Designation: A 336/A 336M – 03

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 check analysis they may deviate from these limits to the extent permitted in Table 1 of this specification.

Current	Formerly
Grade F1	Class F1
Grade F11, Class 2	Class F11
Grade F11, Class 3	Class F11A
Grade F11, Class 1	Class F11B
Grade F12	Class F12
Grade F5	Class F5
Grade F5A	Class F5A
Grade F9	Class F9
Grade F6	Class F6
Grade F21 Class 1	Class F21A
Grade F21, Class 3	Class F21
Grade F22, Class 1	Class F22A
Grade F22, Class 3	Class F22
Grade F91	Class F91
Grade F3V	Class F3V
Grade F22V	Class F22V

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

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings[3]

A 335/A 335M Specification for Seamless Ferritic Alloy Steel Pipe for High-Temperature Service[4]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[5]

A 788 Specification for Steel Forgings, General Requirements[3]

A 965 Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts[3]

E 165 Test Method for Liquid Penetrant Examination[6]

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications[7]

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, 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.

[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] *Annual Book of ASTM Standards*, Vol 01.05.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 01.03.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] Available from the American Society of Mechanical Engineers, 345 East 47th St., New York, NY 10017.

***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	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F91	F911	F3V	F3VCb	F22V
Tensile strength, psi [MPa]	70 000-95 000 [485-660]	70 000-95 000 [485-660]	75 000-100 000 [515-690]	60 000-85 000 [415-585]	70 000-95 000 [485-660]	60 000-85 000 [415-585]	80 000-105 000 [550-725]	85 000-110 000 [585-760]	85 000-110 000 [585-760]	75 000-100 000 [515-690]	60 000-85 000 [415-585]	75 000-100 000 [515-690]	60 000-85 000 [415-585]	85 000-110 000 [585-760]	90 000-120 000 [620-830]	85 000-110 000 [585-760]	85 000-110 000 [585-760]	85 000-110 000 [585-760]
Yield strength, min, psi [MPa]	40 000 [275]	40 000 [275]	45 000 [310]	30 000 [205]	40 000 [275]	36 000 [250]	50 000 [345]	55 000 [380]	55 000 [380]	45 000 [310]	30 000 [205]	45 000 [310]	30 000 [205]	60 000 [415]	64 000 [440]	60 000 [415]	60 000 [415]	60 000 [415]
Elongation in 2 in. or 50 mm, min, %	20	20	18	20	20	20	19	20	18	19	20	19	20	20	20	18	18	18
Reduction of area, min, %	40	40	40	45	40	40	35	40	35	40	45	40	45	40	40	45	45	45

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

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A 788 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 When rough machining is performed, it may be done either before or after heat treatment.

6. Heat Treatment

6.1 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. Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered. For Grade F22V forgings the minimum austenizing temperature shall be 1650°F [900°C]. For Grade F91 and F911 forgings the austenitizing temperature shall be in the range of 1900 to 2000°F [1040 to 1095°C]. Normalizing or liquid quenching shall be followed by tempering at a subcritical temperature. The minimum tempering temperature shall be 1100°F [595°C], except for the following grades:

Grade	Minimum Tempering Temperature, °F [°C]
F6	1150 [620]
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 [730]
F911	1350 [730]

7. Chemical Composition

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

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. 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.

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 For annealed, normalized, and tempered steels not tested per 8.1.1.3, the longitudinal axis of the 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 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 which 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, 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 normalized and tempered and liquid quenched and 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 applies to thick and complex pressure vessel components where the testing in 8.1.1.2 is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.1.2 Except as specified herein, 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 reheat-treated in the

TABLE 2 Chemical Requirements

Composition, %								
	Grade							
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5[A]	F5A[A]	F9	F6
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
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
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
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
Nickel	. . .	. . .	. . .	. . .	0.50 max	0.50 max	. . .	0.50 max
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
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	. . .

	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	8.5–10.5	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	0.04 max	0.04 max	. . .	. . .	. . .
Boron	. . .	0.0003–0.006	0.001–0.003	. .	0.0020 max
Tungsten	. . .	0.90–1.10	. . .	. . .	. . .
Titanium	. . .	. . .	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[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] 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.

† Editorially corrected.

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* by *T* by 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 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