



# 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 reapproval. A superscript epsilon (ε) 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 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 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.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 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

<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, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

### 2.2 Other Standards:

ASME Boiler and Pressure Vessel Code, including Section VIII Pressure Vessels and Section IX<sup>3</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.

<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.



## 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 – 6.5 is not permissible.

6.2 For Grades F304H, F309H, F310H, F316H, F321H, F347H, and F 348H, 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 to 2140°F [1100 to 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 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

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

		TABLE 1. Chemical Requirements										
		Element										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium + Tantalum	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
F321H	S32109	0.04-0.10	2.00	0.045	0.030	1.00	9.0-12.0	17.0-19.0	...	...	...	5x(C+N)-0.70 Ti
F347	S34700	0.08	2.00	0.045	0.030	1.00	9.0-12.0	17.0-19.0	...	...	...	4x(C+N)-0.70 Cb
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	...	10xC-1.10 <sup>B</sup>
F347LN	S34751	0.005-0.020	2.00	0.045	0.030	1.00	9.0-13.0	17.0-19.0	...	...	0.06-0.10	Cb
F348	S34800	0.08	2.00	0.045	0.030	1.00	9.0-12.0	17.0-19.0	...	10xC-1.10	...	0.20-0.50 15xC min Co 0.020, 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, 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	...
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

<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.



Grade	Type	UNS Designation
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
F46	...	S30600

## 8. Mechanical Properties

8.1 *Requirements*—The material shall conform to the requirements for mechanical properties prescribed in [Table 2](#) or, if 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 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.

## 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 [A788/A788M](#) apply.

## 12. Test Reports

12.1 The certification requirements of Specification [A788/A788M](#) shall apply.

## 13. Keywords

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



TABLE 2 Tensile Requirements

Austenitic Steels																								
Grade																								
	F304	F304H	F304L	F304N	F304LN	F309H	F310	F310H	F316	F316H	F316L	F316N	F316LN	F70	F321	F321H	F347	F347H	F347LN	F348	F348H	FXM-19	FXM-11	F46
Tensile strength, min, ksi [MPa]	70 [485]	70 [485]	65 [450]	80 [550]	70 [485]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	80 [550]	70 [485]	70 [480]	70 [485]	70 [485]	70 [485]	70 [485]	70 [485]	70 [485]	70 [485]	100 [690]	90 [620]	78-100 [540-690]
Yield strength (0.2 % offset), min, ksi [MPa]	30 [205]	30 [205]	25 [170]	35 [240]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	25 [170]	35 [240]	30 [205]	25 [175]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	55 [380]	50 [345]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30	25	30	30	30	30	30	30	30	25	30	35	30	30	30	30	30	30	30	30	40	40
Reduction of area, min, %	45	45	45	45	45	45	35	45	45	45	45	45	45	50	45	45	45	45	45	45	45	50	50	50



## SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

### S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be specified.

### S2. Transverse Tension Test

S2.1 Instead of the test specimen orientation requirements in 8.3, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 2, with the exception of the ductility limits which shall be as prescribed in Table S2.1.

### S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

### S4. Stabilization Heat Treatment

S4.1 When specified, Grades F347 and F321 shall receive stabilization treatment, which shall consist of holding the forging at 1500 to 1600°F [815 to 870°C], for not less than 2 h/in. of thickness and then cooling in the furnace or in still air.

### S5. Marking

S5.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

### S6. Individual Forging

S6.1 Forgings, whether identical or not identical, shall be produced individually. They shall not be forged in multiple and separated prior to or after heat treatment.

S6.2 The shape and size of individual forgings shall be agreed between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

### S7. Grain Size Requirements for Service Exceeding 1000°F [540°C]

S7.1 For design metal temperatures above 1000°F [540°C], the forgings shall have a grain size of 7 or coarser as determined in accordance with Test Methods E112. The actual grain size shall be reported on the certificate of test.

### S8. Ultrasonic Inspection

S8.1 An ultrasonic inspection of the machined forging shall be made in accordance with Practice A745/A745M to the quality acceptance level specified in the purchase order or contract.



Grade

	F304	F304H	F304L	F304N	F304LN	F309H	F310	F310H	F316	F316H	F316L	F316N	F316LN	F70	F321	F321H	F347	F347H	F347LN	F348	F348H	FXM19	FXM11	F46
Elongation in 2 in. or 50 mm, min, %	30	30	30	25	30	30	30	30	30	30	30	25	30	40	30	30	30	30	30	30	30	30	40	40
Reduction of area, min, %	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	37	35	35	35	35	40	40	40



## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A965/A965M – 13) that may impact the use of this standard. (Approved May 1, 2014.)

- (1) Added new grade F70, S31730, to the table in 7.3, and to Table 1, Table 2, and Table S2.1      (2) Revised 2.1 and 8.1 to provide for testing to Test Methods A1058.

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