Designation: ~~A336/A336M – 15~~ A336/A336M – 18

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

This standard is issued under the fixed designation A336/A336M; 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 U.S. 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 A335/A335M, may also be ordered under this specification. The chemical, tensile, heat treatment, and marking requirements of Specification A335/A335M shall apply, except the forging shall conform to the chemical requirements of Tables 1 and 2 of Specification A335/A335M 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 A336/A336M formerly included austenitic steel forgings, which are now found in Specification A965/A965M.

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.

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:*[3]

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings
A335/A335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A788/A788M Specification for Steel Forgings, General Requirements
A965/A965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
E165/E165M Practice for Liquid Penetrant Examination for General Industry

2.2 *ASME Boiler and Pressure Vessel Code:*[4]

Section III Nuclear Power Plant Components
Section IX Welding and Brazing Qualifications

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[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, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

***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, Type 1 and Type 2	F911	F92	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]	90-110 [620-760]	90-120 [620-830]	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]	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	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	45

2.3 *AWS Specifications:*[5]
A5.5/A5.5M Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
A5.23/A5.23M Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.28/A5.28M Low-Alloy Steel Electrodes for Gas Shielded Arc Welding
A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A788/A788M, 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 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 For hubbed flatheads and tube sheets ordered for ASME Boiler and Pressure Vessel Code application, Supplementary Requirement S12 of Specification A788/A788M shall be specified.

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

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 A788/A788M, 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, and in 6.1.2 for Grade F91 ~~and~~ Type 1 and Type 2 and Grade F92, 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 austenitizing temperature shall be ~~1650°F [900°C].~~1650 °F [900 °C].

6.1.2 Grade F91 Type 1 and Type 2 forgings having any section thickness greater than 3 in. [75 mm] shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option. Grade F92 forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option.

6.1.2.1 For Grade ~~F91,~~ F91 Type 1 and Type 2, F911, and F92 forgings, the austenitizing temperature shall be in the range of 1900 to ~~1975°F~~1975 °F [1040 to ~~1080°C].~~1080 °C].

6.1.3 For Grade F6NM the austenitizing temperature shall be ~~1850°F [1010°C]~~1850 °F [1010 °C] 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]:~~1100 °F [595 °C]:

Grade	Tempering Temperature Minimum or Range, °F [°C]
F6	1150 [620]
~~F6NM~~	~~1040-1120 [560-600]~~
F6NM	1040–1120 [560–600]
F11, Class 2	1150 [620]

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

F11, Class 3	1150 [620]
F11, Class 1	1150 [620]
F5, F5a	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
~~F91, F92~~	~~1350-1470 [730-800]~~
F91 Type 1 and Type 2, F92	1350–1470 [730–800]
~~F911~~	~~1365-1435 [740-780]~~
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 A788/A788M and shall comply with Table 2.

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 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 A788/A788M.

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 A370 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.

TABLE 2 Chemical Requirements[A]

Composition, %									
	Grade								
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5[B]	F5A[B]	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[C]	. . .	. . .

~~Element~~ Element	~~Grade F91~~ Grade F91 Type 1	~~Grade F911~~ Grade F91 Type 2	~~Grade F92~~ Grade F911	~~F3V~~ Grade F92	~~F3VCb~~ F3V	~~F22V~~ F3VCb	F22V
Carbon	0.08–0.12	0.08–0.12	0.09–0.13	0.07–0.13	0.10–0.15	0.10–0.15	0.11–0.15
Heat Product	. . .	0.07–0.13	. . .	. . .	. . .	. . .	. . .
~~Manganese~~	~~0.30–0.60~~	~~0.30–0.60~~	~~0.30–0.60~~	~~0.30–0.60~~	~~0.30–0.60~~	~~0.30–0.60~~	
Manganese	0.30–0.60	0.30–0.50[D]	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~~	~~0.020~~	~~0.015~~	
Phosphorus, max	0.025	0.020[D]	0.020	0.020	0.020	0.020	0.015
Sulfur, max	0.025	0.005[D]	0.010	0.010	0.020	0.010	0.010
Silicon	0.20–0.50	0.20–0.40[D]	0.10–0.50	0.50	0.10 max	0.10 max	0.10 max
Nickel	0.40 max	0.20 max[D]	0.40 max	0.40	. . .	0.25 max	0.25 max
Chromium	8.0–9.5	8.0–9.5[D]	8.5–9.5	8.50–9.50	2.7–3.3	2.7–3.3	2.00–2.50
Molybdenum	0.85–1.05	0.85–1.05	0.90–1.10	0.30–0.60	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.18–0.25	0.18–0.25	0.18–0.25	0.15–0.25	0.20–0.30	0.20–0.30	0.25–0.35
Heat Product	. . .	0.16–0.27	. . .	. . .	. . .	. . .	. . .
Columbium[C]	0.06–0.10	0.06–0.10	0.06–0.10	0.04–0.09	. . .	0.015–0.070	0.07 max
Nitrogen	0.03–0.07	0.035–0.070[D]	0.04–0.09	0.030–0.070	. . .	. . .	. . .
~~Aluminum~~	~~0.02 max[C]~~	~~0.02 max[C]~~	~~0.02~~	~~. . .~~	~~. . .~~	~~. . .~~	
Aluminum	0.02 max[D]	0.02 max[D]	0.02 max[D]	0.02	. . .	. . .	. . .
~~Boron~~	~~. . .~~	~~0.0003–0.006~~	~~0.001–0.006~~	~~0.001–0.003~~	~~. . .~~	~~0.0020 max~~	
Boron	. . .	0.001 max[D]	0.0003–0.006	0.001–0.006	0.001–0.003	. . .	0.0020 max
N/Al ratio	. . .	≥4.0	. . .	. . .	. . .	. . .	. . .
Tungsten	. . .	0.05 max[D]	0.90–1.10	1.50–2.00	. . .	. . .	. . .
~~Titanium~~	~~0.01 max[C]~~	~~0.01 max[C]~~	~~0.01~~	~~0.015–0.035~~	~~0.015 max~~	~~0.030 max~~	
Titanium	0.01 max[D]	0.01 max[D]	0.01 max[D]	0.01	0.015–0.035	0.015 max	0.030 max
Copper	. . .	0.10 max[D]	. . .	. . .	. . .	0.25 max	0.20 max
~~Calcium~~	~~. . .~~	~~. . .~~	~~. . .~~	~~. . .~~	~~0.0005–0.0150~~	~~0.015 max[D]~~	
Calcium	. . .	. . .	. . .	. . .	. . .	0.0005–0.0150	0.015 max[E]
~~Zirconium~~	~~0.01 max[C]~~	~~0.01 max[C]~~	~~0.01~~	~~. . .~~	~~. . .~~	~~. . .~~	
Zirconium	0.01 max[D]	0.01 max[D]	0.01 max[D]	0.01	. . .	. . .	. . .
Tin	. . .	0.010 max[D]	. . .	. . .	. . .	. . .	. . .
Antimony	. . .	0.003 max[D]	. . .	. . .	. . .	. . .	. . .
Arsenic	. . .	0.010 max[D]	. . .	. . .	. . .	. . .	. . .

[A] Where ellipses (...) appear in this table, there is no requirement, and the element need neither be analyzed for nor reported.
[B] The present Grade F5A (0.25 %, maximum carbon) previous to 1955 was assigned the identification symbol F5. Identification symbol F5 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.
[C] Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.
[D] Applies to both heat and product analyses.

[E] For Grade F22V, 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.

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 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* × *T* × 3*T* 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.