Designation: A 859/A 859M – 04

An American National Standard

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

This standard is issued under the fixed designation A 859/A 859M; 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 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] and a minimum tensile strength of 65 ksi [450 MPa].

1.2.2 *Grade A Class 2*—Quenched-and-precipitation-heat-treated, providing a minimum yield strength of 65 ksi [450 MPa] and a minimum tensile strength of 75 ksi [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 A 788, 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 inch-pound or SI units are to be regarded separately as standard. Within the text, 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.

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 604 Test Method for Dynamic Tear Testing of Metallic Materials

2.2 *ASME Standard:*

ASME[3] Boiler and Pressure Vessel Code—Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, 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 A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary 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 March 1, 2004. Published April 2004. Originally approved in 1986. Last previous edition approved in 2002 as A 859/A 859M – 02.

[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.

[3] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

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

Copyright © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States.

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, 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 A 788 is highly recommended.

4.2 *Heat Treatment*:

4.2.1 Normalizing may, at the 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 [870 to 940°C] and then precipitation hardened in the range from 1000 to 1225°F [540 to 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 [870 to 940°C] and then precipitation hardened in the range from 1000 to 1225°F [540 to 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 tp 1725°F [870 to 940°C], and then precipitation hardened at a temperature in the range of 1000 to 1300°F [540 to 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 A 788 shall comply with Table 1.

5.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

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 A 370 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 6.3 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.

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
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

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

TABLE 2 Tensile Requirements

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]
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

TABLE 3 Charpy Impact Requirements

	Grade A Class1 −50°F [−45°C]	Grade A Class2 −50°F [−45°C]	Grade B 0°F [18°C]	Grade B —120°F [-85°C]
Test Average, ft/lb [J][A]	20 [27]	20 [27]	80 [110]	60 [80]
Minimum single value, ft/lb [J]	15 [20]	15 [20]	75 [100]	55 [75]

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

6.3.3 *Method 3*—¼ *T* 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].

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 recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding any 8-h duration.

6.7.2 *Forgings Weighing 500 to 10 000 lb [250 to 5000 kg] As-Heat-Treated*—One tension and one impact test (three specimens) shall be made for each forging.

6.7.3 Each forging weighing over 10 000 lb [5000 kg] shall require two tension tests and two impact tests, located at opposite ends if the length, excluding test prolongations, exceeds 80 in. [2000 mm], or located 180° apart for shorter length forgings.

7. Workmanship, Finish, and Appearance

7.1 The forgings shall conform to the dimensions specified by the purchaser. The finishes shall permit adequate visual inspection for surface imperfections. If a dimension varies from that specified, the forging may be offered to the purchaser for acceptance.

8. Repair Welding

8.1 Repair welding of forgings shall be permitted only with the approval of the purchaser.

8.2 Preparation for repair welding shall include inspection to ensure complete removal of the defect.

8.3 Repairs shall be made using welding procedures qualified in accordance with ASME Boiler and Pressure Vessel Code Section IX and repair welding shall be done by welders or welding operators meeting the qualification requirements of that code.

9. Test Reports

9.1 A test report shall be furnished and shall include certification that the material was manufactured and tested in accordance with this specification. The report shall include the results of all required tests, including heat analysis, mechanical test results, the type of heat treatment, and the test sampling method.

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

10. Keywords

10.1 precipitation hardening steel; pressure containing parts; pressure vessel service; steel forgings—alloy

SUPPLEMENTARY REQUIREMENTS

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

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

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 thermal 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, times, and cooling rates.

S2. Ultrasonic Examination

S2.1 The forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A 388M.

S2.1.1 *Longitudinal Wave Test:*

S2.1.1.1 Unless otherwise specified, the back-reflection method of tuning shall be used in accordance with 7.2.2.1 of Practice A 388/A 388M.

S2.1.1.2 In addition to the reportable conditions of Section 8 of Practice A 388/A 388M, indications exceeding the resultant back reflection shall be recorded.

S2.1.1.3 The following conditions are subject to rejection:

(a) Complete loss of back reflection 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.

(b) An indication equal in amplitude to that of the back reflection established in an indication-free portion of the forging.

S2.1.2 *Angle Beam Test:*

S2.1.2.1 Calibration notches, calibration reference, and method of scanning shall be in accordance with 7.3 of Practice A 388/A 388M.

S2.1.2.2 A forging that contains a discontinuity that results in an indication exceeding the amplitude of the reference line is subject to rejection.

S2.1.3 The report of the ultrasonic examination shall be in compliance with Section 9 of Practice A 388/A 388M.

S2.1.4 Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious conditions that will not be removed in final machining.

S3. Magnetic Particle Examination

S3.1 Each forging shall be examined by magnetic particle methods described in Test Method A 275/A 275M. Acceptance standards shall be specified by the purchaser.

S3.2 Alternatively the purchaser may specify that Supplementary Requirement S18 of Specification A 788 shall be used as the basis for the magnetic particle examination.

S4. Charpy V-Notch Impact Transition Curve

S4.1 Sufficient impact test 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 [Joule] energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S5. Additional Charpy V-Notch Test Data

S5.1 The percent shear fracture and mils [mm] of lateral expansion shall be reported for each specimen tested.

S6. Charpy V-Notch Test

S6.1 For Grade A, Class 1 or 2 forgings the specified test temperature for the Charpy V-Notch tests required in Section 6 of this specification shall be a temperature lower than −50°F [−45°C]. The specified test temperature shall be stated in the order.

S6.2 The charpy impact test temperature used shall be included in the forging certification and marking.

S7. Drop-Weight Test

S7.1 Drop-weight tests shall be conducted in accordance with Test Method E 208. The fracture plane of the specimen shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 6.3. However, since the drop-weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 2 (see 6.3.2) shall be a minimum distance of 7⁄16 in. [10 mm] from the nearest quenched surface, and 1½ in. [40 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10°F [5°C] warmer than a specified temperature or request a determination of the Nil-Ductility temperature.

S8. Rings and Hollow Cylindrically-Shaped Parts

S8.1 Tests shall be removed in the tangential (circumferential) direction regardless of the direction of maximum working.

S9. Alternative Test Specimen Orientation

S9.1 The longitudinal axis of all test specimens shall be oriented in a direction transverse to the direction of maximum working of the forging.

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale

Dynamic Tear Test

S10.1 For Grade B material, dynamic tear testing shall be carried out in accordance with Test Method E 604. Unless otherwise specified by the purchaser the test temperature shall be –20±3°F [-30±2°C]. Acceptance criteria shall be in accordance with the purchase order requirements.

SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since A 859/A 859M-02 (Approved Sept. 10, 2002) that may impact the use of this standard.

(1) Existing material was named Grade A, new material was named Grade B.
(2) Tables 1, 2, and 3 were revised to include the new grade.
(3) Reference to the original grade was included in the Scope.
(4) Sections 4 and 6 were revised to accomodate Grade B.
(5) SI units were rationalized in 6.3.4 and 6.7.
(6) Supplementary Requirement S6 was revised to reference Grade A.
(7) Supplementary Requirement S10 was added.
(1) Supplementary Requirement S3 revised

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).

Copyright ASTM International
Reproduced by IHS under license with ASTM
No reproduction or networking permitted without license from IHS
Not for Resale