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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 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.

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 Practice for Liquid Penetrant Examination for General Industry

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 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,

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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, 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
	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	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]	85-110 [585-760]	90-120 [620-830]		85-110 [585-760]	85-110 [585-760]	85-110 [585-760]
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]		60 [415]	60 [415]	60 [415]
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		18	18	18
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

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 flanges 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

~~6.1Except as permitted in~~

6.1 Except as permitted in 6.1.1 for Grade F22V, and in 6.1.2 for Grade F91 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.

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

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

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

6.1.2 Grade F91 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, F911, and F92 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]~~
F91, F92	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 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.

TABLE 2 Chemical Requirements[A]

Composition, %									
	Grade								
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5[AB]	F5A[AB]	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~~ Element	~~Grade F91~~ Grade F91	~~Grade F911~~ Grade F911	Grade F92	~~F3V~~ F3V	~~F3VCb~~ F3VCb	~~F22V~~ F22V
~~Carbon~~	~~0.08–0.12~~	~~0.09–0.13~~		~~0.10–0.15~~	~~0.10–0.15~~	~~0.11–0.15~~
Carbon	0.08–0.12	0.09–0.13	0.07–0.13	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~~	
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
Phosphorus, max	0.025	0.020	0.020	0.020	0.020	0.015
~~Sulfur, max~~	~~0.025~~	~~0.010~~		~~0.020~~	~~0.010~~	~~0.010~~
Sulfur, max	0.025	0.010	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~~
Silicon	0.20–0.50	0.10–0.50	0.50	0.10 max	0.10 max	0.10 max
~~Nickel~~	~~0.40 max~~	~~0.40 max~~		~~. . .~~	~~0.25 max~~	~~0.25 max~~
Nickel	0.40 max	0.40 max	0.40	. . .	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~~
Chromium	8.0–9.5	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~~	~~0.90–1.10~~		~~0.90–1.10~~	~~0.90–1.10~~	~~0.90–1.10~~
Molybdenum	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~~		~~0.20–0.30~~	~~0.20–0.30~~	~~0.25–0.35~~
Vanadium	0.18–0.25	0.18–0.25	0.15–0.25	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~~
Columbium	0.06–0.10	0.06–0.10	0.04–0.09	. . .	0.015–0.070	0.07 max
~~Nitrogen~~	~~0.03–0.07~~	~~0.04–0.09~~		~~. . .~~	~~. . .~~	~~. . .~~
Nitrogen	0.03–0.07	0.04–0.09	0.030–0.070	. . .	. . .	. . .
~~Aluminum~~	~~0.02 max[B]~~	~~0.02 max[B]~~		~~. . .~~	~~. . .~~	~~. . .~~
Aluminum	0.02 max[C]	0.02 max[C]	0.02	. . .	. . .	. . .
~~Boron~~	~~. . .~~	~~0.0003–0.006~~		~~0.001–0.003~~	~~. .~~	~~0.0020 max~~
Boron	. . .	0.0003–0.006	0.001–0.006	0.001–0.003	. .	0.0020 max
~~Tungsten~~	~~. . .~~	~~0.90–1.10~~		~~. . .~~	~~. . .~~	~~. . .~~
Tungsten	. . .	0.90–1.10	1.50–2.00	. . .	. . .	. . .
~~Titanium~~	~~0.01 max[B]~~	~~0.01 max[B]~~		~~0.015–0.035~~	~~0.015 max~~	~~0.030 max~~
Titanium	0.01 max[C]	0.01 max[C]	0.01	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]~~
Calcium	. . .	. . .	. . .	. . .	0.0005–0.0150	0.015 max[D]
~~Zirconium~~	~~0.01 max[B]~~	~~0.01 max[B]~~		~~. . .~~	~~. . .~~	~~. . .~~
Zirconium	0.01 max[C]	0.01 max[C]	0.01	. . .	. . .	. . .

[A] ~~T~~The ~~pre ellipsent Grade F 5As~~ (~~0.25%, maximum carbon.~~) ~~aprpevious to 1955 was assr igned theidens tification symbol F5. Iden, tification symbol F5has beren ass igs ned to th re 0.15%, maxquiremument, e arbon grade to bhe ce elemensist need nt weith ASTM specifier be ationsalyzed for nother p roducts such as pipe, tubing, bpolrting, welding, fittings, etc~~.

[B] ~~A~~The ~~pp~~resent Grade F 5A (0.25 %, maximum carbon) previous to 1955 was assigned the identification symbol F5. Identification symbol F5 h~~as~~ been assigned to the 0.15 %, maximum, carbon grade to be consistent with ASTM specifications for other products such as pipe, tubin~~ag~~, bol~~ysting~~, welding, fittings, etc.

[C] ~~Applies to both heat and product analyses.~~

[D] 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.