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Standard Specification for Age-Hardening Alloy Steel Forgings for Pressure Vessel Components[1]

This standard is issued under the fixed designation A859/A859M; 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.

ε[1] NOTE—MPa value was added in 1.2.2 editorially in April 2019.

1. Scope

1.1 This specification covers requirements for low-carbon age-hardening nickel-copper-chromium-molybdenum-columbium alloy steel forgings for pressure vessel components.

1.2 Forgings under this specification are available as Grades A or B. Grade A may be ordered in one or two classes as follows:

1.2.1 *Grade A Class 1*—Normalized-and-precipitation-heat-treated, providing a minimum yield strength of 55 ksi ~~[380 MPa]~~ [380 MPa] and a minimum tensile strength of 65 ksi ~~[450 MPa].~~[450 MPa].

1.2.2 *Grade A Class 2*—Quenched-and-precipitation-heat-treated, providing a minimum yield strength of 65 ksi ~~[450 MPa]~~ [450 MPa] and a minimum tensile strength of 75 ksi ~~[MPa].~~[515 MPa].

1.2.3 Grade A was the original steel composition in this specification.

1.3 Although the material is readily weldable, welding procedures are of fundamental importance and must be such as not to affect adversely the properties of the material, especially in the heat-affected zone. It is presupposed that welding procedures will be suitable for the material being welded.

1.4 Supplementary requirements, including those applicable in Specification A788/A788M, are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 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~~are not ~~be~~necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the ~~other. Combining~~other and values from the two systems ~~may result in non-conformance with the standard.~~shall not be combined.

1.6 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

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]

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
E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E604 Test Method for Dynamic Tear Testing of Metallic Materials

[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 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~~standard's Document Summary page on the ASTM website.

2.2 *ASME Standard:*[3]
ASME Boiler and Pressure Vessel Code—Section IX

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 6.3). When appropriate, the areas of significant loading in the forging shall be designated.

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.

4. Manufacture

4.1 *Melting Practice*—The steel shall be made to a killed, fine austenitic grain size, practice.

4.1.1 Vacuum degassing in accordance with Specification A788/A788M is highly recommended.

4.2 *Heat Treatment:*

4.2.1 Normalizing may, at the ~~manufacturer's~~manufacturer's option, precede the prescribed heat treatment cycle.

4.2.2 Grade A Class 1 forgings shall be normalized at a temperature in the range from 1600 to ~~1725°F~~1725 °F [870 to ~~940°C~~]940 °C] and then precipitation hardened in the range from 1000 to ~~1225°F~~1225 °F [540 to ~~665°C~~]665 °C] for a time to be determined by the material manufacturer.

4.2.3 Grade A Class 2 forgings shall be liquid quenched from a temperature in the range from 1600 to ~~1725°F~~1725 °F [870 to ~~940°C~~]940 °C] and then precipitation hardened in the range from 1000 to ~~1225°F~~1225 °F [540 to ~~665°C~~]665 °C] for a time to be determined by the material manufacturer.

4.2.4 Grade B forgings shall be double quenched and tempered (liquid quenched twice) by austenitizing twice at a temperature in the range of 1600 to ~~1725°F~~1725 °F [870 to ~~940°C~~],940 °C], and then precipitation hardened at a temperature in the range of 1000 to ~~1300°F~~1300 °F [540 to ~~700°C~~]700 °C] for a time to be determined by the manufacturer.

5. Chemical Composition

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

5.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat.

TABLE 1 Chemical Requirements

	Composition, %	
Element	Grade A	Grade B
Carbon	0.07 max	0.02–0.04
Manganese	0.40–0.70	0.75–1.05
Phosphorus, max	0.025	0.015
Sulfur, max	0.025	0.002
Silicon, max	0.40	0.40
Chromium	0.60–0.90	0.45–0.75
Nickel	0.70–1.00	3.35–3.85
Molybdenum	0.15–0.25	0.55–0.65
Copper	1.00–1.30	1.15–1.75
~~Columbium~~	~~0.02 min~~	~~0.02–0.06~~
Columbium	0.02 min	0.02–0.06
Vanadium max	...	0.008
Aluminum max	...	0.03
Titanium max	...	0.003
Tin max	...	0.03
Arsenic max	...	0.025
Antimony max	...	0.025
Nitrogen	...	report

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

6. Mechanical Requirements

6.1 *Tensile Requirements*—The forgings, as represented by the tension test specimens, shall conform to the requirements of Table 2. The largest obtainable tension test specimen as specified in Test Methods and Definitions A370 shall be used.

6.2 *Notch Toughness Requirements:*

6.2.1 For Grade A, Class 1 or 2 forgings, unless Supplementary Requirement S6 is specified, the Charpy impact test results shall conform to the requirements of Table 3. One set of three specimens shall be removed from each specimen location as specified in 6.3. The supplier may select a test temperature colder than that specified in the order, but in any case, the actual test temperature shall be reported with the test results.

6.2.2 For Grade B forgings two sets of Charpy impact specimens shall be removed from each test specimen location as specified in and shall conform to the requirements of Table 3.

6.2.3 Full-size, 10 by 10 mm, Charpy V-notch specimens shall be used unless the material thickness or configuration makes it impossible to obtain full-size specimens. If the use of sub-size specimens is necessary, the largest standard sub-size specimen it is possible to obtain shall be used.

6.2.4 The acceptance values for sub-size specimens shall be reduced in direct ratio to the reduction of specimen width.

6.3 *Sampling*—The longitudinal axis and the mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods as specified by the purchaser:

6.3.1 *Method 1*—This method shall always be used when the maximum as-heat-treated thickness does not exceed 2 in. [50 mm]. Specimens shall be located in the production forging or test forging (as described in Method 4) at mid-thickness and at least 2 in. [50 mm] from other as-heat-treated surfaces.

6.3.2 *Method 2—T* by 2*T*, where *T* is the distance from the area of significant loading (see 3.1) to the nearest as-heat-treated surface. However, the specimen shall not be nearer to one as-heat-treated surface than ¾ in. [20 mm] and not nearer than 1½ in. [40 mm] to a second as-heat-treated surface. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawing showing pre-heat-treatment dimensions and the location of test specimens.

6.3.3 *Method 3—¼T* by *T*, where *T* is the maximum thickness of the forging as-heat-treated. When this method of testing is employed for Class 2, the maximum as-heat-treated thickness shall not exceed 8 in. [200 mm] unless otherwise agreed.

6.3.4 *Method 4*—Test specimens shall be taken from a representative separate test forging or bar made from the same heat of steel that shall receive substantially the same reduction and type of hot working as the production forgings which it represents; except that a longitudinally forged bar may be used to represent a rolled ring of similar cross section. It shall be of the same nominal thickness as the as-heat-treated production forgings and shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed using the ¼*T* by *T* procedure referenced in Method 3 with the same limitation on forging thickness as in 6.3.3. This method shall be limited to forgings with a rough machined weight of not more than 1000 lb ~~[500 kg].~~ [500 kg].

6.4 *Metal Buffers*—The required distances from as-heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at least ½ in. [13 mm] from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.5 Samples shall be removed from forgings after heat treatment. The sample material shall be subjected to a simulated post-weld heat-treatment if Supplementary Requirement S1 is specified.

6.6 *Orientation*—For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging unless Supplementary Requirements S11 or S14 are imposed.

6.7 *Number of Tests:*

6.7.1 *Forgings Under 500 lb [250 kg] As-Heat-Treated*—For duplicate forgings weighing less than 500 lb [250 kg] as-heat-treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat-treatment is performed in continuous-type furnaces with suitable temperature control and equipped with

TABLE 2 Tensile Requirements

Property	Grade A Class 1	Grade A Class 2	Grade B
~~Property~~	~~Grade A Class 1~~	~~Grade A Class 2~~	~~Grade B~~
~~Yield strength 0.2% offset ksi [MPa]~~	~~55 [380 min]~~	~~65 [450] min~~	~~100–115 [690–800]~~
Yield strength 0.2 % offset ksi [MPa]	55 [380 min]	65 [450] min	100–115 [690–800]
Tensile Strength ksi [MPa]	65–85 [450–585]	75–95 [515–650]	105 [725] min
Elongation in 2 in. or 50 mm % min	20	20	16
Reduction of Area % min	45	45	45