Designation: F3217 – 17

Standard Guide for Security Fasteners[1]

This standard is issued under the fixed designation F3217; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The purpose of this guide is to provide technical information related to understanding the features, types of materials, and benefits of various types of security fasteners and provide guidance in the selection and application of security fasteners in detention and corrections facilities.

1.2 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASME Standard:*

ASME B1.1 Unified Inch Screw Threads (UN and UNR Thread Form)[2]

2.2 *British Standard:*

BS 1580–1 Unified Screw Threads. Screw Threads with Diameters ¼ in. and Larger. Requirements[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *bearing surface, n*—area that carries load across the face of the material.

3.1.2 *blind fastener, n*—fastener that can be placed with access to only one side of an application (for example, cage nuts, pop rivet®).

3.1.3 *blind side, n*—side of the joint that cannot be accessed (for example, the inside surface of a tubular or box section).

3.1.4 *body, n*—in blind fasteners, the portion of the rivet that expands into the parent material and in threaded fasteners, the unthreaded portion of the fastener under the head.

3.1.5 *bolt, n*—externally threaded fastener that requires a nut to secure the fastened joint.

3.1.6 *break stem, n*—fastener that is installed by gripping and pulling the end of the mandrel/stem; see Fig. 1.

3.1.6.1 *Discussion*—As installation is completed, the end of the stem fractures at the breaker groove and is discarded, leaving the head of the stem in the fastener body.

3.1.7 *breaker groove, n*—weakened groove in the stem or pin of a fastener allowing breakage at a predetermined load and length; see Fig. 2.

3.1.8 *bulbing, v*—physical action of the fastener body swelling (expanding radially) against the rear face of the joint when placed.

3.1.8.1 *Discussion*—Generally found in break stem fasteners and threaded inserts.

3.1.9 *case hardened, adv*—heat-treated fastener in which the surface is harder than the core.

3.1.10 *chemical-set anchor, n*—anchor designed for blind-hole installations that use a two-component structural grade catalyzing resin (usually epoxy) to bind the bolt securely in the substrate material.

3.1.11 *drive-pin expansion anchor, n*—blind-hole expansion anchor usually manufactured from a relatively soft alloy metal or plastic, but can also be of steel; see Fig. 3.

3.1.11.1 *Discussion*—The anchor is expanded into the blind hole by hammering in a supplied pin or nail into the center of the anchor.

3.1.12 *drive type, n*—the features of a fastener head that allows the fastener to be driven (installed or removed).

3.1.12.1 *Allen head, n*—hexagonal hollow socket drive design.

[1] This guide is under the jurisdiction of ASTM Committee F33 on Detention and Correctional Facilities and is the direct responsibility of Subcommittee F33.04 on Detention Hardware.

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[2] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[3] Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsigroup.com.

[4] See thread terminology, types of bolt and screw heads, and types of screw points for visual reference.

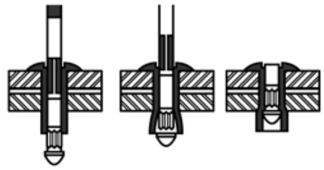


FIG. 1 Break Stem

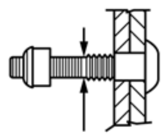


FIG. 2 Breaker Groove

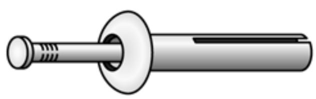


FIG. 3 Drive-pin Expansion Anchor

(1) Discussion—Security fastener versions have a center pin reject feature added.

3.1.12.2 *Key-Rex®, n*—custom-registered computer-designed hollow socket head design requiring a matching tool drive to install or remove; see Fig. 4.[5]

FIG. 4 Key-Rex®

(1) Discussion—Generally considered a maximum security fastener.

3.1.12.3 *McGard Intimidator®, n*—custom-registered computer-designed hollow socket drive design requiring a matching tool drive to install or remove; see Fig. 5.[5]

FIG. 5 McGard Intimidator®

(1) Discussion—Generally considered a maximum security fastener.

3.1.12.4 *one-way drive, n*—drive design that allows for installation but not removal. This is usually a one-way slotted head in which the slot shoulders are removed in the counterclockwise direction.

(1) Discussion—This is not considered a security fastener with the possible exception of one-way slotted heads in which the slot shoulders are removed in the counterclockwise direction.

3.1.12.5 *Penta Nut™, n*—tapered nut with a hollow five-point socket that is used to tighten the nut; see Fig. 6.[5]

FIG. 6 Penta Nut™

3.1.12.6 *Penta-plus™, n*—five-sided hollow socket security fastener with center pin reject; see Fig. 7.[5]

FIG. 7 Penta-plus™

3.1.12.7 *Phillips head, n*—for threaded fasteners, a traditional hollow socket head design characterized by a four-lobed shape; see Fig. 8.

FIG. 8 Phillips Head

(1) Discussion—This is not considered a security fastener.

3.1.12.8 *Raptor™, n*—oversized head with anti-loosening serrations on the flat bearing surface, which increases the holding power of the fastener 20 % and eliminates the need for lock washers.[5]

(1) Discussion—This feature can be added to Key-Rex®, Penta-plus™, Zero™, or any style fastener.

3.1.12.9 *Robertson, n*—a square hollow socket drive often seen in woodworking fasteners.

3.1.12.10 *slotted head, n*—for threaded fasteners, a traditional head design characterized by a cross slot in the head face; see Fig. 9.

FIG. 9 Slotted Head

[5] The sole source of supply of the apparatus known to the committee at this time is Bryce Fasteners, 1230 N. Mondel Dr., Gilbert, AZ 85233. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

3.1.12.11 *spanner head, n*—for threaded fasteners, one with a head design characterized by horizontally opposed notches in the head circumference or round recesses within the head face; see Fig. 10.

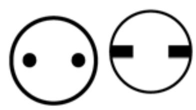


FIG. 10 Spanner Head

(1) Discussion—Such designs are not especially secure and tools for inserting or removing these types of fasteners are easily broken. They are often referred to as "snake eye" fasteners.

3.1.12.12 *Torx head, n*—multi-lobed hollow socket fastener bit design as patented and licensed by Camcar Textron and the design is characterized by a six-lobed shape with rounded lobes.[6] The security version has an added center pin; see Fig. 11.

FIG. 11 Torx Head

3.1.12.13 *Torx plus head, n*—multi-lobed hollow socket fastener bit design characterized by a six-pointed shape as patented and licensed by Camcar Textron and the design characterized by a six-lobed shape with truncated lobes.[6] The security version is a five-lobed version that has an added center pin; see Fig. 12.

FIG. 12 Torx Plus Head

(1) Discussion—This design has better mechanical properties than the standard Torx but is limited in available sizes.

3.1.12.14 *T-REVX®, n*—multi-lobed hollow socket fastener characterized by a seven-point shape as patented and licensed by Bryce Fastener; see Fig. 13.[7]

FIG. 13 T-REVX®

3.1.13 *endurance limit/strength, n*—maximum alternative stress that a fastener can withstand for a specified number of stress cycles without failure. This is not normally an issue in correctional/detention projects.

3.1.13.1 *Discussion*—See *static breaking strengths* (in pounds).

3.1.14 *expansion anchor, n*—anchor designed for blind-hole installations that use a specially designed sleeve, wedge or other device that, as the fastener is tightened, the sleeve or wedge expands into the available space locking the fastener in place.

3.1.15 *hardening, v*—changing the strength or durability characteristics of a fastener through heat treatment or work hardening.

3.1.15.1 *Discussion*—See case *hardening, induction hardening, and through hardening.*

3.1.16 *head form/head style, n*—characteristics of the fastener head and head styles include button, pan, truss, hex, hex flange, socket head large flange, low profile, and countersunk.

3.1.16.1 *button head, n*—for threaded fasteners, one with a low, rounded top surface and a large, flat bearing surface; similar to a round head machine screw; see Fig. 14.

FIG. 14 Button Head

3.1.16.2 *countersunk head, n*—for threaded fasteners, one with a level surface and a conical bearing surface; available in various nominal head angles; see Fig. 15.

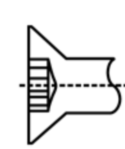


FIG. 15 Countersunk Head

(1) Discussion—See *flat head.*

3.1.16.3 *fillister head*—for threaded fasteners, one with a rounded top, cylindrical sides, and flat bearing surface; see Fig. 16.

3.1.16.4 *flat head, n*—for threaded fasteners, one with a level surface and a conical bearing surface; available in various nominal head angles; see Fig. 17.

(1) Discussion—See *countersunk head.*

[6] The Torx head is covered by a patent. If you are aware of an alternative(s) to the patented item, please attach to your ballot return a description of the alternatives. All suggestions will be considered by the committee. If alternatives are identified, the committee shall reconsider whether the patented item is necessary. The committee, in making its decision, shall follow Regulation 15.

[7] The T-REVX® is covered by a patent. If you are aware of an alternative(s) to the patented item, please attach to your ballot return a description of the alternatives. All suggestions will be considered by the committee. If alternatives are identified, the committee shall reconsider whether the patented item is necessary. The committee, in making its decision, shall follow Regulation 15.

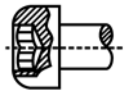


FIG. 16 Fillister Head

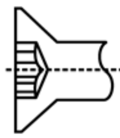


FIG. 17 Flat Head

3.1.16.5 *hexagon flange head/hex flange head, n*—hex head with an integral circular collar connected to the base of the hexagon by a conic section; see Fig. 18.

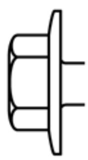


FIG. 18 Hexagon Flange Head/Hex Flange Head

(1) Discussion—Normally, the flanged diameter is larger than the width across the corners of the hexagon.

3.1.16.6 *hexagon head/hex head, n*—for threaded fasteners, one with a flat or indented top surface, six flat sides, and a flat bearing surface; see Fig. 19.

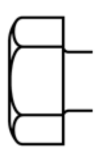


FIG. 19 Hexagon Head/Hex Head

3.1.16.7 *hexagon washer head/hex washer head, n*—hex head with an integral, formed washer at the base of the hexagon and the washer diameter may be equal to or greater than the width across the corners; see Fig. 20.

FIG. 20 Hexagon Washer Head/Hex Washer Head

3.1.16.8 *oval head, n*—for threaded fasteners, one with a rounded top surface and a conical bearing surface with a head angle of nominally 82° (90° for metric); see Fig. 21.

3.1.16.9 *pan head, n*—for threaded fasteners, one with a flat bearing surface and a flat top surface rounding into a cylindrical side surface; see Fig. 22.

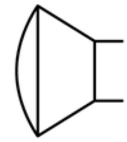


FIG. 21 Oval Head

FIG. 22 Pan Head

(1) Discussion—On recessed pan heads, the top surface is semi-elliptical, rounding into a cylindrical side surface. Pan headed screws normally do not provide enough depth for the tool cavity to develop reasonable strength so it is seldom used in security fastener designs. See *button head* or *fillister head*.

3.1.16.10 *round head, n*—one with a semi-elliptical top surface and a flat bearing surface.

(1) Discussion—This term is also used to describe a fastener head designed without a driving surface or recess; see Fig. 23.

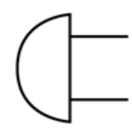


FIG. 23 Round Head

3.1.16.11 *socket head, n*—for threaded fasteners, one with a flat chamfered top surface with a smooth or knurled side surface and a flat bearing surface; see Fig. 24.

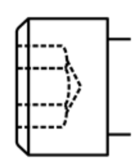


FIG. 24 Socket Head

(1) Discussion—A hexagon or spline (formerly known as "fluted") socket is formed in the center of the top surface.

3.1.16.12 *truss head, n*—for threaded fasteners, one with a rounded top surface and a flat bearing surface; the diameter of the truss head is larger in comparison to the fastener size than the diameter of the corresponding round head; see Fig. 25.

(1) Discussion—The design has improved mechanical properties to Torx having higher torque and the ability to stick to the installation tool. It is more secure because only licensed installation tools can remove it. Not all sizes are in stock.

3.1.17 *induction hardened, adj*—heat-treated fastener that has undergone a selective hardening process, using induction coils, to strengthen further a part of the fastener (usually the initial 1⁄16 in. (1⁄6 mm) of the surface).

FIG. 25 Truss Head

3.1.18 *length of engagement, n*—length of full-sized fastener threads that engage in the nut material.

3.1.18.1 *Discussion*—The length of the lead thread is not counted in the length of engagement since its reduced size minimizes any performance benefits. The length of engagement is usually expressed in relationship to the nominal diameter of the screw (for example, 2 to 2½ diameters of engagement).

3.1.19 *left-hand thread, n*—standard thread design; winds clockwise in a receding direction; see Fig. 26.

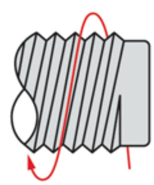


FIG. 26 Left-hand Thread

3.1.20 *maximum torque, n*—see *ultimate torque.*

3.1.21 *minimum torque, n*—see *torque (recommended).*

3.1.22 *passivation/passivated, n/v*—process to remove contaminants from the surface of stainless steel.

3.1.22.1 *Discussion*—Also a name for the chromatic process applied to some metallic finishes to enhance corrosion resistance.

3.1.23 *pilot point, n*—cylindrical point with a diameter somewhat smaller than the shank diameter, which aids alignment and starting during installation; see Fig. 27.

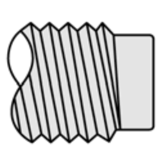


FIG. 27 Pilot Point

3.1.23.1 *Discussion*—Also called a "dog point" (applies normally to set screws).

3.1.24 *pinned head fastener, n*—hollow socket drive design enhancement in which a central pin is introduced into the design to render the fastener less prone to removal using makeshift tools by eliminating adequate bearing surface in which to exert force to the fastener; see Fig. 28.

3.1.24.1 *Discussion—Pinned Allen, pinned Torx,* and *pinned Torx Plus* are examples of such designs common to the detention and correctional industry.

FIG. 28 Pinned Head Fastener

3.1.25 *proof load, n*—amount of load a fastener can withstand before permanent plastic deformation will occur.

3.1.25.1 *Discussion*—See *yield strength.*

3.1.26 *pull out, n*—minimum force required to remove a fastener axially away from the parent material.

3.1.27 *pulling force, n*—axial force the tool applies during the installation of rivets.

3.1.28 *right-hand thread, n*—standard thread design; winds counter-clockwise in a receding direction; see Fig. 29.

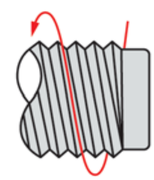


FIG. 29 Right-hand Thread

3.1.29 *Rockwell Hardness Test, n*—test designed to measure the hardness of the fastener based on an alphanumeric scale.

3.1.29.1 *Discussion*—The higher the number, the harder the fastener. Rockwell tests are used to test for decarburization and carburization and determine the amount of resistance to permanent deformation during the testing procedure. They also ensure that heat treating was performed to specification.

3.1.30 *screw, n*—externally threaded fastener that does not require a nut to secure the fastened joint.

3.1.31 *seating torque (recommended), n*—recommended value in inch-pounds or foot-pounds to which a particular threaded fastener should be tightened.

3.1.32 *shank, n*—portion of a fastener under the head; see Fig. 30.

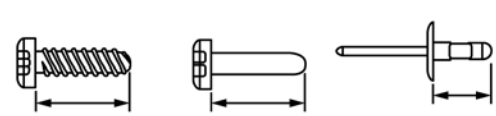


FIG. 30 Shank

3.1.33 *shear, n*—force that tends to divide an object along a plane parallel to the opposing stresses.

3.1.33.1 *Discussion*—Usually measured in lbf/in.^{2}, psi, MPa, or N/m^2.

3.1.34 *shear strength, n*—resistance to transverse loading. Maximum load that can be withstood prior to rupture when loads are applied normal to the fastener's axis.

3.1.34.1 *Discussion*—Usually defined as a force in Newtons (N) or foot-pounds (lbf).

3.1.35 *stem, n*—part of a break stem fastener that is retained within the body.

3.1.35.1 *Discussion*—Also known as the mandrel.

3.1.36 *stem retention, n*—force required to separate the stem from the body of an uninstalled break stem fastener.

3.1.37 *tensile strength, n*—amount of longitudinal load/elongation a fastener can withstand without failure of the fastener or joint.

3.1.37.1 *Discussion*—Measured in lbf/in.^{2}, psi, MPa, or N/m^2. See *ultimate tensile stress*.

3.1.38 *thermoset, n*—polymer characterized by extreme stiffness and undergoes a chemical change when heated. Once molded and cured "set" (hard and solid) the material cannot be melted and re-molded.

3.1.38.1 *Discussion*—Normally used on chemical set anchors.

3.1.39 *thread-cutting shank, n*—portion of a screw of bolt with longitudinal cut(s) in the tip of the threaded portion intended to cut or chase threads in untapped material or clean out threads in the nut or tapped receiver (most common use in this guide); see Fig. 31.

FIG. 31 Thread-cutting Shank

3.1.40 *thread engagement, n*—amount of thread tooth that is filled by the application material.

3.1.40.1 *Discussion*—This measurement is usually expressed as a percentage and is used to determine optimal hole size.

3.1.41 *threaded fastener, n*—any screw/bolt (external threads), nut (internal threads), or combination with machine/standard or engineered threads and does not include custom stamped or formed components with internal or external threads or both.

3.1.42 *threaded insert, n*—fastener that provides load-bearing threads in materials too thin or brittle to accept regular standard fasteners.

3.1.43 *through hardened, adv*—heat-treated fastener with uniform hardness from the surface to the core.

3.1.44 *torsion, n*—twisting force applied to a fastener.

3.1.45 *twist-off head, n*—head design that incorporates a weak shear plane whereby a torque limit is reached and the head shears off leaving a cone or bulb rendering the fastener non-removable; see Fig. 32.

FIG. 32 Twist-off Head

3.1.46 *ultimate tensile stress, n*—peak longitudinal load before rupture.

3.1.46.1 *Discussion*—Usually measured in lbf/in.^{2}, psi, MPa, or N/m^2.

3.1.47 *ultimate torque, n*—amount of force at which a threaded fastener begins to strip or otherwise fail in a joint or strip the threads of an insert or nut.

3.1.47.1 *Discussion*—For threaded inserts and clinch fasteners, it may also be referred to as supported torque.

3.1.48 *Unified Coarse Thread (UNC), n*—inch thread form (60°) standard defined by ANSI/ASME.

3.1.48.1 *Discussion*—Usually used in reference to machine screws. It is covered by ASME B1.1 and British Standard BS 1580.

3.1.49 *Unified Fine Threat, UNF, n*—imperial thread form standard defined by ANSI/AMSE.

3.1.49.1 *Discussion*—Usually used in reference to machine screws. It is covered by ASME B1.1 and British Standard BS 1580.

3.1.50 *washer face, n*—circular boss on the bearing surface of a cap screw or nut.

3.1.50.1 *Discussion*—The only bolt that has a washer face is the heavy hex structural bolt; see Fig. 33.

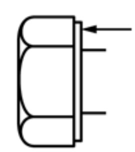


FIG. 33 Washer Face

3.1.51 *wedge anchor, n*—anchor designed for blind-hole installations that use a specially designed wedge or spade that, as the fastener is tightened, the wedge (usually a soft alloy) expands into the available space locking the fastener in place.

3.1.51.1 *Discussion*—Similar to expansion anchors.

3.1.52 *work hardening/cold working, v*—increase in metal hardness that is the result of forming processes such as elongation, rolling, heading, and so forth.

3.1.52.1 *Discussion*—This is particular pronounced in steels, copper, and aluminum alloys.

3.1.53 *yield strength, n*—measure of the resistance of material to plastic deformation. This relates to the point where a fastener will yield before it reaches a point it will not return to its original state.

3.1.53.1 *Discussion*—When a fastener is stretched, yield strength is the point at which the fastener will not return to its original length following testing. It is measured in terms of psi or MPa.

4. Significance and Use

4.1 This guide is intended to be informative in terms of the types and uses of security fasteners in detention and corrections facilities. Useful information related to products and types of fasteners, materials in which fasteners are fabricated and other technical information that will give owners, architects, and end users adequate decision making criteria for the selection and application of such fasteners.

5. Materials

5.1 *Steel:*

5.1.1 *Low-Carbon Steel*—Low-carbon steel (C1006, C1008, C1010) has low yield strength making it undesirable for security fasteners and is also known as mild steel.

5.1.2 *Case-Hardening Steels*—C1018 and C1022 are low carbon steels used for self-threading and self-drilling screws. With a special heat-treating method called case hardening, they can be made to have an extremely hard skin and a ductile internal core. This creates an inexpensive effective self-taping fastener.

5.1.3 *Medium-Carbon 1035 Steel Having 0.35 % Carbon*—This is the steel normally used for Grade 5 bolts. This steel can be through hardened and attain 120 000- to 125 000-psi (827.37- to 861.84-MPa) breaking strength.

5.1.4 *High-Carbon 1038 Steel Having 0.38 % Carbon*—This steel is normally used for Grade 8 bolts. It can be through hardened and obtain 150 000-psi (1034.21-MPa) breaking strength.

5.1.5 *Alloy Steel*—Alloy steels include 4037 and 8740. These are steels with 0.37 to 0.40 % carbon alloyed with other materials to make them tougher (represented by the call out 40 and 87). These are generally used in socket-type screws. They are more ductile than high-carbon steels. They can be heat treated to obtain 150 000 to 180 000 psi (1034.21 to 1241.05 MPa) breaking strength.

5.2 *Stainless Steel:*

5.2.1 *Austenitic Stainless Steel*—Most well-known and used in the construction industry and includes the two most prevalent Types 18-8 and 316. Austenitic steels make up over 70 % of total stainless steel production.

5.2.1.1 *18-8*—Types 305, 304, 303, 302, and 301 fall under the 18-8 heading. These all have the approximate composition of 18 % chromium and 8 % nickel and are similarly anticorrosive. They may also be referred to as A2 stainless. After manufacture, they usually obtain a strength of 90 000 psi (620.52 MPa). They are stronger than mild steels but not as hard as medium carbon steels.

5.2.1.2 *Type 316*—Also known as 18/10 for its composition of 18 % chromium and 10 % nickel. It may also be referred to as marine-grade stainless primarily for its increased resistance to corrosion. It is often used in cutlery and high-quality cookware. Strength is similar to 18-8 stainless steels.

5.2.2 *Martensitic Stainless Steel*—Martensitic stainless steels (usually called 410) are not as corrosion resistant as the other two classes but are extremely strong and tough as well as being highly machinable and hardenable by heat treatment. This rare form of stainless is used only for self-threading screws and self-drilling screws.

5.3 *Heat-Treated Steel:*

5.3.1 *Case-Hardened Steel*—Case hardening is a method of heat treating 1018 and 1022 steel in a "high-carbon atmosphere." The carbon invades the skin of the fastener 0.001 to 0.005 deep making that part extremely hard, sometimes as hard as HRC 60. The internal part is left unaffected making it resilient to shock. The result is a tough and hard fastener, especially effective in self-tapping and self-drilling screws. The overall strength is not much different than a mild steel fastener. This age-old process was used to improve the performance of Roman and Japanese swords.

5.3.2 *Through-Hardened Steel*—High-carbon (1035 and 1038) and alloy steels (4037 and 8740) have enough internal carbon that, when brought to temperature, the carbon changes the structure of the whole fastener hardening it all the way through, not at just the surface. This heat-treating method requires a fast quench (to retain this transformation) followed by tempering to mitigate its brittleness and make the fastener tougher. Through hardening markedly increases the overall strength of the fastener. Medium-carbon steel rises from 60 000 to 120 000 psi (413.68 to 827.37 MPa), high carbon to 150 000 psi (1034.21 MPa), and alloy steels to 150 000 to 180 000 psi (1034.21 to 1241.05 MPa). Low-carbon steels (1002, 1008, and 1010) cannot be through hardened, as there is not enough internal carbon to make them transform.

6. Finish

6.1 *Black Phosphate*—This is an historical coating originally used on socket screws and has been replaced by black oxide. Both of which are poor coatings for the corrections industry as they easily rust.

6.2 *Dip-Spin Coatings*—This is a new method of coating steel fasteners commonly used in the auto industry. It is environmentally friendly and much more anticorrosive than other platings. Thickness ranges from 2 to 3 mils. Since there are many brand names and formulas, it may be best specified by its salt-spray effectiveness. A 500 salt-spray resistance is easily obtained by most. This is also very effective for high-carbon steel fasteners as it does not create hydrogen embrittlement. It is also paintable.

6.3 *Hot-Dipped Galvanizing*—This is a good choice for exterior applications in larger sizes. Hot-dipped galvanizing is a rather "thick" coating and as such can be problematic on smaller sizes and fine threads. This coating is usually found on fasteners used on fencing and structural steel in marine environments.

6.4 *Zinc Electroplating*—This choice offers a mild degree of corrosion resistance (80 to 90 salt-spray hours) but should only be specified for indoor applications. In most cases, some form of chromate is added to increase corrosion resistance. It is the industry standard for steel fasteners but has some environmental problems.

6.5 Tin zinc is a combination of two metals and can obtain 400 to 500 salt-spray resistance. This special order plating has a shiny color.

7. Fastener Types

7.1 *Non-Removable*—These are fasteners that by their design are intended upon installation to have no means of removal. Examples include one-way designs, blind fasteners (pop rivets), drive-pin fasteners, twist-off head fasteners, and other proprietary designs. Such fasteners require the destruction of the head with a saw, grinder, or torch to remove the item fastened. These types are excellent for items that need to be secured and left alone. Examples include:

7.1.1 Toilet partitions,

7.1.2 Detention furnishings,

7.1.3 Detention accessories,

7.1.4 Detention hollow metal to nonmetallic substrates where welding is not an option, and

7.1.5 Door trim hardware (weather stripping and thresholds).

7.2 *Removable—*These are fasteners that by their design are intended to be installed and removed using special tools. For security fasteners, this includes spanner head, pinned head Allen, pinned head Torx, pinned head Torx-Plus, McGard, and others. In these locations, regular access for maintenance or potential access for replacement necessitates the application of removable fasteners. In security applications, a reasonably secure head design is required to make removal by non-authorized individuals extremely difficult. Examples include:

7.2.1 Detention hardware;

7.2.2 Detention glazing stops;

7.2.3 Some elements of detention ceilings;

7.2.4 Detention light fixtures; and

7.2.5 Furniture, fixtures, and equipment requiring regular maintenance.

8. Head Design

8.1 Head design is normally selected for the intended individual use and by the need to be flush with the adjacent surface or not. The overall shape of the head is not specifically related to the security level of the fastener with the exception of nonremovable types. The other facet of head design is the design of the tool required to remove the fastener in the case of removable types.

8.1.1 *Non-removable Security Fastener Head Options for Considerations—*The selection of the right fastener depends on several issues including the size of the fastener, spacing, level of security, required load-carrying capacity, and corrosion resistance.

8.1.1.1 Low-security/low-strength uses in metal substrates normally require the use of blind fasteners (pop rivets). Aluminum can be used for low-strength applications and stainless steel for higher strength applications. One-way screws can also be allowed but only where acceptable to the institution.

8.1.1.2 Moderate-security/moderate-strength uses in concrete and masonry substrates often involve the use of drive-pin fasteners (Zamac) or proprietary deformed shank fasteners (Rawl Spikes).

8.1.1.3 High-security/high-strength uses in concrete and masonry substrates normally indicate the use of bolts or nuts with twist-off heads. The bolts may be chemically set anchors, expansion anchors, or even embedded anchors. For post-applied applications, chemically set anchors are preferred unless the application will be compromised with the application of high heat as in a fire since thermoset polymers can soften on application of heat in the area of a few hundred degrees Fahrenheit. Follow manufacturer's recommendations for use of such products.

8.1.2 *Removable Security Fastener Head Options for Consideration—*The selection of the right fastener also depends on similar factors including the size of the fastener, spacing, level of security, required load-carrying capacity, and corrosion resistance. It is very advantageous to select a fastener tooling solution that requires maintenance personnel to have to carry the least sizes and types of tools.

8.1.2.1 Low-security uses include spanner head designs. However, the utility of such uses may be impractical because of the additional tools required to affect maintenance.

8.1.2.2 Medium-security uses are generally the domain of pinned Torx, pinned hex, or pinned Torx-Plus designs. This fastener type dominates the detention and corrections industry today because they are widely recognized, available, and the cost per unit is reasonable. However, with the tool bits becoming generally available through hardware and home improvement stores, the relative security is somewhat reduced. As a result, institutions shall be more diligent in controlling contraband including such tool bits.

8.1.2.3 High-security uses would include Penta-Plus, Zero, and Penta Nut designs. These fasteners have keys controlled and monitored by the manufacturer. They are also designed to be more difficult to remove by self-made tools. The cost per unit is higher.

8.1.2.4 Maximum security can be obtained through the use of custom registered computer-designed hollow socket head design such as McGard Intimidator or Bryce Key-Rex. Such fasteners are more costly and difficult to obtain making their use limited in the market, but because the head design is registered to the user, no one but the user can purchase tool bits making them more secure. Because they are more difficult to obtain, purchasing and maintenance of spare fasteners is advised.

9. Corrosion Resistance

9.1 Depending on whether the fasteners are intended for exterior use, interior dry locations, or interior wet locations, corrosion resistance is a concern. Galvanic corrosion between dissimilar materials can also be a problem even when fasteners are used in formally dry conditions. Special care in selection shall be taken in areas where extreme environments are expected such as salt air environments, as well as kitchens and laundries where fatty acids and harsh cleaning chemicals are used.

9.1.1 Unplated carbon steels exhibit excellent strength and durability but are not good values where corrosion or humidity is a concern. Such fasteners are normally treated with a phosphate or black oxide coating, but this only adds minor corrosion resistance. Field painting may be added for extra protection. However, care shall be taken for removable fasteners that the removal tool cavity is not filled with paint rendering the fastener difficult or impossible to use.

9.1.2 Plated carbon steels provide similar strength and durability with increased corrosion resistance and are generally adequate for low-humidity indoor applications. The plating can be worn off in the thread contact area so, for areas where corrosion may be a concern, use of a thread-treating compound is recommended.

9.1.3 Dip spin fasteners with 500 salt spray hour finishes are the optimum choice for high-humidity indoor and outdoor applications. Unfortunately, most steel security fasteners are not stocked with this coating and may require a special order plating fee.

9.1.4 Hot-dipped galvanized carbon steels are acceptable for larger bolt sizes, but the relative thickness of such coatings make this coating unworkable for smaller bolt sizes, especially those with finer pitch threads.

9.1.5 Stainless steels provide excellent corrosion resistance but, depending on the type of stainless steel used, care shall be taken not to over torque these fasteners as they can often gall or break. Use of anti-gall or thread-locking compounds as well as careful torqueing procedures can yield excellent results. Type 18-8 stainless steel is more prone to this kind of problem than 316 stainless steels, but Type 18-8 is more common in use in the construction industry. Stainless steel fasteners are normally more costly than their carbon steel counterparts, plated or not.

9.1.6 Per the galvanic chart included as an Appendix X4, fasteners should also be selected relative to the substrates in which they are installed for metal-to-metal contact. Materials for fasteners should be as close together as possible on the chart to avoid corrosion caused by galvanic action. Failure to do so may result in fasteners that may fail or become corroded together and ultimately irremovable.

10. Best Practices

10.1 *Use of Fine Versus Coarse Threads*—In most cases, course threads are better than fine threads though this changes depending on the fastener size, material, and finish. The factors noted in 10.1.1 and 10.1.2 should be considered when selecting/specifying security fasteners.

10.1.1 In general, coarse threads are more durable and have a greater resistance to cross threading and stripping. They are less prone to damage and do not have to be "handled with care." They install faster. They are not as prone to plating buildup and, therefore, a good choice for hot-dipped galvanizing and other "thick" plating methods. Course threads are also less susceptible to thread galling because of more rotations required to tighten a fine thread and, as such, may be a better choice for stainless steel fasteners.

10.1.2 However, fine threads are reported to be stronger than the corresponding coarse threaded bolts or screws. Fine threads also have fewer tendencies to loosen under vibration so use in dynamic use applications is important. Finer threads can also be more easily trapped into difficult-to-tap materials and thin-walled sections such as hollow metal. Fine threads require less tightening torque to develop equivalent preloads to the corresponding coarse thread bolt sizes; an important issue is to avoid bolt breakage during installation. Over tightening is a concern as fine threads tend to strip their threads easily.

10.2 *Use of Thread-Cutting Screws*—In certain conditions, the use of thread-cutting screws is a good practice. This is especially true for removable window stops. During construction, when the stops can be removed, the pre-drilled, pre-tapped holes can be filled with dirt or paint. The thread-cutting shanks on the screws can clean the receiving threads clean of foreign matter, though care shall be taken not to cross thread the hole.

10.3 *Use of Thread Compounds*—Use of thread compounds is highly recommended. These can be pre-applied at the factory or individually as the fastener is being installed.

10.3.1 If there are a large number of the exact sized fasteners to be used, factory applied compounds are more cost effective. In areas where the compound is used to resist galling or corrosion, this practice can yield excellent results in terms of cross threading, stuck fasteners, and even broken fasteners.

10.3.2 When thread-locking compounds are specified, they can enhance not only corrosion resistance, but also security. Depending on the type of thread-locking compound used, some fasteners can only be removed when subjected to heat from a heat gun or iron.

10.3.2.1 Care should be taken though when used in conjunction with laminated glass or polycarbonate glazing applications because the heat required to soften the thread locker may damage the polymer components of such glazing.

10.3.2.2 Examples of factory applied thread locking compounds include Nylock and ND industries.

10.3.2.3 These methods can be added to existing fasteners inexpensively but require a $200.00 minimum. They are more cost effective for installation than Loc Tite, as long as you have over 2000 pieces.

10.3.2.4 There are three different types of these factory applied thread lockers:

(1) "Patch lock" that is a two-part epoxy that is unmixed until it is threaded in,

(2) Nylon pellet drilled in the side, and

(3) Nylon strip slit into the side.

10.3.2.5 Examples of a field-applied thread locker include Loc Tite and other brands. This is normally a single-component fluid applied to the threads immediately before installation. These come in different strengths.

10.4 *Use of Good Torqueing Procedures*—This is an area often neglected. Though security fasteners cannot be a 100 % deterrent, improperly tightened fasteners can be easily removed sometimes even with fingers only. All security screws should be torqued to manufacturer's recommended minimum values. During construction, it is a good practice for the construction manager to randomly test fasteners to check on the subcontractor's diligence in meeting specified fastener tightness. If nonconforming installations are found, then the subcontractor should be required to tighten all screws under direct observation of an authorized inspector.

10.5 *Removing and Replacing Broken Fasteners*—Often during removing and replacing screws, a screw may shear off particularly when the mating pocket is filled with foreign matter. In such cases, the fastener remnants should be removed, and the mating pocket re-drilled and re-tapped. As most fastener spacing is based on good engineering practice, merely leaving a screw out can result in inadequate performance of the assembly, thereby reducing security. Diligence in identifying broken fasteners and repairing them will result in maintenance of required design criteria and anticipated performance.

11. Application Guidelines

11.1 *Overview*—Detention and corrections facilities are complex built environments with many products, assemblies, and systems integrated into the whole. The huge diversity of materials that need to be connected together to form a secure setting means there are as many potential fastening methods and materials which need to be considered in a facility design. These range from fasteners which are fixed once installed and require no disassembly or maintenance to those which must be removed and replaced on a regular basis for regular maintenance or repair. The location and use condition of the fastener also are important considerations. Owners, architects, contractors and material suppliers all play a role in the selection and use of such fasteners. With good information on which to base the selection, the performance of the fastener can be reasonably anticipated and at the expected level of security.

11.2 *Non-removable Fasteners*—There are many locations within a detention and corrections facility where the fastener can be installed and forgotten about. Once installed, any removal can be done through destructive means such as grinding or torching off the fastener head. There are many choices of this type that can be used for everything from light duty fasteners which may secure small parts to large components requiring significant structural loading.

11.2.1 *Small, Light Duty Fasteners*—These would include blind hole fasteners (commonly referred to as pop-rivets), small screws with heads designed to allow tightening but not removal, to small drive pin fasteners. The material and loading capacity of such fasteners should be reviewed, but normally the locations where such devices might be used are low security, and the risk of removal is minimal. This type of use is generally for statically loaded connections (not where vibration or expansion and contraction might loosen the connection). Where the item being removed might be used for some other more dangerous or destructive purpose, more secure selections might be considered.

11.2.1.1 Examples of this type of use:

(1) Non-removable door hardware (thresholds and weatherstripping).

(2) Toilet partitions.

(3) Brackets and Accessories—Marker boards and tack boards, projection screens, hollow metal trims, and similar items.

11.2.1.2 Types of fasteners used:

(1) Blind hold fasteners of aluminum or stainless steel.

(2) One-way slotted head machine bolts and nuts, or self-drilling sheet metal screws of plated steel or stainless steel.

(3) Plastic or metallic drive pin fasteners. Use of plastic should be minimized due to relative ease of defeating such fasteners by mechanical force or application of heat.

(4) Deformed shank nail-ins (Rawl Spikes).

11.2.2 *Medium Duty Fasteners*—These might be used for items which are larger or have moderate loading criteria including slight dynamically loaded conditions (low degree of vibration or expansion and contraction of the items being fastened). This can also include items that have a higher degree of security associated with them.

11.2.2.1 Examples of this type of use:

(1) Hollow metal connections of substrates where blind connections are not possible.

(2) Small equipment mountings.

(3) Small furnishings and accessories mountings in unsupervised areas.

11.2.2.2 Types of fasteners used:

(1) Metallic drive pin fasteners of larger diameter greater than ¼ in. in diameter.

(2) Deformed shank nail-ins (Rawl Spikes) greater than ¼ in. in diameter.

(3) Twist-off head machine screws, bolts, or nuts of moderate diameter (less than ½ in. in diameter).

11.2.3 *Heavy Duty Fasteners*—For use on items which are larger or have high loading criteria including dynamically loaded conditions (high degree of vibration or expansion and contraction of the items being fastened). This also includes items that have a higher degree of security associated with them.

11.2.3.1 Examples of this type of use:

(1) Detention furnishings.

(2) Large equipment in inmate areas.

(3) Exposed securements at hollow metal doors and frames or other locations on the secure perimeter.

11.2.3.2 Types of fasteners used:

(1) Twist-off head machine screws, bolts, or nuts of large diameter (½ in. diameter or greater).

11.3 *Removable Fasteners*—Many of the fasteners in a D&C facility must be accessed on a regular basis. The use of such fasteners must deny access to detainees/inmates but allow for maintenance or service personnel when necessary. Such fasteners are usually of one or two types in order to keep numbers and types of maintenance tools to a minimum. It is not uncommon for these fasteners to be as small as a #6 machine screw to as large as ¾ in. in diameter through the vast majority of such screws are in the #12 to ¼ in. diameter range.

11.3.1 *Drive Design*—In most modern facilities across the country and even the world, the most common product has been the hollow socket Torx head design with the center pin reject also known as "pinned Torx." This design provides a good level of security as well as serviceability in terms of being able to be installed and removed multiple times with limited reduction in security or degradation of the tool head recesses. The Torx head has been out on the marketplace for decades. The pinned Torx design was fairly rare on the open market, but currently the tool bits can be obtained from local home and hardware stores. They are normally offered as inserts to drive tools and are relatively inexpensive. There are other products that have come out in the marketplace including the Torx Plus truncated 6 lobed design. Like original 6 lobed Torx design originally designed for the automotive industry and military, this head design has certain benefits, but the sizes available in the Torx Plus make it a questionable choice for a single tool head platform. Similarly, the pinned Torx Plus tools are not as readily available as the standard pinned Torx tools mostly because of their limited use in the public marketplace. Use of other head designs such as "Pinned Allen," Spanner Head or other type is not recommended if based on nothing else but the need to carry around multiple tool sets. Certainly mixing screw head types would not increase security.

11.3.2 *Custom Drive Designs*—For many years there has been a company, McGard, who made computer generated custom tool head designs. Their primary market was tamper resistant lug nuts for automobiles, but they marketed one-off registerable designs called ***McGard Intimidator***® for other markets including detention and corrections. While the relative security increase was demonstrably higher, the unit cost was often prohibitive and therefore rare in the detention and corrections. The time and coordination involved in developing a series of designs in various fastener sizes and the long lead to procure the number of fasteners required made using this product difficult at best for arguably limited security increase. The McGard design is hollow recess design with a congruent pattern. That is to say the inner edge profile is the same as the outer edge profile. Recently a company by the name of Bryce Fasteners has come out with a line of custom designed tool head/screw pairs called ***Key-Rex***® that are similar to a Pinned Torx in that the inner profile of the hollow socket is circular but the outer edge profile is a custom pattern. This design provides the benefits of a smaller form factor but with a custom registerable tool head shape. This design can more readily be used on flat head, button head, or round head screws and bolts. Again, the time and coordination involved in developing a series of designs in various fastener sizes, and the long lead to procure the number of fasteners required made using this product difficult at best for arguably limited security increase. While for minimum and medium security facilities, this added security may not be cost effective, in maximum security facilities, such a product may be worth the cost and effort. Consideration might be recommended.

11.3.3 *Small, Light Duty Fasteners*—The material and loading capacity of such fasteners should be reviewed, but normally the locations where such devices might be used are low security, and the risk of removal is minimal.

11.3.3.1 Examples of this type of use:

(1) Commercial hardware armor and cover plates.

(2) Food service and laundry equipment control panels.

(3) Small accessories and equipment.

11.3.4 *Medium Duty Fasteners*—Larger screws or moderate loading criteria including slight dynamically loaded conditions (low degree of vibration or expansion and contraction of the items being fastened). This can also include items that have a higher degree of security associated with them.

11.3.4.1 Examples of this type of use:

(1) Detention light fixtures.

(2) Detention window stops.

(3) Detention lock connections to hollow metal.

11.3.5 *Heavy Duty Fasteners*—For use on items which are larger or have high loading criteria including dynamically loaded conditions (high degree of vibration or expansion and contraction of the items being fastened). This also includes items that have a higher degree of security associated with them. These are rarely used since the larger bolts and nuts are normally not required to have frequent maintenance.

12. Keywords

12.1 bolt; screw; security fastener

APPENDIXES

(Nonmandatory Information)

X1. FASTENER STRENGTHS/GRADE MARKINGS

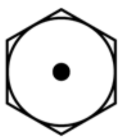
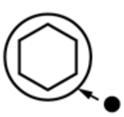
X1.1 Fastener markings are designed to provide the user with two important pieces of information:

X1.1.1 The specification to which the fastener was manufactured and;

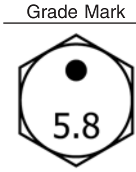
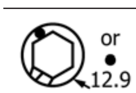
X1.1.2 The manufacturer's identification mark (see Table X1.1).

TABLE X1.1 Fastener Strength/Grade Markings—Inch Sizes

NOTE 1—*WARNING*—Inch standard and SI unit property Class 12.9 socket head cap screws are considered comparable. However, in countries that use the SI units system, the manufacture of socket head cap screws to property classes other than 12.9 are permitted. If your application requires socket head cap screws to property Class 12.9, it is very important that you verify with your supplier that the socket head cap screws you are buying meet those requirements.

	Fastener Properties				Mechanical Properties		
Identification Grade Mark[A]	Product Spec.	Fastener Descr.	Nominal Size Range, in.	Material	Tensile Strength Min., psi	Yield Strength Min., psi	Proof Load, psi
	Grade 2	bolts, screws, studs	¼ through ¾ in.	Low or medium carbon steel	74 000	57 000	55 000
	Grade 5	bolts, screws studs	¼ through 1 in.	Medium carbon steel, quenched and tempered	120 000	92 000	85 000
			1⅛ through 1½ in.		105 000	81 000	74 000
	Grade 8	bolts, screws, studs	¼ through 1½ in.	Medium carbon steel, quenched and tempered	150 000	130 000	120 000
	Socket Screw	socket head cap screws	#0 through ½ in.	Alloy steel, quenched and tempered	180 000	162 000	140 000
			over ½ through 2 in.		170 000	153 000	135 000

Fastener Strength/Grade Markings—SI Unit Sizes

	Fastener Properties				Mechanical Properties		
Identification Grade Mark	Product Spec.	Fastener Descr.	Nominal Size Range	Material	Tensile Strength, Min., MPa	Yield Strength Min., MPa	Proof Load, MPa
	Class 5.8	bolts, screws, studs	M5–M24	Low or medium carbon steel	520 (75 900 psi)	420	380
	Class 8.8	bolts, screws, studs	M16–M72	Medium carbon steel, quenched and tempered	830 (120 000 psi)	660	600
	Class 10.9	bolts, screws, studs	M5–M100	Medium carbon alloy steel, quenched and tempered	1040 (150 000 psi)	940	830
	Class 12.9	bolts, screws, studs	M1.6–M100	Alloy steel, quenched and tempered	1220 (177 000 psi)	1100	970

[A]Denotes location of manufacturer's identification.

X2. DESCRIPTION OF COMMON FASTENER FINISHES

X2.1 Understanding the Use and Final Appearance of Different Finishes

X2.1.1 *Selection/Comparison*—Compare the performance of different finishes (see Table X2.1).

X2.1.2 *Avoiding Galvanic Corrosion*—Overview of causes and how to avoid them (see Table X2.1).

TABLE X2.1 Descriptions

Finish	Fastener Material Suitability	Appearance/Color	Characteristics and Uses
Anodizing	aluminum only	bright	Acid process for aluminum and aluminum alloys; produces an artificial oxide (anodic film) that provides a high level of corrosion and wear resistance.
Black nickel	ferrous metals	black	Generally used as a color-matching finish with or without lacquer coating. Not suitable for blind fasteners that deform.
Bronzes (bright copper, dull copper, statuary bronze, antique bronze, black oxidized)	ferrous metals and copper alloys	ranges from bright gold to dull black[A]	Usually used as decorative finishes to match wood colors. Limited suitability and availability for blind fasteners.
Chromium	ferrous metals	bright blue-white	Bright lustrous finish. Substantially waterproof. Primarily used as a decorative finish. Not suitable for blind fasteners that deform.
Copper	ferrous metals	copper	Often used as undercoating for nickel or as decorative coating.
Deltaseal coating	aluminum and alloys other than ferrous metals	black or silver	Provides high level of protection from corrosion and insulation from application material.
Dichromate dip (chromate conversion coating)	all metals	ranges from clear and shiny to deep brown or olive drab	A dipping for zinc plating that greatly increases rust resistance.
Lacquering	all metals	transparent	Protective coating used to cover unstable decorative finishes.
Nickel	ferrous metals and copper alloys	yellow, white, or bright burnished	Primarily used as a cosmetic finish on screws. Not suitable for blind fasteners that deform.
Nitrate (black)	ferrous metals stainless steels	luster black	Conversion coating: a chemical immersion process that does not add thickness. Good wearing qualities. Not suitable for blind fasteners that deform.
Phosphate	ferrous metals	dull gray or black	Chemical rust-proofing of steel. Supplied plain as a base for paint or black oil stained for appearance.
Passivating	stainless steel	bright	Nitric acid dip applies to stainless steel to remove foreign material and brighten the finish.
Zinc alloy electroplating	ferrous metals	bright	Same as zinc plating but with improved corrosion resistance. Also provides insulation from application materials.
Zinc or zinc alloy electroplating with Deltaseal coating	ferrous metals	black or silver	Same as zinc plating but with improved corrosion resistance. Also provides insulation from application materials.
Zinc electroplate and clear (transparent) chromate passivation	ferrous metals	iridescent yellow	Commonly used, economical finish combining good rust resistance and appearance.
Zinc electroplate and yellow chromate passivation	ferrous metals	iridescent yellow	Commonly used, economical finish combining better rust resistance than transparent chromate.
Zinc electroplate and black chromate passivation	ferrous metals	black	Same as black nickel but sacrificial action of finish provides a greater level of corrosion resistance.
Zinc electroplate and hexavalent chromium-free passivation	ferrous metals	bright	Recently developed finish meets ban on hexavalent chromium; provides greater corrosion resistance than both trivalent and yellow chromates.
Tin and tin/lead electroplating	cooper alloys and ferrous metals	gray	Commonly used for solderable applications. Coatings containing lead will be banned from some applications after 2006. Tin is the preferred substitute.

[A] *Color Ranges*—Final color is determined by original material or customer preference, or both.

X3. FINISH SELECTION

X3.1 See Fig. X3.1 for finish selection.

● Good ▲ Average ■ Poor

	Corrosion Resistance	Galvanic Corrosion	Torque Tension Scatter	Thickness Uniformity	Damage Resistance	Temperature Resistance	Automation Compatibility	Health Problem Avoidance	Appearance	Availability	Cost
With zinc											
Electroplated zinc with transparent trivalent chromate	▲	■	▲	●	▲	■	●	▲	▲	●	▲
Electroplated zinc with black chromate	▲	■	▲	●	▲	■	●	■	▲	●	■
Electroplated zinc with yellow chromate	▲	■	▲	●	▲	■	●	■	▲	●	▲
Electroplated zinc with hexavalent, chromium-free passivation	●	■	■	●	■	■	■	■	■	■	■
Zinc alloy electroplating	●	▲	▲	●	▲	●	●	▲	▲	●	▲
Zinc or zinc alloy electroplating with Deltaseal coating	●	●	▲	▲	▲	▲	▲	●	▲	▲	■
Zinc phosphate & oil compounds	▲	■	●	●	■	■	■	■	▲	●	●
Macro zinc phosphate & polymer or oil film	●	■	▲	●	▲	■	■	■	▲	■	▲
Zinc phosphate & organic paints & oils	▲	■	■	■	■	■	■	■	▲	▲	■
Zinc phosphate & zinc-rich & aluminum coats (organic, inorganic or both)	●	●	■	■	■	■	▲	■	●	●	■
Others											
Electroplated copper, nickel or chrome	■	■	■	●	▲	●	●	▲	●	■	■
Mechanically-cleaned steel with aluminum organic/inorganic & chromates	●	●	▲	■	●	●	▲	▲	▲	■	■
Multi-layered electroplate & organic/inorganic cover coats (with or without chromate)	●	▲	▲	■	■	■	▲	▲	▲	■	■
Deltaseal coating	●	●	▲	▲	▲	▲	▲	●	▲	▲	▲
Tin and tin/lead electroplating	▲	▲	■	▲	▲	▲	●	■	▲	●	■

FIG. X3.1 Finish Selection

X4. GALVANIC CORROSION

X4.1 Galvanic corrosion occurs when two dissimilar metals are in contact with an electrolyte, which is a medium through which an electrical current can flow. The rate of corrosion depends upon the differences in electrical potential, or anodic-cathodic relationship, of the metals in the joint as defined by the galvanic series of metals and alloys (see Fig. X4.1). A highly anodic material in contact with a highly cathodic material will corrode much more quickly than two highly cathodic materials or when the materials used are closer together in the galvanic series.

X4.2 When corrosion does occur, the anodic material is the most likely to corrode, whereas the cathodic material is the least likely to corrode.

X4.3 To reduce the likelihood of galvanic corrosion in a fastened joint, it is recommended the designer choose materials that are grouped together in the galvanic series table. If that is not possible, other recommendations are:

X4.3.1 Select materials that are as close together in the chart as possible;

X4.3.2 Provide a barrier between the two metals, such as paint, nonmetallic washer, or gaskets;

X4.3.3 Design the fastener as the cathode so the cathodic area is small as compared to the anodic area; and

X4.3.4 Use a metallic finish on the fastener that is close on the chart to the mating material.

Anodic End (Most Likey to Corrode)
Magnesium **Magnesium Alloys** **Zinc**
Aluminum 1100 **Cadmium** **Aluminum 2024-T4** **Steel or Iron** **Cast Iron** **Chromium-Iron (active)** **Ni-Resist Cast Iron**
Type 304 Stainless (active) **Type 316 Stainless (active)**
Lead-Tin Solders Lead **Tin**
Nickel (active) **Inconel Nickel-Chromium Alloy (active)** **Hastelloy Alloy C (active)**
Brasses **Copper** **Bronzes** **Copper-Nickel Alloy** **Monel Nickel-Copper Alloy**
Silver Solder **Nickel (passive)** **Inconel Nickel-Chromium Alloy (passive)**
Chromium-Iron (passive) **Type 304 Stainless Steel (passive)** **Type 316 Stainless Steel (passive)** **Hastelloy Alloy C (passive)**
Silver **Titanium** **Graphite** **Gold** **Platinum**
Cathodic (Least Likely to Corrode)

FIG. X4.1 Galvanic Series of Metals and Alloys