



Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification² 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 (other than those directly addressed by this specification; see 6.4), refer to Specifications [A479/A479M](#) and [A739](#) 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 Specifications [A336/A336M](#) and [A965/A965M](#) for the similar ferritic and austenitic grades, respectively, available in those specifications.

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. Several of the ferritic/austenitic (duplex) grades are also found in Specification [A1049/A1049M](#).

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 SI units or inch-pound 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 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 In addition to the referenced documents listed in Specification [A961/A961M](#), the following list of standards apply to this specification.

2.2 ASTM Standards:³

[A262](#) Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

[A275/A275M](#) Practice for Magnetic Particle Examination of Steel Forgings

[A336/A336M](#) Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts

[A388/A388M](#) Practice for Ultrasonic Examination of Steel Forgings

[A479/A479M](#) Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

[A484/A484M](#) Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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² For ASME Boiler and Pressure Vessel Code applications see related Specification SA-182 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.

*A Summary of Changes section appears at the end of this standard

[A739](#) Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
[A763](#) Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
[A788/A788M](#) Specification for Steel Forgings, General Requirements
[A961/A961M](#) Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications
[A965/A965M](#) Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
[A1049/A1049M](#) Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components
[E92](#) Test Method for Vickers Hardness of Metallic Materials (Withdrawn 2010)⁴
[E112](#) Test Methods for Determining Average Grain Size
[E165](#) Practice for Liquid Penetrant Examination for General Industry
[E340](#) Test Method for Macroetching Metals and Alloys
[2.3 ASME Standards:](#)⁵
[B16.11 Forged Steel Fittings, Socket Welding, and Threaded](#)
[2.4 ASME Boiler and Pressure Vessel Codes:](#)⁵
Section IX Welding and Brazing Qualifications
[2.5 AWS Specifications](#)⁶
[A5.4/A5.4M](#) Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
[A5.5/A5.5M](#) Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
[A5.9/A5.9M](#) Specification for Bare Stainless Steel Welding Electrodes and Rods
[A5.11/A5.11M](#) Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
[A5.14/A5.14M](#) Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods
[A5.23/A5.23M](#) Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
[A5.28/A5.28M](#) Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding
[A5.29/A5.29M](#) Low-Alloy Steel Electrodes for Flux Cored Arc Welding

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Specification [A961/A961M](#).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hardened condition, n*—for F23, the metallurgical condition achieved after normalizing and cooling to room temperature but prior to tempering.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification [A961/A961M](#), orders should include the following information:

4.1.1 Additional requirements (see [7.2.1](#), Table 2 footnotes, [9.3](#), and [19.2](#)), and

4.1.2 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 [9.3.1](#)).

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification [A961/A961M](#), including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification [A961/A961M](#) constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification [A961/A961M](#), this specification shall prevail.

6. Manufacture

6.1 The low-alloy ferritic steels shall be made by the open-hearth, electric-furnace, or basic-oxygen process with the option of separate degassing and refining processes in each case.

6.2 The stainless steels shall be melted by one of the following processes: (a) electric-furnace (with the option of separate degassing and refining processes); (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.

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

⁴ The last approved version of this historical standard is referenced on www.astm.org.

⁵ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁶ Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

6.4 The material shall be forged as close as practicable to the specified shape and size.

6.4.1 Flanges of any type, elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

6.4.2 Cylindrically-shaped parts may be machined from forged or rolled solution-annealed austenitic stainless steel bar without additional hot working.

6.4.3 Cylindrically-shaped low alloy, martensitic stainless, and ferritic stainless steel parts, NPS-4 [DN 100] and under, may be machined from forged or rolled bar, without additional hot working.

6.5 Except as provided for in 6.4, the finished product shall be a forging as defined in the Terminology section of Specification [A788/A788M](#).

7. Heat Treatment⁷

7.1 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](#).

7.2 *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 7.1 and [Table 1](#). When more than one heat treatment option is listed for a Grade in [Table 1](#), any one of the heat treatments listed shall be performed. The selection of the heat treatment shall be at the manufacturer's option, unless otherwise stated in the purchase order.

7.2.1 *Liquid Quenching*—Except as permitted in 7.2.2, for F 1, F 2, and F 3, and in 7.2.3, for F 91, and when agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in [Table 1](#) for each grade are used.

7.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked “QT.”

7.2.2 Alternatively, Grade F 1, F 2, and F 12, Classes 1 and 2 may be given a heat treatment of 1200 °F [650 °C] minimum after final hot or cold forming.

7.2.3 Alternatively, Grade F 91 forged fittings having any section thickness greater than 3 in. [75 mm], at the time of heat treatment, shall be normalized and tempered or quenched and tempered at the manufacturer's option, provided that the temperatures in [Table 1](#) for F 91 are used.

7.3 *Austenitic and Ferritic-Austenitic Stainless Steels*—The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 7.1 and [Table 1](#).

7.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solution annealing temperature specified in [Table 1](#), forgings made from austenitic grades (except grades F 304H, F 309H, F 310, F 310H, F 316H, F 321, F 321H, F 347, F 347H, F 348, F 348H, F 45, and F 56) may be individually rapidly quenched in accordance with the requirements of [Table 1](#).

7.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

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

7.5 *Forged or Rolled Bar*—Forged or rolled austenitic stainless bar from which cylindrically shaped parts are to be machined, as permitted by 6.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification [A479/A479M](#) or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

8. Chemical Composition

8.1 A chemical heat analysis in accordance with Specification [A961/A961M](#) shall be made and conform to the chemical composition prescribed in [Table 2](#).

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

8.3 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.

8.4 Steel grades covered in this specification shall not contain an unspecified element, other than nitrogen in stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation or Grade designation and identification symbol in [Table 2](#).

8.5 *Product Analysis*—The purchaser may make a product analysis on products supplied to this specification in accordance with Specification [A961/A961M](#).

⁷ A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in F 321, F 321H, F 347, F 347H, F 348, and F 348H. When specified by the purchaser, a lower temperature stabilization or resolution annealing shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S10).



TABLE 1 Heat Treating Requirements

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C] ⁴	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
Low Alloy Steels					
F 1	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 9	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 91	normalize and temper	1900-1975 [1040-1080]	air cool	<i>B</i>	1350-1470 [730-800]
F 92	normalize and temper	1900-1975 [1040-1080]	air cool	<i>B</i>	1350-1470 [730-800]
F 122	normalize and temper	1900-1975 [1040-1080]	air cool	<i>B</i>	1350-1470 [730-800]
F 911	normalize and temper	1900-1975 [1040-1080]	air cool or liquid	<i>B</i>	1365-1435 [740-780]
F 11, Class 1, 2, 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 12, Class 1, 2	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 22, Class 1, 3	anneal	1650 [900]	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	1650 [900]	air cool	<i>B</i>	1250 [675]
F 22V	normalize and temper or quench and temper	1650 [900]	air cool or liquid	<i>B</i>	1250 [675]
F 23	normalize and temper	1900-1975 [1040-1080]	air cool	<i>B</i>	1350-1470 [730-800]
			accelerated cool		
F 24	normalize and temper	1800-1975 [980-1080]	air cool	<i>B</i>	1350-1470 [730-800]
			or liquid		
FR	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	normalize	1750 [955]	air cool	<i>B</i>	<i>B</i>
	normalize and temper	1750 [955]	air cool	<i>B</i>	1250 [675]
F 36, Class 1	normalize and temper	1650 [900]	air cool	<i>B</i>	1100 [595]
F 36, Class 2	normalize and temper	1650 [900]	air cool	<i>B</i>	1100 [595]
	quench and temper	1650 [900]	accelerated air cool or liquid		1100 [595]
Martensitic Stainless Steels					
F 6a Class 1	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required		<i>B</i>	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required		<i>B</i>	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	<i>B</i>	<i>B</i>
	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-27 Cb	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 429	anneal	1850 [1010]	furnace cool	<i>B</i>	<i>B</i>
F 430	anneal	not specified	furnace cool	<i>B</i>	<i>B</i>
Austenitic Stainless Steels					
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 310MoLN	solution treat and quench	1900-2010 [1050-1100]	liquid	500 [260]	<i>B</i>
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 316Ti	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	<i>B</i>
S31727	solution treat and quench	1975-2155 [1080-1180]	liquid	500 [260]	<i>B</i>



TABLE 1 Continued

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C] ^A	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
S32053	solution treat and quench	1975–2155 [1080–1180]	liquid	500 [260]	B
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	B
F 347LN	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 348H	solution treat and quench	2000 [1095]	liquid	500 [260]	B
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	B
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 20	solution treat and quench	1700–1850 [925–1010]	liquid	500 [260]	B
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	B
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 46	solution treat and quench	2010–2140 [1100–1140]	liquid	500 [260]	B
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	B
F 56	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	B
F 58	solution treat and quench	2085 [1140]	liquid	500 [260]	B
F 62	solution treat and quench	2025 [1105]	liquid	500 [260]	B
F 63	solution treat and quench	1900 [1040]	liquid	500 [260]	B
F 64	solution treat and quench	2010–2140 [1100–1170]	liquid	500 [250]	B
F 904L	solution treat and quench	1920–2100 [1050–1150]	liquid	500 [260]	B
Ferritic-Austenitic Stainless Steels					
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	B
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	B
F 52 ^C			liquid	500 [260]	B
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	B
F 54	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	B
F 55	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	B
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	B
F 59	solution treat and quench	1975–2050 [1080–1120]	liquid	500 [260]	B
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	B
F 61	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	B
F 65	solution treat and quench	1830–2100 [1000–1150]	liquid ^D	500 [260]	B
F 66	solution treat and quench	1870–1975 [1020–1080]	liquid	500 [260]	B
F 67	solution treat and quench	1870–2050 [1020–1120]	liquid	500 [260]	B
F 68	solution treat and quench	1700–1920 [925–1050]	liquid	500 [260]	B

^A Minimum unless temperature range is listed.

^B Not applicable.

^C Grade F 52 shall be solution treated at 1825 to 1875 °F [995 to 1025 °C] 30 min/in. of thickness and water quenched.

^D The cooling media for Grade F 65 shall be quenching in water or rapidly cooling by other means.

9. Mechanical Properties

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

9.2 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.

9.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the be taken at least $\frac{1}{4} T$ plane or deeper position from the nearest surface as-heat-treated, where T is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the mid-length of the test specimen shall be at least T from any second heat-treated surface, all other surfaces as-heat-treated, exclusive of the T dimension surfaces. 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.

9.3.1 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 (see 9.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

TABLE 2 Chemical Requirements^A

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
Low Alloy Steels													
F 1	K12822	carbon-molybdenum	0.28	0.60–0.90	0.045	0.045	0.15–0.35	...	...	0.44–0.65	...	...	...
F 2 ^B	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 ^C	K41545	4 to 6 % chromium	0.15	0.30–0.60	0.030	0.030	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...
F 5a ^C	K42544	4 to 6 % chromium	0.25	0.60	0.040	0.030	0.50	0.50	4.0–6.0	0.44–0.65	...	...	...
F 9	K90941	9 % chromium	0.15	0.30–0.60	0.030	0.030	0.50–1.00	...	8.0–10.0	0.90–1.10	...	...	...
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 91	K90901	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	8.0–9.5	0.85–1.05	0.06–0.10	...	N 0.03–0.07 Al 0.02 ^D V 0.18–0.25 Ti 0.01 ^D Zr 0.01 ^D
F 92	K92460	9 % chromium, 1.8 % tungsten, 0.2 % vanadium plus columbium	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.50–9.50	0.30–0.60	0.04–0.09	...	V 0.15–0.25 N 0.030–0.070 Al 0.02 ^D W 1.50–2.00 B 0.001–0.006 Ti 0.01 ^D Zr 0.01 ^D
F 122	K91271	11 % chromium, 2 % tungsten, 0.2 % vanadium, plus molybdenum, columbium, copper, nickel, nitrogen, and boron	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.00–11.50	0.25–0.60	0.04–0.10	...	V 0.15–0.30 B 0.005 N 0.040–0.100 Al 0.02 ^D Cu 0.30–1.70 W 1.50–2.50 Ti 0.01 ^D Zr 0.01 ^D
F 911	K91061	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.060–0.10	...	W 0.90–1.10 Al 0.02 ^D N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006 Ti 0.01 ^D Zr 0.01 ^D
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	...	2.8–3.2	0.90–1.10	...	0.015–0.035	V 0.20–0.30 B 0.001–0.003
F 3VCb	K31390	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron, columbium, and titanium	0.10–0.15	0.30–0.60	0.020	0.010	0.10	0.25	2.7–3.3	0.90–1.10	0.015–0.070	0.015	V 0.20–0.30 Cu 0.25 Ca 0.0005–0.0150
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50	...	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	...	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	0.25	2.00–2.50	0.90–1.10	0.07	0.030	Cu 0.20 V 0.25–0.35 B 0.002 Ca 0.015 ^E
F 23	K41650	2.25 % chromium, 1.6 % tungsten, 0.25 % vanadium, plus molybdenum, columbium, and boron	0.04–0.10	0.10–0.60	0.030	0.010	0.50	0.40	1.90–2.60	0.05–0.30	0.02–0.08	0.005–0.060 ^F	V 0.20–0.30 B 0.0010–0.006 N 0.015 ^F Al 0.030 W 1.45–1.75

9.3.2 *Metal Buffers*—The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that