

ASTM - A336/A336M

SPECIFICATION FOR ALLOY STEEL FORGINGS FOR PRESSURE AND HIGH-TEMPERATURE PARTS

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

❖ Heat Treatment :-

1. Except as permitted in 'point 3' for Grade F22V, and in 'point 4' 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.
2. For all grades, normalizing or liquid quenching shall be followed by tempering at a subcritical temperature as shown in table 1.
3. Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered at the manufacturer's option. For Grade F22V forgings the minimum austenitizing temperature shall be 1650°F [900°C].
4. 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.
5. 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. For Grade F6NM the austenitizing temperature shall be 1850°F [1010°C] minimum.

Table 1

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, F92	1350-1470 [730-800]
F911	1365-1435 [740-780]
F22, Class 3	1250 [675]
Other grades	1100°F [595°C]

❖ Chemical Composition :-

The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

Table 2^A

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	0.02
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

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	F91	F911	F92	F3V	F3VCb	F22V
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	0.30–0.60
Phosphorus, max	0.025	0.02	0.02	0.02	0.02	0.015
Sulfur, max	0.025	0.01	0.01	0.02	0.01	0.01
Silicon	0.20–0.50	0.10–0.50	0.5	0.10 max	0.10 max	0.10 max
Nickel	0.40 max	0.40 max	0.4	...	0.25 max	0.25 max
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	0.30–0.60	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.18–0.25	0.18–0.25	0.15–0.25	0.20–0.30	0.20–0.30	0.25–0.35

Columbium	0.06–0.10	0.06–0.10	0.04–0.09	...	0.015–0.070	0.07 max
Nitrogen	0.03–0.07	0.04–0.09	0.030–0.070	...	...	...
Aluminum	0.02 max ^C	0.02 max ^C	0.02	...	...	...
Boron	...	0.0003–0.006	0.001–0.006	0.001–0.003	...	0.0020 max
Tungsten	...	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
Copper	...	...	...	...	0.25 max	0.20 max
Calcium	...	...	...	...	0.0005–0.0150	0.015 max ^D
Zirconium	0.01 max ^C	0.01 max ^C	0.01	...	...	...

^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 Applies to both heat and product analyses.

^D 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.

❖ Mechanical Properties :-

The material shall conform to the requirements for mechanical properties prescribed in Table 3.

Table 3

Grade	Tensile strength, ksi [MPa]	Yield strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of area, min, %
F1	70-95 [485-660]	40 [275]	20	40
F11, Class 2	70-95 [485-660]	40 [275]	20	40
F11, Class 3	75-100 [515-690]	45 [310]	18	40
F11, Class 1	60-85 [415-585]	30 [205]	20	45
F12	70-95 [485-660]	40 [275]	20	40
F5	60-85 [415-585]	36 [250]	20	40
F5A	80-105 [550-725]	50 [345]	19	35
F9	85-110 [585-760]	55 [380]	20	40
F6	85-110 [585-760]	55 [380]	18	35
F6NM	115-140 [790-965]	90 [620]	15	45
F21, Class 3	75-100 [515-690]	45 [310]	19	40
F21, Class 1	60-85 [415-585]	30 [205]	20	45
F22, Class 3	75-100 [515-690]	45 [310]	19	40
F22, Class 1	60-85 [415-585]	30 [205]	20	45
F91	90-110 [620-760]	60 [415]	20	40
F911	90-120 [620-830]	64 [440]	20	40
F92	90-120 [620-830]	64 [440]	20	45
F3V	85-110 [585-760]	60 [415]	18	45

F3VCb	85-110 [585-760]	60 [415]	18	45
F22V	85-110 [585-760]	60 [415]	18	45

❖ **Mechanical Test :-**

1. Tension test:-

The number and location of tests are based on forging length, weight, and heat treatment and shall be as prescribed below:

i. Annealed or Normalized and Tempered Forgings:

- a. 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.
- b. 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.

ii. Quenched and Tempered Forgings:

- a. 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.
- b. For quenched and tempered forgings and forged bars weighing over 5000 to 10000 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.
- c. 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.
- d. For quenched and tempered forgings and forged bars weighing more than 10000 lb [4500 kg] at the time of heat treatment, two tension test specimens shall be taken from each forging.

2. Impact test:-
Notch Toughness Requirements—Grades F3V, F3VCb, F22V, and F6NM:

- i. Impact test specimens shall be Charpy V-notch.
- ii. 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].
- iii. The impact test temperature shall be not warmer than 0°F [-18°C].
- iv. Unless 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 -100°F [-73°C].

❖ **Ultrasonic Examination.**

1. For F91 and F92 hollow forgings, either S20, Ultrasonic Examination, or S22, Ultrasonic Examination from the Bore Surface, of Specification A788/A788M, shall be mandatory.

❖ **Supplementary Test :-**

- A. Transverse Mechanical Testing :- The tension test results shall conform with requirements of Table 3, with the exception of the ductility limits which shall be as prescribed in Table 4.

Table 4

	Elongation in 2 in. or 50 mm, min, %	Reduction of area, min, %
F1	20	30
F11, Class 2	18	35
F11, Class 3	18	30
F11, Class 1	19	40
F12	18	25
F5	19	35
F5A	19	35
F9	18	35

F6	18	35
F6NM	14	40
F21, Class 3	18	35
F21, Class 1	19	35
F22, Class 3	18	25
F22, Class 1	20	35
F3V	17	35
F46	40	50
F22V	17	35
F91	19	40
F911	16	30
F92	16	30

- B. Alternative Test Specimen Requirements.
- C. Hydrostatic Test.
- D. Liquid Penetrant Examination.

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