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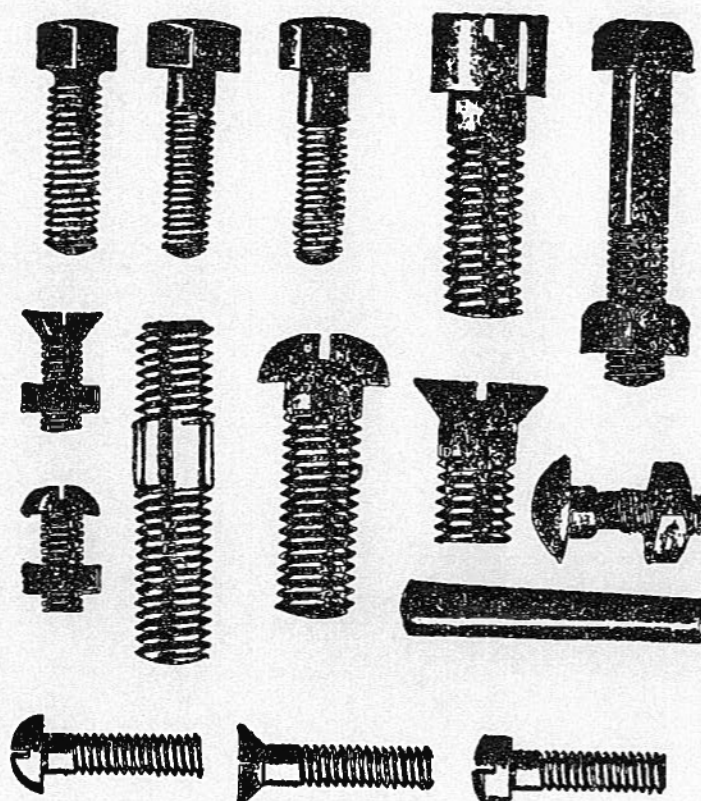
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Technical Bulletin

Threaded Fasteners in Metal Artifacts

17



Technical Bulletin No. 17

Threaded Fasteners in Metal Artifacts

by George Prytulak

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Abstract

In the course of cleaning or restoring historical artifacts, it is often necessary to tighten, loosen or remove threaded fasteners. The fasteners are often permanently damaged or lost in the process due to the use of improper tools and techniques. This Bulletin offers practical guidelines for the removal, cleaning, documentation and reinstallation of threaded fasteners in metal artifacts.

Cover

Illustration from Dyke, A.L. *Dyke's Automobile and Gasoline Engine Encyclopedia*. 21st ed. Chicago: Goodheart-Willcox Co., Inc., 1949.

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Part I: Removal and Documentation of Screws, Nuts, and Bolts

Introduction

A wide variety of metal artifacts are held together with threaded fasteners (screws, nuts and bolts). In order to clean, repair or restore these objects, a certain amount of disassembly is often necessary. Threaded fasteners often have to be removed in the process.

The original fasteners of an artifact are not expendable or easily replaced accessories. They are important and highly visible parts, and they should receive the same respect and care as the parent artifact. Fasteners can easily be damaged and disfigured during loosening, removal and tightening unless the right tools and techniques are used.

Nomenclature

Threaded fasteners are used to hold the parts of an object together in such a way that the object can be disassembled. As opposed to permanent fasteners such as rivets, threaded fasteners are removable. There are basically three types: screws, bolts and nuts. In general, a screw passes through a clear (unthreaded) hole in one part into a tapped (threaded) hole in a second part. Torque (turning force) is applied to the head. A bolt is similar to a screw, but it passes through two clear holes in the parts and is secured by a nut. Torque is applied to the nut rather than to the head of the bolt.

The most important descriptive terms for documenting screws, bolts and nuts are as follows (Figure 1):

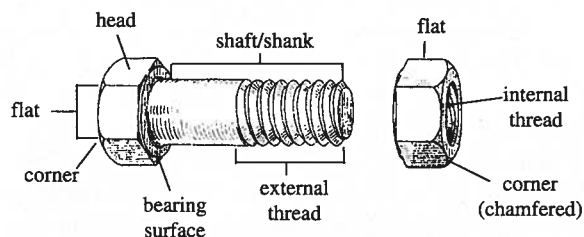


Figure 1. Features of screw or bolt, and nut

Washers and Locking Devices

A washer (Figure 2) is an important accessory in many assemblies. A *flat*, or *plain*, *washer* is a holed metal disc placed under a nut or the head of a screw. It increases the bearing surface of the fastener over a wider area and it protects the underlying surfaces from being scored during tightening. A *lockwasher* (or "shakeproof washer") acts like a compressed spring between a nut and a bearing surface, absorbing vibration and preventing the fastener from working loose. Many different designs appear in museum collections. The most common type on large machinery is the "split" lockwasher, basically a cut steel ring with its ends bent apart. Lockwashers with external or internal teeth (also called "tooth lockwashers") are commonly found in smaller, lighter artifacts

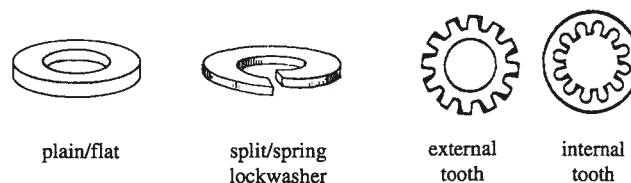


Figure 2. Washers

like electrical appliances. Lockwashers are often used together with flat washers to prevent the teeth or offset ends from damaging the bearing surfaces of the object.

Fasteners used in high-speed machines (airplanes, automobiles and motorcycles) were usually secured with various safety devices to make absolutely certain that the fasteners stayed tight during operation. These devices included cotter pins, tab washers and safety wire (see Figures 8 and 9, page 4, and Glossary, page 10).

Preparatory Cleaning

Cleaning the exposed parts of fasteners is recommended as a preliminary step in disassembly. The cleaning process reveals the true condition of the screw, bolt, or nut before it is removed, and encourages the use of properly fitting screwdrivers or wrenches.

The slots in screw and bolt heads are traps for dirt and grease. Most of the accretion can usually be removed with a sharpened wooden stick (applicator stick, tongue depressor, or matchstick). More detailed cleaning can follow; use tiny balls of cotton dampened with solvent and held with curved-tip forceps. Mineral spirits, ethanol, or acetone will remove most oily residues from a bare metal screw head. If the head is coated with original paint, or if it is surrounded by a painted area, then use aqueous detergent solutions or mineral spirits because these will not affect most paints. Test the solvent action on a small inconspicuous area before application.

Where nut and bolt assemblies are encountered, use the technique described above to clean the threaded portion projecting beyond the outer face of the nut. This will prevent abrasive contaminants from being ground into the internal threads of the nut during removal. A stiff-bristled brush (e.g., an old toothbrush or a stencil brush) will remove most accretions from the threads. Removing loose rust and hardened accretions may require a few passes with a wire brush. Severely rusted or damaged threads may require the use of a thread file, a steel bar with eight different sets of cutting teeth (four at each end) that matches the most common thread configurations. Any paint on the exposed threads may also interfere with turning the nut during disassembly. It can normally be removed with a combination of cotton swabs, acetone, and sharpened wooden implements.

Clean the flat sides of square and hexagonal heads and nuts prior to removal. This encourages the use of properly fitting tools.

Removal

Introduction

Before actually removing any fasteners, one should devise a plan to keep track of them and their original locations. Ideally, every screw, nut, bolt, and washer should be returned to its original position following treatment. This is important because the condition of the fasteners provides a partial record of how an artifact was used and maintained during its working life. Damaged slots or worn corners tell us which parts were adjusted or tightened most frequently, with what kind of tools, and with what degree of care. Improper tools (pliers, vise-grips, pipe wrenches, etc.) and poorly fitting screwdrivers and wrenches always leave telltale marks on the soft metal of fasteners. If we randomly exchange damaged and undamaged fasteners, we could mislead anyone interpreting the use of the artifact in the future. Suggestions for documentation are discussed below.

Slotted Heads

Removing a screw or bolt with a slotted head is a precise operation. The hard steel screwdriver will come into direct contact with the softer metal of the fastener under considerable force, so the blade of the screwdriver must be as close to a perfect fit as possible in both width and thickness. Avoid improvised screwdrivers (e.g., knife blade, nail file, or coin); they will twist in the slot and mar the edges. Most domestic screwdrivers are not acceptable either. They are designed to work as multi-purpose tools (pry bars, paint can openers, etc.), and have a wedge-shaped blade intended to fit a range of screw slot sizes. The slots of screws and bolts are normally straight-sided, so a blade with a wedge profile will never provide a close, even fit (Figure 3).

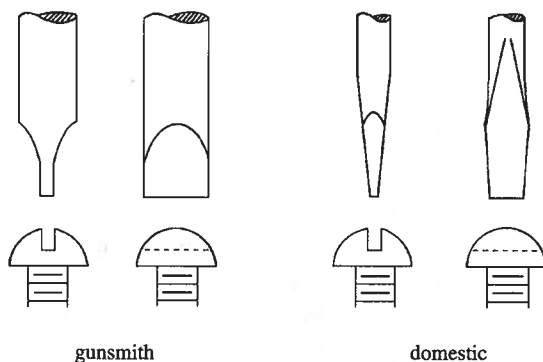


Figure 3. Screwdrivers

The most convenient solution is to obtain a set of gunsmith's screwdrivers with interchangeable bits. The blades of these bits are hollow ground; that is, they have straight parallel faces. They range in both thickness and width, so a virtually perfect fit can be achieved by a process of trial and error. A set of 44 interchangeable bits with two handles and a storage case costs about \$100 (CDN). A supplementary set of 18 ultra-thin bits can be bought for an additional \$40 (CDN).

In some cases, slotted screw heads are greater than 3/8" in diameter. These are beyond the capability of either gunsmith's or domestic screwdrivers. A *drag link socket* will be required. This is a special socket wrench accessory designed specifically for large slotted screws. It is shaped like a large gunsmith's blade, but it is driven with a 3/8" or 1/2" drive ratchet or T-handle. Several sizes are available, up to 24 mm wide (over 15/16") and 4 mm thick (over 5/32"). These can be ground for a perfect fit. Most retail for less than \$15 (CDN).

All specialized screwdrivers must be used with care. The blade fits tightly into the slot, so the shank and handle of the screwdriver should be kept closely aligned with the axis of the screw or bolt as it is turned. Also, a hollow-ground blade is structurally weaker than a wedge-shaped domestic screwdriver of the same size, and the metal is more brittle.

Recessed Heads

Museums are collecting more and more artifacts from the second half of the 20th century, so there is an increasing probability of coming across newer types of fasteners with non-slotted heads. The *cross recess*, for example, consists of two straight slots intersecting at right angles. It was first used in flat-headed wood screws in the late 1930s and was known as a *Phillips recessed head*. It became popular because it centred itself in the work, and there was less chance of the screwdriver slipping out of the head. It could also be driven with power tools. This head configuration was adopted by the automotive industry to attach body and trim parts, because it prevented the screwdriver from slipping and damaging the surrounding painted surfaces.

In a Phillips head, the recess has a large centre opening, tapered wings, and a blunt bottom, with all edges relieved or rounded. Five different sizes of screwdriver (numbered from 0 to 4) are required to fit the full range of screw sizes. This system is still widely used. A second, less popular style of cross recess (the "Reed & Prince" head) appeared in the 1950s. In this screw, the intersecting slots have parallel sides converging to a sharp apex at the bottom of the recess; one screwdriver fits all sizes (Figure 4).

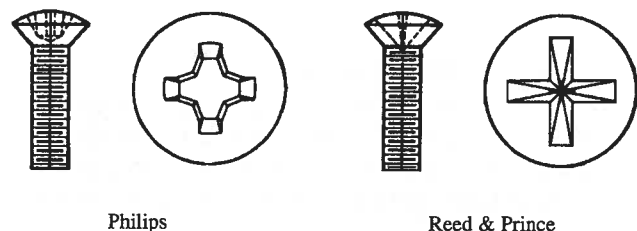


Figure 4. Cross recesses

The potential for damaging a cross recess is very high because the two styles look similar, but their screwdrivers are not interchangeable. Also, more downward pressure is required to turn a cross recess head than a straight slotted head, and this increases the likelihood of slippage and

resulting damage. It is sometimes difficult to judge when a Phillips screwdriver is a perfect fit. The blades should completely fill the four wings of the recess. When in doubt, check the fit with other screwdrivers, one size larger and one size smaller. Never use a screwdriver designed for straight slots in a cross recess. Discard damaged screwdrivers. They cannot be salvaged by regrinding and will only mar the edges of the recess. Screw heads with damaged cross recesses are very difficult to remove without causing further damage.

A square or socket recessed head—known in Canada as the Robertson head—has been steadily gaining popularity over the past few decades. It is still relatively rare in artifact collections, except as replacement fasteners in restoration work. Four sizes of screwdrivers are necessary (numbered from 0 to 3, and colour-coded, respectively as yellow, green, red and black). A damaged or worn Robertson screwdriver should be replaced. It can round off the sides of a square socket, making it almost impossible to remove without cutting a slot across the head.

Square and Hexagonal Nuts and Heads

Turning hexagonal and square nuts and heads is another precise operation requiring closely fitting tools—in this case, wrenches. A poorly fitting wrench can slip while being turned, permanently deforming the corners of the square or hexagon. Even a small amount of slack can leave marks on the fastener. A tight fit is crucial during the initial loosening and final tightening stages of turning. A full set of combination wrenches (one open “crescent” end; one closed “box” end) is essential for this kind of work. A 6-point box end has a full hexagonal opening. This is ideal for turning undamaged hexagonal fasteners, provided the fit is very close. The more common 12-point box end offers less surface contact with the flats and puts excessive pressure on the corners of a hexagonal fastener.

Generally, a set of wrenches in imperial units will be enough for most North American museum collections, but a supplementary metric set will fill in most of the gaps between the fractional sizes. To ensure an absolutely tight fit, a flat metal or hardwood shim can be inserted between the jaws of a crescent wrench and the flats of a square or hexagonal fastener (Figure 5). Alternatively, a thin sheet of brass or aluminum sheet can be wrapped around the flats before applying the wrench.

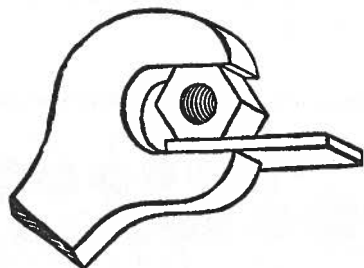


Figure 5. Wrench with shim

Avoid adjustable wrenches. Like domestic screwdrivers, they are inexpensive convenience tools, supposedly offering

a complete set of wrenches for the price of one. These wrenches only provide an approximate fit and they rarely stay tight, so slippage is common. In addition, the length of the handle is fixed, so a disproportionate amount of torque may be applied to small fasteners, resulting in serious damage.

Never use pliers, pipe wrenches or vise-grips on the head or nut of any fastener. The serrated jaws will bite into the softer metal of the fasteners and leave permanent marks.

Socket wrenches are designed for use in close quarters where combination wrenches will barely fit, and when quick, repetitive tightening and loosening is required. The disadvantage of these tools is that they prevent one from seeing what is happening to the fastener inside the socket. Sockets should only be used on fasteners that are in good condition.

To ensure that the correct socket is selected, determine the exact size of the fastener with a crescent wrench. A 6-point hex socket should be used on a hex head for maximum contact with the flats of the hexagon. A 12-point socket provides less contact with the flats and excessive pressure on the corners, posing a greater chance of slippage and damage.

Thumbscrews and Wing Nuts

These fasteners (Figure 6) are designed to be loosened and tightened with fingers, not tools. Pliers and vise-grips will cause permanent damage.



Figure 6. Wing nut and thumbscrew

Stubborn Fasteners

If a fastener resists turning under a reasonable amount of manual force, it will have to be freed up first. This can be done by periodically applying penetrating oil to the edge of the threaded hole, and lightly tapping the head or nut with a hammer and a block of hardwood. (A solid brass or a nylon-faced mallet will also work, but it will be marred in the process.) In extreme cases, the operation may have to be repeated several times a day for a number of weeks.

Loosening can sometimes be accomplished by slightly tightening a fastener, then backing it off to its original position. Applying heat may be useful. The expansion and contraction of the metal parts that occurs during a heating and cooling cycle can sometimes break the grip of seized threads. A heated nut will expand and can be backed off the threads of a cooler bolt more easily. For small fasteners, heat can be applied with an electric soldering iron or gun. Larger fasteners may require the use of a propane or oxyacetylene torch. The possibility of damaging any flammable or painted surfaces in the heated area must be considered before applying this technique.

In some cases, a nut may have been fixed permanently in place. One common practice in the past was to hammer the projecting end of the bolt into a rivet configuration. Another method involved making centre-punch marks around the periphery of the bolt, when the end of the bolt was flush with the face of a nut (Figure 7). Fasteners modified in these ways cannot be removed without causing permanent damage. Alternatives to disassembly should be considered. If disassembly is unavoidable, then close-up photographic documentation is essential before proceeding.

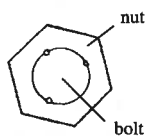


Figure 7.
Centre-punch marks

Locking devices such as cotter pins and tab washers (Figure 8) will have to be bent out of their original position to allow the nut to be removed. Just before bending, heat the part to a glowing red colour with a torch, and reheat it as the bending proceeds in short stages. This will relieve the stress in the metal, which otherwise could fracture during the operation.

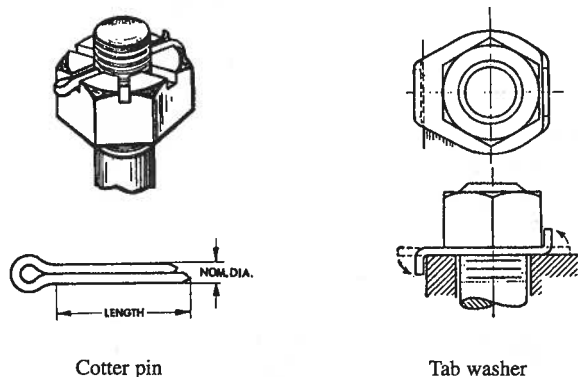


Figure 8. *Locking devices*

Safety wiring (Figure 9) will be permanently altered by any removal process. It should be left intact whenever possible. If it must be removed, try to preserve the original twisted configuration. Cut the wire near the bolt hole and remove the complete assembly rather than untwisting it. It may be possible to reinstall the original wiring later for static display.



Figure 9. *Safety wiring*

Thumbscrews and wing nuts that resist turning should be treated with care. Excessive torque or hammering on the extensions can result in breakage. Use hand tools only after trying penetrating oil, heat, and striking the top of the fastener with a hammer and a block of hardwood.

Set Screws

A set screw (Figure 10) is used to hold a part such as a collar, pulley or crank in a fixed position on a rotating shaft. The screw is tightened until its pointed or cupped end digs into the metal of the shaft. Every time the screw is repositioned it makes a permanent mark, usually a pit or part of a circle. Always ensure that the screw is backed off enough to clear the shaft before moving the part it secures. Otherwise, the tip of the screw will leave deep scratches or smear the metal of the shaft. Document the exact location and position of the part before loosening the set screw. Accurate reassembly could depend on these details later.

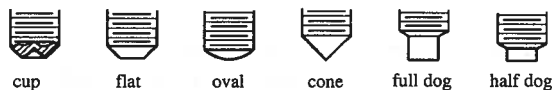


Figure 10. *Set screws*

Detailed Documentation

As each fastener is removed, it should be placed in a Ziploc-type bag to prevent loss and later mix-ups. Label the bag with a permanent marker, listing the fastener's location on the parent artifact and its dimensions. For the sake of clarity, these dimensions should be consistent with established industrial conventions. One such system follows:

Screws and bolts are designated by the following data in the sequence shown: (1) diameter; (2) threads per inch (TPI); (3) length; (4) type of head; (5) name; and (6) material.

Example: 1/4" - 28 x 3/4" Hex Head Machine Bolt, Steel

1. Diameter of the shank is the most important dimension. It is measured at the unthreaded part of the shank under the head. If the shank is entirely threaded, then a nominal diameter can be determined by measuring across the crests of the threads. Diameter is best measured with calipers or with a nut and bolt gauge plate (Figure 11). Diameters greater than 1/4" are specified in fractions of an inch; diameters smaller than 1/4" are numbered from 0 to 12, corresponding to measurements in thousandths of an inch (see chart on page 12). There is no advantage in specifying diameter or any other dimension in metric units unless the artifact was originally made with metric fasteners, indicating that it was probably manufactured in continental Europe.

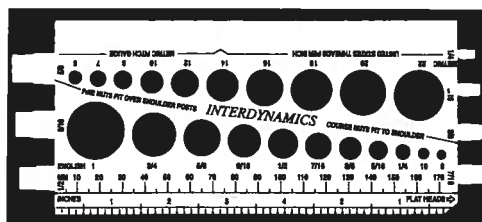


Figure 11. *Nut and bolt gauge plate*

2. *Threads per inch (TPI)* refers to the number of threads in one inch of the shank. This is best determined with a screw pitch gauge (Figure 12). Each folding blade of the gauge is numbered, with a row of teeth corresponding to different thread configurations in cross section. The correct blade is matched to the threads by trial and error. Threads per inch can also be determined with a ruler.

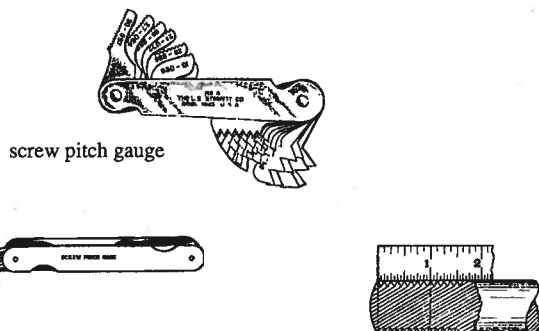


Figure 12. Measuring threads per inch (TPI)

The relationship of diameter to pitch has been standardized since the late 19th century, so it is possible to check one specification against the other by using a chart similar to the one on page 12. Thus, a bolt with 18 TPI will normally be 5/16" in diameter.

3. *Length* of a fastener is measured from its bearing surface to its opposite extremity. It does not designate length of the threaded part or overall length (Figure 13), except in the case of headless set screws.

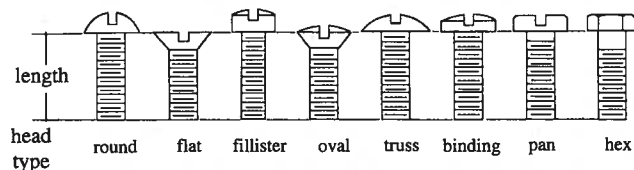


Figure 13. Measuring length of fasteners

4. *Type of head* designates one of seven common profiles: round (*button* for large fasteners), flat, fillister, oval, truss, binding, or pan (Figure 13); otherwise, the head will be hexagonal or square in shape. In most museum artifacts dating up to the 1940s, the heads will be either unslotted or slotted; that is, with a straight, parallel-sided vertical slot running across the entire width of the head. Cross-recessed (Phillips) heads appeared in the late 1930s. Set screws will be square-headed and unslotted or headless and slotted/recessed.

5. *Name* may be determined according to the definitions above and the attached Glossary.

6. *Material* will in most cases be either steel or brass.

7. *Points* of set screws are as follows: cup, flat, oval, cone, full dog and half dog (Figure 10).

Nuts are designated as follows: (1) nominal size; (2) threads per inch; (3) shape; (4) name; and (5) material.

Example: 3/4" - 16 Slotted Hex Nut, Steel

1. *Nominal size* refers to the diameter of the hole, determined by a gauge plate, ruler, or internal calipers.

2. *Threads per inch* refers to the internal threads of the nut, determined with a screw pitch gauge.

3. *Shape* is limited to either square or hexagonal. One should also note if a nut is *slotted* (Figure 14). A slotted nut is prevented from turning by a cotter pin (or "split pin") running through the slots and by a hole drilled through the shank of the bolt (Figure 8). If the slotted area is raised, the nut is called *castellated*, also known as a "castle nut," because the raised areas resemble the battlements of a castle. The bottoms of the slots may be either square or rounded. The bearing surface of a nut can be *washer-faced* (with a raised, machined surface), or both top and bottom surfaces may be *chamfered* (flat with rounded corners and edges) (Figure 14).

4. *Name* simply designates nut or jam nut (see Glossary).

5. *Material* will be either steel or brass.

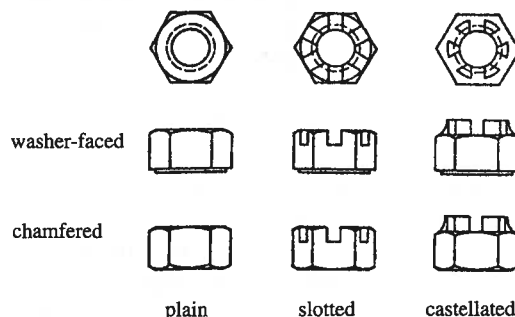


Figure 14. Types of nuts

Washers are commonly designated by (1) nominal size; and (2) type.

Examples: 1/4" Plain Washer; 5/8" Split Lockwasher

1. *Nominal size* refers to the diameter of the hole.

2. *Type* refers to shape and function, i.e., flat/plain, or lockwasher. Lockwashers may be split or have external or internal teeth (Figure 2).

Part II: Cleaning, Derusting, and Reinstallation/Replacement

Introduction

Threaded fasteners often need to be cleaned and derusted after they have been removed from an artifact. Cleaning removes contaminants that can attract and hold moisture, so this will discourage potential corrosion and seizing of the fasteners in place. Derusting removes corrosion products that may already be interfering with smooth turning of the engaged threads. Both treatments make future reassembly and disassembly easier and less likely to result in damage.

Threaded fasteners are relatively small and intricate parts of an artifact. They are also numerous and they all look the same to a casual observer. Cleaning and derusting fasteners thus poses a double challenge: to clean all of the minute crevices and, at the same time, to keep track of each fastener so that it can be returned to its original location without loss or mix-up.

Keeping Track

There is no foolproof method for marking fasteners that will withstand cleaning and derusting operations, unless one chooses to mark the fastener permanently. The practice of making centre-punch marks on a nut or bolt head that correspond to matching marks on the parent artifact is effective and has historical precedent, but is not acceptable for museum artifacts. Wiring tags onto a fastener will not cause any appreciable damage, but it will interfere with the cleaning and derusting action of chemical solutions. Organizing loose fasteners into compartmentalized and labelled trays, muffin tins, and wire baskets is risky because these can be overturned in an instant.

One effective solution is to place each fastener in its own resealable Ziploc-type bag, with the location and dimensions recorded directly on the bag using a fine-point permanent marker (Figure 15). The bags are made of transparent polyethylene, so they are stable and waterproof and the fasteners remain highly visible for retrieval and close inspection. The bags are also unbreakable and they take up little space. Once sealed shut, they will keep the fasteners secure and well identified. Domestic Ziploc-type bags are large compared to most fasteners, but this size makes the labelled bags that much harder to misplace. The standard size also allows one to group the fasteners in convenient rows in storage boxes for later retrieval. Heavy-duty resealable polyethylene bags are available in many different sizes from most scientific supply companies (see "Suppliers"). These bags are stronger than Ziploc-type bags and they stand up better to repeated use. The

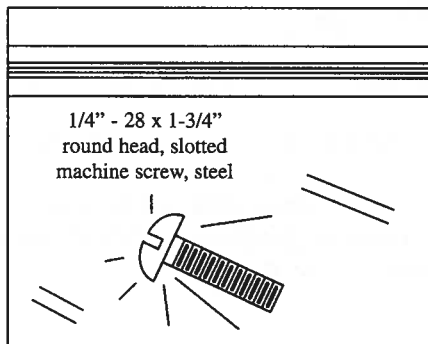


Figure 15. Ziploc-type bag

"permanent" markings can be removed with a small amount of rubbing alcohol and a cotton swab or tissue.

With this bagging method, even if a fastener and its bag are separated, it is possible to reunite the two later by following the documentation on the bag. Confusion can still occur if a bag is lost or mistakenly discarded, however, so keep a separate copy of the documentation information on paper or diskette. In this way, it will at least be possible to identify the likely function of any stray fastener, and to find an appropriate home for it on the main artifact.

The greatest risk of losing or mixing-up fasteners can occur during the immersion treatments described below, because the fasteners and their bags must be physically separated. Bulk treatments are not recommended. Instead, treat each fastener individually in its own beaker or glass jar of solution. (If more than one fastener must be treated in the same container, choose fasteners that are obviously different: it is easier to distinguish between a nut, a large cap screw, and a small set screw than between three slightly different set screws.) To lessen the chance of mix-ups, attach an adhesive label with adequate identifying documentation to every beaker or jar before the treatment. An operation of this type is time-consuming, but should not delay organized disassembly or reassembly activities.

Cleaning

A simple and effective way to clean a threaded fastener is to soak it in a beaker or glass jar of cleaning solution for an extended period, anywhere from a few hours to several days. Occasional scrubbing with a stiff-bristled brush (e.g., a nylon nail brush) will speed up the process, as will periodic agitation of the solution. Mineral spirits is a fairly safe, cheap solvent. Certain commercial cleaners are non-flammable and less toxic than mineral spirits, but they do cost more (see "Suppliers"). All solutions are best used in limited quantities in small beakers. Again, placing only one fastener in an individual labelled beaker or jar is good insurance against loss or mix-up.

The effectiveness of immersion cleaning can be increased dramatically with ultrasonic cleaning (Figure 16). Place the beaker of cleaning solution in an ultrasonic cleaning tank filled with water up to the level of liquid in the beaker. The sound waves from the walls of the cleaning tank will travel through the water to reach the cleaning solution. There is no need to fill the entire tank with expensive chemical solutions. Perforated or wire mesh insert trays or beaker positioning covers can be purchased or constructed to suspend a number of beakers in the solution above the tank bottom. This

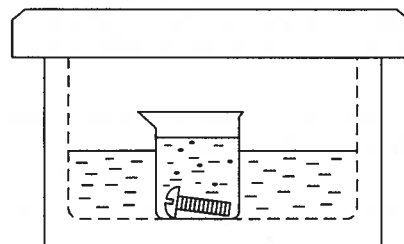


Figure 16. Ultrasonic cleaning

will prevent the partially filled beakers from bobbing or turning over. To reduce evaporation and to prevent spillage, securely cover or seal the beakers at the top with a square of thin plastic film and an elastic band.

After cleaning, rinse the fasteners that are free from rust in clean water and immediately dry them with paper or cotton towels, then coat them with water-displacing penetrating oil (e.g., WD-40) or light machine oil. This will prevent flash rust from forming. If oiling is not desirable, the towel-dried fasteners can be rinsed with acetone in a beaker. Acetone must be used with caution. It is extremely flammable and it evaporates rapidly. Use it only in well-ventilated areas and away from sources of heat or open flames. A non-chemical alternative is to dry the fasteners with a hot-air gun.

Once clean and dry, place the fasteners in a second clean, labelled bag until they are needed for reassembly. Rusted fasteners will require special treatment, as discussed below.

Where cap screws are involved, the artifact will have tapped holes (holes with internal threads) that may require cleaning. Immersion may not be possible or desirable, because of the size, weight, or finish of the parent artifact. In this case, cleaning will have to be carried out locally. The interior helical groove of a tapped hole is difficult to clean. Mechanical - rather than chemical - methods are required (Figure 17). The simplest method is to push a very stiff spiral-bristle brush through the hole with a clockwise turning motion, allowing the bristles to follow the path of the threads. The best brushes for this purpose are chamber or bore brushes used to clean firearms. These are cylindrical brushes, about 8 cm to 13 cm long, that screw onto the end of a steel or aluminum cleaning rod. The most popular bristles are made of phosphor bronze, designed not to scratch the fine interior steel surface of a rifle or pistol barrel; they will not damage steel threads. They are available in different diameters (calibers) and lengths. Softer bore brushes with nylon bristles can be used for light cleaning operations. All of these brushes are best used in open-ended holes, because the brush can be passed right through.



Figure 17. Brushes

Where the tapped holes are blind (i.e., with a closed bottom), a stiff spiral brush will screw itself into the hole, and it will have to be forcibly withdrawn with a counterclockwise turning motion unless it is considerably smaller in diameter than the hole. A round (non-spiral) or flat side-action brush will be easier to extract.

Another option is to use a Foredom tool or Dremel Moto-Tool with an appropriate size of radial brush accessory. Start with a soft nylon-bristle brush and work up to stiffer brass wires.

Blind holes will have to be vacuumed or blown out with compressed air in order to remove the loosened debris. It may be possible to remove residual dirt and grease with curved forceps and small balls of solvent-dampened cotton batting.

Derusting

Derusting nuts, bolts, and screws is most easily and thoroughly done with chemical solutions. Many commercial and industrial derusting solutions based on phosphoric acid are available. These solutions work best on precleaned fasteners, because contaminants such as dirt and grease will interfere with the derusting action and the process will consume more solution. Immerse the fastener for 30 minutes at a time, then withdraw it for inspection. This agitates the solution and aerates the metal; both actions assist the chemical derusting reaction. Brushing off loosened rust occasionally will also speed up the process.

It is essential to immerse the fastener completely. The solution can severely etch the shank of a half-immersed bolt at mid-point if it is left too long in this position, because the chemical action is most aggressive at the air/liquid interface.

An ultrasonic tank, used with this derusting solution for three to five minute intervals (as done in the cleaning operation), will accelerate the reaction. Once derusted, the fastener should be towelled off and air-dried. Rinsing is not recommended because it will remove the residual acid that deposits a protective phosphate coating on the metal.

Removing rust in tapped holes is best accomplished by mechanical means. Stainless steel versions of the bore brushes may be sufficient. As with cleaning, one can also use a Foredom tool or Dremel Moto-Tool with an appropriate size of radial (stainless steel) wire brush accessory.

Surface conditioning materials, such as 3M Unitized Wheels and Scotchbrite Hand Pads, are also effective for derusting internal threads. Discs can be cut from the hand pads with a hole punch and secured to a Dremel tool or power drill with a screw-type mandrel (see CCI Notes 9/8, *Mechanical Removal of Rust from Machined Ferrous Surfaces*).

The most interventive method is to retap the hole with an appropriate tap (same pitch as the threads). There is a serious chance of removing original metal with this technique, especially if the internal threads have been distorted in any way. Watch for metal particles, when backing off the tap, clearing the cutting teeth. This will indicate that metal is being removed. If this is the case, discontinue the treatment.

Repairs

As a rule, keep repairs to a minimum. Leave all original marks and damage intact. This includes mangled screw slots, smeared corners, punch marks, flattened or distorted threads, and slightly bent shanks. As unsightly as these flaws may seem, they are part of the artifact's working history. Allow them to tell their own story of care or misuse. The goal of

the treatments discussed here is to make future removal and reinstallation possible without risk of damage, and to accomplish this without leaving a trace of one's own intervention.

If an original fastener is too damaged to be reused, it is better to replace it with a replica than to repair it (see "Replacement" below). The original should be documented and preserved in a suitable location.

Reinstallation

Cleaned fasteners should be coated before they are reinstalled. A thin coating of machine oil or light grease will reduce the risk of surface rust forming later and it will lubricate the threads for easier turning. Special industrial anti-seize compounds are also available. These products combine grease with fine particles of graphite and powdered metals (usually copper or nickel). They are formulated to act as anti-corrosive coatings and lubricating compounds in severe operating environments, so they provide exceptional protection for museum artifacts in less punishing conditions.

Do not apply primer or paint to the threads of fasteners. Even a thin coat of paint on a coarse thread will seriously interfere with the turning action, resulting in permanent damage or destruction during tightening.

Set screws are difficult to reinstall accurately. Ideally, the point of the screw should fit back into the last recess it made, rather than creating a new one. Align the empty threaded hole of the part with the correct mark or pit on the shaft, then reinstall the fastener and turn it by hand until the point engages the pit. One should be able to feel the fastener centering itself in the recess. Tighten further with hand tools.

The offset ends of split (spring) lockwashers usually have burrs which grip the bearing surfaces as the fasteners are tightened. Tooth lockwashers bite into the metal as well. Both types leave permanent marks every time they are used. To stop this cumulative damage, protect the bearing surfaces of both the fasteners and the parent artifact with thin flat washers ("shim washers") next to the lockwashers.

Locking devices (cotter pins, tab washers and safety wire) on operational artifacts will probably have to be removed many times during maintenance of the machines. Use modern replacements for reasons of safety and to preserve the original parts. Document and save the originals as part of the material history of the artifact.

Tightening

Reinstalled fasteners will require a certain degree of tightening. For artifacts in storage or on static display, tighten the fasteners only to a snug point, about one turn beyond finger-tight. It should be possible to loosen and remove the fastener later without using much force. On the other hand, if the artifact is operational, the fasteners will have to be tightened more firmly and checked regularly, both for safety reasons and to prevent damage from excessive vibrations.

Thumbscrews and wing nuts are designed strictly for finger tightening. Tightening with tools will require later loosening with tools. This could result in damage.

Replacement

Original fasteners are often missing or so badly damaged that they have to be replaced. Always try to replace an original with a matching replica. For example, if the original screw had an oval head, it should be replaced with an oval head screw, not a flat-headed one. Similarly, slotted heads should not be replaced by square socket (Robertson) or cross recess (Phillips) heads. These may be totally inappropriate for the artifact's original time period and place of origin. Attention to this kind of detail is a sign of excellent, responsible restoration work.

Exact replicas of early fasteners can be very difficult to find. There are always subtle differences in dimensions and finishes. Unless one is skilled at making replicas on a lathe, commercially available approximations may have to suffice. Even finding approximations is becoming difficult, because the fasteners appropriate for use in artifacts are quickly becoming obsolete. Most domestic hardware stores no longer carry fasteners with slotted heads. It is worth the effort to find specialty suppliers of fasteners. Spae-Naur in Waterloo, Ontario, offers the widest selection of fasteners in Canada through mail order, but even their inventory of historically appropriate fasteners is narrowing due to falling demand. This makes the proper care of original fasteners all the more important in conservation treatments.



Figure 18. SAE grades

Most modern hex bolts and screws have raised markings on the head designating them as SAE (Society of Automotive Engineers) grade 5, 7, or 8, which indicates their minimum tensile strength and material composition (Figure 18). Only the lowest grade fasteners (Grade 2) are unmarked. It is better to err on the side of safety and to buy fasteners of Grade 5 or better quality. The markings are conspicuous and may not be appropriate for an artifact in a museum collection, so they should be ground off before installation is completed. At the same time, permanently mark newly installed, non-original fasteners in some way to prevent later confusion or misinterpretation. A small letter "R" (for "replica/reproduction") and the year (e.g., "96") can be stamped in a place where it will only be visible upon disassembly (e.g., on a bearing surface, or on the unthreaded length of the shank) (Figure 19). The stamped surface should be filed smooth to remove any burrs.

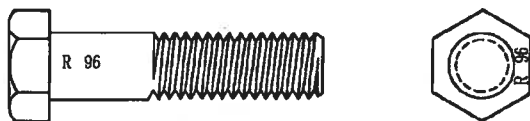


Figure 19. Reproduction or replica mark

Finishes

Threaded fasteners on industrial artifacts pose some interesting problems in terms of how and when they should be finished. In some cases the fasteners were painted at the same time as the parts they held together. That is, the entire assembly or sub-assembly was painted by brushing, dipping or spraying. In other cases, the fasteners were installed on parts or sub-assemblies that had been finished separately. The exposed areas (heads, nuts and ends of bolts) of the added fasteners could then have been touched-up with paint as a final step in manufacturing.

Many manufacturers used plated or oxide-finished fasteners that did not require protective touch-up paint. The most common plating metals were zinc (grey) and chromate-treated cadmium (greenish yellow). Highly visible fasteners on such parts as automobile trim were often solid brass or nickel-plated. Black (oxide or phosphate) finished fasteners were used for automobile engines and chassis. Steel fasteners could be left unfinished if the assembly was coated with oil or operated at high temperatures.

High quality restoration work should duplicate the results of the original manufacturing and finishing techniques as far as possible. An unrestored example of the artifact is the most reliable reference material. If one is not available, then it may be possible to determine such details through archival research. Otherwise, one will have to judge each artifact on a case-by-case basis, trying to reconstruct the thought processes of the original manufacturer.

As a rule, the exposed areas of fasteners should be painted only after installation and final tightening; otherwise their finish will be damaged by wrenches or screwdrivers. Do not paint any of the threads if future disassembly is anticipated; it will seriously interfere with turning the fasteners.

Suppliers

Gunsmith's screwdrivers, bore brushes:

Brownell's, Inc.
200 South Front Street
Montezuma, Iowa 50171
USA
Tel.: (515) 623-5401
Fax: (515) 623-3896

Drag link sockets:

Spae-Naur Inc.
Head Office
815 Victoria Street North
P.O. Box 544
Kitchener, Ontario N2G 4B1
Toll-free: (800) 265-8772

Resealable polyethylene bags:

Ziploc

Grocery/convenience stores

"Zipper" Seal Sample Bags (6 sizes; packs of 50)

Fisher Scientific
Headquarters: 112 Colonnade Road
Nepean, Ontario K2E 7L6
Tel.: (613) 226-8639
Sales offices: Edmonton, Vancouver, Montreal and Toronto
On-line catalog: <http://www.fisher1.com/>

Cleaning solution (Mirachem 500):

Mirachem Corporation
2107 East Fifth Street
Tempe, Arizona 85281-3034
USA
Tel.: (602) 966-3030 for list of local distributors

Ultrasonic cleaning tanks, beaker positioning covers, and insert trays:

Fisher Scientific (see above)
Brownell's, Inc. (see above)

Local sources for the following tools and supplies will be found under the following headings in the Yellow Pages of most telephone directories.

3M Scotchbrite hand pads and unitized wheels:

Abrasives
Automotive supplies
Industrial Equipment & Supplies

Anti-seize and lubricating compounds (Bostik Never-Seez, Regular Grade):

Gaskets

Penetrating oil (Liquid Wrench, WD-40):

Automobile Parts & Supplies
Hardware

Thread file:

Industrial Equipment & Supplies

Screw pitch gauge:

Machine Tools

Nut, bolt, and thread gauge:

Industrial Equipment & Supplies
Fasteners-Industrial

Glossary of Technical Terms

General

head - the formed top of a screw or bolt.

shank - the threaded cylindrical portion (shaft) attached to the head of a screw or bolt.

external thread - the thread on the outside of a screw or bolt shank.

bearing surface - (1) the flat surface under the head of a screw or bolt; (2) the face of a nut that bears against a surface.

washer-faced - a flat, turned bearing surface on a nut or under the head of a screw or bolt.

chamfered - having bevelled edges and/or corners.

Screws

screw - threaded fastener that passes through one clear (unthreaded) hole into a tapped (threaded) hole; torque (turning force) is applied to the head.

machine screw - a slotted screw for relatively light loads; it can have one of four types of heads: flat, oval, fillister, or round.

cap screw - a screw, usually greater than 1/4" in diameter, for heavier loads; it can have one of four common types of heads: hex (unslotted), flat (slotted), button, or fillister.

set screw - a screw used to hold two parts in relative position (e.g., a collar or pulley on a shaft); it is screwed through one part, with a pointed or cupped end tightened against the other part; it usually has a small square, unslotted head or is headless and slotted.

Bolts

bolt/machine bolt - threaded fastener that passes through two clear holes and is secured by a nut; it usually has a square or hexagonal head; torque is applied to the nut rather than to the head of the bolt.

stove bolt - a long, thin bolt (usually 3/16" or 1/4" in diameter) with a flat or round slotted head; the entire shank is threaded; it is secured with a square nut, the top and bottom are flat and without chamfer.

Threads

threads per inch (TPI) - the number of consecutive threads on the shank of a bolt or screw, or inside a nut.

right-hand thread - a thread that advances when turned clockwise; threads are assumed to be right-handed unless otherwise specified.

left-hand thread - a thread that advances when turned counterclockwise.

root - the bottom surface joining the sides of two adjacent threads.

crest - the top surface joining the two sides of a thread.

pitch - the distance between corresponding points on consecutive threads, measured parallel to the axis; the inverse of threads per inch.

lead - the distance the screw will advance axially during one turn in a fixed threaded hole.

Nuts

nut - a square or hexagonal metal fitting, with an internally threaded hole; it is used to secure a bolt.

jam nut - a thin hexagonal nut tightened against a full-sized nut, locking it in place.

castellated - a nut having a raised slotted area; it is secured by a cotter pin or is wired in place.

internal thread - the thread inside the hole of a nut.

Locking Devices

cotter pin/split pin - a split steel pin with a circular eye at one end; it passes through the slots of a slotted or castellated nut and a hole in a shank to prevent loosening or loss; the arms of the pin are bent back after insertion.

tab washer - a flat washer with either a fixed internal tab (keyed to the shank of a bolt) and one external tab, or two external tabs; the tabs are bent after tightening the nut to prevent it from turning.

safety wiring - a length of wire passing through a hole in a bolt head or shank and tightly twisted to prevent the bolt or castellated nut from turning.

Further Reading

Historical References

Historical and technical data pertaining to threaded fasteners can be found in many early technical books. Some examples are listed below.

Berard, S.J. and E.O. Waters. *The Elements of Machine Design*. 2nd ed. New York: D. Van Nostrand Co., Inc., 1932.

Brimm, Daniel J. and H. Edward Boggess. *Aircraft Maintenance*. Toronto: Sir Isaac Pitman & Sons (Canada), Ltd., 1940.

Colvin, Fred H. and Frank A. Stanley. *American Machinists' Handbook*. 2nd ed. New York: McGraw-Hill Book Co., Inc., 1914.

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French, Thomas E. *A Manual for Engineering Drawing*. 6th ed. New York: McGraw-Hill Co., Ltd., 1941.

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Raymond, Howard Monroe. *Modern Shop Practice*. Vol. 1. Chicago: American Technical Society, 1919.

Society of Automobile Engineers. *S.A.E. Handbook*. Vol. 1, Data Sheets. New York: Society of Automobile Engineers, 1913.

Modern References

Bradley, Ian. *Screw Threads and Twist Drills*. 4th ed. Hertfordshire, England: Model & Allied Publications, Ltd., 1974.

Chaddock, D.H. *Introduction to Fastening Systems*. Oxford: Oxford University Press, 1974.

Humphries, John. *How to Choose and Use Car Tools*. Toronto: Coles Publishing Co. Ltd., 1977.

Scharff, Robert. *Successful Putting It All Together*. Farmington, Michigan: Structures Publishing Co., 1979.

Shop Tools. Fundamentals of Service (FOS) Series. 3rd ed. Moline, Illinois: Deere and Company, 1980.

The illustrations in this Technical Bulletin are either copied from or drawn from the following sources.

Figures 1, 2, 8, 10 and 14: French, Thomas E. *A Manual for Engineering Drawing*. 6th ed. New York: McGraw-Hill Co., Ltd., 1941.

Figures 3, 4, 13, 15, 16, 18 and 19: George Prytulak

Figure 5: Homans, James E. *Self-Propelled Vehicles*. New York: Theo. Audel & Co., 1914.

Figure 7: Corlett, J. Campbell. *Rigging and Airframes*. London: Pitman & Sons, Ltd., 1936.

Figure 8a: Dyke, A.L. *Dyke's Automobile and Gasoline Engine Encyclopedia*. 21st ed. Chicago: Goodheart-Willcox Co., Inc., 1949.

Figure 8b: Spae-Naur, Inc., catalogue No. 11.

Figures 6 and 9: Stahn, Charles R. *Automobile Construction and Operation*. Toronto: Ryerson Press, 1965.

Figure 11: Gauge plate made by Coastal Mold and Plastics, Kaysville, Utah. Patent pending.

Figure 12: Dyke, A.L. *Dyke's Automobile and Gasoline Engine Encyclopedia*. 21st ed. Chicago: Goodheart-Willcox Co., Inc., 1949.

Figure 17: Brownells, Inc., catalogue No. 46 (1993-94).

Standard Screw Threads			
Diameter	Threads Per Inch (TPI)		
	Coarse	Fine	Extra Fine
Nos. O (.0600")	...	80	
1 (.0730")	64	72	
2 (.0860")	56	64	
3 (.0990")	48	56	
4 (.1120")	40	48	
5 (.1250")	40	44	
6 (.1380")	32	40	
8 (.1640")	32	36	
10 (.1900")	24	32	
12 (.2160")	24	28	
1/4"	20	28	36
5/16"	18	24	32
3/8"	16	24	32
7/16"	14	20	28
1/2"	13	20	28
9/16"	12	18	24
5/8"	11	18	24
3/4"	10	16	20
7/8"	9	14	20
1"	8	14	20