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## Standard Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts<sup>1</sup>

This standard is issued under the fixed designation A965/A965M; 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 austenitic stainless steel forgings for boilers, pressure vessels, high temperature parts, and associated equipment.

1.2 Supplementary requirements are provided for use when additional testing, inspection, or processing is required. In addition, supplementary requirements from Specification [A788/A788M](#) may be specified when appropriate.

1.3 This specification includes the austenitic steel forgings that were a part of Specification [A336/A336M](#).

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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>

- [A336/A336M](#) Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
- [A370](#) Test Methods and Definitions for Mechanical Testing of Steel Products
- [A745/A745M](#) Practice for Ultrasonic Examination of Austenitic Steel Forgings
- [A788/A788M](#) Specification for Steel Forgings, General Requirements
- [A1058](#) Test Methods for Mechanical Testing of Steel Products—Metric
- [E112](#) Test Methods for Determining Average Grain Size

<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 A01.06 on Steel Forgings and Billets.

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<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.

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

## 2.2 Other Standards:

ASME Boiler and Pressure Vessel Code, including Section VIII Pressure Vessels and Section IX<sup>3</sup>  
A5.11/A5.11M Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding<sup>4</sup>  
A5.14/A5.14M Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods<sup>4</sup>

## 3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, the intended use should be stated if 5.1 is to be applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

3.4 If the forgings are intended for use under the ASME Boiler and Pressure Vessel Code at temperatures exceeding 1000 °F [540 °C], then use Supplementary Requirement S7. Grain size requirements for service exceeding 1000 °F [540 °C] should be specified unless the required grade has the suffix “H.”

## 4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A788/A788M, which may include Supplementary Requirement S8, the following condition applies:

4.1.1 A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

## 5. Machining

5.1 Forged pressure vessels for steam power service shall have the inner surface machined or ground. Unfired pressure vessels shall have the inner surfaces sufficiently free of scale to permit inspection.

5.2 When rough machining is performed, it may be done either before or after heat treatment.

## 6. Heat Treatment

6.1 Forgings shall be furnished in the solution treated condition. On completion of forging operations, the forgings shall be solution annealed and quenched in water, oil, or a polymer water solution. Direct quenching after completion of forging without subsequent reheating to the temperatures prescribed in 6.2 – 6.12 is not permissible.

6.2 For Grades F304H, F309H, F310H, F316H, F321H, F347H, and F348H, the minimum solution annealing temperature shall be 1925 °F [1050 °C].

6.3 Grades ~~Grade~~ FXM-11 and ~~FXM-19~~ shall be solution annealed at a minimum of 1950 °F [1065 °C].

6.4 Grade F20 shall be solution annealed in the temperature range of 1700 °F to 1850 °F [925 °C to 1010 °C].

6.5 Grade F46 shall be solution annealed in the temperature range of 2010 °F to 2140 °F [1100 °C to 1170 °C].

6.6 Grade F62 shall be solution annealed at a minimum of 2025 °F [1107 °C].

<sup>3</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>4</sup> Available from American Welding Society (AWS), 8669 NW 36 St., #130, Miami, FL 33166-6672, <http://www.aws.org>.

- 6.7 Grade F904L shall be solution annealed in the temperature range of 1920 °F to 2100 °F [1050 °C to 1150 °C].
- 6.8 Grade F700 shall be solution annealed in the temperature range of 2025 °F to 2100 °F [1107 °C to 1150 °C].
- 6.9 Grades FNIC and F1925 shall be solution annealed in the temperature range of 1800 °F to 1900 °F [985 °C to 1040 °C].
- 6.10 Grades FNIC10 and FNIC11 shall be solution annealed in the temperature range of 2100 °F to 2150 °F [1150 °C to 1180 °C].
- 6.11 Grade F1925N shall be solution annealed at a minimum of 2150 °F [1180 °C].
- 6.12 The remaining grades in **Table 1** shall be solution annealed at a minimum temperature of 1900 °F [1040 °C].

## 7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification **A788/A788M** shall comply with **Table 1**.

7.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification **A788/A788M** to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis tolerances for carbon shall not apply, and the carbon requirements shall conform to **Table 1**.

7.3 Types (common names) and UNS designations follow:

| Grade  | Type     | UNS Designation |
|--------|----------|-----------------|
| F304   | 304      | S30400          |
| F304H  | 304H     | S30409          |
| F304L  | 304L     | S30403          |
| F304N  | 304N     | S30451          |
| F304LN | 304LN    | S30453          |
| F309H  | 309H     | S30909          |
| F310   | 310      | S31000          |
| F310H  | 310H     | S31009          |
| F316   | 316      | S31600          |
| F316H  | 316H     | S31609          |
| F316L  | 316L     | S31603          |
| F316N  | 316N     | S31651          |
| F316LN | 316LN    | S31653          |
| F70    | ...      | S31730          |
| F321   | 321      | S32100          |
| F321H  | 321H     | S32109          |
| F347   | 347      | S34700          |
| F347H  | 347H     | S34709          |
| F347LN | 347LN    | S34751          |
| F348   | 348      | S34800          |
| F348H  | 348H     | S34809          |
| FXM-19 | XM19     | S20910          |
| FXM-11 | XM11     | S21904          |
| F20    | Alloy 20 | N08020          |
| F46    | ...      | S30600          |
| F62    | ...      | N08367          |
| F904L  | 904L     | N08904          |
| F700   | ...      | N08700          |
| FNIC   | NIC      | N08800          |
| FNIC10 | NIC10    | N08810          |
| FNIC11 | NIC11    | N08811          |
| F1925  | 1925     | N08925          |
| F1925N | 1925N    | N08926          |

## 8. Mechanical Properties

8.1 *Requirements*—The material shall conform to the requirements for mechanical properties prescribed in **Table 2** or, if

**TABLE 1 Chemical Requirements<sup>A</sup>**

|        |                 | Element     |           |            |        |         |           |            |            |                        |                        |   |
|--------|-----------------|-------------|-----------|------------|--------|---------|-----------|------------|------------|------------------------|------------------------|---|
|        |                 | Carbon      | Manganese | Phosphorus | Sulfur | Silicon | Nickel    | Chromium   | Molybdenum | Niobium                | Nitrogen               | Other   |
| Grade  | UNS Designation |             |           |            |        |         |           |            |            |                        |                        |   |
| F304   | S30400          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 8.0–11.0  | 18.0–20.0  | ...        | ...                    | ...                    | ...   |
| F304H  | S30409          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 8.0–11.0  | 18.0–20.0  | ...        | ...                    | ...                    | ...   |
| F304L  | S30403          | 0.030       | 2.00      | 0.045      | 0.030  | 1.00    | 8.0–12.0  | 18.0–20.0  | ...        | ...                    | ...                    | ...   |
| F304N  | S30451          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 8.0–11.0  | 18.0–20.0  | ...        | ...                    | 0.10–0.16              | ...   |
| F304LN | S30453          | 0.030       | 2.00      | 0.045      | 0.030  | 1.00    | 8.0–11.0  | 18.0–20.0  | ...        | ...                    | 0.10–0.16              | ...   |
| F309H  | S30909          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 12.0–15.0 | 22.0–24.0  | ...        | ...                    | ...                    | ...   |
| F310   | S31000          | 0.15        | 2.00      | 0.045      | 0.030  | 1.00    | 19.0–22.0 | 24.0–26.00 | ...        | ...                    | ...                    | ...   |
| F310H  | S31009          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 19.0–22.0 | 24.0–26.00 | ...        | ...                    | ...                    | ...   |
| F316   | S31600          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 10.0–14.0 | 16.0–18.0  | 2.00–3.00  | ...                    | ...                    | ...   |
| F316H  | S31609          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 10.0–14.0 | 16.0–18.0  | 2.00–3.00  | ...                    | ...                    | ...   |
| F316L  | S31603          | 0.035       | 2.00      | 0.040      | 0.030  | 1.00    | 10.0–15.0 | 16.0–18.0  | 2.00–3.00  | ...                    | ...                    | ...   |
| F316N  | S31651          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 10.0–13.0 | 16.0–18.0  | 2.00–3.00  | ...                    | 0.10–0.16              | ...   |
| F316LN | S31653          | 0.030       | 2.00      | 0.045      | 0.030  | 1.00    | 10.0–13.0 | 16.0–18.0  | 2.00–3.00  | ...                    | 0.10–0.16              | ...   |
| F70    | S31730          | 0.030       | 2.00      | 0.040      | 0.010  | 1.00    | 15.0–16.5 | 17.0–19.0  | 3.0–4.0    | ...                    | 0.045                  | Cu 4.0–5.0  |
| F321   | S32100          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | ...                    | 0.10                   | Ti<br>5x(C+N)–<br>0.70  |
| F321H  | S32109          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | ...                    | ...                    | Ti<br>4x(C+N)–<br>0.70  |
| F347   | S34700          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | 10xC–1.10 <sup>B</sup> | ...                    | ...   |
| F347H  | S34709          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | 8xC–1.10               | ...                    | ...   |
| F347LN | S34751          | 0.005–0.020 | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–13.0  | 17.0–19.0  | ...        | 0.20–0.50<br>15xC min  | 0.06–0.10              | ...   |
| F348   | S34800          | 0.08        | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | 10xC–1.10              | ...                    | Co 0.020,<br>Ta 0.10  |
| F348H  | S34809          | 0.04–0.10   | 2.00      | 0.045      | 0.030  | 1.00    | 9.0–12.0  | 17.0–19.0  | ...        | 8xC–1.10               | ...                    | Co 0.020,<br>Ta 0.10  |
| FXM-19 | S20910          | 0.06        | 4.0-6.0   | 0.045      | 0.030  | 1.00    | 11.5–13.5 | 20.5–23.5  | 1.50–3.00  | 0.10–0.30              | 0.20–0.40              | V 0.10–0.30   |
| FXM-11 | S21904          | 0.04        | 8.0-10.0  | 0.045      | 0.030  | 1.00    | 5.5–7.5   | 19.0–21.5  | ...        | ...                    | 0.15–0.40              | ...   |
| F20    | N08020          | 0.07        | 2.00      | 0.045      | 0.035  | 1.00    | 32.0–38.0 | 19.0–21.0  | 2.00–3.00  | 8xC<br>min–1.00        | ...                    | Cu 3.0–4.0  |
| F46    | S30600          | 0.018       | 2.00      | 0.020      | 0.020  | 3.7-4.3 | 14.0–15.5 | 17.0-18.5  | 0.20       | ...                    | ...                    | Cu 0.50   |
| F62    | N08367          | 0.030       | 2.00      | 0.040      | 0.030  | 1.00    | 23.5–25.5 | 20.0–22.0  | 6.0–7.0    | ...                    | 0.18–0.25              | ...   |
| F904L  | N08904          | 0.020       | 2.00      | 0.040      | 0.030  | 1.00    | 23.0–28.0 | 19.0–23.0  | 4.0–5.0    | ...                    | 0.10                   | Cu 1.00–2.00  |
| F700   | N08700          | 0.04        | 2.00      | 0.040      | 0.030  | 1.00    | 24.0–26.0 | 19.0–23.0  | 4.3–5.0    | 8xC min<br>0.40 max    | ...                    | Cu 0.50   |
| FNIC   | N08800          | 0.10        | 1.50      | 0.045      | 0.015  | 1.00    | 30.0–35.0 | 19.0–23.0  | ...        | ...                    | ...                    | Ti 0.15–0.60<br>Al 0.15–0.60<br>Cu 0.75   |
| FNIC10 | N08810          | 0.05–0.10   | 1.50      | 0.045      | 0.015  | 1.00    | 30.0–35.0 | 19.0–23.0  | ...        | ...                    | ...                    | Fe 39.5 min<br>Ti 0.15–0.60<br>Al 0.15–0.60<br>Cu 0.75  |
| FNIC11 | N08811          | 0.06–0.10   | 1.50      | 0.040      | 0.015  | 1.00    | 30.0–35.0 | 19.0–23.0  | ...        | ...                    | ...                    | Fe 39.5 min<br>Ti 0.25–0.60 <sup>C</sup><br>Al 0.25–0.60 <sup>C</sup><br>Cu 0.75<br>Fe 39.5 min |
| F1925  | N08925          | 0.020       | 1.00      | 0.045      | 0.030  | 0.50    | 24.0–26.0 | 19.0–21.0  | 6.0–7.0    | ...                    | 0.10–0.20 <sup>D</sup> | Cu 0.80–1.50  |
| F1925N | N08926          | 0.020       | 2.00      | 0.030      | 0.010  | 0.50    | 24.0–26.0 | 19.0–21.0  | 6.0–7.0    | ...                    | 0.15–0.25 <sup>D</sup> | Cu 0.50–1.50  |

<sup>A</sup> Max. unless min or a range is indicated. Where ellipses (...) appear in this table, there is no requirement and the element need not be analyzed for or reported.

<sup>B</sup> Alternatively, tantalum may be substituted for part of the columbium as approved by the purchaser.

<sup>C</sup> Ti + Al shall be 0.85 % min; 1.20 % max.

<sup>D</sup> The method of analysis for nitrogen shall be a matter of agreement between purchaser and manufacturer.

applicable, Supplementary Requirement S2. The largest obtainable tension test specimen as specified in Test Methods and Definitions **A370** or Test Methods **A1058** shall be used.

**8.2 Number of Tests**—The number and location of tests are based on the heat-treated weight of the forging(s) from the same heat, solution annealed in the same furnace charge.

**8.2.1** For forgings weighing less than 5000 lb [2250 kg] as heat treated, one tension test shall be required on the basis of one test per heat in each heat treatment load. This test shall be taken from a prolongation of one of the forgings. Use of a separately forged test bar for the mechanical test specimens, instead of an integral prolongation, is acceptable for forgings weighing less than 5000 lb [2250 kg], provided that the heat-treated cross section of the test bar is not less than the maximum heat-treated cross section

**TABLE 2 Tensile Requirements**

| Austenitic<br>Stainless Steel Grades | Tensile Strength, min<br>ksi [MPa] | Yield Strength,<br>0.2 % Offset, min<br>ksi [MPa] | Elongation<br>in 2 in. or 50 mm, min % | Reduction of Area,<br>min % |
|--------------------------------------|------------------------------------|---|--|-----------------------------|
| F304                                 | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F304H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F304L                                | 66 [450]                           | 25 [170]  | 30                                     | 45                          |
| F304N                                | 80 [550]                           | 35 [240]  | 25                                     | 45                          |
| F309H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F310                                 | 75 [515]                           | 30 [205]  | 30                                     | 35                          |
| F310H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F316                                 | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F316H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F316L                                | 65 [450]                           | 25 [170]  | 30                                     | 45                          |
| F316N                                | 80 [550]                           | 35 [240]  | 25                                     | 45                          |
| F316LN                               | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F70                                  | 70 [485]                           | 25 [175]  | 35                                     | 50                          |
| F321                                 | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F321H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F347                                 | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F347H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F347LN                               | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F348                                 | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| F348H                                | 70 [485]                           | 30 [205]  | 30                                     | 45                          |
| FXM-19                               | 100 [690]                          | 55 [380]  | 30                                     | 50                          |
| FXM-11                               | 90 [620]                           | 50 [345]  | 40                                     | 50                          |
| F20                                  | 80 [550]                           | 35 [240]  | 30                                     | 50                          |
| F46                                  | 78–100 [540–690]                   | 32 [220]  | 40                                     | 50                          |
| F62                                  | 95 [655]                           | 45 [310]  | 30                                     | 50                          |
| F904L                                | 71 [490]                           | 31 [215]  | 35                                     | ...                         |
| F700                                 | 80 [550]                           | 35 [240]  | 30                                     | ...                         |
| FNIC                                 | 65n [450]                          | 25 [170]  | 30                                     | ...                         |
| FNIC10                               | 65n [450]                          | 25 [170]  | 30                                     | ...                         |
| FNIC11                               | 65n [450]                          | 25 [170]  | 30                                     | ...                         |
| F1925                                | 87 [600]                           | 43 [295]  | 30                                     | ...                         |
| F1925N                               | 94 [650]                           | 43 [295]  | 35                                     | ...                         |

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of the forgings it represents. The separately forged test bar shall be from the same heat as the forgings it represents and shall accompany the forgings during heat treatment.

8.2.2 When heat treatment is performed in continuous type furnaces equipped with recording pyrometers, such that complete heating records are available, a solution annealing charge may be considered as any continuous run not exceeding an 8 h period.

8.2.3 For forgings weighing over 5000 lb [2250 kg], as heat treated, one tension test shall be taken from a prolongation on each forging.

8.3 The longitudinal axis of the tension test specimen shall be parallel to the direction of major working of the forging, except when Supplementary Requirement S2 is specified. For upset disk forgings the longitudinal axis of the specimen shall be in either the tangential or radial direction.

8.3.1 The location of the longitudinal axis of the tension test specimen shall be located midway between the parallel surfaces of the test extension, if added to the periphery of disks, or midway between the center and surface of solid forgings. For hollow forgings, or those heat treated after boring, the specimen shall be located at midwall. For the special case of forgings that are heat treated solid, but are subsequently bored, the tension test specimen may be taken at the location of the minimum inside diameter after boring instead of the mid-radius position.

## 9. Grain Size

9.1 For Grades F304H, F316H, F309H, F310H, F321H, F347H, and F348H, the grain size of the forgings shall be ascertained according to Test Methods E112, after solution treatment. One sample shall be examined for each tensile specimen required in 8.2 and shall be taken from the tension test location. The grain size shall be number 6, or coarser, over at least 75 % of the surveyed area. For annealed Grades FNIC10 and FNIC11, the grain size shall be number 5 or coarser.