hand formed parts. Also, the condition of the material is more uniform than that obtained by hand forming.

Drop Hammer

The drop hammer forming process produces shapes by the progressive deformation of sheet metal in matched dies under the repetitive blows of a gravity-drop hammer or a power-drop hammer. The configurations most commonly formed by the process include shallow, smoothly contoured double-curvature parts, shallow-beaded parts, and parts with irregular and comparatively deep recesses. Small quantities of cup-shaped and box-shaped parts, curved sections, and contoured flanged parts are also formed. Drop hammer forming is not a precision forming method and cannot provide tolerances as close as 0.03-inch to 0.06-inch. Nevertheless, the process is often used for sheet metal parts, such as aircraft components, that undergo frequent design changes, or for which there is a short run expectancy.

Hydropress Forming

The rubber pad hydropress can be utilized to form many varieties of parts from aluminum and its alloys with relative ease. Phenolic, masonite, kirksite, and some types of hard setting moulding plastic have been used successfully as form blocks to press sheet metal parts, such as ribs, spars, fans, etc. To perform a press forming operation:

1. Cut a sheet metal blank to size and deburr edges.
2. Set the form block (normally male) on the lower press platen.
3. Place the prepared sheet metal blank (with locating pins to prevent shifting of the blank when the pressure is applied).
4. Lower or close the rubber pad-filled press head over the form block and the rubber envelope.
5. The form block forces the blank to conform to its contour.

Hydropress forming is usually limited to relatively flat parts with flanges, beads, and lightening holes. However, some types of large radii contoured parts can be formed by a combination of hand forming and pressing operations.

Spin Forming

In spin forming, a flat circle of metal is rotated at a very high speed to shape a seamless, hollow part using the combined forces of rotation and pressure. For example, a flat circular blank such as an aluminum disc, is mounted in a lathe in conjunction with a form block (usually made of hardwood). As the aircraft technician revolves the disc and form block together at high speeds, the disc is molded to the form block by applying pressure with a spinning stick or tool. It provides an economical alternative to stamping, casting, and many other metal forming processes. Propeller spinners are sometimes fabricated with this technique.

Aluminum soap, tallow, or ordinary soap can be used as a lubricant. The best adapted materials for spinning are the softer aluminum alloys, but other alloys can be used if the shape to be spun is not excessively deep or if the spinning is done in stages utilizing intermediate annealing to remove the effect of strain hardening that results from the spinning operation. Hot forming is used in some instances when spinning thicker and harder alloys. *[Figure 4-63]*

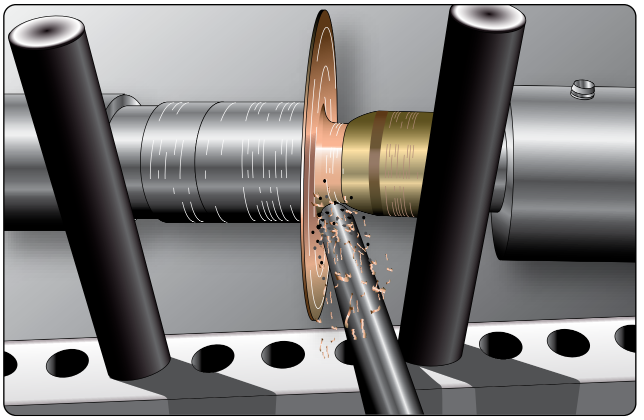


Figure 4-63. *Spin forming.*

Forming with an English Wheel

The English wheel, a popular type of metal forming tool used to create double curves in metal, has two steel wheels between which metal is formed. *[Figure 4-64]* Keep in mind that the English wheel is primarily a stretching machine, so it stretches and thins the metal before forming it into the desired shape. Thus, the operator must be careful not to over-stretch the metal.

To use the English wheel, place a piece of sheet metal between the wheels (one above and one below the metal). Then, roll the wheels against one another under a pre-adjusted

Figure 4-64. *English wheel.*

pressure setting. Steel or aluminum can be shaped by pushing the metal back and forth between the wheels. Very little pressure is needed to shape the panel, which is stretched or raised to the desired shape. It is important to work slowly and gradually curve the metal into the desired shape. Monitor the curvature with frequent references to the template.

The English wheel is used for shaping low crowns on large panels and polishing or planishing (to smooth the surface of a metal by rolling or hammering it) parts that have been formed with power hammers or hammer and shot bag.

Piccolo Former

The Piccolo former is used for cold forming and rolling sheet metal and other profile sections (extrusions). *[Figure 4-65]* The position of the ram is adjustable in height by means of either a handwheel or a foot pedal that permits control of the working pressure. Be sure to utilize the adjusting ring situated in the machine head to control the maximum working pressure. The forming tools are located in the moving ram and the lower tool holder. Depending on the variety of forming tools included, the operator can perform such procedures as forming edges, bending profiles, removing wrinkles, spot shrinking to remove buckles and dents, or expanding dome sheet metal. Available in either fiberglass (to prevent marring the surface) or steel (for working harder materials) faces, the tools are the quick-change type.

Shrinking & Stretching Tools

Shrinking Tools

Shrinking dies repeatedly clamp down on the metal, then shift inward. *[Figure 4-66]* This compresses the material between the dies, which actually slightly increases the thickness of the metal. Strain hardening takes place during this process, so it is best to set the working pressure high enough to complete the shape rather quickly (eight passes could be considered excessive).

Caution: Avoid striking a die on the radius itself when forming a curved flange. This damages the metal in the radius and decreases the angle of bend.

Figure 4-65. *Piccolo former.*

Figure 4-66. *Shrinking and stretching tools.*

Stretching Tools

Stretching dies repeatedly clamp down on the surface and then shift outward. This stretches the metal between the dies, which decreases the thickness in the stretched area. Striking the same point too many times weakens and eventually cracks the part. It is advantageous to deburr or even polish the edges of a flange that must undergo even moderate stretching to avoid crack formation. Forming flanges with existing holes causes the holes to distort and possibly crack or substantially weaken the flange.

Manual Foot-Operated Sheet Metal Shrinker

The manual foot-operated sheet metal shrinker operates very similarly to the Piccolo former though it only has two primary functions: shrinking and stretching. The only dies available are steel faced and therefore tend to mar the surface of the metal. When used on aluminum, it is necessary to gently blend out the surface irregularities (primarily in the cladding), then treat and paint the part.

Since this is a manual machine, it relies on leg power, as the operator repeatedly steps on the foot pedal. The more force is applied, the more stresses are concentrated at that single point. It yields a better part with a series of smaller stretches (or shrinks) than with a few intense ones. Squeezing the dies over the radius damages the metal and flattens out some of the bend. It may be useful to tape a thick piece of plastic or micarta to the opposite leg to shim the radius of the angle away from the clamping area of the dies.

Note: Watch the part change shape while slowly applying pressure. A number of small stretches works more effectively than one large one. If applying too much pressure, the metal has the tendency to buckle.

Hand-Operated Shrinker & Stretcher

The hand-operated shrinker and stretcher is similar to the manual foot-operated unit, except a handle is used to apply force to shrinking and stretching blocks. The dies are all metal and leave marks on aluminum that need to be blended out after the shrinking or stretching operation. *[Figure 4-67]*

Dollies & Stakes

Sheet metal is often formed or finished (planished) over anvils, available in a variety of shapes and sizes, called dollies and stakes. These are used for forming small, odd-shaped parts, or for putting on finishing touches for which a large machine may not be suited. Dollies are meant to be held in the hand, whereas stakes are designed to be supported by a flat cast iron bench plate fastened to the workbench. *[Figure 4-68]*

Most stakes have machined, polished surfaces that have been hardened. Use of stakes to back up material when chiseling, or when using any similar cutting tool, defaces the surface of the stake and makes it useless for finish work.

Hardwood Form Blocks

Hardwood form blocks can be constructed to duplicate practically any aircraft structural or nonstructural part. The wooden block or form is shaped to the exact dimensions and contour of the part to be formed.

V-Blocks

V-blocks made of hardwood are widely used in airframe metalwork for shrinking and stretching metal, particularly angles and flanges. The size of the block depends on the work being done and on personal preference. Although any type of hardwood is suitable, maple and ash are recommended for best results when working with aluminum alloys.

Figure 4-67. *Hand-operated shrinker and stretcher unit.*

Figure 4-68. *Dollies and stakes.*

Shrinking Blocks

A shrinking block consists of two metal blocks and some device for clamping them together. One block forms the base and the other is cut away to provide space where the crimped material can be hammered. The legs of the upper jaw clamp the material to the base block on each side of the crimp to prevent the material from creeping away, but remains stationary while the crimp is hammered flat (being shrunk). This type of crimping block is designed to be held in a bench vise.

Shrinking blocks can be made to fit any specific need. The basic form and principle remain the same, even though the blocks may vary considerably in size and shape.

Sandbags

A sandbag is generally used as a support during the bumping process. A serviceable bag can be made by sewing heavy canvas or soft leather to form a bag of the desired size, and filling it with sand which has been sifted through a fine mesh screen.

Before filling canvas bags with sand, use a brush to coat the inside of the bag with softened paraffin or beeswax, which forms a sealing layer and prevents the sand from working through the pores of the canvas. Bags can also be filled with shot as an alternative to sand.

Sheet Metal Hammers & Mallets

The sheet metal hammer and the mallet are metal fabrication hand tools used for bending and forming sheet metal without marring or indenting the metal. The hammer head is usually made of high carbon, heat-treated steel, while the head of the mallet, which is usually larger than that of the hammer, is made of rubber, plastic, wood, or leather. In combination with a sandbag, V-blocks, and dies, sheet metal body hammers and mallets are used to form annealed metal. *[Figure 4-69]*

Sheet Metal Holding Devices

In order to work with sheet metal during the fabrication process, the aviation technician uses a variety of holding devices, such as clamps, vises, and fasteners to hold the work together. The type of operation being performed and the type of metal being used determine what type of the holding device is needed.

Clamps & Vises

Clamps and vises hold materials in place when it is not possible to handle a tool and the workpiece at the same time. A clamp is a fastening device with movable jaws that has opposing, often adjustable, sides or parts. An essential fastening device, it holds objects tightly together to prevent movement or separation. Clamps can be either temporary or permanent. Temporary clamps, such as the carriage clamp (commonly called the C-clamp), are used to position components while fixing them together.

C-Clamps

The C-clamp is shaped like a large C and has three main parts: threaded screw, jaw, and swivel head. *[Figure 4-70]* The swivel plate or flat end of the screw prevents the end from turning directly against the material being clamped. C-clamp size is measured by the dimension of the largest object the frame can accommodate with the screw fully extended. The distance from the center line of the screw to the inside edge of the frame or the depth of throat is also an important consideration when using this clamp. C-clamps vary in size from two inches upward. Since C-clamps can leave marks on aluminum, protect the aircraft covering with masking tape at the places where the C-clamp is used.

Figure 4-69. *Sheet metal mallet and hammers.*

Figure 4-70. *C-clamps.*

Vises

Vises are another clamping device that hold the workpiece in place and allow work to be done on it with tools such as saws and drills. The vise consists of two fixed or adjustable jaws that are opened or closed by a screw or a lever. The size of a vise is measured by both the jaw width and the capacity of the vise when the jaws are fully open. Vises also depend on a screw to apply pressure, but their textured jaws enhance gripping ability beyond that of a clamp.

Two of the most commonly used vises are the machinist's vise and the utility vise. *[Figure 4-71]* The machinist's vise has flat jaws and usually a swivel base, whereas the utility bench vise has scored, removable jaws and an anvil-faced back jaw. This vise holds heavier material than the machinist's vise and also grips pipe or rod firmly. The back jaw can be used as an anvil if the work being done is light. To avoid marring metal in the vise jaws, add some type of padding, such as a ready-made rubber jaw pad.

Reusable Sheet Metal Fasteners

Reusable sheet metal fasteners temporarily hold drilled sheet metal parts accurately in position for riveting or drilling. If sheet metal parts are not held tightly together, they separate while being riveted or drilled. The Cleco (also spelled Cleko) fastener is the most commonly used sheet metal holder. *[Figure 4-72]*

Figure 4-71. *A utility vise with swivel base and anvil.*

Figure 4-72. *Cleco fastener.*

Cleco Fasteners

The Cleco fastener consists of a steel cylinder body with a plunger on the top, a spring, a pair of step-cut locks, and a spreader bar. These fasteners come in six different sizes: 3⁄32, 1⁄8, 5⁄32, 3⁄16, 1⁄4, and 3⁄8-inch in diameter with the size stamped on the fastener. Color coding allows for easy size recognition. A special type of plier fits the six different sizes. When installed correctly, the reusable Cleco fastener keeps the holes in the separate sheets aligned.

Hex Nut & Wing Nut Temporary Sheet Fasteners

Hex nut and wing nut fasteners are used to temporarily fasten sheets of metal when higher clamp up pressure is required. *[Figure 4-73]* Hex nut fasteners provide up to 300 pounds of clamping force with the advantage of quick installation and removal with a hex nut runner. Wing nut sheet metal fasteners, characterized by wing shaped protrusions, not only provide

Figure 4-73. *Hex nut fastener.*

a consistent clamping force from 0 to 300 pounds, but the aircraft technician can turn and tighten these fasteners by hand. Cleco hex nut fasteners are identical to Cleco wing nut fasteners, but the Cleco hex nut can be used with pneumatic Cleco installers.

Aluminum Alloys

Aluminum alloys are the most frequently encountered type of sheet metal in aircraft repair. AC 43.13-1 Chapter 4, Metal Structure, Welding, and Brazing; Section 1, Identification of Metals (as revised) provides an in-depth discussion of all metal types. This section describes the aluminum alloys used in the forming processes discussed in the remainder of the chapter.

In its pure state, aluminum is lightweight, lustrous, and corrosion resistant. The thermal conductivity of aluminum is very high. It is ductile, malleable, and nonmagnetic. When combined with various percentages of other metals (generally copper, manganese, and magnesium), aluminum alloys that are used in aircraft construction are formed. Aluminum alloys are lightweight and strong. They do not possess the corrosion resistance of pure aluminum and are usually treated to prevent deterioration. Alclad™ aluminum is an aluminum alloy with a protective cladding of aluminum to improve its corrosion resistance.

To provide a visual means for identifying the various grades of aluminum and aluminum alloys, aluminum stock is usually marked with symbols such as a Government Specification Number, the temper or condition furnished, or the commercial code marking. Plate and sheet are usually marked with specification numbers or code markings in rows approximately five inches apart. Tubes, bars, rods, and extruded shapes are marked with specification numbers or code markings at intervals of three to five feet along the length of each piece.

The commercial code marking consists of a number that identifies the particular composition of the alloy. Additionally, letter suffixes designate the basic temper designations and subdivisions of aluminum alloys.

The aluminum and various aluminum alloys used in aircraft repair and construction are as follows:

- Aluminum designated by the symbol 1100 is used where strength is not an important factor, but where weight economy and corrosion resistance are desired. This aluminum is used for fuel tanks, cowlings, and oil tanks. It is also used for repairing wingtips and tanks. This material is weldable.
- Alloy 3003 is similar to 1100 and is generally used for the same purposes. It contains a small percentage of magnesium and is stronger and harder than 1100 aluminum.
- Alloy 2014 is used for heavy-duty forgings, plates, extrusions for aircraft fittings, wheels, and major structural components. This alloy is often used for applications requiring high strength and hardness, as well as for service at elevated temperatures.
- Alloy 2017 is used for rivets. This material is now in limited use.
- Alloy 2024, with or without Alclad™ coating, is used for aircraft structures, rivets, hardware, machine screw products, and other miscellaneous structural applications. In addition, this alloy is commonly used for heat-treated parts, airfoil and fuselage skins, extrusions, and fittings.
- Alloy 2025 is used extensively for propeller blades.
- Alloy 2219 is used for fuel tanks, aircraft skin, and structural components. This material has high fracture toughness and is readily weldable. Alloy 2219 is also highly resistant to stress corrosion cracking.
- Alloy 5052 is used where good workability, very good corrosion resistance, high fatigue strength, weldability, and moderate static strength are desired. This alloy is used for fuel, hydraulic, and oil lines.
- Alloy 5056 is used for making rivets and cable sheeting and in applications where aluminum comes into contact with magnesium alloys. Alloy 5056 is generally resistant to the most common forms of corrosion.
- Cast aluminum alloys are used for cylinder heads, crankcases, fuel injectors, carburetors, and landing wheels.
- Various alloys, including 3003, 5052, and 1100 aluminum, are hardened by cold working rather than by heat treatment. Other alloys, including 2017 and 2024, are hardened by heat treatment, cold working, or a combination of the two. Various casting alloys are hardened by heat treatment.
- Alloy 6061 is generally weldable by all commercial procedures and methods. It also maintains acceptable toughness in many cryogenic applications. Alloy 6061 is easily extruded and is commonly used for hydraulic and pneumatic tubing.
- Although higher in strength than 2024, alloy 7075 has a lower fracture toughness and is generally used in tension applications where fatigue is not critical. The T6 temper of 7075 should be avoided in corrosive environments. However, the T7351 temper of 7075 has excellent stress corrosion resistance and better fracture toughness than the T6 temper. The T76 temper is often used to improve the resistance of 7075 to exfoliate corrosion.

Structural Fasteners

Structural fasteners, used to join sheet metal structures securely, come in thousands of shapes and sizes with many of them specialized and specific to certain aircraft. Since some structural fasteners are common to all aircraft, this section focuses on the more frequently used fasteners. For the purposes of this discussion, fasteners are divided into two main groups: solid shank rivets and special purpose fasteners that include blind rivets.

Solid Shank Rivet

The solid shank rivet is the most common type of rivet used in aircraft construction. Used to join aircraft structures, solid shank rivets are one of the oldest and most reliable types of fastener. Widely used in the aircraft manufacturing industry, solid shank rivets are relatively low-cost, permanently installed fasteners. They are faster to install than bolts and nuts since they adapt well to automatic, high-speed installation tools. Rivets should not be used in thick materials or in tensile applications, as their tensile strengths are quite low relative to their shear strength. The longer the total grip length (the total thickness of sheets being joined), the more difficult it becomes to lock the rivet.

Riveted joints are neither airtight nor watertight unless special seals or coatings are used. Since rivets are permanently installed, they must be removed by drilling them out, a laborious task.

Description

Before installation, the rivet consists of a smooth cylindrical shaft with a factory head on one end. The opposite end is called the bucktail. To secure two or more pieces of sheet metal together, the rivet is placed into a hole cut just a bit larger in diameter than the rivet itself. Once placed in this predrilled hole, the bucktail is upset or deformed by any of several methods from hand-held hammers to pneumatically driven squeezing tools. This action causes the rivet to expand about 1½ times the original shaft diameter, forming a second head that firmly holds the material in place.

Rivet Head Shape

Solid rivets are available in several head shapes, but the universal (also known as protruding head) and the 100° countersunk head are the most commonly used in aircraft structures. Universal head rivets were developed specifically for the aircraft industry and designed as a replacement for both the round and brazier head rivets. These rivets replaced all protruding head rivets and are used primarily where the protruding head has no aerodynamic significance. They have a flat area on the head, a head diameter twice the shank diameter, and a head height approximately 42.5 percent of the shank diameter. *[Figure 4-74]*

The countersunk head angle can vary from 60° to 120°, but the 100° has been adopted as standard because this head style provides the best possible compromise between tension/shear strength and flushness requirements. This rivet is used where flushness is required because the rivet is flat-topped and undercut to allow the head to fit into a countersunk or dimpled hole. The countersunk rivet is primarily intended for use when aerodynamics smoothness is critical, such as on the external surface of a high-speed aircraft.

Typically, rivets are fabricated from aluminum alloys, such as 2017-T4, 2024-T4, 2117-T4, 7050, and 5056. Titanium, nickel-based alloys, such as Monel® (corrosion-resistant steel), mild steel or iron, and copper rivets are also used for rivets in certain cases.

Rivets are available in a wide variety of alloys, head shapes, and sizes and have a wide variety of uses in aircraft structure. Rivets that are satisfactory for one part of the aircraft are often unsatisfactory for another part. Therefore, it is important that an aircraft technician know the strength and driving properties of the various types of rivets and how to identify them, as well as how to drive or install them.

Solid rivets are classified by their head shape, by the material from which they are manufactured, and by their size. Identification codes used are derived from a combination of the Military Standard (MS) and National Aerospace Standard (NAS) systems, as well as an older classification system known as AN for Army/Navy. For example, the prefix MS identifies hardware that conforms to written military standards. A letter or letters following the head-shaped code identify the material or alloy from which the rivet was made. The alloy code is followed by two numbers separated by a dash. The first number is the numerator of a fraction, which specifies the shank diameter in thirty-seconds of an inch. The second number is the numerator of a fraction in sixteenths of an inch and identifies the length of the rivet. Rivet head shapes and their identifying code numbers are shown in *Figure 4-75.*

The most frequently used repair rivet is the AD rivet because it can be installed in the received condition. Some rivet alloys, such as DD rivets (alloy 2024-T4), are too hard to drive in the received condition and must be annealed before they can be installed. Typically, these rivets are annealed and stored in a freezer to retard hardening, which has led to the nickname "ice box rivets." They are removed from the freezer just prior to use. Most DD rivets have been replaced by E-type rivets which can be installed in the received condition.

The head type, size, and strength required in a rivet are governed by such factors as the kind of forces present at the point riveted, the kind and thickness of the material to be riveted, and the location of the part on the aircraft. The type of head needed for a particular job is determined by where it is to be installed. Countersunk head rivets should be used where a smooth aerodynamic surface is required. Universal head rivets may be used in most other areas.

The size (or diameter) of the selected rivet shank should correspond in general to the thickness of the material being riveted. If an excessively large rivet is used in a thin material, the force necessary to drive the rivet properly causes an undesirable bulging around the rivet head. On the other hand,

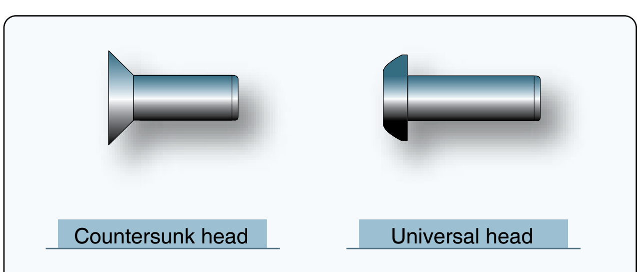


Figure 4-74. *Solid shank rivet styles.*

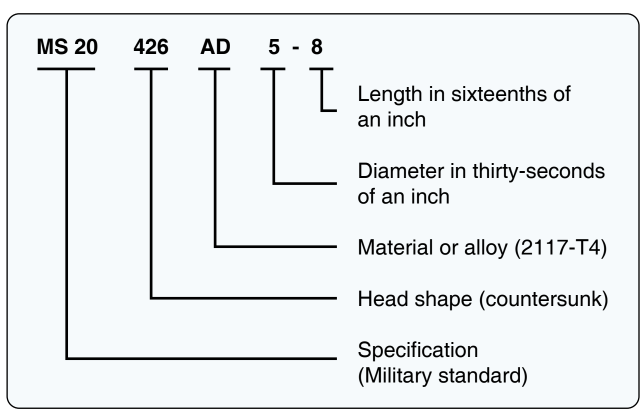


Figure 4-75. *Rivet head shapes and their identifying code numbers.*

if an excessively small rivet diameter is selected for thick material, the shear strength of the rivet is not great enough to carry the load of the joint. As a general rule, the rivet diameter should be at least two and a half to three times the thickness of the thicker sheet. Rivets most commonly chosen in the assembly and repair of aircraft range from 3⁄32-inch to 3⁄8-inch in diameter. Ordinarily, rivets smaller than 3⁄32-inch in diameter are never used on any structural parts that carry stresses.

The proper sized rivets to use for any repair can also be determined by referring to the rivets (used by the manufacturer) in the next parallel row inboard on the wing or forward on the fuselage. Another method of determining the size of rivets to be used is to multiply the skin's thickness by 3 and use the next larger size rivet corresponding to that figure. For example, if the skin is 0.040 inch thick, multiply 0.040 inch by 3 to get 0.120 inch and use the next larger size of rivet, 1⁄8-inch (0.125 inch).

When rivets are to pass completely through tubular members, select a rivet diameter equivalent to at least 1⁄8 the outside diameter of the tube. If one tube sleeves or fits over another, take the outside diameter of the outside tube and use one-eighth of that distance as the minimum rivet diameter. A good practice is to calculate the minimum rivet diameter and then use the next larger size rivet.

Whenever possible, select rivets of the same alloy number as the material being riveted. For example, use 1100 and 3003 rivets on parts fabricated from 1100 and 3003 alloys, and 2117-1 and 2017-T rivets on parts fabricated from 2017 and 2024 alloys.

The size of the formed head is the visual standard of a proper rivet installation. The minimum and maximum sizes, as well as the ideal size, are shown in *Figure 4-76*.

Installation of Rivets

Repair Layout

Repair layout involves determining the number of rivets required, the proper size and style of rivets to be used, their material, temper condition and strength, the size of the holes, the distances between the holes, and the distance between the holes and the edges of the patch. Distances are measured in terms of rivet diameter.

Rivet Length

To determine the total length of a rivet to be installed, the combined thickness of the materials to be joined must first be known. This measurement is known as the grip length. The total length of the rivet equals the grip length plus the amount of rivet shank needed to form a proper shop head. The properly formed shop head equals one and a half times the diameter of the rivet shank. Where A is total rivet length, B is grip length, and C is the length of the material needed to form a shop head, this formula can be represented as A = B + C. *[Figure 4-76]*

Rivet Strength

For structural applications, the strength of the replacement rivets is of primary importance. *[Figure 4-77]* Replace rivets with those of the same size and strength whenever possible. If the rivet hole becomes enlarged, deformed, or otherwise damaged; drill or ream the hole for the next larger size rivet. However, make sure that the edge distance and spacing is not less than minimums listed in the next paragraph. Rivets may not be replaced by a type having lower strength properties, unless the lower strength is adequately compensated by an increase in size or a greater number of rivets. For example, it is acceptable to replace 2017 rivets of 3/16 inch diameter or less, and 2024 rivets of 5/32 inch diameter or less with 2117 rivets for general repairs, provided the replacement rivets are 1/32 inch greater in diameter than the rivets they replace.

The 2117-T rivet is used for general repair work, since it requires no heat treatment, is fairly soft and strong, and is highly corrosion resistant when used with most types of alloys. Always consult the maintenance manual for correct rivet type and material. The type of rivet head to select for a particular repair job can be determined by referring to the

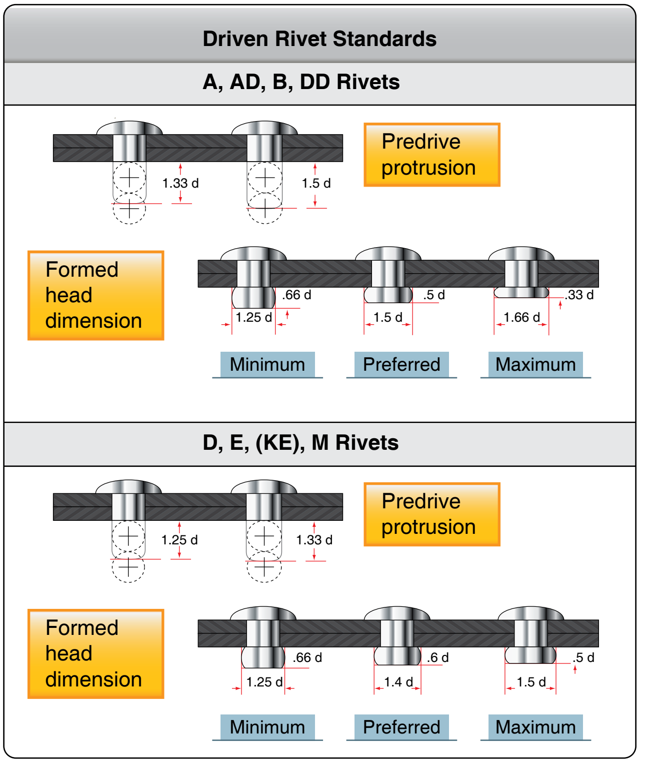


Figure 4-76. *Rivet formed head dimensions.*

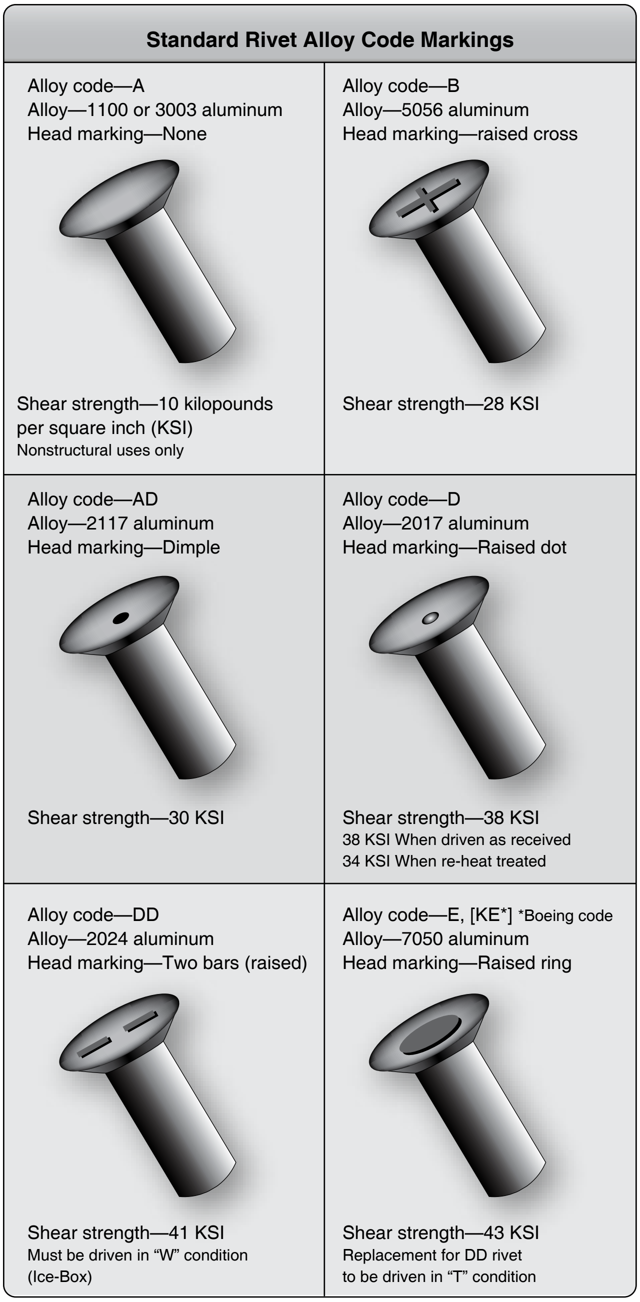


Figure 4-77. *Rivet alloy strength.*

type used within the surrounding area by the manufacturer. A general rule to follow on a flush-riveted aircraft is to apply flush rivets on the upper surface of the wing and stabilizers, on the lower leading edge back to the spar, and on the fuselage back to the high point of the wing. Use universal head rivets in all other surface areas. Whenever possible, select rivets of the same alloy number as the material being riveted.

Stresses Applied to Rivets

Shear is one of the two stresses applied to rivets. The shear strength is the amount of force required to cut a rivet that holds two or more sheets of material together. If the rivet holds two parts, it is under single shear; if it holds three sheets or parts, it is under double shear. To determine the shear strength, the diameter of the rivet to be used must be found by multiplying the thickness of the skin material by 3. For example, a material thickness of 0.040 inch multiplied by 3 equals 0.120 inch. In this case, the rivet diameter selected would be ⅛ (0.125) inch.

Tension is the other stress applied to rivets. The resistance to tension is called bearing strength and is the amount of tension required to pull a rivet through the edge of two sheets riveted together or to elongate the hole.

Rivet Spacing

Rivet spacing is measured between the centerlines of rivets in the same row. The minimum spacing between protruding head rivets shall not be less than 3½ times the rivet diameter. The minimum spacing between flush head rivets shall not be less than 4 times the diameter of the rivet. These dimensions may be used as the minimum spacing except when specified differently in a specific repair procedure or when replacing existing rivets.

On most repairs, the general practice is to use the same rivet spacing and edge distance (distance from the center of the hole to the edge of the material) that the manufacturer used in the area surrounding the damage. The SRM for the particular aircraft may also be consulted. Aside from this fundamental rule, there is no specific set of rules that governs spacing of rivets in all cases. However, there are certain minimum requirements that must be observed.

- When possible, rivet edge distance, rivet spacing, and distance between rows should be the same as that of the original installation.
- When new sections are to be added, the edge distance measured from the center of the rivet should never be less than 2 times the diameter of the shank; the distance between rivets or pitch should be at least 3 times the diameter; and the distance between rivet rows should never be less than 2½ times the diameter.

Figure 4-78 illustrates acceptable ways of laying out a rivet pattern for a repair.

Edge Distance

Edge distance, also called edge margin by some manufacturers, is the distance from the center of the first rivet to the edge of the sheet. It should not be less than 2 or more than 4 rivet diameters and the recommended edge distance is about 2½ rivet diameters. The minimum edge distance for universal rivets is 2 times the diameter of the rivet; the minimum edge distance for countersunk rivets is 2½ times the diameter of the

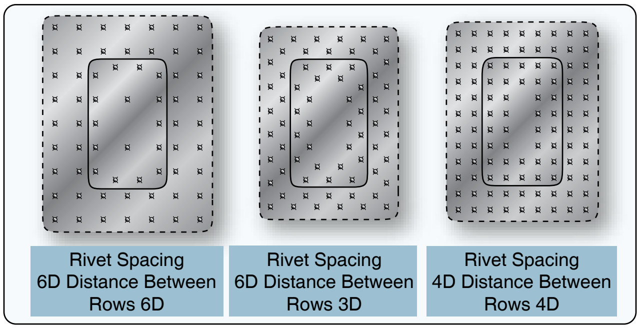
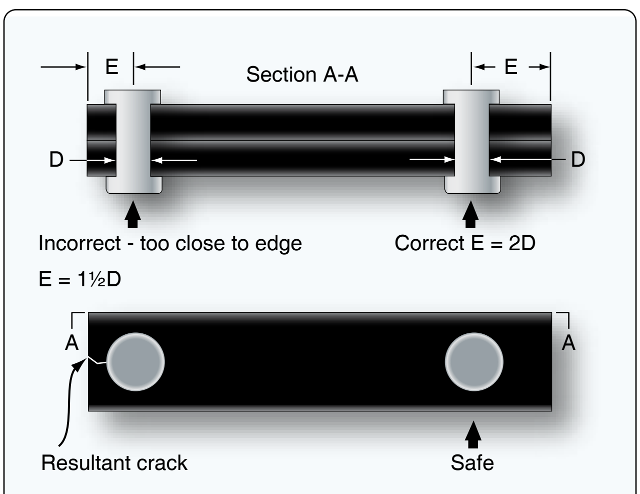


Figure 4-78. *Acceptable rivet patterns.*

rivet. If rivets are placed too close to the edge of the sheet, the sheet may crack or pull away from the rivets. If they are spaced too far from the edge, the sheet is likely to turn up at the edges. *[Figure 4-79]*

It is good practice to lay out the rivets a little further from the edge so that the rivet holes can be oversized without violating the edge distance minimums. Add 1/16-inch to the minimum edge distance or determine the edge distance using the next size of rivet diameter.



Edge Distance/Edge Margin	Minimum Edge Distance	Preferred Edge Distance
Protruding head rivets	2 D	2 D + 1/16″
Countersunk rivets	2½ D	2½ D + 1/16″

Figure 4-79. *Minimum edge distance.*

Two methods for obtaining edge distance:

- The rivet diameter of a protruding head rivet is 3/32-inch. Multiply 2 times 3/32-inch to obtain the minimum edge distance, 3/16-inch, add 1/16-inch to yield the preferred edge distance of 1/4-inch.
- The rivet diameter of a protruding head rivet is 3/32-inch. Select the next size of rivet, which is 1/8-inch. Calculate the edge distance by multiplying 2 times 1/8-inch to get 1/4-inch.

Rivet Pitch

Rivet pitch is the distance between the centers of neighboring rivets in the same row. The smallest allowable rivet pitch is 3 rivet diameters. The average rivet pitch usually ranges from 4 to 6 rivet diameters, although in some instances rivet pitch could be as large as 10 rivet diameters. Rivet spacing on parts that are subjected to bending moments is often closer to the minimum spacing to prevent buckling of the skin between the rivets. The minimum pitch also depends on the number of rows of rivets. One-and three-row layouts have a minimum pitch of 3 rivet diameters, a two-row layout has a minimum pitch of 4 rivet diameters. The pitch for countersunk rivets is larger than for universal head rivets. If the rivet spacing is made at least 1/16-inch larger than the minimum, the rivet hole can be oversized without violating the minimum rivet spacing requirement. *[Figure 4-80]*

Transverse Pitch

Transverse pitch is the perpendicular distance between rivet rows. It is usually 75 percent of the rivet pitch. The smallest allowable transverse pitch is 2½ rivet diameters. The smallest allowable transverse pitch is 2½ rivet diameters. Rivet pitch and transverse pitch often have the same dimension and are simply called rivet spacing.

Rivet Layout Example

The general rules for rivet spacing, as it is applied to a straight-row layout, are quite simple. In a one-row layout, find the edge distance at each end of the row and then lay off the rivet pitch (distance between rivets), as shown in *Figure 4-81*. In a two-row layout, lay off the first row, place the second row a distance equal to the transverse pitch from the first row, and then lay off rivet spots in the second row so that they fall midway between those in the first row. In the

Rivet Spacing	Minimum Spacing	Preferred Spacing
1 and 3 rows protruding head rivet layout	3D	3D + 1/16"
2 row protruding head rivet layout	4D	4D + 1/16"
1 and 3 rows countersunk head rivet layout	3/1/2D	3/1/2D + 1/16"
2 row countersunk head rivet layout	4/1/2D	4/1/2D + 1/16"

Figure 4-80. *Rivet spacing.*

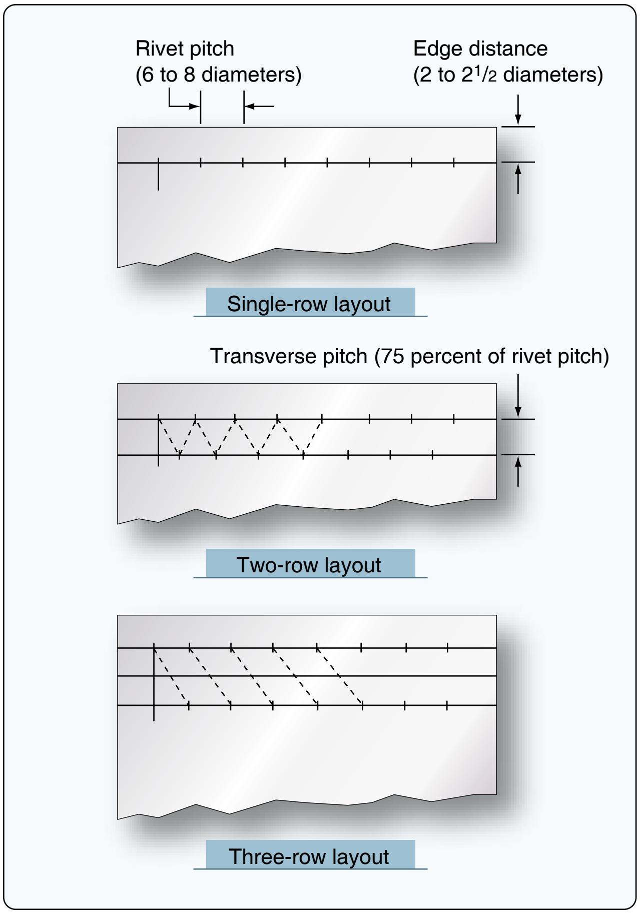


Figure 4-81. *Rivet layout.*

three-row layout, first lay off the first and third rows, then use a straightedge to determine the second row rivet spots.

When splicing a damaged tube, and the rivets pass completely through the tube, space the rivets four to seven rivet diameters apart if adjacent rivets are at right angles to each other, and space them five to seven rivet diameters apart if the rivets are parallel to each other. The first rivet on each side of the joint should be no less than 2½ rivet diameters from the end of the sleeve.

Rivet Installation Tools

The various tools needed in the normal course of driving and upsetting rivets include drills, reamers, rivet cutters or nippers, bucking bars, riveting hammers, draw sets, dimpling dies or other types of countersinking equipment, rivet guns, and squeeze riveters. C-clamps, vises, and other fasteners used to hold sheets together when riveting were discussed earlier in the chapter. Other tools and equipment needed in the installation of rivets are discussed in the following paragraphs.

Hand Tools

A variety of hand tools are used in the normal course of driving and upsetting rivets. They include rivet cutters, bucking bars, hand riveters, countersinks, and dimpling tools.

Rivet Cutter

The rivet cutter is used to trim rivets when rivets of the required length are unavailable. *[Figure 4-82]* To use the rotary rivet cutter, insert the rivet in the correct hole, place the required number of shims under the rivet head, and squeeze the cutter as if it were a pair of pliers. Rotation of the discs cuts the rivet to give the right length, which is determined by the number of shims inserted under the head. When using a large rivet cutter, place it in a vise, insert the rivet in the proper hole, and cut by pulling the handle, which shears off the rivet. If regular rivet cutters are not available, diagonal cutting pliers can be used as a substitute cutter.

Bucking Bar

The bucking bar, sometimes called a dolly, bucking iron, or bucking block, is a heavy chunk of steel whose countervibration during installation contributes to proper rivet installation. They come in a variety of shapes and sizes, and their weights ranges from a few ounces to 8 or 10 pounds, depending upon the nature of the work. Bucking bars are most often made from low-carbon steel that has been case hardened or alloy bar stock. Those made of better grades of steel last longer and require less reconditioning.

Bucking faces must be hard enough to resist indentation and remain smooth, but not hard enough to shatter. Sometimes, the more complicated bars must be forged or built up by welding. The bar usually has a concave face to conform to the shape of the shop head to be made. When selecting a bucking bar, the first consideration is shape. *[Figure 4-83]* If the bar does not have the correct shape, it deforms the rivet head; if the bar is too light, it does not give the necessary bucking weight, and the material may become bulged toward the shop head. If the bar is too heavy, its weight and the bucking force may cause the material to bulge away from the shop head.

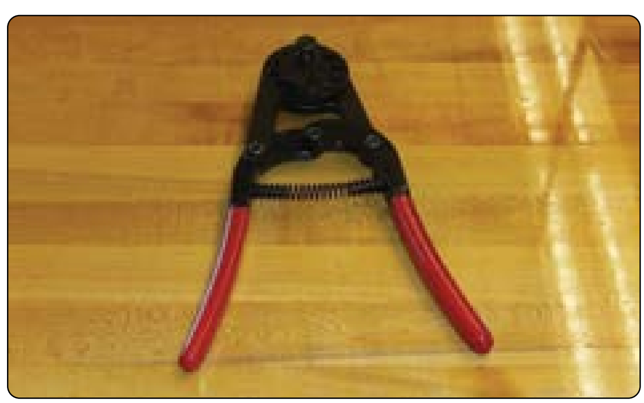


Figure 4-82. *Rivet cutters.*

Figure 4-83. *Bucking bars.*

This tool is used by holding it against the shank end of a rivet while the shop head is being formed. Always hold the face of the bucking bar at right angles to the rivet shank. Failure to do so causes the rivet shank to bend with the first blows of the rivet gun and causes the material to become marred with the final blows. The bucker must hold the bucking bar in place until the rivet is completely driven. If the bucking bar is removed while the gun is in operation, the rivet set may be driven through the material. Allow the weight of the bucking bar to do most of the work and do not bear down too heavily on the shank of the rivet. The operator's hands merely guide the bar and supply the necessary tension and rebound action. Coordinated bucking allows the bucking bar to vibrate in unison with the gun set. With experience, a high degree of skill can be developed.

Defective rivet heads can be caused by lack of proper vibrating action, the use of a bucking bar that is too light or too heavy, and failure to hold the bucking bar at right angles to the rivet. The bars must be kept clean, smooth, and well polished. Their edges should be slightly rounded to prevent marring the material surrounding the riveting operation.

Hand Rivet Set

A hand rivet set is a tool equipped with a die for driving a particular type rivet. Rivet sets are available to fit every size and shape of rivet head. The ordinary set is made of ½-inch carbon tool steel about 6 inches in length and is knurled to prevent slipping in the hand. Only the face of the set is hardened and polished.

Sets for universal rivets are recessed (or cupped) to fit the rivet head. In selecting the correct set, be sure it provides the proper clearance between the set and the sides of the rivet head and between the surfaces of the metal and the set. Flush or flat sets are used for countersunk and flathead rivets. To seat flush rivets properly, be sure that the flush sets are at least 1 inch in diameter.

Special draw sets are used to draw up the sheets to eliminate any opening between them before the rivet is bucked. Each draw set has a hole ⅓₂-inch larger than the diameter of the rivet shank for which it is made. Occasionally, the draw set and rivet header are incorporated into one tool. The header part consists of a hole shallow enough for the set to expand the rivet and head when struck with a hammer.

Countersinking Tool

The countersink is a tool that cuts a cone-shaped depression around the rivet hole to allow the rivet to set flush with the surface of the skin. Countersinks are made with angles to correspond with the various angles of countersunk rivet heads. The standard countersink has a 100º angle, as shown in *Figure 4-84*. Special microstop countersinks (commonly called stop countersinks) are available that can be adjusted to any desired depth and have cutters to allow interchangeable holes with various countersunk angles to be made. *[Figure 4-85]* Some stop countersinks also have a micrometer set mechanism, in 0.001-inch increments, for adjusting their cutting depths.

Dimpling Dies

Dimpling is done with a male and female die (punch and die set). The male die has a guide the size of the rivet hole and with the same degree of countersink as the rivet. The female die has a hole with a corresponding degree of countersink into which the male guide fits.

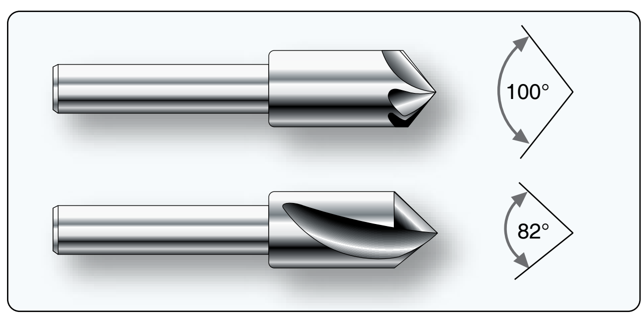


Figure 4-84. *Countersinks.*

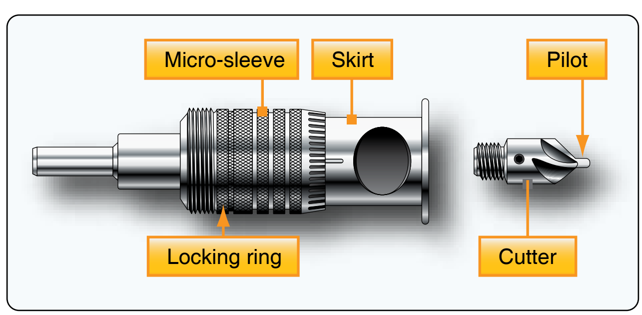


Figure 4-85. *Microstop countersink.*

Figure 4-86. *Rivet guns.*

Power Tools

The most common power tools used in riveting are the pneumatic rivet gun, rivet squeezers, and the microshaver.

Pneumatic Rivet Gun

The pneumatic rivet gun is the most common rivet upsetting tool used in airframe repair work. It is available in many sizes and types. *[Figure 4-86]* The manufacturer's recommended capacity for each gun is usually stamped on the barrel. Pneumatic guns operate on air pressure of 90 to 100 pounds per square inch and are used in conjunction with interchangeable rivet sets. Each set is designed to fit the specific type of rivet and the location of the work. The shank of the set is designed to fit into the rivet gun. An air-driven hammer inside the barrel of the gun supplies force to buck the rivet.

Slow hitting rivet guns that strike from 900 to 2,500 blows per minute are the most common type. *[Figure 4-87]* These blows are slow enough to be easily controlled and heavy enough to do the job. These guns are sized by the largest rivet size continuously driven with size often based on the Chicago Pneumatic Company's old "X" series. A 4X gun (dash 8 or ¼ rivet) is used for normal work. The less powerful 3X gun is used for smaller rivets in thinner structure. 7X guns are used for large rivets in thicker structures. A rivet gun should upset a rivet in 1 to 3 seconds. With practice, an aircraft technician learns the length of time needed to hold down the trigger.

A rivet gun with the correct header (rivet set) must be held snugly against the rivet head and perpendicular to the surface

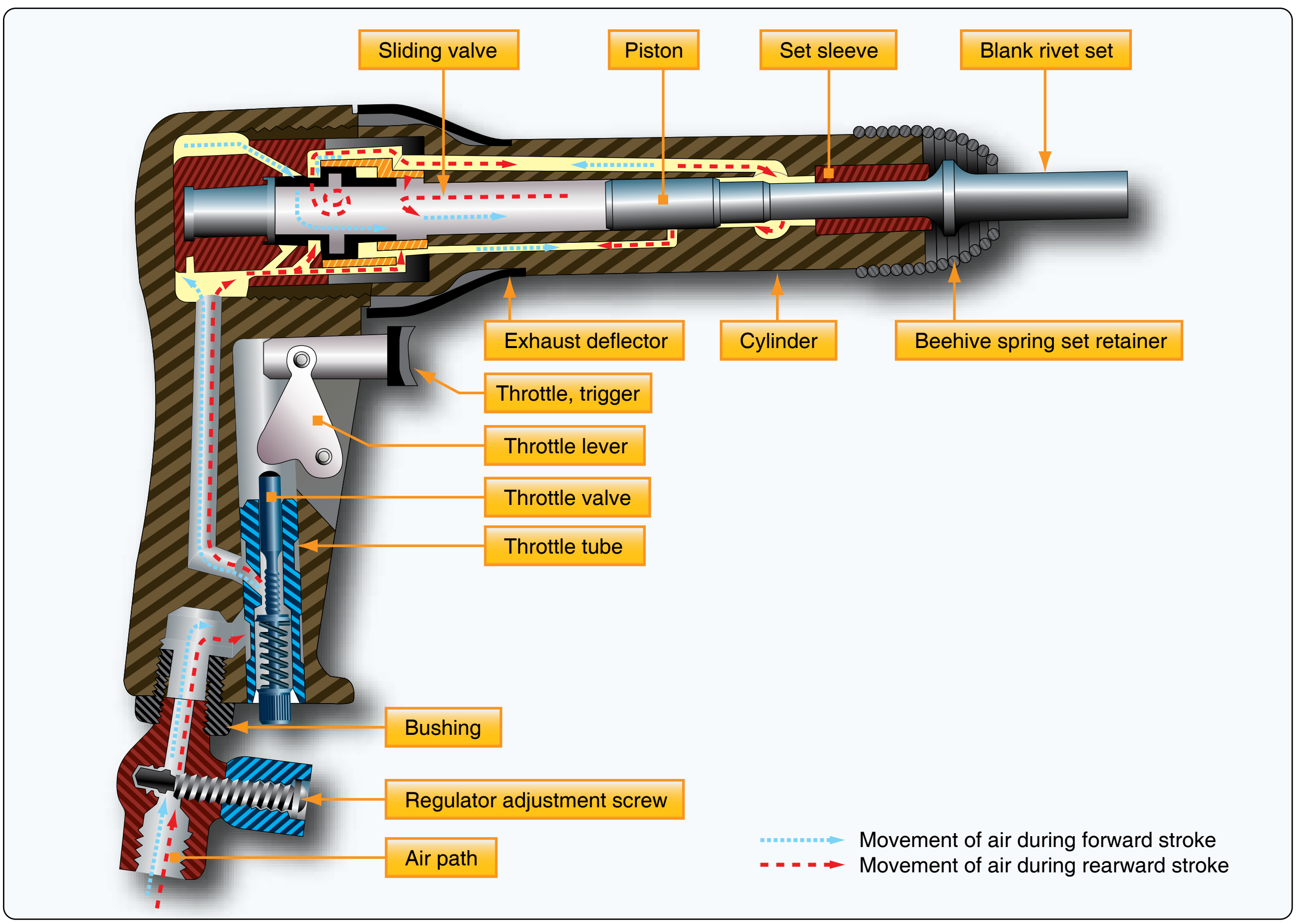


Figure 4-87. *Components of a rivet gun.*

while a bucking bar of the proper weight is held against the opposite end. The force of the gun must be absorbed by the bucking bar and not the structure being riveted. When the gun is triggered, the rivet is driven.

Always make sure the correct rivet header and the retaining spring are installed. Test the rivet gun on a piece of wood and adjust the air valve to a setting that is comfortable for the operator. The driving force of the rivet gun is adjusted by a needle valve on the handle. Adjustments should never be tested against anything harder than a wooden block to avoid header damage. If the adjustment fails to provide the best driving force, a different sized gun is needed. A gun that is too powerful is hard to control and may damage the work. On the other hand, if the gun is too light, it may work to harden the rivet before the head can be fully formed.

The riveting action should start slowly and be one continued burst. If the riveting starts too fast, the rivet header might slip off the rivet and damage the rivet (smiley) or damage the skin (eyebrow). Try to drive the rivets within 3 seconds, because the rivet will work harden if the driving process takes too long. The dynamic of the driving process has the gun hitting, or vibrating, the rivet and material, which causes the bar to bounce, or countervibrate. These opposing blows (low frequency vibrations) squeeze the rivet, causing it to swell and then form the upset head.

Some precautions to be observed when using a rivet gun are:

1. Never point a rivet gun at anyone at any time. A rivet gun should be used for one purpose only: to drive or install rivets.
2. Never depress the trigger mechanism unless the set is held tightly against a block of wood or a rivet.
3. Always disconnect the air hose from the rivet gun when it is not in use for any appreciable length of time.

While traditional tooling has changed little in the past 60 years, significant changes have been made in rivet gun ergonomics. Reduced vibration rivet guns and bucking bars have been developed to reduce the incidence of carpal tunnel syndrome and enhance operator comfort.

Rivet Sets/Headers

Pneumatic guns are used in conjunction with interchangeable rivet sets or headers. Each is designed to fit the type of rivet and location of the work. The shank of the rivet header is designed to fit into the rivet gun. An appropriate header must be a correct match for the rivet being driven. The working face of a header should be properly designed and smoothly polished. They are made of forged steel, heat treated to be tough but not too brittle. Flush headers come in various sizes. Smaller ones concentrate the driving force in a small area for maximum efficiency. Larger ones spread the driving force over a larger area and are used for the riveting of thin skins.

Nonflush headers should fit to contact about the center two-thirds of the rivet head. They must be shallow enough to allow slight upsetting of the head in driving and some misalignment without eyebrowing the riveted surface. Care must be taken to match the size of the rivet. A header that is too small marks the rivet; while one too large marks the material.

Rivet headers are made in a variety of styles. *[Figure 4-88]* The short, straight header is best when the gun can be brought close to the work. Offset headers may be used to reach rivets in obstructed places. Long headers are sometimes necessary when the gun cannot be brought close to the work due to structural interference. Rivet headers should be kept clean.

Compression Riveting

Compression riveting (squeezing) is of limited value because this method of riveting can be used only over the edges of sheets or assemblies where conditions permit, and where the reach of the rivet squeezer is deep enough. The three types of rivet squeezers—hand, pneumatic, and pneudraulic—operate on the same principles. In the hand rivet squeezer, compression is supplied by hand pressure; in the pneumatic rivet squeezer, by air pressure; and in the pneudraulic, by a combination of air and hydraulic pressure. One jaw is stationary and serves as a bucking bar, the other jaw is movable and does the upsetting. Riveting with a squeezer is a quick method and requires only one operator.

These riveters are equipped with either a C-yoke or an alligator yoke in various sizes to accommodate any size of rivet. The working capacity of a yoke is measured by its gap and its reach. The gap is the distance between the movable jaw and the stationary jaw; the reach is the inside length of the throat measured from the center of the end sets. End

Figure 4-88. *Rivet headers.*

sets for rivet squeezers serve the same purpose as rivet sets for pneumatic rivet guns and are available with the same type heads, which are interchangeable to suit any type of rivet head. One part of each set is inserted in the stationary jaw, while the other part is placed in the movable jaws. The manufactured head end set is placed on the stationary jaw whenever possible. During some operations, it may be necessary to reverse the end sets, placing the manufactured head end set on the movable jaw.

Microshavers

A microshaver is used if the smoothness of the material (such as skin) requires that all countersunk rivets be driven within a specific tolerance. *[Figure 4-89]* This tool has a cutter, a stop, and two legs or stabilizers. The cutting portion of the microshaver is inside the stop. The depth of the cut can be adjusted by pulling outward on the stop and turning it in either direction (clockwise for deeper cuts). The marks on the stop permit adjustments of 0.001 inch. If the microshaver is adjusted and held correctly, it can cut the head of a countersunk rivet to within 0.002 inch without damaging the surrounding material.

Adjustments should always be made first on scrap material. When correctly adjusted, the microshaver leaves a small round dot about the size of a pinhead on the microshaved rivet. It may occasionally be necessary to shave rivets, normally restricted to MS20426 head rivets, after driving to obtain the required flushness. Shear head rivets should never be shaved.

Riveting Procedure

The riveting procedure consists of transferring and preparing the hole, drilling, and driving the rivets.

Hole Transfer

Accomplish transfer of holes from a drilled part to another part by placing the second part over first and using established holes as a guide. Using an alternate method, scribe hole location through from drilled part onto part to be drilled, spot with a center punch, and drill.

Figure 4-89. *Microshaver.*

Hole Preparation

It is very important that the rivet hole be of the correct size and shape and free from burrs. If the hole is too small, the protective coating is scratched from the rivet when the rivet is driven through the hole. If the hole is too large, the rivet does not fill the hole completely. When it is bucked, the joint does not develop its full strength, and structural failure may occur at that spot.

If countersinking is required, consider the thickness of the metal and adopt the countersinking method recommended for that thickness. If dimpling is required, keep hammer blows or dimpling pressures to a minimum so that no undue work hardening occurs in the surrounding area.

Drilling

Rivet holes in repair may be drilled with either a light power drill or a hand drill. The standard shank twist drill is most commonly used. Drill bit sizes for rivet holes should be the smallest size that permits easy insertion of the rivet, approximately 0.003-inch greater than the largest tolerance of the shank diameter. The recommended clearance drill bits for the common rivet diameters are shown in *Figure 4-90*. Hole sizes for other fasteners are normally found on work documents, prints, or in manuals.

Before drilling, center punch all rivet locations. The center punch mark should be large enough to prevent the drill from slipping out of position, yet it must not dent the surface surrounding the center punch mark. Place a bucking bar behind the metal during punching to help prevent denting. To make a rivet hole the correct size, first drill a slightly undersized hole (pilot hole). Ream the pilot hole with a twist drill of the appropriate size to obtain the required dimension.

To drill, proceed as follows:

1. Ensure the drill bit is the correct size and shape.

3/32	3/32 (0.0937)	#40 (0.098)
1/8	1/8 (0.125)	#30 (0.1285)
5/32	5/32 (0.1562)	#21 (0.159)
3/16	3/16 (0.1875)	#11 (0.191)
1/4	1/4 (0.250)	F (0.257)

Figure 4-90. *Drill sizes for standard rivets.*

2. Place the drill in the center-punched mark. When using a power drill, rotate the bit a few turns before starting the motor.
3. While drilling, always hold the drill at a 90º angle to the work or the curvature of the material.
4. Avoid excessive pressure, let the drill bit do the cutting, and never push the drill bit through stock.
5. Remove all burrs with a metal countersink or a file.
6. Clean away all drill chips.

When holes are drilled through sheet metal, small burrs are formed around the edge of the hole. This is especially true when using a hand drill because the drill speed is slow and there is a tendency to apply more pressure per drill revolution. Remove all burrs with a burr remover or larger size drill bit before riveting.

Driving the Rivet

Although riveting equipment can be either stationary or portable, portable riveting equipment is the most common type of riveting equipment used to drive solid shank rivets in airframe repair work.

Before driving any rivets into the sheet metal parts, be sure all holes line up perfectly, all shavings and burrs have been removed, and the parts to be riveted are securely fastened with temporary fasteners. Depending on the job, the riveting process may require one or two people. In solo riveting, the riveter holds a bucking bar with one hand and operates a riveting gun with the other.

If the job requires two aircraft technicians, a shooter, or gunner, and a bucker work together as a team to install rivets. An important component of team riveting is an efficient signaling system that communicates the status of the riveting process. This signaling system usually consists of tapping the bucking bar against the work and is often called the tap code. One tap may mean not fully seated, hit it again, while two taps may mean good rivet, and three taps may mean bad rivet, remove and drive another. Radio sets are also available for communication between the technicians.

Once the rivet is installed, there should be no evidence of rotation of rivets or looseness of riveted parts. After the trimming operation, examine for tightness. Apply a force of 10 pounds to the trimmed stem. A tight stem is one indication of an acceptable rivet installation. Any degree of looseness indicates an oversize hole and requires replacement of the rivet with an oversize shank diameter rivet. A rivet installation is assumed satisfactory when the rivet head is seated snugly against the item to be retained (0.005-inch feeler gauge should not go under rivet head for more than one-half the circumference) and the stem is proved tight.

Countersunk Rivets

An improperly made countersink reduces the strength of a flush-riveted joint and may even cause failure of the sheet or the rivet head. The two methods of countersinking commonly used for flush riveting in aircraft construction and repair are:

- Machine or drill countersinking.
- Dimpling or press countersinking.

The proper method for any particular application depends on the thickness of the parts to be riveted, the height and angle of the countersunk head, the tools available, and accessibility.

Countersinking

When using countersunk rivets, it is necessary to make a conical recess in the skin for the head. The type of countersink required depends upon the relation of the thickness of the sheets to the depth of the rivet head. Use the proper degree and diameter countersink and cut only deep enough for the rivet head and metal to form a flush surface.

Countersinking is an important factor in the design of fastener patterns, as the removal of material in the countersinking process necessitates an increase in the number of fasteners to assure the required load-transfer strength. If countersinking is done on metal below a certain thickness, a knife edge with less than the minimum bearing surface or actual enlarging of the hole may result. The edge distance required when using countersunk fasteners is greater than when universal head fasteners are used.

The general rule for countersinking and flush fastener installation procedures has been reevaluated in recent years because countersunk holes have been responsible for fatigue cracks in aircraft pressurized skin. In the past, the general rule for countersinking held that the fastener head must be contained within the outer sheet. A combination of countersinks too deep (creating a knife edge), number of pressurization cycles, fatigue, deterioration of bonding materials, and working fasteners caused a high stress concentration that resulted in skin cracks and fastener failures. In primary structure and pressurized skin repairs, some manufacturers are currently recommending the countersink depth be no more than ⅔ the outer sheet thickness or down to 0.020-inch minimum fastener shank depth, whichever is greater. Dimple the skin if it is too thin for machine countersinking. *[Figure 4-91]*

Keep the rivet high before driving to ensure the force of riveting is applied to the rivet and not to the skin. If the rivet is driven while it is flush or too deep, the surrounding skin is work hardened.

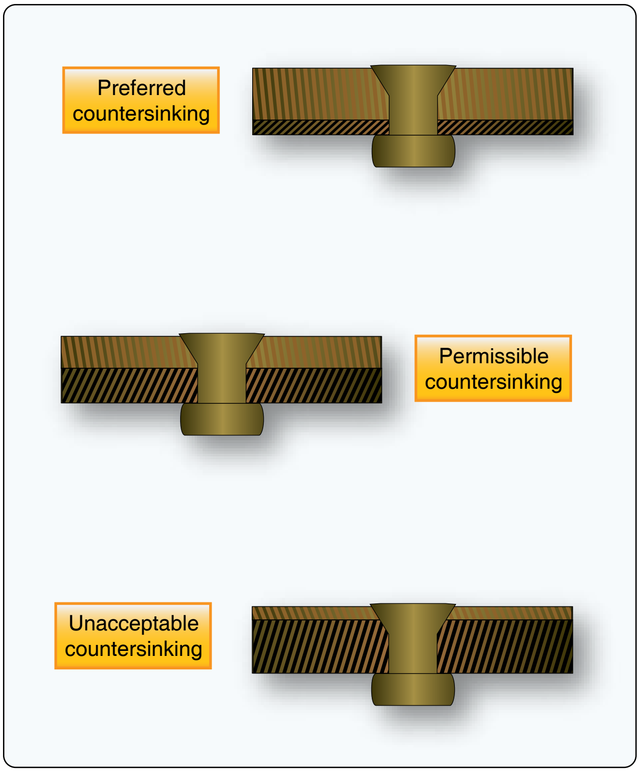


Figure 4-91. *Countersinking dimensions.*

Countersinking Tools

While there are many types of countersink tools, the most commonly used has an included angle of 100°. Sometimes types of 82° or 120° are used to form countersunk wells. *[Figure 4-84]* A six-fluted countersink works best in aluminum. There are also four- and three-fluted countersinks, but those are harder to control from a chatter standpoint. A single-flute type, such as those manufactured by the Weldon Tool Company®, works best for corrosion-resistant steel. *[Figure 4-92]*

The microstop countersink is the preferred countersinking tool. *[Figure 4-85]* It has an adjustable-sleeve cage that functions as a limit stop and holds the revolving countersink in a vertical position. Its threaded and replaceable cutters may have either a removable or an integral pilot that keeps the cutter centered in the hole. The pilot should be approximately 0.002-inch smaller than the hole size. It is recommended to test adjustments on a piece of scrap material before countersinking repair or replacement parts.

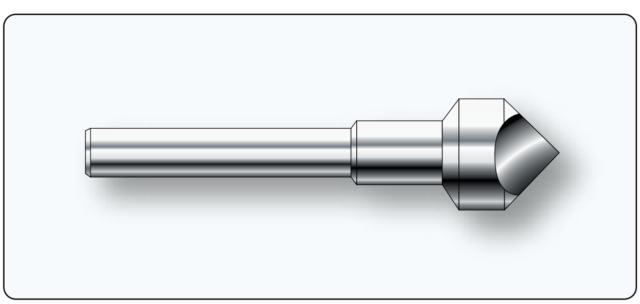


Figure 4-92. *Single-flute countersink.*

Freehand countersinking is needed where a microstop countersink cannot fit. This method should be practiced on scrap material to develop the required skill. Holding the drill motor steady and perpendicular is as critical during this operation as when drilling.

Chattering is the most common problem encountered when countersinking. Some precautions that may eliminate or minimize chatter include:

- Use sharp tooling.
- Use a slow speed and steady firm pressure.
- Use a piloted countersink with a pilot approximately 0.002-inch smaller than the hole.
- Use back-up material to hold the pilot steady when countersinking thin sheet material.
- Use a cutter with a different number of flutes.
- Pilot drill an undersized hole, countersink, and then enlarge the hole to final size.

Dimpling

Dimpling is the process of making an indentation or a dimple around a rivet hole to make the top of the head of a countersunk rivet flush with the surface of the metal. Dimpling is done with a male and female die, or forms, often called punch and die set. The male die has a guide the size of the rivet hole and is beveled to correspond to the degree of countersink of the rivet head. The female die has a hole into which the male guide fits and is beveled to a corresponding degree of countersink.

When dimpling, rest the female die on a solid surface. Then, place the material to be dimpled on the female die. Insert the male die in the hole to be dimpled and, with a hammer, strike the male die until the dimple is formed. Two or three solid hammer blows should be sufficient. A separate set of dies is necessary for each size of rivet and shape of rivet head. An alternate method is to use a countersunk head rivet instead of the regular male punch die, and a draw set instead of the female die, and hammer the rivet until the dimple is formed.

Dimpling dies for light work can be used in portable pneumatic or hand squeezers. *[Figure 4-93]* If the dies are used with a squeezer, they must be adjusted accurately to the thickness of the sheet being dimpled. A table riveter is also used for dimpling thin skin material and installing rivets. *[Figure 4-94]*

Figure 4-93. *Hand squeezers.*

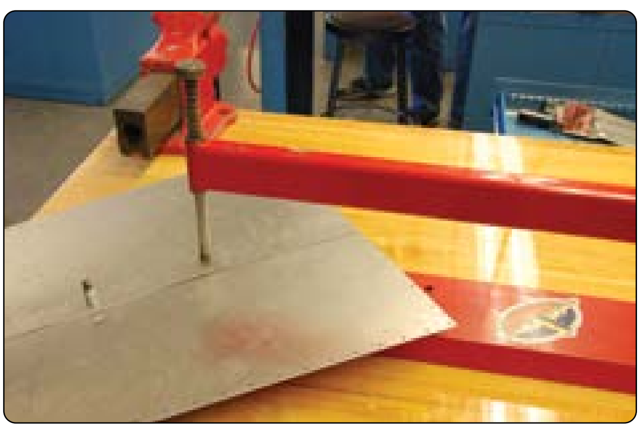


Figure 4-94. *Table riveter.*

Coin Dimpling

The coin dimpling, or coin pressing, method uses a countersink rivet as the male dimpling die. Place the female die in the usual position and back it with a bucking bar. Place the rivet of the required type into the hole and strike the rivet with a pneumatic riveting hammer. Coin dimpling should be used only when the regular male die is broken or not available. Coin pressing has the distinct disadvantage of the rivet hole needing to be drilled to correct rivet size before the dimpling operation is accomplished. Since the metal stretches during the dimpling operation, the hole becomes enlarged and the rivet must be swelled slightly before driving to produce a close fit. Because the rivet head causes slight distortions in the recess, and these are characteristic only to that particular rivet head, it is wise to drive the same rivet that was used as the male die during the dimpling process. Do not substitute another rivet, either of the same size or a size larger.

Radius Dimpling

Radius dimpling uses special die sets that have a radius and are often used with stationary or portable squeezers. Dimpling removes no metal and, due to the nestling effect, gives a stronger joint than the non-flush type. A dimpled joint reduces the shear loading on the rivet and places more load on the riveted sheets.

Note: Dimpling is also done for flush bolts and other flush fasteners.

Dimpling is required for sheets that are thinner than the minimum specified thickness for countersinking. However, dimpling is not limited to thin materials. Heavier parts may be dimpled without cracking by specialized hot dimpling equipment. The temper of the material, rivet size, and available equipment are all factors to be considered in dimpling. *[Figure 4-95]*

Hot Dimpling

Hot dimpling is the process that uses heated dimpling dies to

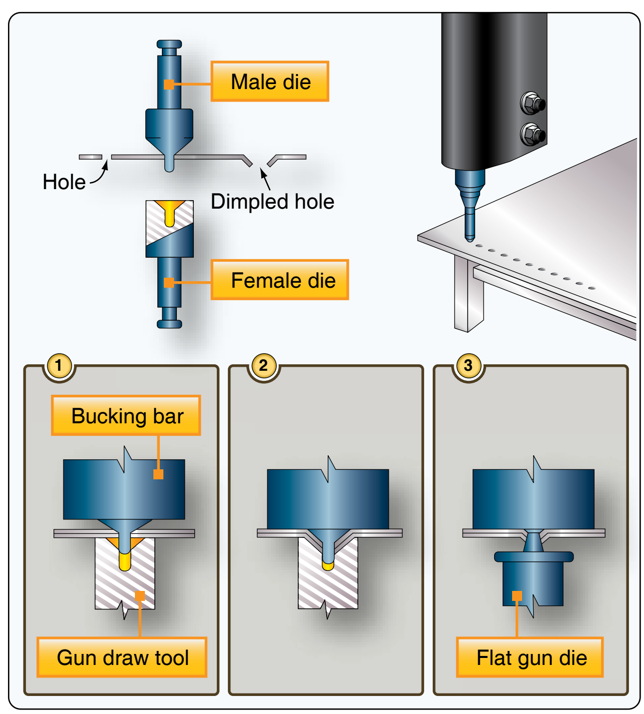


Figure 4-95. *Dimpling techniques.*

ensure the metal flows better during the dimpling process. Hot dimpling is often performed with large stationary equipment available in a sheet metal shop. The metal being used is an important factor because each metal presents different dimpling problems. For example, 2024-T3 aluminum alloy can be satisfactorily dimpled either hot or cold, but may crack in the vicinity of the dimple after cold dimpling because of hard spots in the metal. Hot dimpling prevents such cracking.

7075-T6 aluminum alloys are always hot dimpled. Magnesium alloys also must be hot dimpled because, like 7075-T6, they have low formability qualities. Titanium is another metal that must be hot dimpled because it is tough and resists forming. The same temperature and dwell time used to hot dimple 7075-T6 is used for titanium.

100° Combination Predimple & Countersink Method

Metals of different thicknesses are sometimes joined by a combination of dimpling and countersinking. *[Figure 4-96]* A countersink well made to receive a dimple is called a subcountersink. These are most often seen where a thin web is attached to heavy structure. It is also used on thin gap seals, wear strips, and repairs for worn countersinks.

Dimpling Inspection

To determine the quality of a dimple, it is necessary to make a close visual inspection. Several features must be checked. The rivet head should fit flush and there should be a sharp break from the surface into the dimple. The sharpness of the break is affected by dimpling pressure and metal thickness. Selected dimples should be checked by inserting a fastener to make sure that the flushness requirements are met. Cracked dimples are caused by poor dies, rough holes, or improper heating. Two types of cracks may form during dimpling:

- Radial cracks—start at the edge and spread outward as the metal within the dimple stretches. They are most common in 2024-T3. A rough hole or a dimple that is too deep causes such cracks. A small tolerance is usually allowed for radial cracks.
- Circumferential cracks—downward bending into the draw die causes tension stresses in the upper portion of the metal. Under some conditions, a crack may be created that runs around the edge of the dimple. Such cracks do not always show since they may be underneath the cladding. When found, they are cause for rejection. These cracks are most common in hot-dimpled 7075 T6 aluminum alloy material. The usual cause is insufficient dimpling heat.

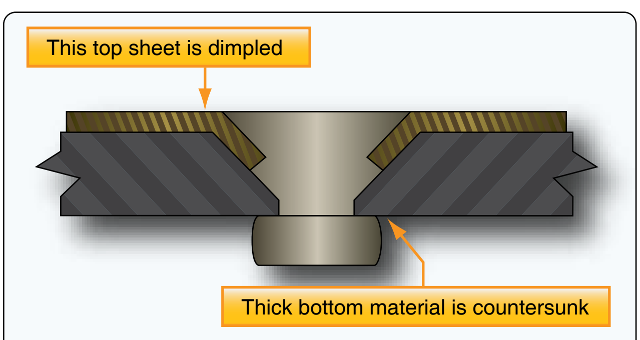


Figure 4-96. *Predimple and countersink method.*

Evaluating the Rivet

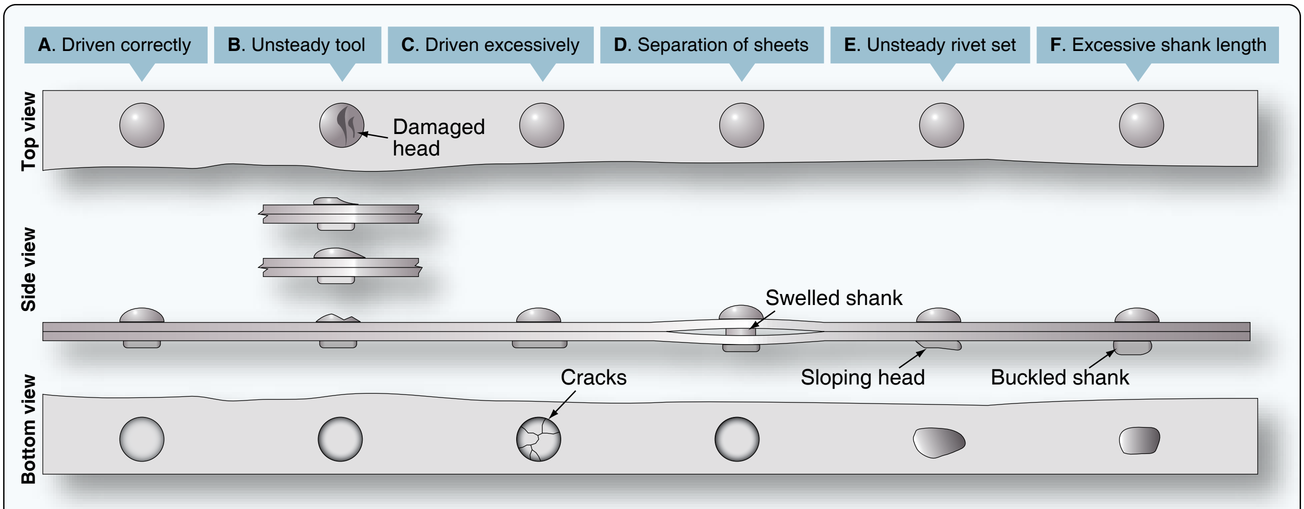
To obtain high structural efficiency in the manufacture and repair of aircraft, an inspection must be made of all rivets before the part is put in service. This inspection consists of examining both the shop and manufactured heads and the surrounding skin and structural parts for deformities. A scale or rivet gauge can be used to check the condition of the upset rivet head to see that it conforms to the proper requirements. Deformities in the manufactured head can be detected by the trained eye alone. *[Figure 4-97]*

Some common causes of unsatisfactory riveting are improper bucking, rivet set slipping off or being held at the wrong angle, and rivet holes or rivets of the wrong size. Additional causes for unsatisfactory riveting are countersunk rivets not flush with the well, work not properly fastened together during riveting, the presence of burrs, rivets too hard, too much or too little driving, and rivets out of line.

Occasionally, during an aircraft structural repair, it is wise to examine adjacent parts to determine the true condition of neighboring rivets. In doing so, it may be necessary to remove the paint. The presence of chipped or cracked paint around the heads may indicate shifted or loose rivets. Look for tipped or loose rivet heads. If the heads are tipped or if rivets are loose, they show up in groups of several consecutive rivets and probably tipped in the same direction. If heads that appear to be tipped are not in groups and are not tipped in the same direction, tipping may have occurred during some previous installation.

Inspect rivets known to have been critically loaded, but that show no visible distortion, by drilling off the head and carefully punching out the shank. If, upon examination, the shank appears joggled and the holes in the sheet misaligned, the rivet has failed in shear. In that case, try to determine what is causing the shearing stress and take the necessary corrective action. Flush rivets that show head slippage within the countersink or dimple, indicating either sheet bearing failure or rivet shear failure, must be removed for inspection and replacement.

Joggles in removed rivet shanks indicate partial shear failure. Replace these rivets with the next larger size. Also, if the rivet



	Imperfection	Cause	Remedy	Action
A	None	None	None	None
B	Cut head	Improperly held tools	Hold riveting tools firmly against work	Replace rivet
C	Excessively flat head, resultant head cracks	Excessive driving, too much pressure on bucking bar	Improve riveting technique	Replace rivet
D	Sheet separation	Work not held firmly together and rivet shank swelled	Fasten work firmly together to prevent slipping	Replace rivet
E	Sloping head	a. Bucking bar not held firmly b. Bucking bar permitted to slide and bounce over the rivet	Hold bucking bar firmly without too much pressure	Replace rivet
F	Buckled shank	Improper rivet length, and E above	E above and rivet of proper length	Replace rivet

Figure 4-97. *Rivet defects.*

holes show elongation, replace the rivets with the next larger size. Sheet failures such as tear-outs, cracks between rivets, and the like usually indicate damaged rivets. The complete repair of the joint may require replacement of the rivets with the next larger size.

The general practice of replacing a rivet with the next larger size ($\frac{1}{32}$-inch greater diameter) is necessary to obtain the proper joint strength of rivet and sheet when the original rivet hole is enlarged. If the rivet in an elongated hole is replaced by a rivet of the same size, its ability to carry its share of the shear load is impaired and joint weakness results.

Removal of Rivets

When a rivet has to be replaced, remove it carefully to retain the rivet hole's original size and shape. If removed correctly, the rivet does not need to be replaced with one of the next larger size. Also, if the rivet is not removed properly, the strength of the joint may be weakened and the replacement of rivets made more difficult.

When removing a rivet, work on the manufactured head. It is more symmetrical about the shank than the shop head, and there is less chance of damaging the rivet hole or the material around it. To remove rivets, use hand tools, a power drill, or a combination of both.

The procedure for universal or protruding head rivet removal is as follows:

1. File a flat area on the head of the rivet and center punch the flat surface for drilling.

   Note: On thin metal, back up the rivet on the upset head when center punching to avoid depressing the metal.

2. Use a drill bit one size smaller than the rivet shank to drill out the rivet head.

   Note: When using a power drill, set the drill on the rivet and rotate the chuck several revolutions by hand before turning on the power. This procedure helps the drill cut a good starting spot and eliminates the chance of the drill slipping off and tracking across the metal.

3. Drill the rivet to the depth of its head, while holding the drill at a 90° angle. Do not drill too deeply, as the rivet shank will then turn with the drill and tear the surrounding metal.

   Note: The rivet head often breaks away and climbs the drill, which is a signal to withdraw the drill.

4. If the rivet head does not come loose of its own accord, insert a drift punch into the hole and twist slightly to either side until the head comes off.
5. Drive the remaining rivet shank out with a drift punch slightly smaller than the shank diameter.

On thin metal or unsupported structures, support the sheet with a bucking bar while driving out the shank. If the shank is unusually tight after the rivet head is removed, drill the rivet about two-thirds through the thickness of the material and then drive the rest of it out with a drift punch. *Figure 4-98* shows the preferred procedure for removing universal rivets.

The procedure for the removal of countersunk rivets is the same as described above except no filing is necessary. Be careful to avoid elongation of the dimpled or the countersunk holes. The rivet head should be drilled to approximately one-half the thickness of the top sheet. The dimple in 2117–T rivets usually eliminates the necessity of filing and center punching the rivet head.

To remove a countersunk or flush head rivet, you must:

1. Select a drill about 0.003-inch smaller than the rivet shank diameter.
2. Drill into the exact center of the rivet head to the approximate depth of the head.
3. Remove the head by breaking it off. Use a punch as a lever.
4. Punch out the shank. Use a suitable backup, preferably wood (or equivalent), or a dedicated backup block. If the shank does not come out easily, use a small drill and drill through the shank. Be careful not to elongate the hole.

Replacing Rivets

Replace rivets with those of the same size and strength whenever possible. If the rivet hole becomes enlarged, deformed, or otherwise damaged, drill or ream the hole for the next larger size rivet. Do not replace a rivet with a type having lower strength properties, unless the lower strength is adequately compensated by an increase in size or a greater number of rivets. It is acceptable to replace 2017 rivets of $\frac{3}{16}$-inch diameter or less, and 2024 rivets of $\frac{5}{32}$-inch diameter or less with 2117 rivets for general repairs, provided the replacement rivets are $\frac{1}{32}$-inch greater in diameter than the rivets they replace.

National Advisory Committee for Aeronautics (NACA) Method of Double Flush Riveting

A rivet installation technique known as the National Advisory Committee for Aeronautics (NACA) method has primary applications in fuel tank areas. *[Figure 4-99]* To make a NACA rivet installation, the shank is upset into a 82° countersink. In driving, the gun may be used on either the head or shank side. The upsetting is started with light blows, then the force increased and the gun or bar moved on the shank end so as to form a head inside the countersink well. If desired, the upset head may be shaved flush after driving. If utilizing this method, it is important to reference the manufacturer's instructions for repair or replacement.

Special Purpose Fasteners

Special purpose fasteners are designed for applications in which fastener strength, ease of installation, or temperature properties of the fastener require consideration. Solid shank rivets have been the preferred construction method for metal aircraft for many years because they fill up the hole, which results in good load transfer, but they are not always ideal. For example, the attachment of many nonstructural parts (aircraft interior furnishings, flooring, deicing boots, etc.) do not need the full strength of solid shank rivets.

To install solid shank rivets, the aircraft technician must have access to both sides of a riveted structure or structural part. There are many places on an aircraft where this access is impossible or where limited space does not permit the use of a bucking bar. In these instances, it is not possible to use solid shank rivets, and special fasteners have been designed that can be bucked from the front. *[Figure 4-100]* There are also areas of high loads, high fatigue, and bending on aircraft. Although the shear loads of riveted joints are very good, the tension, or clamp-up, loads are less than ideal.

Special purpose fasteners are sometimes lighter than solid shank rivets, yet strong enough for their intended use. These fasteners are manufactured by several corporations and have unique characteristics that require special installation tools, special installation procedures, and special removal procedures. Because these fasteners are often inserted in locations where one head, usually the shop head, cannot be seen, they are called blind rivets or blind fasteners.

Typically, the locking characteristics of a blind rivet are not as good as a driven rivet. Therefore, blind rivets are usually not used when driven rivets can be installed. Blind rivets shall not be used:

1. In fluid-tight areas.
2. On aircraft in air intake areas where rivet parts may be ingested by the engine.
3. On aircraft control surfaces, hinges, hinge brackets, flight control actuating systems, wing attachment fittings, landing gear fittings, on floats or amphibian

Rivet Removal

Remove rivets by drilling off the head and punching out the shank as illustrated.

1. File a flat area on the manufactured head of non-flush rivets.
2. Place a block of wood or a bucking bar under both flush and nonflush rivets when center punching the manufactured head.
3. Use a drill that is $^{1}/_{32}$ (0.0312) inch smaller than the rivet shank to drill through the head of the rivet. Ensure the drilling operation does not damage the skin or cut the sides of the rivet hole.
4. Insert a drift punch into the hole drilled in the rivet and tilt the punch to break off the rivet head.
5. Using a drift punch and hammer, drive out the rivet shank. Support the opposite side of the structure to prevent structural damage.

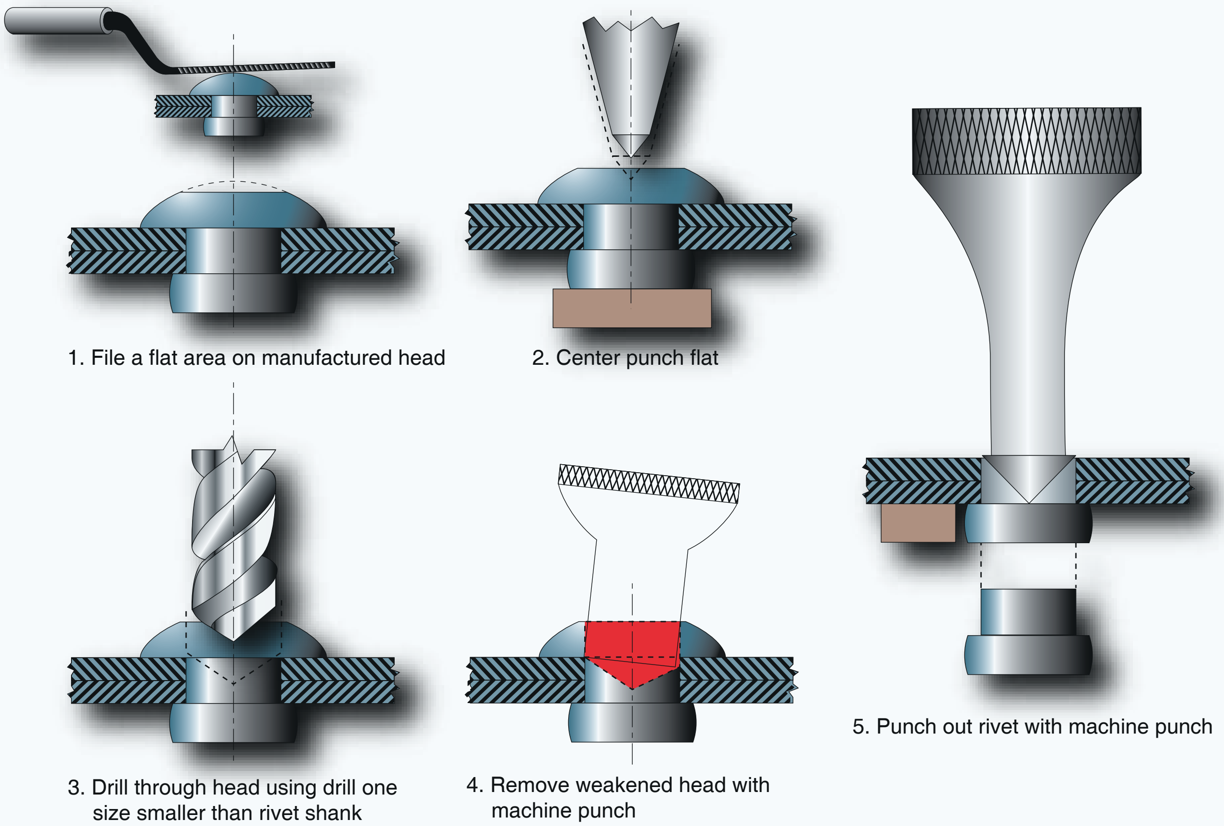


Figure 4-98. *Rivet removal.*

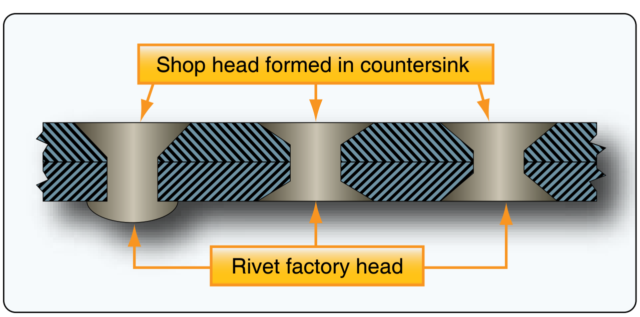


Figure 4-99. *NACA riveting method.*

Figure 4-100. *Assorted fasteners.*

hulls below the water level, or other heavily stressed locations on the aircraft.

Note: For metal repairs to the airframe, the use of blind rivets must be specifically authorized by the airframe manufacturer or approved by a representative of the Federal Aviation Administration (FAA).

Blind Rivets

The first blind fasteners were introduced in 1940 by the Cherry Rivet Company (now Cherry® Aerospace), and the aviation industry quickly adopted them. The past decades have seen a proliferation of blind fastening systems based on the original concept, which consists of a tubular rivet with a fixed head and a hollow sleeve. Inserted within the rivet's core is a stem that is enlarged or serrated on its exposed end when activated by a pulling-type rivet gun. The lower end of the stem extends beyond the inner sheet of metal. This portion contains a tapered joining portion and a blind head that has a larger diameter than the stem or the sleeve of the tubular rivet.

When the pulling force of the rivet gun forces the blind head upward into the sleeve, its stem upsets or expands the lower end of the sleeve into a tail. This presses the inner sheet upward and closes any space that might have existed between it and the outer sheet. Since the exposed head of the rivet is held tightly against the outer sheet by the rivet gun, the sheets of metal are clamped, or clinched, together.

Note: Fastener manufacturers use different terminology to describe the parts of the blind rivet. The terms "mandrel," "spindle," and "stem" are often used interchangeably. For clarity, the word "stem" is used in this handbook and refers to the piece that is inserted into the hollow sleeve.

Friction-Locked Blind Rivets

Standard self-plugging blind rivets consist of a hollow sleeve and a stem with increased diameter in the plug section. The blind head is formed as the stem is pulled into the sleeve. Friction-locked blind rivets have a multiple-piece construction and rely on friction to lock the stem to the sleeve. As the stem is drawn up into the rivet shank, the stem portion upsets the shank on the blind side, forming a plug in the hollow center of the rivet. The excess portion of the stem breaks off at a groove due to the continued pulling action of the rivet gun. Metals used for these rivets are 2117-T4 and 5056-F aluminum alloy. Monel® is used for special applications.

Many friction-locked blind rivet center stems fall out due to vibration, which greatly reduces its shear strength. To combat that problem, most friction-lock blind rivets are replaced by the mechanical-lock, or stem-lock, type of blind fasteners. However, some types, such as the Cherry SPR® ³⁄₃₂-inch Self-Plugging Rivet, are ideal for securing nutplates located in inaccessible and hard-to-reach areas where bucking or squeezing of solid rivets is unacceptable. *[Figure 4-101]*

Friction-lock blind rivets are less expensive than mechanical-lock blind rivets and are sometimes used for nonstructural applications. Inspection of friction-lock blind rivets is visual. A more detailed discussion on how to inspect riveted joints can be found later in this chapter. Removal of friction-lock blind rivets consists of punching out the friction-lock stem and then treating it like any other rivet.

Mechanical-Lock Blind Rivets

The self-plugging, mechanical-lock blind rivet was developed to prevent the problem of losing the center stem due to vibration. This rivet has a device on the puller or rivet head that locks the center stem into place when installed. Bulbed, self-plugging, mechanically-locked blind rivets form a large, blind head that provides higher strength in thin sheets when installed. They may be used in applications where the blind head is formed against a dimpled sheet.

Manufacturers such as Cherry® Aerospace (CherryMAX®, CherryLOCK®, Cherry SST®) and Alcoa Fastening Systems (Huck-Clinch®, HuckMax®, Unimatic®) make many variations of this of blind rivet. While similar in design, the tooling for these rivets is often not interchangeable.

The CherryMAX® Bulbed blind rivet is one of the earlier types of mechanical-lock blind rivets developed. Their main

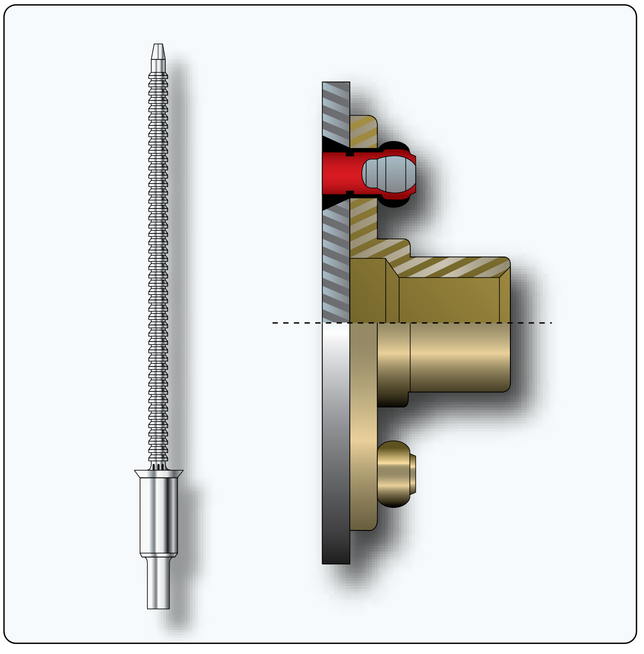


Figure 4-101. *Friction-lock blind rivet.*

advantage is the ability to replace a solid shank rivet size for size. The CherryMAX® Bulbed blind rivet consists of four parts:

1. A fully serrated stem with break notch, shear ring, and integral grip adjustment cone.
2. A driving anvil to ensure a visible mechanical lock with each fastener installation.
3. A separate, visible, and inspectable locking collar that mechanically locks the stem to the rivet sleeve.
4. A rivet sleeve with recess in the head to receive the locking collar.

It is called a bulbed fastener due to its large blind side bearing surface, developed during the installation process. These rivets are used in thin sheet applications and for use in materials that may be damaged by other types of blind rivets. This rivet features a safe-lock locking collar for more reliable joint integrity. The rough end of the retained stem in the center on the manufactured head must never be filed smooth because it weakens the strength of the lockring, and the center stem could fall out.

CherryMAX® bulbed rivets are available in three head styles: universal, 100° countersunk, and 100° reduced shear head styles. Their lengths are measured in increments of $\frac{1}{16}$ inch. It is important to select a rivet with a length related to the grip length of the metal being joined. This blind rivet can be installed using either the Cherry® G750A or the newly released Cherry® G800 hand riveters, or either the pneumatic-hydraulic G704B or G747 CherryMAX® power tools. For installation, please refer to *Figure 4-102*.

The CherryMAX® mechanical-lock blind rivet is popular with general aviation repair shops because it features the one tool concept to install three standard rivet diameters and their oversize counterparts. *[Figure 4-103]* CherryMAX® rivets are available in four nominal diameters: $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, and $\frac{1}{4}$-inch and three oversized diameters and four head styles: universal, 100° flush head, 120° flush head, and NAS1097 flush head. This rivet consists of a blind header, hollow rivet shell, locking (foil) collar, driving anvil, and pulling stem complete with wrapped locking collar. The rivet sleeve and the driving washer blind bulbed header takes up the extended shank and forms the bucktail.

The stem and rivet sleeve work as an assembly to provide radial expansion and a large bearing footprint on the blind side of the fastened surface. The lock collar ensures that the stem and sleeve remain assembled during joint loading and unloading. Rivet sleeves are made from 5056 aluminum, Monel® and INCO 600. The stems are made from alloy steel, CRES, and INCO® X-750. CherryMAX® rivets have an ultimate shear strength ranging from 50 KSI to 75 KSI.

Removal of Mechanically-Locked Blind Rivets

Mechanically-locked blind rivets are a challenge to remove because they are made from strong, hard metals. Lack of

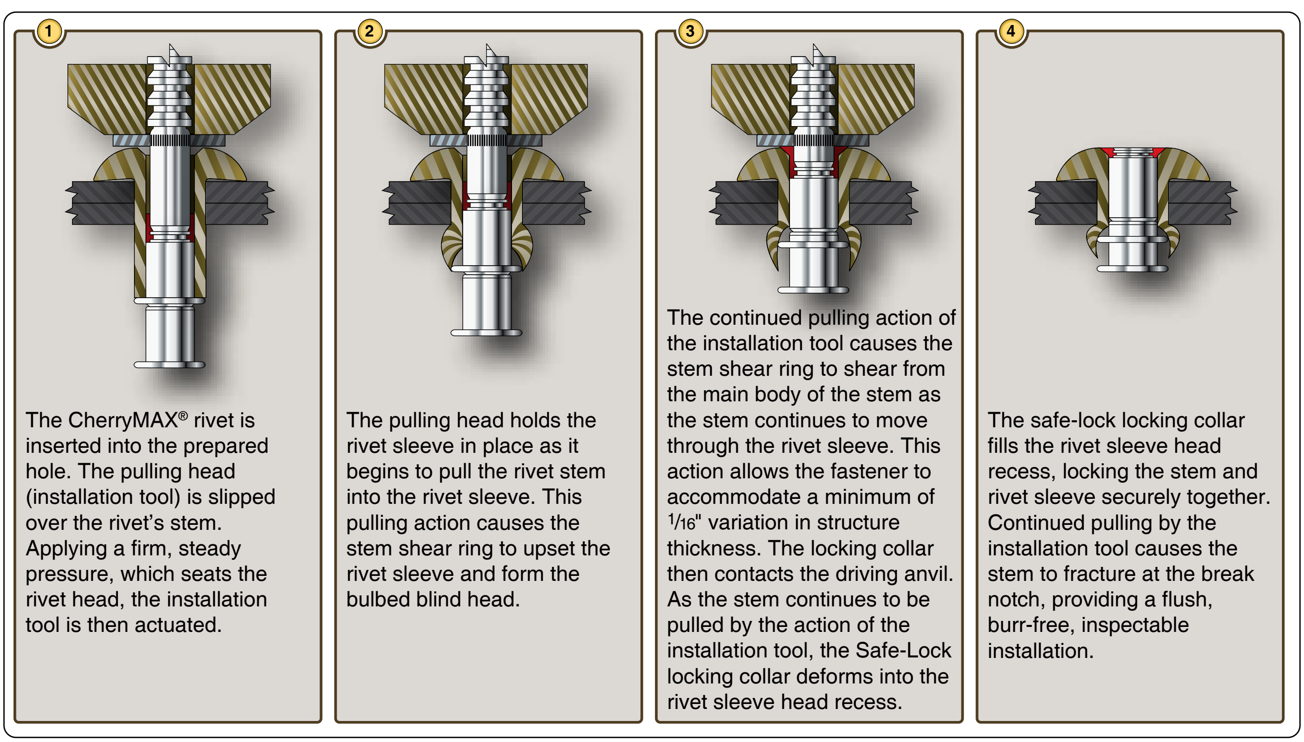


Figure 4-102. *CherryMAX® installation procedure.*

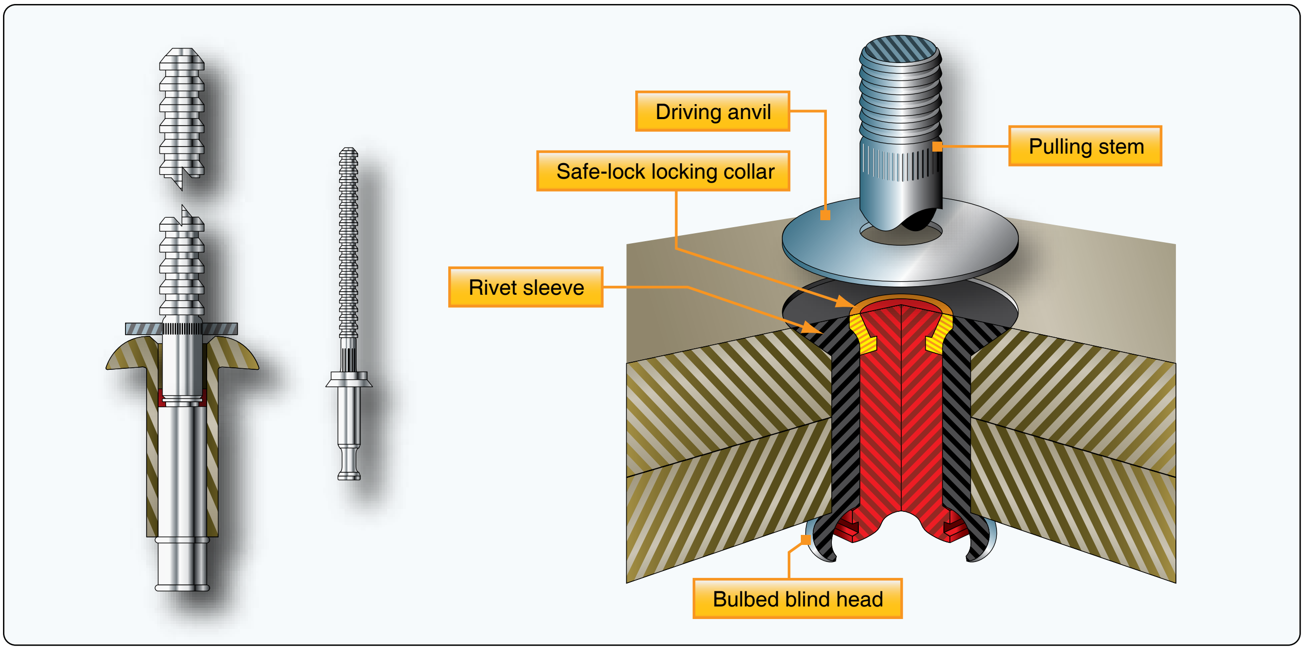


Figure 4-103. *CherryMAX® rivet.*

access poses yet another problem for the aviation technician. Designed for and used in difficult to reach locations means there is often no access to the blind side of the rivet or any way to provide support for the sheet metal surrounding the rivet's location when the aviation technician attempts removal.

The stem is mechanically locked by a small lock ring that needs to be removed first. Use a small center drill to provide a guide for a larger drill on top of the rivet stem and drill away the upper portion of the stem to destroy the lock. Try to remove the lock ring or use a prick punch or center punch to drive the stem down a little and remove the lock ring. After the lock ring is removed, the stem can be driven out with a drive punch. After the stem is removed, the rivet can be drilled out in the same way as a solid rivet. If possible, support the back side of the rivet with a backup block to prevent damage to the aircraft skin.

Pin Fastening Systems (High-Shear Fasteners)

A pin fastening system, or high-shear pin rivet, is a two-piece fastener that consists of a threaded pin and a collar. The metal collar is swaged onto the grooved end, effecting a firm tight fit. They are essentially threadless bolts.

High-shear rivets are installed with standard bucking bars and pneumatic riveting hammers. They require the use of a special gun set that incorporates collar swaging and trimming and a discharge port through which excess collar material is discharged. A separate size set is required for each shank diameter.

Installation of High-Shear Fasteners

Prepare holes for pin rivets with the same care as for other close tolerance rivets or bolts. At times, it may be necessary to spot-face the area under the head of the pin to ensure the head of the rivet fits tightly against the material. The spot-faced area should be $\frac{1}{16}$-inch larger in diameter than the head diameter. Pin rivets may be driven from either end. Procedures for driving a pin rivet from the collar end are:

1. Insert the rivet in the hole.
2. Place a bucking bar against the rivet head.
3. Slip the collar over the protruding rivet end.
4. Place previously selected rivet set and gun over the collar. Align the gun until it is perpendicular to the material.
5. Depress the trigger on the gun, applying pressure to the rivet collar. This action causes the rivet collar to swage into the groove on the rivet end.
6. Continue the driving action until the collar is properly formed and excess collar material is trimmed off.

Procedures for driving a pin rivet from the head end are:

1. Insert the rivet in the hole.
2. Slip the collar over the protruding end of rivet.
3. Insert the correct size gun rivet set in a bucking bar and place the set against the collar of the rivet.
4. Apply pressure against the rivet head with a flush rivet set and pneumatic riveting hammer.

5. Continue applying pressure until the collar is formed in the groove and excess collar material is trimmed off.

Inspection

Pin rivets should be inspected on both sides of the material. The head of the rivet should not be marred and should fit tightly against the material.

Removal of Pin Rivets

The conventional method of removing rivets by drilling off the head may be utilized on either end of the pin rivet. Center punching is recommended prior to applying drilling pressure. In some cases, alternate methods may be needed:

- Grind a chisel edge on a small pin punch to a blade width of ⅛-inch. Place this tool at right angles to the collar and drive with a hammer to split the collar down one side. Repeat the operation on the opposite side. Then, with the chisel blade, pry the collar from the rivet. Tap the rivet out of the hole.
- Use a special hollow punch having one or more blades placed to split the collar. Pry the collar from the groove and tap out the rivet.
- Sharpen the cutting blades of a pair of nippers. Cut the collar in two pieces or use nippers at right angles to the rivet and cut through the small neck.
- A hollow-mill collar cutter can be used in a power hand drill to cut away enough collar material to permit the rivet to be tapped out of the work.

The high-shear pin rivet family includes fasteners, such as the Hi-Lok®, Hi-Tigue®, and Hi-Lite® made by Hi-Shear Corporation and the CherryBUCK® 95 KSI One-Piece Shear Pin and Cherry E-Z Buck® Shear Pin made by Cherry® Aerospace.

Hi-Lok® Fastening System

The threaded end of the Hi-Lok® two-piece fastener contains a hexagonal shaped recess. *[Figure 4-104]* The hex tip of an Allen wrench engages the recess to prevent rotation of the pin while the collar is being installed. The pin is designed in two basic head styles. For shear applications, the pin is made in countersunk style and in a compact protruding head style. For tension applications, the MS24694 countersunk and regular protruding head styles are available.

Figure 4-104. *Hi-Lok®.*

The self-locking, threaded Hi-Lok® collar has an internal counterbore at the base to accommodate variations in material thickness. At the opposite end of the collar is a wrenching device that is torqued by the driving tool until it shears off during installation, leaving the lower portion of the collar seated with the proper torque without additional torque inspection. This shear-off point occurs when a predetermined preload or clamp-up is attained in the fastener during installation.

The advantages of Hi-Lok® two-piece fastener include its lightweight, high fatigue resistance, high strength, and its inability to be overtorqued. The pins, made from alloy steel, corrosion-resistant steel, or titanium alloy, come in many standard and oversized shank diameters. The collars are made of aluminum alloy, corrosion-resistant steel, or alloy steel. The collars have wrenching flats, fracture point, threads, and a recess. The wrenching flats are used to install the collar. The fracture point has been designed to allow the wrenching flats to shear when the proper torque has been reached. The threads match the threads of the pins and have been formed into an ellipse that is distorted to provide the locking action. The recess serves as a built-in washer. This area contains a portion of the shank and the transition area of the fastener.

The hole shall be prepared so that the maximum interference fit does not exceed 0.002-inch. This avoids build up of excessive internal stresses in the work adjacent to the hole. The Hi-Lok® pin has a slight radius under its head to increase fatigue life. After drilling, deburr the edge of the hole to allow the head to seat fully in the hole. The Hi-Lok® is installed in interference fit holes for aluminum structure and a clearance fit for steel, titanium, and composite materials.

Hi-Tigue® Fastening System

The Hi-Tigue® fastener offers all of the benefits of the Hi-Lok® fastening system along with a unique bead design that enhances the fatigue performance of the structure making it ideal for situations that require a controlled interference fit. The Hi-Tigue® fastener assembly consists of a pin and collar. These pin rivets have a radius at the transition area. During installation in an interference fit hole, the radius area will "cold work" the hole. These fastening systems can be easily confused, and visual reference should not be used for identification. Use part numbers to identify these fasteners.

Hi-Lite® Fastening System

The Hi-Lite® fastener is similar in design and principle to the Hi-Lok® fastener, but the Hi-Lite® fastener has a shorter transition area between the shank and the first load-bearing thread. Hi-Lite® has approximately one less thread. All Hi-Lite® fasteners are made of titanium.

These differences reduce the weight of the Hi-Lite® fastener without lessening the shear strength, but the Hi-Lite® clamping forces are less than that of a Hi-Lok® fastener. The Hi-Lite® collars are also different and thus are not interchangeable with Hi-Lok® collars. Hi-Lite® fasteners can be replaced with Hi-Lok® fasteners for most applications, but Hi-Loks® cannot be replaced with Hi-Lites®.

CherryBUCK® 95 KSI One-Piece Shear Pin

The CherryBUCK® is a bimetallic, one-piece fastener that combines a 95 KSI shear strength shank with a ductile, titanium-columbium tail. Theses fasteners are functionally interchangeable with comparable 6AI-4V titanium alloy two-piece shear fasteners, but with a number of advantages. Their one piece design means no foreign object damage (FOD), it has a 600 °F allowable temperature, and a very low backside profile.

Lockbolt Fastening Systems

Also pioneered in the 1940s, the lockbolt is a two-piece fastener that combines the features of a high-strength bolt and a rivet with advantages over each. *[Figure 4-105]* In general, a lockbolt is a nonexpanding fastener that has either a collar swaged into annular locking grooves on the pin shank or a type of threaded collar to lock it in place. Available with either countersunk or protruding heads, lockbolts are permanent type fasteners assemblies and consist of a pin and a collar.

A lockbolt is similar to an ordinary rivet in that the locking collar, or nut, is weak in tension and it is difficult to remove once installed. Some of the lockbolts are similar to blind rivets and can be completely installed from one side. Others are fed into the workpiece with the manufactured head on the far side. The installation is completed on the near side with a gun similar to blind rivet gun. The lockbolt is easier and more quickly installed than the conventional rivet or bolt and eliminates the use of lockwashers, cotter pins, and special nuts. The lockbolt is generally used in wing splice fittings, landing gear fittings, fuel cell fittings, longerons, beams, skin splice plates, and other major structural attachment.

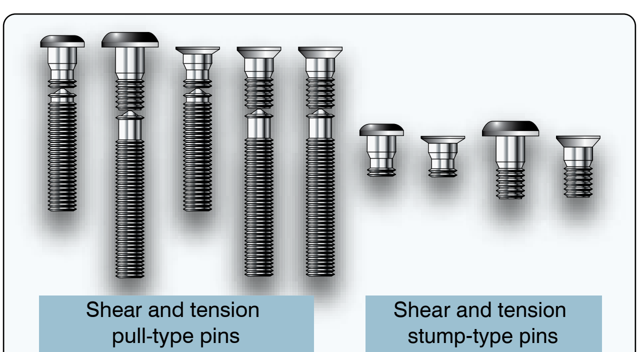


Figure 4-105. *Lockbolts.*

Often called huckbolts, lockbolts are manufactured by companies such as Cherry® Aerospace (Cherry® Lockbolt), Alcoa Fastening Systems (Hucktite® Lockbolt System), and SPS Technologies. Used primarily for heavily stressed structures that require higher shear and clamp-up values than can be obtained with rivets, the lockbolt and Hi-lok® are often used for similar applications. Lockbolts are made in various head styles, alloys, and finishes.

The lockbolt requires a pneumatic hammer or pull gun for installation. Lockbolts have their own grip gauge and an installation tool is required for their installation. *[Figure 4-106]* When installed, the lockbolt is rigidly and permanently locked in place. Three types of lockbolts are commonly used: pull-type, stump-type, and blind-type.

The pull-type lockbolt is mainly used in aircraft and primary and secondary structure. It is installed very rapidly and has approximately one-half the weight of equivalent AN steel bolts and nuts. A special pneumatic pull gun is required for installation of this type lockbolt, which can be performed by one operator since buckling is not required.

The stump-type lockbolt, although not having the extended stem with pull grooves, is a companion fastener to the pull-type lockbolt. It is used primarily where clearance does not permit effective installation of the pull-type lockbolt. It is driven with a standard pneumatic riveting hammer, with a hammer set attached for swaging the collar into the pin locking grooves, and a bucking bar.

The blind-type lockbolt comes as a complete unit or assembly and has exceptional strength and sheet pull-together characteristics. Blind-type lockbolts are used where only one side of the work is accessible and generally where it is difficult to drive a conventional rivet. This type lockbolt is installed in a manner similar to the pull-type lockbolt.

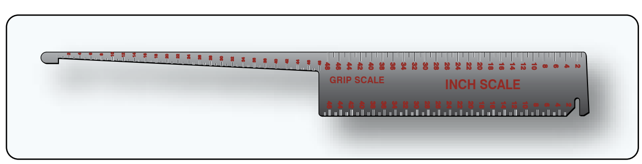


Figure 4-106. *Lockbolt grip gauge.*

The pins of pull- and stump-type lockbolts are made of heat-treated alloy steel or high-strength aluminum alloy. Companion collars are made of aluminum alloy or mild steel. The blind-type lockbolt consists of a heat-treated alloy steel pin, blind sleeve, filler sleeve, mild steel collar, and carbon steel washer.

These fasteners are used in shear and tension applications. The pull-type is more common and can be installed by one person. The stump type requires a two-person installation. An assembly tool is used to swage the collar onto the serrated grooves in the pin and break the stem flush to the top of the collar.

The easiest way to differentiate between tension and shear pins is the number of locking grooves. Tension pins normally have four locking grooves and shear pins have two locking grooves. The installation tooling preloads the pin while swaging the collar. The surplus end of the pin, called the pintail, is then fractured.

Installation Procedure

Installation of lockbolts involves proper drilling. The hole preparation for a lockbolt is similar to hole preparation for a Hi-Lok®. An interference fit is typically used for aluminum and a clearance fit is used for steel, titanium, and composite materials. *[Figure 4-107]*

Lockbolt Inspection

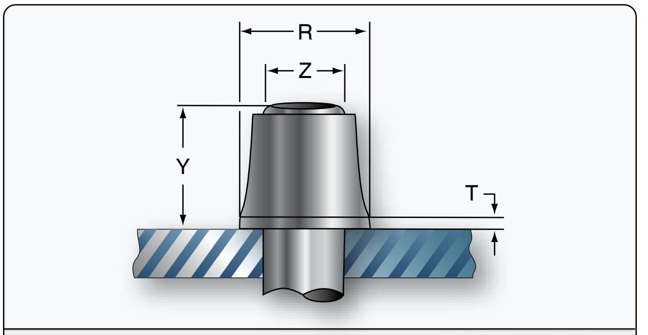
After installation, a lockbolt needs to be inspected to determine if installation is satisfactory. *[Figure 4-108]*

Inspect the lockbolt as follows:

1. The head must be firmly seated.
2. The collar must be tight against the material and have the proper shape and size.
3. Pin protrusion must be within limits.

Lockbolt Removal

The best way to remove a lockbolt is to remove the collar and



Lockbolt/Collar Acceptance Criteria

Nominal Fastener Diameter	Y	Z (Ref.)	R Max.	T Min.
5/32	.324/.161	.136	.253	.037
3/16	.280/.208	.164	.303	.039
1/4	.374/.295	.224	.400	.037
5/16	.492/.404	.268	.473	.110
3/8	.604/.507	.039	.576	.120

Figure 4-108. *Lockbolt inspection.*

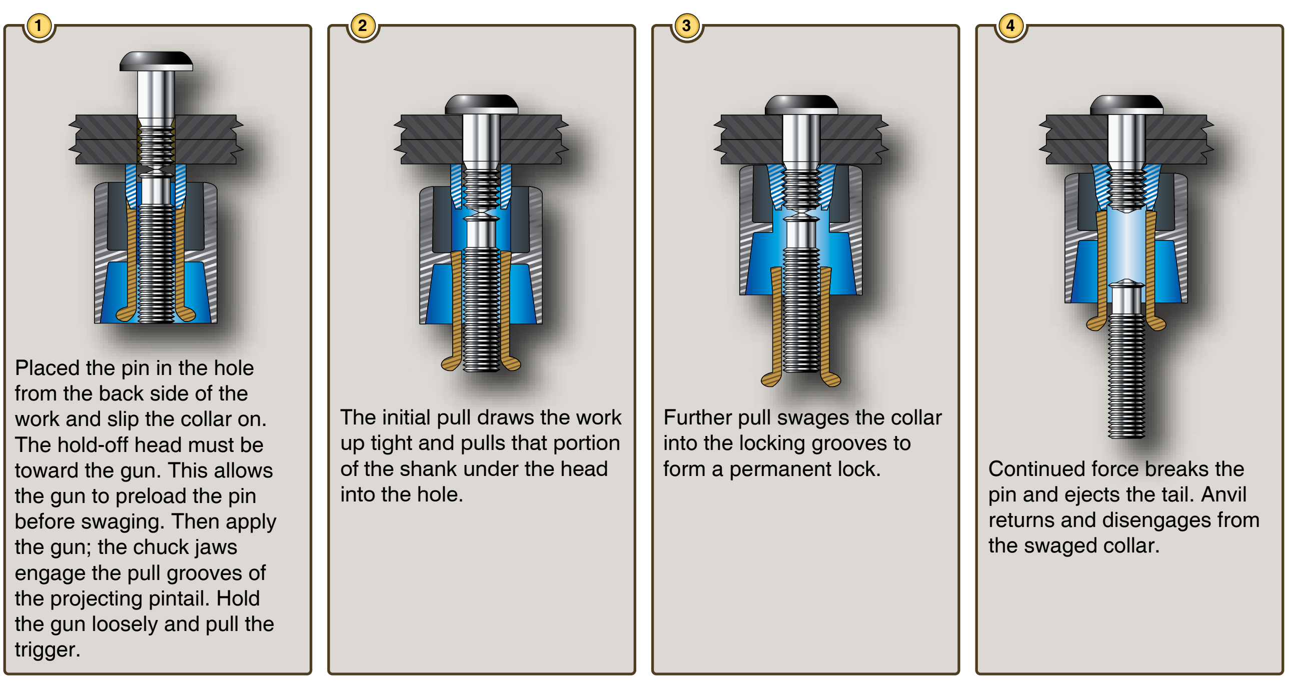


Figure 4-107. *Lockbolt installation procedure.*

drive out the pin. The collar can be removed with a special collar cutter attached to a drill motor that mills off the collar without damaging the skin. If this is not possible, a collar splitter or small chisel can be used. Use a backup block on the opposite side to prevent elongation of the hole.

The Eddie-Bolt® 2 Pin Fastening System

The Eddie-Bolt® 2 looks similar to the Hi-Lok®, but has five flutes, equally spaced along a portion of the pin thread area. A companion threaded collar deforms into the flutes at a predetermined torque and locks the collar in place. The collar can be unscrewed using special tooling. This fastening system can be used in either clearance or interference-fit holes.

Blind Bolts

Bolts are threaded fasteners that support loads through pre-drilled holes. Hex, close-tolerance, and internal wrenching bolts are used in aircraft structural applications. Blind bolts have a higher strength than blind rivets and are used for joints that require high strength. Sometimes, these bolts can be direct replacements for the Hi-Lok® and lockbolt. Many of the new generation blind bolts are made from titanium and rated at 90 KSI shear strength, which is twice as much as most blind rivets.

Determining the correct length of the fastener is critical to correct installation. The grip length of a bolt is the distance from the underhead bearing surface to the first thread. The grip is the total thickness of material joined by the bolt. Ideally, the grip length should be a few thousands of an inch less than the actual grip to avoid bottoming the nut. Special grip gauges are inserted in the hole to determine the length of the blind bolt to be used. Every blind bolt system has its own grip gauge and is not interchangeable with other blind bolt or rivet systems.

Blind bolts are difficult to remove due to the hardness of the core bolt. A special removal kit is available from the manufacturer for removing each type of blind bolt. These kits make it easier to remove the blind bolt without damaging the hole and parent structure. Blind bolts are available in a pull-type and a drive-type.

Pull-Type Blind Bolt

Several companies manufacture the pull-type of blind bolt fastening systems. They may differ in some design aspects, but in general they have a similar function. The pull-type uses the drive nut concept and is composed of a nut, sleeve, and a draw bolt. Frequently used blind bolt systems include but are not limited to the Cherry Maxibolt® Blind Bolt system and the HuckBolt® fasteners which includes the Ti-Matic® Blind Bolt and the Unimatic® Advanced Bolt (UAB) blind bolt systems.

Cherry Maxibolt® Blind Bolt System

The Cherry Maxibolt® blind bolt, available in alloy steel and A-286 CRES materials, comes in four different nominal and oversized head styles. *[Figure 4-109]* One tool and pulling head installs all three diameters. The blind bolts create a larger blind side footprint and they provide excellent performance in thin sheet and nonmetallic applications. The flush breaking stem eliminates shaving while the extended grip range accommodates different application thicknesses. Cherry Maxibolts® are primarily used in structures where higher loads are required. The steel version is 112 KSI shear. The A286 version is 95 KSI shear. The Cherry® G83, G84, or G704 installation tools are required for installation.

Huck Blind Bolt System

The Huck Blind Bolt is a high strength vibration-resistant fastener. *[Figure 4-110]* These bolts have been used successfully in many critical areas, such as engine inlets and leading edge applications. All fasteners are installed with a combination of available hand, pneumatic, pneudraulic, or hydraulic pull-type tools (no threads) for ease of installation.

Huck Blind Bolts can be installed on blind side angle

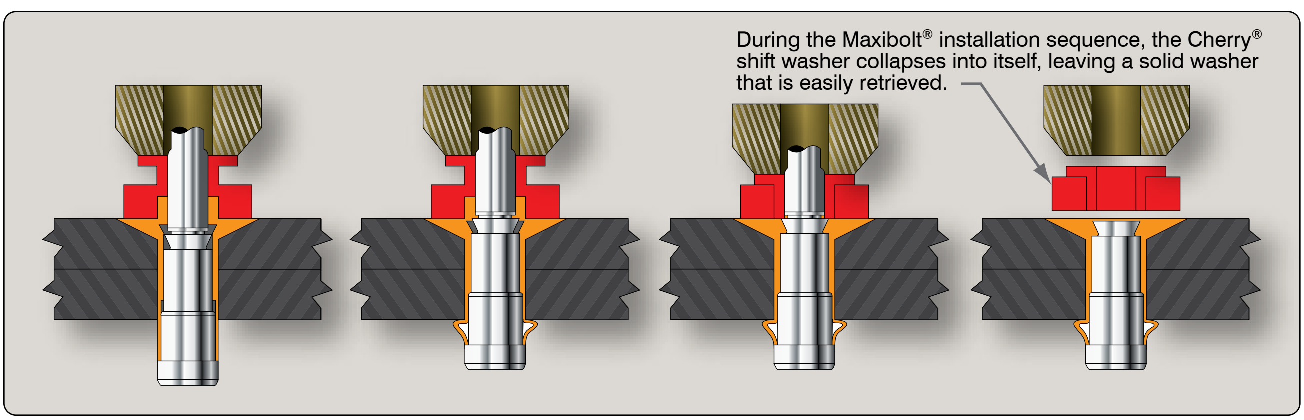


Figure 4-109. *Maxibolt® Blind Bolt System installation.*

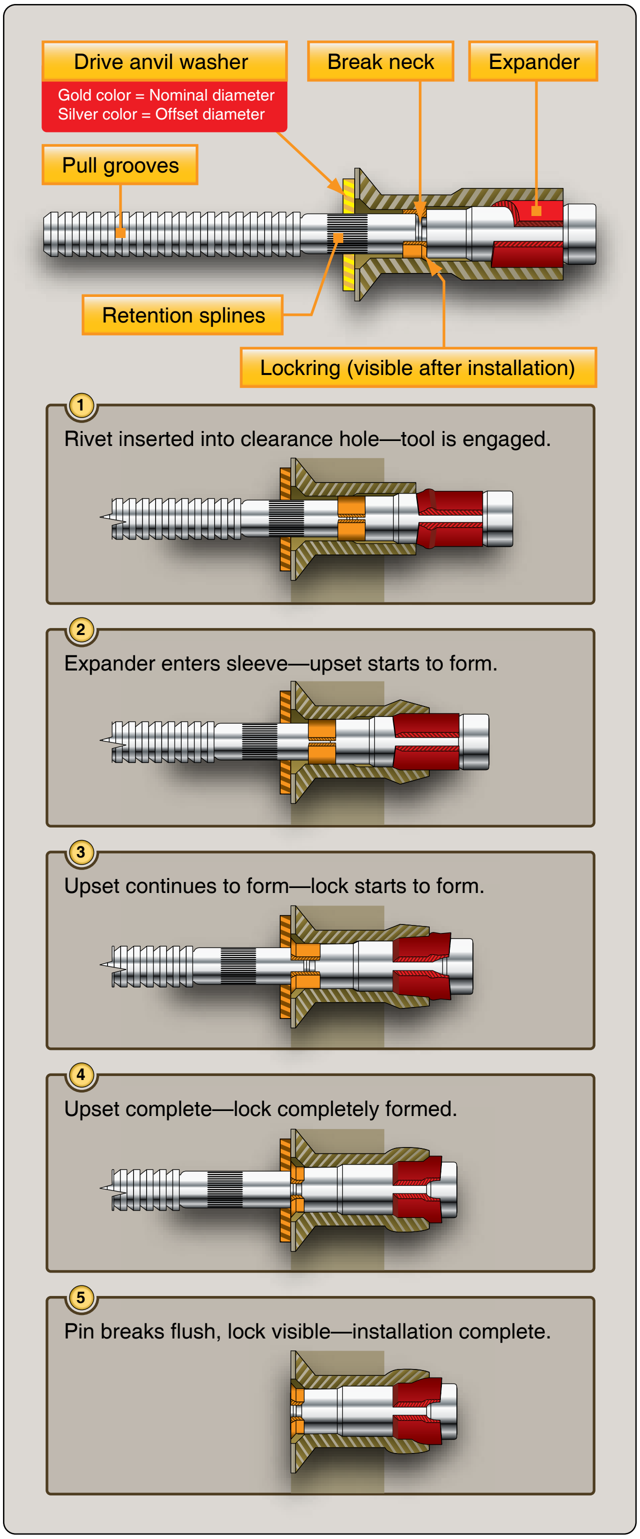


Figure 4-110. *Huck Blind Bolt system.*

surfaces up to 5° without loss of performance. The stem is mechanically locked to provide vibration-resistant FOD-free installations. The locking collar is forced into a conical pocket between stem and sleeve, creating high tensile capability. The lock collar fills the sleeve lock pocket to prevent leakage or corrosion pockets (crevice corrosion).

Flush head blind bolts are designed to install with a flush stem break that often requires no trimming for aerodynamic surfaces. The Huck Blind Bolt is available in high-strength A286 CRES at 95KSI shear strength in $\frac{5}{32}$-inch through $\frac{3}{8}$-inch diameters in 100° flush tension and protruding head. Also available are shear flush heads in $\frac{3}{16}$-inch diameter. A286 CRES Huck Blind Bolts are also available in $\frac{1}{64}$-inch oversize diameters for repair applications.

Drive Nut-Type of Blind Bolt

Jo-bolts, Visu-lok®, Composi-Lok®, OSI Bolt®, and Radial-Lok® fasteners use the drive nut concept and are composed of a nut, sleeve, and a draw bolt. *[Figure 4-111]* These types of blind bolts are used for high strength applications in metals and composites when there is no access to the blind side. Available in steel and titanium alloys, they are installed with special tooling. Both powered and hand tooling are available. During installation, the nut is held stationary while the core bolt is rotated by the installation tooling. The rotation of the core bolt draws the sleeve into the installed position and continues to retain the sleeve for the life of the fastener. The bolt has left hand threads and driving flats on the threaded end. A break-off relief allows the driving portion of the bolt to break off when the sleeve is properly seated. These types of bolts are available in many different head styles, including protruding head, 100° flush head, 130° flush head, and hex head.

Use the grip gauge available for the type of fastener and select the bolt grip after careful determination of the material thickness. The grip of the bolt is critical for correct installation. *[Figure 4-112]*

Installation procedure:

1. Install the fastener into the hole, and place the installation tooling over the screw (stem) and nut.

Figure 4-111. *Drive nut blind bolt.*

Figure 4-112. *Drive nut blind bolt installation tool.*

2. Apply torque to the screw with the installation tool while keeping the drive nut stationary. The screw continues to advance through the nut body causing the sleeve to be drawn up over the tapered nose of the nut. When the sleeve forms tightly against the blind side of the structure, the screw fractures in the break groove. The stem of Jo-bolts, Visu-lok®, and Composi-Lok® II fasteners does not break off flush with the head. A screw break-off shaver tool must be used if a flush installation is required. The stem of the newer Composi-Lok3® and OSI Bolt® break off flush.

Tapered Shank Bolt

Tapered shank bolts, such as the Taper-Lok®, are lightweight, high strength shear or tension bolts. This bolt has a tapered shank designed to provide an interference fit upon installation. Tapered shank bolts can be identified by a round head (rather than a screwdriver slot or wrench flats) and a threaded shank. The Taper-Lok® is comprised of a tapered, conical-shank fastener, installed into a precision tapered hole. The use of tapered shank bolts is limited to special applications such as high stress areas of fuel tanks. It is important that a tapered bolt not be substituted for any other type of fastener in repairs. It is equally as important not to substitute any other type of fastener for a tapered bolt.

Tapered shank bolts look similar to Hi-Lok® bolts after installation, but the tapered shank bolts do not have the hex recess at the threaded end of the bolt. Tapered shank bolts are installed in precision-reamed holes, with a controlled interference fit. The interference fit compresses the material around the hole that results in excellent load transfer, fatigue resistance, and sealing. The collar used with the tapered shank bolts has a captive washer, and no extra washers are required. New tapered shank bolt installation or rework of tapered shank bolt holes needs to be accomplished by trained personnel. Properly installed, these bolts become tightly wedged and do not turn while torque is applied to the nut.

Sleeve Bolts

Sleeve bolts are used for similar purposes as tapered shank bolts, but are easier to install. Sleeve bolts, such as the two piece SLEEVbolt®, consist of a tapered shank bolt in an expandable sleeve. The sleeve is internally tapered and externally straight. The sleeve bolt is installed in a standard tolerance straight hole. During installation, the bolt is forced into the sleeve. This action expands the sleeve which fills the hole. It is easier to drill a straight tolerance hole than it is to drill the tapered hole required for a tapered shank bolt.

Rivet Nut

The rivet nut is a blind installed, internally-threaded rivet invented in 1936 by the Goodrich Rubber Company for the purpose of attaching a rubber aircraft wing deicer extrusion to the leading edge of the wing. The original rivet nut is the Rivnut® currently manufactured by Bollhoff Rivnut Inc. The Rivnut® became widely used in the military and aerospace markets because of its many design and assembly advantages.

Rivet nuts are used for the installation of fairings, trim, and lightly loaded fittings that must be installed after an assembly is completed. *[Figure 4-113]* Often used for parts that are removed frequently, the rivet nut is available in two types: countersunk or flat head. Installed by crimping from one side, the rivet nut provides a threaded hole into which machine screws can be installed. Where a flush fit is required, the countersink style can be used. Rivet nuts made of alloy steel are used when increased tensile and shear strength is required.

Hole Preparation

Flat head rivet nuts require only the proper size of hole while flush installation can be made into either countersunk or dimpled skin. Metal thinner than the rivet nut head requires a dimple. The rivet nut size is selected according to the thickness of the parent material and the size of screw to be used. The part number identifies the type of rivet nut and the maximum grip length. Recommended hole sizes are shown in *Figure 4-114*.

Figure 4-113. *Rivet nut installation.*

Rivnut® Size	Drill Size	Hole Tolerance
No. 4	5/32	.155–.157
No. 6	#12	.189–.193
No. 8	#2	.221–.226

Figure 4-114. *Recommended hole sizes for rivet nut.*

Correct installation requires good hole preparation, removal of burrs, and holding the sheets in contact while heading. Like any sheet metal fastener, a rivet nut should fit snugly into its hole.

Blind Fasteners (Nonstructural)

Pop Rivets

Common pull-type pop rivets, produced for non-aircraft-related applications, are not approved for use on certificated aircraft structures or components. However, some homebuilt noncertificated aircraft use pull-type rivets for their structure. These types of rivets are typically made of aluminum and can be installed with hand tools.

Pull-Through Nutplate Blind Rivet

Nutplate blind rivets are used where the high shear strength of solid rivets is not required or if there is no access to install a solid rivet. The 3⁄32-inch diameter blind rivet is most often used. The nut plate blind rivet is available with the pull-through and self-plugging locked spindle. *[Figure 4-115]*

The new Cherry® Rivetless Nut Plate, which replaces standard riveted nutplates, features a retainer that does not require flaring. This proprietary design eliminates the need for two additional rivet holes, as well as reaming, counterboring, and countersinking steps.

Forming Process

Before a part is attached to the aircraft during either manufacture or repair, it has to be shaped to fit into place. This shaping process is called forming and may be a simple process, such as making one or two holes for attaching; it may be a complex process, such as making shapes with complex curvatures. Forming, which tends to change the shape or contour of a flat sheet or extruded shape, is accomplished by either stretching or shrinking the material in a certain area to produce curves, flanges, and various irregular shapes. Since the operation involves altering the shape of the stock material, the amount of shrinking and stretching almost entirely depends on the type of material used. Fully annealed (heated and cooled) material can withstand considerably more stretching and shrinking and can be formed at a much smaller bend radius than when it is in any of the tempered conditions.

When aircraft parts are formed at the factory, they are made on large presses or by drop hammers equipped with dies of the correct shape. Factory engineers, who designate specifications for the materials to be used to ensure the finished part has the correct temper when it leaves the machines, plan every part. Factory draftsmen prepare a layout for each part. *[Figure 4-116]*

Forming processes used on the flight line and those practiced in the maintenance or repair shop cannot duplicate a manufacturer's resources, but similar techniques of factory metal working can be applied in the handcrafting of repair parts.

Forming usually involves the use of extremely light-gauge alloys of a delicate nature that can be readily made useless by coarse and careless workmanship. A formed part may seem outwardly perfect, yet a wrong step in the forming procedure may leave the part in a strained condition. Such a defect may hasten fatigue or may cause sudden structural failure.

Of all the aircraft metals, pure aluminum is the most easily formed. In aluminum alloys, ease of forming varies with

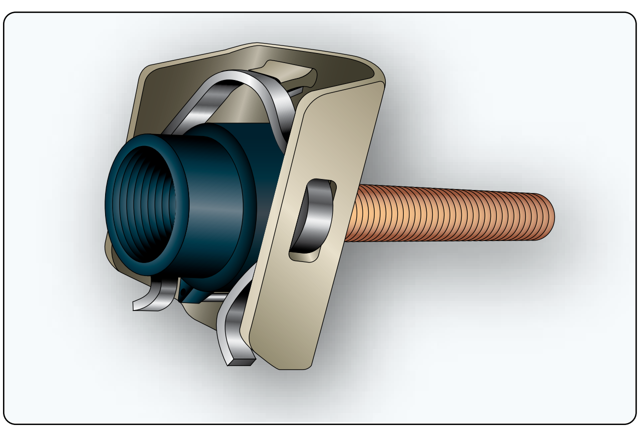


Figure 4-115. *Rivetless pull-through nutplate.*

Figure 4-116. *Aircraft formed at a factory.*

the temper condition. Since modern aircraft are constructed chiefly of aluminum and aluminum alloys, this section deals with the procedures for forming aluminum or aluminum alloy parts with a brief discussion of working with stainless steel, magnesium, and titanium.

Most parts can be formed without annealing the metal, but if extensive forming operations, such as deep draws (large folds) or complex curves, are planned, the metal should be in the dead soft or annealed condition. During the forming of some complex parts, operations may need to be stopped and the metal annealed before the process can be continued or completed. For example, alloy 2024 in the "0" condition can be formed into almost any shape by the common forming operations, but it must be heat treated afterward.

Forming Operations & Terms

Forming requires either stretching or shrinking the metal, or sometimes doing both. Other processes used to form metal include bumping, crimping, and folding.

Stretching

Stretching metal is achieved by hammering or rolling metal under pressure. For example, hammering a flat piece of metal causes the material in the hammered area to become thinner in that area. Since the amount of metal has not been decreased, the metal has been stretched. The stretching process thins, elongates, and curves sheet metal. It is critical to ensure the metal is not stretched too much, making it too thin, because sheet metal does not rebound easily. *[Figure 4-117]*

Stretching one portion of a piece of metal affects the surrounding material, especially in the case of formed and extruded angles. For example, hammering the metal in the horizontal flange of the angle strip over a metal block causes its length to increase (stretched), making that section longer than the section near the bend. To allow for this difference in length, the vertical flange, which tends to keep the material near the bend from stretching, would be forced to curve away from the greater length.

Shrinking

Shrinking metal is much more difficult than stretching it. During the shrinking process, metal is forced or compressed into a smaller area. This process is used when the length of a piece of metal, especially on the inside of a bend, is to be reduced. Sheet metal can be shrunk in by hammering on a V-block or by crimping and then using a shrinking block.

To curve the formed angle by the V-block method, place the angle on the V-block and gently hammer downward against the upper edge directly over the "V." While hammering, move the angle back and forth across the V-block to compress the material along the upper edge. Compression of the material along the upper edge of the vertical flange will cause the formed angle to take on a curved shape. The material in the horizontal flange will merely bend down at the center, and the length of that flange will remain the same. *[Figure 4-118]*

To make a sharp curve or a sharply bent flanged angle, crimping and a shrinking block can be used. In this process, crimps are placed in the one flange, and then by hammering the metal on a shrinking block, the crimps are driven, or shrunk, one at a time.

Cold shrinking requires the combination of a hard surface, such as wood or steel, and a soft mallet or hammer because a steel hammer over a hard surface stretches the metal, as opposed to shrinking it. The larger the mallet face is, the better.

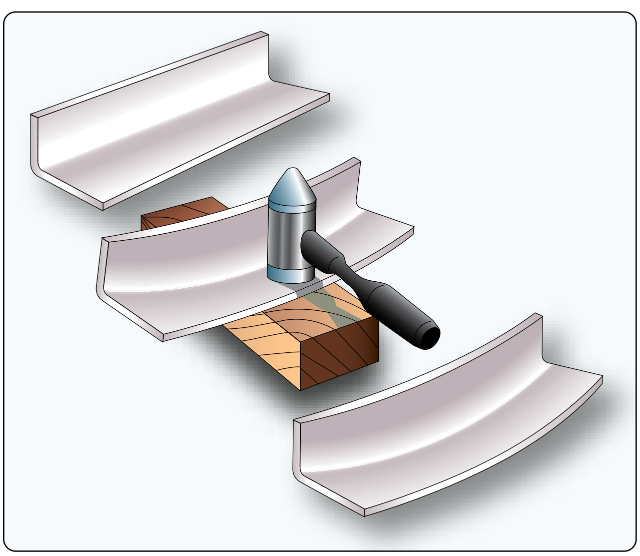


Figure 4-117. *Stretch forming metal.*

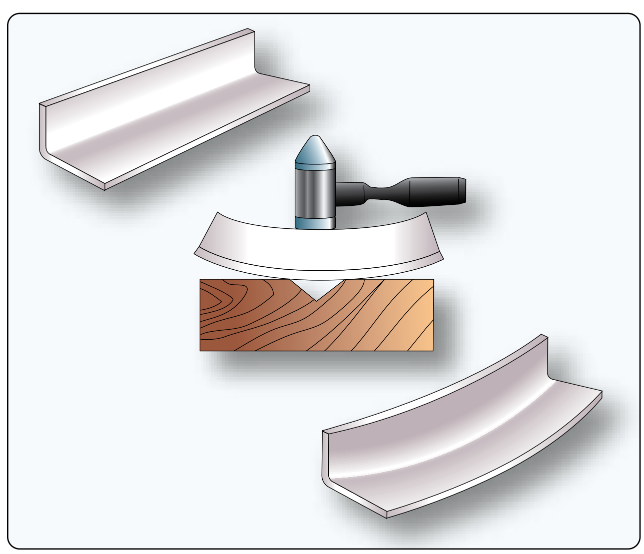


Figure 4-118. *Shrink forming metal.*

Bumping

Bumping involves shaping or forming malleable metal by hammering or tapping—usually with a rubber, plastic, or rawhide mallet. During this process, the metal is supported by a dolly, a sandbag, or a die. Each contains a depression into which hammered portions of the metal can sink. Bumping can be done by hand or by machine.

Crimping

Crimping is folding, pleating, or corrugating a piece of sheet metal in a way that shortens it or turning down a flange on a seam. It is often used to make one end of a piece of stove pipe slightly smaller so that one section may be slipped into another. Crimping one side of a straight piece of angle iron with crimping pliers causes it to curve. *[Figure 4-119]*

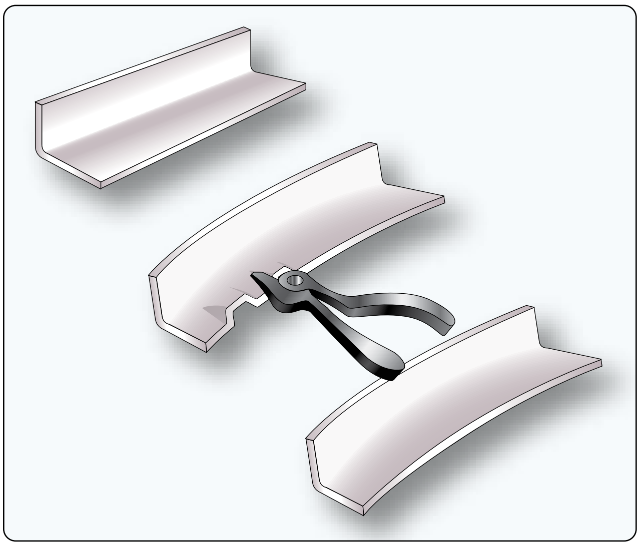


Figure 4-119. *Crimping metal.*

Folding Sheet Metal

Folding sheet metal is to make a bend or crease in sheets, plates, or leaves. Folds are usually thought of as sharp, angular bends and are generally made on folding machines such as the box and pan brake discussed earlier in this chapter.

Layout & Forming

Terminology

The following terms are commonly used in sheet metal forming and flat pattern layout. Familiarity with these terms aids in understanding how bend calculations are used in a bending operation. *Figure 4-120* illustrates most of these terms.

Base measurement—the outside dimensions of a formed part. Base measurement is given on the drawing or blueprint or may be obtained from the original part.

Leg—the longer part of a formed angle.

Flange—the shorter part of a formed angle—the opposite of leg. If each side of the angle is the same length, then each is known as a leg.

Grain of the metal—natural grain of the material is formed as the sheet is rolled from molten ingot. Bend lines should be made to lie at a 90º angle to the grain of the metal if possible.

Bend allowance (BA)—refers to the curved section of metal within the bend (the portion of metal that is curved in bending). The bend allowance may be considered as being the length of the curved portion of the neutral line.

Bend radius—the arc is formed when sheet metal is bent. This arc is called the bend radius. The bend radius is measured

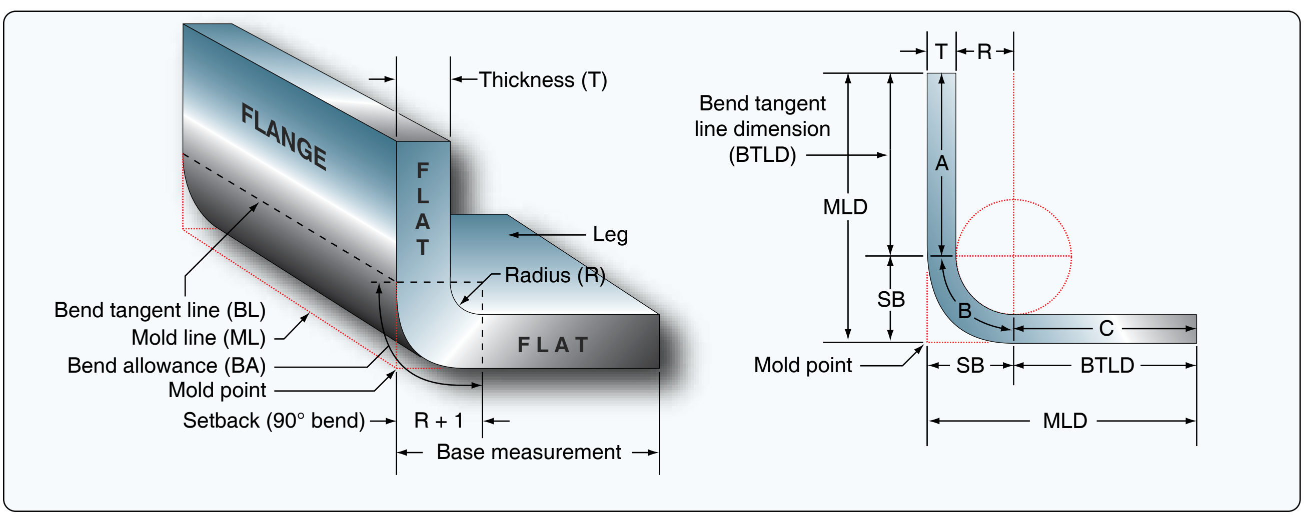


Figure 4-120. *Bend allowance terminology.*