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Low Observable Aircraft Structural Maintenance Journeyman

Volume 1. Structural Maintenance Basics

Air Force Career Development Academy

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Author: MSgt Charles W. Anderson
359th Training Squadron, Detachment 1
Aircraft Structural Maintenance (AETC)
359 TRS/DET/TDE
230 Chevalier Field Ave, Suite A
Naval Air Station Pensacola, FL 32508-5142
DSN: 459-7477
E-mail address: charles.anderson.14@us.af.mil

Instructional Systems Specialist: Regina Lucas

Editor: Todd Knowles

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell AFB, Gunter Annex, Alabama 36114-3107

Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the *Weighted Airman Promotion System Catalog* to determine the correct references to study.

THIS 5-skill level career development course (CDC) 2A755, *Low Observable Aircraft Structural Maintenance Journeyman*, is designed to prepare you for the responsibilities and duties of a journeyman in the low observable aircraft structural maintenance (LOASM) career field. It is also a prerequisite for the awarding of your 5-skill level. A journeyman must be able to perform repairs using basic hand tools, specialized equipment, and an in-depth knowledge of low observable principles.

The subjects covered in this first volume range from basic hand tools to layout techniques. Unit 1 covers the most common measuring and layout tools, as well as basic metal working tools. In addition, it will provide instructions on using drills and fastener tools.

In unit 2 you will learn how to read and interpret blueprints and drawings, as well as the mathematics used in developing these documents. Finally, you will study the proper layout development.

Unit 3 explains aircraft metal characteristics and fabrication procedures for the different metals you will work with.

In unit 4 you will learn about the different fasteners and common hardware used in the structural maintenance.

Lastly, unit 5 will provide you with information on aircraft tubing assemblies, as well as their repair.

Volume 2 covers aircraft tubing, publications and forms, corrosion, along with corrosion inspection equipment, and coatings and materials.

Volume 3, the final volume of this CDC, covers composite repair, low observable (LO) fundementals, LO materials, LO coating application and removal, and RADAR materials. A glossary of acronyms used in this text is included at the end of this volume.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

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This volume is valued at 21 hours and 7 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises

Acknowledgment

PREPARATION of this volume was aided through the cooperation of Alcoa Fastening Systems. Alcoa Fastening Systems furnished technical materials for the Eddie-Bolt®2 fastening system. Permission to use this information is gratefully acknowledged. Unit 2 of this volume uses extracts and illustrations from Alcoa Fastening Systems, *Eddie-Bolt 2 Fastening System Process Manual*.

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Date	Process Manual Figure Title	CDC Fig. No.
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2004	Eddie Nut	4-17
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Unit 1. Basic Tools

AS A LOW OBSERVABLE (LO) aircraft structural maintenance journeyman, you will be required to use a variety of tools on a daily basis. Regardless of the type of job to be done, you must be able to choose and effectively use the correct tools to do the work quickly, properly, and accurately. Without the proper tools and knowledge of how to use them, you waste time, cut efficiency, and may injure yourself or damage equipment. This unit explains the specific purposes, correct use, and proper care of the most common tools you use in your daily duties.

1–1. Measuring and Layout Tools

Measuring and layout tools are precision-designed, carefully machined and accurately marked. Some of these tools are made of very delicate parts, and you should exercise care when using them. You should especially avoid bending, dropping, or otherwise causing damage that impairs their performance. The successful outcome of the job depends on the accuracy of the measurements and layouts you make. It is important to fully understand how to read, use, and care for these tools.

001. Measurement tools

In aircraft metalwork, the unit of measure most commonly used is the inch. The inch may be divided into smaller parts by means of common fraction or decimal divisions. The fractional divisions for an inch are determined by dividing the inch into equal parts, and then continuing to divide each part into halves ($^1/_2$), quarters ($^1/_4$), eighths ($^1/_8$), sixteenths ($^1/_{16}$), thirty-seconds ($^1/_{32}$), and sixty-fourths ($^1/_{64}$).

See figure 1–1 for examples of fractional divisions and figure 1–2 for types of rules. Fractions of an inch may also be expressed in decimals, which are called decimal equivalents of an inch (e.g., $^1/_8$ inch is expressed as 0.125 [one hundred twenty-five one-thousandths of an inch]).

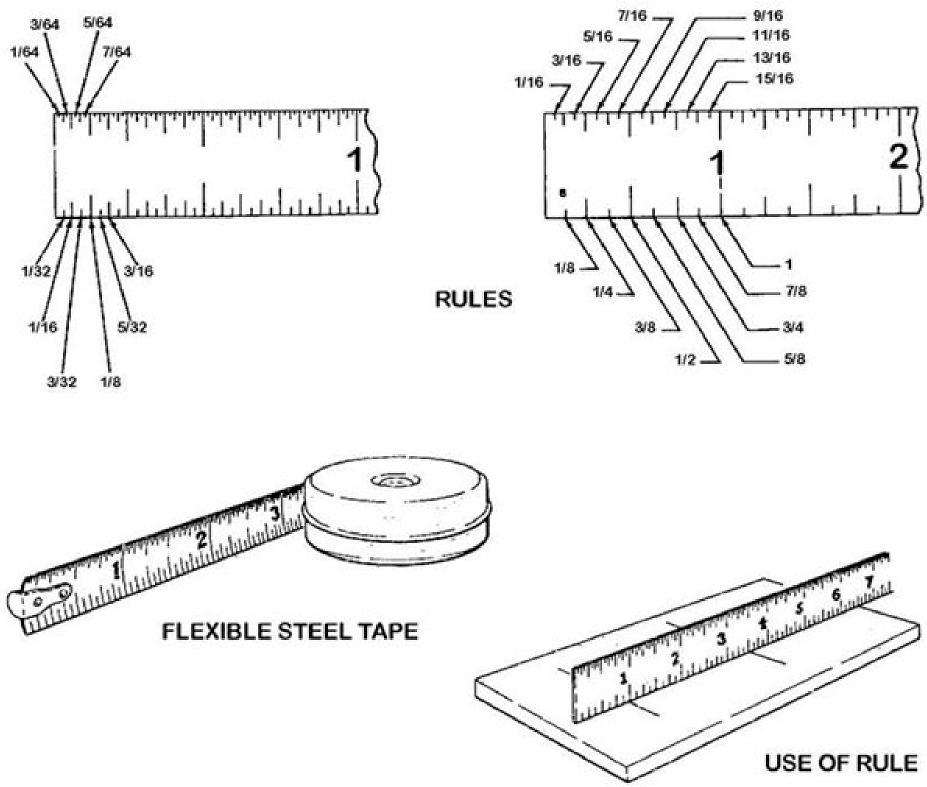


Figure 1–1. Rules and tapes.

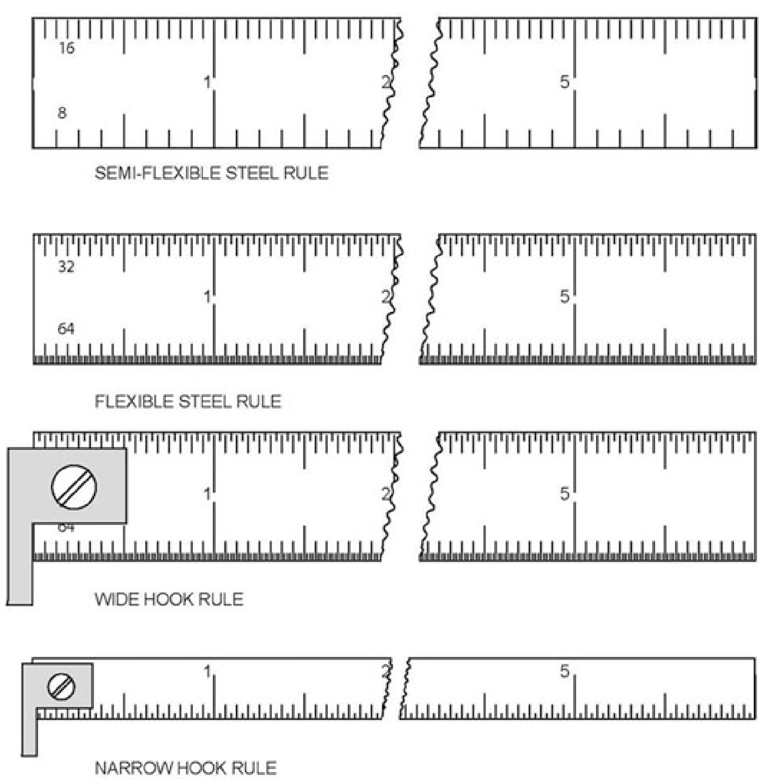


Figure 1–2. Types of rules.

Rule

Rules provided for your use are made of steel, and are rigid or flexible. Do not bend the flexible steel rule intentionally, as it may easily break. Steel rules or scales come in 6-, 12-, and 24-inch lengths. They usually contain four separate scales, one on each edge. The most common fractional steel rules have one side with a $^{1}/_{16}$-inch scale and a $^{1}/_{8}$-inch scale. The other side of the rule contains a $^{1}/_{32}$-inch scale and a $^{1}/_{64}$-inch scale. Steel rules also are available with the graduations marked off in either decimal or metric scales. Some rules have a hook on one end, which allows you to measure from the edge of an object more accurately.

A rule may be used as a measuring tool or straightedge. To measure a piece of stock, place the rule flat across the surface or distance to be measured while holding or steadying the work. Figure 1–3 illustrates how a steel rule can be used to take measurements. To measure the length of a line, lay the rule alongside the line with the end of the rule at one end of the line, and read the graduation of the rule that is opposite the other end of the line. Care for the rule by wiping it with light machine oil and carefully storing it in a separate compartment of the tool box to protect it from rust, scratches, and other damage.

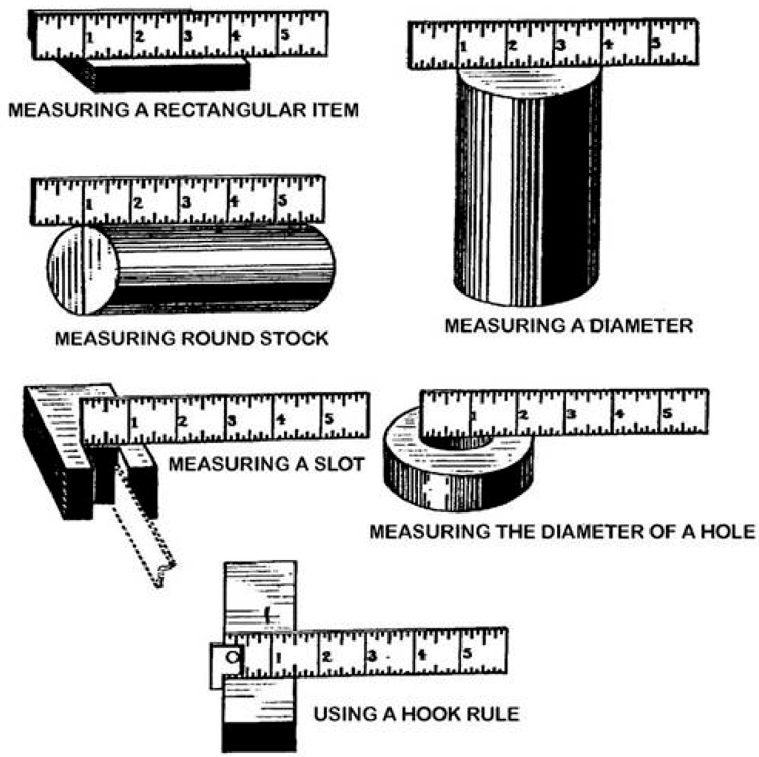


Figure 1–3. Uses for steel rule.

Tapes

There are several kinds and lengths of tapes, but the most commonly used is 6 feet long and made of flexible steel, which is coiled in a circular case. The tape is usually graduated on one side in divisions of $^{1}/_{2}$-inch, $^{1}/_{4}$-inch, $^{1}/_{16}$-inch, and $^{1}/_{32}$-inch. A small lip on the extending end is used to steady the tape while measuring. The tape bends, but it should not be bent intentionally, as it may break easily.

002. Layout tools

In addition to using measurement tools, you will also be required to use layout tools; these are also precision instruments that require careful handling. A layout tool that has been well-maintained and properly used is invaluable when making precision layouts.

Scriber

The scriber is designed to serve in the same way a pencil or pen serves a writer. In general, it is used to scribe or mark cut lines on metal surfaces. The scriber (fig. 1–4) is made of tool steel and is four to 12 inches long with two needle point ends. One needle point end is bent at a 90° angle for reaching and marking through holes.

Figure 1–4. Scriber.

Before using a scriber, always inspect the points for sharpness. Ensure the steel rule being used as a straightedge is flat on the metal and in position for scribing. While holding the scriber like a pencil, tilt it slightly in the direction toward which it will be moved and keep the scriber's point close to the guiding edge of the steel rule as you make your line. The scribed line should be heavy enough to be visible, but no deeper than necessary to serve its purpose.

Dividers

Dividers are used for measuring distances between two points for transferring or comparing measurements directly from a rule, or for scribing an arc, radius, or circle. Figure 1–5 illustrates two types of dividers: the spring and wing types.

Spring divider

The spring divider consists of two sharp points at the end of straight legs, which are held apart by a spring and adjusted by means of a screw and nut. The spring divider is available in sizes from three to 10 inches in length.

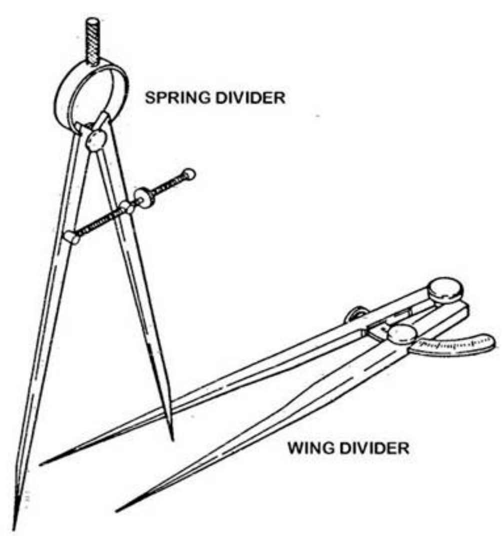


Figure 1–5. Dividers.

Wing divider

The wing divider has an incremented steel bar that separates the legs, a locking nut for securing a rough measurement, and an adjusting screw for fine adjustments. The wing divider is available in 6-, 8-, and 12-inch lengths. One version of the wing divider has the tip of one leg removable so a pencil can be inserted.

To set the dividers, hold them so one leg is at a determined mark on the material or rule, turn the adjustment nut, and bring the other leg to rest on the material or rule at the point of the required measurement.

To draw an arc or circle with a divider, hold the top with your thumb and forefinger, position one leg on the determined mark on the material; then, with pressure exerted on both legs, swing (or rotate) the dividers and draw the arc or circle. You can offset the tendency of the legs to slip by inclining the dividers in the direction in which they are being rotated. When working on metal, use the dividers only to scribe arcs or circles that will later be removed by cutting. Draw all other arcs or circles with a pencil compass (fig. 1–6) to avoid scratching the material.

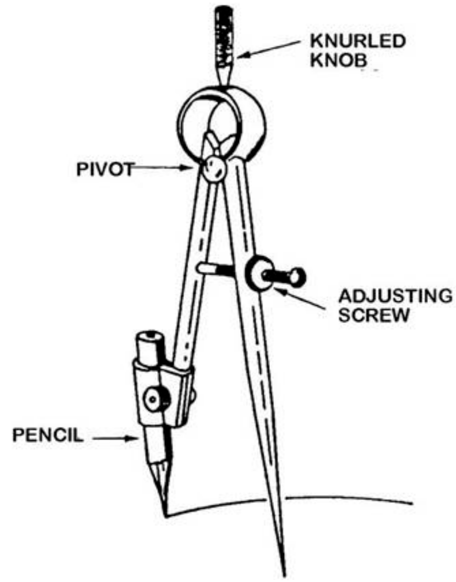


Figure 1–6. Pencil compass.

Combination set

The combination set (fig. 1–7) has several uses. The set has a 12-inch, grooved, steel blade with graduated markings similar to a 12-inch rule. The set also has cast-steel center, protractor, and stock heads; each of the heads is made to slide along the blade and clamp at any desired position.

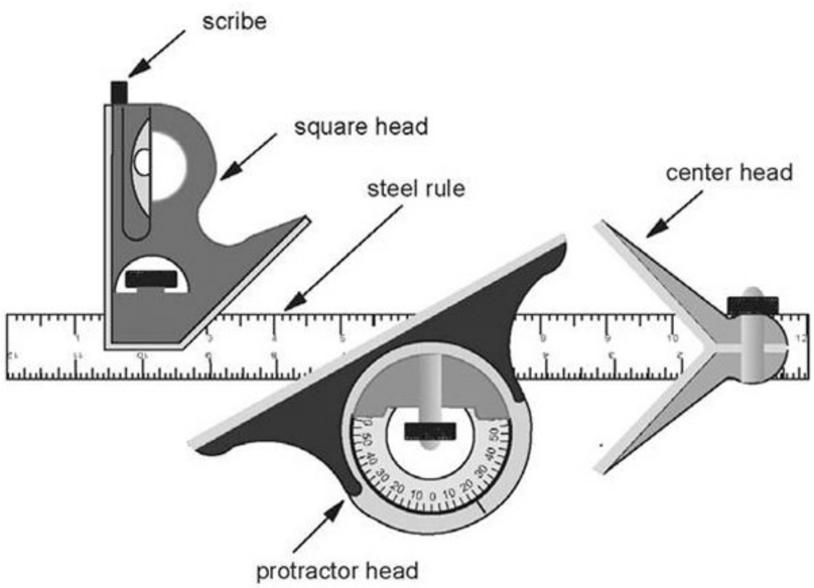


Figure 1–7. Combination set.

- The center head is used to find the center of shafting or other cylindrical work.
- The protractor head can be set at any angle, enabling you to draw lines at angles from 0° to 180°.
- The stock head, often called the square head because it’s set at 90°, has a scriber and a spirit level that can be used to check the squareness and levelness of a shear cut. You can also use it as a simple level.

Figure 1–8 illustrates some of the various uses of the combination set.

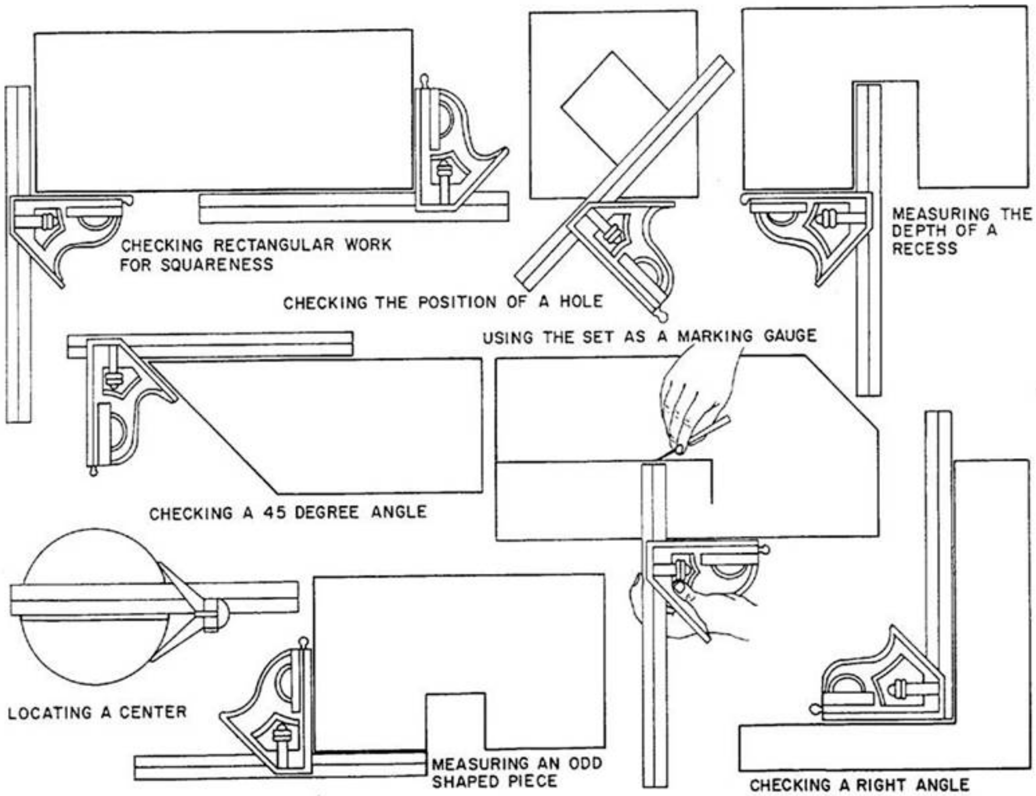


Figure 1–8. Uses of combination set.

Layout punches

Of the variety of punches you may find in your tool kit, the prick and center punches do double duty because they are also layout tools. As shown on figure 1–9, the *major* difference between prick and center punches is the angular degree of sharpness in their points.

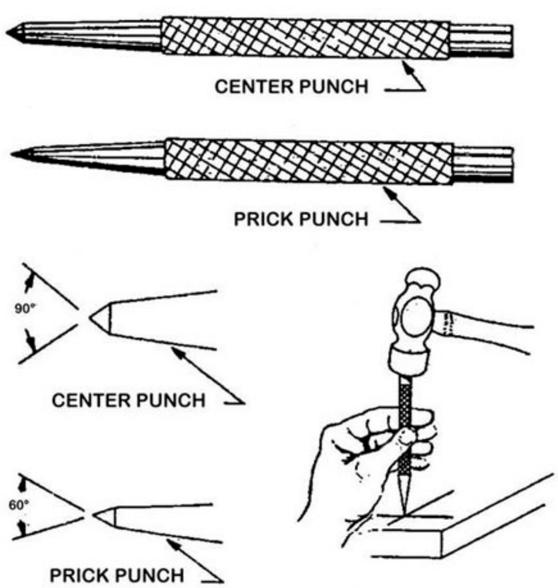


Figure 1–9. Center and prick punches.

Prick punch

You should use the prick punch only for making fine punch marks along scribed lines to mark their position in those cases where the lines are likely to be rubbed off, or for locating centers of holes and centers for divider legs during layout of circles and arcs.

Center punch

To increase the depth of the hole centers in preparation for drilling, be sure to use the heavier-pointed center punch; it has a bigger point which makes a deeper depression. You must grind the points of the center punches frequently to keep them sharp. While sharpening the punch point, you should also check the driving end to ensure it is flat and perpendicular to the centerline of the punch. Also, this is the time to remove any dangerous burrs that have formed around the edges.

The included angle of the point of the center punch should be 90°, which allows the standard ground drill bit to seat well into the bottom of the conical depression. If, as sometimes happens, the location for the drill point is slightly off center, you can tilt the punch and drive the point in the direction desired. When the error has been corrected, bring the punch to a vertical position and give it a sharp rap to ensure a perfect new location for the drill point.

T-squares

T-squares (fig. 1–10) are made with a fixed or adjustable head. The T-square most often used has a hardwood blade equipped with transparent plastic edges and rigidly attached to a hardwood head. This arrangement places the upper edge of the blade and inner edge of the head at right angles; these are the working edges of the T-square. Only use the blade to draw horizontal lines. Be careful not to mar the edges of the blade.

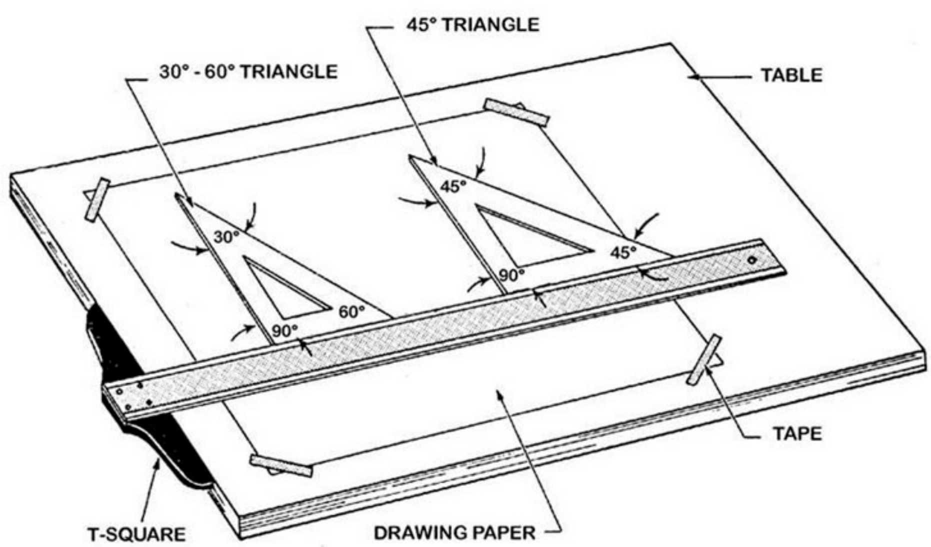


Figure 1–10. Drawing board setup.

Triangles

Triangles are usually made of transparent celluloid or plastic material. Figure 1–10 shows two common triangles, the 30°–60° and 45° triangles. Standard sizes are 10 inches for the longest leg of the 30°–60° triangle and eight inches for the legs of the 45° triangle. Vertical and sloping lines are drawn with the use of triangles. The base of the triangle should rest flat and on the edge of the blade of the T-square. As with the T-square, take care to avoid marring the edges.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

001. Measurement tools

1. What is the most commonly used unit of measurement in aircraft metal work?

2. What are two ways a steel rule can be used?

3. How is the common 6-feet steel tape usually graduated?

002. Layout tools

1. When do you use a scriber?

2. What types of measuring functions can be done with dividers?

3. What do you use the protractor head of the combination set for?

4. Why is a center punch used instead of a prick punch to locate the centers of holes to be drilled?

1–2. Metal Working Tools

When you think of hammering tools, you probably automatically think of hammers. While hammers are essential to working on metal and other material, you also use mallets and punches when molding and shaping aircraft structures.

003. Hammers, mallets, and punches

Because of the different work you need to do on aircraft structures, you need various tools specifically designed or intended for each task. Figure 1–11 shows different types of hammers and mallets you may use in metalworking.

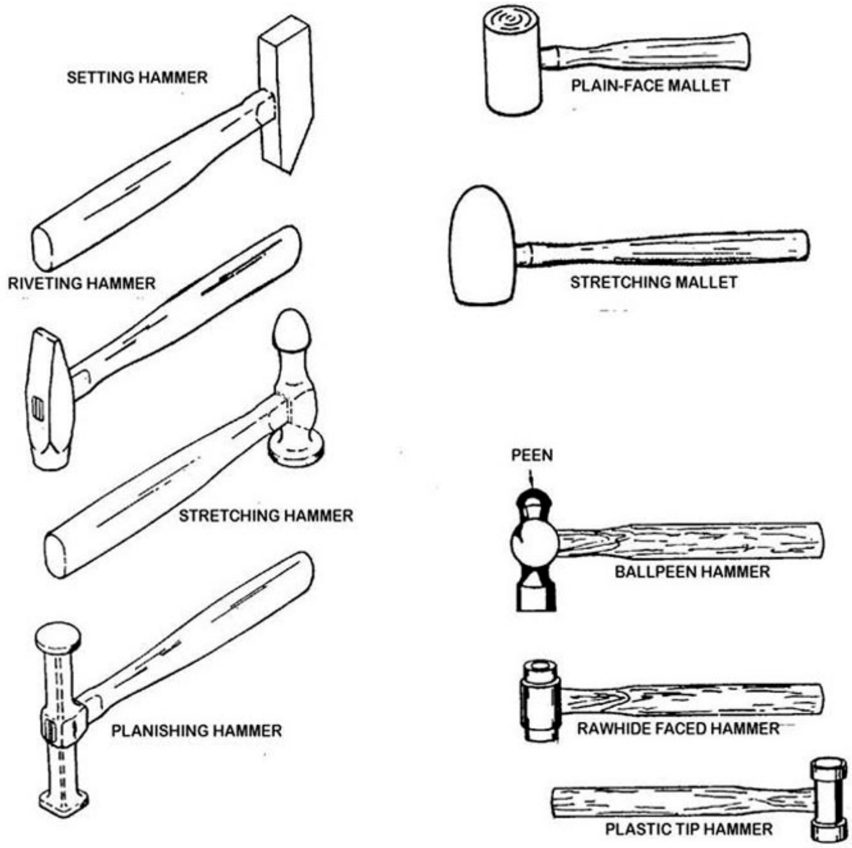


Figure 1–11. Types of hammers and mallets.

Hammers

The following metalworking hammers are used for riveting, setting, stretching, and planishing. They are classified by usage.

Riveting hammers

Riveting hammers are used for driving rivets and *light* chiseling. One end of the hammerhead is cross-peened (cross-pointed); the other may have a square or chamfered face. The sizes of riveting hammers range from $^1/_8$-inch to $^5/_8$-inch, measured across the face.

Ballpeen hammer

The 8-ounce ballpeen hammer is the most common hammer you will use. You use it for striking punches (such as a center punch to create a hole for drilling) and chisels, peening and riveting, and performing other light-duty work. You use the 16-ounce ballpeen hammer for heavy-duty work.

Mallets

Mallets are made of rubber, plastic, or rawhide, and may be classified as plain-faced and stretching. They are generally used for pounding down seams or forming sheet metal over forms or stakes. Since the mallets do not dent or mar the metal as steel hammers do, they are often used for finishing. Two of the more common mallets you'll encounter are the plain-faced mallet and stretching mallet.

Use and care of hammers or mallets

The handle is a very important part of any hammer or mallet. Do not choke or hold the handle too close to the head because this reduces the force of the blow and makes it difficult to hold the handle level when the head makes contact with the work. The handle must also be the right size and length for the proper balance and swing. Without balance and proper swing, the head does not contact the work flatly and you cannot consistently strike the same spot.

Most accidents involving hammers are caused by loose heads. Notice in figure 1–12 how the head is secured to the handle. Always check the head for security and the handle for fractures when you take a hammer from your toolbox.

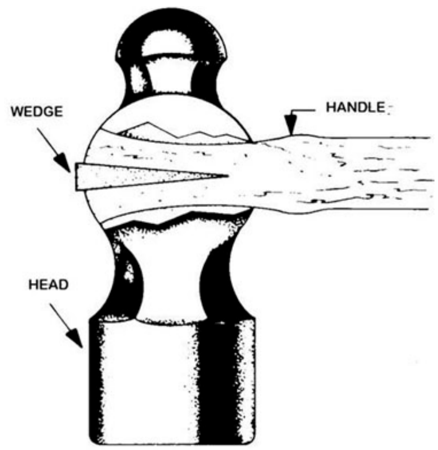


Figure 1–12. Securing hammer head to handle.

The eye in the hammerhead is oval-shaped with a bell mouth at either end. The end of the hammer handle is tapered to fit the eye. The handle is driven into the eye far enough to wedge it at the rear of the eye, and then a steel wedge is driven into the end of the handle to spread the wood and wedge it at the front of the eye, thus preventing the head from slipping in either direction. Usually, you can eliminate any slight tendency of the head to slip in either direction by driving the steel wedge a little farther into the end of the handle.

It is good practice to occasionally grind the face of the hammer lightly to keep it smooth and perpendicular to the centerline of the head. Be careful not to grind it flat; the face should be slightly convex. Grind off any burrs that form around the edge of the face.

Punches

There are many different types of punches used in repair work, including those for marking metal before drilling, for removing pins and rivets, and for aligning and piercing holes. Each punch is designed for a specific job. There are many types of hand punches you can use; however, the punches you will use most often are the center punch and pin punch (fig. 1–13).

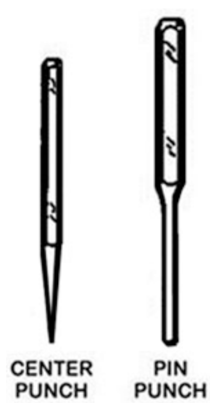


Figure 1–13. Punches.

Both punches discussed in the following table are driven with a hammer:

Type of Punch	Description
Center	Used to make a small depression on metal before drilling or punching. The *depression prevents* a twist drill from “walking” during the drilling operation. The punch should never be struck with such force as to dimple the material around the indentation or cause the metal to protrude through the other side of the sheet. A center punch has a heavier body than a prick punch and is ground to a point at an angle of about 90°.
Pin	This punch doesn’t have a taper; it is used to drive out rivet shanks from drilled holes when the shanks have had their heads drilled off. The pin punch is also used to drive pins out of holes, which are too deep for the starting punch or drift punch to reach without damaging the base metal. In general practice, a pin or bolt, which is to be driven out, is usually started and driven out with a drift punch until the sides of the punch touch the side of the hole. A pin punch is then used to drive the pin or bolt the rest of the way out of the hole. Placing a thin piece of scrap copper, brass, or aluminum directly against the pin, and then striking it with a heavy hammer until the pin begins to move may start stubborn pins. Never use a prick or center punch to remove objects from holes because the point of the punch will spread the object and cause it to bind even more.

004. Snips, files, and chisels

Very often, you will find it impractical to use power-driven metal cutting tools because of the type or location of the work. In such cases, you must rely on your skill to use hand-held cutting tools. There are several methods of cutting sheet metal with hand-held tools, and naturally several kinds of tools. Among the most frequently used tools are straight snips, aviation snips, files, and chisels.

Metal-cutting snips

You should be able to find most of these snips in your work center. These are *not* all the different types of snips, but some of the most common available.

Straight snips

Metal-cutting straight snips (fig. 1–14), commonly known as tinners snips, are designed for cutting thin sheets of metal. The metal-cutting straight snips resemble scissors with long handles and short blades. They consist of two cutting edges held together with a pivot screw or bolt. These snips vary from six to 16 inches in length, and are made with straight or curved blades.

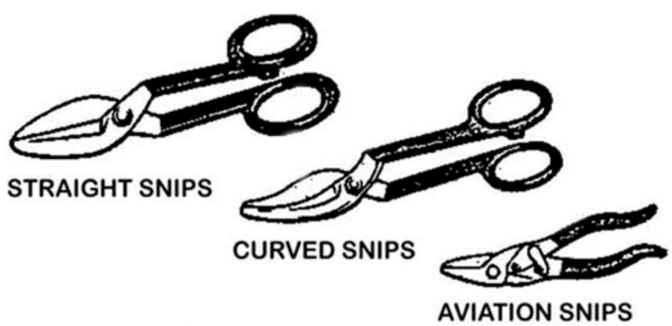


Figure 1–14. Types of metal cutting shears.

Uses

Straight snips are designed for right-handed operators, so the cutting line can always be in full view for accurate cutting. Hold the snips in the right hand so the flat sides of the blade are at a right angle to the work surface. If you don’t hold the snips at a right angle, the edges of the cut will be slightly bent and burred.

To use the straight snips, place the metal being cut on a table or bench, with a marked guideline along the edge of the table (fig. 1–15). While cutting, hold the sheet down with one hand and keep the metal well back into the jaws of the snips to make the cutting easier. Use the edge of the table to steady the snips and keep them at the correct angle for the cutting. This allows the scrap metal portion of the work to bend downward so it does not interfere with cutting. If making a curved cut, make the cut in a counter-clockwise direction whenever possible so you can see the guideline. Once started, cut without stopping because starting and stopping causes rough edges.

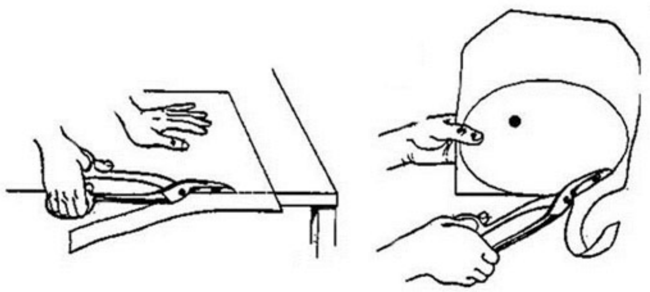


Figure 1–15. Using straight snips.

At times, you will want to cut notches or make other small cuts on a piece of metal. In these cases, it is practical to use only the tips of the straight snips. When you are nearing the end of the line-of-cut in a long cut, use the tips of the snips to finish the cut while being careful not to let them go beyond the stopping mark.

Care

Place snips in a special compartment of the toolbox when not in use. Because the snips can be bent or broken, do not throw them into a toolbox or place them where heavy objects can be piled or dropped on them. Wash grease or dirt from the snips with a solvent and dry them with a soft cloth. Apply a light coat of oil before prolonged storage to prevent rust. Lubricate the pivot screw or bolt with light oil frequently and keep it tight enough to prevent side play, but not tight enough to cause binding. Do not spring the jaws of these snips by trying to cut wire, cable, or similar materials with them, and do not use them on metal heavier than they are designed to cut.

CAUTION: *Never* use straight snips on tempered steel; it is too hard for them and will ruin the cutting edges.

Aviation snips

Aviation snips are *designed especially* for cutting heat-treated aluminum alloy and stainless steel. They are also adaptable for *enlarging* small holes. The blades have small teeth on the cutting edges and are shaped for cutting very small circles and irregular outlines. The compound-leverage type handles make it possible to cut material as thick as 0.050-inch. Aviation snips are available in two styles—those that cut from right to left and those that cut from left to right.

Never use aviation snips as pliers or wire cutters, nor on material heavier than 0.050-inch. Such improper use may spring the blades and make the snips useless. When cutting, place the upper blade of the snips on the line to be followed and keep the blade perpendicular to the surface of the metal. The waste metal (or the smaller piece) should curl up along the upper edge of the lower blade.

Files

No shop or individual tool kit is complete without at *least* several files. The bottom of figure 1–16 illustrates the *six* shapes of files you will use *most* often.

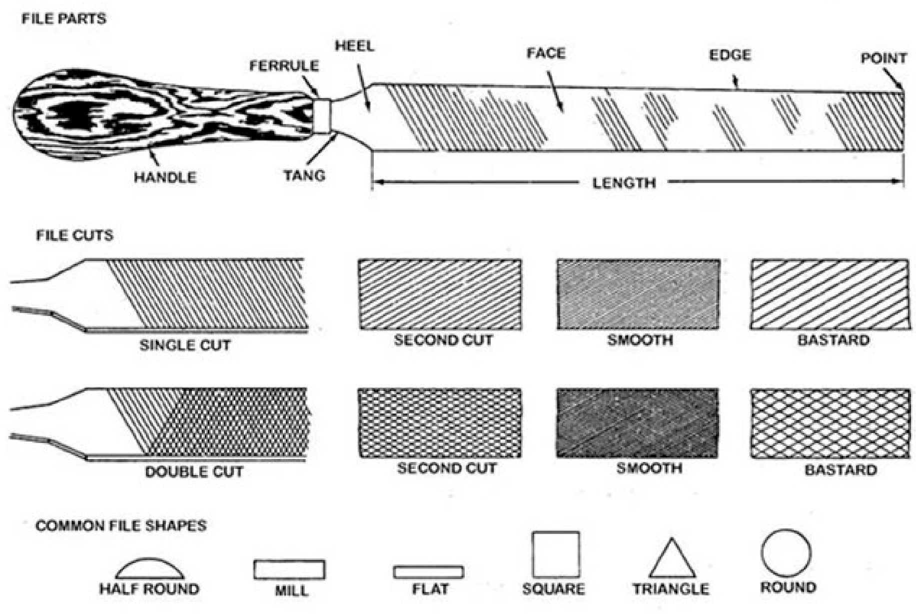


Figure 1–16. Files.

Files are very useful tools, but their life and usefulness depend a great deal on the way they are used and maintained. To keep them working well, clean them frequently with a file card or brush, and keep them separated from other tools to prevent damage.

Files are usually made in two types of cuts—single and double cut. The single cut file has a single row of teeth extending across the face at an angle from 65° to 85° for the length of the file. The size of the cuts that can be made depends on the coarseness of the file.

The double cut file has two rows of teeth that cross each other. For general work, the angle of the first row is from 40° to 45°. The first row is generally referred to as the over cut, while the second row is referred to as the up cut, which is finer than and not as deep as the over cut.

Single cut files are *recommended* for *sharpening* cutting tools (e.g., the blades of shears and snips). Apply light pressure to single cut files to obtain a smooth finish. Use double cut files when a rough finish is permissible; heavy pressure may be applied for fast cutting.

One of the factors in selecting a file is the composition of the metal to be filed (i.e., stainless steel is hard and requires a file with a deep up cut and fine over cut).

The parts of a file are the tang, face, heel, and point. Generally, all files are manufactured in the same way. A file blank flank of carbon steel is heated, the teeth are cut into it, and it is quenched in water to harden it. This method has the disadvantage of making the file brittle.

Shapes

The *six* shapes of files you will *most* often use are the half-round, mill, flat, square, triangle, and round.

Half-round

Half-round files are *not* complete half circles as the name implies, because the arcs are only about one-third of a circle. They are the best files to use when filing *concave* surfaces and are available in all cuts, *except* dead smooth. Half-round files are double cut, tapered in width and thickness toward the point, and have one flat and one oval side.

Mill

A mill file is tapered slightly in thickness and width for about one-third of its length. They are single cut in bastard, second cut, or smooth forms. Mill files are available with square edges and with one or two round edges for filing the gullets between saw teeth. They are used *principally* for sharpening mill or circular saws, edge tools, and machine knives, and for lathe work, draw filing, or finishing compositions of brass and bronze.

Flat

Flat files are tapered slightly toward the point in width and thickness. They are double cut on both sides and single cut on both edges. They are available in bastard, second cut, and smooth-cut, and are best suited for all common filing operations.

Square

Square files are square in cross-section, may be tapered or blunt, and are double cut on all four sides. They are made in bastard, second cut, and smooth forms, and are used for filing keyways, slots, and corners, and general surface filing.

Triangle

Three-corner files are triangular in cross-section, and may be tapered or blunt, with the edges forming a perfect triangle. They are double cut and are made in bastard, second cut, and smooth forms. Triangle files are used for filing acute internal angles, clearing out square corners, and filing cutters and taps. Taper files are also triangular in shape, but are single cut.

Round

Round files are circular in cross-section, may be tapered or blunt, and are single or double cut. They are made in bastard, second cut, and smooth forms. Round files are principally used to file or enlarge circular openings, or to file concave surfaces.

Procedures

When using a file, hold the handle in one hand with your fingers underneath and your thumb on top. With your other hand, grip the point of the file between the thumb and fingers. (This position is the preferred grip, but the job and location may force you to use a different grip.) If possible, the work should be at the height of your elbow because this position lets you file in long, smooth strokes, approximately 60 per minute.

Filing too fast actually causes the points of the teeth to get hot enough to lose their hardness. Do not put pressure on the file as you draw it back over the material, because the cutting teeth slant forward and the pressure on the back stroke may break them off. An exception to this rule is in the filing of very soft metals (e.g., lead, solder, or aluminum). When working with these metals, apply a slight pressure on the back stroke. Soft metal will not break the teeth, and the slight pressure aids in cleaning the file.

Let’s take a closer look at three filing procedures: crossfiling, drawfiling, and rounding corners.

Crossfiling

When moving the file endwise across the work (commonly known as crossfiling), grasp the handle in such a manner that its end fits into and against the fleshy part of your palm. Then, with your thumb lying lengthwise along the top of the handle (fig. 1–17), grasp the end of the file between your thumb and first two fingers, and file using long, smooth strokes. To prevent undue wear, relieve the pressure during the return stroke. Hold narrow work surfaces near the vise jaws to prevent vibration. If a surface is straight, place it parallel to the top of the vise.

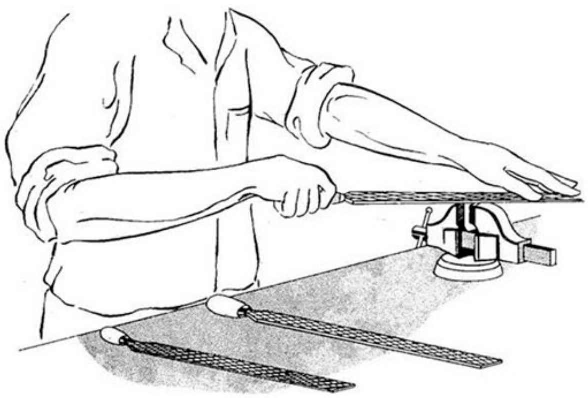


Figure 1–17. Crossfiling procedures.

Drawfiling

A file is sometimes used by grasping it at each end, crosswise to the work, then moving it lengthwise with the work (fig. 1–18). When done properly, the drawfiling method gives a finer finish than crossfiling with the same file. In drawfiling, the teeth of the file should produce a shearing effect. To do this, vary the angle at which you hold the file with respect to its line of movement and the angle at which the teeth are cut. You should also relieve the pressure during the back stroke as in crossfiling.

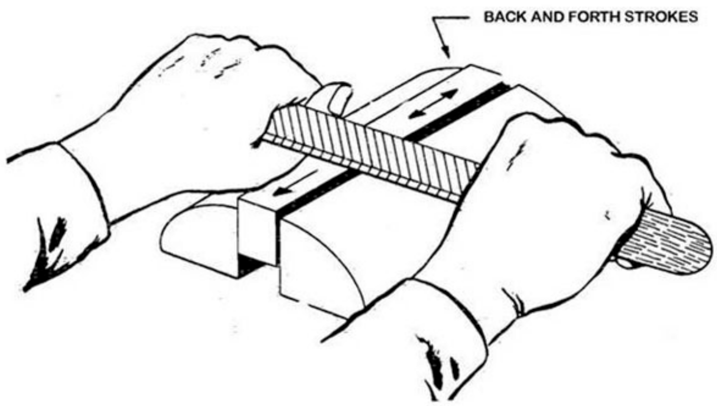


Figure 1–18. Drawfiling procedures.

Rounding corners

The method used in filing a rounded surface depends on the width and radius of the rounded surface. If the surface width is narrow or only a portion of a surface is to be rounded, you can use the method illustrated in figure 1–19. This method allows use of the full length of the file.

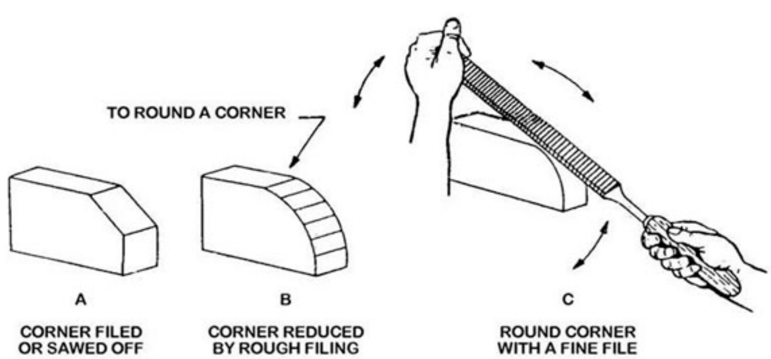


Figure 1–19. Rounding corners.

Figure 1–20. File card.

Cleaning files

Particles of metal collect between the teeth of a file and may make deep scratches as the file passes over the work. When the metal particles become firmly lodged between the file teeth and cannot be removed by tapping the edge of the file, you can remove them by using a file card or wire brush (fig. 1–20). Draw the brush across the file so the bristles press down the gullet and between the teeth.

NOTE: Never oil a file because oil causes the file to slide across the work, hindering a fast cut.

Precautions

Never use a file without a handle. A file with a handle is much easier to use and less likely to injure your hands. Never use a file as a pry bar or a hammer. The metal is too brittle and will probably break.

Chisels

A chisel is made of a hard, tough metal (usually tool steel) onto which a cutting edge has been ground.

Types of chisels

There are several different types of chisels, but the one you will use most often is a flat chisel (fig. 1–21). The flat (cold) chisel is the most common and has a cutting edge ground at an angle from 60° to 70°. It is used for chipping, cutting sheet metal, heads off screws, and flat stock. For more information on other types of chisels, consult technical order (TO) 32–1–101, *Use and Care of Hand Tools and Measuring Tools*.

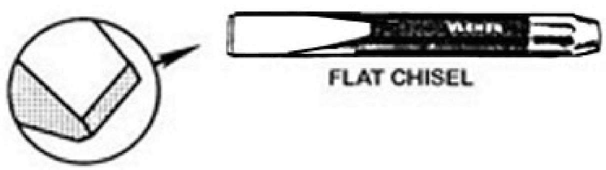


Figure 1–21. Flat chisel.

Use of chisels

To use a chisel, you must first select the correct type. Next, hold the chisel firmly and strike the head with short, quick blows. Be sure to strike the head with the full face of the hammer (fig. 1–22). To do a good job, watch the cutting edge of the chisel, *not* the head.

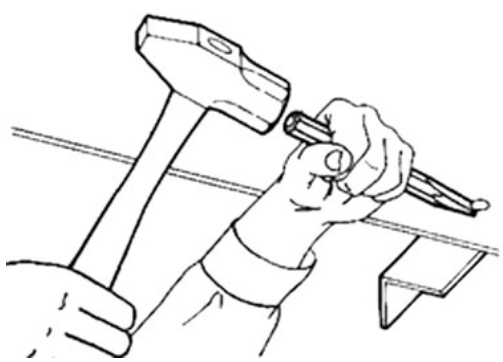


Figure 1–22. Correct use of chisel.

Care of chisels

The care of chisels is very important and includes sharpening and dressing the chisel head. Chisels, like all cutting tools, must be sharp to give satisfactory service (fig. 1–23). When you sharpen a chisel, grind the cutting edge to an included angle of 60° or 70°. If you grind the cutting angle too small, the chisel is not safe to use. If the angle is too great, the tool cannot cut properly. The sharpening is usually done on an ordinary coarse grinding wheel. When you grind a chisel, don't let it become red hot. If you press the chisel too hard against the wheel, you generate enough heat to remove some of the hardness from the steel. Overheating causes the chisel's cutting edge to lose its temper, and it won't be hard enough to cut metal.

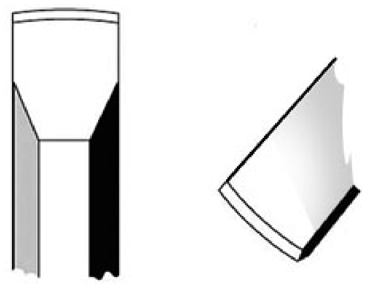


Figure 1–23. Chisel sharpened with a slight convex edge.

The blows of the hammer eventually cause the head of the chisel to spread out until it resembles a mushroom. When this happens, grind the head back to its original shape. It is dangerous to use a chisel with a mushroomed head because pieces may fly off and cause injury.

005. Hacksaws and shears

Hacksaws are designed to cut metal in much the same fashion as a carpenter's saw cuts wood. Hacksaws are available in pistol grip and straight styles. They consist of a frame, handle, and blade, and come in lengths of six to 16 inches, with the 10-inch size most common. Hacksaw blades are identified by the length of the blade and pitch (the number of teeth per inch).

Hacksaws

The hacksaw is a useful cutting tool when used properly. It is capable of cutting a variety of materials. The material thickness is only limited to the throat of the tool. There are two types of hacksaw frames: solid and adjustable. The solid frame is stronger, but only holds one length of blade. The adjustable frame (fig. 1–24) is more commonly used and can accommodate blades of 8-, 10-, or 12-inch lengths (as measured between the centers of the stud pin holes). To install the blade, you mount the blade on pins located in sliding studs at each end and adjust the blade tension by turning the wing nut located at the far end of the frame. Tighten the frame enough to prevent the blade from buckling and drifting, but do not tighten it so much you break the blade, shear the pins, or bend the frame. When you install a blade on the frame, always remember to install the blade with the angles of the teeth forward (away from the handle).

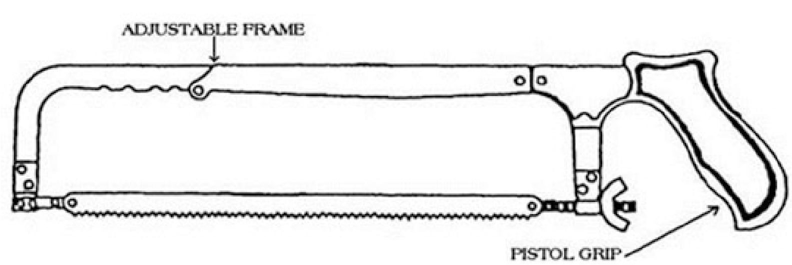


Figure 1–24. Pistol grip hacksaw.

When using a hacksaw, you should use two hands on the saw—one to keep the saw steady and aid in maintaining the angle of cut while applying very slight downward pressure; the other to make the forward stroke. To get the best cutting results, clamp the material to be cut in a vise so it provides as much bearing surface as possible and engages the greatest number of teeth on the blade. Start the cut with a light, steady, forward stroke just outside the cutting line. At the end of the stroke, relieve the pressure and draw the blade back. (The cut is made on the forward stroke.) After the first few strokes, make each stroke as long as the hacksaw frame allows. Apply just enough pressure on the forward stroke to cause each tooth to remove a small amount of metal. The strokes should be long and steady with a speed of not more than 40 to 50 strokes per minute.

Hand-operated lever-type shears

Let's talk about the different types of lever shears and how you use them as an Aircraft Structural Maintenance Journeyman.

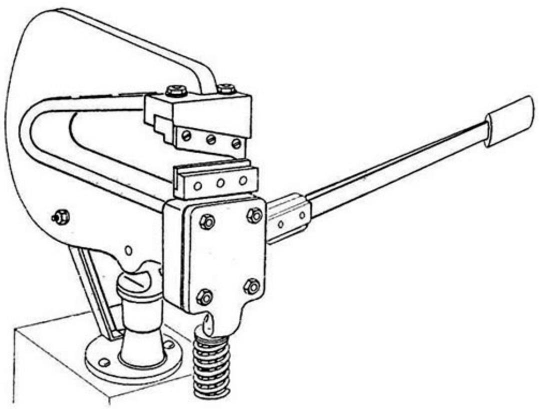


Figure 1–25. Scroll shear.

Scroll shear

The scroll shear (fig. 1–25) is designed for making straight and irregular cuts on sheet metal. The scroll shear is *particularly adaptable* for making inside cuts. With this shear, you can make many of the same cuts made with hand snips. The size of the parts that may be cut is limited by the frame or yoke.

The upper cutting blade is stationary, while the lower blade moves. Pushing the handle downward raises the lower blade and produces the cutting action. Cuts must always be started from an edge, another cut, or hole.

When cutting, it is preferable to keep the scrap material on the side of the stationary blade and the good material on the side of the movable blade. While the cutting capacity of the scroll shear varies with the type of metal, you should not try to cut metal thicker than 0.063-inch aluminum. Observe ordinary safety precautions (e.g., keeping your fingers away from the cutting blades) and do not exceed the recommended material thickness while cutting.

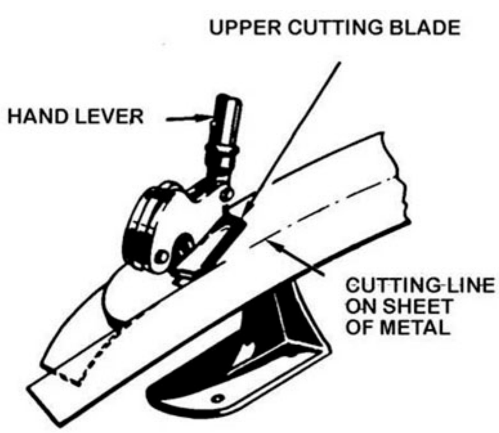


Figure 1–26. Throatless shear.

Throatless shear

Throatless shears (fig. 1–26) get their name from their construction. The frame of the shear never obstructs the cutting operation. This allows sheets of *any* length or width to be cut.The metal being cut may be turned in any direction, which allows for the cutting of irregular outlines and making notches.

The throatless shear is quite sturdy and cuts materials of heavier gauge than the scroll shear. The upper blade of the shear is directly connected to a hand lever. During the cutting operation, the upper blade moves down, shearing the metal. This motion tends to force the scrap down and away from the pattern.

After completing the cutting operations, return the handle to full UP position. Observe ordinary safety precautions (e.g., keeping your fingers away from the cutting blades), and do not exceed the recommended material thickness while cutting.

Squaring shears

Perhaps the most important piece of stationary cutting equipment commonly found in the shop is the squaring shear.

Manually operated squaring shears

The squaring shears (fig. 1–27) have two large springs, one at each end of the housing. The springs raise the blade when pressure is removed from the treadle. A graduated scale is scribed on the bed as a guide for cutting specific lengths. At each end of the bed, a side gauge aids in keeping the metal square with the blades. The foot supplies the action and power required to operate the cutting blade. The back gauge and holddown handles are also operated manually.

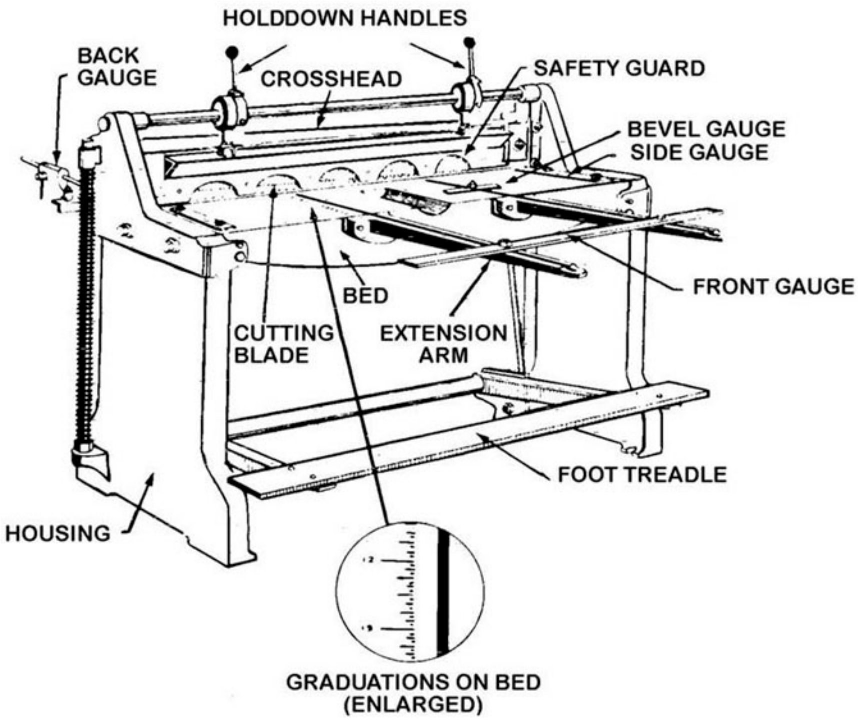


Figure 1–27. Manually operated squaring shear.

For 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. Pull the holddown handles forward to lock the metal in place. Then, cut the material by stepping on the treadle, which completes the cutting cycle.

Squaring a piece of metal requires several steps, the first of which is the trimming of one edge. You do this by inserting the metal between the blades of the shears and by cutting off approximately $^{1}/_{4}$-inch of metal. Square the remaining edges by holding a trimmed edge against the side gauge and making the remaining cuts one edge at a time. If you find the metal is *not* square after the *first* cut, loosen the locking bolts and readjust the side gauge.

For cutting several pieces of metal to the same dimensions, use the back gauge (production gauge). This gauging device consists of two support rods graduated in fractions of an inch, and a square fence that can be set at any point on the support rods. To use the gauge, set the squaring fence at the desired distance from the cutting blade and lock the fence in position. Once the gauge adjustments are made, many pieces of metal can be cut to the same dimensions without additional measuring.

Ensure you observe all safety precautions and wear the proper protective equipment when using the manually operated squaring shears. Pushing down on the foot treadle requires considerable force, so be sure your other foot is clear of the foot treadle. The metal gauge limit of a manually operated squaring shears is 16-gauge mild carbon steel. If the metal is heavier gauge, use power shears.

Power-operated squaring shears

Power-operated squaring shears (fig. 1–28) provide a convenient means of cutting and squaring sheet metal stock. A major difference between the foot-powered and power-operated shears is the operation of the holddown. When the trip levers of the power-operated shear are compressed, the holddown automatically moves down, clamping the metal into place.

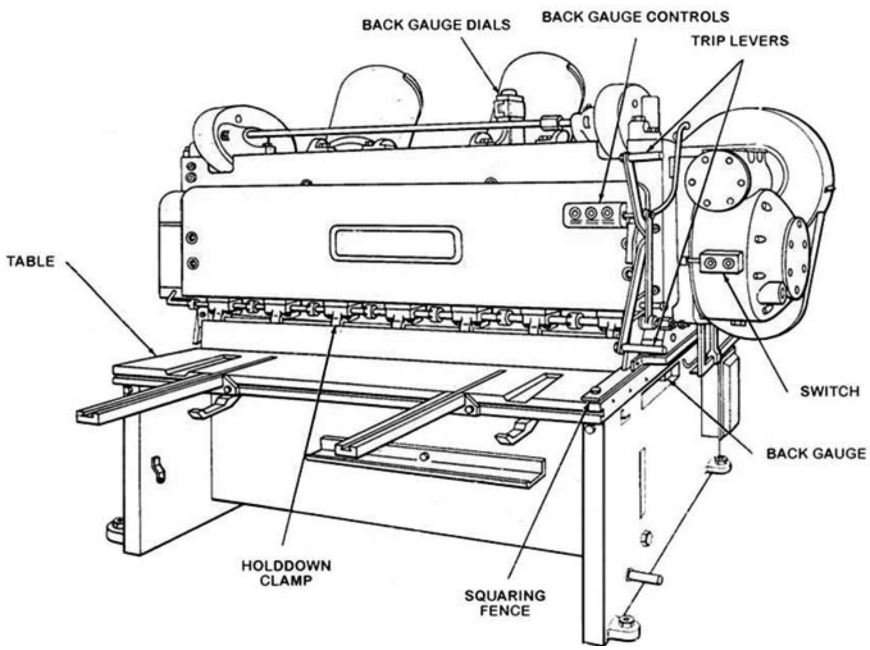


Figure 1–28. Power-operated squaring shear.

Before using the shear, you should check the data plate (usually found on the front of the shear) to ensure the gauge of material being cut is within the capacity of the shear. Cutting procedures on this shear (squaring metal, cutting to a line, and multiple cutting) are similar to those for the foot-operated shear. If adjustments are needed for the cutting operations, they should always be made before the motor is started or after the motor is turned off.

WARNING: Do *not* adjust this machine while the motor is running.

Before operating power shears, you should check the machine to ensure it is clear of material and personnel. The machines you use are equipped with guards for your protection, and the guards should never be removed except when the machine is disconnected from its power source for repairs. The blade guard, similar to the safety guard, is designed to keep your hands and fingers away from the cutting blades during operation. Wheel and belt guards are provided to protect personnel and to keep foreign objects from being caught in the moving parts. When making cuts, always ensure the cutting blades are clear before releasing the clutch to actuate the holddown dogs and blade. Ensure your fingers are clear of the holddown dogs when they are actuated. Also, ensure your fingers are not under the sheet of metal you are cutting. To keep your metal in place during shearing, tremendous pressure is applied by the holddown dogs. These holddown dogs have been responsible for the crushing or loss of many fingers.

006. Using the contour metal cutting saw

Power cutting tools are some of the most used tools in the shop. These tools are used to make parts for repairs and other requirements. Of all the machines you use, the contour metal cutting saw is probably the greatest challenge to your resourcefulness and skill. Safety, especially with this machine, is a must.

Contour metal cutting saw

The contour metal cutting saw, such as the DO ALL (fig. 1–29), is designed to make straight and irregular cuts. The contour saw is used in the repair and replacement of aircraft fittings or parts made of a material too heavy to be stamped out or cut by shears. With the proper blade and using the job selector dial as a guide, you may adjust this machine to cut many types of metal *dependent on* material composition and thickness. The contour saw has several speeds and the table can be adjusted to various angles; consult the equipment manual for table adjustments and angles. Some saws are equipped with butt welding and grinding attachments that permit the saw blade to be cut, inserted, and welded without delay when making internal cuts. Also, the welding and grinding attachments can be used to mend broken blades. Continuous file and polishing bands are also available as accessories for finishing parts once they have been cut. Successful sawing depends on the following essential factors:

- Selection of the saw blade.
- Joining (welding) the saw blade.
- Mounting and adjusting the saw blade.

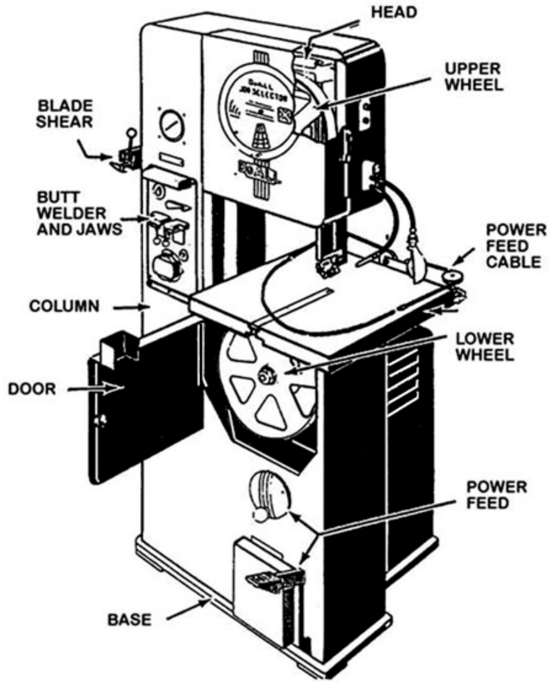


Figure 1–29. Contour metal cutting saw.

Selection of the saw blade

There is a best saw blade for every sawing job; therefore, you must know the various types and features of the saw blades available so you can select the proper blade. Each saw blade is made of high-grade tool steel, designed for a specific purpose, and constructed to close tolerances to ensure uniformity of quality. Before you can select a saw blade, knowledge of the saw blade terms in the following table is a must. Refer to figure 1–30 as you cover the terms:

Term	Explanation
Teeth	Front edge or cutting part of a blade. It is mainly from the general tooth shape and tooth spacing that the blade gets its name or type.
Tooth gullet	Throat or opening within the curved area at the base of the tooth, tooth face, and back of the next tooth. The tooth gullet removes chips from the cut.
Width	Measurement of the blade from tooth tip to the back edge of the blade. Saw widths may vary from $^1/_{16}$-inch to $^1/_2$-inch.
Blade thickness	For saws up to $^1/_2$-inch width, the gauge is usually 0.025-inch.
Set pattern	Pattern formed on the teeth, depending on the manner in which the teeth are set. There are three set patterns: raker, wave, and straight.
Pitch	Number of teeth per inch.
Set	Amount of bend given the teeth. This makes it possible for a saw to cut a kerf or slot wider than the thickness of the blade, thus providing side clearance.

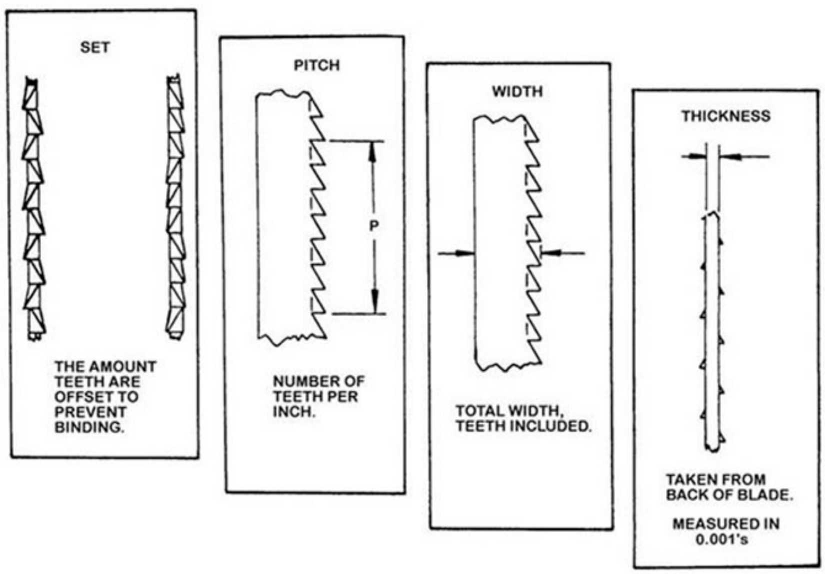


Figure 1–30. Saw blade features.

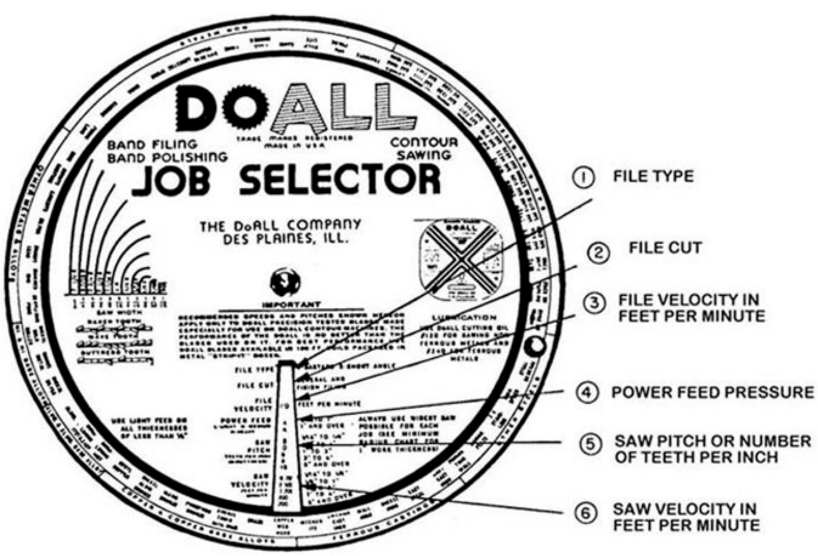


Figure 1–31. Job selection dial.

A job selector dial (fig. 1–31) is mounted on the upper door of the machine and serves as a quick, convenient source of operating recommendations for the saw. The job selector recommends the types and thicknesses of the materials the machine can saw.

The other dial of the job selector contains the names of various types of materials. To use the job selector, turn this dial until the desired type of material is listed in the bottom position. Recommendations for cutting different types of material appear in the vertical slot of the inner disk.

In addition to the recommendations for cutting specific materials, the job selector also indicates the smallest radius that can be cut with a particular width of blade. This is indicated on the left side of the job selector disk. Always remember to select a blade that has at least two teeth engaged in the work at all times. Too small a pitch (too few teeth per inch) allows the possibility of teeth straddling the material and being stripped.

Mounting the saw blade

Before installing the saw blade into the machine, correct size saw guides and inserts must be installed. Consult the equipment manual for proper installation instructions.

Using the contour saw

After the new blade is installed and tracking properly, make the necessary guide adjustments and lower the post to within $^{1}/_{8}$-inch of the working surface. As with other metal-working machines, keep your hands and fingers clear of the cutting blade. Also, since the sawing operations involve an eye hazard, you must wear goggles or a face shield when you are using a contour metal cutting saw. Before using, always check saws blades for dullness, insufficient set, broken teeth, or faulty welds. If the blade is dull or the set is worn off, discard it.

007. Using grinders and sanders

Grinding and sanding machines use abrasives to dress, shape, or finish work surfaces. As a structural technician, you will perform many tasks that require the use of grinding and sanding machines to finish work piece surfaces.

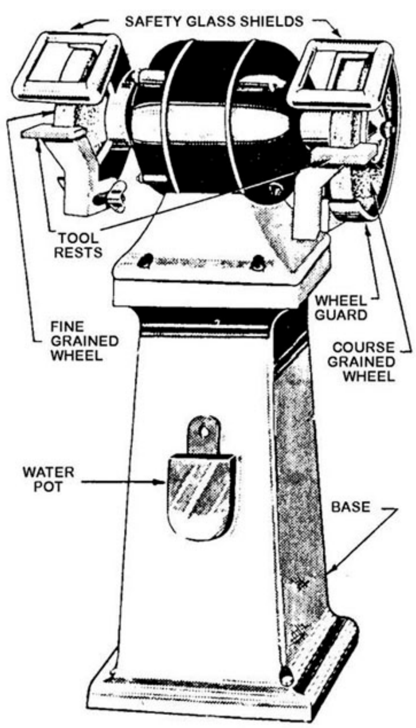


Figure 1–32. Pedestal grinder.

Grinders

Grinding is the act of dressing, shaping, or finishing surfaces using a rotating wheel made of abrasive substances (e.g., silicon carbide or aluminum oxide). Figure 1–32 shows the type of pedestal grinder commonly found in the shop for sharpening chisels or screwdrivers, or removing excess metal from work pieces.

As shown, the grinder is usually fitted with coarse- and fine-grain abrasive wheels. The coarse-grain wheel is for rough grinding when a considerable amount of metal is to be removed or a smooth finish is not important. The fine wheel is for sharpening tools, since removing the metal more slowly gives the work a smoother finish and does not usually generate excessive heat that might soften cutting edges. The fine wheel is also more accurate, although accuracy ultimately depends on your skill in using the grinder.

Grinding wheels

A grinding wheel is actually a cutting tool with a large number of cutting edges arranged so that, as they become dull, they break off and new cutting edges take their place. Four factors affect grinding wheels:

1. Kind of abrasive.
2. Size of the abrasive particles.
3. Kind of bond.
4. Amount of bond.

There are various types of abrasives used in grinding wheels. Ensure you are using the correct abrasive for the type of metal you are grinding. The bond is the material that holds the abrasive particles together in forming the wheel. The kind and amount of bond used determines the hardness or softness of the wheel. The commonly used bonds are the vitrified bond used in approximately three-fourths of all grinding wheels. This bonding material forms a very uniform wheel and is not affected by oils, acids, water, heat, or cold. The silicate bond, however, is best suited for grinding edged tools. Resinoid-bonded wheels are for heavy-duty grinding. Rubber-bonded wheels are used when a high polish is required. Shellac-bonded wheels are used to form grinding materials when a buffed or burnished surface is needed.

Grinding wheels are removable and grinder motors are usually designed so wire brushes, polishing wheels, or buffing wheels can be substituted for the abrasive wheels.

Maintenance of grinding wheels

Proper maintenance is important to ensure the grinding wheel operates properly and safely. Failure to properly maintain the grinding wheel could cause damage to equipment and personnel. Ensure you consult the machine forms, maintenance TOs, and manufacturer's guidance for proper maintenance procedures.

Precautions

You must know the correct cutting edge angle of a tool before attempting to sharpen it. After determining the correct cutting angle, turn on the grinder switch and hold the work firmly at the correct angle on the tool rest provided. Feed the tool into the wheel with just enough pressure to remove the proper amount of metal without generating too much heat.

Grinders are very hazardous; be careful when operating them. You *must not* use the work rest when it is *more than* ⅛-inch from the grinding wheel. When starting a grinder, stand to the side until it attains operating speed. This protects you if a defective wheel disintegrates. If the grinder chatters or vibrates excessively, something is wrong; turn off the power at once. As a rule, it is not good practice to grind work on the side of an abrasive wheel. When an abrasive wheel becomes worn, its cutting efficiency is reduced because surface speed decreases. Discard a worn wheel and install a new one.

Before installing a new wheel, inspect it because wheels may become damaged from improper storage. Immediately on receipt, closely inspect all wheels to ensure they have not been damaged. You should inspect every wheel and rung for cracks. Check small wheels for imperfection by suspending them on one finger and tapping them gently with a light instrument (e.g., the handle of a screwdriver). Strike very large wheels with a wooden mallet. If you don't get a clear ring, examine the wheel for cracks; discard cracked wheels. All wheels do not produce the same tone when rung, nor does a low tone necessarily signify a cracked wheel because some wheels are often filled with various resins and greases to modify their cutting action. This deadens the tone of the wheel. Vitrified and silicate wheels emit a clear metallic ring, while organic bonded wheels (e.g., resinoid, rubber, and shellac) give a less clear tone. In any case, the sound of a cracked wheel is clearly apparent.

Before using a grinder, ensure the abrasive wheels are held firmly on the spindles by the flange nuts. If an abrasive wheel comes off or becomes loose, it can ruin the grinder and seriously injure you. Another safety hazard is loose tool rests. If the rest is loose, it could cause the tool or piece of work to be grabbed by the abrasive wheel and cause your hand to come in contact with the wheel. Severe wounds may result.

Always wear goggles, even if the machine is equipped with face guards. The only sure way to protect your eyes from fine pieces of steel is to use goggles that fit firmly against your face and nose. Exchange goggles that do not fit properly for ones that do.

Before starting the machine, inspect the wheel for cracks. A cracked abrasive wheel is likely to fly apart when running at high speed. Never use a grinder unless it is equipped with wheel guards.

Belt sander

Powered sanders come in different designs, the most common being the belt sander (fig. 1–33), disc sander, and belt/disc sander combination. The designs of these pieces of equipment are similar. Each has motor, belt or disc pad, sanding bed, and stand.

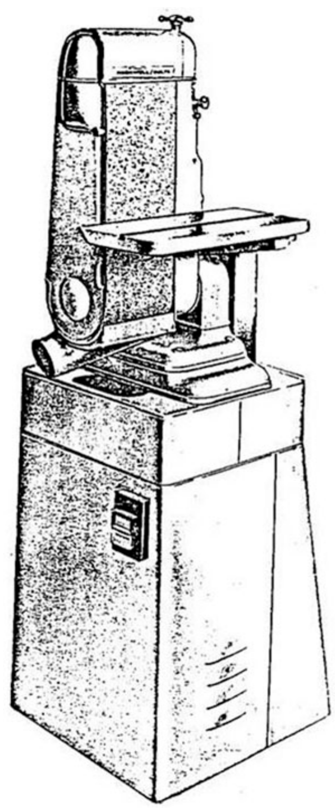


Figure 1–33. Powered belt sander.

Belt sanders are inherently safer machines than grinders because they do not have the dangers associated with grinding wheels. However, if not carefully used, sanders can be very dangerous. Follow these safety precautions when using these machines:

- Always wear eye protection when belt-grinding.
- Never grind on the “up” side of an abrasive belt (with the belt rotating toward you).
- Bring sharp corners and edges into contact with the belt lightly to prevent tearing the belt.
- Have a small quench tank or container of water available to cool the part.

Safety guards

All sanders must be fully guarded to protect pinch points and unused portions of belt track areas. Guards are easily removed to permit access for rapid changing of belts. Before operating a sander, inspect it to ensure all guards are in place. Never operate sanders without all the guards in place.

Maintenance

To keep your sander in top working condition, it must be properly maintained. Sanders, like pedestal grinders, have very few maintenance items. They are fairly simple machines; however, don’t make the mistake of not properly maintaining them. Ensure you consult the machine forms, maintenance TOs, and manufacturer’s guidance for proper maintenance procedures. Like all industrial equipment, you must follow lock-out/tag-out procedures when performing any maintenance on this machine. The following table provides explanations for each type of maintenance.

Type of maintenance	Explanation
Cleaning	Thoroughly clean the machine at regular intervals. Sanding grit and dust are very abrasive and can get into the bearings, electrical connections, and other parts of the machine.
Changing belts	Follow the manufacturer’s instructions for installing a new belt and ensure it is installed in the correct direction. Installing a belt to run backwards will cause it to catch and grab parts. This usually results in a torn belt and a ruined part.
Belt tracking	On belt sanders, the abrasive belt must be tracked to run in line with the contact wheels. This adjustment must be done while the machine is running. Follow the manufacturer’s instructions to correctly adjust the belt tracking.
Dust collectors	If your machine is equipped with a dust collector, maintain it according to the manufacturer’s recommendation. Dust collectors with clogged or dirty filters will not protect you from small particles and dust.

Disc sander

Another piece of sanding equipment is the disc sander. The sanding discs are easy to replace on the disc sander. You can use preglued sanding discs or sanding discs that require you to apply glue. The disc size depends on your particular piece of equipment. The bed is adjustable to more than 180°, but the most important factor to consider is the spacing between the bed and the disc. This space should *not exceed* $^1/_8$-inch.

Safety *must* be practiced with this equipment just as with all other tools and equipment. Never stand to the side of the equipment when it is being operated. Always wear eye protection and keep loose clothing and fingers away from moving parts. Never walk away when the machine is running or when the disc is rotating.

Combination belt/disc sander

As its name implies, this machine is a combination of the belt and disk sanders. The sanding belt and the sanding disk are configured in a vertical position. The combination belt/disc sander is operated and adjusted just like the disc or belt sanders. Replacement and adjustment procedures for the belt and the disk are the same as those detailed in the previous sections.

Use the same safety guidelines as previously mentioned. Remember, to prevent your piece of work from being drawn into the machine, spacing between the bed and the disc should not exceed $^{1}/_{8}$-inch.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

003. Hammers, mallets, and punches

1. What do you use a riveting hammer for?

2. What type and size of hammer do you use to center punch holes for drilling?

3. For finishing purposes, what type of hammering tool is selected?

4. When is a center punch used?

5. Which punch is used to remove rivet shanks from drilled holes?

004. Snips, files, and chisels

1. If you *must* cut out a triangle from a thin piece of metal, which type of snips gives you the *best* results?

2. Why should the cutting direction be counterclockwise when using straight snips to cut out a circle?

3. If you *must* enlarge a small hole in a piece of metal, which type of snips do you select?

4. If you are using the upper blade as a guide during a cutting operation, what kind of snips are you probably using?

5. What type of file is *best* suited for common filing operations?

6. Why is pressure on the back stroke usually *not* permitted when filing?

7. When should you use a slight pressure on the back stroke while filing?

8. How should material for crossfiling be positioned in a vise?

9. When do you drawfile a piece of metal?

10. What is the main precaution to remember when using a file?

11. What are the correct uses of the flat chisel?

12. When sharpening a chisel, what may soften it and cause it to lose hardness?

005. Hacksaws and shears

1. How can you position a stock to obtain the best results when using a hacksaw?

2. Which stroke (forward or backward) is the cutting stroke?

3. What type of lever shear is used to make cuts on the inside of a sheet of metal?

4. Why is it possible to cut any length or width of cut with a throatless shear?

5. When do you readjust the side gauge on a manually operated squaring shear?

6. When do you adjust the back gauge on a manually operated squaring shear?

7. How does the operation of the holddown on a power-operated squaring shear differ from a manually operated squaring shear?

8. What must you do before operating a power-operated squaring shear?

006. Using the contour metal cutting saw

1. When selecting a saw blade to use in a contour metal cutting saw, what factor concerning the pitch of saw blade must you consider?

2. How high should the post be adjusted from the work table?

3. What type of safety equipment must be used when operating a contour metal cutting saw?

4. When you inspect the saw blade before operating a contour metal cutting saw, what should you look for?

007. Using grinders and sanders

1. When you have completed the dressing operation, how far from the grinding wheel should you adjust the tool rest?

2. What should you do to cracked grinding wheels?

3. What safety equipment *must* be worn when using a grinding wheel?

4. What are the three different types of powered sanders?

5. List four safety factors you must follow when using a belt sander.

6. What are the two types of sanding discs that can be used on a disc sander?

1–3. Using Drills and Fastener Tools

This section deals with equipment and tools, along with the required procedures necessary for preparing metal surfaces to receive fasteners. The skills you develop in drilling and countersinking have a direct bearing on the quality of your work.

Nearly all fabrication and installation of sheet metal components involve the drilling of holes. You must, therefore, be familiar with the tools and equipment used and the operations involved. It is important for you to use the correct terms when speaking about drilling equipment. For example, the word "drill," when used loosely, may cause some confusion in communication. A twist drill is the part that cuts the hole; whereas a hand drill, power (portable) drill (pneumatic, electric, or battery powered), or drill press supplies the rotary motion and torque to rotate the twist drill.

008. Using drills and accessories

Various work situations dictate the type of drilling equipment you use. The two basic types of equipment you use to drill holes are the portable drill and drill press.

Portable drills

Portable drills (fig. 1–34) are manufactured in several sizes, which include $^{1}/_{4}$-, $^{3}/_{8}$-, and $^{1}/_{2}$-inch. The $^{1}/_{4}$-inch drill is used extensively when drilling holes for rivets, screws, small bolts, and other small fasteners. A $^{3}/_{8}$- or $^{1}/_{2}$-inch drill is used to drill holes larger than $^{1}/_{2}$-inch. Battery-powered drills are used for convenience on small flight line jobs when certain safety criteria are met. Never use battery-powered drills when there is a suspected or known fuel leak; to remove or install fasteners from fuel tanks, fuel cell cavities, or engine enclosures; or within five feet of a fuel vent or open fuel tank.

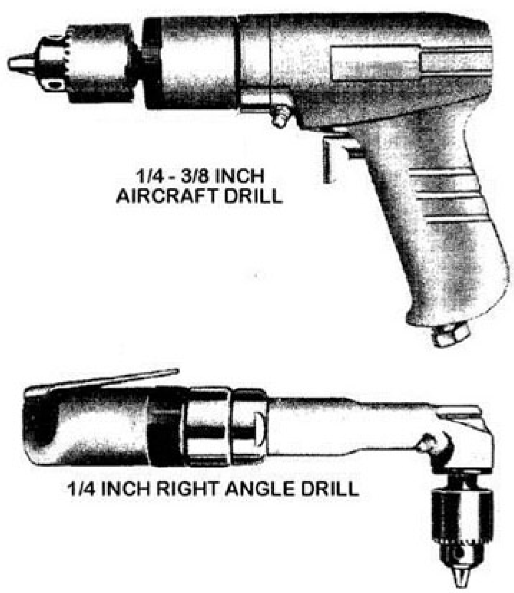


Figure 1–34. Types of portable pneumatic drills.

Pneumatic drills are recommended because most of your work is located around flammable materials. An electric drill causes a fire hazard because of the sparks it produces. When you find difficulty drilling a hole due to limited access, various types of drill extensions and adapters are available.

Drill presses

The drill press is a precision machine 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 to be drilled, provides the operator with a feed control lever to regulate the drilling pressure, and makes the task of feeding the drill into the material easier. Among the many types of drill presses available, the most common type is the upright drill press (fig. 1–35).

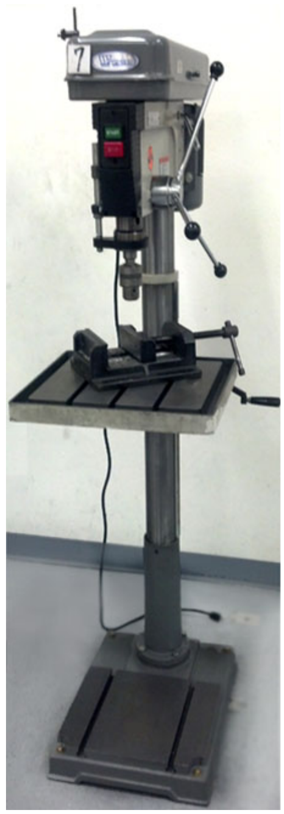


Figure 1–35. Drill press.

When you use a drill press, adjust the height of the working table to accommodate the height and thickness of the part to be drilled; then, clamp the material into position so the center-punch mark is directly in line with the twist drill. Material or parts not properly clamped may bind on the drill and start spinning. This could possibly cause the loss of your fingers or hands, or leave serious cuts in your arms or body. Therefore, always ensure the part being drilled is properly clamped to the drill press before starting any drilling operations. As with other drills, you must always wear eye protection while operating a drill press.

Avoid continued heavy feed and excessive speed, because these may cause twist drill breakage or damage to the machine. The speed of the chuck and rate of feed through the material varies, depending on the material you are drilling. Check the manufacturer’s handbook or the technical manual for information concerning the feeds and speeds recommended for various drilling operations. When drilling hard metal or steels, use a *cutting oil that acts as a coolant* to prevent rapid dulling of the twist drill. To prevent binding or breakage, always reduce feed or pressure just before the drill goes through the metal.

Preventive maintenance for a drill press includes keeping it cleaned, adequately lubricated, and properly adjusted. Ensure you consult the machine forms, maintenance TOs, and manufacturer’s guidance for proper maintenance procedures.

Twist drills

There are several types of twist drills: carbide, carbon steel or high-speed steel (HSS). Carbide twist drills maintain a shaper cutting edge longer than other types of drill bits, but they are brittle and can break easily. Carbon steel twist drills are satisfactory for general work, but lose their hardness if heated excessively. HSS drills may become very hot and still retain their temper. HSS drills have the letters "HS" stamped on the shank to distinguish them from carbon drills. To ensure satisfactory results when drilling, do not overheat the twist drill during drilling operations. If you are drilling holes in hard or thick metal, apply a few drops of cutting oil in the hole to lubricate and prevent excessive heating. Excessive heating can also be caused by using a dull twist drill, or exerting too much or too little pressure on the twist drill. If a twist drill becomes overheated, allow it to cool slowly. Do not cool an overheated twist drill in water, oil, or fast-moving air because the metal may crack.

Twist drill sizes are expressed in terms of numbers, letters, and inches or fractions of inches. The size is stamped on the shank of the twist drill (e.g., a $^{3}/_{16}$-inch twist drill, often used in sheet metal work, has a decimal equivalent size of 0.1875-inch).

Figure 1–36 shows a twist drill with the nomenclature of its parts, including the shank, body, heel, flute, and land. A twist drill used for most operations has a lip angle of 59° and a heel angle of 12° to 15°. A lip angle of 68° is recommended for hard materials (e.g., stainless steel). Soft metals (e.g., brass or bronze) can be drilled with a twist drill having a lip angle between 50° to 60°. The drill shank is the end that fits into the chuck of a drill motor or hand drill. The body is the part of the drill from one point to the shank, or from the point to where the flute ends. Flutes (channels) are designed in the twist drill to allow the chips, which are formed while drilling, to curl tightly and *escape* from the hole being drilled. These flutes also allow the lubricant to flow easily down to the lips of the twist drill, where it is needed as a coolant.

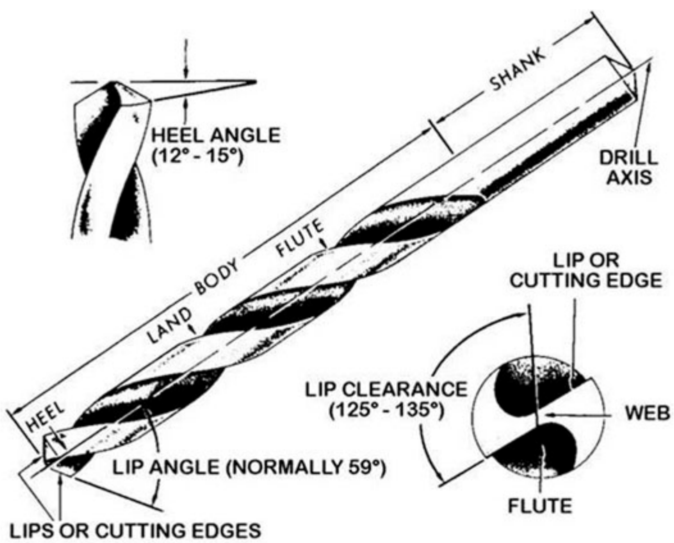


Figure 1–36. Twist drill nomenclature.

The lips (cutting edges) are the parts of the point that actually do the cutting. The drill axis, which runs from the center of the web to the extreme end of the shank, is the exact center of your twist drill. The web is the metal column that separates the flutes and is sometimes called the backbone of the twist drill. The point of a twist drill is the entire cone-shaped surface at the cutting edge. It should not be confused with the web. The heel is that part of a twist drill point just back of the cutting lips; its sole purpose is to allow the twist drill to work at its maximum effectiveness.

Generally, you select a twist drill for a given job according to the thickness and type alloy, and the machine to be used.

Drilling holes to install fasteners

When you are drilling a hole with a twist drill installed in a pneumatic or battery powered drill, ensure the chuck is tight enough to prevent slippage. The twist drill must make a hole with its center at the exact spot desired. Use a center punch to sink a mark deep enough to prevent the twist drill from "walking" away from the center point (fig. 1–37). Be careful not to dimple the material by striking the center punch too hard.

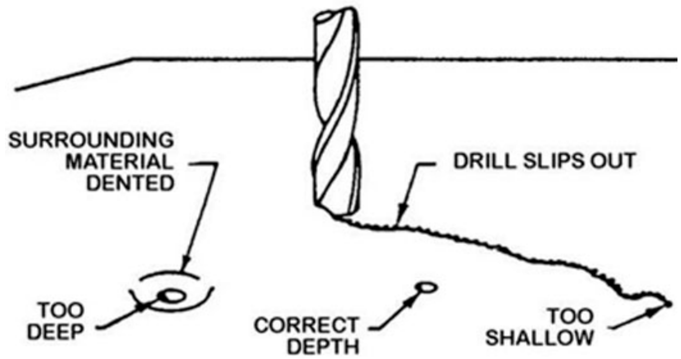


Figure 1–37. Center punching.

Next, secure the work and place the point of the twist drill into the punch mark. After beginning the drilling, always hold the twist drill at right angles to the work (fig. 1–38), regardless of the position or curvature involved. By tilting the twist drill at any time when you are drilling into or withdrawing from the material, you may elongate (produce an egg-shape) the hole. Ease the pressure the instant the twist drill breaks through the material, but continue drilling until you have finished the hole.

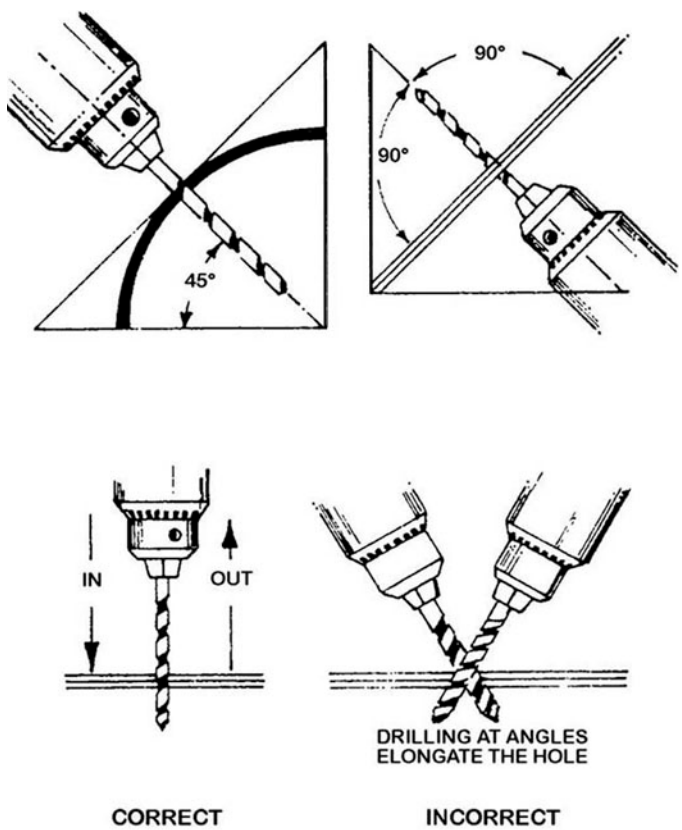


Figure 1–38. Drilling procedures.

When drilling through sheet stock, you can find small burrs around the edge of the hole. You must remove these burrs to prevent scratching, and allow rivets or bolts to fit snugly. These burrs can be removed with a countersink, reamer, or twist drill larger than the hole.

To make a rivet hole of the correct size, first drill a hole slightly undersize. This process is known as predrilling or pilot drilling, and the hole is called a pilot hole. Ream the pilot hole with a twist drill of the correct size to get the required dimension. The recommended clearance for rivet holes is 0.002-inch to 0.004-inch.

For *most* metals, *select* a twist drill having an *included angle of* 118° and turn it at low speeds. For soft metals, use a twist drill having an included angle of 90° and turn it at higher speeds. A drill having an included angle of 118° can drill thin sheets of aluminum alloys with greater accuracy, because the large angle of the drill has fewer tendencies to tear or elongate the hole.

Drill accessories

Just as you use each type of drill for a specific purpose, you also must use the appropriate accessory for the job.

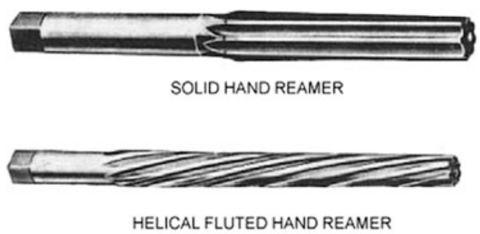


Figure 1–39. Types of reamers.

Reamers

Reamers smooth and enlarge holes to the exact size needed. Hand reamers (fig. 1–39) have square end shanks so you can turn them with a tap wrench or similar handle. A hole to be reamed to the exact size must be drilled 0.003-inch to 0.006-inch undersize. Cuts that remove more than 0.006-inch place too much load on the reamer and should not be attempted. Reamers are made of carbon tool steel or HS steel.

Reamers are hardened to the point of being brittle and must be handled carefully to avoid chipping them. When reaming a hole, rotate the reamer in the cutting direction only. Turn the reamer steadily and evenly to prevent chattering, marking, or scoring of the hole walls. Reamers are available in any standard size. The straight flute reamer is less expensive than the spiral flute reamer, but the *spiral* type has *fewer* tendencies to chatter. Both types are tapered for a short distance back from the point to aid starting. Bottoming reamers have *no taper* and are used to complete the reaming of blind holes.

Countersinks

The countersink (fig. 1–40) 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.

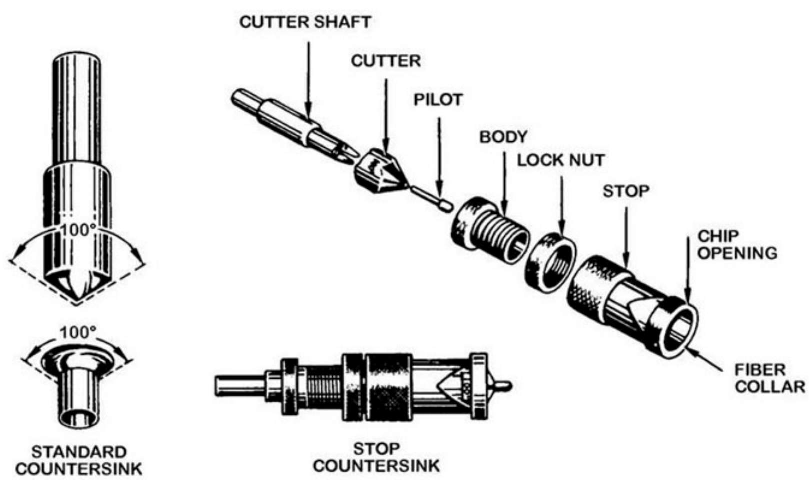


Figure 1–40. Countersinks.

Countersinks are made with an angle to correspond to the countersunk rivet head (e.g., the angle of the standard countersink is 100°). Special stop countersinks are available. Stop countersinks are adjustable to any desired depth, and the cutters are interchangeable so holes of various countersunk angles may be made. Stop countersinks have a micrometer set arrangement (*in increments of* 0.001-inch) for adjusting the cutting depths.

Figure 1–41 shows general rules for countersinking. Note in the left-hand example, the material is quite thick and the head of the countersunk rivet extends only about halfway through the upper layer of metal. Proper countersinking leaves plenty of material for gripping. Only countersink material that is twice as thick as the countersunk portion of the rivet being installed.

Figure 1–41. Countersinking standards.

In the middle example, the countersunk head reaches completely through the upper layer. This condition is permissible, but is frowned on. This is due to the possibility of elongating the hole, and does not permit the proper amount of bearing strength in the skin sheet.

In the right-hand example, the head extends well into the second layer of material. This indicates the material is thin and most of it would be ground away by countersinking; therefore, dimpling is preferred.

Countersinking is done with a suitable cutting tool machined to the desired angle, which cuts away the edge of the hole so the countersunk head rivet fits snugly into the recess. This recess is referred to as the "well" or "nest." Two factors that determine the size of countersink to use are the angles of the countersunk rivets being used and the diameter of the hole to be countersunk.

During the process of countersinking, first drill the original rivet hole to the exact rivet size. The limits within which the head of the rivet may extend above or below the surface of the metal are close. Perform the countersinking accurately, using equipment capable of producing results within the specified tolerance. Hold the countersinking tool firmly at right angles to the material. Tipping the countersink to one side, creating oversized rivet holes or undersized countersink pilots, improperly using the countersink, using a countersink in poor condition, or using a countersink not running true in the drill chuck *elongates* the well and prevents the countersunk rivet head from fitting properly.

009. Using fastener tools

Now that we've looked at drilling tools, let's look at fastening tools. Earlier, the importance of using drilling tools and equipment skillfully was stressed. Just as important is your ability to use the tools and equipment for pneumatic riveting. One mistake when riveting will ruin hours of work in preparing repair or replacement parts.

Pneumatic rivet guns

Pneumatic guns, or riveters, are available in various sizes and shapes but the most common type you will use is the slow hitting gun with an offset handle (fig. 1–42). The capacity of each gun, as recommended by the manufacturer, is usually stamped on the barrel. Pneumatic guns operate on air pressure of 90 to 100 pounds per square inch (psi).

Figure 1–42. Pneumatic rivet gun.

Rivet sets

Pneumatic guns are used in conjunction with interchangeable rivet sets (fig. 1–43), which are designed to buck a particular type and size of rivet. Some rivet sets are also designed for a specific rivet installation or location of the job. The shank of the set is designed to fit into the rivet gun. The force required to buck the rivet is supplied by the air-driven hammer inside the barrel of the gun. The sets are made of high-grade carbon tool steel, and are heat treated to give them strength and the ability to withstand wear.

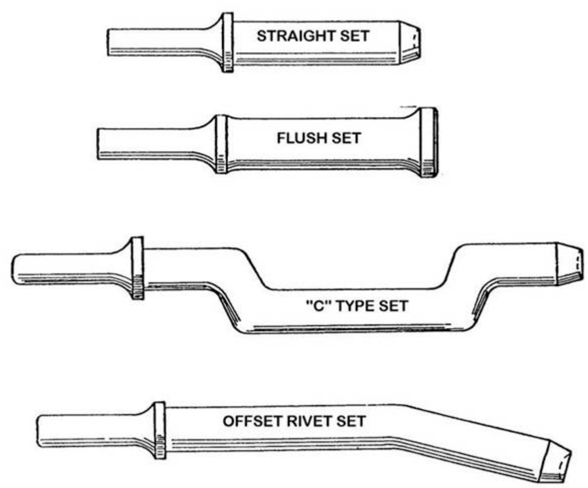


Figure 1–43. Types of rivet sets.

Precautions

The following are four *precautions* you need to observe when using a rivet gun:

1. Never point the gun at anybody; it is a rivet gun and meant to be used for only one purpose—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. Never use the rivet gun as a toy; it is a tool to use in the right way to perform a job.
4. Always disconnect the air hose from the rivet gun when it will not be in use for any appreciable length of time.

Squeeze riveters

Sometimes, it is necessary for you to use the squeeze method of riveting. This method has *limited* use, however, since it can be used *only* over the edges of sheets or assemblies where conditions permit and where the reach of the squeeze riveter is deep enough.

There are three types of rivet squeezers—hand, pneumatic, and pneudraulic. Basically, the only difference is how the compression is supplied. With the hand rivet squeezer, compression is supplied by hand pressure; the pneumatic rivet squeezer, by air pressure; and the pneudraulic rivet squeezer, 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.

Squeeze riveters are usually equipped with a C- or alligator yoke. Yokes are available in various sizes to accommodate any size of rivet. The working capacity of a yoke is measured by its gap and 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. Figure 1–44 shows two types of squeeze riveters.

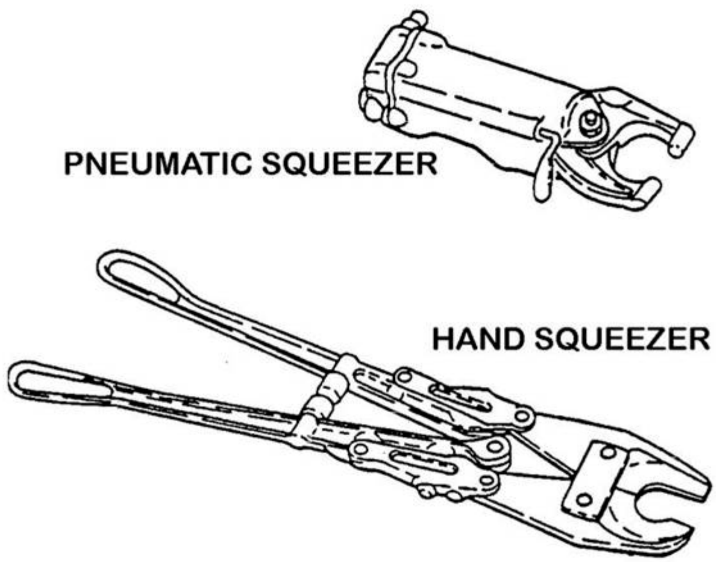


Figure 1–44. Squeeze riveters.

End sets for squeeze riveters serve the same purpose as do rivet sets for pneumatic rivet guns and are available with the same type of rivet head. One part of each set is inserted into 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. However, during some operations, it may be necessary to reverse the end sets by placing the manufactured head end set on the movable jaw.

Before you use the pneumatic riveter, drop one or two drops of oil in the air inlet. This is the only way to get oil to all moving parts. Set the regulator adjustment screw to the position for proper operation of the riveter. Select the rivet set for the job and install the set in the barrel of the riveter.

Bucking bars

A bucking bar is a tool held against the shank end of a rivet while the shop head is being formed. Most bucking bars are made of alloy bar stock, but those made of better grades of steel last longer and require less reconditioning. Bucking bars are made in a number of different shapes and sizes (fig. 1–45) to facilitate rivet bucking in all places where rivets are used.

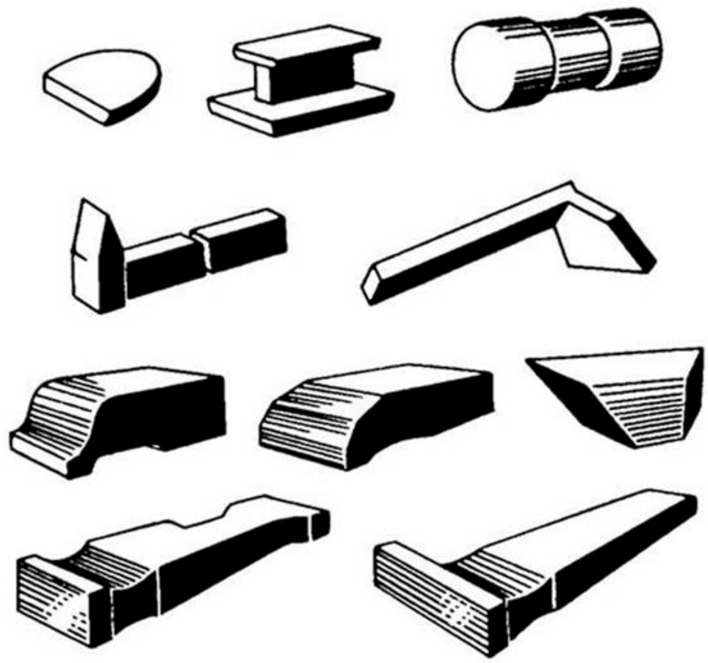


Figure 1–45. Types of bucking bars.

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. The face of the bar is usually concave to conform to the shape of the shop head to be made. The face should have a radius slightly larger than the thin head to ensure solid bucking and to prevent marring the material to be riveted. The average bucking bar weighs three pounds. These bars are sometimes called dollies, bucking irons, or bucking blocks.

Hand rivet and draw sets

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 $^{1}/_{2}$-inch carbon tool steel, is about six inches long, and is knurled to prevent its slipping in your hand. Only the face of the set is hardened and polished.

Sets for roundhead and universal-head rivets are recessed (or cupped) to fit the rivet head. In selecting the correct set, ensure it will provide the proper clearance between the set and the side of the rivet head, and between the surfaces of the metals and the set. Flush or flat sets are used for countersunk and flathead rivets. To seat flush rivets properly, ensure flush sets are at least one 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 $^{1}/_{32}$-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 sufficiently shallow, so the set will expand the rivet and head when struck with a hammer.

Rivet cutters

In case you cannot obtain rivets of the required length, rivet cutters (fig. 1–46) can be used to cut rivets to the desired length. When using the rotary rivet cutter, insert the rivet in the correct hole, place the required number of shims (each shim is $^{1}/_{16}$-inch) under the rivet head, and squeeze as you would a pair of pliers. Rotations of the discs cut the rivet to give the right length (as determined by the number of shims inserted under the head). When using the large rivet cutter, place it in a vise, insert the rivet in the proper hole, and cut by pulling the handle; thus shearing off the rivet. If regular rivet cutters are not available, diagonal cutting pliers can be used as an emergency cutter.

Figure 1–46. Rivet cutter.

Microshaver

Sometimes, it is necessary for you to use a microshaver (fig. 1–47) when making a repair involving the use of countersunk rivets. If the smoothness of the surface (such as skin) requires all countersunk rivets be driven within a specific tolerance, use a microshaver. This tool has a cutter, stop, and two legs or stabilizers.

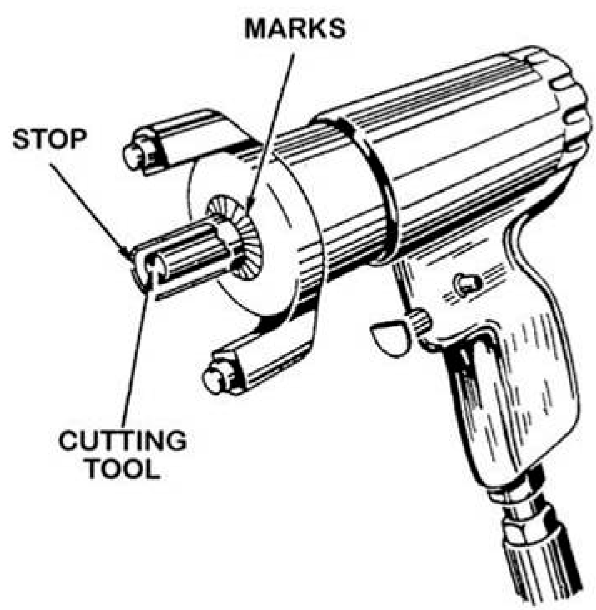


Figure 1–47. Microshaver.

The cutting portion of the microshaver is located inside the stop. Adjust the depth of cut by pulling outward on the stop and turning it in either direction (clockwise for deeper cuts, counter-clockwise for shallower cuts). The marks on the stop permit adjustments of 0.001-inch.

If you adjust and hold the microshaver correctly, you can cut the head of a countersunk rivet to *within* 0.002″ without damaging the surrounding material. When correctly adjusted, the shaver leaves a small round dot about the size of a pinhead on the microshaved rivet.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

008. Using drills and accessories

1. Why are portable pneumatic drills recommended for use in aircraft work?

2. When *must* you use a drill press?

3. What safety device is used when operating any type of drilling equipment?

4. When drilling with a twist drill, what must you avoid to ensure satisfactory results?

5. Why is it essential that a twist drill *not* be cooled in water?

6. Why are flutes necessary on a twist drill?

7. What must you do first when drilling a rivet hole to the correct size?

8. Why do you use a reamer?

9. What physical property of reamers makes it necessary that they are handled carefully at all times?

10. Why are bottom reamers used?

11. Each increment on a stop countersink represents how many thousandths of an inch?

12. How can you ensure countersunk holes have plenty of gripping surface?

13. What two factors determine the size of countersink to use?

14. What are four causes of elongated holes when countersinking?

009. Using fastener tools

1. What is the average weight of bucking bars?

2. To ensure countersunk rivets are seated properly, what size flush rivet set is recommended?

3. If a countersunk rivet extends .010 inch above the surface, how much of the head can you microshave off, before damaging the surface?

Answers to Self-Test Questions

001

1. The inch.
2. Measuring tool and straightedge.
3. On one side in divisions of $^1/_2$-, $^1/_4$-, $^1/_{16}$-, and $^1/_{32}$-inch.

002

1. When scribing or marking cut lines on metal surfaces.
2. When measuring distances between two points for transferring or comparing measurements directly from a rule, or for scribing an arc, radius, or circle.
3. To draw lines at angles from 0° to 180°.
4. Because it has a bigger point to make deeper depressions.

003

1. Driving rivets and light chiseling.
2. Eight-ounce ballpeen.
3. Mallets.
4. Before a punching or drilling operation.
5. Pin.

004

1. Straight.
2. To allow seeing the guideline.
3. Aviation.
4. Aviation.
5. Flat.
6. Because the cutting teeth slant forward and the pressure on the back stroke may break them off.
7. When filing very soft materials.
8. Near the vise jaws to prevent vibration; in addition, if the surface is straight, place it parallel to the top of the vise.
9. When a finer surface is required.

10. Always use a file handle.
11. Chipping, and cutting sheet metal, heads off screws, and flat stock.
12. Pressing too hard against the wheel and allowing too much heat to generate.

005

1. Clamp the material in a vise, providing as much bearing surface as possible so the greatest number of teeth on the blade will be engaged.
2. Forward.
3. Scroll.
4. Because the frame of the shear never obstructs the cutting operation.
5. When the metal isn't cutting square.
6. For cutting a number of pieces to the same dimensions.
7. The holddown is automatically lowered on the power-operated squaring shear when the cut is made.
8. Check the data plate to ensure the metal being cut is within the capacity of the machine, and ensure the machine is clear of material and personnel.

006

1. At least two teeth must be on the cutting surface at all times.
2. Within $^{1}/_{8}$-inch of the working surface.
3. Goggles or face shield.
4. Dullness, insufficient set, broken teeth, and faulty welds.

007

1. Maximum of $^{1}/_{8}$-inch.
2. Discard them.
3. Goggles.
4. Disc, belt, and combination disc/belt.
5. Always wear eye protection when belt-grinding, never grind on the "up" side of an abrasive belt (with the belt rotating toward you), bring sharp corners and edges into contact with the belt lightly to prevent tearing the belt, and have a small quench tank or container of water available to cool the part.
6. Preglued sanding discs as well as sanding discs that require you to apply glue.

008

1. Because most of the work is located around flammable materials.
2. For drilling holes when a high degree of accuracy is required.
3. Eye protection.
4. Overheating the twist drill.
5. Because the metal may crack.
6. They allow the chips to escape, plus they allow the lubricant to flow easily down to the lips.
7. Pilot drill the hole.
8. To smooth and enlarge the holes to the exact size needed.
9. They are very brittle.
10. To complete the reaming of blind holes.
11. 0.001.
12. By using only countersink material that is twice as thick as the countersunk portion of the rivet being installed.
13. Angles of the countersunk rivets and diameter of the hole to be countersunk.
14. Any four of the following: Tipping the countersink to one side, creating oversized rivet holes or undersized countersink pilots, improperly using the countersink, using a countersink in poor condition, and using a countersink not running true in the drill chuck.

009

1. Three pounds.
2. At least 1-inch diameter.
3. 0.008-inch.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (001) The fractional divisions of an inch are determined by
   a. dividing the inch into equal parts.
   b. the decimal equivalent.
   c. length of scale.
   d. size of the job.

2. (002) What type of layout tool do you use to mark cut lines on metal surfaces?
   a. Scriber.
   b. Dividers.
   c. Prick punch.
   d. Layout punch.

3. (002) The included angle of a center punch point should be
   a. 30˚.
   b. 45˚.
   c. 60˚.
   d. 90˚.

4. (003) What type of punch do you use to create a *depression* in a metal surface to *prevent* your twist drill from walking?
   a. Pin.
   b. Center.
   c. Hollow.
   d. Starting.

5. (004) What snips are *best* suited for enlarging small holes in sheet metal?
   a. Aviation.
   b. Straight.
   c. Tinner.
   d. Offset.

6. (004) What type of file do you use to sharpen blades?
   a. Square.
   b. Triangle.
   c. Single-cut.
   d. Double-cut.

7. (004) What type of chisel is *best* suited for cutting sheet metal and heads off screws?
   a. Flat.
   b. Cape.
   c. Diamond point.
   d. Half roundnose.

8. (005) When using a hacksaw, the cutting strokes should be long and steady with a speed of *not* more than how many strokes per minute?
   a. 20 to 30.
   b. 30 to 40.
   c. 40 to 50.
   d. 50 to 60.

9. (005) Which lever shear can cut sheet metal of *unlimited* length or width?
   a. Scroll.
   b. Lever.
   c. Circle.
   d. Throatless.

10. (005) When squaring metal on the manually operated squaring shears, what step do you take if a piece of metal that has been sheared is *not* square?
    a. Adjust the side gauge.
    b. Move the back gauge.
    c. Calibrate the bevel gauge.
    d. Straighten the cutting blade.

11. (006) What *must* you know to use the job selector dial on a contour metal cutting saw?
    a. Type blade already installed.
    b. Material's composition and thickness.
    c. Pitch of the material being cut based on thickness.
    d. Degree the material being cut placed in relationship to the blade.

12. (007) What is the *maximum safe* gap between the wheel and the work rest of the pedestal grinder?
    a. $^{1}/_{32}$ inch.
    b. $^{1}/_{16}$ inch.
    c. $^{1}/_{8}$ inch.
    d. $^{1}/_{4}$ inch.

13. (008) When using a stop countersink, each increment of the micrometer adjustment increases or decreases the depth-of-cut by
    a. 0.001 inch.
    b. 0.002 inch.
    c. 0.003 inch.
    d. 0.004 inch.

14. (008) The countersinking tool should *not* be tipped because the well will
    a. have an improper angle.
    b. be cut too shallow.
    c. be cut too deep.
    d. be elongated.

15. (009) You determine that the microshaver needs to cut .004 inch *deeper*. To adjust it properly, you would pull out the stop and turn it
    a. clockwise two marks.
    b. clockwise four marks.
    c. counterclockwise two marks.
    d. counterclockwise four marks.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Layout Techniques

AS A LOW OBSERVABLE (LO) aircraft structural maintenance journeyman, it's imperative you have the ability to interpret and develop drawings accurately. As you go about your job, you'll find there are many times when a technical drawing comes into your shop for the local manufacture of a part. At other times, an engineering drawing may come in for you to complete a time compliance technical order (TCTO). In addition to these examples, you'll often make drawings to convey ideas on paper or metal for repairs.

We've prepared the material in this unit to ensure you have the fundamentals you need to interpret blueprints and drawings. To begin, we'll cover the techniques used to interpret blueprints and drawings. Just as important as interpreting blueprints and drawings is understanding general shop mathematics. While we're confident you were taught basic mathematics in school, we'll offer a quick refresher in the basics of working with fractions and decimals. We do this because nearly all the measurements you'll work with will be one or the other. Then, we'll discuss the procedures for drawing and layout development.

2–1. Blueprints and Drawings

Whether your job involves mowing the grass or manufacturing the most complex aircraft part, conveying what must be done involves some means of communication—the exchange of ideas. Doing this usually requires you to use a written or oral form, but under some conditions, these two means may be impractical. In this section, we'll explore two important factors that deal with blueprint and drawing interpretation—the history and terms, as well as dimensions and dimensioning.

010. Interpreting blueprints and drawings

Many years ago—before writing became somewhat standardized—pictures were used to convey ideas. Ironically, in these days of computers, space travel, and supersonic complexities, isn't it a wonder that the ideal means of expressing the idea of building something *still* usually takes place through the use of pictures? Although that implies a simple process, there are certain rules you must follow. There are also certain things you must understand. These include the different lines, notes, abbreviations, and symbols used in drawings.

In this lesson, we'll cover how to read and understand blueprints and drawings.

Terms

You may call blueprints by other names—mechanical drawings and engineering graphics are two examples. Simply stated, a blueprint or drawing is the means of conveying an idea from a designer to the person who produces the end result. The complexity of the blueprint or drawing determines just how accurate and detailed the design must be.

The Air Force stores and catalogs enormous numbers of drawings for the equipment it controls. The drawings are miniaturized and stored electronically, and each is filed by a specific part number for reference. As a journeyman, you must be able to pick up a drawing and, through proper interpretation of lines and notes, manufacture or repair an item to the specifications outlined. You also must be able to know and understand the terms used on blueprints. The two terms you need to be familiar with are title block and zones.

Title block

The title block tells you what the part is. Other information provided in the title block is the name, number, and material from which the part is fabricated. The title block is located in the lower right hand corner of the drawing. The figure shows what the title block looks like, not the placement on the drawing.

Anytime you work from a blueprint, you should first look at the title block (fig. 2–1). In addition to the title, you find such information as the material needed to make a part, specific tolerances, drawing scale, any heat treating requirements, and notes on the finishing required.

The blueprint also contains the complete print identification (name of the part, drawing number, engineer or draftsman, organization responsible, and date drawn). On certain types of prints, you can also find a bill of materials which gives you a listing of parts needed to standardize production of a particular assembly.

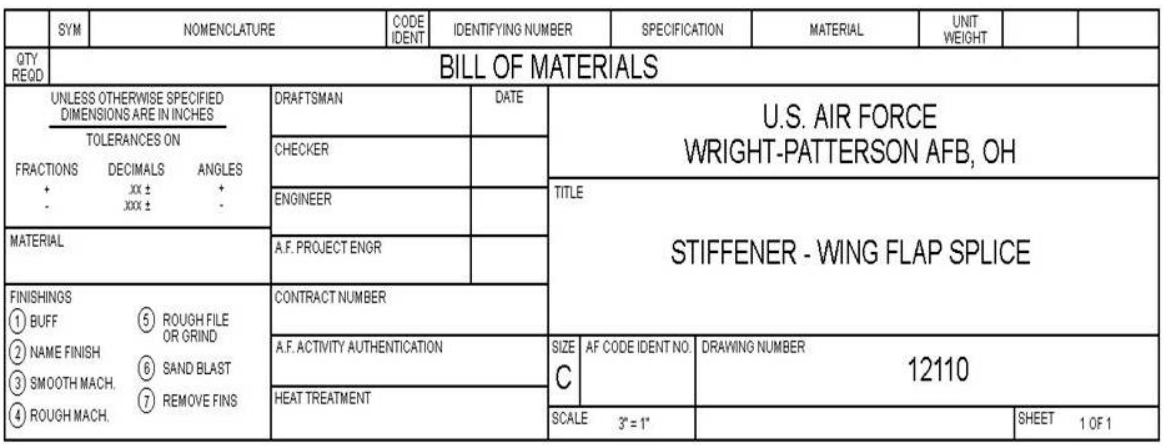


Figure 2–1. Sample engineering drawing title block.

Zones

Zone numbers and letters on a blueprint are similar to the numbers and letters printed on the borders of a map. They help you *locate* a particular point.

Lines and their uses

Your ability to read this printed page depends on your skill in recognizing the characters of the alphabet. In addition to recognizing these characters, you must know how they’re used in the construction of words and sentences. Likewise, being able to read drawings and blueprints depends on your ability to recognize the characters of the lines used in making drawings and understand how they fit into the description of the objects represented. The following below lists some of the lines you will use most often.

Term	Explanation
Visible outlines	The surfaces visible to the eye are always outlined in solid lines, which are the most important of the lines. Visible outlines are bold, solid lines that are the basis for comparison of the weights of all other lines. As you look at figure 2–2, notice the weight of the bold, solid line. For an example of how visible outlines are used, refer to figure 2–3.

Term	Explanation
Invisible outlines	Surfaces that are invisible or hidden are always outlined by using dashed lines called hidden lines. They consist of a series of short uniform dashes of medium weight, about half as heavy as the lines used to indicate visible surfaces. For an example of how invisible outlines are used, refer to figure 2–3 (arrow G).
Center lines	Used to indicate the central axis of the object, a center line is a *lightweight* line made of *alternating* long and short dashes with a long dash on each end. The central axis of objects or parts must be shown in a drawing to ensure accuracy when manufacturing. It's essential to lay out the dimensions from the center of the object rather than from a face or side; particularly for irregular shapes, or circular objects and objects made of circular curved parts. Look at figure 2–3 and see how arrow D depicts the way center lines are used on a drawing.
Dimension lines	Indicating dimensions of the part, these are solid lines lighter than visible outlines recognized by the arrowheads on their ends. A dimension line's purpose is to show the distance from one reference point to another. It has a space near the center for inserting the size of the dimension. An example of the dimension line is illustrated at arrow C in figure 2–3.
Extension lines	Used to extend the limits of a dimension out and away from the feature, these lines begin a very short distance from the object, and are solid and lighter in weight than a visible outline. The major difference in appearance between extension lines and dimension lines is extension lines do not have arrowheads on the end. Observe the extension lines shown at arrow B in figure 2–3.
Leader lines	These lines *indicate* a part or areas to which a number, note, or other reference applies. Leader lines usually terminate in an arrowhead.
Border lines	Border lines are extra-heavy lines used to frame or enclose the entire drawing and give the drawing a finished appearance, as at arrow J in figure 2–3.

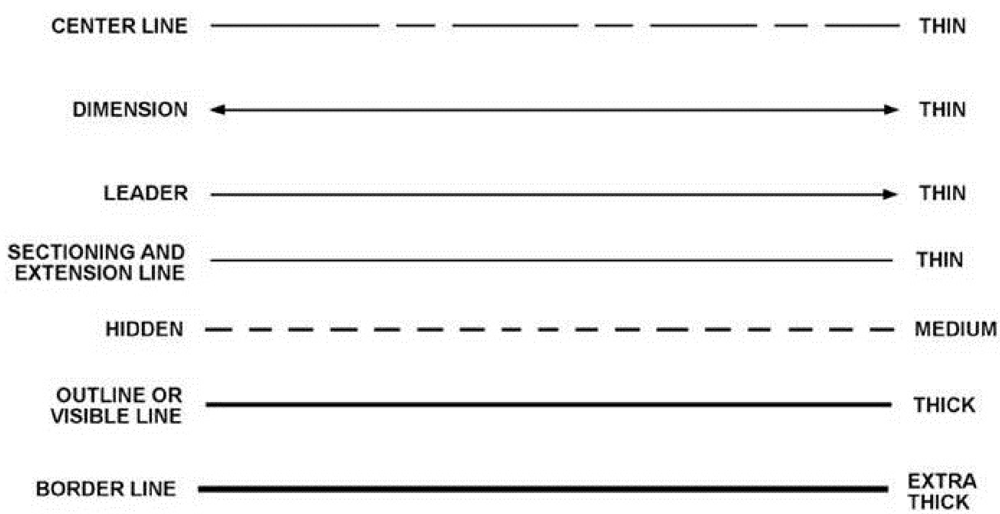


Figure 2–2. Types of drawing lines.

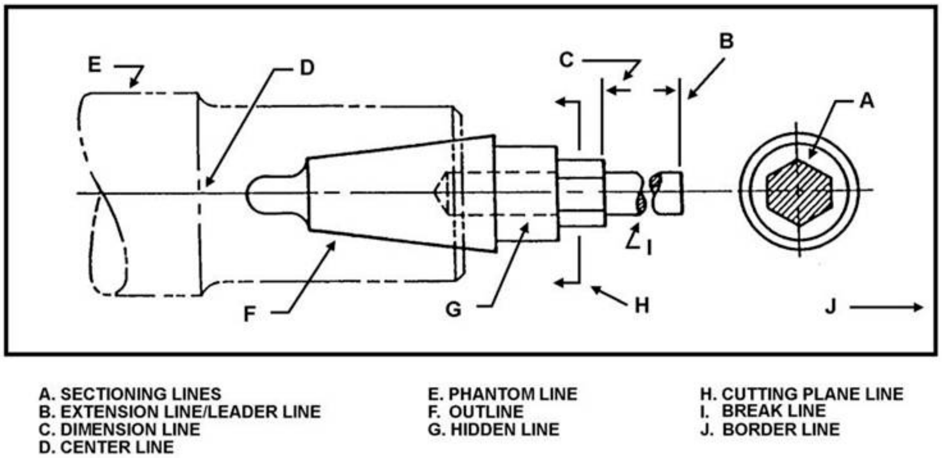


Figure 2–3. Use of various drawing lines.

011. Creating Drawings

Now that we've covered how to interpret drawings and blueprints, let's look at the types of drawings you may use for the fabrication of parts. There are two types of drawings—surface and mechanical. In this lesson we will focus on mechanical drawings as this is the most common type you will use.

Surface drawings

The face of any solid object is called a surface, and the limits of any surface on a drawing are shown by means of lines. A surface has only two dimensions—length and width. When it's necessary to show an edge view of a surface, a line is used; even though the line has thickness, the surface doesn't.

To show three dimensions, it's *usually* necessary to show at *least two* views and, in many cases, it's *desirable* to make a drawing with *three* views of an object. This is necessary when an object has special features that can't be shown in two views with sufficient completeness for a technician to make the object without more information. For this reason, projection drawings having three views are used. These views are usually the front, top, and right or left side views.

Single-view drawings are used *only* for objects made of *thin* material (e.g., sheet stock) and when the objects are perfectly *flat*. They're *never* used when objects are bent or curved. Figure 2–4 illustrates a one-view drawing of a reinforcement plate. Since a note stating the thickness of the material can be made, it's put on the single-view drawing.

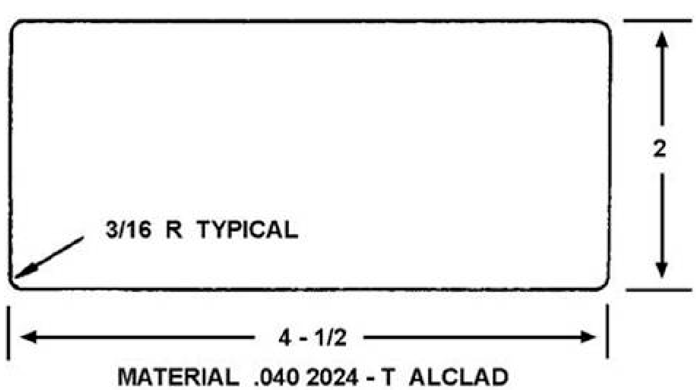


Figure 2–4. Reinforcement plate.

Mechanical drawings

Mechanical drawings are usually employed to represent a three-dimensional object on a two-dimensional piece of drawing paper. In essence, mechanical drawings are a series of two-dimensional views. As such, they usually give an exact representation of an object and show all parts in their true size relation. In this way, a draftsman turns a rough sketch into a detailed drawing everyone can understand in the same way. The two most common types of mechanical drawings you will encounter are orthographic and isometric.

Orthographic drawings

The best way to draw many objects is to project them on paper in some combination of front, top, and side views. Showing several (usually three) views of an object from viewpoints at 90° to each other is called orthographic projection. To understand this view alignment, imagine swinging the hinged sides of the plastic box around and flattening them out into a single plane as though you were laying them flat on drawing paper. Note in figure 2–5, the top view aligns directly over the front view, and the side view appears directly to the right of, and in line with, the front view on the same plane. This is an orthographic projection showing the exact size and shape of the object. When it's copied on paper with the necessary dimensions added, you have a working drawing. You can work from an orthographic projection much more easily than from a picture of the object as your eye sees it.

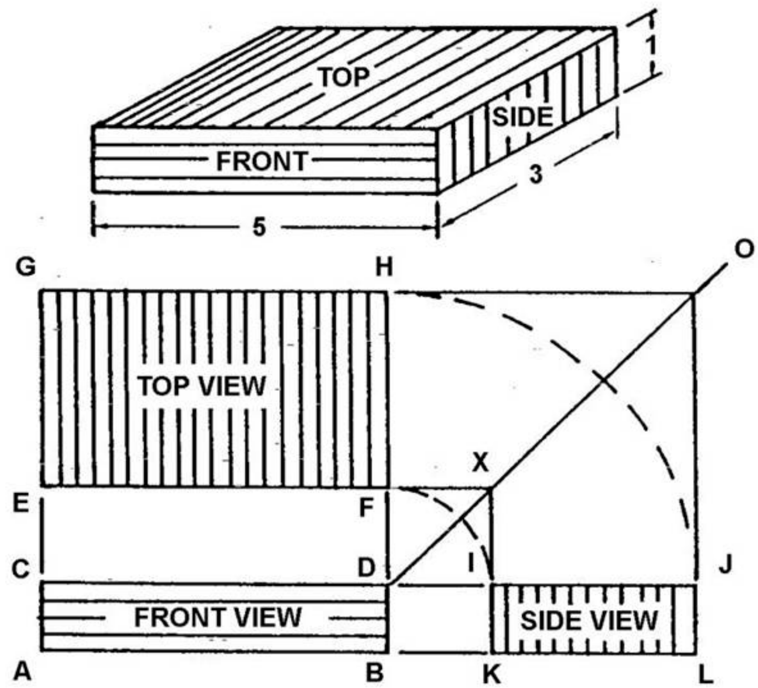


Figure 2–5. Orthographic projection.

Isometric drawings

Isometric drawings show three sides, all in dimensional proportion, but none are shown as a true shape. For example, the sides of a box are drawn as vertical lines, but all horizontal lines are drawn at 30° to the base line (fig. 2–6). For some objects, isometric drawings are used alone, but more often they're used with orthographic drawings so the individual fabricating the part can to see what it will look like when it is "completed." The isometric drawings often help you to visualize an object and give depth to a drawing. They combine some dimensional accuracy with pictorial representation.

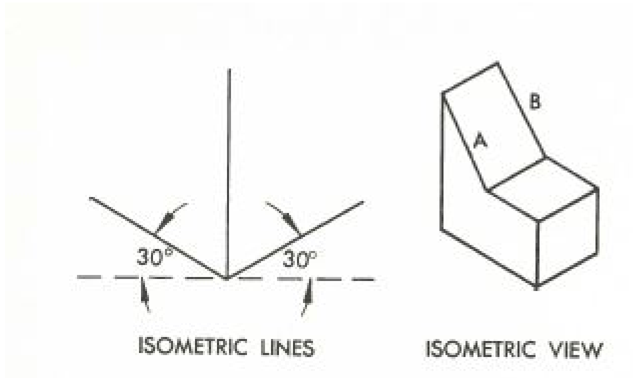


Figure 2–6. Isometric drawing.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

010. Interpreting blueprints and drawings

1. What is the purpose of a drawing?

2. Why is the proper interpretation of a drawing essential?

3. Where is the title block located on a blueprint?

4. What eight types of information can be found in the title block of a blueprint?

5. Why are zone numbers placed on a blueprint?

6. Which type of line is the basis for comparing the weights of all other lines?

7. What type of line is represented by a series of short uniform dashes?

8. What type of line consists of lightweight alternating long and short dashes with a long dash on each end?

9. How do extension lines differ from dimension lines?

10. What is the function of leader lines?

011. Creating drawings

1. How many dimensions does a surface have, and what are they called?

2. How many views of an object are usually shown on a projection drawing?

3. What views of a box are shown in an orthographic projection?

4. How do the various views of an orthographic projection align?

5. What other types of drawings are isometric used with?

2–2. Basics of Shop Mathematics

To do your job quickly and efficiently, you must be able to use fractional parts of numbers in mathematical operations as easily and accurately as you use decimal numbers. To aid you in accomplishing this, we've developed two lessons on adding, subtracting, dividing, multiplying, and converting fractions and decimals.

012. How to add, subtract, divide, multiply, and convert common fractions to decimals

Within this lesson, you will learn to perform operations with common fractions, as well as converting them to decimal format. However, before we get into the rules and mechanical operations of shop mathematics, let's ensure you know the meanings of some important terms. Without knowing these terms, you just might be spinning your wheels.

Terms

Before we begin our discussion about working with fractions, there are some terms that you need to be familiar with. These are defined in the following table.

Fraction Terminology	
Term	**Definition**
Fraction	A fraction is a number that shows how many equal parts of a unit are taken. Examples include $^3/_4$, $^1/_{32}$, and $^9/_{16}$. The $^3/_4$ shows that three of four parts of a unit are taken; similarly, $^7/_{32}$ shows that seven of thirty-two parts are taken, and so forth.
Denominator	The *denominator* is written *below* the line. It's the number that shows into how many equal parts the unit has been divided.
Numerator	The *numerator* is written *above* the line. It shows how many equal parts of the unit have been taken to make a fraction.

Fraction Terminology	
Term	**Definition**
Common fraction	A common fraction is a fraction with both terms (numerator and denominator) expressed. Common fractions are classed in two ways: • A *proper fraction* is one whose numerator is less than its denominator (e.g., $^3/_8$ and $^5/_{16}$). • An *improper fraction* is one whose numerator is larger than the denominator (e.g., $^{80}/_{31}$ and $^{16}/_5$).
Mixed number	A mixed number is a number made up of an integer (whole number) and a fraction taken together (e.g., $3^1/_4$ and $7^1/_2$).

Reducing common fractions

Let's look at the procedure for reducing common fractions. The basic rule is the value of a fraction isn't changed by multiplying the numerator and denominator by the same number. Also, the value of a fraction isn't changed by dividing the numerator and denominator of a fraction by the same number. When both the numerator and denominator can't be divided by the same number, the fraction is said to be in lowest terms. In the following example, $^2/_3$ is in the lowest terms:

$$\frac{8}{12} = \frac{8 \div 4}{12 \div 4} = \frac{2}{3}.$$

An improper fraction may be reduced to a mixed number by dividing the numerator by the denominator. Let's look at this example:

$$\frac{95}{8} = 95 \div 8 = 11\frac{7}{8}.$$

Rules for adding common fractions

There are three basic rules for adding fractions.

Rule 1

Fractions can't be added or subtracted unless they have a common denominator. Fractions have a common denominator when all the denominators are the same (e.g., $^3/_8$, $^7/_8$, and $^{12}/_8$). In adding fractions, select the least common denominator. This is the lowest denominator into which all denominators divide evenly.

To convert fractions to the least common denominator, divide the least common denominator by the denominator of each fraction and multiply both terms of the fraction by that quotient. Let's look at an example.

Express $^2/_3$, $^3/_4$, and $^1/_2$ as fractions with a common denominator. The lowest number into which the denominators 3, 4, and 2 divide is 12; therefore, 12 is the least common denominator. By the first rule, then, the fractions are reduced to the least common denominator as follows:

$$\frac{2}{3} = \frac{8}{12}, \frac{3}{4} = \frac{9}{12}, \text{and } \frac{1}{2} = \frac{6}{12}.$$

Rule 2

To add fractions using the second rule, first reduce them to a common denominator, and then add the numerators and write their sum over the common denominator. If the result is an improper fraction, reduce it to a mixed number and reduce the fractional part to its lowest terms.

Let's look at some examples:

Find the common denominator: $\frac{1}{2}+\frac{3}{4}+\frac{5}{12}$.

$$\frac{1}{2}=\frac{6}{12}. \qquad \frac{3}{4}=\frac{9}{12}. \qquad \frac{5}{12}=\frac{5}{12}.$$

Now add the fractions together: $\frac{6}{12}+\frac{9}{12}=\frac{5}{12}=\frac{20}{12}$.

Reduce to lowest terms: $\frac{20}{12}=1\frac{8}{12}=1\frac{2}{3}$.

Rule 3

To add whole and mixed numbers, you use rule three. In this case, add the whole numbers and the fractions separately, and then add the results. The following is an example where we give you the two numbers, add the whole numbers, add the fractions, and then combine the results:

$$4\frac{3}{16}+2\frac{1}{8}.$$
$$4+2=6.$$
$$\frac{3}{16}+\frac{1}{8}=\frac{3}{16}+\frac{2}{16}=\frac{5}{16}.$$
$$\text{Answer is } 6\frac{5}{16}.$$

Subtracting common fractions

For *subtracting common fractions*, use the following procedure:

- Reduce the fractions to the *least* common denominator.
- *Subtract* the numerators.
- Write the difference over the least common denominator.
- Reduce the resulting answer to lowest terms.

Let's look at two examples:

$$\frac{7}{8}-\frac{3}{4}=\frac{7}{8}-\frac{6}{8}=\frac{1}{8}.$$
$$4\frac{19}{32}-2\frac{5}{16}=4\frac{19}{32}-2\frac{10}{32}=2\frac{9}{32}.$$

Multiplying common fractions

To *multiply two or more fractions* together, accomplish the following:

- Multiply the numerators together.
- Multiply the denominators together.
- Write the product of the numerators over the product of the denominators.
- Then, reduce the resulting fraction to lowest terms.

Here is an example: $\frac{3}{4}\times\frac{8}{9}=\frac{3\times 8}{4\times 9}=\frac{24}{36}=\frac{2}{3}$.

Another way to obtain the answer is to use the *cancellation method*. This method consists of striking out the factors common to both numerators and denominators of the given fractions.

In the preceding example, both numerator and denominator can be divided by 3 to get 1 in the numerator and 3 in the denominator.

$$\frac{3}{4} \times \frac{8}{9} \qquad \frac{1}{4} \times \frac{8}{3}$$

Also, by dividing by 4, we get 2 in the numerator and 1 in the denominator which gives us the following:

$$\frac{1}{4} \times \frac{8}{3} \qquad \frac{1}{1} \times \frac{2}{3}$$

The solution is now very simple: $\frac{1}{1} \times \frac{2}{3} = \frac{2}{3}$.

Dividing common fractions

Perform the following to divide common fractions:

- Invert the *divisor* (second fraction).
- Then multiply.

When a fraction is inverted, the numerator becomes the denominator, and the denominator becomes the numerator. After inverting the divisor, change the division sign to a multiplication sign and solve the problem.

Here is an example: $\frac{5}{7} \div \frac{3}{4} = \frac{5}{7} \times \frac{4}{3} = \frac{20}{21}$.

Converting a common fraction to a decimal

The word decimal is usually short for decimal fraction. In a decimal fraction, only the numerator is expressed. To convert a common fraction to a decimal, you must remember the line between the numerator and denominator shows division. For example, $^7/_8$ means 7 ÷ 8. Since 8 doesn't go into 7, put a decimal after the 7, add three zeros, and then carry out the division. Put the decimal point in the answer directly over the decimal point in the dividend. The quotient is a decimal fraction. The numerator is 875 and is expressed, while the implied denominator is 1,000; thus, 0.875 equals $^{875}/_{1000}$. The following conversion demonstrates how this all looks:

$$\begin{array}{r} 0.875 \\ 8\overline{)7.000} \\ 64 \\ 060 \\ 056 \\ 0040 \\ 0040 \\ 0000 \end{array}$$

013. How to add, subtract, divide, multiply, and convert decimals to common fractions

Now that we've discussed operations with common fractions, and their conversion to decimal format, this lesson will cover similar operations with decimals, including converting decimals to common fractions.

Decimals

A decimal is a fraction whose *denominator* is *always* 10 or a *power* of 10 (e.g., 100, 1000, etc.). As a result, you can write a decimal fraction by omitting the denominators entirely (e.g., $^{7}/_{10}$ is written as 0.7, $^{77}/_{100}$ is written as 0.77, and $^{777}/_{1000}$ is written as 0.777, etc.).

You distinguish the decimal 0.7 from the whole number 7 by placing a decimal (.) in front of the 7. Any number with a decimal point in front of it is a fraction whose numerator is the number after the decimal point and whose denominator is a 1 with as many zeros as there are figures in the number to the right of this point.

For example:

- 0.7 means $^{7}/_{10}$.
- 0.77 means $^{77}/_{100}$.
- 0.777 means $^{777}/_{1000}$.

The following list displays the relative value of the same digits when pointed off by various locations of the decimal point from left to right.

- 700. = seven hundred.
- 70. = seventy.
- 7 = seven.
- 0.7 = seven tenths.
- 0.07 = seven hundredths.
- 0.007 = seven thousandths.
- 0.0007 = seven one hundred thousandths.

Adding and subtracting decimals

The biggest difference between adding and subtracting decimals and regular numbers is dealing with the decimal point.

Adding decimals

When adding decimals, first arrange the given numbers so the decimal points are in a column (they line up):

3.25

72.004

864.0725

647.

0.875

Then to avoid errors, add zeros to the numbers with the fewer places so the numbers have an equal number of places after the decimal points:

3.2500

72.0040

864.0725

$$\begin{array}{r} 647.0000 \\ 0.8750 \end{array}$$

Finally, proceed as in addition of ordinary whole numbers and put the decimal point in the sum in the same column as the other decimal points.

Subtracting decimals

Just as with addition, when subtracting decimals, write the numbers so the decimal points are under each other (in a column). Be sure the subtrahend (smaller number) is under the minuend (larger number):

$$\begin{array}{rl} 42.63 & \text{Minuend} \\ -18.275 & \text{Subtrahend} \end{array}$$

Again, as with adding decimals (to avoid errors), add zeros to one number if it has fewer figures after the decimal point than the other. In the following example, you add a zero after the 3 in the minuend:

$$\begin{array}{r} 42.630 \\ -18.275 \end{array}$$

Now, proceed as in the subtraction of whole numbers and put the decimal point in the difference in the same column as the other decimal points.

Multiplying decimals

To multiply decimals, multiply the same as you would with whole numbers. To locate the decimal point in the product, begin at the right and point off the product as many decimal places as there are decimal places in the multiplier and multiplicand. In this problem, the multiplicand (43.286) has three places after the decimal point, while the multiplier (6.04) has two, making a total of five places; therefore, the product (261.44744) *must* have five decimal places.

$$\begin{array}{r} 43.286 \\ \underline{\times 6.04} \\ 173144 \\ \underline{25971600} \\ 261.44744 \end{array}$$

Dividing decimals

When dividing decimals, you put the dividend (the number being divided) inside the division symbol bracket and put the divisor (the number you're dividing by) outside and to the left of the bracket.

If the divisor has numbers to the right of the decimal point, convert the divisor into a whole number by moving the decimal point to the right. Then move the decimal point in the dividend an equal number of places to the right. If the dividend has fewer figures than the divisor, add zeros.

Put the decimal point in the quotient directly above the decimal point in the dividend. If the quotient isn't an even whole number, add zeros after the decimal point in the dividend and continue the division to as many decimal places as is needed. Here's an example:

$$\begin{array}{r@{}l} & .809 \quad \text{Quotient} \\ 964 & \overline{)780.000} \\ & \underline{771.2} \\ & 8800 \\ & \underline{8676} \\ & 124 \end{array}$$

Converting a decimal to a common fraction

To convert a decimal fraction to a common fraction, remember the following rule:

The number after the decimal point is the numerator of the fraction, and the denominator is a 1 with the same number of zeros after it as there are figures to the right of the decimal point.

As an example, let's convert the decimal 0.375 to a common fraction. The numerator is 375. The denominator is 1 with three zeros, because there are three figures to the right of the decimal point. Therefore, the denominator is 1000. Remember, always reduce the fraction to its lowest terms. Here in equation form is our example of a decimal to a fraction conversion:

$$0.375 = \frac{375}{1000} = \frac{3}{8}.$$

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

012. How to add, subtract, divide, multiply, and convert common fractions to decimals

For these fraction problems, you need to record *only* your final answers, *not* the step-by-step procedures. (Use scratch paper if you like.)

1. Reduce to lowest terms:

   (a) $^{2}/_{4}$.

   (b) $^{8}/_{16}$.

2. Reduce to lowest terms:

   (a) $^{4}/_{8}$.

   (b) $^{9}/_{64}$.

3. Find the sums:

   (a) $^{1}/_{2} + ^{2}/_{3}$.

   (b) $^{5}/_{6} + ^{3}/_{8}$.

4. Find the differences:

   (a) $^{2}/_{3} - ^{1}/_{2}$.

   (b) $^{23}/_{32} - ^{5}/_{8}$.

5. Multiply:

   (a) $^{1}/_{2} \times ^{1}/_{8}$.

   (b) $^{3}/_{4} \times ^{3}/_{5}$.

6. Divide:
   (a) $^{9}/_{16} \div {}^{3}/_{4}$.
   (b) $^{9}/_{64} \div {}^{3}/_{32}$.

7. Convert these fractions to decimals:
   (a) $^{3}/_{32}$.
   (b) $^{3}/_{4}$.

013. How to add, subtract, divide, multiply, and convert decimals to common fractions

For these fraction problems, you need to record *only* your final answers, not the step-by-step procedures. (Use scratch paper if you like.)

1. Solve the following:
   (a) 283.5 + 69.2.
   (b) 0.067 + 37.762 + 762.37 + 7.9.

2. Solve the following:
   (a) 685.57 – 2.4.
   (b) 1.70853 – 0.00852.

3. Multiply:
   (a) 2 × 1.5.
   (b) 0.375 × 0.875.

4. Divide:
   (a) 12 ÷ 1.5.
   (b) 0.0021 ÷ 0.007.

5. Convert these decimal fractions to common fractions.
   (a) 0.25.
   (b) 0.875.

2–3. Layout Development

Layout work is the careful measuring and marking of sheet metal before cutting and shaping the metal. Measurements for a layout can be obtained from a blueprint or from the original part to be duplicated. In this section, we'll cover two important factors that apply to layout development—terms used to develop layouts and determining setback and bend allowance.

014. Developing metal layouts

The three main reasons for using a flat layout when making or repairing aircraft component parts include accuracy, duplication and economy.

Accuracy

The flat layout ensures the bends and sizes duplicate the original part. When aircraft repairs aren't exactly made to size, the applied stresses concentrate at the weak points, which eventually cause failure of the part.

Duplication

The flat layout is used when more than one part having the same size and shape is to be made. Identical measurements are easily transferred to the new metal, and duplication is quickly achieved.

Economy

The use of the flat layout ensures the least amount of metal is used on each job. This method guarantees a minimum of cost for each job.

Since most of the layouts you'll develop will lead to some type of forming operation, we'll discuss terms associated with layout and the actual bending together. For a different understanding of a flat metal layout to be bent, you *must* be familiar with the following terms:

- Overall dimensions.
- Bend allowance.
- Setback.

Overall dimensions

Overall dimensions are the outside dimensions of a complete or formed part. Overall dimensions determine how large a part is to be made. These measurements by themselves don't determine the amount of metal to be used, but show only the desired size of the completed part. The overall dimensions are given on drawings and blueprints, or can be obtained from the original part. Overall measurements are sometimes called base measurements. As such, they must be accurate because you calculate the other bending factors from them.

Flanges are measured from the top of the flange to a reference point called the *mold point*. Figure 2–7 shows the location of the mold point, which is used as a reference for figuring overall dimensions. When the outside surfaces of a formed part are extended, as shown in figure 2–7, they intersect at a point outside the formed mold point. The mold point is quickly found with the aid of a combination square head and rule. Overall dimensions for outside areas of a "U" channel are measured from mold point to mold point.

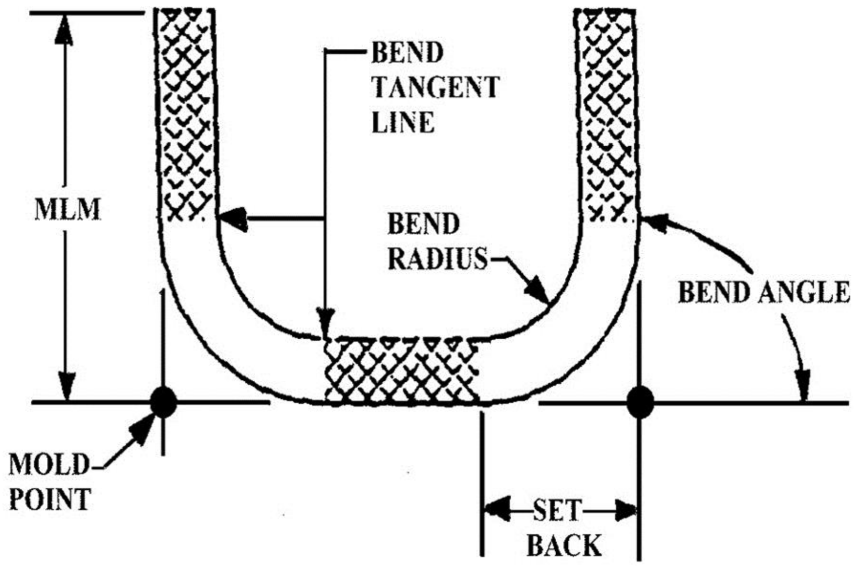


Figure 2–7. Bending terms.

Bend allowance

The *amount* of metal needed to *form* the *bent* section of a part is called bend allowance. The starting and ending points of the bent area are called *bend tangent lines*. During the bending operation, the material on the inside of the curve compresses and the material on the outside stretches. The neutral axis isn't affected by either of these forces. Consequently, bend allowance is figured along the neutral axis within the metal. Note the location of the bend allowance line in figure 2–7.

Bend allowance depends on the four factors explained in the following table:

Factor	Explanation
Degree of bend	This term is used to identify the formed position of the material after forming. The degree of the bend or fold can be anything from 1° up to and including 360°. The shape could be an angle or curve. Tubing and piping are examples of a 360° bend.
Radius of bend	The radius of bend for a sheet of material is the bend in the metal, as measured on the inside of the curved material. The minimum radius of a sheet of material is the sharpest curve or bend to which the sheet can be bent without critically weakening the part at the bend. If the radius of bend is too small, stresses and strains weaken the metal and may result in cracking. A minimum radius of bend is specified for each type of aircraft sheet metal. The kind of material, thickness, and temper condition of the sheet are factors to be considered. You may bend annealed sheet to a radius about equal to its thickness. Stainless steel and 2024–T aluminum alloy require a fairly large bend radius.
Thickness of the material	The radius of the bend is generally proportional to the thickness of the material. Furthermore, the sharper the radius of bend, the less material needed for the bend allowance. The degree of bend affects the overall strength of the metal, whereas the thickness influences the bend radius.
Type of material	The type of material is also important. If the material is soft, it can be bent very sharply; if hard, the radius of bend and, therefore, the bend allowance must be greater.

NOTE: As you can see from the preceding table, a change in one factor directly affects the other three.

Setback

When you're bending a piece of sheet stock, you must know the starting and ending points of the bend so the length of the "flat" of the stock can be determined. Flats are the unbent sections of a formed part. Notice the location of the flats in figure 2–7. The following factors are important in determining the location of the flats:

- The radius of bend.
- The thickness of the material.

In figure 2–7, setback is the distance from the bend tangent line to the mold point. The mold point is the point of intersection of the lines extending from the outside surface, while the bend tangent lines are the starting and ending points of the bend. Note the setback is the same for the vertical and horizontal flats.

015. Setback and bend allowance calculations

Let's look at two important calculations—bend allowance and setback—you *must* complete before you begin to bend metal.

Calculating bend allowance

To bend metal to exact dimensions, you *must first* determine how much metal you need to allow sufficient material for the bend. Next you layout those dimensions on flat metal and you're ready to bend. You will find a bend allowance data table in TO 1–1A–9, *Aerospace Metals General and Usage Factors*, as shown in the excerpt in the following table.

Bend	Material Thickness									
Radii	0.012	0.016	0.020	0.025	0.032	0.040	0.050	0.063	0.071	0.080
1/32	0.00065	0.00068	0.00072	0.00076	0.00082	0.00089	0.00099	0.00110	0.00118	0.00125
1/16	0.00120	0.00123	0.00126	0.00131	0.00137	0.00145	0.00153	0.00165	0.00172	0.00180
3/32	0.00174	0.00178	0.00181	0.00185	0.00191	0.00198	0.00208	0.00219	0.00226	0.00234
1/8	0.00229	0.00232	0.00235	0.00240	0.00246	0.00253	0.00262	0.00274	0.00281	0.00289
5/32	0.00283	0.00286	0.00290	0.00294	0.00300	0.00307	0.00317	0.00328	0.00335	0.00343
3/16	0.00338	0.00341	0.00345	0.00349	0.00355	0.00362	0.00372	0.00383	0.00390	0.00398
7/32	0.00392	0.00396	0.00400	0.00404	0.00410	0.00417	0.00426	0.00438	0.00444	0.00453
1/4	0.00447	0.00450	0.00454	0.00458	0.00464	0.00471	0.00481	0.00492	0.00499	0.00507
9/32	0.00501	0.00505	0.00508	0.00513	0.00519	0.00526	0.00535	0.00547	0.00554	0.00562
5/16	0.00556	0.00559	0.00563	0.00567	0.00573	0.00580	0.00590	0.00601	0.00608	0.00616

Proper bend allowance

Using the preceding table, you can find the proper bend allowance for a 1° bend. You must take that amount and multiply it by the degree you are bending to.

Bend allowance, bend radius, and bend

For example, to find the bend allowance when the sheet thickness is 0.063 inch, the bend radius is 1/4 inch and the bend is 20°. Consider the following steps:

1. In the column labeled "Bend Radii," find 1/4 inch.
2. In the row labeled "Material Thickness," find the .063 column and follow it down until it intersects the 1/4 inch row. As you can see from the preceding table, the bend allowance is 0.00492.

3. Since the table only gives us bend allowance for a 1° bend and we need to know the bend allowance for a 20° bend, we will need to multiply to obtain our answer: $20 \times 0.00492 = 0.0984$.

As a result, the amount of material needed for the bend, or bend allowance, of 20° with a 1/4 inch radius, 0.063 thick material is 0.0984 inch.

Setback calculations

Setback is found by adding together the radius of the bend plus the thickness of the metal and multiplying by the "K" value. The value for K varies with the number of degrees in the bend; you can find "K" values on the chart following the equation for determining setback.

Setback may be found easier if expressed as an equation, where SB refers to setback, R refers to "Radius of the Bend," and T refers to "Thickness of the Metal," as shown in the following equation:

SB = "K" x (Radius of the Bend + Thickness of the Metal)

or

$$SB = K\,(R+T)$$

ANGLE DEGREES	K Value	ANGLE DEGREES	K Value	ANGLE DEGREES	K Value	ANGLE DEGREES	K Value
1	.00873	46	.42447	91	1.0176	136	2.4751
2	.01745	47	.43481	92	1.0355	137	2.5386
3	.02618	48	.44523	93	1.0538	138	2.6051
4	.03492	49	.45573	94	1.0724	139	2.6746
5	.04366	50	.46631	95	1.0913	140	2.7475
6	.05241	51	.47697	96	1.1106	141	2.8239
7	.06116	52	.48773	97	1.1303	142	2.9042
8	.06993	53	.49858	98	1.1504	143	2.9887
9	.07870	54	.50952	99	1.1708	144	3.0777
10	.08749	55	.52057	100	1.1917	145	3.1717
11	.09629	56	.53171	101	1.2131	146	3.2708
12	.10510	57	.54295	102	1.2349	147	3.3759
13	.11393	58	.55431	103	1.2572	148	3.4874
14	.12278	59	.56577	104	1.2799	149	3.6059
15	.13165	60	.57735	105	1.3032	150	3.7320
16	.14054	61	.58904	106	1.3270	151	3.8667
17	.14945	62	.60086	107	1.3514	152	4.0108
18	.15838	63	.61280	108	1.3764	153	4.1653
19	.16734	64	.63487	109	1.4019	154	4.3315
20	.17633	65	.63707	110	1.4281	155	4.5107
21	.18534	66	.64941	111	1.4550	156	4.7046
22	.19438	67	.66188	112	1.4826	157	4.9151
23	.20345	68	.67451	113	1.5108	158	5.1455
24	.21256	69	.68728	114	1.5399	159	5.3995
25	.22169	70	.70021	115	1.5697	160	5.6713
26	.23087	71	.71329	116	1.6003	161	5.9758
27	.24008	72	.72654	117	1.6318	162	6.3137
28	.24933	73	.73996	118	1.6643	163	6.6911

ANGLE DEGREES	K Value	ANGLE DEGREES	K Value	ANGLE DEGREES	K Value	ANGLE DEGREES	K Value
29	.25862	74	.75355	119	1.6977	164	7.1154
30	.26795	75	.76733	120	1.7320	165	7.5957
31	.27732	76	.78128	121	1.7675	166	8.1443
32	.28674	77	.79543	122	1.8040	167	8.7769
33	.29621	78	.80978	123	1.8418	168	9.5144
34	.30573	79	.82434	124	1.8807	169	10.3850
35	.31530	80	.83910	125	1.9210	170	11.4300
36	.32492	81	.85408	126	1.9626	171	12.7060
37	.33459	82	.86929	127	2.0057	172	14.3010
38	.34433	83	.88472	128	2.0503	173	16.3500
39	.35412	84	.90040	129	2.0965	174	19.0810
40	.36397	85	.91633	130	2.1445	175	22.9040
41	.37388	86	.93251	131	2.1943	176	26.6360
42	.38386	87	.94896	132	2.2460	177	38.1880
43	.39391	88	.96596	133	2.2998	178	57.2900
44	.40403	89	.98270	134	2.3558	179	
45	.41421	90	1.0000	135	2.4142	180	
NOTE: Do *not* round off the "K" value.							

NOTE: You can use a decimal equivalent chart to help with your fraction-to-decimal conversions, or you can use the method taught in unit one of this volume.

Example setback problems

Now that you know the formula, let's try to solve a couple of setback problems.

Example 1

For a 90° bend, if the material is 0.050-inch thick and the radius of bend is specified to be $^1/_8$ inch (0.125 inch), substitute this information in the formula as follows:

SB = K(R+T)

SB = 1(0.125+0.050)

SB = 1(0.175)

SB = 0.175.

Example 2

For a 120° bend with a bend radius of 0.125 inch in a sheet 0.032-inch thick, obtain the value of K from the setback chart (K for 120° bend = 1.732). Substitute this information in the formula SB = K (R + T), and solve as follows:

SB= K(R+T)

SB = 1.732(0.125+0.032)

SB = 1.732(0.157)

SB = 0.272.

Laying out a flat pattern

Let's say you want to lay out a flat pattern like the one shown in figure 2–8. Using the following known variables, we'll go through the procedures step-by-step shown in the table after these variables.

1. Side A is 1 inch.
2. Side C $1^1/_4$ inch or 1.250 inches in decimal form.
3. Side B is 2 inches.
4. Material thickness is 0.050 inch.
5. Radius of bend is $^3/_{16}$ inch or 0.188 inch in decimal form.
6. Bend angles are 90°.

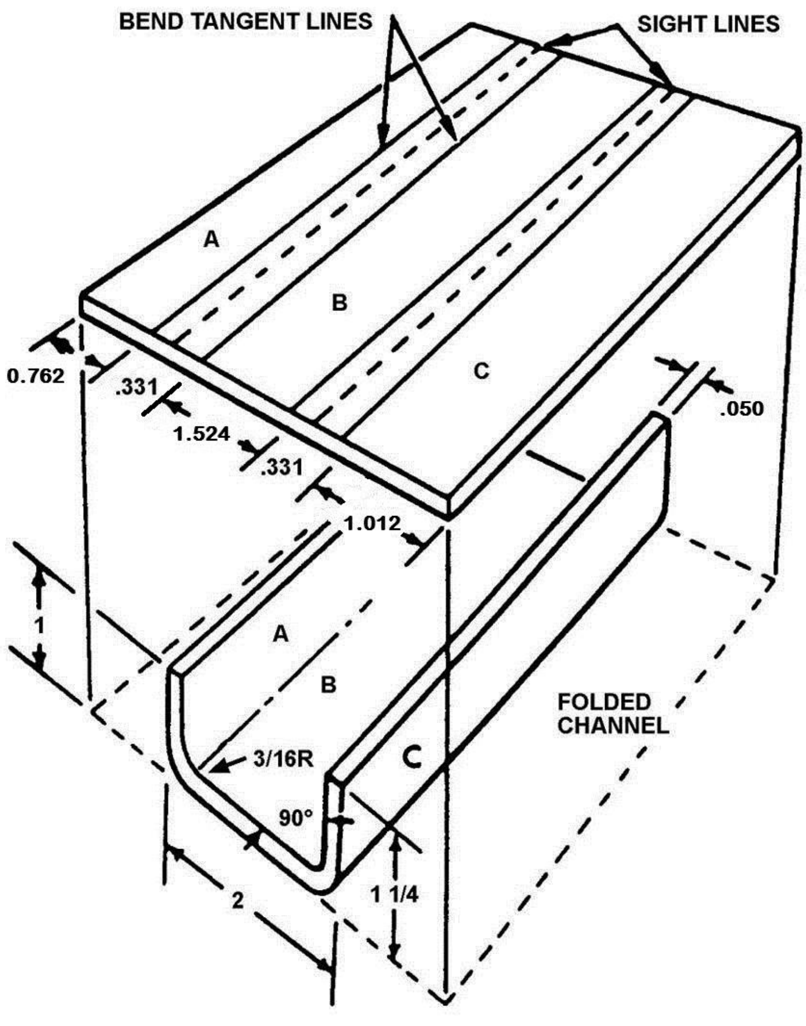


Figure 2–8. Flat layout of a channel.

Steps in Laying Out a Flat Pattern	
Step	**Action**
1	Determine the setback to establish the distance of the flats. To do that you substitute the numbers into the formula: SB = K(R+T) SB = 1(0.188+0.050) SB = 1(0.238) SB = 0.238.
2	To get the flat dimension for side A and C, you must subtract the setback from the overall dimensions. • Side A overall dimension is 1 inch, so 1 – 0.238 = 0.762. • Side C overall dimension is $1^1/_4$ inch. So first we must convert the mixed number to a decimal then subtract: 1.250 - 0.238 = 1.012.
3	Now you need the flat dimension for side B. It is the same as the preceding, but with one minor difference. Because B has bends on both sides, you must subtract the setback twice from the overall dimension. • Side B overall dimension is 2 inches; thus 2 – (0.238 + 0.238) = 2 – 0.476 = 1.524.
4	Calculate the bend allowance for the bends by using the bend allowance table. If you follow the $^3/_{16}$ bend radius row over to the .050 material thickness column, you'll find the bend allowance is 0.331. Because both of our bends are 90°, you only need to calculate the bend allowance once.
5	Now that you have all the dimensions, start laying them out on metal, beginning with side A and working to side C, as shown in figure 2–8.

Adding the measurements of flats A, B, and C, and both bend allowances (0.762 + 0.331 + 1.524 + 0.331 + 1.012), you obtain 3.96 inches. If you had simply added the three overall dimensions 1 inch, 2 inches, and $1^1/_4$ inches, you'd have a total of 4.250 inches of material length. You can see how setback and bend allowance affect material lengths in forming straight-line bends. In this case, the reduction is about .254 or approximately $^1/_4$ inch.

After you calculate all measurements, cut the material and mark off the sight lines, as shown in figure 2–8. You're now ready to use the brake to form the channel.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

014. Developing metal layouts

1. What is meant by the term "mold point?" How is it used?

2. What is the difference between degree of bend and radius of bend?

3. Why is it necessary to determine the amount of setback allowance?

015. Setback and bend allowance calculations

Refer to the bend allowance charts in the text when answering the following four questions. Round off your answers to three decimal places.

1. What is the bend allowance for a 90° bend of $^{3}/_{16}$–inch radius if the sheet is 0.040 inch thick?

2. What is the bend allowance for a $^{7}/_{32}$–inch radius bend of 50° in a sheet 0.071 inch thick?

3. What is the setback dimension for a 90° angle which is 0.032 inch thick and has a bend radius of $^{3}/_{32}$ inch?

4. What is the setback dimension for a 60° angle which is 0.064 inch thick and has a bend radius of $^{1}/_{2}$ inch?

Answers to Self-Test Questions

010

1. To convey an idea from a designer to the person who produces the end result.
2. To ensure you manufacture or repair an item to specification.
3. Lower right-hand corner of the drawing.
4. (1) Material from which the part is fabricated.
   (2) Materials needed.
   (3) Specific tolerances.
   (4) Drawing scale.
   (5) Heat treating requirements.
   (6) Notes on the finishing required.
   (7) Complete print identification.
   (8) Bill of materials.
5. To help locate a particular point.
6. Visible outline.
7. Invisible outline.
8. Center line.
9. Extension lines do not have arrowheads on the end.
10. They indicate a part or area to which a number, note, or other reference applies.

011

1. Two; length and width.
2. Three.
3. Top, front, and side.

4. Top view directly above the front view, and the side view directly to the right of, and in line with, the front view on the same plane.
5. Orthographic.

012

1. (a) $^1/_2$.
   (b) $^1/_2$.
2. (a) $^1/_2$.
   (b) $^9/_{64}$.
3. (a) $1^1/_6$.
   (b) $1^5/_{24}$.
4. (a) $^1/_6$.
   (b) $^3/_{32}$.
5. (a) $^1/_{16}$.
   (b) $^9/_{20}$.
6. (a) $^3/_4$.
   (b) $1^1/_2$.
7. (a) 0.09375.
   (b) 0.75.

013

1. (a) 352.7.
   (b) 808.099.
2. (a) 683.17.
   (b) 1.70001.
3. (a) 3.
   (b) 0.328125.
4. (a) 8.
   (b) 0.3.
5. (a) $^1/_4$.
   (b) $^7/_8$.

014

1. The point of intersection of the lines extending from the outside surfaces; a reference point used for figuring overall dimensions.
2. The degree of bend is the formed position of the material after forming; radius of bend is the bend in the metal, measured on the inside of the curved material.
3. To determine the dimensions of the flats.

015

1. 0.3258.
2. 0.222.
3. 0.126.
4. 0.326.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

16. (010) To locate a specific point on a blueprint, you use
    a. zone numbers and letters.
    b. station numbers and letters.
    c. drawing numbers and letters.
    d. usage block numbers and letters.

17. (010) A leader line in a drawing is *best* described as
    a. a dark, heavy line used as a frame.
    b. a series of short and evenly spaced dashes.
    c. light, straight lines ending about $^{1}/_{16}''$ from the object.
    d. a line indicating a part of the drawing to which some reference note applies.

18. (011) What are the *least* amount of views *usually* necessary to show three dimensions on a drawing?
    a. Two.
    b. Three.
    c. Four.
    d. Five.

19. (012) What is the difference when the fraction $^{1}/_{8}$ is *subtracted* from the sum of the fractions $^{3}/_{4}$ and $^{5}/_{32}$?
    a. $^{29}/_{64}$.
    b. $^{11}/_{16}$.
    c. $^{25}/_{32}$.
    d. $1^{1}/_{16}$.

20. (012) The product of *multiplying* the common fraction $^{5}/_{6}$ by the common fraction $^{3}/_{5}$ is
    a. $1^{7}/_{18}$.
    b. $^{18}/_{25}$.
    c. $^{8}/_{11}$.
    d. $^{1}/_{2}$.

21. (013) A decimal is a fraction whose denominator is *always* a power of
    a. 5.
    b. 10.
    c. 15.
    d. 20.

22. (013) The quotient 0.62 results from dividing
    a. 0.463 by 0.73.
    b. 0.464 by 0.76.
    c. 0.465 by 0.75.
    d. 0.466 by 0.77.

23. (014) The amount of metal needed to form a *bend* is called the
    a. bend allowance.
    b. radius of the bend.
    c. degree of the bend.
    d. setback allowance.

24. (014) A bend in sheet metal should *begin* at the bend
    a. sight line.
    b. mold point.
    c. tangent line.
    d. neutral point.

25. (015) If the K-value for 90° is 1 then what is the *required* amount of setback for a 90° bend with a radius of $^{1}/_{4}$″ and the metal thickness is 0.062″?
    a. 0.187″.
    b. 0.312″.
    c. $^{11}/_{32}$″.
    d. $^{3}/_{8}$″.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Characteristics of Materials and Metals

WHY IS IT IMPORTANT to know the characteristics of the different metals? It's important because not all metals are created equal. Some metals are stronger than others, some are extremely vulnerable to corrosion, and some work better in high heat while others are more suited to cooler temperatures. One metal is even flammable! Knowing the characteristics of the different metals is especially important when you start repairing aircraft. For instance, say you need to repair a titanium part on the aircraft but when you get back to the shop you find there is no titanium. You decide to proceed anyway and pick the first piece of metal you see that is big enough for the repair. If you pick a metal that does not have properties similar to titanium, the part could fail, leading to potential catastrophic consequences if that repair fails while the aircraft is flying.

In this unit we'll cover the essential information you need to acquire to become a proficient and accomplished LO Aircraft Structural Maintenance Journeyman. We'll begin with a discussion on the general characteristic of metals. Then, we'll cover the characteristics of metals you will use or come in contact with on a regular basis. We'll conclude the unit with a look at the types and fabrication procedures for these different metals.

3–1. Characteristic Features of Metals

The properties of metals are of *primary* concern when you're selecting metals for aircraft construction and repair. While some metal properties are necessary for aircraft maintenance, others must be reduced or eliminated so they don't hinder aircraft maintenance. Since a study of all the possible properties of metals is far beyond the scope of this course, we'll limit our discussion in this lesson to two principle areas—the properties of metals and structural stresses encountered in metal structures.

016. Properties of metals

Before we discuss the various metal properties important in your work, we first need to talk about metal classification.

Metal classification

For the purpose of our lesson, all metal may be classified in two ways—*ferrous and nonferrous*.

Ferrous metal

A ferrous metal is any metal that has iron as its *main* element. Even though a metal may contain *less* than 50 percent iron, it is *still* considered ferrous as long as it has *more* iron than *any other* metal. Ferrous metals *include* cast iron, steel, and various steel alloys.

All steels are an alloy of iron and carbon, but the term "alloy steel" normally refers to steel that also has one or more other elements (e.g., if the main alloy element is tungsten, the steel is a "tungsten steel" or a "tungsten alloy"). The alloys used (nickel, chromium, tungsten, etc.) give distinct properties to the steel. While these vary, the main result shared by all is increased hardness and toughness. If there's no alloying material, it's a carbon steel.

Nonferrous metals

A metal is considered *nonferrous* if it has *more of any other metal than it does of iron*. Nonferrous metals include many metals used mainly for metal plating or as alloying elements (i.e., tin, zinc, silver, and gold). In your job, you're mainly concerned with the metals used in the manufacture of parts (i.e., aluminum, titanium and their alloys).

Metal properties

Now that we have the important aspects of ferrous and nonferrous clearly in mind, we'll turn our attention to the properties of metals vital to your job success. We are primarily concerned with the metal properties described in the following table.

Metal Properties	
Property	**Explanation**
Hardness	Refers to the metal's ability to *resist* abrasion, penetration, cutting, or permanent distortion. Hardness increases by working the metal and, in the case of steel and certain aluminum alloys, by heat treatment and cold-working. Structural parts made from metals are in their soft state, and then heat-treated to harden them to maintain their finished shape.
Malleability	Describes a metal that can be hammered, rolled, or pressed into various shapes *without* cracking, breaking, or suffering other detrimental effects. This property is necessary in sheet metal worked into curved shapes (e.g., cowlings, fairings, and wing tips).
Ductility	The property of a metal that permits it to be permanently drawn, bent, or twisted without breaking. This property is essential for metals used in wire and tubing.
Elasticity	Refers to a metal's ability to return to its original shape when a force that caused a change of shape is removed. This property is extremely valuable because it's highly undesirable to have a part permanently distorted after an applied load is removed.
Toughness	In metal, it means it can withstand tearing or shearing, and may be stretched or otherwise deformed *without* breaking. Obviously, toughness is a desirable property in aircraft metals.
Density	The weight of a unit volume of a material. Density is important in choosing a material to be used in the design of a part, and for maintaining the proper weight and balance of the aircraft. By knowing the weight per cubic inch of repair material, you can find the weight of the repair part before it's manufactured. Density, or weight per unit volume, is also helpful in identifying metals and alloys because ferrous metals are usually heavy, while nonferrous metals are usually light.
Brittleness	Refers to the metal's ability to bend or deform without shattering. A brittle metal is apt to break or crack without change of shape. Because structural metals are often subjected to shock loads, brittleness is not a desirable property.
Melting point	The temperature at which a metal changes from a solid to a liquid. Different metals have different melting points.
Color	Color is a big aid in identifying metals and alloys. Copper and its alloys are recognized by their reddish or bronze color, while aluminum alloys are light gray, and so forth.

Factors to consider in selecting a metal for aircraft use

The selection of appropriate materials is a primary consideration for proper aircraft maintenance and repair. Keep in mind the properties of metals as we consider the specific requirements metals must meet to be suitable for use in aircraft maintenance and repair as explained in the following table.

Factors in Selecting Metal for Aircraft Use	
Factor	**Explanation**
Strength/weight ratio	The *relationship between* the strength of a material and its weight per cubic inch is known as the strength/weight ratio.. Neither strength nor weight alone is a means of true comparison. Airframes must be strong, and yet as light as possible. For example, an aircraft could be so heavy it could not support over a few hundred pounds of additional weight. In this case, the aircraft would be of little use.
Corrosive properties	Corrosion is the eating away or pitting of the surface or the internal structure of metals. Because of the thin sections and the safety factors used in aircraft design and construction, it is dangerous to select a metal subject to severe corrosion. Corrosion is caused by the exposure of metals to fumes, water, acids, or moist air; especially moist salt air.
Workability	Another significant factor in aircraft maintenance and repair is the ability of a material to be formed, bent, or machined into required shapes. This factor depends on some of the characteristics of metal we discussed previously, specifically brittleness.
Tensile strength	Tensile strength is the *resistance* of a metal to being pulled apart by a slowly applied load. Tensile strength increases or decreases as hardness increases or decreases.
Shear strength	Shear strength is the *resistance* to a cutting action like that done by a pair of scissors. Shear strength is controlled in the same way as tensile strength—by varying the hardness of the metal.
Compressive strength	Compressive strength is the maximum compressive load (pressing or squeezing force) a material can withstand.
Torsional strength	Torsional strength is the maximum twisting stress a material can withstand.

017. Structural stresses encountered in metal structures

No matter whether the aircraft is on the ground or in the air, forces are acting on it. These forces cause pulling, pushing, or twisting within the various aircraft structural members. While the aircraft is on the ground, forces created by the weight of the wings, fuselage, engines, and empennage act downward on the wing and stabilizer tips, along the spars and stringers, and on the bulkheads and formers. As these forces are passed on from member to member they cause bending, twisting, pulling, compression, and shearing.

As the aircraft takes off, most of the forces in the fuselage continue to act in the same direction but increase in intensity due to the aircraft’s motion. In contrast, the forces on the wingtips and the wing surfaces reverse direction and become upward forces of lift instead of being downward forces of weight. The lift forces are first exerted against the skin and stringers; then, they’re passed on to the ribs. Finally, spars transmit and distribute the lifting forces through the fuselage to any deadweight items carried in the fuselage.

In flight the wings bend upward at the end and may flutter slightly. This wing bending factor can’t be ignored by the manufacturer in the original design and construction, and it also can’t be ignored during maintenance. It’s quite surprising how an aircraft component, such as a wing, composed of structural members and skin rigidly riveted or bolted together, can still be so flexible.

The forces that cause pulling, pushing, or twisting within the various aircraft structural members also contribute to stress in the aircraft. In general, there are five types of stresses in an aircraft. The first three—tension, compression, and shear—are commonly called the *basic stresses*. The last two—bending and torsion—are the *combination stresses*.

<table>
<tr><th colspan="2">Metal Stress Types</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td>Tension</td><td>Tension (or tensile stress) is the force per unit area tending to stretch a structural member.

Figure 3–6 is presented following this table. In (section A), drilling the bolt hole in the strap removed much of the material and reduced the cross-sectional area. The load is constant from one end of the strap to the other, and the area on each side of the hole is carrying not only its normal share of the load, but also that part of the load that should have been carried by the removed material. If the load is increased until the strap fails, the break in the material will occur near the hole. See figure 3–1 for an example of tension stress.

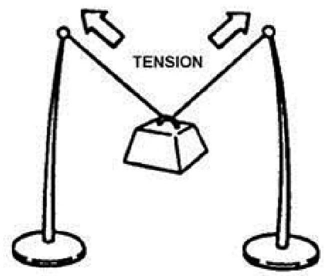


Figure 3–1. Tension.

NOTE: Placing rivets or bolts in holes makes no appreciable difference in added strength because the rivets or bolts don’t transfer tensional loads across the holes.</td></tr>
<tr><td>Compression</td><td>Compression (or compressive stress) is the force per unit area that tends to shorten (or compress) a structural member at any cross section.

Under a compressive load, an undrilled member is stronger than an identical member that has holes drilled through it. But, if a plug of equivalent or stronger material is fitted tightly in a drilled member, it transfers compressive loads across the plugged hole and the member carries about as large a load as if the hole weren’t there. See figure 3–2 for an example of compression stress.

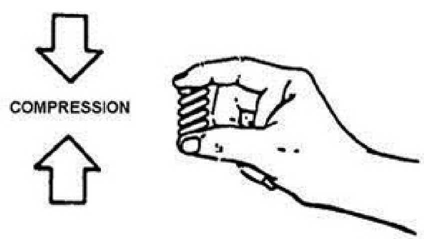


Figure 3–2. Compression.</td></tr>
<tr><td>Shear</td><td>Shear is the force per unit area that acts to slide adjacent particles of material past each other.

The term “shear” is used because it’s a sideways (lateral) stress of the type put on a piece of paper or a sheet of metal cut with a pair of shears. Shear stress is especially important in rivet and bolt applications, particularly when attaching sheet stock (e.g., if a rivet used in a shear application fails, the rivet parts are pushed sideways). See figure 3–3 for an example of shear stress.

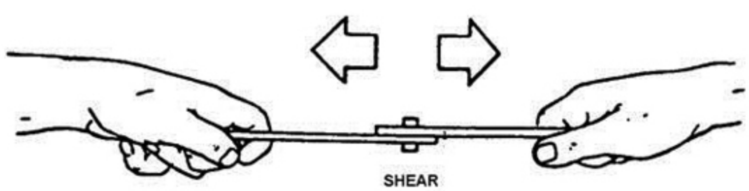
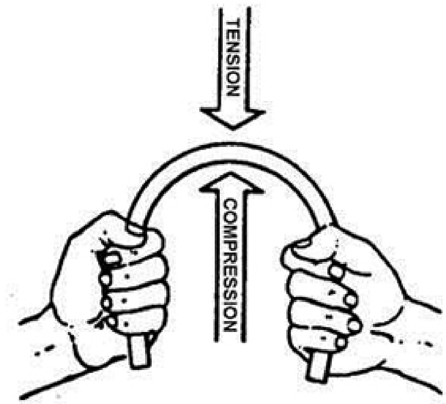
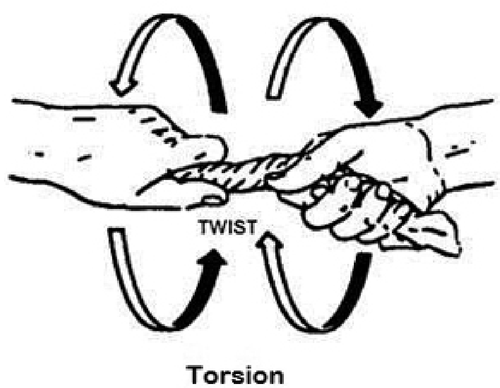


Figure 3–3. Shear.</td></tr>
</table>

Metal Stress Types	
Type	**Description**
Torsion	Torsion (or twisting stress) is the force that tends to twist a structural member. Torsion may be illustrated by a rod fixed solidly at one end and twisted by a weight placed on a lever arm at the other, thus producing the equivalent of two equal and opposite forces acting on the rod at some distance from each other. See figure 3–4 for an example of torsion stress.  **Figure 3–4. Torsion.**
Bending	Bending (or beam stress) is a *combination* of two forces (tension and compression) acting on a structural member at one or more points. In figure 3–6 (view B), on the following page, note the bending stress *causes* a *tensile* stress to act on the upper half of the metal and a *compressive* stress on the lower half. These stresses act in opposite directions on the two sides of the centerline of the member, called the neutral axis. See figure 3–5 for an example of bending stress.  **Figure 3–5. Bending.**

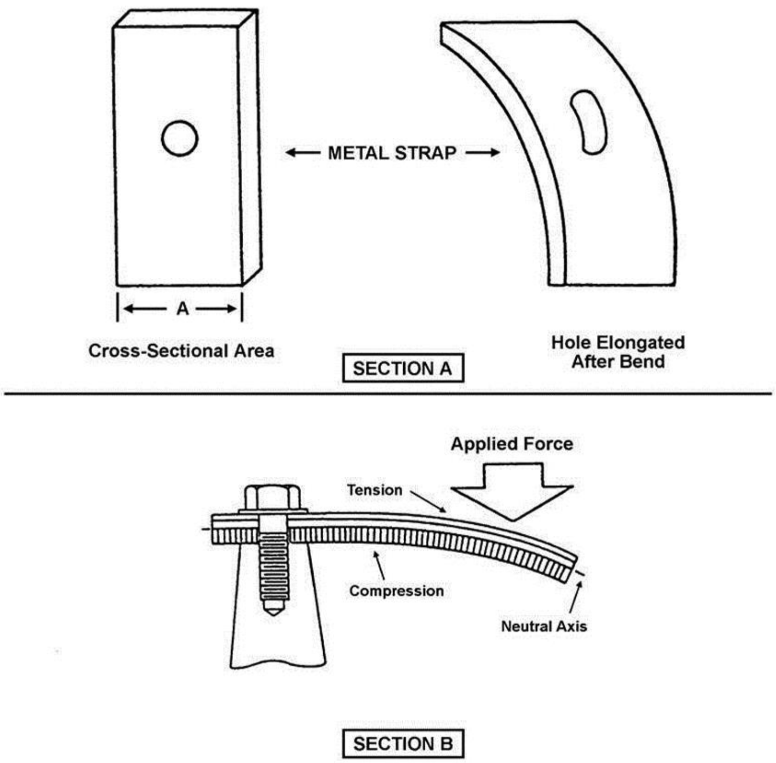


Figure 3–6. Tensile stress.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

016. Properties of metals

1. What is a *ferrous* metal?

2. What is the general definition of "alloy steel?"

3. What is a *nonferrous* metal?

4. What property of metal permits it to be hammered into various shapes without breaking?

5. What property of metal allows it to return to its original shape after a load is removed?

6. Why is *brittleness* an undesirable property in structural metals?

7. Define the term "workability."

017. Structural stresses encountered in metal structures

1. How many *basic stresses* are there? Name them.

2. Define the term "tensile stress."

3. Which type of stress can be transferred across the plugged area if a tightly fitted plug is inserted in a drilled member?

4. Shear stresses are applied in which direction?

3–2. Aircraft Metal Characteristics and Fabrication

Keeping in mind the terms we've discussed covering metal properties and selection factors, let's turn our attention to metals used in aircraft construction and repair. The lessons in this section focus on the different metals used in aircraft manufacture, their properties, and the methods employed when the metal is used for repair or fabricating parts. Identifying and selecting the right metal for the repair or fabrication of a part is just the starting point. Once you have determined the appropriate metal, you must thoroughly consider its working characteristics such as shearing, forming, grinding, drilling, sawing, and nibbling before you start any operation. Then, using the correct methods, you'll not only ensure proper fabrication but also prolong the life of the tools and machinery you use.

We'll start with the most frequently used metal—aluminum. We'll discuss why this metal is one of the most desirable of metals for general use on aircraft, the methods used to identify aluminum, and the various types of aluminum. We will also cover titanium, magnesium, and types of steels that you will encounter on the job.

018. Aluminum and aluminum alloys

In this lesson, we will discuss aluminum, which is one of the most abundant metals of the Earth. In fact, about one-twelfth of the Earth's crust has aluminum—almost twice as much as the Earth's iron content.

Identifying characteristics

Commercially pure aluminum is a white, lustrous metal that stands second on the scale of malleability, sixth in ductility, and ranks high in its resistance to corrosion. Commercially pure aluminum has a tensile strength of about 13,000 psi, but its strength can be almost doubled by rolling or other cold-working processes. By alloying aluminum with other metals and using heat-treating processes, the tensile strength may be raised to as high as 100,000 psi or within the range of structural steel. Aluminum weighs far less than most metals. In the alloy form, it weighs about 0.1 pound per cubic inch. This is about one-third the weight of iron (0.28 pounds) and copper (0.32 pounds). Aluminum is slightly heavier than magnesium (0.066 pounds) and somewhat lighter than titanium (0.163 pounds).

Aluminum melts at the comparatively low temperature of 1,250 degrees Fahrenheit (°F). It's nonmagnetic and is an excellent electrical conductor. Aluminum's outstanding characteristic is its light weight. *Because* of its high strength/weight ratio and comparative *ease of fabrication,* aluminum is one of the *most* widely used metals in modern aircraft construction.

Aluminum does, however, have one *disadvantage:* it is difficult to weld. Oxidation of the heated metal's surface prevents soft solder from adhering to the material. This means that a riveting process must be used to produce good joints when working with aluminum alloys.

Aluminum alloys

Aluminum is combined with various percentages of other metals (usually copper, manganese, magnesium, and chromium) to form alloys used in aircraft construction. For wrought alloy types, the total percentage of alloying elements is seldom more than six or seven percent. Aluminum alloys that use manganese, magnesium, chromium, or magnesium and silicon as the principal alloying ingredients aren't greatly affected by corrosive environments. By contrast, alloys using substantial percentages of copper are more susceptible to corrosive action.

Classes of aluminum alloys

Aluminum alloys are divided into the following two classes based on the methods that can be used to shape them:

- *Cast aluminum alloys* are those suitable for casting in sand, permanent mold, and die castings.
- *Wrought alloys* are those which may be shaped by rolling, drawing, or forging.

Wrought alloys are the more widely used in aircraft construction for stringers, bulkheads, skin, rivets, and extruded sections so this lesson will focus only on wrought alloys.

Most wrought aluminum alloys have less than seven percent of alloying elements. By regulating the amount and type of elements added, aluminum's properties are enhanced and the working characteristics are improved. Special compositions have been developed for particular fabrication such as forging and extrusion. Like casting alloys, wrought alloys are produced in both heat-treatable and nonheat-treatable types. Alloyed aluminum's principal wrought forms are plate and sheet, foil, extruded shapes, tube, bar, and forging.

When working with wrought aluminum, you'll encounter the terms "Alclad" and "Pureclad." Both terms designate metal sheets that have an aluminum core coated with a thin layer of pure aluminum on one or both sides. The thickness of the pure aluminum coating depends on the thickness of the sheet. Aluminum coated in this manner affords a dual protection for the core in the following two ways:

- Prevents contact with any corrosive agents.
- Prevents any attack from scratching or other abrasion.

Aluminum identification system

The Air Force *requires that all* aluminum-base alloys be marked with Federal specification numbers or code markings on about every square foot of material. Figure 3–7 is an example of how the sheet, bar, and tube should be marked according to Federal specifications. If the material isn't marked, you *must* identify the material *before* use. To prevent unmarked material, you *must* remark any unused portion of metal with alloy, temper, and thickness *before* you place it into storage.

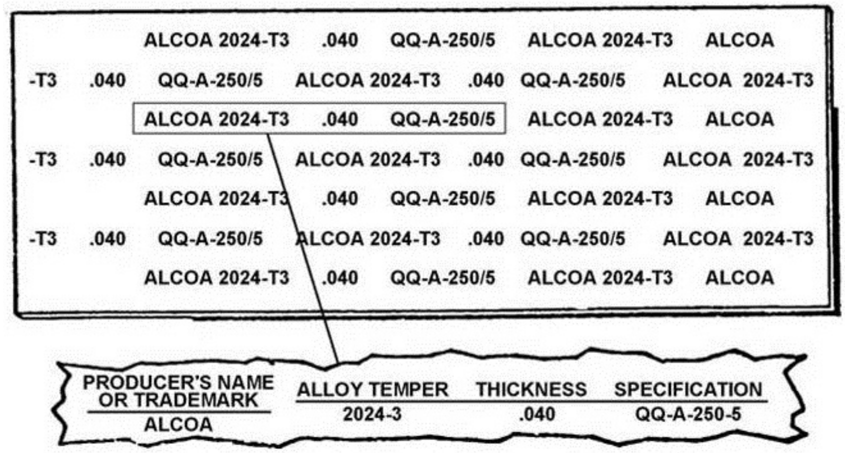


Figure 3–7. Markings for aluminum alloys.

The material composition of wrought aluminum and wrought aluminum alloy is designated by a four-digit index system. The system is divided into three groups as explained in the following table.

Aluminum Alloy Indexing System	
Group	**Explanation**
1xxx	In the 1xxx group, the *first* number indicates the alloy has at *least* 99 percent pure aluminum. The second digit of the group indicates controls over the impurities contained in the alloy. If the second number is zero, it indicates no special control over individual impurities. Otherwise, the second digit (1 – 9) indicates the number of controls over individual impurities in the metal. The last two digits of the 1xxx group are used to show hundredths of 1 percent above the original 99 percent designated by the first digit (e.g., if the last two digits are 30, the alloy has 99 percent plus 0.30 percent of pure aluminum for a total or 99.30 percent pure aluminum). Examples of alloys in this group include the following: • 1100: 99.00 percent pure aluminum with one control over individual impurities. • 1130: 99.30 percent pure aluminum with one control over individual impurities. • 1275: 99.75 percent pure aluminum with two controls over individual impurities.
2xxx – 8xxx	In the 2xxx through 8xxx group, the first digit indicates the major alloying element used in the formation of the alloy. The following are a few examples; for information on the other alloying elements consult TO 1–1A–9, *Aerospace Metals – General Data and Usage Factors.* • 2xxx—copper. • 5xxx—magnesium. • 7xxx—zinc.

In addition to these groups, the following three additional factors are important parts of the number or color coding system:

- Alloy number (if followed by a dash and a number, also shows temper designator).
- Thickness.
- Federal specification numbers.

Temper designator

Temper refers to the metal's hardness. The temper of aluminum alloys is essentially produced by one of three methods:

1. Cold-working (strain-hardening).
2. Heat treatment.
3. A combination of cold-working and heat treatment.

The temper designation follows the alloy designation and is separated from it by a dash (e.g., 7075–T6, 2024–T4, etc.). The temper designation consists of a letter indicating the basic temper, which may be more specifically defined by the addition of one or more digits. A few temper designators for the heat-treatable aluminum alloys (e.g., 2014, 2017, 2024, 6061, 7075, and 7178) are shown in the following table; for information on other temper designators, consult TO 1–1A–9.

Temper Designators for Heat-Treatable Aluminum Alloys	
Designator	**Meaning**
–O	Annealed.
–T3	Solution heat-treated, and then cold-worked.
–T4	Solution heat-treated.
–T7	Solution heat-treated, and then stabilized.

When a number is added to the preceding designators, it denotes a modification of a standard temper (e.g., for –T36, the numeral "6" indicates a different amount of cold-work than that used in –T3).

The temper designators for *nonheat-treatable aluminum alloys* (e.g., 1100, 3003, 3004, 5050, and 5052) are shown in the following table:

Temper Designators for Nonheat-treatable Aluminum Alloys	
Designator	**Meanings**
–F	As fabricated.
–O	Annealed.
–H	Strained-hardened.
–H1 (plus one or more digits)	Strain-hardened only.
–H2 (plus one or more digits)	Strain-hardened and partially annealed.
–H3 (plus one or more digits)	Strain-hardened and stabilized.

Thickness

Another important bit of information printed on the aluminum sheet is the thickness of the metal. This thickness (sometimes called gauge) is measured in thousandths of an inch and is printed as a decimal fraction of an inch (examples: .040, .063, or .250).

Aluminum alloy uses

In your job, you'll deal with two general types of aluminum alloys: heat- and nonheat-treatable.

Heat-treatable alloys

Because heat-treatable alloys provide greater strength, they're used for aircraft structural elements. The following table describes a few of the heat-treatable aluminum alloys used in aircraft construction and identifies the typical uses for each. For information on other heat-treatable aluminum alloys consult TO 1–1A–9.

Heat-Treatable Alloys	
Type	**Use**
2017	Used to make rivets, stressed-skin covering, and other structural members.
2024	Used for heat-treated parts, airfoil covering, and fittings. It's stronger than alloy 2017 and may be used when alloy 2017 is specified.
6061, 6062, and 6063	Used for oxygen and hydraulic lines, and for some applications, such as extrusions and wrought sheets. Alloy 6061 offers the *best* weldability of the heat-treatable alloys.

Nonheat-treatable alloys

These alloys only response to any heat treatment is a softening annealing effect. They may be hardened only by cold-working. The following table describes the three commonly used nonheat-treatable alloys. Consult TO 1–1A–9 for information on other nonheat-treatable aluminum alloys.

Nonheat-Treatable Alloys	
Type	**Use**
1100	Used where strength isn't an important factor, but weight, economy, and corrosion resistance are desirable. Alloy 1100 *is not used* for structural aircraft parts, but *is used* for the fabrication and repair of fuel and oil tanks, fairings, and wingtips.
5052 and 5053	These alloys are for fuel and hydraulic lines, fuel tanks, and wingtips. Substantially higher strength *without* too much sacrifice of workability can be obtained *with* alloy 5052. Therefore, alloy 5052 is preferred over alloys 1100 and 3003 for many applications.

Fabricating aluminum and aluminum alloys

Because of aluminum's working characteristics, several precautions are required to ensure a safe and usable product once aluminum fabrication processes are completed. In this lesson, you'll learn about some common fabrication procedures for the aluminum and aluminum alloys you'll use in your job.

Drilling

Standard twist drills may be used satisfactorily for many aluminum alloy drilling operations. But where you are working with soft material, drilling thick material, or drilling deep holes, you can get better results with the improved-design twist drills. These twist drills (center bit, fig. 3–8) are usually designed with more spiral twists per inch. The additional spiral twist gives more work action or force, causing the twist drill to cut and feed faster. The added force is also helpful in removing chips, especially for deep hole-drilling operations. A double-fluted twist drill with a spiral angle of 47° F gives good results on aluminum alloys.

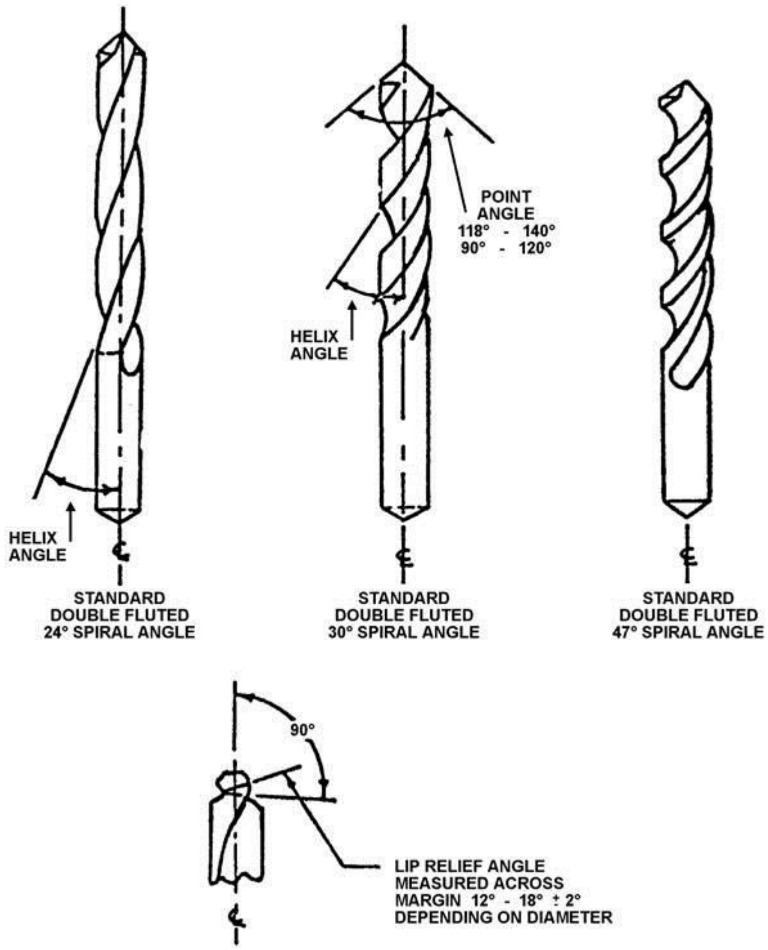


Figure 3–8. Twist drill designs and recommended cutting angles for aluminum.

Drilling of thin material normally doesn't require coolant/lubrication; however, when drilling holes of $^1/_4$-inch depth or more, adequate lubrication is essential to twist drill life and hole quality. Where possible, the lubrication should be applied by forced feed spray or flow, and the twist drill should be withdrawn at intervals to be sure the lubricant flows to the twist drill tip.

Reaming

Generally, most reamer types may be used for aluminum; but for best results, the spiral-fluted reamers (e.g., solid, expansion, or adjustable types) are recommended. The spiral should be opposite to the rotation to prevent the reamer from feeding and hogging into the hole. Holes to be finished by reaming should be drilled 0.005 – 0.015 inch *undersize to ensure positive cutting* rather than scraping and swedging. The usual indication of oversize drilled holes and improper feed is the projection of a lip around the hole's diameter after the reaming operation is complete. Finish reamers should be maintained with exceptionally keen cutting edges and highly polished flutes for smooth work.

Shearing

The accuracy of shearing is affected by the following:

- The material's thickness.
- Type of shear or knife blades.

- Condition of the material.
- Adjustment and sharpness of the blades.
- Size of the cut.
- Relationship of the width of the cut to sheet thickness.

Normally, most aluminum alloys of $^1/_2$ inch and less in thickness can be sheared. Correct clearance between shear blades is important for good shearing. Too little clearance quickly dulls or otherwise damages the blades or knives; too much clearance causes the material to be burred, or even to fold between blades. Normal clearance is from $^1/_{10}$ to $^1/_8$ the sheet thickness. When you are not sure of the shear's capacity, check the documentation or consult the equipment manual.

Sawing

A good, simple general rule when sawing aluminum is the spacing of the teeth on bandsaw blades should be as coarse as is consistent with the thickness of the material being sawed. The softer alloys require more blade set than do the harder, heat-treated alloys. Usually, an alternate side rake of about 15, and a top rake or "hook" of 10 to 20 provides satisfactory results. This amount of hook requires a power feed and securely clamped work. For hand feeds, the top rake must be reduced considerably to avoid overfeeding.

Bandsaw blades must be well-supported by side rollers, and back support immediately below the saw table and about 2 or 3 inches above the work. Put the top blade supports slightly in advance of those below the table and allow the blade to vibrate freely to eliminate excessive blade breakage. As a general rule, a noisy bandsaw cuts more efficiently than a quiet band saw. Quiet, smooth-cutting band saws usually produce smooth, burnished surfaces accompanied by excessive heat and, consequently, decreased blade life.

Forming

A variety of forming operations can be done on aluminum alloys when alloy, temper, forming methods, and tools are considered and selected appropriately. Ordinary presses, brakes, and rollers are suitable for the work. Sand and file any sheared or cut edges smooth before bending or forming to reduce the possibility of cracking. Also, when possible, as opposed to forming the metal *with the direction* of the grain flow, form the metal *across the direction* of the grain flow to prevent cracking.

Filing

Single-cut hand files with milled teeth usually give the best results for filing aluminum. The main consideration in selecting a file for working aluminum is to give ample chip space clearance. The cuttings generated are large and have a tendency to powder, pack, and clog between file teeth. To overcome the clogging problem, use a file with increased chip space, deeper cut grooves, and teeth that cut with generous side and top rake. You can also machine file using rotary files (miniature milling cutters having spiraled sharp teeth with smooth, deeply cut flutes).

Grinding

The grinding characteristics of aluminum alloys vary from one alloy to another. Refer to TO 1–1A–9 for specific characteristics for the type of aluminum alloy you are grinding.

019. Titanium

In a mineral state, titanium is the fourth most abundant structural metal in the Earth's crust; however, processing it into a metal is a complex and expensive process. Titanium is a light, strong, corrosion-resistant, ductile metal. Titanium and its alloys are used chiefly for parts that need good corrosion resistance; moderate strength up to 600 °F, which equates to 315 degrees Celsius (°C); and light weight. Due to its high cost, titanium is used only where outstanding results are obtained.

Strength/weight ratio

Although titanium is about 43 percent lighter than steel, it can often (on a strength/weight basis) be equated to steels having yield-strength levels of about 300 kilograms per square inch. Compared to aluminum, titanium alloys (60 percent heavier than aluminum) are much stronger, and show a higher fatigue resistance and greater hardness.

Corrosion resistance

Titanium's corrosion resistance is excellent, due mainly to the tenacity of its natural oxide surface. This thin, stable, continuous film of oxide, or absorbed oxygen, forms readily at low temperatures. As temperatures increase, the protective oxide film's thickness and permeability increases to the point where oxygen diffuses into the metal and produces brittleness and corrosion. This tendency limits the use of titanium in areas where high temperatures are encountered.

In general, titanium is equal to, or better than, most metals in terms of resistance to direct corrosion by a wide variety of chemicals. It's generally resistant to stress corrosion, erosion corrosion, galvanic corrosion, and oxidation.

Thermal conductivity

Titanium is a metal that falls between aluminum and stainless steel in terms of elasticity, density, and strength at high temperatures. It has a melting point of 2,730 to 3,155° F, low thermal conductivity, and low coefficient of expansion. Titanium is non-magnetic and its electrical resistance characteristics are like those of corrosion-resistant steel.

Titanium identification and sheet markings

There are currently two military specifications covering alloyed and unalloyed titanium. It is classified based on its chemical composition. You can find information on the designations and identifications of titanium in TO 1–1A–9.

Sheet titanium is marked in much the same way as aluminum alloy sheet (fig. 3–9). The metal is marked with a continuous ink-roll marker. The marking includes the following:

- Brand name or trade name.
- Type of titanium: Type I (commercially pure), Type II (alpha phase), Type III (alpha-beta phase), Type IV (beta phase).
- Composition (letters A – F denote the actual composition of the material).
- Thickness (in thousandths of an inch).
- Previous heat treatment.
- Specification number.

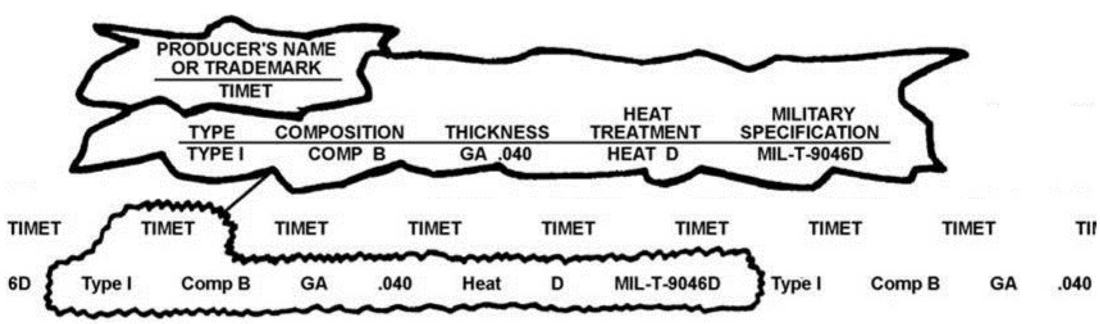


Figure 3–9. Markings for titanium.

Identification testing

Titanium is similar in appearance to stainless steel. One quick identification method is the spark test. Titanium gives off a *brilliant white trace ending in a brilliant white burst* when touched to a grinding wheel.

Fabricating titanium

Titanium presents no serious or complex problems in the working process. However, you need to thoroughly consider its characteristics before shearing, forming, grinding, drilling, and sawing. Let's take a look at each of these processes for titanium.

Shearing

Titanium and its alloys can be successfully sheared if the shear blades are in perfect condition. Shears made for cutting steel can be used to cut titanium if the shear blades are sharp and in good adjustment. You must add *over allowances*—the material added to the last dimension that must be sanded off after shearing—when shearing titanium. Otherwise, stress risers can cause a tear in the part during forming operations.

Because the force required for titanium and its alloy is greater, the shear blades wear faster. Power contour shears, power roll shears, and unishears may be used.

Forming

By using the methods developed for stainless steel, you can do straightedge bending of titanium to a limited degree using a power brake or hand-forming equipment. Compensation for springback and the bend radii are the factors that require control. Springback is comparable to that of hard stainless steel when formed at room temperature. The bend radii depend on the type of alloy and whether forming is done hot or cold.

Finished parts and materials to be formed must be free from shear cracks, tool marks, and other imperfections caused by cutting operations. All burrs must be removed. Edges to be formed must be filed free of burrs, grooves, scratches, and sharp corners. In edge preparation, ensure defects are removed and not merely covered over. On edges to be formed, you must do the last sanding with a No. 240 grit or finer abrasive sheet. Do the last sanding of other edges with No. 120 grit or finer abrasive sheets. Abrasive marks on edges must be as nearly parallel to the sheet surface as practicable. Be careful to keep your edge finishing from excessively heating the metal. *Heating accompanied by a blue discoloration is excessive.* Round all edges to be formed as necessary to ensure satisfactory forming.

Grinding

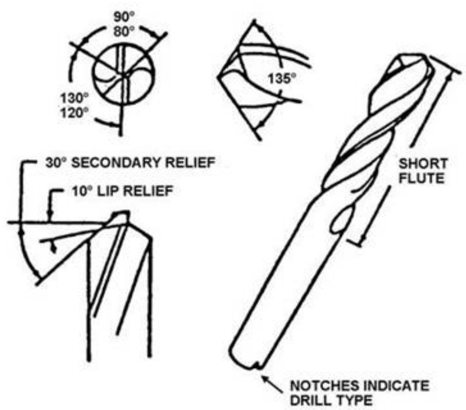
Grinding titanium and its alloys can be done at about the same rate of speed as hardened high-speed steels and die steels. Moderately light cuts are recommended. Excessive wheel loading is likely to cause poor grinding action with subsequent poor surface finish, high residual tensile stresses, and low grinding ratios. Grinding difficulties can be minimized by using proper wheels at low wheel speed and feed, and by flooding the grinding area with a TO approved cutting fluid. Keep the grinding temperature low to keep stresses low.

Grinding removes metal slowly and gives a poor surface finish with heavy burring. Titanium is very susceptible to cracking if the heavy burring isn't removed by sanding before forming.

Drilling and reaming

Titanium and its alloys may be difficult to drill and ream unless certain procedures are carefully followed. When drilling and reaming holes in titanium, it is important that enough power and pressure is applied to keep the tool cutting until the hole is completed. If the drill is allowed to ride in the partially drilled hole, hardening of the *area of work on the surface of the metal tends to harden*, and further drilling is extremely difficult, if not impossible. When possible, use a power feed setup (e.g., drill press) and the shortest twist drill possible for the job.

Specially ground twist drills are used when drilling titanium. The best is a short, two-fluted, HS twist drill ground to a 135° split point. Figure 3–10 shows an example of this type of twist drill and recommended speeds. HS, spiral-fluted reamers are required at cutting speeds about half those for drilling. Carbide twist drills, reamers, and other cutting tools are recommended. Use a TO approved lubricant when drilling each hole, and clean the chips from cutting lips after each hole is completed. *Do not try to use a chipped or dull twist drill.*



DRILLING SPEEDS			
MOTOR SPEED RPM	FRACTIONAL DRILL SIZE	NUMBERED DRILL SIZE	LETTERED DRILL SIZE
1000	3/32 - 3/16	40 - 13	A - F
750	13/64 - 1/4	12 - 1	G - Z
500	17/64 - 1/2		

Figure 3–10. Twist drill design and recommended drilling speeds for titanium.

If you need to loosen and remove a broken tool (e.g., a twist drill from titanium), then submerge the part in a saturated solution of ferric ammonium sulfate or nitric acid. Use all precautions to avoid scratches because scratches lead to cracks and part failure. Blend out long, deep scratches *using* an abrasive sheet or emery cloth of No. 120 grit or finer.

Sawing

Use bandsaws for sawing titanium and its alloys. Apply fairly heavy pressure because the surface of the metal tends to harden if you let the blade ride across the metal. During sawing operation, the metal may tend to tear and clog the saw blade. Use water-soluble coolants when sawing titanium.

020. Steels

To be a successful aircraft structural maintenance journeyman, you must be able to recognize steels and their physical properties. A steel's physical properties determine its strength, safety, and corrosion resistance, and, therefore, its suitability for a given use. Numbering systems and color codes, plus in-shop testing procedures are readily available to help you select the proper steel for a given repair situation. Let's look at some of the numbering systems and codes that you will use.

Society of Automotive Engineers' numbering system

The Society of Automotive Engineers' (SAE) system of identifying steels uses four- or five-digit numbers. The *first number* indicates the type of steel (i.e., 1 indicates a carbon steel, 2 a nickel steel, etc.). In the case of alloy steels, the *second number*—and sometimes the third—usually indicate the approximate percentage of the principal alloying element. The *last two numbers*—sometimes three—show the appropriate carbon content. The following table shows a few examples of the SAE-series numbering system; refer to TO 1–1A–9 for more information.

Type Of Steel	SAE Numbers
Carbon.	1XXX.
Chromium-vanadium.	6XXX.
Tungsten.	7XXXX and 7XXX.
Silicon-manganese.	9XXX.

The examples in the following table should help you understand this system.

Example	Explanation
SAE–1045	1 – Type of steel (carbon). 0 – Percent of alloy (none). 45 – Carbon content (0.45 percent carbon).

The American Iron and Steel Institute code

The American Iron and Steel Institute's (AISI) numerical code is essentially the same as the SAE code (i.e., SAE–1030 and AISI–C1030 are carbon steels of identical chemical composition). The two organizations have worked together in expanding the SAE code to cover more specifications for ferrous metals. One difference between the two codes is the AISI number prefix indicates the process used in the manufacture of the metal.

Aeronautical Material Specification code

The Aeronautics Division of the SAE Standards Committee has developed the Aeronautical Material Specification (AMS) code. These specifications are complete procurement specifications for materials used to manufacture aircraft, aircraft engines, propellers, and other aircraft accessories. The chemical and physical compositions of AMS metals are coordinated as closely as possible with SAE general standards for similar metals. AMS specification numbers show many detailed requirements besides the chemical analysis of the metal.

The American Society for Testing and Materials code

The American Society for Testing and Materials (ASTM) numerical code has much in common with the AMS code. The ASTM specifications are also complete procurement specifications and have many detailed requirements besides the chemical composition of the materials.

Shop identification

The spark test is a common means of identifying various ferrous metals that have become mixed in a scrap pile. You can use it in the shop to differentiate between types of ferrous metals. Spark testing an unknown sample alone is difficult. The *best* way to identify metals accurately is to *compare* the individual characteristics of the spark stream of the *unknown* metal *with* the characteristics of a spark stream of a *known* metal.. Refer to TO 1–1A–9 to perform this test.

NOTE: Few nonferrous metals, except titanium, give off sparks when touched to a moving grinding stone. Therefore, these metals can't be identified successfully by the spark test.

General characteristics of steels

While plain carbon-type steel remains the principal product of the steel mills, so-called alloy or special steels are being turned out in ever increasing amounts. You'll use these metals in your day-to-day work on aircraft. Refer to the following table for characteristics of the various alloy types.

General Characteristics of Steel Alloy Types		
Types	**SAE Numbers (General Numbers)**	**Characteristics Resulting From the Alloying Element Added**
Carbon	1000	Surface hardness and strength.
Nickel	2000	Toughness.
Chrome-nickel	3000	Toughness and depth hardness.
Molybdenum	4000	Eliminates brittleness and increases depth hardness.
Chrome-molybdenum	4100	High strength and toughness.
Chromium	5000	Corrosion resistance and hardness.
Chrome-vanadium	6000	Depth hardness and toughness at sub-zero temperatures.
Tungsten	7000	Hardness at high temperatures.
Chrome-nickel-molybdenum	8000	Toughness and strength (general-purpose steel).
Silicon-manganese	9000	Depth hardness and toughness under impact.

Fabricating stainless steel

Working stainless steel is like working other metals. You must take special precautions when cutting, drilling, bending, and punching. The pressure needed for working stainless steel in comparison to mild steel is about double. Corrosion-resisting steels are more difficult to work than carbon steels and other metals. Even though they're difficult to work, the same general methods are used with modification or compensation for each type or grade's individual characteristics.

Drilling

Carbide and HS twist drills are commonly used for drilling stainless steel. Special twist drills that are abrasive in nature due to their high carbon content are used for drilling grades 420, 440, and so forth. In comparison to the other grades, the drilling speeds for HS twist drills are usually reduced 25 to 50 percent.

When you drill the corrosion-resisting steels, control the speed to prevent hardening of metal and excessive twist drill damage from heat. Remember, *slow speed, heavy feed!* It's *extremely important* to use adequate lubrication or coolant when drilling stainless steel because of its poor heat conduction.

Reaming

The carbide-tipped, spiral-fluted type reamer made from HS steel is recommended for corrosion-resisting steels. These special fluted reamers are used to help alleviate the chatter and difficult chip removal associated with the straight-fluted reamers.

Due to the work-hardening characteristics of corrosion-resisting steel, leave enough stock to ensure the cutting is behind the work-hardening surface resulting from drilling. Speeds for reaming vary according to the type of material being cut. Refer to the TO for proper reamer specifications and speeds.

Sawing

The band saw is well-suited for low speed straight line or contour sawing of stainless or corrosion-resistant steel within prescribed limitations. Follow the saw manufacturer's recommendations for cutting speed, blade selections, and so forth. Speeds usually vary with the physical properties, temper, etc. of the type or grade being cut. As a general guide, speeds range from 100 to 125 feet per minute for material under 0.062 inch, and 60 to 100 feet per minute for thickness over 0.062 inch.

Heavy pressure to maintain the cut usually is not necessary. Use just enough pressure to create proper heating and softening at the cut point without forcing the saw. Do not use lubricants.

Bending

Most steel sheets can be bent, if adequate bending and cutting capacity is available. Springback allowances vary according to the type and temper of material being formed. Always avoid the use of sharp bend radii on parts subject to flexing (cycle) or concentrated stresses because of possible fatigue or stress-corrosion failure. Check the bend area for strain, grain, or bend cracking. If parts show any presence of these problems, increase the radius by one thickness or more until the difficulty is remedied.

Observe the following general rules in handling and forming steel materials:

1. Handle sheet, sheared or sawed strips, and blanks with care to prevent cutting your hands and other parts of your body.
2. Sand, file, or polish sheared or cut edges before forming. Remove rough and sharp edges before starting other machining operations to reduce hazards in handling.
3. Form material across the grain when possible, using correct or specified bend radii. Also, provide bend relief holes in corners when required.
4. Observe the load capacity of equipment (e.g., brakes, presses, rolls, drills, shears, etc.).

CAUTION: Machines rated for carbon steel must not be used at over 60 percent of rated capacity when cutting or forming stainless steel, unless approved by a responsible technical authority.

CAUTION: Avoid handling parts, especially corrosion-resistant steel, with bare hands after cleaning and heat treating or passivation; fingerprints cause carburization and pitting of the surface when the part is heated.

Shearing

To prevent damage to shears and ensure clean, accurate cuts, the clearance between shear blades should be about $^{1}/_{20}$ (one-twentieth) of the thickness of the material to be cut. Maintain blades or knives in a sharp condition, and ensure they are clean and free of nicks. Use a clearance of 0.005 to 0.006 inch for general shearing of sheet stock up to 0.125-inch thick where only one shear is available. Avoid excessive blade clearance to prevent work-hardening of the cut area, which increases the susceptibility of stress corrosion and burring. Apply lubrication (e.g., lightweight oil) at regular intervals to prevent galling and to clean blades for prolonged shear blade life.

Punching

Punching requires close control of the die clearance and shearing action of the punch die. Clearance for punching should be 5 percent of the thickness of the metal and be closely controlled for all gauges. Maintain punches and dies in clean, sharp condition, and lubricate them by swabbing or spraying the material to be punched with lightweight lube oil to prevent galling, and aid in keeping the punch and die clean.

Forming

Forming steel varies depending on the type of steel and alloying elements. More power is needed to form some types more than others because of higher tensile strengths, and their yield strength increases rapidly during forming and bending. Springback allowance also varies according to the types of steel being formed. Sharp radii must be avoided where parts are subjected to flexing or concentrated stresses that could lead to fatigue or stress-corrosion failure. Because of the different requirements for the differing types of steel, please refer to TO 1–1A–9 when perform forming operation on steel.

Hot-forming is used to form shapes in stainless steel that cannot be achieved by cold-forming. In using heat for forming, it's important that you control the temperature closely. Fully anneal finished parts to relieve them of residual stress and carbide precipitation that affects corrosion resistance.

021. Factors to consider in the substitution of metals

In selecting interchangeable or substitute materials for the repair and maintenance of aircraft, check the appropriate TOs when specified materials aren't in stock or obtainable from another source. It's impossible to know if another material is as strong as the original by just looking at it.

You *must* keep the following requirements clearly in mind when you're selecting interchangeable or substitute materials:

- Maintain the original strength of the structure (most important).
- Maintain the contour or aerodynamic smoothness.
- Maintain the original weight, if possible, or keep the added weight to a minimum.
- Maintain the original corrosive-resistant properties of the metal.

Because different manufacturers design structural members to meet various load requirements for specific aircraft, you can see that it's important you check the specific –3 TO for the aircraft you're working on. While apparently similar in construction, these structural members and their repair procedures vary in different aircraft according to their load-carrying design. Structural repair instructions (including tables of interchangeability and substitution for ferrous and nonferrous metals, and their specifications for all types of aircraft used by the Air Force) are normally prepared by the aircraft contractor. These instructions are usually compiled in the following two separate series of handbooks and manuals:

- The 1–1A series of handbooks, known as *General Engineering Manual.*
- The structural repair TO of the basic handbook instructions for specific aircraft models.

Since we can't cover all of the interchangeability or substitutions authorized for specific aircraft in this volume, use your appropriate –3 TO for this purpose. For the same reason, our discussion is limited to general substitution factors and substitution requirements.

Substitution factors

As we mentioned previously, strength, contour, weight, and corrosion resistance are of primary concern when you're selecting substitute material. You can't select or substitute metals based only on the factors of thickness, composition, or tensile strength. However, there are some general rules that make selection of metals easier to understand.

Strength

The following two basic rules apply when material substitution is necessary:

1. The substitute material must provide cross-sectional strength in tension, compression, shear, and bearing at least equal to that of the original material.
2. Never substitute a material thinner than the original or with a cross-sectional area less than the original.

Rule 1

The explanation for Rule 1 is most parts in an aircraft structure carry a tension, compression, shear, and bearing load at some time during the aircraft's operation. The magnitude of these loads is seldom known when repairs are made. Therefore, the tensile, compression, shear, and bearing strengths of a part made of a substitute material must be at least equal to those of the original part.

Strict adherence to Rule 1 leads to this paradox: If in one application 2024–T4 is substituted for 2024–T6 and in another application 2024–T6 is substituted for 2024–T4, a substitute thicker than the original must be used in either application. This seeming inconsistency, which occurs with other combinations of metals, is explained by a comparison of mechanical properties:

Mechanical Properties	2024–T4 (bare)	2024–T6 (clad)
Ultimate tensile strength	62,000 psi	60,000 psi
Compressive yield strength	40,000 psi	47,000 psi

If 2024–T4 is substituted for 2024–T6, the substitute material must be thicker, unless the reduction in compressive strength is known to be acceptable. On the other hand, if 2024–T6 is substituted for 2024–T4, the material must be thicker, unless the reduction in tensile strength is known to be acceptable.

Rule 2

The explanation for Rule 2 is the buckling and torsional strengths of many sheet metal and tubular parts depend primarily on the thickness rather than the allowable compressive and shear strengths of the material. Therefore, a *substitute that is thinner than the original reduces the buckling and torsional strengths* of a part considerably, even though the thinner substitute material has higher allowable compressive and shear strengths.

Contour

Maintaining the contour of the original structure means the flow of air over the completed repair will *not* create drag on the aircraft or change the flight characteristics due to a vortex or drag condition created by your repair. It also means the repair will include bends and angles incorporated to match the original structure. You must be extremely careful in the metal substitution, especially in flush repairs, to ensure the material used can do the required job without creating new problems. If the required strength cannot be maintained by using the original thickness of material, do *not* increase the strength at the sacrifice of smoothness. Instead, find some other method (e.g., in some instances, you can maintain strength by increasing doubler or backing plate thickness).

Weight

Depending on the particular aircraft and the position of the repair on it, added weight can become a problem. Weight control is secondary in some cases, but it can become a primary problem. A control surface that needs balancing is one example where added weight is a major concern during repair. The weight of substitute material should correspond to the original as closely as possible.

Extrusion substitution

Earlier, we discussed how an extrusion is formed and its composition. On some occasions, the damage you find may include extruded shapes in the aircraft structure.

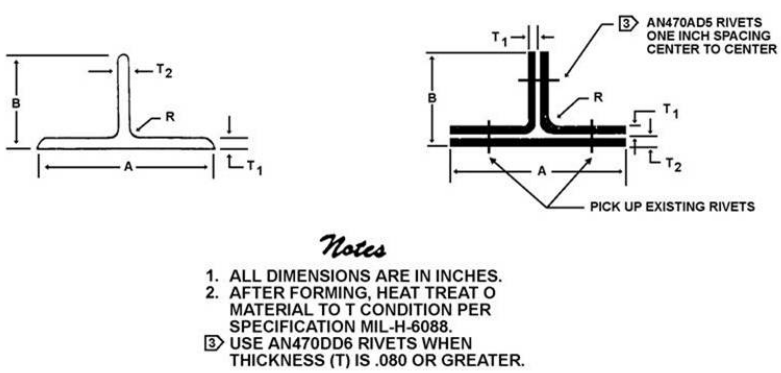


Figure 3–11. Substitute repair manual.

In the event of damaged extrusion, you must determine the proper replacement of the piece. You'll also need to find (or calculate) the dimensions and forming angles for any authorized substitutions that can be formed from sheet stock. Figure 3–11 shows the typical substitution method (material composition, metal thickness, and proper forming angles) used to fabricate a replacement angle.

If a TO identifies an extrusion numbered AND10136–2404 as the material to be used in a repair, consult the structural TO for information on material composition and size like that shown in the following table. Using this table, you can see that the material composition for the AND10136–2404 extrusion is the 7075–T6 aluminum alloy with a base (column A) 2.500-inches wide and a leg (column B) 1.625-inches wide. The thickness of the base (column T_1) and leg is .094 inch. All radii on the extrusion (column R) are $^1/_8$ inch (0.125 inch). If an extrusion of the same composition and dimensions is obtainable, use it to make the necessary repair by complying with the TO instructions.

EXTRUSION NUMBER	MAT'L AL. AL	A	B	T_1	T_2	R
AND10136–1605	2024-T4	1.750	1.375	.094	.094	.125
AND10136–1706	2024-T4	1.875	1.500	.094	.094	.125
AND10136–2001	7075-T6	2.000	1.000	.078	.078	.125
AND10136–2005	7075-T6	2.000	1.250	.094	.094	.125
AND10136–2401	7075-T6	2.500	1.250	.094	.094	.125
AND10136–2402	7075-T6	2.500	1.250	.125	.125	.125
AND10136–2404	7075-T6	2.500	1.625	.094	.094	.125

On many occasions, such an extrusion isn't available and must be fabricated from flat-sheet stock. In this situation, you need to find the extrusion number for substitute dimensions. To do this, you'd use a table similar to the following table. In this example, the extrusion number is AND10136–2404. The material to be formed is the 7075–0 aluminum alloy (7075 in the annealed condition). The dimensions of the base and leg remain the same as the original—a base 2.500 inches wide and a leg of 1.625 inches.

EXTRUSION NUMBER	MAT'L AL. AL	A	B	T_1	T_2	R
AND10136–1605	2024-0	1.750	1.375	.071	.071	.13
AND10136–1706	2024-0	1.875	1.500	.071	.071	.13
AND10136–2001	7075-0	2.000	1.000	.063	.063	.13
AND10136–2005	7075-0	2.000	1.250	.071	.071	.16
AND10136–2007	7075-0	2.000	1.750	.071	.071	.16
AND10136–2401	7075-0	2.500	1.250	.071	.071	.16
AND10136–2402	7075-0	2.500	1.250	.100	.100	.22
AND10136–2404	7075-0	2.500	1.625	.071	.071	.16

NOTE: In the repair sample, three pieces are needed to replace the extruded original.)

In the replacement part within the table, T_1 includes the T_1 and T_2 of the original part. Make T_1 0.071 inches thick and T_2 0.071 inches thick. The radius of the angles changes from 0.125 inch on the original extrusion to 0.160 inch on the substitute material to allow for bending the sheet stock with a bending brake.

After forming and dressing the substitute pieces, you must heat-treat the material to give it the strength needed to carry the stresses involved. Referring back to figure 3–8, note that you heat-treat the material to the –T condition. In this particular case, you must bring it to the –T6 condition, the same as the original extrusion.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

018. Aluminum and aluminum alloys

1. In alloyed form, what is the weight of aluminum in comparison to iron, magnesium, and titanium?

2. What is the best method to join aluminum?

3. On what factor does the amount of Alclad coating on wrought aluminum sheets depend?

4. What information should you include when remarking unused metal?

5. In the 2xxx through 8xxx group, what does the *first* number of the four-digit index system used for aluminum indicate?

6. How is the thickness of aluminum displayed on wrought materials?

7. Which heat-treatable aluminum alloy offers the *best* results for *welding*?

8. When is a coolant or lubrication required when drilling aluminum alloys?

9. In which direction should metal be formed to prevent cracking?

10. Why must ample chip space be given when filing aluminum alloys?

019. Titanium

1. Why is titanium used in aircraft construction?

2. If titanium gives excellent results when used for aircraft parts, why is it not used more widely?

3. What happens to titanium if it's exposed to high temperatures?

4. What TO has information on the designations and identifications of titanium?

5. How is titanium's thickness indicated on titanium sheets?

6. What is meant by over allowance?

7. How do you *minimize* difficulties when grinding titanium?

8. What condition results from allowing a twist drill or saw blade to ride over the material being cut?

9. How do you remove long, deep scratches from titanium?

10. What type of coolant is desired when you are sawing titanium?

020. Steels

1. What is the main difference between the SAE numbering and AISI coding systems?

2. What is the best way to identify steels using the spark-test method?

3. What are the characteristics of carbon steel?

4. Which steel alloy has the characteristics corrosion resistance and hardness?

5. How can you overcome the poor heat conduction of stainless steel when you are drilling?

6. Why are spiral-fluted reamers preferred over straight-fluted reamers for reaming corrosion-resistant steels?

7. What factors affect the amount of springback allowance for bending steel?

8. When cutting steels, what procedure do you follow to prolong shear blade life?

021. Factors to consider in the substitution of metals

1. What is the *most important factor* in selecting substitute metal?

2. Why is it necessary to check the specific –3 TO before selecting a substitute metal?

3. When you are making repairs, when do you have to monitor the problem of weight control very closely?

4. What three factors make up the typical substitution method used to fabricate a replacement angle?

3–3. Forming Procedures

Once you've determined the working dimensions of a part or assembly to be attached to an aircraft, there are two basic ways of fabricating the part—bend or form the part by machine or hand. The machines in this section are the ones usually found in most shops. Hand forming requires the best of your knowledge and skill since it normally involves extremely light-gauge materials. These materials can quickly be rendered useless by rough and careless workmanship. In this section, we'll provide information you can use to become skilled in both machine and hand-forming metal. To do this, we'll first cover the methods used in machine forming and then, we'll cover hand-forming operations.

022. Using machine-forming equipment

Once you've determined the working dimensions of a part or assembly to be attached to an aircraft, there are two basic ways of fabricating the part—bend or form the part by machine. The machines discussed in this section are the ones usually found in most shops. As you perform your job, you'll use different breaks when shaping or molding metals and other components. Many of these machines are similar; you decide which to use by the size and shape of the part to be formed or folded. With only slight variation, many jobs use the same machine, which avoids changing from one machine to another when forming or folding metal.

Brakes enable you to bend and shape metal of various thicknesses. The brakes you have in your shop are based on the type of metal forming your shop performs.

Cornice brake

The cornice brake (fig. 3–12) has a much greater range of usefulness than other types of forming equipment. While some equipment can form a bend or edge only as wide as the depth of the jaws, the cornice brake allows the sheet to pass through the jaws from front to rear without any limitations, allowing it to make larger bends.

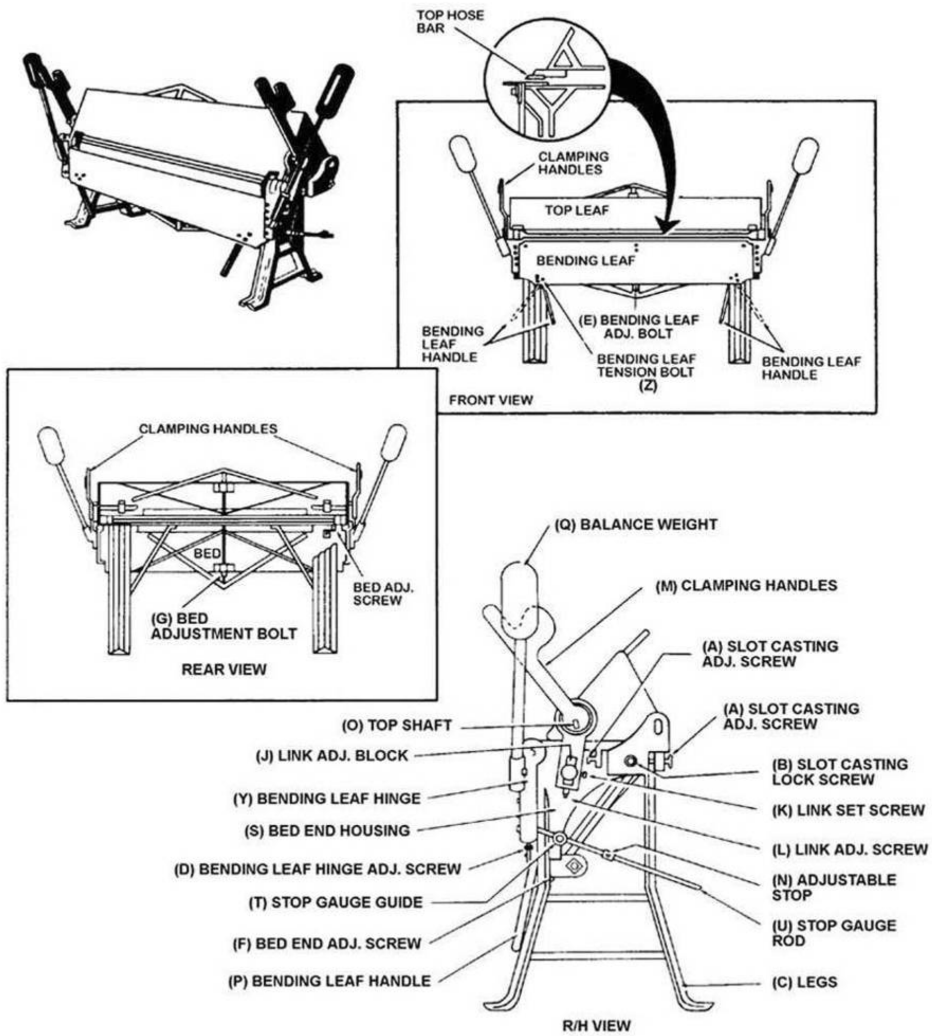


Figure 3–12. Cornice brake.

When you make ordinary bends with the cornice brake, place the sheet on the bed with the sight line (mark indicating line of bend) directly under the edge of the clamping bar (fig. 3–13). Then bring the clamping bar down to hold the sheet firmly in place. Set the stop at the right side of the brake for the proper angle or amount of bend, and then raise the bending leaf until it strikes the stop. To make other bends, lift the clamping bar and move the sheet to the correct position for bending.

When bending thick sheets, raise the clamping bar an amount equal to the thickness of the metal and set it back the same distance. When bending thick, heavy sheets, reinforce the bending leaf with angle iron.

The manufacturer's design determines the bending capacity of a cornice brake, and depends on the bending edge thickness of the various bending leaf bars.

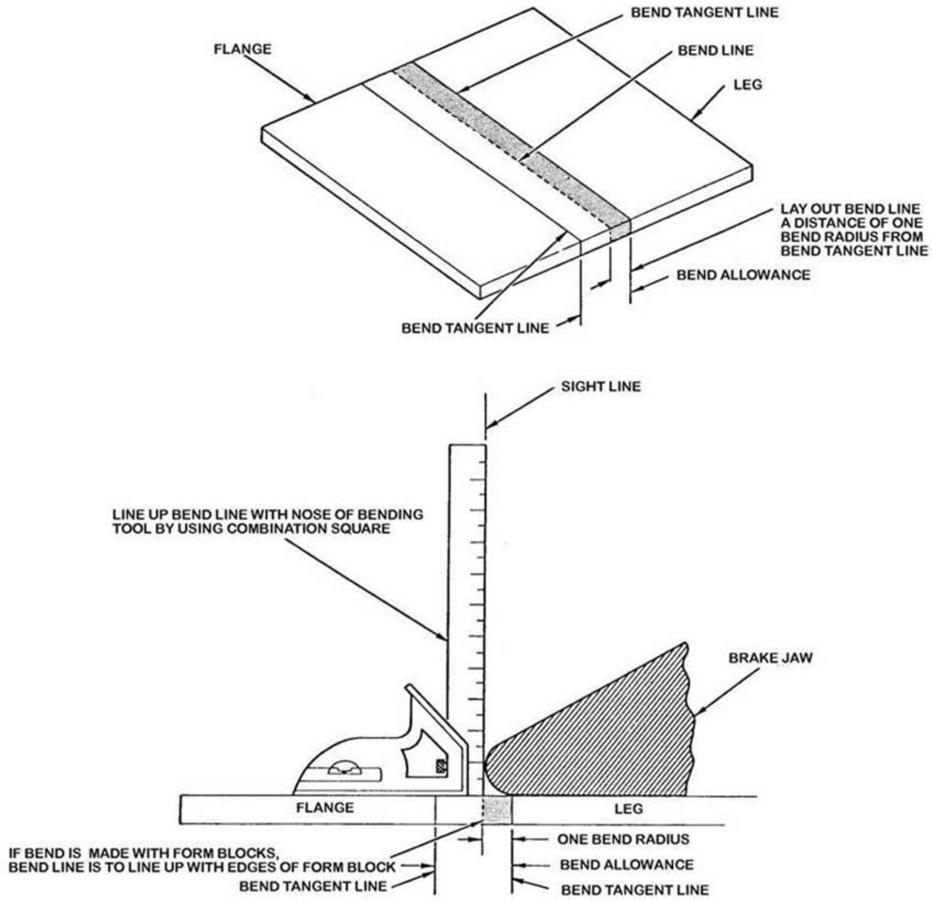


Figure 3–13. Use of bend lines—cornice brake.

Most metals have a tendency to return to their normal shape, a characteristic known as springback. If you set your cornice brake for a 90° bend, the metal bent will probably form an angle of about 87° to 88°. Therefore, if you desire a 90° bend, set your cornice brake to bend an angle of about 93° to allow for springback.

There may be occasions when you find the material bends *excessively* or bends further on one side of the brake than on the other. To correct this condition, set the *top* leaf back on the end where the sheet is overbending.

To get the most out of a cornice brake, you must know how to adjust it for various operations. For the remainder of this discussion, refer to figure 3–13. These *brake adjustments* are very important because they save time and improve the quality of your work.

To adjust for bending various thicknesses of sheet metal stock with the cornice brake, move the upper nose bar back at the bending edge. If the material to be bent is within four gauges of the capacity of the machine, move the top leaf back equal to twice the thickness of the material.

When making sharp bends on lightweight metal, move the top leaf forward. To adjust the top leaf, loosen the slot casting lock screws and move the top left forward or backward by adjusting the slot casting adjustment screws, which have right-hand threads. Once the correct adjustment is made, lock the adjustment with the slot casting lock screws.

Ensure the clamping pressure is tight enough to hold the metal in place while making the bend. Different gauges of metal require different adjustments; in other words, every gauge of metal has unique adjustments. Remember, the pressure should be equal on both ends of the machine. This clamping pressure can be changed by adjusting the link adjusting blocks (J). To adjust the link blocks, loosen the link set screws (K), which hold the link adjustment block. Adjust the blocks to the thickness of the metal with the link adjustment screws (L), and then lock the adjustment with the link set screws. Check the adjustment by using a test strip. If it's not right, repeat the adjustment procedures.

If the bend leaf becomes bowed after heavy use, tighten both bending leaf tension bolts (Z) until the center is brought into line. This line should be straight; check it with a straightedge.

Box and pan brake

The construction of the box and pan brake is a great deal like that of a cornice brake, except the clamping leaf is divided into sections called *fingers* or *shoes*. These fingers vary in width and are all interchangeable. The machine (fig. 3–14) is especially designed for making boxes of various sizes and shapes. The design permits the forming of all four sides without distorting any of the finished bends, which is an advantage over a cornice brake. For that matter, if necessary, this brake can be used to do any work that can be done on a standard cornice brake.

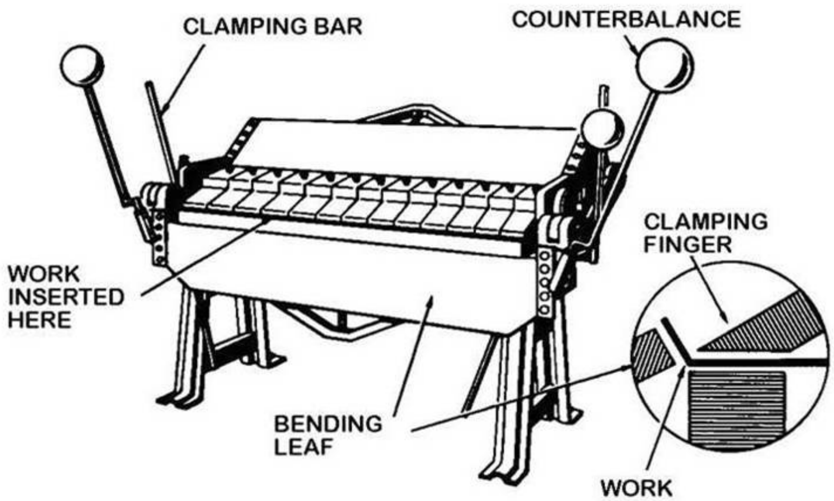


Figure 3–14. Box and pan brake.

Since it is a great deal like the cornice brake, make all necessary adjustments (e.g., radius and thickness) by following the same procedures for adjusting the cornice brake. The upper beam allows securing of the steel fingers by thumbscrews. Seat the fingers securely and tighten the thumbscrews before using the brake. To remove any of the fingers, simply loosen the thumbscrews, raise the clamping fingers by pushing the clamping bar backward, and then pull the fingers forward. When installing the fingers, reverse this procedure.

NOTE: Before you start any work on the cornice brake, or box and pan brake, make all adjustments for the thickness of metal you are using. Do not bend rod, wire, band iron, or spring-tempered sheets on the box and pan, or cornice brakes.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

022. Using machine-forming equipment

1. What is the *largest* flange (depth) that you can form on a cornice brake?

2. How many degrees *must* you add on to allow for springback when using a cornice brake?

3. How can you check to ensure the bending leaf is *not* bowed?

4. How does a box and pan brake differ from a cornice brake?

5. What advantage does a box and pan brake have over a cornice brake?

6. What must you perform prior to starting any work on the cornice, box and pan brakes?

Answers to Self-Test Questions

016

1. Any metal that has iron as its *main* element.
2. A steel that also has one or more elements besides carbon and iron.
3. Any metal that has more of any other metal than it does iron.
4. Malleability.
5. Elasticity.
6. Because of the shock loads they are subjected to.
7. The ability of a metal to be formed, bent, or machined to required shapes.

017

1. Three; tension, compression, and shear.
2. The force per unit area tending to stretch a structural member.
3. Compression.
4. Sideways (lateral).

018

1. About one-third the weight of iron and copper, slightly heavier than magnesium, and somewhat lighter than titanium.
2. Riveting process.
3. The thickness of the sheet.

4. Alloy, temper, and thickness.
5. Major alloying element.
6. In thousandths of an inch.
7. Alloy 6061.
8. When drilling holes of $^{1}/_{4}$-inch depth or more.
9. Across the direction of the grain flow.
10. To overcome clogging and binding problems.

019

1. Because of its corrosion resistance, moderate strength, and light weight.
2. Because of the high cost.
3. Oxygen diffuses into the metal and produces embrittlement and corrosion.
4. 1–1A–9.
5. In thousandths of an inch.
6. The material added to the last dimension in shearing, which is later sanded off.
7. By using the proper wheels at low wheel speed and feed, and by flooding the grinding area with a TO approved cutting fluid.
8. Hardening of the material.
9. Blend them out using an abrasive sheet or emery cloth of No. 120 grit or finer.
10. Water-soluble.

020

1. The AISI uses a number prefix indicating the process used in the manufacture of the metal.
2. Compare the individual characteristics of the spark stream of the unknown metal with the characteristics of a spark stream of a known metal.
3. Surface hardness and strength.
4. Chromium.
5. By using adequate lubrication or coolant.
6. They help alleviate the chatter and difficult chip removal associated with the straight-fluted reamers.
7. Type of steel and temper of material being formed.
8. Lubricate with lightweight oil at regular intervals.

021

1. Maintaining original strength of the structure.
2. Because different manufacturers design structural members to meet various load requirements for specific aircraft.
3. When adjusting the balance of control surfaces.
4. Material composition, metal thickness, and proper forming angle.

022

1. There is no limitation.
2. Three degrees.
3. Use a straightedge.
4. The clamping leaf is divided into sections called fingers or shoes.
5. It permits forming of all four sides of a box without distorting any of the finished bends.
6. Make all adjustments for the thickness of the metal you are using.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

26. (016) A metal that can hammered, rolled, or pressed into various shapes *without* cracking or breaking has a high degree of
    a. malleability.
    b. elasticity.
    c. ductility.
    d. density.

27. (016) The *relationship between* the strength of a material and its weight per cubic inch is the
    a. strength/weight ratio.
    b. tensile strength.
    c. shear strength.
    d. density.

28. (016) What metal property strength is defined as the *resistance* of a metal to being pulled apart by a slowly applied load?
    a. Shear.
    b. Tensile.
    c. Torsional.
    d. Compressive.

29. (016) What metal property strength is defined as the *resistance* to a cutting action like the cutting done by a pair of scissors?
    a. Shear.
    b. Tensile.
    c. Torsional.
    d. Compressive.

30. (017) Which stress is a *combination* stress in an aircraft?
    a. Shear.
    b. Tension.
    c. Bending.
    d. Compression.

31. (018) In addition to a high strength-to-weight ratio, what is another reason for using aluminum in the construction of an aircraft?
    a. Appearance.
    b. Ease of fabrication.
    c. Ease of attachment.
    d. Resistance to corrosion.

32. (018) The heat-treatable aluminum alloy that offers the *best* weldability is
    a. 2024.
    b. 2025.
    c. 5053.
    d. 6061.

33. (018) When you are reaming holes in aluminum, what is the *most* probable cause if the reamer starts to scrape and swedge the material, rather than cut it?
    a. Holes were drilled oversize.
    b. Holes were drilled undersize.
    c. Spirals on the reamer are opposite to the rotation of the reamer.
    d. Spirals on the reamer are pointed in the same direction as the rotation of the reamer.

34. (018) If a piece of metal is formed with the grain flow of the metal, it can possibly
    a. snap.
    b. crack.
    c. deform.
    d. work harden.

35. (019) What technical order (TO) has information on the designations and identification of titanium?
    a. 00–20–1.
    b. 34–1–1.
    c. 1–1A–9.
    d. 1–1–691.

36. (019) Lack of constant pressure when you are drilling titanium causes
    a. undersized holes.
    b. annealing of the metal.
    c. hardening of the metal.
    d. contamination of the metal.

37. (020) What test can you commonly use in the shop to differentiate between ferrous metals in a scrap pile?
    a. Spark.
    b. Magnetic.
    c. Chemical.
    d. Ultrasonic.

38. (020) The *best* way to identify different metals accurately when you are performing a spark-test is to
    a. watch the spark stream against a dark background.
    b. set the grinding wheel speed at 2,500 revolutions per minute.
    c. grind the metal on the side of the grinding wheel to get a large volume of sparks.
    d. compare the spark stream of unknown metal with the spark stream of a known metal.

39. (021) When you substitute a *thinner* metal that is *stronger* than an original metal, you
    a. decrease torsional strength.
    b. increase torsional strength.
    c. decrease tensile strength.
    d. increase tensile strength.

40. (022) You secure the steel fingers on a box and pan break by using
    a. heat treatment.
    b. thumbscrews.
    c. spot welds.
    d. riveting.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Common Hardware and Fasteners

YOU WILL ENCOUNTER many different types of hardware while working structural maintenance. In this unit, we will first discuss common hardware—such as bolts, screws, and nuts—you will work with as you go about your duties. Next we will cover the characteristics, installation, and removal procedures for the different types of open area fasteners you will most likely use. Finally, we'll turn our attention to the types of fasteners designed for use in blind areas.

4–1. Common Hardware

Some of the devices used to fasten materials together are designed to allow for quick dismantling or replacing of aircraft parts that are often taken apart and put back together. Riveting and blind fasteners are prime examples. However, riveting the parts each time they're serviced soon weakens or ruins the joint. Also, some joints need greater tensile strength and stiffness than rivets can provide. Because of these limitations, bolts and certain types of screws are used to provide the required strength and rigidity.

Bolts, screws, washers, and nuts are used to ensure a sound structure when installing rivets and blind fasteners is impractical in aircraft fabrication. Bolts are used to join parts under high tension or shear loads. Consequently, the materials these bolts are made from must be as strong as the other materials used in the aircraft. Screws are like bolts, but have a lower material strength and a loose thread fit, and their shanks are threaded along the entire length.

NOTE: Several types of structural screws are available that differ from structural bolts only in the type of their head styles. The material compositions of both are equivalent and both have definite grip lengths.

023. Aircraft bolts

As we stated earlier, bolts and screws are alike in many ways. Both are made from similar materials and have a manufactured head on one end and threads on the other. Regardless of the similarities, there are several distinct differences between them. For example, the threaded end of a bolt is always blunt, but a screw's may be blunt or pointed. Bolt assemblies are generally tightened by turning the nut on the bolt. *Keep in mind, the head of a bolt may or may not be designed for turning.* In contrast, a screw is always tightened by turning its head.

In this lesson, we'll cover the following important factors you need to know to successfully work with aircraft bolts:

- Dimensional features.
- Identification of bolts.
- Types of aircraft bolts.
- Installation of aircraft bolts.

Dimensional features

Aircraft bolts are made from cadmium or zinc-plated, corrosion-resistant steel (CRES); unplated CRES; and anodized aluminum alloy. The configuration of a bolt (fig. 4–1) includes grip length (G), bolt length (L), thread length (T), and diameter (D).

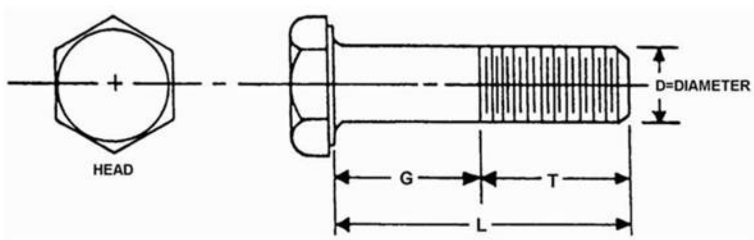


Figure 4–1. Bolt configuration.

The following table provides descriptions for each bolt dimensional feature mentioned in the preceding paragraph, and displayed in figure 4–1.

Bolt Dimensional Features	
Feature	**Description**
Grip length	The distance from the underhead bearing surface to the start of the thread is called the grip length. Accordingly, the thickness of material held together by the bolt is called the grip. The ideal installation is a bolt whose grip length is a few thousandths of an inch shorter than the actual material thickness. This allows you to avoid bottoming the nut.
Bolt length	The bolt length is the overall length of the bolt, including the grip length and threaded parts. All bolt installations involving self-locking or plain nuts must have at least two complete threads protruding through the nut. These two threads include the chamfered end of the bolt. However, bolts of slightly greater grip length than that required may be used if washers are placed under the nut or bolt head. If plate nuts are used, shims are added under the plate nut. **NOTE:** Although there's no maximum for the number of threads over the minimum of two, they should be kept to a practical minimum in the interest of weight and appearance.
Thread length	Bolts are equipped with inclined threads for the purpose of rotating on a nut that has like threads. Threads can be coarse or fine. TO 1–1A–8, *Structural Hardware*, contains tables describing the different threads. Both types of threads are named for the number of times the incline (threads) rotate around a given diameter bolt or screw.
Diameter	The diameter of a bolt refers to the shank diameter of the bolt. When you're installing bolts, you must know the correct nominal diameter to get proper fit requirements. You can use a micrometer to separate bolts into their nominal diameter sizes.

Identification of bolts

Bolts come in many shapes and varieties. They may be classified by the shape of head, method of securing, or usage. The head shape may be hexagon, square, eye, or internal wrenching. They're identified by either bolt-head markings or part number designations.

Bolt-head markings

Bolts are designed for their individual heat ranges and grip stresses and made of different materials with different tensile strengths. Each bolt is marked with a code identifying its physical characteristics. These marking can be found on the head of the bolt (fig. 4–2). A complete listing of markings is located in TO 1–1A–8.

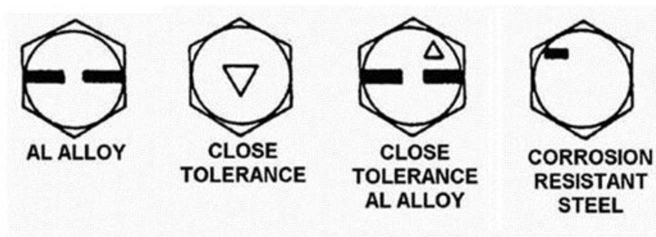


Figure 4–2. Bolt-head markings.

Part number designation

Government agencies and civilian organizations have established several standards and specifications that govern manufacture of aerospace materials. The following are the four most common:

1. Air Force–Navy Standard (AN).
2. National Aircraft Standards (NAS).
3. Military Standards (MS).
4. Aerospace Material Specification (AMS) – previously introduced in Unit 3 of this volume.

The AN and MS are military-generated standards and are in general use by the respective government agencies. Many AN standards have been converted to and replaced by MS and NAS standards.

The part number designation gives the following information:

- Type of bolt.
- Diameter.
- Length.
- Length of grip.

NOTE: The designation also states if the head or shank is drilled.

Let's look at how to read a part number designation. We'll use NAS1104–10D for our example. This part number is broken down as shown in the following table:

Breakdown of Part Number NAS1104–10D	
Element	**Meaning**
NAS110	Signifies the bolt is an NAS-designed bolt (hex head).
4	In the NAS number indicates the bolt is $^{1}/_{4}$-inch in diameter.
–10	Indicates the grip length is 0.625 inch.
D	Denotes the shank is drilled. (If the head were drilled, a letter H would be used.).

Consult TO 1–1A–8 for tables of the various types of bolts and an explanation of the code numbers used to identify the individual bolts.

Installation of aircraft bolts

When you must replace aircraft fasteners, always use duplicate fasteners when possible. If duplicate fasteners are unavailable, use extreme care and caution when making a fastener substitution. If fastener substitution is necessary, refer to the substitution charts in the aircraft specific TO or TO 1–1A–8 to assist you in making the proper selection.

The following are two important considerations you must keep in mind when you're installing aircraft bolts:

- Bolt and hole sizes.
- Torque.

Bolt and hole sizes

Just as the size of the hole for rivet installation is important, the size of the hole is also important for bolt installation. All holes drilled for bolts should produce a good mechanical fit. Bolt holes must *not* be oversized or elongated. A bolt in such a hole will *not* carry its shear load until the parts have yielded or deformed enough to allow the bearing surface of the oversized hole to come in contact with the bolt. Remember, bolts, unlike rivets, do *not* become swaged to fill up the holes. Therefore, when working with oversized or elongated holes, you may drill or ream the hole to accommodate an oversize diameter or the next-larger bolt provided that the larger hole size does *not weaken the part*. All bolt holes must be perpendicular to the work surface to provide full bearing surface for the bolt head and nut.

Torque

All nuts and bolts must be torqued to proper specifications to avoid stripping threads, cracking nuts, or snapping bolts, and to ensure all bolts carry their share of the load. This means that you use a torque wrench to measure the tightening or twisting force for every nut you install.

Nuts tightened without a torque wrench are seldom drawn up to the correct tightness. Instead, they are either overtightened because of the variables involved or undertorqued because of unsuspected friction. Such guesswork may result in structural failure. To avoid guesswork, tables for torquing nuts have been established for you to use when you're applying nuts. Follow the directions in the TOs for the specific aircraft you are working on.

024. Aircraft screws

Screws are generally made of lower strength materials than those used for bolts. They can be installed with loose-fitting threads, and the head shapes are made to engage a screwdriver or wrench. Some screws have a clearly defined grip or unthreaded part, while others are threaded along their entire length. Just like a bolt, screws are marked with a code for identification of physical characteristics. The same coding system is used to identify screws and bolts and is available in TO 1–1A–8.

Sometimes the screws can be difficult to remove with just a screwdriver and require using other tools. Before you attempt removing any screw, first check the screw slot or apex socket in the screw head. If the slot or socket is packed with dirt or paint, a screwdriver or apex won't seat properly and won't remove the screw. Often all that's needed is to remove the dirt or paint with a scribe or a similar sharp-pointed object first, and then use a screwdriver or speed handle and adapter to remove the screw. At other times, however, the problem may be more complex and require you to use other methods such as:

- Speed handle.
- Fastener removal tool.

- Fastener extractor.
- Drilling.

CAUTION: Using impact devices (such as a pneumatic hammer) can damage aircraft structure and skin. *Their use is not authorized.*

Speed handles

Many people have trouble removing screws simply because they don't use enough pressure on the screwdriver or speed handle. The more pressure applied to the screwdriver or speed handle, the harder it is for the tip of the tool to slip up and out of the screw slot or socket. You can apply much more pressure to a speed handle (fig. 4–3, view B) than to a screwdriver. Also, you can modify a speed handle so that you can apply even more pressure than normally possible. Most speed handles have a handle that's approximately $^{3}/_{4}$ inches in diameter, which isn't very comfortable to press on. By making a 2- to 3-inch diameter head (slightly convexed on the top surface) (fig. 4–3, view A) and pressing it onto the end of the handle, you can provide a palm-sized pressure pad that allows you to lean into it and use your body weight, as well as arm muscles, to apply the needed pressure.

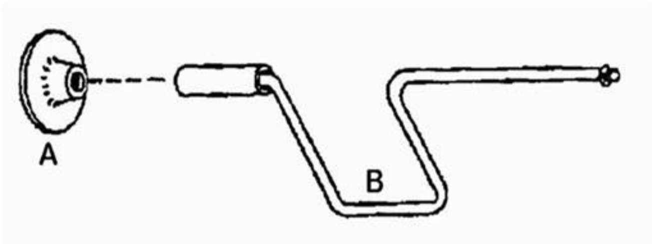


Figure 4–3. Speed handle and pressure pad.

Fastener removal tool

Figure 4–4 shows a typical screw removal tool, commonly referred to as a Johnson bar. This tool is primarily designed to use on flat surfaces. It is difficult to obtain the needed "in-line" alignment requirement on contoured surfaces. These tools apply higher end loads and removal torques while keeping the tool "in-line" with the fastener. The foot of the tool is held in place at an adjacent fastener location and the span is adjusted so that the (proper) bit is located directly over, and in line with, the fastener to be removed. End load is applied at the handle and torque is applied through the "T" handle.

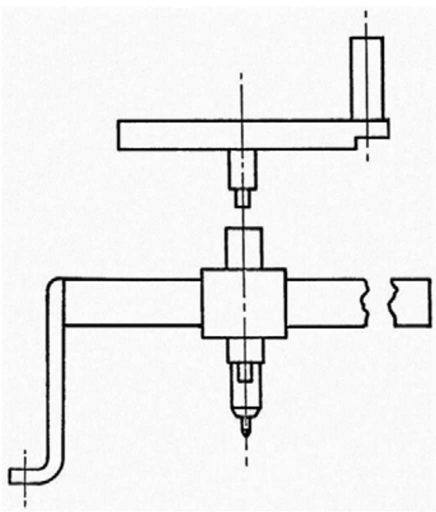


Figure 4–4. Fastener removal tool.

Fastener extractor

The fastener extractor, also called a screw extractor or E-Z Out, is another tool you can use to remove stuck screws. It is quick and fairly simple to use. To remove a stuck screw, drill a hole in the center of the screw and drive the extractor into the hole (fig. 4–5). Next, use an open-ended wrench or tap wrench to turn the extractor counter clockwise to remove the screw. Use a pair of clamp pliers to remove the screw from the extractor.

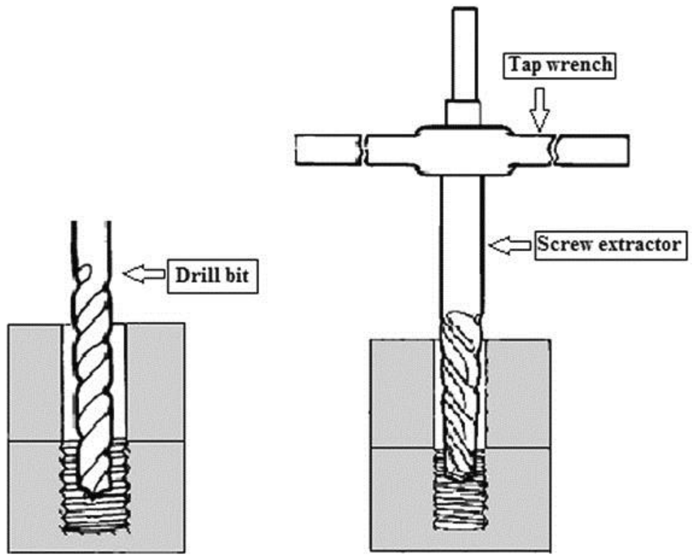


Figure 4–5. Fastener extractor.

Drilling

In some instances, you must resort to drilling to remove damaged or corroded screws. Drilling off the screw head requires drilling through the head and separating it from the body of the screw. It's most useful when removing an entire surface panel with several badly damaged screws. By drilling the heads off, you can remove the panel, leaving the body of the screws extending slightly above the parent threads. Normally, you can easily remove the body of the screw with a pair of clamp pliers. However, *ensure you remove all of the screws after you've drilled the heads off.* Don't stop after you've removed the panel—your job isn't complete until you've removed all of the screws.

025. Aircraft nuts

Often the nut and washer's importance to the total strength requirements of a bolted or screwed assembly is overlooked. Although they're small in size and may seem insignificant in comparison to other aircraft parts, you cannot overlook the importance of aircraft nut and washer hardware or treat them haphazardly. The safe and efficient operation of any aircraft can depend on correctly selecting and using aircraft nuts and washers.

Aircraft nut identification

Aircraft nuts come in many shapes, sizes, and different material compositions. Although a table listing the identification markings for nuts is included in TO 1–1A–8, aircraft nuts do not always have identification markings. When there are no markings, the part numbers are used to designate the type of nut. In addition to the part numbers, they can also be identified by the following factors:

- Characteristic metallic luster or color of the aluminum, brass, or nylon.
- Their construction.
- Thread size.

Types aircraft nuts

Aircraft nuts come in a variety of styles to match the application requirements for a given area of the aircraft. In the following paragraphs, we'll cover some of the nuts you'll use most often in your work.

Nutplates

Nutplates, also known as plate nuts, are installed in areas where it may be difficult or impossible to use a traditional nut. The nutplate assembly consists of a nut and a plate retainer that is attached to the structure using either a riveted or rivetless process. Nutplates come in two styles, floating and stationary. Floating type nuts use a retaining clip or the plate is formed to hold the nut element to provide a controlled amount of nut movement to compensate for subassembly misalignment. Stationary type nuts don't move once they are installed, so perfect alignment of all parts is an absolute *must*. Both types can be self-locking or non-self-locking, depending on the application.

Riveted nutplates

The following four basic types of riveted nutplates are used:

One lug—the attaching rivets are on the same end of the retaining plate (fig. 4–6).

Figure 4–6. One lug nutplate.

Two lug—the attaching rivets are on each end of the retaining plate (fig. 4–7).

Figure 4–7. Two lug nutplate.

Corner—the retaining plate is formed to allow a corner installation (fig. 4–8).

Figure 4–8. Corner nutplate.

Right angle—the retaining plate is formed so that the nut element is at a right angle to the structure (fig. 4–9).

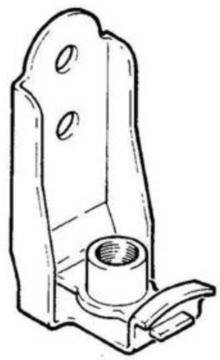


Figure 4–9. Right angle nutplate.

These nutplates are installed by riveting the nut plate to the backside of the structure. When you drill rivet holes for a first time installation, you can use one of two methods. One method is to use the nutplate itself as a template. Hold the nutplate in place with a cleco or screw on the front side of the structure. Then, using the rivet holes in the lug, drill the rivet holes. If you are not careful when installing the floating style nutplate, the nutplate will float off center during the drilling operation. A second and more convenient way to locate rivet holes is to use a nutplate hole finder (fig. 4–10).

Figure 4–10. Nutplate hole finder.

Rivetless nutplates

There are two primary ways of installing rivetless nutplates: by cold working and by adhesive bonding. Cold worked rivetless nutplates are gaining popularity in aircraft manufacture because their installation is relatively simple and cost effective. In addition, the installation of a rivetless nutplate eliminates the need for additional rivet holes, which are required for most nut plate installations.

Cold worked nutplates are fastened to the structure by radially expanding the nut plate barrel into the hole. The expansion creates high interference between the barrel and the structure that allows the nut plate to resist torque and pushout. In addition, cold expansion of the retainers into the hole imparts compressive residual stresses into the surrounding material, increasing the fatigue performance of the hole.

Another important feature of the rivetless nutplate process is the elimination of small rivet holes used for attaching conventional nut plates. These holes increase stress concentration, cause placement problems in short edge margin configurations, and are a known source of cracks. The following is the basic cold work nutplate installation sequence:

1. Slide an appropriate steel split sleeve over.
2. The correct size tapered mandrel insert.
3. Insert nutplate retainer into hole.

4. Insert mandrel through retainer.
5. Hold nosecap flush against structure.
6. Actuate trigger of the puller unit to withdraw mandrel.
7. Remove and discard sleeve.

Another method of installing a rivetless nutplate is through adhesive bonding. The basic premise of the bonded nutplate is that you use a structural adhesive to bond the nutplate to the structure instead of riveting it. Bonded nutplates are popular on both composite and metallic structures because, like the cold work nutplate, they eliminate the need to drill small diameter rivet holes needed to attach a traditional nutplate.

A popular type of bonded nutplate is the Click Bond nutplate, which is used on several aircraft including the F–22. Click Bond has made the installation of adhesive bonded nutplates easy by providing installation kits that contain everything you need to install their nut plates. The kits include solvent for cleaning, an abrasive mat for abrading the surface, adhesive for bonding the nutplate, the nutplate assembly and a disposable elastic fixture to hold the nutplate in place while the adhesive cures. Using this kit eliminates the possibility of improper installation due to the lack of proper tools and materials.

The basic Click Bond nutplate (fig. 4–11) installation sequence is as follows:

1. Use an approved cleaning solvent to remove any impurities on the surface.
2. Abrade the surface of the structure to accept bonding.
3. Solvent clean the area again and wipe with a clean dry cloth.
4. Mix adhesive and apply to the nutplate assembly.
5. Pull the disposable elastic fixture though the existing hole for the nutplate.
6. Allow the adhesive to cure; when fully cured, remove the disposable elastic fixture.

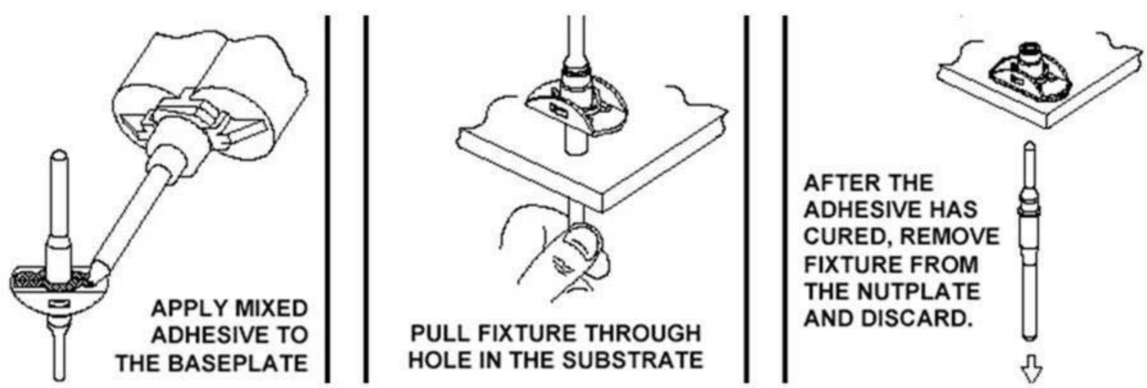


Figure 4–11. Clickbond installation.

Removal procedures are extremely important with Click Bond nutplates. Care must be taken because heat is used to soften the adhesive, which holds the nutplate on; the heat could cause damage to the parent structure or surrounding bonded structures in several ways. If you are not careful, you can cause the loss of temper and strength in metallic structures, disbonds and delaminations in composite structures, blistering and loss of bond strength of protective coatings, and failure of adjacent temperature sensitive components. Therefore, all substrate materials must be protected from excessive temperatures and aircraft specific technical manuals must be followed.

Removal procedures for the Click Bond nutplate are as follows:

1. Determine the correct temperature and dwell time using the aircraft specific technical manual.
2. Select the appropriate heat gun.

3. Verify temperature of heat gun using a digital thermometer.
4. If heat sensitive components are present, cut silicone rubber mask to protect those components.
5. Apply heat at as near to a right angle as possible. This will cause the fastest heating of the nutplate and minimize heat transfer to the parent structure. You position the tip of the gun approximately 1 inch above the base plate and airstream centered on the nutplate. Dwell heat for the minimum time as specified in the technical manual.
6. After correct dwell time is achieved, promptly grasp the nutplate with a pair of pliers and remove.
7. Remove residual adhesive using a PLASTIC scraper; the use of heat may be needed to further soften the remaining adhesive.
8. Inspect the local area for any damage to the structure or surrounding components.

Channel

Use channel (gang channel) in applications requiring anchored nuts equally spaced around openings (i.e., access and inspection doors, and removable leading edges). Straight or curved channel nut strips offer a wide range of nut spacings and provide a multiple nut unit that has all the advantages of floating type nuts. They're usually self-locking with different types of nut spacings and grip lengths. Figure 4–12 shows an example of a U-shaped gang channel.

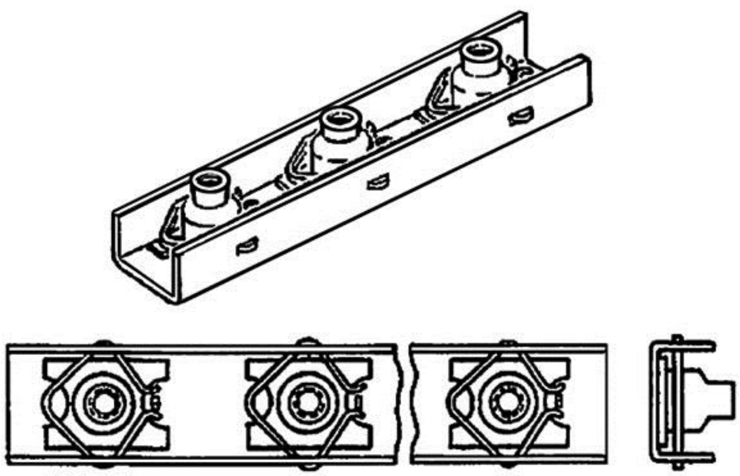


Figure 4–12. Gang channel nut.

Installation consists of riveting the assembly to the structure. In some cases, individual nuts can be replaced by spreading the channel slightly, snapping out the bad nut, and replacing it with a new one before squeezing the channel back into position. You must take extreme care not to crack or distort the channel or surrounding structure. Gang channel nutplates are installed in regular drilled holes.

Fatigue failure

Fatigue failure accounts for over 75 percent of all fastener problems. Fatigue breaks are caused by insufficient tightening fasteners and lack of proper preload or clamping force. This results in movement between the parts of the assembly in use, and in bending back and forth or cyclic stressing of the screw. Eventually, a tiny crack forms at the high-stress points; as the vibration, movement, and bending are continued, a second crack, then a third, fourth, and so on, are formed. These tiny cracks occur progressively as the bending takes place, causing the part to become weaker until it can no longer support the load. At this point, the screw or bolt breaks from tension or pulls apart.

Torque

In addition to fatigue failure, loose assemblies often spell disaster to individuals and equipment. Neglecting to apply or maintain enough of a preload can cause early fatigue in fasteners. Using a strong bolt isn't enough. *You achieve a proper safety factor only when you tighten the bolt or nut to the correct torque specifications.* By following the proper torque specifications, you can reduce the tendency of parts to creep or shift. In addition, you can greatly reduce the chance of a nut backing off or loosening in service.

NOTE: Always use torque values included in aircraft or equipment specific TOs, not the values listed in TO 1–1A–8.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

023. Aircraft bolts

1. Why should the grip length of a bolt be a few thousandths of an inch shorter than the material thickness?

2. What factors do you use to determine the length of a bolt?

3. What are the two methods for identifying bolts?

4. Where do you look if you cannot identify the code marked on the head of a bolt?

5. What kind of information does the part number designation give you about a bolt?

6. How can you avoid stripping the threads of a bolt during installation?

024. Aircraft screws

1. How can you use a scribe to aid in removing screws?

2. How can you remove stuck screws?

3. What method is not authorized for screw removal? Why?

4. How can you increase the effectiveness of the standard speed handle?

5. Which screw removal tool is primarily designed for use on *flat surfaces*?

6. When using a fastener extractor, what is the *first step* in removing a screw?

025. Aircraft nuts

1. How can you identify a nut that has no identification markings?

2. Where are nutplates used?

3. What are two primary ways of installing rivetless nutplates?

4. How are cold worked nutplates fastened to the aircraft structure?

5. Why is the use of bonded nutplates popular on both composite and metallic structures?

6. How can you help to prevent fatigue failure?

7. How can you reduce the tendency of parts to creep or shift when installing bolts?

4–2. Open Area Fasteners

Installing certain fasteners requires access to both sides of the structure being fastened together. The results from using these fasteners are directly related to how well you prepare the parts being fastened. Hole preparation, proper selection of fastener grip length and diameter, and correct installation procedures are some of the critical points we'll discuss in this section. More specifically, we'll look at the characteristics and working procedures for these open area fasteners:

- Hi-shear rivets.
- Hi-lok and high-fatigue fasteners.
- Lock bolts.
- Taper-lok fasteners.
- Solid rivets.

026. Hi-lok fasteners

Hi-lok fasteners are held in place by using a collar that is attached to the pin by threads. This eliminates the need for pneumatic hammers, bucking bars, and special pneumatic pull guns. In this lesson, we'll discuss the main features of hi-lok fasteners, focusing on characteristics, identification, preinstallation factors, installation procedures, inspection procedures, and removal procedures.

Characteristics

Hi-lok fasteners (fig. 4–13) are basically threaded fasteners that combine the best features of rivets and bolts. They have a threaded pin and a threaded collar. The threaded pin is designed in two basic head styles:

- Protruding.
- Flush.

Hi-lok fasteners are available for shear and tension applications. The threaded end of the hi-lok pin has a hexagonal recess; when engaged with an Allen wrench, this recess prevents the hi-lok pin from rotating while the collar is being installed. At the opposite end of the collar is a wrenching device that's torqued by the driving tool until it shears off during installation.

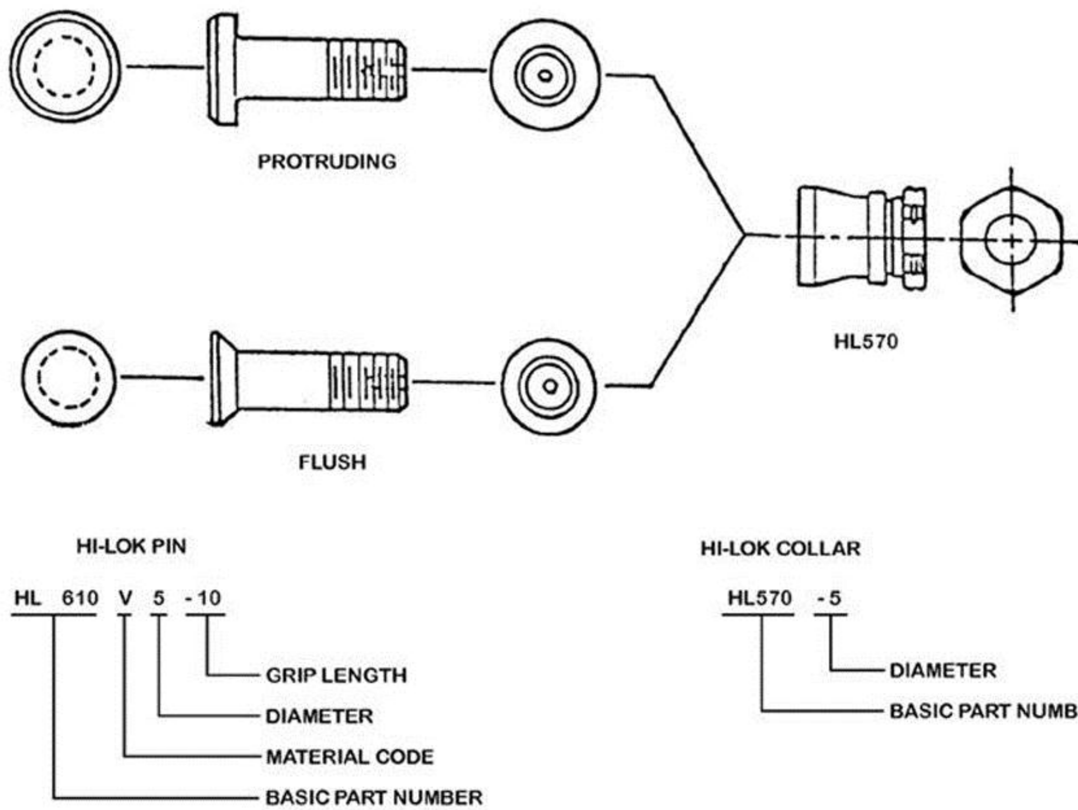


Figure 4–13. Hi-lok fasteners.

Identification

Hi-loks are available in titanium and CRES. Letters and numbers stamped on the head of a hi-lok pin show the basic hi-lok pin type and the material composition. Specific aircraft TOs list head markings and their meanings. Hi-lok collar composition materials are identified by the part number, which also identifies the type, style, diameter, and grip range of the fastener. The lower part of figure 4–13 shows the breakdown of the part numbers for the hi-lok pin and collar. A single part number is also used for the pin and collar as shown in the following table.

Part Number HL 18-PB–8–1	
HL	Designation for hi-lok fasteners.
18	Basic pin part number (protruding head).
-PB	Pin finish code.
–8	The diameter of the pin measured in $^{1}/_{32}$ inch increments ($^{8}/_{32}$ or $^{1}/_{4}$ inch diameter).
–12	The grip length of the pin measured in $^{1}/_{16}$ inch increments ($^{12}/_{16}$ or $^{3}/_{4}$ inch grip length).

Some hi-lok collar types require washers to be attached to the bottom section of the collar. When a washer is to be attached, the letter W is added to the part number of the collar (e.g., HL70 indicates *no washer*; in contrast, HL70W indicates a *washer is attached*).

Preinstallation factors

Before you can install hi-lok fasteners, you must consider certain factors to ensure the fastener is installed correctly. The following are the key factors to consider:

- Hardware selection.
- Fastener spacing allowances.
- Hole preparation procedures.

The following table takes a closer look at each of these factors.

Hi-lok and Hi-fatigue Installation Factors	
Factor	**Description**
Hardware selection	The very first step in selecting a hi-lok fastener for installation is to determine the diameter and grip length required, which are directly related to the material thickness of the parts being fastened. Consult the aircraft specific TO or TO 1–1A–8 for protrusion limits, specific diameter, and grip length requirements.
Fastener spacing	When repairs require installing a hi-lok fastener, follow the guidelines given in the applicable TO. Spacing allowance depends on the head style of the hi-lok fastener being installed.
Hole preparation	Holes prepared for hi-lok fasteners are drilled to produce an interference fit. Twist drill sizes and hole-clearance requirements are contained in specific aircraft TOs. After drilling, deburr the edge of the hole to permit the head to be properly seated in the hole and, if required, countersink in accordance withthe aircraft specific TO or TO 1–1A–8.

Installation procedures

Tools for installing hi-lok fasteners are available in hand- and power-operated styles. Hand-operated installation tools usually have a ratchet wrench (with a socket that matches the outside diameter of the locking collar) and an Allen wrench. The ratchet wrench must have a hole that allows the Allen wrench to be inserted (fig. 4–14). The Allen wrench is extended through the socket into the recess in the end of the hi-lok pin. This setup allows the Allen wrench to hold the pin in place while the collar is torqued on the pin. The procedure is the same for power-operated tools; the difference is the fastener installation is much faster.

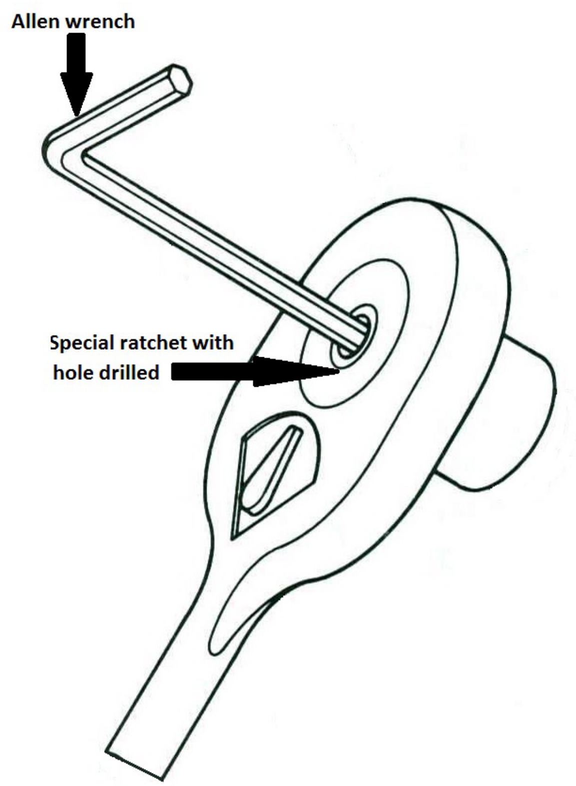


Figure 4–14. Hi-lok ratchet.

A key factor in installing hi-lok fasteners is the hole fit. When installing hi-loks in interference fit holes, drive the pin through the hole until the head is seated before you install the collar. You can drive pins by tapping the head with a plastic mallet or by driving with a light rivet gun. *Under no circumstances should hi-lok pins be turned or torqued into the interference holes.*

Installing Hi-lok Fasteners Refer to figure 4–15 for these installation steps	
Step	**Action**
1	Once the pin is inserted, manually screw the collar on the pin. A minimum of two threads (three-quarters [$^3/_4$] of a turn) must be engaged before torque is applied to the collar.
2	Insert the hex wrench tip into the pin hex recess.
3	Firmly press the installation tool against the collar and operate the power drive or ratchet wrench until the collar's wrenching device has been torqued off.
4	Refer to Step 4 in figure 4–15 showing an installed hi-lok fastener.

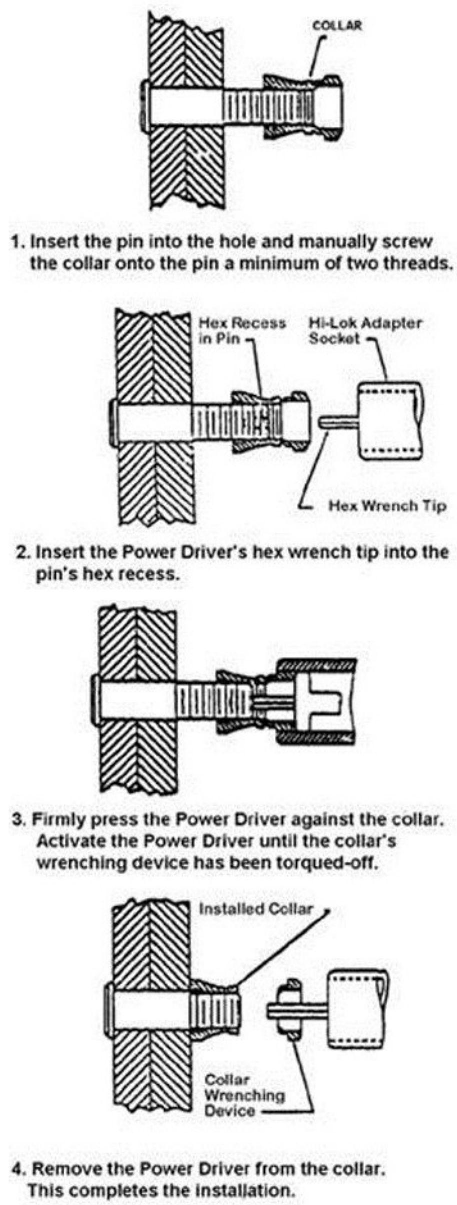


Figure 4–15. Hi-lok installation.

When you install hi-lok pins in interference fit holes, you don’t need an Allen wrench to keep the pin from turning because the pin fits tightly. After installing the hi-lok fasteners, inspect them to ensure they meet TO specifications.

Inspection procedures

When you inspect the manufactured head of hi-lok fasteners, check for surface contact, countersink fit, and aerodynamic smoothness requirements. The amount of gap permitted between the hi-lok fastener’s head and the surface depends on the diameter of the fastener. Flush-head fasteners installed on aerodynamic surfaces must conform to the contour requirement of the aircraft.

Inspecting the back side involves checking the pin protrusion and visually checking the physical features of the locking collar. The collar should be free of cracks. Replace any collars that have wrench marks, cuts, or show evidence of being reinstalled or retightened. Replace any loose hi-lok fasteners that can be moved or rotated with your fingers.

Removal procedures

You can remove hi-lok fasteners with standard hand tools in the same way you remove a nut from a bolt. By holding the pin with an Allen wrench, you can use pliers to remove the collar. When hi-lok fasteners have been pressed or tapped into interference fit holes, the fit is sufficiently tight to grip the pin and keep it from rotating; as a result, you do not need the Allen wrench when removing these. Once the locking collar is removed, punch out the pin.

NOTE: Use extreme care in removing fasteners to prevent damage to the hole and the surrounding structure.

027. Characteristics and working procedures for Eddie-Bolt® fasteners

The Eddie-Bolt® was designed in the late 1990's and is now used on the F–22 and F–35 aircraft. It is a high-performance aerospace fastening system, consisting of the Eddie-Pin (fig. 4–16) and the Eddie-Nut (fig. 4–17), which at first glance resemble a hi-lok fastener. The Eddie-Pin has five flutes in the *upper* portion of the threaded area (fig. 4–18) which *allow* a positive mechanical lock with the Eddie-Nut during installation.

Figure 4–16. Eddie-Pin. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Figure 4–17. Eddie-Nut. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Figure 4–18. Eddie-Pin flutes.

Depending on the application and part number, the Eddie-Bolt® 2 uses a spline-lok recess (fig. 4–19) or a hexagon recess as in the hi-lok fastener. The spline-lok feature *allows* for higher torque applications without the tooling slipping out of the fastener. The three external lobes on the Eddie-Nut serve as driving lands for the Delta-Rad driver. The specially designed driver has an internal three-sided shape (fig. 4–20) which fits over the three external lobes of the Eddie-Nut.

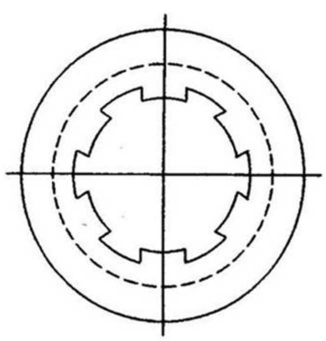


Figure 4–19. Spline-lok recess shape.

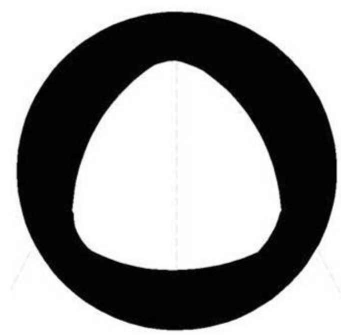


Figure 4–20. Internal three-sided shape of delta-rad driver.

When torque is applied and the automatic preload of the nut is obtained, the nut will automatically deform into and across the flutes of the Eddie-Pin. This deformation creates a positive mechanical lock and completes the installation free from foreign object debris (FOD).

Eddie-Bolt® fastener pins come in lengths graduated in $^1/_{16}$-inch increments. The material being fastened can vary $^1/_{16}$-inch *without* changing pin length; the counterbore within the collar automatically adjusts for variations of material thickness. To determine the correct length, you can use a grip gage. The grip gage (fig. 4–21) for the Eddie-Pin shows both inch and metric scale. The tapered probe of the grip gage is inserted through the prepared hole and hooked on the backside of the material. The scale is read to the nearest $^1/_{16}$-inch grip increment at the work surface. If sheet line falls between values on grip gage, round up to the next grip.

Figure 4–21. Eddie-Bolt® grip gage. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Head markings and part numbers

Eddie-Bolt®s are identified by a standard part number sequence. Refer to applicable technical material for specific part number identification. Figure 4–22 is an example of an Eddie-Pin with a spline-loc recess part number.

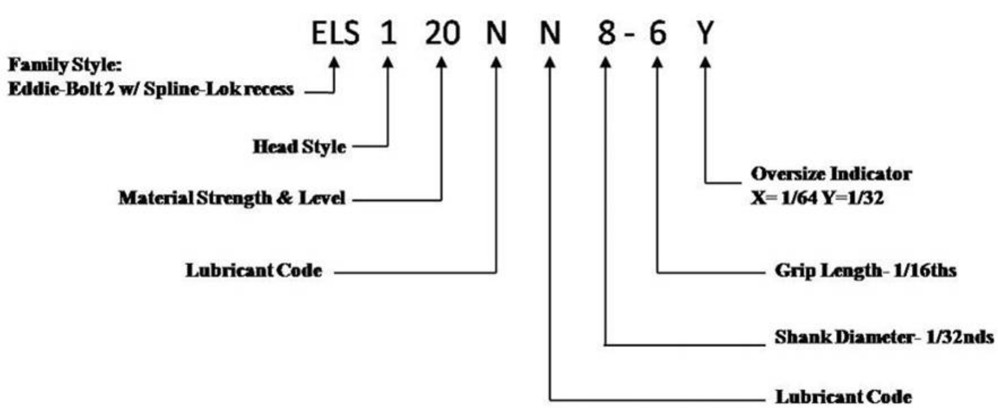


Figure 4–22. Eddie-Pin part number. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Hole preparation

Clean, round holes within tolerance and with minimal burrs are fundamental for good joint performance and durability. Eddie-Bolts® may be installed in the following four different *recommended* hole types, depending on application:

- Clearance fit—whenever steel, titanium, or composites are present in the material stack-up.
- Close ream fit—for net to minimal clearance conditions.
- Transition fit—in an aluminum structure where a close to slight interference fit is needed.
- Interference fit—in an aluminum structure, to provide improved load transfer and improved fatigue performance.

Installation

Installing the Eddie-Bolt® is an easy process. Installation tooling includes a choice of hand or power equipment. Common to all tooling options is an internal three-sided shape Delta-Rad driver for engagement on the three lobes of the Eddie-Nut.

Hand tool options

Hand tool options include the following:

- Standard non-ratchet wrench.
- Delta-Rad drive socket.
- Roller wrench which applies torque in limited or large arc sweeps.

Power tool options

Power tool options include the following:

- Straight pistol grip tool.
- Offset pistol grip tool.
- 17º offset ratchet tool with indexing head.
- 20º offset ratchet tool.
- Automatic Nut Tool (ANT) which provides a built-in feed mechanism specially designed for Eddie-Nuts.

Eddie-Bolt® installation

Follow these steps to install Eddie-Bolts®:

1. Ensure that you do not pull the pin into the hole using the nut when installing the Eddie-Pin.
2. Ensure the pin is clean of any excess sealant. Excess sealant on the threads of the pin can contaminate installation tooling and should be wiped off prior to engaging the tool. Excessive amounts of sealant may also interfere with proper installation of the nut. Small traces of sealant remaining in the root of the threads after wiping will not affect the installation of the nut and need not be removed.
3. Hand start the nut onto the pin at least $^3/_4$ of a turn. The nut may be spun down until it is seated on the structure.
4. Use the proper tooling. Tools with a center spline-lok key, or a hex key, shall be used to keep the pin from rotating when installed in clearance fit, close ream, or transition fit holes.
5. Place the Delta-Rad installation tool firmly down over the nut ensuring that the key is engaged in the recess of the pin. The installation tool must be engaged over the lobes of the nut and bottomed out on the base of the nut.
6. Maintain perpendicularity between the drive tool and the fastener.
7. Operate tooling as necessary to apply correct amount of torque to the fastener.
8. Remove and replace the pin and nut if the pin spins during the nut installation.
9. When the installation tool becomes free running on the nut, the lobes have been swaged into and across the flutes of the pin and the installation is complete.

Inspection after installation

If swaging of the nut is incomplete, reswaging is *not* permitted. If a nut is found incompletely swaged, remove and replace both the nut and pin. It is not required to have the chamfer of the pin protruding through the nut. The end of the pin may be flush with the top of the nut provided pin protrusion is acceptable.

Countersink hole concentricity and angularity are critical. An Eddie-Pin can typically absorb up to 2º of angular misalignment (fig. 4–23). Ideally, the head should contact the countersink to prevent a

.002-inch feeler gage (fig. 4–24) from entering. The limiting condition is that the feeler gage must wedge before contacting the shank of the Eddie-Pin.

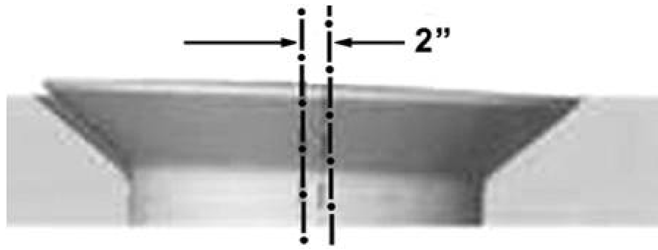


Figure 4–23. Angular misalignment. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Figure 4–24. .002-inch feeler gage. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

To inspect for proper nut installation, you will use a specialty gage to confirm that the correct deformation has occurred. All lobes of the installed nut must be sufficiently deformed or swaged equally along their full length to allow the inspection gage to pass completely over the lobe area. You can use either the paddle (fig. 4–25) or the thimble (fig. 4–26) type gages to confirm the correct nut profile after installation.

Figure 4–25. Paddle gage. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

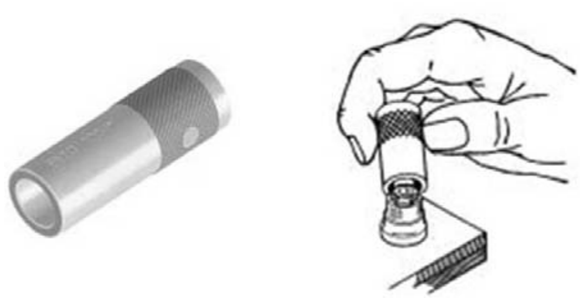


Figure 4–26. Thimble gage. (Reproduced by permission of Alcoa Global Fasteners, Inc.)

Removal

Eddie-Bolt®s can be removed by specially designed tools in a manner similar to removing a nut and a bolt. Use a spline type key in the spline-lok recess to prevent the pin from rotating while the collar is being unscrewed. Removed Eddie-Nuts shall not be reused and Eddie-Pins must be replaced before installing a new Eddie-Nut. Conventional hex or similar nuts cannot be used on Eddie-Pins.

028. Solid rivets

Solid or one piece rivets are the most common type fastener used in aircraft assembly. When driven, the shank swells to fill the fastener hole and a flat collar shop head is formed. Solid rivets are available in either the protruding or flush 100° countersunk head styles. When making a repair, it is important to select the proper rivet to maintain structural integrity. In this lesson, we'll discuss identification, preinstallation considerations, installing, inspecting, and removing solid rivets.

Identification

Each rivet can be identified with respect to head style, type of material from which the rivet is made, and its size. Markings on the rivet's head indicate the type of material from which the rivet is made. Figure 4–27 shows the rivet head style with its basic code number for corresponding materials, its material code, and its identifying head markings. A complete listing of rivets can be found in the aircraft specific TO or TO 1–1A–8. The size of the rivet is measured in increments of $^1/_{32}$ of an inch for the diameter and $^1/_{16}$-inch increments for the length.

RIVET STYLE	BASIC NUMBER	MATERIAL	MATERIAL CODE	HEAD MARKING	TEMPERATURE LIMITATION
100 DEGREE COUNTER SINK	3M268	5056 ALUMINUM ALLOY	B	RAISED CROSS	250°
		2117 ALUMINUM ALLOY	AD	DIMPLE	250°
	MS20426	5056 ALUMINUM ALLOY	B	RAISED CROSS	250°
		2117 ALUMINUM ALLOY	AD	DIMPLE	250°
		7050 ALUMINUM ALLOY	E	RAISED RING	250°
		TI-45Cb TITANIUM COLUMBIAN ALLOY	T	DIAMOND INDENTED	600°
	NAS1200	STEEL HIGH TEMPERATURE CORROSION RESISTANT	A-286	ONE RAISED TEAT	1200°
		MONEL	M	TWO RAISED OR RECESSED MARKS	800°
UNIVERSAL HEAD	MS20470	5056 ALUMINUM ALLOY	B	RAISED CROSS	250°
		2117 ALUMINUM ALLOY	AD	DIMPLE	250°
		7050 ALUMINUM ALLOY	E	RAISED RING	250°
		TI-45Cb TITANIUM COLUMBIAN ALLOY	U	RAISED DIAMOND	600°
	MS20615	MONEL	M	TWO DIMPLES	900°

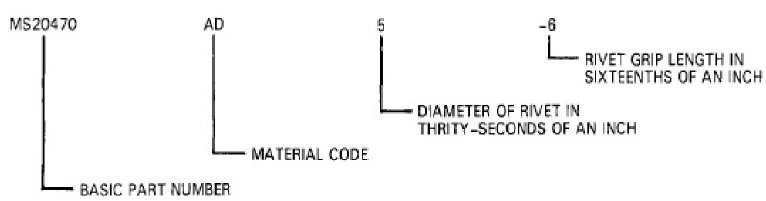


Figure 4–27. Solid fastener identification.

Preinstallation

When determining the total length of a rivet for installation, you need to know the combined thickness of the materials to be joined. This measurement is known as *grip length* (fig. 4–28, view B). The amount (length) of rivet material required to form a *shop head* is $1\frac{1}{2}$ times the diameter of a rivet shank (fig. 4–28, view C). The total length of the rivet (fig. 4–28, view A) should equal the grip length plus the amount of rivet material necessary to form a proper shop head. Figure 4–28, view D, shows properly installed rivets.

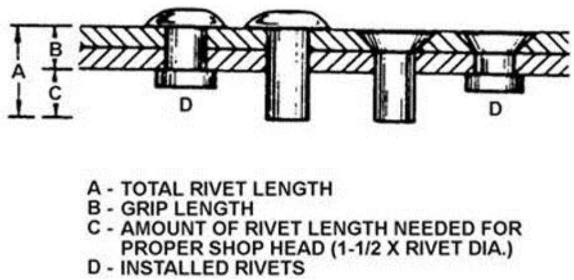


Figure 4–28. Determining the length of rivets.

You must also consider the area's material thickness. Excessive riveting pressure causes the repair area of thin material to sink inward. When you're riveting thin materials, it is important to properly adjust the rivet gun for the diameter rivets being installed and use the correct weight bucking bar.

Installation

There are several different methods of installing rivets. You can use a pneumatic rivet gun with a bucking bar, either pneumatic or hand rivet squeezers, or you can use a ball peen hammer with a rivet set and drive the rivet by hand. Regardless of what method you use, the preinstallation steps described in the following table are required.

Rivet Preinstallation Steps	
Step	**Action**
1	Secure the parts to be joined firmly in position with skin fasteners (also called clecos) to prevent slipping during the riveting operations.
2	Select correct size rivet for thickness of material to be joined.
3	Select rivet set for type rivet to be installed.
4	Install rivets using one of the approved methods.

The sequence of rivet installation is also important. For example, when installing rivets in any repairs, spot the first few rivets throughout the rivet layout. This keeps the repair parts from shifting during the riveting process. Starting at one side of a repair and working towards the other side causes the rivet holes to be misaligned. This is especially true when repairing a curved surface.

When replacing a skin panel, start riveting in the center and work towards the sides. Once the center area has been riveted, alternate the remaining rivets from side to side and top to bottom, working outwards. It's recommended you skip a few rivets in a row, install a rivet, and then come back to the ones you've passed over. This process keeps the metal from shifting, helps maintain the proper contour, and reduces the possibility of misaligned holes at the ends of the panel.

Pneumatic

The most common and most satisfactory method of riveting is completed using pneumatic rivet guns with a separate bucking bar (fig. 4–29). These guns have interchangeable rivet sets in different sizes and shapes to fit the type and location of the rivet. Insert the proper set in the gun and apply the gun to the rivet head. Pressure is applied in a series of rapid strokes which upset the shank end against the bucking bar. The gun and bucking bar must be held at right angles to the work at all times, and sufficient pressure exerted to keep the tool from jumping off the rivet. Avoid excessive pressure because it may result in dented surfaces.

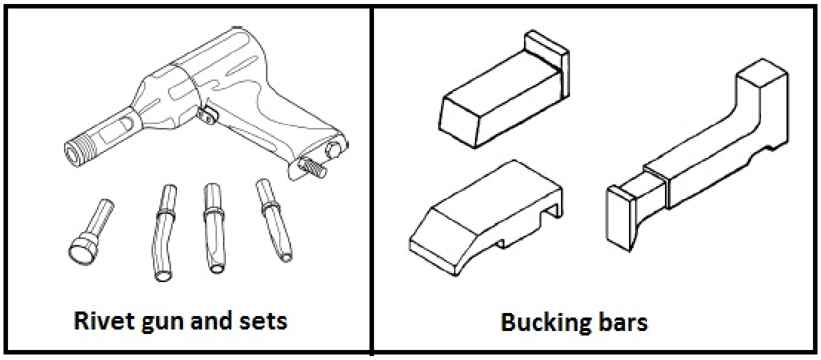


Figure 4–29. Pneumatic riveting tools.

Squeeze

The use of squeeze riveters is limited. They can only be used over the edge of sheets. The two types of squeeze riveters—hand and pneumatic (fig. 4–30)—are basically the same; the difference is in the actuating power. One jaw of the squeezer is stationary and is placed against the manufactured head, while the movable jaw upsets the shank. However, during some operations it may be necessary to reverse the sets, placing the manufactured head set on the movable jaw.

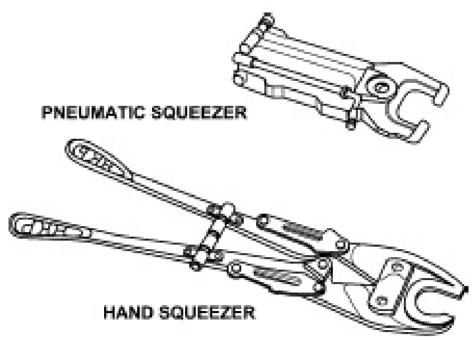


Figure 4–30. Rivet squeezers.

Hand

Hand riveting should be done only when power riveting is not possible due to lack of facilities or inaccessibility of the work area. Hand riveting is accomplished by placing the head of the rivet into a rivet set that has been attached to a bucking bar; ensure the bucking bar and the set are held square to the work. After the rivet head is secure in the set, drive the shank with a 12- to 16-ounce ballpeen hammer. To ensure good results, use as few hammer strokes as possible.

Inspection

The height of the shop head of a rivet should be $^1/_2$ of the shank's diameter, and the diameter of the shop head should be $1^1/_2$ times the shank's diameter. If there's any appreciable deviation from this rule, remove the rivet and replace it. The condition of the shop head is also important to maintain the strength. The head should be uniform in size and evenly bucked with a smooth bucking bar. If shop heads feel rough or sharp on the edges, they were probably driven too slowly and became work hardened before the riveting was complete. Because these rivets do not have maximum strength, remove and replace them. If the rivet set has damaged the manufactured head, the strength cannot be considered adequate for stressed areas. Figure 4–31 shows some conditions to look for when inspecting. Always refer to your aircraft specific TO or TO 1–1A–8 for a complete listing of acceptable and unacceptable conditions.

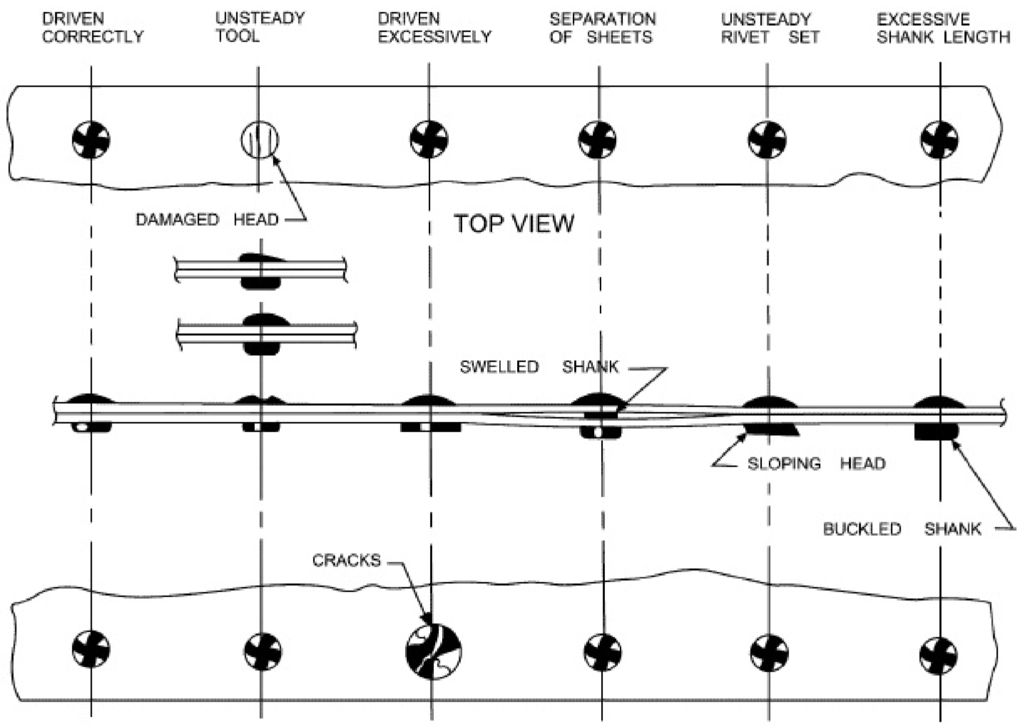


Figure 4–31. Correctly and incorrectly driven rivets.

Microshaving

When smoothness of the surface (such as skin) requires all countersunk rivets be driven within a specific tolerance, use a microshaver. First, adjust the microshaver by pressing the tool firmly against a flat piece of scrap metal while the cutter is turning. If the cutter marks the surface, readjust and try again. Keep adjusting until the cutter no longer marks the surface. The correct adjustment will bring the cutter to within .002 inch of the metal. Once you have properly adjusted the microshaver, center the nose piece over the rivet and press firmly; if the surface is curved, you may have to rock the microshaver lightly to completely trim the rivet head. When correctly adjusted, the shaver will leave a small round dot about the size of a pinhead on the microshaved rivet.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

026. Hi-lok fasteners

1. What are the two basic head styles of a hi-lok fastener?

2. What is the part number designation for hi-lok fasteners?

3. When installing hi-lok fasteners, what tools are required?

4. How do you install the collar on the pin?

5. What three conditions should you check when you are inspecting the manufactured head of installed hi-lok fasteners?

6. What corrective action do you take when you find a collar with wrench marks during post installation inspection?

7. When is an Allen wrench not needed to hold the hi-lok pin during removal?

027. Characteristics and working procedures for Eddie-Bolt® fasteners

1. What two components make up the Eddie-Bolt® fastening system?

2. What is the purpose of the five flutes on the Eddie-Pin?

3. What is the purpose of the spline-lok feature?

4. What happens when the automatic preload value is reached on the Eddie-Nut?

5. In what length increments do Eddie-Bolts® fastener pins come?

6. What feature of the Eddie-Bolt® fastener system automatically adjusts for variations in material thickness?

7. What type of hole is recommended if you are fastening together titanium with an Eddie-Bolt® fastener?

8. What is used to keep the Eddie-Bolt® fastener pin from rotating in the hole during installation?

9. How can you tell when the installation of an Eddie-Bolt® fastener is complete?

10. While inspecting Eddie-Bolt® fastener installation, what *must* you do if you find a nut that is not completely swaged?

11. When using an inspection gage to verify proper installation, how can you tell if the Eddie-Nut has been installed properly?

028. Solid rivets

1. How can you identify the type of material from which a rivet is made?

2. What should you do when riveting thin material to prevent the repair area from sinking inward?

3. How do you prevent parts from *slipping* during riveting operations?

4. What rivet installation sequence is *not* recommended?

5. What do you do if you find a rivet shop head that is ¼ of the shank's diameter?

6. How do you adjust the microshaver?

4–3. Blind Area Fasteners

Just as there are blind rivets to use in place of solid-shank rivets, there are blind fasteners to use in place of the "open" area fasteners. Blind area fasteners are available in various styles and types. Our discussions will focus on the characteristics and working procedures for the Jo-bolt, mechanical-lock blind bolt, mechanical-lock blind rivet, Composi-lok, and pull through rivets.

If you need information for other types of blind area fasteners not covered, consult TO 1–1A–8 and the specific TO for the aircraft being repaired.

Since these are blind fasteners, give special attention to the selection factors, hole preparation, and installation procedures.

029. Jo-bolt fasteners

The Jo-bolt fastener is a high-strength, blind structural fastener used on difficult riveting jobs when access to one side of the work is impossible. In this lesson, we'll present detailed discussions on the characteristics and working procedures for Jo-bolt fasteners. We'll cover characteristics, identification, preinstallation procedures, installation procedures, inspection, and removal procedures.

Characteristics

A Jo-bolt is also known and referred to as a Visu-Lok. The fastener consists of three parts: an aluminum alloy or alloy steel nut, a threaded alloy steel bolt, and a corrosion resistant steel sleeve, which are factory preassembled. As the Jo-Bolt is installed, the bolt is turned while the nut is held, causing the sleeve to expand over the end of the nut, forming the blind head and clamping against the work. When driving is complete, the bolt wrenching end breaks off from flush to below the head. Head styles available for Jo-Bolts are the 100° flush head, hexagon protruding head, and the 100° flush millable head. The high shear and tension strength of this fastener make it suitable for use in areas of high stress when some of the other blind fasteners aren't practical.

Identification

Jo-bolts are identified by a basic part number that shows the type and style of the Jo-bolt, nominal diameter, and grip range. Figure 4–32 breaks down an NAS part number for a Jo-bolt.

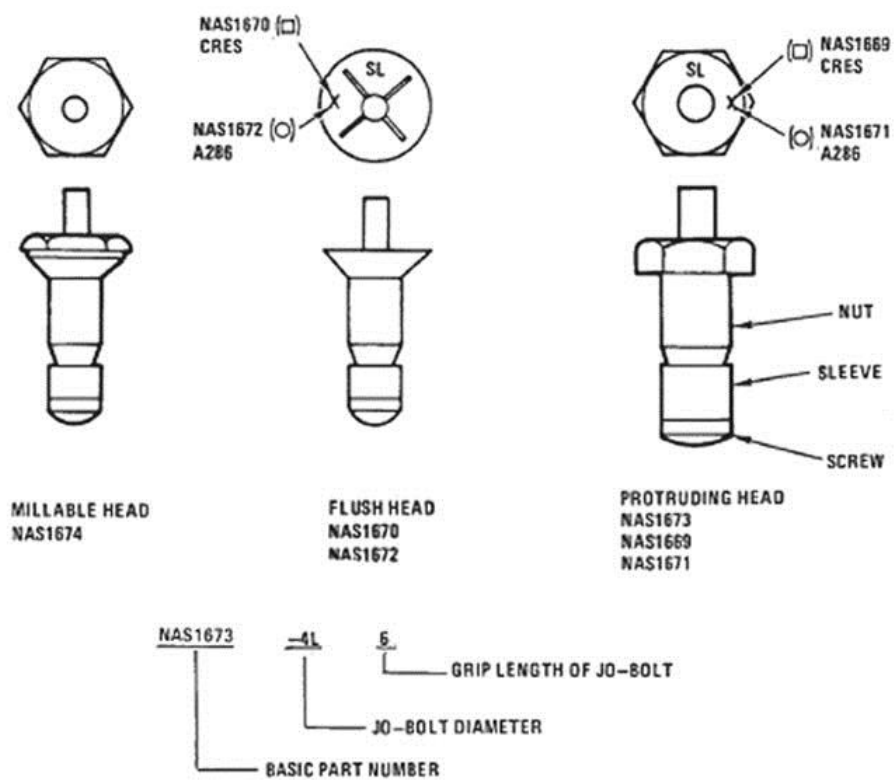


Figure 4–32. Jo-bolt identification.

Preinstallation procedures

The proper installation of Jo-bolt fasteners requires that you pay extra attention to two factors in the preinstallation stage: grip length and hole preparation. These are both covered in the following table.

<table>
<tr><th colspan="2">Jo-bolt Preinstallation Factors</th></tr>
<tr><th>Factor</th><th>Description</th></tr>
<tr><td>Grip length</td><td>When you install replacement Jo-bolts in previously drilled holes, figure the required grip length by using a hook scale to measure the thickness of the parts being fastened. In work situations where you know the thickness of the part being fastened, all you need to do is consult a grip-length table located in the aircraft specific TO or TO 1–1A–8. Minimum and maximum grip range is usually given.

Figure 4–33 shows the correct procedures to use when you're measuring both head styles of Jo-bolts. Measure the full length of the Jo-bolt to the nearest $^1/_{16}$ inch.

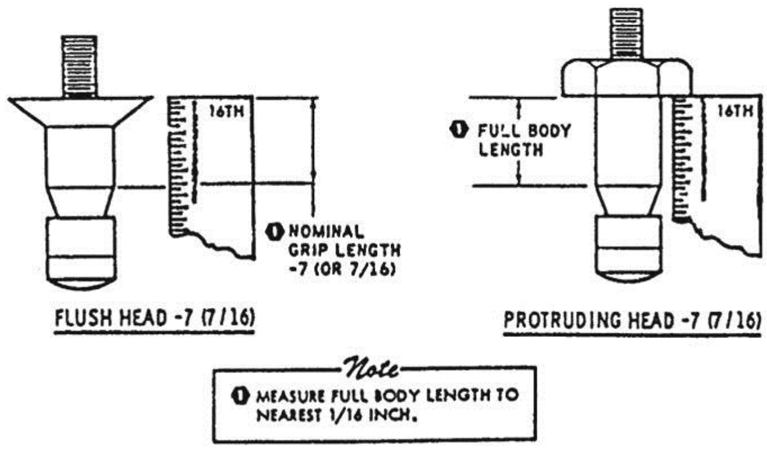


Figure 4–33. Jo-bolt measuring procedures.</td></tr>
<tr><td>Hole preparation</td><td>Close-fit holes are needed for proper Jo-bolt installation.

In addition, the holes should be straight and perpendicular to the surface against which the manufactured head will bear.

Also, holes should be round and all burrs must be removed.

For best results, drill holes for Jo-bolts undersize, and then bring them to final size by reaming.</td></tr>
</table>

Installation procedures

Once you have the holes prepared, you're ready to install the Jo-bolts. You can do this by hand or with pneumatically operated installation tools. The most important thing to remember when using these tools is the *nose and wrench adapter must be properly matched to the Jo-bolt* being used. The nose adapter must match the head style and diameter of the Jo-bolt, and the wrench adapter must match the diameter of the bolt stem.

The following table lists the basic installation procedures for the jo-bolt. For more detailed installation information, refer to your aircraft TO or TO 1–1A–8.

<table>
<tr><th colspan="2">Installing Jo-bolts</th></tr>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Insert the Jo-bolt into the hole.</td></tr>
<tr><td>2</td><td>Place the nose adapter of the driving tool over the bolt stem and press the nose adapter downward to engage the head of the Jo-bolt.</td></tr>
<tr><td>3</td><td>Hold the driving tool firmly against the Jo-bolt and perpendicular to the surface of the work. Failure to do so may cause the bolt stem to break off before the Jo-bolt is tight.</td></tr>
<tr><td>4</td><td>Apply power. As driving is completed, the bolt stem snaps off.</td></tr>
</table>

Installing Jo-bolts	
Step	**Action**
5	Shave millable-head Jo-bolts to meet flushness requirements with a standard rivet shaver equipped with a carbide cutter. **NOTE:** You must inspect millable head jo-bolts for looseness before they are shaved!

Inspection

After installation is complete, inspect fasteners to ensure they are within applicable TO limits. You should inspect these areas:

- Flush-head Jo-bolts on aerodynamic surfaces must conform to the flush requirements of the area where they're installed in accordance with the aircraft specific TO.

NOTE: Shaving of steel Jo-bolt heads to meet the flush requirements is <u>not</u> permitted.

- Gaps between the manufacturer's head of flush and protruding Jo-bolts and the surface are permitted if they meet TO specifications.
- Be sure you check each newly installed Jo-bolt for looseness Torque values vary depending on the Jo-bolt diameter, so consult your aircraft TO or TO 1–1A–8 for the appropriate torque to apply. *If the Jo-bolt turns when a light torque is applied, it must be removed and replaced.*

For some additional examples of unsatisfactory conditions, refer to the aircraft specific TO or TO 1–1A–8.

Removal procedures

Jo-bolts are removed under two conditions: nonrotating Jo-bolts and rotating Jo-bolts. The following table lists the basic removal procedures for the Jo-bolt. For more detailed removal information, refer to your aircraft TO or TO 1–1A–8.

Removing Jo-Bolts	
Type	**Description**
Nonrotating	As the name implies, removing nonrotating Jo-bolts applies to Jo-bolts that are tight and do not rotate in the hole. This condition usually involves removing existing Jo-bolts in a repair area or when too short of a Jo-bolt has been installed. To remove a nonrotating Jo-bolt, simply drill through the head to the top of the shank. Next, use a punch and hammer to sever the Jo-bolt head; then drive out the shank and blind head.
Rotating	This condition applies when a Jo-bolt is loose and rotates within the hole. This usually results from the installation of a Jo-bolt that's too long. Select a twist drill based on the diameter of the Jo-bolt being removed. Keep the Jo-bolt from turning by using a drill bushing fixture having "dogs" to engage the head slots for flush Jo-bolts or a wrench recess for hexagonal-head Jo-bolts. Drill completely through the shank of the Jo-bolt, severing the bolt head. Remove the remaining nut from the hole with a punch.

030. Mechanical-lock blind bolts

This lesson covers the information you need to know to successfully work with mechanical-lock blind bolts. We cover their characteristics, identification, preinstallation factors, installation procedures, and removal procedures.

Characteristics

Mechanical-lock blind bolts (fig. 4–34) incorporate the positive locking features of a mechanical-lock blind rivet and the high-strength requirements of conventional NAS bolts.

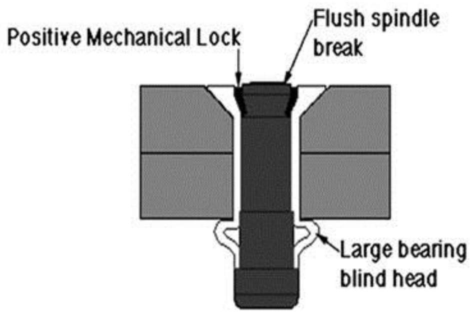


Figure 4–34. Mechanical-lock blind bolt.

Each mechanical-lock blind bolt has two main parts described in the following table.

Mechanical-lock Blind Bolt Parts	
Part	**Description**
Shank	The *shank* incorporates a long cylindrical sleeve, locking collar, and conical recess to accommodate the locking collar when the bolt is driven.
Pulling Pin	The *pulling pin* has a grooved pulling section that protrudes above the rivet head and fits into the jaws of the pulling gun and a locking groove portion that receives the locking collar. The pin's blind end section incorporates a head and a land section with an extruding angle that expands the bolt shank to form the blind head when driven.

Mechanical-lock blind bolts are available in 100° flush-head and protruding-head styles. Both types are made from alloy steel or stainless steel and are available in various grip lengths and diameters.

Identification

Mechanical-lock blind bolts can be identified by the MS number or the manufacturer's part number. The breakdown of an MS number is shown in the part number example at the bottom of figure 4–35.

NOTE: The dash number stamped on the head of the blind bolt indicates grip length.

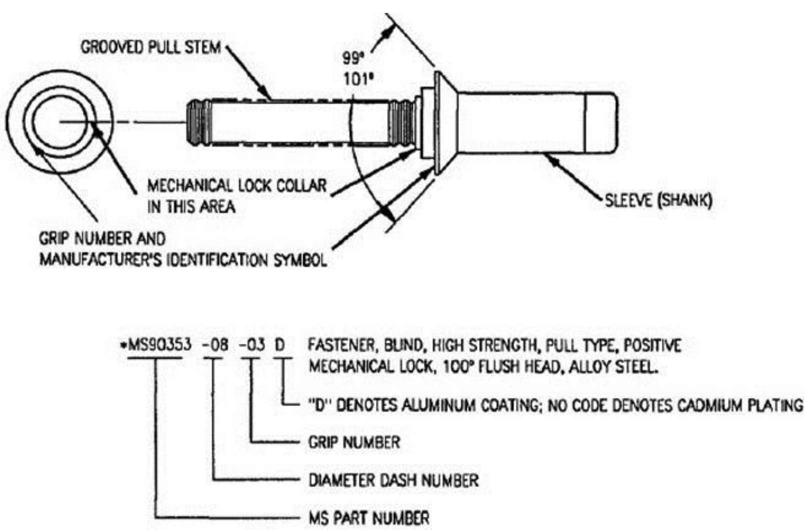


Figure 4–35. Mechanical-lock blind bolt identification.

Preinstallation factors

Preinstallation procedures are determined by whether you're replacing existing blind bolts or installing new blind bolts. When you *replace existing blind bolts*, first accurately measure the existing hole to ensure it's still within the hole limits for the size diameter you're replacing. If the hole isn't within tolerance or not round enough, consult the aircraft specific TO for corrective actions. Where the hole is so far out of tolerance that the next size diameter must be used, approval of a structural engineer is usually required.

Hole preparation

When you're drilling new holes, make every effort to produce a tight fit. For the best results, pilot drill the holes and ream to final size. You also want to make sure you make the holes perpendicular to the work surface and free all holes of all burrs.

Determine grip length

After you prepare the hole, select the right grip length. When you replace an existing blind bolt, this problem is eliminated because the grip length of the existing fastener is stamped on the manufactured head. In this case, use the same length the manufacturer used. For new holes, use the special depth gages available from the blind bolt's manufacturer.

Installation tools

The diameter and head style of the mechanical-lock blind bolt being installed determine the tools you'll select. For $^{5}/_{32}$- and $^{3}/_{16}$-inch diameter blind bolts, use a pulling gun with a double action, such as the model 200 Huck installation gun (fig. 4–36).

NOTE: This pulling gun must have the shift pressure valve set for *each different diameter* blind bolt being installed. Special adjustment kits are available from the manufacturer.

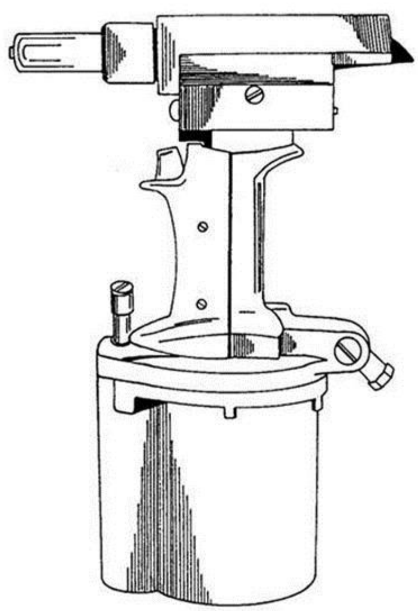


Figure 4–36. Mechanical-lock blind bolt installation tool.

For larger diameter blind bolts ($^{1}/_{4}$- to $^{1}/_{2}$-inch), a single-action pulling gun is required. Huck installation guns can be used. These pulling guns must also be adjusted for the specific diameter of the blind bolt being installed.

The nose adapter must match the head style and diameter of the blind bolt. Each nose adapter includes a set of jaws that grip the grooves on the pin; an outer anvil that bears against the outer part of the manufactured head during the driving operation; and an inner anvil that advances automatically to drive the locking collar home, mechanically locking the pin in place after the blind-side head is formed.

Installation procedures

Once you've prepared the hole and picked the right grip length and installation tools, you can begin installation. The following table lists the basic installation procedures; for more detailed installation information refer to your aircraft TO or TO 1–1A–8.

Installing Blind Bolts	
Step	**Action**
1	Insert the blind bolt into the hole.
2	Put the pulling gun over the blind bolt and insert the grooved part of the pin into the nose adapter.
3	Maintain a breakdown pressure against the head of the blind bolt, ensuring the pulling gun is 90° from the work surface.
4	Press the trigger of the pulling gun, maintaining the downward pressure and proper alignment.
5	Remove the pulling gun from the blind bolt *only after* the pin breaks. Premature removal prevents the locking collar from properly seating.
6	Inspect the blind bolt for proper installation.

Inspection procedures

Inspecting installed mechanical-lock blind bolts is limited to the fit of the manufacturer's head against the work surface, position of the pin, and position of the locking collar. Flush-head mechanical-lock blind bolts installed on aerodynamic surfaces must conform to the aircraft's contour smoothness requirements.

NOTE: Bolt heads cannot be shaved or milled to meet flushness requirements.

For nonaerodynamic surfaces, the flush and protruding-head styles must meet the specific aircraft TO requirements.

Gaps between the heads of blind bolts and the work surface caused by burrs or foreign material are cause for rejection. Allowable gaps under the head of blind bolts depend on the diameter of the blind bolt and the amount of surface contact. The specific aircraft TO spells out the gap limitations.

Removal procedures

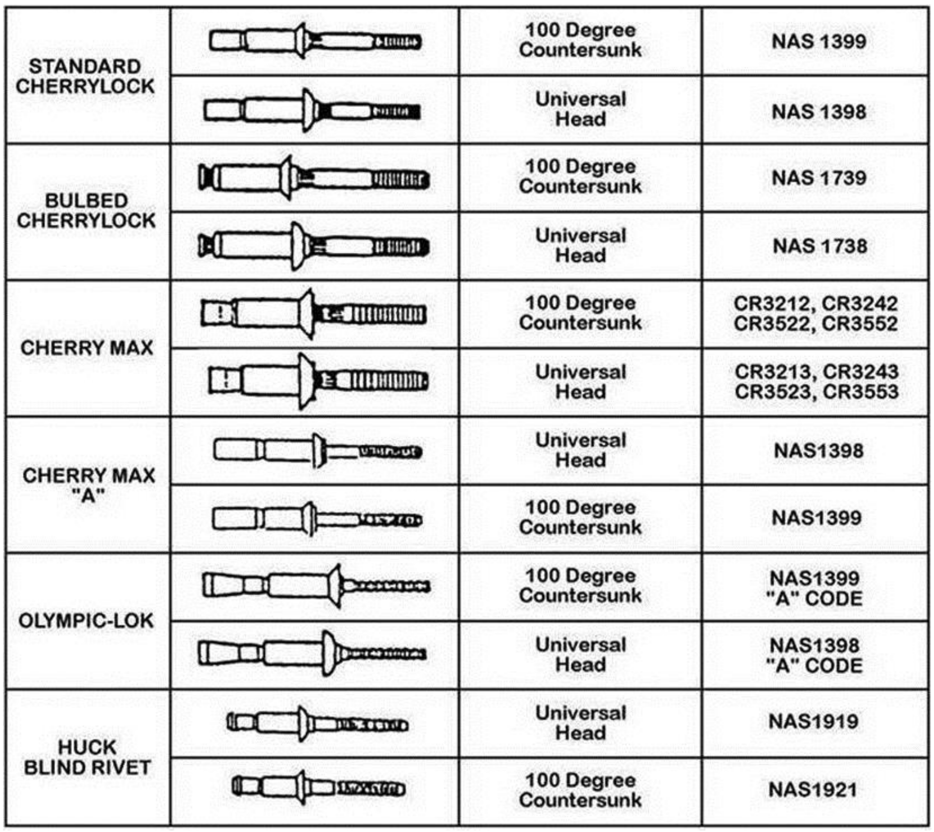
When removing mechanical-lock blind bolts because of inspection failure or repair, you will need an appropriate diameter drill bit, drill bushing fixture, pin punch, sleeve punch, and an adjustable micro-limit cutter. The following table lists basic removal procedures; the sequence of removal steps in the TO *must be followed.*

Removing Mechanical-lock Blind Bolts	
Step	**Action**
1	Drill the pin. The drill bit is based on the diameter of the blind bolt being removed. Use a drill bushing fixture to maintain proper alignment during drilling. Drill the pin only to the depth stated in the drill pin chart located in the TO.
2	Knock out the pin. After you drill the pin, place a pin punch on the remaining part of the pin and drive out the pin.
3	Counterbore the sleeve. This operation requires using an adjustable micro-limit cutting tool to grind away a part of the sleeve.
4	Remove the sleeve. After the sleeve has been counterbored to the desired depth, position a sleeve punch into the remaining portion of the sleeve and drive it out.

NOTE: Blind bolt removal kits are available from mechanical-lock blind bolt manufacturers.

031. Mechanical-lock blind rivets

The mechanical-lock blind rivet has a mechanical locking collar that creates a positive lock between the rivet head and the stem. This lock resists vibration and aids in pin retention. The collar is seated into the locking position during installation of the rivet. Another feature of the mechanical-lock blind rivet is that the stem breaks off flush with the head, eliminating further work on the rivet stem. Figure 4–37 shows styles of mechanical-lock blind rivets in use. Because of the similarities of mechanical-lock blind rivets, our discussion will focus on the Cherrylock system.



STANDARD CHERRYLOCK		100 Degree Countersunk	NAS 1399
		Universal Head	NAS 1398
BULBED CHERRYLOCK		100 Degree Countersunk	NAS 1739
		Universal Head	NAS 1738
CHERRY MAX		100 Degree Countersunk	CR3212, CR3242 CR3522, CR3552
		Universal Head	CR3213, CR3243 CR3523, CR3553
CHERRY MAX "A"		Universal Head	NAS1398
		100 Degree Countersunk	NAS1399
OLYMPIC-LOK		100 Degree Countersunk	NAS1399 "A" CODE
		Universal Head	NAS1398 "A" CODE
HUCK BLIND RIVET		Universal Head	NAS1919
		100 Degree Countersunk	NAS1921

Figure 4–37. Mechanical-lock blind rivet identification.

In this lesson, we present the information you need to work successfully with mechanical-lock blind rivets. We cover their characteristics, preinstallation procedures, installation procedures, inspection, and removal procedures.

Characteristics

Mechanical-lock blind rivets are used where access to one side of the work area is impossible. They have the strength characteristics of a solid shank rivet. The loads allowable for self-plugging (mechanical-lock) blind rivets are like those for solid shank rivets of the same shear strength, regardless of sheet thickness. Mechanical-lock blind rivets are made of three basic parts and come in two different types, listed in the following table.

Mechanical-Lock Blind Rivets	
Parts	**Types**
• A hollow sleeve (including a conical recess for the locking collar). • A serrated stem that extends through the sleeve. • A separate locking collar. **NOTE:** The material composition of the individual parts differs depending on the type of rivet they are made in two head styles - 100° countersunk and Universal protruding head.	• Standard. • Bulbed.

We'll take a closer look at both standard and bulbed types in the following paragraphs.

Standard type

The standard-type rivet is a mechanical-lock blind rivet that has a serrated stem with an enlarged (constant-diameter) plug section. This serrated stem produces a shop head as shown in the far bottom right-hand side of figure 4–38. The rivet sleeve and stem are available in material compositions of aluminum alloys, Monel, and CRES.

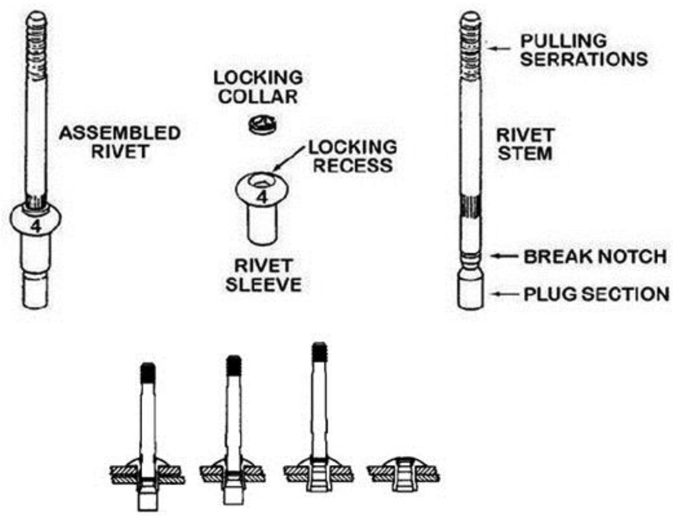


Figure 4–38. Standard-type mechanical-lock blind rivet (Cherrylock).

Standard mechanical-lock blind rivets are used in thick sheet and sealing applications. *Do not* use them in thin-skin applications or in plastic materials because there's insufficient bearing strength in thin sheets to provide the necessary resistance between the sleeve of the rivet and the hole in the sheet. The necessary resistance is needed to keep the sleeve of the rivet from over expanding and allowing the pin to be in the wrong position to accept the locking collar or be completely pulled through the sleeve of the rivet. Most plastics do not have enough strength to keep from cracking when the rivet sleeve is expanding, thus creating a problem like that with thin sheets.

Standard mechanical-lock blind rivets must meet NAS 1400 specifications. Figure 4–39 shows the NAS 1400 series part number breakdown.

NATIONAL AEROSPACE STANDARD NAS

MATERIAL	MATERIAL CODE NO.
2017 ALUMINUM ALLOY	D
5056 ALUMINUM ALLOY	B
CAD. PLATED MONEL	MW
MONEL UNPLATED	M
A-286 CRES	C

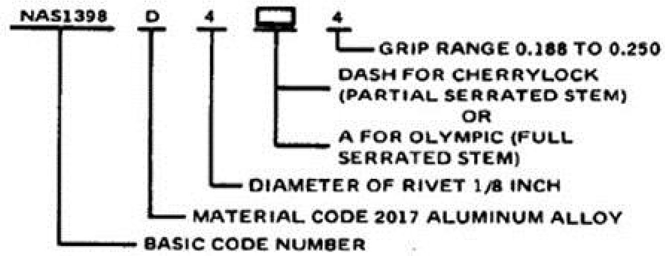


Figure 4–39. NAS numbering system for mechanical-lock blind rivets.

Bulbed type

The bulbed blind rivet (fig. 4–40) has a serrated stem with a machined variable diameter cone-shaped section. This type of stem design produces a “bulbed”-shaped” shop head (upper right-hand corner of figure 4–40). The rivet sleeve is made from aluminum, Monel, or Inconel; the stem is made from Inconel, 8740 steel, or CRES; and the locking ring is made from Monel or Inconel.

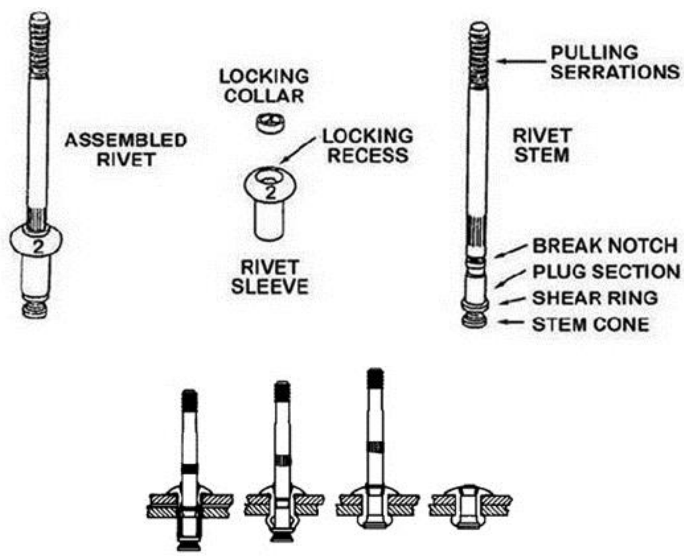


Figure 4–40. Bulbed-type mechanical-lock blind rivet (Cherrylock).

Bulbed mechanical-lock blind rivets are most effective in dimpled and thin-skinned applications because they clamp the sheet together versus swelling the sleeve in the hole as the standard type does. Very little (if at all) swelling takes place in the hole when the bulbed blind rivet is installed. Because of this feature, it’s a good rivet to use for composites, thin sheets of metal, and thermoplastics. The bulbed rivet comes in $^{1}/_{64}$-inch oversize, making it a good substitute blind rivet for elongated holes without going to the next size diameter rivet.

Preinstallation procedures

Before you install a mechanical-lock blind rivet, you need to make sure the hole is drilled correctly and to the right size, you have the proper grip length rivet, and the material composition is compatible with the material being riveted.

Hole preparation

Hole size and hole alignment are critical. Undersized and misaligned holes cause the stem to break off prematurely, resulting in a defective rivet. Oversized and elongated holes also result in a defective rivet. Be sure to drill holes to the diameter specified in the TO, hold the drill 90° to the surface of the part, and do not use unnecessary pressure when drilling. To ensure proper hole alignment, and to keep burrs and chips from lodging between the sheets, clamp the material to be drilled tightly together. Before clamping the material, remove any foreign matter that may be lodged between the sheets.

For information on correct size drills for standard-type, mechanical-lock blind rivets (NAS 1400 series) and bulbed-type mechanical-lock blind rivets (NAS 1740 series), refer to TO 1–1A–8.

Grip length

The correct grip length and proper diameter are critical factors for installing blind rivets. The *grip length* of mechanical-lock blind rivets refers to the *maximum total thickness of the parts to be riveted together* and is measured in sixteenths of an inch. The maximum grip length is stamped on the head of these blind rivets. In figure 4–41, note the number 4 on the rivet head. This number (4) refers to the *maximum material thickness* ($^{1}/_{4}$ inch) that can be successfully riveted with this rivet.

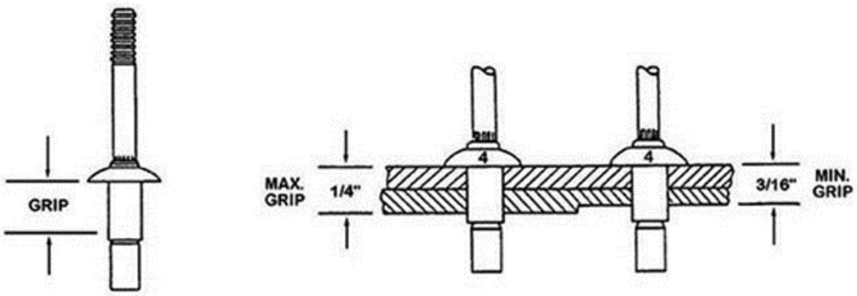


Figure 4–41. Mechanical-lock blind rivet grip range.

NOTE: The *minimum grip length* for mechanical-lock blind rivets is always $^{1}/_{16}$ inch *less* than that shown on the rivet head. In this case, it's $^{3}/_{16}$ inch.

The diameters of mechanical-lock blind rivets are measured in increments of thirty-seconds ($^{1}/_{32}$) of an inch. The standard mechanical-lock blind rivets are made in diameters of $^{3}/_{32}$, $^{4}/_{32}$ ($^{1}/_{8}$), $^{5}/_{32}$, $^{6}/_{32}$ ($^{3}/_{16}$), and $^{8}/_{32}$ ($^{1}/_{4}$) of an inch. In contrast, the bulbed mechanical-lock blind rivets are made in sleeve diameters $^{4}/_{32}$ ($^{1}/_{8}$), $^{5}/_{32}$, and $^{6}/_{32}$ ($^{3}/_{16}$) inch. Figure 4–42 shows the head markings on a mechanical-lock blind rivet.

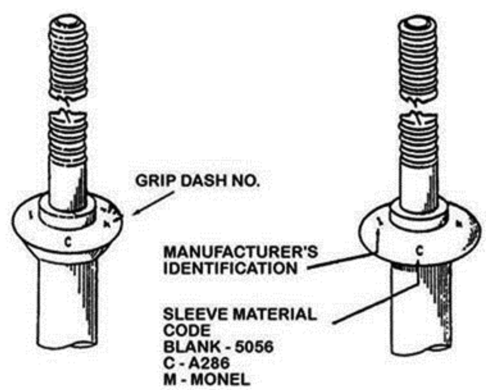


Figure 4–42. Head markings of mechanical-lock blind rivets.

Material composition

In addition to grip length, you also need to consider material composition of the fastener and material being riveted together. The composition of the material being riveted together determines the composition of the rivet sleeve. Markings in the form of a letter or symbol, indicating the material composition of the rivet, are stamped on the head of the rivet. Aluminum-sleeved rivets usually do not have a head marking to show material composition. Refer to your aircraft or equipment specific TO or TO 1–1A–8 for material composition requirements.

Substitution factors

When you're substituting mechanical-lock blind rivets, you should *substitute only rivets of equal or greater strength*. Always refer to your aircraft specific TO or TO 1–1A–8 for substitution allowances.

NOTE: A standard-type mechanical-lock blind rivet should not be used to replace a bulbed type because of the differences in diameters.

Installation

Mechanical-lock blind rivets need special driving assemblies. For best results, always use tools made by the company that produces the rivet you're installing. The type of equipment available may be hand or power operated. Your choice should be influenced by these four factors: the quantity of rivets to be installed, size and type of rivets, availability of an air supply, and accessibility of the work area.

When you select installation tools, be sure to use the correct "pulling head." Figure 4–43 shows some of the tools used to install mechanical-lock blind rivets.

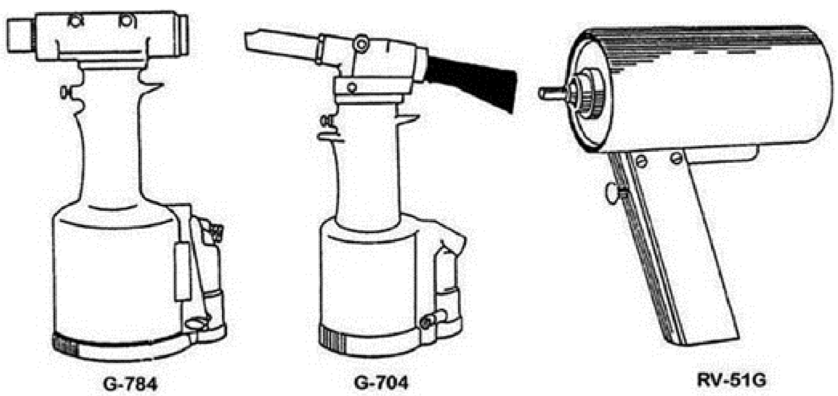


Figure 4–43. Mechanical-lock blind rivet installation tools.

Always hold the rivet gun in line with the axis of the rivet being installed. Once the shophead is formed and the stem locked in the rivet, the stem will break off flush with the head of the rivet. Ensure the stem has snapped before removing the rivet gun. After each rivet is installed, check for proper stem breakage and locking collar retention. The rivet stem should snap off even with the head of the rivet. The locking collar should be firmly seated into the locking recess of the rivet head. Figure 4–44 shows how the shophead is formed and where in the process the stem snaps off.

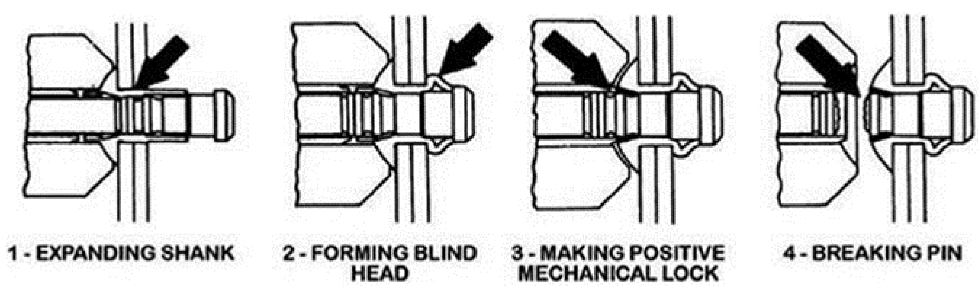


Figure 4–44. Mechanical-lock blind rivet installation sequence.

Inspection

Visual inspection of the seating of the pin in the manufactured head is the most reliable and simplest way to inspect mechanical-lock rivets. If the proper grip range has been used, and the locking collar and broken end of the stem are about flush with the manufactured head, the rivet has been properly set and the lock formed.

There are generally two causes of an unsatisfactory lock, as described in the following table:

Causes of An Unsatisfactory Lock	
Cause	**Description**
Insufficient grip length	This problem is indicated by the stem breaking below the surface of the manufactured head.
Excessive grip length	This problem is indicated by the stem breaking off well above the manufactured head.

NOTE: In either case, the locking collar might not be seated properly, thus forming an unsatisfactory lock.

Gaps between rivet and the surface are permitted, provided they meet TO specifications. If there are gaps caused by burrs or foreign material, or there are gaps under the head of protruding head rivets, the rivet must be removed and replaced.

In work situations where the shop head can be inspected, check for structurally inadequate blind heads. Superficial stretch marks that may appear in the rivet sleeve aren’t detrimental to rivet strength and are acceptable. For more detailed inspection criteria, refer to TO 1–1A–8.

Removal procedures

Removal of mechanical-lock blind rivets can be done easily without damage to the work surface by following procedures in TO 1–1A–8 (fig. 4–45). The following table lists basic removal procedures.

Removing Mechanical-lock Blind Rivets	
Step	**Action**
1	Shear the lock by driving out the pin. If you’re working on thin material, back up the material while driving out the pin. If inaccessibility prohibits this, partially remove the rivet head by filing or with a rivet shaver.
2	Pry the remainder of the locking collar out with a drift pin.
3	Use the proper size drill to drill nearly through the rivet head.
4	Break off the drilled head, using a drift pin as a pry. **NOTE:** Do not drill completely through the sleeve to remove the rivet as this tends to enlarge the hole.
5	Drive out the remainder of the rivet with a drift pin having a diameter equal to, or slightly less than, the rivet diameter.

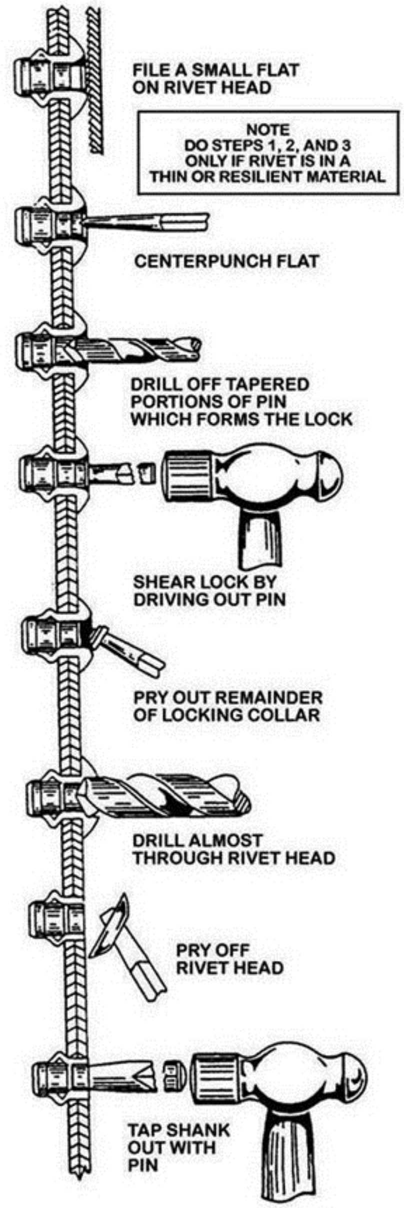


Figure 4–45. Mechanical-lock blind rivet removal sequence.

032. Composi-Lok

Composi-Lok fasteners are specifically designed for fastening graphite/epoxy composite structures. They are installed by torque feed control rather than by impact driving, which reduces the possibility of matrix crushing or delamination of the structure. Also, the blind head forms a larger footprint against the composite skin. They are manufactured from titanium which does not induce corrosion when used with graphic composite structures. The Composi-Lok II fastener is similar to the Composi-Lok; the difference is the Composi-Lok II is designed with a drive nut which reduces installation time. The drive nut also reduces the tooling required to install the fastener. A Composi-Lok requires a nose assembly for every diameter, whereas the Composi-Lok II only has two nose assemblies that will install a variety of diameters. Figure 4–46 shows a Composi-Lok II fastener example.

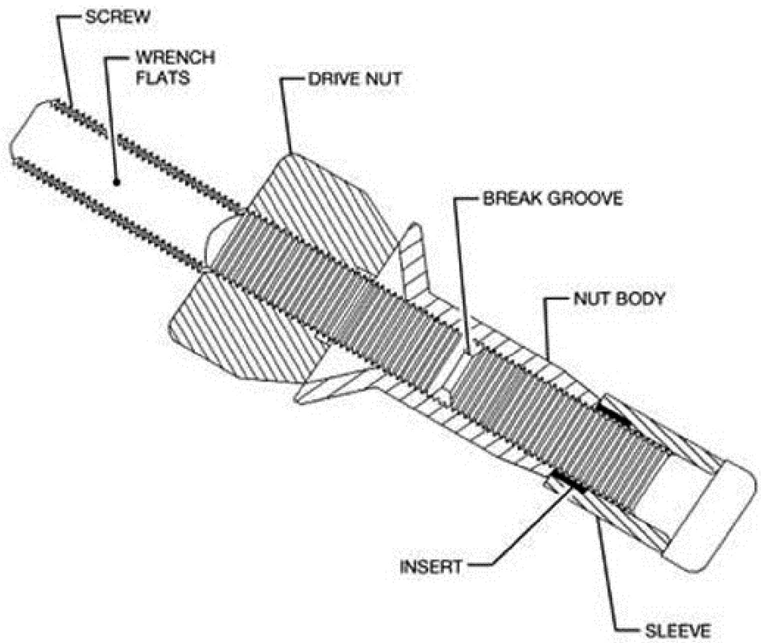


Figure 4–46. Composi-Lok II.

Identification

The drive nut will have the grip length; the head will have the manufacturer’s code, the material code, and the basic three-digit part number. Head markings will have a basic four-digit number to coincide with the fastener’s part number. The manufacturer’s head also has a material code and manufacturer’s symbol. Part numbers are illustrated in figure 4–47.

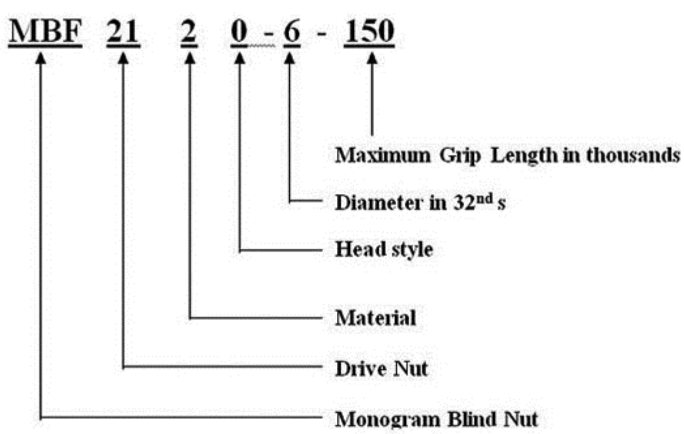


Figure 4–47. Composi-Lok part number.

Installation and inspection

The Composi-Lok fastener uses pneumatic pistol-type installation tooling with a variety of nose adapters to install all basic Composi-Lok fastener configurations in $^{5}/_{32}$- thru $^{3}/_{8}$-inch diameters. The basic installation steps are listed in the following table.

Installing Composi-Lok Fasteners	
Step	**Action**
1	Insert the proper fastener in the prepared hole and attach the driving tool.
2	Actuate the driving tool to tightly clamp up the sheets being joined.

Installing Composi-Lok Fasteners	
Step	**Action**
3	The corebolt will fracture when the sleeve is fully formed against the blind side of the structure (fig. 4–48).
4	Inspect fastener using stem break off gage and ensure measurements are within TO specifications (fig. 4–49).

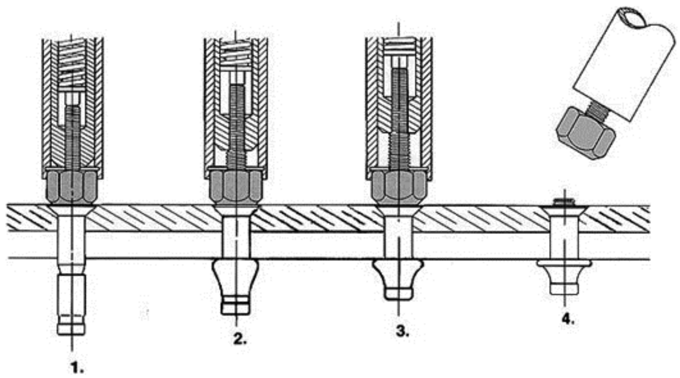


Figure 4–48. Composi-Lok installation.

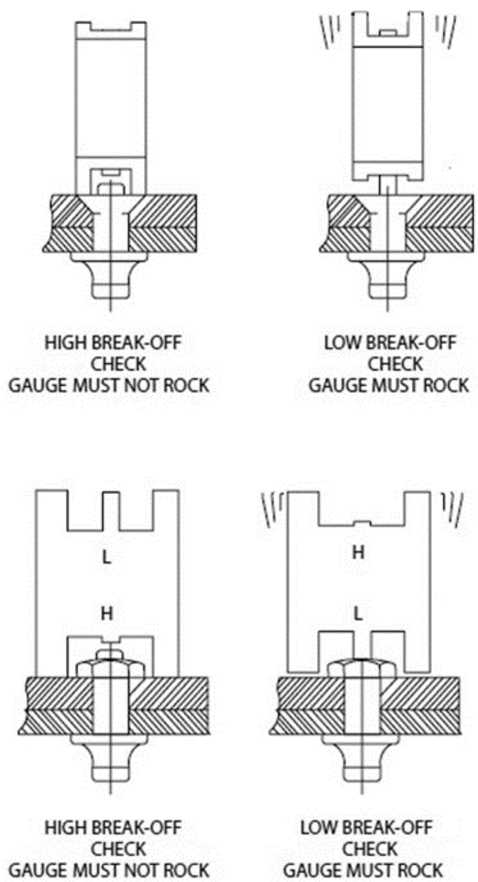


Figure 4–49. Composi-Lok inspection.

Removal

Fasteners may be removed with common composite hand tools if a fastener removal kit is unavailable. However, exercise extreme care not to damage the laminate surrounding the fastener hole. If a fastener removal kit is not used, the fastener hole must be inspected for damage. Refer to your aircraft specific TO for removal procedures.

033. Pull-thru blind rivets

In this lesson, we turn our attention to pull-thru blind rivets. These rivets are used where the structural requirements do not call for a solid-shank or self-plugging blind rivet. With the introduction of stronger material compositions for sleeve construction, pull-thru rivets are being used for attaching structural hardware such as nut plates and channel nut assemblies. Here we'll provide the job knowledge you need to successfully deal with pull-thru blind rivets. This lesson covers three major topics about pull-thru blind rivets:

- Main features.
- Installation procedures.
- Removal procedures.

Main features

This type of blind mechanically expanded rivet has the following two parts:

- A serrated stem.
- A hollow sleeve.

The pull-thru blind rivet differs from the two previously discussed blind rivets as the stem is pulled completely through the sleeve of the rivet during installation (fig. 4–50).

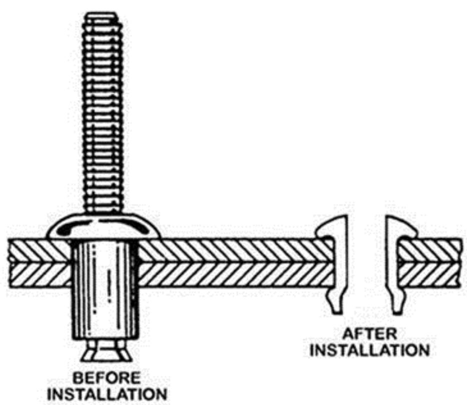
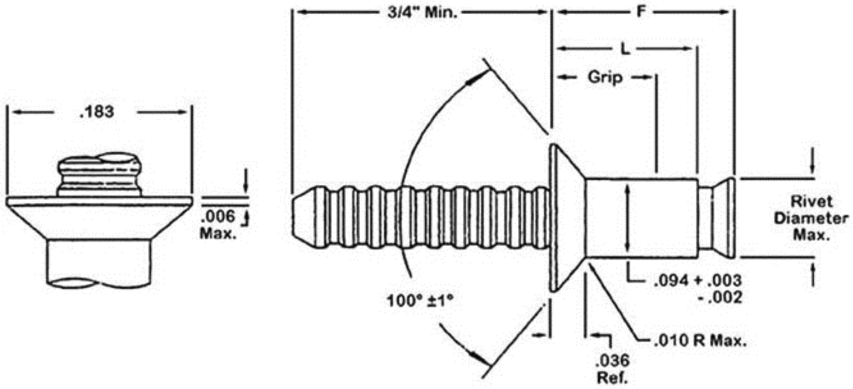


Figure 4–50. Pull-thru blind rivets.

NOTE: Pull-thru rivets are structurally weaker than other blind rivets because of the hollow center and are considerably weaker than solid-shank rivets. *Use these rivets only where allowed by TO specifications.*

Pull-thru blind rivets are available in a variety of head styles, material compositions, and diameters. Most of your work will involve the countersunk steel, $3/32$-inch diameter type. You'll use this type to install nut plates and channel nut assemblies.

Figure 4–51 is a data sheet for a 100° steel pull-thru blind rivet. Take a few minutes to study the data given on the figure. Problems of replacing nut plates and channel nut assemblies in blind areas and areas of limited access are eliminated by using the steel pull-thru blind rivets. Also, using pull-thru blind rivets eliminates damage to the skin surface and nut plate assemblies caused by a misplaced bucking bar.



Recommended Drilling Procedure	
Size Drill	Hole Limits
#40 (.098)	.097 / .101

1. Shank Dia. to be measured within 0.1" of base of Head.
2. Mat'l: Sleeve = C1018 Steel
   : Stem = Steel
3. Finish: Sleeve = Cadmium Plate, QQ-P-416, Type II, Class 3
   : Stem = #18 Max.
4. Grip lengths are test proven for use in mat'l thickness 1/64 or .015 thicker than grip indicated.

Figure 4–51. Steel pull-thru blind rivet data.

Installation procedures

The combined thicknesses of the material and the nut plate are used to figure the grip length required. Once you've figured the grip length, align the nut plate with the existing rivet holes. Clamp the nut plate tightly against the surface of the material during rivet installation. Gaps between the surface and the nut plate let the rivet swell between them, causing the fastener hole to be misaligned.

Figure 4–52 illustrates how to install pull-thru blind rivets. After you align the nut plate and clamp it in place, put the rivet stem into the pulling head of the rivet gun. Place the rivet into the rivet hole, holding the pulling head firmly and squarely against the head of the rivet and in line with the rivet stem. Keeping a steady pressure against the rivet head, squeeze the handles to install the rivet. An added stroke may be necessary, depending on the rivet length and material thickness.

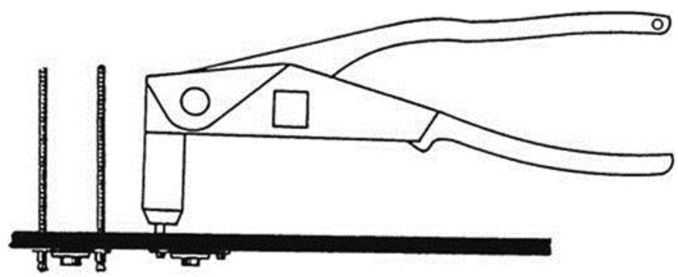


Figure 4–52. Pull-thru blind rivet installation tool.

After the rivets are installed, check the alignment of the bolt or screw hole. You can do this best by hand starting a bolt into the fastener hole. Also, while the bolt is in place, move it back and forth, checking the tightness of the rivets.

NOTE: Any rivet movement shows the nut plate is not tight, and the rivet must be replaced.

Removal procedures

The absence of a stem in a pull-thru rivet makes removing it relatively simple. Drill off the head of the rivet, making sure not to damage the countersunk or dimpled area of the hole. Take a drift punch and punch out the rest of the sleeve. When you're drilling out pull-thru blind rivets, remove the blind end that was punched into the structure if the area is accessible.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

029. Jo-bolt fasteners

1. How do you determine grip length when you know the thickness of the parts being fastened?

2. For best results, how should you prepare Jo-bolt holes?

3. What extra installation step must you take for *millable* Jo-bolts?

4. When do you inspect *millable* Jo-bolts for looseness?

5. What are the two removal conditions when removing jo-bolts?

030. Mechanical-lock blind bolts

1. What do you do when replacing mechanical-lock blind bolts and find the existing fastener holes are oversized?

2. When installing mechanical-lock blind bolts, how do you prepare the holes to provide the *best* results?

3. What three specific areas of the manufactured head do you check when inspecting an installed mechanical-lock bolt?

4. List the five tools you use to remove a mechanical-lock blind bolt.

5. When removing mechanical-lock blind bolts, what tool is used to counterbore the sleeve?

031. Mechanical-lock blind rivets

1. What type of mechanical-lock blind rivet do you select to fasten thin dimpled sheets together?

2. What actions can you take to prevent improperly drilled holes for mechanical-lock blind rivets?

3. When installing mechanical-lock blind rivets, what tooling should you use to ensure the *best* results?

4. What factors influence the type of installation tools you should use when you are installing mechanical-lock blind rivets?

5 What is the main cause when the stem of a mechanical-lock blind rivet breaks off *below the surface* of the manufactured head?

6. Excessive grip length causes the stem of mechanical-lock blind rivets to break off at what position in relation to the manufactured head?

032. Composi-Lok

1. How are Composi-Lok fasteners installed?

2. What is the difference between a Composi-Lok and Composi-Lok II fastener?

3. What tool do you use to install Composi-Lok fasteners?

4. How do you inspect the fastener *after installation*?

033. Pull-thru blind rivets

1. In what type of repair situation are you most likely to install pull-thru blind rivets?

2. How can you prevent the fastener hole from becoming misaligned when installing a nutplate with pull-thru rivets?

3. After you rivet a nut plate or channel assembly in place using pull-thru rivets, what must you do to make sure the installation was done correctly?

4. How do you remove a pull-thru rivet?

Answers to Self-Test Questions

023

1. To prevent bottoming of the nut.
2. Overall length, including the grip length and threaded parts.
3. Bolt-head markings and part number designation.
4. TO 1–1A–8.
5. Type of bolt, diameter, length, length of grip, and if the head or shank is drilled.
6. Torque all nuts to proper specifications.

024

1. Remove dirt and paint to facilitate easy screw removal.
2. Through use of a speed handle, fastener removal tool, fastener extractor, or by drilling.
3. Use of impact devices (like a pneumatic hammer); their use can cause damage to the aircraft structure and skin.
4. Place a 2- to 3-inch diameter head pressed onto the end of the handle. This provides a palm-sized pressure pad that allows you to lean into it and use your body weight, as well as arm muscles, to apply the needed pressure.
5. The typical screw removal tool, commonly referred to as a Johnson bar.
6. Drill a hole in the center of the screw.

025

1. Part number, luster or color, their construction, and thread size.
2. In areas where it may be difficult or impossible to use a traditional nut.
3. Cold working and adhesive bonding.
4. By radially expanding the nut plate barrel into the hole.
5. They eliminate the need to drill small diameter rivet holes needed to attach a traditional nutplate.
6. By sufficiently tightening the fastener and applying proper preload or clamping force.
7. By following the proper torque specifications.

026

1. Protruding and Flush.
2. HL.
3. An Allen wrench and a ratchet wrench with a hole that allows the Allen wrench to be inserted.
4. Manually screw the collar approximately three-quarters of a turn so that a minimum of two threads are engaged on the pin.
5. Surface contact, Countersink fit, aerodynamic smoothness requirements.
6. Replace the locking collar.
7. When the hi-lok fasteners have been pressed or tapped into interference fit holes.

027

1. The Eddie-Pin and Eddie-Nut.
2. They allow for a positive mechanical lock with the Eddie-Nut during installation.
3. It allows for higher torque applications without the tooling slipping out of the fastener.
4. The nut will automatically deform into and across the flutes of the Eddie-Pin.

5. $^{1}/_{16}$ inch.
6. The counterbore within the collar.
7. Clearance fit.
8. Spline-lok or hex key.
9. The installation tool becomes free running on the nut.
10. Remove and replace both the nut and the pin.
11. All lobes of the installed nut must be sufficiently deformed or swaged equally along their full length to allow the inspection gage to pass completely over the lobe area.

028

1. Markings on the head of the rivet.
2. Properly adjust the rivet gun for the diameter rivets being installed and use the correct weight bucking bar.
3. Ensure the parts to be joined are secured firmly in position with skin fasteners.
4. Starting at one side of a repair and working towards the other side.
5. Remove the rivet and replace it.
6. Press the microshaver firmly against a flat piece of scrap metal while the cutter is turning. If the cutter leaves a mark, continue to adjust until the cutter no longer marks the surface. When adjusted correctly, the cutter will be within 0.002 inch of the metal.

029

1. Consult a grip-length table located in the aircraft specific TO or TO 1–1A–8.
2. Drilled undersized and then reamed to final hole size.
3. They must be shaved to meet flushness requirements.
4. Before they are shaved.
5. Nonrotating Jo-bolts and rotating Jo-bolts.

030

1. Consult the specific aircraft TO for corrective actions.
2. Pilot drill the holes, and then ream to final size.
3. Fit of the manufactured head against the work surface, position of the pin, and position of the locking collar.
4. An appropriate diameter drill bit, drill bushing fixture, pin punch, sleeve punch, and an adjustable micro-limit cutter.
5. An adjustable micro-limit cutting tool.

031

1. Bulbed type.
2. Drill holes to the diameter specified in the TO, hold the drill 90° to the surface of the part, do not use unnecessary pressure when drilling, keep burrs and chips from lodging between the sheets, and clamp the material to be drilled tightly together.
3. Use installation tools from the manufacturer of the rivets being installed.
4. The quantity of rivets to be installed, size and type of rivets, availability of an air supply, and accessibility of the work area.
5. Insufficient grip length.
6. Above the manufactured head.

032

1. By torque feed control.
2. The Composi-Lok II is designed with a drive nut which reduces installation time. The drive nut also reduces the tooling required to install the fastener. A Composi-Lok requires a nose assembly for every diameter, whereas the Composi-Lok II only has two nose assemblies that will install a variety of diameters.

3. A pneumatic pistol type installation tool with a variety of nose adapters.
4. By using a stem break off gage and ensure measurements are within TO specifications.

033

1. Where the structural requirements do not call for a solid-shank or self-plugging blind rivet, and for attaching structural hardware such as nut plates and channel nut assemblies.
2. After figuring the grip length, align the nut plate with the existing rivet holes. Then, clamp the nut plate tightly against the surface of the material during rivet installation.
3. Check the alignment of the bolt or screw hole. Hand start a bolt into the fastener hole; while the bolt is in place, move it back and forth, checking the tightness of the rivets.
4. Drill off the head of the rivet and punch out the rest of the sleeve.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

41. (023) How can you identify different types of bolts?
    a. Use the technical order (TO).
    b. Use the bolt-head markings.
    c. By looking at the color or luster.
    d. By determining the thread length.

42. (023) How can you avoid stripping threads when installing a nut and bolt?
    a. Choose the proper nut.
    b. Install washers as necessary.
    c. Torque the nut to proper specifications.
    d. Ensure the bolt has a proper interference fit.

43. (024) What screw removal procedure is *not* authorized for use?
    a. Drilling.
    b. Screw punch.
    c. Fastener extractor.
    d. Pneumatic hammer.

44. (024) What kind of surface is the fastener removal tool primarily designed for use on?
    a. Concave.
    b. Convex.
    c. Curved.
    d. Flat.

45. (025) What nut style do you use if all the bolt hole locations are equally spaced around an opening?
    a. Point wrenching.
    b. Nut plates.
    c. Channel.
    d. Barrel.

46. (025) Seventy-five percent of all bolt and nut installation fatigue failures are caused by
    a. overtorquing the nut during installation.
    b. improper torquing due to insufficient bolt length.
    c. a lack of standardized torque values on all of the bolts.
    d. insufficient tightening and lack of proper preload or clamping force.

47. (026) To properly inspect the locking collar of an installed hi-lok fastener, you visually check the physical features of the locking collar and
    a. pin protrusion.
    b. fillet clearance.
    c. counterbore limitations.
    d. pin recess area alignment.

48. (027) How many flutes are there in the *upper* threaded portion of the Eddie-Pin?
    a. 2.
    b. 3.
    c. 4.
    d. 5.

49. (027) The flutes on the Eddie-Pin allow for what type of mechanical lock with the Eddie-Nut?
    a. Positive.
    b. Negative.
    c. Neutral.
    d. Combination.

50. (027) What type of hole preparation (fit) is *recommended* in an aluminum structure to provide improved load transfer and improved fatigue performance?
    a. Clearance.
    b. Transition.
    c. Close ream.
    d. Interference.

51. (028) To properly replace a skin panel, you start the riveting process at
    a. the top of the skin, working toward the bottom.
    b. the center, working toward the top, then the bottom.
    c. one side of the skin panel, working toward the other side.
    d. the center, working alternately from side to side and from top to bottom.

52. (028) What shank height and diameter requirements do you look for when inspecting newly formed solid rivet shop heads?
    a. Height is ¼ of the rivet's diameter; diameter is 1¼ of the rivet's diameter.
    b. Height is ⅜ of the rivet's diameter; diameter is 1⅜ of the rivet's diameter.
    c. Height is ½ of the rivet's diameter; diameter is 1½ of the rivet's diameter.
    d. Height is ⅝ of the rivet's diameter; diameter is 1⅝ of the rivet's diameter.

53. (029) What should you do before shaving a millable Jo-bolt?
    a. Inspect it for flushness.
    b. Inspect it for looseness.
    c. Check to ensure the bolt stem snapped off correctly.
    d. Check for gaps between the manufacturer's head and the surface.

54. (029) If a Jo-bolt turns after you apply a light torque during installation, you must
    a. remove and replace the Jo-bolt.
    b. tighten the Jo-bolt in a clockwise direction.
    c. tighten the Jo-bolt in a counterclockwise direction.
    d. center punch the corners of the Jo-bolt to secure the fastener into position.

55. (029) How do you determine the size twist drill you need to use to remove a Jo-bolt that is rotating in the hole?
    a. Diameter of the Jo-bolt.
    b. Head style of the Jo-bolt.
    c. Grip length of the Jo-bolt.
    d. Material composition of the Jo-bolt.

56. (030) To properly inspect the installation of a mechanical-lock blind bolt, you check the fit of the manufactured head against the work surface,
    a. thread protrusion, and core-bolt flushness.
    b. pin break-off position, and tightness of the core bolt.
    c. position of the pin, and position of the locking collar.
    d. position of the alignment slots, and locking-collar position.

57. (030) Which is *not* a removal step for a mechanical-lock blind bolt?
    a. Drill out the pin.
    b. Knock out the pin.
    c. Remove the sleeve.
    d. Drill out the sleeve.

58. (031) If the grip length of the mechanical-lock blind rivet you are installing is insufficient, the
    a. shop head may break off.
    b. manufactured head may break off.
    c. stem breaks off below the manufactured head.
    d. stem breaks off flush with the manufactured head.

59. (032) How many nose assemblies are required to install Composi-Lok II fasteners?
    a.One.
    b.Two.
    c.Three.
    d. A nose assembly is required for every diameter.

60. (032) What tool do you use to inspect a Composi-Lok fastener after installation?
    a. Grip gauge.
    b. Corebolt gauge.
    c. Drive nut gauge.
    d. Stem break off gauge.

61. (033) If you find the nut plate is misaligned after installing it using pull-through blind rivets, the probable cause is the
    a. grip length of the rivet was too long.
    b. grip length of the rivet was too short.
    c. nut plate was clamped too tight during installation.
    d. nut plate was clamped too loosely during installation.

62. (033) The *best* procedure to use when you are removing a pull-through blind rivet is to
    a. reduce the speed of the drill to prevent the head of the rivet from work hardening.
    b. lightly center punch the head of the rivet to provide a starting point for the twist drill.
    c. drill off the head of the rivet while ensuring the countersunk or dimpled area is not damaged.
    d. slit the head of the rivet with a chisel before you drill off the head to prevent the stem from spinning.

Please read the unit menu for unit 5 and continue ➔

Student Notes

Unit 5. Aircraft Tubing Assemblies

MODERN-DAY AIRCRAFT have hundreds of feet of tubing throughout the wings and fuselage. The tubing carries fuel to the engines, hydraulic fluid to actuators, and oxygen to the flight crews. You aren't responsible for maintaining the fluid systems; however, you're responsible for repairing damaged tubing and, sometimes, making tubing replacement assemblies. If you're to do these tasks successfully, you need a working knowledge of the materials, tools, and equipment used to do them. In this unit, we provide that working knowledge.

5–1. Tubing Assemblies

Tubing assemblies installed on aircraft consist of tubing and fittings made from various types of metal. These metal tubing and fittings can be used for low-pressure lines, such as drain lines, or for high-pressure or critical systems such as hydraulic lines.

034. Selecting aircraft tubing material and tubing hardware

Selecting the correct aircraft tubing material and hardware is essential to safety of flight. In this lesson, we'll cover the three main types of tubing you'll work with—aluminum alloy, stainless steel and titanium. In addition, we will cover types and uses of tube fittings as they apply to flared and flareless tubing fittings.

Aircraft tubing

Generally, the composition of metal tubing material can be identified by visual inspection. In most cases, the actual material composition is stenciled on the tubing. Always refer to the aircraft specific TOs to make sure the material you are using is approved for that particular use.

Aluminum alloy tubing

Aluminum alloy tubing can be used for a multitude of applications ranging from general-purpose lines and conduits for low pressure systems, to higher pressure lines carrying up to 3,000 psi. Because of its ease of fabrication, aluminum tubing is easily bent, flared or beaded; however, this also means it is easily scratched, nicked or dented.

Military specifications limit the use of aluminum alloy tubing in certain areas of airborne systems. Be sure to consult the applicable drawing or illustrated parts breakdown (IPB) to find the correct material for the tubing system.

NOTE: Some aluminum alloy will *not* withstand high pressure and are *not* used on hydraulic systems. It is imperative to always consult your aircraft or equipment specific TO for material specifications.

Stainless steel tubing

Corrosion-resistant stainless-steel tubing type 304 is used in high-pressure hydraulic systems up to 3,000 psi. These pressures are encountered in such areas as landing gears, wing flaps, and brakes. All external brake lines should be made out of *stainless-steel* components (tubing, sleeves, and nuts) to prevent damage caused by flying particles from the ground. In other systems where stainless-steel tubing isn't necessarily used (i.e., aluminum systems), a stainless-steel sleeve should be used. This minimizes sleeve and nut cracking that can be induced by overtorquing the B-nut.

The high tensile strength of stainless-steel tubing permits the use of thinner walls; therefore, the weight is about the same for thin-wall stainless-steel as for thicker-walled aluminum alloy tubing.

Titanium tubing

Titanium alloy tubing is currently being incorporated in newer model aircraft. Titanium tubing is used in high-pressure systems such as that used to carry hydraulic fluid to fast acting weapons bay doors and landing gear. Repair and fabrication of assemblies using titanium may require special procedures. You can find general information on titanium tubing in TO 42E1–1–1, *Aviation Hose and Tube Manual*, but you should refer to your aircraft specific TO for more detailed guidance.

Tubing hardware

All the tubing in the world will do you no good if you don't have a way to attach the tubing to the aircraft. When researching and selecting the materials used to fabricate a tubing assembly, special attention must be paid to the type of hardware that will be used. There is a vast array of tube fittings available, and you must refer to aircraft or equipment specific technical data to help you determine the correct fitting for your application.

Tubing fittings are used with aircraft tubing and support equipment to connect one piece of tubing to another. Fittings are made in many shapes and forms. The fittings you're mainly concerned with are those installed on the tubing itself. The two most common types of fittings used on aluminum and steel tubing assemblies are flared AN and flareless MS. Titanium tubing assemblies require special fittings and will be covered in the next section.

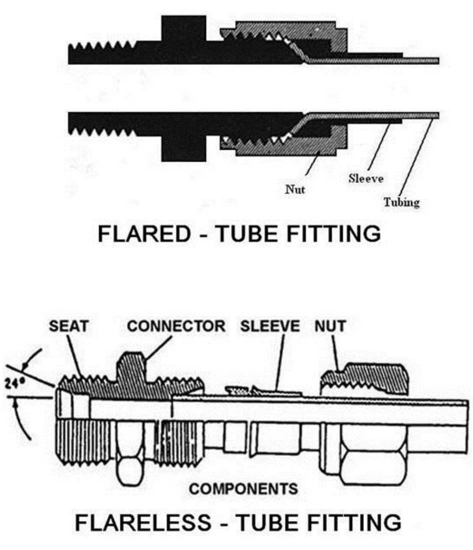


Figure 5–1. Flared AN and flareless MS fittings.

Flared AN fitting

The AN standard fitting is use for attaching the tubing to the fittings in the tubing systems of support equipment (SE) and older aircraft. AN standard fittings includes a nut and a sleeve. The sizes of these fittings are equal to the outside diameter (OD) of the tubing and given in dash numbers measured in $^{1}/_{16}$-inch increments.

The nut fits over the sleeve and, when tightened, draws the sleeve and tubing flare tightly against the male-fitting connector to form the seal. The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tubing so vibration doesn't concentrate at the edges of the flare. It also distributes the stresses over a wider area for added strength (fig. 5–1).

Flareless MS fitting

Flareless-tube fittings are made of aluminum, steel, or stainless steel. This type of fitting has a sleeve and a nut that is installed on the tubing that is *not* flared. To create a seal between the tubing and the sleeve, an operation called presetting is carried out. Presetting consists of deforming the sleeve to bite into the tube OD and deforming the end of the tube to form a shallow conical ring-seating surface. The bottom portion of figure 5–1 shows a typical flareless tube fitting.

Uses of tubing fittings

The material composition of AN and MS tube fittings is easily identified by distinguishing colors—*blue* for aluminum alloy and *black* for carbon steel. CRES fittings aren't colored.

Aluminum alloy sleeves may be used with aluminum alloy tubing and aluminum B-nuts on aerospace ground equipment (AGE) and all other nonairborne systems.

Steel fittings are used with steel tubing. Steel lines and fittings, if not stainless steel, must be plated to prevent corroding.

035. Repair and replacement of tubing assemblies

Damage to metal tubing such as chafing, galling, or fretting causes mechanical property changes. These changes greatly reduce the tubing's ability to withstand internal pressures and vibrations. Any visible damage to the tubing wall caused by chafing, galling, or fretting *requires* the two following actions:

1. Correction of the conditions that originated the damage.
2. Replacement or repair of the tubing assembly or damaged section regardless of the type metal, system media, or pressure ranges involved.

Damage such as dents, nicks, or scratching of tubing can be minimized by using care while performing maintenance. Most damage occurs from the careless handling of tools during maintenance.

Damage limitations

Tubing damage consists of dents, scratches, nicks, and gouges. How you repair the damage depends on the severity of the damage. Small nicks and scratches can sometimes be buffed or burnished out. Deeper dents and gouges will require you to repair the damaged section of tubing through replacement. Look in the aircraft specific technical order for more detailed information on damage limitations.

Repair or replacement

Scratches, abrasions, and minor corrosionmay be considered negligible damage and can be smoothed out with a burnishing tool or light sandpaper. More severe damage requires the replacement of damaged section of tubing. Three operations are usually involved in replacement of tubing assemblies: forming, cutting, and cleaning.

Forming

The first step is to form replacement tubing pieces. This can be completed one of three ways: as per sample (use damaged section of tubing as a template), blueprint, or with a template made of wire or similar material.

Cutting

Once the piece is formed to fit in place of the damaged area, it needs to be cut to fit. The preferred method of cutting is with a tubing cutter (fig. 5–2). Tubing can also be cut using a bandsaw, hacksaw, or cut-off wheel. After the tube has been cut, it is important to ensure the ends are square and free from burrs (fig. 5–3).

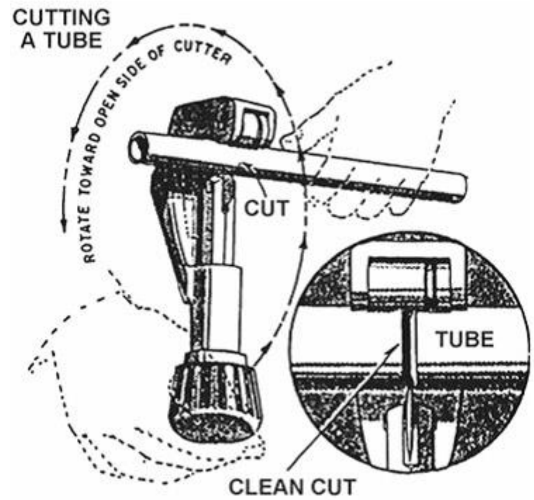


Figure 5–2. Tube cutting.

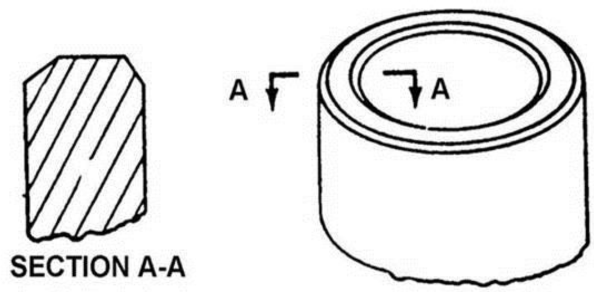


Figure 5–3. Properly prepared tubing end.

Cleaning

Before a new tubing assembly is installed on an aircraft, ensure it's clean and free of foreign materials (i.e., metal shavings, dust, dirt, oil, or grease). If the tubing assembly is to be used on oxygen systems, follow the special cleaning procedures outlined in TO 42E1–1–1. It's important to ensure the assembly is completely free from grease or oil; these agents cause a violent reaction when they come in contact with oxygen.

036. Operation procedures for tube-bending machines

Tubing can be bent with a variety of bending tools. Also, it can be bent without the aid of tools by carefully forming the desired radius by hand; however, you should only use this method in the absence of proper tools. In this lesson, we'll cover two types of tube-bending machines—production, and hydraulic.

Production tube bender

You can use a manually operated production tube bender (fig. 5–4) to bend all sizes of aluminum material tubing from $^{3}/_{8}$ inch to $1^{1}/_{2}$ inch OD, and steel tubing from $^{3}/_{8}$ inch to 1 inch OD. The way the bender is constructed permits changing the radius, clamp, and slide blocks for each size of tubing and bend radius. Benders are equipped with a mandrel-rod stop assembly and suitable mandrels to prevent kinks, wrinkles, and flat spots in the bent tube. Mandrel adjustment is key to preventing such defects (fig. 5–5).

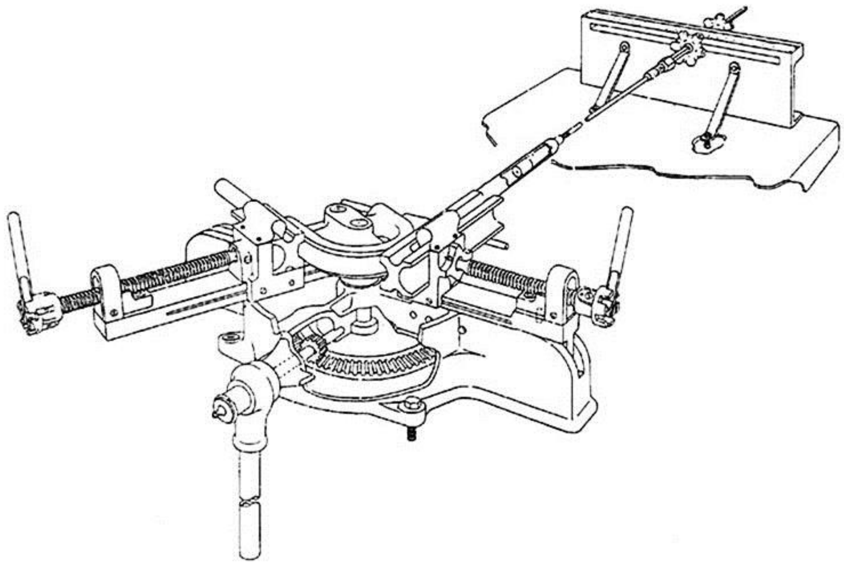


Figure 5–4. Production tube bender.

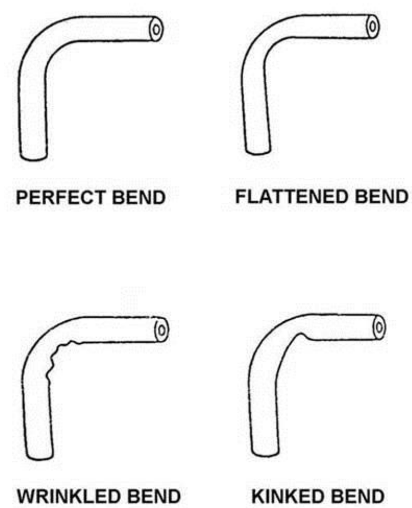


Figure 5–5. Tube bending troubleshooting.

Hydraulic tube bender

The manually operated production tube bender is by far the most common tube bender found in the structural maintenance shop. However, hydraulic tube benders are increasingly finding their way into the field, especially in larger shops.

There are many different types of hydraulic tube benders. The differences between them can be great, depending on the manufacturer, and even between models from the same manufacturer. Therefore, we'll mention just a few facts about these machines so you know they exist.

The typical hydraulic tube bender looks like a manual production tube bender. Also, the parts (i.e., mandrel, slide block, radius block, etc.) and setup are predominately the same. Unlike the production tube bender, hydraulic tube benders have electric pumps to build up hydraulic pressure. Somewhere on the machine, an ON/OFF switch (usually a push-button switch), controls the electrical power to the pump. On the simplest machines, this switch stands alone; on the more complicated machines, the switch is located on a control panel or can be computerized.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

034. Selecting aircraft tubing material and tubing hardware

1. What are the three main types of tubing materials you will work with?

2. What type of hardware is included in an AN standard fitting?

3. What determines the size of AN tube fittings?

4. Flareless MS fittings are installed on what type of tubing?

5. How can you identify the material composition of tube fittings?

035. Repair or replacement of tubing assemblies

1. What three types of tubing damage cause mechanical property changes?

2. What determines how you will repair tubing damage?

3. What may scratches, abrasions, and minor corrosion be considered?

4. What is the preferred method for cutting tubing?

036. Operation procedures for tube-bending machines

1. What size aluminum tubing can be bent with a manually operated production tube bender?

2. When using a hydraulic tube bender, what can you do to aid in producing a rounded tubing cross section?

5–2. Tubing Repair

In the past, when a tubing assembly was damaged, it was necessary to remove the entire assembly from the aircraft and replace it with a new one. Depending on the size and length of the tubing assembly, a large number of man-hours were expended to remove and replace it. Modern tubing repair technology has provided the capability and techniques for the permanent repair of damaged tubing. In most cases, modern tubing repair procedures allow the damaged tubing assembly to be repaired right on the aircraft. These repairs can restore the tube to its original strength, and, in most cases, the repaired area is actually stronger than the original tubing. In this section, we'll cover the predominant types of tubing repair available—Permaswage, Rynglok, Dynatube, and Permalite. Each system is designed to meet the high-temperature, high-pressure, and no-leak requirements of aircraft fluid systems.

037. Permaswage repairs

You can use the Permaswage method to repair tubing subjected to pressures *up to* 3,000 psi. The basic element of this repair technique is the Permaswage fitting, which is mechanically swaged to the OD of the tubing by an air-operated or hand-operated hydraulic pump.

Fittings include permanent and threaded fittings (i.e., elbows, unions, tees, and crosses). Figure 5–6 shows the basic types of permaswage fittings.

NOTE: Do not use this repair procedure on annealed CRES or 5052 aluminum alloy tubing.

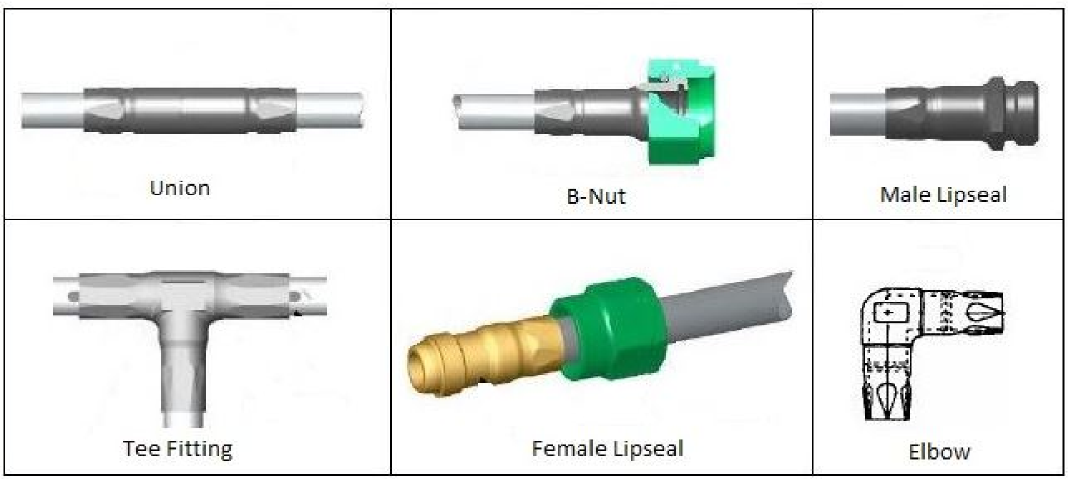


Figure 5–6. Permaswage fittings.

The Permaswage procedure for tubing repair involves the basic steps of cutting, deburring, tube end preparation, and fitting installation. During the swaging procedure, pressure supplied by the portable hydraulic power supply is converted into mechanical movement. This mechanical movement is of sufficient force to cause die segments contained within the swaging tool to do the swaging function.

Tooling consists of individual repair kits for different diameters of tubing. By changing die-block assemblies, you can make the Permaswage operate over a range of tubing diameters and various types of fittings. For example:

- Kit 1 is for $^{1}/_{16}$-inch to $^{3}/_{8}$-inch diameter tubing.
- Kit 2 is for $^{1}/_{2}$-inch to $^{3}/_{4}$-inch diameter tubing.
- Kit 3 is for 1-inch to $1^{1}/_{2}$-inch diameter tubing.

Chipless cutter

To make a cut with the Permaswage system, you'll use a chipless cutter (fig. 5–7). Before using the cutter, ensure the ratchet is operating freely and the cutting wheel is clear of the cutter head opening. Use caution not to over tighten the drive screw which can cause burrs on the tubing and excessive wear on the cutter wheel.

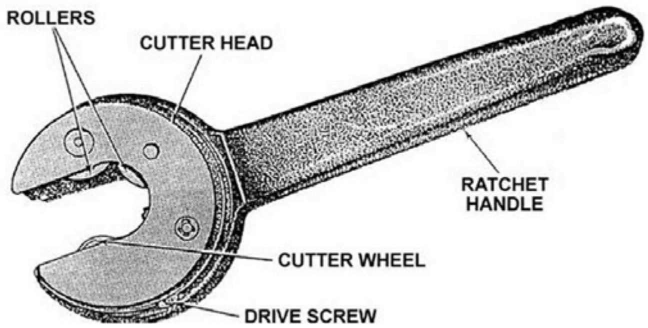


Figure 5–7. Chipless cutter.

NOTE: Ensure you lubricate the ratchet rollers and cutter wheel regularly with general-purpose lubricating oil to ensure ease of operation.

Deburring tool

Special deburring tools (fig. 5–8) are provided to remove burrs from the inner diameter of the tubing. Three sizes of deburring tools are provided to enable deburring of all sizes of tubing ranging from $^1/_4$ inch to $1^1/_2$ inch diameter. Each tool comes with a set of subassemblies to allow precise matching to the tube sizes within its range.

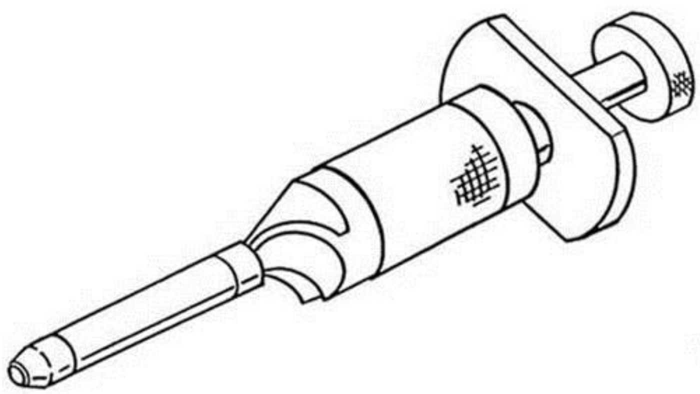


Figure 5–8. Tube deburring tool.

The tool has a plunger-activated stem subassembly that incorporates an elastic plug, which is inserted into the tube-end up to the point where the cutter makes contact with the burr. Deactivating (releasing) the plunger causes the elastic plug of the stem subassembly to expand, thus creating interference fit with the inner diameter of the tube. Hand rotating of the knurled tool body operates the cutter and does the deburring, while the elastic plug prevents chips generated during the deburring operation from entering the tubing. After trapping the chips, the plug wipes the tube's inner diameter clean as it's withdrawn.

CAUTION: Excessive deburring causes too deep a chamfer on the tube's inner diameter and is to be avoided. Chamfer width should generally *not exceed* one-half ($^1/_2$) the wall thickness of the tubing.

Swaging procedures

Mark the end of the tube using a marking tool and pen provided in the repair kit. Figure 5–9 shows an example of the marking tool.

Figure 5–9. Marking with Permaswage marking tool.

After the tube has been marked, insert the fitting over the tube end. The fitting should sit on the insertion mark ensuring some portion of the mark is visible.

NOTE: The tube must be positioned properly within the fitting; insufficient or excessive tube insertion results in rejection of the joint.

After the fitting has been properly inserted on the tubing, insert the assembly into the proper sized swaging tool and apply hydraulic pressure (fig. 5–10).

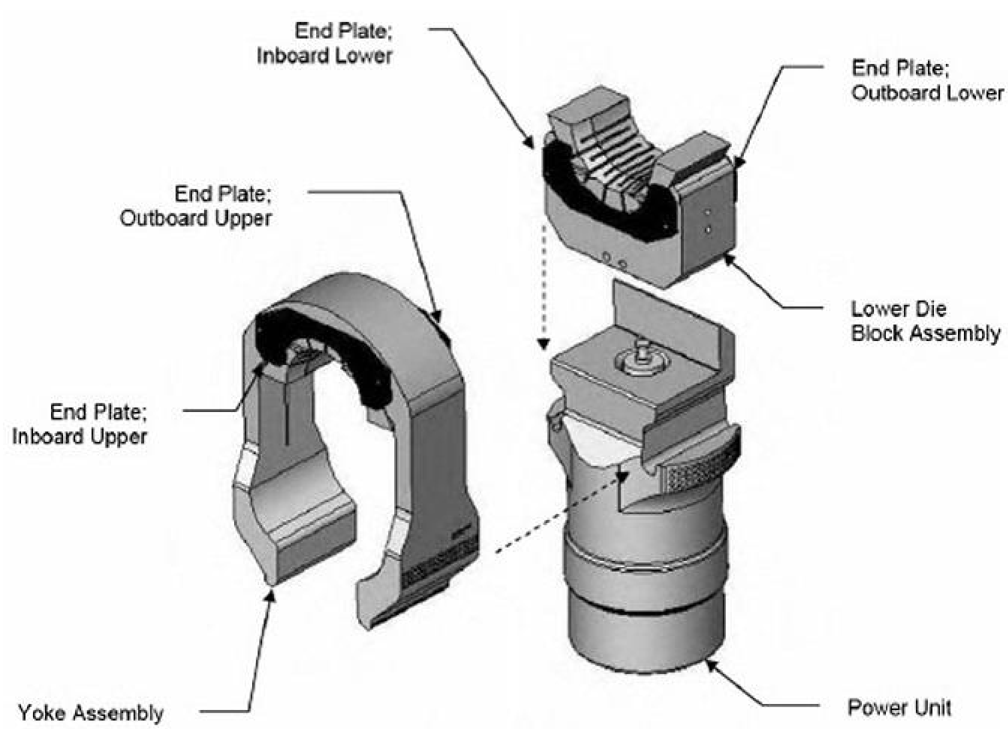


Figure 5–10. Swaging tool.

After swaging is complete, inspect the joint with the appropriate “go/no-go” gauge like the one shown in figure 5–11.

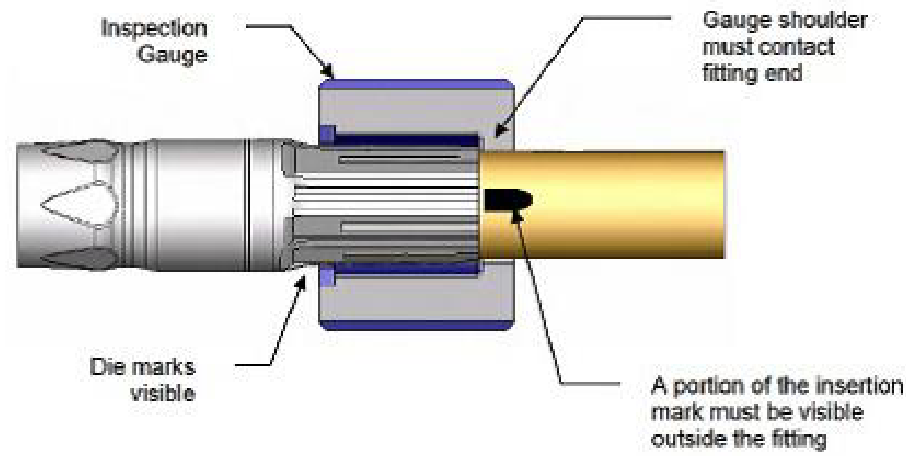


Figure 5–11. Go/no-go gauge inspection criteria.

038. Rynglok repairs

The Rynglok tubing repair system is designed to repair tubing assemblies that have operating pressures up to 8,000 psi. Similar to the Permaswage system, the basic element of this repair technique is the Rynglok fitting, which is also mechanically swaged to the OD of the tubing by an air-operated or hand-operated pump. Fittings are available in AN flared and MS flareless styles, and include permanent and threaded fittings, such as elbows, unions, and tees (fig. 5–12).

Figure 5–12. Rynglok fittings.

Rynglok incorporates a unique metal-to-metal method of attachment that isn't sensitive to tubing wall thickness or material type. Unlike the Permaswage system, no assembly of the tool head is required, except to connect it to the power source. Kits can be designed for your shop's specific repair or production needs, eliminating the need to maintain unneeded tool heads.

Like Permaswage, Rynglok tubing repair involves cutting, deburring, tube end preparation, and installation. During the swaging operation, pressure supplied by the portable hydraulic power supply is converted into mechanical movement. This mechanical movement is of sufficient force to cause a moveable jaw contained within the assembly tool to do the swaging function. Assembly tools are available in tube diameters ranging from $^{3}/_{16}$ through $1^{1}/_{2}$ inch.

Preparation

Before any Rynglok fittings can be installed, you must properly cut and prepare the tube you'll be repairing. You can cut tubes using any appropriate cutting tool—discussed earlier in this unit.

Prior to installing Rynglok fittings to tubing, deburr the tube ends with appropriate deburring tools on the outside and inside diameters. This prevents damage to the inside of the fitting during insertion. While deburring, be careful to prevent all metal shavings and other objects from entering the tube. If you don't, shavings can lead to system contamination.

Installation

Initially, Rynglok fitting installation may seem complicated; however, it's actually quite simple when using the six easy steps described in the following paragraphs.

End marking

Apply a pair of marks (positioning and inspection) to the tube prior to installing the fitting. Use the supplied tube-marking gauge (fig. 5–13) and a suitable permanent ink, felt-tipped pen. Bottom the marking gauge on the end of the cut tube. If an out-of-square condition exists, position the gauge toward the tube end where it's most square.

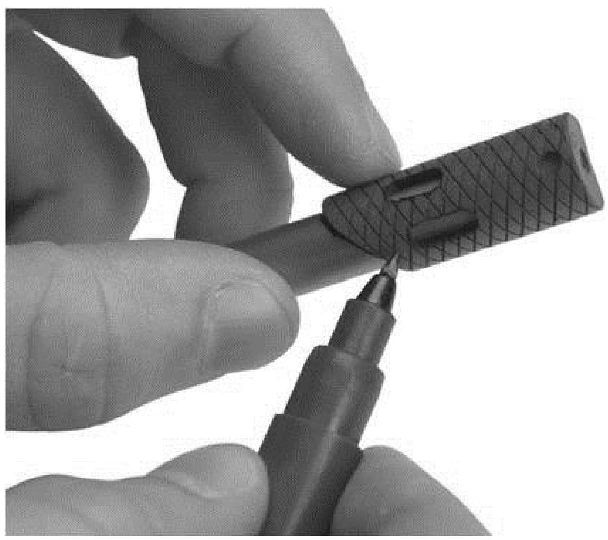


Figure 5–13. Application of tube insertion marks.

CAUTION: Due to the possibility of contaminating titanium tubing, do *not* use inks containing lead or halogens.

Positioning the fitting correctly

Use the previously mentioned positioning marks to position the edge of the unswaged fitting ring over the mark (fig. 5–14). The length of the positioning mark is the amount of positioning tolerance allowed. The edge of the fitting ring may be anywhere along the length of the positioning mark. In general, end fittings are designed with a positive stop or "bottoming" feature that prevents over insertion of the tube. Even with this bottoming condition, the tube end should still be marked for inspection purposes. This ensures the tube was inserted to at least the minimum insertion depth.

Figure 5–14. Position and inspection marks.

Choosing the proper assembly tool

Select the correct size assembly tool (noted on the face of the tool) and pressure class assembly tool. Pressure class assembly tools are *categorized* by the following colors:

- 8,000 psi—silver.
- 6,000 psi—blue.
- 4,000 psi—black.
- 2,500 psi—green.

Making the tool pressure connection

The assembly tool is connected to the pump by way of a flexible hose. Attach the hose to the nipple at the bottom of the assembly tool, and then to the pump. The pump may be a hand pump, foot-operated air/hydraulic intensifier, or switch-operated air/hydraulic intensifier. Attach the pump to an air source.

Making the fitting installation

At this point, you're ready to install your fitting. Position the fitting onto the tube using the alignment marks discussed earlier. Align the assembly tool to one leg of the fitting with the ring resting in the moveable jaw of the tool and the front opening of the tool bottomed into the fitting body (fig. 5–15). The compactness of the assembly tool allows access to the fitting from nearly any radial angle. Apply 8,000 to 8,500 psi hydraulic pressure to the tool to *advance* the fitting ring to complete the assembly process (fig. 5–16). Figure 5–17 shows the Rynglok fitting before and after assembly.

Figure 5–15. Tool position (tube position before pressurization).

NOTE: Tool pressure is 8,000—8,500 psig, regardless of fitting size or pressure class.

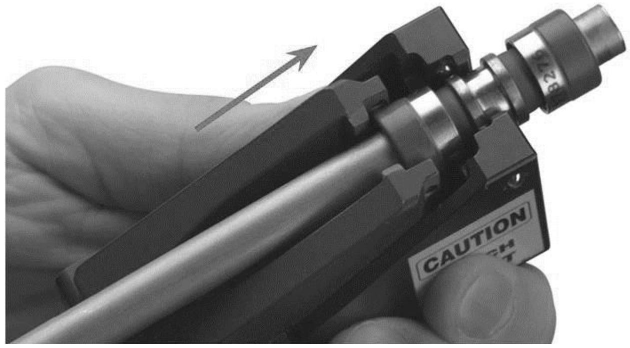


Figure 5–16. Tool position (tube position during pressurization).

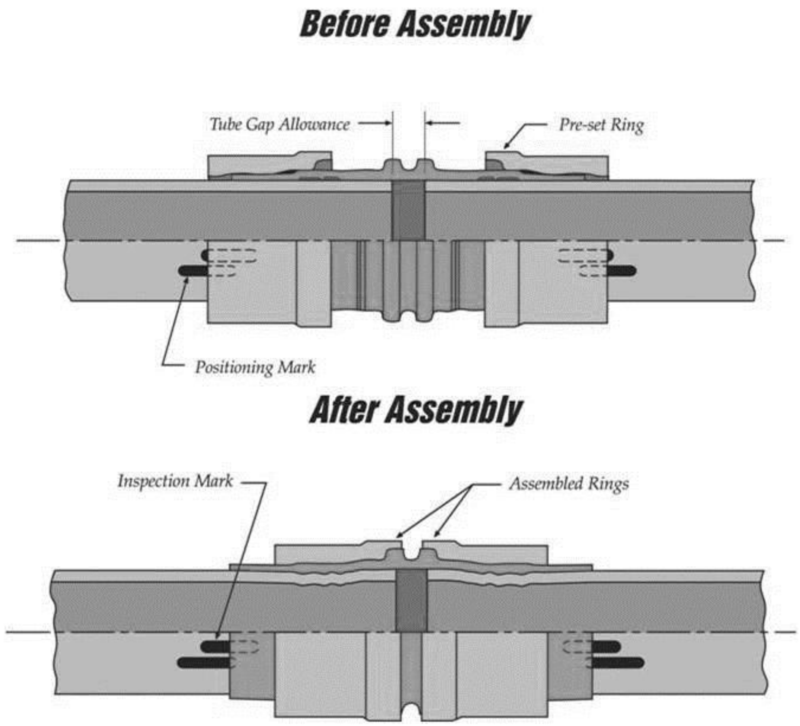


Figure 5–17. Rynglok fitting before and after assembly.

Inspection

After you've completed the installation, verify the ring advancement using a Rynglok go/no-go guage. The edge of the fitting ring may be anywhere along the length of the inspection mark (fig. 5–18), and the inspection gauge should fit over the ring area.

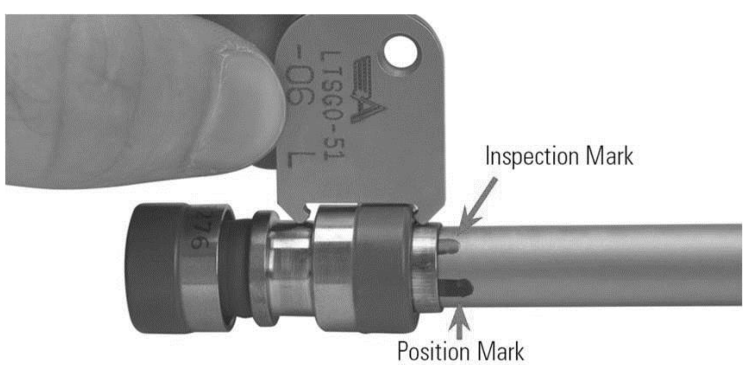


Figure 5–18. Using a Rynglok go/no-go gauge (complete/incomplete ring advancement inspection).

039. Dynatube repairs

Unlike Permaswage and Rynglok, the Dynatube repair method features a strictly hand-operated method of attaching a fitting to the tube from the inside. The fittings are fabricated from 6Al–4V (six percent aluminum, four percent vanadium) titanium.

Like other tubing repair systems, the Dynatube tubing repair procedure also involves cutting, deburring, and tube end preparation. Dynatube fittings are permanently attached to tubing by mechanical expansion; that is, the fitting is attached by physically expanding the tube's inside diameter into grooved receptacles in the fitting. To make Dynatube repairs, you need a working knowledge of tooling, preparation, minimum straight length requirement, and installation procedures.

Tooling

The required tooling consists of tube expanders, holding fixture dies, and gauges for measuring expander settings, and finished swage diameters.

Expanders are available for each tube diameter, wall thickness, and material. Dies are available for each size and style of fitting. Individual repair kits are available for different diameters of tubing:

- Kit 1 is for $^{1}/_{4}$ to $^{5}/_{8}$ inch diameter tubing.
- Kit 2 is for $^{3}/_{4}$ to $1^{1}/_{4}$ inch diameter tubing.

Tube expanders are furnished with a band that identifies the tooling part number, tube OD, tube wall thickness, and specific material for which the tooling was designed.

NOTE: Expanders designed for titanium tubing have an area on the stop collar painted yellow. Blue identifies aluminum and green is used for stainless steel.

Preparation

Tube ends must be burr free, clean, and free of any oils prior to assembly. Cut the ends square and remove any burrs or distortion caused by cutting, such as that caused by a rolling type tube cutter. The OD should have a square edge, but a 60º chamfer is recommended on the inside diameter.

Minimum straight length requirement

The properties of Dynatube tooling necessitate a minimum straight length be maintained between the tube end and the nearest bend start point. This minimum straight length provides mandrel clearance and assures an adequate amount of undisturbed cylindrical tubing at the fitting is maintained.

Installation

The thirteen steps in the following table describe the correct procedure for the swaging operation.

Dynatube Swaging Operation	
Step	**Action**
1	Slip the fitting over the end of the tube until the tube hits the tube stop shoulder in the fitting.
2	Lubricate the rollers and mandrel of the expander. Apply lubricant at the lubrication point in front end of the expander until the lubricant comes out past the rollers.
3	Fully retract the mandrel from the expander and insert the expander into the tube.
4	Place the tube, fitting, and expander in one die half. **NOTE:** Ensure the tube end is against the tube stop shoulder in the fitting.
5	Push the mandrel in and turn it clockwise until it is finger tight.
6	Position the second die to mate with the first die half.
7	With the large diameter of the taper in the collar facing the expander, slip the collar over the expander and dies until the collar bottoms out against the shoulder of the dies. Tighten the collar

Dynatube Swaging Operation	
Step	**Action**
	thumbscrew hand tight. **CAUTION**: The thumbscrew on the collar must be placed approximately 15º to 45º from the parting line of the dies or damage to the dies will result.
8	Using the flat spots on the collar, clamp the entire assembly in a vice or other suitable holding fixture.
9	Push in on the tube to ensure it has remained against the tube stop shoulder in the fitting. **CAUTION**: Do not push the mandrel into the tube. If you do, you'll disturb the tube alignment with the fitting. The mandrel feeds through the expander on its own as it's rotated.
10	Use a hand wrench to turn the mandrel *clockwise* in continuous revolutions. When the shoulder of the mandrel contacts the adjustment sleeve, continue to turn for an additional 10 rotations.
11	Turn the mandrel *counterclockwise* until it's loose. **NOTE:** If the expander cannot be removed from the tube freely, verify that the mandrel is fully retracted and apply a light side pressure on the expander to release the roller or rollers that may be stuck in an expanded position.
12	Loosen the thumbscrew and remove the collar, die halves, and expander.
13	Measure the inside diameter of the tube in the swaged area using an internal caliper.

NOTE: Underswaged or overswaged tube assemblies must be rejected. *Reswaging is not permitted.*

Inspection

When you've completed the installation, it's very important you inspect the finished product to ensure you've produced a safe and reliable tubing assembly. Measure the inside diameter of the tube in the swaged area using an internal caliper. Again, underswaged or overswaged tube assemblies must be rejected. *Reswaging is not permitted.*

Visually inspect each swaged tube assembly for the following:

- Tight fittings on the tube.
- No gaps between the tube end and the tube stop shoulder in the fitting.
- A smooth, polished appearance of the inside area of the tube in the swaged area. Rings with a dull even surface finish are acceptable.
- Tighten the tube against the fitting. Cracks or hanging slivers of metal are not acceptable.

040. Permalite repairs

Permalite fittings come in aluminum, titanium, and CRES, and can be used to repair systems that operate up to 5,000 psi. The fittings come in various designs (i.e., straight, tee, and cross). These fittings are mechanically attached to the tube by axial swaging using a Deutsch axial swage tool (DAT). The benefits of using Permalite are its ease of installation and inspection of the completed swage.

As with the other tubing repair systems, the Permalite system also requires cutting, deburring, and tube end preparation. The installation equipment consists of a hydraulic pump and tool kit containing the DAT tooling along with accessories. The makeup of the kit may vary based upon the fitting sizes being swaged and the special needs of the user.

In this lesson, we present the five procedural steps required to make Permalite repairs—preparation, fitting, positioning, swaging operations, and inspection.

Preparation

Tube ends shall be de-burred and the tube seal area shall be free of cracks, splits, seams, folds, scratches or any other imperfections that is detrimental to the performance of the swaged joint. In addition, this area shall be clean and free of paint, glue and other substance.

Select the proper marking template according to the tube's OD and snap the template into position on the end of the tube (fig. 5–19). Use the sight hole in the template to ensure the template is sitting flush against the tube end. Mark the tube through all three slots—positioning, verification, and inspection—located in the template using the marking pen provided in the kit or any felt tip marker that doesn't contain lead or halogens. Ensure the marks are clearly visible to verify the position of the fitting before and after the swaging.

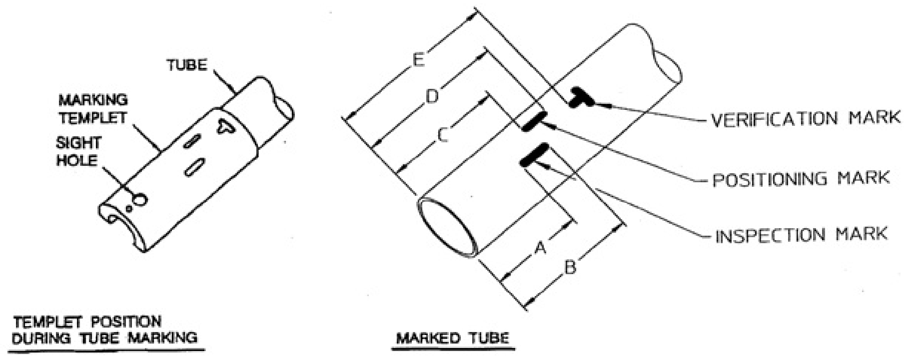


Figure 5–19. Marking template.

Fitting positioning

Slide the fitting onto the tube, locating it on the positioning mark (fig. 5–20). Note the positioning mark is the center one of the three marks you made in the previous step. Some Permalite fittings come with a tube stop built in. Slide this type fitting onto the tube until it stops.

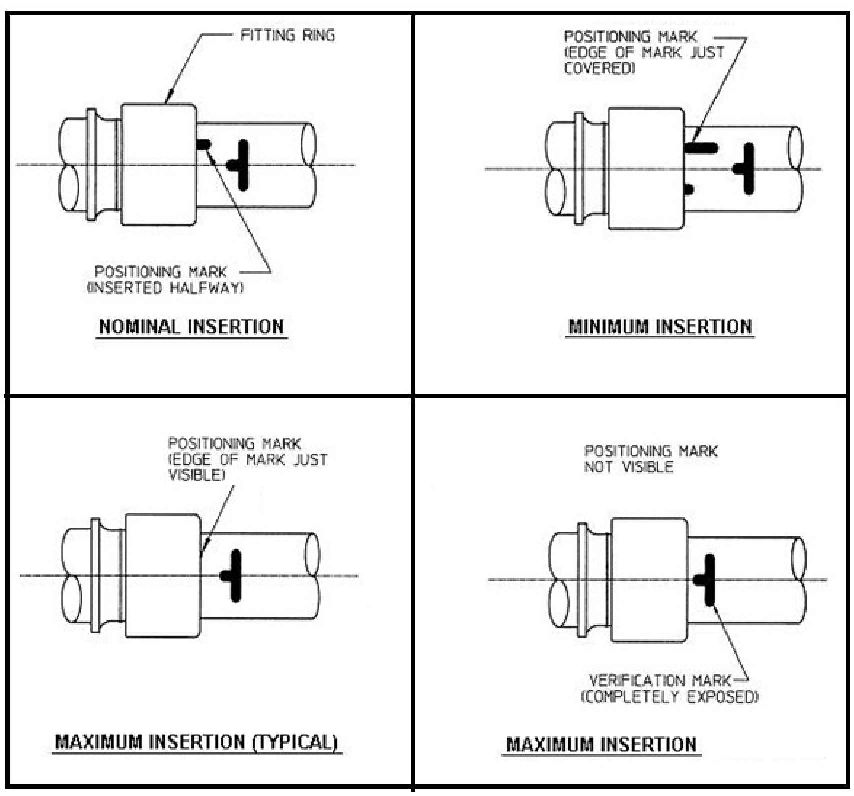


Figure 5–20. Fitting /tube position before swaging.

Swaging operations

After you've marked the fitting positioned on the tube, use the three-step procedure for swaging as presented in the following table:

Swaging Procedures	
Step	**Action**
1.	Position the DAT onto the fitting so the fitting groove is bottomed against the swage tool and the ring is nested within its jaws.
2.	While holding the tool in place, actuate the hydraulic pump until the pressure gauge needle is in the green area of the gauge (8,000–8,500 psi) and the pressure relief valve has functioned. A minimum of 80 psi shop air is required to operate the hydraulic pump. **WARNING:** Never exceed 10,000 psi.
3.	Release the pressure. The jaws retract, allowing the tool to be easily removed from the joint.

NOTE: Every DAT is capable of swaging a fitting in the PUSH or PULL position. However, not all fittings can be swaged in the pull position. Using the DAT in the PULL position requires special attention to ensure the fitting doesn't move during the swaging process.

Inspection

After you've completed the swage, you must inspect for proper tube insertion, proper ring position, and possible fitting anomalies due to swaging.

Proper tube insertion

Visually inspect the position of the swaged fitting on the tube. At least two marks should be visible in whole or in part (fig. 5–21). If you can't see at least two marks, then you made a mistake and inserted the tube too far into the fitting. The verification mark should always be completely exposed. The positioning mark is completely exposed or partly covered. The inspection mark should always be partly or completely covered, or just touching the swaged fitting.

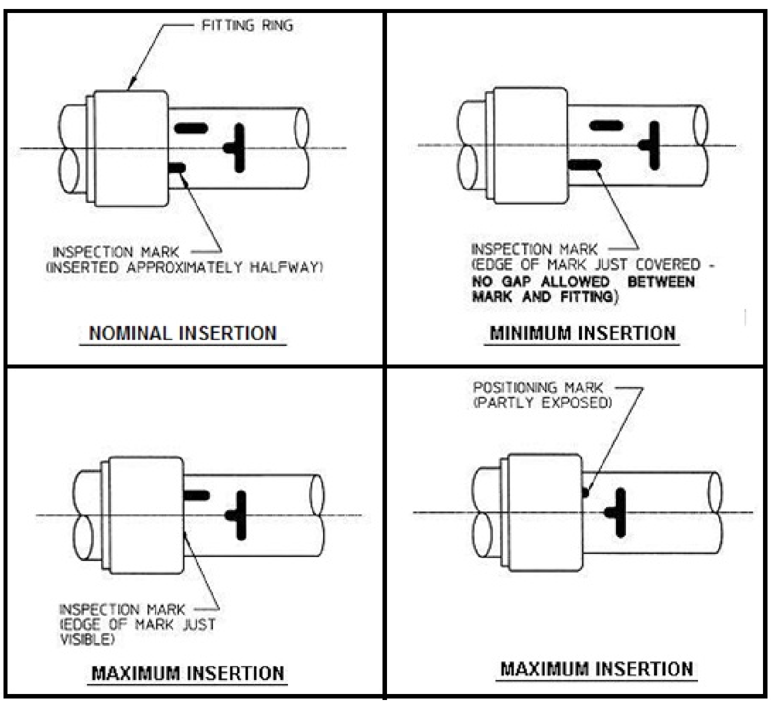


Figure 5–21. Fitting/tube position after swaging.

NOTE: In no event should there be a visible gap between the inspection mark and the swaged fitting. This indicates insufficient tube insertion.

Proper ring position

Use a go/no-go gauge (fig. 5–22) contained in the kit and inspect the ring position. Select the gauge that corresponds to the diameter tube being repaired and place the gauge onto the completed swage. The flat gauge should fit all around the fitting ring/flange without forcing it. The cylindrical gauge should fit around the fitting ring/flange without forcing it in at least one location. If the gauge doesn't fit, it's allowable for you to reswage the fitting. When you're reswaging, it's recommended the DAT be repositioned at least 90º from the position the DAT was originally in.

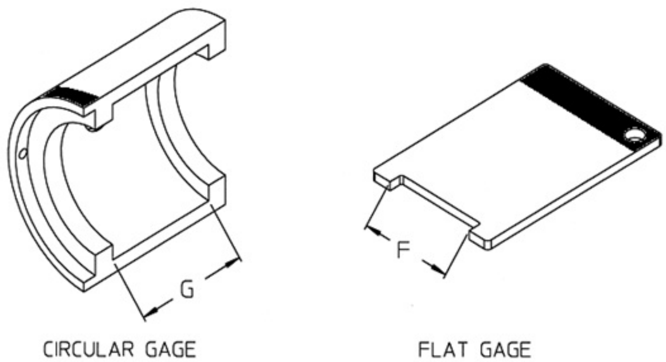


Figure 5–22. Go/no-go gauges (inspection gauge).

Possible fitting anomalies due to swaging

The following are two possible fitting anomalies you may encounter (fig. 5–23):

1. Gaps—Visually inspect the swaged fitting for a gap between the fitting flange and the ring leading edge. A gap is allowable as long as it meets the go/no-go gauge requirements.
2. Deformation—Inspect the flange/ring for deformation and ensure no deformities exceed 0.030 inch. If the deformity is greater than 0.030 inch or any metal is missing, the fitting should be rejected.

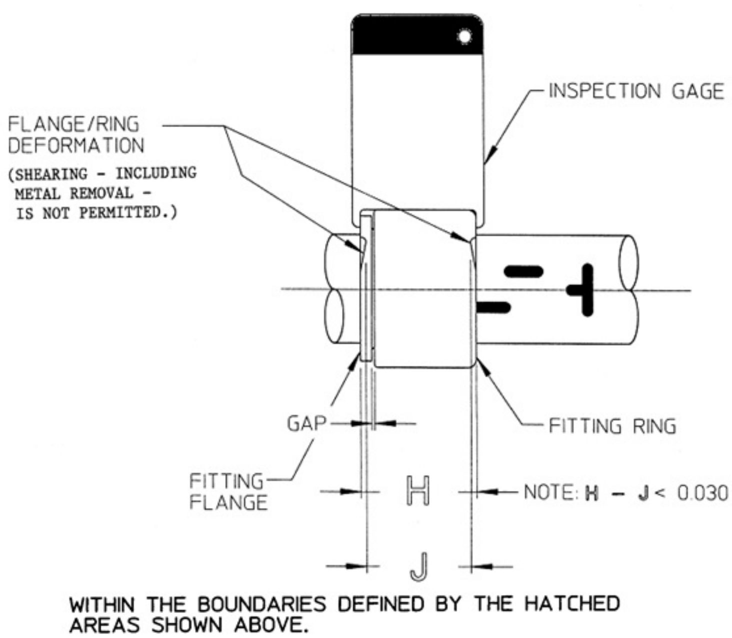


Figure 5–23. Inspection criteria.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

037. Permaswage repairs

1. What is the basic element of the Permaswage tube repair method?

2. What types of tubing material composition cannot be used with the Permaswage repair?

3. What basic steps *must* be done to complete a Permaswage repair?

4. What function does the elastic plug serve during the deburring operation?

038. Rynglok repairs

1. Why must you be careful to prevent all metal shavings and other objects from entering a tube while deburring with a Rynglok?

2. What type of marks do you apply to the tube prior to making a Rynglok repair?

3. What are the identifying colors and their classifications for the pressure class assembly tool?

4. What type of pumps are available for the Rynglok repair system?

5. How much pressure is *required* to advance the Rynglok fitting ring?

6. What do you do after you have completed a Rynglok fitting installation?

039. Dynatube repairs

1. What tooling makes up the Dynatube repair system?

2. What does the identification band on a Dynatube expander indicate?

3. Besides a clean, square edge, what else is recommended for a tube end prior to installing a Dynatube fitting?

4. What is the purpose of the minimum straight length on a tube?

5. Why must you place the collar thumbscrews 15º to 45º from the parting line of the dies?

6. When can you reswage a tube assembly using the Dynatube repair method?

040. Permalite repairs

1. What are the names of the three marks you must make when you are using the tube marking template?

2. Which one of the three marks identified in self-test question #1 do you use when you are placing the new fitting onto the tube?

3. How do you position the DAT on the fitting for swaging?

4. How much shop air pressure is required to operate the hydraulic pump during swaging operations?

5. Name the three conditions you must inspect for after you have completed a swaging operation.

Answers to Self-Test Questions

034

1. Aluminum, stainless steel, and titanium.
2. A nut and a sleeve.
3. They are equal to the OD of the tubing.
4. Tubing that is not flared.
5. By their color.

035

1. Chafing, galling, and fretting.

2. The severity of the damage.
3. Negligible damage.
4. Using a tubbing cutter.

036
1. $^{3}/_{8}$ to $1^{1}/_{2}$ inch OD.
2. Electric pump to build up hydraulic pressure.

037
1. The Permaswage fitting, which is mechanically swaged to the OD of the tubing.
2. Annealed CRES and 5052 aluminum alloy.
3. Cutting, deburring, tube end preparation, and fitting installation.
4. It prevents chips generated during the deburring operation from entering the tube.

038
1. To prevent system contamination.
2. Positioning and inspection.
3. Silver—8,000 psi; blue—6,000 psi; black—4,000 psi; and green—2,500 psi.
4. Hand pump, foot-operated air/hydraulic intensifier, and switch-operated air/hydraulic intensifier.
5. 8,000–8,500 psig.
6. Verify the ring advancement using a Rynglok go/no-go gauge.

039
1. Tube expanders, holding fixture dies, and gauges.
2. Tooling part number, tube OD, tube wall thickness, and specific material for which the tooling was designed.
3. A 60º chamfer on the inside diameter.
4. It provides mandrel clearance and assures an adequate amount of undisturbed cylindrical tubing at the fitting is maintained.
5. To prevent damage to the dies.
6. Never; reswaging is not permitted.

040
1. Verification, positioning, and Inspection.
2. Positioning.
3. So the fitting groove is bottomed against the swage tool and the ring is nested within its jaws.
4. A minimum of 80 psi.
5. Proper tube insertion, proper ring position, possible fitting anomalies due to swaging.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

63. (034) The tubing material for manufacturing external aircraft brake lines is
    a. corrosion-resistant stainless steel tubing type 304.
    b. 2024-T aluminum alloy tubing.
    c. 5052–0 aluminum alloy tubing.
    d. 6061-T aluminum alloy tubing.

64. (035) What are the three operations usually involved in replacement of a tubing assembly?
    a. Forming, Cutting, and Cleaning.
    b. Washing, Deburring, and Cutting.
    c. Forming, Deburing, and Cleaning.
    d. Washing, Pressurizing, and Fitting.

65. (035) What is the preferred method of cutting tubing?
    a. Hacksaw.
    b. Bandsaw.
    c. Tin snips.
    d. Tubing cutter.

66. (036) What size outside diameter (OD) of aluminum tubing can be bent with a production tube bender?
    a. $^1/_4$ inch to $^1/_2$ inch.
    b. 1 inch to 2 inches.
    c. $^3/_8$ inch to 1.5 inches.
    d. 2 inches to 2.5 inches.

67. (037) You can use the Permaswage repair method to repair damaged tubing that carries pounds per square inch (psi) pressures *up to a maximum of*
    a. 2,000 psi.
    b. 3,000 psi.
    c. 4,000 psi.
    d. 5,000 psi.

68. (037) The step *not* required when preparing a piece of tubing for a Permaswage repair is tube
    a. cutting.
    b. deburring.
    c. chamfering.
    d. end preparation.

69. (038) You can use the Rynglok repair method to repair damaged tubing assemblies that have operating pounds per square inch (psi) pressures *up to a maximum* of
    a. 2,000 psi.
    b. 4,000 psi.
    c. 6,000 psi.
    d. 8,000 psi.

70. (039) Dynatube expanders designed for *titanium* are identified by an area on the stop collar painted
    a. red.
    b. blue.
    c. green.
    d. yellow.

71. (040) The end marking template for a Permalite fitting is based on the
    a. temper of the tubing.
    b. wall thickness of the tubing.
    c. outside diameter of the tubing.
    d. material composition of the tubing.

72. (040) For the swage of a Permalite fitting to be acceptable, *at least*
    a. one alignment mark should be visible.
    b. two alignment marks should be visible.
    c. three alignment marks should be visible.
    d. four alignment marks should be visible.

Student Notes

Glossary of Abbreviations and Acronyms

AGE	aerospace ground equipment
AISI	American Iron and Steel Institute
AMS	Aerospace Material Specification
AN	Air Force–Navy Standard
ANT	Automatic Nut Tool
ASTM	American Society for Testing and Materials
°C	degrees Celsius
CRES	corrosion-resistant steel
DAT	Deutsch axial swage tool
°F	degrees Fahrenheit
FOD	foreign object debris
HS	high-speed
HSS	high-speed steel
IPB	illustrated parts breakdown
LO	low observable
LOASM	low observable aircraft structural maintenance
MS	military standard
NAS	National Aerospace Standard
OD	outside diameter
psi	pounds per square inch
SAE	Society of Automotive Engineers
SE	support equipment
TO	technical order
TCTO	time compliance technical order

Student Notes

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