API Specification 20E
Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries

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This standard specifies requirements for the qualification, production and documentation of alloy and carbon steel bolting used in the petroleum and natural gas industries. This standard applies when referenced by an applicable API equipment standard or otherwise specified as a requirement for compliance. An annex for supplemental requirements that may be invoked by the purchaser is included.

This standard establishes requirements for three bolting specification levels (BSL). 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 severity in order to reflect increasing technical, quality and qualification criteria.

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 (BSL-1 only);
- 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.

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API Specification 20E

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

History and Highlights
Presenters

- **Tom Goin** – TSP / US Bolt Director of Sales and Supply Chain Programs, Chair of AWHEM Bolting Task Group and API SC 20E on Bolting

- **Lester Burgess** – TSP / US Bolt Director of Quality and Technical Services, Chair of ASTM Subcommittee A01.13 on Steel Testing and ASTM A01.22.01 on High Pressure / High Temperature Bolting
API product specifications traditionally reference ASTM specifications for bolting.

ASTM bolting standards are material specifications.

ASTM A01 bolting specifications are primarily directed toward pressure vessel and piping applications.

ASTM does not have enforcement power.
History of the Specification

- Subsea bolting failures lead to huge financial losses
- Reaction was introduction of multiple OEM and User specifications adding testing and procurement requirements to ASTM specifications
- AWHEM standard developed to combine requirements – published as technical guide
- API SC 20 on Supply Chain requested development of a true API specification for bolting.
Purpose:
This API standard specifies requirements for the qualification, production and documentation of alloy and carbon steel bolting used in the petroleum and natural gas industries.

- 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.
20E has no design authority. Implementation is to be done by designer, or purchaser.

Should be applicable to Christmas trees, blow-out preventers, sub-sea pumps, wellhead connectors, hydraulic tensioning systems, drilling risers, etc.
This API Standard establishes requirements for three bolting specification levels (BSL). 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 severity in order to reflect increasing technical, quality and qualification criteria. It is anticipated that BSL3 would be adopted for critical-service, highly stressed structural or pressure-boundary applications.
Bolting Types

- machined studs;
- machined bolts, screws and nuts;
- cold formed bolts, screws and nuts (BSL–1 only);
- hot formed bolts and screws < 1.5 in. (38.1mm) nominal diameter;
- hot formed bolts and screws ≥ 1.5 in. (38.1mm) nominal diameter;
- roll threaded studs, bolts, and screws < 1.5 in. (38.1mm) diameter;
- roll threaded studs, bolts, and screws ≥ 1.5 in. (38.1mm) diameter;
- hot formed nuts < 1.5 in. (38.1mm) nominal diameter;
- hot formed nuts ≥ 1.5 in. (38.1mm) nominal diameter.
1.1 Qualification Testing  Each category of Bolting type to be qualified.

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>
<thead>
<tr>
<th>BSL</th>
<th>Material</th>
<th>Heat Treat</th>
<th>Chemistry</th>
<th>Mechanical</th>
<th>Metallurgical</th>
<th>Hardness</th>
<th>NDE Surface</th>
<th>NDE Volumetric</th>
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</thead>
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<td>5.3.4</td>
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<td>5.6</td>
<td>5.7.2</td>
<td>5.8.2.2</td>
<td>5.9.1</td>
<td>---</td>
</tr>
<tr>
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<td>5.4.2</td>
<td>5.3.5</td>
<td>5.5</td>
<td>5.6.1</td>
<td>5.7.3</td>
<td>5.8.2.3</td>
<td>5.9.2</td>
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<td>BSL-3</td>
<td>5.4.3</td>
<td>5.3.6</td>
<td>5.5</td>
<td>5.6.1</td>
<td>5.7.4</td>
<td>5.8.2.4</td>
<td>5.9.3.1</td>
<td>5.9.3.2</td>
</tr>
</tbody>
</table>

4.2.2 All required tests, including those certified by the raw material supplier, shall be performed by a laboratory qualified in accordance with an internationally recognized international standard for the qualification of test laboratories, such as 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 retain and have available a 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.
Field Failures

- Excessive hardness
- Heat treatment
- Microstructure
- Chemistry
- Internal forging defects/bursts
- Forging cracks (nuts)
- Over-tapped threads (nuts)
- Thread rolling bursts
Bolt section showing banding and non-metallic inclusions
Sectioned Bolt Head Revealing Massive Forging Defect
Stud Cross-section – Internal Burst
BSL – Raw Material

BSL–1
The steel shall be fully wrought.
The reduction ratio based on starting material diameter shall be a minimum of 4:1.
The steel shall conform to the requirements of the standards listed in 4.3.1, as applicable.
Intentional additions of boron are not allowed.
All elements intentionally added to the heat shall be reported.

BSL–2
The requirements specified for BSL–1 are required for BSL–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.
The allowable sulfur content shall be .025% maximum and the allowable phosphorus content shall be .025% maximum.
Residual boron content shall not exceed .0005%.

BSL–3
The requirements specified for BSL–2 are required for BSL–3 except as specified below.
The reduction ratio based on starting material diameter shall be 10:1 minimum.
Allowable sulfur content shall be .015% maximum and the allowable phosphorus content shall be .015% maximum.
The continuous cast steel making process is prohibited.
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.
Process Controls

The bolting manufacturer shall prepare a manufacturing procedure specification (MPS) to include, as a minimum allowable levels for all bolting manufacturing parameters including the process control variables listed in 5.3.2 and the heat treatment parameters listed in 5.3.3.

General Variables
heading equipment;
hot forming heating method;
hot forming temperature control method;
machining and threading equipment: single point (lathe), multiple chaser, roll, tap;
machining and threading control methods.

Heat Treatment Parameters
The following are heat treat parameters, as applicable:
equipment (batch, continuous, induction, direct resistance);
times and temperatures;
cooling media (e.g. type, polymer concentration, quench temperature, agitation);
control and calibration methods;
maximum transfer time;
quench media start and finish temperature;
furnace load diagrams.
Forging

- Advantage – radial grain flow
- Improper processing can lead to service failure
- Need for control
  - Heating
  - Dimensional control
  - Die wear
Sectioned 3” Bolt Forging – Macroetched to show grain flow
Sectioned Bolt Head Revealing Massive Forging Defect
BSL – Heat treatment

BSL–2 Requirements
Requirements specified for BSL–1 are required for BSL–2. ASTM A320 Grade L43 and ASTM A540, Grade B23 material shall be double tempered. 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. Done to control the increase of thread hardness / stress increase caused by the rolling process.

BSL–3 Requirements
Variables specified for BSL–2 are required for BSL–3. Austenitizing temperatures shall not exceed 1700°F (925°C). Tempering temperatures for ASTM A193, Grade B7, ASTM A320, Grade L7, and Grade L43, and ASTM A540 Grade B23 shall not exceed 1300°F (700°C). Induction and direct–resistance heat treating processes can exceed these temperatures, causing potential metallurgical problems.
BSL – Microstructure

BSL–2

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 ¼T.

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

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.

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

Banding
Heavily banded microstructures, as shown in ASTM E1268, Figure A1.20, are not permitted. When a banded structure is observed of questionable acceptability, (Comment 71) 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.

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

BSL–3

Requirements specified for BSL–2 are required for BSL–3.
For grain size and banding, one test shall be performed per each heat lot.
When any banding is observed, the hardness test evaluation required under BSL–2 shall be required for a minimum of 2 bands.

Microstructure Testing – to be done to confirm quality of heat treated condition and insure freedom from heavily banded microstructure. Banding has been implicated in past failures.
BSL – Hardness

Upper limit hardness control necessary due to introduction of CP.

BSL–2
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 must be within 3 HRC. Hardness testing of fasteners: Each piece shall be tested.

For nuts not listed in ASTM A194 Tables 3 and 4 (not subject to mandatory proof load), a sample nut from each heat lot shall be sectioned and the cross-section hardness tested in accordance with ASTM F606. Hardness shall meet the acceptance criteria.

BSL–3
Hardness testing requirements specified for BSL–2 are required for BSL–3.
Electromagnetic sorting is not permitted.
Thread forming

- Single point
- Chasers
  - Disadvantage – rough surface finish, potential thread form inaccuracy
- Roll
  - Advantages – potential enhanced fatigue resistance, polished surface finish at thread root
  - Disadvantage – hardness increase at thread root
Bolt sectioned and etched to reveal grain structure in cut threads
Bolt sectioned and etched to reveal grain structure – rolled threads

14679-003
718 per 310W026-160
Ht# 38066
500X kallinge Reagent
Rolled Thread Form
Lb
BSL – NDE

Nondestructive Examination Requirements

BSL–1
No requirements except as required by the referenced ASTM specification.

BSL–2
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.

BSL–3
Surface NDE requirements specified for BSL–2 are required for BSL–3 except each piece shall be inspected.
Volumetric NDE is required on bar, rod, wire or on bolting 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). Each piece shall be examined. Results shall be documented on the test report.
General
- All dimensions and visual inspections shall meet the requirements of the applicable ASTM specification. Results shall be documented on an inspection report. Oversizing of nut threads or under sizing of bolt threads is not permissible.

BSL–1 Sample Size
- Sample size shall be as required by the applicable ASTM specification.

BSL–2 Sample Size
- Sample size shall be in accordance with Table 3

BSL–3 Sample Size
- Each piece shall be dimensionally and visually inspected
## Licensing Information Form for API Spec 20E

<table>
<thead>
<tr>
<th>Products</th>
<th>Sizes</th>
<th>Thread Forming</th>
<th>Bolting Specification Level: Check highest BSL to be manufactured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold formed bolts, screws, and nuts</td>
<td>All</td>
<td>Machined or rolled threads</td>
<td>□ BSL 1 only</td>
</tr>
<tr>
<td>Studs</td>
<td>All</td>
<td>Machined</td>
<td>□ 1 □ 2 □ 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rolled threads</td>
<td>□ 1 □ 2 □ 3</td>
</tr>
<tr>
<td>Fully machined bolts, screws, and nuts</td>
<td>All</td>
<td>Machined</td>
<td>□ 1 □ 2 □ 3</td>
</tr>
<tr>
<td>Hot formed bolts and screws</td>
<td>&lt; 1.50 in (38.1mm)</td>
<td>Machined</td>
<td>□ 1 □ 2 □ 3</td>
</tr>
<tr>
<td></td>
<td>≥ 1.50 in (38.1mm)</td>
<td>Rollsed threads</td>
<td>□ 1 □ 2 □ 3</td>
</tr>
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