Designation: A 336/A 336M – 09

Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts[1]

This standard is issued under the fixed designation A 336/A 336M; 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 Department of Defense.

1. Scope*

1.1 This specification[2] covers ferritic steel forgings for boilers, pressure vessels, high-temperature parts, and associated equipment.

1.2 Forgings made of steel grades listed in Specification A 335/A 335M, may also be ordered under this specification. The chemical, tensile, heat treatment, and marking requirements of Specification A 335/A 335M shall apply, except the forging shall conform to the chemical requirements of Tables 1 and 2 of Specification A 335/A 335M only with respect to heat analysis. On product analysis they may deviate from these limits to the extent permitted in Table 1 of this specification.

1.3 Supplementary Requirements S1 to S9 are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.5 Specification A 336/A 336M formerly included austenitic steel forgings, which are now found in Specification A 965/A 965M.

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings

A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788/A 788M Specification for Steel Forgings, General Requirements

A 965/A 965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts

E 165 Test Method for Liquid Penetrant Examination

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code Section III, Nuclear Facility Components and Section IX, Welding Qualifications[4]

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788/A 788M, the purchaser should include with the inquiry and order the following information:

3.1.1 A drawing or sketch that shows test locations when the testing is in accordance with 8.1.1.3.

3.1.2 The intended use of forgings if 5.1 is applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788/A 788M, 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/A 788M, the requirements of this specification shall prevail.

3.4 For hubbed flanges and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A 788/A 788M shall be specified.

3.5 At the purchaser's request the forgings shall be rough machined before heat treatment (5.2).

[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 ASME Boiler and Pressure Vessel Code applications, see related Specification SA-336/SA-336M in Section II of that Code.

[3] 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.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

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

TABLE 1 Tensile Requirements

	Ferritic Steels																		
	Grade																		
	F1	F11, Class 2	F11, Class 3	F11, Class 1	F12	F5	F5A	F9	F6	F6NM	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F91	F911	F3V	F3VCb	F22V
Tensile strength, ksi [MPA]	70-95 [485-660]	70-95 [485-660]	75-100 [515-690]	60-85 [415-585]	70-95 [485-660]	60-85 [415-585]	80-105 [550-725]	85-110 [585-760]	85-110 [585-760]	115-140 [790-965]	75-100 [515-690]	60-85 [415-585]	75-100 [515-690]	60-85 [415-585]	85-110 [585-760]	90-120 [620-830]	85-110 [585-760]	85-110 [585-760]	85-110 [585-760]
Yield strength, min, ksi [MPa]	40 [275]	40 [275]	45 [310]	30 [205]	40 [275]	36 [250]	50 [345]	55 [380]	55 [380]	90 [620]	45 [310]	30 [205]	45 [310]	30 [205]	60 [415]	64 [440]	60 [415]	60 [415]	60 [415]
Elongation in 2 in. or 50 mm, min, %	20	20	18	20	20	20	19	20	18	15	19	20	19	20	20	20	18	18	18
Reduction of area, min, %	40	40	40	45	40	40	35	40	35	45	40	45	40	45	40	40	45	45	45

3.6 For Section III, Part NB of the ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S3 shall be specified.

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A 788/A 788M, which may be supplemented by Supplementary Requirement S8, the following conditions apply:

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 Unless otherwise specified by the purchaser, when rough machining is performed, it may be done either before or after heat treatment at the manufacturer's option.

6. Heat Treatment

6.1 Except as permitted in 6.1.1 for Grade F22V, the steel forgings shall be annealed or normalized and tempered but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. For all grades, normalizing or liquid quenching shall be followed by tempering at a subcritical temperature as shown in 6.1.4.

6.1.1 Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option.

6.1.1.1 For Grade F22V forgings the minimum austenizing temperature shall be 1650°F [900°C].

6.1.2 For Grade F91 and F911 forgings the austenitizing temperature shall be in the range of 1900 to 1975°F [1040 to 1080°C].

6.1.3 For Grade F6NM the austenitizing temperature shall be 1850ºF [1010ºC] minimum. The tempering temperature range shall be as shown in 6.1.4.

6.1.4 Except for the following grades, the minimum tempering temperature shall be 1100°F [595°C]:

Grade	Tempering Temperature Minimum or Range, °F [°C]
F6	1150 [620]
F6NM	1040-1120 [560-600]
F11, Class 2	1150 [620]
F11, Class 3	1150 [620]
F11, Class 1	1150 [620]
F5	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
F91	1350-1470 [730-800]
F911	1365-1435 [740-780]
F22, Class 3	1250 [675]

7. Chemical Composition

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A 788/A 788M and shall comply with Table 2.

7.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A 788/A 788M to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis for columbium and calcium for Grade F22V shall conform to the requirements of Table 2 of this specification. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788/A 788M.

8. Mechanical Properties

8.1 *General Requirements*—The material shall conform to the requirements for mechanical properties prescribed in Table 1. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 Except as required in 3.4, for annealed, normalized, and tempered or quenched and tempered forgings, the longitudinal axis of the tension test specimens, and, when required, Charpy impact test specimens, 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 test specimen shall be in the tangential direction.

8.1.1.1 Except as provided for liquid quenched and tempered forgings in 8.1.1.3, the longitudinal axis of the 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, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed, as defined in 8.1.3, the tension test specimens shall be taken from a location that represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane. Alternatively, and when specified by the purchaser, the specimens shall be taken in accordance with Supplementary Requirement S3.

8.1.1.2 For liquid quenched and tempered forgings, the test specimens shall have their longitudinal axis at least ¼ *T* of the maximum heat-treated thickness from any surface and with the mid-length of the specimens at least one *T* from any second surface. This is normally referred to as ¼ *T* × *T*, where *T* is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the above condition.

8.1.1.3 For liquid quenched and tempered forgings with prior purchaser approval, test specimens may be taken at a depth (*t*) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance (2 *t*) from any second surface. However, the test depth shall not be nearer to one heat-treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location normally (known as tx2t testing) applies to thick and complex pressure vessel components where the testing in accordance with 8.1.1.2 is not practical. Sketches showing the proposed exact test locations shall be approved by the purchaser when this method is used.

8.1.2 Except as specified in this specification, tests for acceptance shall be made after heat treatment has been completed in accordance with Section 6. When the ends of the

TABLE 2 Chemical Requirements

Composition, %									
	Grade								
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5[A]	F5A[A]	F9	F6	F6NM
Carbon	0.20–0.30	0.10–0.20	0.05–0.15	0.10–0.20	0.15 max	0.25 max	0.15 max	0.12 max	0.05 max
Manganese	0.60–0.80	0.30–0.80	0.30–0.60	0.30–0.80	0.30–0.60	0.60 max	0.30–0.60	1.00 max	0.50–1.00
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.020
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015
Silicon	0.20–0.35	0.50–1.00	0.50–1.00	0.10–0.60	0.50 max	0.50 max	0.50–1.00	1.00 max	0.60 max
Nickel	. . .	. . .	. . .	. . .	0.50 max	0.50 max	. . .	0.50 max	3.5–5.5
Chromium	. . .	1.00–1.50	1.00–1.50	0.80–1.10	4.0–6.0	4.0–6.0	8.0–10.0	11.5–13.5	11.5–14
Molybdenum	0.40–0.60	0.45–0.65	0.44–0.65	0.45–0.65	0.45–0.65	0.45–0.65	0.90–1.10	. . .	0.50–1.00

	Grade	
Element	F21, Classes 1 and 3	F22, Classes 1 and 3
Carbon	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.025
Sulfur, max	0.025	0.025
Silicon	0.50 max	0.50 max
Nickel	. . .	. . .
Chromium	2.7–3.3	2.00–2.50
Molybdenum	0.80–1.06	0.90–1.10
Vanadium	. . .	. . .
Copper	. . .	. . .
Nitrogen	. . .	. . .
Columbium	. . .	. . .

Element	Grade F 91	Grade F911	F3V	F3VCb	F22V
Carbon	0.08–0.12	0.09–0.13	0.10–0.15	0.10–0.15	0.11–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.020	0.020	0.020	0.015
Sulfur, max	0.025	0.010	0.020	0.010	0.010
Silicon	0.20–0.50	0.10–0.50	0.10 max	0.10 max	0.10 max
Nickel	0.40 max	0.40 max	. . .	0.25 max	0.25 max
Chromium	8.0–9.5	8.5–9.5	2.7–3.3	2.7–3.3	2.00–2.50
Molybdenum	0.85–1.05	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.18–0.25	0.18–0.25	0.20–0.30	0.20–0.30	0.25–0.35
Columbium	0.06–0.10	0.06–0.10	. . .	0.015–0.070	0.07 max
Nitrogen	0.03–0.07	0.04–0.09	. . .	. . .	. . .
Aluminum	0.02 max[B]	0.02 max[B]	. . .	. . .	. . .
Boron	. . .	0.0003–0.006	0.001–0.003	. .	0.0020 max
Tungsten	. . .	0.90–1.10	. . .	. . .	. . .
Titanium	0.01 max[B]	0.01 max[B]	0.015–0.035	0.015 max	0.030 max
Copper	. . .	. . .	. . .	0.25 max	0.20 max
Calcium	. . .	. . .	. . .	0.0005–0.0150	0.015 max[C]
Zirconium	0.01 max[B]	0.01 max[B]	. . .	. . .	. . .

[A] The present Grade F 5A (0.25 %, maximum carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 has been assigned to the 0.15 %, maximum, carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding, fittings, etc.

[B] Applies to both heat and product analyses.

[C] For Grade F 22V, rare earth metals (REM) may be added in place of calcium subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

cylindrical forgings are closed in by reforging, the cylindrical forgings may be normalized and tempered or annealed and tested before reforging. After reforging, the entire forging shall be re-heat treated in the same manner and at the same temperature range as employed when the forging was heat treated before certification testing.

8.1.3 When mutually agreed upon between the manufacturer and the purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot-working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than $T \times T \times 3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 1—In using separately forged test blocks, attention is drawn to the effect of mass differences between the production forgings and the test blocks. This can be particularly significant when forgings are either normalized and tempered or quenched and tempered.

8.2 *Number and Location of Tests*—The number and location of tests are based on forging length, weight, and heat treatment and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed or Normalized and Tempered Forgings*:

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings*:

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 to 10 000 lb [2250 to 4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 Quenched and tempered forgings that exceed 12 ft [3.7 m] in length shall be tension tested at both ends of the forging under test.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

8.3 *Notch Toughness Requirements–Grades F3V, F3VCb, F22V, and F6NM*:

8.3.1 Impact test specimens shall be Charpy V-notch, as shown in Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

8.3.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.1 and 8.2. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.3.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

8.3.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft·lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft·lbf [54 J] and it shall meet a minimum value of 35 ft·lbf [48 J].

8.3.5 The impact test temperature shall be not warmer than 0°F [–18°C].

8.3.6 Unless Supplementary Requirement S13 of Specification A 788/A 788M is specified by the purchaser, for Grade F6NM forgings a minimum average absorbed energy of 20 ft·lbf [27 J] for each test shall apply at a temperature not warmer than –100ºF [–73ºC].

9. Workmanship, Finish, and Appearance

9.1 When forgings have been heat treated by quenching and tempering, all accessible surfaces shall subsequently be examined for quench cracks by the magnetic particle method in accordance with Practice A 275/A 275M.

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 the ASME Boiler and Pressure Vessel Code, Section IX.

11. Marking

11.1 In addition to the marking requirements of Specification A 788/A 788M, the specification marking shall be followed by the letter A for annealed, N for normalized and tempered, or Q for liquid quenched and tempered as applicable.

12. Test Reports

12.1 The certification requirements of Specification A 788/A 788M shall apply.

13. Keywords

13.1 chromium alloy steel; chromium-molybdenum steel; martensitic stainless steel; pressure containing parts; pressure vessel service; steel forgings—alloy; temperature service applications—high

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 Mechanical Testing

S2.1 Instead of test specimens taken in accordance with 8.1.1, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The tension test results shall conform with requirements of Table 1, with the exception of the ductility limits which shall be as prescribed in Table S2.1. When required, the Charpy impact test results shall conform to 8.3.

S3. Alternative Test Specimen Requirements

S3.1 The test requirements for materials of the ASME Boiler and Pressure Code, Section III, Article NB-2223.3, shall be used in place of that specified in 8.1.1.1.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S6. Liquid Penetrant Examination

S6.1 After forgings have been heat treated by quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E 165 as an alternative to magnetic particle examination.

S7. Marking

S7.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

S8. Forging Requirements

S8.1 Large drum forgings shall be made from solid cast ingots, punched, bored, or trepanned, or from hollow ingots cast in metal molds. The walls of the hollowed or hollow ingots shall be reduced in thickness at least one-half by forging on mandrels.

S8.2 Drum forgings with one solid closed end may be hollow forged in closed dies or on a draw bench provided the metal is worked thoroughly.

S8.3 Drum forgings, either with open ends or one solid closed end, may also be produced by hot extrusion provided the metal is worked thoroughly.

S8.4 Small drum forgings may be made as solid forgings, subsequently bored, provided the purchaser agrees to this method of forging. The cross-sectional area of the solid forgings shall have a reduction by forging from that of the ingot in the ratio of not less than 3:1.

S8.5 Small sections or component parts of pressure vessels, which are to be subsequently assembled to form drums, may be made by expanding on a mandrel under a press or hammer, by hot extrusion or by ring rolling methods, provided the wall thickness is reduced at least one-half in the process.

S8.6 Heads or covers shall be forged as disks, upset from blocks cut from ingots or billets. The length of block before upsetting shall be at least twice the thickness of the as-forged head or cover.

S9. Individual Forging

S9.1 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.

S9.2 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.

TABLE S2.1 Ductility Limits

	Grade																		
	F1	F11, Class 2	F11, Class 3	F11, Class 2	F12	F5	F5A	F9	F6	F6NM	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F3V	F46	F22V	F91	F911
Elongation in 2 in. or 50 mm, min, %	20	18	18	19	18	19	19	18	18	14	18	19	18	20	17	40	17	19	16
Reduction of area, min, %	30	35	30	40	25	35	35	35	35	40	35	35	25	35	35	50	35	40	30

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 336/A 336M – 08) that may impact the use of this standard. (Approved Feb. 15, 2009.)

(*1*) Added Grade F6NM to 6.1.3, 6.1.4, 8.3.6, Table 1, Table 2, and Table S2.1.

(*2*) Revised 5.2 and converted customary units in Table 1.

(*3*) Deleted the list of grades in 1.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 336/A 336M – 07) that may impact the use of this standard. (Approved May 1, 2008.)

(*1*) Revised 8.1.1 and Supplementary Requirement S2.