



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

This standard is issued under the fixed designation A 965/A 965M; 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.

## 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 A 788 may be specified when appropriate.

1.3 This specification includes the austenitic steel forgings that were a part of A 336/A 336M.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

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

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 336/A 336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts<sup>2</sup>

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>3</sup>

A 788 Specification for Steel Forgings, General Requirements<sup>2</sup>

E 112 Test Methods for Determining the Average Grain Size<sup>4</sup>

### 2.2 Other Standards:

ASME Boiler and Pressure Vessel Code, including Section VIII Pressure Vessels and Section IX Welding Qualifications<sup>5</sup>

## 3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, 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 A 788, 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 A 788, the requirements of this specification shall prevail.

3.4 If the forgings are intended for use under the ASME Boiler and Pressure Vessel rules 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 A 788, 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.

NOTE 1—Because of difficulties in retaining nitrogen, vacuum melting or remelting processes should not be specified for Grades F304N, F304LN, F316N, F316LN, and FXM-11.

## 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

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.05.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>5</sup> Available from American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.

prescribed in 6.2-6.5 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 FXM-11 and FXM-19 shall be solution annealed at 1950°F [1065°C].

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

6.5 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 A 788 shall comply with Table 1.

7.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

7.3 UNS designations follow:

Grade	UNS Designation
F304	S30400
F304H	S30409
F304L	S30403
F304N	S30451
F304LN	S30453
F309H	S30909
F310	S31000
F310H	S31009
F316	S31600
F316H	S31609
F316L	S31603
F316N	S31651
F316LN	S31653
F321	S32100
F321H	S32109
F347	S34700
F347H	S34709
F348	S34800
F348H	S34809
FXM-19	S20910
FXM-11	S21904
F46	S30600

## 8. Mechanical Properties

8.1 *Requirements*—The material shall conform to the requirements for mechanical properties prescribed in Table 2 and Supplemental Requirement S2. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 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. This shall be taken from a prolongation of one of the forgings from the same

heat in the same heat treatment load.

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 E 112, 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.

## 10. Repair Welding

10.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

## 11. Marking

11.1 The marking requirements of Specification A 788 apply.

## 12. Test Reports

12.1 The certification requirements of Specification A 788 shall apply.

## 13. Keywords

13.1 austenitic stainless steel forgings; high temperature service; pressure containing parts; pressure vessel service

**TABLE 1 Chemical Requirements**

Austenitic Steels

Grade

Element	F 304	F 304H	F 304L	F 304N	F 304LN	F 309H	F 310	F 310H	F 316	F 316H	F 316L	F 316N	F 316LN	F 321	F 321H	F 347	F 347H	F 348	F 348H	F XM-19	F XM-11	F 46 <sup>A</sup>
Carbon	0.08 max	0.04–0.10	0.030 max	0.030 max	0.030 max	0.04–0.10	0.15 max	0.04–0.10	0.08 max	0.04–0.10	0.035 max	0.08 max	0.030 max	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.06 max	0.04 max	0.018 max
Manganese	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	4.0–6.0	8.0–10.0	8.0–10.0
Phosphorus, max	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.040	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.020
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.020
Silicon	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	3.7–4.3
Nickel	8.0–11.0	8.0–11.0	8.0–12.0	8.0–11.0	8.0–11.0	12.0–15.0	19.0–22.0	19.0–22.0	10.0–14.0	10.0–14.0	10.0–15.0	10.0–13.0	10.0–13.0	9.0–12.0	9.0–12.0	9.0–12.0	9.0–12.0	9.0–12.0	9.0–12.0	9.0–13.5	11.5–13.5	5.5–7.5
Chromium	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	22.0–24.0	24.0–26.0	24.0–26.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	17.0–19.0	17.0–19.0	17.0–19.0	17.0–19.0	17.0–19.0	17.0–19.0	20.5–23.5	19.0–21.5	17.0–18.5
Molybdenum	...	...	...	...	...	...	...	...	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	...	...	...	...	...	...	1.50–3.00	...	0.20 max
Nitrogen	...	...	...	0.10–0.16	0.10–0.16	...	...	...	...	...	...	0.16	0.10–0.16	0.10 max	...	...	...	...	...	0.20–0.40	0.15–0.40	...
Columbium and tantalum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Titanium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Tantalum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cobalt, max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
UNS Designation	S30400	S30409	S30403	S30451	S30453	S30909	S31000	S31009	S31600	S31609	S31603	S31651	S31653	S32100	S32109	S34700	S34709	S34800	S34809	S20910	S21904	S30600

<sup>A</sup> F46 shall have a maximum copper content of 0.50.

<sup>B</sup> F347 shall have a columbium content of not less than ten times the carbon content and not more than 1.10%. (Alternatively, tantalum may be substituted for part of the columbium as approved by the purchaser.)

<sup>C</sup> F321 shall have a titanium content of not less than 5x (C+N) and not more than 0.70%.

<sup>D</sup> F321H shall have a titanium content of not less than 4x (C+N) and not more than 0.70%.