Designation: A965/A965M – 21a

Standard Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts[1]

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 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:*[2]

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

2.2 *Other Standards:*

ASME Boiler and Pressure Vessel Code, including Section VIII Pressure Vessels and Section IX[3]

A5.11/A5.11M Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding[4]

A5.14/A5.14M Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods[4]

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,

[1] 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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[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

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

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 Grade FXM-11 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].

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 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

TABLE 1 Chemical Requirements[A]

		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 5×(C+N)–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 4×(C+N)–0.70
F347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	...	10×C–1.10[B]	...	...
F347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0-12.0	17.0–19.0	...	8×C-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 15×C 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	...	10×C–1.10	...	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	...	8×C–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	...
F20	N08020	0.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8×C 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	8×C min 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 Al 0.15–0.60 Cu 0.75 Fe 39.5 min
FNIC10	N08810	0.05–0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	...	...	Ti 0.15–0.60 Al 0.15–0.60 Cu 0.75 Fe 39.5 min
FNIC11	N08811	0.06–0.10	1.50	0.040	0.015	1.00	30.0–35.0	19.0–23.0	...	...	...	Ti 0.25–0.60[C] Al 0.25–0.60[C] Cu 0.75 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[D]	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[D]	Cu 0.50–1.50

[A] 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.
[B] Alternatively, tantalum may be substituted for part of the columbium as approved by the purchaser.
[C] Ti + Al shall be 0.85 % min: 1.20 % max.
[D] The method of analysis for nitrogen shall be a matter of agreement between purchaser and manufacturer.

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

TABLE 2 Tensile Requirements

Austenitic Stainless Steel Grades	Tensile Strength, min ksi [MPa]	Yield Strength, 0.2 % Offset, min ksi [MPa]	Elongation in 2 in. or 50 mm, min %	Reduction of Area, 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	...

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.

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.[5]

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

[5] Weld deposits made on N08020, N08367, M08700, N08800, N08810, N08811, N08925, and N08926 shall be made using filler metal with a composition conforming to the base materials or the equivalent classification in the AWS filler metal Specifications A5.11/A5.11M and A5.14/A5.14M. It is possible that the weld deposit chemistry will not meet the limits of either the base metal or the filler metal for some elements. The weld deposit chemistry shall meet the lowest minimum and highest maximum values for each specification element in either of the base metal or filler metal specification. Dilution of the base metal and the filler metal must be considered when determining weld deposit criteria for over-alloyed filler metals. In either case, the weld deposit chemistry shall be tested and recorded on the procedure qualification record (PQR).