#### **UM328 WELDING OF MATERIALS**

Welding shall be in accordance with paras. M311.1 and U328, except examination shall be in accordance with para. UM341.

### UM335 ASSEMBLY AND ERECTION OF METALLIC PIPING

Paragraph M335 applies, except for para. M335.3.3. See para. UM335.3.3.

**UM335.3.3 Straight-Threaded Joints.** The requirements of para. M335.3.3 are subject to the limitations in para. UM322.

### **UM341 EXAMINATION**

Paragraph M341 applies. See UM341.4(b)(1) and UM341.4(b)(2).

#### UM341.4 Extent of Required Examination

#### (b) Other Examination

(1) The 100% radiography/ultrasonic examination required in para. M341.4(b) applies.

(2) The in-process examination alternative permitted in para. 341.4.1(b)(1) applies, except a weld coupon examination in accordance with para. U344.8 is also an acceptable substitute when specified in the engineering design or by the Inspector.

### **UM345 TESTING**

Paragraph M345(a) applies. See (b).

(b) A sensitive leak test in accordance with para. U345.8 shall be included in the required leak test (para. U345.1).

# APPENDIX A ALLOWABLE STRESSES AND QUALITY FACTORS FOR METALLIC PIPING AND BOLTING MATERIALS

Begins on the next page.

### Specification Index for Appendix A

Spec. No.	Title
ASTM	
A36	Carbon Structural Steel
A47	Ferritic Malleable Iron Castings
A48	Gray Iron Castings
A53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
A105	Carbon Steel Forgings for Piping Applications
A106	Seamless Carbon Steel Pipe for High-Temperature Service
A126	Gray Iron Castings for Valves, Flanges, and Pipe Fittings
A134	Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
A135	Electric-Resistance-Welded Steel Pipe
A139	Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)
A179	Seamless Cold-Drawn Low-Carbon Steel Heat- Exchanger and Condenser Tubes
A181	Carbon Steel Forgings, for General-Purpose Piping
A182	Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A193	Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
A194	Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A197	Cupola Malleable Iron
A203	Pressure Vessel Plates, Alloy Steel, Nickel
A204	Pressure Vessel Plates, Alloy Steel, Molybdenum
A213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
A216	Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
A217	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High- Temperature Service
A234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
A240	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
A268	Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
A269	Seamless and Welded Austenitic Stainless Steel Tubing for General Service
A270	Seamless and Welded Austenitic and Ferritic/ Austenitic Stainless Steel Sanitary Tubing
A276	Stainless Steel Bars and Shapes
A278	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F (350°C)
A283	Low and Intermediate Tensile Strength Carbon Steel Plates

Spec.	No. Title
ASTM	(Cont'd)
A285	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A299	Pressure Vessel Plates, Carbon Steel, Manganese- Silicon
A302	Pressure Vessel Plates, Alloy Steel, Manganese- Molybdenum and Manganese-Molybdenum- Nickel
A307	Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
A312	Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
A320	Alloy-Steel and Stainless Steel Bolting for Low- Temperature Service
A333	Seamless and Welded Steel Pipe for Low- Temperature Service and Other Applications with Required Notch Toughness
A334	Seamless and Welded Carbon and Alloy-Steel Tube for Low-Temperature Service
A335	Seamless Ferritic Alloy-Steel Pipe for High- Temperature Service
A350	Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Component
A351	Castings, Austenitic, for Pressure-Containing Part
A352	Steel Castings, Ferritic and Martensitic, for Pressure Containing Parts, Suitable for Low-Temperature Service
A353	Pressure Vessel Plates, Alloy Steel, Double- Normalized and Tempered 9% Nickel
A354	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A358	Electric-Fusion-Welded Austenitic Chromium- Nickel Stainless Steel Pipe for High-Temperatur Service and General Applications
A369	Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A376	Seamless Austenitic Steel Pipe for High- Temperature Service
A381	Metal-Arc-Welded Carbon or High-Strength Low- Alloy Steel Pipe for Use With High-Pressure Transmission Systems
A387	Pressure Vessel Plates, Alloy Steel, Chromium- Molybdenum
A395	Ferritic Ductile Iron Pressure-Retaining Castings fo Use at Elevated Temperatures
A403	Wrought Austenitic Stainless Steel Piping Fittings
A409	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A420	Piping Fittings of Wrought Carbon Steel and Allo Steel for Low-Temperature Service
A426	Centrifugally Cast Ferritic Alloy Steel Pipe for High Temperature Service
A437	Stainless and Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High- Temperature Service

Spec.	No. Title	Spec. No.
ASTM	(Cont'd)	ASTM (Cor
A451	Centrifugally Cast Austenitic Steel Pipe for High- Temperature Service	A815
A453	High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels	A860
A479	Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels	A928
A487	Steel Castings Suitable for Pressure Service	
A494	Castings, Nickel and Nickel Alloy	A992
		A995
A515	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	
A516	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service	A1010
A524	Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	A1011
A536	Ductile Iron Castings	
A537	Pressure Vessel Plates, Heat-Treated, Carbon- Manganese-Silicon Steel	A1053
A553	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 7, 8, and 9 % Nickel	
A563	Carbon and Alloy Steel Nuts	B21
A571	Austenitic Ductile Iron Castings for Pressure-	B26
	Containing Parts Suitable for Low-Temperature	B42
4587	Flortric-Resistance-Welded Low-Carbon Steel Pine	D43
A307	for the Chemical Industry	B62
		B68
A645	Pressure Vessel Plates, 5 % and 5 $^{1}\!\!\!/_{2}$ % Nickel Alloy	B75
	Steels, Specially Heat Treated	B88
A671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	B96
A672	Electric-Fusion-Welded Steel Pipe for High- Pressure Service at Moderate Temperatures	В98
A675	Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	B127
A691	Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	B148
A694	Carbon and Alloy Steel Forgings for Pipe Flanges,	B150
	Fittings, Valves, and Parts for High-Pressure	B152
A696	Steel Bars, Carbon, Hot-Wrought or Cold-Finished	B160
11070	Special Quality, for Pressure Piping Components	B161
		B162
A707	Forged Carbon and Alloy Steel Flanges for Low- Temperature Service	B163
A789	Seamless and Welded Ferritic/Austenitic Stainless	B164
	Steel Tubing for General Service	B165
A790	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	B166
A813	Single- or Double-Welded Austenitic Stainless Steel Pipe	
A814	Cold-Worked Welded Austenitic Stainless Steel Pipe	

Specification	Index for	Appendix <i>A</i>	(Cont'd)
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Spec.	No.	Title
ASTM	(Cor	nťd)
A815		Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings
A860		Wrought High-Strength Ferritic Steel Butt-Welding Fittings
A928		Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
A992		Structural Steel Shapes
A995		Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
A1010		Higher-Strength Martensitic Stainless Steel Plate, Sheet, and Strip
A1011		Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High- Strength Low-Alloy with Improved Formability, and Ultra-High Strength
A1053		Welded Ferritic-Martensitic Stainless Steel Pipe
B21		Naval Brass Rod, Bar, and Shapes
B26		Aluminum-Alloy Sand Castings
B42		Seamless Copper Pipe, Standard Sizes
B43		Seamless Red Brass Pipe, Standard Sizes
B61		Steam or Valve Bronze Castings
B62		Composition Bronze or Ounce Metal Castings
B68		Seamless Copper Tube, Bright Annealed
B75		Seamless Copper Tube
B88		Seamless Copper Water Tube
B96		Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels
B98		Copper-Silicon Alloy Rod, Bar and Shapes
B127		Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
B148		Aluminum-Bronze Sand Castings
B150		Aluminum Bronze Rod, Bar and Shapes
B152		Copper Sheet, Strip, Plate and Rolled Bar
B160		Nickel Rod and Bar
B161		Nickel Seamless Pipe and Tube
B162		Nickel Plate, Sheet and Strip
B163		Seamless Nickel and Nickel Alloy Condenser and Heat Exchanger Tubes
B164		Nickel-Copper Alloy Rod, Bar, and Wire
B165		Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
B166		Nickel-Chromium-Aluminum Alloy, Nickel- Chromium-Iron Alloys, Nickel-Chromium-Cobalt- Molybdenum Alloy, Nickel-Iron-Chromium- Tungsten Alloy, and Nickel-Chromium- Molybdenum-Copper Alloy Rod, Bar, and Wire

Specification	Index for	Appendix	A (	Cont	d)
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Spec.	No. Title
ASTM	(Cont'd)
B167	Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt- Molybdenum Alloy (UNS N06617), and Nickel- Iron-Chromium-Tungsten Alloy (UNS N06674) Seamless Pipe and Tube
B168	Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt- Molybdenum Alloy (UNS N06617), and Nickel- Iron-Chromium-Tungsten Alloy (UNS N06674) Plate, Sheet and Strip
B169	Aluminum Bronze Sheet, Strip, and Rolled Bar
B171	Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers
B187	Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes
B209	Aluminum and Aluminum-Allov Sheet and Plate
B210	Aluminum and Aluminum-Alloy Drawn Seamless Tubes
B211	Aluminum and Aluminum-Alloy Rolled or Cold Finished Bar, Rod, and Wire
B221	Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
B241	Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B247	Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
B265	Titanium and Titanium Alloy Strip, Sheet, and Plate
B280	Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
B283	Copper and Copper-Alloy Die Forgings (Hot- Pressed)
B333	Nickel-Molybdenum Alloy Plate, Sheet, and Strip
B335	Nickel-Molybdenum Alloy Rod
B345	Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube for Gas and Oil Transmission and Distribution Piping Systems
B348	Titanium and Titanium Alloy Bars and Billets
B361	Factory-Made Wrought Aluminum and Aluminum- Alloy Welding Fittings
B363	Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
B366	Factory-Made Wrought Nickel and Nickel Alloy Fittings
B367	Titanium and Titanium Alloy Castings
B371	Copper-Zinc-Silicon Alloy Rod
B381	Titanium and Titanium Alloy Forgings
B407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
B408	Nickel-Iron-Chromium Alloy Rod and Bar

Spec. No.	Title
ASTM (Co	ont'd)
B409	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B423	Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825, N08221, and N06845) Seamless Pipe and Tube
B424	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825, UNS N08221, and UNS N06845) Plate, Sheet, and Strip
B425	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825, UNS N08221, and UNS N06845) Rod and Bar
B435	UNS N06002, UNS N06230, UNS N12160, and UNS R30556 Plate, Sheet, and Strip
B443	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium- Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip
B444	Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625 and UNS N06852) and Nickel- Chromium-Molybdenum-Silicon Alloy (UNS N06219) Pipe and Tube
B446	Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), Nickel-Chromium-Molybdenum- Silicon Alloy (UNS N06219), and Nickel- Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar
B462	Forged or Rolled Nickel Alloy Pipe Flanges, Forged Fittings, and Valves and Parts for Corrosive High- Temperature Service
B463	UNS N08020 Alloy Plate, Sheet, and Strip
B464	Welded UNS N08020 Alloy Pipe
B466	Seamless Copper-Nickel Pipe and Tube
B467	Welded Copper-Nickel Pipe
B474	Electric Fusion Welded Nickel and Nickel Alloy Pipe
B491	Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications
B493	Zirconium and Zirconium Alloy Forgings
B514	Welded Nickel-Iron-Chromium Alloy Pipe
B515	Welded UNS N08120, UNS N08800, UNS N08810, and UNS N08811 Alloy Tubes
B517	Welded Nickel-Chromium-Iron-Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Pipe
B523	Seamless and Welded Zirconium and Zirconium Alloy Tubes
B550	Zirconium and Zirconium Alloy Bar and Wire
B551	Zirconium and Zirconium Alloy Strip, Sheet, and Plate
B564	Nickel Alloy Forgings
B572	UNS N06002, UNS N06230, UNS N12160, and UNS R30556 Rod
B574	Low-Carbon Nickel-Chromium-Molybdenum, Low- Carbon Nickel-Molybdenum-Chromium, Low- Carbon Nickel-Molybdenum-Chromium- Tantalum, Low-Carbon Nickel-Chromium- Molybdenum-Copper, and Low-Carbon Nickel- Chromium-Molybdenum-Tungsten Alloy Rod

Spec.	No. Title	Spec.	No.	Title
ASTM	(Cont'd)	ASTM	(Co	nťd)
B575	Low-Carbon Nickel-Chromium-Molybdenum, Low- Carbon Nickel-Chromium-Molybdenum-Copper,	B688		Chromium-Nickel-Molybdenum-Iron (UNS N08367) Plate, Sheet, and Strip
	Low-Carbon Nickel-Chromium-Molybdenum- Tantalum, Low-Carbon Nickel-Chromium- Molybdenum-Tungsten, and Low-Carbon Nickel- Molybdenum-Chromium Alloy Plate. Sheet and	B690		Iron-Nickel-Chromium-Molybdenum Alloy (UNS N08367) Seamless Pipe and Tube
DE01	Strip Nided Chromium Iron Melvhdenum Connor Allow	B704		Welded UNS N06625, UNS N06219 and UNS N08825 Alloy Tubes
D201	Rod	B705		Nickel-Alloy (UNS N06625, N06219 and N08825) Welded Pipe
D302	Plate, Sheet, and Strip	B709		Iron-Nickel-Chromium-Molybdenum Alloy (UNS N08028) Plate, Sheet, and Strip
D304	Copper Anoy Sand Castings for General Applications	B725		Welded Nickel (UNS N02200/UNS N02201) and Nickel Copper Alloy (UNS N04400) Pipe
B619	Welded Nickel and Nickel-Cobalt Alloy Pipe	B729		Seamless UNS N08020, UNS N08026, and UNS
B620	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Plate, Sheet, and Strip			N08024 Nickel-Alloy Pipe and Tube
B621	Nickel-Iron-Chromium-Molybdenum Alloy (UNS N08320) Rod	B804		UNS N08367 and UNS N08926 Welded Pipe
B622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube	B861 B862		Titanium and Titanium Alloy Seamless Pipe Titanium and Titanium Alloy Welded Pipe
B625	UNS N08925, UNS N08031, UNS N08932, UNS N08926, UNS N08354, UNS N08830, and UNS R20033 Plate, Sheet, and Strip	E112		Standard Test Methods for Determining Average Grain Size
B626	Welded Nickel and Nickel-Cobalt Alloy Tube			
B649	Ni-Fe-Cr-Mo-Cu-N Low-Carbon Alloys (UNS N08925, UNS N08031, UNS N08034, UNS N08354, and UNS N08926), and Cr-Ni-Fe-N Low-Carbon Alloy (UNS R20033) Bar and Wire, and Ni-Cr-Fe- Mo-N Alloy (UNS N08936) Wire	F3125		High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength
B658	Seamless and Welded Zirconium and Zirconium	API		
	Alloy Pipe	5L		Line Pipe
B668	UNS N08028 Seamless Pipe and Tube			
B675	UNS N08367 Welded Pipe	CSA		
		Z245.1	L	Steel Pipe

# Specification Index for Appendix A (Cont'd)

GENERAL NOTE: It is not practical to refer to a specific edition of each standard throughout the Code text. Instead, the approved edition references, along with the names and addresses of the sponsoring organizations, are shown in Appendix E.

162

## NOTES FOR TABLES A-1, A-1M, A-1A, A-1B, A-2, AND A-2M (20)

#### GENERAL NOTES:

- (a) The allowable stress values, P-Number assignments, weld joint and casting quality factors, and minimum temperatures in Tables A-1, A-1A, A-1B, A-2, and A-2M, together with the referenced Notes in the stress tables, are requirements of this Code.
- (b) Notes (1) through (7) are referenced in column headings and in body headings for material type and product form; Notes
  (8) and following are referenced in the Notes column for specific materials. Notes marked with an asterisk (\*) restate requirements found in the text of the Code.
- (c) The stress values given in ksi as shown in Tables A-1 and A-2, and given in MPa as shown in Tables A-1M and A-2M, may be used. The values stated in ksi are not exact equivalents to the values stated in MPa. Therefore, for any given material, the user of the Code should use only the ksi or the MPa values.
- (d) For copper and copper alloys, the following symbols are used in the Temper column: H = drawn; H01 = quarter hard; H02 = half hard; H06 = extra hard; H55 = light drawn; H58 = drawn, general purpose; H80 = hard drawn; HR50 = drawn, stress relieved; M20 = hot rolled; O25 = hot rolled, annealed; O50 = light annealed; O60 = soft annealed; O61 = annealed; W050 = welded, annealed; and W061 = welded, fully finished, annealed.
- (e) For nickel and nickel alloys, the following abbreviations are used in the Class column: ann., annealed; C.D., cold worked; forg., forged; H.F., hot finished; H.R., hot rolled; H.W., hot worked; plt., plate; R., rolled; rel., relieved; sol., solution; str., stress; and tr., treated.
- (f) In Table A-1M, the following abbreviations are used in the Product Form column: forg., forgings; ftg., fittings; pl., plate; shps., shapes; sht., sheet; smls., seamless; struct., structural; and wld., welded.

NOTES:

- (1) \*The stress values in Tables A-1 and A-1M, and the design stress values in Tables A-2 and A-2M, are basic allowable stresses in tension in accordance with para. 302.3.1(a). For pressure design, the stress values from Tables A-1 and A-1M are multiplied by the appropriate quality factor *E* (*E<sub>c</sub>* from Table A-1A or *E<sub>j</sub>* from Table A-1B). Stress values in shear and bearing are stated in para. 302.3.1(b); those in compression in para. 302.3.1(c).
- (2) \*The quality factors for castings  $E_c$  in Table A-1A are basic factors in accordance with para. 302.3.3(b). The quality factors for longitudinal weld joints  $E_j$  in Table A-1B are basic factors in accordance with para. 302.3.4(a). See paras. 302.3.3(c) and 302.3.4(b) for enhancement of quality factors. See also para. 302.3.1(a), footnote 1.
- (3) The stress values for austenitic stainless steels in these Tables may not be applicable if the material has been given a final heat treatment other than that required by

the material specification or by reference to Note (30) or (31).

- (4a) \*In Table A-1, stress values printed in *italics* exceed twothirds of the expected yield strength at temperature. Stress values in **boldface** are equal to 90% of expected yield strength at temperature. See paras. 302.3.2(d)(3) and 302.3.2(e).
- (4b) \*In Table A-1M, stress values printed in *italics* are tensilecontrolled values. Yield-controlled stress values are in normal font and time-dependent stress values are in **bold**face.
- (5) \*See ASME BPVC, Section IX, QW-200.3 for a description of P-Number groupings. P-Numbers are indicated by number or by a number followed by a letter (e.g., 8, 5B, or 11A).
- (6) \*The minimum temperature shown is that design minimum temperature for which the material is normally suitable without impact testing other than that required by the material specification. However, the use of a material at a design minimum temperature colder than -29°C (-20°F) is established by rules elsewhere in this Code, including para. 323.2.2 and other impact test requirements. For carbon steels with a letter designation in the Min. Temp. column, see para. 323.2.2(e) and the applicable curve and Notes in Figure 323.2.2A.
- (7) The letter "a" indicates alloys that are not recommended for welding and that, if welded, must be individually qualified. The letter "b" indicates copper base alloys that must be individually qualified.
- (8) \*There are restrictions on the use of this material in the text of the Code as follows:
- (a) See para. 305.2.1; temperature limits are  $-29^{\circ}$ C to 186°C ( $-20^{\circ}$ F to 366°F).
- *(b)* See para. 305.2.2; pipe shall be safeguarded when used outside the temperature limits in Note (8a).
  - (c) See Table 323.2.2, box B-2.
  - (d) See para. 323.4.2(a).
  - (e) See para. 323.4.2(b).
  - (f) See para. 309.2.1.
  - (g) See para. 309.2.2.
- (9) \*For pressure-temperature ratings of components made in accordance with standards listed in Table 326.1, see para. 326.2.1. Stress values in Tables A-1 and A-1M may be used to calculate ratings for unlisted components, and special ratings for listed components, as permitted by para. 303.
- (9a) Component standards listed in Table 326.1 impose the following restrictions on this material when used as a forging: composition, properties, heat treatment, and grain size shall conform to this specification; manufacturing procedures, tolerances, tests, certification, and markings shall be in accordance with ASTM B564.

- (10) \*This casting quality factor is applicable only when proper supplementary examination has been performed (see para. 302.3.3).
- (11) \*For use under this Code, radiography shall be performed after heat treatment.
- (12) \*Certain forms of this material, as stated in Table 323.2.2, must be impact tested to qualify for service below -29°C (-20°F). Alternatively, if provisions for impact testing are included in the material specification as supplementary requirements and are invoked, the material may be used down to the temperature at which the test was conducted in accordance with the specification.
- (13) Properties of this material vary with thickness or size. Stress values are based on minimum properties for the thickness listed.
- (14) For use in Code piping at the stated stress values, the required minimum tensile and yield properties must be verified by tensile test. If such tests are not required by the material specification, they shall be specified in the purchase order.
- (15) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.
- (16) DELETED.
- (17) DELETED.
- (18) DELETED.
- (19) \*This specification includes requirements for random radiographic inspection for mill quality control. If the 0.90 joint factor is to be used, the welds shall meet the requirements of Table 341.3.2 for longitudinal butt welds with spot radiography in accordance with Table 302.3.4. This shall be a matter of special agreement between purchaser and manufacturer.
- (20) For pipe sizes ≥DN 200 (NPS 8) with wall thicknesses ≥Sch 140, the specified minimum tensile strength is 483 MPa (70 ksi).
- (21) For material thickness >127 mm (5 in.), the specified minimum tensile strength is 483 MPa (70 ksi).
- (21a) For material thickness >127 mm (5 in.), the specified minimum tensile strength is 448 MPa (65 ksi).
- (22) The minimum tensile strength for weld (qualification) and stress values shown shall be multiplied by 0.90 for pipe having an outside diameter less than 51 mm (2 in.) and a D/t value less than 15. This requirement may be waived if it can be shown that the welding procedure to be used will consistently produce welds that meet the listed minimum tensile strength of 165 MPa (24 ksi).
- (23) DELETED.
- (24) Yield strength is not stated in the material specification. The value shown is based on yield strengths of materials with similar characteristics.
- (25) This steel may develop embrittlement after service at approximately 316°C (600°F) and higher temperature.
- (26) This unstabilized grade of stainless steel increasingly tends to precipitate intergranular carbides as the carbon content increases above 0.03%. See also para. F323.4(c)(2).

- (27) For temperatures above 427°C (800°F), these stress values apply only when the carbon content is 0.04% or higher.
- (28) For temperatures above 538°C (1,000°F), these stress values apply only when the carbon content is 0.04% or higher.
- (29) The stress values above 538°C (1,000°F) listed here shall be used only when the steel's austenitic micrograin size, as defined in ASTM E112, is No. 6 or less (coarser grain). Otherwise, the lower stress values listed for the same material, specification, and grade shall be used.
- (30) For temperatures above 538°C (1,000°F), these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1093°C (2,000°F) and quenching in water or rapidly cooling by other means.
- (31) For temperatures above 538°C (1,000°F), these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1038°C (1,900°F) and quenching in water or rapidly cooling by other means.
- (32) Stress values shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of fitting. If a higher strength base material is used, the higher stress values for that material may be used in design.
- (33) For welded construction with work hardened grades, use the stress values for annealed material; for welded construction with precipitation hardened grades, use the special stress values for welded construction given in the Tables.
- (34) If material is welded, brazed, or soldered, the allowable stress values for the annealed condition shall be used.
- (35) This steel is intended for use at high temperatures; it may have low ductility and/or low impact properties at room temperature after being used above the temperature indicated by para. F323.4(c)(4).
- (36) The specification permits this material to be furnished without solution heat treatment or with other than a solution heat treatment. When the material has not been solution heat treated, the minimum temperature shall be  $-29^{\circ}$ C ( $-20^{\circ}$ F) unless the material is impact tested in accordance with para. 323.3.
- (37) Impact requirements for seamless fittings shall be governed by those listed in this Table for the particular base material specification in the grades permitted (A312, A240, and A182). When A276 materials are used in the manufacture of these fittings, the Notes, minimum temperatures, and allowable stresses for comparable grades of A240 materials shall apply.
- (38) DELETED.
- (39) This material when used below -29°C (-20°F) shall be impact tested if the carbon content is above 0.10%.
- (40) \*This casting quality factor can be enhanced by supplementary examination in accordance with para. 302.3.3(c) and Table 302.3.3C. The higher factor from Table 302.3.3C may be substituted for this factor in pressure design equations.
- (41) Design stresses for the cold drawn temper are based on hot rolled properties until required data on cold drawn are submitted.

(42) This is a product specification. No design stresses are necessary. Limitations on metal temperature for materials covered by this specification are as follows:

Grade(s)	Metal Temperature, °C (°F)
1	-29 to 482 (-20 to 900)
2, 2H, and 2HM	-48 to 593 (-55 to 1,100)
3	-29 to 593 (-20 to 1,100)
6	-29 to 427 (-20 to 800)
7	-48 to 593 (-55 to 1,100)
7L	-101 to 593 (-150 to 1,100)
7M	-48 to 593 (-55 to 1,100)
7ML	-73 to 593 (-100 to 1,100)
8FA [see Note (39)]	-29 to 427 (-20 to 800)
8MA and 8TA	-198 to 816 (-325 to 1,500)
8, 8A, and 8CA	-254 to 816 (-425 to 1,500)

(42a) DELETED.

- (42b) This is a product specification. No design stresses are necessary. For limitations on usage, see paras. 309.2.1 and 309.2.2.
- (43) \*The stress values given for this material are not applicable when either welding or thermal cutting is employed [see para. 323.4.2(c)].
- (44) DELETED.
- (45) Stress values shown are applicable for "die" forgings only.
- (46) Lines of allowable stresses in Tables A-1 and A-1M for all materials in A312 include heavily cold worked (HCW) material as defined in A312, para. 6.1.4.
- (47) If no welding is employed in fabrication of piping from these materials, the stress values may be increased to 230 MPa (33.3 ksi).
- (48) The stress value to be used for this gray iron material at its upper temperature limit of 232°C (450°F) is the same as that shown in the 204°C (400°F) column.
- (49) If the chemical composition of this Grade is such as to render it hardenable, qualification under P-No. 6 is required.
- (50) This material is grouped in P-No. 7 because its hardenability is low.
- (51) This material may require special consideration for welding qualification. See ASME BPVC, Section IX, QW/ QB-422. For use in this Code, a qualified WPS is required for each strength level of material.
- (52) Copper-silicon alloys are not always suitable when exposed to certain media and high temperature, particularly above 100°C (212°F). The user should satisfy himself/herself that the alloy selected is satisfactory for the service for which it is to be used.
- (53) Stress relief heat treatment is required for service above 232°C (450°F).
- (54) The maximum operating temperature is arbitrarily set at 260°C (500°F) because hard temper adversely affects design stress in the creep rupture temperature ranges.
- (55) Pipe produced to this specification is not intended for high temperature service. The stress values apply to either nonexpanded or cold expanded material in the asrolled, normalized, or normalized and tempered condition.

- (56) Because of thermal instability, this material is not recommended for service above 427°C (800°F).
- (57) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 427°C (800°F). See para. F323.4(b)(2).
- (58) Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 468°C (875°F). See para. F323.4(b)(3).
- (59) For temperatures above 482°C (900°F), consider the advantages of killed steel. See para. F323.4(b)(4).
- (60) For all design temperatures, the maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least 3 mm ( $\frac{1}{8}$  in.) across, prepared by removing threads. No more material than necessary shall be removed to prepare the area. Hardness determination shall be made at the same frequency as tensile tests.
- (61) Annealed at approximately 982°C (1,800°F).
- (62) Annealed at approximately 1 121°C (2,050°F).
- (63) For stress relieved tempers (T351, T3510, T3511, T451, T4510, T4511, T651, T6510, T6511), stress values for material in the listed temper shall be used.
- (64) The minimum tensile strength of the reduced section tensile specimen in accordance with ASME BPVC, Section IX, QW-462.1, shall not be less than 758 MPa (110.0 ksi).
- (65) The minimum temperature shown in Tables A-1 and A-1M is for the heaviest wall meeting the specified mechanical property requirements in the specification. The minimum temperature for lighter walls shall be as shown in the following tabulation:

#### Impact Test Temperature (°C) for Plate Thicknesses Shown

Spec. No. and Grade	Max. 51 mm	Over 51 mm to 76 mm
A203 A	-68	-59
A203 B	-68	-59
A203 D	-101	-87
A203 E	-101	-87

#### Impact Test Temperature (°F) for Plate Thicknesses Shown

Spec. No. and Grade	Max. 2 in.	Over 2 in. to 3 in.
A203 A	-90	-75
A203 B	-90	-75
A203 D	-150	-125
A203 E	-150	-125

- (66) Stress values shown are 90% of those for the corresponding core material.
- (67) For use under this Code, the heat treatment requirements for pipe manufactured to A671, A672, and A691 shall be as required by para. 331 for the particular material being used.
- (68) The tension test specimen from plate 12.7 mm ( $\frac{1}{2}$  in.) and thicker is machined from the core and does not include the cladding alloy; therefore, the stress values listed are those for materials less than 12.7 mm.
- (69) This material may be used only in nonpressure applications.

- (70) Alloy 625 (UNS N06625) in the annealed condition is subject to severe loss of impact strength at room temperature after exposure in the range of 538°C to 760°C (1,000°F to 1,400°F).
- (71) These materials are normally microalloyed with Cb, V, and/or Ti. Supplemental specifications agreed to by manufacturer and purchaser commonly establish chemistry more restrictive than the base specification, as well as plate rolling specifications and requirements for weldability (i.e., C-equivalent) and toughness.
- (72) For service temperature >454°C (850°F), weld metal shall have a carbon content >0.05%.
- (73) Heat treatment is required after welding for all products of zirconium Grade R60705. See Table 331.1.1.
- (74) Mechanical properties of fittings made from forging stock shall meet the minimum tensile requirements of one of the bar, forging, or rod specifications listed in Table 2 of B366 for which tensile testing is required.
- (75) Stress values shown are for materials in the normalized and tempered condition, or when the heat treatment is unknown. If material is annealed, use the following values above 510°C (950°F):

Temp., °C	538	566	593	621	649
<i>S</i> , MPa	55.1	39.3	26.2	16.5	9.6
Temp., °F	1,000	1,050	1,100	1,150	1,200
S, ksi	8.0	5.7	3.8	2.4	1.4

- (76) DELETED.
- (77) The pipe grades listed below, produced in accordance with CSA (Canadian Standards Association) Z245.1, shall be considered as equivalents to API 5L and treated as listed materials.

Grade Equivalents								
API 5L	CSA Z245.1							
В	241							
X42	290							
X46	317							
X52	359							
X56	386							
X60	414							
X65	448							
X70	483							
X80	550							

- (78) Not permitted for the P4 and P5 materials in Table 302.3.5 for Elevated Temperature Fluid Service.
- (79) For use under this Code, impact testing shall be performed in accordance with para. 323.3 at the design minimum temperature but not warmer than  $-29^{\circ}C$  ( $-20^{\circ}F$ ).

### ASME B31.3-2020

Material	Spec.	Type/ Grade	UNS No	Class/ Condition/	Notes	Min. Temp., °F (6)	Specifie Strengt	d Min. h, ksi	Basic Allowable Stress, <i>S</i> , ksi, at Metal Temperature, °F [Notes (1), (4a)]						/etal [a]]
							Tensile	Yield	Min. Temp. to 100	200	300	400	500	600	650
Iron — Cast	ings			<b>r</b>		- (-)									
Gray	A48	20	F11401		(8e) (48)	-20	20		2.0	2.0	2.0	2.0			
Gray	A278	20	F11401		(8e) (48)	-20	20		2.0	2.0	2.0	2.0			
Gray	A126	А	F11501		(8e) (9) (48)	-20	21		2.0	2.0	2.0	2.0			
Gray	A48	25	F11701		(8e) (48)	-20	25		2.5	2.5	2.5	2.5			
Gray	A278	25	F11701		(8e) (48)	-20	25		2.5	2.5	2.5	2.5			
Gray	A48	30	F12101		(8e) (48)	-20	30		3.0	3.0	3.0	3.0			
Gray	A278	30	F12101		(8e) (48)	-20	30		3.0	3.0	3.0	3.0			
Gray	A126	В	F12102		(8e) (9) (48)	-20	31		3.0	3.0	3.0	3.0			
Gray	A48	35	F12401		(8e) (48)	-20	35		3.5	3.5	3.5	3.5			
Gray	A278	35	F12401		(8e) (48)	-20	35		3.5	3.5	3.5	3.5			
Gray	A48	40	F12801		(8e) (9) (48)	-20	40		4.0	4.0	4.0	4.0			
Gray	A126	С	F12802		(8e) (9) (48)	-20	41		4.0	4.0	4.0	4.0			
Gray	A278	40	F12803		(8e) (53)	-20	40		4.0	4.0	4.0	4.0	4.0	4.0	4.0
Gray	A48	45	F13101		(8e) (48)	-20	45		4.5	4.5	4.5	4.5			
Gray	A48	50	F13501		(8e) (48)	-20	50		5.0	5.0	5.0	5.0			
Gray	A278	50	F13502		(8e) (53)	-20	50		5.0	5.0	5.0	5.0	5.0	5.0	5.0
Gray	A48	55	F13801		(8e) (48)	-20	55		5.5	5.5	5.5	5.5			
Gray	A48	60	F14101		(8e) (48)	-20	60		6.0	6.0	6.0	6.0			
Gray	A278	60	F14102		(8e) (53)	-20	60		6.0	6.0	6.0	6.0	6.0	6.0	6.0
Cupola malleable	A197		F22000		(8e) (9)	-20	40	30	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Malleable	A47	32510	F22200		(8e) (9)	-20	50	32.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Ferritic ductile	A395	60-40-18	F32800		(8d) (9)	-20	60	40	20.0	19.0	17.9	16.9	15.9	14.9	14.1
Austenitic ductile	A571	D-2M	F43010	1	(8d)	-20	65	30	20.0						
Ductile	A536	65-45-12	F33100		(8d) (9)	-20	65	45	21.7	21.7	21.7	21.7	21.6		

### Table A-1 Basic Allowable Stresses in Tension for Metals

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

167