

Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries

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Alloy and Carbon Steel 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 alloy and carbon steel 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

This standard establishes requirements for three bolting specification levels (BSLs). These three BSL designations define different levels of technical, quality, and qualification requirements, BSL-1, BSL-2, and BSL-3. The BSLs are numbered in increasing levels of requirements in order to reflect increasing technical, quality, and qualification criteria.

1.4 Bolting Types

This standard covers the following finished 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 (BSL-1 only);
- d) hot formed bolts and screws <1.5 in. (38.1 mm) nominal diameter;
- e) hot formed bolts and screws \geq 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 \geq 1.5 in. (38.1 mm) diameter;
- h) hot formed nuts <1.5 in. (38.1 mm) nominal diameter;
- i) hot formed nuts \geq 1.5 in. (38.1 mm) nominal diameter.

1.5 Application of the API Monogram

If product is manufactured at a facility licensed by API and is intended to be supplied bearing the API Monogram, the requirements of Annex A apply.

2 Normative References

The following documents contain provisions that, through reference in this text, constitute provisions of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document (including amendments) applies.

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

API 6A, 20th Edition, *Specification for Wellhead and Christmas Tree Equipment*

API 6HT, 2nd Edition, *Heat Treatment and Testing of Carbon and Low Alloy Steel Large Cross Section and Critical Section Components*

ASTM ¹ A29/A29M, *Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought*

ASTM A193, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194, *Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service or Both*

ASTM A320, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low Temperature Service*

ASTM A370, *Standard Test Method and Definitions for Mechanical Testing of Steel Products*

ASTM A540, *Standard Specification for Alloy Steel Bolting for Special Applications*

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

ASTM A941, *Standard Terminology Relating to Steel, Stainless Steel, Related Alloys and Ferroalloys*

ASTM A962, *Standard Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range*

ASTM B850-98(15), *Standard Guide for Post-Coating Treatments of Steel for Reducing the Risk of Hydrogen Embrittlement*

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

ASTM E18, *Standard Test Method for Rockwell Hardness of Metallic Materials*

ASTM E45, *Standard Test Method for Determining the Inclusion Content of Steel*

ASTM E112, *Standard Test Method for Determining Average Grain Size*

ASTM E381, *Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ASTM E1268, *Standard Practice for Assessing Degree of Banding or Orientation of Microstructure*

ASTM F519, *Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments*

ASTM F606, *Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets*

ASTM F1470-12, *Standard Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection*

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ANSI/NCSL ² Z540.3, *Requirements for the Calibration of Measuring and Test Equipment*

ISO 17025 ³, *General Requirements for the Competence of Testing and Calibration Laboratories*

SAE AMS2750 ⁴, *Pyrometry*

SAE AMSH6875, *Heat Treatment of Steel Raw Materials*

3 Terms, Definitions, 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 (at a temperature below the recrystallization temperature) up-setting 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

heat

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

3.1.5

heat lot

- a) Batch furnace: bolting or raw material of a single heat and diameter, heat treated together as a single austenitizing, quenching, tempering, and stress-relieving charge.
- b) Continuous furnace: bolting or raw material of a single heat and diameter heat treated without interruption in a continuous charge (see 5.7).

3.1.6

hot formed bolts, screws, and nuts

Parts formed through the mechanical hot (at a temperature above the recrystallization temperature) up-setting of wire, rod, or bar in order to generate the bolt or screw head (hot heading) or the configuration of the nut.

3.1.7

machined bolts, screws and nuts

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

² American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

³ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

⁴ SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096, www.sae.org.

3.1.8**manufacturing process specification**

A written document describing the complete production sequence and method.

NOTE Manufacturing process specification is usually proprietary by manufacturer and not for general publication but is available for review by customers or authorized third parties.

3.1.9**production lot**

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

3.1.10**raw material**

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

3.1.11**raw material supplier**

The manufacturer of raw material used to produce qualified bolting defined as the steel mill or forging supplier.

NOTE A distributor is not considered a raw material supplier.

3.1.12**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).

3.1.13**wrought structure**

Structure that contains no cast dendritic elements.

3.2 Abbreviations

BSL bolting specification level

MPS manufacturing process specification

NDE nondestructive examination

4 Qualification Bolting**4.1 General**

4.1.1 This standard states the requirements for three BSLs and nine bolting types. The manufacturer may qualify to one or more of the bolting types listed in 1.4 and to one or more BSLs. Each individual bolting type shall be qualified. Qualification to a higher BSL shall qualify to a 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) from a bolting material grade listed in 4.3.1.

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.

Table 1—Bolting Test Requirements

BSL	Material	Forge/Heat Treat	Chemistry	Mechanical	Metallurgical	Hardness	NDE Surface	NDE Volumetric
BSL-1	5.5.1	5.4.5	5.6	5.7.1	5.8.2	5.9.2.2	5.10.1	—
BSL-2	5.5.2	5.4.6	5.6	5.7.2	5.8.3	5.9.2.3	5.10.2.1	5.10.2.2
BSL-3	5.5.3	5.4.7	5.6	5.7.2	5.8.4	5.9.2.4	5.10.3.1	5.10.3.2

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 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.

4.3 Materials and Dimensions

4.3.1 The following bolting material grades are covered by this standard:

- ASTM A193 Grades B7 and B7M;
- ASTM A194 Grades 2H, 4, 7, 2HM, and 7M;
- ASTM A320 Grades L7, L7M, and L43;
- ASTM A540 Grades B22 and B23;
- equipment manufacturer's proprietary bolting material specification.

4.3.2 All requirements of the referenced ASTM specifications or the equipment manufacturer's proprietary bolting material specification 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. Bolting manufactured from proprietary materials shall conform to the requirements of this standard.

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

4.3.4 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 reevaluation of the MPS and the processes and procedures used, and requalification is required.

4.4.2.2 When a qualification sample selected from a production lot, defined in 3.1.9, 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 treatments is permitted.

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) ASTM specification number, edition, and grade or the equipment manufacturer's proprietary bolting material specification;
- b) heat number;
- c) steel manufacturer;
- d) steel 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 Sections 4 and 5;
- m) inspection;
- n) personnel qualifications;
- o) test laboratory qualification;
- p) records of qualification test failures and corrective action;
- q) subcontractor(s) name and address and records of qualification (as specified in 5.2) for each subcontracted process.

4.6 Limits of Bolting Qualification

4.6.1 BSL-1

A change of heat treat method (type of equipment, furnace control method, cooling methods) requires

requalification.

4.6.2 BSL-2 and BSL-3

Limits of bolting qualification for BSL-1 are required for BSL-2 and BSL-3. Additionally, the following changes require requalification:

- a) change of raw material supplier;
- b) change of machining or threading methods or equipment;
- c) change of hot forming practice—type of equipment, heating method, and temperature control method;
- d) subcontractor of processes listed in 5.2.1 a), b), c), and d).

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 and a technical evaluation. The approval process shall establish the methodology by which the raw material supplier will be evaluated on an ongoing basis to maintain 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 technical capability to produce materials meeting this standard and shall have documented procedures that demonstrate capability to consistently produce acceptable product. The methods for the technical approval of a raw material supplier for the various BSLs are the following:

- a) BSL-1—use of one or more of the following four methods:
 - 1) raw material receipt inspection that includes nondestructive examination (NDE), chemistry check, macroetch, etc.;
 - 2) raw material first article evaluation;
 - 3) demonstration of technical capability, such as tests/inspections, quality of material received, nonconformance analysis, etc.;
 - 4) onsite technical audits at scheduled 3-year intervals, at a minimum.
- b) BSL-2—three of the four methods listed in 5.1.2.a) shall be used.
- c) BSL-3—all of the 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, macrostructure, etc., as applicable);
- g) no welding.

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 be based on the following.

5.2.2.1.1 A quality management system evaluation in accordance with ISO 9001, API Q1, or ISO 17025 for all BSLs.

5.2.2.1.2 An onsite process evaluation performed by a technical authority per methods listed in 5.2.3.

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 methods for the technical evaluation of a subcontractor for the various BSLs are listed in a), b), and c) below:

- a) BSL-1 requirements.

A quality management system evaluation in accordance with ISO 9001, API Q1, or ISO 17025.

- b) BSL-2 requirements.

- 1) Requirements specified for BSL-1 are required for BSL-2.
- 2) Onsite process audit performed by a technical authority at an interval no greater than 3 years.

- 3) Evaluation of the supplier's documented evidence of technical capability to perform subcontracted operations in accordance with 5.4. At a minimum, the evaluation shall include certifications, production logs, written procedures, and nonconformance analyses.
- c) BSL-3 requirements.
 - 1) Requirements specified for BSL-1 and 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 In addition to the requirements of 4.3, the bolting manufacturer shall prepare and document raw material requirements in the form of a material specification. For BSL-1, this may be the applicable ASTM specification. For BSL-2 and BSL-3, material specifications shall include the following:

- a) material grade, including element chemistry and allowable ranges;
- b) acceptable melt practices and ladle refinements, as applicable per BSL;
- c) acceptable hot work reduction range, as applicable per BSL;
- d) acceptable cleanliness level range, as applicable per BSL;
- e) heat treatment requirements, as applicable per BSL;
- f) mechanical properties, as applicable per BSL;
- 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, as a minimum, allowable levels for all bolting manufacturing parameters including the process control variables listed in 5.4.2 and the heat treatment parameters listed in 5.4.3.

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);
- 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;
- e) dimensional control.

5.4.4 Heat Treatment Parameters

The following are heat treat parameters, as applicable:

- a) equipment (batch, continuous, induction, direct resistance);
- b) times and temperatures;
- c) cooling media (e.g. type, polymer concentration, quench temperature, agitation);
- d) control and calibration methods;
- e) maximum transfer time;
- f) quench media start and finish temperature;
- g) furnace load diagrams.

5.4.5 BSL-1 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 applicable standard listed in 4.3.1.

5.4.5.3 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. External Unified National Threads shall be "R" (UNR controlled radius root) series.

5.4.5.4 Furnace calibration shall be in accordance with API 6A, Annex M; SAE AMS2750; or SAE AMSH6875. For induction or direct resistance heat treatment, calibration shall be in accordance with the manufacturer's written procedure. For forging furnaces, calibration shall be in accordance with the manufacturer's written procedure.

5.4.6 BSL-2 Requirements

5.4.6.1 Requirements specified for BSL-1 are required for BSL-2.

5.4.6.2 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 equipment shall include temperature monitoring equipment and an automatic fail-safe system to prevent overheating.

5.4.6.3 ASTM A320 Grade L43, ASTM A540 Grade B23, and the equipment manufacturer's proprietary bolting material specification based on AISI 4340 material shall be double tempered.

5.4.6.4 When threads are rolled, parts shall subsequently be stress relieved at a temperature within 50 °F (28 °C) of, but not exceeding, the final tempering temperature.

5.4.6.5 Furnace loading shall be in accordance with API 6HT, Section 6.3.3.

5.4.6.6 Furnace loading diagram shall be prepared for each load configuration.

5.4.6.7 Water, oil and polymer quenchant media shall be controlled in accordance with API 6HT, Section 6.2.2.

5.4.7 BSL-3 Requirements

5.4.7.1 Requirements specified for BSL-2 are required for BSL-3.

5.4.7.2 A minimum of one contact thermocouple attached to a part shall be used to verify heat treatment times and temperatures. This referenced thermocoupled part shall be placed either in a location deemed to have the slowest heating rate or centrally in the furnace load.

5.4.7.3 Batch process heat treatment is allowed.

5.4.7.4 Continuous process heat treatment is prohibited.

5.4.7.5 Induction and direct resistance heat treatments are prohibited for normalizing, austenitizing, tempering, and stress relieving operations.

5.4.8 Plating and Coating

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

5.4.8.2 Plating and coating shall be specified in accordance with industry or the equipment manufacturer's proprietary bolting material specification.

5.4.8.3 Zinc electroplating is not permitted for splash zone or subsea service.

5.4.8.4 Internal hydrogen embrittlement prevention:

— All electroplated parts (regardless of strength level) shall be baked within 2 hours after plating at 375 °F–425 °F (191 °C–218 °C) for 8 hours minimum at temperature.

NOTE Refer to ASTM B850-98(15) Class ER9.

— The requirements of 5.4.5.4 shall apply to the ovens used for baking.

— Control of the electroplating bath shall be in conformance with ASTM F519 on sample strengths referenced in ASTM F519, verified at a frequency of not more than 60 days. Acceptance criteria shall be a tensile sample (type 1a.1) with no failure after 200 hours at 75 % UTS.

5.4.8.5 The following shall be specified when ordering plating and coating:

- a) part description;
- b) specification number and revision (year date for ASTM specifications);
- c) description of plating/coating including type, thickness, finish, and other applicable requirements;
- d) requirement for supplier's statement of conformance with 5.4.8 of this document.

5.5 Raw Material

5.5.1 BSL-1

5.5.1.1 The steel shall be fully wrought.

5.5.1.2 The reduction ratio based on starting material diameter shall be a minimum of 4:1.

5.5.1.3 The steel shall conform to the requirements of the standards listed in 4.3.1, as applicable.

5.5.1.4 Intentional additions of boron are not allowed.

5.5.1.5 All elements intentionally added to the heat shall be reported.

5.5.2 BSL-2

5.5.2.1 The requirements specified for BSL-1 are required for BSL-2.

5.5.2.2 Melting method of the raw material shall be fine grain practice as defined by ASTM A941. Steel shall be produced by electric furnace or vacuum induction melting followed by secondary refining practices or ladle refining.

5.5.2.3 The allowable sulfur content shall be 0.025 % maximum, and the allowable phosphorus content shall be 0.025 % maximum.

5.5.2.4 Residual boron content shall not exceed 0.0005 %.

5.5.3 BSL-3

5.5.3.1 The requirements specified for BSL-2 are required for BSL-3 except as specified below.

5.5.3.2 The reduction ratio based on starting material diameter shall be 10:1 minimum.

5.5.3.3 Allowable sulfur content shall be 0.015 % maximum, and the allowable phosphorus content shall be 0.015 % maximum.

5.5.3.4 The continuous cast steel making process is prohibited.

5.5.3.5 In addition to the heat analysis performed by the raw material supplier, the bolting manufacturer shall perform a product analysis in accordance with ASTM A29.

5.6 Chemical Analysis

Methods and practices relating to chemical analysis shall be in accordance with ASTM A751. The frequency for 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 stress relief. When heat treated without interruption in continuous furnaces, as defined in 3.5.1, testing shall be as follows: Not fewer than two tests for the first 20,000 lb. (9000 kg) or less, and an additional test for every 10,000 lb. (4500 kg) or fraction thereof.

Results shall be documented on the test report.

5.7.2 BSL-2 and 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

5.8.1 General

The following tests shall be performed, as applicable to the specified BSL. Any of the specified tests not performed by the raw material supplier shall be performed by the bolting manufacturer. Results shall be documented on the test report.

5.8.2 BSL-1

The microstructure and macrostructure shall conform to the requirements of the standards listed in 4.3.1, as applicable.

5.8.3 BSL-2

5.8.3.1 Microstructure Testing

5.8.3.1.1 General

Microstructure specimens shall be tested in accordance with ASTM E45, Method A, for inclusion content. For other microstructure evaluations, the specimens shall be taken in the longitudinal direction at $\frac{1}{4}T$.

5.8.3.1.2 Inclusion Content

The microstructure shall conform to the requirements of Table 2. One test shall be conducted per heat.

5.8.3.1.3 Grain Size

Grain size shall be determined for each heat in accordance with ASTM E112 following etching with a suitable reagent. Grain size shall conform to Table 2.

5.8.3.1.4 Microstructure

The microstructure shall be predominately tempered martensite. One test shall be performed per each heat.

5.8.3.1.5 Banding

Heavily banded microstructures, as shown in ASTM E1268, Figure A1.20, are not permitted. When a banded structure is observed of questionable acceptability, a minimum of 3 Knoop micro-hardness readings per test, in accordance with ASTM E384, shall be taken on the most predominate bands. The test load shall be 500 g, unless extremely thin bands are observed that will not permit an accurate 500 g test, in which case it is

permissible to reduce the test load to as low as 50 g to obtain an accurate reading. Individual readings shall not exceed 470 HK. One test shall be conducted per heat.

NOTE A banded microstructure in this specification refers to the presence of a featureless phase that etches white in etchants such as nital. When present, this phase appears as white featureless bands. These bands may have extremely high hardness levels and should be confirmed by micro-hardness testing across the width of the bands.

Table 2—Microstructure and Macrostructure Requirements for BSL-2 and BSL-3

Test	BSL-2	BSL-3
Inclusion content, ASTM E45 Method A	Severity Level Number 2 for thin, 1.5 for thick, all categories	Severity Level Number 2 for thin, 1.5 for thick, all categories
Inclusion test frequency	One per heat	One per heat
Grain size	Size 5 or finer	Size 5 or finer
Grain size test frequency	One per each heat	One per each heat lot
Microstructure	Predominately tempered martensite	Predominately tempered martensite
Microstructure test frequency	One per each heat (after heat treat)	One per each heat lot
Macrostructure testing	ASTM E381 S1, R1, C2	ASTM E381 S1, R1, C2
Macrostructure test frequency	One per heat	One per heat
Banding	ASTM E1268 Figure A1.20 is not permitted	ASTM E1268 Figure A1.20 is not permitted
Banding test frequency	One per each heat	One per each heat lot

5.8.3.2 Macrostructure Testing

Macrostructure specimens shall be prepared and evaluated in accordance with ASTM E381 and ASTM A962. The results shall meet the requirements of Table 2. One test shall be conducted per heat.

5.8.4 BSL-3

5.8.4.1 Requirements specified for BSL-2 are required for BSL-3.

5.8.4.2 For grain size and banding, one test shall be performed per each heat lot.

5.8.4.3 When any banding is observed, the hardness test evaluation required under BSL-2 shall be required for a minimum of 2 bands.

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 the 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 reinspected 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-1

5.9.2.2.1 Hardness Testing of Bars and Fasteners

The hardness test results shall conform to the requirements of ASTM A193, ASTM A194, ASTM A320, ASTM A540 or the equipment manufacturer's proprietary material specification as applicable, except that maximum hardness for Grades B7, L7, 2H, 4, 7, L43, B22, B23 and the equipment manufacturer's proprietary material specification shall not exceed 34 HRC (319 HBW). Test frequency shall conform to ASTM F1470, Table 3, sample size A except when 100 % hardness testing is required by the ASTM specification for the grade.

5.9.2.2.2 Hardness Testing of Bars Heat Treated by Induction or Electric Resistance Methods

For bars heated by induction or electric resistance methods, a cross section of the bar shall be taken at the same test frequency as the required for lot testing of the heat-treated bar per ASTM A193. The cross-section shall be ground and a Rockwell hardness traverse performed with tests as close to the edge as permitted by ASTM E18, approximately mid radius, and approximately center. All hardness measurements in the traverse shall meet the acceptance criteria of 5.9.2.2.1.

5.9.2.2.3 Electromagnetic testing for hardness in accordance with ASTM A193 is permitted.

5.9.2.3 BSL-2

5.9.2.3.1 Hardness Testing of Bars and Fasteners

Hardness testing requirements specified for BSL-1 are required for BSL-2 except that when a hardness traverse for bars heat treated by induction or electric resistance methods is required, all readings shall be within 3 HRC.

5.9.2.3.2 Hardness Testing of Fasteners

Each piece shall be tested.

5.9.2.3.3 Nuts Not Subject to Mandatory Proof Load

For nuts not listed in ASTM A194 Tables 3 and 4, a sample nut from each heat lot shall be sectioned and the cross-section hardness tested in accordance with ASTM F606 or ASTM A370. Hardness shall meet the acceptance criteria of 5.9.2.2.1.

5.9.2.4 BSL-3

5.9.2.4.1 Hardness testing requirements specified for BSL-2 are required for BSL-3.

5.9.2.4.2 Electromagnetic testing for hardness is not permitted.

5.10 Nondestructive Examination Requirements

5.10.1 BSL-1

No requirements except as required by the referenced ASTM specification.

5.10.2 BSL-2

5.10.2.1 Surface NDE is required. Either magnetic particle examination or liquid penetrant examination is permitted. Magnetic particle examination shall be in accordance with ASTM A962 S55, including personnel qualification. Liquid penetrant examination shall be in accordance with ASTM A962 S56, including personnel qualification. Acceptance criteria shall be per ASTM A962 S57. Five (5) % of the pieces shall be examined. Results shall be documented on an examination report.

5.10.2.2 Ultrasonic examination is required on bar, rod, wire, or bolting with a diameter greater than 2.5 in. (63.5 mm) nominal after heat treatment and prior to threading. Ultrasonic examination shall be performed in accordance with API 6A volumetric NDE examination of stems (PSL-3 and PSL-4), including personnel qualification. Each piece shall be examined. Results shall be documented on the test report.

5.10.3 BSL-3

5.10.3.1 Surface NDE requirements specified for BSL-2 are required for BSL-3 except each piece shall be inspected.

5.10.3.2 Ultrasonic examination is required on bar, rod, wire, or on bolting of diameters 1 in. (25.4 mm) nominal and larger after heat treatment and prior to threading. Ultrasonic examination shall be performed in accordance with API 6A volumetric NDE examination of stems (PSL-3 and PSL-4), including personnel qualification. Each piece shall be examined. Results shall be documented on the test report.

5.11 Dimensional and Visual Inspection

5.11.1 General

All dimensions and visual inspections shall meet the requirements of the applicable ASTM or the equipment manufacturer's proprietary material specification. Inspections shall be performed prior to coating. Results shall be documented on an inspection report. Oversizing of nut threads or under sizing of bolt threads is not permissible.

5.11.2 BSL-1 Sample Size

Sample size shall be as required by the applicable ASTM specification.

5.11.3 BSL-2 Sample Size

Sample size shall be in accordance with Table 3.

5.11.4 BSL-3 Sample Size

Each piece shall be dimensionally and visually inspected.

Table 3—Sampling for Dimensional 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.	

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

7.1 General

The test report shall be supplied to the purchaser and shall include the following.

7.2 BSL-1

BSL-1 test reports are as required by the applicable ASTM or equipment manufacturer's proprietary material specification.

7.3 BSL-2 and BSL-3

BSL-2 and BSL-3 test reports include the following, as applicable:

- copy of original mill certification;
- hot work reduction ratio;
- heat treat procedure including times, temperatures, quench media, and diagram or photo of furnace loading;
- results of mechanical tests;
- results of macrostructure evaluations;
- results of microstructure evaluations;

- results of dimensional inspection;
- results of NDE inspections;
- BSL qualification level;
- certification that the product meets the requirements of this standard;
- statement of no weld repair.

8 Marking

8.1 ASTM Product Marking

Product marking shall be in accordance with ASTM A193, ASTM A194, ASTM A320, ASTM A540, ASTM A962 or the equipment manufacturer's proprietary bolting material specification, as applicable.

NOTE The referenced ASTM specifications require marking of individual parts for headed bolting $\frac{1}{4}$ in. nominal diameter and larger, for studs $\frac{3}{8}$ in. nominal diameter and larger and for nuts of all sizes.

8.2 Marking Required by This Specification

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

- a) "20E1" for BSL-1,
- b) "20E2" for BSL-2,
- c) "20E3" for BSL-3.

Each piece 1 in. nominal diameter and larger shall be marked. For bolting less than 1 in. 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 relevant ASTM or equipment manufacturer's proprietary bolting material specifications 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 10 years. Documents and data may be in any type of media (hard copy or electronic) and shall be:

- a) maintained to demonstrate conformance with specified requirements,
- b) legible,
- c) retained and readily retrievable,
- d) stored in an environment to prevent loss,
- e) available and auditable by user/purchaser.

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**

A.1 Scope

A.1.1 Applicability

This annex is normative (mandatory) for products supplied bearing the API Monogram and manufactured at a facility licensed by API; for all other instances it is not applicable.

A.1.2 General

The API Monogram® is a registered certification mark owned by the American Petroleum Institute (API) and authorized for licensing by the API Board of Directors. Through the API Monogram Program, API licenses product manufacturers to apply the API Monogram to products which comply with product specifications and have been manufactured under a quality management system that meets the requirements of API Q1. API maintains a complete, searchable list of all Monogram licensees on the API Composite List website (www.api.org/compositelist).

The application of the API Monogram and license number on products constitutes a representation and warranty by the licensee to API and to purchasers of the products that, as of the date indicated, the products were manufactured under a quality management system conforming to the requirements of API Q1 and that the product conforms in every detail with the applicable standard(s) or product specification(s). API Monogram program licenses are issued only after an on-site audit has verified that an organization has implemented and continually maintained a quality management system that meets the requirements of API Q1 and that the resulting products satisfy the requirements of the applicable API product specification(s) and/or standard(s). Although any manufacturer may claim that its products meet API product requirements without monogramming them, only manufacturers with a license from API can apply the API Monogram to their products.

Together with the requirements of the API Monogram license agreement, this annex establishes the requirements for those organizations that wish to voluntarily obtain an API license to provide API monogrammed products that satisfy the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program requirements.

For information on becoming an API Monogram Licensee, please contact API, Certification Programs, 1220 L Street NW, Washington, DC 20005 or call (202) 682-8145 or by email at certification@api.org.

A.2 Normative References

In addition to the referenced standards listed earlier in this document, this annex references the following standard:

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

For Licensees under the Monogram Program, the latest version of this document shall be used. The requirements identified therein are mandatory.

A.3 API Monogram Program: Licensee Responsibilities

A.3.1 Monogram Program Requirements

For all organizations desiring to acquire and maintain a license to use the API Monogram, conformance with the following shall be required at all times:

- a) quality management system requirements of API Q1;
- b) API Monogram Program requirements of API Q1, Annex A;
- c) requirements contained in the API product specification(s) to which the organization is licensed;
- d) requirements contained in the API Monogram Program License Agreement.

A.3.2 Control of the Application and Removal of the API Monogram

Each licensee shall control the application and removal of the API Monogram in accordance with the following:

- a) products that do not conform to API specified requirements shall not bear the API Monogram;
- b) each licensee shall develop and maintain an API Monogram marking procedure that documents the marking/monogramming requirements specified by this annex and any applicable API product specification(s) and/or standard(s). The marking procedure shall:
 - 1) define the authority responsible for application and removal of the API Monogram and license number;
 - 2) define the method(s) used to apply the Monogram and license number;
 - 3) identify the location on the product where the API Monogram and license number are to be applied;
 - 4) require the application of the date of manufacture of the product in conjunction with the use of the API Monogram and license number;
 - 5) require that the date of manufacture, at a minimum, be two digits representing the month and two digits representing the year (e.g. 05-12 for May 2012) unless otherwise stipulated in the applicable API product specification(s) or standard(s);
 - 6) define the application of all other required API product specification(s) and/or standard(s) marking requirements.
- c) only an API licensee shall apply the API Monogram and its designated license number to API monogrammmable products;
- d) the API Monogram and license number, when issued, are site specific and subsequently the API Monogram shall only be applied at that site-specific licensed facility location;
- e) the API Monogram may be applied at any time appropriate during the production process but shall be removed in accordance with the licensee's API Monogram marking procedure if the product is subsequently found to be out of conformance with any of the requirements of the applicable API product specification(s) and/or standard(s) and API Monogram Program.

For certain manufacturing processes or types of products, alternative API Monogram marking procedures may be acceptable. Requirements for alternative API Monogram marking are detailed in the API Monogram Program Alternative Marking of Products License Agreement, available on the API Monogram Program website at http://www.api.org/products-and-services/api-monogram-and-apiqr/apply-renew#tab_documents.

A.3.3 Design and Design Documentation

Each licensee and/or applicant for licensing shall maintain current design documentation as identified in API Q1 for all of the applicable products that fall under the scope of each Monogram license. The design document information shall provide objective evidence that the product design meets the requirements of the applicable and most current API product specification(s) and/or standard(s). The design documentation shall be made available during API audits of the facility.

In specific instances, the exclusion of design activities is allowed under the Monogram Program, as detailed in Advisory #6, available on API Monogram Program website at http://www.api.org/products-and-services/api-monogram-and-apiqr#tab_advisories.

A.3.4 Manufacturing Capability

The API Monogram Program is designed to identify facilities that have demonstrated the ability to manufacture equipment that conforms to API specifications and/or standards. API may refuse initial licensing or suspend current licensing based on a facility's level of manufacturing capability. If API determines that an additional review is warranted, API may perform additional audits (at the organization's expense) of any subcontractors to ensure their conformance with the requirements of the applicable API product specification(s) and/or standard(s).

A.3.5 Use of the API Monogram in Advertising

An API Monogram licensee shall not use the API Monogram and/or license number on letterheads, buildings or other structures, websites, or in any advertising without an express statement of fact describing the scope of Licensee's authorization (license number and product specification). The Licensee should contact API for guidance on the use of the API Monogram other than on products.

A.4 Product Marking Requirements

A.4.1 General

These marking requirements shall apply only to those API Licensees wishing to mark applicable products in conjunction with the requirements of the API Monogram Program.

A.4.2 Product Specification Identification

Manufacturers shall mark products as specified by the applicable API specifications or standards. Marking shall include reference to the applicable API specification and/or standard. Unless otherwise specified, reference to the API specifications and/or standards shall be, as a minimum, "API [Document Number]" (e.g. API 6A or API 600). Unless otherwise specified, when space allows, the marking may include use of "Spec" or "Std", as applicable (e.g. API Spec 6A or API Std 600).

A.4.3 Units

Products shall be marked with units as specified in the API specification and/or standard. If not specified, equipment shall be marked with U.S. customary (USC) units. Use of dual units [USC units and metric (SI) units] may be acceptable, if such units are allowed by the applicable product specification and/or standard.

A.4.4 Nameplates

Nameplates, when applicable, shall be made of a corrosion-resistant material unless otherwise specified by the API specification and/or standard. Nameplate shall be located as specified by the API specification and/or standard. If the location is not specified, then the licensee shall develop and maintain a procedure detailing the location to which the nameplate shall be applied. Nameplates may be attached at any time during the manufacturing process.

The API Monogram and license number shall be marked on the nameplate, in addition to the other product marking requirements specified by the applicable product specification and/or standard.

A.4.5 License Number

The API Monogram license number shall not be used unless it is marked in conjunction with the API Monogram. The license number shall be used in close proximity to the API Monogram.

A.5 API Monogram Program: Nonconformance Reporting

API solicits information on products that are found to be nonconforming with API specified requirements, as well as field failures (or malfunctions), which are judged to be caused by either specification and/or standard deficiencies or nonconformities against API specified requirements. Customers are requested to report to API all problems with API monogrammed products. A nonconformance may be reported using the API Nonconformance Reporting System available at <http://compositelist.api.org/ncr.aspx>.

Bibliography

- [1] ANSI/ASQ⁵ Z1.4-2003 (R2013), *Sampling Procedures and Tables for Inspection by Attributes*
- [2] ISO 9001, *Quality Management Systems — Requirements*

⁵ American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, <https://asq.org>.



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