



Designation: A691/A691M – 09 (Reapproved 2014)

Standard Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures¹

This standard is issued under the fixed designation A691/A691M; 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 carbon and alloy steel pipe, electric-fusion-welded with filler metal added, fabricated from pressure-vessel-quality plate of several analyses and strength levels and suitable for high-pressure service at high temperatures. Heat treatment may or may not be required to attain the desired mechanical properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. [400 mm] in outside diameter and larger with wall thicknesses up to 3 in. [75 mm] inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used as listed in **Table 1**.

1.3.2 *Class* designates the type of heat treatment performed in the manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in **1.3.3**.

1.3.3 Class designations are as follows (**Note 1**):

| Class | Heat Treatment on Pipe | Radiography, see Section | Pressure Test, see Section |
|-------|------------------------------------|--------------------------|----------------------------|
| 10 | none | none | none |
| 11 | none | 9 | none |
| 12 | none | 9 | 8.3 |
| 13 | none | none | 8.3 |
| 20 | stress relieved, see 5.3.1 | none | none |
| 21 | stress relieved, see 5.3.1 | 9 | none |
| 22 | stress relieved, see 5.3.1 | 9 | 8.3 |
| 23 | stress relieved, see 5.3.1 | none | 8.3 |
| 30 | normalized, see 5.3.2 | none | none |
| 31 | normalized, see 5.3.2 | 9 | none |
| 32 | normalized, see 5.3.2 | 9 | 8.3 |
| 33 | normalized, see 5.3.2 | none | 8.3 |
| 40 | normalized and tempered, see 5.3.3 | none | none |
| 41 | normalized and tempered, see 5.3.3 | 9 | none |
| 42 | normalized and tempered, see 5.3.3 | 9 | 8.3 |
| 43 | normalized and tempered, see 5.3.3 | none | 8.3 |
| 50 | quenched and tempered, see 5.3.4 | none | none |
| 51 | quenched and tempered, see 5.3.4 | 9 | none |
| 52 | quenched and tempered, see 5.3.4 | 9 | 8.3 |
| 53 | quenched and tempered, see 5.3.4 | none | 8.3 |

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A20/A20M may be consulted.

1.4 Optional requirements of a supplementary nature are provided, calling for additional tests and control of repair welding, when desired.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. 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 non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2014. Published April 2014. Originally approved in 1974. Last previous edition approved in 2009 as A691/A691M – 09^{ε1} DOI: 10.1520/A0691_A0691M-09R14.

² For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-691 in Section II of that Code.

TABLE 1 Plate Materials

| Pipe Grade | Type of Steel | ASTM Specification | | HB, max ^A |
|------------|---|--------------------|-------|----------------------|
| | | Number | Grade | |
| CM-65 | carbon-molybdenum steel | A204/A204M | A | 201 |
| CM-70 | carbon-molybdenum steel | A204/A204M | B | 201 |
| CM-75 | carbon-molybdenum steel | A204/A204M | C | 201 |
| CMSH-70 | carbon-manganese-silicon steel, normalized | A537/A537M | 1 | |
| CMS-75 | carbon-manganese-silicon steel | A299/A299M | ... | ... |
| CMSH-80 | carbon-manganese-silicon steel, quenched and tempered | A537/A537M | 2 | |
| ½ CR | ½ % chromium, ½ % molybdenum steel | A387/A387M | 2 | 201 |
| 1CR | 1 % chromium, ½ % molybdenum steel | A387/A387M | 12 | 201 |
| 1¼ CR | 1¼ % chromium, ½ % molybdenum steel | A387/A387M | 11 | 201 |
| 2¼ CR | 2¼ % chromium, 1 % molybdenum steel | A387/A387M | 22 | 201 |
| 3CR | 3 % chromium, 1 % molybdenum steel | A387/A387M | 21 | 201 |
| 5CR | 5 % chromium, ½ % molybdenum steel | A387/A387M | 5 | 225 |
| 9CR | 9 % chromium, 1 % molybdenum steel | A387/A387M | 9 | 241 |
| 91 | 9 % chromium, 1 % molybdenum, vanadium, columbium | A387/A387M | 91 | 241 |

^A Hardness values listed are applicable to S3.

2. Referenced Documents

2.1 ASTM Standards:³

[A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels](#)

[A204/A204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum](#)

[A299/A299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon](#)

[A370 Test Methods and Definitions for Mechanical Testing of Steel Products](#)

[A387/A387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum](#)

[A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates](#)

[A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe](#)

[A537/A537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel](#)

[E165 Practice for Liquid Penetrant Examination for General Industry](#)

[E709 Guide for Magnetic Particle Testing](#)

2.2 ASME Boiler and Pressure Vessel Code:⁴

Section II

Section III

Section VIII

Section IX

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 A lot shall consist of 200 ft [60 m] or fraction thereof of pipe from the same heat of steel.

3.1.1.1 The description of a lot may be further restricted by use of Supplementary Requirement S12.

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>.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of the material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish,

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 11.4, 13.1), and

4.1.9 Supplementary requirements, if any (refer to S1 through S12).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 Welding:

5.2.1 The joints shall be double-welded full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joints shall have positive reinforcement at the center of each side of the weld, but no more than ¼ in. [3 mm]. This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by

the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in a furnace controlled to ± 25 °F [15 °C] and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in **Table 2** for a minimum of 1 h/in. [0.4 hr/cm] of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in **Table 2** and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in **Table 2** as a minimum and held at temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in **Table 2** and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in **Table 2** as a minimum and held at that temperature for a minimum of ½ h/in. [0.2 hr/cm] of thickness or for ½ h, whichever is greater, and air cooled.

5.4 Grade 91 shall be produced only to classes 4X and 5X. In addition, post-weld heat treatment is required after weld repair.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification **A530/A530M**, unless otherwise provided herein.

7. Chemical Requirements

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld metal from each 200 ft [60 m] or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of these tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Requirements

8.1 Tension Test:

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimen shall be made transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

TABLE 2 Heat Treatment Parameters^A

| Pipe Grade | ASTM Specification | Post-Weld Heat-Treat Temperature Range (Stress Relieving), °F (°C) | Normalizing Temperature, max unless otherwise noted, °F (°C) | Quenching Temperature, max unless otherwise noted, °F (°C) | Tempering Temperature, min, °F (°C) |
|------------|--------------------|--|--|--|-------------------------------------|
| CM-65 | A204/A204M | 1100 to 1200 [590 to 650] | 1700 [925] | ... | ... |
| CM-70 | A204/A204M | 1100 to 1200 [590 to 650] | 1700 [925] | ... | ... |
| CM-75 | A204/A204M | 1100 to 1200 [590 to 650] | 1700 [925] | ... | ... |
| CMSH-70 | A537/A537M | 1100 to 1200 [590 to 650] | 1700 [925] | ... | ... |
| CMS-75 | A299/A299M | 1100 to 1200 [590 to 650] | 1700 [925] | ... | ... |
| CMSH-80 | A537/A537M | 1100 to 1200 [590 to 650] | ^B | 1700 [925] | 1100 to 1250 [590 to 675] |
| ½ CR | A387/A387M | 1100 to 1300 [590 to 705] | 1850 [1010] | 1700 [925] | 1150 to 1375 [620 to 745] |
| 1CR | A387/A387M | 1100 to 1350 [590 to 730] | 1850 [1010] | 1700 [925] | 1150 to 1375 [620 to 745] |
| 1¼ CR | A387/A387M | 1100 to 1375 [590 to 745] | 1850 [1010] | 1700 [925] | 1150 to 1375 [620 to 745] |
| 2¼ CR | A387/A387M | 1200 to 1400 [650 to 760] | 1850 [1010] | 1700 [925] | 1250 to 1400 [675 to 760] |
| 3CR | A387/A387M | 1200 to 1400 [650 to 760] | 1850 [1010] | 1700 [925] | 1250 to 1400 [675 to 760] |
| 5CR | A387/A387M | 1200 to 1400 [650 to 760] | 1850 [1010] | 1650 [900] | 1300 to 1400 [705 to 760] |
| 9CR | A387/A387M | 1325 to 1375 [715 to 745] | ^C | ... | 1325 to 1375 [715 to 745] |
| 91 | A387/A387M | 1350 to 1420 [730 to 770] | 1900 to 2000 [1040 to 1095] | 1900 min [1040 min] | 1350 to 1440 [730 to 780] |

^AWhere ellipses (...) appear in the table, there is no requirement.

^BRequires quenching and tempering.

^C9 CR steel is an air-hardenable steel, at times retaining austenite down to near atmospheric temperature. Good practice is to allow the steel to cool to 150°F or lower before subjecting the steel to a tempering treatment or post-weld heat treatment.