



Designation: **A487/A487M – 14<sup>e1</sup> A487/A487M – 20**

## Standard Specification for Steel Castings Suitable for Pressure Service<sup>1</sup>

This standard is issued under the fixed designation A487/A487M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

<sup>e1</sup> NOTE—Table 1 was corrected editorially in June 2017.

### 1. Scope\*

1.1 This specification<sup>2</sup> covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

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 ~~non-conformance~~ nonconformance with the standard.

1.3.1 Within the text, the SI units are shown in brackets.

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>3</sup>

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

[A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel](#)

[A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts](#)

[A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts](#)

[E165/E165M Practice for Liquid Penetrant Testing for General Industry](#)

[E709 Guide for Magnetic Particle Testing](#)

2.2 *American Society of Mechanical Engineers:*<sup>4</sup>

[ASME Boiler and Pressure Vessel Code, Section IX](#)

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*<sup>5</sup>

[SP-55 Quality Standard for Steel Castings—Visual Castings—Visual Method](#)

### 3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification [A703/A703M](#),<sub>2</sub> including any supplementary requirements that are indicated in the purchase order. Failure to comply with the

<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 March 1, 2014; May 1, 2020. Published March 2014; May 2020. Originally approved in 1963. Last previous edition approved in 2012 as A487/A487M – 93 (2012)–14. DOI: 10.1520/A0487\_A0487M-14E01; 10.1520/A0487\_A0487M-20.

<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications, see related Specifications SA-487 in Section II of that code.

<sup>3</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>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>.

<sup>5</sup> Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, <http://www.mss-hq.com>.

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

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.

#### 4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

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

4.1.2 ASTM designation and year of issue,

4.1.3 Grade and class of steel,

4.1.4 Options in the specification, and

4.1.5 The supplementary requirements desired, including the standard of acceptance.

#### 5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in **Table 1**. Preliminary heat treatment prior to final heat treatment, as well as multiple tempering, is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

#### 6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in **Table 2**. Product analysis tolerance shall conform to the product analysis tolerance shown in Specification **A703/A703M**. For investment castings, the product analysis tolerance shall conform to the product analysis tolerance shown in Specification **A985/A985M**. Product analysis tolerances for stainless grades are not presently applicable pending development of these limits.

#### 7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in **Table 3**.

#### 8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 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 and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in **Table 4**.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

#### 9. Repair By Welding

9.1 For ~~castings~~ castings other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice **A488/A488M**.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

9.3 After repair welding, all castings shall be ~~postweld~~ post-weld heat treated in accordance with **Table 4** or reheat treated in accordance with **Table 1**.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. ~~Re-examination~~ Re-examination of the weld repair by radiography when Supplementary Requirement S5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller.

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 in.<sup>2</sup> [65 cm<sup>2</sup>].

#### 10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).



TABLE 1 Heat Treat Requirement

| Grade       | Class | Austenitizing Temperature, min, °F [°C] | Media <sup>A</sup> | Quenching Cool Below °F [°C] | Tempering Temperature, °F [°C] <sup>B</sup> |
|-------------|-------|---|--------------------|------------------------------|---|
| 1           | A     | 1600 [870]                              | A                  | 450 [230]                    | —1100 [595]                                 |
| 1           | B     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 1           | G     | 1600 [870]                              | A or L             | 500 [260]                    | —1150 [620]                                 |
| 2           | A     | 1600 [870]                              | A                  | 450 [230]                    | —1100 [595]                                 |
| 2           | B     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 2           | G     | 1600 [870]                              | A or L             | 500 [260]                    | —1150 [620]                                 |
| 4           | A     | 1600 [870]                              | A or L             | 500 [260]                    | —1100 [595]                                 |
| 4           | B     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 4           | G     | 1600 [870]                              | A or L             | 500 [260]                    | —1150 [620]                                 |
| 4           | D     | 1600 [870]                              | L                  | 500 [260]                    | —1150 [620]                                 |
| 4           | E     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 6           | A     | 1550 [845]                              | A                  | 500 [260]                    | —1100 [595]                                 |
| 6           | B     | 1550 [845]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 7           | A     | 1650 [900]                              | L                  | 600 [315]                    | —1100 [595]                                 |
| 8           | A     | 1750 [955]                              | A                  | 500 [260]                    | —1250 [675]                                 |
| 8           | B     | 1750 [955]                              | L                  | 500 [260]                    | —1250 [675]                                 |
| 8           | G     | 1750 [955]                              | L                  | 500 [260]                    | —1250 [675]                                 |
| 9           | A     | 1600 [870]                              | A or L             | 500 [260]                    | —1100 [595]                                 |
| 9           | B     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 9           | G     | 1600 [870]                              | A or L             | 500 [260]                    | —1150 [620]                                 |
| 9           | D     | 1600 [870]                              | L                  | 500 [260]                    | —1150 [620]                                 |
| 9           | E     | 1600 [870]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 10          | A     | 1550 [845]                              | A                  | 500 [260]                    | —1100 [595]                                 |
| 10          | B     | 1550 [845]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 11          | A     | 1650 [900]                              | A                  | 600 [315]                    | —1100 [595]                                 |
| 11          | B     | 1650 [900]                              | L                  | 600 [315]                    | —1100 [595]                                 |
| 12          | A     | 1750 [955]                              | A                  | 600 [315]                    | —1100 [595]                                 |
| 12          | B     | 1750 [955]                              | L                  | 400 [205]                    | —1100 [595]                                 |
| 13          | A     | 1550 [845]                              | A                  | 500 [260]                    | —1100 [595]                                 |
| 13          | B     | 1550 [845]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 14          | A     | 1550 [845]                              | L                  | 500 [260]                    | —1100 [595]                                 |
| 16 (J31200) | A     | 1600 [870] <sup>C</sup>                 | A                  | 600 [315]                    | —1100 [595]                                 |
| CA15        | A     | 1750 [955]                              | A or L             | 400 [205]                    | —900 [480]                                  |
| CA15        | B     | 1750 [955]                              | A or L             | 400 [205]                    | —1100 [595]                                 |
| CA15        | G     | 1750 [955]                              | A or L             | 400 [205]                    | —1150 [620] <sup>DE</sup>                   |
| CA15        | D     | 1750 [955]                              | A or L             | 400 [205]                    | —1150 [620] <sup>DE</sup>                   |
| CA15M       | A     | 1750 [955]                              | A or L             | 400 [205]                    | —1100 [595]                                 |
| CAGNM       | A     | 1850 [1010]                             | A or L             | 200 [95]                     | —1050–1150 [565–620]                        |
| CAGNM       | B     | 1850 [1010]                             | A or L             | 200 [95]                     | —1225–1275 [665–690] <sup>EE</sup>          |
|             |       |   |                    |                              | —1050–1150 [565–620] <sup>GG</sup>          |

TABLE 1 Heat Treat Requirement

| Grade | Class | Austenitizing Temperature, min, °F [°C] | Media <sup>A</sup> | Quenching Cool Below °F [°C] | Tempering Temperature, °F [°C] <sup>B</sup> |
|-------|-------|---|--------------------|------------------------------|---|
| 1     | A     | 1600 [870]                              | A                  | 450 [230]                    | 1100 [595]                                  |
| 1     | B     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 1     | C     | 1600 [870]                              | A or L             | 500 [260]                    | 1150 [620]                                  |
| 2     | A     | 1600 [870]                              | A                  | 450 [230]                    | 1100 [595]                                  |
| 2     | B     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 2     | C     | 1600 [870]                              | A or L             | 500 [260]                    | 1150 [620]                                  |
| 4     | A     | 1600 [870]                              | A or L             | 500 [260]                    | 1100 [595]                                  |
| 4     | B     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 4     | C     | 1600 [870]                              | A or L             | 500 [260]                    | 1150 [620]                                  |
| 4     | D     | 1600 [870]                              | L                  | 500 [260]                    | 1150 [620]                                  |
| 4     | E     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 6     | A     | 1550 [845]                              | A                  | 500 [260]                    | 1100 [595]                                  |
| 6     | B     | 1550 [845]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 7     | A     | 1650 [900]                              | L                  | 600 [315]                    | 1100 [595]                                  |
| 8     | A     | 1750 [955]                              | A                  | 500 [260]                    | 1250 [675]                                  |
| 8     | B     | 1750 [955]                              | L                  | 500 [260]                    | 1250 [675]                                  |
| 8     | C     | 1750 [955]                              | L                  | 500 [260]                    | 1250 [675]                                  |
| 9     | A     | 1600 [870]                              | A or L             | 500 [260]                    | 1100 [595]                                  |
| 9     | B     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 9     | C     | 1600 [870]                              | A or L             | 500 [260]                    | 1150 [620]                                  |
| 9     | D     | 1600 [870]                              | L                  | 500 [260]                    | 1150 [620]                                  |
| 9     | E     | 1600 [870]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 10    | A     | 1550 [845]                              | A                  | 500 [260]                    | 1100 [595]                                  |
| 10    | B     | 1550 [845]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 11    | A     | 1650 [900]                              | A                  | 600 [315]                    | 1100 [595]                                  |



| Grade       | Class | Austenitizing Temperature, min, °F [°C] | Media <sup>A</sup> | Quenching Cool Below °F [°C] | Tempering Temperature, °F [°C] <sup>B</sup> |
|-------------|-------|---|--------------------|------------------------------|---|
| 11          | B     | 1650 [900]                              | L                  | 600 [315]                    | 1100 [595]                                  |
| 12          | A     | 1750 [955]                              | A                  | 600 [315]                    | 1100 [595]                                  |
| 12          | B     | 1750 [955]                              | L                  | 400 [205]                    | 1100 [595]                                  |
| 13          | A     | 1550 [845]                              | A                  | 500 [260]                    | 1100 [595]                                  |
| 13          | B     | 1550 [845]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 14          | A     | 1550 [845]                              | L                  | 500 [260]                    | 1100 [595]                                  |
| 16 (J31200) | A     | 1600 [870] <sup>C</sup>                 | A                  | 600 [315]                    | 1100 [595]                                  |
| 17          | ABCD  | 1590 [865]                              | L                  | 500 [260]                    | 1095 [590] <sup>F,G</sup>                   |
| CA15        | A     | 1750 [955]                              | A or L             | 400 [205]                    | 900 [480]                                   |
| CA15        | B     | 1750 [955]                              | A or L             | 400 [205]                    | 1100 [595]                                  |
| CA15        | C     | 1750 [955]                              | A or L             | 400 [205]                    | 1150 [620] <sup>D,E</sup>                   |
| CA15        | D     | 1750 [955]                              | A or L             | 400 [205]                    | 1150 [620] <sup>D,E</sup>                   |
| CA15M       | A     | 1750 [955]                              | A or L             | 400 [205]                    | 1100 [595]                                  |
| CA6NM       | A     | 1850 [1010]                             | A or L             | 200 [95]                     | 1050–1150 [565–620]                         |
| CA6NM       | B     | 1850 [1010]                             | A or L             | 200 [95]                     | 1225–1275 [665–690] <sup>E,F</sup>          |
|             |       |   |                    |                              | 1050–1150 [565–620] <sup>G</sup>            |

<sup>A</sup> A = air, L = Liquid, liquid.

<sup>B</sup> Minimum temperature unless range is specified.

<sup>C</sup> Double austenitize.

<sup>D</sup> Double temper with the final temper at a lower temperature than the intermediate temper.

<sup>E</sup> Air cool to below 200°F [95°C] 200 °F [95 °C] after first temper.

<sup>F</sup> Intermediate.

<sup>G</sup> Final.

## 11. Keywords

11.1 alloy steel; martensitic stainless steel; ~~pressure-containing~~ pressure-containing parts; stainless steel; steel castings

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TABLE 2 Chemical Requirements (Maximum Percent Unless Range is Given)

| Grade                               | 1-1                   | 2-2                               | 4-4                                       | 6-6  | 7-7   | 8-8                              | 9-9                                | 10-10                                  | 11-11                                  | 12-12                                  |
|-------------------------------------|-----------------------|-----------------------------------|---|--|---|----------------------------------|------------------------------------|--|--|--|
| Class Type                          | ABC Vanadium (J13002) | ABC Manganese-Molybdenum (J13005) | ABCDE Nickel-Chromium-Molybdenum (J13047) | AB Manganese-Nickel-Chromium-Molybdenum (J13855) | A Nickel-Chromium-Molybdenum-Vanadium <sup>A</sup> (J12084) | ABC Chromium-Molybdenum (J22091) | ABCDE Chromium-Molybdenum (J13345) | AB Nickel-Chromium-Molybdenum (J23015) | AB Nickel-Chromium-Molybdenum (J12082) | AB Nickel-Chromium-Molybdenum (J22000) |
| Carbon                              | -0.30                 | -0.30                             | -0.30                                     | -0.05-0.38                                       | -0.05-0.20  | -0.05-0.20                       | -0.05-0.33                         | -0.30                                  | -0.05-0.20                             | -0.05-0.20                             |
| Carbon                              | 0.30                  | 0.30                              | 0.30                                      | 0.05-0.38  | 0.05-0.20   | 0.05-0.20                        | 0.05-0.33                          | 0.30                                   | 0.05-0.20                              | 0.05-0.20                              |
| Manganese                           | -1.00                 | -1.00-1.40                        | -1.00                                     | -1.30-1.70                                       | -0.60-1.00  | -0.50-0.90                       | -0.60-1.00                         | -0.60 to 1.00                          | -0.50-0.80                             | -0.40-0.70                             |
| Manganese                           | 1.00                  | 1.00-1.40                         | 1.00                                      | 1.30-1.70  | 0.60-1.00   | 0.50-0.90                        | 0.60-1.00                          | 0.60-1.00                              | 0.50-0.80                              | 0.40-0.70                              |
| Phosphorus                          | -0.035                | -0.035                            | -0.035                                    | -0.035   | -0.035  | -0.035                           | -0.035                             | -0.035                                 | -0.035                                 | -0.035                                 |
| Phosphorus                          | 0.035                 | 0.035                             | 0.035                                     | 0.035  | 0.035   | 0.035                            | 0.035                              | 0.035                                  | 0.035                                  | 0.035                                  |
| Sulfur                              | -0.035                | -0.035                            | -0.035                                    | -0.035   | -0.035  | -0.035                           | -0.035                             | -0.035                                 | -0.035                                 | -0.035                                 |
| Sulfur                              | 0.035                 | 0.035                             | 0.035                                     | 0.035  | 0.035   | 0.035                            | 0.035                              | 0.035                                  | 0.035                                  | 0.035                                  |
| Silicon                             | -0.80                 | -0.80                             | -0.80                                     | -0.80  | -0.80   | -0.80                            | -0.80                              | -0.80                                  | -0.60                                  | -0.60                                  |
| Silicon                             | 0.80                  | 0.80                              | 0.80                                      | 0.80   | 0.80  | 0.80                             | 0.80                               | 0.80                                   | 0.60                                   | 0.60                                   |
| Nickel                              | ...                   | ...                               | -0.40-0.80                                | -0.40-0.80                                       | -0.70-1.00  | ...                              | ...                                | -1.40-2.00                             | -0.70-1.10                             | -0.60-1.00                             |
| Nickel                              | ...                   | ...                               | 0.40-0.80                                 | 0.40-0.80  | 0.70-1.00   | ...                              | ...                                | 1.40-2.00                              | 0.70-1.10                              | 0.60-1.00                              |
| Chromium                            | ...                   | ...                               | -0.40-0.80                                | -0.40-0.80                                       | -0.40-0.80  | -2.00-2.75                       | -0.75-1.10                         | -0.55-0.90                             | -0.50-0.80                             | -0.50-0.90                             |
| Chromium                            | ...                   | ...                               | 0.40-0.80                                 | 0.40-0.80  | 0.40-0.80   | 2.00-2.75                        | 0.75-1.10                          | 0.55-0.90                              | 0.50-0.80                              | 0.50-0.90                              |
| Molybdenum                          | ...                   | -0.10-0.30                        | -0.15-0.30                                | -0.30-0.40                                       | -0.40-0.60  | -0.90-1.10                       | -0.15-0.30                         | -0.20-0.40                             | -0.45-0.65                             | -0.90-1.20                             |
| Molybdenum                          | ...                   | 0.10-0.30                         | 0.15-0.30                                 | 0.30-0.40  | 0.40-0.60   | 0.90-1.10                        | 0.15-0.30                          | 0.20-0.40                              | 0.45-0.65                              | 0.90-1.20                              |
| Vanadium                            | -0.04-0.12            | ...                               | ...                                       | ...  | -0.03-0.10  | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Vanadium                            | 0.04-0.12             | ...                               | ...                                       | ...  | 0.03-0.10   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Boron                               | ...                   | ...                               | ...                                       | ...  | -0.002-0.006  | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Boron                               | ...                   | ...                               | ...                                       | ...  | 0.002-0.006   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Copper                              | ...                   | ...                               | ...                                       | ...  | -0.15-0.50  | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Copper                              | ...                   | ...                               | ...                                       | ...  | 0.15-0.50   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Residual Elements:                  |                       |                                   |   |  |   |                                  |                                    |  |  |  |
| —Copper                             | -0.50                 | -0.50                             | -0.50                                     | -0.50  | -0.50   | -0.50                            | -0.50                              | -0.50                                  | -0.50                                  | -0.50                                  |
| Copper                              | 0.50                  | 0.50                              | 0.50                                      | 0.50   | 0.50  | 0.50                             | 0.50                               | 0.50                                   | 0.50                                   | 0.50                                   |
| —Nickel                             | -0.50                 | -0.50                             | ...                                       | ...  | ...   | ...                              | -0.50                              | ...                                    | ...                                    | ...                                    |
| Nickel                              | 0.50                  | 0.50                              | ...                                       | ...  | ...   | ...                              | 0.50                               | ...                                    | ...                                    | ...                                    |
| —Chromium                           | -0.35                 | -0.35                             | ...                                       | ...  | ...   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Chromium                            | 0.35                  | 0.35                              | ...                                       | ...  | ...   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| —Mo + W                             | -0.25                 | ...                               | ...                                       | ...  | ...   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| Mo + W                              | 0.25                  | ...                               | ...                                       | ...  | ...   | ...                              | ...                                | ...                                    | ...                                    | ...                                    |
| —Tungsten                           | -0.10                 | -0.10                             | -0.10                                     | -0.10  | -0.10   | -0.10                            | -0.10                              | -0.10                                  | -0.10                                  | -0.10                                  |
| Tungsten                            | 0.10                  | 0.10                              | 0.10                                      | 0.10   | 0.10  | 0.10                             | 0.10                               | 0.10                                   | 0.10                                   | 0.10                                   |
| —Vanadium                           | -0.03                 | -0.03                             | -0.03                                     | -0.03  | ...   | -0.03                            | -0.03                              | -0.03                                  | -0.03                                  | -0.03                                  |
| Vanadium                            | 0.03                  | 0.03                              | 0.03                                      | 0.03   | ...   | 0.03                             | 0.03                               | 0.03                                   | 0.03                                   | 0.03                                   |
| —Total content of residual elements | -1.00                 | -1.00                             | -0.60                                     | -0.60  | -0.60   | -0.60                            | -1.00                              | -0.60                                  | -0.50                                  | -0.50                                  |
| Total Content of Residual Elements  | 1.00                  | 1.00                              | 0.60                                      | 0.60   | 0.60  | 0.60                             | 1.00                               | 0.60                                   | 0.50                                   | 0.50                                   |

  

| Grade      | 13-13                         | 14-14                        | 16                                     | 17                              | CA15                               | CA15M                           | CA6NM                                   |
|------------|-------------------------------|------------------------------|--|---------------------------------|------------------------------------|---------------------------------|---|
| Class Type | AB Nickel-Molybdenum (J13080) | A Nickel-Molybdenum (J15580) | A Low Carbon Manganese-Nickel (J31200) | ABCD Nickel-Chromium-Molybdenum | ABCD Martensitic Chromium (J91150) | A Martensitic Chromium (J91151) | AB Martensitic Chromium-Nickel (J91540) |
| Carbon     | —0.30                         | —0.55                        | —0.12 <sup>B</sup>                     | —0.15                           | —0.15                              | —0.06                           |   |
| Carbon     | 0.30                          | 0.55                         | 0.12 <sup>B</sup>                      | 0.15-0.20                       | 0.15                               | 0.15                            | 0.06                                    |
| Manganese  | —0.80-1.10                    | —0.80-1.10                   | —2.10 <sup>B</sup>                     | —1.00                           | —1.00                              | —1.00                           |   |
| Manganese  | 0.80-1.10                     | 0.80-1.10                    | 2.10 <sup>B</sup>                      | 0.55-0.70                       | 1.00                               | 1.00                            | 1.00                                    |
| Phosphorus | —0.035                        | —0.035                       | —0.02                                  | —0.035                          | —0.035                             | —0.035                          |   |
| Phosphorus | 0.035                         | 0.035                        | 0.02                                   | 0.01                            | 0.035                              | 0.035                           | 0.035                                   |
| Sulfur     | —0.035                        | —0.035                       | —0.02                                  | —0.035                          | —0.035                             | —0.03                           |   |
| Sulfur     | 0.035                         | 0.035                        | 0.02                                   | 0.005                           | 0.035                              | 0.035                           | 0.03                                    |
| Silicon    | —0.60                         | —0.60                        | —0.50                                  | —1.50                           | —0.65                              | —1.00                           |   |
| Silicon    | 0.60                          | 0.60                         | 0.50                                   | 0.20-0.50                       | 1.50                               | 0.65                            | 1.00                                    |
| Nickel     | —1.40-1.75                    | —1.40-1.75                   | —1.00-1.40                             | —1.00                           | —1.0                               | —3.5-4.5                        |   |
| Nickel     | 1.40-1.75                     | 1.40-1.75                    | 1.00-1.40                              | 3.0-3.80                        | 1.00                               | 1.0                             | 3.5-4.5                                 |
| Chromium   | ...                           | ...                          | ...                                    | —11.5-14.0                      | —11.5-14.0                         | —11.5-14.0                      |   |
| Chromium   | ...                           | ...                          | ...                                    | 1.35-1.60                       | 11.5-14.0                          | 11.5-14.0                       | 11.5-14.0                               |
| Molybdenum | —0.20-0.30                    | —0.20-0.30                   | —...                                   | —0.50                           | —0.15-1.0                          | —0.4-1.0                        |   |



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| Grade                               | <del>13-13</del>              | <del>14-14</del>             | 16                                     | 17                              | CA15                               | CA15M                           | CA6NM                                   |
|-------------------------------------|-------------------------------|------------------------------|--|---------------------------------|------------------------------------|---------------------------------|---|
| Class Type                          | AB Nickel-Molybdenum (J13080) | A Nickel-Molybdenum (J15580) | A Low Carbon Manganese-Nickel (J31200) | ABCD Nickel Chromium Molybdenum | ABCD Martensitic Chromium (J91150) | A Martensitic Chromium (J91151) | AB Martensitic Chromium Nickel (J91540) |
| Molybdenum                          | 0.20–0.30                     | 0.20–0.30                    | ...                                    | 0.35–0.60                       | 0.50                               | 0.15–1.0                        | 0.4–1.0                                 |
| Boron                               | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| Boron                               | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| Copper                              | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| Copper                              | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| Residual Elements                   |                               |                              |  |                                 |                                    |                                 |   |
| —Copper                             | —0.50                         | —0.50                        | —0.20                                  | —0.50                           | —0.50                              | —0.50                           |   |
| —Copper                             | 0.50                          | 0.50                         | 0.20                                   | 0.20                            | 0.50                               | 0.50                            | 0.50                                    |
| —Nickel                             | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| —Nickel                             | ...                           | ...                          | ...                                    | ...                             | ...                                | ...                             | ...                                     |
| —Chromium                           | —0.40                         | —0.40                        | —0.20                                  | ...                             | ...                                | ...                             | ...                                     |
| —Chromium                           | 0.40                          | 0.40                         | 0.20                                   | ...                             | ...                                | ...                             | ...                                     |
| —Molybdenum                         | ...                           | ...                          | —0.10                                  | ...                             | ...                                | ...                             | ...                                     |
| —Molybdenum                         | ...                           | ...                          | 0.10                                   | ...                             | ...                                | ...                             | ...                                     |
| —Tungsten                           | —0.10                         | —0.10                        | —0.10                                  | —0.10                           | —0.10                              | —0.10                           | ...                                     |
| —Tungsten                           | 0.10                          | 0.10                         | 0.10                                   | ...                             | 0.10                               | 0.10                            | 0.10                                    |
| —Vanadium                           | —0.03                         | —0.03                        | —0.02                                  | —0.05                           | —0.05                              | —0.05                           | ...                                     |
| —Vanadium                           | 0.03                          | 0.03                         | 0.02                                   | 0.03                            | 0.05                               | 0.05                            | 0.05                                    |
| —Total content of residual elements | —0.75                         | —0.75                        | —0.50                                  | —0.50                           | —0.50                              | —0.50                           | ...                                     |
| —Total Content of Residual Elements | 0.75                          | 0.75                         | 0.50                                   | 0.50                            | 0.50                               | 0.50                            | 0.50                                    |

<sup>A</sup> Proprietary steel composition.

<sup>B</sup> For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 2.30 %.

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TABLE 3 Required Mechanical Properties

| Previous Designation | Grade        | Class | Tensile Strength, <sup>4</sup><br>min, ksi [MPa] | Yield Strength,<br>min, ksi [MPa],<br>at 0.2 % Offset | Elongation, 2 in.<br>[50 mm] or 4d,<br>min, % | Reduction<br>of Area,<br>min % | Hardness<br>max, HRC<br>[HB] | Max<br>Thickness,<br>in. [mm] |
|----------------------|--------------|-------|--|---|---|--------------------------------|------------------------------|-------------------------------|
| —1N                  | —1           | A     | 85 [585]–110 [760]                               | 55 [380]  | 22  | 40                             | —                            | —                             |
| —1Q                  | —1           | B     | 90 [620]–115 [795]                               | 65 [450]  | 22  | 45                             | —                            | —                             |
|                      | —1           | C     | 90 [620]   | 65 [450]  | 22  | 45                             | 22 [235]                     | —                             |
| —2N                  | —2           | A     | 85 [585]–110 [760]                               | 53 [365]  | 22  | 35                             | —                            | —                             |
| —2Q                  | —2           | B     | 90 [620]–115 [795]                               | 65 [450]  | 22  | 40                             | —                            | —                             |
|                      | —2           | C     | 90 [620]   | 65 [450]  | 22  | 40                             | 22 [235]                     | —                             |
| —4N                  | —4           | A     | 90 [620]–115 [795]                               | 60 [415]  | 18  | 40                             | —                            | —                             |
| —4Q                  | —4           | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
|                      | —4           | C     | 90 [620]   | 60 [415]  | 18  | 35                             | 22 [235]                     | —                             |
|                      | —4           | D     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
| —4QA                 | —4           | E     | 115 [795]  | 95 [655]  | 15  | 35                             | —                            | —                             |
| —6N                  | —6           | A     | 115 [795]  | 80 [550]  | 18  | 30                             | —                            | —                             |
| —6Q                  | —6           | B     | 120 [825]  | 95 [655]  | 12  | 25                             | —                            | —                             |
| —7Q                  | —7           | A     | 115 [795]  | 100 [690]   | 15  | 30                             | —                            | 2.5 [63.5]                    |
| —8N                  | —8           | A     | 85 [585]–110 [760]                               | 55 [380]  | 20  | 35                             | —                            | —                             |
| —8Q                  | —8           | B     | 105 [725]  | 85 [585]  | 17  | 30                             | —                            | —                             |
|                      | —8           | C     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
| —9N                  | —9           | A     | 90 [620]   | 60 [415]  | 18  | 35                             | —                            | —                             |
| —9Q                  | —9           | B     | 105 [725]  | 85 [585]  | 16  | 35                             | —                            | —                             |
|                      | —9           | C     | 90 [620]   | 60 [415]  | 18  | 35                             | 22 [235]                     | —                             |
|                      | —9           | D     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
|                      | —9           | E     | 115 [795]  | 95 [655]  | 15  | 35                             | —                            | —                             |
| —10N                 | —10          | A     | 100 [690]  | 70 [485]  | 18  | 35                             | —                            | —                             |
| —10Q                 | —10          | B     | 125 [860]  | 100 [690]   | 15  | 35                             | —                            | —                             |
| —11N                 | —11          | A     | 70 [484]–95 [655]                                | 40 [275]  | 20  | 35                             | —                            | —                             |
| —11Q                 | —11          | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
| —12N                 | —12          | A     | 70 [485]–95 [655]                                | 40 [275]  | 20  | 35                             | —                            | —                             |
| —12Q                 | —12          | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
| —13N                 | —13          | A     | 90 [620]–115 [795]                               | 60 [415]  | 18  | 35                             | —                            | —                             |
| —13Q                 | —13          | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
| —14Q                 | —14          | A     | 120 [825]–145 [1000]                             | 95 [655]  | 14  | 30                             | —                            | —                             |
| —16N                 | —16 (J31200) | A     | 70 [485]–95 [655]                                | 40 [275]  | 22  | 35                             | —                            | —                             |
| —CA15A               | —CA15        | A     | 140 [965]–170 [1170]                             | 110 [760]–130 [895]                                   | 10  | 25                             | —                            | —                             |
| —CA15                | —CA15        | B     | 90 [620]–115 [795]                               | 65 [450]  | 18  | 30                             | —                            | —                             |
| —                    | —CA15        | C     | 90 [620]   | 60 [415]  | 18  | 35                             | 22 [235]                     | —                             |
| —                    | —CA15        | D     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
| —CA15M               | —CA15M       | A     | 90 [620]–115 [795]                               | 65 [450]  | 18  | 30                             | —                            | —                             |
| —CA6NM               | —CA6NM       | A     | 110 [760]–135 [930]                              | 80 [550]  | 15  | 35                             | —                            | —                             |
| —CA6NM               | —CA6NM       | B     | 100 [690]  | 75 [515]  | 17  | 35                             | 23 [255] <sup>B</sup>        | —                             |

TABLE 3 Required Mechanical Properties

| Previous Designation | Grade | Class | Tensile Strength, <sup>4</sup><br>min, ksi [MPa] | Yield Strength,<br>min, ksi [MPa],<br>at 0.2 % Offset | Elongation, 2 in.<br>[50 mm] or 4d,<br>min, % | Reduction<br>of Area,<br>min % | Hardness<br>max, HRC<br>[HB] | Max<br>Thickness,<br>in. [mm] |
|----------------------|-------|-------|--|---|---|--------------------------------|------------------------------|-------------------------------|
| 1N                   | 1     | A     | 85 [585]–110 [760]                               | 55 [380]  | 22  | 40                             | —                            | —                             |
| 1Q                   | 1     | B     | 90 [620]–115 [795]                               | 65 [450]  | 22  | 45                             | —                            | —                             |
|                      | 1     | C     | 90 [620]   | 65 [450]  | 22  | 45                             | 22 [235]                     | —                             |
| 2N                   | 2     | A     | 85 [585]–110 [760]                               | 53 [365]  | 22  | 35                             | —                            | —                             |
| 2Q                   | 2     | B     | 90 [620]–115 [795]                               | 65 [450]  | 22  | 40                             | —                            | —                             |
|                      | 2     | C     | 90 [620]   | 65 [450]  | 22  | 40                             | 22 [235]                     | —                             |
| 4N                   | 4     | A     | 90 [620]–115 [795]                               | 60 [415]  | 18  | 40                             | —                            | —                             |
| 4Q                   | 4     | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
|                      | 4     | C     | 90 [620]   | 60 [415]  | 18  | 35                             | 22 [235]                     | —                             |
|                      | 4     | D     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
| 4QA                  | 4     | E     | 115 [795]  | 95 [655]  | 15  | 35                             | —                            | —                             |
| 6N                   | 6     | A     | 115 [795]  | 80 [550]  | 18  | 30                             | —                            | —                             |
| 6Q                   | 6     | B     | 120 [825]  | 95 [655]  | 12  | 25                             | —                            | —                             |
| 7Q                   | 7     | A     | 115 [795]  | 100 [690]   | 15  | 30                             | —                            | 2.5 [63.5]                    |
| 8N                   | 8     | A     | 85 [585]–110 [760]                               | 55 [380]  | 20  | 35                             | —                            | —                             |
| 8Q                   | 8     | B     | 105 [725]  | 85 [585]  | 17  | 30                             | —                            | —                             |
|                      | 8     | C     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
| 9N                   | 9     | A     | 90 [620]   | 60 [415]  | 18  | 35                             | —                            | —                             |
| 9Q                   | 9     | B     | 105 [725]  | 85 [585]  | 16  | 35                             | —                            | —                             |
|                      | 9     | C     | 90 [620]   | 60 [415]  | 18  | 35                             | 22 [235]                     | —                             |
|                      | 9     | D     | 100 [690]  | 75 [515]  | 17  | 35                             | 22 [235]                     | —                             |
|                      | 9     | E     | 115 [795]  | 95 [655]  | 15  | 35                             | —                            | —                             |
| 10N                  | 10    | A     | 100 [690]  | 70 [485]  | 18  | 35                             | —                            | —                             |
| 10Q                  | 10    | B     | 125 [860]  | 100 [690]   | 15  | 35                             | —                            | —                             |
| 11N                  | 11    | A     | 70 [484]–95 [655]                                | 40 [275]  | 20  | 35                             | —                            | —                             |
| 11Q                  | 11    | B     | 105 [725]–130 [895]                              | 85 [585]  | 17  | 35                             | —                            | —                             |
| 12N                  | 12    | A     | 70 [485]–95 [655]                                | 40 [275]  | 20  | 35                             | —                            | —                             |