OBJECTIVES

- Describe threaded fastening systems and relevant applications.
- Describe nonthreaded fastening systems and relevant applications.

Many types of metal fastening devices are used by agricultural mechanics for repair, construction, and fabrication purposes. These devices include nails, staples, screws, and bolts. Nails are the primary type of wood fasteners. Staples are frequently used for lighter applications. Screws are often specified for certain applications. Bolts may be used for applications where the ability to remove the fasteners is required. Adhesives are used in combination with nails, staples, and screws for applications where additional holding power is required.

The proper tools must be used to prevent injuries and to avoid damaging fasteners during installation or removal. In addition, appropriate personal protective equipment (PPE), such as safety glasses or goggles, must be worn to prevent or minimize injuries.

THREADED FASTENERS

A fastener is a component used for fixing the relative positions of parts in an assembly. Fasteners may form permanent or nonpermanent connections. Permanent connections cannot be disconnected without destroying the fastener, but nonpermanent connections can.

A threaded fastener is a device, such as a nut and bolt, that joins or fastens parts together with threads. Threaded fasteners have several advantages for joining parts. Threaded fasteners are available in a variety of sizes, styles, strengths, and materials and are capable of joining similar or dissimilar materials. They are easily installed with hand or power tools and are easily removed and replaced. Threaded fasteners are an inexpensive method for joining metal and require minimal skill to use. The most common threaded fasteners used in agricultural applications are screws, bolts, and nuts.

Threaded fasteners are based on the principle of a spiral rib of material, or thread, wrapped on the inside or outside of a cylinder. A thread is a ridge of uniform section in the form of a helix on the internal or external surface of a cylinder. See Figure 7-1.

Thread Types

An external thread is a thread on the external surface of a cylinder. For example, threads on bolts are external. An internal thread is a thread on the internal surface of a hollow cylinder. Threads on nuts are internal.

A right-hand thread is a thread that, when viewed from the fastener head, winds in a clockwise direction. Viewed from the side, a right-hand thread always slopes up to the right regardless of the position it occupies. Right-hand threads are the most common type of thread used in agricultural applications. Threads are assumed to be right-handed unless otherwise specified. A left-hand thread is a thread that, when viewed from the fastener head, winds in a counterclockwise direction. Viewed from the side, a left-hand thread always slopes up to the left regardless of the position it occupies. All left-hand threads are designated LH. See Figure 7-2.
Thread Dimensions

The dimensions of fastener threads are based on their pitch and the diameter. Pitch determines the number of threads per inch, and the diameter determines the width of the thread. The three distinct features of threads are flanks, crests, and roots. A flank is the surface on a fastener connecting the crest with the root. A thread angle is the angle created between two facing flanks of a thread. A crest is the surface on a fastener that connects two flanks, which form a peak on the thread. A root is the surface on a fastener that joins the flanks and is identical in position with, or immediately adjacent to, the cylinder from which the thread projects. Crests and roots are comparable to the peaks and valleys of mountain ranges, with flanks as the sloping sides. See Figure 7-3.

Figure 7-1. A thread is a ridge of uniform section in the form of a helix on the internal or external surface of a cylinder.

Figure 7-2. Threads are external or internal and right- or left-hand.

Figure 7-3. Thread dimensions include the root, crest, flank, thread angle, and pitch.
**Pitch** is the distance, measured parallel to the thread's axis, between two crests. The measurement of the pitch (when measured in inches) is threads per inch (TPI).

A **major diameter** is the thread diameter of the imaginary coaxial cylinder that bounds the crest of an external thread or the root of an internal thread. A **minor diameter** is a straight thread diameter of the imaginary coaxial cylinder that bounds the root of an external thread or the crest of an internal thread.

**Thread Identification**

There are numerous types of screw thread classifications used for bolts, but the two most common classifications in U.S. agriculture are the Unified Thread Standard (UTS) and metric thread identification. The **United Thread Standard (UTS)** is a standard thread classification with allowances, tolerances, and designations for screw threads commonly used in the United States and Canada.

**Unified Thread Identification.** The UTS is based on a 60° standard thread angle. The 60° thread angle is the same as the ISO metric screw thread used outside of North America, but the outer diameter and pitch dimensions of each UTS thread were chosen as an inch fraction rather than a round millimeter value. Two commonly used thread pitches are Unified National Coarse (UNC) and Unified National Fine (UNF). UNC threads are stronger, while UNF threads that are attached to equipment are less likely to vibrate loose.

Subsequent developments led to the Unified National Inch Screw Thread Form, which includes the profiles of Unified National (UN) and Unified National Rounded (UNR) threads. These two are the same, except that the roots and crests of UNR threads are rounded.

**Metric Thread Identification.** Metric threads share the same basic profile as UN threads but differ in diameter and thread pitch, which are based on the metric system. Metric threads are the primary system in most countries besides the United States and are defined in ISO Standard 68-1, *General-Purpose Screw Threads*. With metric threads becoming more common in American manufacturing, the American National Standards Institute (ANSI) and ASME International have developed the ANSI/ASME Standard B1.13M, *Metric Screw Threads: M Profile*, which closely follows the ISO standard.

Size designations for metric threads begin with a capital letter M, are followed by the diameter in millimeters, an “x”, and then the pitch. However, ISO practice calls for the pitch to be omitted when designating coarse series threads. Therefore, an ISO metric 10 mm coarse series thread with a pitch of 1.5 mm would simply be designated M10, whereas the same diameter in the fine thread series would be designated M10 x 1.25.

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**TECH TIP**

Because of the varying screw thread sizes in use at the time, the National Screw Thread Commission was established by the U.S. Congress in 1918. The purpose was to adopt new screw thread standards for American industries and government services in order to eliminate unnecessary screw thread sizes and to use predominant existing screw sizes as much as possible.

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**Thread Classes**

The class of thread indicates its tolerance and allowance. **Tolerance** is the amount of variation allowed above or below a dimension. **Allowance** is the minimum clearance between the maximum dimensions of mating parts. Tolerance and allowance determine the condition of the fit (loose or tight) of mating threads. The screw thread classes have been developed for the thread forms based on desired fit.

**Unified Thread Classes.** Thread classes in the UN are designated by a numeral followed by the letter A for external threads and B for internal threads. The three classes of external threads are 1A, 2A, and 3A. The three classes of internal threads are 1B, 2B, and 3B. Classes 1A and 1B have the greatest amount of allowance. They are intended for applications that require frequent and rapid assembly and disassembly with minimum binding, even with slightly bruised or dirty threads.

Classes 2A and 2B are considered standard for general-purpose threads on bolts, nuts, and screws. They provide standard allowances to ensure minimum clearance between external and internal threads, which minimizes galling and seizing in high-cycle wrench assembly. Because of their realistic tolerances, classes 2A and 2B are widely used for mass-production purposes.

Classes 3A and 3B are suitable for applications requiring closer tolerances than those provided by classes 2A and 2B. They are designated for set screws, socket head cap screws, aircraft bolts, and high strength materials where it is necessary to limit the variations of the thread elements.
The requirements for screw thread fits depend on their end use. A combination of thread classes for components is possible. For example, a Class 2A external thread may be used with a Class 1B, 2B, or 3B internal thread. Cost generally increases proportionately to the accuracy required. For economy, no closer thread fit should be used than is needed for the proper functioning of the components.

**Metric Thread Classes.** Metric threads follow a combination number and letter system for classifying thread tolerances and fit. The number specifies the tolerance grade and ranges from 3 to 9, depending on the application. The smaller numbers indicate tighter tolerances. The most common grades are 4, 5, and 6. The letter specifies the tolerance position, which is the distance of the tolerance from the basic size of the thread profile. Capital letters G and H are used for internal threads, and lowercase letters e, f, g, and h are used for external threads.

A property class is a metric bolt designation used to describe bolt strength and consists of two numbers separated by a decimal point. Common property classes of metric bolts are 8.8, 10.9, and 12.9. Property class 8.8 is roughly equivalent to grade 5, and property class 10.9 is roughly equivalent to grade 8. ISO metric bolts are easily identified by the property class designations exhibited on the bolt heads.

**Thread Specifications.** Thread specifications are designated in a standardized format. This provides the necessary information in a compact format. UN thread specifications are designated in the following sequence:
1. nominal size in inches
2. number of threads per inch
3. thread series (if omitted, size and thread combination indicates the series)
4. thread class (if omitted, class 2 is assumed)

For example, the specification "3/4"-16 UNC-2B" indicates an internal ¾" diameter, 16 threads per inch, Unified National Coarse thread, and a general purpose allowance. In most cases, this thread is specified simply as a ¾"-16 internal thread. Metric screw threads specifications are designated in the following sequence:
1. capital letter “M” for metric
2. nominal size in millimeters
3. thread pitch in millimeters
4. thread tolerances

For example, the designation “M20 x 2-5g6g” indicates a metric external thread with a nominal diameter of 20 mm, thread pitch of 2 mm, a tolerance grade and position for the thread pitch diameter of 5g, and major diameter that has a tolerance grade and position of 6g.

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**Screws**

For most agricultural applications, screws provide greater holding power than nails. In general, wood screws, sheet-metal screws, and machine screws are used for fastening hardware to wood or metal members, attaching cabinets to walls, and fastening trim to metal surfaces. Specialty screws are used for applications such as drywall, paneling, concrete, machine tools, and electrical connections.

Most screws are made of soft steel. Brass, bronze, and copper screws are also available. For decorative purposes and for matching different hardware finishes, steel screws are available in many finishes, including nickel, chromium, silver plate, and gold plate.

**Wood Screws.** A wood screw is a fastener with a helical threaded shaft designed to grasp and hold in wood. Screw heads can be round, oval, or flat and have a single recessed slot, a recessed cross slot (Phillips), a recessed square (Robertson), or a recessed shape (Torx®). See **Figure 7-4.** Phillips and Robertson square screw heads provide better grip than single slot screw heads when driven by an electric screwdriver. They are also more attractive when in place.
**Figure 7-4.** The three basic screw heads are round, oval, or flat. Screw heads have a single slot, a recessed cross slot, a square recess, or a Torx® recess.

**TECH TIP**

Construction-grade screws, driven by power screwdrivers or automatic screw guns, are used for many agricultural framing operations. Construction-grade screws are commonly used to fasten subfloor, roof sheathing, and wall sheathing to framing members. Construction-grade screws are self-driving and do not require a pilot hole. Care should be taken not to over-torque screws when driving them into panels with power tools.

Wood screws range in size from 1/4” to 5” long. The diameter of the screw shank is identified by a gauge number. A higher gauge number indicates a thicker screw. When using wood screws to fasten wood pieces together, a shank hole should be drilled in the piece being fastened. See Figure 7-5. An undersized pilot hole for the threads going into the receiving piece will make driving the screw easier and prevent splitting. Flat-head screws may be countersunk or counterbored. Countersinking a screw places the top of the screw head flush with the wood surface. Counterboring is used when the screw head is to be concealed with a wood plug.

**Figure 7-5.** A higher gauge number for wood screws indicates a thicker screw shank. Shank and pilot holes should be drilled when using wood screws to fasten wood pieces together.
Self-Tapping Screws. A self-tapping screw is a screw with a tip that cuts into metal and forms its own hole. Self-tapping screws are used to fasten metal framing members to each other and to fasten other materials to metal framing members. Self-tapping screws tap their own threads as they are being driven into the metal members. Self-tapping screws are available as self-drilling and self-piercing screws with different heads for various applications. See Figure 7-6.

Figure 7-6. Self-tapping screws are used to fasten metal framing members to each other and to fasten other materials to metal framing members.

A self-drilling screw is a threaded fastening device that, when driven into thinner metals, will drill a hole, cut threads, and fasten in one operation. Self-drilling screws are the most frequently used metal-to-metal fasteners. The points of self-drilling screws drill through the metal layers before the screw threads engage. The drill point of the screw must be sharp and long enough to penetrate the steel being fastened together. Coarse screw threads are commonly used for light-gauge steel-framing operations. Finer threads may be used when tapping into thicker steel material.

A self-piercing screw is a threaded fastening device with a sharp point capable of penetrating and tapping thin metal. Screw diameters are identified by gauge numbers, which range from #6 to #14. The most frequently used self-piercing screw diameters are #6, #8, and #10, which are 0.138", 0.164", and 0.190", respectively.

Concrete Screws. Concrete screws are used to fasten items, such as plates, furring strips, and electrical boxes, to concrete, brick, or block. Concrete screws are cold-formed fasteners with twin-lead threads and a nail-point tip. Concrete screws are available in 3/16", 1/4", and 5/16" diameters and lengths ranging from 1 1/4" to 4".

Concrete screws are available with Phillips, square (Robertson), and hex heads. Phillips-head concrete anchors are used when appearance is important or when the head must be flush with the surface. Hex-head screws are typically used since the head will engage better with the driver, making them easier to drive. Concrete screws provide excellent corrosion resistance in dry environments and can be removed without damaging the base material.

When installing concrete screws, first the proper length of screw to be installed is determined. The thickness of the material to be fastened is added to the minimum depth of embedment, and a screw of that length or longer is selected. Concrete screws must be embedded a minimum of 1". Maximum strength is achieved when the screw is embedded approximately 1 1/4". A hole is drilled for the screw. Screws that are 3/16" require a 3/16" diameter drill, 1/4" screws require a 5/32" diameter drill, and 5/32" screws require a 3/16" diameter drill. The hole should be drilled 1 1/4" deeper than the length of the screw embedment. Hammer drills are commonly used to drill into masonry. Excess grit must be removed from the hole before installing the fastener.

The screw is driven into the predrilled hole until the screw is fully seated. A slow to moderate drill speed is used, and firm and even pressure is applied when driving the screw.

Machine Screws. Machine screws are available with a variety of head shapes. Machine screws screw into threaded holes in metal and have greater holding power than other types of screws that fasten to metal.

The size of a machine screw or machine bolt is expressed as the length, diameter (in inches), and number of threads per inch if the screw or bolt is 1/4" diameter or larger. For example, a 2" x 1/4-20 designates a screw or bolt that is 2" long, is 1/4" in diameter, and has 20 threads per inch. For smaller machine screws or bolts, a gauge number is used to specify the diameter.

Bolts and Nuts

Bolts and nuts are purchased parts. A bolt is a cylindrical fastener made from metal and has a head or hooked end and a fully or partially threaded body. A nut is a piece of metal or other hard material that is female threaded to
receive a bolt or other male-threaded device. A drive is the shape of the recess on a fastener head that fits the tool used to rotate the fastener. Bolts and nuts are available in a wide range of sizes (diameters and lengths), strengths, head styles, and materials and can be removed as needed for assembly or disassembly of parts. See Figure 7-7.

Anchor bolts are typically used in the construction of agricultural structures. An anchor bolt is a steel rod threaded at one end used to secure structural members to concrete or masonry. Anchor bolts are commonly formed in an L or J shape.

The length of a threaded fastener is the distance from the bearing surface of the head to the tip measured parallel to the axis. Usually only part of the length is threaded. The thread length for standard bolts is generally twice the diameter plus ¼" for bolts below 6" in length. For bolts 6" in length and higher, the thread length is generally twice the diameter plus ½".

Figure 7-7. Bolts and nuts are fasteners that can be removed as needed for assembly or disassembly of parts.
Nuts are square or hexagonal in shape so that they can be rotated with a wrench. The distance between opposite flats is the size of the corresponding wrench. Many styles of standard and specialty nuts are available. Some nuts are designed specifically to resist loosening.

**Bolt Head Markings.** Bolts, screws, and nuts are purchased parts. The Society of Automotive Engineers (SAE) and ASTM International have established standards for classifying bolts and screws into grades based on their tensile strength and yield strength. Markings of radial lines on a bolt head indicate the grade. See Figure 7-8. This information must be referenced when the fastener is initially used and during service and repair of an assembled component. Threaded fasteners that are replaced must match the characteristics of the original threaded fastener.

<table>
<thead>
<tr>
<th>BOLT HEAD MARKING</th>
<th>SAE/ASTM DEFINITIONS</th>
<th>MATERIAL</th>
<th>MINIMUM TENSILE STRENGTH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO MARKS</td>
<td>SAE Grade 1</td>
<td>Low-carbon steel</td>
<td>65,000</td>
</tr>
<tr>
<td></td>
<td>SAE Grade 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Indeterminate quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 MARKS</td>
<td>SAE Grade 5</td>
<td>Medium-carbon steel, quenched and tempered</td>
<td>120,000</td>
</tr>
<tr>
<td></td>
<td>ASTM A 449 Common commercial quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 MARKS</td>
<td>SAE Grade 7</td>
<td>Medium-carbon alloy steel, quenched and tempered, rolled threaded after heat treatment</td>
<td>133,000</td>
</tr>
<tr>
<td>6 MARKS</td>
<td>SAE Grade 8</td>
<td>Medium-carbon alloy steel, quenched and tempered</td>
<td>150,000</td>
</tr>
<tr>
<td></td>
<td>ASTM A 354</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Best commercial quality</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*In psi

**Figure 7-8.** Bolt head markings indicate grade, material, and tensile strength.

**Bolt Thread Length Calculations**

Calculate the thread length for the following standard bolt sizes.

<table>
<thead>
<tr>
<th>Length</th>
<th>Threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO 6&quot;</td>
<td>2D + 1/4&quot;</td>
</tr>
<tr>
<td>OVER 6&quot;</td>
<td>2D + 1/2&quot;</td>
</tr>
</tbody>
</table>

1. 1/2"-13 x 4"
2. 5/8"-11 x 3"
3. 3/4"-10 x 5"
4. 3/8"-10 x 8"
5. 7/8"-9 x 2"
6. 7/8"-9 x 6"
7. 1 1/4"-7 x 5"
8. 9/8"-11 x 11"
9. 3/4"-10 x 7"
10. 1"-8 x 10"
Washers

A washer is a small metallic disc with a hole in its center. A washer is used under the head of a bolt or screw, and/or under a nut, to spread the tightening force over a larger area. Some washers also provide resistance to loosening of the connection. The three basic types of washers are plain, spring lock, and tooth lock.

Plain Washers. Plain washers are round and flat. They are used under the head of a screw or bolt or under a nut to spread a load over a greater area. They are also used to prevent the marring of parts during assembly as a result of turning the screw, bolt, or nut. Plain washers are available in zinc, stainless steel, SAE zinc, fender, and SAE grade zinc. See Figure 7-9.

Spring Lock Washers. Spring lock washers are split on one side and are helical in shape. They are made of hardened steel, bronze, or aluminum alloys. Spring lock washers have several functions. As springing devices, they provide good bolt tension and protect against loosening from vibration or corrosion. See Figure 7-10. Spring lock washers also act as hardened bearing surfaces and provide uniform load distribution.

Tooth Lock Washers. Tooth lock washers have hardened teeth along an edge that are bent and offset in opposite directions to bite or grip both the work surface and the bolt head or nut. This locks fasteners to the assembly or increases the friction between the fastener and the assembly. The teeth can be external, internal, internal-external, or countersunk external. See Figure 7-11. Tooth lock washers also make good electrical contacts. Unlike spring lock washers, they do not provide spring action to counteract wear or stretch in the parts of an assembly.

An external tooth lock washer is the most commonly used tooth lock washer, but an internal tooth lock washer is used where it is necessary to consider appearance and to ensure engagement of teeth with the bearing surface of the fastener. Where additional locking ability is required or where there is need for a large bearing surface, such as over a clearance hole, an internal-external tooth lock washer may be used. Countersunk external tooth lock washers are used with flat head and oval head machine screws.

Thread Lock Coatings. Thread lock coatings can be used in place of lock washers. A thread lock coating is a liquid coating applied to a threaded fastener to prevent the loosening of assembled parts from vibration, shock, and/or chemical leakage. The coating is selected based on the fastener and application. Special high-temperature and chemical-resistant thread lock coatings are available. Fasteners can also be purchased with the threads precoated.
To remove a broken bolt or screw with a screw extractor, apply the following procedure:
1. Drill a small pilot hole in the center of the broken bolt or screw.
2. Drill a second, larger extractor hole into the pilot hole.
3. Apply penetrating oil and use a hammer to tap the proper size screw extractor into the drilled hole.
4. Rotate the extractor counterclockwise for a broken bolt or screw with a right-hand thread (clockwise for a left-hand thread) and remove the broken bolt or screw.

Damaged internal threads can be repaired by creating new ones with a tap or by using a threaded insert. A threaded insert is a small device that is turned into a pre-drilled hole to form screw threads. Threaded inserts may be used where an internal thread is damaged or stripped.

A threaded insert is installed by enlarging a hole to a specified oversize, tapping it with a special tap designed for the threaded insert, and screwing the insert into the hole. The insert stays in the hole as a permanent repair. Threaded inserts enable the use of the original bolt because the internal threads are the same size as the original. When correctly installed, a threaded insert is often stronger than the original threads. See Figure 7-13.

**NONTHREADED FASTENERS**

A nonthreaded fastener is a device that joins or fastens parts together without threads. Nonthreaded fasteners may be either temporary (easily removed) or permanent (removable only with special tools, great force, or destruction of the fastener). The most common types of nonthreaded fasteners are nails, staples, rivets, pins, keys, and adhesives.

Many types of metal fastening devices are used for construction purposes including nails, staples, screws, and bolts. Nails are the primary type of wood fasteners. Staples are frequently used for lighter applications, such as plastic sheeting. Screws have gained greater acceptance in construction and are specified for certain applications. Bolts may be used for applications where the ability to remove the fasteners is required. A variety of anchoring devices are also used to fasten materials to concrete, masonry, and steel. Adhesives (glues and mastics) are used in combination with nails, staples, and screws for applications where additional holding power is required.

The proper tools must be used to prevent injuries and damaging fasteners during installation or removal. In addition, appropriate personal protective equipment (PPE), such as safety glasses or goggles, must be worn to prevent or minimize injuries.
**Screw Extractors—Broken Bolt Removal Procedure**

1. **DRILL SMALL PILOT HOLE IN CENTER OF BROKEN BOLT.**

2. **DRILL LARGER EXTRACTOR HOLE INTO PILOT HOLE.**

3. **APPLY PENETRATING OIL AND USE HAMMER TO TAP PROPER SIZE SCREW EXTRACTOR INTO DRILLED HOLE.**

4. **USE WRENCH TO ROTATE SCREW EXTRACTOR AND REMOVE BROKEN BOLT.**

*Figure 7.12. Screw extractors are used to remove broken bolts and screws from equipment without causing damage to screw threads or equipment.*

**Threaded Insert Installation**

1. **DRILL SLIGHTLY OVERSIZED HOLE**

2. **TAP HOLE**

3. **THREADED INSERT**

*Figure 7.13. A threaded insert is installed by drilling a hole to a specified oversize, tapping it with a special tap, and screwing the insert into the hole.*

**Nails**

A *nail* is a fastener used to secure together two or more pieces of material, such as wood or masonry. Nails are straight, slender pieces of metal with one pointed end and one end that is struck with a hammer or driven with pneumatic or powder-actuated gun. Nails are available in many shapes and sizes and with a variety of heads, shanks, and points. Flat-head, diamond-point nails are commonly used in agricultural applications. See *Figure 7-14.* Some nails, typically those with special finishes or deformed shanks (barbs, spirals, rings), have greater holding power than other nails. Aluminum, stainless steel, and galvanized steel nails are used to fasten finish materials to a building exterior since they are corrosion-resistant and will not cause rust streaks on the surface of wood materials.

Special fasteners may be required when installing engineered wood products. For example, common cement-coated or ring-shank nails are used when installing subfloors. Common smooth-shank, ring-shank, screw-shank, or galvanized box nails are used when installing wall sheathing. Common smooth-, ring-, or screw-shank nails are recommended when installing roof sheathing. Hot-dipped galvanized box, siding, or casing nails are used to install rated siding directly to studs or over nonstructural sheathing.
A number and the letter “d” are commonly used to designate nail sizes. Typical sizes are 6d, 8d, and 16d. A 6d nail is 2” long, an 8d nail is 2⅛” long, and a 16d nail is 3⅛” long. See Figure 7-15. The letter “d” represents denarius, an ancient Roman word for coin (or penny). The penny system originated hundreds of years ago in England where nails were priced by the cost (in pennies) per hundred nails. Smaller nail sizes cost less per hundred than larger sizes. The gauge, or diameter, of a nail depends on the type and length of the nail. The gauge of a nail increases as the length increases.

Nail sizes may also be designated as the gauge of the nail and the length. For example, a 0.131 × 1½” nail may be specified to fasten metal connectors to framing members.

**Rough Work Nails.** A *common nail* is a nail with a smooth cylindrical shaft and a flat head. Common nails are used most often in wood-frame construction (roughing work). See Figure 7-16. A common nail is cut from wire and given a head and a point. Common nails are available in sizes from 2d (1” long) to 60d (6” long).

A *box nail* is a fastener with a flat head and a shank not as thick as that of a common nail. Box nails are similar in appearance to common nails, but their heads and shanks are thinner, making them less likely to split framing members. Box nails are often used to fasten exterior insulation board and siding and are available in sizes from 2d (1” long) to 40d (5” long). A disadvantage of box nails is that they bend more easily than common nails when driven.
A masonry nail is a hardened nail with a fluted shank that can be driven into a concrete or masonry surface without deforming. See Figure 7-17. Masonry nails are made with specialty-grade hardened steel. They are used to fasten wood to masonry (solid concrete, concrete block, brick, or stone). Masonry nails must be driven in perfectly perpendicular or they may chip the masonry.

Figure 7-17. Masonry nails can be driven into concrete or masonry.

Finish Nails. A finish nail is a nail with a smooth shank and a small barrel-shaped head. The head on a finish nail creates a small void in the surface of the workpiece that is filled after setting the nail head. Nails used for finish work are thinner than common nails, making them easier to drive and less likely to split wood. See Figure 7-18. Finish nails are used for applications where a nice final appearance is important, such as trim and moldings. Finish nails have small, tulip-shaped heads, which are easily driven below the wood surface with a nail set. Finish nails are available in sizes from 2d (1” long) to 20d (4” long).

Figure 7-18. Finish work nails include finish nails, casing nails, and wire brads.

A duplex nail, also known as double-headed or staging nail, is a nail used for temporary construction such as formwork or scaffolding. The double head on a duplex nail makes it easy to pull out when dismantling forms or scaffolding.

Figure 7-16. Rough work nails include common, box, and duplex nails.

Finish Work Nails

Figure 7-18. Finish work nails include finish nails, casing nails, and wire brads.
A casing nail is a nail with a flared head. Casing nails are a thicker version of a finish nail. The head of a casing nail is slightly larger than the head of a finish nail and is tapered toward the bottom. Casing nails are used to fasten heavier pieces of trim material.

A wire brad is a thin, small nail made of wire with uniform thickness throughout and a small head. Wire brads are identified by their length in inches and gauge (diameter) rather than by the penny system. Wire brad sizes range from 3/8" to 3" long and from #14 to #20 gauge. Wire brads are thinner than finish or casing nails and are used with light trim materials.

Nail Holding Strength. When a nail is driven into wood, the shank compresses and pushes aside the wood fibers. When the nail is in place, the wood fibers spring back toward their original position. The pressure of the wood fibers against the surface of the nail gives the nail its holding strength. See Figure 7-19.

Nails can have smooth or deformed shanks. Smooth-shank nails have sufficient holding power for most construction applications. Deformed-shank nails are recommended when greater holding power is required. See Figure 7-20.

Spiral-shank and ring-shank nails are two commonly used types of deformed-shank nails. Spiral-shank nails have a spiral thread that causes them to rotate as they are driven into the wood (similar to driving a screw). Spiral-shank nails are specifically designed for use with hardwoods and are commonly used for siding, flooring, and roof trusses. Ring shank nails have a series of small rings along the shank, which help to resist removal from the wood. Ring-shank nails are commonly used for plywood, underlayment, and roofing applications. The holding power of nails is also increased with cement-, resin-, or zinc-coated nails.

Staples

A staple is a U-shaped metal or wire fastener with pointed ends. Staples are available in a variety of shapes and sizes. See Figure 7-21. Staples may be used to fasten subflooring, sheathing, and paneling. Heavy-duty staples are driven in by electric or pneumatic tools. Smaller, light-duty staples may be driven in by hand-operated tools.
Rivets

A rivet is a cylindrical metal pin with a preformed head. The rivet shank is inserted through holes and pressed or driven into a second head to hold the parts together. The riveting process can also be automated with a hydraulic- or pneumatic-powered tool to save time. A rivet shank is the cylindrical body of a rivet. Shank diameters commonly range from \( \frac{3}{16} \)" up to \( \frac{1}{4} \)". The shape of the preformed head and the length and diameter of the shank distinguish one rivet from another. See Figure 7-22.

Two parts are joined together by the grip of a rivet, which fits through predrilled holes slightly larger than the rivet shank. The length of the shank must exceed the thickness of the two parts to be joined by enough material to allow the shank to be upset or shaped into the final form. A rivet grip is the effective holding length of a rivet. The size of the rivet required is determined by the thickness of the parts being joined. Rivet grip ranges start at approximately \( \frac{3}{4} \)" and reach a maximum of \( 1\frac{1}{2} \)".

Figure 7-21. Heavy-duty staples may be used to fasten plywood sheathing and subflooring. Light-duty and medium-duty staples are used for attaching molding and other interior trim.

Figure 7-22. Rivets are nonthreaded fasteners used to join or fasten parts.
Rivets are relatively inexpensive and are generally manufactured from ductile metals such as steel, aluminum, copper, brass, and bronze. Riveting can also be used to join materials that cannot be welded, such as dissimilar metals, plastics, or materials that could be damaged by heat.

A riveted joint is not easily disassembled and is considered permanent. However, rivets can loosen under stress and become ineffective. Rivets are also subject to corrosion by liquids and generally cannot hold pressure because of the possibility of leaks.

Rivets are classified into three groups: large, small, and blind. A large rivet is a rivet with a shank of $\frac{1}{4}$ or greater in diameter. The second head of large rivets can only be formed by applying force to the rivet after it has been heated red-hot. A small rivet is a rivet with a shank of $\frac{3}{8}$ or less in diameter. The second head of some small rivets can be formed by force alone, without heating. A blind rivet is a rivet with a hollow shank that joins two parts when only one side of the hole is accessible to rivet the parts together. Blind rivets are available in different materials, including steel, stainless steel, aluminum, copper, and plastic. Blind rivets can be set with a rivet hand tool.

### Pins

A pin is a cylindrical, nonthreaded fastener that is placed into a hole to secure the position of two or more parts. A wide variety of pin types, sizes, and materials are commercially available. Standard pins include straight, dowel, taper, clevis, cotter, grooved, slotted spring, and spirally coiled. See Figure 7-23.

![Figure 7-23. Standard pins include straight, dowel, taper, clevis, cotter, grooved, slotted spring, and spirally coiled.](image-url)
Straight Pins. Straight pins are usually fabricated from bar stock. The ends are either square or chamfered. They are often used to transmit torque in round shafts.

Dowel Pins. Dowel pins are fabricated from bar stock. Hardened dowel pins are bullet-nosed on the entry end. Soft dowel pins are chamfered on both ends. Dowel pins are used in machine and tool fabrication, to retain parts in a fixed position, or to preserve alignment.

Taper Pins. Taper pins have rounded ends and a uniform taper of 1/4" per foot of length. Taper pins are available in commercial and precision classes, the latter having tighter tolerances. Taper pins are used to transmit small torques or to position parts.

Clevis Pins. Clevis pins are fabricated from bar stock. The heads are radiused, and the entry ends have broken corners. They are used to attach clevises to rod ends and rigging and serve as bearings. Clevis pins are held in place by cotter pins.

Cotter Pins. Cotter pins are used with clevis pins and other devices such as axles and shafts to prevent disengagement. The entry ends are bent open after insertion to keep the cotter pin in place.

Grooved Pins. Grooved pins are solid and have three parallel, equally spaced grooves. The grooves provide a tight fit and a locking feature. They are used for the semipermanent fastening of levers, collars, gears, cams, and other parts to shafts.

Slotted Spring Pins. Slotted spring pins are tubular with one longitudinal slot, and both ends are chamfered. The pins are squeezed into slightly smaller diameter holes, which lock them into place.

Spirally Coiled Pins. Spirally coiled pins (roll pins) are rolled from spring stock and have both ends chamfered. The spring stock compresses upon entry and then expands.

Parallel Keys. Parallel keys are square or rectangular in shape. They are used for transmitting unidirectional torques in shafts and hubs that do not have heavy starting loads. Parallel keys may be easily withdrawn.

Taper Keys. Taper keys may be either plain taper, alternate plain taper, or gib head taper. They are used for transmitting heavy unidirectional torques in shafts and hubs that are reversed frequently and subject to vibration. Taper keys may be easily withdrawn.

Woodruff Keys. Woodruff keys are semicircular in shape. They may have a full radius or flat bottom. Woodruff keys are used for transmitting light torques or locating parts on tapered shafts. The main advantage of a Woodruff key is that it prevents the milling of a keyway near shaft shoulders, which are already weakened because of stress concentrations. Common agricultural applications for Woodruff keys include machine tools, mobile farming equipment, snow throwers, lawn mowers, and tractor implements.

**Keys**

A key is a void or groove in a member designed to accept a corresponding projection from another member. A key is a removable part that provides a means of transmitting torque between a shaft and a hub when mounted in a keyseat. A keyway is a rectangular groove along the axis of a shaft or hub. The basic shapes of keys include parallel, taper, and Woodruff. See Figure 7-24. Keys are available in stock sizes in the English and metric measurement system.

**Figure 7-24.** The basic shapes of keys include parallel, taper, and Woodruff.
Adhesives

Adhesive bonding is the joining of parts with an adhesive placed between mating surfaces. Adhesive bonding is used for the joining of dissimilar metals, plastics, and composites in agricultural fabrication and repair operations. Adhesive bonding can be used to reduce the numbers of fasteners required and strengthen joints prone to failure from vibration.

When using adhesives, the stresses in the joint are distributed more evenly in order to eliminate high stress points. The adhesive leaves no voids in the joint, which helps eliminate corrosion caused by moisture. There are no rivet heads or weld reinforcement present, which produces a smoother surface. In agriculture, labor time and cost can be decreased by using the appropriate adhesives for repair work. Adhesive bonding products should be applied with proper eye and hand protection to reduce the possibility of injury.

Thin parts subject to heat distortion can be joined with adhesives. For example, sheet metal panels joined with adhesives do not have the distortions that welded panels would have (caused by the heat from resistance welding). Also, joint member dimensions do not affect bonding strength. Thin parts can be joined with thick parts. Adhesives fill voids between parts without breaking surface contours. The flexibility of many adhesives also allows distortion without failure. Adhesive bonding joints require large contact areas for adhesion.

Adhesive bonding requires proper surface preparation, application, and curing procedures. The mating surfaces must be clean and free of foreign matter. Adhesives are cured by chemical action using catalyst cure, evaporation, ultraviolet (UV) light, heat, pressure, or both heat and pressure. Equipment required for adhesive bonding varies depending on the application and curing methods.

Adhesives are available with various viscosities. Viscosity is the measure of the resistance of a fluid to flow. Low-viscosity adhesives are liquid in form and flow readily into small spaces. High-viscosity adhesives are thicker than low-viscosity types and range from gel to plasticlike forms. High-viscosity adhesives are used for filling small voids and gaps between mating surfaces. Adhesives are classified by chemical content or base as acrylic, anaerobic, cyanoacrylate, epoxy, hot melt, polyurethane, polysulfide, silicone, solvent-base, or water-base adhesives. See Figure 7-25.

<table>
<thead>
<tr>
<th>ADHESIVE</th>
<th>COMPONENTS</th>
<th>CURE TIME</th>
<th>VISCOSITY VOID-FILLING</th>
<th>VISCOSITY</th>
<th>HEAT RESISTANCE</th>
<th>COLD RESISTANCE</th>
<th>THERMAL RESISTANCE</th>
<th>WATER RESISTANCE</th>
<th>METAL BONDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>Two-part or one-part (UV or heat cure)</td>
<td>Medium to fast</td>
<td>Medium</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
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<tr>
<td>Anaerobic</td>
<td>One-part</td>
<td>Medium</td>
<td>Low</td>
<td>Poor to fair</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Cyanoacrylate</td>
<td>One-part</td>
<td>Fast</td>
<td>Low</td>
<td>Poor to fair</td>
<td>Poor to fair</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Epoxy</td>
<td>Two-part</td>
<td>Slow to medium</td>
<td>Medium to high</td>
<td>Excellent</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Hot melt</td>
<td>One-part</td>
<td>Fast</td>
<td>High</td>
<td>Excellent</td>
<td>Fair to good</td>
<td>Poor to fair</td>
<td>Fair</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>One-part</td>
<td>Medium</td>
<td>Medium</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Polysulfide</td>
<td>One-part Two-part</td>
<td>Medium</td>
<td>High</td>
<td>Excellent</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Silicone</td>
<td>One-part Two-part</td>
<td>Medium</td>
<td>High</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
<tr>
<td>Solvent-base</td>
<td>One-part</td>
<td>Medium</td>
<td>Low to medium</td>
<td>Poor to fair</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Water-base</td>
<td>One-part</td>
<td>Medium</td>
<td>Low to medium</td>
<td>Poor to fair</td>
<td>Poor to fair</td>
<td>Fair</td>
<td>Fair</td>
<td>Poor to fair</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Figure 7-25. Adhesive selection is determined by the material and application of the parts joined.
Glues. Glues, in conjunction with nails, staples, or screws, are commonly used to hold together joints in mill and cabinet work. See Figure 7-26. Glues are sold in a liquid form or as a powder to which water must be added. Polyvinyl and aliphatic resin glues are available in different sizes of ready-to-use plastic squeeze bottles.

Polyvinyl and aliphatic resin glues have a good rating for bonding wood together and dry quickly after being applied. However, although these glues have moisture resistance, they are not totally waterproof and should not be used on work that will be subject to constant moisture exposure. Resin glues include urea resin, phenolic resin, resorcinol resin, and contact cement.

Urea resin is a plastic resin glue that is available in a powder form. The powder is mixed with water at the time it is needed. Urea resin makes an excellent bond for wood to wood applications and has fair moisture resistance.

Phenolic resin is a plastic resin glue that has moisture resistance and resistance to extreme temperature fluctuations. Phenolic resin is commonly used to bond the veneer layers of exterior grade plywood.

Resorcinol resin is a plastic resin glue that has moisture resistance and resistance to extreme temperature fluctuations. Resorcinol resin is used to bond heavier parts than phenolic resin. Resorcinol resin creates a strong bond and is frequently used for bonding the wood layers of glulam timbers.

Resin glue is primarily used to bond plastic laminates to wood surfaces. Contact cement has a neoprene rubber base. Since contact cement sets quickly, it is useful for joining parts that are difficult to clamp together. Contact cement is applied to both surfaces being joined. Contact cement must be allowed to begin to dry (until it has a tacky texture) before pressing the glued surfaces together.

In addition to fastening materials such as wood and plastic, certain types of resin glues are used as a threadlocking sealant with threaded fasteners, such as bolts and screws. Threadlocking sealant is a type of adhesive applied directly to the threads of a fastener immediately prior to installation. The sealant cures, providing the threaded fastener with extra holding strength. See Figure 7-27.

Figure 7-26. Glue is used to help fasten the joints of wooden cabinets.
Mastics. *Mastic* is a puttylike adhesive that maintains a degree of elasticity after setting. Mastics have a thicker consistency than glues. Mastics are typically sold in cans, tubes, or canisters that fit into hand-operated or pneumatic caulking guns. See Figure 7-28.

Mastics bond materials directly to masonry or concrete walls. If furring strips are required on an uneven wall, they can be fastened with mastic rather than with concrete nails. A *furring strip* is a narrow wood strip nailed to a wall or ceiling surface as a nailing base for finish materials. In addition, insulation board can be permanently fastened to masonry and concrete walls with mastic.

Mastics also bond gypsum board directly to wall studs, furring strips, and concrete or masonry walls. No nail indentations remain after installation, simplifying gypsum board finishing operations.

Prefinished wall panels used in commercial and residential construction have a neater appearance if nails are not driven through them. Mastics make it possible to apply paneling with very few or no nails at all. The panels can be bonded to studs, furring strips, or concrete or masonry walls.

Mastics provide an important structural function for glued floor systems by increasing the stiffness and strength of the floor unit. Using an adhesive in addition to nailing or screwing produces a bond strong enough to cause the floor and joists to behave like integral T-beam units. Glued tongue-and-groove edges provide improved sound control by reducing the number of gaps between the panels. Glued floor systems also help to eliminate squeaks, bounce, and nail popping. Glued floors can be laid down quickly and efficiently, even during cold weather conditions, using standard construction materials and procedures.
In glued floor systems, a bead of mastic is applied with a caulking gun to the upper surface of the joists before each panel is placed. When tongue-and-groove panels are installed, another bead of mastic is applied into the grooved edges of a row of floor panels before the tongues of the next row of panels are inserted in the grooves. The floor panels are then nailed or screwed down before the adhesive sets. See Figure 7-29. The setting time of mastics varies, and manufacturer recommendations should be followed. As a general rule, the setting time is not as long during warm weather.

**Glued Floor Systems**

![Diagram of glued floor systems](image)

**Figure 7-29.** When panels with tongue-and-groove edges are used for a subfloor, the mastic is placed in the grooves and on top of the joists.

**Summary**

- Mechanical fasteners can be threaded or nonthreaded and in English or metric units.
- Nonmechanical fasteners include glues and mastics.
- Threaded fasteners include screws, bolts, and nuts.
- Nonthreaded fasteners include nails, staples, rivets, pins, and keyways.
- Fasteners are specific to the type of materials to be fastened together and for the type of application.