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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 reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

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 inch-pound or SI [metric] units are to be regarded separately as the standard. Within the text and the 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.

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

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.

2. Referenced Documents

2.1 ASTM Standards:³

- A275/A275M ~~Test Method~~ 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 Heavy 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 the Average Grain Size
- E165 ~~Practice for Liquid Penetrant Examination~~ Practice for Liquid Penetrant Examination for General Industry
- E290 ~~Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials~~⁶ Test Methods for Bend Testing of Material for Ductility
- E433 Reference Photographs for Liquid Penetrant Inspection

3. Ordering Information and General Requirements

- 3.1 In addition to the ordering information required by Specification ~~A 788A 788A~~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 ~~A 788A 788A~~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 ~~A 788A 788A~~A788/A788M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Melting Practice:

- 4.1.1 The steel melting procedures of Specification ~~A 788A 788A~~A788/A788M shall apply except that for Grade M forgings, only steel that has been vacuum treated prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen, shall be used.

4.2 Production Methods:

- 4.2.1 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, D and Classes 55, 65, 70 of Grades E, F, G, H, and J forgings shall be normalized, normalized and tempered, or liquid-quenched and tempered.

- 4.3.2 Grades K, L, M, and Class 110 of Grade J forgings shall be liquid-quenched and tempered.

- 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	1100°F [595°C]
Grade K	1100°F [595°C]
Grade L	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 prior to 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.

5. Chemical Composition

- 5.1 Heat Analysis—The heat analysis obtained from sampling in accordance with Specification ~~A 788A 788A~~A788/A788M shall comply with Table 1.

- 5.2 Product Analysis—The purchaser may use the product analysis provision of Specification ~~A 788A 788A~~A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat.

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, Vol 01.05, volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 Chemical Requirements

Elements	Composition, %				
	Grade A	Grade B	Grade C	Grade D	
Carbon	0.30 max	0.35 max	0.48 max	0.40–0.50	
Manganese	1.00 max	1.35 max	1.65 max	1.40–1.80	
Phosphorus, max	0.025	0.025	0.025	0.025	
Sulfur, max	0.025	0.025	0.025	0.025	
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	
Nickel	—	—	—	—	
Chromium	—	—	—	—	
Molybdenum	—	—	—	0.17–0.27	
	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
Carbon	0.25–0.35	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50
Manganese	0.40–0.90	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05
Phosphorus, max	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	—	—	—	—	—
Chromium	0.80–1.15	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25
	Grade K	Grade L	Grade M Classes 85 and 100		
Carbon	0.18 max	0.38–0.43	0.23 max		
Manganese	0.10–0.40	0.60–0.80	0.20–0.40		
Phosphorus, max	0.025 max	0.025	0.020		
Sulfur, max	0.025 max	0.025	0.020		
Silicon	0.15–0.35	0.15–0.35	0.30 max		
Nickel	2.0–3.3	1.65–2.00	2.8–3.9		
Chromium	1.00–1.80	0.70–0.90	1.50–2.00		
Molybdenum	0.20–0.60	0.20–0.30	0.40–0.60		
Vanadium	—	—	0.08 max		

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 ~~A-788~~A788/A788M shall apply.

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 A370A370, 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 A530A530/A530M/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 Arrangement C of Test Method E290Methods E290 is required. The bend test pin 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.

6.4 *Orientation and Location of Test Specimens:*

6.4.1 Test specimens representing vessel bodies or shells shall be taken from a prolongation of a forging, from test rings that have been heat treated with the forgings they represent, or from a representative forging after heat treatment in accordance with 4.3.

6.4.1.1 Test specimens representing vessel bodies or shells shall be located at a position corresponding to the mid-wall location of the parallel side wall of the heat-treated forging and shall be oriented parallel to the longitudinal axis of the vessel.

6.4.1.2 A test ring shall be in the shape of a right circular cylinder having the same diameter and wall thickness as the cylinders it represents. In addition, the test ring shall be from the same heat of steel and be subjected to the same heat treatment as the cylinders it represents. The method of quenching the test ring must duplicate that of the cylinders; if the cylinders are quenched