



Designation: A336/A336M – 18a

# Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts<sup>1</sup>

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 ( $\epsilon$ ) 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<sup>2</sup> 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:*<sup>3</sup>

[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:*<sup>4</sup>

[Section III Nuclear Power Plant Components](#)

[Section IX Welding and Brazing Qualifications](#)

2.3 *AWS Specifications:*<sup>5</sup>

[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](#)

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>4</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

<sup>5</sup> 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



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]	90-120 [620-830]	90-120 [620-830]	90-120 [620-830]	85-110 [585-760]	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]	64 [440]	64 [440]	64 [440]	60 [415]	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	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	45

### 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 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].

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 Type 1 and Type 2, 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 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]:

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, F5a	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
F91 Type 1 and Type 2, 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**.

### 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<sup>A</sup>**

Composition, %									
Grade									
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5 <sup>B</sup>	F5A <sup>B</sup>	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 <sup>C</sup>	...	...							

  

Element	Grade F91 Type 1	Grade F91 Type 2	Grade F911	Grade F92	F3V	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	0.30–0.50 <sup>D</sup>	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 <sup>D</sup>	0.020	0.020	0.020	0.020	0.015
Sulfur, max	0.025	0.005 <sup>D</sup>	0.010	0.010	0.020	0.010	0.010
Silicon	0.20–0.50	0.20–0.40 <sup>D</sup>	0.10–0.50	0.50	0.10 max	0.10 max	0.10 max
Nickel	0.40 max	0.20 max <sup>D</sup>	0.40 max	0.40	0.25 max	0.25 max	0.25 max
Chromium	8.0–9.5	8.0–9.5 <sup>D</sup>	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 <sup>C</sup>	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 <sup>D</sup>	0.04–0.09	0.030–0.070	...	...	...
Aluminum	0.02 max <sup>D</sup>	0.02 max <sup>D</sup>	0.02 max <sup>D</sup>	0.02	...	...	...
Boron	...	0.001 max <sup>D</sup>	0.0003–0.006	0.001–0.006	0.001–0.003	...	0.0020 max
N/Al ratio	...	≥4.0	...	...	...	...	...
Tungsten	...	0.05 max <sup>D</sup>	0.90–1.10	1.50–2.00	...	...	...
Titanium	0.01 max <sup>D</sup>	0.01 max <sup>D</sup>	0.01 max <sup>D</sup>	0.01	0.015–0.035	0.015 max	0.030 max
Copper	...	0.10 max <sup>D</sup>	...	...	...	0.25 max	0.20 max
Calcium	...	...	...	...	...	0.0005–0.0150	0.015 max <sup>E</sup>
Zirconium	0.01 max <sup>D</sup>	0.01 max <sup>D</sup>	0.01 max <sup>D</sup>	0.01	...	...	...
Tin	...	0.010 max <sup>D</sup>	...	...	...	...	...
Antimony	...	0.003 max <sup>D</sup>	...	...	...	...	...
Arsenic	...	0.010 max <sup>D</sup>	...	...	...	...	...

<sup>A</sup> Where ellipses (...) appear in this table, there is no requirement, and the element need neither be analyzed for nor reported.

<sup>B</sup> 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.

<sup>C</sup> Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.

<sup>D</sup> Applies to both heat and product analyses.

<sup>E</sup> 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