



Designation: **A372/A372M—16 A372/A372M – 20**

Standard Specification for Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels¹

This standard is issued under the fixed designation A372/A372M; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope*

1.1 This specification² covers relatively thin-walled forgings (including gas bottles) for pressure vessel use. Three types of carbon steel and six types of alloy steel are included. Provision is made for integrally forging the ends of vessel bodies made from seamless pipe or tubing.

NOTE 1—When working to the chemical and tensile requirements of this specification, the influence of wall thickness and cooling rate will necessarily eliminate certain forging sizes in each class.

NOTE 2—Designations have been changed as follows:

Current	Formerly
Grade A	Type I
Grade B	Type II
Grade C	Type III
Grade D	Type IV
Grade E Class 55	Type V Grade 1 Class 55
Grade E Class 65	Type V Grade 1 Class 65
Grade E Class 70	Type V Grade 1 Class 70
Grade F Class 55	Type V Grade 2 Class 55
Grade F Class 65	Type V Grade 2 Class 65
Grade F Class 70	Type V Grade 2 Class 70
Grade G Class 55	Type V Grade 3 Class 55
Grade G Class 65	Type V Grade 3 Class 65
Grade G Class 70	Type V Grade 3 Class 70
Grade H Class 55	Type V Grade 4 Class 55
Grade H Class 65	Type V Grade 4 Class 65
Grade H Class 70	Type V Grade 4 Class 70
Grade J Class 55	Type V Grade 5 Class 55
Grade J Class 65	Type V Grade 5 Class 65
Grade J Class 70	Type V Grade 5 Class 70
Grade K	Type VI
Grade L	Type VII
Grade J Class 110	Type VIII
Grade M Class 85	Type IX Class A
Grade M Class 100	Type IX Class B

1.2 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 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.~~

1.3 Unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 *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.*

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-372/SA-372M in Section II of that code.

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

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](#)
- [A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe](#)
- [A788/A788M Specification for Steel Forgings, General Requirements](#)
- [E112 Test Methods for Determining Average Grain Size](#)
- [E165/E165M Practice for Liquid Penetrant Testing for General Industry](#)
- [E290 Test Methods for Bend Testing of Material for Ductility](#)
- [E433 Reference Photographs for Liquid Penetrant Inspection](#)

2.2 ASME Standard:

- [ASME Boiler and Pressure Vessel Code⁴](#)

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 areas of significant loading in the forging when required (see [6.4.2.2](#)).

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. Materials and Manufacture

4.1 *Melting Practice*—The steel melting procedures of Specification [A788/A788M](#) shall apply except that for ~~Grade M~~ Grades M, N, P, and Grades J and Class 110 forgings, only steel that has been vacuum treated before or during the pouring of the ingot, to remove objectionable gases, particularly hydrogen, shall be used.

4.2 *Production Methods*—Methods for the production of gas bottles and similar vessels shall include the cupping of slabs or plates, the piercing of billets or plates, and the subsequent drawing of cups so produced. Such semifinished forgings or seamless steel pipe or tubing shall be closed by spinning, swedging, or pressing. In all cases, there shall be sufficient discard to ensure soundness in the completed forging.

4.3 Heat Treatment:

4.3.1 At the option of the manufacturer, Grades A, B, C, and D and Classes 55, 65, and 70 of Grades E, F, G, H, and J forgings shall be normalized, normalized and tempered, liquid quenched and tempered, or normalized followed by liquid quench and temper.

4.3.2 ~~Grades K, L, M, N, P, and P~~ and ~~Classes 90 and 110 of Grade~~ Grades J and R forgings shall be liquid quenched and tempered, or normalized followed by liquid quench and temper.

4.3.3 When normalized forgings are to be tempered, or when forgings have been quenched, they shall be reheated to a subcritical temperature and held for at least ½ h/in. [25 mm] of maximum cross section.

4.3.3.1 Minimum tempering temperatures shall be as follows:

Grades E, F, G, H, J in Classes 55, 65, 70, 90	1100 °F [595 °C]
Grade K	1100 °F [595 °C]
Grade L, N, P	1000 °F [540 °C]
Grades L, N, P, R	1000 °F [540 °C]
Grade J Class 110	1000 °F [540 °C]
Grade M	1100 °F [595 °C]

4.3.3.2 If an attachment is welded onto a previously quenched and tempered pressure vessel, the post-weld heat treatment temperature of a weldment shall not exceed the prior tempering temperature of the pressure vessel. Fabrication welding of pressure shell is not permitted. Attachment welding before heat treatment is not permitted.

4.3.4 All quenched and tempered forgings shall be subject to magnetic particle examination in accordance with Section [7](#).

4.3.5 Heat treatment is to be performed after all forming operations.

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), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

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.

5.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in **Table 1** for the applicable grade of material is not permitted. This does not preclude use of deoxidation or inclusion control additions. Supplementary Requirements S1 and S2 of Specification **A788/A788M** shall apply.

5.4 *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 A372/A372M.

6. Mechanical Properties

6.1 Mechanical tests for acceptance shall be made after the final heat treatment of the forgings.

6.2 *Tension Test*—When tested in accordance with Test Methods and Definitions **A370**, the material shall conform to the requirements of **Table 2**. The yield strength shall be determined by the 0.2 % offset method.

6.3 *Bending Properties*—Depending upon the outside diameter, D , and the wall thickness, T , of hollow or bored forgings, a bend test or flattening test will be required.

6.3.1 For bored or hollow forgings with outside diameters of 14 in. [355 mm] or less and with a D/T ratio of more than 10.0, a flattening test is required. This shall be carried out in accordance with Specification **A530/A530M** and **Table 3**. No breaks or cracks in the test ring are acceptable until the distance between the plates is less than that shown in **Table 3**.

6.3.2 For bored or hollow forgings with outside diameters over 14 in. [355 mm], or where the D/T ratio is 10.0 or less at the manufacturer’s option, the flattening test specified in **6.3.1**, or a transverse bend test in accordance with Test Methods **E290** is required. In cases in which the Test Methods **E290** method used stipulates a bend test pin or mandrel, the diameter shall be as specified in **Table 4**. No cracks or ruptures in the test piece are allowable when the test piece is bent through the required angle.

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TABLE 1 Chemical Requirements

Element	Composition, %				
	Grade A	Grade B	Grade C	Grade D	Grade E Classes 55, 65, 70
Carbon	0.30 max	0.35 max	0.48 max	0.40–0.50	0.25–0.35
Manganese	1.00 max	1.35 max	1.65 max	1.40–1.80	0.40–0.90
Phosphorus, max	0.015	0.015	0.015	0.015	0.015
—max	—	—	—	—	—
Sulfur, max	0.010	0.010	0.010	0.010	0.010
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	—	—	—	—	—
Nickel	—	—	—	—	—
Chromium	—	—	—	—	—
Chromium	—	—	—	—	—
Chromium	—	—	—	—	—
Molybdenum	—	—	—	—	—
Molybdenum	—	—	—	—	—
Molybdenum	—	—	—	—	—
Vanadium	—	—	—	—	—
Vanadium	—	—	—	—	—
Boron	—	—	—	—	—
	Grade E Classes 55, 65, 70	Grade F Classes 55, 65, 70	Grade G Classes 55, 65, 70	Grade H Classes 55, 65, 70	Grade J Classes 55, 65, 70, 110
	Grade F Classes 55, 65, 70	Grade G Classes 55, 65, 70	Grade H Classes 55, 65, 70	Grade J Classes 55, 65, 70, 110	Grade K
Carbon	0.25–0.35	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50
Carbon	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50	0.18 max
Manganese	0.40–0.90	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05
Manganese	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05	0.10–0.40
Phosphorus, max	0.015	0.015	0.015	0.015	0.015
—max	—	—	—	—	—
Sulfur, max	0.010	0.010	0.010	0.010	0.010
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	—	—	—	—	—
Nickel	—	—	—	—	—
Nickel	—	—	—	—	—
Chromium	0.80–1.15	0.80–1.15	0.40–0.65	0.40–0.65	2.0–3.3
Chromium	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15	0.80–1.15
Chromium	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15	1.00–1.80
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.20–0.60
Vanadium	—	—	—	—	—
Vanadium	—	—	—	—	—
Boron	—	—	—	—	—
	Grade K	Grade L	Grade M Classes 85 and 100	Grade N Classes 100, 120, 140	Grade P Classes 100, 120, 140
	Grade L	Grade M Classes 85 and 100	Grade N Classes 100, 120, 140	Grade P Classes 100, 120, 140	Grade R Classes 55, 65, 70, 90, 110
Carbon	0.18 max	0.38–0.43	0.23 max	0.35 max	0.40 max
Carbon	0.38–0.43	0.23 max	0.35 max	0.40 max	0.35–0.50
Manganese	0.40–0.40	0.60–0.80	0.20–0.40	0.90 max	0.90 max
Manganese	0.60–0.80	0.20–0.40	0.90 max	0.90 max	0.75–1.05
Phosphorus, max	0.015	0.015	0.015	0.015	0.015
—max	—	—	—	—	—
Sulfur, max	0.010	0.010	0.010	0.015	0.015
Sulfur, max	0.010	0.010	0.015	0.015	0.010
Silicon	0.15–0.35	0.15–0.35	0.30 max	0.35 max	0.35 max
Silicon	0.15–0.35	0.30 max	0.35 max	0.35 max	0.15–0.35
Nickel	2.0–3.3	1.65–2.00	2.8–3.9	1.5–2.25	2.3–3.3
Nickel	1.65–2.00	2.8–3.9	1.5–2.25	2.3–3.3	—
Chromium	1.00–1.80	0.70–0.90	1.50–2.00	0.80–2.00	0.80–2.00
Chromium	0.70–0.90	1.50–2.00	0.80–2.00	0.80–2.00	0.80–1.15
Molybdenum	0.20–0.60	0.20–0.30	0.40–0.60	0.20–0.40	0.30–0.50
Molybdenum	0.20–0.30	0.40–0.60	0.20–0.40	0.30–0.50	0.15–0.25
Vanadium	—	—	0.08 max	0.20 max	0.20 max
Vanadium	—	0.08 max	0.20 max	0.20 max	—
Vanadium	—	0.08 max	0.20 max	0.20 max	—
Boron	—	—	—	—	5–20 ppm