Designation: B994/B994M – 15

Standard Specification for Nickel-Cobalt Alloy Coating[1]

This standard is issued under the fixed designation B994/B994M; 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 This specification describes the requirements for corrosion-resistant coatings of electrodeposited nickel-cobalt on metallic substrates and electrodeposited nickel-cobalt used for electroforming.

NOTE 1—The nickel-cobalt alloy is principally deposited as a coating on steel products. It can also be electrodeposited on iron, stainless steel, aluminum, titanium and any other metal substrate.

NOTE 2—The nickel-cobalt alloy coating has a low coefficient of friction of 0.08 that provides a dry lubricant on part surfaces that are in contact with each other and are subject to galling.

1.2 This specification incorporates an accelerated exposure test method to evaluate the effects of corrosion and galling on the coating, and incorporates a means of reporting the results to the purchaser.

1.3 The specification incorporates a classification scheme that establishes service conditions for thickness, classes of deposits based on the level of monitoring, and type based on supplemental coatings used after deposition.

1.4 The coating thickness ranges from 5 to >30 µm, and it can be applied to machined parts, springs, latches, threaded parts, fasteners, etc. The deposit can also be used to electroform parts requiring high strength with the alloy being maintained at 50% nickel-cobalt.

1.5 The nickel-cobalt alloy is used to protect ferrous metals in contact with corrosive environments such as: oil and gas production facilities, costal marine, and ACQ (Alkaline Copper Quaternary) treatments for wood treatments.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.7 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This standard has been revised to comply with the Restriction of Hazardous Substances* ***RoHS Requirements*** *that seek to limit the exposure of workers and the public to toxic metals. The nickel-cobalt alloy does not contain any of the six Restricted Hazardous Substances.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A681 Specification for Tool Steels Alloy

B117 Practice for Operating Salt Spray (Fog) Apparatus

B183 Practice for Preparation of Low-Carbon Steel for Electroplating

B242 Guide for Preparation of High-Carbon Steel for Electroplating

B254 Practice for Preparation of and Electroplating on Stainless Steel

B320 Practice for Preparation of Iron Castings for Electroplating

B322 Guide for Cleaning Metals Prior to Electroplating

B368 Test Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)

B374 Terminology Relating to Electroplating

B568 Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

B571 Practice for Qualitative Adhesion Testing of Metallic Coatings

B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings

B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings

[1] This test method is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.03 on Engineering Coatings.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

B849 Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement
B850 Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement
D1193 Specification for Reagent Water
E2465 Test Method for Analysis of Ni-Base Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
F519 Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
G59 Test Method for Conducting Potentiodynamic Polarization Resistance Measurements
G85 Practice for Modified Salt Spray (Fog) Testing
G102 Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements
G193 Terminology and Acronyms Relating to Corrosion

2.2 *ISO Standard:*[3]

ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification are in accordance with Terminologies B374 and G193.

4. Classification

4.1 The coatings of nickel-cobalt have been classified as follows: service condition by thickness, class by test methods required, and type by secondary treatments.

4.2 *Service Condition (SC)*—This number signifies the thickness requirement based on the type of environment and desired mechanical properties.

NOTE 3—The 50% NiCo alloy produces a high strength alloy that is used in electroforming to manufacture parts. These deposits can be used at various thicknesses ranging from 1 µm to hundreds of microns.

4.2.1 SC5 signifies that the application is slightly corrosive and that a minimum 5 µm of coating is sufficient for protection and to provide the mechanical properties.

4.2.2 SC12 signifies that the application is mildly corrosive and that a minimum 12 µm of coating is sufficient to protect against corrosion and provide the mechanical properties.

4.2.3 SC18 signifies that the application is corrosive and that a minimum of 18 µm of coating is sufficient to protect against corrosion and provide the mechanical properties.

4.2.4 SC25 signifies that the application is corrosive and that a minimum 25 µm of coating is sufficient to protect against corrosion and provide the mechanical properties.

4.3 *Class*—This number signifies the type and frequency of testing and monitoring programs that are used to control the process.

4.3.1 *Class 1*—Incorporates these standard tests: Galling (see Appendix X1) , Composition (see 9.3), Test Methods F519 and B368, and Practices B117 and G85.

4.3.2 *Class 2*—Incorporates these standard tests: Composition (see 9.3), Test Methods F519 and B368, and Practices B117 and G85.

4.3.3 *Class 3*—Incorporates these standard tests: Composition (see 9.3) and Practice B117.

4.3.4 *Class 4*—Incorporates the standard test of composition (see 9.3).

4.4 *Type*—This number signifies the type of secondary treatment applied after the coating to modify the surface properties.

NOTE 4—The type classification is used to identify supplemental coating that enhances the performance in various applications. For qualification test purposes, if a supplemental coating is not used, that is Type 0. Type 1 supplemental coatings are used to lock the threads or metal-to-metal contact points to increase the amount of energy needed to disassemble the junction. Type 2 supplemental coatings are used to reduce the friction and aid in disassembly. Materials like gold, thallium, and PTFE can be used to provide lubricity and reduce the break torque.

4.4.1 Type 0 coatings are not treated with any supplemental coatings.

4.4.2 Type 1 coatings are treated with a material to secure the coating to itself.

4.4.3 Type 2 coatings are treated with a material to reduce the friction between coated surfaces.

5. Ordering Information

5.1 The purchaser shall specify the following when ordering this coating:

5.1.1 The specification number and revision year,

5.1.2 The service condition, class, and type,

5.1.3 The significant surface on the part as identified on a drawing,

5.1.4 The base metal alloy designation under ASTM standard or equivalent,

5.1.5 The tensile strength of the base metal in MPa,

5.1.6 Any supplemental requirements including Type 1 and Type 2 secondary treatments,

5.1.7 Any exception to stress relief prior to coating (see section 7.3),

5.1.8 Any exceptions to post anneal heat treatments (see section 7.4),

5.1.9 Any exceptions to tests specified in the acceptance tests (see section 8), and

5.1.10 Any exceptions to tests specified in the qualifications tests (see section 9).

5.1.11 Any special requirements of shot peening or location of rack or wire in the coating process, or both, should be specified by the purchaser. Otherwise refer to 7.2.3 and 7.3.

6. Coating Requirements

6.1 The coatings shall be nickel-cobalt alloy produced by electrodeposition.

6.2 The nickel shall be in the range of 43 to 61% and the cobalt shall be in the range of 39 to 57%.

6.3 This coating shall be applied to the significant surface to the desired minimum thickness of the service condition.

6.4 The coating shall meet all applicable requirements as established in the purchase order in accordance with Section 5.

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

7. Materials and Manufacture

7.1 *Substrate*—Defects in the surface of the basis metal such as scratches, porosity, pits, inclusions, roll and die marks, laps, cracks, burrs, cold shuts, and roughness may adversely affect the appearance and performance of the deposit, despite the observance of the best plating practice. Any such defects on significant surfaces shall be brought to the attention of the purchaser before plating. The producer shall not be responsible for coatings defects resulting from surface conditions of the metal, if these conditions have been brought to the attention of the purchaser.

7.2 The substrate may be subjected to such polishing or buffing operations as are necessary to yield deposits with the desired final performance and appearance.

7.2.1 *Peening*—Peening prior to plating may be required on high-strength steel parts to induce residual compressive stresses in the surface, which can reduce loss of strength and improve stress corrosion resistance after plating.

7.2.2 Steel parts that are designed for unlimited life under dynamic loads shall be shot peened or rotary flap peened.

NOTE 5—Controlled shot peening is the preferred method because there are geometries where rotary flap peening is not effective.

7.2.3 Unless otherwise specified, the shot peening shall be accomplished on all surfaces for which the coating is required and all immediate adjacent surfaces when they contain notches, fillets, or other abrupt changes of section size where stresses will be concentrated.

7.3 *Racking*—Parts should be positioned so as to minimize trapping of hydrogen gas in cavities and holes, allowing free circulation of solution over all surfaces to obtain uniform coating thickness. The location of rack or wire marks in the coating shall be agreed upon between the producer and purchaser.

7.4 *Cleaning of Basis Metal*—Proper preparatory procedures and thorough cleaning of the basis metal are essential to ensure satisfactory adhesion and corrosion resistance performance of the coating. It is recommended that the following appropriate standards be used: Practices B183, B254, and B320, and Guides B242 and B322.

7.5 *Pretreatment*—A suitable method shall activate the surface and remove oxide and foreign materials, which may cause poor adhesion and coating porosity.

7.6 *Pretreatment of Iron or Steel for the Purpose of Reducing the Risk of Hydrogen Embrittlement*—All steel parts having an ultimate tensile strength greater than 1000 MPa (31 HRC) and that have been machined, ground, cold formed, or cold straightened, shall be heat treated for stress relief to reduce the risk of hydrogen embrittlement in the part before clean and electroplate processes. If these heat treatments are not required, the purchaser shall specify in the ordering information SR-0. If the purchaser does not specify an SR-0 exception to heat treatment, then the plater shall use Table 1 in Specification B849 to determine the appropriate heat treatment for the steel based on its tensile strength.

7.7 *Post-Coating Treatments of Iron and Steel for the Purpose of Reducing the Risk of Hydrogen Embrittlement*—All electroplated steel parts having a tensile strength greater than 1000 MPa (31 HRC) as well as surface-hardened parts, shall be baked to reduce the risk of hydrogen embrittlement. If these heat treatments are not required, the purchaser shall specify in the ordering information ER-0. If the purchaser does not specify an ER-0 exception to heat treatment, then the producer shall use Guide B850 to determine the appropriate heat treatment for the steel based on its tensile strength.

8. Acceptance Tests

8.1 These tests are performed on the article that has been coated and can be performed by the producer prior to delivery and by the purchaser upon delivery.

8.2 *Appearance*—The surface of the article shall be uniform in appearance, free of visible coating defects, such as blisters, pits, roughness, nodules, burning, cracks, or unplated areas, and other defects that will affect the function of the coating.

8.3 *Adhesion*—The adhesion of the coating shall be such that when examined by one of the test methods described in Practice B571 it shall not show separation from the basis metal.

8.4 *Coating Thickness*—Coating thickness shall meet the minimum as specified in the purchase order by service condition. Use an appropriate method for the part. Test Method B568 provides a rapid measurement of the mass per unit area of the deposit.

9. Qualification Tests

9.1 These tests are performed on the process to ensure the system is capable of meeting the coating requirements by class. These tests shall be performed on SC25, Type 0 coupons at a frequency established in subsection 9.8 based on the class.

9.2 *Galling Test*—The producer shall perform the galling test in accordance with the procedures established in Appendix X1. The producer shall prepare the finishing lot galling report and shall demonstrate that loaded specimens will pass 608 days of evaluation with the torque ration of less than 2.5.

9.3 *Chemical Composition*—The nickel-cobalt alloy composition shall be measured quarterly or more frequently as specified using Test Method E2465 or other elemental analysis methods that can be demonstrated to meet precision and bias requirements of better than 1% mass weight.

9.4 *Hydrogen Embrittlement Test*—The producer shall perform quarterly, or more frequently, the procedure outlined in Test Method F519 by processing a set of four standard 1a specimens. They shall pass Test Method F519 criteria of no failure after 200 hours at 75% UTS.

9.5 Corrosion Testing:

9.5.1 *Electrochemical Corrosion Rate*—The nickel-cobalt alloy coated article shall have a corrosion rate of less than 0.8636 µm/y when tested under Test Method G59. Corrosion rate shall be calculated in accordance with Practice G102. The test solution shall be prepared by dissolving 5 ± 1 parts by mass of sodium chloride in 95 parts of water conforming to Type IV water in Specification D1193 (except that for this practice, limits for chlorides and sodium may be ignored). Careful attention should be given to the chemical content of the

salt. The salt used shall be sodium chloride with not more than 0.3 % by mass of total impurities. Halides (bromide, fluoride, and iodide) other than chloride shall constitute less than 0.1 % by mass of the salt content. Copper content shall be less than 0.3 ppm by mass. Sodium chloride that has had anti-caking agents added shall not be used because such agents may act as corrosion inhibitors. The level of pH shall be equal to 6.5 to 7.2, temperature 25 ± 3° C, with atmospheric pressure and static conditions. The frequency of this shall be quarterly unless the purchaser specifies an increased frequency.

9.6 Environmental Testing

9.6.1 *CASS Test*—The producer shall evaluate the process corrosion protection by performing Test Method B368 on test coupons quarterly or more frequently as required. Panels processed to SC25 shall not show any red rust before 120 hours of exposure

9.6.2 *Salt Spray (Fog) Test*—The producer shall evaluate the process corrosion protection of the nickel-cobalt alloy by Practice B117 quarterly or more frequently as specified. Panels processed to SC25 shall pass with no red rust before 500 hours of exposure to salt spray (fog) as outlined in Practice B117.

9.6.3 *Modified Salt Spray (Fog) Test*—The producer shall evaluate the process corrosion protection of the nickel-cobalt alloy by Test Method G85 (A2 cyclic acidified salt fog testing) quarterly or more frequently as specified. Coupons processed to SC25 shall pass with no red rust before 200 hours of exposure to the Test Method G85 testing.

9.7 *Third Party Reports*—If a third party is used to perform these qualification tests, the test report shall include: Testing laboratory name, name and signature of person responsible for the test, location, list of equipment, current calibration certificates, and required permits for operating equipment (x-ray).

9.8 *Frequency of Qualification Tests*—The maintenance of a process requires frequent testing to ensure the quality is maintained and to instruct the operators in good practice to ensure good workmanship at all times. Table 1 shall be used to establish the maximum frequency for qualification testing of the process by class.

10. Sampling

10.1 The purchaser and producer are urged to employ statistical process control in the coating process. Properly performed, statistical process control will ensure coated products of satisfactory quality and will ensure the amount of acceptance inspection.

10.2 When a collection of coated articles are examined for compliance with the requirements placed on the articles, a relatively small number of the articles (sample) is selected at random and is inspected. The inspection lot is then classified as complying with the requirements based on the results of the inspection of the sample. The size of the sample and the criteria for compliance are determined by the application of statistics. The procedure is known as sampling inspection. Test Method B602, Guide B697, and Test Method B762 contain sampling plans that are designed for sampling inspection of coatings.

10.3 Test Method B602 contains four sampling plans, three for use with tests that are nondestructive and one when they are destructive. Test Method B602 provides a default plan if one is not specified.

10.4 Guide B697 provides a large number of plans and also gives guidance in the selection of a plan. Guide B697 provides a default plan if one is not specified.

10.5 Test Method B762 can be used only for coating requirements that have a numerical limit, such as coating thickness. The test must yield a numeric value and certain statistical requirements must be met. Test Method B762 contains several plans and also gives instructions for calculating plans to meet special needs. Test Method B762 provides a default plan if one is not specified.

10.6 Practice F1470 may be used for threaded articles such as internally threaded, externally threaded, and non-threaded fasteners and washers. This guide provides for two plans: one designated the “detection process” and one designated the “prevention process.”

10.7 An inspection lot shall be defined as a collection of coated articles that are the same kind, that have been produced to the same specification, that have been coated by a single supplier at one time or approximately the same time, under essentially identical conditions, and that are submitted for acceptance or rejection as a group.

11. Rejection

11.1 The purchaser can randomly test any article in accordance with the material testing report in 12.3. Failure to pass any test is cause of rejection of the purchase order.

12. Certification

12.1 *Acceptance Test*—Upon passing of acceptance tests, the producer shall specify that the plated articles are in compliance with the acceptance requirements in the test report.

12.2 *Qualification Tests*—Upon passing of the qualification tests, the producer shall specify that the plated articles were processed in a qualified process incorporating the most recent results in the test report.

TABLE 1

	Galling	Composition	Hydrogen Embrittlement	Corrosion	Test Method B368	Practice B117	Test Method G85
Class 1	120 days	30 days	90 days	90 days	90 days	30 days	90 days
Class 2	None	90 days	90 days	90 days	90 days	90 days	90 days
Class 3	None	90 days	None	None	None	30 days	None
Class 4	None	30 days	None	None	None	None	None

12.3 *Test Report*—The test report shall provide a summary of the acceptance and qualification test results. These results shall be described in the following order, indicating the date the evaluation was sampled, date the evaluation was completed, results of the test, and name of person and organization, if applicable, certifying the specific test results.

12.3.1 *Provider Information*
12.3.1.1 Producer name
12.3.1.2 Date processed
12.3.1.3 Process used
12.3.1.4 Finishing lot number
12.3.1.5 Quality manager's name
12.3.2 *Part Identification*
12.3.2.1 Part description
12.3.2.2 Manufacturer of article
12.3.2.3 Base metal
12.3.2.4 Alloy
12.3.2.5 Tensile strength in MPa
12.3.2.6 Hardness value
12.3.2.7 Hardness unit
12.3.2.8 Production lot number
12.3.3 *Acceptance Tests*
12.3.3.1 Appearance statement
12.3.3.2 Adhesion statement
12.3.3.3 Thickness value
12.3.3.4 Thickness unit
12.3.4 *Qualification Tests*
12.3.4.1 Finishing lot galling report
12.3.4.2 Composition in wt%
12.3.4.3 Hydrogen embrittlement statement
12.3.4.4 Corrosion resistance MPY<0.034
12.3.4.5 Environmental testing
(1) Test Method B368 statement
(2) Practice B117 statement
(3) Test Method G85 statement
12.3.5 *Supplementary Testing Requirement Results*
12.3.6 *Signed and Dated Certification Statement*

13. Keywords

13.1 alloy; coating; cobalt; corrosion; corrosion in threaded articles; corrosion rate; dismantle; electrochemical testing; metal coating; nickel; nickel-cobalt alloy; performance; protective coating; salt spray (fog) chamber; torque ratio

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply when specified by the purchaser in the contract or order.

S1. Pre-Qualification Lot

The purchaser may use a pre-qualification lot to qualify the producer. In such cases the pre-qualification lot shall be produced using the same operating parameters as the subsequent production articles and tested in accordance to the SC25 Class and Type 0.

S2. Product Service Marking

To help identify the article in the field and replace those articles that are reaching the end of their service life, it is advisable to incorporate a marking system to identify the producer and finishing lot.

S2.1 If this supplemental requirement is required, the article shall bear the producer's identification mark and finishing lot number.

S2.2 The service mark shall be applied by the producer using indelible ink or other methods that will survive continuous exposure to a salt environment.

S2.3 The producer shall maintain copies of the test reports for the finishing lots for a minimum of seven years.

S2.4 The producer shall provide notification to the purchaser when the galling breaking torque results exceed 250%.

$$\text{breaking torque} = \frac{\text{unthread torque}}{\text{loading torque}} \quad (1)$$

APPENDIX

(Nonmandatory Information)

X1. GALLING TEST

X1.1 Scope

X1.1.1 This test evaluates the long-term performance of the coating when exposed to the Practice B117 Salt Fog corrosive environment under mechanical stress. Torque is applied to the specimen to accomplish tension to the assembly. After environmental exposure, the threaded bar and nut is dismantled and the torque measured. The ratio of dismantle torque to loading torque shall be less than 2.5 for the coating to pass this test.

X1.1.2 Specimens are processed and loaded every 120 days and become the test set that is evaluated for a minimum of 20 months at 120 day evaluation periods. The effective maximum environmental exposure is 84 months.

X1.1.3 This test incorporates a means of reporting the results to the purchaser to demonstrate the performance of the coating in galling applications and provide early warning for potential field failures when disassembling systems.

X1.2 Standard Specimen for Testing

X1.2.1 All tests shall be performed on a standard specimen for testing as defined as follows. The following size and type of steel shall be considered the standard specimen for testing: a Specification A193/A193M-grade B7 threaded bar with two Specification A194/A194M-grade 2H nuts, the diameter shall be ⅝ by 4 in. in length, the threaded bar shall be chamfered and marked with the steel grade and the producer's identification mark, the nuts shall have the producer's identification mark and corresponding steel grade marking. The bar and nuts shall be coated with the nickel-cobalt alloy SC18, Class 1, Type 0.

X1.2.2 No over-sizing or under-sizing of nut or threaded bar is permissible on the standard specimen for testing.

X1.2.3 No lubricant or waxes shall be used when applying torque.

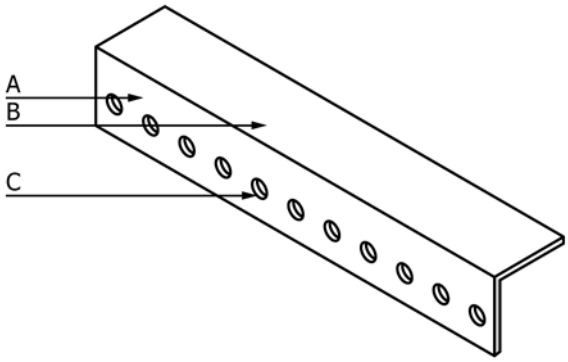

FIG. X1.1 Part 1, Placement of Specimen for Torquing

FIG. X1.2 Part 1, Frontal View

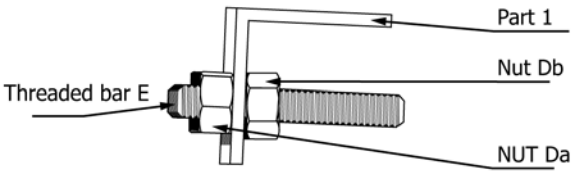

FIG. X1.3 Part 1, Lateral View

X1.3 Description of Device

X1.3.1 The part used to hold the standard specimen for testing is shown in Figure Fig. X1.1 and Fig. X1.2; this consists of an AISI 4140 steel angle with 5⁄16 in. thickness, featuring flat (A) and flat (B). Flat (A) positions the specimens; they are placed through the openings (C), which are present along the entire length of this section.

X1.3.2 Fig. X1.3 is an illustration of the specimen (threaded bar-nut assembly) setting in Part 1. In the assembly, threaded bar (E), and nut (Da) and nut (Db) are observed; however, the evaluation must be made by loosening the nut (Da) from the threaded bar (E). The nut (Db) aids in tightening the threaded bar (E) and its subsequent loosening. Flat (B) of the angle links Part 1 and Part 2 (see Fig. X1.7).

X1.3.3 Fig. X1.4 illustrates Part 2. This geometry allows Part 1 to be supported through an angle relative to the vertical

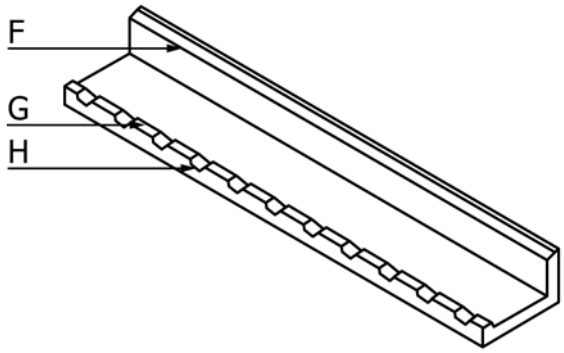

FIG. X1.4 Part 2, Support for Part

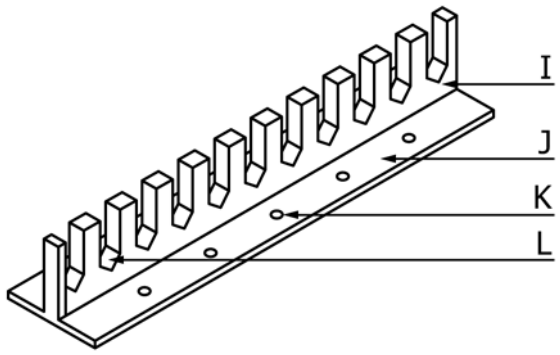

FIG. X1.5 Part 3

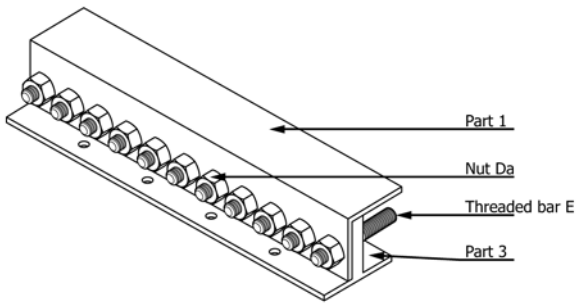

FIG. X1.6 Part 3 Coupled to Part 1

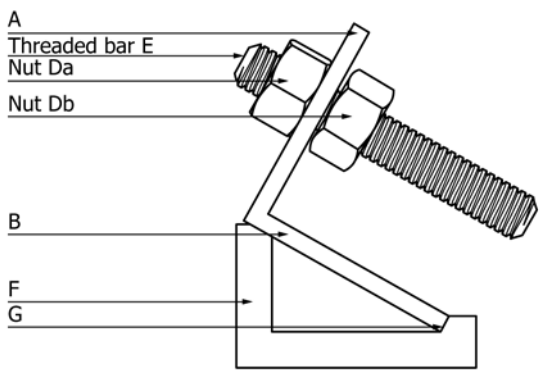

FIG. X1.7 Position of Part 1 and Part 2

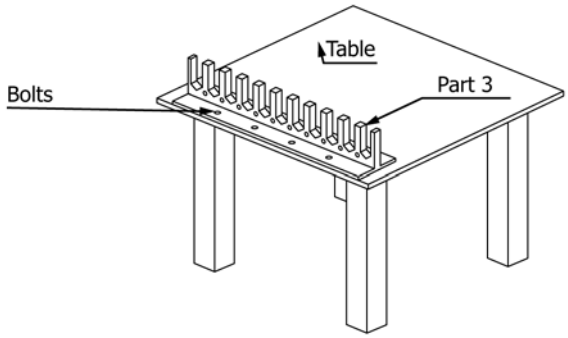

FIG. X1.8 Part 3 Bolted to the Table

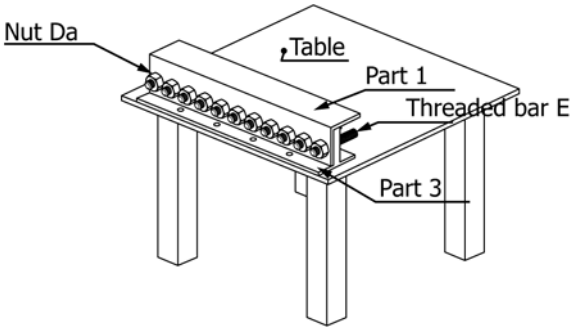

FIG. X1.9 Part 1 Engaged to Part 3, Part 3 Bolted to the Table

and parallel to the flow direction of the corrosive environment on the base of the surface area being tested; in this way, the flat (F) is higher than the flat (G). Part 2 shows semicircular drainage channels (H) along its entire length, thus avoiding accumulation of condensation. Part 2 shall be made of a material that will not be affected by the corrosive environment of the chamber, such as plastic.

X1.3.4 The geometry of Part 1 and Part 2 allows each specimen to be exposed to the corrosive environment without being affected by the adjacent specimen or the accumulated sludge. A 5⁄16 in.-thick AISI steel angle with no coating for Part 1 ensures that the nut can be torqued correctly.

X1.3.5 Fig. X1.5 illustrates Part 3; this part is not exposed to the corrosive environment.

X1.3.6 Part 3 consists of a plate (I) where opening (L) allows the nuts to rest and be anchored, preventing movement, thus achieving the fastening and loosening of the specimens under evaluation. (L) must be fabricated with a resistant-to-deformation material, preferably H19, H41, H42, A8, O1, O7, D3, or S1 according to Specification A681, except for P21.

X1.3.7 Flat (J) from Part 3, perpendicular to (I), presents openings (K) along its flat so it can be bolted to a table as shown in Fig. X1.8.

X1.3.8 Part 3 must be bolted to the table, then Part 1 is coupled. The (Da) nuts must be torqued to 72 lbf·ft for the test. No lubricants, waxes, or additives are permissible when applying torque. See Fig. X1.9.

X1.4 Positioning of Standard Specimen for Testing in the Device

X1.4.1 The standard specimen for testing must be free of debris or any foreign matter. Rinse with water and degreaser at room temperature using a soft bristle brush, making sure the surface or coating is not damaged. Dry using compressed air. No lubricant or waxes are permissible.

X1.4.2 Part 1 presents numbered openings in ascending order, shown in Fig. X1.1 and Fig. X1.2.

X1.4.3 The standard specimens for testing are placed through the openings (C) that are present along the entire length of Part 1. The nuts are then hand-tightened until the flat of the angle in (A) is reached. A minimum of three full threads (E) must be towards the exterior of the angle of Part 1 (Fig. X1.3).

X1.4.4 Part 3 must be bolted to a table; these bolts are placed through the openings (K). See Fig. X1.8.

X1.4.5 Once the specimens have been placed in Part 1, it is coupled to Part 3 by aligning the nut (Db) into the opening in (L) of Part 3.

X1.4.6 When Part 1 and Part 3 are coupled, using a conventional torque tool, 72 lbf·ft torque force is applied to nut (Da). See Fig. X1.6.

X1.4.7 After all nuts are tightened, Part 1 is separated from Part 3.

X1.4.8 Part 1 is then placed inside the salt spray (fog) chamber following Practice B117, using a support (Part 2). The support permits the part to follow the required angle described in the salt spray test. See Fig. X1.7.

X1.5 Evaluation and Results

X1.5.1 The evaluation will be done every 120 days, not to exceed 130 days on a test set exposed to neutral salt spray (fog) (Practice B117).

X1.5.2 The evaluation shall be at least three specimens that are able to be dismantled for the evaluation period with less than 2.5 times the dismantle torque or loading torque. Extra specimens may be included to ensure enough specimens are available to accomplish the 84 months of reporting. If five specimens fail for the evaluation period, that test set is concluded.

X1.5.2.1 At the end of every 120 day evaluation period, the specimen shall be treated as follows:

X1.5.2.1.1 Part 1 is carefully taken out the chamber or corrosive environment.

X1.5.2.1.2 Part 1 is coupled to Part 3 as described in the procedure.

X1.5.2.1.3 Using a conventional torque tool, the first nut (Da) to be evaluated is loosened. No antifreeze or lubricants shall be used for dismantle procedure.

NOTE X1.1—Only the nut (Da) is evaluated in this method.

X1.5.2.1.4 The torque used for loosening the nut should be the same as the one used for tightening, 72 lbf·ft. If using the initial torque value of the nut (Da) does not loosen, torque can be increased up to 2.5 times the initial torque value.

X1.5.2.1.5 The final torque value that was required for disassembly shall be recorded. The final value shall be divided into the initial value and the result will be the reported value as number of times of the initial torque for assembly.

X1.5.2.1.6 If the nut does not loosen after applying the maximum torque value, the person performing the test can use an extra specimen until there are three samples for the minimum report period. Use of extra samples shall be reported. If no nut can loosen, the test shall be concluded and report shall be sent to the purchasers.

X1.5.2.1.7 If the nut under evaluation can be loosened, the threaded part and nut are detached from (C1) in Part 1. Part 1 is separated from Part 3 and returned for further exposure to the corrosive chamber environment until the next evaluation period is reached. The same method is performed again to the nut (Da) in the corresponding opening (C).

X1.5.2.1.8 Repeat steps for each specimen and designated evaluation test period.

X1.6 Finishing Lot Galling Report

X1.6.1 The producer shall produce a finishing lot galling report that summarizes the evaluation results for this test set.

X1.6.2 The following information shall be recorded:

X1.6.2.1 Date of production of the coating on the specimens.

X1.6.2.2 Finishing lot number of production.

X1.6.2.3 Number of samples being evaluated, including extra samples.

X1.6.2.4 Rack number and position in the chamber.

X1.6.2.5 Loading date for the specimens and rack in the chamber.

X1.6.2.6 Period being evaluated, date of evaluation, and actual days of exposure of the specimens being evaluated.

X1.6.2.7 For each specimen being evaluated, divide the dismantle torque in lbf·ft by the loading torque value of 72 lbf·ft and record the torque ratio value.

X1.6.2.8 The finishing lot galling report shall incorporate a summary of evaluation periods indicating the torque ratio and days to dismantle failure.