General Specification for Alloy Steel Bolting in Corrosive Environments for the Petroleum and Natural Gas Industries with Ni-Co Coating

General Specification for Bolting GS324.16
November 2017

This specification complies with the API 20E Alloy and Carbon Steel Bolting for use in the Petroleum and Natural Gas Industries.

For the used in the following Upstream and downstream applications:

- Subsea
- Splash zone
- Topside
- Drilling Equipment
- Vessels
- Pipeline

The temperature range for this specification is -328 °F to 1300 °F
Revisions and approval for users

The GS324.16 Specification has been revised and approved for use in the following:

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<thead>
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<th>Applications</th>
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<td>☑ Subsea</td>
</tr>
<tr>
<td>☑ Downstream</td>
<td>☑ Splash zone</td>
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<tr>
<td>☑ Green Field</td>
<td>☑ Topside</td>
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<tr>
<td>☑ Brown field</td>
<td>☑ Drilling Equipment</td>
</tr>
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<td>☑ Vessels</td>
<td>☑ Pipeline</td>
</tr>
<tr>
<td>☑ Other</td>
<td></td>
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</table>

User: ________________________________

Project: ________________________________________________

(Name of project / or regions that apply)

Users specifications and notes: Approve Doxsteel’s GS324.16

User/Company: _____________________________

Approved by: _____________________________

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Vice President of Sales
Date______________
General Specification for Bolting in Corrosive Environments for the Petroleum and Natural Gas Industries

General Specification GS324.16
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Foreword
This general specification defines the minimum requirements for Bolting in Corrosive Environments for the Petroleum and Natural Gas Industries. For the used in upstream and downstream facilities with pressurized piping systems designed to ASME B31.1, B31.3, B31.4, B31.8, API 6A, API 17D and applications where API 20E is required.

Introduction
Carbon and low alloy steel fasteners systems in the oil and gas industry are exposed to corrosive environments. While these are not a major risk of failure, long term protection systems of operating facilities are considered good engineering proactive practice.

The ASTM B994 Nickel-Cobalt alloy plating is applied for corrosion protection; it has a life product expectancy of 20 years and it is manufactured to prevent the fastener from seizing for at least for 5 years. The warranties are limited to those included in the corresponding purchasing agreement.

1. Scope
This specification covers the requirements for the correct application of ASTM B994 Nickel-Cobalt alloy plating to API 20E Bolting. This ASTM B994 Nickel-Cobalt alloy plating satisfies all the plating requirements in API 20E and the bolting substrate is in compliance with the requirements in API 20E.

This specification includes traceability of the base material and the ASTM B994 Nickel-Cobalt alloy plating. The following grades of steel bolting are applicable: ASTM A320 grade L7, L7M & L43, ASTM A193 grade B7, B7M and B16 Band ASTM A194 grade 4, 7, 2H, 2HM.

The ASTM B994 Nickel-Cobalt alloy plating is applied for corrosion protection, consistent nut (k) factor and to prevent the fasteners and nut from seizing or from requiring hot bolting during turnarounds.

The service temperature range for the Ni-Co coated low alloy steel bolts is -328°F to 1300°F (-200 °C TO 700 °C)

The bolting requirements shall be those in API 20E BSL1 as a minimum, BSL2 and BSL3 shall be specified when required by purchase order.

2. Normative references
The following documents are used as references in one or more of the requirements in this specification. For dated references, only the cited version applies, for undated references, the latest version of the referenced document (including any amendments) applies.

American Petroleum Institute (API)
API Spec 6A Wellhead and Christmas Tree Equipment.
API Spec 17D Specification for Subsea Wellhead and Christmas Tree Equipment
API Spec 20E Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries.

**American Society of Mechanical Engineering (ASME)**

ASME B1.1-2003 Unified Inch Screw Threads (UN and UNR Thread Form
ASME B18.2.1-2012, Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series).
ASME B18.2.2-2015, Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
ASME B18.18-2011, Quality Assurance for Fasteners
ASME B18.31.2-2014, Continuous Thread Stud, Double-End Stud, and Flange Bolting Stud (Stud Bolt) (Inch Series),

**American Society for Non Destructive Testing (ASNT)**

ASNT SNT TC 1A Personnel Qualification and Certification in Non destructive Testing.

**American Society for Testing and Materials (ASTM)**

ASTM A193/A193M – 15a, Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

ASTM A194/A194M – 15a, Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

ASTM A320/A320M – 15a, Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service


ASTM B117-1 Practice for Operating Salt Spray (Fog) Apparatus

ASTM B322-14 Guide for Cleaning Metals Prior to Electroplating

ASTM B368-14 Test Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)

ASTM B374-11 Terminology Relating to Electroplating

ASTM B568-14 Test Method for Measurement of coating thickness by X-Ray Spectrometry.
ASTM B571-13 Practice for Qualitative Adhesion Testing of Metallic coatings.
ASTM F1470-12 Standard Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
ASTM NACE / ASTM G31-12 Standard Guide for Laboratory Immersion Corrosion Testing of Metals
ASTM G102-15 Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements
ISO 9001  Quality management systems  Requirements.
ISO 9712  Nondestructive testing. Qualification and certification of NDT personnel.
ISO/IEC 17025  General requirements for the competence of testing and calibration laboratories.

3. Terms and definitions
For the purposes of this document, the following terms and definitions apply:

**Bolt:** all thread studs, tap-end studs, double-ended studs, headed bolts, cap screws, screws, and nuts with Nickel-Cobalt alloy plating.

**Production testing (PT):** All tests that the manufactured shall perform to verify quality of the final product

**Material Test Report (MTR):** Written document that includes traceability from base material to finished product including all production testing and raw material.

**Manufacturer:** Business in charge of designing, developing, and applying the Nickel-Cobalt alloy plating to the base-material.
4. Coating Composition and Thickness

The Bolts shall have a Nickel-Cobalt alloy plating under ASTM B994 produced by electro deposition using a racking system, the nickel range shall be in 43 to 80% and cobalt shall be in the range of 20 to 57%. The thickness shall have a minimum of 18 µm including the valleys of the threads of the fastener the maximum should not interfering with the functionality of the fastener.

Application of the ASTM B994 Nickel-Cobalt alloy plating shall comply to ASTM B994 SC18 Class 1, the plating thickness shall be controlled by the process to ensure that the dimensions of ANSI B1. Class 2A for external and 2B for internal dimensions are not affected.

After plating nuts must run freely by hand past where they will come to rest after tightening in accordance to ASME PCC1 section 7 paragraph c. The fit and function of the assembly shall be in accordance to ANSI B1.1.

The requirements for bolts and plating materials shall be in compliance with:

- API 20E
- ASTM A193
- ASTM A194
- ASTM A320
- ASTM B994, SC18, Class 1

5. Qualification Testing for Ni-Co plating

The ASTM B994 Nickel-Cobalt alloy plating shall be used for carbon steel and low alloy bolting. The acceptance frequency and qualification tests shall be based on table 1, 2 and 32: the criteria for qualification are establish on the standards.

5.1 Types of specimen.

Table 1. Specimens Description

<table>
<thead>
<tr>
<th>Specimen No</th>
<th>Description</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coupons (ANSI 4140 size 3” x 4”)</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>Fastener Threads (Crest and Valleys)</td>
<td>b</td>
</tr>
<tr>
<td>3</td>
<td>Wrenching Flats of Nuts</td>
<td>c</td>
</tr>
<tr>
<td>4</td>
<td>Interior area of the Nut</td>
<td>d</td>
</tr>
<tr>
<td>5</td>
<td>Fastener under ASTM A193 GR B7 and two ASTM A194 2H nuts (5/8” x 4 ¾”)</td>
<td>e</td>
</tr>
<tr>
<td>6</td>
<td>Hydrogen Embrittlement specimen accordance to ASTM F519 A1.1 Type 1a.</td>
<td>f</td>
</tr>
</tbody>
</table>
Table 2. Acceptance Tests Frequency

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Adhesion</th>
<th>Appearance</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Production parts</td>
<td>Production parts</td>
<td>Production parts</td>
</tr>
<tr>
<td>Specimen</td>
<td>b, c</td>
<td>b, c</td>
<td>b, c</td>
</tr>
</tbody>
</table>

Table 3 Qualification Test Frequency

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120 days</td>
<td>30 days</td>
<td>30 days</td>
<td>30 days</td>
<td>30 days</td>
<td>30 days</td>
<td>30 days</td>
</tr>
<tr>
<td>Specimen</td>
<td>e</td>
<td>f</td>
<td>a, b, c</td>
<td>a, b, c, d</td>
<td>a, b</td>
<td>a, b, c, d</td>
<td>a, b, c, d</td>
</tr>
</tbody>
</table>

5.2 Materials for sour service
Unless specified otherwise in the Purchase Order, carbon and low alloy steel forgings sour service requirements shall conform to NACE MR0175/ISO 15156 Part 1 and Part 2 when specified

5.3 Material grades
The manufacturer shall have a list of approved steel providers; these providers should be API20E certified and audited by the manufacturer at least once every three years. If the authorized steel provider makes any changes in the manufacturing process or any related operation, this provider must be re-evaluated and re-audited by the manufacturer.
Typical material base standards and grades are listed in Table 4.

**Table 4 Material base standards and grades**

<table>
<thead>
<tr>
<th>Base standard</th>
<th>Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>ASTM A193 B7, B7M, B16</td>
</tr>
<tr>
<td></td>
<td>ASTM A193 B16 for High temperature</td>
</tr>
<tr>
<td></td>
<td>ASTM A194 2H, 2HM, 7</td>
</tr>
<tr>
<td>Low alloy steel</td>
<td>ASTM A 320 L7, L7M, L43</td>
</tr>
<tr>
<td>AISI 41XX (UNS G41XXX)</td>
<td>4130 and 4140</td>
</tr>
</tbody>
</table>

The materials must be inspected and approved by the Quality Control Department before entering the plating process, the material shall comply with the ASTM A193, ASTM A194, ASTM A320 standards or the applicable standard for the base material.

6. **Ni-Co Plating Manufacturing procedure specification (MPS)**

The base metal shall be substantially free from flaws or defects that will be detrimental to the appearance or the protective value of the plating. It shall be subjected to such cleaning, pickling, and plating procedures as are necessary to yield deposits with the desired quality. Shot-peening is prohibited as a form of cleaning or to generate compressive surface stresses on the fastener.

The surface preparation ensures proper plating application and assembly without interfering with the K factor

6.1 **Plating**

The vendor shall have a API Q1 certified procedure for ASTM B994 Nickel-Cobalt alloy plating. The plating must be applied by rack system smooth, fine-grained, adherent, and free from blisters, pits, nodules, and indications of burning and other defects. Superficial staining resulting from rinsing, or slight discoloration resulting from baking, shall not be cause for rejection.

6.2 **Pretreatment for the purpose of Reducing the Risk of Hydrogen Embrittlement**

All steel parts having an ultimate tensile strength greater than 145 Ksi (1000 MPa; 34 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 any cleaning and electroplating processes. The plating vendor shall use Table 1 in ASTM B849 (latest revision) to determine the appropriate heat treatment for the steel based on its reported ultimate tensile strength.
Cleaning of Base Metal—Proper preparatory procedures and thorough cleaning of the basis metal are essential to ensure satisfactory adhesion and corrosion resistance performance of the plating. It is recommended that the following appropriate standard be used: Practices ASTM B322.

6.3 Post-Plating Treatment for Reducing the Risk of Hydrogen Embrittlement
All electroplated steel parts having an ultimate tensile strength greater than 145Ksi (1000 MPa; 34 HRC), as well as surface hardened parts, shall be heat treated (i.e. baked) to reduce the risk of hydrogen embrittlement. The baking treatment shall be done before the application of the supplementary treatments and within 2 hours of removal from the last plating process.

7. Acceptance and qualification testing (AQT)
After plating, the material shall comply with the following production quality control and performance tests. Acceptance tests (Table 5) shall be performed to the daily production, and the qualification tests (Table 6) shall be performed each month for the parts produced for this purpose, all samples (Specimen) are above ASTM F1470 and ASTM B994.

Table 5 Acceptance test

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Test method</th>
<th>Specimen Type (Production part, PP(^1))</th>
<th>Acceptance Criteria</th>
<th>Test frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>PP</td>
<td>No Damage</td>
<td>By Load bar</td>
<td></td>
</tr>
<tr>
<td>Adhesion</td>
<td>ASTM B571</td>
<td>PP</td>
<td>No Damage</td>
<td>By Load bar</td>
</tr>
<tr>
<td>Plating thickness</td>
<td>ASTM B568</td>
<td>PP</td>
<td>ASTM B568 x-ray spectrometry of all external threads, crests and roots for a length 2 times the diameter on one side, and wrenching flats of nuts. Acceptance: Total coating thickness shall meet an average minimum of 18 microns. Maximum thickness shall not interfere with functionality.</td>
<td>By Load bar</td>
</tr>
</tbody>
</table>

1.- Stud, bolts.
### Table 6 qualification tests

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Test method</th>
<th>Specimen Type (5.1 Table 1) or Production part, PP¹</th>
<th>Acceptance Criteria</th>
<th>Test Frequency From ASTM B994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>ASTM E2465</td>
<td>PP/a</td>
<td>Average of Nickel 43 to 80% Cobalt 20 to 57%.</td>
<td>Month</td>
</tr>
<tr>
<td>Hydrogen embrittlement test</td>
<td>ASTM F519</td>
<td>f</td>
<td>No failure after 200 h at 75% UTS(Pass)</td>
<td>Month</td>
</tr>
<tr>
<td>Electrochemical corrosion rate</td>
<td>ASTM G59</td>
<td>PP/a</td>
<td>&lt;0.8636 µm/year</td>
<td>Month</td>
</tr>
<tr>
<td>CASS test</td>
<td>ASTM B368</td>
<td>a</td>
<td>120 h No RR</td>
<td>Month</td>
</tr>
<tr>
<td>Salt fog test</td>
<td>ASTM B117</td>
<td>a</td>
<td>500 h No RR</td>
<td>Month</td>
</tr>
<tr>
<td>Modified salt fog test</td>
<td>ASTM G85-A2</td>
<td>a</td>
<td>200 h No RR</td>
<td>Month</td>
</tr>
</tbody>
</table>

¹- Stud, bolts.

7.1 Appearance—The surface of the article shall be uniform in appearance, free of visible plating defects, such as blisters, pits, roughness, nodules, burning, cracks, or non-plated areas, and other defects that will affect the function of the plating or the bolt.

7.2 Adhesion—The adhesion of the plating shall be such that when examined with Practice ASTM B571 described in point 10 “Impact test” it shall not show separation from the basis metal.

7.3 Plating Thickness—Plating thickness shall meet the minimum 18 microns with the use of test Method ASTM B568.

7.4 Galling Test. The manufacturer shall perform the Galling Test in accordance with the procedures established in ASTM B994. Appendix X1. The manufacturer shall prepare the galling report and demonstrate that loaded specimens will pass 1825 days of evaluation with the torque ratio of less than 2.5.

7.5 Chemical Composition—The ASTM B994 Nickel-Cobalt alloy composition shall be measured as specified using Test Method E2465.

7.6 Hydrogen Embrittlement Test—The manufacturer shall perform as specified, 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.

7.7 Electrochemical Corrosion Rate—The ASTM B994 Nickel-Cobalt alloy coated fastener shall have a corrosion rate of less than 0.6620 µm/y when tested under Test Method ASTM G59. Corrosion rate shall be calculated in accordance with Practice ASTM 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).

7.8 CASS Test—The manufacturer shall evaluate the corrosion protection by performing Test Method ASTM B368 on test coupons as specified. Panels processed to SC25 shall not show any red rust before 200 hours of exposure.

7.9 Salt Spray (Fog) Test—The manufacturer shall evaluate the corrosion protection of the ASTM B994 Nickel-Cobalt alloy by Practice ASTM B117 as specified. Panels processed to SC25 shall pass with no red rust before 3,000 hours of exposure to salt spray (fog) as outlined in Practice ASTM B117.

7.10 Modified Salt Spray (Fog) Test—The manufacturer shall evaluate the corrosion protection of the ASTM B994 Nickel-Cobalt alloy by Test Method ASTM G85 (A2 cyclic acidified salt fog testing) as specified. Coupons processed to SC25 shall pass with no red rust before 200 hours of exposure to the Test Method ASTM G85 testing.

7.11 Frequency of 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 always. Table 2 shall be used to establish the frequency for testing of the process by class.

The quality management system shall include all requirements in this specification and be certified by API Q1.

8. Manufacturing Procedure Certification (MPC)

Application of the ASTM B994 Nickel-Cobalt alloy plating shall be in compliance to ASTM B994 SC18 Class 1, the plating thickness shall be controlled by the process to ensure that the dimensions ANSI B1.1 are not affected.

Each plated fastener shall be visually inspected. Fasteners shall be free from excess buildup in threads, lack of adhesion (see 7.1.2), blisters, peeling, flaking, and discoloration.

All testing shall be performed according to this specification. All testing shall be performed by the manufacturer.

8.1 Materials test certification and traceability

The bolt manufacturer must be able to track and trace each part from point of raw material origin to point of use in service and have the ability to identify all products point of use at any given time. This includes date product goes in service, length of time in use, environment product is being used in along with torque values.

The Bolts shall be accompanied by the corresponding Material Test Report (MTR) that includes the substrate’s and plating testing traceability. The original mill certificates shall be available upon request.
The plating applicator shall provide an MTR certifying that all the fasteners on the order were processed and found to be acceptable in accordance with this specification. In order to meet the requirements in the specifications, the bolt substrate and plating lot shall be traceable and included in the MTR.

8.2 Acceptance and qualification test
a) Acceptance tests must be according to table 1 acceptance tests frequency
b) Qualification tests must be according to table 2 qualifications tests frequency

9. Installation guidelines
The manufacturer must present a Nut factor study and data showing the consistency of the k factor in order to obtain a homogenous torque and tension during installation of the flanges.

API Q1 Quality Management System (QMS)
The quality management system shall conform to ISO 9001 and API Specification Q1 to ensure that the bolts complies to API 20E and the plating to this specification.

Testing facilities shall be integral part of the quality management system.

10. Inspection and test plan (ITP)
Prior to the start of manufacture, an ITP shall be submitted for review and approval by the user.

The ITP shall include inspection and testing activities to be performed, including those at sub suppliers’ works and shall make reference to all testing procedures, control documents, and resulting records and reports.

API 20E Bolts substrate and ASTM B994 Nickel-Cobalt alloy plating lot shall be traceable and all testing records shall be maintained for a period of 10 years.

The MTR shall certify that all bolts included in the order were processed and found to be acceptable in accordance with this specification.

Company and the Company appointed representative shall, at all times, have access to the workshops and testing facilities, including workshops of sub suppliers engaged in supplying material or in fabricating the equipment for the purpose of inspecting the purchased equipment.

11. Packaging, Preservation and Marking System (PPMS)
The bolts shall be adequately packaged in cardboard cylinders to ensure that the plating and threads are not damaged during shipping. The cardboard box or wood crate must have a printed label and each bolt shall be marked to identify the plating lot traceability and the API 20E specification requirements.
The boxes must be identified externally by labels with the following information:

Manufacturer Mark
Part number
Material grade
Diameter
Length
Quantity
Traceability code
Weight
The assembly with plating shall comply with ANSI B1.1 Class 2A and 2B dimensions

The pallet must be identified externally by labels with the following information:

Order number
Client information
Number of boxes or pallet