Section 1 Threaded fasteners

Nuts and inserts

Basic nuts and locknuts

NUTS are internally threaded fastener elements designed to mate with a bolt. Hex and square nuts, also called full nuts, are the most commonly used and billions are manufactured each year. Square nuts are normally used for lighter duty than hex nuts. Surfaces may be flat, chamfered, or washer-face. Flanged nuts are available with integral washers to simplify handling and may be used to bridge oversize holes.

Under many assembly or load conditions, standard hex or square nuts cannot maintain a sufficiently tight joint.

Several methods are used (in addition to conventional preloading) to prevent nuts from working loose:

- Peening the bolt end which extends through the nut.
- Staking or deforming threads of the nut.
- Using lockwashers.
- Providing special threads on both nut and bolt.
- Doping the mating threads with adhesives, lacquers, or special sealants.

Locknuts should be considered when:

- The joint is subject to vibratory or cyclic motions.
- Accurate preloading of assembly is difficult or impossible because of resilience of parts.
- Joint members are too fragile to withstand preload.
- Added safety factor provided by the addition of a locking feature is desirable because of unknown service conditions.
- Accurate positioning of the nut along a threaded element is required, such as in spacer applications where parts must be free to rotate without end play.

The four principal types of nuts which provide such locking features are jam nuts, castle or slotted nuts, free-spinning locknuts, and prevailing-torque locknuts.

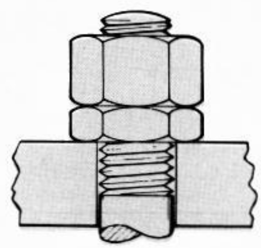
Jam nuts

A standardized fastener, the jam nut is a thin nut normally used under a full nut, to develop locking action.

Recommended practice is to torque the jam nut to seat only, then assemble a full nut on top of the jam nut and torque to full preload value while the jam nut is held stationary.

The same effect can also be achieved with two full nuts if preload must be developed when the first nut is tightened into position.

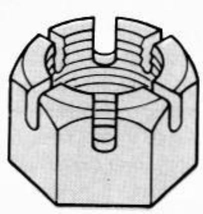
It is recommended on assemblies where long travel of the nut along the thread under load is required to bring mating parts properly into position.



Castle and slotted nuts

Both of these standardized nut forms are slotted to receive a cotter pin or wire which passes through a drilled hole in the bolt and serves as the locking member. These nuts are used primarily as safety nuts.

In assembly the nuts are torqued to preload value, then nut position is adjusted to line up the slots with the hole in the bolt. This method introduces a disadvantage on critical preload applications because of the possible alignment variations which may lead to application of too much or too little torque.



Free-spinning nuts

A common commercial nut, the free-spinning type of locknut, turns freely onto a bolt until seated against a base.Further tightening of the nut produces locking action.

Operating principles of all of these nuts are similar. When the locking element engages the base surface, a spring or wedging action is produced to create a tight friction grip against the bolt threads.

Unique bolt designs are available to develop the locking action including:

- Two piece nuts in which the elements distort against each other or the bearing surface when tightened.
- Spring nuts which are notched or grooved to deform when seated.
- Insert nuts containing soft metal or nylon collars that deforms to grip the bolt thread when tightened.
- Toothed nuts or nuts that have built-in toothed washers that engage and lock against the bearing surface. Some nuts may also cause a wedging action against the bolt threads.
- Special-thread nuts that obtain their holding power by deforming the bolt thread.

In application, these nuts should be seated to the torque values recommended by the manufacturer.

The free-spinning nut is often advantageous where long travel under load is required to seat the nut. If the pressure on the nut is not sufficient to develop its locking action, the nut will turn freely into position without danger of damage to the locking feature.

For all free-spinning locknuts, preloading is essential to develop proper locking action. Except for the two-piece nut designs, in which one nut element serves as the base surface for the other, free-spinning locknuts are not recommended for use on assemblies where there is relative motion between bolted parts or in joints with multiple laminations that may relax bolt tension by embedding or plastic deformation. Use of these nuts should also be avoided with fragile parts.

Prevailing-torque locknuts

This nut has a built-in locking feature that develops full locking action as soon as it is engaged with the bolt threads, and then must be wrenched to final seated position.

Of the techniques commonly used to achieve the locking action, several rely on a distortion of the nut thread or nut shape to create an interference fit.

Metal or non-metal inserts (plugs, strips, or collars) that plastically deform are also used to create an interference fit.

Separate locking pins, wires, or springs are fitted to the nut, or the nut may have a large slotted crown with spring-like fingers that grip the bolt.

Ideally, prevailing-torque nuts should be

Thread and face friction

Prevailing-torque and free-spinning locknuts are the two types most widely used. The illustrations here show a representative sample of common designs.

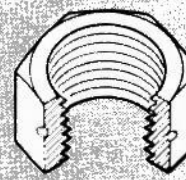
Prevailing-torque locknuts incorporate features which increase friction between mating threads. The locking force takes effect as soon as the threads are engaged. The nuts must, therefore, be torqued into their seated position. Generally, prevailing-torque nuts are used when long-term dynamic loading is expected. This type has an estimated 90% of the locknut market.

Free-spinning locknuts turn freely on the bolt until seated. Additional turning activates the locking mechanisms. Free-spinning nuts improve holding power by creating an interference fit, by increasing the friction at the bearing face, or by a combination of the two effects. Because of high initial holding power, a free-spinning nut is suitable for random shock loads. However, once it breaks loose, the nut may become free spinning once again. Free-spinning nuts which cause some permanent deformation of the bolt threads continue to have some holding power once the nut has broken free.

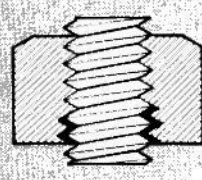
Prevailing Torque

DISTORTED SHAPE

Distorted portion of nut thread produces an interference fit. Center dimple allows nut to be assembled with either side up.

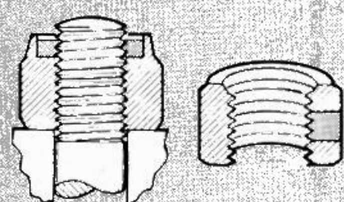


Top-crimp nut is easy to start but must be properly oriented before assembly.

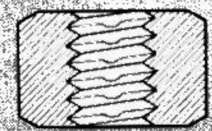


INSERT

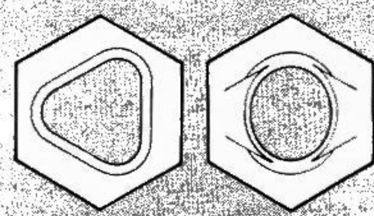
Plastic or metal section is added to the nut to increase mating-thread friction. In the most commonly used versions, a plastic (usually nylon), is added as a built-in washer, a plug through the side of the nut, or as a sprayed-on patch. Nylon is thought to provide damping



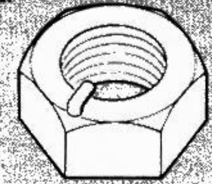
Threaded profile is distorted, increasing interference. Complex manufacturing process increases cost.



Nut hole, forced into an out-of-round shape after initial forming, produces spring action that maintains an interference fit after assembly.



action which imparts good vibration resistance. An insert may also be a soft metal such as lead. The added element plastically deforms when the nut is installed.



Metal-insert locknut has a projecting hardened wire or pin built in to provide a ratchet-like locking action. Reuse is limited by wear of the pin tip.

used with the minimum thread engagement necessary to develop the holding strength of the nut and the locking action. Torquing of these nuts over a long thread travel under load could damage the locking feature.

Prevailing-torque locknuts can be used as spacer or stop nuts where components must be free to rotate without end play.

Captive nuts

Captive, or self-retained, nuts are permanent, strong, multiple-threaded fasteners used on many types of thin materials. They are especially good in blind locations, and can generally be attached without damaging finishes.

Captive nuts can be attached in a variety of ways and designers should consider what assembly tools or systems are needed before selecting the fastener.

There are the four general categories of self-retained nuts:

Plate or anchor nuts have mounting lugs which are riveted, welded, or screwed to the part.

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Caged nuts use a spring-steel cage that retains a standard nut. The cage may snap into a holder or clip over a panel edge. These nuts are available in strips to 6-ft long for applications requiring fixed nuts in equally spaced sequences.

Clinch nuts have pilot shanks that are clinched or staked into the parent part through a precut hole.

Other forms have a knurled or lobed base ring that is pressed into the panel, displacing the sheet metal to become self-retaining. Lobed types have a smooth sinusoidal lobe shape with a radius greater than 5% of the nut's nominal thread diameter. Such lobes meet the requirements of MS33588, and do not create stress risers in the parent material. Lobed nuts are available in both standard and self-sealing versions.

Self-piercing nuts are a form of clinch nut that cuts its own hole.

Anchor nuts

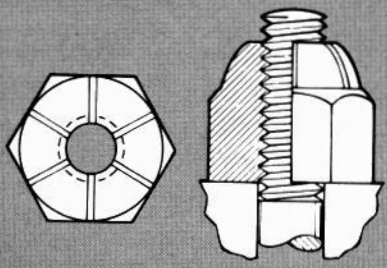
Plate nuts, or anchor nuts, have one or more lugs projecting from the base of the threaded body. The nuts are attached by riveting or welding the lugs to the work surface.

Plate nuts provide permanent attachment for threaded fasteners at inaccessible or blind locations. They assure positive positioning of the mating bolt and are self-wrenching. Plate nuts are the preferred nut type for stressed-skin applications because they do not introduce additional stresses around the bolt hole.

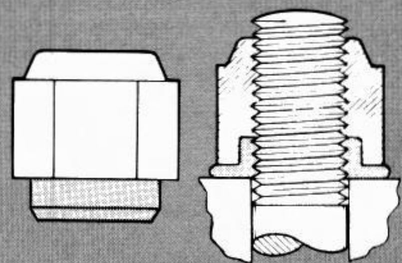
Riveting is the most common method of attaching plate nuts. Projection and spot welding are specified when it is desirable, for stress purposes, to minimize the number of drilled holes in the workpiece. The most common anchor nut is the two-lug

Free-Spinning

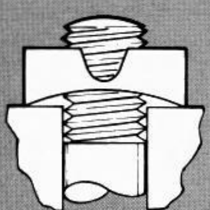
SLOTTED SECTION
Spring arms formed on the domed nut top are deflected inward. When the nut is threaded on, these arms grip the bolt threads.



INSERT
A plastic or metal washer built into the nut base is permanently deformed and grips the bolt threads when the nut is seated.

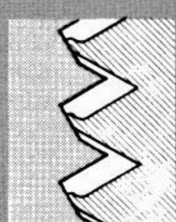


SPRING HEAD
When fully seated, the concave portion of the nut is forced inward and clamps against the bolt threads.



SERRATED FACE
Serrated or grooved face of nut digs into the bearing surface during final tightening.

MODIFIED THREAD
Nut threads have a modified cross section which crimps the bolt-thread crests when clamp load is applied.

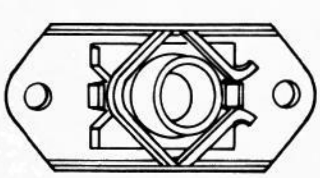


CAPTIVE WASHER
Toothed or spring washer attached to the bearing face of the nut increases friction between the bearing surface.

plate nut. The lugs protrude on either side of the nut body. A corner anchor nut has two lugs at a 90 deg angle.

A number of nuts can be assembled on a single retainer, generally referred to as a "gang channel." Gang channels are produced in straight or curved lengths, with a variety of nut spacings.

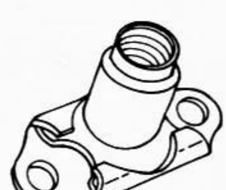
Nonfloating Plate Nuts: These are used where little or no misalignment can be tolerated. Bolts may be specified as regular-height nuts to utilize full bolt tensile strength. Or, low-height, lightweight designs may be selected for shear applications. Miniature designs are available for close-clearance installations. For safety,



appearance, and sealing, capped nuts which cover the bolt ends may be used.

For flush mounting, countersunk nuts can be used with dimpled sheet metal to accommodate the screw head. Variable-depth counterbore nuts permit use of constant bolt lengths to fasten panels of various thicknesses.

Floating Plate Nuts: These nuts are used where bolt hole misalignment can occur in assemblies. Tolerances between holes can

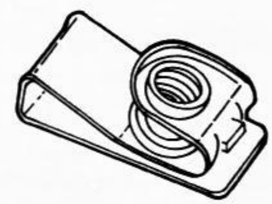


also affect alignment. Units with 0.015, 0.020, and 0.030-in. radial float are provided for such misalignments. Oversize retainer holes facilitate assembly.

Swivel, or self-aligning, plate nuts are three-piece units consisting of a nut, concave or convex base ring, and retainer. These nuts simplify assembly of tapered or nonparallel components. The self-aligning design accommodates angular misalignment of mounting surfaces as well as some bolt-hole radial misalignment.

Floating, Replaceable - Element Plate Nuts: These are multipiece units which allow the nut element to be removed and replaced without disturbing the permanently attached retainer. These are usually high-performance nuts and are usually in applications where they are used repeatedly.

Clip nuts are sometimes used as plate nuts to eliminate riveting. They are self-retaining and easily installed and removed.



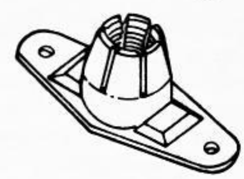


Plate nuts use the following locking techniques:

Nylon inserts are held like a washer in a cylindrical counterbore at one end of the nut. Walls of the nut are crimped or rolled over the washer to hold it firmly in place.

Elliptical offsets produce locking torque by deforming the reduced portion of the nut body. Usually, this portion is a turret-like section at the top of the nut.

Beam offsets contain multiple segments in the top portion of the nut which are bent inward, providing elastic interference with the bolt. A lubricant must be used with this type.

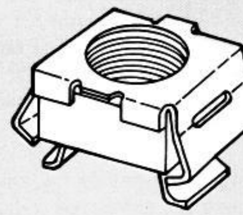
Plate nuts are not usually used in primary tensile applications. Most are specified as 125,000 or 140,000-psi nuts. Some anchor, swivel, variable-counterbore and channel designs are rated at 160 ksi, and specials to 180 ksi.

Caged nuts

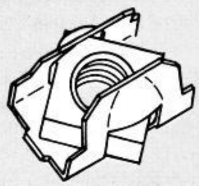
A multiple-threaded nut enclosed in a spring-steel retainer, this fastener has both the high-strength characteristics associated with multiple-threaded fasteners, and the versatility and self-retaining features of spring-steel fasteners.

Typical cage nuts

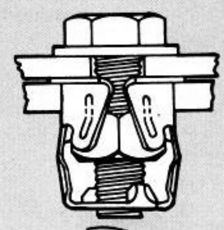
Full-cage retainer: Lugs are designed for use with thin sheet metal.



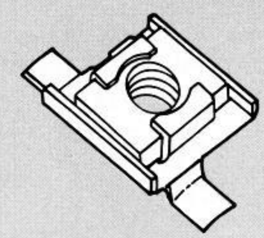
Prevailing-torque: Cage nut has lugs which engage and lock the screw thread.



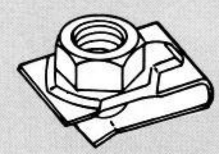
Heavy-duty caged nut: Used in applications with round, blind holes. Driving the screw causes the locking lugs to engage.



Square-hold cage nut: Lugs lock behind the panel.



Nut retainer: Design is used on panel edges.

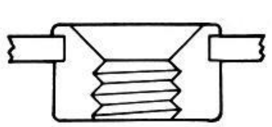


Caged nuts are particularly useful in blind fastening locations. Their self-retaining feature eliminates the need for welding, clinching, or staking the nut in place. They can be installed after painting or coating, making masking or retapping unnecessary.

In some nut retainers, the multiple-threaded nut floats within the spring-steel cage, allowing enough tolerance to offset normal assembly misalignment. In types where the nuts are staked to the retainer, misalignment is accommodated by oversizing the mounting hole.

Clinch nuts

A clinch nut is a solid nut with a knurled or smooth shank or pilot projecting from one end. These shanks are inserted into preformed holes in sheet metal and spread, crimped or rolled over, thus "clinching" them to the parent material. Clinch nuts provide multiple-threads in materials too thin to be extruded or tapped.



Clinch nuts use various configurations of pilot holes including hex, D-shaped, round and rectangular. The nut shank must be soft enough to roll over or be clinched by a tool.

Self-clinching nuts

Self-clinching nuts are squeezed into round punched or drilled holes in sheet metal between a parallel punch and flat anvil. The nut is flush or less on the back side. No special hole preparation or tooling shape is necessary.

The self-clinching nut must always be harder than the parent sheet material so when it is squeezed into the sheet, the nut forces the sheet to cold flow into the undercut, thus locking the fastener to the parent material. For most self-clinching steel nuts, the mounting material should be less than Rockwell B-80 in hardness.

Self-clinching nuts can be used in materials as thin as 0.03 in. and with some small threads as thin as 0.02 in. They are available as self-locking prevailing torque types, floating types, floating self-locking nuts and flush both sides types. The fasteners are made of heat treated steel, stainless steel or aluminum. They can be used in metals that are unsuitable for welding. They should be installed after the parent metal is painted, plated or anodized. Self-clinching studs and standoffs are also available.

Because self-clinching nuts fit into prepared drilled or punched holes, locating jigs and fixtures are not necessary. They can be installed with available automated installation equipment at great labor savings.

Self-piercing nuts

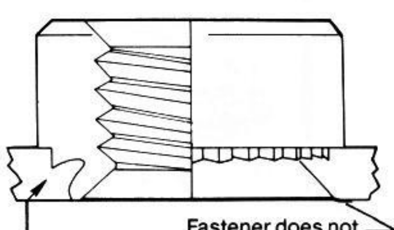
Self-piercing nuts are an internally threaded, precision, work-hardened steel nut with external undercuts on two sides. Used in sheet-metal panels and installed by automatic machinery, these nuts are permanently attached threaded fasteners that can be installed in most open or blind locations. Self-piercing nuts have high resistance to torque, vibration, tension, and shear loads, and particularly to a combination of such forces.

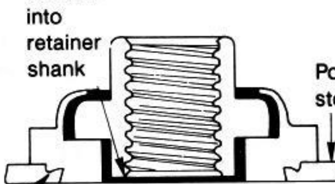
In the assembly operation, pierce nuts are fed continuously under a plunger. With each press stroke, the nut pilot is driven through the metal panel, piercing the mounting hole for the fastener. Clinching die ribs cold-flow

How self-clinching fasteners work

Clinching ring squeezes sheet and material flows around back tapered shank, securely locking fastener.

Based on material supplied by Penn Engineering and Manufacturing Corp., Doylestown, Pa.





panel metal into the undercut, securing the nut to the panel.

Self-piercing nuts can either pierce and be clinched simultaneously, or be clinched into prepierced holes.

Nut installation may proceed simultaneously with other forming, blanking, and piercing operations at high speed in both single and progressive die setups. The nut can be installed progressively in strip or coil stock, as multiples in one panel, or individually.

Standard self-piercing nuts may be installed in metal panels up to 0.145-in. thick. The work-hardened steel nut has a pilot-head hardness greater than Rockwell B 85. Proper malleability is retained in threaded areas.

Self-piercing nuts for flush mounting are available where thin metals and high stresses are factors. Application of the high-stress nut is generally limited to metal thicknesses of 0.03 to 0.09 in.

A locknut feature can be produced by projections on the driver (nut plunger). Controlled distortion of the last threads in the nut provides a locking action that can be made to torque requirements.

Self-piercing nuts can be installed in unplated, plated, or painted panels. Installation in a painted panel has little, if any, effect on the painted surfaces.

For proper torque resistance, a self-piercing nut should have an irregular, not symmetrical shape. A pilot should protrude a minimum of 0.005 in. through sheetmetal to ensure proper slug removal. When piercing two metal thicknesses, the pilot should protrude a minimum of 10% of the total maximum thickness of both metals.

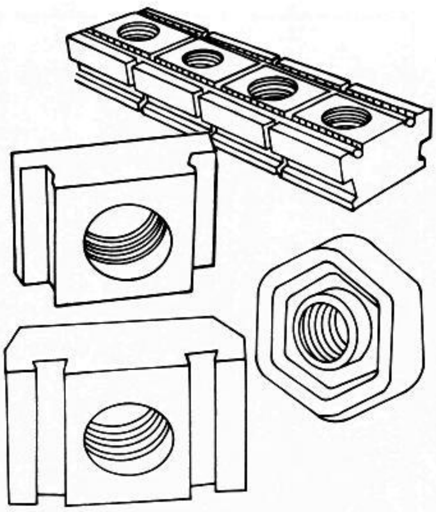
Self-piercing nuts can be located on 1.5-in. centers with standard tools, or closer with special tooling. Rotation of the nut on the panel allows some deviation in the center distances.

When the pilot protrudes through the panel metal, the nut should be placed in an embossment great enough to place the pilot surface of the nut 0.010 to 0.020 in. below the mating-part surface.

Some pierce nuts can also be used as clinch nuts.

Pierce nuts

The universal pierce nut is the most economic of this nut type. Dies coin the metal and force it into nut undercuts. This nut is also available as a strip pierce nut in which strands of wire hold nuts together in a con-



tinuous strip. The nut strip simplifies automatic assembly by eliminating feed hoppers and nut orientation stations.

High strength pierce nuts are used where greater stresses are encountered. They provides good panel-to-panel clamping force. There is no embossment.

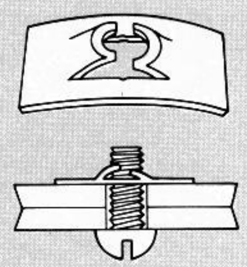
Pierce die nuts are designed for dynamically stressed applications. They have great resistance to pull through, shear, and impact loads. Flush mounting makes the nut self-sealing.

Single-thread nuts

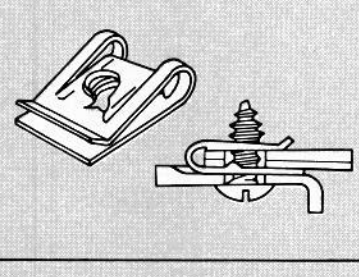
Single-thread engaging spring nuts are formed by stamping a thread-engaging impression in a flat piece of metal. They are used for lighter-duty applications than multiple-thread nuts of the same size. These fasteners reduce assembly costs when used in place of ordinary fasteners such as nuts or lockwashers. They eliminate several assembly steps and reduce the number of

Typical single-thread nuts

Flat type: Has prongs which engage the screw threads. It has the advantages of positive locking and vibration resistance.

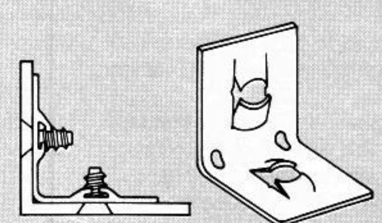


U-type nut: Used on panel edges. It keeps the screw perpendicular to prevent cross threading during assembly.

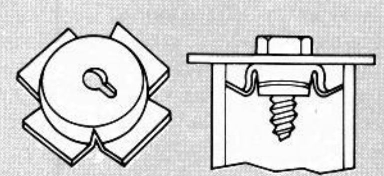


Dome nut: Has an opening which matches the pitch of the engaging screw. Advantages of this type of nut are high torque and 360° thread engagement.

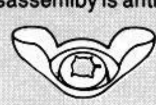
Angle nut: Joins perpendicular panels quickly and easily combining the functions of 3 to 6 separate pieces.



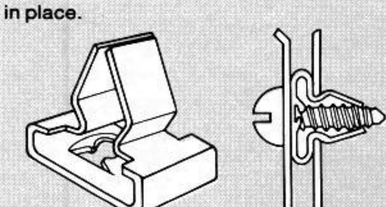
Tube nut: Components can be joined to tubes with this nut which wedges within the tube. Various sizes are available to match tube ID.



Wing nut: Used in applications where frequent disassemlby is anticipated.



Spring arm nut: Arms expand when screw is threaded locking the fastener in place.



parts which must be purchased, handled, and inventoried.

Unlike multiple-thread nuts, single-thread engaging types do not require a large amount of torque. Their holding power and resistance to vibration loosening depend solely on spring action.

For a more detailed discussion of panel nuts, see "Nuts that speed panel assembly," Dec 9, 1982

Because only one screw thread is engaged at a time, the prongs cannot "freeze." This can be an important advantage in applications where fasteners are exposed to corrosive conditions, and ease of removal is a factor.

Single-thread engaging nuts will withstand greater tensile loads when screw holes have minimum clearance. (This does not apply to the self-retaining type where part of the nut snaps into the clearance hole.)

The proper machine screw length to be used with single-thread engaging nuts is determined by the general practice used with conventional threaded nuts: Allow one thread to protrude beyond the thread-engaging element of the fastener.

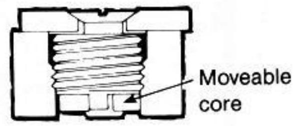
Sheetmetal screws that taper at the end should protrude a minimum of three threads beyond the thread-engaging element to assure engagement on the full screw root diameter.

It is possible to design this fastening device in almost any physical shape. The helically formed prong and truncated-cone types are best used as nuts into which the screw is driven. Spirally formed, thread-engaging elements can be stamped into hexagonally formed nuts, acorn locknuts, washer nuts, and wing nuts. Single-thread engaging spring nuts can also be furnished with preassembled clinched screws.

Because of their spring lock and resistance to vibration loosening, single-thread nuts eliminate the need for lock-washers. In addition, their design versatility makes them valuable in blind fastening locations, and multiple fastening locations.

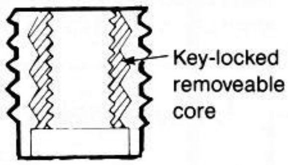
Special-purpose inserts

Inserts are sometimes needed that can solve fastening problems beyond the capabilities of the general purpose varieties.



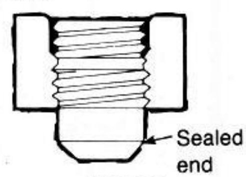
FLOATING

Internal thread element, locked within the insert body, allows up to 0.040 in. radial movement to accommodate misalignment of flush-head screws.



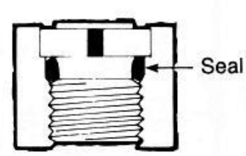
REPLACEABLE SLEEVE

Separate internally threaded core can be easily replaced. Insert is suitable for applications where frequent reuse may damage screw threads or where removal of the entire insert for repair is not practical.



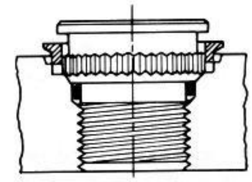
BLIND END

Closed-end insert isolates the screw and protects the thread from dust and debris. Protected insert is used frequently in electrical applications.



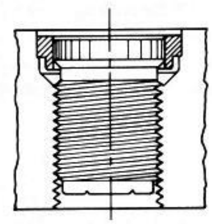
HYDRAULIC

Built-in seal prevents fluid from leaking through the insert.



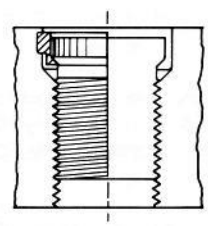
HIGH-PRESSURE HYDRAULIC

This insert provides a steel thread that accepts standard hydraulic fittings and is capable of operating in 3,000-psi systems.



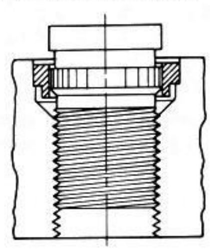
EXTENDED USE

A staked polyimide resin locks this insert in place, and allows up to 50 cycles of reuse. Most inserts allow only about 15 cycles.



SOLID

Solid inserts allow mislocated holes to be repaired and special internal configurations to be machined.



FLANGE

An extended neck at the top of the insert furnishes a guide, locator, or support for mounting purposes.

Inserts

An insert is a special form of nut that acts as a tapped hole in both open and blind locations. It is used to provide a strong, wear-resistant anchor for a standard screw in weak material, such as plastics and nonferrous metals, that do not have adequate shear strength to withstand the desired fastener loads alone.

Typical applications include: soft materials such as plastics or fiber board, wood, molded or die-cast parts, difficult to tap materials such as very hard metals, and materials where it is important not to damage the parent metal.

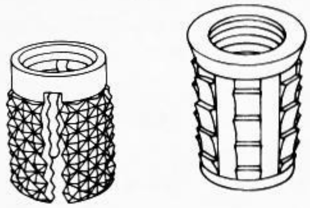
They can also give more precise threading to conventionally tapped holes, provide a thread-locking feature in hard materials, or repair tapped holes.

Types available

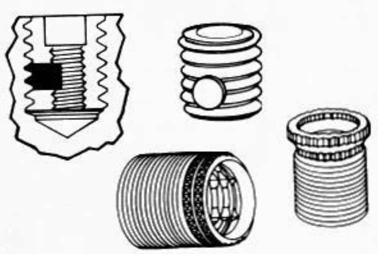
Inserts can be classified into two general categories: those that are held in place by external threads and those that use some

Commonly used inserts

Pressed in: Also called knurled, press-fit, or expansion inserts, non-threaded inserts require a prepared hole slightly larger than the insert OD. This type is frequently the easiest to install. It is used chiefly for lightly loaded applications. A variety of techniques are used to expand the insert after it is in place.

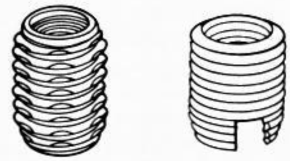


Solid-bushing: Inserts are installed in any material that can be drilled and tapped. They are held in place by: mechanical locks such as built in or separate locking keys and locking rings; the swaging action of knurls or distorted threads; and nylon pellets or strips. Solid bushings may also have internal thread-locking features to help secure the screw.



Molded-in: Used where the design and production considerations make it practical to have the insert cast in place when the part is formed. This type is frequently used with ceramics, rubber, and thermosetting plastics. Insert base is frequently knurled or knurled and grooved. Pull out torque is usually higher in plastics than with self-tapping or ultrasonically installed inserts.

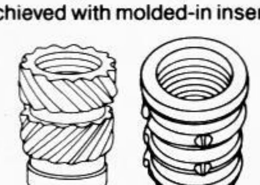
Self-tapping/self-threading: Used chiefly on nonferrous metals and plastic materials, they eliminate the need for a separate tapping operation. Interference fit produced by the cutting action locks the insert in place. Nylon plugs or strips, or distorted thread may be used to gain additional holding strength. Internal threads may also have locking capability. They can be used with both thermosetting plastics and thermoplastics. A thread-forming version for softer materials generates no material cuttings. Several types are symmetrical in design to allow high-speed, automatic installation.



Wire-thread inserts: Used for tapped hole repair and to provide a strong thread in softer metals such as aluminum. It is inserted with a special driving tool. The tang is broken off after installation. Where vibration or shock is a problem, distorted thread locking is recommended.

Knife-thread: Primarily for use in wood. Knife threads slice wood fibers, providing a strong joint. These inserts are installed with a screwdriver that fits the slot at the top.

Ultrasonic: Used with thermoplastics, these inserts require a prepared hole. Friction from vibration melts a small area which solidifies to lock the insert in place. Holding power may be less than that achieved with molded-in inserts.



means other than threads (knurls, grooves, interference fit) for their holding power.

Externally threaded inserts can be further subdivided into the three following types:

Wire-thread inserts: Precision coils of diamond-shaped stainless wire that form both internal and external threads. They are screwed into pretapped holes to provide an accurate standard internal thread for screws, bolts, or studs.

Solid self-tapping/self-threading inserts: Thread-cutting or thread-forming external threads for use in either drilled or cored holes. The thread-cutting types have thread interruptions on the external threads in the form of slots or holes to provide cutting edges similar to a tap. Thread-forming types have external threads shaped in a series of lobes to effect a thread forming action in the base material. Self-threading types create no chips or residue.

Solid bushing: These inserts use a number of locking techniques to match a variety of materials and design situations. One version has built in locking keys that are driven in after the insert is in place to provide resistance to rotation. Other two-piece inserts have a separate key ring or serrated locking ring to provide the torsional resistance.

Modified or distorted external-thread inserts are used to create an interference fit with the tapped hole through a swaging action.

Nylon plugs and strips attached to inserts may also provide locking action.

Inserts without external threads used in drilled or cored holes include these basic types:

Molded-in inserts: Used in thermosetting plastics, thermoplastics, rubber, and ceramics. They usually have one or more external knurled sections. Cast-in inserts, which are similar, are used on nonferrous metals.

Pressed-in inserts: Have external retention rings, knurls, or other elements for locking the insert in the base material. Some designs have slotted segments that are forced into the hole when the fastening screw engages the internal thread. Others have integral washers or cones that spread or expand the locking segments as the insert is driven into the hole.

Ultrasonic inserts: Solid bushings with annular and longitudinal grooves to prevent both pull-out and rotation after installation. Applications are limited to thermoplastics.

Sandwich-panel inserts: Used on honeycomb and composite sandwich panels, these can be of either one or two-piece construction. The one-piece type is usually applied on one side of a panel with a potting compound to obtain the required strength. The two-piece construction is usually swaged together with some interlocking feature and applied through both sides of the panel.

Specialty inserts are also available that provide an external male thread, or other fastening means. One insert of this type is the stud insert. One end may have any of the previously listed holding and locking configurations on one end and a standard thread on the opposite end.

Design factors

These requirements should be considered in selecting the best insert: shear strength of parent material, operating temperature, load requirement, presence of vibratory loads, ease of installation, and installed cost.

Boss radius and edge distance: The distance from the center of the hole to the nearest edge is usually equal to the insert OD. Brittle material inserts that produce high installation stresses may require greater edge clearance.

Material thickness: For blind holes and through holes, hole depth equal to the insert's nominal length is generally needed. When inserts are installed in cored, drilled or tapped holes, hole depth is usually greater than the insert nominal length. Drill point depth, length of tap chamfer, space for chips from self-tapping inserts, and clearance for the installation tooling should be considered.

Floor thickness: The dimension from the bottom of a blind hole to the far side of the material must be adequate to withstand the various machining forces and insert installation forces. Porous materials must be thick enough to prevent leakage if a leakproof assembly is required.

Locking: Assemblies subject to shock and vibration should be protected by inserts with screwlocking features. Locking adhesives may also be used.

Metallic locking action is by a deformed internal-thread portion of the insert that provides a controlled interference fit to the mating screw. Wire-type inserts have a polygonal resilient coil, while solid inserts have internal threads that are deformed by one or more indentations on the outside of the insert. Reusability with metallic locks is good, with customary life beyond 15 cycles. Some versions can be used for service temperatures up to 1,200°F.

Nonmetallic locks generally incorporate a fiber or plastic (usually nylon) pellet, strip, or collar that forces the mating screw into a frictional lock with the internal thread of the insert. The upper temperature limit is 250°F.

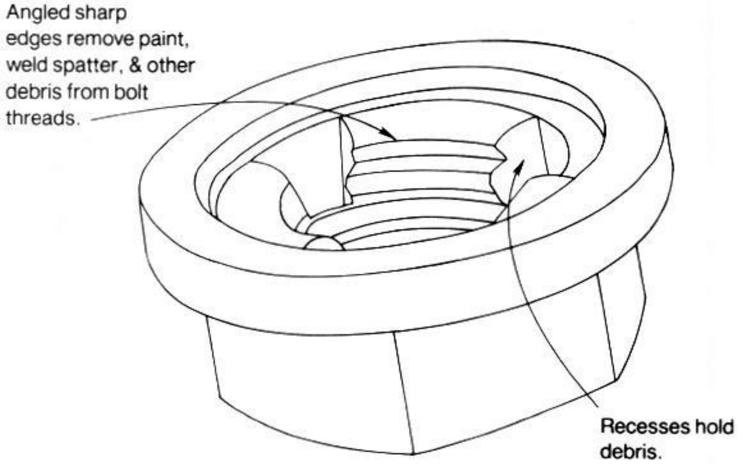
Anaerobic adhesive can be applied to insert threads as a liquid. The locking fluids crystallize to a hard plastic in the absence of air and bond the interfaces together. The hardened plastic must be sheared to separate the parts. Upper temperature limit using this method is 400°F. Other thread-locking adhesives in liquid or encapsulated form may also be used.

Temperature and cold flow: If the parent material expansion rate is greater than that of the insert, some relaxation or clearance can develop. High operating temperatures may reduce the shearing strength of the base material.

Cold flow or yielding of the parent material over a period of time, especially under load, also affects the insert retention force.

Flange nut clears debris

Flange fastener has threads with angled sharp edges that clear paint, rust, weld spatter, undercoating, and other debris from bolt and stud threads. Recesses formed on the inside of the flange hold excess gummy material so that clamp load is not affected by thread debris. The design eliminates the need for dies to remove excess paint or weld spatter, and allows components to be painted without masking studs.



Bolts, screws, and studs

A BOLT IS basically defined as a threaded fastener intended to be mated with a nut. A screw can engage either preformed or self-made internal threads. Bolts and screws share a number of head shapes and drive configurations. Only those bolts which have a shank configuration preventing rotation (such as a carriage or plow bolt) cannot be considered—or used—as a screw. Conversely, only those fasteners with cutting or tapered threads not intended to mate with a nut, such as self-tapping screw, cannot be used as a bolt.

A stud is an externally threaded headless fastener. One end usually mates with a tapped component and the other with a standard nut.

Captive screws

Captive screws are those that remain attached to the panel or parent material even when disengaged from the mating part. They are used to meet military requirements, to prevent screws from being lost, to speed assembly and disassembly operations, and to prevent damage from loose screws falling into moving parts or electrical circuits.

The most common ways of attaching captive screws to the parent material include:

- Split washers that are clipped on after the screw has been inserted in the panel.
- Threaded panel holes used in conjunction with a screw that has an externally relieved shank, a long groove between the head and threads.
- A ferrule or sleeve that is pressed, threaded, swaged, or flared to the parent material.

Captive screws are available with either inch or metric threads, and with most of the common finishes and head styles available in ordinary machine screws. Because there are no universally accepted standards for captive screws, many apparently similar captive screws are not interchangeable with each other.

Tapping screws

Tapping screws cut or form a mating thread when driven into preformed holes. These one-piece fasteners permit rapid installation, since nuts are not used and access is required from only one side of the joint. The mating thread produced by the tapping screw fits the screw threads closely, and no clearance is necessary. Tapping screws are used in steel, aluminum, die castings, cast iron, forgings, plastics, reinforced plastics, asbestos, and resin-impregnated plywood.

Standard tapping screws

The two basic types of tapping screws are classified as thread-forming and thread-cutting.

Socket screws vary in strength

ISO specifications permit five different strength levels of socket-head cap screws, ranging from Grade 4.6 to Grade 12.9, a difference in strength of 200%.

U.S. inch specifications allow only one strength level, comparable to Grade 12.9. Reputable U.S.manufacturers are adhering to the same practice in metric socket-head cap screws, manufacturing only Grade 12.9 or higher strength levels. For further details on proper specifications for socket screws, see "Socket Screws that Don't Meet Specs," MD, Oct. 8, 1981.

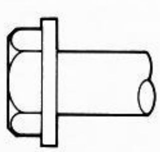
	Metric class*					
Strength grade	**4.6**	**5.8**	**8.8**	**9.8**	**10.9**	**12.9**
Approx. SAE strength grade	1	2	5		8	
Nominal tensile strength *(MPa)*	400	500	800	900	1,000	1,200
Minimum tensile Strength *(MPa)*	400	520	830	900	1,040	1,220
Approx. minimum tensile strength *(Ksi)*	58	75	120	130	151	171

Class designation represents an abbreviated minimum tensile strength of the part, the decimal being a ratio of yield strength to tensile strength. For example, a 1,200-MPa fastener has a yield of 0.9 x 1,200, or 1,080 MPa. The strength level must be marked on the screw.

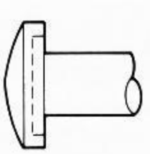
Head styles

Which of the various head configurations to specify depends on the type of driving equipment used (screwdriver, socket wrench), the type of joint load, and the external appearance desired. Head styles shown can be used for both bolts and screws but are most commonly identified with the fastener category called "machine screw" or "cap screw."

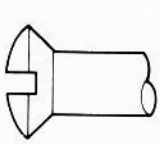
WASHER
Also called flanged head, this configuration eliminates the need for a separate assembly step when a washer is required, increases the bearing areas of the head, and protects the material finish during assembly.



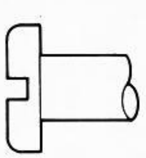
BINDING
A head commonly used in electrical connections because the undercut prevents fraying of stranded wire.



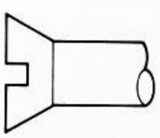
OVAL
Characteristics are similar to a flat head but it is sometimes preferred because of its neat appearance.



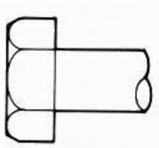
PAN
Head which combines the qualities of the truss, binding, and round heads.



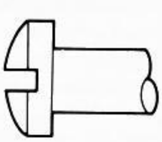
FLAT
Available with various head angles, the fastener centers well and provides a flush surface.



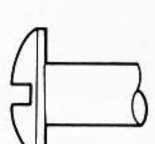
HEX AND SQUARE
Has the same advantages as listed for bolts of the same head style.



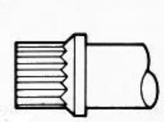
FILLISTER
Deep slot and small head allow a high torque to be applied during assembly.



TRUSS
Head covers a large area. It is used where extra holding power is needed, holes are oversize, or material is soft.



12-POINT
A twelve-sided head, normally used on aircraft-grade fasteners. Multiple sides allow for a very sure grip and high torque during assembly.



Thread-forming tapping screws displace or form the material adjacent to the pilot hole so that it flows around the screw threads. Generally they are used in materials where large internal stresses are desirable to increase resistance to loosening. The mating parts create a fit with zero clearance, since no material is removed from the engaged section. Lockwashers or other locking devices are usually not needed.

Thread-cutting tapping screws have cutting edges and chip cavities that create a mating thread by removing material from the engaged section. These screws are applied in materials where disruptive internal stresses are undesirable.

Tapping screws are available in both coarse and fine-thread series. Coarse threads should be used with weak materials. Fine threads are recommended if two or more full threads of engagement must be above the top of the cutting slot, but the thickness of materials is insufficient to allow two full threads of the coarse-thread series.

High-performance, thread-rolling tapping screws are used with thicker-gage metals, such as steel, brass, zinc, and aluminum forgings and castings. They are used in applications where high driving torques are encountered, or where chips resulting from thread-cutting screws are undesirable.

Self-drilling tapping screws have points that drill their own holes. No other drilling or punching is needed, but these screws must be driven by a power screwdriver. Once the self-drilling screw pierces the metal, it forms or cuts threads the same way as standard tapping screws.

Special tapping screws

Typical specials include self-captive tapping screws and double-thread combinations. Self-captive screws combine coarse-pitch starting threads with finer pitch farther along the screw shank. Initially, the coarse threads cut the hole, but then the fine threads retap the hole and change the thread pitch. Attempts to back the screw out cause the coarse thread to interfere with the fine threads, and consequently the screw is held captive.

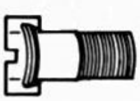
Double-thread screws combine a left-

Typical locking screws

A pellet strip insert, or a fused nylon patch projects beyond the thread crest. It is compressed when mating threads are engaged, creating the locking action.

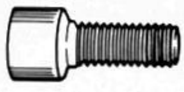
The locking action of thread deformation or deflection fasteners depends on metal-to-metal interference between the screw threads and mating threads.

Undercut causes the head to act as a spring, absorbing shock and vibration load when the fastener is tightened.



Flanged-head fastener has serrated or ratchet-like teeth which bite into the mating surface when the fastener is tightened. This type eliminates the need for a separate lock washer.

Locking action of the Orlo thread comes from compressing a spring rib in the thread against the nonpressure flanks of the internal thread. Orlo threads are said to resist loosening even after reuse.



"Tamper-proof" fasteners

The constant battle against theft, vandalism, and unauthorized entry has created a growing market for "tamper-resistant" or "security" fasteners. Although almost all fasteners can, in some cases, be considered theft-resistant, several types of threaded fasteners are specifically designed to be non-removable once inserted, or to require special tools for removal.

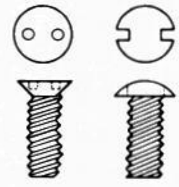
CAP SCREW

Cap screw has a plug added so that conventional socket wrench cannot be used.

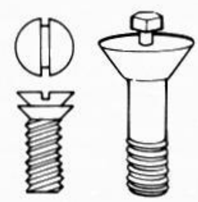
ONE WAY

One-way head is designed so that there is no bearing surface for the drive tool (a conventional screwdriver) in the reverse direction.

SPANNER

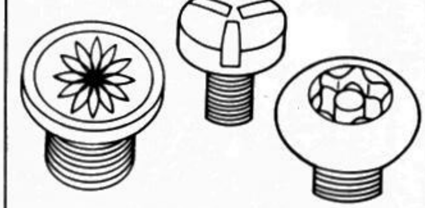


Spanner head does not have conventional drive slot. A modified screwdriver must be used as the drive tool.



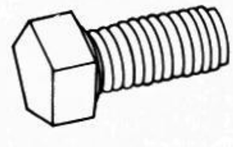
BREAK-AWAY HEADS

Break-away screw has a double head. When the fastener is seated, extra torque is applied to shear off the drive head, leaving the second head, which has no drive area, flush with the surface.



PROPRIETARY HEADS

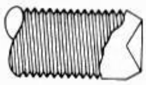
Drive tools are usually available only through the fastener manufacturer.



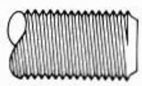
5 SIDE

Five-sided head requires special wrench.

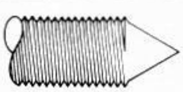
Standard points



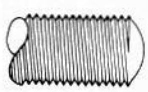
CUP
Most widely used where cutting-in action of point is not objectionable. Heat-treated screws of Rockwell C 45 hardness or greater can be used on shafts with surface hardness up to Rockwell C 35 without deforming the point.



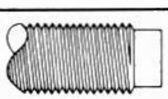
FLAT
Used when frequent resetting of a machine part is required. Particularly suited for use against hardened steel shafts. Can also be used as adjusting screws for fine linear adjustments. A flat is usually ground on the shaft for better point contact. This point is preferred where walls are thin or threaded member is a soft metal.



CONE
Used for permanent location of parts. It develops greatest axial and torsional holding power when bearing against material of Rockwell C 15 hardness or greater. Usually spotted in a hole to half its length.



OVAL
Used when frequent adjustment is necessary or for seating against angular surfaces. In some applications, shaft is spotted to receive the point. It has the lowest axial or torsional holding power.



HALF DOG
Normally applied where permanent location of one part in relation to another is desired. It is spotted in a shaft hole. Drilled hole must match the point diameter to prevent side play. Recommended for use with hardened members and on hollow tubing, provided some locking device holds the screw in place.

hand thread near the screw head and a right-hand thread over the rest of the shank. These screws can be driven only to the point where the left-hand threads start.

Another large group of special screws come with preassembled washers. Some have a serrated face on the underside of the head which cuts into the assembly when tightened. This minimizes stripping caused by overdriving and increases holding power of the assembly.

Sealing tapping screws, with preassembled washers or O-rings, can control leaks and crazing of enamel.

Setscrews

Setscrews are semipermanent fasteners that hold collars, pulleys, or gears on shafts. They are categorized by the drive type and point style.

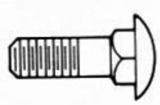
Size selection

The most important consideration in size selection is the holding power provided by

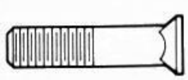
Common standard bolts

Countersunk: For flush mounting of assemblies. Also called a stove bolt when supplied with a machine screw.

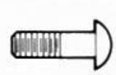
Carriage: Normally made with a round head for an attractive external appearance with ribs or flats on the shank to prevent turning when the bolt is tightened. Some versions require a prepunched square hole; others are pressed into place.



Plow: Usually made for flush mounting, this bolt has a square countersunk head, sometimes also including a key to prevent rotation.

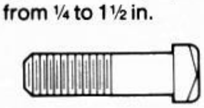


Round: Presents a smooth, attractive external appearance and is tightened by torquing the mated nut.



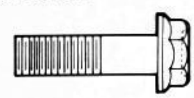
Track: One of the family of bolts designed specifically for use with railroad tracks. This version has an elliptical head to prevent rotation.

Square: This bolt is supplied in two strength grades and in popular sizes ranging from ¼ to 1½ in.



Lag: A square headed fastener with a threaded conical point. Normally used in wood or masonry with an expansion anchor.

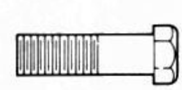
Flanged: Head gives a large bearing area. Often eliminates the need for a separate washer.



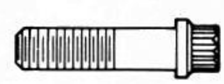
Elevator: Large diameter flat head bolt provides a nearly flush surface and large bearing area for use in softer materials. Square neck prevents rotation.

Bent: A threaded rod with an end formed to meet special requirements such as an eye or right angle bend.

Hex: The most commonly used of the standard fasteners, it is supplied in three basic strength grades and in popular shank diameters ranging from ¼ to 4 in. The hex head design offers greater strength, ease of torque input and area for manufacturer's identification than the square head.



Aircraft: The name is becoming a generic term for any high-strength fastener but officially it is any bolt which conforms to DOD military standards.



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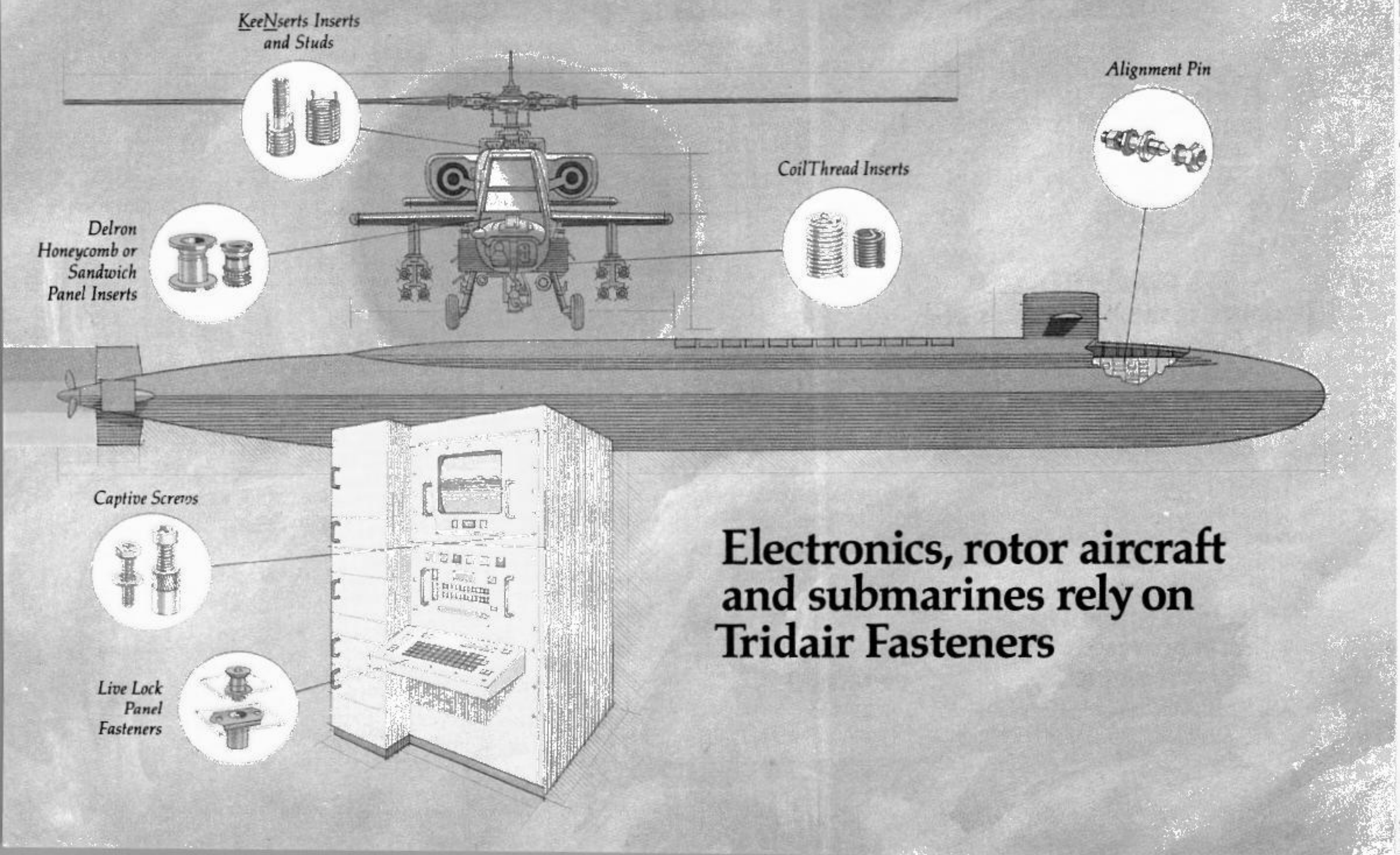

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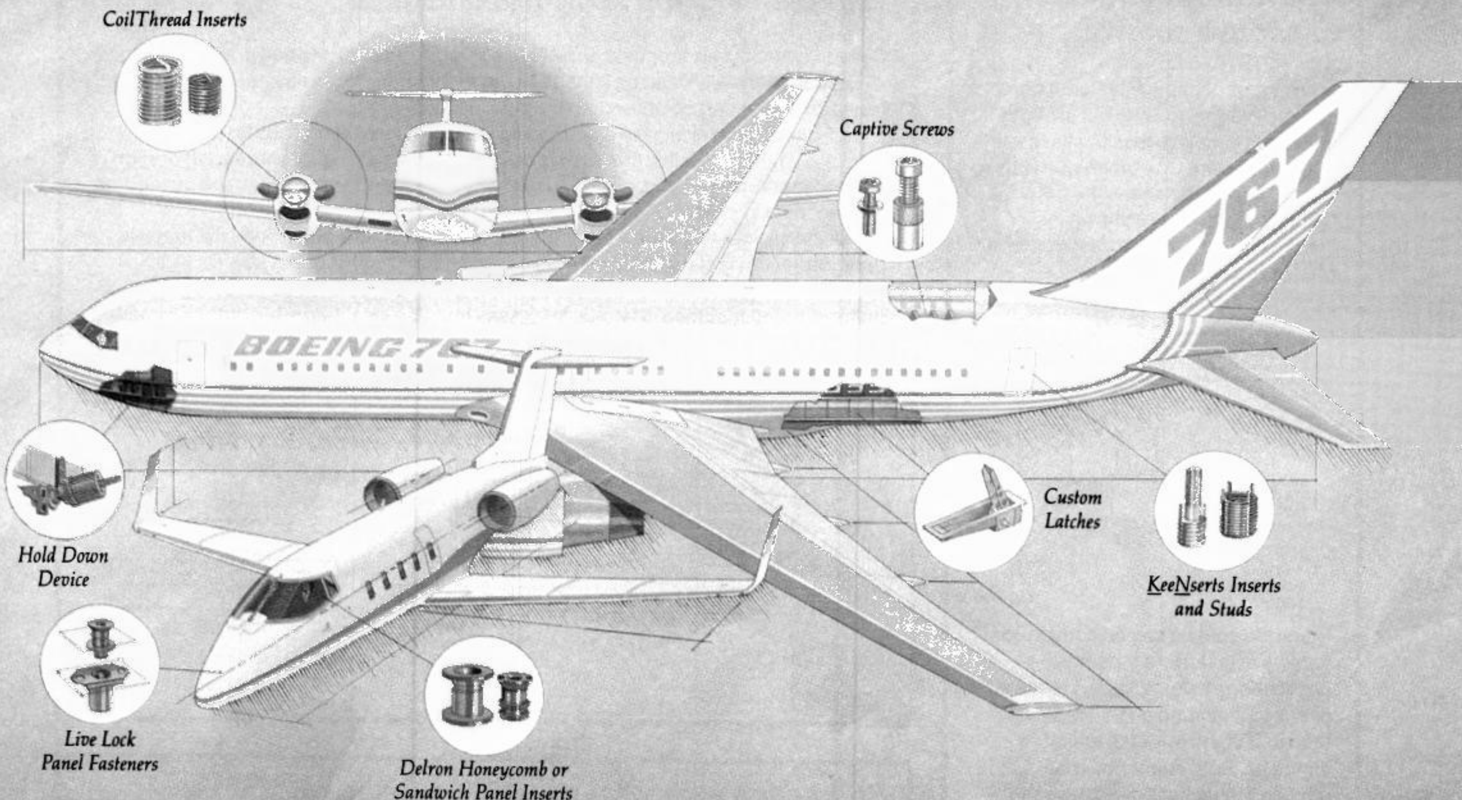

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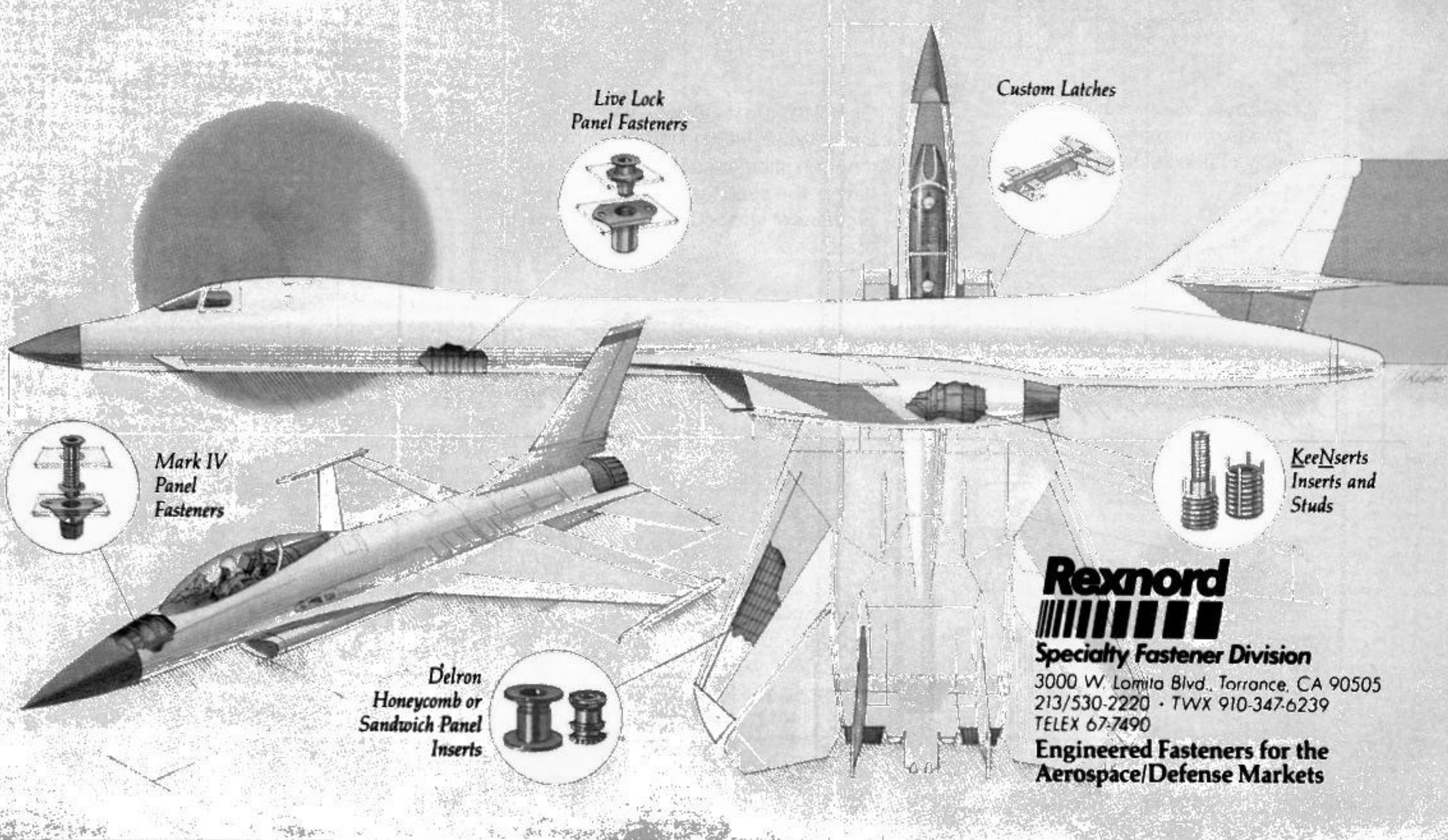

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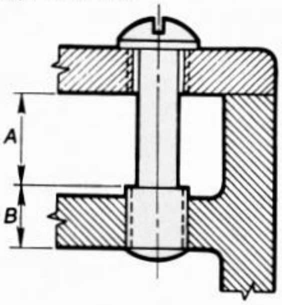
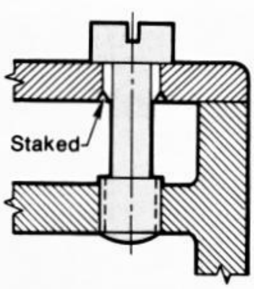
Converting standard to captive screws

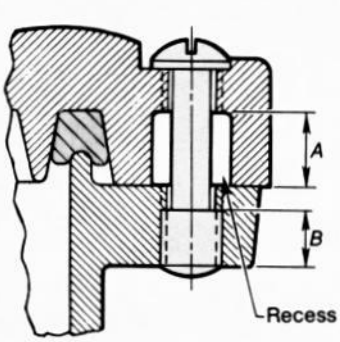
Many types of captive fasteners are commercially available, but in some instances it may be less costly to make your own. One technique is to reduce part of the shank diameter. Other techniques are shown in "'Home Made' Captive Fasteners," MD, April 22, 1982.



Standard screws can be converted to captive fasteners for some applications by turning part of the shank to a dimension that is less than that of the thread's major diameter. Both elements to be attached must be tapped, with the screw retained in the outer element.



A low-cost version of this type of captive fastener can be made by staking, instead of tapping, the outer element.



For this idea to work, length *A* must be greater than *B*. If the assembly does not meet this requirement, a recess must be created, possibly by casting it into a component.

Self-piercing and self-drilling screws

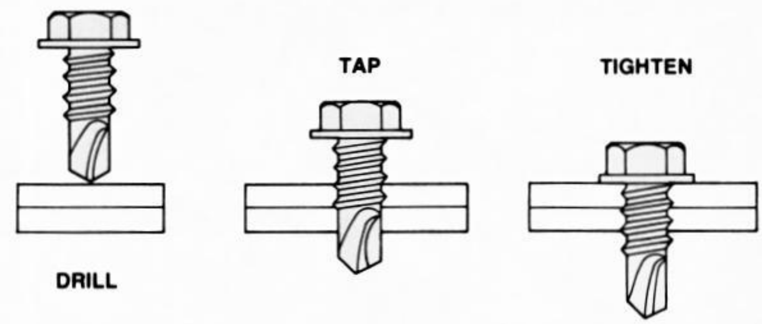
Several types of self-tapping screws are available that do not need predrilled holes.

They are normally used on light gage metal for such things as sheet metal ducts. However, some can be driven into material up to ½-in. thick.

Self-piercing screws have a pointed tip that forms a pilot hole under pressure from assembly tool. After the point is driven into the material, the threaded portion of the fastener forms threads as it is turned. The metal deformation caused by forming the pilot hole increases the thread-engagement area.

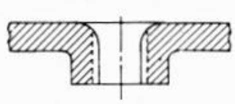
Self-drilling screws have a self-contained bit that drills a hole. Once the metal is penetrated, the fastener functions as a conventional self-tapping screw.

The unthreaded fastener bit must be at least as long as the thickness of the material being fastened. Material thickness must be less than the length of threaded portion of the screw.

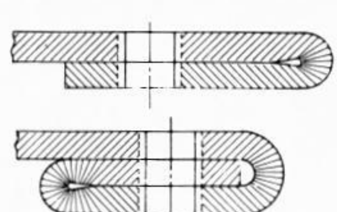


Stampings with threads

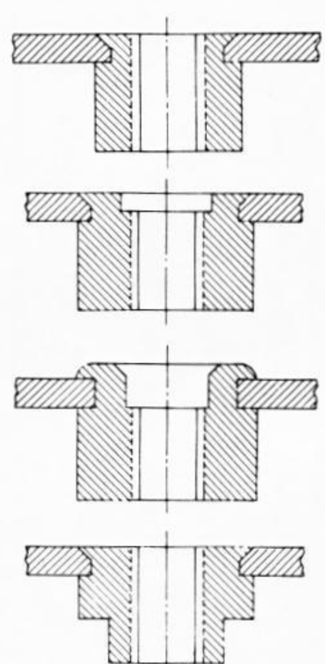
Stock thickness of steel or brass stampings should usually be at least half the major diameter of the thread to provide adequate strength. For aluminum or zinc, thickness should be at least two-thirds of major diameter. Three cost-effective ways to achieve required thickness are shown here. For further details, see "Tapped Holes in Metal Stampings," MD, Feb. 11, 1982.



One of the most efficient, yet inexpensive, ways to increase thread length in sheet metal is to extrude, or flange, the punched holes. This method provides at least double the thickness of the sheet.



When holes can be located near a straight edge of the stamping, folding the sheet once or twice provides the thickness needed.



Staking is another way to secure a threaded member to a stamping. Several variations are practical.

the clamping action. Some additional resistance to rotation is contributed by point penetration. Cup-point and cone-point setscrews are used without a spotting hole. They penetrate the shaft deeper than oval-point or flat-point setscrews. Holding power is generally specified as the tangential force in pounds, since design considerations may cause different sizes of shaft to be used with a particular size of setscrew.

Setscrew selection is usually based on this rule-of-thumb: setscrew diameter should be roughly equal to one-half shaft diameter. This rule often gives satisfactory results, but its range of usefulness is limited. Data supplied by manufacturers or standard texts give more reliable results.

Design considerations

Seating torque: Torsional holding power is almost directly proportional to the seating torque of cup, flat, and oval-point setscrews.

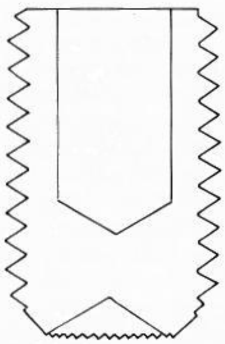
Point style: Setscrew point penetration contributes as much as 15% to the total holding power. When the cone-point setscrew is used (without a spotting or predrilled hole in the shaft), it requires the greatest installation torque because of its deeper penetration. Oval point, which has the smallest contact area, yields the smallest increase in holding power.

Relative hardness: Hardness becomes a significant factor in setscrew selection when there is less than 10 Rockwell C scale points difference between setscrew point and shafting. Lack of point penetration reduces holding power.

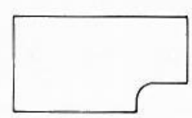
Flatted shafting: About 6% more torsional holding power can be expected when a screw seats on a flat surface. Flatting, however, does little to prevent the 0.01-in. relative movement usually considered as a criterion of failure. Axial holding power is the same.

What to look for in a socket screw

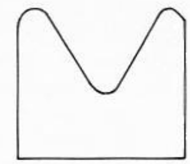
Deep, accurate socket ensures uniform wrenching power; radius on socket corners minimizes stress concentrations.



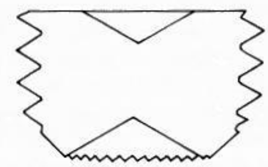
Controlled head-to-shank fillet and forged head (note continuous grain flow) add to strength and reduce chances of fatigue failure.



Fully formed threads, rolled to maintain continuous grain flow, minimize shearing potential.



Knurled cup point provides secure self-locking and resists vibration.



Knurled head lug aids handling and assembly operations.

Length of thread engagement: The length of thread engagement has no noticeable effect on axial and torsional holding power, provided there is sufficient engagement to prevent thread stripping during tightening. In general, the minimum length of engagement recommended is 1 to 1.5 times the major diameter of the setscrew for threading in brass, cast iron, and aluminum; and to one times the diameter for use in steel and other materials of comparable hardness.

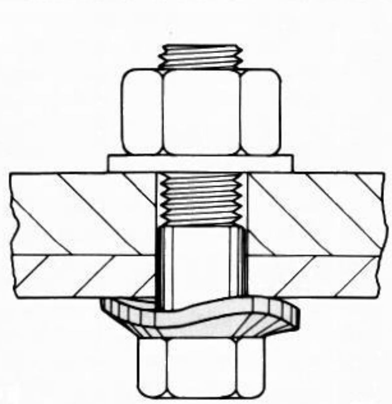
The lengths of engagement specified are for full threads engaged, not overall screw length.

Thread type: A negligible difference exists in the performance of coarse and fine threads of the same class of fit.

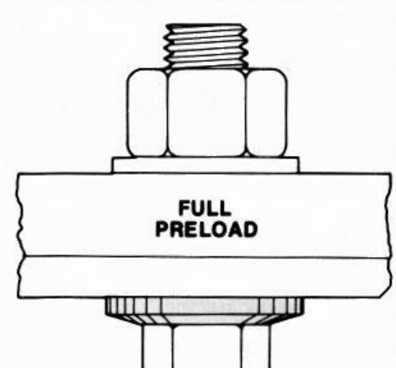
Drive type: The shape of the screw head has an effect on the seating torque that can be attained because it determines how much torque can be transmitted to the screw. Less torque can be transmitted through a slotted setscrew than a socket head setscrew. Holding power of the slotted screw is therefore about 45% less.

Bolts that Indicate preload

Most nuts and bolts provide no visual indication of preload, although there are a number of systems that provide varying degrees of assurance that proper preload has been applied. A new bolt provides such indication with a wavy flange. Tightening to the desired clamp load flattens the flange flush with the clamped assembly. For increased precision, a small notch in the flange allows measurement with a feeler gauge. Flanged nuts provide similar assurance.



BEFORE TIGHTENING



Square-head setscrews can be tightened with a wrench until the screw fails. Recommended seating torques for square heads are about twice that for the socket setscrews, giving a proportional increase in holding power.

Number of setscrews: Two setscrews give more holding power than one, but not necessarily twice as much. Holding power is approximately doubled when the second screw is installed in an axial line with the first, but is only about 30% greater when the screws are diametrically opposed. Where design dictates that the two screws both be installed on the same circumferential line, displacement of 60 deg is recommended as the best compromise between maximum holding power and minimum metal between tapped holes. This displacement gives 1.75 times the holding power of one screw.

Torque force: This is the amount of compressive force developed at the point and depends on lubrication, finish, and material.

Plating and lubrication: Most unplated setscrews are used with a thin film of rust-preventive oil. For added corrosion protection, setscrews can be plated with cadmium or zinc, but care must be exercised to avoid hydrogen embrittlement with high-strength screw materials. An increase in the holding power for the same tightening torque results when the screw is plated or used with a suitable thread lubricant. However, the addition of these lubricants to the screw can reduce vibrational resistance to loosening.

Setscrews and keyways: When a setscrew is used in combination with a key, the screw diameter should be equal to the width of the key. In this combination, the setscrew holds the parts in an axial direction only. Torsional load on the parts is carried by the key.

The key should be tight fitting so that no motion is transmitted to the screw. Under high reversing or alternating loads, a poorly fitted key will cause the screw to back out and lose its clamping force.

Locking devices

Externally threaded fasteners with locking devices use the same techniques to achieve locking as locknuts. These techniques are described in detail in the Nuts and Inserts Section.

Prevailing-torque locking screws employ distorted threads, interference fit, inserts, or a chemical adhesive coating. Free-spinning locking screws and bolts have a locking feature incorporated into the head, or an additive on the threads.

Studs

Studs require a two part assembly operation, but offer several distinct advantages.

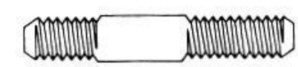
Studs eliminate the problem of deviations from perfect squareness in an assembly. The ability of a nut to "float" and adjust on the nut end threads is one main advantage of using the stud over the bolt or screw. The thicker the cover plate, or the longer the tapped hole, the more important this reason becomes.

In assembling and reassembling heavy parts such as turbine casings and cylinder heads, studs can act as pilots.

In the automatic assembly of small, lightweight units, studs reduce assembly costs since they permit quick and easy "stack-up" of gaskets or other different parts of a joint.

Studs reduce the need for the large hole clearance, and close hole alignment required by a cap screw or bolt. During assembly, the "runout" or eccentricity of cap screws and bolts is doubled as the fastener is turned. Clearance holes accommodate the runout which may cause eccentric loading and bending stresses in the joint.

Studs with an interference fit thread or proprietary lock thread on the tap end provide a positive lock against turning and loosening. The lock facilitates assembly and disassembly of locknuts on studs and is particularly important where maintenance of prestress is required to combat fatigue failures.



Studs supplied with sealant prevent leakage of fluids through holes tapped in porous materials.

There are four basic stud types: Class 1, also known as a gland or tap-end stud, has an interference fit at one end and a free running thread at the other. Class 2, or double-end stud, has free-running threads at both ends. Class 3 is a continuous three bolt stud for use in high-temperature and high-pressure applications. Class 4 is a continuous thread stud for general purpose applications.

Design notes

Bottoming or shouldering of studs should be avoided by driving them only to a predetermined depth. Bottoming or shouldering causes uneven stand-out and sets up undesirable radial compressive stresses which often become relieved during service operation, permitting the stud to loosen. Tapped holes in ferrous materials should be lubricated before driving studs.

Driving torque increases directly with length of engagement. For thinwall applications, it may be desirable to use longer engagement rather than large pitch diameter interference to obtain desired driving torque.

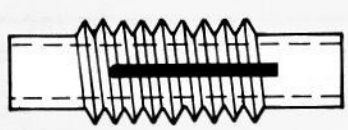
For driving into ferrous material 160 Bhn and harder, the minimum length of engagement should be 1 D (stud diameter); the maximum and minimum major diameter limits are reduced to permit plastic flow and to reduce and stabilize driving torque.

For driving into brass and ferrous materials with a hardness less than 160 Bhn, the minimum length of engagement should be 1 D. For driving into other nonferrous materials, it should be 2 D.

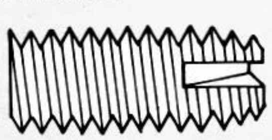
For lengths of engagement of 1 D, the external thread length should be 1 D, with a tolerance of plus 2 pitches, minus zero. For lengths of engagement of 2 D, the length of external thread and depth of full form thread in the tapped hole should be set at 2 D, with a tolerance of plus 2 pitches, minus zero.

Special-purpose studs

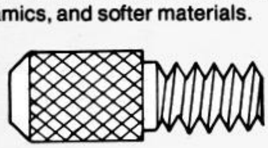
Locking studs: May use one of the variations of thread displacement to achieve locking action. For studs not subjected to high temperatures, nylon strips or plugs can be used as the locking element.



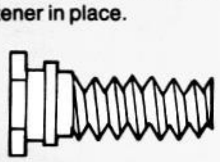
Self-tapping studs: Require a prepared hole and are used with ductile materials.



Molded-in studs: Have grooves, knurls or other end protrusions for insertion or molding into plastics, ceramics, and softer materials.



Pressed-in studs: Are machine pressed into sheet metal or softer material. Material flow around the stud base during installation holds the fastener in place.



Welded fasteners

FASTENERS and fastening elements (screws, nuts, studs) designed for permanent attachment to a surface by welding are used with some type of automatic assembly equipment. The most common forms of welded fasteners are screws and nuts. Welded pins or unthreaded studs are also used as locating or bearing surfaces, rather than as fasteners. In this section, welded fasteners are grouped into resistance-welded threaded fasteners and arc-welded studs.

Resistance-welded fasteners

A resistance-welded fastener is an externally or internally threaded metal part designed to be fused permanently in place by standard production-welding equipment. Two methods of resistance welding are used:

Projection welding: Heat is localized through embossed or coined projections on the fastener. During the welding process, the projections coalesce with the part surface to form the weld. For best results a press-type welder with electronic controls is usually recommended. This type of welder gives positive electrode alignment and equalized welding pressures.

Spot welding: The current is directed through the entire area under the electrode tip. Welding is usually performed by a rocker-arm type spot welder. This type of welding equipment, originally designed for spot welding large sheets, can satisfactorily weld a number of fastener designs.

Cost of equipment is considerably less for spot welding than for projection welding. However, the projection welder is more flexible and permits far greater latitude in design.

Design considerations

The materials of both part and fastener must be suitable for resistance welding. The material most commonly used for weld fasteners is low-carbon steel such as 1010. Parts to be welded must be portable enough to be carried to the welder. Use of portable welding equipment with these types of fasteners is generally not recommended.

Production volume should be large enough to justify tooling costs. As a general rule of thumb, at least 1,000 parts are necessary to make the application of weld fasteners economically feasible.

Greatest use of weld fasteners is with sheetmetal parts from 0.030 to 0.125-in. thick. However, almost any size fastener can be welded to any thickness of material as long as the materials are compatible, the welding operation is controlled, and the fastener itself is properly designed.

Arc-welded studs

Stud welding is a process in which the heat of an electric arc drawn between the fastener and the work melts a quantity of metal, after which the two heated parts are brought together under pressure. Welded fasteners must be made of a weldable material, and one end of the fastener must be designed for welding. Stud welding makes possible leakproof, pressure-tight connections and is adaptable to automatic and semiautomatic operation. Automatically welds can be made at rates of up to 60 per minute.

There are two basic stud welding processes, electric-arc and capacitor-discharge.

Electric-arc stud welding: The more widely used stud-welding process is a semiautomatic electric-arc process in which the heat for end welding the studs is from motor-generator or transformer-rectifier supplied dc current passing through an arc from the stud (electrode) to the plate (work). Weld cycle depends on stud diameter and may vary from 1/10 to 1 sec.

A high-strength bond is obtained because the full cross-sectional area of the fastener or stud is fused to the base metal. Electric-arc stud welding is best used when the base plate is heavy enough to support the full strength of the welded fastener. However, lighter-gage materials are often arc welded. As a rule of thumb, to avoid burn-through the plate thickness should be at least 1/5 the weld base diameter. To develop full fastener strength, basic plate thickness should be a minimum of 1/3 the weld base diameter.

Capacitor-discharge stud welding: The second basic stud-welding process derives heat from an arc produced by a rapid discharge of capacitor-stored electrical energy, with pressure applied to the stud during or immediately following the electrical discharge. Like arc stud welding, the heat for end welding of studs is developed by passage of current through an arc from the stud (electrode) to the plate (work).

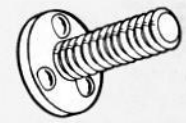
A prime advantage of the capacitor-discharge system is its ability to weld studs to thin materials without great distortion, burn-through, or discoloration. Also, weld penetration is slight, so many dissimilar metals can be welded without metallurgical problems. Plate thicknesses may be as thin as 0.016 in. for steel and 0.040 in. for aluminum.

The three main capacitor-discharge stud-welding systems are: initial contact, initial gap, and drawn arc. These processes vary primarily in the manner of arc initiation. Gap welding is especially suited to the fabrication of heat-sensitive components. It is

Welded fasteners

PROJECTION-WELD SCREWS

Through-hole screw requires prepared hole and is used where flush surface for a mating part is necessary.

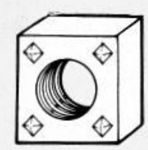


Blind-location screw provides a flush exterior.

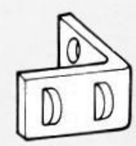
Space screw normally attached to a sheet metal edge.

PROJECTION-WELD NUTS

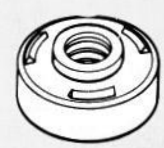
Pilotless nut is used where no hole can be drilled or on slightly curved surfaces.



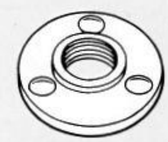
Right angle bracket nut supplies an anchor at 90 deg to a surface.



Piloted nut requires prepared hole and is suitable where the weld is in tension.



Automatic-feeding nut is self-locating and easy for automatic feeders to orient.



also preferred for welding to nonferrous metals, especially to aluminum, and thin-gage metals, because it produces the least reverse-side marking.

Applications

Fasteners smaller than 3/32-in. diameter and bolts or unthreaded pins up to $1\frac{1}{4}$-in. diameter can be successfully welded. Fastener lengths vary from $\frac{1}{4}$ to 40 in., depending upon end use. Fasteners may be made of mild steel, stainless steel, alloy steel, aluminum, brass, bronze, or magnesium.

Welded stud fasteners may be used to replace studs normally secured by drilling and tapping, arc welding, resistance welding, or brazing. The studs may be placed, where required, without regard to clearances behind the plate, and may be secured to expose surfaces after other assembly operations have been completed. The base metal must be weldable. Straight low-carbon steels or austenitic (300 series) stainless steels, except free-machining grades, produce good weld results with normal techniques. Other steel alloys can be welded, but heat treatment may be required to develop full weld strength. Many aluminum, brass, and copper alloys can also be welded. Weld quality with special materials may have to be determined through testing of prototype samples.

The most common fasteners used in electric-arc stud welding are made from low-carbon steels, with a minimum tensile strength of 60,000 psi and a minimum yield strength of 50,000 psi. Special high-strength fasteners, comparable in strength to SAE grade 5 bolts, are also available. Capacitor-discharge fasteners are generally made from C-1008 or C-1010 steels in the annealed condition. Tensile strengths are 40,000 to 50,000 psi. Austenitic stainless steel, magnesium-aluminum, silicon-aluminum, and other nonferrous fasteners are made most commonly from materials in the as-rolled condition.

Fasteners for capacitor-discharge welding are most effectively used on flat or nearly flat surfaces. Since point contact is not needed for drawn-arc capacitor-discharge welding, fasteners can be welded to round or contoured surfaces. Electric-arc stud welding is adaptable to round or angle surfaces, since it depends on the ferrule for the formation of a relatively large pool of molten metal. The ferrule must be made to fit the contour in question.

Weld fasteners should be considered when:

- Assembly requires any resistance welding of parts, sections, or braces. A fastener can often be welded in place along with the other parts to speed up production and assembly.

- Fastener must be mounted in a location where wrenching or assembly operations would be difficult or impossible with conventional fasteners.

- Assembly requires a threaded section of a sheetmetal part or plate member. Welding a nut in place to serve as a thread anchor is often more convenient, less costly, and faster than forming and tapping a hole.

- Hidden fasteners are required in blind locations. Weld fasteners, either screws or nuts, can be readily attached to the enclosed side of a sheetmetal or plate section.

- Loosening of a fastener under vibration or shock is a critical problem.

- Permanent fastener attachment is required to avoid loose parts that might fall into equipment or get lost in assembly.

- Hermetically sealed fastener is required. Use of sealing-type weld fastener can eliminate the need for separate sealing elements.

Where through-hole screws or nuts are used, the diameter of the hole in which the fastener is located should be at least 0.010 to 0.015-in. larger than the fastener's major diameter. This clearance is generally considered optimum for handling ease and weld-spatter elimination. A smaller clearance will hinder positioning of the fastener. A larger clearance may lead to misalignment and faulty welds. Through-hold fasteners eliminate the need for locating templates, jigs, and fixtures.

Combinations of spot and projection-welded fasteners on the same assembly should be avoided. This practice can lead to extra material handling operations and added costs.

Nuts should be used as the welded parts wherever possible. Subsequent production handling of assemblies with screws attached could lead to thread damage.

When multiple fasteners are required on a single assembly, standardizing on one size should be stressed. Although this standardization may lead to overdesign in some places, it usually is justified by the advantages gained in materials handling, assembly, production, and inventory simplification.

Where clearance conditions or part shape indicates a need for special welding electrodes, consider reversing the fastener assembly. That is, if a weld screw with a conventional nut has been specified, try changing over to a weld nut and a conventional screw.