SPECIFICATION FOR FORGED OR ROLLED ALLOY-STEEL PIPE FLANGES, FORGED FITTINGS, AND VALVES AND PARTS FOR HIGH-TEMPERATURE SERVICE

SA-182/SA-182M

(Identical with ASTM Specification A 182/A 182M-98 except for the clarified heat treatment requirements by the addition of Note 4 to Table 1.)

1. Scope

1.1 This specification covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar, refer to Specifications A 479/A 479M and A 739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications refer to Specification A 336 for the similar grades available in that specification.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

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

A 336/A 336M Specification for Steel Forgings, Alloy, for Pressure and High-Temperature Parts

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

A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

A 479/A 479M Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

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A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A 788 Specification for Steel Forgings, General Requirements
E 112 Test Methods for Determining the Average Grain Size
E 165 Practice for Liquid Penetrant Inspection Method
E 340 Test Method for Macroetching Metals and Alloys

2.2 *MSS Standard:*
SP 25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.3 *ASME Boiler and Pressure Vessel Codes:*
Section IX Welding Qualifications
SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

2.4 *ANSI Standards:*
B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B16.11 Forged Steel Fittings, Socket Weld, and Threaded

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number, grade, and class if applicable (The year date should be included),

3.1.4 Supplementary requirements,

3.1.5 Additional requirements (See 5.2.2, Table 2 footnotes, 7.3, 15.1, and 18.2), and

3.1.6 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 7.3.1).

4. Manufacture

4.1 The low-alloy ferritic steels may be made by the open-hearth, electric-furnace, or basic-oxygen process with separate degassing and refining optional. The basic-oxygen process shall be limited to steels containing not over 6% chromium.

4.2 The stainless steels shall be melted by one of the following processes: (*a*) electric-furnace (with separate degassing and refining optional); (*b*) vacuum-furnace; or (*c*) one of the former followed by vacuum or electroslag-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting. Because of difficulties that may be met in retaining nitrogen, vacuum melting or remelting processes should not be specified for Grades F XM-11, F 304LN, F 316LN, F 304N, F 316N, F XM-19, F 44, F 45, F 48, F 49, F 50, F 51, F 52, F 53, F 54, F 55, F 58, or F 59.

4.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

4.4 The material shall be forged as close as practicable to the specified shape and size. Except for flanges of any type, forged or rolled bar may be used without additional hot working for small cylindrically shaped parts within the limits defined by Specification A 234/A 234M for low alloy steels and martensitic stainless steels and Specification A 403/A 403M for austenitic and ferritic-austenitic stainless steels. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as provided for in 4.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788.

5. Heat Treatment

5.1 After hot working, forgings shall be cooled to a temperature below 1000°F [538°C] prior to heat treating in accordance with the requirements of Table 1.

5.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels* — The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 5.1 and Table 1.

5.2.1 Grade F 22V shall be furnished in the normalized and tempered, or liquid quenched and tempered condition. The minimum austenitizing temperature shall be 1650°F [900°C], and the minimum tempering temperature shall be 1250°F [677°C].

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5.2.2 *Liquid Quenching* — When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

5.2.2.1 *Marking* — Parts that are liquid quenched and tempered shall be marked "QT."

5.2.3 Alternatively, Grade F1, F2, and F12, Classes one and two may be given a heat treatment of 1200°F (650°C) minimum after final hot of cold forming.

5.3 *Austenitic and Ferritic-Austenitic Stainless Steels* — The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 5.1 and Table 1.

5.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solutioning temperature specified in Table 1, forgings made from austenitic grades (except grades F304H, F316H, F321, F321H, F347, F347H, F348, and F348H) may be individually rapidly quenched in accordance with the requirements of Table 1.

5.3.2 See Supplementary Requirement S14 if a particular heat treatment method is to be employed.

5.4 *Time of Heat Treatment* — Heat treatment of forgings may be performed before machining.

5.5 *Forged or Rolled Bar* — Forged or rolled austenitic stainless bar from which small cylindrically shaped parts are to be machined, as permitted by 4.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479 or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S9 if annealing must be the final operation).

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as listed in Table 2. Test Methods, Practices, and Terminology A 751 shall apply.

6.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

6.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material, is not permitted.

7. Mechanical Properties

7.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

7.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50°F [30°C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

7.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4}$ T plane or deeper position where T is the maximum heat treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

7.3.1 With prior purchase approval, the test specimen for ferritic steel forgings, 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 ($2t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where $\frac{1}{4}$ $T \times T$ testing (7.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.4 For annealed low alloy steel, ferritic stainless steels, and martensitic stainless steels and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

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7.5 *Tension Tests:*

7.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels* — One tension test shall be made for each heat in each heat treatment charge.

7.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (Note 1) and section size is required instead of one test from each heat in each heat-treatment charge.

NOTE 1 — "Type" in this case is used to describe the forging shape such as a flange, ell, tee, etc.

7.5.2 *Austenitic and Ferritic-Austenitic Stainless Steel Grades* — One tension test shall be made for each heat.

7.5.2.1 When heat treated in accordance with 5.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

7.5.2.2 When the alternative method in 5.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

7.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

7.6 *Hardness Test:*

7.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 7.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

7.6.2 When the reduced number of tension tests permitted by 7.5.1.1 is applied, additional hardness tests shall be made on forgings or samples as defined in 7.2 scattered throughout the load (Note 2). At least eight samples shall be checked from each batch load and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 7.5.1 shall apply.

NOTE 2 — The tension test required in 7.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 7.6.2 are required when 7.5.1.1 is applied to assure the prescribed heat-treating cycle and uniformity throughout the load.

7.7 *Notch Toughness Requirements* — Grades F3V, F3VCb, and F22V.

7.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 11a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

7.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 7.2, 7.3 and 7.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

7.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

7.7.4 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].

7.7.5 The impact test temperature shall be 0°F [−18°C].

8. Grain Size for Austenitic Grades

8.1 All H grades shall be tested for average grain size by Test Methods E 112.

8.1.1 Grades F304H, F309H, F310H, and F316H shall have a grain size of ASTM No. 6 or coarser.

8.1.2 Grades F321H, F347H, and F348H shall have a grain size of ASTM No. 7 or coarser.

9. Corrosion Testing for Austenitic Grades

9.1 Corrosion testing is not required by this specification.

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9.2 Austenitic Grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S10.

10. Cast or Heat (formerly Ladle) Analysis

10.1 Each heat or furnace ladle of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made from a test specimen preferably taken during the pouring of the steel. For multiple-heat ingots, either individual heat analyses or a weighted average analysis may be reported. The steel shall conform to the chemical composition requirements prescribed in Table 2.

10.1.1 If the test sample is lost or declared inadequate for chemical determinations, the manufacturer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

10.1.2 If consumable remelting processes are employed, a chemical analysis made on one remelted ingot (or the product of one remelted ingot) per heat shall be taken as the heat analysis, and shall conform to the chemical composition requirements prescribed in Table 2. For this purpose, a heat is defined as all of the ingots remelted from a single primary melt.

11. Product Analysis

11.1 The purchaser may make a product analysis on forgings supplied to this specification. Samples for analysis shall be taken from midway between the center and surface of solid forgings, midway between the inner and outer surfaces of hollow forgings, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 2 with the tolerances as stated in Table 4 or Table 5.

12. Retreatment

12.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 7.

13. Workmanship, Finish, and Appearance

13.1 The forgings shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13.2 At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 13.4 are not scattered but appear over a large area in excess of what is considered to be a workmanlike finish.

13.3 *Depth of Injurious Imperfections* — Linear imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

13.4 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

13.4.1 Seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not be removed. If these imperfections are removed, they shall be removed by machining or grinding.

13.4.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 13.4.1. Imperfections that are deeper than $\frac{1}{16}$ in. [1.6 mm], but which do not encroach on the minimum wall thickness of the forging shall be removed by grinding to sound metal.

13.4.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at an imperfection not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of the forging, and the remainder shall be not less than the minimum specified or required wall thickness.

14. Repair by Welding

14.1 Weld repairs shall be permitted (see Supplementary Requirement S7) at the discretion of the manufacturer with the following limitations and requirements:

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14.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

14.1.2 The weld metal shall be deposited using the electrodes specified in Table 6 except as otherwise provided in Supplementary Requirement S11. The electrodes shall be purchased in accordance with ASME Specification SFA-5.4, SFA-5.5, SFA-5.9 or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

14.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid penetrant inspection in accordance with Practice E 165 for all grades.

14.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

14.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 6 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 6, provided purchaser approval is obtained prior to repair.

14.1.6 Repair by welding shall not exceed 10% of the surface area of the forging nor $33\frac{1}{3}$% of the wall thickness of the finished forging or $\frac{3}{8}$ in. [9.5 mm], whichever is less without prior approval of the purchaser.

14.1.7 When approval of the purchaser is obtained, the limitations set forth in 14.1.6 may be exceeded, but all other requirements of Section 14 shall apply.

14.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

16. Rejection

16.1 Each forging that develops injurious defects during shop working operations or in service shall be rejected and the manufacturer notified.

16.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

17. Certification

17.1 For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, the application of identification marks as required in 18.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

17.2 Test reports, when required, shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

17.2.1 Type heat treatment, Section 5.

17.2.2 Product analysis results, Section 11 (Tables 2, 4, and 5).

17.2.3 Tensile property results, Section 7 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent.

17.2.4 Chemical analysis results, Section 6 (Table 2).

17.2.5 Hardness results, Section 7 (Table 3).

17.2.6 Grain size results, Section 8, and

17.2.7 Any supplementary testing required by the purchase order.

18. Product Marking

18.1 Identification marks consisting of the manufacturer's symbol or name (Note 3), the heat number or manufacturer's heat identification, designation of service rating, the specification number, the designation, F1, F2, etc., showing the grade of material, and the size shall be legibly stamped on each forging or the forgings may be marked in accordance with Standard SP 25 of the Manufacturer's Standardization Society of the Valve and Fittings Industry, and in such position so as not

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to injure the usefulness of the forging. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 3 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

18.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 6, the letters "WNS" shall be marked following the specification designation.

18.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (18.1.1 and 18.1.2 shall apply).

18.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, etc.

18.2 *Bar Coding* — In addition to the requirements in 18.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirement; pipe fittings, steel; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service application, high; wrought material

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TABLE 1
HEAT TREATING REQUIREMENTS

Grade	Heat Treat Type	Austenitizing/ Solutioning Temperature, min °F (°C) [Notes (1), (4)]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min °F (°C)
		Low Alloy Steels			
F 1	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 2	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 9	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 91	normalize and temper	1900–2000 [1040–1095]	air cool	[Note (2)]	1350 [730]
F 11, Class 1, 2 and 3	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 12, Class 1 and 2	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 22, Class 1 and 3	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1250 [675]
FR	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize	1750 [955]	air cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
		Martensitic Stainless Steels			
F 6a Class 1	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[Note (2)]	[Note (2)]	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[Note (2)]	[Note (2)]	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040–1120 [560–600]
		Ferritic Stainless Steels			
F XM-27Cb	anneal	1850 [1010]	furnace cool	[Note (2)]	[Note (2)]
F 429	anneal	1850 [1010]	furnace cool	[Note (2)]	[Note (2)]
F 430	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]

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TABLE 1
HEAT TREATING REQUIREMENTS (CONT'D)

Grade	Heat Treat Type	Austenitizing/ Solutioning Temperature, min °F (°C) [Notes (1), (4)]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min °F (°C)
		Austenitic Stainless Steels			
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 310MoLn	solution treat and quench	1900–2010 [1050–1100]	liquid	500 [260]	[Note (2)]
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	[Note (2)]
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 348H	solution treat and quench	2000 [1100]	liquid	500 [260]	[Note (2)]
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	[Note (2)]
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 20	solution treat and quench	1700–1850 [925–1010]	liquid	500 [260]	[Note (2)]
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	[Note (2)]
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 46	solution treat and quench	2010–2140 [1100–1140]	liquid	500 [260]	[Note (2)]
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	[Note (2)]
F 56	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	[Note (2)]
F 58	solution treat and quench	2025 [1105]	liquid	500 [260]	[Note (2)]
		Ferritic-Austenitic Stainless Steels			
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	[Note (2)]
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	[Note (2)]
F 52 [Note (3)]	...	...	liquid	500 [260]	[Note (2)]
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	[Note (2)]
F 54	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	[Note (2)]
F 55	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	[Note (2)]
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	[Note (2)]
F 59	solution treat and quench	1975–2050 [1080–1120]	liquid	500 [260]	[Note (2)]

NOTES:
(1) Minimum unless temperature range is listed.
(2) Not applicable.
(3) Grade F 52 shall be solution treated at 1825 to 1875°F [995 to 1025°C] 30 min/in. of thickness and water quenched.
(4) For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments.

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TABLE 2
CHEMICAL REQUIREMENTS

Identification Symbol	UNS Designation	Grade	Composition, %									
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Titanium
			Low Alloy Steels										
F 1	K12822	carbon-molybdenum	0.28 max	0.60–0.90	0.045	0.045	0.15–0.35	...	...	0.44–0.65	...	...	...
F 2[A]	K12122	0.5% chromium, 0.5% molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60	...	0.50–0.81	0.44–0.65	...	...	...
F 5[B]	K41545	4 to 6% chromium	0.15 max	0.30–0.60	0.030	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	...	...	...
F 5a[B]	K42544	4 to 6% chromium	0.25 max	0.60 max	0.040	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	...	...	...
F 9	K90941	9% chromium	0.15 max	0.30–0.60	0.030	0.030	0.50–1.00	...	8.0–10.0	0.90–1.10	...	...	...
F 91		9% chromium, 1% molybdenum, 0.2% vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40 max	8.0–9.5	0.85–1.05	Other Elements Cb 0.06–0.10 N 0.03–0.07 Al 0.04 max V 0.18–0.25		
F 11 Class 1	K11597	1.25% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 11 Class 2	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 11 Class 3	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	...	1.00–1.50	0.44–0.65	...	...	...
F 12 Class 1	K11562	1% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max	...	0.80–1.25	0.44–0.65	...	...	...
F 12 Class 2	K11564	1% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60	...	0.80–1.25	0.44–0.65	...	...	...
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.7–3.3	0.80–1.06	...	...	...
F 3V	K31830	3% chromium, 1% molybdenum, 0.25% vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10 max	...	2.8–3.2	0.90–1.10	Other Elements V 0.20–0.30 B 0.001–0.003		0.015–0.035
F 3VCb	...	...	0.10–0.15	0.30–0.60	0.020	0.010	0.10 max	0.25 max	2.7–3.3	0.90–1.10	Other Elements V 0.20–0.30 Cb 0.015–0.070 Cu 0.25 max Ca 0.0005–0.0150		0.015 max
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.00–2.50	0.87–1.13	...	...	...
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	...	2.00–2.50	0.87–1.13	...	...	...
F 22V	K31835	2.25% chromium, 1% molybdenum, 0.25% vanadium	0.11–0.15	0.30–0.60	0.015	0.010	0.10 max	0.25 max	2.00–2.50	0.90–1.10	Other Elements Cu 0.20 max V 0.25–0.35 Cb 0.07 max B 0.002 max Ca 0.015 max[C]		0.030 max
FR	K22035	2% nickel, 1% copper	0.20 max	0.40–1.06	0.045	0.050	...	1.60–2.24	...	...	Other Elements Cu 0.75–1.25		

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TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

Martensitic Stainless Steels													
F 6a	S41000	13% chromium	0.15 max	1.00 max	0.040	0.030	1.00 max	0.50 max	11.5–13.5	...	...	...	...
F 6b	S41026	13% chromium, 0.5% molybdenum	0.15 max	1.00 max	0.02	0.02	1.0 max	1.0–2.0	11.5–13.5	0.40–0.60	Other Elements Cu 0.50 max		
F 6NM	S41500	13% chromium, 4% nickel	0.05 max	0.5–1.0	0.030	0.030	0.60 max	3.5–5.5	11.5–14.0	0.5–1.0	...	...	...
Ferritic Stainless Steels													
F XM-27Cb[D]	S44627	27 chromium, 1 molybdenum	0.010 max	0.40 max	0.020	0.020	0.40 max	0.50 max	25.0–27.5	0.75–1.50	Other Elements N 0.015 max Cu 0.20 max Cb 0.05–0.20		
F 429	S42900	15 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	14.0–16.0	...	...	...	...
F 430	S43000	17 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	16.0–18.0	...	...	...	...
Austenitic Stainless Steels													
F 304[E]	S30400	18 chromium, 8 nickel	0.08 max	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...
F 304H	S30409	18 chromium, 8 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...
F 304L[E]	S30403	18 chromium, 8 nickel, low carbon	0.035 max	2.00 max	0.045	0.030	1.00 max	8.0–13.0	18.0–20.0	...	...	...	...
F 304N[F]	S30451	18 chromium, 8 nickel, modified with nitrogen	0.08 max	2.00 max	0.045	0.030	0.75 max	8.0–10.5	18.0–20.0	...	...	...	...
F 304LN[F]	S30453	18 chromium, 8 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	0.75 max	8.0–10.5	18.0–20.0	...	...	...	...
F 309H	S30909	23 chromium, 13.5 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	...	...	...	...
F 310	S31000	25 chromium, 20 nickel	0.25 max	2.00 max	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	...
F 310H[F]	S31009	25 chromium, 20 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	...
F 310MoLN[F]	S31050	25 chromium, 22 nickel, modified with molybdenum and nitrogen, low carbon	0.020 max	2.00 max	0.030	0.010	0.050	20.5–23.5	24.0–26.0	1.60–2.60	...	Other Elements N 0.09–0.15	
F 316[E]	S31600	18 chromium, 8 nickel, modified with molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum	0.04–0.10	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316L[E]	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.035 max	2.00 max	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...
F 316N[F]	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08 max	2.00 max	0.045	0.030	0.75 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F316LN[F]	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030 max	2.00 max	0.045	0.030	0.75 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.03 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 321	S32100	18 chromium, 8 nickel modified with titanium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0 min	...	...	...	[G]
F 321H	S32109	18 chromium, 8 nickel, modified with titanium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0 min	...	...	...	[H]
F 347	S34700	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[I]	...	...
F 347H	S34709	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[J]	...	...
F 348	S34800	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[I]	0.10	...

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TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Titanium
						Austenitic Stainless Steels							
F 348H	S34809	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	. . .	[J]	0.10	. . .
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese	0.040 max	8.0–10.0	0.060	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	Other Elements N 0.15–0.40	
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese	0.06 max	4.0–6.0	0.040	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.0	0.10–0.30	Other Elements N 0.20–0.40 V 0.10–0.30	
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0	. . .	. . .	. . .	. . .
F 20	N08020	35 nickel, 20 chromium, 3.5 copper, 2.5 molybdenum	0.07 max	2.00 max	0.045 max	0.035 max	1.00 max	32.0–38.0	19.0–21.0	2.00–3.00	8xC min –1.00 max	Other Elements Cu 3.0–4.0	
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020 max	1.00 max	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	Other Elements Cu 0.50–1.00 N 0.18–0.22	
F 45	S30815	21 chromium, 11 nickel modified with nitrogen and cerium	0.05–0.10	0.80 max	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	Other Elements N 0.14–0.20 Ce 0.03–0.08	
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018 max	2.00 max	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20 max	. . .	Other Elements Cu 0.50 max	
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.0–17.5	18.0–20.0	4.0–5.0	. . .	Other Elements N 0.10 max	
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.5–17.5	17.0–20.0	4.0–5.0	. . .	Other Elements N 0.10–0.20	
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030 max	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	0.1	Other Elements N 0.4–0.6	
F 56	S33228	32 nickel, 27 chromium, with columbium	0.04–0.08	1.00 max	0.020	0.015	0.30 max	31.0–33.0	26.0–28.0	. . .	0.6–1.0	Other Elements Ce 0.05–0.10 Al 0.025	
F 58	N08367	21 chromium, 25 nickel, 6.5 molybdenum	0.030 max	2.0 max	0.040 max	0.030 max	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	. . .	Other Elements N 0.18–0.25 Cu 0.75 max	
						Ferritic-Austenitic Stainless Steels							
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	1.00 max	5.5–6.5	24.0–26.0	1.2–2.0	. . .	Other Elements N 0.14–0.20	
F 51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030 max	2.00 max	0.030	0.020	1.00 max	4.5–6.5	21.0–23.0	2.5–3.5	. . .	Other Elements N 0.08–0.20	
F 52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.03 max	2.00 max	0.035	0.010	0.60 max	3.5–5.2	26.0–29.0	1.00–2.50	. . .	Other Elements N 0.15–0.35	
F 53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030 max	1.2 max	0.035	0.020	0.8 max	6.0–8.0	24.0–26.0	3.0–5.0	. . .	Other Elements N 0.24–0.32 Cu 0.5 max	

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TABLE 2
CHEMICAL REQUIREMENTS (CONT'D)

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Titanium
			Ferritic-Austenitic Stainless Steels										
F 54	S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030 max	1.0 max	0.030 max	0.020 max	0.80 max	6.0–8.0	24.0–26.0	2.50–3.50	. . .	Other Elements N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50	
F 55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030 max	1.00 max	0.030	0.010	1.00 max	6.00–8.00	24.00–26.00	3.00–4.00	. . .	Other Elements N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00 [K]	
F 57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025 max	0.80 max	0.025	0.002	0.80 max	6.5–8.0	24.0–26.0	3.0–4.0	. . .	Other Elements Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33	
F 59	S32520	25 chromium, 6.5 nickel, 4 molybdenum with nitrogen	0.030 max	1.5 max	0.035	0.020	0.8 max	5.5–8.0	24.0–26.0	3.0–5.0	. . .	Other Elements N 0.20–0.35 Cu 0.50–3.00	

NOTES:
[A] Grade F 2 was formerly assigned to the 1% chromium, 0.5% molybdenum grade which is now Grade F 12.
[B] The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, etc.
[C] 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.
[D] Grade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002%.
[E] Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10%.
[F] Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10 to 0.16%.
[G] Grade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70%.
[H] Grade F 321H shall have a titanium content of not less than 4 times the carbon content and not more than 0.70%.
[I] Grades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10%.
[J] Grades F 347H and F 348H shall have a columbium content of not less than 8 times the carbon content and not more than 1.10%.
[K] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] [Note (1)]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
Low Alloy Steels:					
F 1	70 [485]	40 [275]	20.0	30.0	143–192
F 2	70 [485]	40 [275]	20.0	30.0	143–192
F 5	70 [485]	40 [275]	20.0	35.0	143–217
F 5a	90 [620]	65 [450]	22.0	50.0	187–248
F 9	85 [585]	55 [380]	20.0	40.0	179–217
F 91	85 [585]	60 [415]	20.0	40.0	248 max
F 11 Class 1	60 [415]	30 [205]	20.0	45.0	121–174
F 11 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 11 Class 3	75 [515]	45 [310]	20.0	30.0	156–207
F 12 Class 1	60 [415]	32 [220]	20.0	45.0	121–174
F 12 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 21	75 [515]	45 [310]	20.0	30.0	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18.0	45.0	174–237
F 22 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
F 22 Class 3	75 [515]	45 [310]	20.0	30.0	156–207
F 22V	85–110 [585–780]	60 [415]	18.0	45.0	174–237
FR	63 [435]	46 [315]	25.0	38.0	197 max
Martensitic Stainless Steels:					
F 6a Class 1	70 [485]	40 [275]	18.0	35.0	143–207
F 6a Class 2	85 [585]	55 [380]	18.0	35.0	167–229
F 6a Class 3	110 [760]	85 [585]	15.0	35.0	235–302
F 6a Class 4	130 [895]	110 [760]	12.0	35.0	263–321
F 6b	110–135 [760–930]	90 [620]	16.0	45.0	235–285
F 6NM	115 [790]	90 [620]	15.0	45.0	295 max
Ferritic Stainless Steels:					
F XM-27Cb	60 [415]	35 [240]	20.0	45.0	190 max
F 429	60 [415]	35 [240]	20.0	45.0	190 max
F 430	60 [415]	35 [240]	20.0	45.0	190 max
Austenitic Stainless Steels:					
F 304	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 304H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 304L	70 [485] [Note (3)]	25 [170]	30.0	50.0	...
F 304N	80 [550]	35 [240]	30.0 [Note (4)]	50.0 [Note (5)]	...
F 304LN	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 309H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 310	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 310MoLN	78 [540]	37 [255]	25.0	40.0	...
F 310H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 316	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 316H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 316L	70 [485] [Note (3)]	25 [170]	30.0	50.0	...
F 316N	80 [550]	35 [240]	30.0 [Note (4)]	50.0 [Note (5)]	...
F 316LN	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 317	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 317L	70 [485] [Note (3)]	25 [170]	30.0	50.0	...
F 347	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 347H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 348	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 348H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 321	75 [515] [Note (2)]	30 [205]	30.0	50.0	...
F 321H	75 [515] [Note (2)]	30 [205]	30.0	50.0	...

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TABLE 3
TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] [Note (1)]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
Austenitic Stainless Steels:					
F XM-11	90 [620]	50 [345]	45.0	60.0	...
F XM-19	100 [690]	55 [380]	35.0	55.0	...
F 10	80 [550]	30 [205]	30.0	50.0	...
F 20	80 [550]	35 [240]	30.0	50.0	...
F 44	94 [650]	44 [300]	35.0	50.0	...
F 45	87 [600]	45 [310]	40.0	50.0	...
F 46	78 [540]	35 [240]	40.0	50.0	...
F 47	75 [525]	30 [205]	40.0	50.0	...
F 48	80 [550]	35 [240]	40.0	50.0	...
F 49	115 [795]	60 [415]	35.0	40.0	...
F 56	73 [500]	27 [185]	30.0	35.0	...
F 58	95 [655]	45 [310]	30.0	50.0	...
Ferritic-Austenitic Stainless Steels:					
F 50	100–130 [690–900]	65 [450]	25.0	50.0	...
F 51	90 [620]	65 [450]	25.0	45.0	...
F 52	100 [690]	70 [485]	15.0	...	...
F 53	116 [800] [Note (6)]	80 [550] [Note (6)]	15.0	...	310 max
F 54	116 [800]	80 [550]	15.0	30.0	310 max
F 55	109–130 [750–895]	80 [550]	25.0	45.0	...
F 57	118 [820]	85 [585]	25.0	50.0	...
F 59	112 [770]	80 [550]	25.0	40.0	...

NOTES:
(1) Determined by the 0.2% offset method. For ferritic steels only, the 0.5% extension-under-load method may also be used.
(2) For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
(3) For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].
(4) Longitudinal. The transverse elongation shall be 25% in 2 in. or 50 mm, min.
(5) Longitudinal. The transverse reduction of area shall be 45% min.
(6) For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 106 ksi [730 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

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TABLE 4
PRODUCT ANALYSIS TOLERANCES FOR LOW ALLOY STEELS WITH A MAXIMUM CHROMIUM LIMIT OF 4% OR MORE AND STAINLESS STEELS[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 5.00, incl	0.10
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 27.50, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 22.00, incl	0.20
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Columbium-tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45 to 0.60	0.05
Columbium	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	−0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 1.00, incl	0.03

NOTES:
[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05% have not been established and the producer should be consulted for those limits.

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TABLE 5
PRODUCT ANALYSIS TOLERANCES FOR LOW-ALLOY STEELS WITH MAXIMUM CHROMIUM LIMIT LESS THAN 4%

Element[A]	Limit or Maximum of Specified Range, %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %[B]			
		100 in.^{2} (6.45 × 10^4 mm^2), or less	Over 100 to 200 in.^{2} (1.290 × 10^5 mm^2), incl	Over 200 to 400 in.^{2} (2.581 × 10^5 mm^2), incl	Over 400 in.^{2}
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.00 incl	0.04	0.05	0.06	0.07
Phosphorus	to 0.045 incl	0.005	0.010	0.010	0.010
Sulfur	to 0.045 incl	0.005	0.010	0.010	0.010
Silicon	to 0.40 incl	0.02	0.02	0.03	0.04
	over 0.40 to 1.00 incl	0.05	0.06	0.06	0.07
Nickel	to 0.50	0.03	0.03	0.03	0.03
Chromium	to 0.90 incl	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 incl	0.05	0.06	0.06	0.07
	over 2.10 to 3.99 incl	0.10	0.10	0.12	0.14
Molybdenum	to 0.20 incl	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 incl	0.02	0.03	0.03	0.04
	over 0.40 to 1.15 incl	0.03	0.04	0.05	0.06
Copper	to 1.00 incl	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
Titanium	to 0.10	0.01	0.01	0.01	0.01
Vanadium	to 0.10 incl	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
	0.26 to 0.50 incl	0.03	0.03	0.03	0.03

NOTES:
[A] Product analysis for carbon boron, columbium and calcium shall conform to Table 2.
[B] Cross-sectional area.

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TABLE 6
REPAIR WELDING REQUIREMENTS

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
	Low Alloy Steels		
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 91	9% Cr, 1% Mo, VCbN	400–700 [205–370]	1300 [705]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3% Cr, 1% Mo, ¼% V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25% Cr, 1% Mo, 0.25% V-Cb	300–600 [150–315]	1250 [675]
	Martensitic Stainless Steels		
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13% Cr, 1½% Ni, ½% Mo	400–700 [205–370]	1150 [620]
F 6NM	13% Cr, 4% Ni	300–700 [150–370]	1050 [565]
	Ferritic Stainless Steels		
F XM-27Cb	26% Cr, 1% Mo	NR[B]	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
	Austenitic Stainless Steels		
F 304	E 308-15 or 16	NR	1900 [1040] + WQ[C]
F 304L	E 308L-15 to 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16[D]	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16	NR	1900 [1040] + WQ
F 310MoLN	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321[E]	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H[E]	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 10[E]	. . .	. . .	. . .
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45[E]	. . .	. . .	. . .

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TABLE 6
REPAIR WELDING REQUIREMENTS (CONT'D)

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
	Austenitic Stainless Steels		
F 46	. . .	. . .	. . .
F 47	. . .[F]	. . .	2100 [1150] + WQ
F 48	. . .[F]	. . .	2100 [1150] + WQ
F 49	. . .[F]	. . .	2100 [1150] + WQ
F 58	E NiCrMo-3	NR	2025 [1105] + WQ
	Ferritic-Austenitic Stainless Steels		
F 50	25% Cr, 6% Ni, 1.7% Mo	NR	NR
F 51	22% Cr, 5.5% Ni, 3% Mo	NR	NR
F 52	26% Cr, 8% Ni, 2% Mo	NR	NR
F 53	25% Cr, 7% Ni, 4% Mo	NR	NR
F 54	25% Cr, 7% Ni, 3% Mo, W	NR	NR
F 55	25% Cr, 7% Ni, 3.5% Mo	NR	NR
F 57	25% Cr, 7% Ni, 3% Mo, 1.5% Cu, 1% W	NR	NR
F 59	E Ni CrMo-10	NR	NR

NOTES:
[A] Electrodes shall comply with ASME SFA 5.4, SFA 5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] NR = not required.
[C] WQ = water quench.
[D] Filler metal shall additionally have 0.04% minimum carbon.
[E] Purchaser approval required.
[F] Match filler metal is available. Fabricators have also used AWS A5.14, Class ER, NiCrMo-3 and AWS A5.11, Class E, NiCrMo-3 filler metals.

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SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis shall be made from each heat offered for delivery. The analysis shall conform to the requirements specified in Table 2 with tolerances in Table 4 or Table 5. If the results of any test fail to comply, two additional forgings or representative test pieces from the same heat shall be retested and the results shall comply with the tables listed. If the results of either one of these pieces fail to comply, each forging shall be checked or the heat rejected. All results shall be reported to the purchaser and all forgings which do not comply shall be rejected.

S3. Tension Test

S3.1 In addition to the requirements of Section 7, one tension specimen shall be obtained from a representative forging from each heat at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Practice E 165. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Repair Welding

S7.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 14 shall apply.

S8. Heat Treatment Details

S8.1 The manufacturer shall furnish a detailed test report containing the information required in 17.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S9. Material for Optimum Resistance to Stress-Corrosion Cracking

S9.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S10. Corrosion Tests

S10.1 All austenitic stainless steel shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A 262.

S10.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

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S10.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S11. Special Filler Metal

S11.1 In repair welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F W308.

S12. Hardness Test

S12.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S13. Alternate Heat Treatment (Grade F 91)

S13.1 Grade F 91 shall be normalized in accordance with Section 5 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 5. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S13" shall be included with the required marking of the forging.

S14. Heat Treatment of Austenitic Forgings

S14.1 The purchaser shall specify the heat treatment method (in 5.1 or in 5.3.1) that shall be employed.

S14.2 The manufacturer shall provide a test report containing the information required in 17.2 and shall include a statement of the heat treatment method employed.

S15. Grain Size for Austenitic Grades

S15.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

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