



Designation: A1091/A1091M – 21

# Standard Specification for Steel Castings, Creep-Strength Enhanced Ferritic Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service<sup>1</sup>

This standard is issued under the fixed designation A1091/A1091M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope\*

1.1 This specification covers creep-strength enhanced alloy steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for high-temperature service (see **Note 1**). However, they are not restricted to such applications and the castings may be used for other applications for which the attributes of the material, as defined by this specification, are suitable.

1.2 One grade of martensitic alloy steel, Grade C91 (UNS Number J84090), is covered (see **Note 2**). It is provided in two classes, differentiated by the type of heat treatment after welding. This and similar steels are characterized by a predominantly tempered martensitic or tempered Bainitic microstructure that is stabilized by the precipitation of temper-resistant particles at various precipitate nucleation sites in the microstructure. Such steels are designed to have creep-rupture strengths significantly superior to those of alloys of nominally similar compositions, but in which the precipitates or nucleation sites are absent. Since this crucial difference cannot be revealed by room-temperature mechanical property tests, these alloys require tighter controls on manufacturing and processing.

**NOTE 1**—The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

**NOTE 2**—The committee formulating this specification has included one grade of material that is considered to represent a type of ferritic alloy steel suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels will be considered for inclusion in this specification by the committee as the need becomes apparent.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.18 on Castings.

Current edition approved May 1, 2021. Published June 2021. Originally approved in 2016. Last previous edition approved in 2016 as A1091/A1091M – 16. DOI: 10.1520/A1091\_A1091M-21.

1.3 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 exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A802/A802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

### 2.2 ANSI Standard:<sup>3</sup>

ANSI B46.1 Surface Texture

### 2.3 ASME Boiler and Pressure Vessel Code:<sup>4</sup>

ASME Boiler and Pressure Vessel Code Section I

ASME Boiler and Pressure Vessel Code Section III

ASME Boiler and Pressure Vessel Code Section IV

ASME Boiler and Pressure Vessel Code Section VIII

ASME Boiler and Pressure Vessel Code Section IX

ASME Boiler and Pressure Vessel Code Section XII

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

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

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

#### 2.4 Other ASME Codes:<sup>4</sup>

**B16.34 Valves Flanged, Threaded and Welding End**

**B31.1 Power Piping**

**B31.3 Process Piping**

#### 2.5 AWS Specifications:<sup>5</sup>

**A5.5/A5.5M Low-Alloy Steel Electrodes for Shielded Metal Arc Welding**

**A5.23/A5.23M Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding**

**A5.28/A5.28M Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding**

**A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding**

### 3. General Conditions for Delivery

3.1 Except for investment castings and centrifugally cast pipe, castings furnished to this specification shall conform to the requirements of Specification **A703/A703M**, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification **A703/A703M** constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification **A703/A703M**, this specification shall prevail.

3.2 Investment castings furnished to this specification shall conform to the requirements of Specification **A985/A985M**, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification **A985/A985M** constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification **A985/A985M**, Specification **A985/A985M** shall prevail.

3.3 Centrifugally cast pipe furnished under this specification shall conform to the requirements of Specification **A999/A999M**, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification **A999/A999M** constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification **A999/A999M**, this specification shall prevail.

### 4. Ordering Information

4.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately:

4.1.1 Except for centrifugally cast pipe:

4.1.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.1.2 Grade and class of steel,

4.1.1.3 Options in the specification (see **5.1.5**, **5.2**, **7.1.4**, **8.4**, **10.3.5**, and **10.3.7**, **10.3.8.2**, and **10.3.8.3**),

4.1.1.4 Whether the castings are to be produced using the investment casting process, and

<sup>5</sup> Available from American Welding Society (AWS), 8669 NW 36 St., #130, Miami, FL 33166-6672, <http://www.aws.org>.

4.1.1.5 The supplementary requirements desired including the standards of acceptance.

4.1.2 Centrifugally cast pipe:

4.1.2.1 Quantity (feet, centimeters, or number of lengths),

4.1.2.2 Name of material (centrifugally cast pipe),

4.1.2.3 Grade of steel,

4.1.2.4 Size (outside or inside diameter and minimum wall thickness),

4.1.2.5 Length (specific or random) (Section on Permissible Variations in Length of Specification **A999/A999M**),

4.1.2.6 End finish (Section on Ends of Specification **A999/A999M**),

4.1.2.7 Options in the specification (see **5.1.5**, **5.2**, **7.1.4**, **8.4**, **10.3.5**, and **10.3.7**, **10.3.8.2**, and **10.3.8.3**),

4.1.2.8 Whether the castings are to be used in ASME Boiler and Pressure Vessel Code Sections I, III, IV, VIII, and XII construction; or in ASME Codes **B16.34**, **B31.1**, **B31.3**, or other ASME construction codes, and

4.1.2.9 The supplementary requirements desired.

### 5. Materials and Manufacture

5.1 *Heat Treatment*—Castings shall be furnished in the austenitized and tempered condition.

5.1.1 Before heat treatment, castings shall be allowed to cool to a temperature below the transformation range.

5.1.2 Castings shall be heat treated by heating to a temperature range of 1900 to 1975 °F [1040 to 1080 °C] and either air cooled or accelerated cooled from the austenitizing temperature by air blasting or liquid quenching, to a temperature of 200 °F [95 °C] or below, followed by tempering at 1350 to 1470 °F [730 to 800 °C].

5.1.3 Compliance with the temperature ranges specified in **5.1.2**, for castings heat treated singly, shall be verified by a thermocouple or thermocouples placed directly on the castings.

5.1.4 Compliance with the temperature ranges specified in **5.1.2**, for castings heat treated in batches, shall be verified by thermocouples placed on selected castings in each batch.

5.1.5 Unless specified by the purchaser, the number and locations of thermocouples to be placed on each casting, or on castings in each heat-treatment batch, shall be at the discretion of the producer.

5.1.6 A record of the final austenitizing and tempering heat treatment and, if specified in the order (see **10.3.7**) of any and all subsequent subcritical heat treatments, shall be made and shall be shown on the material test report. The record shall include both the number and locations of thermocouples applied to each casting, or to each heat-treatment batch of castings.

5.2 *Machining*—Centrifugally cast pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250 µin. [6.35 µm] arithmetical average deviation (AA) from the mean line unless otherwise specified as in ANSI B46.1.

### 6. Chemical Composition

6.1 The steel shall conform to the requirements specified in **Table 1** (see **Note 3**).

NOTE 3—The role of alloying elements in the development of Grade

**TABLE 1 Chemical Composition Requirements for Grade C91  
(UNS Number J84090)<sup>A</sup>**

| Element              | Weight %    |
|----------------------|-------------|
| Carbon               | 0.08–0.12   |
| Manganese            | 0.30–0.60   |
| Phosphorus           | 0.025       |
| Sulfur               | 0.010       |
| Silicon              | 0.20–0.50   |
| Nickel               | 0.40        |
| Chromium             | 8.0–9.5     |
| Molybdenum           | 0.85–1.05   |
| Niobium <sup>B</sup> | 0.060–0.10  |
| Nitrogen             | 0.030–0.070 |
| Vanadium             | 0.18–0.25   |
| Aluminum             | 0.02        |
| Titanium             | 0.01        |
| Zirconium            | 0.01        |

<sup>A</sup> All values are maximums unless a range is provided.

<sup>B</sup> Columbium (Cb) and Niobium (Nb) are interchangeable names for element 41. Both names are acceptable for use in A01 specifications.

C91 has been extensively investigated. V and Cb (Nb) contribute to precipitation strengthening by forming fine and coherent precipitation of M(C, N)X carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. The two elements are more effective in combination. Therefore, the addition of strong nitride-forming elements, those with a stronger affinity for nitrogen than Cb (Nb) and V, as de-oxidation agents interferes with these high-temperature strengthening mechanisms.<sup>6</sup>

## 7. Mechanical Properties

### 7.1 Tensile Testing:

7.1.1 One tension test shall be made from each heat per heat treatment lot. Test results shall conform to the tensile requirements specified in **Table 2**.

7.1.2 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

7.1.3 Except as permitted by **7.1.4**, and except for investment castings, test coupons from which tension test specimens are prepared shall be removed from heat-treated casting prolongations.

7.1.4 When agreed upon between the manufacturer and the purchaser, test coupons from which test specimens are prepared shall be cast as separate blocks from the same heat as the casting represented. The test blocks shall be heat treated in the same manner as the casting represented.

<sup>6</sup> Viswanathan, R. and Bakker, W. T., *Materials for Ultra Supercritical Fossil Power Plants*, EPRI, Palo Alto, CA, 2000. TR-114750.

**TABLE 2 Tensile Requirements<sup>A</sup>**

| Grade<br>(UNS<br>Number) | Tensile<br>Strength,<br>ksi [MPa] | Yield<br>Strength, <sup>B</sup><br>ksi [MPa] | Elongation in<br>2 in. [50 mm.],<br>% <sup>C</sup> | Reduction of<br>Area, % |
|--------------------------|-----------------------------------|--|--|-------------------------|
| C91<br>(J84090)          | 85–110<br>[585–760]               | 60 [415]                                     | 18   | 45                      |

<sup>A</sup> All values are minimums unless a range is provided.

<sup>B</sup> Determined by 0.2 % offset method.

<sup>C</sup> When ICI test bars are used in tensile testing as provided for in Specification **A703/A703M** or **A985/A985M** for investment castings, the gauge length to reduced section diameter ratio shall be 4 to 1.

7.2 *Hardness Testing*—Each casting shall be Brinell hardness tested in accordance with Supplementary Requirement S13 of Specification **A703/A703M** or **A985/A985M** for investment castings and shall have a Brinell hardness of 185 to 248 HBW.

## 8. Quality

8.1 All accessible surfaces of the castings shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice **A802/A802M** or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal of discontinuities, castings shall be preheated to at least 400 °F [200 °C].

8.2 Except for centrifugally cast pipe, hollow castings larger than NPS 4 [DN 100] and whose internal surfaces are not accessible to the visual examination in **8.1** shall be examined by the ultrasonic examination prescribed in Supplementary Requirement S7 of Specification **A703/A703M**; or for investment castings, Supplementary Requirement S7 of Specification **A985/A985M**.

8.2.1 Castings producing a signal equal to or greater than the lowest signal produced by the referenced discontinuities shall be considered to contain defects, and they shall be identified and separated from the acceptable castings. The area producing the signal may be re-examined.

8.2.2 Castings containing defects shall be rejected if the test signals were produced by imperfections that cannot be identified or were produced by cracks or crack-like imperfections.

8.2.3 Castings containing defects may be repaired. To be accepted, a repaired casting shall pass the ultrasonic examination and shall meet the minimum wall thickness requirements of the purchase order.

8.3 Each length of centrifugally cast pipe shall be ultrasonically examined in accordance with Specification **A999/A999M**.

8.4 When additional inspection is desired, Supplementary Requirements S4, S5, S6, and S10 of Specification **A703/A703M**; or, for investment castings, Specification **A985/A985M**, may be ordered.

## 9. Permissible Variations in Dimensions of Centrifugally Cast Pipe

9.1 *Thickness*—The wall thickness of centrifugally cast pipe shall not vary over that specified by more than 1/8 in. [3 mm]. There shall be no variation under the specified wall thickness.

## 10. Rework, Welding, and Retreatment

10.1 Defects, as defined in Section **8**, shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspecting with supplementary requirements specified in the order shall be removed or reduced to an acceptable size.