

Corrosion-resistant Bolting for Use in the Petroleum and Natural Gas Industries

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Corrosion-resistant Bolting for Use in the Petroleum and Natural Gas Industries

1 Scope

1.1 Purpose

This standard specifies requirements for the qualification, production, and documentation of corrosion-resistant bolting used in the petroleum and natural gas industries.

1.2 Applicability

This standard applies when referenced by an applicable API equipment standard or otherwise specified as a requirement for compliance.

1.3 Bolting Specification Levels (BSL)

This standard establishes requirements for two bolting specification levels (BSL). These two BSL designations define different levels of technical, quality, and qualification requirements: BSL-2 and BSL-3. The BSLs are numbered in increasing levels of requirements in order to reflect increasing technical, quality, and qualification criteria. BSL-2 and BSL-3 are intended to be comparable to BSL-2 and BSL-3, as found in API 20E. BSL-1 is omitted from this standard.

1.4 Bolting Types for Qualification

This standard covers the following product forms, processes, and sizes:

- a) machined studs;
- b) machined bolts, screws, and nuts;
- c) cold-formed bolts, screws, and nuts with cut or cold-formed threads;
- d) hot-formed bolts and screws <1.5 in. (38.1 mm) nominal diameter;
- e) hot-formed bolts and screws ≥1.5 in. (38.1 mm) nominal diameter;
- f) roll threaded studs, bolts, and screws <1.5 in. (38.1 mm) diameter;
- g) roll threaded studs, bolts, and screws ≥1.5 in. (38.1 mm) diameter;
- h) hot-formed nuts <1.5 in. (38.1 mm) nominal diameter;
- i) hot-formed nuts ≥1.5 in. (38.1 mm) nominal diameter.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Specification Q1, Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry

API 6A, Specification for Wellhead and Christmas Tree Equipment

API 6HT, Heat Treatment and Testing of Carbon and Low Alloy Steel Large Cross Section and Critical Section Components

API Standard 6ACRA, Age-hardened Nickel-based Alloys for Oil and Gas Drilling and Production Equipment

ANSI/NCSL Z540.3¹, Requirements for the Calibration of Measuring and Test Equipment

ASTM A370², Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A453, Standard Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels

ASTM A751, Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

ASTM A962-17, Standard Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

ASTM E10, Standard Test Method for Brinell Hardness of Metallic Materials

ASTM E18, Standard Test Methods for Rockwell Hardness of Metallic Materials

ASTM E354 Standard Method for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel and Cobalt Alloys

ASTM E1476, Standard Guide for Metals Identification, Grade Verification, and Sorting

ASTM F788, Standard Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

ASTM F812, Standard Specification for Surface Discontinuities of Nuts, Inch and Metric Series

ISO 9001, Quality management systems – Requirements

ISO/IEC 17020, Conformity assessment – Requirements for the operation of various types of bodies performing inspection

ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories

NACE MR0175/ISO 15156³, Petroleum and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production, parts 1, 2, and 3

SAE AMS 2750⁴, Pyrometry

SAE AMS 5844, Alloy, Corrosion-Resistant, Round Bars, 20Cr-35Ni-35Co-10Mo, Vacuum Induction Plus Consumable Electrode Vacuum Remelted, Solution Heat Treated and Work Strengthened

SAE AMS H-6875, Heat Treatment of Steel Raw Materials

¹ NCSL International, 2995 Wilderness Place, Suite 107, Boulder, Colorado 80301-5404, www.ncsli.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

³ NACE International, 15835 Park Ten Place, Houston, TX 77084, www.nace.org

⁴ SAE International, www.sae.org

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

bolting

All-thread studs, tap-end studs, double-ended studs, headed bolts, cap screws, screws, and nuts.

3.1.2

bolting manufacturer

An organization that, through the use of manufacturing equipment and processes appropriate for the bolting product form, transforms raw material into finished bolting.

3.1.3

cold-formed bolts, screws, and nuts

Parts formed through the mechanical cold upsetting of wire, rod, or bar in order to generate the bolt or screw head (cold heading) or the configuration of the nut.

3.1.4

corrosion-resistant bolting

Bolting manufactured from metal that achieves improved resistance to corrosion through the addition of alloying elements.

3.1.5

heat

Material originating from a final melt, or for remelted alloys, the raw material originating from a single remelted ingot.

3.1.6

heat lot

- a) Batch furnace: bolting or raw material of a single heat and diameter, heat treated together as a single solution annealing, quenching, and aging or precipitation hardening charge;
- b) Continuous furnace (applies to ASTM A453 Grade 660 Class D only): bolting or raw material of a single heat and diameter heat treated without interruption in a continuous charge, as defined in ASTM A453.

3.1.7

hot-formed bolts, screws, and nuts

Parts formed through the mechanical hot upsetting of wire, rod, or bar in order to generate the bolt or screw head (hot heading) or the configuration of the nut.

3.1.8

machined bolts, screws, and nuts

Parts manufactured by machining from raw material to generate the bolt, screw head, or the configuration of the nut.

3.1.9

manufacturing process specification

MPS

A written document describing the complete production sequence and method.

NOTE MPSs are usually proprietary by manufacturer and not for general publication, but are available to customers or authorized third parties for information.

3.1.10

production lot

Bolting of a single nominal diameter and grade made from the same heat lot.

3.1.11

raw material

bar, coil, rod, or wire used to manufacture bolting.

3.1.12

raw material supplier

A melting mill where raw material is manufactured to be used in qualified bolting.

NOTE A distributor is not considered a raw material supplier.

3.1.13

technical authority

A competent and technically qualified person or organization with evidence to demonstrate the expertise, skills, and experience regarding quality and manufacturing processes necessary to perform the required verification(s).

3.1.14

wrought structure

A structure that contains no cast dendritic elements.

3.2 Abbreviations

BSL bolting specification level

MPS manufacturing process specification

NDE nondestructive examination

OEM original equipment manufacturer

UT ultrasonic testing

4 Qualification Bolting

4.1 General

4.1.1 This standard states the requirements for two bolting specification levels (BSL) and nine bolting types. The manufacturer may qualify to one or more of the bolting types listed in 1.4 and to one or both BSLs. Each individual bolting type shall be qualified. Qualification to the higher BSL shall qualify to the lower BSL. The following paragraphs describe the conditions that, when met, allow the bolting to meet the appropriate bolting type and BSL classification level.

4.1.2 Qualification bolts and nuts shall be produced from raw material procured from an approved supplier as defined in 5.1 and manufactured in accordance with an applicable manufacturing process specification (MPS) for a bolting material.

4.2 Qualification Testing

4.2.1 Qualification bolting shall be tested and evaluated by the bolting manufacturer in order to establish qualification to the bolting types listed in 1.4 and a BSL. Qualification bolting shall meet all of the requirements indicated in Table 1 for the applicable sections of this standard.

4.2.2 All required tests, including those certified by the raw material supplier, shall be performed by a laboratory qualified in accordance with ISO/IEC 17025. For ultrasonic examination, magnetic particle inspection, and liquid penetrant inspection, qualification to ISO/IEC 17020 is an acceptable alternative to ISO/IEC 17025.

4.2.3 Qualification may be performed on parts specifically manufactured for qualification or random parts selected from a production lot. A sufficient number of parts shall be used to provide adequate material for all required tests.

4.2.4 The manufacturer shall have a quality management system that, at a minimum, meets the requirements of API Q1.

4.2.5 The manufacturer shall retain and have available an MPS (see 5.3) and qualification records (see 4.5) for each product qualified. The qualification records shall show all of the products, processes, and sizes qualified and all of the Table 1 requirements for each qualification, including the results of tests and inspections.

Table 1—Bolting Test Requirements

BSL	Material	Heat Treatment	Chemistry	Mechanical	Metallurgical	Hardness	NDE Surface	NDE Volumetric
BSL-2	5.5.1	5.4.5	5.6	5.7.2	5.8.	5.9.2	5.10.1.1	5.10.1.2
BSL-3	5.5.2	5.4.5	5.6	5.7.3	5.8	5.9.2	5.10.2.1	5.10.2.2

4.3 Materials and Dimensions

4.3.1 The following bolting materials are covered by this standard:

- precipitation hardened nickel-based alloys in accordance with API 6ACRA;
- precipitation hardened austenitic iron-based ASTM A453 Grade 660 Class D;
- cold-reduced only, or cold-reduced and high-temperature aged heat treated condition cobalt-based alloy UNS R30035.

4.3.2 All requirements of API 6ACRA, ASTM A453, or UNS R30035 shall be met, except as modified by this standard. In the case of conflict between the requirements of referenced specifications and this standard, the requirements of this standard shall apply.

4.3.3 For UNS R30035, the bolting manufacturer shall have a written specification that complies with the SAE AMS 5844 chemistry, melting practice, solution annealing, furnace tolerances, and average grain size, with additional requirements shown below.

4.2.1.1 For UNS R30035 with a maximum hardness of 35 HRC, raw material shall be supplied in the solution annealed and cold-reduced condition and not subsequently aged.

4.2.1.2 For UNS R30035 with a maximum hardness of 51 HRC, raw material shall be supplied in the solution annealed, cold-reduced, and one of the aged conditions specified in NACE MR0175-3/ISO 15156-3.

4.2.1.3 UNS R30035 shall only be heat treated/reheat treated by the raw material supplier.

4.3.4 Oversizing of nut threads or undersizing of bolt threads is not permissible.

4.3.5 Welding is not permitted.

4.4 Acceptance of Qualification Bolting

4.4.1 General

Results of the tests specified in Table 1 shall comply with the acceptance criteria specified in Section 5 and the bolting manufacturer's written specification. Results shall be documented in accordance with 4.5.

4.4.2 Qualification Samples

4.4.2.1 Samples failing to meet acceptance criteria shall be cause for re-evaluation of the MPS and the processes and procedures used. Requalification is required.

4.4.2.2 When a qualification sample is selected from a production lot, as defined in 3.1.10, and fails to meet acceptance criteria, the entire lot shall be rejected.

4.4.2.3 Should the manufacturer choose to continue the qualification process with the same lot, the entire lot shall be reprocessed. A maximum of two full reheat treatment cycles is permitted for API 6ACRA alloys and ASTM A453 Grade 660 Class D.

4.4.2.4 For reprocessed lots, all qualification tests shall be repeated. Should any of the qualification tests fail to meet the acceptance criteria, the entire lot shall be rejected.

4.4.2.5 If reprocessing results in any changes to the MPS, the MPS shall be revised to reflect the new process control variables.

4.5 Records of Qualification

The following records are required to document the qualification of bolting:

- a) edition and alloy of API 6ACRA, ASTM A453 Grade 660 Class D (including revision level), or applicable manufacturer specification for UNS R30035 (including revision level);
- b) heat number, heat lot, and production number for API 6ACRA alloys, ASTM A453 Grade 660 Class D, and UNS R30035 materials;
- c) raw material supplier;
- d) raw material refining method;
- e) size;
- f) process control variables;
- g) MPS;
- h) forming, as applicable;
- i) heat treatment;
- j) machining, as applicable;
- k) thread rolling, as applicable;
- l) record of test results, as applicable, in Section 4 and Section 5;
- m) inspection;
- n) personnel qualifications;
- o) test laboratory qualification;
- p) records of qualification test failures and corrective action; and
- q) subcontractor(s) name, address, and records of qualification (as specified in 5.2) for each subcontracted process.

4.6 Limits of Bolting Qualification—BSL-2 and BSL-3

The following are the limits of bolting qualification. A change in any of these variables requires requalification:

- a) change of heat treat method (type of equipment, furnace control method, cooling methods);
- b) addition of raw material supplier not previously qualified in accordance with Section 5;

- c) change of machining or threading methods (type of equipment, control);
- d) change of hot-forming practice (type of equipment, heating method, temperature control method);
- e) for UNS R30035, change in the amount of total cold reduction (work strengthening);
- f) subcontractor of processes listed in 5.2.1.

5 Production of Qualified Bolting

5.1 Qualification of Procurement Sources for Raw Material

5.1.1 Only sources for raw material that are approved by the bolting manufacturer are to be used to supply raw material. The bolting manufacturer shall have a documented and fully implemented procedure for qualifying raw material suppliers for each grade and heat treat condition of material. The approval process shall be based on both a quality assurance evaluation and technical evaluation. The approval process shall establish the methodology by which the raw material supplier will be evaluated on an ongoing basis to maintain their status as an approved supplier.

5.1.2 In addition to the maintenance of a quality management system meeting an applicable standard, such as API Q1 or ISO 9001, the raw material supplier shall maintain documented evidence of their technical capability to produce materials meeting this standard, and shall have documented procedures that demonstrate their capability to consistently produce acceptable product. The methods for the technical approval of a raw material supplier for the two BSL are the following:

- a) BSL-2

Use of three or more of the following four methods:

- raw material receipt inspection that includes volumetric and surface NDE, chemistry check, metallurgical properties, mechanical properties and dimensions, as applicable;
- raw material first article evaluation;
- demonstration of technical capability, such as tests/inspections, quality of material received, nonconformance analysis;
- on-site technical audits at scheduled 3-year intervals, at a minimum.

- b) BSL-3

All of the four methods listed in 5.1.2.a) shall be used.

5.1.3 The bolting manufacturer is responsible for ensuring that a raw material supplier has implemented controls addressing the following for each grade of raw material ordered:

- a) chemistry controls;
- b) melting practice controls;
- c) pouring practice;
- d) hot work practice controls;
- e) heat treatment controls, as applicable;
- f) raw material inspection and acceptance criteria (cleanliness requirements, limitations on porosity or inclusions, grain size, secondary phases, microstructure, as applicable);
- g) controls to assure that no welding was performed.

5.2 Qualification of Suppliers for Subcontracted Operations

5.2.1 General

If any of the following operations are subcontracted, the suppliers of the subcontracted operations shall be qualified by the manufacturer in accordance with this section:

- a) head forging/head forming of individual fasteners;
- b) heat treatment;
- c) threading;
- d) plating/coating;
- e) NDE;
- f) mechanical and hardness testing;
- g) metallurgical examination as specified in 5.8;
- h) chemical analysis.

5.2.2 Qualification Requirements

5.2.2.1 Only qualified suppliers shall be used to perform subcontracted operations. The bolting manufacturer shall have a documented and fully implemented procedure for qualifying subcontracted suppliers for operations performed. The qualification process shall include:

- a) a quality management system evaluation in accordance with ISO 9001 or API Q1 for all bolting specification levels;
- b) an onsite process evaluation performed by a technical authority per methods listed in 5.2.3; and
- c) test laboratory evaluation in accordance with ISO/IEC 17020 (for NDE only) or ISO/IEC 17025, at a minimum.

5.2.2.2 Suppliers of subcontracted operations shall have an onsite technical authority available, and the technical authority's competency shall be documented.

5.2.3 Technical Evaluation

The technical evaluation of suppliers of subcontracted processes shall include the requirements for the various BSls listed in a) and b) below.

- a) BS_L-2 requirements:
 - 1) a quality management system evaluation, ensuring that the subcontractor's QMS is compliant with ISO 9001, API Q1, ISO/IEC 17020 (for NDE only), or ISO/IEC 17025;
 - 2) independent or third-party evidence of conformance to ISO/IEC 17020 or ISO/IEC 17025 for the required laboratory service is acceptable in lieu of an onsite audit or technical evaluation;
 - 3) onsite process audit performed by a technical authority at an interval no greater than 3 years;
 - 4) evaluation of the supplier's documented evidence of technical capability to perform subcontracted operations in accordance with 5.2. At a minimum, the evaluation shall include certifications, calibration of test and measurement equipment, production logs, written procedures, and nonconformance analyses.

b) BSL-3 requirements:

- 1) requirements specified for BSL-2 are required for BSL-3;
- 2) first article evaluation of each subcontracted process per manufacturer's documented procedure.

5.3 Material Specifications

5.3.1 The bolting manufacturer shall prepare and document raw material requirements in the form of a material specification. Material specifications shall include the following items as applicable per the referenced API, ASTM, SAE AMS, NAC/ISO standards, or OEM or bolting manufacturer's purchasing specification:

- a) material grade, including element chemistry and allowable ranges;
- b) acceptable melt practices and ladle refinement;
- c) acceptable hot work reduction range (not required for cold-reduced UNS R30035 material);
- d) acceptable microstructure (applicable to alloys covered by API 6ACRA only);
- e) heat treatment requirements, including mill heat treatments;
- f) mechanical properties;
- g) acceptable inspection practices and criteria, as applicable per BSL.

5.3.2 The bolting manufacturer shall document acceptance of incoming raw material to the requirements of the material specification prior to use in the production of bolting.

5.4 Manufacturing Process Specification

5.4.1 General

The bolting manufacturer shall prepare an MPS to include, at a minimum, allowable levels for all bolting manufacturing parameters, including the process control variables listed in 5.4.2, the forging/hot heading parameters listed in 5.4.3, and the heat treatment parameters listed in 5.4.4.

The requirements of Annex B shall be followed during processing.

5.4.2 General Variables

The following are general variables, as applicable:

- a) heading equipment;
- b) hot-forming heating method;
- c) hot-forming temperature control method;
- d) heat treating equipment and processes;
- e) machining and threading equipment: single point (lathe), multiple chaser, roll, cutting tap; form tap;
- f) machining and threading control methods;
- g) mill source (name and address); and
- h) outsourced activity supplier (name and address).

5.4.3 Forging/Hot Heading Parameters

The following are forging/hot heading parameters, as applicable;

- a) equipment;
- b) heating method (furnace, induction);
- c) temperature control (thermocouple, optical, or infrared pyrometer, fail safe cut-off);
- d) times and temperatures; and
- e) dimensional control.

5.4.4 Heat Treatment Parameters

The following are heat treatment parameters, as applicable:

- a) equipment (batch, continuous);
- b) times and temperatures;
- c) cooling media (e.g. type, polymer concentration, quench temperature, agitation);
- d) control and calibration methods;
- e) furnace load diagram or photo. For mill heat treated products, this requirement is waived, provided that the bolting manufacturer has performed first article evaluation in accordance with 5.1.2 a) 2).

5.4.5 BSL-2 and BSL-3 Requirements

5.4.5.1 Forging and hot heading shall be in accordance with the manufacturer's standard procedure.

5.4.5.2 Heat treatment shall be in accordance with the relevant API, NACE/ISO, or ASTM standard.

5.4.5.3 Heat treatment of API 6ACRA material shall be performed and qualified after the material's final hot-forming operation. Heat treatment equipment qualification and calibration, temperature monitoring, solution annealing, and age hardening times and temperatures shall be in accordance with the requirements of API Standard 6ACRA.

5.4.5.4 Heat treatment of ASTM A453 660 Class D shall be in accordance with ASTM A453.

5.4.5.5 Heat treatment of UNS R30035 shall be in accordance with NACE MR0175-3/ISO 15156-3. Furnace qualification shall be in accordance with API 6A, SAE AMS 2750, or SAE AMS H-6875. Solution annealing and aging furnace tolerance shall be +/- 25 °F.

5.4.5.6 Manufacturing processes shall be performed so as to avoid the introduction of stress risers that can occur from sharp angles and tool marks. Threads may be cut or rolled. Thread form shall be UN for internal threads and UNR for external threads, per ANSI/ASME B1.1.

5.4.5.7 The following apply to material not heat treated by the raw material supplier:

- a) Furnace loading shall be in accordance with API 6HT, Section 6.3.3.
- b) A furnace loading diagram or photo shall be prepared for each load configuration.
- c) Temperature shall be monitored using a contact thermocouple or a heat sink placed at the center of the load.
- d) Water, oil, and polymer quenching media shall be controlled in accordance with API 6HT.

- e) The manufacturer shall have a written forging procedure defining, at a minimum, the parameters defined in 5.4.3. When induction heating is used for forging, the manufacturer's procedure shall include temperature monitoring equipment and an automatic fail-safe system to prevent overheating.

5.4.6 Plating and Coating

5.4.6.1 Plating and coating shall be provided only when specified in the purchase agreement.

5.4.6.2 Plating and coating shall be specified in accordance with the industry standard or the purchaser's specification.

5.5 Raw Material

5.5.1 BSL-2

5.5.1.1 The metal shall have a fully wrought structure.

5.5.1.2 The hot work reduction ratio based on starting material diameter shall be a minimum of 4.0:1. This requirement does not apply to UNS R30035.

5.5.1.3 The metal shall conform to the requirements of the relevant API or ASTM Standard, or to AMS 5844 for UNS R30035.

5.5.1.4 All elements intentionally added to the heat, except those used for processing, shall be reported.

5.5.2 BSL-3

5.5.2.1 The requirements specified for BSL-2 are required for BSL-3.

5.5.2.2 In addition to the heat analysis performed by the mill, the bolting manufacturer shall perform a product analysis in accordance with ASTM A453 Grade 660 Class D, API 6ACRA, or UNS R30035.

5.6 Chemical Analysis

Methods and practices relating to chemical analysis shall be in accordance with ASTM A751 or ASTM A354, as applicable. The frequency of chemical analysis shall be one per heat. Results shall be documented on the test report.

5.7 Mechanical Properties

5.7.1 General

Mechanical properties testing shall be performed by the raw material supplier or bolting manufacturer after all thermal treatments, including precipitation hardening and strain hardening. All mechanical property tests required by the applicable API standard, NACE/ISO standard, ASTM standard, or manufacturer's specification shall be performed on each heat lot. Results shall be documented on the test report.

5.7.2 BSL-2

The results shall conform to the requirements of the relevant API standard, NACE/ISO standard, ASTM standard, or manufacturer's specification for UNS R30035.

5.7.3 BSL-3

The requirements for BSL-2 are required for BSL-3. When any of the testing has been performed by the raw material supplier, the bolting manufacturer shall perform a retest.

5.8 Metallurgical Requirements

Metallurgical requirements shall be performed by the raw material supplier or bolting manufacturer after all thermal treatments, including precipitation hardening and strain hardening. All microstructure tests required by the applicable API standard, NACE/ISO standard, ASTM standard, or manufacturer's specification shall be performed on each heat lot. Results shall be documented on the test report. The microstructure of nickel base alloys shall conform to the requirements of API 6ACRA.

5.9 Examination and Test Requirements

5.9.1 General

When inspecting or testing production lots, a sample that fails to meet the applicable requirements shall result in rejection of the entire lot. The rejected lot shall be scrapped, reworked, or, where practical, inspected 100 %, and the defective parts removed. In the case of rework or 100 % inspection, the lot shall be re-inspected or tested for the failed characteristic and any characteristic affected by rework.

5.9.2 Hardness Test Requirements

5.9.2.1 General

Hardness testing, including specimen preparation, shall be performed in accordance with ASTM A370, including Annex A3, except that testing shall also be in conformance with ASTM E10 or ASTM E18. Results shall be documented on the test report.

5.9.2.2 BSL-2 and BSL-3

The hardness test results shall conform to the requirements of API 6ACRA, ASTM A453, or NACE MR0175-3/ISO 15156-3 for UNS R30035. Each piece shall be tested.

5.10 Nondestructive Examination (NDE) Requirements

5.10.1 BSL-2

5.10.1.1 Surface NDE is required. Liquid penetrant examination is required for ASTM A453 Grade 660 Class D, the alloys covered by API 6ACRA, and UNS R30035. Liquid penetrant examination shall be in accordance with ASTM A962 S56. Acceptance criteria shall be per ASTM A962 S57. The number of pieces examined shall be as stated in Table 2. Results shall be documented on an examination report.

5.10.1.2 Volumetric NDE is required on bar, rod, and wire, and on bolting 2.5 in. (63.5 mm) or greater nominal diameter prior to threading and after any heading and heat treat operations, with the exception of aging performed after threading. Ultrasonic examination shall be performed in conformance with the methods and acceptance criteria of API 6A, volumetric NDE examination of stems (PSL-3). Each piece shall be examined. Results shall be documented on the test report.

5.10.2 BSL-3

5.10.2.1 Surface NDE is required. Liquid penetrant examination is required for ASTM A453 Grade 660 Class D, the alloys covered by API 6ACRA, and UNS R30035. Liquid penetrant examination shall be in accordance with ASTM A962 S56. Acceptance criteria shall be per ASTM A962 S57. Each piece shall be examined. Results shall be documented on an examination report.

5.10.2.2 Volumetric NDE is required on bar, rod, and wire, and on bolting 1 in. (25.4 mm) or greater nominal diameter prior to threading and after any heading or heat treat operations, with the exception of aging performed after threading. Ultrasonic examination shall be performed in conformance with the methods and acceptance criteria of API 6A, volumetric NDE examination of stems (PSL-3). Each piece shall be examined. Results shall be documented on the test report.

5.11 Dimensional Inspection and Visual Inspection

5.11.1 General

All dimensions shall meet the requirements of ASTM A962. Visual inspection shall be performed in accordance with ASTM F788 and ASTM F812. Dimensions not specified by ASTM A962 shall be as specified by the purchaser. Results shall be documented on an inspection report. Oversizing of nut threads or undersizing of bolt threads is not permissible.

5.11.2 BSL-2 Sample Size

Sample size shall be in accordance with Table 2.

5.11.3 BSL-3 Sample Size

Each piece shall be dimensionally inspected.

Table 2—Sampling for Dimensional, Surface NDE, and Visual Inspection

Lot Size	Sample Size
2 to 8	ALL
9 to 50	8
51 to 90	13
91 to 150	20
151 to 280	32
281 to 500	50
501 to 1200	80
Based on ANSI/ASQ Z1.4 Table 1	General Inspection Level II

NOTE 1 Acceptance number is zero.
 NOTE 2 Sample shall be random.

5.12 Final Positive Material Identification

5.12.1 General

Pieces shall be examined using methods conforming to ASTM E1476 and ASTM A751 to confirm the material type.

5.12.2 BSL-2 Sample Size

Sample size shall be in accordance with Table 2. If any of the samples fail, the entire lot shall be examined.

5.12.3 BSL-3 Sample Size

Each piece shall be examined.

6 Calibration Systems

Inspection, measuring, and testing equipment used for acceptance shall be identified, inspected, calibrated, and adjusted at specific intervals in accordance with ANSI/NCSL Z540.3 and this standard. Calibration standards shall be traceable to the applicable national or international standards agency and shall be no less stringent than the requirements included herein. Inspection, measuring, and testing equipment shall be used only within the calibrated range. Calibration intervals shall be established based on repeatability and degree of usage.

7 Test Report

The test report shall be supplied to the purchaser and shall include the following as applicable:

- copy of original mill certificate;
- cold-reduced production run number (for UNS R30035 only);
- chemistry check analysis;
- hot work reduction ratio (not required for UNS R30035);
- heat treat procedure, including times, temperatures, and quench media, and diagram or photo of furnace loading (diagram or photo exception for mill heat treated bar; see 5.4.4.e);
- results of mechanical tests;
- results of macrostructure evaluations (not required for Grade 660D or UNS R30035);
- results of microstructure evaluations (not required for Grade 660D or UNS R30035);
- results of dimensional inspection;
- results of any surface modification operations, if applicable, per Section 5.4.6;
- results of NDE inspections;
- BSL qualification level;
- certification that the product meets the requirements of this standard;
- results of Positive Material Identification;
- additional certification requirements stated in API 6ACRA and ASTM A453, and the purchaser's or manufacturer's specification for UNS R30035;
- statement of no weld repair.

8 Marking Requirements

8.1 Product Marking

8.1.1 Product marking for Grade 660 Class D shall be in accordance with ASTM A453.

8.1.2 Product marking for API 6ACRA and UNS R30035 shall consist of the manufacturer's identification and the grade identification listed in Table 3.

Table 3—API 6ACRA and UNS R30035 Grade Identification Markings

API 6ACRA or UNS and Material Designation	Marking
N07716 120K	N1A
N07716 140K	N1B
N07718 120K	N2A
N07718 140K	N2B
N07725 120K	N3A
N09925 110K	N4A
N09935 110K	N5A
N09945 125K	N6A
N09946 140K	N7A
N09946 150K	N7B
N09946 160K	N7C
R30035 work strengthen only	R3A
R30035 work strengthen and aged 1300 °F	R3B
R30035 work strengthen and aged 1350 °F	R3C
R30035 work strengthen and aged 1425 °F	R3D
R30035 work strengthen and aged 1450 °F	R3E
R30035 work strengthen and aged 1475 °F	R3F
R30035 work strengthen and aged 1500 °F	R3G

8.2 Additional Marking Required by this Standard

Bolting shall be marked with unique heat lot identification and the following:

- a) "20F2" for BSL-2;
- b) "20F3" for BSL-3.

Each piece 1 in. (25.4 mm) nominal diameter and larger shall be marked. For bolting less than 1 in. (25.4 mm) nominal diameter, the bolting shall be securely containerized to maintain heat lot identification and traceability. Multiple heat lots shall not be mixed in a single container. Containers used in the processing, storing, and shipping of bolting not individually marked shall be clearly labeled with all marking information required by the ASTM specification, as applicable, and this standard.

9 Record Retention

The bolting manufacturer shall establish and maintain documented procedures to control all documents and data required by this standard. Records required by this standard shall be maintained for a minimum of 10 years from the date of manufacture. Documents and data may be in any type of media (hard copy or electronic) and shall be:

- maintained to demonstrate conformance to specified requirements;
- legible;
- retained and readily retrievable;
- stored in an environment to prevent loss.

10 Storage and Shipping

Bolting shall be packaged for storage and shipping in accordance with the written specifications of the bolting manufacturer.

Annex A (informative)

API Monogram Program Use of the API Monogram by Licensees

The information in this annex has been intentionally removed.

See API Specification Q1 (Annex A) or the API website for information pertaining to the API Monogram Program and use of the API Monogram on applicable products.

Annex B (normative)

Avoidance of Contamination of Nickel Alloys

B.1 Introduction

Nickel alloys may become contaminated during various manufacturing operations. Contamination with some substances may result in embrittlement and cracking failures, while contamination with other substances may result in pitting and corrosion failures.

B.2 Lubricants

Sulfur can embrittle nickel alloys at elevated temperatures, such as those used for heat treating or forging the nickel alloys. Sulfur-containing lubricants may be used during manufacturing, but shall be completely removed prior to any hot forging or heat treatment operations.

Chlorine can promote pitting corrosion of nickel alloys after long exposure. Chlorine-containing lubricants may be used for cold forming but shall be completely removed after the forming operations.

Pigmented oils and greases should be selected with care. Oils and greases with lead carbonate, zinc oxide, or other low melting point metals shall not be used. These low melting point metallic compounds can embrittle nickel alloys during exposure to elevated temperatures, such as those used for heat treating or forging nickel alloys.

B.3 Marking Materials

Markers containing sulfur, chlorine, phosphorus, and low melting point metals can cause embrittlement or corrosion issues as described above and shall not be used.

Bibliography

- [1] ASTM A193-15, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*, 2015



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