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

Where this method of testing is employed, the following limitations for T_C shall generally apply:

Grades 1 and 1a	3 in. [75 mm], max
Grades 2 Class 2 and 3 Class 2	6 in. [150 mm], max
Grades 2 Class 1 and 3 Class 1	8 in. [205 mm], max
Grade 4N Class 2 and 5 Class 2	16 in. [405 mm], max
Grade 4N Class 1 and 5 Class 1	30 in. [760 mm], max
Grade 4N Class 3	40 in. [1015 mm], max
Grades 3V and 3VCb	20 in. [510 mm], max
Grade 22 Class 3	20 in. [510 mm], max
Grade 22 Classes 4, 5, 6, and 7	12 in. [305 mm], max

7.1.6.3 *Method 3*—Test specimens shall be taken from a representative separate test forging made from the same heat of steel and shall receive substantially the same reduction and type of hot working as the production forgings that it represents and shall have the same T_C as the as-quenched production forgings. The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed from the region midway between the mid-thickness and the surface, and not closer than T_C to a second heat treated surface with the same limitation on forging thickness as in 7.1.6.2. Alternatively, an extra production forging of the same configuration (right and left handed configurations being considered equivalent) as that ordered, may be tested as described in Method 2.

7.1.6.4 *Method 4*—A thermal buffer ring, at least T_C by T_C in cross section, or segments of such a ring at least 3 T_C in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial-penetration type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the buffer ring segment at a minimum distance of T_C from each end of that segment. In either case, the test specimens shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface of the forging, and at least ¼ T_C from a quenched surface of the forging. Where this method of testing is employed, the limitations for T_C given in 7.1.6.2 shall generally apply.

NOTE 5—For forgings with a maximum T_C of 2 in. [50 mm], the specimens shall be taken at midthickness and at least 2 in. from a second surface. This provision is applicable to all four methods in 7.1.6.

7.1.7 Tension specimens shall be the standard 0.5 in. [12.5 mm] round by 2 in. [50 mm] gauge length, as shown in Test Methods and Definitions A370.

7.2 *Impact Test*—The steel shall conform to the requirements of Table 3, or Supplementary Requirement S10 may be specified instead of these requirements.

7.2.1 *Number, Location, and Orientation of Specimens:*

7.2.1.1 One set of three Charpy V-notch specimens shall be taken from each tensile specimen location required in 7.1.2. Orientation shall be the same as in 7.1.4. When S10 is specified, the required number of tests shall be governed by NB, NC, ND, NE, NF, or NG 2300, as applicable.

7.2.1.2 The requirements of 7.1.3 also apply to impact specimens.

7.2.1.3 The longitudinal axis and mid-length of the impact specimen shall be located similarly to the longitudinal axis of the tension test specimens as defined in 7.1.6. The axis of the notch shall be normal to the nearest heat-treated surface of the forging. When Supplementary Requirement S10 is specified the orientation shall be governed by NB, NC, ND, NE, NF, or NG 2300.

7.2.2 Impact specimens shall be Charpy V-notch as shown in Test Methods and Definitions A370.

8. Workmanship and Quality Level Requirements

8.1 See requirements in 9.1, 9.2.2, 9.3.1.1, and 9.3.2.2.

9. Nondestructive Inspection Requirements

9.1 *General Requirements*—Dimensional and visual inspections, and magnetic particle and ultrasonic inspection shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other injurious indications.

9.2 *Magnetic Particle Inspection:*

9.2.1 Following final machining by the manufacturer all accessible surfaces of each forging shall be examined by the continuous current magnetic particle method. This examination shall be in accordance with Practice A275/A275M unless the purchaser has required the use of the AC yoke in accordance with Practice A966/A966M instead (see 4.3.1).

9.2.2 The following conditions are subject to rejection or removal:

9.2.2.1 Indications with major dimension exceeding 3⁄16 in. [4.8 mm].

9.2.2.2 Four or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions that are aligned and separated by 1⁄16 in. [1.6 mm] or less end to end.

9.2.2.3 Ten or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions contained in any 6 $in.^2$ [39 cm^2] of surface, with the major dimension of this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

9.3 *Ultrasonic Inspection*—Forgings shall be ultrasonically inspected in accordance with the procedures of Practice A388/A388M.

9.3.1 *Longitudinal Wave Inspection:*

9.3.1.1 Unless otherwise specified by Supplementary Requirement S2, the back reflection method of tuning shall be used in accordance with 7.2.2.1 of Practice A388/A388M. In addition to the reportable conditions in Section 7 of Practice A388/A388M, indications exceeding the resultant back reflection shall be recorded. The following conditions are considered rejectable:

9.3.1.2 Complete loss of back reflection not associated with forging configuration or surface and accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5 % of full screen height shall be considered complete loss of back reflection.

9.3.1.3 Indications whose amplitude equals or exceeds that of the back reflection established in an indication-free area of the forging.

TABLE 3 Charpy Impact Requirements

	Grades 1 and 1a at +40 °F [4.4 °C]	Grades 2 Class 1 and 3 Class 1 at +40 °F [4.4 °C]	Grades 2 Class 2 and 3 Class 2 at +70 °F [21 °C]	Grades 4N (all classes) and 5 (all classes) at –20 °F [–29 °C]	Grade 22, Class 3, and Grades 3V and 3VCb at 0 °F [–18 °C]	Grade 6 Classes 1, 2, 3, and 4 at –75 °F [–59 °C]	Grade 22 Classes 4, 5, 6, and 7 at –75 °F [–60 °C]
Minimum average value of set of three specimens, ft·lbf [J][A]	15 [20]	30 [41]	35 [48]	35 [48]	40 [54]	20 [27]	40 [55]
Minimum value of one specimen, ft lbf [J]	10 [14]	25 [34]	30 [41]	30 [41]	35 [50]	15 [20]	35 [50]

[A] Not more than one specimen from a set may be below this value.

9.3.2 *Angle Beam Inspection:*

9.3.2.1 Calibration notches shall be cut into the inside- and outside-diameter surfaces with a depth equal to 3 % of the nominal section thickness (or ⅜ in. [9.5 mm], max), a length of approximately 1 in. [25 mm], and a width not greater than twice its depth. Adjust instrument controls to obtain an indication from the inside-diameter notch approximately 75 % of full screen height. Measure the amplitude of indication from the outside-diameter notch. Draw a straight line on the shield in front of the cathode ray tube from this peak to that of the inside-diameter notch and continue it as a horizontal line to the initial pulse. This line constitutes the angle beam reference line.

9.3.2.2 A forging containing a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

NOTE 6—Signals from discontinuities within approximately ¼ in. [6.4 mm] of inside and outside surfaces are reinforced by wave trapping during angle beam inspection; they are therefore amplified in respect to internal discontinuities.

9.3.3 The report of the ultrasonic inspection shall be in compliance with Section 8 of Practice A388/A388M.

9.3.4 Additional nondestructive inspection or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious indications which will not be removed in final machining.

10. Repair Welding

10.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

10.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11. Certification and Reports

11.1 In addition to items to be reported by Specification A788/A788M, the following items shall also be reported:

11.1.1 Product chemical analysis,

11.1.2 The method used for locating test specimens, and

11.1.3 Sketches showing the locations of all recordable indications in the report of all nondestructive examinations.

11.1.3.1 If Practice A966/A966M has been used, this also shall be recorded in the certification.

11.1.4 Details of the heat treatment cycle, as listed in Specification A788/A788M.

12. Product Marking

12.1 The purchaser may specify additional identification marking and the location of the stamping. The type of stamps to be used when impression stamping is performed shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of 1/32 in. [0.8 mm].

13. Keywords

13.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steels; pressure vessel service; quenched and tempered steels; steel forgings—alloy; steel forgings—carbon; vacuum-treated steels

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, timers, and cooling rates.

S2. Ultrasonic Testing-Reference Block Calibration (for examining sections 24-in. [610 mm] thick or less)

S2.1 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S2.1.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25 %.

S2.1.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E428.

S2.2 For test sections up to 12 in. [305 mm] thick, the reference blocks shall contain a ¼-in. [6.4-mm] diameter flat-bottom hole; for over 12 to 18 in. [305 to 457 mm], the hole diameter shall be ⅜ in. [9.5 mm]; and for over 18 to 24 in. [457 to 610 mm], it shall be ½ in. [13 mm].

S2.3 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S2.4 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection.

S3. Charpy V-Notch Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test-temperature range shall be wide enough to establish

the upper and lower shelf foot-pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Additional Charpy Data

S4.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A370, shall be reported for each Charpy specimen tested.

S4.2 Acceptance values for percent shear fracture and/or lateral expansion values shall be as specified by the purchaser.

S5. Alternative Impact Test

S5.1 Charpy impact tests shall be made in accordance with the provisions of 7.2 of the specification except that the test temperature shall be lower than specified in Table 3. This test shall be instead of that specified in 7.2.

S6. Drop-Weight Test

S6.1 Drop-weight tests shall be conducted in accordance with the requirements of Test Method E208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 7.1.6. However, since the drop weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 1 (7.1.6.1) shall be a minimum distance of 7⁄16 in. [11 mm] from the nearest quenched surface, and 1½ in. [38 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10 °F [6 °C] warmer than a specified temperature or request a determination of the NDT temperature.

S7. Restrictive Chemistry for Grades 4N and 5

S7.1 Phosphorus and sulfur limits for Grades 4N and 5 shall be 0.015 % maximum heat and 0.018 % maximum product.

S8. Additional Vanadium

S8.1 The vanadium content for Grade 5 forgings shall be 0.05 to 0.15 %.

S9. Restrictive Chemistry for Grades 2, 3, or 4N

S9.1 Grades 2, 3, or 4N shall be specified with restricted phosphorus and copper limits, as follows:

S9.1.1 P 0.012 maximum heat and 0.015 maximum product; Cu 0.10 maximum heat and product, or

S9.1.2 P 0.015 maximum heat and 0.018 maximum product; Cu 0.15 maximum heat and product.

S9.2 Grades 2, 3, 4N shall be specified with restricted sulfur of 0.015 heat and 0.018 product.

S10. Alternative Fracture Toughness Requirements

S10.1 The fracture toughness requirements (drop weight and Charpy impact tests) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, or NG 2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S11. Vacuum Carbon-Deoxidized Steels

S11.1 Material made to Grades 1, 1a, 2, 3, 4N, or 5 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.10 % max. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S12. Vacuum-Treated Basic Oxygen Furnace Steels

S12.1 For Grades 1, 1a, 2, or 3 material, vacuum-treated basic oxygen furnace steel shall be used.

S13. Minimum Tempering Temperature

S13.1 For Grades 2 Class 1 and 3 Class 1 the minimum tempering temperature shall be 1175 °F [635 °C] and the simulated post weld heat treatment temperature shall not exceed 1150 °F [620 °C] when S1 is required.

S14. Cooling from the Tempering Temperature

S14.1 The purchaser shall provide specific cooling rates from the tempering temperature.

S15. Product Analysis

S15.1 More than one forging per heat shall be subject to product analysis by either the manufacturer or purchaser. The purchaser shall indicate in the ordering information the number of forgings to be tested, and whether the manufacturer, purchaser, or both shall perform the additional analyses.

S16. Silicon Content

S16.1 The silicon content shall be 0.05 to 0.15 % as a result of ladle refining with aluminum as the deoxidizer. Use of Vacuum Ladle Degassing is optional.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A508/A508M – 16) that may impact the use of this standard. (Approved May 1, 2017.)

(1) Revisions to 7.1.2.1 on allowing forgings made as identical individuals (<1000 lb) to be qualified on a per lot basis. Identical individual forgings from multiple forgings can be tested on a per lot basis as well, regardless how many multiple forgings they came from.

Committee A01 has identified the location of selected changes to this standard since the last issue (A508/A508M – 14) that may impact the use of this standard. (Approved May 1, 2016.)

(1) Added "Grade" to column heading for Grade 22 Class 7 in Table 2.
(2) Added T_C limits from 7.1.6.2 to 7.1.6.4.
(3) Revisions to 7.1.2.2 to include forgings with weight = 10 000 lb.