



Designation: A1099/A1099M – 17

## Standard Specification for Modified Alloy Steel Forgings, Forged Bar, and Rolled Bar Commonly Used in Oil and Gas Pressure Vessels<sup>1</sup>

This standard is issued under the fixed designation A1099/A1099M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers modified high-strength alloy steel forgings and rolled and forged bar for oil and gas pressure vessels and oilfield equipment. See [Appendix X1](#). Oil and gas product specifications for which this material is intended include, but are not limited to, the following:

1.1.1 API 6A Specification for Wellhead and Christmas Tree Equipment and Errata,

1.1.2 API RP 6AR Recommended Practice for Repair and Remanufacture of Wellhead and Christmas Tree Equipment,

1.1.3 API 16A Specification for Drill-Through Equipment,

1.1.4 API 16R Specification for Marine Drilling Riser Couplings,

1.1.5 API 17D Specification for Subsea Wellhead and Tree Equipment and Errata,

1.1.6 API 8C Specification for Drilling and Production Hoisting Equipment.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 In the case of conflict between a requirement of this specification and a requirement of referenced general specifications, this specification takes precedence. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order or contract, the purchase order or contract take precedence. The purchase order or contract requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification, for example, by the waiving of a test requirement or by making a test requirement less stringent. In the case of conflict in terminology between API standards and Terminology [A941](#), Terminology [A941](#) definitions shall be applied.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee [A01](#) on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee [A01.22](#) on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved May 15, 2017. Published May 2017. DOI: 10.1520/A1099\_A1099M-17.

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

1.5 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

[A370](#) Test Methods and Definitions for Mechanical Testing of Steel Products

[A388/A388M](#) Practice for Ultrasonic Examination of Steel Forgings

[A534](#) Specification for Carburizing Steels for Anti-Friction Bearings

[A700](#) Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

[A788/A788M](#) Specification for Steel Forgings, General Requirements

[A941](#) Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

[A961/A961M](#) Specification for Common Requirements for

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

Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

**A991/A991M** Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products

**A1058** Test Methods for Mechanical Testing of Steel Products—Metric

**E10** Test Method for Brinell Hardness of Metallic Materials

**E21** Test Methods for Elevated Temperature Tension Tests of Metallic Materials

**E45** Test Methods for Determining the Inclusion Content of Steel

**E110** Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

**E112** Test Methods for Determining Average Grain Size

**E165/E165M** Practice for Liquid Penetrant Examination for General Industry

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

**E1444/E1444M** Practice for Magnetic Particle Testing

**E1820** Test Method for Measurement of Fracture Toughness

## 2.2 *API Standards:*<sup>3</sup>

**API 6A** Specification for Wellhead and Christmas Tree Equipment

**API RP 6AR** Recommended Practice for Repair and Re-manufacture of Wellhead and Christmas Tree Equipment

**API 8C** Specification for Drilling and Production Hoisting Equipment

**API 16A** Specification for Drill-Through Equipment

**API 16R** Specification for Marine Drilling Riser Couplings

**API 17D** Specification for Subsea Wellhead and Tree Equipment

**API RP 6HT** Heat Treatment and Testing of Large Cross-Section and Critical Section Components

## 2.3 *ASNT Standard:*<sup>4</sup>

**ANST SNT-TC-1A** Topical Outlines for Qualification of Nondestructive Testing Personnel

## 2.4 *SAE Standards:*<sup>5</sup>

**AMS 2750** Pyrometry

**AMS-H-6875** Process for Heat Treatment of Steel

## 2.5 *ISO Standard:*<sup>6</sup>

**ISO 6506** Metallic Materials—Brinell Hardness Test—Part 1: Test Method

## 2.6 *Norsok Standard:*<sup>7</sup>

**Norsok M-650** Qualification of Manufacturers of Special Materials

## 2.7 *British Standard:*<sup>8</sup>

**BS 7448-1** Method for Determination of  $K_{Ic}$ , Critical CTOD and Critical  $J$  Values of Metallic Materials

## 3. Ordering Information and General Requirements

### 3.1 *General:*

3.1.1 Quantity (mass), length, or number of pieces;

3.1.2 Name of material (forgings or rolled or forged bar);

3.1.3 ASTM International specification designation and year date to which the product is to be furnished and certified as meeting or as capable of meeting;

3.1.4 Condition (as forged, as rolled, annealed, normalized, re-austenitized, liquid quenched and tempered, austenitized, and liquid quenched and tempered);

3.1.5 Grade, class, and type designations;

3.1.6 Dimensions;

3.1.7 Shape and finish characteristics;

3.1.8 Test location, a drawing or sketch may be used to show test locations, when applicable;

3.1.9 American Petroleum Institute (API) product specification, when applicable; and

3.1.10 Any supplementary requirements.

3.2 Material supplied to this specification shall conform to the requirements of Specifications **A961/A961M** or **A788/A788M**, which outline additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements. Specification **A961/A961M** shall apply to bar and forged bar as defined in Specification **A961/A961M** and Specification **A788/A788M** shall apply to forgings and forged bar unless otherwise stated.

## 4. Melting

4.1 In addition to the melting and forging requirements of Specifications **A961/A961M** and **A788/A788M**, which may be supplemented by supplementary requirements, the following conditions apply:

4.1.1 Material shall be produced by electric arc furnace or induction melting, followed by a secondary process including ladle refining and degassing, for example, argon oxygen decarburization (AOD), vacuum oxygen decarburization (VOD) or vacuum arc degassing (VAD), vacuum tank degassing, and RH (Ruhstahl Heraeus) or DH (Dortmund-Horde) degassing. Material may be secondarily remelted by vacuum arc remelting (VAR) or electroslag remelting (ESR).

4.1.2 Material shall be fully killed.

4.1.3 Material shall meet the fine austenitic grain size requirements as stated in **9.1.1.1**.

## 5. Hot Working

5.1 The total hot work reduction ratio shall be 4:1 minimum.

5.1.1 Total hot work reduction ratio for bars:

5.1.1.1 The cross-sectional area of the original ingot or strand divided by the cross-sectional area of the finished bar.

<sup>8</sup> Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com>.

<sup>3</sup> Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, <http://www.api.org>.

<sup>4</sup> Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlington Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

<sup>5</sup> Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

<sup>6</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

<sup>7</sup> Available from the Norsk Søkkel Konkuranseposisjon, [www.standard.no](http://www.standard.no).



5.1.1.2 The cross-section resulting in the lowest hot work reduction ratio shall be used.

5.1.2 Total hot work ratio for forgings (forging reduction ratio):

5.1.2.1 The product of the reduction ratios for each hot work operation including the original starting material reduction and each subsequent hot work operation. When the cross section of the starting material or forged part varies, the cross section resulting in the lowest calculated hot work reduction ratio shall be used.

5.2 Forgings shall have a surface finish adequate for intended inspection as stated in Specification **A788/A788M**.

## 6. Heat Treatment

6.1 When a heat-treated condition is not specified, any heat treatment shall be at the option of the manufacturer.

6.2 When the heat-treated condition is specified, the following apply:

6.2.1 Forgings and bars shall be normalized, re-austenitized followed by liquid quench and temper or alternatively, austenitized, followed by liquid quench and tempered.

6.2.2 Forgings and bars shall be allowed to cool down to a temperature below 200°C [400°F] before commencing any operation of heat treatment cycle. This includes before a normalizing cycle.

6.2.3 Forgings shall be near net shape before quenching. The rough machine dimensions (or near net shape forging dimensions) before quenching shall comply with the purchaser's near net shape drawings. When drawings are not available, the forging supplier shall adhere as close as possible to the recommended practices of API RP 6HT. When no drawings or instructions are provided by the purchaser, it is the responsibility of the manufacturer to meet the required mechanical properties.

6.3 Heat treatment equipment calibration and furnace surveys shall be in accordance with API 6A Annex M or API 16A Annex A. Alternatively, heat treatment equipment survey and calibration may be performed in accordance with an internationally recognized industry standard such as SAE AMS 2750, SAE-H-AMS 6875, Test Method **A991/A991M** (uniformity survey), or Norsok M650 provided that the supplier demonstrates that the requirements of API 6A or API 16A have been exceeded. Induction heating equipment survey and calibration shall be in accordance with the manufacturer's written procedures.

6.4 Heat treatment of bars, forgings, and forged bars shall be performed in a furnace meeting the requirements of **6.3**. See API RP 6HT for additional guidance.

6.5 The heat treatment temperatures shall be in accordance with **Table 1**.

**TABLE 1 Heat Treatment Temperatures**

| Material         | Normalizing <sup>A</sup>   | Austenitizing <sup>A</sup>     | Quench Media      | Tempering Minimum <sup>B</sup> |
|------------------|----------------------------|--------------------------------|-------------------|--------------------------------|
| F22OF Class 75   | 1675–1750°F<br>[900–950°C] | 1650–1725°F<br>[900–950°C]     | Water/polymer/oil | 1225°F<br>[650°C]              |
| F22OF Class 80   | 1675–1750°F<br>[900–950°C] | 1650–1725°F<br>[900–950°C]     | Water/polymer/oil | 1200°F<br>[650°C]              |
| F22OF Class 85   | 1675–1750°F<br>[900–950°C] | 1650–1725°F<br>[900–950°C]     | Water/polymer/oil | 1175°F<br>[625°C]              |
| F22OFA Class 105 | 1675–1750°F<br>[900–950°C] | 1650–1725°F<br>[900–950°C]     | Water/polymer/oil | 1100°F<br>[600°C]              |
| 4130OF Class 60  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1250°F<br>[675°C]              |
| 4130OF Class 75  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1200°F<br>[650°C]              |
| 4130OF Class 80  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1200°F<br>[650°C]              |
| 4130OF Class 95  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1125°F<br>[600°C]              |
| 4130OF Class 110 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1075°F<br>[575°C]              |
| 4130OF Class 125 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1050°F<br>[575°C]              |
| 8630OF Class 75  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1225°F<br>[650°C]              |
| 8630OF Class 80  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1200°F<br>[650°C]              |
| 8630OF Class 85  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1200°F<br>[650°C]              |
| 8630OF Class 95  | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1075°F<br>[575°C]              |
| 8630OF Class 100 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1075°F<br>[575°C]              |
| 8630OF Class 110 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1050°F<br>[575°C]              |
| 8630OF Class 120 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[850–900°C]     | Water/polymer/oil | 1050°F<br>[575°C]              |
| 8630OF Class 135 | 1600–1700°F<br>[875–925°C] | 1575–1650°F<br>[857.2–898.8°C] | Water/polymer/oil | 1025°F<br>[550°C]              |

<sup>A</sup>Temperature uniformity shall be ±25°F [±14°C] for normalizing and austenitizing.

<sup>B</sup>Temperature uniformity shall be ±15°F [±8°C] for tempering.

## 7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis as determined by the steel producer as being representative of a heat of steel (see Terminology **A941**) meeting the composition of a grade shown in **Table 2**. Additions of nonspecified elements are not allowed.

7.2 *Product Analysis*—The manufacturer shall perform a product analysis in accordance with Specifications **A961/A961M** or **A788/A788M** from a bar, forged bar, or forging representing each heat. The permissible variations shall meet those in Specifications **A961/A961M** or **A788/A788M**, as applicable.

7.3 For multiple-heat ingots, either individual heat analyses or a weighted average may be taken. The results of the method used shall conform to the requirements of the product specification. Annex A2 in Specification **A788/A788M** details the calculation steps for the weighted average.

## 8. Mechanical Properties and Testing

8.1 For forgings or bar supplied in normalized, re-austenitized, quenched, and tempered or austenitized, quenched, and tempered condition, all tests shall be conducted as specified in Specifications **A961/A961M** or **A788/A788M** as applicable in accordance with Test Methods and Definitions **A370** if inch-pound units are specified or Test Methods **A1058** if the M suffix (SI units) is specified.

8.2 Test specimens shall be obtained from a test coupon in the form of a sacrificial production forging or a prolongation. The thickness and location of the prolongation or the area for sampling from a sacrificial forging or both shall be stipulated on the purchase order. In the case of bar or forged bar, the test coupon shall be a prolongation with the same dimensions as the bar it represents.

8.3 The test coupon shall qualify the bar, forged bar, or forgings per heat, per heat treat charge.

8.4 It is recommended that the forging manufacturer give due consideration to providing sufficient test material to allow for retesting per **9.1.2**.

8.5 Test sampling for tensile and impact specimens shall be in the depth and orientation given in **Table 3**, except as noted in **8.5.3**.

8.5.1 The tensile and impact properties of the material shall comply with the requirements of **Table 4** for each grade and class.

8.5.2 The mid-gauge length of tensile specimens and root of the notch of impact specimens of hollow forgings shall be  $T$  away from quenched ends. The mid-gauge length of tensile specimens and root of the notch of impact specimens of bar, forged bar, and solid forgings shall be  $\frac{1}{2} T$  away from quenched ends.

8.5.3 Alternatively, per agreement between the purchaser and the supplier, specimens may be taken from an area of significant loading in lieu of **Table 3** test depths.

8.6 At least one Brinell hardness test shall be performed on the material and test coupon after the final heat treatment cycle.

8.6.1 Hardness testing shall be performed in accordance with the procedures in ISO 6506 (all parts), or Test Methods **E10** or **E110**.

8.6.2 The hardness of the material and test coupon shall comply with the requirements of **Table 4** for each grade and class. A minimum of one hardness test shall be performed on each test coupon and a minimum of one hardness test shall be performed on at least one production part.

8.7 If the results fail to meet any requirement in **Table 4**, then additional tests shall be performed on the test coupon with no additional heat treatment as follows:

8.7.1 *Tensile*—Two additional specimens for each failed specimen, both of which shall meet the requirements;

8.7.2 *Charpy V-Notch*—One additional set of three specimens for each failed set all of which shall meet the minimum average requirements; and

8.7.3 *Hardness*—Two additional indentations for each failed test.

8.7.4 If both the original test and the re-test fail to meet the requirement, the material shall be subject to rejection.

## 9. Metallurgical Requirements

9.1 Specimens for the following metallurgical requirements may be obtained from the bars, billets/blooms, or forgings.

9.1.1 *Test Requirements*:

9.1.1.1 *Grain Size*—The austenitic grain size shall be of six or finer as determined by one of the three methods stated in accordance with Test Methods **E112** including Annex A3. The McQuaid-Ehn, oxidation, or correlation procedures shall be used to generate an austenitic grain size with the following modifications. The sample shall be from the condition prior to final heat treatment and shall be austenitized at the maximum austenitizing temperature for the grade per **Table 1**. Time at temperature shall be reported. One grain size shall be tested per each heat of material.

9.1.1.2 *Macrostructure*—Cross-sectional macrostructure as determined in accordance with Test Method **E381** obtained from specimens prepared in accordance with Specification **A534** shall be no worse than S1, R1, C2. Testing is required when S4 is specified.

9.1.1.3 *Microcleanliness*—The microcleanliness as determined in accordance with Test Methods **E45** Method A shall be sampled for each heat of material. The specimen may be obtained from any convenient bar, billet, or forging size. The results shall meet the following maximum ratings in **Table 5**.

9.1.2 *Retest and Resampling*—Should any test in **9.1.1** fail to meet the requirement, an additional specimen for each failed specimen shall be sampled and tested. If the retest fails, the material shall be subject to rejection.

## 10. Nondestructive Examination (NDE) Requirements

10.1 *Volumetric NDE Examination*—Each forging, forged bar, or bar shall be volumetrically inspected using the ultrasonic techniques in accordance with Practice **A388/A388M** except that the immersion method may be used. The inspection shall be conducted after final heat treatment (exclusive of

TABLE 2 Grade Chemical Composition<sup>A</sup>

| Grade  | C             | Mn            | P     | S     | Si            | Cr            | Mo            | Ni            | Cu   | V    | Ti    | Al    | Sn    | As    | Sb    | Pb    | Bi    | N      | H        | O         | Nb<br>(Cb)    | B      |
|--------|---------------|---------------|-------|-------|---------------|---------------|---------------|---------------|------|------|-------|-------|-------|-------|-------|-------|-------|--------|----------|-----------|---------------|--------|
| F220F  | 0.10–<br>0.15 | 0.30–<br>0.60 | 0.015 | 0.010 | 0.15–<br>0.50 | 2.0–<br>2.50  | 0.87–<br>1.13 | 0.50          | 0.25 | 0.04 | 0.025 | 0.055 | 0.015 | 0.020 | 0.020 | 0.010 | 0.010 | 0.0120 | 2<br>PPM | 25<br>PPM | 0.02          | 0.0005 |
| F220FA | 0.15–<br>0.20 | 0.40–<br>0.80 | 0.015 | 0.010 | 0.50          | 2.0–<br>2.50  | 0.90–<br>1.10 | 0.50          | 0.25 | 0.04 | 0.025 | 0.055 | 0.015 | 0.020 | 0.020 | 0.010 | 0.010 | 0.0120 | 2<br>PPM | 25<br>PPM | 0.01          | 0.0005 |
| 4130OF | 0.25–<br>0.33 | 0.60–<br>0.90 | 0.015 | 0.010 | 0.20–<br>0.35 | 1.20–<br>1.50 | 0.65–<br>0.75 | 0.25          | 0.25 | 0.04 | 0.025 | 0.055 | 0.015 | 0.020 | 0.020 | 0.010 | 0.010 | 0.0120 | 2<br>PPM | 25<br>PPM | 0.02–<br>0.05 | 0.0005 |
| 8630OF | 0.27–<br>0.33 | 0.80–<br>0.95 | 0.015 | 0.010 | 0.20–<br>0.35 | 0.85–<br>1.00 | 0.35–<br>0.45 | 0.80–<br>0.90 | 0.25 | 0.04 | 0.025 | 0.055 | 0.015 | 0.020 | 0.020 | 0.010 | 0.010 | 0.0120 | 2<br>PPM | 25<br>PPM | 0.02          | 0.0005 |

<sup>A</sup>Notes: (1) Chemical composition by weight %. (2) Specified values are considered maximum unless otherwise specified. (3) Calcium may be added for inclusion shape control. Amount of calcium shall not exceed 0.005 %.



TABLE 3 Sampling<sup>A</sup>

| Thickness, $T$ | Depth                                 | Orientation                |
|----------------|---------------------------------------|----------------------------|
|                | Tensile and Charpy                    |                            |
| ≤4 in. [10 cm] | $\frac{1}{2} T$                       | Longitudinal or transverse |
| >4 in. [10 cm] | $\frac{1}{4} T$ for solids            | Longitudinal or transverse |
|                | $\frac{1}{2} T$ for hollows and rings |                            |

<sup>A</sup>Notes:

(1) Thickness ( $T$ ) is the thickness of the test coupon, that is, critical section at time of heat treatment.

(2) Position  $\frac{1}{2} T$  is at the center of a solid forging or at mid wall in a hollow forging. Position  $\frac{1}{4} T$  shall be one-quarter thickness below the heat-treated surface. These positions are intended for the centerline axis of a tensile specimen and the root of the notch of impact specimens.

(3) Sampling of solid forgings when center will subsequently be removed may be at the finish ID instead of  $\frac{1}{2} T$ .

(4) Specimen orientation as defined in Test Methods and Definitions A370.

(5) For ring and disk forgings, axial and tangential orientation shall be used.

(6) Specific orientation may be requested by purchase order as supplementary requirement. See S5.

re-tempering and stress relief treatments) and before machining operations that limit effective interpretation of the results of the examination.

### 10.2 Calibration:

10.2.1 *Longitudinal Wave*—A distance amplitude curve (DAC) shall be based on a  $\frac{1}{16}$  in. [1.6 mm] flat-bottom hole for metal thickness through  $1\frac{1}{2}$  in. [38 mm], a  $\frac{1}{8}$  in. [3.2 mm] flat-bottom hole for metal thickness from  $1\frac{1}{2}$  through 6 in. [38 through 150 mm], and a  $\frac{1}{4}$  in. [6.4 mm] flat-bottom hole for metal thickness exceeding 6 in. [150 mm].

10.2.2 *Shear Wave*—When specified, radial and axial shear wave testing may be used in accordance with Practice A388/A388M except that a  $\frac{1}{16}$  in. [1.6 mm] side drilled hole, 1 in. [25 mm] deep, shall be used for calibration. Test metal distances shall be as appropriate for the zones to be inspected as follows:  $\frac{1}{16}$  in. [1.6 mm] SDH at mid thickness for material 2 in. [50 mm] and under and  $\frac{1}{16}$  SDH at  $\frac{1}{4} T$ ,  $\frac{1}{2} T$ , and  $\frac{3}{4} T$  for material greater than 2 in. [50 mm].

10.3 *Acceptance Criteria for Volumetric NDE*—A forging or bar containing a discontinuity that results in an indication exceeding the amplitude of the reference line is subject to rejection.

## 11. Permissible Variations

11.1 The product shall conform to the requirements of Specifications A961/A961M or A788/A788M. In addition, the manufacturer shall document the dimensional inspection and sampling.

## 12. Workmanship, Finish, and Appearance

12.1 The products shall meet the requirements of Specifications A961/A961M and A788/A788M.

## 13. Rework and Retreatment

13.1 Rework, including repair welding, shall meet the requirements of Specifications A961/A961M and A788/A788M. Repair welding is not permitted on bar. When repair welding is required for forgings, it shall be approved by the purchaser. The purchaser shall approve the welding procedure to be used.

13.2 Re-heat treatment to correct noncompliant mechanical properties and hardness may be conducted at the discretion of the manufacturer provided those re-heat treatment efforts meet the requirements of this specification and the applicable product specifications.

## 14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to be satisfied that the product is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

## 15. Rejection and Rehearing

15.1 *Rejection*—Product found to be defective subsequent to its acceptance at the manufacturer's works may be rejected, and the manufacturer shall be notified.

15.2 *Rehearing*—Samples representing product rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

## 16. Certification

16.1 *Product Marking*—Application of the identification markings, as required under Section 17, shall constitute certification the product has been supplied in accordance with the requirements of this specification.

16.2 *Certificate of Compliance*—The producer or supplier shall furnish a certificate of compliance stating the product was manufactured, sampled, tested, and inspected in accordance with this specification (including year date) and any other requirements designated in the purchase order or contract and has been found to meet such requirements.

16.3 *Certification*—The manufacturer shall provide certification including the following:

- 16.3.1 Purchase order number;
- 16.3.2 Heat number and heat treat lot identification;
- 16.3.3 Part numbers, as applicable;
- 16.3.4 Chemical composition;
- 16.3.5 Hot work reduction ratio;
- 16.3.6 Furnace heat treat records, as applicable;
- 16.3.7 Mechanical properties testing results, as applicable;
- 16.3.8 Metallurgical testing results, as applicable;
- 16.3.9 NDE results, as applicable; and
- 16.3.10 Visual and dimensional inspections results.

16.4 A signature or notarization is not required; however, the document shall clearly identify the organization submitting it. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

16.5 Copies of the original manufacturer's test report shall be included with any subsequent test report.

16.6 A certificate of compliance (or test report) printed, or used in electronic form, from an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the supplier.



TABLE 4 Mechanical Properties (Minimum Unless Otherwise Specified)

| Grade  | F22OF     |           |           | F22OFA    |           |           |           |           |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Class  | 75        | 80        | 85        | 105       |           |           |           |           |
| Tensile (psi min)  | 95 000    | 100 000   | 105 000   | 125 000   |           |           |           |           |
| [MPa minimum]  | [650]     | [700]     | [725]     | [850]     |           |           |           |           |
| Yield (psi min % min at 0.2 % offset)                    | 75 000    | 80 000    | 85 000    | 105 000   |           |           |           |           |
| [MPa minimum]  | [525]     | [550]     | [575]     | [725]     |           |           |           |           |
| Elongation (% min)                                       | 18 %      | 18 %      | 18 %      | 18 %      |           |           |           |           |
| Reduction (% min)  | 35 %      | 35 %      | 35 %      | 35 %      |           |           |           |           |
| Hardness (HBW)   | 197–237   | 207–237   | 217–237   | 269–302   |           |           |           |           |
| Charpy V-Notch at 0°F [–20°C] (ft-lbf minimum average)   | 31 ft-lbf | 31 ft-lbf | 31 ft-lbf | 31 ft-lbf |           |           |           |           |
| [J minimum average]                                      | [42 J]    | [42 J]    | [42 J]    | [42 J]    |           |           |           |           |
| Charpy V-Notch (ft-lbf minimum single value)             | 24 ft-lbf | 24 ft-lbf | 24 ft-lbf | 24 ft-lbf |           |           |           |           |
| [J minimum single value]                                 | [32 J]    | [32 J]    | [32 J]    | [32 J]    |           |           |           |           |
| Grade  | 4130OF    |           |           |           |           |           |           |           |
| Class  | 60        | 75        | 80        | 95        | 110       | 125       |           |           |
| Tensile (psi min)  | 85 000    | 95 000    | 100 000   | 105 000   | 125 000   | 135 000   |           |           |
| [MPa minimum]  | [575]     | [650]     | [700]     | [725]     | [825]     | [925]     |           |           |
| Yield (psi min, % min at 0.2 % offset)                   | 60 000    | 75 000    | 80 000    | 95 000    | 110 000   | 125 000   |           |           |
| [MPa minimum]  | [425]     | [525]     | [550]     | [650]     | [750]     | [850]     |           |           |
| Elongation (% min)                                       | 20 %      | 18 %      | 18 %      | 17 %      | 16 %      | 15 %      |           |           |
| Reduction (% min)  | 40 %      | 35 %      | 35 %      | 35 %      | 35 %      | 35 %      |           |           |
| Hardness (HBW)   | 174–237   | 197–237   | 207–237   | 217–255   | 269–302   | 277–321   |           |           |
| Charpy V-Notch at –40°F [–40°C] (ft-lbf minimum average) | 31 ft-lbf | 31 ft-lbf | 31 ft-lbf | 30 ft-lbf | 30 ft-lbf | 30 ft-lbf |           |           |
| [J minimum average]                                      | [42 J]    | [42 J]    | [42 J]    | [41 J]    | [41 J]    | [41 J]    |           |           |
| Charpy V-Notch (ft-lbf minimum single value)             | 24 ft-lbf | 24 ft-lbf | 24 ft-lbf | 22 ft-lbf | 22 ft-lbf | 22 ft-lbf |           |           |
| [J minimum single value]                                 | [32 J]    | [32 J]    | [32 J]    | [30 J]    | [30 J]    | [30 J]    |           |           |
| Grade  | 8630OF    |           |           |           |           |           |           |           |
| Class  | 75        | 80        | 85        | 95        | 100       | 110       | 120       | 135       |
| Tensile (psi min)  | 95 000    | 100 000   | 105 000   | 115 000   | 120 000   | 130 000   | 145 000   | 150 000   |
| [MPa minimum]  | [650]     | [700]     | [725]     | [800]     | [825]     | [900]     | [1000]    | [1025]    |
| Yield (psi min, % min at 0.2 % offset)                   | 75 000    | 80 000    | 85 000    | 95 000    | 100 000   | 110 000   | 120 000   | 135 000   |
| [MPa minimum]  | [525]     | [550]     | [575]     | [650]     | [700]     | [750]     | [825]     | [925]     |
| Elongation (% min)                                       | 18 %      | 18 %      | 18 %      | 17 %      | 16 %      | 16 %      | 15 %      | 15 %      |
| Reduction (% min)  | 35 %      | 35 %      | 35 %      | 35 %      | 35 %      | 35 %      | 30 %      | 30 %      |
| Hardness (HBW)   | 197–237   | 207–237   | 217–237   | 241–293   | 248–302   | 269–302   | 302–352   | 321–375   |
| Charpy V-Notch at 0°F [–20°C] (ft-lbf minimum average)   | 31 ft-lbf | 31 ft-lbf | 31 ft-lbf | 20 ft-lbf | 20 ft-lbf | 20 ft-lbf | 20 ft-lbf | 20 ft-lbf |
| [J minimum average]                                      | [42 J]    | [42 J]    | [42 J]    | [27 J]    | [27 J]    | [27 J]    | [27 J]    | [27 J]    |
| Charpy V-Notch (minimum single value)                    | 24 ft-lbf | 24 ft-lbf | 24 ft-lbf | 15 ft-lbf | 15 ft-lbf | 15 ft-lbf | 15 ft-lbf | 15 ft-lbf |
| [J minimum single value]                                 | [32 J]    | [32 J]    | [32 J]    | [20 J]    | [20 J]    | [20 J]    | [20 J]    | [20 J]    |

TABLE 5 Maximum Ratings

| Type  | A | B | C | D  |
|-------|---|---|---|----|
| Thin  | 1 | 1 | 1 | 1½ |
| Heavy | ½ | ½ | ½ | 1  |

treat lot; manufacturer identification; and any additional marking required by the product specification. All stamping shall be low stress.

## 18. Keywords

18.1 bar; forged bar; forging; gas; low alloy steel; oil and gas; oilfield; petroleum

## 17. Product Marking

17.1 Marking shall include the following: heat number; specification designation and year date; grade, class, and heat

## SUPPLEMENTARY REQUIREMENTS

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

S1. Crack-Tip Opening Displacement (CTOD) testing shall be conducted in accordance with Test Method E1820 or BS 7448-1. A minimum of one set of three specimens on a heat or heat treat lot basis shall be tested.

S1.1 The producer and user shall agree upon the testing specimen type, temperature, acceptance criteria, and frequency of testing—heat or heat treat lot.

S2. Elevated tensile testing shall be performed in accordance with Test Methods E21. A minimum of one specimen per heat or heat treat lot shall be tested. The purchasers and user

shall agree upon the test temperature, acceptance criteria, and frequency of testing—heat or heat treat lot.

## S3. Surface NDE Examination

S3.1 All accessible surfaces of each finished piece shall be examined by liquid penetrant or magnetic particle methods after final heat treatment and final machining operations. Magnetic particle inspection shall be in accordance with Practice E1444/E1444M. Liquid penetrant testing shall be in accordance with Practice E165/E165M.



S3.2 If any indications are believed to be nonrelevant on the basis that they are not associated with a surface rupture (that is, magnetic permeability variations, nonmetallic stringers), they shall be examined by liquid penetrant surface NDE methods or removed and reinspected to confirm their nonrelevancy.

S3.2.1 Only indications that have any dimension greater than  $\frac{1}{16}$  in. [1.6 mm] shall be considered relevant.

S3.2.2 A linear indication is one having a length greater than three times the width.

S3.2.3 A rounded indication is one of circular or elliptical shape with a length equal to or less than three times its width.

S3.2.4 Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

#### S3.3 *Acceptance Criteria for Surface NDE:*

S3.3.1 No relevant indication with a major dimension equal to or greater than  $\frac{3}{16}$  in. [5 mm];

S3.3.2 No more than ten relevant indications in any continuous 6 in.<sup>2</sup> [40 cm<sup>2</sup>] area;

S3.3.3 Four or more relevant indications in a line separated by less than  $\frac{1}{16}$  in. [1.6 mm] (edge to edge) are unacceptable; and

S3.3.4 No relevant indications in pressure contact sealing surfaces.

S3.4 Individuals conducting the examinations shall be certified in accordance with ASNT SNT-TC-1A.

### **S4. Macroetch**

S4.1 The cross-sectional macrostructure as determined in accordance with Test Method E381 obtained from specimens prepared in accordance with Specification A534 shall be no worse than S1, R1, C2. One macroetch shall be tested for each heat of material.

### **S5. Specimen Orientation**

S5.1 The specimen orientation shall be in the longitudinal direction.

S5.2 The specimen orientation shall be in the transverse direction.

### **S6. Special Impact Requirements**

S6.1 Impact test result shall meet the following: Average 44 ft-lb [60 J], Minimum 33 ft-lb [45 J].

## **APPENDIX**

### **(Nonmandatory Information)**

#### **X1. REQUIREMENTS**

X1.1 This specification has been written to meet requirements special to oil and gas applications, particularly offshore and subsea applications. The requirements may be difficult to meet. The requirements in many cases exceed those found in other industry standards. It is unlikely that commercial material will be capable of meeting all of the requirements found in this specification. It is expected that material for this specification will have to be specially produced. This specification intentionally does not define limits of size and geometry, although it is recognized that it will not be possible to meet the mechanical requirements of this specification in all sizes and geometries.

Consequently, not all sizes and geometries can be manufactured to meet this specification. The actual sizes and geometries that can be manufactured to meet this specification vary with manufacturer and specific heats. For this reason, size and geometry limits are left to the producers and users. When an order for material to this specification is accepted by the producer, it is the responsibility of the producer to meet all the requirement of this specification as stated on the purchase order documents whatever size and geometry. As noted, the requirements of this specification are unique and necessary for the applications for which this specification is intended.

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; http://www.copyright.com/*