



**Designation: A350/A350M – 26a**

# Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components<sup>1</sup>

This standard is issued under the fixed designation A350/A350M; 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.

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

## 1. Scope\*

1.1 This specification<sup>2</sup> covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ASME and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 5.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation heat treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable “M” specification designation (SI units), the material shall be furnished to inch-pound units.

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.

1.6 *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>

**A788/A788M** Specification for Steel Forgings, General Requirements

**A961/A961M** Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

### 2.2 ASME Standards:

**B 16.5** Steel Pipe Flanges and Flanged Fittings<sup>4</sup>

**B 16.9** Factory-Made Wrought Steel Butt-Welding Fittings<sup>4</sup>

**B 16.10** Face-to-Face and End-to-End Dimensions of Ferrous Valves<sup>4</sup>

**B 16.11** Forged Steel Fittings, Socket-Welding and Threaded<sup>4</sup>

**B 16.30** Unfired Pressure Vessel Flange Dimensions<sup>4</sup>

**B 16.34** Valves-Flanged, Threaded, and Welding End<sup>4</sup>

**B 16.47** Large Diameter Steel Flanges<sup>4</sup>

2.3 **ASME Boiler and Pressure Vessel Code: Section IX**<sup>2</sup>

### 2.4 AWS Standards:

**A 5.1** Mild Steel Covered Arc-Welding Electrodes<sup>5</sup>

**A 5.5** Low-Alloy Steel Covered Arc-Welding Electrodes<sup>5</sup>

### 2.5 API Standards:<sup>6</sup>

**600** Steel Gate Valves with Flanged or Butt-Welding Ends

**602** Compact Design Carbon Steel Gate Valves for Refinery Use

**605** Large Diameter Carbon Steel Flanges

<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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SA-350 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 [www.astm.org/contact](http://www.astm.org/contact). 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 American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

<sup>6</sup> Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, <http://api-ec.api.org>.

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

### 3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification **A961/A961M**, orders should include the following information:

- 3.1.1 The number of test reports required (see Section 14).
- 3.1.2 Additional requirements (see **Table 1** footnotes).
- 3.1.3 Options in the specification. See **5.4.2.1**.
- 3.1.4 Forgings intended for flanges to ASME B16.5 or B16.47 shall be ordered to the requirements of **7.3**.

NOTE 1—The requirements of **7.3** are provided to ensure that consistent testing of the flanges is performed.

### 4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification **A961/A961M**, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification **A961/A961M** constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification **A961/A961M**, this specification shall prevail.

### 5. Manufacture

5.1 *Melting Process*—The steel shall be produced by any of the following primary processes: open-hearth, basic oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting (ESR), or vacuum-arc remelting (VAR).

- 5.1.1 The steel shall be fully killed, fine-grain practice.
- 5.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

5.2 *Discard*—A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

#### 5.3 Forging Process:

5.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

5.3.2 The finished product shall be a forging as defined in the Terminology section of Specification **A788/A788M**.

5.3.3 Hollow parts may be machined from rolled bar or seamless tubular materials provided the longitudinal axis of the part is parallel to the longitudinal axis of the bar. Other parts, up to and including NPS4, may be machined from hot-rolled or forged bar provided the longitudinal axis of the part is parallel to the longitudinal axis of the bar. Flanges, elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

#### 5.4 Heat Treatment:

5.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

5.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or normalized and tempered, or quenched and tempered condition. At the option of the manufacturer, forgings furnished in the quenched and tempered condition may be normalized prior to the austenitize/quench operation.

##### 5.4.2.1 Quenching shall consist of either:

- (1) fully austenitizing the forgings followed by quenching in a suitable liquid medium, or
- (2) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially re-austenitize, followed by quenching in a suitable liquid medium.

(3) Unless otherwise specified by the purchaser, the choice of (1) or (2) shall be at the option of the manufacturer.

##### 5.4.2.2 All quenched forgings shall be tempered to **5.4.2.3**

5.4.2.3 Forgings, when tempered, shall be tempered at 1100 °F [593 °C], minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min.

5.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation heat treated condition or in the

**TABLE 1 Chemical Requirements**

| Element              | Composition, wt. %      |                         |                       |                       |                         |                       |             |
|----------------------|-------------------------|-------------------------|-----------------------|-----------------------|-------------------------|-----------------------|-------------|
|                      | Grade LF1               | Grade LF2               | Grade LF3             | Grade LF5             | Grade LF6               | Grade LF9             | Grade LF787 |
| Carbon, max          | 0.30                    | 0.30                    | 0.20                  | 0.30                  | 0.22                    | 0.20                  | 0.07        |
| Manganese            | 0.60–1.35               | 0.60–1.35               | 0.90 max              | 0.60–1.35             | 1.15–1.50               | 0.40–1.06             | 0.40–0.70   |
| Phosphorus, max      | 0.035                   | 0.035                   | 0.035                 | 0.035                 | 0.025                   | 0.035                 | 0.025       |
| Sulfur, max          | 0.040                   | 0.040                   | 0.040                 | 0.040                 | 0.025                   | 0.040                 | 0.025       |
| Silicon <sup>A</sup> | 0.15–0.30               | 0.15–0.30               | 0.20–0.35             | 0.20–0.35             | 0.15–0.30               | ...                   | 0.40 max    |
| Nickel               | 0.40 max <sup>B</sup>   | 0.40 max <sup>B</sup>   | 3.3–3.7               | 1.0–2.0               | 0.40 max <sup>B</sup>   | 1.60–2.24             | 0.70–1.00   |
| Chromium             | 0.30 max <sup>B,C</sup> | 0.30 max <sup>B,C</sup> | 0.30 max <sup>C</sup> | 0.30 max <sup>C</sup> | 0.30 max <sup>B,C</sup> | 0.30 max <sup>C</sup> | 0.60–0.90   |
| Molybdenum           | 0.12 max <sup>B,C</sup> | 0.12 max <sup>B,C</sup> | 0.12 max <sup>C</sup> | 0.12 max <sup>C</sup> | 0.12 max <sup>B,C</sup> | 0.12 max <sup>C</sup> | 0.15–0.25   |
| Copper               | 0.40 max <sup>B</sup>   | 0.40 max <sup>B</sup>   | 0.40 max              | 0.40 max              | 0.40 max <sup>B</sup>   | 0.75–1.25             | 1.00–1.30   |
| Niobium <sup>E</sup> | 0.02 max <sup>D</sup>   | 0.02 max <sup>D</sup>   | 0.02 max              | 0.02 max              | 0.02 max                | 0.02 max              | 0.02 min    |
| Vanadium             | 0.08 max                | 0.08 max                | 0.03 max              | 0.03 max              | 0.04–0.11               | 0.03 max              | 0.03 max    |
| Nitrogen             | ...                     | ...                     | ...                   | ...                   | 0.01–0.030              | ...                   | ...         |

<sup>A</sup> When vacuum carbon-deoxidation is required by Supplementary Requirement S3, the silicon content shall be 0.12 % maximum.

<sup>B</sup> The sum of copper, nickel, chromium, vanadium and molybdenum shall not exceed 1.00 % on heat analysis.

<sup>C</sup> The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.

<sup>D</sup> By agreement, the limit for niobium (columbium) may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.

<sup>E</sup> Niobium and columbium are interchangeable names for the same element and both names are acceptable for use in A01.22 specifications.