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Standard Specification for Alloy Steel Forgings for High-Strength Pressure Component Application[1]

This standard is issued under the fixed designation A723/A723M; 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[2] covers requirements for high-strength quenched and tempered alloy steel forgings for pressure vessels, isostatic presses, shock tubes, and similar components.

1.2 These materials are not intended for welded construction.

1.3 Three grades of nickel-chromium-molybdenum steels and six classes of increasing tensile strength are included. The strength class, section size, and configuration of the forging will largely dictate the applicable type(s) of steel.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

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

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

2.2 *Other Standards:*

ASME Boiler and Pressure Vessel Code[4]

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the method of selecting test location (see 6.2). When appropriate, the areas of significant loading in the forging shall be designated. The purchaser may also include appropriate supplementary requirements from Specification A788/A788M as well as from this specification.

3.2 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.

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

3.4 When forgings are required to be in compliance with Division 3 of the ASME Boiler and Pressure Vessel Code, Supplementary Requirement S6 should be specified.

4. Materials and Manufacture

4.1 *Melting Practice*—The steel melting procedures of Specification A788/A788M shall apply except that the open-hearth process shall not be used, and that the steel shall be vacuum degassed prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

4.1.1 Use of secondary remelting or refining operations may be considered for particularly demanding applications.

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

[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–723/SA–723M 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.

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

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

4.3 *Heat Treatment:*

4.3.1 Forgings shall be rough-machined prior to final heat treatment if it is necessary to reduce the mass to ensure full hardening or to meet the requirements of 6.2. The risk of cracking during heat treatment with high-hardenability steels of the type covered by this specification should be borne in mind when deciding on the degree of surface preparation before heat treatment.

4.3.2 *Heat Treatment for Mechanical Properties*—Heat treatment shall consist of normalizing (which may be part of the preliminary treatment), reaustenitization, liquid quenching, and tempering. The forgings shall be quenched in a suitable liquid medium by spraying or immersion. Quenching shall be followed by tempering at a minimum temperature of 1000°F [540°C]. The minimum time at tempering temperature shall be ½ h/in. [½ h/25 mm] of maximum section thickness, unless otherwise agreed between supplier and purchaser.

5. Chemical Composition

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

5.1.1 *Temper Embrittlement Control*—The purchaser's attention is drawn to Supplementary Requirement S24 in Specification A788/A788M for application of the J Factor which may be of assistance in the control of temper embrittlement in forgings produced to Specification A723/A723M.

5.2 *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 purchaser may also make this determination in accordance with Specification A788/A788M.

6. Mechanical Properties

6.1 *General Requirements*—The forging shall conform to the requirements of Table 2 and Table 3. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 (that is, standard round 0.500-in. [12.5-mm] diameter specimen) shall be used. Charpy V-notch Type A impact specimens, as shown in Test Methods and Definitions A370, shall be used.

6.2 *Sampling*—The mid-point of the gage length of tension test specimens and the area under the notch of impact specimens shall be located in accordance with one of the following methods as specified by the purchaser, or suggested by the supplier and approved by the purchaser. Wherever practical, all testing shall be from integral prolongations of the forging.

TABLE 1 Chemical Requirements

	Composition, %		
	Grade 1	Grade 2	Grade 3
Carbon, max	0.35	0.40	0.40
Manganese, max	0.90	0.90	0.90
Phosphorus, max	0.015	0.015	0.015
Sulfur, max	0.015	0.015	0.015
Silicon, max	0.35	0.35	0.35
Nickel	1.5 to 2.25	2.3 to 3.3	3.3 to 4.5
Chromium	0.80 to 2.00	0.80 to 2.00	0.80 to 2.00
Molybdenum	0.20 to 0.40	0.30 to 0.50	0.40 to 0.80
Vanadium, max	0.20	0.20	0.20

6.2.1 *Method 1*—This method shall always be used when the maximum quenched thickness does not exceed 4 in. [100 mm]. Datum points of the specimens, as described in 6.2, shall be located in the forging or test forging (6.2.4) at mid-thickness and at least ⅔ T (T is the maximum heat-treated thickness) from the quenched end surface or nearest adjacent surfaces.

6.2.2 *Method 2—t* by 2*t*, where *t* is the distance from the area of significant loading (3.1) to the nearest quenched surface. However, the datum points of the specimens as described in 6.2 shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1 ½ in. [40 mm]. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawing showing prequenched dimensions and the location of mechanical test specimens. It is commonly used for disk-type forgings such as tube sheets and covers.

6.2.3 *Method 3*—For maximum quenched thicknesses in excess of 4 in. [100 mm] as heat treated. Where this method of testing is employed, the datum points of the test specimen, as described in 6.2, shall be removed ¼ *T* from the nearest quenched surface and ⅔ *T* from the quenched end surface or nearest adjacent surface.

6.2.4 *Method 4*—Test specimens shall be taken from a representative separate test forging made from the same heat of steel, which shall receive substantially the same reduction and type of hot working, and have a cross section not less than the production forgings which it represents. It shall be heat treated in the same furnace charge and under the same conditions as the production forgings. The test specimen shall be removed using the Method 3 procedure.

6.3 *Thermal Buffers:*

6.3.1 Thermal buffer rings, at least *T* by *T* in cross section or sections of such a ring at least 3 *T* in length, shall be welded to the test end(s) 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 the latter are used, the test coupons shall be removed from the forging in the area under the center ⅓ of the buffer ring segment length. 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* from a quenched surface of the forging. Buffered weld areas must be at least 1 in. [25 mm] from any finished machining surface of the complete forging.

6.3.2 Bearing in mind the characteristics of the base materials included in this specification, precautions should be taken, such as the use of pre- and post-weld heating and austenitic weld metal, to minimize the occurrence of crack-like defects.

6.3.3 Approval of the purchaser should be obtained for the use of this method.

6.4 Samples shall be removed from the forgings after quenching and tempering.

TABLE 2 Tensile Requirements

	Class 1	Class 2	Class 2a	Class 3[A]	Class 4[B]	Class 5[C]
Tensile strength, min, ksi [MPa]	115 [795]	135 [930]	145 [1000]	155 [1070]	175 [1205]	190 [1310]
Yield strength, 0.2 % offset, min, ksi [MPa]	100 [690]	120 [825]	130 [895]	140 [965]	160 [1105]	180 [1240]
Elongation in 2 in. or 50 mm, min, %	16	14	13.5	13	12	10
Reduction of area, min, %	50	45	43	40	35	30

[A] Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[B] Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[C] Typical maximum section size of 4 in. [100 mm].

TABLE 3 Charpy V-Notch Impact Requirements at 40°F [4.5°C] max[A]

	Class 1	Class 2	Class 2a[A]	Class 3[B]	Class 4[C]	Class 5[D]
Minimum average value of set of three specimens, ft·lbf[E] [J]	35 [47]	30 [41]	28 [38]	25 [34]	20 [27]	12 [16]
Minimum value of one specimen, ft·lbf [J]	30 [41]	25 [34]	23 [31]	20 [27]	15 [20]	10 [14]

[A] Or such other lower temperature as is specified when supplementary requirement S3 is involved.
[B] Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[C] Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[D] Typical maximum section size of 4 in. [100 mm].
[E] Not more than one specimen from a set may be below this value.

6.5 *Orientation*—For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential or radial direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging, or as agreed between manufacturer and purchaser.

6.6 *Number of Tests:*

6.6.1 For forgings weighing 1000 lb [455 kg] or less, as heat treated but not exceeding 80 in. [2030 mm] in length, excluding test material, one tension test and one set of impact tests (three specimens) shall be taken to represent each heat in each heat-treatment charge. This testing shall be repeated at the opposite end of the same test forging, if the heat-treated length excluding test material exceeds 80 in. [2030 mm]. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding 8 h in duration.

6.6.2 Forgings weighing over 1000 lb [455 kg] but not over 5000 lb [2270 kg] as heat treated and not over 80 in. [2030 mm] in length excluding test material, one tension test and one set of three impact tests shall be removed from each forging. When the length of the forging exceeds 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging.

6.6.3 Forgings exceeding 5000 lb [2270 kg] and not over 80 in. [2030 mm] in length, excluding test material, shall have one tension test and one set of three impact tests removed from each of two locations, 180° apart. For forgings with lengths exceeding 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging. Supplementary Requirement S6 is applicable for forgings intended for use under the rules of Section VIII, Division 3 of the ASME Boiler and Pressure Vessel Code.

7. Nondestructive Examination Requirements

7.1 *Ultrasonic Examination:*

7.1.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A388/A388M.

7.1.1.1 *Straight-Beam Examination:* (*a*)Unless otherwise specified, the back-reflection method of tuning shall be used in accordance with Practice A388/A388M.

(*b*) In addition to the reportable conditions of Practice A388/A388M, indications exceeding the resultant back-reflection shall be recorded.

(*c*) A forging shall 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 complete loss of back-reflection.

7.1.1.2 *Angle-Beam Examination:* (*a*) Calibration notches shall be cut into the inside diameter and outside diameter surfaces in accordance with Practice A388/A388M.

(*b*) A forging that contains a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

(*c*) The report of the ultrasonic test shall be in compliance with Practice A388/A388M.

(*d*) Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious defects that will not be removed in final machining.

7.2 *Magnetic Particle Examination:*

7.2.1 Each forging shall be examined by magnetic particle methods described in Practice A275/A275M. Acceptance and rejection standards shall be as follows: Only indications with major dimensions greater than 1/16 in. [1.6 mm] shall be considered relevant. The following relevant indications are unacceptable:

7.2.1.1 Any linear indications greater than 1/16 in. [1.6 mm] long for materials less than 5/8 in. [16 mm] thick; greater than 1/8 in. [3.2 mm] long for materials from 5/8 in. to under 2 in. [50

mm] thick; and 3⁄16 in. [4.8 mm] long for materials 2 in. [50 mm] thick and greater. A linear indication is defined as one whose length is three times its width.

7.2.1.2 Rounded indications with dimensions greater than 1⁄8 in. [3.2 mm] for thicknesses less than 5⁄8 in. [16 mm], and greater than 3⁄16 in. [4.8 mm] for thicknesses 5⁄8 in. [16 mm] and greater.

7.2.1.3 Four or more relevant indications in a line separated by 1⁄16 in. [1.6 mm] or less, edge to edge.

7.2.1.4 Ten or more relevant indications in any 6 in.^{2} [3870 mm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

8. Rework and Retreatment

8.1 Repair welding shall not be permitted. For retreatment, see 7.2.1.

9. Certification and Reports

9.1 In addition to the certification requirements of Specification A788/A788M, the manufacturer shall include the following in the certification data:

9.1.1 Results of the product analysis,

9.1.2 Method used to locate mechanical test specimens (see Section 6), and

9.1.3 Sketches or drawings as necessary to supplement the nondestructive examination report.

10. Packaging and Package Marking

10.1 Marking shall be in accordance with Specification A788/A788M but stamping shall be permitted only in areas designated by the purchaser. If no such suitable area is available, a separate nameplate, with the required stamping, shall be permanently affixed to the vessel in a manner that will not be injurious to the vessel.

11. Keywords

11.1 alloy steel forgings; high pressure vessels; high strength; impact tested; isostatic presses; nonweldable; quenched and tempered; vacuum-treated steel

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 by the manufacturer and the purchaser.

S1. Charpy V-Notch Impact Transition Curve

S1.1 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-force energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S1.2 Instead of plotting an impact transition curve, impact requirements may be specified as 50 % fibrous fracture at a specified maximum temperature.

S2. Additional Charpy Data

S2.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A370, shall be reported for each Charpy specimen tested.

S3. Charpy Impact Tests

S3.1 Charpy impact tests shall be made in accordance with the provisions of Section 6 of this specification, except that the tests shall be at a specified temperature lower than 40°F [4.5°C]. These tests shall be instead of those specified in Section 6, and shall meet the requirements of Table 3.

S4. Impact Testing

S4.1 For Class 2a forgings, impact tests shall be made in accordance with the provisions of Section 6 of this specification except that the acceptance criteria shall be a minimum of 45 ft·lbf [61 J] and 25 mils [0.635 mm] lateral expansion at a test temperature specified by the purchaser.

S5. Mechanical Test Location Discard

S5.1 Instead of the discard of ¼ *T* x ⅔ *T* required by 6.2.3, a minimum discard of ¼ *T* x *T* shall be employed for Method 3.

S6. Alternate Mechanical Testing

S6.1 Forgings exeeding 5000 lb [2270kg] at the time of heat treatment, and not over 80 in. [2030 mm] in length, excluding test material, require one set of test specimens to be taken from each end of the forging. Each test specimen set shall consist of one tension test and three Charpy V-notch specimens. The test specimen set locations shall be spaced 180º apart, end to end. When the forging length exceeds 80 in. [2030 mm] excluding test material two sets of mechanical test specimens shall be removed from each end of the forging, and spaced 180º apart at the same end, and rotated 90º end to end.