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ASME CODE FOR PRESSURE PIPING, B31
AN AMERICAN NATIONAL STANDARD

ASME B31.5a-1994

ADDENDA

to

ASME B31.5-1992 EDITION
REFRIGERATION PIPING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

United Engineering Center • 345 East 47th Street • New York, N.Y. 10017

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ASME B31.5a-1994
Summary of Changes

Revisions, additions, deletions, and errata to ASME B31.5-1992 Edition are published in loose-leaf, replacement-page format. The affected material is incorporated directly into the page on which it does, or should, appear; any excess material appears on a point page, or if space permits, on the following page.

This Addenda, ASME B31.5a-1994, is the first Addenda to be issued to ASME B31.5-1992 Edition. A margin designator, either an (a) or a bullet (•), is used to identify the affected material and corresponds to the items listed in the Summary of Changes pages. The margin designators will remain on the pages until the 1997 Edition of B31.5 is published.

Page	*Location*	*Change*
ix, xi	Contents	Updated to reflect Addenda (a)
3, 4	500.2	*refrigerant and refrigerant mixtures* revised
	Footnote 1	Added
4.1	Table 500.2	Table 501.2.4 redesignated as Table 500.2, moved from p. 6 to p. 4.1, and revised as follows: (1) Group column revised (2) Minimum Design Gage Pressures columns deleted (3) Chemical formulas revised for R-123 and R-134a
5	501.2.4	Revised in its entirety
6	Table 501.2.4	See Summary of Changes item above for Table 500.2
10, 11	Table 502.3.1	Stress lines revised for A 333 1, second A 53 B, A 135 B, and A 178 C
12, 13	Table 502.3.1	Stress lines revised for A 334 6, 5L B, and A 134 A 283 Gr. D
14, 15	Table 502.3.1	(1) Stress lines revised for A 211 A 570 Grs. 30 and 33, first A 333 9, A 334 9, and A 213 304 and 304L (2)(a) A 254 Cl. I redesignated as A 254 with its Min. Yield Strength revised (b) A 254 Cl. II deleted
16, 17	Table 502.3.1	(1) A 269 304 and 304L in two places each, A 271 304 and 304L, A 376 304L, A 358 304 and 304L, and A 409 304 and 304L deleted (2) Stress lines revised for A 312 304 and 304L in two places each, A 376 304, and A 249 304 and 304L (3) Min. Yield Strength revised for A 249 304L
20, 21	Table 502.3.1	(1) Order of appearance on page reversed for B 111 C60800 and C68700 (2) Stress lines revised for both B 466 C70600
22, 23	Table 502.3.1	(1) Stress lines revised for second B 467 C70600 and both B 543 C70600 (2) B 467 C71000 and second B 543 C12200 deleted

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Summary of Changes (Cont'd)

Page	*Location*	*Change*
24, 25	Table 502.3.1	(1) Stress lines revised at 100°F for fourth B 165 N04400 and first B 241 Temper 0 (2) General Note revised
27	504.1.2	Equation (3) corrected by Errata
35	504.3.1(h)(4)	Revised
39	505.1.1	Revised
42	514(c)	Revised
	514(d)	Revised
43	517(a)(1)	Revised
	517(a)(2)	Revised
44–46	519.3.1	Revised
	Table 519.3.2	General Note revised
	519.3.2	Revised
51, 52	519.4.6	Nomenclature for S_h added
54	Table 521.3.5	General Note revised
	520.1.6(b)	Revised
55	521.3.1(a)	Revised
58–62	Table 523.1	(1) For specifications indicated by bullets (•), Material column revised (2) In Component column, Steel and iron plate revised to read Steel plate
64, 65	Table 526.1	(1) B16.1 through B16.28 revised (except B16.18 is unchanged); also, B1.1 and B1.20.1 revised (2) B16.34, SP-70, SP-71, and SP-80 added
71	Fig. 527.4.4-C	Middle callout on right-hand side corrected by Errata
81	536(a)(2)	Revised
	537.3.2.1	Revised
	537.3.2.2	Revised
82	537.4.1.1	Revised
	537.4.1.2	Revised
	537.4.1.3	Revised
83, 84	Appendix A	Entries indicated by bullets (•) revised, added, or deleted
85	Appendix A	EJMA and NIST added

NOTES:

(1) The Interpretations to ASME B31.5 issued between October 1, 1991, and July 31, 1994, follow the last page of this Addenda as a separate supplement, Interpretations No. 5. The supplement is not part of ASME B31.5 or its Addenda.

(2) There is no Cases supplement following this Addenda. The Cases are not part of ASME B31.5 or its Addenda.

CONTENTS

(a)

Figures

skelp and subsequently cut into individual lengths, having its longitudinal butt joint force welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls

(c) electric-fusion welded pipe — pipe having a longitudinal or spiral butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The weld may be single or double and may be made with or without the use of filler metal. Spiral welded pipe is also made by the electric-fusion welded process with either a lap joint or a lock-seam joint.

(d) electric-flash welded pipe — pipe having a longitudinal butt joint wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

(e) double submerged-arc welded pipe — pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe. Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal for the inside and outside welds is obtained from the electrode or electrodes.

pipe supporting elements — pipe supporting elements consist of fixtures and structural attachments. They do not include support structures and equipment, such as stanchions, towers, building frames, pressure vessels, mechanical equipment, and foundations.

fixtures — fixtures are elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors, and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

structural attachments — structural attachments are elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts

piping — means the pipe or tube mains for interconnecting the various parts of a refrigerating system. Piping includes pipe, flanges, bolting, gaskets, valves, fittings, the pressure containing parts of other components, such as expansion joints, strainers, and devices which serve such purposes as mixing, separating, snubbing, distributing, metering, or controlling flow, pipe supporting fixtures, and structural attachments.

postheating — the application of heat to an assembly after a welding, brazing, soldering, or cutting operation

preheating — the application of heat to the base metal immediately before a welding, brazing, soldering, or cutting operation

premises — the buildings and that part of the grounds of one property, where an installation would affect the safety of those buildings or adjacent property

pressure vessel, general — see Section VIII, Division 1, ASME Boiler and Pressure Vessel Code (hereinafter referred to as the ASME BPV Code)

pressure vessel, refrigerant — any refrigerant containing receptacle of a refrigerating system, other than evaporators (each separate section of which does not exceed ½ cu ft of refrigerant containing volume), evaporator coils, compressors, condenser coils, controls, headers, and piping. (See ANSI/ASHRAE 15.)

refrigerant and refrigerant mixtures — the fluid used for heat transfer in a refrigerating system which absorbs heat during evaporation at low temperature and pressure, and releases heat during condensation at a higher temperature and pressure. The safety classification group consists of two characters, e.g., A1 or B2. The capital letter indicates the toxicity and the Arabic numeral indicates the flammability, based on the following criteria[1]: **(a)**

Class A — refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm (parts per million), based on data used to determine Threshold Limit Values–Time Weighted Average (TLV–TWA) or consistent indices

Class B — refrigerants for which there is evidence of toxicity at concentrations below 400 ppm, based on data used to determine TLV–TWA or consistent indices

Class 1 — refrigerants that do not show flame propagation when tested in air at 14.7 psia (101 kPa) and 65°F (18°C).

Class 2 — refrigerants having a Lower Flammability Limit (LFL) of more than 0.00625 lb/ft^3 (0.10 kg/m^3) at 70°F (21°C) and 14.7 psia (101 kPa) *AND* a heat of combustion of less than 8174 Btu/lb (19,000 kJ/kg)

Class 3 — refrigerants that are highly flammable as defined by having an LFL of less than or equal to

[1]See Table 500.2. **(a)**

0.00625 lb/ft^3 (0.10 kg/m^3) at 70°F (21°C) and 14.7 psia (101 kPa) *OR* a heat of combustion greater than or equal to 8174 Btu/lb (19,000 kJ/kg)

refrigerating system — a combination of interconnecting refrigerant containing parts constituting a closed refrigerant circuit in which a refrigerant is circulated for the purpose of extracting heat

reinforcement of weld — weld metal in excess of the specified weld size

root opening — the separation between the members to be joined, at the root of the joint

root penetration — the depth a groove weld extends into the root of a joint measured on the center line of the root cross section

seal weld — any weld used primarily to provide a specific degree of tightness against leakage

secondary coolant — any liquid used for the transmission of heat without a change in its state and having no flash point, or a flash point above 150°F as determined by ASTM D 93

self-contained system — a complete factory-made and factory-tested system in a suitable frame or enclosure which is fabricated and shipped in one or more sections and in which no refrigerant containing parts are connected in the field other than by companion flanges or block valves

semiautomatic arc welding — arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

shall — where "shall" or "shall not" is used for a provision specified, that provision is intended to be a Code requirement

shielded metal-arc welding (SMAW) — an arc welding process wherein coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

should — "should" or "it is recommended" is used to indicate provisions which are not mandatory but recommended good practice

size of weld

groove weld — the joint penetration (depth of chamfering plus the root penetration when specified)

fillet weld — a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint

slag inclusion — nonmetallic solid material entrapped in weld metal or between weld metal and base metal

soldered joint — a gas-tight joint obtained by the joining of metal parts with metallic mixtures or alloys which melt at temperatures not exceeding 800°F and above 400°F

submerged arc welding (SAW) — an arc welding process wherein coalescence is produced by heating an arc(s) between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

tack weld — a weld made to hold parts of a weldment in proper alignment until the final welds are made

throat of a fillet weld

theoretical — the distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right-triangle that can be inscribed within the fillet-weld cross section

actual — the shortest distance from the root of a fillet weld to its face

toe of weld — the junction between the face of the weld and the base metal

tube — see *pipe*

undercut — a groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal

weld — a localized coalescence of metal wherein coalescence is produced by heating to suitable temperature, with or without the application of pressure, and with or without the use of filler metal. The filler metal has a melting point approximately the same as the base metals.

welder — one who is capable of performing a manual or semiautomatic welding operation

welding operator — one who operates machine or automatic welding equipment

welding procedures — the detailed methods and practices including all joint welding procedures involved in the production of a weldment

weldment — an assembly whose component parts are joined by welding

(a)

TABLE 500.2
REFRIGERANT CLASSIFICATION

Group [Note (1)]	Refrigerant	Name	Chemical Formula
A1	R-11	Trichlorofluoromethane	CCl_3F
A1	R-12	Dichlorodifluoromethane	CCl_2F_2
A1	R-13	Chlorotrifluoromethane	$CClF_3$
A1	R-13B1	Bromotrifluoromethane	$CBrF_3$
A1	R-14	Tetrafluoromethane	CF_4
B1	R-21	Dichlorofluoromethane	$CHCl_2F$
A1	R-22	Chlorodifluoromethane	$CHClF_2$
B2	R-30	Methylene chloride	CH_2Cl_2
B2	R-40	Methyl chloride	CH_3Cl
A1	R-113	Trichlorotrifluoroethane	CCl_2FCClF_2
A1	R-114	Dichlorotetrafluoroethane	$CClF_2CClF_2$
A1	R-115	Chloropentafluoroethane	$CClF_2CF_3$
B1	R-123	Dichlorotrifluoroethane	$CHCl_2CF_3$
A1	R-134a	Tetrafluoroethane	CH_2FCF_3
A2	R-142b	1-Chloro-1, 1-Difluoroethane	CH_3CClF_2
A2	R-152a	1,1-Difluoroethane	CH_3CHF_2
A3	R-170	Ethane	C_2H_6
A3	R-290	Propane	C_3H_8
A1	R-C318	Octafluorocyclobutane	C_4F_8
A1	R-400	. . .	$CCl_2F_2/C_2Cl_2F_4$
A1	R-500	Dichlorodifluoromethane, 73.8%, and ethylidene fluoride, 26.2%	CCl_2F_2/CH_3CHF_2
A1	R-502	Chlorodifluoromethane, 48.8%, and chloropenta-fluoroethane, 51.2%	$CHClF_2/CClF_2CF_3$
Note (2)	R-503	R-23 (40.1%) & R-13 (59.9%)	$CHF_3/CClF_3$
A3	R-600	N-butane	C_4H_{10}
A3	R-600a	Isobutane (2 methyl propane)	$CH(CH_3)_3$
B2	R-611	Methyl formate	$HCOOCH_3$
B2	R-717	Ammonia	NH_3
A1	R-744	Carbon dioxide	CO_2
B1	R-764	Sulfur dioxide	SO_2
A3	R-1150	Ethylene	C_2H_4
A3	R-1270	Propylene	C_3H_6

NOTES:
(1) Information in this table is established by ANSI/ASHRAE 34 and is shown here for convenience.
(2) No classification assigned as of this date.

CHAPTER II DESIGN

PART 1 CONDITIONS AND CRITERIA

501 DESIGN CONDITIONS

501.1 General

Paragraph 501 defines the temperatures, pressures, and various forces applicable to the design of piping systems. It also states considerations that shall be given to ambient and mechanical influences and various loadings.

501.2 Pressure

501.2.2 Internal Design Pressure

(a) The piping component shall be designed for an internal pressure representing the most severe condition of coincident pressure and temperature expected in normal operation or standby (including fluid head) and also shall allow for shipping conditions considering possible loss of external pressure. The most severe condition of coincident pressure and temperature shall be that condition which results in the greater required piping component thickness and the highest component rating.

(b) Any piping connected to components other than piping shall have a design pressure no less than the lowest design pressure of any component to which it is connected.

501.2.3 External Design Pressure. The piping component shall be designed for an external pressure representing the most severe condition of coincident pressure and temperature expected during shutdown or in normal operation (including fluid head) considering possible loss of internal pressure. Refrigerant piping systems shall be designed to resist collapse when the internal pressure is zero absolute and the external pressure is atmospheric. This is to permit drying the pipe by evacuation. The most severe condition of coincident pressure and temperature shall be that condition which results in the greatest required pipe thickness and the highest component rating.

501.2.4 Minimum Design Pressure. Minimum design gage pressure shall be not less than 15 psi (103 kPa), and except as noted in para. 501.2.5, shall be not less than the saturation pressure of the refrigerant at the following temperatures: (a)

(a) low sides of all systems: 80°F (27°C);

(b) high side of water or evaporatively cooled systems: 104°F (40°C);

(c) high sides of air cooled systems: 122°F (50°C).

501.2.5 Minimum Design Pressure for Specific Service

(a) Design pressure for either high or low side need not exceed the critical pressure of the refrigerant unless the system is intended to operate at these conditions.

(b) When components of a system are protected by a pressure relief device, the design pressure of the piping need not exceed the setting of the pressure relief device.

(c) In a compound system the piping between stages shall be considered the low side of the next higher stage compressor.

501.3 Temperature

In this Code, metal temperature of piping in service is considered to be the temperature of the fluid conveyed.

501.3.1 Brittle Fracture. Consideration must be given to a reduction in impact strength occurring in some materials when subjected to low temperatures. Notch effects should be avoided. See para. 523.2.

(a) Table 501.2.4 redesignated as Table 500.2, revised, and moved to p. 4.1

The creep and stress-rupture strengths are determined by plotting the results of the creep and stress-rupture tests in the manner described in "Interpretation of Creep and Stress-Rupture Data" by Francis B. Foley, *Metal Progress*, June 1947, pp. 951–958.

(d) Allowable stress values in shear shall be 0.80 of the values obtained from para. 502.3.1 and Table 502.3.1, and allowable stress values in bearing shall be 1.60 of the values obtained from para. 502.3.1 and Table 502.3.1.

(e) When steel materials of unknown specifications are used at a temperature not to exceed 400°F for structural supports and restraints, the allowable stress value shall not exceed 12.0 ksi.

(f) For components not having established pressure–temperature ratings, allowable stress values may be adjusted in accordance with para. 502.2.4 for other than normal operation.

502.3.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion or Contraction

(a) Internal Pressure Stresses. The calculated stress due to internal pressure shall not exceed the allowable stress values given in Table 502.3.1 except as permitted by paras. 502.3.2(b), (c), and (d).

(b) External Pressure Stresses. Stress due to external pressures shall be considered safe when the wall thickness of the piping component and means of stiffening meet the requirements of paras. 503 and 504.

(c) Allowable Stress Range for Expansion Stresses in Systems Stressed Primarily in Bending and Torsion. The expansion stress range S_E (see para. 519.4.5) shall not exceed the allowable stress range S_A given by Eq. (1):

$$S_A = f(1.25S_c + 0.25S_h) \tag{1}$$

where

S_c = basic material allowable stress at minimum (cold) normal temperature (use S, not SE from para. 502.3.1 and Table 502.3.1)

S_h = basic material allowable stress at maximum (hot) normal temperature (use S, not SE from para. 502.3.1 and Table 502.3.1)

NOTE: Does not include abnormal conditions, such as exposure to fires.

f = stress-range reduction factor for cyclic conditions [see Note (1)] for total number N of full temperature cycles over total number of years during which system is expected to be in active operation (read or interpolate from Fig. 502.3.2). By full temperature cycles is meant the number of cycles of temperature change from minimum to maximum temperature expected to be encountered [see Note (2)].

NOTES:

(1) Applies to essentially noncorrosive services. Corrosion can sharply decrease cyclic life. Corrosion resistant materials should be used where a large number of major stress cycles is anticipated.

(2) If the range of temperature changes varies, equivalent full temperature cycles may be computed from the equation:

$$N = N_E + r_1{}^5 N_1 + r_2{}^5 N_2 + \ldots + r_n{}^5 N_n$$

where

N_E = number of cycles of full temperature change T_E for which expansion stress S_E has been calculated

$N_1, N_2, \ldots, N_n$
= number of cycles of lesser temperature change $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

$r_1, r_2, \ldots, r_n$
= $\Delta T_1/\Delta T_E, \Delta T_2/\Delta T_E, \ldots \Delta T_n/\Delta T_E$
= ratio of any lesser temperature cycle to that for which S_E has been calculated

(d) The sum of the longitudinal stresses (in the corroded condition) due to pressure, weight, and other sustained external loading shall not exceed S_h. Where the sum of these stresses is less than S_h, the difference between S_h and this sum may be added to the term in parentheses in Eq. (1).

In calculating the longitudinal pressure stress, consider the internal pressure as acting only on the area established by the internal diameter.

502.3.3 Limits of Calculated Stresses Due to Occasional Loads

(a) Operation. The sum of the longitudinal stresses produced by pressure, live and dead loads, and those produced by occasional loads, such as wind or earthquake, may not exceed 1.33 times the allowable stress values given in Table 502.3.1. It is not necessary to consider wind and earthquake as occurring concurrently.

(b) Test. Stresses due to test conditions are not subject to the limitations of para. 502.3 of this Code. It is not necessary to consider other occasional loads, such as wind and earthquake, as occurring concurrently with the live, dead, and test loads existing at the time of test.

502.4 Allowances

502.4.1 Corrosion and Erosion. When corrosion or erosion is expected, an increase in wall thickness of the components over that dictated by other design require-

TABLE 502.3.1
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

	Material	Spec. No.	Grade, Type, or Class	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes	Longitudinal or Spiral Joint Factor
	Seamless Carbon Steel Pipe and Tube						
	Steel pipe	ASTM A 53	A	48.0	30.0	...	...
	Steel pipe	ASTM A 53	B	60.0	35.0	...	...
	Steel pipe	ASTM A 106	A	48.0	30.0	...	...
	Steel pipe	ASTM A 106	B	60.0	35.0	...	...
	Steel pipe	ASTM A 106	C	70.0	40.0	...	...
	Steel tube	ASTM A 179	C	47.0	26.0	...	...
	Steel tube	ASTM A 192	...	47.0	26.0	...	...
	Steel tube	ASTM A 210	A-1	60.0	37.0	...	...
(a)	Steel pipe	ASTM A 333	1	55.0	30.0	...	...
	Steel pipe	ASTM A 333	6	60.0	35.0	...	...
	Steel tube	ASTM A 334	1	55.0	30.0	...	...
	Steel tube	ASTM A 334	6	60.0	35.0	...	...
	Steel pipe	API 5L	A	48.0	30.0	...	...
	Steel pipe	API 5L	B	60.0	35.0	...	...
	Carbon Steel Pipe and Tube						
	Electric Resistance Welded Pipe and Tube						
(a)	Steel pipe	ASTM A 53	A	48.0	30.0	...	0.85
	Steel pipe	ASTM A 53	B	60.0	35.0	...	0.85
(a)	Steel pipe	ASTM A 135	A	48.0	30.0	...	0.85
	Steel pipe	ASTM A 135	B	60.0	35.0	...	0.85
	Steel tube	ASTM A 178	A	47.0	26.0	...	0.85
	Steel tube	ASTM A 178	C	60.0	37.0	...	0.85
	Steel tube	ASTM A 214	...	47.0	26.0	...	0.85
	Steel tube	ASTM A 226	...	47.0	26.0	...	0.85

TABLE 502.3.1
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
							Seamless Carbon Steel Pipe and Tube	
12.0	12.0	12.0	12.0	12.0	12.0	12.0	ASTM A 53	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 53	
12.0	12.0	12.0	12.0	12.0	12.0	12.0	ASTM A 106	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 106	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	ASTM A 106	
11.8	11.8	11.8	11.8	11.8	11.8	11.8	ASTM A 179	
11.8	11.8	11.8	11.8	11.8	11.8	11.8	ASTM A 192	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 210	
13.7	13.7	13.7	13.7	13.7	13.7	13.7	ASTM A 333	(a)
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 333	
13.7	13.7	13.7	13.7	13.7	13.7	13.7	ASTM A 334	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 334	
12.0	12.0	12.0	12.0	12.0	12.0	12.0	API 5L	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	API 5L	
							Carbon Steel Pipe and Tube Electric Resistance Welded Pipe and Tube	
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 53	(a)
12.7	12.7	12.7	12.7	12.7	12.7	12.7	ASTM A 53	
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 135	(a)
12.7	12.7	12.7	12.7	12.7	12.7	12.7	ASTM A 135	
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 178	
12.7	12.7	12.7	12.7	12.7	12.7	12.7	ASTM A 178	
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 214	
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 226	

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

	Material	Spec. No.	Grade, Type, or Class	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes	Longitudinal or Spiral Joint Factor
	Carbon Steel Pipe and Tube (Cont'd)						
	Electric Resistance Welded Pipe and Tube (Cont'd)						
(a)	Steel pipe	ASTM A 333	1	55.0	30.0	...	0.85
	Steel pipe	ASTM A 333	6	60.0	35.0	...	0.85
	Steel tube	ASTM A 334	1	55.0	30.0	...	0.85
	Steel tube	ASTM A 334	6	60.0	35.0	...	0.85
	Steel pipe	ASTM A 587	...	48.0	30.0	...	0.85
(a)	Steel pipe	API 5L	A	48.0	30.0	...	0.85
	Steel pipe	API 5L	B	60.0	35.0	...	0.85
	Electric Fusion Welded Pipe						
	Steel	ASTM A 134	A 570 Gr. 30	49.0	30.0	(1)	0.80
	Steel	ASTM A 134	A 570 Gr. 33	52.0	33.0	(1)	0.80
	Steel	ASTM A 134	A 283 Gr. A	45.0	24.0	(1)	0.80
	Steel	ASTM A 134	A 283 Gr. B	50.0	27.0	(1)	0.80
	Steel	ASTM A 134	A 283 Gr. C	55.0	30.0	(1)	0.80
(a)	Steel	ASTM A 134	A 283 Gr. D	60.0	33.0	(1)	0.80
	Steel	ASTM A 134	A 285 Gr. A	45.0	24.0	...	0.80
	Steel	ASTM A 134	A 285 Gr. B	50.0	27.0	...	0.80
	Steel	ASTM A 134	A 285 Gr. C	55.0	30.0	...	0.80
	Steel	ASTM A 139	A	48.0	30.0	...	0.80
	Steel	ASTM A 139	B	60.0	35.0	...	0.80

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
							Carbon Steel Pipe and Tube (Cont'd)	
							Electric Resistance Welded Pipe and Tube (Cont'd)	
11.7	11.7	11.7	11.7	11.7	11.7	11.7	ASTM A 333	(a)
12.7	12.7	12.7	12.7	12.7	12.7	12.7	ASTM A 333	
11.7	11.7	11.7	11.7	11.7	11.7	11.7	ASTM A 334	
12.7	12.7	12.7	12.7	12.7	12.7	12.7	ASTM A 334	
10.2	10.2	10.2	10.2	10.2	10.2	10.2	ASTM A 587	
10.2	10.2	10.2	10.2	10.2	10.2	10.2	API 5L	(a)
12.7	12.7	12.7	12.7	12.7	12.7	12.7	API 5L	
							Electric Fusion Welded Pipe	
9.0	9.0	9.0	9.0	9.0	9.0	9.0	ASTM A 134	
9.6	9.6	9.6	9.6	9.6	9.6	9.6	ASTM A 134	
8.3	8.3	8.3	8.3	8.3	8.3	8.3	ASTM A 134	
9.2	9.2	9.2	9.2	9.2	9.2	9.2	ASTM A 134	
10.1	10.1	10.1	10.1	10.1	10.1	10.1	ASTM A 134	
11.0	11.0	11.0	11.0	11.0	11.0	11.0	ASTM A 134	(a)
9.0	9.0	9.0	9.0	9.0	9.0	9.0	ASTM A 134	
10.0	10.0	10.0	10.0	10.0	10.0	10.0	ASTM A 134	
11.0	11.0	11.0	11.0	11.0	11.0	11.0	ASTM A 134	
9.6	9.6	9.6	9.6	9.6	9.6	9.6	ASTM A 139	
12.0	12.0	12.0	12.0	12.0	12.0	12.0	ASTM A 139	

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

	Material	Spec. No.	Grade, Type, or Class	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes	Longitudinal or Spiral Joint Factor
	Carbon Steel Pipe and Tube (Cont'd)						
	Electric Fusion Welded Pipe (Cont'd)						
(a)	Steel	ASTM A 211	A 570 Gr. 30	49.0	30.0	(1)	0.80
(a)	Steel	ASTM A 211	A 570 Gr. 33	52.0	33.0	(1)	0.80
	Copper Brazed Tubing						
(a)	Steel	ASTM A 254	...	42.0	25.0	...	...
	Low and Intermediate Alloy Steel Pipe and Tube						
	Seamless Alloy Steel Pipe and Tube						
(a)	3½Ni pipe	ASTM A 333	3	65.0	35.0	...	...
	Cr–Cu–Ni–Al pipe	ASTM A 333	4	60.0	35.0	...	...
	2½Ni pipe	ASTM A 333	7	65.0	35.0	...	...
	2Ni pipe	ASTM A 333	9	63.0	46.0	...	...
(a)	3½Ni tube	ASTM A 334	3	65.0	35.0	...	...
	2½Ni tube	ASTM A 334	7	65.0	35.0	...	...
	2Ni tube	ASTM A 334	9	63.0	46.0	...	...
	Electric Resistance Welded Pipe and Tube						
	3½Ni pipe	ASTM A 333	3	65.0	35.0	...	0.85
	2½Ni pipe	ASTM A 333	7	65.0	35.0	...	0.85
	2Ni pipe	ASTM A 333	9	63.0	46.0	...	0.85
	3½Ni tube	ASTM A 334	3	65.0	35.0	...	0.85
	2½Ni tube	ASTM A 334	7	65.0	35.0	...	0.85
	Austenitic Stainless Steel Pipe and Tube						
	Seamless Pipe and Tube						
(a)	18–8 tube	ASTM A 213	304	75.0	30.0	...	...
	18–8 tube	ASTM A 213	304L	70.0	25.0	...	...

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
							Carbon Steel Pipe and Tube (Cont'd)	
							Electric Fusion Welded Pipe (Cont'd)	
9.8	9.8	9.8	9.8	9.8	9.8	9.8	ASTM A 211	(a)
10.4	10.4	10.4	10.4	10.4	10.4	10.4	ASTM A 211	(a)
							Copper Brazed Tubing	
6.0	5.8	5.5	5.1	4.7	4.0	3.0	ASTM A 254	(a)
							Low and Intermediate Alloy Steel Pipe and Tube	
							Seamless Alloy Steel Pipe and Tube	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 333	(a)
15.0	15.0	15.0	15.0	15.0	15.0	15.0	ASTM A 333	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 333	
15.7	15.7	15.7	15.7	15.7	15.7	15.7	ASTM A 333	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 334	(a)
16.3	16.3	16.3	16.3	16.3	16.3	16.3	ASTM A 334	
15.7	15.7	15.7	15.7	15.7	15.7	15.7	ASTM A 334	
							Electric Resistance Welded Pipe and Tube	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 333	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 333	
13.4	13.4	13.4	13.4	13.4	13.4	13.4	ASTM A 333	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 334	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	ASTM A 334	
							Austenitic Stainless Steel Pipe and Tube	
							Seamless Pipe and Tube	
18.8	...	17.8	...	16.6	...	16.2	ASTM A 213	(a)
16.7	...	16.5	...	15.3	...	14.7	ASTM A 213	

(a)

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

Material	Spec. No.	Grade, Type, or Class	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes	Longitudinal or Spiral Joint Factor
Austenitic Stainless Steel Pipe and Tube (Cont'd)						
Seamless Pipe and Tube (Cont'd)						
18–8 pipe	ASTM A 312	304	75.0	30.0	...	...
18–8 pipe	ASTM A 312	304L	70.0	25.0	...	...
18–8 pipe	ASTM A 376	304	75.0	30.0	...	...
Welded Pipe and Tube						
18–8 tube	ASTM A 249	304	75.0	30.0	...	0.85
18–8 tube	ASTM A 249	304L	70.0	35.0	...	0.85
18–8 pipe	ASTM A 312	304	75.0	30.0	...	0.85
18–8 pipe	ASTM A 312	304L	70.0	25.0	...	0.85

(a)

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding							
100	150	200	250	300	350	400	Spec. No.
							Austenitic Stainless Steel Pipe and Tube (Cont'd) **Seamless Pipe and Tube (Cont'd)**
18.8	...	17.8	...	16.6	...	16.2	ASTM A 312
16.7	...	16.5	...	15.3	...	14.7	ASTM A 312
18.8	...	17.8	...	16.6	...	16.2	ASTM A 376
							Welded Pipe and Tube
16.0	...	15.1	...	14.1	...	13.8	ASTM A 249
14.2	...	14.0	...	13.0	...	12.5	ASTM A 249
16.0	...	15.1	...	14.1	...	13.8	ASTM A 312
15.7	...	15.7	...	15.3	...	14.7	ASTM A 312

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes
Seamless Copper and Copper Alloy Pipe and Tube							
Copper pipe	ASTM B 42	1/8–2 1/2 incl.	C10200 C12000 C12200	Annealed	30.0	9.0	...
Copper pipe	ASTM B 42	1/8–2 1/2 incl.	C10200 C12000 C12200	Drawn	45.0	40.0	(2)
Copper pipe	ASTM B 42	2 1/2–12 incl.	C10200 C12000 C12200	Drawn	36.0	30.0	(2)
Red brass pipe	ASTM B 43	...	C23000	Annealed	40.0	12.0	...
Copper tube	ASTM B 68	...	C10200 C12000 C12200	Annealed	30.0	9.0	...
Copper tube	ASTM B 75	...	C10200 C12000 C12200 C14200	Annealed	30.0	9.0	...
Copper tube	ASTM B 75	...	C10200 C12000 C12200 C14200	Light drawn	36.0	30.0	(2)
Copper tube	ASTM B 75	...	C10200 C12000 C12200 C14200	Hard drawn	45.0	40.0	(2)
Copper tube	ASTM B 88	...	C10200 C12000 C12200	Drawn	36.0	30.0	(2)
Copper tube	ASTM B 88	...	C10200 C12000 C12200	Annealed	30.0	9.0	...

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding							
100	150	200	250	300	350	400	Spec. No.
				Seamless Copper and Copper Alloy Pipe and Tube			
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 42
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 42
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 42
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B 43
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 68
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 75
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 75
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 88
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 88

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

	Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes
	Seamless Copper and Copper Alloy Pipe and Tube (Cont'd)							
	Copper tube	ASTM B 111	Up to 2	C10200 C12000 C12200 C14200	Light drawn	36.0	30.0	(2)
	Copper tube	ASTM B 111	Up to 2	C10200 C12000 C12200 C14200	Hard drawn	45.0	40.0	(2)
	Copper alloy	ASTM B 111	Up to 2	C19200	Annealed	38.0	12.0	...
	Red brass condenser tube	ASTM B 111	Up to 2	C23000	Annealed	40.0	12.0	...
	Muntz metal condenser tube	ASTM B 111	Up to 2	C28000	Annealed	50.0	20.0	...
	Admiralty metal condenser tube	ASTM B 111	Up to 2	C44300 C44400 C44500	Annealed	45.0	15.0	...
(a)	Aluminum bronze condenser tube	ASTM B 111	Up to 2	C60800	Annealed	50.0	19.0	...
(a)	Aluminum brass condenser tube	ASTM B 111	Up to 2	C68700	Annealed	50.0	18.0	...
	95Cu–5Ni condenser tube	ASTM B 111	Up to 2	C70400	Annealed	38.0	12.0	...
	95Cu–5Ni condenser tube	ASTM B 111	Up to 2	C70400	Light drawn	40.0	30.0	...
	90Cu–10Ni condenser tube	ASTM B 111	Up to 2	C70600	Annealed	40.0	15.0	...
	80Cu–20Ni condenser tube	ASTM B 111	Up to 2	C71000	Annealed	45.0	16.0	...
	70Cu–30Ni condenser tube	ASTM B 111	Up to 2	C71500	Annealed	52.0	18.0	...
	Copper tube	ASTM B 280	...	C10200 C12000 C12200	Annealed	30.0	9.0	...
	Copper silicon A pipe	ASTM B 315	...	C65500	Annealed	50.0	15.0	...
(a)	90Cu–10Ni pipe	ASTM B 466	...	C70600	Annealed	38.0	13.0	...
	90Cu–10Ni tube	ASTM B 466	...	C70600	Annealed	38.0	13.0	...
	70Cu–30Ni pipe	ASTM B 466	...	C71500	Annealed	50.0	18.0	...

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
					Seamless Copper and Copper Alloy Pipe and Tube (Cont'd)			
9.0	9.0	9.0	9.0	8.7	8.5	8.2	ASTM B 111	
11.3	11.3	11.3	11.3	11.0	10.3	4.3	ASTM B 111	
7.5	7.0	6.7	6.5	6.1	...	...	ASTM B 111	
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B 111	
12.5	12.5	12.5	12.5	12.5	10.8	5.3	ASTM B 111	
10.0	10.0	10.0	10.0	10.0	9.8	3.5	ASTM B 111	
12.5	12.4	12.2	11.9	11.6	10.0	6.0	ASTM B 111	(a)
12.0	11.9	11.8	11.7	11.7	6.5	3.3	ASTM B 111	(a)
8.0	8.0	...	...	...	...	...	ASTM B 111	
10.0	10.0	...	...	...	...	...	ASTM B 111	
10.0	9.7	9.5	9.3	9.0	8.7	8.5	ASTM B 111	
10.7	10.6	10.5	10.4	10.3	10.1	9.9	ASTM B 111	
12.0	11.6	11.3	11.0	10.8	10.6	10.3	ASTM B 111	
6.0	5.1	4.8	4.8	4.7	4.0	3.0	ASTM B 280	
10.0	10.0	10.0	10.0	10.0	5.0	5.0	ASTM B 315	
8.7	8.4	8.3	8.0	7.8	7.7	7.6	ASTM B 466	(a)
8.7	8.4	8.3	8.0	7.8	7.7	7.6	ASTM B 466	
12.0	11.6	11.3	11.0	10.8	10.6	10.3	ASTM B 466	

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

	Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes
	Welded Copper and Copper Alloy Pipe and Tube							
(a)	90Cu–10Ni pipe and tube	ASTM B 467	Up to 4½ incl.	C70600	Annealed	40.0	15.0	(3)
	90Cu–10Ni pipe and tube	ASTM B 467	Over 4½	C70600	Annealed	38.0	13.0	(3)
(a)								
	70Cu–30Ni pipe and tube	ASTM B 467	Up to 4½ incl.	C71500	Annealed	50.0	20.0	(3)
	70Cu–30Ni pipe and tube	ASTM B 467	Over 4½	C71500	Annealed	45.0	15.0	(3)
	70Cu–30Ni pipe and tube	ASTM B 467	Up to 2	C71500	Welded, drawn, and tempered	72.0	50.0	(3)
	Copper tube	ASTM B 543	Up to 3⅛	C12200	Light cold worked	32.0	15.0	(3)
(a)								
	Copper alloy tube	ASTM B 543	Up to 3⅛	C19400	Annealed	45.0	15.0	(3)
	Copper alloy tube	ASTM B 543	Up to 3⅛	C19400	Light cold worked	45.0	22.0	(3)
	Red brass tube	ASTM B 543	Up to 3⅛	C23000	Annealed	40.0	12.0	(3)
	Red brass tube	ASTM B 543	Up to 3⅛	C23000	Light cold worked	42.0	20.0	(3)
	Admiralty metal tube	ASTM B 543	Up to 3⅛	C44300 C44400 C44500	Annealed	45.0	15.0	(3)
	Aluminum brass tube	ASTM B 543	Up to 3⅛	C68700	Annealed	50.0	18.0	(3)
	95Cu–5Ni tube	ASTM B 543	Up to 3⅛	C70400	Annealed	38.0	12.0	(3)
(a)	90Cu–10Ni	ASTM B 543	Up to 3⅛	C70600	Annealed	40.0	15.0	(3)
	90Cu–10Ni	ASTM B 543	Up to 3⅛	C70600	Light cold worked	45.0	35.0	(3)
	70Cu–30Ni	ASTM B 543	Up to 3⅛	C71500	Annealed	52.0	18.0	(3)

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
					Welded Copper and Copper Alloy Pipe and Tube			
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 467	(a)
7.4	7.1	7.1	6.8	6.6	6.5	6.5	ASTM B 467	
								(a)
10.6	9.6	8.9	8.8	8.8	8.8	8.8	ASTM B 467	
8.5	8.2	8.0	7.8	7.7	7.5	7.3	ASTM B 467	
15.3	15.3	15.3	15.3	15.3	14.9	14.7	ASTM B 467	
5.1	4.3	4.1	4.0	4.0	3.4	2.5	ASTM B 543	
								(a)
8.5	8.5	8.3	8.1	7.8	7.3	6.0	ASTM B 543	
8.5	8.5	8.3	8.1	7.8	7.3	6.0	ASTM B 543	
6.8	6.8	6.8	6.8	6.8	5.9	4.2	ASTM B 543	
6.8	6.8	6.8	6.8	6.8	5.9	4.2	ASTM B 543	
8.5	8.5	8.5	8.5	8.5	8.3	3.0	ASTM B 543	
10.2	10.1	10.0	9.9	9.9	5.5	2.7	ASTM B 543	
6.8	6.8	. . .	. . .	. . .	. . .	. . .	ASTM B 543	
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 543	(a)
8.5	8.2	8.1	7.9	7.6	7.4	7.2	ASTM B 543	
10.2	9.9	9.6	9.3	9.2	9.0	8.8	ASTM B 543	

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

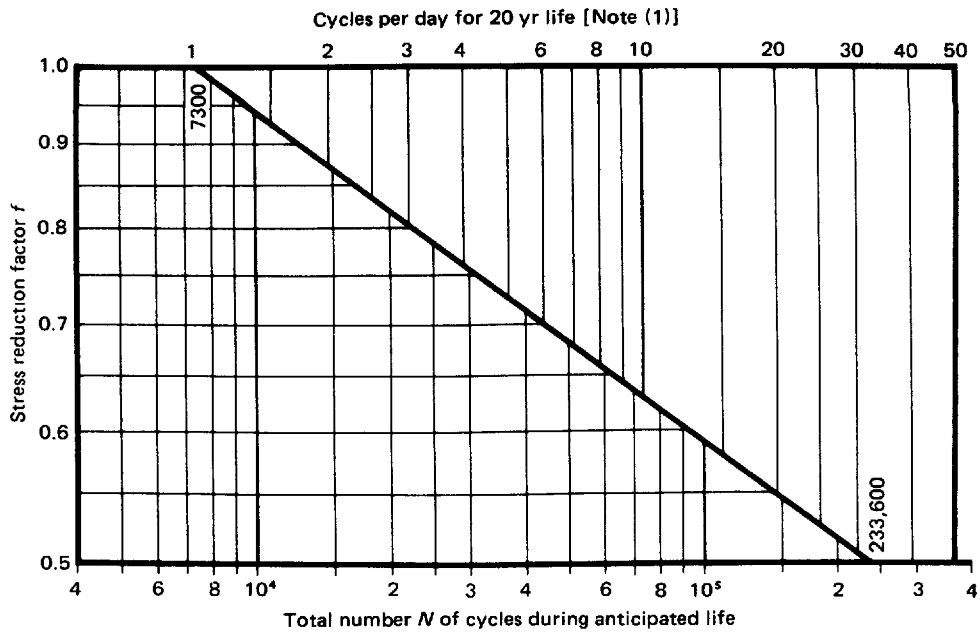
Material	Spec. No.	NPS	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi	Min. Yield Strength, ksi	Notes
Seamless Nickel Base Alloy Pipe and Tube							
Nickel and copper pipe	ASTM B 165	5 O.D. and under	N04400	Annealed	70.0	28.0	...
Nickel and copper pipe	ASTM B 165	Over 5 O.D.	N04400	Annealed	70.0	25.0	...
Nickel and copper tube	ASTM B 165	5 O.D. and under	N04400	Annealed	70.0	28.0	...
(a) Nickel and copper tube	ASTM B 165	Over 5 O.D.	N04400	Annealed	70.0	25.0	...
Seamless Aluminum Base Alloy Pipe and Tube							
3003 tube	ASTM B 210	...	...	0	14.0	5.0	...
3003 tube	ASTM B 210	...	...	H14	20.0	17.0	(4)
6063 tube	ASTM B 210	...	...	T6	33.0	28.0	(5)
6063 tube	ASTM B 210	...	...	T6 welded	17.0	...	...
6061 tube	ASTM B 210	...	...	T4	30.0	16.0	(5)
6061 tube	ASTM B 210	...	...	T6	42.0	35.0	(5)
6061 tube	ASTM B 210	...	...	T6 welded	24.0	...	...
6061 tube	ASTM B 234	...	...	T4	30.0	16.0	(5)
6061 tube	ASTM B 234	...	...	T6	42.0	35.0	(5)
6061 tube	ASTM B 234	...	...	T6 welded	24.0	...	...
(a) 3003 tube or pipe	ASTM B 241	...	...	0	14.0	5.0	...
3003 pipe	ASTM B 241	Under 1	...	H18	27.0	24.0	(4)
3003 pipe	ASTM B 241	1 and over	...	H112	14.0	5.0	(4)
5083 tube	ASTM B 241	...	...	0	39.0	16.0	...
6063 tube	ASTM B 241	...	...	T5	22.0	16.0	(5)
6063 tube	ASTM B 241	...	...	T6	30.0	25.0	(5)
6061 tube	ASTM B 241	...	...	T4	26.0	16.0	(5)
6061 pipe	ASTM B 241	1 and over	...	T6	38.0	35.0	(5)
6061 pipe	ASTM B 241	...	...	T6 welded	24.0	...	...

(a) GENERAL NOTE: Except where specific omissions of stress values occur in this Table, the values in Section II, Part D for Section VIII, Division 1, of the ASME BPV Code may be used to supplement this Table for allowable stresses.

NOTES:
(1) A quality factor of 92% is included for structural grade.
(2) Where brazed construction is employed, stress values for annealed material shall be used.
(3) 85% joint efficiency has been used in determining the allowable stress value for welded tube.
(4) For brazed or welded construction or where thermal cutting is employed, stress value for "0" temper material shall be used.
(5) The stress values given for this material are not applicable when either brazing, welding, or thermal cutting is used.

TABLE 502.3.1 (CONT'D)
ALLOWABLE STRESSES, ksi
Multiply by 1000 to obtain psi

For Metal Temperatures, °F, Not Exceeding								
100	150	200	250	300	350	400	Spec. No.	
							Seamless Nickel Base Alloy Pipe and Tube	
17.5	...	16.4	...	15.4	...	14.8	ASTM B 165	
16.6	...	14.6	...	13.6	...	13.2	ASTM B 165	
17.5	...	16.4	...	15.4	...	14.8	ASTM B 165	
16.6	...	14.6	...	13.6	...	13.2	ASTM B 165	(a)
							Seamless Aluminum Base Alloy Pipe and Tube	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	ASTM B 210	
5.0	5.0	5.0	4.9	4.3	3.0	2.4	ASTM B 210	
8.3	8.3	7.9	7.4	5.5	3.4	2.0	ASTM B 210	
4.3	4.3	4.3	4.2	3.9	3.0	2.0	ASTM B 210	
7.5	7.5	7.5	7.4	6.9	6.3	4.5	ASTM B 210	
10.5	10.5	10.5	9.9	8.4	6.3	4.5	ASTM B 210	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 210	
7.5	7.5	7.5	7.4	6.9	6.3	4.5	ASTM B 234	
10.5	10.5	10.5	9.9	8.4	6.3	4.5	ASTM B 234	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 234	
3.4	3.4	3.4	3.0	2.4	1.8	1.4	ASTM B 241	(a)
6.8	6.8	6.7	6.3	5.4	3.5	2.5	ASTM B 241	
3.3	3.3	3.3	3.0	2.4	1.8	1.4	ASTM B 241	
9.8	9.8	...	...	...	...	...	ASTM B 241	
5.5	5.5	5.4	5.1	4.6	3.4	2.0	ASTM B 241	
7.5	7.5	7.4	6.8	5.0	3.4	2.0	ASTM B 241	
6.5	6.5	6.5	6.4	6.0	5.8	4.5	ASTM B 241	
9.5	9.5	9.5	9.1	7.9	6.3	4.5	ASTM B 241	
6.0	6.0	6.0	5.9	5.5	4.6	3.5	ASTM B 241	



NOTE:
(1) Assuming 365 day per year operation.

FIG. 502.3.2 STRESS RANGE REDUCTION FACTORS

ments shall be provided, consistent with the expected life of the particular piping involved.

502.4.2 Threading and Grooving. [See definition for c in para. 504.1.1(b).]

502.4.4 Mechanical Strength. When necessary to prevent damage, collapse, or buckling due to superimposed loads from supports, backfill, or other causes, the pipe wall thickness shall be increased or, if this is impractical or would cause excessive local stresses, the factors that would contribute to damage of the piping shall be compensated for by other design methods.

PART 2 PRESSURE DESIGN OF PIPING COMPONENTS

503 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components, considering the effects of pressure, and providing for mechanical, corrosion, and erosion allowances, shall be in accordance with para. 504. In addition, the designs must be checked for adequacy of mechanical strength under other applicable loadings as given in para. 501.

504 PRESSURE DESIGN OF COMPONENTS

504.1 Straight Pipe

504.1.1 General

(a) The required thickness of straight sections of pipe shall be determined in accordance with Eq. (2). (Also see para. 503.)

$$t_m = t + c \qquad (2)$$

(b) The notations described below are used in the equations for the pressure design of straight pipe.

t_m = minimum required thickness, in., satisfying requirements for design pressure and mechanical, corrosion, and erosion allowances

t = pressure design thickness, in., as calculated from Eq. (3) for internal pressure, or in accordance with the procedures given in para. 504.1.3 for external pressure

c = for internal pressure, the sum, in., of the mechanical allowances (thread, groove depth, and manufacturers' minus tolerance) plus corrosion and erosion allowances. (See para. 502.-4.1.) For threaded components, the nominal thread depth (dimension h of ANSI B1.20.1, or equivalent) shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be 1/64 in. in addition to the specified depth of the cut.

= for external pressure, the sum, in., of corrosion and erosion allowances plus manufacturer's minus tolerance (see para. 502.4.1)

P = internal design pressure (see para. 501.2.2), psig, or external design pressure (see para. 501.2.3), psi

D_o = outside diameter of pipe, in.

d = inside diameter of pipe, in. (excluding metal required for corrosion or erosion allowance, manufacturers' minus tolerance, and any allowance required for the depth of internal threads or grooves)

S = applicable allowable hoop stress in accordance with para. 502.3.1 and Table 502.3.1, psi

y = coefficient for materials indicated: for ductile nonferrous materials, use $y = 0.4$ (see Note); for ferritic steels, use $y = 0.4$ (see Note); for austenitic steels, use $y = 0.4$ (see Note).

NOTE: If D_o/t in range of 4–6, use $y = d/(d + D_o)$ for ductile materials.

For cast iron, use $y = 0.0$.

A, B = factors for external pressure design, from Figs. 504.1.1-A or 504.1.1-B corresponding to the design temperature of the pipe. (These figures apply only if the pipe material is of carbon steel with a minimum specified yield strength of 24.0 ksi to 38.0 ksi. D_o/t should not exceed 100. To find factors A and B for other materials, use the charts in Section VIII, Division 1, of the ASME BPV Code.)

A_s = cross-sectional area of the stiffening ring, in.^{2}

I_s = required moment of inertia of the transverse cross-sectional area of a circumferential stiffening ring about its neutral axis parallel to axis of the pipe, in.^{4}

L = design length of pipe section taken as the largest of the following:

(a) distance between flanges or stiffening rings;

(b) distance between the point of tangency on an elbow or cap and a flange or stiffening ring; or

(c) the distance between the points of tangency of two elbows or caps where there are no intermediate flanges or stiffening rings, in.

(a) **504.1.2 Straight Pipe Under Internal Pressure.** For metallic pipe with diameter-thickness ratios $D_o/t > 4$, the internal pressure design thickness t shall be calculated using Eq. (3).

$$t = \frac{PD_o}{2(S + Py)} \quad \text{or} \quad t = \frac{Pd}{2(S + Py - P)} \tag{3}$$

$$P = \frac{2St}{D_o - 2yt}$$

NOTE: The following simpler alternative equation may be employed which gives somewhat greater pipewall thickness:

$$t = \frac{PD_o}{2S} \quad \text{or} \quad t = \frac{Pd}{2(S - P)}$$

$$P = \frac{2St}{D_o}$$

504.1.3 Straight Pipe Under External Pressure. The pressure design thickness t for straight pipe under external pressure shall be determined (see Note) in accordance with the following procedure:

Step 1. Assume a value for t. Determine L/D_o and D_o/t.

Step 2. For carbon steel materials enter the left hand side of Fig. 504.1.1-A (specified minimum yield strength of 24.0 ksi to 30.0 ksi) or Fig. 504.1.1-B (specified minimum yield strength of 30.0 ksi to 38.0 ksi) at the value of L/D_o determined in Step 1. (For other materials use the charts in Section VIII, Division 1, of the ASME BPV Code).

Step 3. Move horizontally to the line representing D_o/t as determined in Step 1.

Step 4. From this intersection move vertically to the line for design temperature.

Step 5. From this intersection move horizontally to the right and read the value of factor B.

Step 6. Compute the allowable external working pressure P_a using Eq. (4)

$$P_a = \frac{B}{D_o/t} \tag{4}$$

Step 7. Compare P_a with P. If P_a is smaller than P, a greater value for t must be selected (or the design length L may be shortened by addition of stiffeners; see para. 504.1.4 for the design of stiffener rings) and the design procedure repeated until a value of P_a is obtained that is equal to or greater than P.

NOTE: Where applicable, the method outlined in UG-31 of Section VIII, Division 1, of the ASME BPV Code is also acceptable for designing pipe under external pressure using appropriate design stress values from Subsection C of that Code.

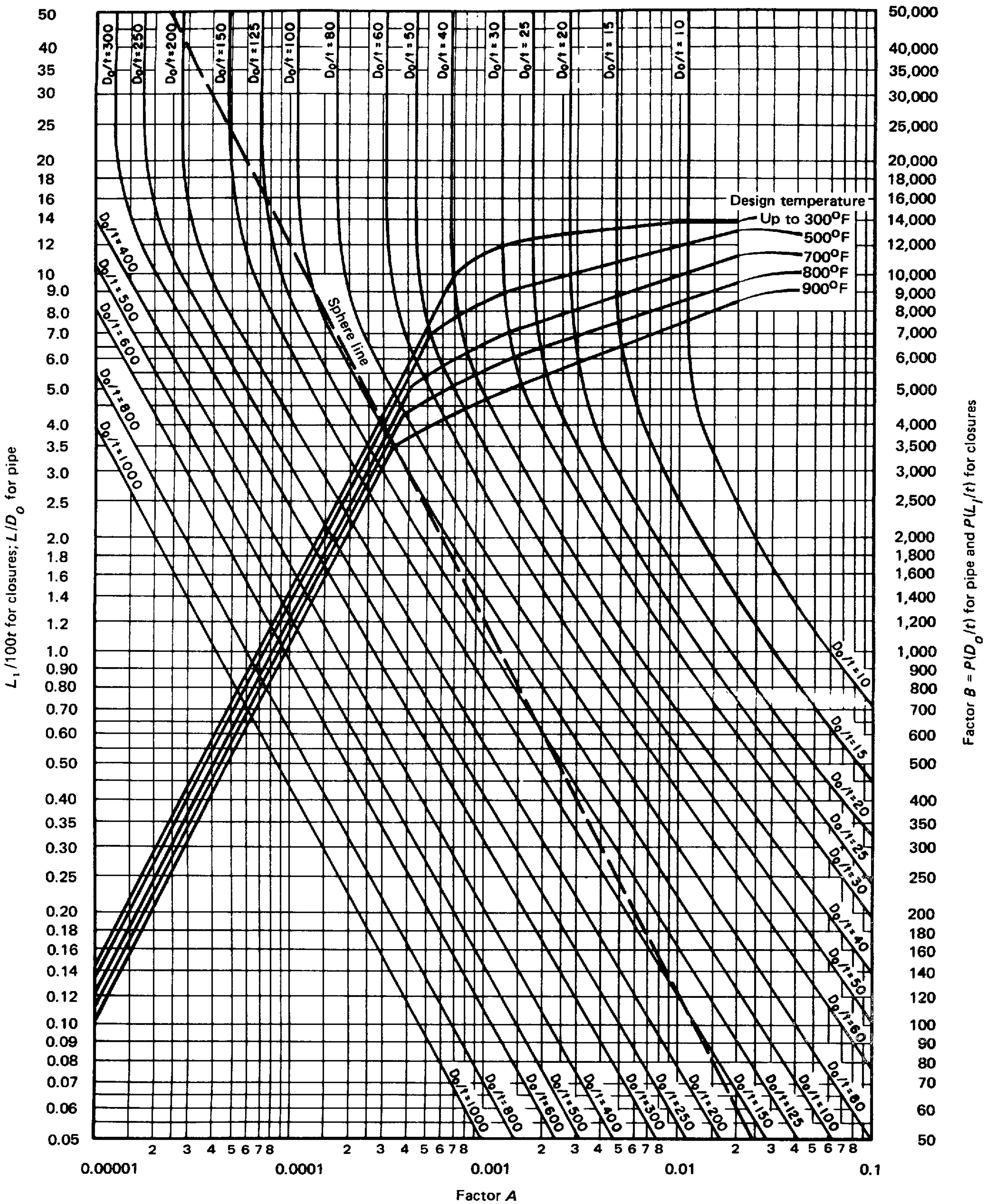


FIG. 504.1.1-A CHART FOR DETERMINING THICKNESS OF PIPE AND CLOSURES UNDER EXTERNAL PRESSURE WHEN CONSTRUCTED OF CARBON STEEL (MINIMUM SPECIFIED YIELD STRENGTH 24,000 psi TO 30,000 psi)

apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(3) Notations. The notations used herein are illustrated in Fig. 504.3.1-B. Note the use of subscript x for extruded outlet. Refer to (f) above for notations not listed here.

d_x = the design inside diameter of the extruded outlet, in., measured at the level of the outside surface of the run

h_x = height of the extruded outlet, in. This must be equal to or greater than r_x [except as shown in sketch (b) in Fig. 504.3.1-B].

L_5 = height of reinforcement zone, in.
$= 0.7 \sqrt{D_{ob} T_x}$

T_x = corroded finished thickness of extruded outlet measured at a height equal to r_x above the outside surface of the run, in.

d_2 = half-width of reinforcement zone, in. (equal to d_x)

r_x = radius of curvature of external contoured portion of outlet measured in the plane containing the axis of the run and branch, in. This is subject to the following limitations.

(a) Minimum Radius. This dimension shall not be less than $0.05D_{ob}$ except that on branch diameters larger than NPS 30 it need not exceed 1.50 in.

(b) Maximum Radius. For outlet pipe sizes NPS 8 and larger, this dimension shall not exceed $0.10D_{ob} + 0.50$ in. For outlet pipe sizes less than NPS 8, this dimension shall not be greater than 1.25 in.

(c) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg. shall meet the requirements for maximum and minimum radii.

(d) Machining shall not be employed in order to meet the above requirements.

(4) Required Area. The required area is defined as $A_1 = Kt_h d_x$ where K shall be taken as follows.

(a) For D_{ob}/D_{oh} greater than 0.60, $K = 1.00$.

(b) For D_{ob}/D_{oh} greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3} D_{ob}/D_{oh}$$

(c) For D_{ob}/D_{oh} equal to or less than 0.15, $K = 0.70$.

The design must meet the criteria that the reinforcement area defined in (g)(5) below is not less than the required area A_1.

(5) Reinforcement Area. The reinforcement area shall be the sum of areas $A_2 + A_3 + A_4$ as defined below.

(a) Area A_2. The area lying within the reinforcement zone resulting from any excess thickness available in the run wall.

$$A_2 = d_x(T_h - t_h)$$

(b) Area A_3. The area lying within the reinforcement zone resulting from any excess thickness available in the branch pipe wall.

$$A_3 = 2L_5(T_b - t_b)$$

(c) Area A_4. The area lying within the reinforcement zone resulting from any excess thickness available in the extruded outlet lip.

$$A_4 = 2r_x(T_x - T_b)$$

(6) Reinforcement of Multiple Openings. The rules of (f)(5) above shall be followed except that the required area and reinforcement area shall be as given in para. 504.3.1(g).

(7) In addition to the above, the manufacturer shall be responsible for establishing and marking, on the header containing extruded outlets, the design pressure and temperature and this Code Section. The manufacturer's name or trademark shall be marked on the header.

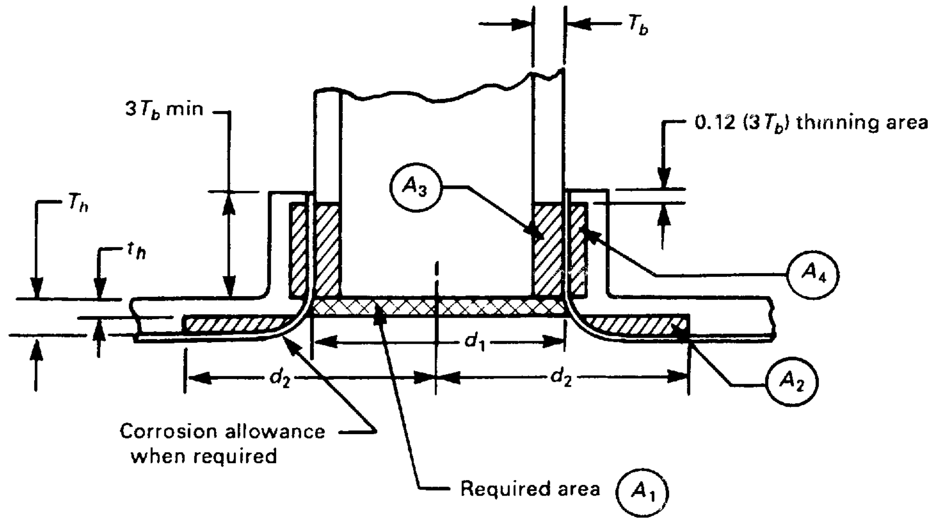
(h) Mechanically Formed Tee Connections in Copper Materials (Type K, L, M)

(1) These mechanically formed connections shall be perpendicular to the axis of the run tube (header). They shall be formed by drilling a pilot hole and drawing out the tube surface to form a collar having a height of not less than three times the thickness of the branch wall. The collaring device shall be such as to assure proper fit up of the joint.

(2) The inner branch tube end shall conform to the shape of the inner curve of the run tube. Insertion of the branch tube shall be controlled to assure alignment with specified depth into the collar without extending into the flow stream so as to provide internal reinforcement to the collar as illustrated in Fig. 504.3.1-C.

(3) Branches can be formed up to the run tube size. Manufacturing procedures shall be in accordance with tool manufacturer's recommendations.

(4) These types of connections may *not* be used in other than Group A1 refrigerant service. **(a)**



A_1 = required area, sq in. = $t_h d_1$
A_2 = area lying within the reinforcement zone resulting from any excess thickness available in the header wall
A_3 = area lying within the reinforcement zone resulting from any excess thickness in the branch tube wall
A_4 = area lying within the reinforcement zone resulting from any excess thickness available in the extruded lip

$A_2 + A_3 + A_4 \geq A_1$

T = actual thickness of tube wall
b = branch
d_1 = opening size in header tube
d_2 = d_1 = reinforcement zone
h = header
t = pressure design thickness

FIG. 504.3.1-C MECHANICALLY FORMED TEE CONNECTIONS IN COPPER MATERIALS

(5) All joints shall be brazed in accordance with paras. 528.1 and 528,2.

(i) Other Designs. Components to which design rules given in (c) and (d) above are not applicable shall meet the requirements of para. 504.7.

(j) The requirements of the preceding subparagraphs are designed to assure satisfactory performance of a branch connection subjected only to pressure. However, in addition, external forces and moments are usually applied to a branch connection by such agencies as thermal expansion and contraction, by dead weight of piping, valves and fittings, covering and contents, and by earth settlement. Special consideration shall be given to the design of a branch connection to withstand these forces and moments.

Where the ratio of branch diameter to run diameter is large or where repetitive stresses may be imposed on the connection due to vibration, pulsating pressure, temperature cycling, etc., it is recommended that the design be rather conservative and that consideration be given to the use of tee fittings or complete encirclement types of reinforcement.

Use of ribs, gussets, and clamps is permissible to stiffen the branch connection but their areas cannot be counted as contributing to the reinforcement area defined in (d)(3) above. Consideration should be given to stress arising from a temperature gradient between the piping and gussets during a sudden change in temperature of the fluid in the piping.

It is not practicable to give definite rules for design to accommodate the effects mentioned in this subparagraph. The purpose is to call them to the attention of the engineer so that from experience and judgment he may adequately provide for them.

Attention is especially directed to the design of small branches out of large and relatively heavy runs. Adequate flexibility must be provided in the smaller line to accommodate thermal expansion and other movements of the larger line.

504.3.2 Openings in Closures

(a) The rules of this paragraph are intended to apply to openings in closures in which the size of the opening is not greater than one-half of the inside diameter of the

t_m = minimum required thickness, in., satisfying requirements for pressure, mechanical, corrosion, and erosion allowances

t = pressure design thickness, in., as calculated for the given closure shape and direction of pressure loading from the appropriate equations and procedures in Section VIII, Division 1, of the ASME BPV Code. (Certain symbols used in these equations, namely P and S, shall be considered to have the meanings described in this subparagraph instead of those given in the ASME BPV Code. All other symbols shall be as defined in the ASME BPV Code.)

c = sum of the corrosion and erosion allowances, in.

P = internal design gage pressure (see para. 501.2.-2), psig, or external design gage pressure (see para. 501.2.3), psi

S = applicable allowable stress in accordance with para. 502.3.1 and Table 502.3.1, ksi

504.5.3 Blanks

(a) The pressure design thickness of permanent blanks (see Fig. 504.5.3) shall be calculated in accordance with Eqs. (8) and (9).

$$t = d_g\sqrt{\frac{3P}{16S}} \qquad (9)$$

where

d_g = inside diameter of gasket for raised or flat (plain) face flanges, or the gasket pitch diameter for retained gasketed flanges, in.

P = internal design gage pressure (see para. 501.2.-2), psig, or external design gage pressure (see para. 501.2.3), psi

S = applicable allowable stress in accordance with para. 502.3.1 and Table 502.3.1, ksi

(b) Blanks to be used for test purposes only shall be designed in accordance with Eq. (9), except that P shall be at least equal to the test pressure and S may be as great as 95% of the specified minimum yield strength of the blank material. (This applies only if the test fluid is incompressible.)

504.7 Pressure Design of Other Pressure Containing Components

Other pressure containing components manufactured in accordance with the standards listed in Table 526.1 shall be considered suitable for use at the pressure–temperature ratings specified by such standards. Pressure containing components not covered by the standards listed in Table 526.1 and for which design formulas or procedures are not given in this paragraph (para. 504), may be used where they have been proven satisfactory by successful performance under comparable service conditions. (Where such satisfactory service experience exists, interpolation may be made to other sized components with a geometrically similar shape.) In the absence of such service experience, the pressure design shall be based on an analysis consistent with the general design philosophy embodied in this Code Section and substantiated by at least one of the following:

(a) proof tests (as described in UG-101 of Section VIII, Division 1, of the ASME BPV Code);

(b) experimental stress analysis.

PART 3
DESIGN APPLICATION OF PIPING COMPONENTS SELECTION AND LIMITATIONS

505 PIPE

505.1 General

Pipe and tubes conforming to the standards and specifications listed in Tables 502.3.1 and 526.1 shall be used within the limitations of temperature and stress given in para. 502.3.1 and Table 502.3.1 and within the additional limitations contained in this Code.

505.1.1 Additional Limitations for Carbon Steel Pipe. No less than Schedule 80 (ANSI B36.10) wall thickness shall be used for other than Group A1 refrigerant liquid lines for NPS 1½ and smaller. (a)

No less than Schedule 40 (ANSI B36.10) wall thickness shall be used for Group A1 refrigerant liquid lines NPS 6 and smaller, other than Group A1 refrigerant liquid lines NPS 2 through 6, and all Groups of refrigerant vapor lines NPS 6 and smaller.

ASTM A 53 Grade F is not permitted.

505.1.2 Additional Limitations for Cast Iron Pipe. Cast iron pipe shall not be used for refrigerant service.

505.2 Nonferrous Pipe or Tube

505.2.1 Copper, copper alloy, aluminum, or aluminum alloy pipe and tube of any size may be used for any refrigerant service where compatible with the refrigerant used and when selected in accordance with the design rule in para. 504.1 and allowable stress values in Table 502.3.1.

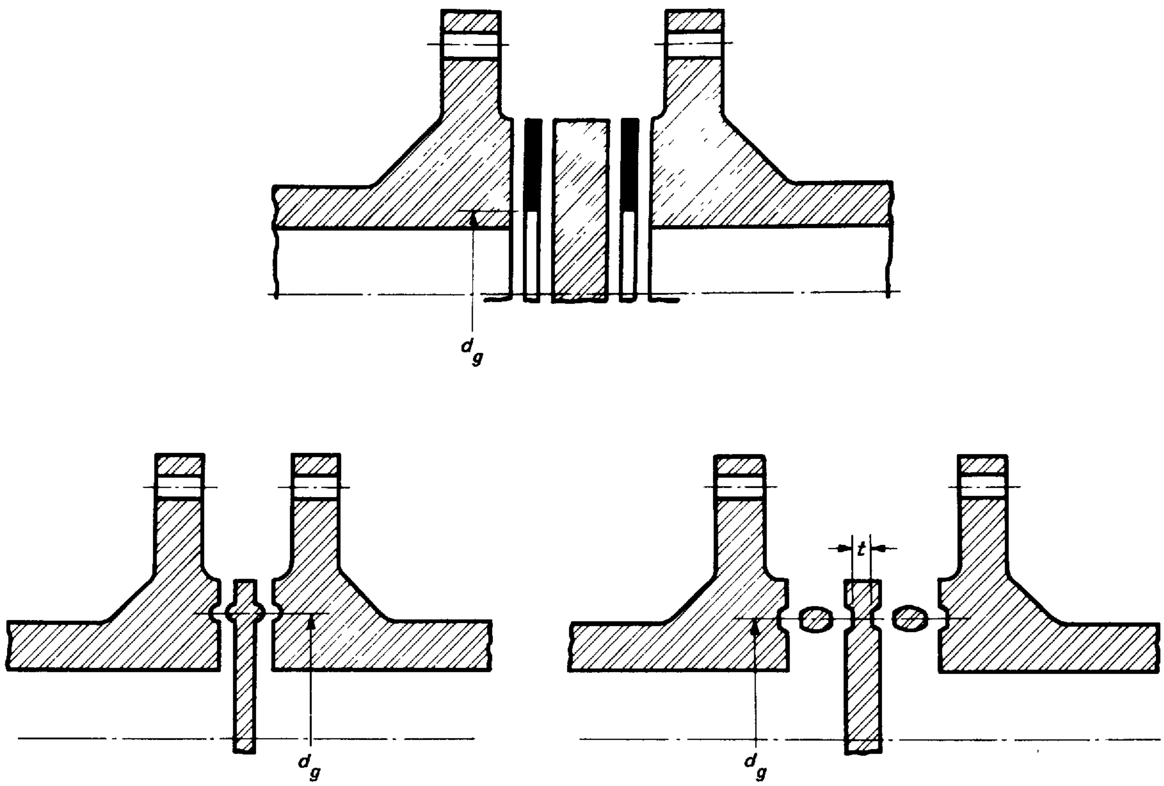


FIG. 504.5.3 BLANKS

505.2.2 Soft annealed copper tubing larger than 1⅜ in. O.D. shall not be used for field assembled refrigerant piping, unless it is protected from mechanical damage.

506 FITTINGS, BENDS, AND INTERSECTIONS

506.1 Fittings

506.1.1 General. If fittings complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code.

Other fittings, including those exceeding the range of sizes in the standards listed in Table 526.1, may be used provided the designs meet the requirements in para. 504.

506.1.2 Bell and Spigot Fittings. Bell and spigot fittings shall not be used for refrigerant service.

506.2 Bends and Intersections

Bends, miters, and extruded branch connections may be used when they are designed in accordance with the principles in Chapter II, Part 2.

506.3 Couplings

Couplings made of cast or malleable iron shall not be used on pipe containing flammable or toxic fluids.

507 VALVES

(a) Valves complying with the standards listed in Table 526.1 may be used in accordance with the limitations listed in the specific standards and in this Code.

(b) Refrigerant gate valves, ball valves, and plug cocks shall not be used in liquid refrigerant lines unless consideration is given to the expansion of liquid trapped in the valve cavities when the valve or cock is closed.

508 FLANGES, BLANKS, FLANGE FACINGS, GASKETS, AND BOLTING

508.1 Flanges

508.1.1 General. If flanges complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code.

Other flanges, including those exceeding the range of sizes in the standards listed in Table 526.1, may be used provided the designs meet the requirements of para. 504.

508.1.2 Screwed Flanges. Screwed flanges are subject to restrictions on threaded joints established in para. 514(e).

508.2 Blanks

Blanks shall conform to design requirements in para. 504.5.3.

508.3 Flange Facings

Flange facings complying with standards listed in Table 526.1 are suitable for use under this Code. Other special facings may be used provided they meet the requirements of para. 504.7.

Class 150 steel flanges may be bolted to cast iron valves, fittings, or other cast iron piping components having either Class 125 cast integral or screwed flanges. If such construction is used, it is preferred that the 1/16 in. raised face on steel flanges be removed. If the raised face is removed and a ring gasket extending to the inner edge of the bolt holes is used, or if the raised face is not removed, the bolting shall be carbon steel not stronger than ASTM A 307, Grade B. If a full-face gasket is used, the bolting may be alloy steel (ASTM A 193).

Class 300 steel flanges may be bolted to cast iron valves, fittings, or other cast iron piping components having either Class 250 cast iron integral or screwed flanges, without any change in the raised face on either flange. If such construction is used, the bolting shall be carbon steel not stronger than ASTM A 307, Grade B.

508.4 Gaskets

Gaskets shall be made of materials which are not injuriously affected by the nature of the fluid nor its temperature.

Only metallic or asbestos-metallic gaskets shall be used on flat or raised face flanges if the expected normal operating gage pressure exceeds 720 psi. Confined compressed-sheet-asbestos gaskets are not limited as to pressures provided the gasket material is suitable for the temperature.

The use of metal or metal-asbestos gaskets is not limited as to pressures.

508.5 Bolting

508.5.1 General. If bolts, nuts, and washers complying with applicable standards and specifications listed in Tables 523.1 and 526.1 are used, they shall be used within the limitations specified in this Code and shall also be subject to the requirements of Chapter III and paras. 508.3 and 508.5.2(a) and (b).

508.5.2 Bolting for Cast Iron Flanges

(a) Classes 25 and 125 cast iron integral or screwed companion flanges may be used with a full-face gasket or with a flat ring gasket extending to the inner edge of the bolts. When using a full-face gasket, the bolting may be alloy steel (ASTM A 193). When using a flat ring gasket, the bolting shall be of carbon steel equal to or less than ASTM A 307, Grade B. Materials other than carbon steels may be used provided the physical properties are equal to or less than the requirements of ASTM A 307, Grade B.

(b) When bolting together two Class 250 cast iron, integral, or screwed companion flanges having 1/16 in. raised faces, the bolting shall be of carbon steel equal to or less than ASTM A 307, Grade B. Materials other than carbon steels may be used provided the physical properties are equal to or less than the requirements of ASTM A 307, Grade B.

PART 4
SELECTION AND LIMITATIONS OF PIPING JOINTS

510 PIPING JOINTS

510.1 General

The type of piping joint used shall be suitable for the pressure–temperature conditions, and shall be selected giving consideration to joint tightness and mechanical strength under the service conditions (including thermal expansion and vibration) and to the nature of the fluid handled with respect to corrosion, erosion, flammability, and toxicity.

The following limitations are in addition to applicable requirements in other portions of this Code Section.

511 WELDED JOINTS

511.1 General

Welded joints may be used with any materials for which it is possible to qualify welding procedures, welders, and welding operators in conformance with Chapter V.

511.2 Butt Welds

Butt welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. When backing rings are used in services where their use will result in severe corrosion or erosion, the backing ring should be removed and the internal joint ground smooth. In such services where it is impractical to remove the backing ring, consideration shall be given to welding the joint without backing rings, or consumable inserts may be used.

511.3 Socket Welds

511.3.1 Socket welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. Dimensions of socket welding piping joints shall conform to ANSI B16.5 for flanges and ANSI B16.11 for fittings, and the weld dimensions shall be not less than the minimum dimensions shown in Figs. 527.4.4-B and 527.4.4-C.

511.3.2 Socket welded connections inserted directly into the wall of the run pipe shall be in accordance with requirements of para. 504.3.1(c).

511.3.3 Drains and bypasses may be attached to a fitting or valve by socket welding, provided the socket depth, bore diameter, and shoulder thickness conform to the requirements of ANSI B16.5.

511.4 Fillet Welds

Fillet welds shall be made in accordance with the applicable requirements of Chapter V and para. 500. Fillet welds shall not have dimensions less than the minimum dimensions shown in Figs. 527.4.4-B, 527.4.4-C, and 527.4.6-D.

511.5 Seal Welds

Seal welds may be used to avoid joint leakage; however, they shall not be considered as contributing any strength to the joint. (See also para. 527.4.5.)

512 FLANGED JOINTS

Flanged joints shall meet the requirements of para. 508.

513 EXPANDED JOINTS

Expanded joints may be used where experience or tests have demonstrated that the joint is suitable for the conditions and where adequate provisions are made in the design to prevent separations of the joints.

514 THREADED JOINTS

(a) Threaded joints may be used within the limits stated in (b) through (f) below.

(b) When used, all pipe threads shall be taper pipe threads where the tightness of joint depends upon the seating of the thread. Straight threads on pipe joints which depend upon a seating surface other than the thread are allowed within the limitations of para. 518 if the thread root is no deeper than a standard pipe thread and if the thread is sealed from the contained fluid.

(c) Threaded joints shall not be used for Group A2 or Class 3 refrigerants, unless suitably seal welded or brazed. **(a)**

(d) Threaded joints larger than NPS 1 should not be used for Group A2 or Class 3 refrigerants. **(a)**

(e) Threaded joints larger than NPS 6 should not be used for salt brines.

(f) Pipe with a wall thickness less than ANSI B36.10 Standard Weight or Schedule 40 up to NPS 6 and Schedule 30 in NPS 8, 10, and 12 should not be threaded.

515 FLARED, FLARELESS, AND COMPRESSION JOINTS

515.1

In selecting and applying flared, flareless, and compression type tube fittings, the designer shall consider the adverse effects on the joints of such factors as assembly and disassembly, cyclic loading, vibration, shock, thermal expansion and contraction, and the problem of frost growth between the tube and fitting.

515.2

Piping joints using flared, flareless, or compression fittings may be used within the limitations of applicable standards or specifications listed in Table 526.1 and the following requirements.

(a) Fittings and their joints shall be suitable for the tubing with which they are to be used with consideration to minimum tubing wall thickness and method of assembly recommended by the manufacturer.

(b) Fittings shall not be used in services which exceed the manufacturer's maximum pressure–temperature recommendations.

515.3

For piping joints using flared, flareless, or compression fittings for which there are no applicable standards or specifications listed in Table 526.1, the engineer shall determine that the type of fitting selected is adequate and safe for the design conditions and that it meets the requirements of paras. 515.2(a) and (b) and the following requirements.

(a) The pressure design shall meet the requirements of para. 504.7.

(b) A suitable quantity of the type and size of fitting to be used shall meet successful performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, hydraulic shock, or frost growth are anticipated, the applicable conditions shall be incorporated in the test.

517 BRAZED AND SOLDERED JOINTS

(a) Brazed and soldered socket type joints may be used with the following limitations for the attachment of valves, fittings, and flanges to nonferrous pipe and tubing.

(a) *(1)* Soldered joints shall not be used for piping containing other than Group A1 refrigerants or any other toxic or flammable fluid.

(a) *(2)* Bores and depths of sockets of brazed and soldered fittings shall conform to the dimensions in ANSI B16.18 or ANSI B16.22. Depths of sockets for brazed fittings only may conform to MIL-F-1183J.

(3) Brazed socket type joints may be used provided it is determined that the fittings are adequate and safe for the design conditions in accordance with the requirements listed in paras. 515(a) through (d) for flared and flareless fittings.

(4) The piping systems should be kept free of flux and other foreign materials.

(5) Solder joints shall not be used for temperatures in excess of those given in ANSI B16.22.

518 SLEEVE COUPLED AND OTHER NOVEL OR PATENTED JOINTS

Coupling type, mechanical gland type, and other patented or novel type joints may be used provided adequate provisions are made to prevent separation of the joints and provided a prototype joint has been subjected to performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are anticipated, the applicable conditions shall be incorporated in the tests.

PART 5
EXPANSION, FLEXIBILITY, STRUCTURAL ATTACHMENTS, SUPPORTS, AND RESTRAINTS

519 EXPANSION AND FLEXIBILITY

519.1 General

The following clauses define the objectives of piping flexibility analysis and alternative ways in which these can be realized.

519.1.1 Objectives. Piping systems shall be designed to have sufficient flexibility to prevent thermal expansion from causing:

(a) failure of piping or anchors from overstress or overstrain;

(b) leakage at joints; or

(c) detrimental distortion of connected equipment (pumps, turbines, or valves) resulting from excessive thrusts and moments.

519.1.2 Expansion Strains. Expansion strains may be taken up in two ways, either primarily by bending or torsion in which case only the extreme fibers at the critical location are stressed to the limit, or by axial compression and tension in which case the entire cross-sectional area over the entire length is substantially equally stressed.

(a) Bending or torsional flexibility may be provided by the use of bends, loops, or offsets; or by swivel joints, ball joints, corrugated pipe, or expansion joints of the bellows type permitting angular movement. Suitable anchors, ties, or other devices shall be provided as necessary to resist end forces from fluid pressure, frictional, or other resistance to joint movement and other causes.

(b) Axial flexibility may be provided by expansion joints of the slip-joint or bellows types. Pipe running

from anchors to the joints must be guided where necessary to keep the pipe from bowing because of end forces originating in the joint from fluid pressure, friction, and deformation of the bellows. Anchors must be adequate for these forces plus the force arising from friction in the guides. For design and selection of expansion joints of the bellows type, reference to the Standards of the Expansion Joint Manufacturers Association is recommended.

519.2 Concepts

Concepts peculiar to piping flexibility analysis and requiring special consideration are explained in the following paragraphs.

519.2.1 Stress Range. As contrasted with stresses from sustained loads (such as internal pressure or weight), stresses caused by thermal expansion in systems stressed primarily in bending and torsion are permitted to attain sufficient initial magnitude to cause local yielding or creep. The attendant relaxation or reduction of stress in the hot condition leads to the creation of a stress reversal when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The amount of self-springing depends on the initial magnitude of the expansion stress, the material, the temperature, and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the arithmetic sum of the expansion stresses in the hot and cold conditions during any one cycle remains substantially constant. This sum, referred to as the stress range, is the determining factor in the thermal design of piping.

519.2.2 Expansion Range. In computing the stress range, the full thermal expansion range from the minimum to maximum metal temperature normally expected during installation and operation shall be used, whether the piping is cold sprung or not. Linear or angular movements of the equipment to which the piping is attached shall be included. For values of the unit thermal expansion range, refer to para. 519.3.1.

Where substantial anchor or terminal movements are anticipated as a result of tidal changes (unloading dock piping) or wind sway (piping attached to slender towers), these effects shall be considered analogous to terminal movements caused by thermal expansion.

519.2.3 Cold Spring. Cold spring is recognized as beneficial in that it serves to balance hot and cold stresses without drawing on the ductility of the material, for which reason it is recommended in particular for materials of relatively low ductility. In addition, it helps assure minimum departure from as-erected hanger settings. Inasmuch as the life of a system under cyclic conditions depends primarily on the stress range rather than the stress level at any one time, no credit for cold spring is given for stress range calculations. In calculating end thrusts and moments where actual reactions at any one time rather than their range are considered significant, cold spring is credited. (See para. 519.4.6.)

519.2.4 Local Overstrain. All the commonly used methods of piping flexibility analysis assume elastic behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain, or where, in piping operating in the creep range, the strain distribution is very uneven. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic followup of the stiffer or lower stressed portions. Unbalance can be produced:

(a) by use of small pipe runs in series with larger or stiffer pipe with the small lines relatively highly stressed;

(b) by local reduction in size or cross section, or local use of a weaker material;

(c) in a system of uniform size, by use of a line configuration for which the neutral axis (actually, the wrench axis) is situated close to the major portion of the line with only a very small portion projecting away from it absorbing most of the expansion strain.

Conditions of this type should preferably be avoided, particularly where materials of relatively low ductility are used; if unavoidable, they should be mitigated by the judicious application of cold spring.

519.3 Properties

The following paragraphs deal with materials and geometric properties of pipe and piping components and the manner in which they are to be used in piping flexibility analysis.

519.3.1 Unit Thermal Expansion Range. The thermal expansion range e (in./100 ft) shall be determined from Table 519.3.1 as the algebraic difference between the unit expansion shown for the maximum normal-operating metal temperature and that for the minimum normal-operating metal temperature. For materials not included in this Table, reference shall be made to au- **(a)**

TABLE 519.3.1
THERMAL EXPANSION DATA

Material	Linear Thermal Expansion, in./100 ft — Temperature Range, °F, 70 to −325	−150	−50	70	200	300	400
Carbon steel; carbon moly steel	−2.37	−1.45	−0.84	0.00	0.99	1.82	2.70
Nickel steel (3½Ni)	−2.37	−1.43	−0.81	0.00	1.00	1.80	2.61
Nickel steel (9Ni)	−2.27	−1.43	−0.81	0.00	0.98	1.77	2.57
Austenitic stainless steels	−3.85	−2.27	−1.24	0.00	1.46	2.61	3.80
Cast iron	. . .	. . .	. . .	0.00	0.90	1.64	2.42
Monel (67Ni–30Cu)	−2.62	−1.79	−0.98	0.00	1.22	2.21	3.25
Copper (99.90Cu) Alloys C12000 and C12200	−3.70	−2.28	−1.28	0.00	1.51	2.67	3.88
Red brass (85Cu) Alloy C23000	−3.88	−2.24	−1.29	0.00	1.52	2.76	4.05
Copper–nickel (90Cu–10Ni) Alloy C70600	−4.10	−2.26	−1.29	0.00	1.49	2.62	3.77
Copper–nickel (70Cu–30Ni) Alloy C71500	−3.15	−1.95	−1.13	0.00	1.35	2.46	3.59
Aluminum	−4.68	−2.88	−1.67	0.00	2.00	3.66	5.39
Copper silicon (3Si) Alloy C65500	−4.21	−2.31	−1.32	0.00	1.51	2.67	3.88

(a)

TABLE 519.3.2
MODULI OF ELASTICITY

Material	E = Modulus of Elasticity, psi (Multiply Tabulated Values by 10^6) — Temperature, °F −325	−150	−50	70	200	300	400
Carbon steels with carbon content 0.30 or less	30.0	29.2	28.7	27.9	27.7	27.4	27.0
Cast iron	. . .	. . .	. . .	13.4	13.2	12.9	12.6
Monel (67Ni–30Cu)	26.8	26.4	26.1	26.0	26.0	25.8	25.6
Copper (99.90Cu) Alloys C12000, C12200	17.5	16.8	16.5	16.5	16.3	16.2	16.0
Red brass (85Cu) Alloy C23000	18.2	17.7	17.5	17.0	16.6	16.4	15.8
Copper–nickel (90Cu–10Ni) Alloy C70600	20.2	19.6	18.8	18.8	18.2	17.7	17.4
Copper–nickel (70Cu–30Ni) Alloy C71500	22.8	22.8	21.8	21.8	21.5	21.2	21.0
Aluminum	11.3	11.0	10.8	10.6	10.4	10.2	9.5
Copper silicon (3Si) Alloy C65500	16.6	15.8	15.3	15.3	14.7	14.2	13.7

GENERAL NOTE: Refer to National Institute of Standards and Technology.

thoritative source data, such as publications of the National Institute of Standards and Technology.

(a) **519.3.2 Moduli of Elasticity.** The cold and hot moduli of elasticity, E_c and E_h, respectively, shall be taken from Table 519.3.2 for the minimum and maximum normal-operating metal temperatures in Table 519.3.2. For materials not included in these Tables, reference shall be made to authoritative source data, such as publications of the National Institute of Standards and Technology.

519.3.3 Poisson's Ratio. Poisson's Ratio is the ratio of the unit deformation at right angles to the direction of the load to the unit deformation in the direction of the load, and may be taken as 0.3 at all temperatures for all metals. However, more accurate data may be used if available.

519.3.4 Allowable Expansion Stress Range. The allowable basic expansion stress range S_A and permissible additive stresses shall be as specified in paras. 502.3.2(c) and (d) for systems primarily stressed in bending or torsion.

519.3.5 Dimensions. Nominal dimensions of pipe and fittings, and cross-sectional areas, moments of inertia, and section moduli based thereon shall be used in flexibility calculations, including the permissible additive stresses.

519.3.6 Flexibility and Stress Intensification Factors. Calculations shall take into account stress intensification factors found to exist in components other than plain straight pipe. Credit may be taken for the extra flexibility of such components. In the absence of more directly applicable data, the flexibility and stress intensification factors shown in Table 519.3.6 may be used. For piping components or attachments (such as valves, strainers, anchor rings or bands) not covered in the Table, suitable stress intensification factors may be assumed by comparison of their significant geometry with that of the components shown.

519.4 Analysis for Bending Flexibility

The following paragraphs establish under what circumstances and in what manner piping flexibility analyses are to be made where the system primarily derives its flexibility from bending or torsional strains.

519.4.1 Formal calculations or model tests shall be required only where reasonable doubt exists as to the adequate flexibility of a system.

519.4.2 Adequate flexibility may generally be assumed to be available in systems which:

(a) are duplicates of successfully operating installations or replacements of systems with a satisfactory service record;

(b) can be readily adjudged adequate by comparision with previously analyzed systems;

(c) are of uniform size, have no more than two points of fixation and no intermediate restraints, are designed for essentially noncyclic service (less than 7000 total cycles), and satisfy the following approximate criterion:

$$\frac{DY}{(L-U)^2} \le \frac{30S_A}{E_c}$$

where

D = nominal pipe size, in.

Y = resultant of movements to be absorbed by pipeline, in.

U = anchor distance (length of straight line joining anchors), ft

L = developed length of piping between anchors, ft

S_A = allowable stress range, psi, include stress range reduction factor f where more than 7000 cycles of movement are anticipated during the life of the installation (see Fig. 502.3.2)

E_c = modulus of elasticity of the piping material in the cold condition, psi

519.4.3 Methods of Analysis. Systems which do not meet the requirements of para. 519.4.2 shall be analyzed by a method appropriate to the hazard entailed by failure of the line, the importance of maintaining continuous service, the complexity of the layout, and strain sensitivity of the pipe material. Simplified or approximate methods may be applied without correction only if they are used for the range of configurations for which their adequate accuracy has been demonstrated. Accompanying any flexibility calculation, there shall be an adequate statement of the method and any simplifying assumptions used.

519.4.4 Standard Assumptions. Standard assumptions specified in para. 519.3 shall be followed in all cases. In calculating the flexibility of a piping system between anchor points, the system shall be treated as a whole. The significance of all parts of the line and of all restraints, such as solid hangers or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, and also the restraint introduced by support friction, shall be recognized. Not only the expansion of the line itself, but also linear and angular movements

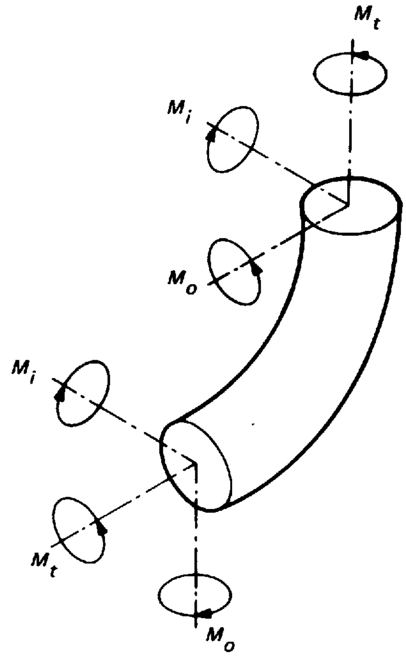


FIG. 519.4.5-B BENDS

of the equipment to which it is attached shall be considered.

519.4.5 Flexibility Stresses

(a) Bending and torsional stress shall be computed using the as-installed modulus of elasticity E_a ($E_a = E_c$ at installation temperature) and then combined in accordance with Eq. (24) to determine the computed stress range S_E, which shall not exceed the allowable stress range S_A in para. 502.3.2.

$$S_E = \sqrt{S_b{}^2 + 4S_t{}^2} \qquad (24)$$

where

S_b = resultant bending stress, psi
S_t = torsional stress, psi
= $M_t/2Z$
M_t = torsional moment, in-lb
Z = section modulus of pipe, in.^{3}

(b) The resultant bending stresses S_b, psi, to be used in Eq. (24) for elbows and miter bends shall be calculated in accordance with Eq. (25), with moments as shown in Fig. 519.4.5-B.

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z} \qquad (25)$$

where

i_i = inplane stress intensification factor from Table 519.3.6
i_o = outplane stress intensification factor from Table 519.3.6
M_i = inplane bending moment, in.-lb
M_o = outplane bending moment, in.-lb
Z = sectional modulus of pipe, in.^{3}

(c) The resultant bending stresses S_b to be used in Eq. (24) for branch connections shall be calculated in accordance with Eqs. (26) and (27) with moments as shown in Fig. 519.4.5-C.

(1) For header (Legs 1 and 2),

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z} \qquad (26)$$

(2) For branch (Leg 3),

$$S_b = \frac{\sqrt{(i_iM_i)^2 + (i_oM_o)^2}}{Z_e} \qquad (27)$$

where

S_b = resultant bending stress, ksi
Z_e = effective section modulus for branch of tee, in.^{3}
= $\pi r_m{}^2 t_s$
r_m = mean branch cross-sectional radius, in.
t_s = effective branch wall thickness, in. (lesser of t_h and $i_o t_b$)
t_h = thickness of pipe matching run of tee or header exclusive of reinforcing elements, in.
t_b = thickness of pipe matching branch, in.
i_o = outplane stress intensification factor
i_i = inplane stress intensification factor

(d) Allowable stress range S_A and permissible additive stresses shall be computed in accordance with paras. 519.2.1 and 519.2.2.

519.4.6 Reactions. The reactions (forces and moments) R_h and R_c in the hot and cold conditions, respectively, shall be obtained from the reaction range R derived from the flexibility calculations, using Eqs. (28) and (29): **(a)**

In the design of anchors and restraints and in the evaluation of some mechanical effects of expansion on terminal equipment (such as pumps, heat exchangers, etc.) either reaction range R (see definition below) or instantaneous values of reaction forces and moments in the hot or cold condition may be of significance. Deter-

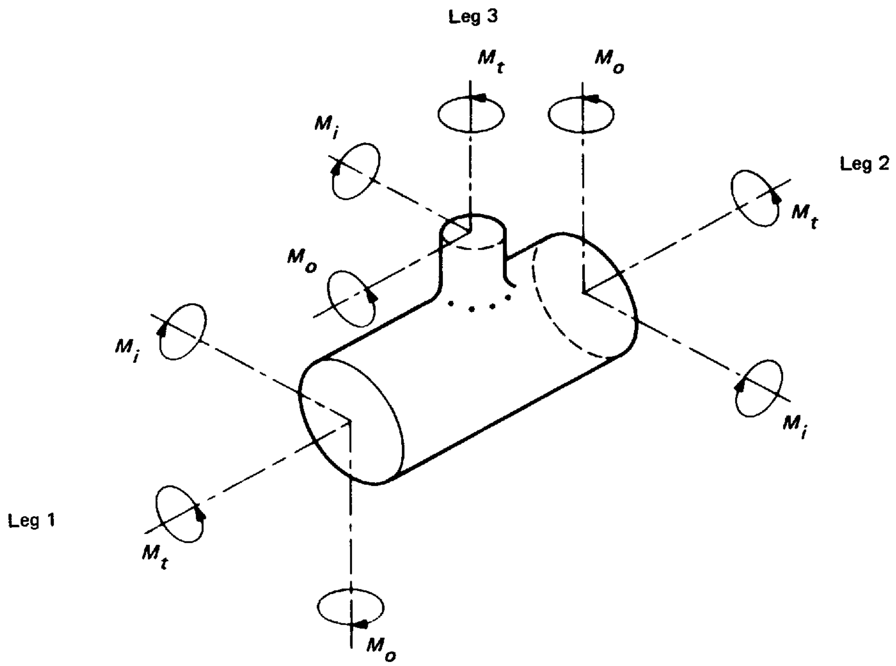


FIG. 519.4.5-C BRANCH CONNECTIONS

mination of the latter may be complicated by the difficulty of performing the desired cold spring and by other factors. Thus their determination may imply an elaborate engineering calculation, the basis of which should be clearly set forth. In the absence of a better procedure, in the case of one material uniform-temperature two anchor systems without intermediate constraints, the hot and cold reactions may be estimated by the formulas:

$$R_h = (1 - \tfrac{2}{3}C)\,\frac{E_h}{E_c}R \qquad (28)$$

$$R_c = CR \text{ or } C_1R, \text{ whichever is greater} \qquad (29)$$

where

C = cold spring factor varying from zero for no cold spring to one for 100% cold spring

NOTE: Factor ⅔ appearing in Eq. (28) accounts for observation that specified cold spring cannot be fully assured, even with elaborate precautions.

C_1 = estimated self-spring or relaxation factor; use zero if value becomes negative
$= 1 - S_hE_c/S_EE_h$

E_c = modulus of elasticity in the cold condition, ksi

E_h = modulus of elasticity in the hot condition, ksi

R = range of reaction forces or moments corresponding to the full expansion range based on E_c, lb or in.-lb

R_c, R_h = maximum reaction forces or moments estimated to occur in the cold and hot conditions, respectively, lb or in.-lb

S_E = maximum computed expansion stress range at any point in the line, ksi (see paras. 519.2.1 and 519.2.2)

S_h = basic material allowable stress at maximum (hot) normal temperature, ksi. (Use *S,* not *SE,* from para. 502.3.1 and Table 502.3.1.)

519.4.7 Reaction Limits. The computed reactions shall not exceed limits which connected equipment, specifically strain sensitive components, such as pumps, compressors, valves, strainers, tanks, and pressure vessels, can safely sustain.

519.4.8 Movements. Calculation of displacements and rotations at specific locations may be required where clearance problems are involved. In cases where small-size branch lines attached to stiff main lines are to be calculated separately, the linear and angular movements of the junction point must be calculated or estimated for proper analysis of the branch.

520 DESIGN OF PIPE SUPPORTING ELEMENTS

520.1 General

Loads on equipment supporting, bracing, guiding, or anchoring piping include, in addition to weight effects, loads due to service pressure and temperatures, vibration, wind, earthquake, shock, erection contingencies (including testing), thermal expansion and contraction, and differential settlement of foundations, all as defined in para. 501. The design of all elements supporting or restraining pipe shall have regard to the degree of probability of concurrence of loads and whether they are sustained or tend to relax themselves as defined in para. 519.2.1.

520.1.1 Objectives. Supporting elements shall be designed to prevent the loadings and deflections due to the influences delineated in para. 520.1 from causing:

(a) piping stresses in excess of those permitted in this Section of the Code;

(b) leakage at joints;

(c) detrimental distortion of connected equipment (such as pumps, turbines, valves, etc.) resulting from excessive forces and moments;

(d) excessive stresses in the pipe supporting (or restraining) elements themselves;

(e) resonance with imposed vibrations;

(f) excessive interference with the thermal expansion and contraction of a piping system which is otherwise adequately flexible;

(g) unintentional disengagement of the piping from its supports;

(h) excessive piping sag in systems requiring drainage slope.

520.1.2 Allowable Stresses in Piping. The design of piping-support elements shall be such that the sustained piping stresses shall not exceed the allowable value as defined in paras. 502.3.2(d) and 523.2.2(f)(4).

520.1.3 Allowable Stresses in Piping Support and Restraint Components

(a) The allowable stress for the base material of all parts of supporting and restraint assemblies shall not exceed the appropriate S value taken from para. 502.-3.1 and Table 502.3.1 including Notes except as permitted in 520.1.3(b). It is not necessary to include joint factors.

The allowable stress shall be reduced 25% for threaded members and for welds in support assemblies or for attachments to piping. For threaded members stresses shall be based on the root area of the threads.

(b) An increase in allowable stress of 20% shall be allowed for short-time overloading conditions.

(c) For requirements pertaining to springs, see para. 521.3.2.

(d) For requirements pertaining to anchors and guides, see paras. 521.1.3 and 521.1.4.

(e) The principles in para. 502.3.1(d) are not applicable to design of springs.

(f) Pipe support and hanger components conforming to the requirements of para. 502.3.1 may have an increase in their working stress to 80% of minimum yield strength at room temperature for the period of hydrostatic testing. This applies only to supports that have been engineered by the designer and not to standard catalog items unless they have been carefully analyzed by the designer.

520.1.4 Materials — Steel. All equipment for permanent supports and restraints shall be fabricated from durable materials suitable for the service conditions. Unless otherwise permitted in para. 520.1.5, steel shall be used for pipe supporting elements. All materials shall be capable of meeting the respective standard specifications given in Table 523.1 with regard to the tests and physical properties.

Parts of supporting elements which are subjected principally to bending or tension loads and which are subjected to working temperatures for which carbon steel is not recommended shall be made of suitable alloy steel, or shall be protected so that the temperature of the supporting members will be maintained within their temperature limits.

520.1.5 Materials Other Than Those in Para. 520.1.4. Cast iron may be used for roller bases, rollers, anchor bases, brackets, and parts of pipe supporting elements upon which the loading will be mainly that of compression. Malleable or nodular iron castings may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, swivel rings, and parts of pipe supporting elements. Treated wood may be used for pipe supporting elements which are primarily in compression when the metal temperatures are at or below ambient temperature.

Materials other than those listed in Table 523.1 may be employed to take advantage of their superior properties, in specialty items such as constant support hangers. In such cases, allowable stresses shall be determined in accordance with the principles given in para. 502.3.1.

520.1.6 Protective Coatings

(a) Under conditions causing mild corrosion, such as atmospheric rusting, which are not of an intensity to

(a)

TABLE 521.3.5
MINIMUM SIZES OF STRAPS, RODS, AND CHAINS FOR HANGERS

Nominal Pipe Size	Component (Steel)	Minimum Stock Size, in.	
		Exposed to Weather	Protected from Weather
1 and smaller	Strap	1/8 thick	1/16 thick × 3/4 wide
Above 1	Strap	1/4 thick	1/8 thick × 1 wide
2 and smaller	Rod	3/8 diameter	3/8 diameter
Above 2	Rod	1/2 diameter	1/2 diameter
2 and smaller	Chain	3/16 diameter or equivalent area	3/16 diameter or equivalent area
Above 2	Chain	3/8 diameter or equivalent area	3/8 diameter or equivalent area
All sizes	Bolted clamps	3/16 thick; bolts 3/8 diameter	3/16 thick; bolts 3/8 diameter

GENERAL NOTE: For nonferrous materials, the minimum stock area shall be increased by the ratio of allowable stress of steel to the allowable stress of the nonferrous material.

warrant the use of corrosion resistant materials, a durable protective coating, such as hot-dipped galvanizing, weather resistant paint, or other suitable protection, should be applied to all parts after fabrication or after installation.

(a) *(b)* Under any conditions, exposed screw threads on parts of the equipment where corrosion resistant materials are not used shall be greased immediately after fabrication. Paints, slushes, or other suitable protective coatings may be used instead of grease.

520.1.7 Threaded Components. Threads shall be in accordance with ANSI B1.1, except that other thread forms may be used to facilitate adjustment under heavy loads. All threaded adjustments shall be provided with lock nuts or be locked by other positive means. Turnbuckles and adjusting nuts shall have the full length of thread in service. Means shall be provided for determining that full length of thread is in service.

521 DESIGN LOADS FOR PIPE SUPPORTING ELEMENTS

521.1 General

521.1.1 Forces and moments at pipe supporting elements caused by thermal expansion or contraction shall be determined as necessary.

521.1.2 Weight calculations for gas, vapor, or safety valve discharge piping should not include the weight of liquid if the possibility of these lines containing liquid is remote and provided the lines are not subjected to hydrostatic tests.

521.1.3 Restraints, such as anchors and guides, shall be provided where necessary to control movement or to direct expansion and/or other effects into those portions of the system which are adequate to absorb them for the purpose of protecting terminal equipment and/or other (weaker) portions of the system. The effect of friction in other supports of the system shall be considered in the design of such anchors and guides.

521.1.4 Anchors or guides for expansion joints of the corrugated or slip-type (or variants of these types) shall be designed to resist end forces from fluid pressure and frictional or other applicable resistance to joint movement, in addition to other loadings.

521.2 Resilient Variable-Support and Constant-Support Types

Reactions or load calculations for resilient or constant effort type supports, such as springs or weight loaded supports and braces, shall be based on the maximum working conditions of the piping. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided for the test period. The amount of variation that can be tolerated shall be determined by incorporating the change in supporting effect in the flexibility analysis or shall be based on such considerations as bending effect, control of piping elevation, allowable terminal reactions, etc.

521.3 Design Details

521.3.1 General

(a) *(a) Hanger Rods.* Safe axial loads for threaded hanger rods shall be based on the root area of the threads and subject to 25% reduction in allowable stress as in para. 520.1.3(a). Pipe, straps, or bars of strength and effective area equal to the equivalent hanger rod may be used instead of hanger rods. See also Table 521.3.5.

(b) Chains. Chain may be used for pipe hangers and shall be designed in accordance with para. 521.3.1(a).

(c) Sliding Supports. Sliding supports (or shoes) and brackets shall be designed to resist the forces due to friction in addition to the loads imposed by bearing. The dimensions of the support shall provide for the expected movement of the supported piping.

(d) At point of support subject to horizontal movement, the movement shall be provided for by the swing of long hanger rods or chains or by the use of trolleys, rollers, sliding or swinging supports.

(e) Covering on insulated piping shall be protected from damage at all hanger locations. Saddles, bases, or suitable shields properly constructed and secured to the covered pipe shall be used at points of roller, base, and trapeze support.

(f) Lugs, plates, angle clips, etc., used as part of an assembly for the support or guiding of pipe may be welded directly to the pipe provided the material is of good weldable quality and the design is adequate for the load. Preheating, welding, and postheating *shall* be in accordance with the rules of Chapter V.

(g) See MSS SP-58 for typical design details.

521.3.2 Spring Supports. Spring type supports shall be provided with means to prevent misalignment, buckling, or eccentric loading of the spring, and to prevent unintentional disengagement of the load. Materials shall be in accordance with the provisions of paras. 520.1.4 and 520.1.5. Constant support spring hangers shall be designed to provide a substantially uniform supporting force throughout the range of travel. All spring elements shall be provided with means of adjustment for the pipe position in the operating and nonoperating condition. Means shall be provided to prevent overstressing the spring due to excessive deflections. It is desirable that all spring hangers be provided with position indicators.

521.3.3 Counterweights. Counterweights when used instead of spring hangers shall be provided with stops to prevent overtravel. Weights shall be positively secured. Chains, cables, hanger and rocker arm details, or other devices used to attach the counterweight load to the piping, shall be subject to requirements of para. 521.3.1.

521.3.4 Hydraulic Type Supports. An arrangement utilizing a constant hydraulic head may be installed to give a constant supporting effort. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

521.3.5 Sway Braces or Vibration Dampeners. Sway braces and vibration dampeners may be used to limit the movement of piping due to vibration.

CHAPTER III
MATERIALS

523 MATERIALS — GENERAL REQUIREMENTS

523.1 Acceptable Materials and Specifications

The materials used shall conform to the specifications listed in Table 523.1 or shall meet the requirements of this Code for materials not so established.

Reclaimed pipe and piping components may be used provided they are properly identified as conforming to a specification listed in Table 523.1 and otherwise meet applicable requirements of this Code.

523.2 Limitations on Materials

523.2.1 General. The materials listed in Table 502.-3.1 shall not be used at design temperatures above those for which stress values are given in the Table. The materials shall not be used below −20°F, unless they meet the impact test requirements of para. 523.2.2.

523.2.2 Impact Tests. Materials subject to temperatures below −20°F, except for those exempted in (f) below, shall be impact tested as required by UG-84 of Section VIII, Division 1, of the ASME BPV Code, with the following substitution for UG-84(b)(2).

(a) A welded test section shall be prepared from a piece of plate, pipe, or tubing for each material specification certified by the manufacturer in accordance with UG-84(e).

(b) If the material to be used is not certified, test sections shall be prepared from each piece of pipe, plate, or tubing used.

(c) One set of impact-test specimens shall be taken across the weld (the metal tested is the weld metal) with the notch in the weld, and one set shall be taken similarly with the notch at the fusion line (the metal tested is the base metal).

(d) Impact test specimens shall be cooled to a temperature not higher than the lowest temperature to which the pipe, plate, or tubing may be subjected in its operating cycle.

(e) One set of impact-test specimens with the notch in the weld metal and one set with the notch at the fusion line, shall be made for each range of pipe thickness that does not vary by more than ¼ in. over and under the tested thickness for each material specification used on the job.

(f) The following materials are exempted from the requirements for impact testing.

(1) Impact tests are not required for aluminum; Types 304 or CF8, 304L or CF3, 316 or CF8M, and 321 austenitic stainless steel; copper; red brass; copper–nickel alloys; and nickel–copper alloys.

(2) Impact tests are not required for bolting material conforming with A 193, Grade B7, for use at temperatures above −50°F.

(3) Impact tests are not required for bolting materials conforming with A 320, Grades L7, L10, and L43, at temperatures above −150°F or above −225°F for A 320, Grade L9.

(4) Impact tests are not required for ferrous materials used in fabricating a piping system for metal temperatures between −20°F and −150°F provided the maximum circumferential or longitudinal tensile stress resulting from coincident pressure, thermal contraction, or bending between supports does not exceed 40% of the allowable stress for the materials as given in Table 502.3.1. See paras. 502.3.2, 519, and 520.

523.2.3 Cast Iron and Malleable Iron. Cast iron and malleable iron shall not be used for piping components in hydrocarbon or other flammable fluid service at temperatures above 300°F, nor at gage pressures above 300 psi. Cast iron or malleable iron shall not be used at temperatures below −150°F.

523.2.4 Nodular Iron. Nodular iron shall not be used for piping components at gage pressures above 1000 psi or at temperatures below −150°F.

TABLE 523.1
ACCEPTABLE MATERIALS — SPECIFICATIONS

Component	Specification	Material
Bolting	ASTM A 193	Alloy steel and stainless steel bolting materials for high temperature service
	ASTM A 194	Carbon and alloy steel nuts for bolts for high pressure and high temperature service
	•ASTM A 307	Carbon steel bolts and studs, 60,000 psi tensile
	ASTM A 320	Alloy steel bolting materials for low-temperature service
	ASTM A 325	High strength bolts for structural steel joints
	ASTM A 354	Quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners
	ASTM B 21	Naval brass rod, bar, and shapes
	ASTM B 98	Copper-silicon alloy rod, bar, and shapes
	•ASTM B 211	Aluminum and aluminum alloy bars, rods, and wire
Fittings, valves, flanges	•ASTM A 47	Ferritic malleable iron castings
	ASTM A 48	Gray iron castings
	ASTM A 105	Forgings, carbon steel, for piping components
	ASTM A 126	Gray iron castings for valves, flanges, and pipe fittings
	•ASTM A 181	Forgings, carbon steel for general purpose piping
	ASTM A 182	Forged or rolled alloy steel pipe flanges, forged fittings, and valves and parts for high temperature service
	ASTM A 197	Cupola malleable iron
	•ASTM A 216	Steel castings, carbon, suitable for fusion welding for high temperature service
	•ASTM A 217	Steel castings, martensitic stainless and alloy, for pressure containing parts suitable for high temperature service
	ASTM A 234	Piping fittings of wrought carbon steel and alloy steel for moderate and elevated temperatures
	ASTM A 278	Gray iron castings for pressure containing parts for temperatures up to 650°F (345°C)
	ASTM A 350	Forgings, carbon and low alloy steel, requiring notch toughness testing for piping components
	•ASTM A 351	Steel castings for high temperature service
	•ASTM A 352	Steel castings, ferritic and martensitic, for pressure containing parts, suitable for low temperature service
	ASTM A 395	Ferritic ductile iron for pressure retaining castings for use at elevated temperatures
	•ASTM A 403	Wrought austenitic stainless steel piping fittings
	ASTM A 420	Piping fittings of wrought carbon steel and alloy steel for low temperature service
	ASTM A 522	Forged or rolled 8% and 9% nickel alloy steel flanges, fittings, valves, and parts for low temperature service
	•ASTM A 743	Castings, iron–chromium, iron–chromium–nickel, and nickel base, corrosion resistant, for general application
	•ASTM A 744	Castings, iron–chromium–nickel and nickel base, corrosion resistant, for severe service

• = (a)

TABLE 523.1 (CONT'D)
ACCEPTABLE MATERIALS — SPECIFICATIONS

Component	Specification	Material
Fittings, valves, flanges (cont'd)	ASTM B 16	Free-cutting brass rod, bar, and shapes for use in screw machines
	ASTM B 21	Naval brass rod, bar, and shapes
	ASTM B 26	Aluminum alloy sand castings
	ASTM B 61	Steam or valve bronze castings
	ASTM B 62	Composition bronze or ounce metal castings
	ASTM B 85	Aluminum alloy die castings
	ASTM B 124	Copper and copper alloy forging rod, bar, and shapes
	ASTM B 179	Aluminum alloys in ingot form for sand castings, permanent mold castings, and die castings
	•ASTM B 247	Aluminum and aluminum alloy die, hand, and rolled ring forgings
	ASTM B 283	Copper and copper alloy die forgings (hot pressed)
	ASTM B 361	Factory made wrought aluminum and aluminum alloy welding fittings
	ASTM B 584	Copper alloy sand castings for general applications
	AWWA C110	Gray iron and ductile iron fittings 2 in. through 48 in. for water and other liquids
Steel pipe	ASTM A 53 [Note (1)]	Pipe, steel, black and hot dipped, zinc coated, welded and seamless
	ASTM A 106	Seamless carbon steel pipe for high temperature service
	•ASTM A 134	Pipe, steel electric-fusion-(arc) welded (sizes NPS 16 in. and over)
	ASTM A 135	Electric-resistance welded steel pipe
	•ASTM A 139	Electric-fusion-(arc) welded steel pipe (sizes NPS 4 in. and over)
	ASTM A 211	Spiral-welded steel or iron pipe
	ASTM A 312	Seamless and welded austenitic stainless steel pipe
	ASTM A 333	Seamless and welded steel pipe for low temperature service
	ASTM A 358	Electric-fusion welded austenitic chromium–nickel alloy steel pipe for high temperature service
	ASTM A 376	Seamless austenitic steel pipe for high-temperature central-station service
	•ASTM A 409	Welded large outside diameter austenitic steel pipe for corrosive or high temperature service
	ASTM A 587	Electric-welded low carbon steel pipe for the chemical industry
	API 5L	Line pipe
Nonferrous pipe	ASTM B 42	Seamless copper pipe, standard sizes
	ASTM B 43	Seamless red brass pipe, standard sizes
	ASTM B 165	Nickel–copper alloy (UNS N04400) seamless pipe and tube
	•ASTM B 241	Aluminum and aluminum alloy seamless pipe and seamless extruded tube
	ASTM B 302	Threadless copper pipe
	ASTM B 315	Seamless copper alloy pipe and tube
	•ASTM B 345	Aluminum and aluminum alloy seamless pipe and seamless extruded tube for gas and oil transmission and distribution piping systems
	ASTM B 466	Seamless copper–nickel alloy pipe and tube
	ASTM B 467	Welded copper-nickel pipe

• = (a)

TABLE 523.1 (CONT'D) ACCEPTABLE MATERIALS — SPECIFICATIONS

	Component	Specification	Material
	Steel tube	ASTM A 178	Electric-resistance welded carbon steel boiler tubes
		ASTM A 179	Seamless cold-drawn low carbon steel heat exchanger and condenser tubes
		ASTM A 192	Seamless carbon steel boiler tubes for high pressure service
		ASTM A 210	Seamless medium-carbon steel boiler and superheater tubes
		ASTM A 213	Seamless ferritic and austenitic alloy steel boiler, superheater, and heat exchanger tubes
		ASTM A 214	Electric-resistance welded carbon steel heat exchanger and condenser tubes
		ASTM A 226	Electric-resistance welded carbon steel boiler and superheater tubes for high pressure service
		•ASTM A 249	Welded austenitic steel boiler, superheater, heat exchanger and condenser tubes
		ASTM A 254	Copper brazed steel tubing
		ASTM A 269	Seamless and welded austenitic stainless steel tubing for general service
		ASTM A 271	Seamless austenitic chromium–nickel steel still tubes for refinery service
		•ASTM A 334	Seamless and welded carbon and alloy steel tubes, for low temperature service
	Nonferrous tube	•ASTM B 68	Seamless copper tube, bright annealed
		ASTM B 75	Seamless copper tube
		ASTM B 88	Seamless copper water tube
		ASTM B 111	Copper and copper alloy seamless condenser tubes and ferrule stock
		ASTM B 165	Nickel–copper alloy (UNS N04400) seamless pipe and tube
		ASTM B 210	Aluminum alloy drawn seamless tubes
		•ASTM B 234	Aluminum and aluminum alloy drawn seamless tubes for condensers and heat exchangers
		ASTM B 280	Seamless copper tube for air conditioning and refrigeration field service
		ASTM B 315	Seamless copper alloy pipe and tube
		ASTM B 466	Seamless copper–nickel pipe and tube
(a)	Steel plate	ASTM A 36	Structural steel
		ASTM A 240	Heat-resisting chromium and chromium–nickel stainless steel plate, sheet, and strip for pressure vessels
		•ASTM A 283	Low and intermediate tensile strength carbon steel plates
		ASTM A 285	Pressure vessel plates, carbon steel, low and intermediate tensile strength
		•ASTM A 353	Pressure vessel plates, alloy steel, 9% nickel, double-normalized and tempered
		ASTM A 515	Pressure vessel plates, carbon steel, for intermediate- and higher-temperature service

• = (a)

TABLE 523.1 (CONT'D)
ACCEPTABLE MATERIALS — SPECIFICATIONS

	Component	Specification	Material
(a)	Steel plate (cont'd)	ASTM A 516	Pressure vessel plates, carbon steel, for moderate- and lower-temperature service
		ASTM A 553	Pressure vessel plates, alloy steel, quenched and tempered 8% and 9% nickel
		•ASTM A 570	Hot rolled carbon steel sheet and strip, structural quality
		•ASTM A 611	Steel, cold rolled sheet, carbon, structural
	Nonferrous plate	•ASTM B 96	Copper–silicon alloy plate, sheet, strip, and rolled bar for general purposes and pressure vessels
		ASTM B 152	Copper, sheet, strip, plate, and rolled bar
		ASTM B 171	Copper alloy condenser tube plates
		ASTM B 209	Aluminum and aluminum alloy sheet and plate
		ASTM B 248	General requirements for wrought copper and copper alloy plate, sheet, strip, and rolled bar
	Welding electrodes and rods for steel and iron	•ASME SFA-5.1 or AWS A5.1	Covered carbon steel arc welding electrodes
		•ASME SFA-5.2 or AWS A5.2	Carbon and low alloy steel rods for oxyfuel gas welding
		•ASME SFA-5.4 or AWS A5.4	Covered corrosion resisting chromium and chromium–nickel steel welding electrodes
		•ASME SFA-5.9 or AWS A5.9	Corrosion resisting chromium and chromium–nickel steel bare and composite metal cored and stranded welding electrodes and welding rods
	Welding electrodes for nonferrous metals	AWS A5.3	Aluminum and aluminum alloy covered arc welding electrodes
		ASME SFA-5.6 or AWS A5.6	Copper and copper alloy covered electrodes
		ASME SFA-5.7 or AWS A5.7	Copper and copper alloy bare welding rods and electrodes
		•ASME SFA-5.10 or AWS A5.10	Bare aluminum and aluminum alloy welding electrodes and rods
		AWS A5.12	Tungsten arc welding electrodes
	Solder and brazing metal	ASTM B 32	Solder metal
		ASME SFA-5.8 or AWS A5.8	Brazing filler metal
	Springs	ASTM A 125	Steel springs, helical, heat treated
	Chains	•ASTM A 413	Carbon steel chain
		ASTM A 466	Weldless carbon steel chain
		•ASTM A 467	Machine and coil chain

• = (a)

TABLE 523.1 (CONT'D)
ACCEPTABLE MATERIALS — SPECIFICATIONS

Component	Specification	Material
Bars	•ASTM A 663	Steel bars, carbon, merchant quality, mechanical properties
	ASTM A 675	Steel bars, carbon, hot wrought, special quality, mechanical properties
	•ASTM B 221	Aluminum alloy extruded bars, rods, wire, shapes, and tubes

GENERAL NOTES:
(a) For specific edition of specifications referred to in this Code, see Appendix A and subsequent addenda.
(b) All ASME SFA specifications appear in Section II, Part C, of the ASME BPV Code.

NOTE:
(1) Excluding Grade F (see para. 505.1.1).

• = (a)

523.2.5 Clad and Lined Materials. Clad and lined materials may be used in accordance with the applicable requirements in Part UCL of Section VIII, Division 1, of the ASME BPV Code.

523.2.6 Nonmetallic Pressure Containing Components. Nonmetallic pressure containing components, such as plastics, glass, carbon, rubber, or ceramics, may be used even if not specifically listed in this Code. If stress data are not available for establishment of allowable stresses, the components may be qualified per para. 504.7. Consideration shall be given to the suitability of the material for the service temperature, its resistance to deterioration from the service fluid or environment, its flammability, its resistance to shock, its creep, and its proper support and protection from mechanical damage.

523.3 Deterioration of Materials in Service

The selection of materials to resist deterioration in service is outside the scope of this Code. It is the responsibility of the engineer to select materials suitable for the conditions of operation.

524 MATERIALS APPLIED TO MISCELLANEOUS PARTS

524.1 Gaskets

Limitations on gasket materials are covered in para. 508.4.

524.2 Bolting

Limitations on bolting materials are covered in paras. 508.5 and 523.2.2.

CHAPTER IV
DIMENSIONAL REQUIREMENTS

526 DIMENSIONAL REQUIREMENTS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

526.1 Standard Piping Components

Dimensional standards for piping components are listed in Table 526.1. Also, certain material specifications listed in Table 523.1 contain dimensional requirements which are requirements of para. 526. Dimensions of piping components shall comply with these standards and specifications unless the provisions of para. 526.2 are met.

526.2 Nonstandard Piping Components

The dimensions for nonstandard piping components shall, where possible, provide strength and performance equivalent to standard components, except as permitted under para. 504. For convenience, dimensions shall conform to those of comparable standard components.

526.3 Threads

The dimensions of all piping connection threads not otherwise covered by a governing component standard or specification shall conform to the requirements of applicable standards listed in Table 526.1.

(a)

TABLE 526.1
DIMENSIONAL STANDARDS

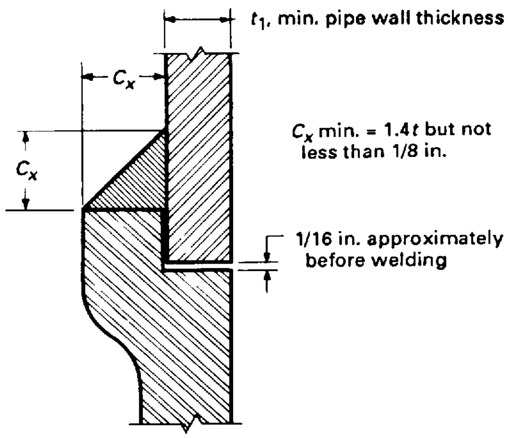
Standard	Designation
Bolting	
Square and Hex Bolts and Screws	ANSI B18.2.1
Square and Hex Nuts	ANSI B18.2.2
Fittings, Valves, Flanges, and Gaskets	
Cast Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, 250, and 800	ASME/ANSI B16.1
Malleable Iron Threaded Fittings, Classes 150 and 300	ASME B16.3
Cast-Iron Threaded Fittings, Classes 125 and 250	ASME B16.4
Steel Pipe Flanges and Flanged Fittings	ASME/ANSI B16.5
Factory Made Wrought Steel Buttwelding Fittings	ASME B16.9
Face-to-Face and End-to-End Dimensions of Valves	ASME B16.10
Forged Steel Fittings, Socket-Welding and Threaded	ASME B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts With Pipe Threads	ASME B16.14
Cast Bronze Threaded Fittings, Classes 125 and 250	ANSI/ASME B16.15
Cast Copper Alloy Solder-Joint Pressure Fittings	ANSI B16.18
Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings	ASME/ANSI B16.22
Cast Copper Alloy Pipe Flanges and Flanged Fittings: Class 150, 300, 400, 600, 900, 1500, and 2500	ASME B16.24
Buttwelding Ends	ASME B16.25
Wrought Steel Buttwelding Short Radius Elbows and Returns	ASME/ANSI B16.28
Valves-Flanged, Threaded, and Welding Ends	ASME/ANSI B16.34
Gray-Iron and Ductile-Iron Fittings, 2-Inch Through 48-Inch for Water and Other Liquids	ANSI/AWWA C110
Gate Valves 3 Through 48 Inch NPS for Water and Sewage Systems	ANSI/AWWA C500
Refrigeration Type Fittings	ANSI/SAE J513
Flanged and Butt-Welded-End Steel Gate and Plug Valves for Refinery Use	API 600
Metallic Gaskets for Refinery Piping	API 601
Fittings, Tube, Cast Bronze, Silver Brazing	MIL-F-1183E
Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron, and Steel Flanges	MSS SP-9
Standard Marking System for Valves, Fittings, Flanges, and Unions	MSS SP-25
Class 150 Corrosion-Resistant Gate, Globe, Angle, and Check Valves With Flanged and Buttwelding Ends	MSS SP-42
Wrought Stainless Steel Butt-Welding Fittings	MSS SP-43
Bypass and Drain Connection Standard	MSS SP-45
Class 150LW Corrosion-Resistant Cast Flanges and Flanged Fittings	MSS SP-51
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
Bronze Gate, Globe, Angle and Check Valves	MSS SP-80
Pipe Hanger and Supports-Materials Design and Manufacture	ANSI/MSS SP-58

(a)

TABLE 526.1 (CONT'D)
DIMENSIONAL STANDARDS

Standard	Designation
Pipe and Tube	
Welded and Seamless Wrought Steel Pipe	ANSI B36.10
Stainless Steel Pipe	ANSI B36.19
Miscellaneous	
Unified Screw Threads	ASME B1.1
Pipe Threads	ANSI/ASME B1.20.1
Dryseal Pipe Threads	ANSI B1.20.3
Mechanical Refrigeration, Safety Code for	ANSI/ASHRAE 15
Number Designation for Refrigerants	ANSI/ASHRAE 34

GENERAL NOTE: For specific edition of specifications referred to in this Code, see Appendix A and subsequent Addenda.



(a) FIG. 527.4.4-C MINIMUM WELDING DIMENSIONS REQUIRED FOR SOCKET WELDING COMPONENTS OTHER THAN FLANGES

t_e = nominal thickness of reinforcing element (ring or saddle), in. (t_e = 0 if there is no added reinforcement.)

t_{min} = t_n or t_e, whichever is smaller

(c) Branch connections (including specially made integrally reinforced branch connection fittings) which abut the outside surface of the run (header) wall, or which are inserted through an opening cut in the run (header) wall, shall have opening and branch contour where necessary to provide a good fit and shall be attached by means of fully penetrated groove welds. The fully penetrated groove welds shall be finished with cover fillet welds having a minimum throat dimension not less than t_c [see Fig. 527.4.6-D sketches (a) and (b)]. The limitations as to imperfection of these groove welds shall be as set forth in para. 527.4.2(d) for butt welds.

(d) In branch connections having reinforcement pads or saddles, the reinforcement shall be attached by welds at the outer edge and at the branch periphery as follows.

(1) If the weld joining the added reinforcement to the branch is a fully penetrated groove weld, it shall be finished with a cover fillet weld having a minimum throat dimension not less than t_c; the weld at the outer edge, joining the added reinforcement to the run (header), shall be a fillet weld with a minimum throat dimension of $0.5t_e$ [see Fig. 527.4.6-D sketches (c) and (d)].

(2) If the weld joining the added reinforcement to the branch is a fillet weld, the throat dimension shall not be less than $0.7t_{min}$ [see Fig. 527.4.6-D sketch (e)]. The weld at the outer edge joining the outer reinforcement to the run (header) shall also be a fillet weld with a minimum throat dimension of $0.5t_e$.

(e) When rings or saddles are used, a vent hole shall be provided (at the side and not at the crotch) in the ring or saddle to reveal leakage in the weld between branch and main run and to provide venting during welding and heat treating operations. Rings or saddles may be made in more than the one piece if the joints between the pieces have adequate strength and if each piece is provided with a vent hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

527.4.7 Welded Flat Plate Closures. Figures 527.4.7-A and 527.4.7-B show acceptable and unacceptable welds for flat plate closures in pipe. See para. 504.4.2 for nomenclature.

527.4.8 Heat Treatment for Welds. Heat treatment of welds shall be in accordance with para. 531.

527.5 Qualification

527.5.1 General

(a) The qualification of welding procedures and welders performance for both ferrous and nonferrous materials shall be in accordance with Section IX, ASME BPV Code, or with AWS welding procedure, AWS D10.9 Level AR-1 for refrigerant piping, Level AR-1 or AR-3 for nonvolatile brine piping.

(b) General Requirements

(1) The following rules shall apply to the qualification of welding procedures and welder performance for all types of manual, semiautomatic, and automatic arc and gas welding processes.

(2) Each employer is responsible for the welding done by personnel of its organization and shall conduct the tests required in Section IX, ASME BPV Code, or AWS D10.9, to qualify the welding procedures used in the construction of weldments constructed under this Code Section and to qualify welders and welding operators who apply these procedures, and the employer shall maintain records thereof.

(3) To avoid duplication of qualification tests of procedures, welders or welding operators, the procedures, welders, or welding operators qualified as required above by one employer may be accepted by another employer on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME BPV Code, or AWS D10.9. The contractor, fabricator, or

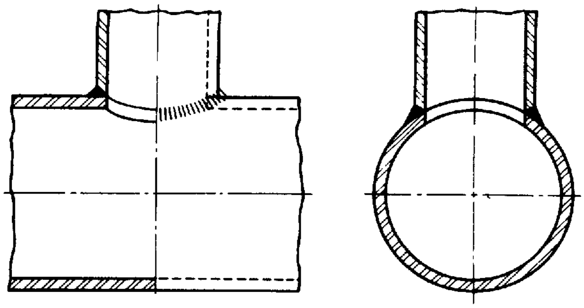


FIG. 527.4.6-A TYPICAL WELDED BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

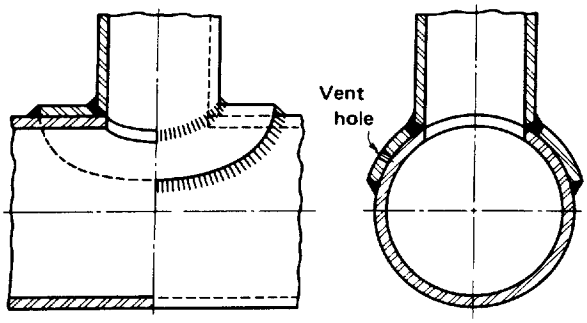


FIG. 527.4.6-B TYPICAL WELDED BRANCH CONNECTION WITH ADDITIONAL REINFORCEMENT

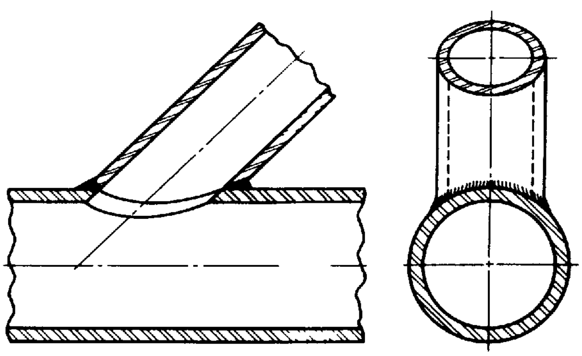
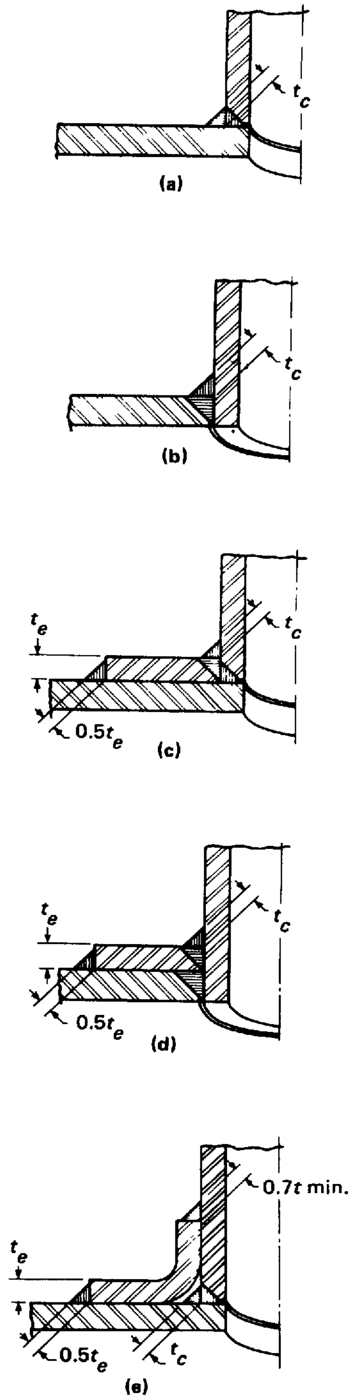


FIG. 527.4.6-C TYPICAL WELDED ANGULAR BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT



GENERAL NOTE:
Weld dimensions may be larger than the minimum values shown here.

FIG. 527.4.6-D SOME ACCEPTABLE TYPES OF WELDED BRANCH ATTACHMENT DETAILS SHOWING MINIMUM ACCEPTABLE WELDS

CHAPTER VI
INSPECTION AND TEST

536 INSPECTION

(a) Prior to initial operation, a piping installation shall be inspected to the extent necessary to assure compliance with the engineering design, material, fabrication, assembly, and test requirements of this Code. Systems shall be inspected visually after complete installation and before operation, except that parts of the system that would not be accessible after complete installation shall be inspected after completion of those parts. Parts not previously tested and inspected which are to be insulated shall be left uninsulated until all tests have been completed.

(1) All joints and connections shall be examined for apparent faults. Soldered joints that appear to be burned or which are obviously defective shall be disassembled and resoldered before testing. Visual inspection of joints shall not be accepted as a substitute for tests in accordance with para. 537.

(a) *(2)* Circumferential welds subject to a sustained longitudinal stress of 70% or more of the allowable stress or to an expansion stress of 50% or more of the allowable stress range shall all be identified on the drawings and shall be inspected visually or by other equivalent means to establish that they comply with the requirements of para. 527.4. For Group A2 or Class 3 refrigerant piping the inspection requirements of Chapter VI of ASME B31.3 shall be followed.

537 TESTS

537.1 Tests Before Erection or Assembly at the Factory or on the Premises

537.1.1 When piping components including valves, gauges, regulators, pipe, tube, and fittings have been tested by the component manufacturer according to standards or applicable specification, no further tests of these components are required.

537.2 Preparation for Testing

537.2.1 All joints, including welds and bonds, are to be left uninsulated and exposed for examination during leak testing, except that joints previously tested in accordance with this Code may be insulated and covered. All such welds and bonds that are required to be uninsulated and exposed for examination shall be unpainted (uncoated) and free of rust, dirt, oil, and other foreign materials.

537.3 Factory Tests

537.3.1 All refrigerant containing piping of every system shall be tested and proved tight by the manufacturer at not less than the design pressure for which it is rated except as noted in paras. 537.3.2 and 537.3.2.2.

537.3.2 The test pressure applied to the high pressure side piping of each factory-assembled refrigerating system shall be at least equal to the design pressure of the component in the high pressure side which has the lowest rated design pressure. The test pressure applied to the low pressure side piping of each factory-assembled refrigerating system shall be at least equal to the design pressure of the component in the low pressure side which has the lowest rated design pressure.

537.3.2.1 For Group A2 or Class 3 refrigerant piping the testing requirements of Chapter VI of ASME B31.3 shall be followed. (a)

537.3.2.2 In testing piping of systems using non-positive displacement compressors, the entire piping shall be considered for test purposes as the low pressure side. For Group A2 or Class 3 refrigerant piping, block valves between the high and low sides shall be used if necessary to permit testing per para. 537.3.2.1. (a)

537.4 Field Tests

537.4.1 All refrigerant containing piping of every system that is erected on the premises, except piping components that are factory tested, shall be tested and proved tight after complete installation, and before operation.

The high and low pressure side piping of each system erected on the premises shall be tested and proved tight at not less than the lower of the design pressure or the setting of the pressure relief device protecting the high or low pressure side of the system, respectively, except as noted in paras. 537.4.1.1 and 537.4.1.2.

(a) **537.4.1.1** Piping for systems erected on the premises using Group A1 refrigerant and with copper tubing not exceeding ⅝ in. outside diameter may be tested by means of the refrigerant charged into the system at the saturated vapor pressure of the refrigerant at 68°F minimum.

(a) **537.4.1.2** For Group A2 or Class 3 refrigerant piping, the test requirements of Chapter VI of ASME B31.3 shall be followed.

(a) **537.4.1.3** In testing piping of systems erected on the premises and using nonpositive displacement compressors, the entire piping system shall be considered for test purposes as the low pressure side. For Group A2 or Class 3 refrigerant piping, install block valves between the high and low pressure sides, if necessary, to permit testing per para. 537.4.1.2.

537.5 Test Medium

Oxygen or any combustible gas or combustible mixture of gases shall not be used within the piping for testing.

Water or water solutions should not be used to test refrigerant piping but if used it must be completely removed.

537.5.1 The means used to build up the test pressure shall have either a pressure limiting device or a pressure reducing device with a pressure relief device and a gage on the outlet side. The pressure relief device shall be set above the test pressure, but low enough to prevent permanent deformation of any of the system components.

537.6 Tests for Secondary Coolant Piping

(a) Piping systems for secondary coolant shall be tested at least at the design pressure.

(b) A piping system using refrigerant as a secondary coolant shall be treated as refrigerant piping.

(c) Water should not be used as a test medium for secondary coolant piping when the presence of water may be detrimental.

537.7 Pressure Gages

Pressure gages shall be checked for accuracy prior to test, either by comparison with master gages or by setting the pointer as determined by a dead-weight pressure gage tester.

537.8 Repair of Joints

(a) All leaking joints shall be repaired.

(b) Solder joints which leak shall be disassembled, cleaned, refluxed, reassembled, and resoldered. Solder joints shall not be repaired by brazing.

(c) Brazed joints which leak may be repaired by cleaning the exposed area, refluxing, and rebrazing.

(d) Welded joints which leak shall have the defective areas of the weld removed and rewelded.

537.8.1 After joints have been repaired, the repair shall be retested in accordance with paras. 537.3 and 537.4.

APPENDIX A
REFERENCED STANDARDS

Standards incorporated in this Code by reference and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; instead, the specific edition reference dates are shown here. This Appendix will be revised at intervals as needed.

ASTM Specifications

•A 36/36M-91
•A 47-84(R-90)
•A 48-83 (R-90)

•A 53-90a
•A 105/A 105M-90
•A 106-91
A 125-81
•A 126-84 (R-91)
•A 134-90
•A 135-89
•A 139-90

•A 178/178M-90
•A 179/A 179M-90a
•A 181/A 181M-90
•A 182/A 182M-91
•A 192/A 192M-90
•A 193/A 193M-91a
•A 194/A 194M-91
A 197-87

•A 210/A 210M-90
A 211-75(R-85)
•A 213/A 213M-91a
•A 214/A 214M-90
•A 216/A 216M-89
•A 217/A 217M-91
•A 226/A 226M-90
•A 234/A 234M-91c
•A 240-91a
•A 249/A 249M-91

•A 254-90
•A 269-90a
A 271-88
•A 278-85 (R-91)
•A 283/A 283M-91
•A 285/A 285M-90

•A 307-91
•A 312/A 312M-91b

ASTM Specifications (Cont'd)

•A 320/A 320M-91
•A 325-91c/A 325M-91c
•A 333/A 333M-91a
•A 334/A 334M-91
•A 350/A 350M-91a

•A 351/A 351M-91a
•A 352/A 352M-89
•A 353/A 353M-90
•A 354-91
•A 358/A 358M-89
•A 376/A 376M-91
A 395-88

•A 403/A 403M-91
•A 409M-91
A 413-80
•A 420/A 420M-91
•A 450/A 450M-89
•A 466-91
A 467-86a

•A 515/A 515M-90
•A 516/A 516M-90
•A 522/A 522M-90

•A 553/A 553M-90
•A 570/A 570M-90
•A 587-89a

•A 611-89

A 663-88
•A 675/A 675M-90

•A 743/A 743M-92a
•A 744/A 744M-89

•B 16-85/B 16M-85
•B 21-83b/B 21M-90
•B 26/B 26M-91
B 32-89

ASTM Specifications (Cont'd)

•B 42-92
•B 43-91

•B 61-90
•B 62-90
•B 68-92/B 68M-92
•B 75-92a/B 75M-92a
•B 85-90
•B 88-92a/B 88M-92a
•B 96-92
•B 98-92

B 111-88/B 111M-88a
B 124-89

B 152-88/B 152M-88
B 165-87
•B 171-89/B 171M-91a
•B 179-90

•B 209-90/B 209M-90
•B 210-90/B 210M-90
•B 211-90/B 211M-90
•B 221-91/B 221M-91
B 234-88/B 234M-88
•B 241/B 241M-90
•B 247-90/B 247M-90
•B 248-91b/B 248M-90

•B 280-92
•B 283-91

B 302-87
B 315-86
•B 345-90

B 361-88

B 466-86/B 466M-86
B 467-88

•B 543-89

• = (a)

REFERENCED STANDARDS (CONT'D)

ASTM Specifications (Cont'd)

•B 584-90b

•D 93-90

ASCE Standards

A58.1-1982

ASME Codes

B31.3-1990

•ASME Boiler and
Pressure Vessel Code, 1992 & Addenda
Section II Part C
Section VIII, Division 1
Section IX

B1.1-1989
•B1.20.1-1992
•B1.20.3-1976(R1991)

•B2.1-84

B16.1-1989
B16.3-1985
B16.4-1985
B16.5-1988
B16.9-1986
•B16.10-1992

•B16.11-1991
•B16.14-1991
B16.15-1985
B16.18-1984

B16.22-1989
•B16.24-1991
•B16.25-1992
B16.28-1986

ASME Codes (Cont'd)

•B18.2.1-1981 (R-92)
B18.2.2-1987

B36.10M-1985
B36.19M-1985

AWS Specifications

A5.1-81(R-1989)
A5.2-88
A5.3-88
A5.4-81(R-1989)
A5.6-84
A5.7-84
A5.8-89
A5.9-81
A5.10-88

A5.12-80

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MSS Standard Practices

•SP-6-90
•SP-9-92
•SP-25-1978(R1988)
•SP-42-1990
•SP-43-1982(1991)
•SP-45-1992

•SP-51-1991
•SP-58-1998
•SP-97-1987

API Specifications

•5L, 40th Ed., 1992

•600, 9th Ed., 1991

•

AWWA Standard

C110-87
•C111-85
C500-86

CDA Publication

Copper Tube Handbook, 1980

MIL Standard

•MIL-F-1183J-5/87

ASHRAE Standards

•15-92
•34-92

SAE Specification

J 513f-1977

GENERAL NOTE: The issue date shown immediately following the hyphen after the number of the standard (e.g., A-36-81a, B16-83, and SP-6-1980) is the effective date of the issue (edition) of the standard.

• = (a)

REFERENCED STANDARDS (CONT'D)

Specifications and standards of the following organizations appear in this Appendix:

ANSI — American National Standards Institute
11 West 42nd Street, New York, New York 10036
(212) 642-4900

API — American Petroleum Institute
1220 L Street, N.W., Washington, District of Columbia 20005
(202) 682-8375

ASCE — American Society of Civil Engineers
345 East 47th Street, New York, New York 10017
(212) 705-7538

ASHRAE — American Society of Heating, Refrigerating, and Air-Conditioning Engineers
1791 Tullie Circle, N.E., Atlanta, Georgia 30329
(404) 636-8400

ASME — The American Society of Mechanical Engineers
345 East 47th Street, New York, New York 10017
(212) 705-7722

ASME Order Department
22 Law Drive, Box 2300, Fairfield, New Jersey 07007-2300
(201) 882-1167

ASTM — American Society for Testing and Materials
1916 Race Street, Philadelphia, Pennsylvania 19103
(215) 299-5400

AWS — American Welding Society
P.O. Box 351040
550 N.W. LeJeune Road, Miami, Florida 33135
(305) 443-9353

AWWA — American Water Works Association
6666 W. Quincy Avenue, Denver, Colorado 80235
(303) 794-7711

CDA — Copper Development Association
Box 1840
Greenwich Office Park 2
Greenwich, Connecticut 06836
(203) 625-8210

MIL — Department of Defense (DOD) Single Stock Point
U.S. Naval Publications and Forms Center
5801 Tabor Avenue, Philadelphia, Pennsylvania 19120-5099
(215) 697-2000

MSS — Manufacturers Standardization Society of the Valve and Fittings Industry
127 Park Street N.E., Vienna, Virginia 22180
(703) 281-6613

SAE — Society of Automotive Engineers
400 Commonwealth Drive, Warrendale, Pennsylvania 15096
(412) 776-4841

(a) Other organizations mentioned in this section:

EJMA — Expansion Joint Manufacturers Association
25 North Broadway, Tarrytown, New York 10591
914 332-0040

NIST — National Institute of Standards and Technology
Publications available from
Superintendent of Documents
United States Government Printing Office
Washington DC 20402
202 783-3238