1.0 SCOPE

Fastener coating performance and basic requirements are covered for coating thickness, corrosion resistance, appearance, assembly performance, and hydrogen embrittlement relief. This is a multiple variation specification. (See Article 3.0, Figure 1)

2.0 APPLICATION

2.1 These coatings provide corrosion protection and torque-tension performance in a bolted joint for fasteners (bolts, screws, studs, nuts), washers, and other fastener components.

2.2 Inquiries regarding interpretation or application of this specification shall be directed to Design Control A516.

2.3 Materials shall be RoHS compliant (refer to 1E4246D). Receipt of Cadmium plated parts is prohibited. Parts shall be hexavalent chrome (Cr6) free. Applicable Cr6 free subdivisions are 1E1675D, 1E1675F, 1E1675G, and 1E1675X.

3.0 DRAWING DESIGNATIONS

DESIGNATION		GENERAL APPLI-CATION	COATING DESCRIPTION	MIN THICK-NESS (µm)	ASTM B117 OR ISO 9227 SALT SPRAY RESISTANCE	IN SERVICE TEMPERATURE RANGE (°C) REFERENCE	SEE ARTICLE/ PARAGRAPH
CURRENT	FORMER						
1E1675A	1E1675A	Fastener	Zinc Phosphate + Oil	NA	72 h to Red	-50 to 330	4.0 & 5.1
	1E1675B	Nut					
	1E1675C	Washer					
1E1675D	1E1675D	Fastener	Electroplated Zinc + (Trivalent Cr or Cr Free) + Top Sealer	5	96 h to White	-50 to 170	4.0 & 5.2
	1E1675E	Nut					
	1E1675H	Locknut					
1E1675F	1E1675F	Fastener, Washer	Mechanical Zinc + (Trivalent Cr or Cr Free) + Top Sealer	5	96 h to White	-50 to 170	4.0 & 5.3
1E1675G	1E1675G	Fastener, Washer	Zinc Flake Coating	8	720 h to Red	-50 to 220	4.0 & 5.4
1E1675J	1E1675I	Fastener, Washer	Oil with Corrosion Inhibitor	N/A	----	N/A	5.5
1E1675X	1E1675X	Fastener, Washer	Defined on Drawing	---	----	----	4.0 & 5.6

Figure 1 - Drawing Designations

4.0 GENERAL REQUIREMENTS

4.1 Corrosion Resistance - A salt spray test is the process evaluation method to establish a coating process will meet corrosion life expectations. The corrosion resistance requirement is quantified as a minimum exposure time to the first sign of pre-defined three-dimensional corrosion products, such as Iron (Fe) [red corrosion] or Zinc (Zn) [white corrosion]. The type of corrosion product depends upon the type of coating, topcoat, and substrate material. The corrosion resistance of the coating is measured by neutral salt spray testing in a salt spray environment operated per ISO 9227 or ASTM B117. Detergent or solvent shall not be used to clean the coated samples before salt spray testing. After completion of the required exposure time, no evidence of the pre-defined type of corrosion shall be seen on significant surfaces* when observed with the unaided eye at a distance of one meter. Corrosion bleed or presence of salt deposits should not be counted as corrosion. If there is a question on presence of corrosion, wipe the surface with a damp cloth to remove the corrosion and return the test article to the test chamber, if corrosion reoccurs within 2 hours, failure is confirmed.

***Note:** Significant surfaces are those normally visible, which are essential to the appearance or serviceability of the fastener when assembled. Significant surfaces include flat or slightly rounded surfaces on the head and the unthreaded shank on partially threaded bolts, and the end of the bolt. Figure 2 illustrates significant surfaces on standard externally threaded and internally threaded fasteners.

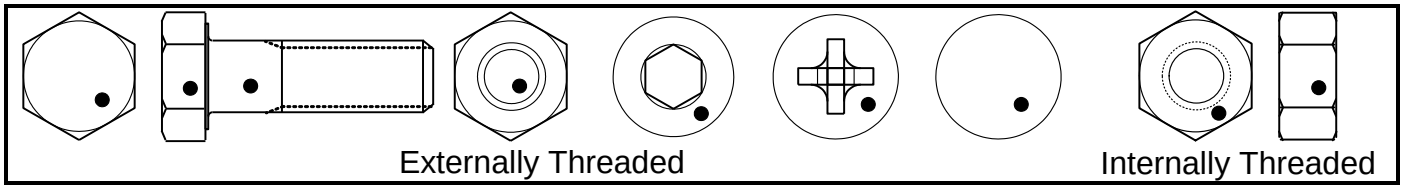

Figure 2 – Significant Surfaces – Reference For Coating Test Locations (●)

4.2 Appearance - The coating shall have a continuous and uniform appearance without tears, flakes, blisters, rough spots, cracks, uncoated areas, or excessive coating mass that will affect function and performance. Marks and blemishes may be incurred during handling and shipping. It is expected that these marks will not have a significant impact on coating performance.

Note: A rack application process may leave small areas without coating or discolored spots at contact points. Processes using multiple coating steps should move the parts between steps to provide partial coating coverage. Bolts shall be capable of meeting salt spray test requirements on significant surfaces next to rack marks without masking.

4.3 Adhesion - The coating and topcoat (i.e., chemical conversion coating) shall be tightly adherent to the substrate and shall be able to sustain ordinary handling without compromising coating functionality.

4.4 Coating Thickness - Part dimensions apply prior to coating. Thread dimensions shall conform to all thread acceptance and other dimensional requirements specified in 1E0500 and 1E2650. Coating in the threads or the recess of a fastener shall not adversely affect the normal installation and/or removal operations. To obtain the expected coating thickness, fastener producers are expected to control thread dimensions to near the upper limit for internal thread and near the lower limit for external thread. For screws with a thread pitch 1.0 mm and smaller (6 mm nominal diameter and smaller), the threads may be made to tolerance class 6f prior to coating (Class 1A for inch). Threads with a pitch greater than 1 mm may be produced undersize only with approval from Design Control A516. Product with threads produced undersize shall meet all required mechanical properties.

4.4.1 Minimum Thickness - The coating thickness shall be measured on a significant surface on several parts and the lowest values averaged. Minimum average thickness is only required on significant surfaces. Edges, corners, holes, and threads shall be coated, but are excluded from the minimum thickness requirements. (Refer to ISO 2064 for thickness definitions and conventions.) Approved methods for measuring thickness include: ISO 1463 or ASTM B487 (metallographic cross-sectioning), ASTM E376 (magnetic-field or eddy-current), and ASTM B568 (x-ray spectrometry).

4.4.2 Small Screws - For screws with a thread pitch 1 mm and smaller (6 mm nominal diameter and smaller), the threads may be made to tolerance class 6f prior to coating (Class 1A for inch). The maximum and minimum coating thickness is reduced to accommodate the reduced clearances between internal and external threads. Corrosion performance is also reduced with the reduction in MIN thickness. Adjust the expected thickness and performance for the Article 5.0 coatings by Figure 3.

THREAD PITCH (P) (mm)	DIAMETER (mm) REFERENCE	1E1675D WHITE / RED CORROSION (HR)	1E1675D MIN THICK (µm)	1E1675G RED CORROSION (HR)	1E1675G MIN THICK (µm)
P > 1.0	(6+)	96 / 240 [See Paragraph 5.2]	5	720 [See Paragraph 5.4]	8
P = 1.0	(6)	96 / 240 [See Paragraph 5.2]	5	480	5
0.7 < P < 1.0	(4-6)	48 / 120	3	480	5
0.5 < P ≤ 0.7	(3-4)	48 / 120	3	(240) *	(4) *
<0.5	(2-3)	24 / 48	1.5	N/A	N/A
* Expected performance					

Figure 3 - Reduction In MIN Coating Thickness And Corrosion Performance Due To Thread Pitch

4.4.3 Maximum Thickness – Externally Threaded Parts - The coating thickness is limited by the specified thread size and tolerance. After all coating processes, fasteners shall assemble with appropriate basic size GO thread gage. Coated metric threads shall accept a class h (6h or 4h) GO gauge and coated inch threads shall accept a class 3A GO gauge. The NOTGO gauge is the same after coating as before coating. The coating thickness under the fastener head shall not exceed 25 μm (micrometer).

4.4.4 Maximum Thickness – Internally Threaded Parts - The maximum coating thickness is limited by the specified thread size and tolerance. After all coating processes, fasteners shall assemble with appropriate basic size GO thread gage. Coated metric threads shall accept a class 6H GO gauge and coated inch threads shall accept a class 3B GO gauge. The NOTGO gauge is the same after coating as before coating. The maximum coating thickness on the fastener bearing faces shall not exceed 25 μm (micrometer).

Note: Thick Coatings With Internal Threads (Nuts) - Tightness to thread inspection gauges may occur for paint and other thick coatings like Zn Flake (1E1675G). Thick coatings in internal threads may be functional tested using a phosphate coated or Zn plated bolt [using a bolt with similar coating that freely gauges]. The nut shall engage/start by hand and the maximum prevailing torque shall meet the torque allowance in the thread specification.

Note: Thick Coatings In An Internal Drive Recess - Tightness to socket inspection gauge may occur for paint and other thick coatings like Zn Flake (1E1675G). Thick coatings in internal drive features may be functional tested using force applied to the penetration gauge or an assembly tool. The minimum socket depth requirement shall be met using 45 N or less.

4.5 The coating process shall not adversely impact the strength or performance of the fastener.

4.5.1 Hydrogen Embrittlement Relief - Hydrogen embrittlement can cause reduced tensile and fatigue strengths in high-strength steel fasteners and result in catastrophic failure. Fastener integrity and the freedom from hydrogen embrittlement is the ultimate responsibility of the fastener supplier. Hydrogen may be absorbed during cleaning, plating, and other surface finishing operations. Due diligence is required by applicators to minimize the effects of hydrogen absorption during cleaning and pickling operations. Alkaline strippers are recommended. Acid cleaning is the least desirable method for corrosion and heat-treat scale removal for high-strength steel fasteners due to the concern of hydrogen embrittlement. Controls shall be in place to remove fasteners from a cleaning bath and rinse within 10 minutes after the start of any downtime. If fasteners having a hardness of HRC32 or greater are cleaned with acid, an inhibited acid should be used with a maximum exposure time of 10 minutes.

4.5.1.1 Documentation shall be kept on the type and strength of the acid and inhibitor. Records shall be kept for every fastener lot of the exposure to acids or alkali baths for: type of solution, strength of solution, and duration of exposure.

4.5.1.2 Baking - Electroplated (from aqueous baths) high-strength steel fasteners are required to be processed through a post-plating heat treatment commonly referred to as baking. Figure 4 provides the minimum baking time and part temperature requirements. The fastener shall reach the baking temperature within two hours after electroplating.

X* – MAX CORE HARDNESS (HRC)	BOLT STRENGTH (REFERENCE)	ISO 9588 ACTUAL UTS (MPa)	ISO 9588	MIN BAKING TIME AND TEMPERATURE [ISO 9588, SAE USCAR 5]	HYDROGEN EMBRITTLEMENT TEST [ISO 15330, ASTM F606(M)]
X ≤ 32	ISO Class 8.8 SAE Grade 5	<1000	(ER-0)	Not Required	Not Required
32 < X ≤ 39	ISO Class 10.9 SAE Grade 8	1000-1220	(ER-12)	4 h @ 190-220 °C	See Paragraph 4.5.1.3
37 < X ≤ 42	Class 11.9 (Caterpillar)	1170-1330	(ER-7)	14 h @ 190-220 °C	----
39 < X ≤ 44	ISO Class 12.9 ASTM A574	1220-1500	(ER-7)	14 h @ 190-220 °C	----
X > 44	Class 45H (setscrews)	>1500	(ER-17)	24 h @ 130-160 °C	----
Case Hardened X > 36	Thread Forming Screws (ASME B18.6.3)	>1500 (Surface)	(ER-7)	14 h @ 130-180 °C	----
* X = Maximum Core Hardness (HRC), e.g., If the Fastener Hardness Range is HRC33-39, X = HRC39					

Figure 4 - Minimum Baking Times For Hydrogen Embrittlement Relief

4.5.1.3 Embrittlement Testing - Coating processers may avoid baking of elecroplated fasteners thru embrittlement testing and validated process controls. Each lot of fasteners with a core hardness range of HRC 32-39 may be embrittlement tested to ISO 15330 or ASTM F606(M) to certify performance. To avoid testing every lot, the plating process may be certified on a monthly basis to meet ASTM F1940. If embrittlement testing is not performed or if ASTM F1940 testing failed, baking is manditory for all lots.

4.5.1.4 Acid / Alkali Cleaning - Parts which are acid or alkali cleaned and subsequently phosphated, mechanically (non-electrolytically) plated, or painted, shall be held for 48 hours at supplier before shipping. Alkali cleaning is the preferred process. A 1-hour baking process at a minimum part temperature of 110 °C following cleaning or coating application is recommended but optional.

4.5.1.5 Rework with Acid or Alkali Stripping - If high-strength (>1000 MPa UTS) fasteners need to be recoated or changed to a different coating, they shall be baked according to Figure 4 after chemical stripping.

4.5.2 Thread Damage - All parts are expected to be free of damage in the as-received condition. Gauging torque in 1E0500 (inch thread) or 1E2650 (metric thread) may be used to determine if the level of damage is unacceptable. Figure 5 is provided as a guideline for determining which parts should be processed using a rack or barrel process. Some parts may be particularly susceptible to damage and should be considered for special processing. This includes parts with fine thread or parts over 300 grams. Suppliers are responsible for selection of the coating application process to avoid damage to threads and other locations on the part. Suppliers may add a reroll operation after coating to ensure all parts are free of damage. Evidence of a process study may be requested to show that the selected coating application process is effective in providing damage free parts.

THREAD SIZE (D) mm	FASTENER LENGTH (L) IN DIAMETERS (D)				
	L ≤ 5D	5D < L ≤ 10D	10D < L ≤ 20D	20D < L ≤ 30D	L > 30D
D ≤ 5	Barrel	Barrel	Barrel	Barrel	Rack
5 < D ≤ 11	Barrel	Barrel	Barrel	Rack	Rack
11 < D ≤ 16	Barrel	Barrel	Rack	Rack	Rack
16 < D ≤ 22	Barrel	Rack	Rack	Rack	Rack
D > 22	Rack	Rack	Rack	Rack	Rack

Figure 5 – Barrel VS Rack Application Process Guide

4.5.3 Topcoat - The sealant/lubricant topcoat shall not negatively impact the intended function: i.e. sealant is not expected on parts that are welded in place like weld nuts or weld studs. When topcoat is not applied to electroplated parts due to their function, the time to white corrosion does not apply, but the time to red corrosion does. The topcoat should be selected with consideration that paint adhesion is required for most fastener applications. Without a topcoat, friction performance requirements have limited applicability. Topcoats may incorporate ultraviolet trace to identify their presence and or coating system (applicable variations 1E1675D, 1E1675F, and 1E1675G).

5.0 REQUIREMENTS

5.1 1E1675A (Zinc Phosphate and Oil) - In accordance with ASTM F1137 Grade B or D. This coating is intended to provide corrosion and galling protection for parts up through the time of assembly. Parts shall have a heavy zinc phosphate conversion coating and a lubricant that meet the following requirements:

5.1.1 Coating Weight - 11-27 g/m^2.

5.1.2 Salt Spray - 72 hours minimum to red corrosion.

5.1.3 Appearance - Coating shall appear as a dark gray material, free from streaks, stains or other evidence of non-uniformity.

5.1.4 Torque-Tension - The coating process shall manifest a coefficient of total friction, μ_{tot} within 0.09 to 0.14 (a torque coefficient (**K**) within 0.12 to 0.18 with surrogate parts). The details of torque-tension testing and measurement are given in Article 6.1.

5.1.5 Lubricant - The coating is designed to retain oil to provide corrosion resistance. The part may be oily when touched. Surfaces shall not be tacky. The specific lubricant shall be at the supplier's discretion.

5.1.6 Hydrogen Embrittlement Relief Process - Baking is not required for 1E1675A fasteners as the phosphating application process is not expected to cause hydrogen embrittlement. If acid cleaning is used, Article 4.5.1 requirements shall be followed.

5.2 1E1675D (Electroplated Zinc with Trivalent Chromium Conversion Coating and Sealant/Lubricant Topcoat) - In Accordance with ISO 4042 A2K or ASTM F1941(M) Fe/Zn 5BNSL. This coating is intended to provide low to moderate corrosion protection for parts after assembly. Zinc electroplated parts shall meet the following requirements:

5.2.1 Plating Thickness - 5 µm (micrometer) minimum.

5.2.2 Coating Color - Silver (clear or blue-bright iridescent finished).

5.2.3 Salt Spray - 96 hours minimum to white corrosion. If white corrosion appears before 96 hours, the parts may be accepted if red corrosion does not occur within 240 hours. A sealer and or a lubricant topcoat shall be applied to ensure the coating meets the salt spray requirement and torque tension requirements.

5.2.4 Torque-Tension - The coating process shall manifest a coefficient of total friction, μ_{tot} within 0.09 to 0.14 (a torque coefficient (**K**) within 0.12 to 0.18 with surrogate parts). The details of torque-tension testing and measurement are given in Article 6.1.

5.2.5 Hydrogen Embrittlement Relief Process - A baking process after electroplating is required for electroplated fasteners that will be used in tension. Baking is not required for electroplated nuts. The baking time at part temperature shall be in accordance with Paragraph 4.5.1 and Figure 4. Certain processes may exclude or alter the post plating baking. If the baking process is altered, the supplier shall document this in writing.

5.2.6 Testing and Shipment - The salt spray test shall be started after coating application and before handling and shipment. Fasteners shall be dry and aged for at least 24 hours before testing or shipment. Embrittlement testing shall begin within 24 hours of plating.

5.2.7 Alternate Coatings - Acceptable alternate coatings to electroplated Zinc:

- Electroplated Zinc; ASTM F1941(M) Fe/Zn 5ANSL
- Zinc-Nickel Alloy; ISO 4042 P2K or ASTM 1941(M) Fe/Zn-Ni 5BNSL
- 1E1675F (Mechanical Zinc Deposition) per Paragraph 5.3

5.3 1E1675F (Mechanical Zinc Deposition with Trivalent Chromium Conversion Coating and Sealant/Lubricant Topcoat) - Refer to ISO 12683 or ASTM B695 for guidance. This coating is intended to provide low to moderate corrosion protection for parts after assembly. Mechanically applied zinc coatings shall meet all the following requirements:

5.3.1 Plating Thickness - 5 μm (micrometer) minimum

5.3.2 Surface Roughness - 80 μm (micrometer) maximum. Surface roughness is only required on bearing surfaces. Marking locations are excluded from this requirement.

5.3.3 Coating Color - Light gray (clear or blue-bright finished).

5.3.4 Salt Spray - 96 hours minimum to white corrosion. If white corrosion appears before 96 hours, the parts may be accepted if red corrosion does not occur within 240 hours. A sealer and/or lubricant topcoat shall be applied to ensure the coating meets the salt spray requirement and torque tension requirements.

5.3.5 Torque-Tension - The coating process shall manifest a coefficient of total friction μ_{tot} within 0.09 to 0.14 (a torque coefficient (**K**) within 0.12 to 0.18 with surrogate parts). The details of torque-tension testing and measurement are given in Article 6.1.

5.3.6 Hydrogen Embrittlement Relief Process - The mechanical deposition application process is non-electrolytic and is not expected to cause hydrogen embrittlement. Paragraph 4.5.1 requirements apply to control the possible hydrogen absorption during cleaning operations.

5.3.7 Testing And Shipment - The salt spray test shall be started after coating application and before handling and shipment. Fasteners shall be dry and aged for at least 24 hours before testing or shipment.

5.3.8 Alternate Coatings - Acceptable alternate coatings to mechanical Zinc (except for externally threaded fasteners):

- 1E1675D (electroplated Zinc) per Paragraph 5.2

5.4 1E1675G (Zinc Flake or Zinc/Aluminum Flake Coatings) - These coatings are intended to provide medium to high corrosion protection for parts after assembly. This coating is a multilayer zinc-rich paint system. Lubricant is required to be applied to or embedded in the coating in order to meet the torque-tension requirement. Phosphating is the preferred surface preparation process prior to coating. (Note: These coatings require curing temperatures of 200 to 330 °C. Case or work hardened part properties may be adversely affected due to hardness loss. Select the coating system to minimize curing temperature for these parts.) Parts specifying 1E1675G zinc flake coating shall meet the following requirements:

5.4.1 Threaded fastener Zinc flake coating shall be in accordance with one of the following:

- ISO 10683 flZn/nc/TL/x/720h/μ_{tot}=0.115±0.025 (**K**=0.15±0.03 with surrogate part testing)
- ISO 10683 flZnL/nc/x/x/720h/μ_{tot}=0.115±0.025 (**K**=0.15±0.03 with surrogate part testing)

5.4.2 Washer Zinc flake coating shall be in accordance with one of the following:

- ISO 10683 flZn/nc/TL/x/720h/μ_{tot}=0.13±0.03 (**K**=0.16±0.03 with surrogate part testing)
- ISO 10683 flZnL/nc/x/x/720h/μ_{tot}=0.13±0.03 (**K**=0.16±0.03 with surrogate part testing)

5.4.3 Coating Thickness - 8 μm (micrometer) minimum.

5.4.4 Salt Spray - 720 hours minimum to red corrosion. (Note: Salt spray performance will be increased to 1008 hours minimum with a specification update in 2020).

5.4.5 Color - The natural color is light gray. The topcoat may contain dyes to modify color. When a specific color is required, it will be stated on the drawing.

5.4.6 Torque-Tension - The details of torque-tension testing and measurement are given in Paragraph 6.1.

5.4.7 Hydrogen Embrittlement Relief Process - The Zinc flake coating application process is non-electrolytic and not expected to cause hydrogen embrittlement. Paragraph 4.5.1 requirements apply to control the possible hydrogen absorption during cleaning operations.

5.4.8 Testing and Shipment - Fasteners shall be dry and aged for at least 24 hours before salt spray testing. Test coating adhesion to ASTM D3359 method A X-cut tape adhesion test, acceptance criteria 4A. After the X-cut tape adhesion test, the coating shall show only trace peeling or removal along incisions or at their intersection.

Note: Due to the nature of the coating, some removal of material is expected, but removal of the coating to expose the substrate is an indication of poor coating adhesion.

5.4.9 Internal Recess Process - Parts with internal recesses should be processed in a system capable of tilting to avoid pooling.

5.4.10 Alternate Coatings - Acceptable alternate coatings to Zinc Flake:

- Zinc-Nickel Alloy; ISO 4042 P3F or ASTM 1941(M) Fe/Zn-Ni 8BNSL
- Zinc Alloy Thermo-Diffusion Coating; ASTM A1059(M) (Refer to ISO 14713-3)

5.5 1E1675J (Oil with Corrosion Inhibitor) - Typical parts will have a plain or black oxide finish before application. Parts shall have an oil coating that contains a corrosion inhibitor, intended primarily for corrosion protection during shipping or shall be packaged with corrosion inhibitors. Corrosion inhibitors shall be selected to preserve the parts such that they are received at the initial receipt facility corrosion free. It is anticipated after oil application or packaging, the parts should withstand a 24 h humidity chamber test without the appearance of corrosion. The part may be oily when touched. Surfaces shall not be tacky. The specific oil coating product shall be at the supplier's discretion. A sealant topcoat is acceptable. Parts that will be welded as part of their function shall be provided with a rust preventative suitable for welding (reference 1E4969). The part shall be useable without removal of the oil. Alternate coating:

- 1E1675A (Phosphate and Oil) per Paragraph 5.1

5.6 1E1675X - Coating as specified on print. The coating shall satisfy the general requirements for thickness, adhesion, and embrittlement concerns specified in Article 4.0 and specific requirements noted on the drawing.

5.7 Coatings From OEMs And Catalog Parts - Caterpillar uses fasteners supplied in OEM assemblies and catalog sources. When 1E1675 is specified on those part drawings, it is indicating a relative coating type and level of performance. The OEM is responsible for ensuring performance to their requirements. Parts shall comply with RoHS. Parts produced specifically to Caterpillar specifications shall meet the relevant 1E1675 variation.

6.0 TESTING

6.1 Torque Tension Testing

6.1.1 Torque-Tension Measurement - The testing conditions shall meet the standard test conditions specified in ISO 16047. Either production parts or surrogate bolts may be used with test standards for routine testing and reporting. The mean and ±1 standard deviation of **K** shall be within the required range (for surrogate testing), or the mean and ±1 standard deviation of μ_{tot} shall be within the required range. The test report shall be available upon request. When a disagreement occurs, the “Coefficient of Total Friction” (μ_{tot}) of the production part tested

against test standards will be used to determine acceptance or rejection. Inquiries regarding the measurement of torque-tension shall be directed to Design Control A516.

6.1.2 Surrogate Testing - For process control and certification of the coating process, use of surrogate Class 10.9 M10×1.5 hexagon head test bolts. Each related finish line shall be monitored per day.

6.1.3 Flange head bolts and flange nuts - Torque Coefficient (**K**) does not account for part geometry like a flange with a large rotating surface. Standard hex head fasteners will have a **K** of 0.12-0.18, and standard flanged fasteners with the same coating exhibit a **K** of 0.14-0.22. Physical testing of flanged geometries like flanged bolts and flanged nuts for compliance requires using a μ_{tot} analysis as specified in ISO 16047.

6.1.4 Torque Coefficient, (K) - The torque coefficient (**K**) shall be determined by the following formula:

$$K = \frac{T}{F \cdot d}$$

6.1.5 Coefficient of Total Friction (μ_{tot}) - The coefficient of total friction (μ_{tot}) shall be determined by the following formula.

$$\mu_{tot} = \frac{(T / F) - (P / 2\pi)}{0.577 \cdot d_2 + 0.25 \cdot (D_0 + d_h)}$$

6.1.6 Variables used:

K = Torque Coefficient (unitless)
T = Torque (Nm)
μ_{tot} = Coefficient of Total Friction (unitless)
d_2 = Basic Pitch Diameter of Thread (mm)
d_h = Inner Diameter of Bearing Surface (mm)
d = Nominal Thread Diameter (mm)
F = Fastener Load (kN)
P = Pitch of Thread (mm)
D_0 = Outer Diameter of Bearing Surface (mm)

6.2 Figure 6 lists the tests that are expected to be performed by the coating applicator. These tests along with the expected test frequency should be listed in the coating control plans and test results should be included as part of PPAP submission. Clear, color photographs may serve as test results for corrosion, appearance and adhesion tests.

TEST	COATING				
	1E1675A	**1E1675D**	**1E1675F**	**1E1675G**	**1E1675X**
Corrosion to White (See Paragraph 4.1 & Figure 1)	----	D, P	D, P	----	As Applicable
Corrosion to Red (See Paragraph 4.1 & Figure 1)	P	----	----	D, P	
Visual Appearance (See Paragraph 4.2)	L, P	L, P	L, P	L, P	
Adhesion (See Paragraphs 4.3 & 5.4.8)	----	----	----	L, P	
Thickness (See Paragraph 4.4)	L, P	L, P	L, P	L, P	
Friction – Surrogate Test (See Paragraph 6.1)	D, P	D, P	D, P	D, P	
D – Daily (surrogate parts per coating line) L – Per Lot P – PPAP					

Figure 6 – Testing Interval Requirements

7.0 REFERENCES

Abbreviations	1E0011
Caterpillar Specifications	1E0500, 1E2650, 1E4969
ISO	1463, 2064, 4042, 9227, 9588, 10683, 12683, 14713-3, 15330, 16047
ASTM	A1059(M), B117, B487, B568, B695, D3359, E376, F606(M), F1137, F1940, F1941(M)