Designation: ~~A1099/A1099M – 17~~ A1099/A1099M – 20

Standard Specification for Modified Alloy Steel Forgings, Forged Bar, and Rolled Bar Commonly Used in Oil and Gas Pressure Vessels[1]

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 (ε) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ 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.

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~~ safety, health, and ~~health~~environmental 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*:[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

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[1] 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.

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

***A Summary of Changes section appears at the end of this standard**

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 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 Testing 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:*[3]
API 6A Specification for Wellhead and Christmas Tree Equipment
API RP 6AR Recommended Practice for Repair and Remanufacture 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:*[4]
ANST SNT-TC-1A Topical Outlines for Qualification of Nondestructive Testing Personnel

2.4 *SAE Standards:*[5]
AMS 2750 Pyrometry
AMS-H-6875 Process for Heat Treatment of Steel

2.5 *ISO Standard:*[6]
ISO 6506 Metallic Materials—Brinell Hardness Test—Part 1: Test Method

2.6 *Norsok Standard:*[7]
Norsok M-650 Qualification of Manufacturers of Special Materials

2.7 *British Standard:*[8]
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, 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] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.
[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.
[6] 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.
[7] Available from the Norsk Sokkels Konkuranseposisjon, www.standard.no.
[8] Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsigroup.com.

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.

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.

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.

TABLE 1 Heat Treatment Temperatures

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

[A] ~~Temperature~~ Temperature uniformity shall be ±25°F [±14°C] for normalizing and austenitizing.
[B] ~~Temperature~~ Temperature uniformity shall be ±15°F [±8°C] for tempering.

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.

TABLE 2 Grade Chemical Composition[A]

Grade	C	Mn	P	S	Si	Cr	Mo	Ni	Cu	V	Ti	Al	Sn	As	Sb	Pb	Bi	N	H	O	Nb (Cb)	B
F22OF	0.10–0.15	0.30–0.60	0.015	0.010	0.15–0.50	2.0–2.50	0.87–1.13	0.50	0.25	0.04	0.025	0.055	0.015	0.020	0.020	0.010	0.010	0.0120	2 PPM	25 PPM	0.02	0.0005
F22OFA	0.15–0.20	0.40–0.80	0.015	0.010	0.50	2.0–2.50	0.90–1.10	0.50	0.25	0.04	0.025	0.055	0.015	0.020	0.020	0.010	0.010	0.0120	2 PPM	25 PPM	0.01	0.0005
4130OF	0.25–0.33	0.60–0.90	0.015	0.010	0.20–0.35	1.20–1.50	0.65–0.75	0.25	0.25	0.04	0.025	0.055	0.015	0.020	0.020	0.010	0.010	0.0120	2 PPM	25 PPM	0.02–0.05	0.0005
8630OF	0.27–0.33	0.80–0.95	0.015	0.010	0.20–0.35	0.85–1.00	0.35–0.45	0.80–0.90	0.25	0.04	0.025	0.055	0.015	0.020	0.020	0.010	0.010	0.0120	2 PPM	25 PPM	0.02	0.0005

[A]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[A]

Thickness, *T*	Depth	Orientation
	Tensile and Charpy	
≤4 in. [10 cm]	½*T*	Longitudinal or transverse
>4 in. [10 cm]	¼*T* for solids	Longitudinal or transverse
	½*T* for hollows and rings	

[A]Notes:
(*1*) Thickness (*T*) is the thickness of the test coupon, that is, critical section at time of heat treatment.
(*2*) Position ½*T* is at the center of a solid forging or at mid wall in a hollow forging. Position ¼*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 ½*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.

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 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 1⁄16 in. [1.6 mm] flat-bottom hole for metal thickness through 1½ in. [38 mm], a ⅛ in. [3.2 mm] flat-bottom hole for metal thickness from 1½ through 6 in. [38 through 150 mm], and a ¼ 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 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: 1⁄16 in. [1.6 mm] SDH at mid thickness for material 2 in. [50 mm] and under and 1⁄16 SDH at ¼*T*,½*T*, and ¾*T* for material greater than 2 in. [50 mm].