

Submitted for recognition as an American National Standard

PROTECTIVE COATINGS FOR FASTENERS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

Protective coating finishes for fasteners not only enhance resistance to corrosion and appearance, but they are very important in the consideration of stresses developed and in the torque-tension tightening of the applied assembly. The effect of the coating on fastener torque-tension relationship is covered in a separate SAE Information Guide J1701.

- 1. Scope**—This SAE Information Report is provided as an advisory guide. Careful discretion as to application is recommended. The content has been presented as accurately as possible, but responsibility for its application lies with the user. It covers finishes applied to fasteners and related topics, corrosion resistance, lubricity, electrical grounding, ultraviolet light, and embrittlement.

Table 1 lists these coatings and their properties so that finish selection can be reasonably made in accordance with known and anticipated fastener assembly applications.

Application of protective coatings will affect fastener dimensions. This is especially critical for the thread fit of mating parts because the pitch diameter increases by four times the coating thickness. Explanation is covered in Section 5.

2. References

- 2.1 Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

- 2.1.1 SAE PUBLICATIONS**—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J995—Mechanical and Material Requirements for Steel Nuts

SAE J1701—Torque-Tension Tightening for Fasteners

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TABLE 1—PROTECTIVE FINISHES FOR FASTENERS

Coat or Finish	For Use on Fastener	Surface	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Protection	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Hours Min	Description and Requirements	Specification Finish Reference	Thickness Micrometer μm	Temperature Resistance in Degrees
Nickel Electroplate	bolts, nuts, rivets, screws, studs, washers	steel	very mild indoor	2	Decorative silver appearance, good wear	ASTM F 871M	2.5	(204 °C)
Zinc Electroplate	bolts, nuts, rivets, screws, studs, washers	steel	moderate suburban sacrificial	32	Bright blue or white appearance. Smooth sacrificial.	ISO 2001	5.0	(177 °C)
Zinc Mechanical Plate	bolts, nuts, rivets, screws, studs, washers	steel	moderate suburban	48	Less susceptible to hydrogen embrittlement than electroplated zinc.	ASTM F 871M ASTM B 633 ASTM B 695	7.5	(149 °C)
Zinc Electroplate with Bright Chromate	bolts, nuts, rivets, screws, studs, washers	steel	moderate suburban	40 (R) 12 (W)	Thin bright conversion coating over the plate can be dyed for paint bonding.	ASTM B 201 ASTM B 633 ISO 4520	5.0	(120 °C)
Zinc Electroplate with Yellow Chromate	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	144 (R) 72 (W)	Thicker conversion than clear with same characteristics and increased corrosion resistance.	ASTM B 201 ASTM B 633 ISO 4520	6.0	(120 °C)
Zinc Electroplate with Olive Drab Chromate	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	240 (R) 96 (W)	Thicker coating than yellow and better corrosion resistance.	ASTM B 201 ASTM B 633 ISO 4520	5.0	(120 °C)
Zinc Electroplate with Chromate + Organic	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	240 (R) 120 (W)	Additional organic coating provokes greater corrosion resistance.	ASTM F 1136	13.0	(190 °C)
Zinc Mechanical with Bright Chromate	bolts, nuts, rivets, screws, studs, washers	steel	moderate suburban	40 (R) 12 (W)	Thin bright conversion coating over the plate can be dyed for paint bonding.	ASTM B 201 ASTM B 695 ISO 4520	5.0	(120 °C)
Zinc Mechanical with Yellow Chromate	bolts, nuts, rivets, screws, studs, washers	steel	Industrial	144 (R) 72 (W)	Thicker conversion than clear with same characteristics and increased corrosion resistance.	ASTM B 201 ASTM B 695 ISO 4520	5.0	(120 °C)

TABLE 1—PROTECTIVE FINISHES FOR FASTENERS (CONTINUED)

Coat or Finish	For Use on Fastener	Surface	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Protection	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Hours Min	Description and Requirements	Specification Finish Reference	Thickness Micrometer μm	Temperature Resistance in Degrees
Zinc Mechanical with Olive Drab Chromate	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	168 (R) 96 (W)	Thicker coating than yellow and better corrosion resistance.	ASTM B 201 ASTM B 695 ISO 4520	5.0	(120 °C)
Zinc Mechanical with Chromate + Organic	bolts, nuts, rivets, screws, studs, washers	steel	very severe Industrial	336 (R) 100 (W)	Additional organic coating (cured) provides greater corrosion resistance.	ASTM F 1135	13.0	(190 °C)
Black Oxide + Oil	bolts, nuts, rivets, screws, studs, washers	steel	very mild Indoors	1	Porous thin; hydrogen embrittlement susceptible; oiling may be necessary.		2.5	(93 °C)
Brass Plate, Lacquered	bolts, nuts, rivets, screws, studs, washers	steel	very mild indoors	1	Decorative electroplated finish recommended for indoor use.	ASTM F 871M	2.5	(93 °C)
Chromium Electroplate	bolts, nuts, rivets, screws, studs, washers	steel and other metals	very mild indoors	2	Bright lustrous blue - white finish.	ASTM F 871M	7.5	(204 °C)
Chromium Electroplate with Copper and Nickel Undercoat	bolts, nuts, rivets, screws, studs, washers	steel and other metals	very mild indoors	8	Surface is hard and abrasive resistant. Primarily for decorative use.	ASTM B 456 ISO 1456	7.5	(260 °C)
Cadmium (Electroplate/Mechanical Plate)	bolts, nuts, rivets, screws, studs, washers	steel	nonindustrial urban and marine applications	144	Bright silvery gray, dull gray, has lubricating (reduction of friction) property.	ASTM B 766 ASTM F 871M ASTM B 696 ISO 2082	5.0	(177 °C)
With Clear Chromate	bolts, nuts, rivets, screws, studs, washers	steel	nonindustrial urban and marine applications	192 (R) 12 (W)	Thin conversion coating base over the plate, bright, can be dyed for paint bonding.	ASTM B 201 ASTM B 696 ASTM B 766 ISO 4520	5.0	(120 °C)
With Yellow Chromate	bolts, nuts, rivets, screws, studs, washers	steel	nonindustrial urban and marine applications	240 (R) 72 (W)	Thicker conversion coating than clear with same characteristics.	ASTM B 201 ASTM B 696 ASTM B 766 ISO 4520	5.0	(120 °C)

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TABLE 1—PROTECTIVE FINISHES FOR FASTENERS (CONTINUED)

Coat or Finish	For Use on Fastener	Surface	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Protection	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Hours Min	Description and Requirements	Specification Finish Reference	Thickness Micrometer µm	Temperature Resistance in Degrees
With Olive Drab Chromate	bolts, nuts, rivets, screws, studs, washers	steel	nonindustrial urban and marine	240 (R) 150 (W)	Thicker conversion coating than yellow with same characteristics.	ASTM B 201 ASTM B 696 ASTM B 766 ISO 4520	5.0	(120 °C)
With Chromate + Organic Coating	bolts, nuts, rivets, screws, studs, washers	steel	nonindustrial urban and marine applications	336 (R) 216 (W)	Additional organic coating (cured) provides greater corrosion resistance.	ASTM F 1135	12.0	(190 °C)
Chromium/Zinc Inorganic	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	240	Bright gray, an aqueous coating dispersion containing chromium in a proprietary organic. Zinc flake is dispensed evenly. The coating provoked encapsulating and sacrificial corrosion protection. Cannot be soldered or welded. Relatively hard and resistant to abrasion similar to cured paint finishes.	ASTM F 1136	6.2 - 13.0 g/m ² 20.4 - 27.0	(260 °C)
With Sealant	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	400	In addition to the previous the cured supplementary sealant may be clear or black and provokes greater corrosion resistance.	ASTM F 1136	6.2 - 13.0	(260 °C)
Copper Electroplate Lacquered	bolts, nuts, rivets, screws, studs, washers	steel	very mild indoors	1	Bright decorative electrically conductive.	ASTM F 871M	2.5	(93 °C)
Copper Flash Deposit (Immersion)	bolts, nuts, rivets, screws, studs, washers	steel	very, very mild indoors	0	Bright to dull electrically conductive.	—	1.2	(93 °C)

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TABLE 1—PROTECTIVE FINISHES FOR FASTENERS (CONTINUED)

Coat or Finish	For Use on Fastener	Surface	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Protection	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Hours Min	Description and Requirements	Specification Finish Reference	Thickness Micrometer μm	Temperature Resistance in Degrees
Zinc, Hot Dip, Mechanical Galvanize	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	950	Dull gray color, very thick deposit.	ASTM A 90 ASTM A 153	42 min g/m ² 305 500 avg. g/m ² 300 avg.	(177 °C)
Solder, Electro	bolts, nuts, rivets, screws, studs, washers	steel	very mild indoors	2	60% tin/40% lead coating bright silver appearance excellent bond and solderability. Used primarily indoors.		3.8	(93 °C)
Phosphate, Zinc (bare)	bolts, nuts, rivets, screws, studs, washers	steel	none, serves as basis for paint and other supplementary coatings	0	Light gray, crystalline, rough, powdery serves as base for supplementary coating.		11-16 g/m ²	(120 °C)
Phosphate, Manganese (bare)	bolts, nuts, rivets, screws, studs, washers	steel	none, serves as basis for paint and other supplementary coatings	0	Darker than zinc phosphate, finer crystalline.		11-16 g/m ²	(120 °C)
Phosphate, Zinc with Dry Lubricant	bolts, nuts, rivets, screws, studs, washers	steel	severe urban	48	Gray appearance.		11-16 g/m ²	(120 °C)
Phosphate, Zinc with Oil Wax	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	168	Appearance varies from dark gray to black. Supplementary oil or wax enhances corrosion resistance.	ASTM F 1137	5.0	(120 °C)
Phosphate, Zinc with 1 Coat Paint + Organic	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	144	Smooth, can be in different colors. Organic is a thin oil on top of the paint.		12.0	(190 °C)

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TABLE 1—PROTECTIVE FINISHES FOR FASTENERS (CONTINUED)

Coat or Finish	For Use on Fastener	Surface	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Protection	Corrosion Resistance ⁽¹⁾ Environment Salt Spray Hours Min	Description and Requirements	Specification Finish Reference	Thickness Micrometer μm	Temperature Resistance in Degrees
Phosphate, Zinc with 2 Coat Paint + Organic	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	240	Smooth, can be in different colors. Organic is a thin oil on top of the paint.		25.0	(190 °C)
Phosphate, Zinc with Zinc - Rich Resin Flake + Clear Organic Top Coat	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	240	Gray metallic color, smooth	ASTM F 1137	15 - 25	(260 °C)
Phosphate, Zinc with Zinc - Rich Resin Powder + Clear Organic Top Coat	bolts, nuts, rivets, screws, studs, washers	steel	very severe industrial	400	Gray metallic color, smooth	ASTM F 1137	10 - 20	(260 °C)

1. Refer to Table 3 for service life values.

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2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 90—Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles
ASTM A 153—Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A 239—Test Method for Locating the Thinnest Spot in a Zinc (Galvanized) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip)
ASTM B 117—Method of Salt Spray (Fog) Testing
ASTM B 183—Preparation of Low Carbon Steel for Electroplating
ASTM B 201—Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces
ASTM B 242—Preparation of High Carbon Steel for Electroplating
ASTM B 368—Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)
ASTM B 456—Specification for Electrodeposited Coatings of Copper Plus Nickel Plus Chromium and Nickel Plus Chromium
ASTM B 487—Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section
ASTM B 499—Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals
ASTM B 504—Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method
ASTM B 530—Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates
ASTM B 633—Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM B 695—Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
ASTM B 696—Specification for Coatings of Cadmium Mechanically Deposited
ASTM B 766—Specification for Electrodeposited Coatings of Cadmium
ASTM B 839—Test Method for Residual Embrittlement in Metallic Coated Externally Threaded Fasteners and Rods
ASTM B 849—Pre-Treatments of Iron and Steel for Reducing the Risk of Hydrogen Embrittlement
ASTM D 450—Specification for Coal-Tar Pitch Used in Roofing, Dampproofing, and Waterproofing
ASTM E 376—Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods
ASTM F 606—Method for Conducting Tests to Determine the Mechanical Properties of Externally and Internally Threaded Fasteners
ASTM F 871M—Specification for Electrodeposited Coatings on Threaded Components (Metric)
ASTM F 1135—Specification for Cadmium or Zinc Chromate Organic Corrosion Protective Coating for Fasteners
ASTM F 1136—Specification for Chromium/Zinc Corrosion Protective Coatings for Fasteners
ASTM F 1137—Specification for Phosphate/Oil and Phosphate/Organic Corrosion Protective Coatings for Fasteners

2.1.3 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 1456—Metallic coatings—Electrodeposited coatings of nickel plus chromium and of copper plus nickel plus chromium
ISO 2080—Metallic coatings—Electrodeposited coatings of zinc plus chromium and of copper plus nickel plus chromium
ISO 2082—Metallic coatings—Electroplated coatings of cadmium on iron or steel
ISO 4520—Chromate conversion coatings on electroplated zinc and cadmium coatings
ISO/DIS 9587—Pre-treatments of iron and steel for reducing the risk of hydrogen embrittlement
ISO/DIS 10587—Test method for residual embrittlement in metallic coated externally threaded fasteners and rods

3. General Requirements

3.1 Surface Condition Prior to Coating—The fasteners must be clean and free from rust, chips, scale, dirt, abrasives, excessive iron oxide, or other foreign materials. If protective lubricants or coatings are applied to prevent rusting in storage then they must not be tacky or difficult to remove in the cleaning process before finishing.

3.2 Cleaning

3.2.1 PRIOR TO ELECTROPLATING—Steel fasteners containing 0.35% or more carbon at the surface or heat treated to 32 HRC (320 HV) or higher hardness shall be cleaned per the requirements in ASTM B 242. Steel parts containing less than 0.35% carbon at the surface, or lower than 30 HRC (302 HV) in hardness shall be cleaned per instructions in ASTM B 183.

3.2.2 PRIOR TO MECHANICAL PLATING—The same procedures apply for the different steel carbon contents and hardnesses expressed for cleaning prior to electroplating, except electrolytic cleaning is not permitted and acids for treatment must be inhibited. Flash copper deposit must be applied by the immersion plating process.

3.2.3 PRIOR TO PHOSPHATING—Similarly, acids employed for cleaning or activation must be inhibited.

3.3 Brittleness—Fasteners shall be free from hydrogen embrittlement or other factors which may impart brittleness from the finishing processes. That includes cleaning, coating, and coating stripping. All heat treat operations including stress relief after cold forming, temper after quench, and hydrogen embrittlement relief must be completed before subsequent plating and phosphating.

Refer to ASTM B 839 (ISO/DIS 10587) for test method to determine if detrimental embrittlement remains in threaded fasteners. It includes three levels of confidence. ASTM B 849 (ISO/DIS 9587) contains eight standard stress relief treatments. Refer to 7.4 for additional test information.

3.3.1 ELECTROPLATED FASTENERS—Metal coatings are deposited electrically onto steel surfaces with evolution of hydrogen which infiltrates into the grain boundaries.

Generally, high stressed fasteners containing 0.35% carbon or more cold worked or heat treated to hardness 32 HRC (320 HV) or higher must be baked within 1 h maximum after electroplating at a temperature of 205 °C for 4 h at heat. Higher temperatures depending upon plate tolerance and/or longer times may be used to reduce risk of detrimental hydrogen embrittlement.

However, if verified by test data, some electroplated stressed steel fasteners with the previous hardness may be excluded from bake procedure because of the function of the special plating bath and their nonsusceptible microstructure for hydrogen infiltration and entrapment.

Hardened parts which have been tempered at less than 205 °C shall be baked within 1 h after plating to 150 °C for 8 h at heat or longer as required.

It may be necessary to provide coatings other than electroplating for fasteners with a hardness above 40 HRC (390 HV).

3.3.2 MECHANICAL PLATED OR PHOSPHATED FASTENERS—The mechanical plating process cold welds powdered zinc onto cleaned and immersion copper-plated steel surfaces by means of tumble peening with a nonmetallic media.

Mechanical plated parts with hardnesses of 32 HRC (320 HV) or higher must not be used for 48 h or be baked at 120 °C for 1 h minimum at heat within 4 h of processing.

Phosphated parts can become hydrogen embrittled due to the acidic condition of the chemical bath. However, this condition is relieved within 48 h because the crystalline coating is porous.

4. Fastener Coatings Description and Requirements—Finish selection is based on the desired tightened assembly application, the corrosion resistance, and appearance of the fastener.

4.1 Plain—The surface is without a coating or with a light protective oil film.

4.2 Copper—The finish is smooth, fine, and grained. It can be lustrous or dull. Thickness can vary from 2.5 μm or greater for electroplating and 1.2 μm for immersion plating.

4.3 Chromium—Chromium is a thin 0.025 μm hard, blue white chromium electroplate top coat applied to provide color, luster, and decorativeness. It is generally plated over substrates of a copper flash plus a corrosion resistant nickel totaling 7.5 μm thickness.

4.4 Nickel—The slight yellow or white bright color of this metal provides attractiveness for interior applications. Coatings for appearance only may be as thin as 2.5 μm . Coatings for corrosion resistance may be 5 μm or greater.

4.5 Phosphated/Organic Finishes—Phosphate is a conversion coating of fine or medium grain size crystals weighing 11 to 16 g/m^2 minimum. The zinc-phosphate type is primarily used as a base for supplementary coatings such as oil, wax, paint, or organic with dispersed zinc flake or dust. Another top sealant of oil, wax, or polymer may be applied over the paint.

NOTE— μm = micrometer

Manganese-phosphate, a more dense crystalline base, can be utilized also. Oil coatings on either type must be dry to touch as determined by Waterman #41 filter blot test.

4.6 Zinc—Zinc is another coating which can be applied, either electrically or mechanically onto steel fasteners, generally to 5 μm thickness. Corrosion products are very flocculent. Bright, yellow, and olive drab chromate conversion coatings are applied to deter this and to increase the corrosion resistance. However, chromates provide reduced zinc protection when subsequent heating exceeds 65 °C temperature.

4.6.1 HEAVIER—Thicker, 50 μm , zinc finishes applied by the hot-dip or mechanical galvanize processes offer greater corrosion resistance for better outdoor environment conditions. But fastener dimensions and threads must be made to allow for the thicker coating.

WARNING—Property Class 8.8 fasteners and greater can accommodate 5 to 7.5 μm coating thicknesses. However, if dimensions and threads are made to allow for thicker coatings, the undersized parts cannot be certified as conforming to the property class.

4.7 Chromium/Zinc/Organic—The chromium/zinc/organic gray colored finish is comprised of a dispersion of chromium and zinc flake or dust in a proprietary organic over which a clear or black polymer top coat is applied. The combination of organic seal and zinc sacrificial action retards corrosion.

5. The Effects of Finishes on Dimensions

5.1 Electroplating—It must be realized that deposition of the metal coating is not uniform on all areas of the fastener because of the following factors.

5.1.1 The “throwing” characteristics of electroplate bath deposit metal lightly in recessed areas as opposed to external areas.

- 5.1.2 The geometric design of the fastener:
- a. Plating builds up at sharp corners.
 - b. Plated thickness is greater near ends and edges.
 - c. Plated thickness will be least in recessed areas.
 - d. External threads plating will be thickest at the apex tapering down to the root, causing a slight change in the thread's angle.
 - e. Internal threads, the opposite is true.
 - f. Plating builds up more rapidly at the mouth of the threaded hole of nuts rather than in the interior.
 - g. Coating the surface of the fastener increases its size and may cause fit problems with plated mating parts, particularly with threaded fasteners.
- 5.1.3 The operating conditions of the bath, chemical concentrations, temperature, and acidity/alkalinity.
- 5.1.4 Distribution of the parts to be plated, whether in rack or barrel bulk.
- 5.1.5 The current density, amperes/square meter, at which the plating takes place.
- 5.2 Mechanical Plating**—Since coatings are cold welded onto surface areas they also are nonuniform because of the following factors.
- 5.2.1 The tumbling process burnishes edges and external surfaces making the plate thinner than in internal areas.
- a. Plated thickness will be less on edges and corners.
 - b. Plated thickness will be greater in interior areas.
 - c. External threads plating will be thinner at the apex and tapering down to the thickest at the root.
 - d. Internal threads plating will be thicker varying to greatest in the root.
 - e. Plating will be thinner at the mouth of the threaded hole of nuts rather than the interior.
 - f. Greater chance of having thread fit problems with plated mating parts.
- 5.2.2 The geometric design of the fastener which will vary with the tumbling abrasion.
- 5.2.3 The operating conditions of proprietary chemical solution, concentration, and temperature.
- 5.2.4 The kind of media, size proportion, and ratio to parts to be plated.
- 5.2.5 Tumbler type, size, and speed.
- 5.3 Phosphate and Organic Coatings**—Phosphating is deposited by direct chemical reaction with fastener steel surfaces. Therefore, the coating is uniform on internal and external areas. However, the following factors influence the quality of the deposit plus its supplementary organic coatings.
- 5.3.1 The type of phosphate bath material, zinc-phosphate, or manganese.
- 5.3.2 The coarse or fine size of phosphate crystals.
- 5.3.3 The operating conditions of the bath-temperature, chemical concentration, iron buildup, etc.
- 5.3.4 Type and concentration of oil supplementary coating.
- 5.3.5 Type, viscosity, and number of paint coatings.
- 5.3.6 Sealant top coat over the phosphate plus paint finishes.

5.4 Fastener Thread Fit—Coated mating parts with external and internal threads having minimum clearance between them can have fit problems.

5.4.1 The thread fit of fasteners before application of coatings must be in accordance with unified Class 2A for external and Class 2B for internal inch threads and 6g external and 6H internal metric threads.

5.4.2 Coating thicknesses up to 1/6 of the clearance allowance between Class 2A external (6g metric) and Class 2B internal (6H metric) can be applied without causing thread fit interference. However, consideration has to be given to the plating thickness process variations.

5.4.3 If the coating thickness is greater than 1/6 of the allowance, either the external thread has to be undercut or the internal thread has to be retapped to assure noninterference during assembly.

WARNING—If the external thread has to be undercut, or the internal thread retapped to assure noninterference during assembly, the overall thread proof load tensile strength will be reduced.

5.5 Functionality—Extra thick metallic coatings and thicker organics applied by dip-spinning or electro-disposition processes can cause other than thread fit assembly problems. It is important to recognize these before design finalization.

Possibly, they may be alleviated by reduced coating thickness to improve functionality, but at the expense of reduced corrosion resistance. The following examples illustrate the problems that may be encountered.

5.5.1 Parts sticking together or leaving a residue of oil or coating which hampers feeding systems and containers during handling, supply, and assembly.

5.5.2 Superfluous coating on fasteners preventing the driver tool from completing recess fits, as in the case of recess screw assemblies.

6. Corrosion Resistance

6.1 General Explanation—Corrosion occurs when water or moisture is present in the surrounding environment. This may be in the form of rain, dew, fog, ground water, condensation, or humidity. The rate of deterioration depends on other factors combining with the water and moisture in the environment, such as chemical concentrations from pollution, marine salt, spray electric currents, and dissimilar metals in contact with each other.

6.2 Types of Corrosion

6.2.1 **DIRECT CHEMICAL ATTACK**—The environment may contain sulfur from industrial plants which expel these gases. The resulting sulfuric acid is very corrosive. The same thing applies to salt atmosphere from sea spray.

6.2.2 **ELECTRO CHEMICAL ACTION**—Metal fasteners may be subjected to and conduct stray electric currents caused by grounded electric power, generators, and welding equipment.

6.2.3 **GALVANIC CORROSION**—Dissimilar metals in contact with each other in the presence of an electrolyte such as water causes a flow of current which deteriorates the anodic metal whether a coating or base material (for example, steel).

Refer to Figure 1, the galvanic series of metals and alloys. The upper end metals will sacrifice themselves to protect the adjacent. For example: cadmium or zinc coatings will be depleted to protect the base steel fastener. Metals at the lower end of the series serve to encapsulate thereby shutting out the environment.

Corroded End (anodic, or least noble)

Magnesium
 Zinc
 Aluminum 1100
 Cadmium
 Steel
 Cast iron
 18-8 Stainless
 Tin
 Nickel
 Brasses
 Copper
 Bronzes
 Titanium
 Silver
 Graphite
 Gold
 Platinum

Protected End (cathodic, or more noble)

FIGURE 1—GALVANIC SERIES OF METALS

6.2.4 STRESS CORROSION CRACKING—When fasteners are under either static or dynamic stresses, corrosion may cause cracking in the metal. Also, cyclic stresses from vibration oscillation or other flexing in combination with a corrosive environment will produce fatigue corrosion failures. They occur more readily in that environment than in the absence of the corrosive medium.

6.2.5 PITTING CORROSION—This phenomenon is caused by fast attack at small points on the surface while the rest of the surface is attacked hardly at all. The tops of bolt heads and nuts are subject to this corrosion. Remedy is thicker plating.

7. Test Methods for Evaluating Finishes on Fasteners

7.1 Definition of Significant Surfaces—Significant surfaces are all surfaces which are visible and that can be a source of corrosion in an assembly or where appearance is important.

7.2 Plating Thickness Measurements

7.2.1 METALLOGRAPHIC TESTS—Copper, nickel, chromium, and zinc thicknesses can be determined by this so-called “umpire method.” ASTM B 487, ASTM B 499, ASTM B 504, also ASTM B 530 for nickel only.

7.2.2 ELECTRONIC DEPLETION TEST (KOCOUR)—The acidic removal of plating.

7.2.3 ACID DROP TEST—Similar to 7.2.2 but number of drops/minute signifies thickness.

7.2.4 MAGNETIC FIELD OR EDDY CURRENT TEST, ASTM E 376—Zinc organic (paint) thickness is measured by its resistance to current passing through to base steel.