Designation: A508/A508M – 17

Standard Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels[1]

This standard is issued under the fixed designation A508/A508M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers quenched and tempered vacuum-treated carbon and alloy steel forgings for pressure vessels such as those used in reactor systems. Specifically, it covers forgings for vessel closures, shells, flanges, tube sheets, rings, heads, and similar parts.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

1.3 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 non-conformance with the standard.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

NOTE 1—Grades 1 and 1A are composed of different chemistries but have the same mechanical requirements.

NOTE 2—Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 4
Grade 4N Class 2	Class 4A
Grade 4N Class 3	Class 4B
Grade 5 Class 1	Class 5
Grade 5 Class 2	Class 5A
Grade 22 Class 3	Class 22B
Grade 22 Classes 4, 5, 6, and 7	
Grade 3V	Class 3V

1.5 *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.*

1.6 *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:*[3]

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

A966/A966M Practice for Magnetic Particle Examination of Steel Forgings Using Alternating Current

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

[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.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-508/SA-508M in Section II of that Code.

[3] 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**

2.2 *American Society of Mechanical Engineers Standard:*
Boiler and Pressure Vessel Code—Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, NG 2300[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *controlling cross section thickness (T_C)*—the diameter of the largest theoretical sphere which can be inscribed within the volume of the forging.

4. Ordering Information

4.1 *Purchase Order*—In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing that locates the areas of significant loading in the forging (when required), the method of selecting test locations (see 7.1.5 and 7.1.6), and purchase options (see 5.2.2, 7.2, and 11.1) and any supplementary requirements desired.

4.2 *Forging Drawing*—Each forging shall be manufactured in accordance with a purchaser-approved drawing showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to significant loading, and the locations of mechanical test specimens.

4.3 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

4.3.1 When specified by the purchaser, it is permissible to perform Magnetic particle examination using the AC yoke in accordance with Practice A966/A966M instead of using Practice A275/A275M (see 9.2.1).

4.4 The optional minimum silicon content as expressed in Footnote B to Table 1, if required.

4.5 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 *Melting Process:*

5.1.1 The steel shall be made by the basic electric-furnace process except when secondary ladle refining or the remelting process is employed, in which case the melting processes of Specification A788/A788M are permitted.

5.1.2 The molten steel shall be vacuum treated in accordance with the methods described in Specification A788/A788M, prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

Grade 22 Classes 4, 5, 6, and 7 liquid steel shall be produced to a fine grain melting practice which has been shown to result in a prior austenitic grain size of five or finer.

5.1.3 *Discard*—Sufficient discard shall be made from each ingot to secure freedom from piping and excessive segregation.

5.2 *Heat Treatment:*

5.2.1 *Preliminary Heat Treatment*—After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Preliminary heat treatment may be applied to improve machinability and to enhance subsequent heat treatments.

5.2.2 *Heat Treatment for Mechanical Properties*—The forgings shall be heated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium by spraying or immersion. For Grade 4N, Classes 1 and 3, the austenitizing temperature shall be 1540 °F [840 °C] min to 1640 °F [895 °C] max. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of one-half hour per inch of maximum section thickness. Except when Supplementary Requirement S 13 is specified for Grades 2 and 3, the minimum tempering temperatures shall be as follows:

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

TABLE 1 Chemical Requirements

	Composition, %									
	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 4N	Grade 5	Grade 22[A]	Grade 3V	Grade 3VCb	Grade 6
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.23 max	0.23 max	0.11–0.15	0.10–0.15	0.10–0.15	0.28–0.33
Manganese	0.40–1.05	0.70–1.35	0.50–1.00	1.20–1.50	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60	0.75–1.15
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.020 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.010 max	0.025 max
Silicon[B]	0.40 max	0.40 max	0.40 max	0.40 max	0.40 max	0.30 max	0.35 max	0.10 max	0.10 max	0.35 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	2.8–3.9	2.8–3.9	0.25 max	. . .	0.25 max	0.75–0.95
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	1.50–2.00	1.50–2.00	2.00–2.50	2.8–3.3	2.7–3.3	0.70–1.00
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.40–0.60	0.40–0.60	0.90–1.10 max	0.90–1.10	0.90–1.10	0.30–0.45
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.03 max	0.08 max	0.02 max	0.20–0.30	0.20–0.30	0.05 max
Columbium	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.015–0.070	0.01 max
Copper	0.20 max	0.20 max	0.20 max	0.20 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max
Calcium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.0005–0.0150	0.015 max
Boron	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.001–0.003	0.003 max	0.003 max
Titanium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015–0.035	0.015 max	0.015 max
Aluminum[C]	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.015 max	0.015 max	0.025 max

[A] For Grade 22 Classes 5, 6, and 7 with section thickness at heat treat of 8 in. or greater, the carbon and manganese shall be held to 0.13 to 0.15 and 0.50 to 0.60, respectively.
[B] When required by the purchaser a minimum silicon content of 0.15 % shall apply for Grades 1, 1A, 2, 3, and 4N.
[C] Aluminum content reported shall be the combined total soluble and insoluble aluminum.

Grades 1, 1A, 2 Class 2, and 3 Class 2	1150 °F [620 °C]
Grades 2 Class 1 and 3 Class 1	1200 °F [650 °C]
Grades 4N Classes 1 and 2, and 5 Classes 1 and 2	1100 °F [595 °C]
Grade 4N Class 3	1125 °F [605 °C]
Grades 3V and 3VCb	1250 °F [675 °C]
Grade 22, Class 3	1200 °F [650 °C]
Grade 22, Classes 4, 5, 6, and 7	1100 °F [593 °C]

Specific cooling rates from the tempering temperature shall be applied if Supplementary Requirement S14 is specified.

5.3 For Grades 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 5.2.2.

6. Chemical Composition

6.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1 except that the additional features of Supplementary Requirements S7, S8, S9, and S11 shall also apply as individually specified in the ordering information.

6.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations provided in the table on Permissible Variations in Product Analysis for Killed Steel in Specification A788/A788M apply for manganese, nickel, chromium, molybdenum, and vanadium only. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A788/A788M.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 The steel shall conform to the requirements of Table 2.

7.1.2 The location and number of tension test specimens for each forging or multiple forging shall be as follows:

7.1.2.1 *Individual Forgings with Weights Not Exceeding 1000 lb [455 kg] or Multiple Forgings Separated into Identical Individual Forgings with Weights not Exceeding 1000 lb [455 kg] Prior to Quenching and Tempering Treatment*—At least one individual forging from each heat and each heat-treating lot shall be tested using the test specimen locations of 7.1.5 or 7.1.6 as specified on the purchase orders, except that test specimens located at midlength may be closer to the ends of the production forging than the specified distance to the second surfaces. All forgings shall be quenched and tempered in the same furnace charge. All forgings from the multiple shall be Brinell hardness tested after heat treatment and forgings not tested for mechanical properties shall have a Brinell Hardness within 20 points of the Brinell Hardness of the forging that has been tested for mechanical properties.

7.1.2.2 *Forgings or Multiple Forgings (Note 3) with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation (Note 4) shall be located at one end. One tension test specimen shall be taken from the test prolongation.

7.1.2.3 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. One tension test specimen shall be taken from each test prolongation. An orientation of 180° shall be established between the two tension test specimens.

7.1.2.4 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation shall be located at one end. Two tension test specimens shall be taken from the test prolongation and shall be oriented 180° apart.

7.1.2.5 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. The tension test specimens oriented 180° apart from each other shall be taken from each test prolongation. The two tension specimens located in one test prolongation shall be oriented 90° in relation to the two tension specimens located in the other test prolongation.

NOTE 3—Multiple forgings in 7.1.2.2 through 7.1.2.5 are those which will be separated after the quench and temper treatment.

NOTE 4—A test prolongation is defined as that integral test metal located at an end of the forging or forging multiples.

7.1.3 Samples for mechanical test specimen shall be removed from forgings after the quenching and tempering heat treatment. The sample material shall be subjected to a simulated post weld heat treatment if Supplementary Requirement S1 is specified.

7.1.4 For upset disk forgings, the longitudinal axis of the test specimens shall be in the tangential direction. For all other parts, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging.

7.1.5 Each forging shall be manufactured in accordance with a purchaser-approved drawing, showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to critical stresses, and the location of mechanical test specimens.

7.1.6 The tension test specimens shall be positioned so that the longitudinal axis and mid-length is in accordance with one of the following methods:

7.1.6.1 *Method 1—t* by 2*t*, where *t* is the distance from the area of significant loading (see 4.1) to the nearest quenched surface. Specimens shall be removed at least 2*t* from the nearest second surface. However, they shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1½ in. [40 mm].

7.1.6.2 *Method 2—¼ T_C* by T_C. Specimens shall be removed ¼ T_C from the nearest quenched surface and at least T_C from all other surfaces exclusive of the T_C dimension surfaces.

TABLE 2 Tensile Requirements

	Grades 1 and 1a	Grades 2 Class 1 and 3 Class 1	Grades 2 Class 2 and 3 Class 2	Grades 4N Class 1 and 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grade 22 Class 3	Grades 3V and 3VCb	Grade 6 Class 1	Grade 6 Class 2	Grade 6 Class 3	Grade 6 Class 4	Grade 22 Class 4	Grade 22 Class 5	Grade 22 Class 6	Grade 22 Class 7
Tensile strength, ksi [MPa]	70–95 [485–655]	80–105 [550–725]	90–115 [620–795]	105–130 [725–895]	115–140 [795–965]	90–115 [620–795]	85–110 [585–760]	85–110 [585–760]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]
Yield strength, min [0.2 % offset], ksi [MPa]	36 [250]	50 [345]	65 [450]	85 [585]	100 [690]	70 [485]	55 [380]	60 [415]	60 [415]	75 [515]	80 [550]	85 [585]	60 [415]	75 [515]	80 [550]	85 [585]
Elongation in 2 in. or 50 mm, min, %	20	18	16	18	16	20	18	18	20	18	18	18	20	18	18	18
Reduction of area, min, %	38	38	35	45	45	48	45	45	35	35	35	35	35	35	35	35