



Standard Specification for Pressure Vessel Forgings, Alloy Steel, Higher Strength Chromium-Molybdenum-Tungsten for Elevated Temperature Service¹

This standard is issued under the fixed designation A1048/A1048M; 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

1.1 This specification covers chromium-molybdenum-tungsten alloy steel forgings intended primarily for use in boilers and pressure vessels for elevated temperature service.

1.1.1 Elevated temperatures are temperatures in the range where creep and stress rupture properties are important for the alloy steels in this specification.

1.2 Supplementary requirements are provided both in this specification and in the General Requirements Specification [A788/A788M](#) for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the purchase order or contract.

1.3 Unless the order specifies the applicable “M” specification designation, the forgings shall be supplied to the inch-pound units.

1.4 The values stated in either inch-pound or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. 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 specification.

2. Referenced Documents

2.1 ASTM Standards:²

[A275/A275M Practice for Magnetic Particle Examination of Steel Forgings](#)

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

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

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 [A01.06](#) on Steel Forgings and Billets.

Current edition approved Oct. 1, 2011. Published January 2012. Originally approved in 2006. Last previous edition approved in 2006 as A1048/A1048M – 06. DOI: 10.1520/A1048_A1048M-06R11.

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.

[A966/A966M Practice for Magnetic Particle Examination of Steel Forgings Using Alternating Current](#)

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification [A788/A788M](#), the purchaser should include with the inquiry and order the following information:

3.1.1 A drawing, sketch, or written description of the required forging and the manner of providing test material (see Section 6).

3.1.2 Desired supplementary requirements including those from Specification [A788/A788M](#).

3.1.3 Requirements for alternate ultrasonic examination procedure (see [7.1.2](#)).

3.1.4 At the purchaser's option Test Method [A966/A966M](#) shall be used for the magnetic particle examination.

3.2 Forgings supplied to this specification shall conform to the requirements of Specification [A788/A788M](#) which, in addition to ordering information, includes manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with those of Specification [A788/A788M](#), the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 The steel melting procedures of Specification [A788/A788M](#) shall apply except that the open hearth process shall not be used, and that the molten steel shall be vacuum degassed prior to or during teeming of the ingot to remove objectionable gasses, notably hydrogen.

4.2 Heat Treatment:

4.2.1 After being permitted to transform following completion of forging the material may be given an intermediate heat treatment such as normalizing and tempering or a subcritical anneal prior to preliminary machining to the required heat treatment contour. The purchaser may specify supplementary requirement S1 to have the forgings rough machined before the final heat treatment.

4.2.2 Heat treatment applied either after rough machining or directly after cooling from forging shall consist of normalizing and tempering as follows:

Normalize from 1950 to 2050°F [1065 to 1120°C]
Temper at 1290 to 1400°F [700 to 760°C]

4.2.3 Multiple normalize or temper cycles, or both, may be applied providing the final stages comply with the temperatures shown in 4.2.2.

5. Chemical Composition

5.1 *Heat Analysis*—The heat analysis obtained from samples taken in accordance with Specification **A788/A788M** shall comply with **Table 1**.

5.2 The manufacturer shall use the product analysis provisions of Specification **A788/A788M** to obtain a product analysis from a forging representing each heat or multiple heat. The purchaser may also make this determination in accordance with Specification **A788/A788M**.

6. Mechanical Properties

6.1 Tension and Charpy impact test specimens shall be oriented in the longitudinal direction, that is, with their major axes parallel to the direction of maximum working.

6.2 Both the tensile and Charpy impact specimens shall be located at the mid-radius or ¼ thickness location in the integral test prolongation or, if applicable (see 6.4), in the test forging.

6.3 The integral test prolongation or prolongations shall be no smaller in diameter or effective section thickness than the maximum diameter or cross section of the connected forging.

6.4 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, a separately forged test bar may be used to provide material for mechanical testing.

6.4.1 The heat-treated diameter or section thickness of the test forging must be at least equal to the heat-treated diameter or effective section of the forgings it represents.

6.4.2 One test forging, yielding one tension test and a Charpy impact test (consisting of three specimens) is required to represent each heat in each heat treatment charge.

6.5 For heat-treated weights over 5000 lb [2250 kg] but not more than 10 000 lb [4500 kg] an integral prolongation is required at one end of each forging. One tension test and one Charpy test (three specimens) is required for each forging.

6.6 For heat-treated weights over 10 000 lb [4500 kg] and heat-treated lengths up to 10 ft [3 m], excluding the test prolongation, two sets of mechanical test specimens shall be taken from an integral prolongation at one end of each forging. These sets shall be located 180° apart and each set shall consist of one tension test and a Charpy test.

6.6.1 For heat-treated weights over 10 000 lb [4500 kg] and heat-treated lengths over 10 ft [3 m], a test prolongation is required to be located at each end of the forging. One set of mechanical test specimens shall be taken from each prolongation, and each test set shall consist of one tension test and a Charpy test.

6.7 The tension and Charpy test results shall conform to the requirements of **Tables 2 and 3**, respectively.

7. Nondestructive Examination

7.1 Ultrasonic Examination:

7.1.1 Forgings shall undergo ultrasonic examination in accordance with the procedures of Practice **A388/A388M**.

7.1.2 *Straight-Beam Examination*—Unless otherwise specified by the purchaser (see 3.1.3) back-reflection method shall be used.

7.1.3 In addition to the reportable conditions referenced in Practice **A388/A388M** indications exceeding the resultant back-reflection shall be recorded.

7.1.4 A forging shall be considered to be unacceptable when one or more reflections are present producing indications accompanied by a complete loss of back-reflection, not attributable to nor associated with the geometric configuration. For this purpose a back-reflection of less than 5 % of full screen height shall be considered to be complete loss of back-reflection.

7.1.5 *Angle-Beam Examination*—Bored or hollow forgings shall be provided with calibration notches in accordance with Practice **A388/A388M**.

7.1.6 A forging that contains a discontinuity that results in an indication exceeding the amplitude of the reference line is subject to rejection.

7.1.7 The report of the complete ultrasonic test shall be in compliance with Practice **A388/A388M**.

7.2 Magnetic Particle Examination :

7.2.1 Each forging shall be examined by a magnetic particle method in accordance with Test Method **A275/A275M** after heat treatment and in the final machined condition, except that at the purchaser's option (see 3.1.4) the AC Yoke from Test Method **A966/A966M** shall be used.

7.2.2 Only indications with major dimensions exceeding ⅛ in. [1.5 mm] shall be considered to be relevant. The following relevant indications are unacceptable:

TABLE 1 Chemical Composition %

Element	Grade 315	Grade 315Ta
Carbon	0.08-0.12	0.08-0.12
Manganese	0.25-0.45	0.25-0.45
Phosphorous, max	0.010	0.010
Sulfur, max	0.010	0.010
Silicon	0.15-0.40	0.15-0.40
Nickel, max	0.25	0.25
Chromium	2.8-3.2	2.8-3.2
Molybdenum	0.65-0.85	0.65-0.85
Vanadium	0.20-0.30	0.20-0.30
Boron, max	0.0007	0.0007
Tungsten	1.35-1.75	1.35-1.75
Tantalum	...	0.07-0.13
Aluminum, max	0.015	0.015

TABLE 2 Tensile Requirements

Property	Grade 315 and Grade 315Ta
Tensile Strength, ksi [MPa]	105-135 [725-930]
Yield Strength, ksi [MPa] min	85 [585]
Elongation in 2 in. [50 mm], % min	16
Reduction of Area, % min	50

TABLE 3 Charpy V-Notch Impact Requirements Tested at 32°F [0°C] max

Property	Grades 315 and 315Ta
Lateral Expansion, mils [mm] min	25 [0.6 mm]
Min Average Absorbed Energy, ft-lbf [J] ⁴	35 [48]
Min Single Value, ft-lbf [J]	25 [34]

⁴ Not more than one specimen from a set of three may be below this value.

7.2.2.1 Any linear indication greater than 1/16 in. [1.5 mm] in length for forgings up to and including 1 in. [25 mm] in thickness, or greater than 1/8 in. [3 mm] in length for forgings greater than 1 in. [25 mm] but not more than 3 in. [75 mm] in thickness, or greater than 3/16 in. [5 mm] in length for forgings greater than 3 in. [75 mm] in thickness.

7.2.2.2 Rounded indications with dimensions greater than 1/8 in. [3 mm] for thickness dimensions up to and including 1 in. [25 mm] and 3/16 in. [5 mm] for thicknesses over 1 in. [25 mm].

7.2.2.3 Four or more relevant indications (linear or rounded) in a line and separated by 1/16 in. [1.5 mm] or less, edge to edge.

7.2.2.4 Ten or more relevant indications in any 6 in.² [40 cm²] of surface with the major dimension of this area not to exceed 6 in. [150 mm].

8. Certification and Reports

8.1 In addition to the certification and reporting requirements of Specification **A788/A788M**, the manufacturer shall include the following:

8.2 Product analysis results, and

8.3 Sketches or drawings as needed to illustrate the nondestructive examination reports.

9. Keywords

9.1 alloy steel forgings; boilers; chromium-molybdenum-tungsten; elevated temperature service; mandatory nondestructive testing; pressure vessels

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the order. Additional supplementary requirements are included in Specification **A788/A788M** for use by the purchaser. Details of the selected supplementary requirements shall have been agreed upon between the manufacturer and purchaser.

S1. Preliminary Machining

S1.1 Forgings shall be rough machined to a drawing provided by, or agreed to by the purchaser prior to heat treatment.

S2. Special Tension Test Requirements for Hubbed Tube Sheets and Flanges

S2.1 For hubbed tube sheets and flanges supplied for ASME Boiler and Pressure Vessel Code applications, tension and impact test specimens shall be taken from the hub location as shown in S12 of Specification **A788/A788M**.

S2.2 The number of tests shall be as required in Section 6 and shall replace those required in Section 6.

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