CHAPTER A2
PIPING COMPONENTS

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The term *piping* refers to the overall network of pipes, fittings, flanges, valves, and other components that comprise a conduit system used to convey fluids. Whether a piping system is used to simply convey fluids from one point to another or to process and condition the fluid, piping components serve an important role in the composition and operation of the system. A system used solely to convey fluids may consist of relatively few components, such as valves and fittings, whereas a complex chemical processing system may consist of a variety of components used to measure, control, condition, and convey the fluids. In the following sections, the characteristics and functions of the various piping components are described.

PIPE AND TUBE PRODUCTS

Pressure pipe and tube products are manufactured to a variety of standard specifications of varying designs, employing different manufacturing practices and using a wide variety of materials. The end user of these products must apply the least-cost product suitable for the specified service conditions. Typically, steel and alloy pressure piping is available in cast, wrought, and seam-welded forms. Welded and seamless wrought steel pipe is supplied in standard sizes and wall thickness conforming to ASME B36.10M. Stainless-steel pipe is supplied in standard sizes and wall thickness conforming to ASME B36.19M. These standard pipe dimensions are tabulated in Apps. E2 and E2M, and the metric size equivalent DN of the NPS is given in Chap. A1. Some commonly specified piping materials are listed in Table A2.1.

Pressure Tubing

Pressure-tube applications commonly involve external heat applications, as in boilers or superheaters. Pressure tubing is produced to the actual outside diameter and minimum or average wall thickness specified by the purchaser. Pressure tubing may be hot- or cold-finished. The wall thickness is normally given in decimal parts of an inch rather than as a fraction or gauge number. When gauge numbers are given

TABLE A2.1 Prevalent Piping Specifications

Specification	Product form	Size range (NPS)	Application
ASTM A53	Seamless/welded	⅛ to 26	Ordinary use in gas, air, oil, water, steam
ASTM A106	Seamless	⅛ to 48	High-temperature service (steam, water, gas, etc.)
ASTM A369	Forged and bored	Custom	High-temperature service
ASTM A335	Seamless	Custom	High-temperature service
ASTM A333	Seamless/welded	⅛ and larger	Service requiring excellent fracture toughness at low temperatures
ASTM A671	Electric fusion-welded	16 and larger	Low-temperature service
ASTM A672	Electric fusion-welded	16 and larger	Moderate-temperature service
ASTM A691	Electric fusion-welded	16 and larger	High-temperature service
ASTM A312	Seamless/welded	⅛ and larger	Low- to high-temperature and corrosive service
API 5L	Seamless/welded		Line pipe, refinery, and transmission service

without reference to a system, Birmingham wire gauge (BWG) is implied. Weights of commercial tubing are given in Apps. E3 and E3M.

Pressure tubing is usually made from steel produced by the open-hearth, basic oxygen, or electric furnace processes. Seamless pressure tubing may be either hot-finished or cold-drawn. Cold-drawn steel tubing is frequently process-annealed at temperatures above 1200°F (650°C). To ensure quality, maximum hardness values are frequently specified. Hot-finished or cold-drawn seamless low-alloy steel tubes generally are process-annealed at temperatures between 1200°F (650°C) and 1350°F (730°C). Austenitic stainless-steel tubes are usually annealed at temperatures between 1800°F (980°C) and 2100°F (1150°C), with specific temperatures varying somewhat with each grade. This is generally followed by pickling, unless bright annealing was done.

Pipe Fittings

The major piping materials are also produced in the form of standard fittings. Among the more widely used materials are ductile or cast iron, malleable iron, brass, copper, cast steel, forged steel, and wrought steel. Other major nonferrous piping materials are also produced in the form of cast and wrought fittings. Ductile and cast-iron fittings are made by conventional foundry methods for a variety of joints including bell-and-spigot, push-on flanged, and mechanical (gland-type) or other proprietary designs.

Ductile and Cast-Iron Fittings

Cast-iron fittings are covered by a number of ASME and ANSI/AWWA standards:

ASME B16.1	Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800 (The standard also includes bolt, nut, and gasket data.)

ASME B16.4	Gray Iron Threaded Fittings, Class 125 and 250
ASME B16.12	Cast Iron Threaded Drainage Fittings
ANSI/AWWA C110/A21.10	Ductile Iron and Gray Iron Fittings, 3-in through 48-in (76 mm through 6200 mm), for Water and Other Liquids
ANSI/AWWA C115/A21.15	Ductile Iron and Gray Iron Fittings, 3-in through 48-in (76 mm through 1200 mm), for Water
ANSI/AWWA C153/A21.53	Ductile Iron Compact Fittings, 3-in through 24-in (76 mm through 610 mm) and 54-in through 64-in (1400 mm through 1600 mm), for Water Service

Cast-Iron Threaded Fittings

Cast-iron threaded fittings are covered by ASME Standard B16.4. The standard specifies the below-listed attributes for Class 125 and Class 250 tees, crosses, 45° and 90° elbows, reducing tees, caps, couplings, and reducing couplings in sizes ranging from NPS ¼ (DN 6) through NPS 12 (DN 300), inclusive. However, in Class 250, the standard only covers 45° and 90° elbows, straight tees, and straight crosses.

- Pressure-temperature ratings
- Size and method of designating openings of reducing fittings
- Marking
- Minimum requirements for materials
- Dimensions and tolerances
- Threading
- Coatings

TABLE A2.2 Pressure-Temperature Rating of ANSI/ASME B16.4 Cast-Iron Fittings

Temperature (°F)	Class 125 (psi)	Class 250 (psi)
−20 to 150	175	400
200	165	370
250	150	340
300	150	310
350	125*	300
400	. . .	250†

* Permissible for service temperature up to 353°F, reflecting the temperature of saturated steam at 125 psig.

† Permissible for service temperature up to 406°F, reflecting the temperature of saturated steam at 250 psig.

The pressure-temperature ratings of Class 125 and Class 250 are listed in Table A2.2. The ratings are independent of the contained fluid and are the maximum nonshock pressure at the listed temperature. As a minimum, the material must conform to class A of ASTM A126. The fittings are threaded with ASME B1.20.1 pipe threads.

TABLE A2.3 Pressure-Temperature Rating of ASME B16.3 Malleable-Iron Threaded Fittings

Temperature (°F)	Class 150 (psig)	Class 300 (psig)		
		Sizes ¼ to 1	Sizes 1¼ to 2	Sizes 2½ to 3
−20 to 150	175	2000	1500	1000
200	265	1785	1350	910
250	225	1575	1200	825
300	185	1360	1050	735
350	150*	1150	900	650
400	. . .	935	750	560
450	. . .	725	600	475
500	. . .	510	450	385
550	. . .	300	300	300

* Permissible for service temperature up to 366°F, reflecting the temperature of saturated steam at 150 psig.

Malleable-Iron Threaded Fittings

Malleable-iron fittings are also extensively produced. They are generally made with threaded joints. Malleable-iron threaded fittings for Classes 150 and 300 are standardized in ASME B16.3. The standard specifies the same attributes for Class 150 and 300 fittings as discussed under ASME B16.4 for gray-iron fittings. The fittings are available in a variety of configurations from NPS ⅛ (DN 3) through NPS 6 (DN 150). The pressure-temperature ratings of these fittings are listed in Table A2.3. As with cast-iron fittings, the ratings are independent of the contained fluid and are maximum nonshock pressures at the listed temperatures. Malleable-iron fittings are furnished black, galvanized, or as otherwise ordered by the buyer. The galvanized threaded fittings commonly used in water piping for homes are Class 150 malleable iron. Minimum properties of malleable iron are required to meet ASTM A197 Cupola Malleable Iron requirements. The fittings are threaded with ASME B1.20.1 pipe threads.

Cast-Brass and Cast-Bronze Threaded Fittings

Cast-brass and -bronze threaded fittings are commonly produced for use with brass pipe. The fittings are manufactured in accordance with ASME B16.15 in pressure Classes 125 and 250. The standard establishes pressure-temperature ratings, size and method of designating openings of reducing fittings, marking, minimum requirements for casting quality, and materials. The nonshock pressure-temperature ratings are listed in Table A2.4. The permitted materials for the fittings are:

ASTM B62, alloy C83600

ASTM B584, alloy C83800 and C84400

ASTM B16, alloy C36000 (bar stock)*

ASTM B140, alloy C32000 or C31400 (bar stock)*

* Used for manufacture of threaded plugs, bushings, and caps.

TABLE A2.4 Pressure-Temperature Rating for Classes 125 and 250 Cast-Bronze Threaded Fittings (ANSI/ASME B16.15-1985)*

Temperature (°F)	Class 125 (psi)	Class 250 (psi)
−20 to 150	200	400
200	190	385
250	180	365
300	165	335
350	150	300
400	125	250

* Ratings are independent of the contained fluid.

Soldered-Joint Fittings

Soldered-joint wrought metal and cast-brass or -bronze fittings for use with copper water tubes are covered by ASTM B88 and H23.1. The fittings are made in accordance with ASME B16.22 and B16.18, respectively. Joints using these types of fittings and made with 50–50 tin-lead solder, 95-tin 5-antimony solder, or solder melting above 1100°F (593°C) have the pressure-temperature ratings shown in Table A2.5. (*Note:* Lead-bearing solder is not permitted for potable water service.)

Wrought copper fittings normally have a minimum copper content of 83 percent. Cast-brass fittings conform to ASTM B62 and have a nominal composition of 85 percent copper, 5 percent tin, 5 percent lead, and 5 percent zinc. The minimum requirements for 50–50 tin-lead solder generally used with these fittings are covered in ASTM B32 alloy grade 50A. Metal thickness tolerances and general dimensions of fittings are given in ASME B16.18.

TABLE A2.5 Pressure Ratings for Solder Joints (ASME B16.18-1984). Maximum Working Pressure (psi).

Solder used in joints	Working temperatures (°F)	⅛–1 in, incl.*	1¼–2 in, incl.*	2½–4 in, incl.*	5–8 in, incl.*
50–50 tin-lead†	100	200	175	150	135
	150	150	125	100	90
	200	100	90	75	70
	250	85	75	50	45
95–5, tin-antimony	100	500	400	300	270
	150	400	350	275	250
	200	300	250	200	180
	250	200	175	150	135
Solders melting at or above 1100°F	‡	‡	‡	‡	‡

* Standard water tube sizes.
† ASTM B32 alloy grade 50A.
‡ Rating to be consistent with materials and procedures employed.

Cast-Iron Flanged Fittings

Cast-iron flanged fittings are produced in accordance with ASME B16.1. The standard specifies pressure-temperature ratings, sizes, marking, minimum requirements for materials, dimensions and tolerances, bolting, gasketing, and testing requirements. The fittings are manufactured in a variety of configurations (tees, elbows, crosses, laterals, etc.) in pressure Classes 25, 125, 250, and 800. Not all sizes and styles are available in all ratings. The sizes available in each class are listed below:

Pressure class	Size range, NPS (DN)
25	4 (100) through 72 (1800)
125	1 (25) through 96 (2400)
250	1 (25) through 30 (750)
800	2 (50) through 12 (300)

The nonshock pressure-temperature ratings for the four pressure classes are listed in Table A2.6. The materials of construction are ASTM A 126 class A or B, as shown in Table A2.6.

Cast- and Forged-Steel and Nickel-Alloy Flanged Fittings

Flanged fittings of steel and nickel alloys are manufactured in accordance with ASME B16.5. The standard covers ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings in sizes NPS ½ (DN 15) through NPS 24 (DN 600) and in rating Classes 150, 300, 400, 600, 900, 1500, and 2500. However, not all sizes are available in all pressure classes. Dimensions of more commonly used fittings are given in Table A2.7. The standard also contains recommendations and requirements for bolting and gaskets.

Within each pressure class, the dimensions of the fittings are held constant, irrespective of the materials being used. Since the physical properties of different materials vary, the pressure-temperature ratings within each pressure class vary with the material. As an example, a Class 600 forged carbon steel (A105) flange is rated at 1270 psig at 400°F, whereas a Class 600 forged stainless steel (A182, F304) flange is rated at 940 psig at 400°F. The matrix of materials and pressure classes is too numerous to reproduce here; therefore, the reader is referred to ASME B16.5 for the flanged fitting pressure-temperature ratings. Figures A2.1, A2.2, and A2.3 illustrate the reduction in pressure rating with increase in temperature for group 1.1 (ASTM A105), 1.10 (ASTM A182, Gr. F22, Cl. 3), and 2.1 (ASTM A182, Gr. F304) materials.

Forged-Steel Threaded and Socket-Welding Fittings

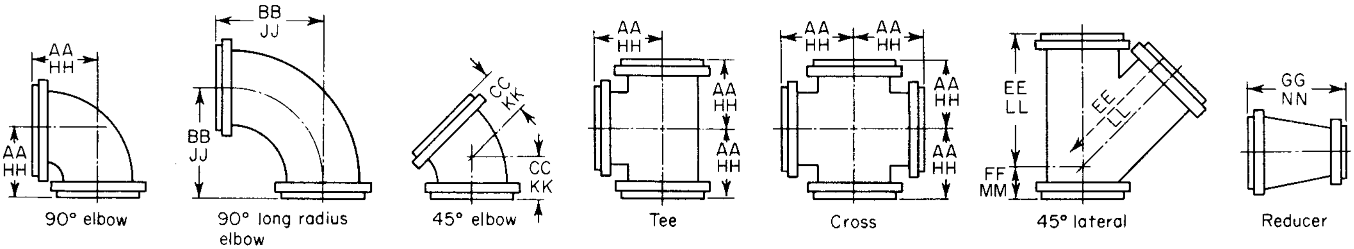
Forged-steel socket welding and threaded fittings are manufactured in accordance with ASME B16.11. The standard covers pressure-temperature ratings, dimensions, tolerances, marking, and material requirements for forged carbon and alloy steel fittings in the styles and sizes listed in Tables A2.8 and A2.9. Acceptable material forms are forgings, bars, seamless pipe, and seamless tubes which conform to the

TABLE A2.6 Pressure-Temperature Rating of Cast-Iron Pipe Flanges and Flanged Fittings (ASME B16.1-1989).

	Class 25*, ASTM A 126, Class A		Class 125, ASTM A 126				Class 250,* ASTM A 126				Class 800,* ASTM A 126, Class B
			Class A	Class B			Class A	Class B			
Temperature, °F	NPS 4–36	NPS 42–96	NPS 1–12	NPS 1–12	NPS 14–24	NPS 30–48	NPS 1–12	NPS 1–12	NPS 14–24	NPS 30–48	NPS 2–12
−20 to 150	45	25	175	200	150	150	400	500	300	300	800
200	40	25	165	190	135	115	370	460	280	250	. . .
225	35	25	155	180	130	100	355	440	270	225	. . .
250	30	25	150	175	125	85	340	415	260	200	. . .
275	25	25	145	170	120	65	325	395	250	175	. . .
300	. . .	. . .	140	165	110	50	310	375	240	150	. . .
325	. . .	. . .	130	155	105	. . .	295	355	230	125	. . .
353†	. . .	. . .	125	150	100	. . .	280	335	220	100	. . .
375	. . .	. . .	. . .	145	. . .	. . .	265	315	210	. . .	. . .
406‡	. . .	. . .	. . .	140	. . .	. . .	250	290	200	. . .	. . .
425	. . .	. . .	. . .	130	. . .	. . .	. . .	270	. . .	. . .	. . .
450	. . .	. . .	. . .	125	. . .	. . .	. . .	250	. . .	. . .	. . .

Pressure is in lb/in^2 gauge.
NPS is nominal pipe size.
Hydrostatic tests are not required unless specified by user. The test pressure is equal to 1.5 times the 100°F pressure rating.
* Limitations:
(1) Class 25. When Class 25 cast-iron flanges and flanged fittings are used for gaseous service, the maximum pressure shall be limited to 25 psig. Tabulated pressure-temperature ratings above 25 psig for Class 25 cast-iron flanges and flanged fittings are applicable for nonshock hydraulic service only.
(2) Class 250. When used for liquid service, the tabulated pressure-temperature ratings in NPS 14 and larger are applicable to Class 250 flanges only and not to Class 250 fittings.
(3) Class 800. The tabulated rating is not a steam rating and applies to nonshock hydraulic pressure only.
† 353°F (max.) to reflect the temperature of saturated steam at 125 psig.
‡ 406°F (max.) to reflect the temperature of saturated steam at 250 psig.

TABLE A2.7 Dimensions of Typical Commercial Cast-Steel Flanged Fittings (from ASME B16.5-1996)



Nominal pipe size	1⁄16-in raised-face						Ring joint							
	AA	*BB*	*CC*	*EE*	*FF*	*GG*	*HH*	*JJ*	*KK*	*LL*	*MM*	*NN*	*L**	*D†*
Class 150														
1	3½	5	1¾	5¾	1¾	4½	3¾	5¼	2	6	2		¼	5⁄32
1¼	3¾	5½	2	6¼	1¾	4½	4	5¾	2¼	6½	2		¼	5⁄32
1½	4	6	2¼	7	2	4½	4¼	6¼	2½	7¼	2¼		¼	5⁄32
2	4½	6½	2½	8	2½	5	4¾	6¾	2¾	8¼	2¾		¼	5⁄32
2½	5	7	3	9½	2½	5½	5¼	7¼	3¼	9¾	2¾		¼	5⁄32
3	5½	7¾	3	10	3	6	5¾	8	3¼	10¼	3¼		¼	5⁄32
3½	6	8½	3½	11½	3	6½	6¼	8¾	3¾	11¾	3¼		¼	5⁄32
4	6½	9	4	12	3	7	6¾	9¼	4¼	12¼	3¼		¼	5⁄32
5	7½	10¼	4½	13½	3½	8	7¾	10½	4¾	13¾	3¾		¼	5⁄32
6	8	11½	5	14½	3½	9	8¼	11¾	5¼	14¾	3¾	See	¼	5⁄32
8	9	14	5½	17½	4¼	11	9¼	14¼	5¾	17¾	4¾	note‡	¼	5⁄32
10	11	16½	6½	20½	5	12	11¼	16¾	6¾	20¾	5¼		¼	5⁄32
12	12	19	7½	24½	5½	14	12¼	19¼	7¾	24¾	5¾		¼	5⁄32
14	14	21½	7½	27	6	16	14¼	21¾	7¾	27¼	6¼		¼	⅛
16	15	24	8	30	6½	18	15¼	24¼	8¼	30¼	6¾		¼	⅛
18	16½	26½	8½	32	7	19	16¾	26¾	8¾	32¼	7¼		¼	⅛
20	18	29	9½	35	8	20	18¼	29¼	9¾	35¼	8¼		¼	⅛
24	22	34	11	40½	9	24	22¼	34¼	11¼	40¾	9¼		¼	⅛

TABLE A2.7 Dimensions of Typical Commercial Cast-Steel Flanged Fittings (from ASME B16.5-1996) (*Continued*)

Nominal pipe size	1/16-in raised-face						Ring joint							
	AA	*BB*	*CC*	*EE*	*FF*	*GG*	*HH*	*JJ*	*KK*	*LL*	*MM*	*NN*	*L**	*D*†
Class 300														
1	4	5	2¼	6½	2	4½	4¼	5¼	2½	6¾	2¼		¼	5/32
1¼	4¼	5½	2½	7¼	2¼	4½	4½	5¾	2¾	7½	2½		¼	5/32
1½	4½	6	2¾	8½	2½	4½	4¾	6¼	3	8¾	2¾		¼	5/32
2	5	6½	3	9	2½	5	5 5/16	6 13/16	3 5/16	9 5/16	2 13/16		5/16	7/32
2½	5½	7	3½	10½	2½	5½	5 13/16	7 5/16	3 13/16	10 13/16	2 13/16		5/16	7/32
3	6	7¾	3½	11	3	6	6 5/16	8 1/16	3 13/16	11 5/16	3 5/16		5/16	7/32
3½	6½	8½	4	12½	3	6½	6 13/16	8 13/16	4 5/16	12 13/16	3 5/16		5/16	7/32
4	7	9	4½	13½	3	7	7 5/16	9 5/16	4 13/16	13 13/16	3 5/16		5/16	7/32
5	8	10¼	5	15	3½	8	8 5/16	10 9/16	5 5/16	15 5/16	3 13/16		5/16	7/32
6	8½	11½	5½	17½	4	9	8 13/16	11 13/16	5 13/16	17 13/16	4 5/16		5/16	7/32
8	10	14	6	20½	5	11	10 5/16	14 5/16	6 5/16	20 13/16	5 5/16	See note‡	5/16	7/32
10	11½	16½	7	24	5½	12	11 13/16	16 13/16	7 5/16	24 5/16	5 13/16		5/16	7/32
12	13	19	8	27½	6	14	13 5/16	19 5/16	8 5/16	27 13/16	6 5/16		5/16	7/32
14	15	21½	8½	31	6½	16	15 5/16	21 13/16	8 13/16	31 5/16	6 13/16		5/16	7/32
16	16½	24	9½	34½	7½	18	16 13/16	24 5/16	9 13/16	34 13/16	7 13/16		5/16	7/32
18	18	26½	10	37½	8	19	18 5/16	26 13/16	10 5/16	37 13/16	8 5/16		5/16	7/32
20	19½	29	10½	40½	8½	20	19⅞	29⅜	10⅞	40⅞	8⅞		⅜	7/32
24	22½	34	12	47½	10	24	22 15/16	34 7/16	12 7/16	47 15/16	10 7/16		7/16	¼

TABLE A2.7 Dimensions of Typical Commercial Cast-Steel Flanged Fittings (from ASME B16.5-1996) (*Continued*)

Nominal pipe size	¼-in raised-face					Ring joint						
	AA	*CC*	*EE*	*FF*	*GG*	*HH*	*KK*	*LL*	*MM*	*NN*	*L**	*D*†
Class 400 (for sizes smaller than NPS 4 use Class 600)												
4	8	5½	16	4½	8¼	8 1/16	5 9/16	16 1/16	4 9/16		5/16	7/32
5	9	6	16¾	5	9¼	9 1/16	6 1/16	16 13/16	5 1/16		5/16	7/32
6	9¾	6¼	18¾	5¼	10	9 13/16	6 5/16	18 13/16	5 5/16		5/16	7/32
8	11¾	6¾	22¼	5¾	12	11 13/16	6 13/16	22 5/16	5 13/16		5/16	7/32
10	13¼	7¾	25¾	6¼	13½	13 5/16	7 13/16	25 13/16	6 5/16		5/16	7/32
12	15	8¾	29¾	6½	15¼	15 1/16	8 13/16	29 13/16	6 9/16		5/16	7/32
14	16¼	9¼	32¾	7	16½	16 5/16	9 5/16	32 13/16	7 1/16	See	5/16	7/32
16	17¾	10¼	36¼	8	18½	17 13/16	10 5/16	36 5/16	8 1/16	note‡	5/16	7/32
18	19¼	10¾	39¼	8½	19½	19 5/16	10 13/16	39 5/16	8 9/16		5/16	7/32
20	20¾	11¼	42¾	9	21	20⅞	11⅜	42⅞	9⅛		⅜	7/32
24	24¼	12¾	50¼	10½	24½	24 7/16	12 15/16	50 7/16	10 11/16		7/16	¼
Class 600												
½	3¼	2	5¾	1¾	5	3 7/32	1 31/32	5 23/32	1 23/32		7/32	⅛
¾	3¾	2½	6¾	2	5	3¾	2½	6¾	2		¼	5/32
1	4¼	2½	7¼	2¼	5	4¼	2½	7¼	2¼		¼	5/32
1¼	4½	2¾	8	2½	5	4½	2¾	8	2½		¼	5/32
1½	4¾	3	9	2¾	5	4¾	3	9	2¾		¼	5/32
2	5¾	4¼	10¼	3½	6	5 13/16	4 5/16	10 5/16	3 9/16		5/16	3/16
2½	6½	4½	11½	3½	6¾	6 9/16	4 9/16	11 9/16	3 9/16		5/16	3/16
3	7	5	12¾	4	7¼	7 1/16	5 1/16	12 13/16	4 1/16		5/16	3/16
3½	7½	5½	14	4½	7¾	7 9/16	5 9/16	14 1/16	4 9/16		5/16	3/16
4	8½	6	16½	4½	8¾	8 9/16	6 1/16	16 9/16	4 9/16		5/16	3/16
5	10	7	19½	6	10¼	10 1/16	7 1/16	19 9/16	6 1/16	See	5/16	3/16
6	11	7½	21	6½	11¼	11 1/16	7 9/16	21 1/16	6 9/16	note‡	5/16	3/16
8	13	8½	24½	7	13¼	13 1/16	8 9/16	24 9/16	7 1/16		5/16	3/16
10	15½	9½	29½	8	15¾	15 9/16	9 9/16	29 9/16	8 1/16		5/16	3/16
12	16½	10	31½	8½	16¾	16 9/16	10 1/16	31 9/16	8 9/16		5/16	3/16
14	17½	10¾	34¼	9	17¾	17 9/16	10 13/16	34 5/16	9 1/16		5/16	3/16
16	19½	11¾	38½	10	19¾	19 9/16	11 13/16	38 9/16	10 1/16		5/16	3/16
18	21½	12¼	42	10½	21¾	21 9/16	12 5/16	42 1/16	10 9/16		5/16	3/16
20	23½	13	45½	11	23¾	23⅝	13⅛	45⅝	11⅛		⅜	3/16
24	27½	14¾	53	13	27¾	27 11/16	14 15/16	53 3/16	13 3/16		7/16	7/32

TABLE A2.7 Dimensions of Typical Commercial Cast-Steel Flanged Fittings (from ASME B16.5-1996) (*Continued*)

Nominal pipe size	¼-in raised-face					Ring joint						
	AA	*CC*	*EE*	*FF*	*GG*	*HH*	*KK*	*LL*	*MM*	*NN*	*L**	*D*†
Class 900 (for sizes smaller than NPS 3 use Class 1500)												
3	7½	5½	14½	4½	7¾	7 9/16	5 9/16	14 9/16	4 9/16		5/16	5/32
4	9	6½	17½	5½	9¼	9 1/16	6 9/16	17 9/16	5 9/16		5/16	5/32
5	11	7½	21	6½	11¼	11 1/16	7 9/16	21 1/16	6 9/16		5/16	5/32
6	12	8	22½	6½	12¼	12 1/16	8 1/16	22 9/16	6 9/16		5/16	5/32
8	14½	9	27½	7½	14¾	14 9/16	9 1/16	27 9/16	7 9/16		5/16	5/32
10	16½	10	31½	8½	16¾	16 9/16	10 1/16	31 9/16	8 9/16		5/16	5/32
12	19	11	34½	9	17¾	19 1/16	11 1/16	34 9/16	9 1/16	See	5/16	5/32
14	20¼	11½	36½	9½	19	20 7/16	11 11/16	36 11/16	9 11/16	note‡	7/16	5/32
16	22¼	12½	40¾	10½	21	22 7/16	12 11/16	40 15/16	10 11/16		7/16	5/32
18	24	13¼	45½	12	24½	24¼	13½	45¾	12¼		½	3/16
20	26	14½	50¼	13	26½	26¼	14¾	50½	13¼		½	3/16
24	30½	18	60	15½	30½	30⅞	18⅜	60⅜	15⅞		⅝	7/32
Class 1500												
½	4¼	3	....	....	....	4¼	3	.....	.....		¼	5/32
¾	4½	3¼	....	....	....	4½	3¼	.....	.....		¼	5/32
1	5	3½	9	2½	5	5	3½	9	2½		¼	5/32
1¼	5½	4	10	3	5¾	5½	4	10	3		¼	5/32
1½	6	4¼	11	3½	6¼	6	4¼	11	3½		¼	5/32
2	7¼	4¾	13¼	4	7¼	7 5/16	4 13/16	13 5/16	4 1/16		5/16	⅛
2½	8¼	5¼	15¼	4½	8¼	8 5/16	5 5/16	15 5/16	4 9/16		5/16	⅛
3	9¼	5¾	17¼	5	9¼	9 5/16	5 13/16	17 5/16	5 1/16		5/16	⅛
4	10¾	7¼	19¼	6	10¾	10 13/16	7 5/16	19 5/16	6 1/16		5/16	⅛
5	13¼	8¾	23¼	7½	13¾	13 5/16	8 13/16	23 5/16	7 9/16		5/16	⅛
6	13⅞	9⅜	24⅞	8⅛	14½	14	9½	25	8¼	See	⅜	⅛
8	16⅝	10⅞	29⅞	9⅛	17	16 9/16	11 1/16	30 1/16	9 5/16	note‡	7/16	5/32
10	19½	12	36	10¼	20¼	19 11/16	12 3/16	36 3/16	10 7/16		7/16	5/32
12	22¼	13¼	40¾	12	23	22 9/16	13 9/16	41 1/16	12 5/16		9/16	3/16
14	24¾	14¼	44	12½	25¾	25⅛	14⅝	44⅜	12⅞		⅝	7/32
16	27¼	16¼	48¼	14¾	28¼	27 11/16	16 11/16	48 11/16	15 3/16		11/16	5/16
18	30¼	17¾	53¼	16½	31½	30 11/16	18 3/16	53 11/16	16 15/16		11/16	5/16
20	32¾	18¾	57¾	17¾	34	33 3/16	19 3/16	58 3/16	18 3/16		11/16	⅜
24	38¼	20¾	67¼	20½	39¾	38 13/16	21 5/16	67 13/16	21 1/16		13/16	7/16

* L = height of raised face of ring-joint flanges.

† D = approximate distance between flange faces when ring is compressed.

‡ Center-to-face dimensions shown for fittings with ring-joint flanges apply to straight sizes only. For reducing fittings and reducers, use dimensions shown for raised-face flanges of largest opening; Class 400 and higher classes, subtract the ¼-in raised face for each flange (do not subtract the 1/16-in raised face in Class 150 and 300); add height of ring-joint raised face (L) applying to each flange.

For calculating the "laying length" of fittings with ring joints, add the approximate distance (D) between flange faces when ring is compressed to the center-to-face dimensions in these tables.

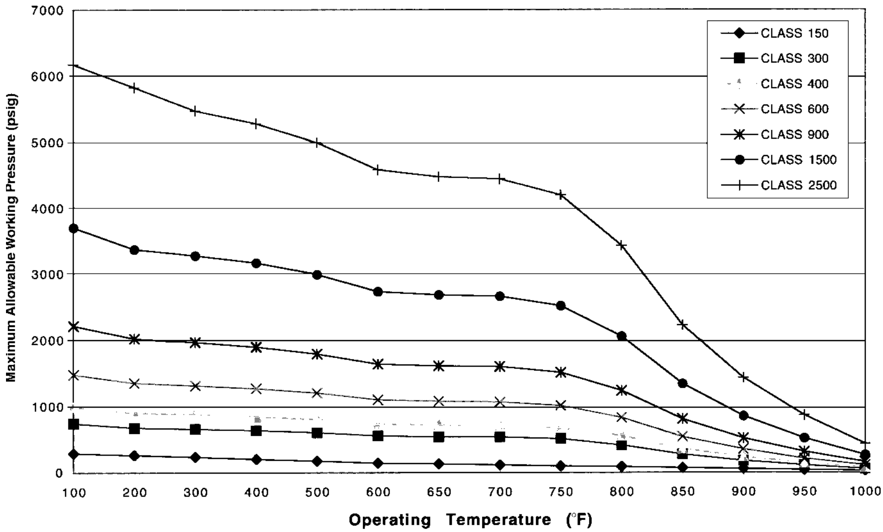


FIGURE A2.1 Operating temperature versus allowable working pressure for ASME B16.5 flanges and flanged fittings—Group 1.1 materials. (*From ASME B16.5, 1996*)

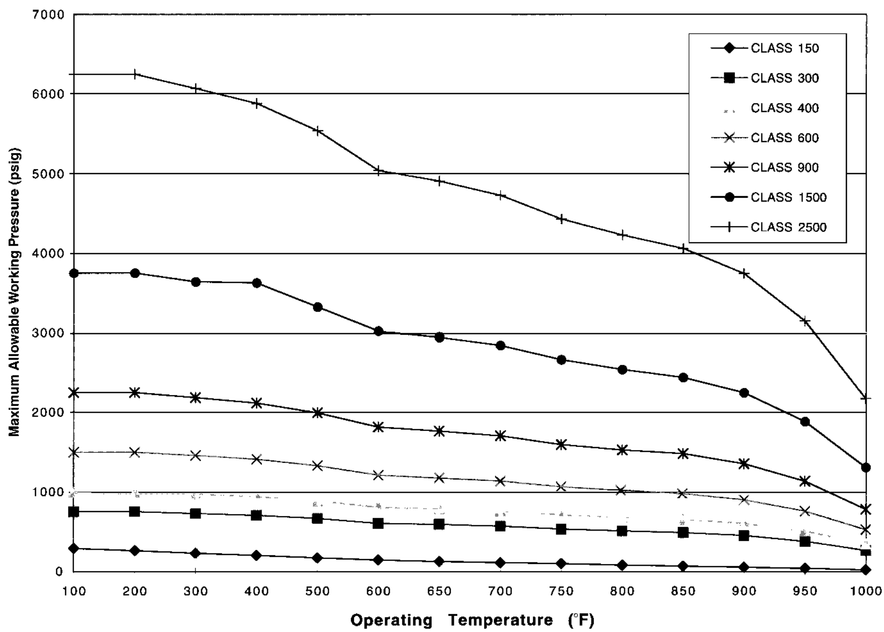


FIGURE A2.2 Operating temperature versus allowable working pressure for ASME B16.5 flanges and flanged fittings—Group 1.10 materials. (*From ASME B16.5, 1996*)

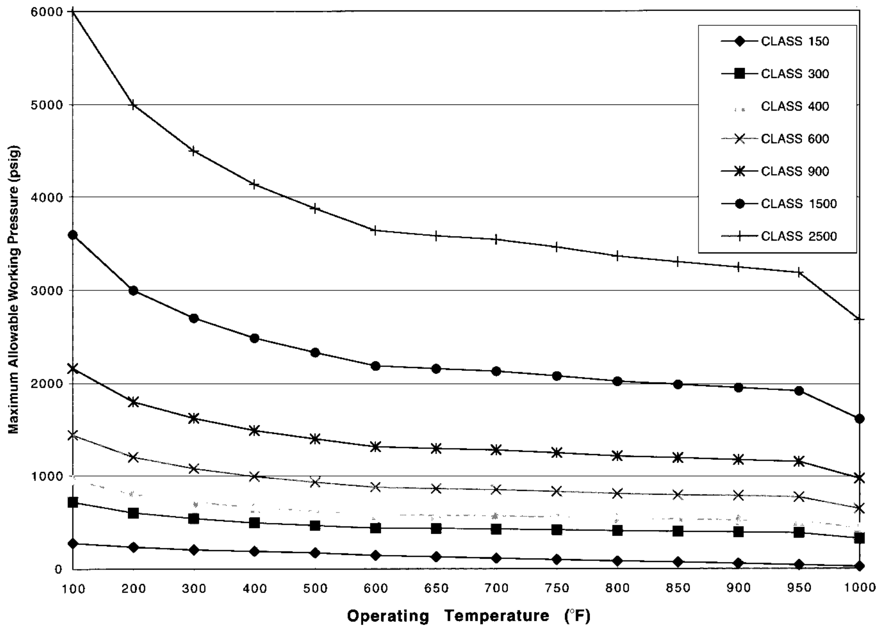


FIGURE A2.3 Operating temperature versus allowable working pressure for ASME B16.5 flanges and flanged fittings—Group 2.1 materials. (*From ASME B16.5, 1996*)

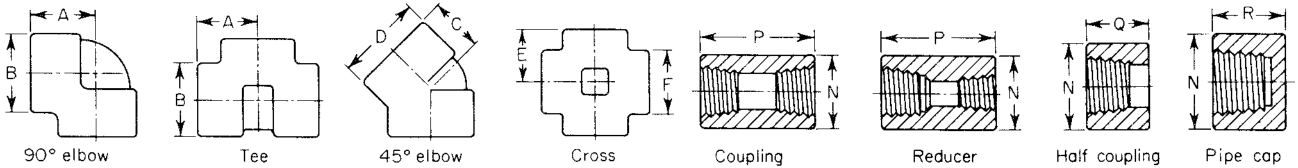
chemical compositions, melting practices, and mechanical property requirements of ASTM A105, A182, or A350.

Threaded fittings are available in pressure Classes 2000, 3000, and 6000. Socket-welded fittings are available in pressure Classes 3000, 6000, and 9000. Limitations on fitting size and service conditions are as provided for by the code governing the installation. The maximum allowable pressure of the fitting is equal to that computed for straight seamless pipe of equivalent material, considering manufacturing tolerance, corrosion allowance, and mechanical strength allowance. Also, for socket-welding fittings, the pressure rating must be matched to the pipe wall thickness to ensure that the flat of the band can accommodate the size of the fillet weld required by the applicable code. The recommended fitting pressure class for the various pipe wall thicknesses is as follows:

Pipe schedule and designation	Threaded class	Socket-welded class
80/XS or less	2000	3000
160	3000	6000
XXS	6000	9000

Internal threads of threaded fittings are in accordance with ASME B1.20.1-Pipe Threads, General Purpose (Inch).

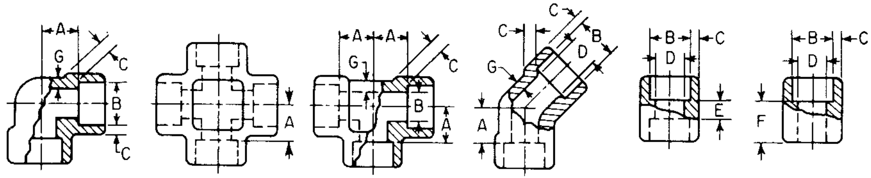
TABLE A2.8 Dimensions of Typical Commercial Forged-Steel Threaded Fittings (ASME B16.11-1996)



	Dimensions, in											
	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	4
Class 2000												
A	0.81	0.81	0.97	1.12	1.31	1.50	1.75	2.00	2.38	3.00	3.38	4.19
B	0.88	0.88	1.00	1.31	1.50	1.81	2.19	2.44	2.97	3.62	4.31	5.756
C	0.69	0.69	0.75	0.88	1.00	1.12	1.31	1.38	1.69	2.06	2.50	3.12
T	0.125	0.125	0.125	0.125	0.125	0.145	0.153	0.158	0.168	0.221	0.236	0.258
Class 3000												
A	0.81	0.97	1.12	1.31	1.50	1.75	2.00	2.38	2.50	3.25	3.75	4.50
B	0.88	1.00	1.31	1.50	1.81	2.19	2.44	2.97	3.31	4.00	4.75	6.00
C	0.69	0.75	0.88	1.00	1.12	1.31	1.38	1.69	1.72	2.06	2.50	3.12
T	0.125	0.13	0.138	0.161	0.170	0.196	0.208	0.219	0.281	0.301	0.348	0.440
N	0.68	0.75	0.88	1.12	1.38	1.75	2.25	2.50	3.00	3.62	4.25	4.75
P	1.25	1.38	1.50	1.88	2.00	2.38	2.62	3.12	3.38	3.62	4.25	4.75
R	0.75	1.00	1.00	1.25	1.44	1.62	1.75	1.75	1.88	2.38	2.58	2.69
Class 6000												
A	0.97	1.12	1.31	1.50	1.75	2.00	2.38	2.50	3.25	3.75	4.19	4.50
B	1.00	1.31	1.50	1.81	2.19	2.44	2.97	3.31	4.00	4.75	5.75	6.00
C	0.75	0.88	1.00	1.12	1.31	1.38	1.69	1.72	2.06	2.50	3.12	3.12
T	0.250	0.260	0.275	0.321	0.336	0.391	0.417	0.436	0.476	0.602	0.655	0.735
N	0.88	1.00	1.25	1.50	1.75	2.25	2.50	3.00	3.62	4.25	5.00	6.25
P	1.25	1.38	1.50	1.88	2.00	2.38	2.62	3.12	3.38	3.62	4.25	4.75
R	...	1.06	1.06	1.31	1.50	1.69	1.81	1.88	2.00	2.50	2.69	2.94

Manufacturers' catalogs should be consulted for dimensions of street elbows and of laterals since these two types of fittings are no longer covered by ANSI Standards.

TABLE A2.9 Dimensions of Typical Commercial Forged-Steel Socket-Welding Fittings*
(ASME B16.11-1996)



Nominal pipe size	Socket bore diameter† B	Depth of socket min.	Wall thickness, minimum						Bore diameter of fitting *D*			Center to bottom of socket (A)						Laying lengths	
			Class 3000		Class 6000		Class 9000					90° ells, tees, crosses‡			45° ells‡				
			Socket C	Body G	Socket C	Body G	Socket C	Body G	Class 3000	Class 6000	Class 9000	Class 3000	Class 6000	Class 9000	Class 3000	Class 6000	Class 9000	Couplings‡ E	Half couplings‡ F
⅛	0.420								0.254	0.141									
	0.430	0.38	0.125	0.095	0.135	0.124	...	...	0.284	0.171	...	0.44	0.44	...	0.31	0.31	...	0.25	0.62
¼	0.555								0.349	0.235									
	0.565	0.38	0.130	0.119	0.158	0.195	...	...	0.379	0.265	...	0.44	0.53	...	0.31	0.31	...	0.25	0.62
⅜	0.690								0.478	0.344									
	0.700	0.38	0.138	0.126	0.172	0.158	...	...	0.508	0.374	...	0.53	0.62	...	0.31	0.44	...	0.25	0.69
½	0.855								0.607	0.451	0.222								
	0.865	0.38	0.161	0.147	0.204	0.188	0.322	0.294	0.637	0.481	0.282	0.62	0.75	1.00	0.44	0.50	0.62	0.38	0.88
¾	1.065								0.809	0.599	0.404								
	1.075	0.50	0.168	0.154	0.238	0.219	0.337	0.308	0.839	0.629	0.464	0.75	0.88	1.12	0.50	0.56	0.75	0.38	0.94
1	1.330								1.034	0.800	0.569								
	1.340	0.50	0.196	0.179	0.273	0.250	0.392	0.358	1.064	0.830	0.629	0.88	1.06	1.25	0.56	0.69	0.81	0.50	1.12
1¼	1.675								1.365	1.145	0.866								
	1.685	0.50	0.208	0.191	0.273	0.250	0.418	0.382	1.395	1.175	0.926	1.06	1.25	1.38	0.69	0.81	0.88	0.50	1.19
1½	1.915								1.595	1.323	1.070								
	1.925	0.50	0.218	0.200	0.307	0.281	0.438	0.400	1.625	1.353	1.130	1.25	1.50	1.50	0.81	1.00	1.00	0.50	1.25
2	2.406								2.052	1.674	1.473								
	2.416	0.62	0.238	0.218	0.374	0.344	0.477	0.436	2.082	1.704	1.533	1.50	1.62	2.12	1.00	1.12	1.12	0.75	1.62
2½	2.906								2.439										
	2.921	0.62	0.301	0.276	...	0.375	...	...	2.499	...	...	1.62	...	...	1.12	...	...	0.75	1.69
3	3.535								3.038										
	3.550	0.62	0.327	0.300	...	0.438	...	...	3.098	...	...	2.25	...	...	1.25	...	...	0.75	1.75
4	4.545								3.996										
	4.560	0.75	0.368	0.337	...	0.531	...	...	4.056	...	...	2.62	...	...	1.62	...	...	0.75	1.88

* Dimensions for caps and reducers are not standardized. Refer to manufacturer's literature for dimensions.
† Values are lower/upper limits.
‡ For tolerances, refer to Table A2.10.

TABLE A2.10 Center-to-Bottom and Laying Length Tolerances for Classes 3000, 6000, and 9000 Socket-Welding Fittings (from ASME B16.11-1996)

	Tolerances plus or minus		
NPS	*A*	*E*	*F*
⅛	0.03	0.06	0.03
¼	0.03	0.06	0.03
⅜	0.06	0.12	0.06
½	0.06	0.12	0.06
¾	0.06	0.12	0.06
1	0.08	0.16	0.08
1¼	0.08	0.16	0.08
1½	0.08	0.16	0.08
2	0.08	0.16	0.08
2½	0.10	0.20	0.10
3	0.10	0.20	0.10
4	0.10	0.20	0.10

Refer to Table A2.9 for nomenclature.

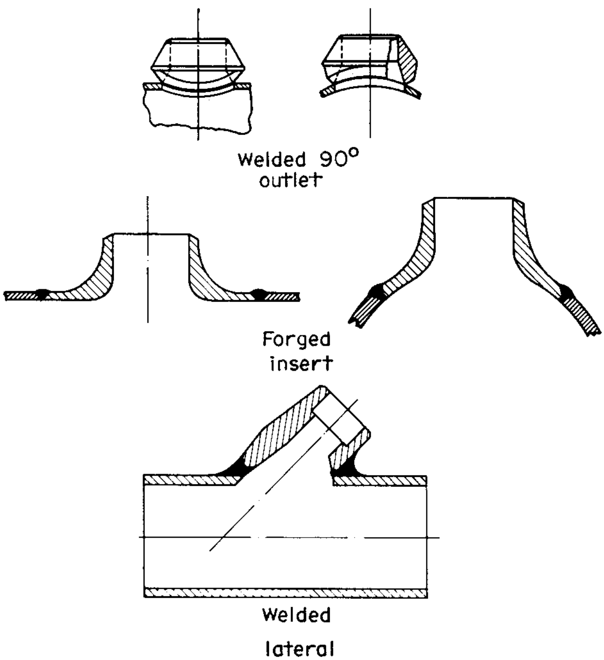
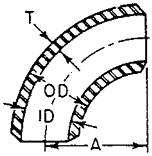


FIGURE A2.4 Typical welding outlet fittings.

TABLE A2.11 Dimensions of Typical Commercial 90° Long-Radius Butt-Welding Elbows (ASME B16.9-1993)



Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to face *A*	Pipe schedule number*	Weight (approx) (lb†)
			Standard			
½	0.840	0.622	0.109	1½	40	0.2
¾	1.050	0.824	0.113	1⅛	40	0.2
1	1.315	1.049	0.133	1½	40	0.4
1¼	1.660	1.380	0.140	1⅞	40	0.6
1½	1.900	1.610	0.145	2¼	40	0.9
2	2.375	2.067	0.154	3	40	1.4
2½	2.875	2.469	0.203	3¾	40	2.9
3	3.500	3.068	0.216	4½	40	4.5
3½	4.000	3.548	0.226	5¼	40	6.4
4	4.500	4.026	0.237	6	40	8.7
5	5.563	5.047	0.258	7½	40	14.7
6	6.625	6.065	0.280	9	40	22.9
8	8.625	7.981	0.322	12	40	46.0
10	10.750	10.020	0.365	15	40	81
12	12.750	12.000	0.375	18	●‡	119
14	14.000	13.250	0.375	21	30	154
16	16.000	15.250	0.375	24	30	201
18	18.000	17.250	0.375	27	●‡	256
20	20.000	19.250	0.375	30	20	317
22	22.000	21.250	0.375	33	20	385
24	24.000	23.250	0.375	36	20	458
26	26.000	25.250	0.375	39	●‡	539
28	28.000	27.250	0.375	42	●‡	626
30	30.000	29.250	0.375	45	●‡	720
32	32.000	31.250	0.375	48	●‡	818
34	34.000	33.250	0.375	51	●‡	926
36	36.000	35.250	0.375	54	●‡	1040
42	42.000	41.250	0.375	63	●‡	1420

TABLE A2.11 Dimensions of Typical Commercial 90° Long-Radius Butt-Welding Elbows (ASME B16.9-1993) (*Continued*)

Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to face *A*	Pipe schedule number*	Weight (approx) (lb†)
			Extra strong			
½	0.840	0.546	0.147	1½	80	0.3
¾	1.050	0.742	0.154	1⅛	80	0.3
1	1.315	0.957	0.179	1½	80	0.5
1¼	1.660	1.278	0.191	1⅞	80	0.8
1½	1.900	1.500	0.200	2¼	80	1.0
2	2.375	1.939	0.218	3	80	2.0
2½	2.875	2.323	0.276	3¾	80	3.8
3	3.500	2.900	0.300	4½	80	6.1
3½	4.000	3.364	0.318	5¼	80	8.7
4	4.500	3.826	0.337	6	80	11.9
5	5.563	4.813	0.375	7½	80	20.6
6	6.625	5.761	0.432	9	80	34.1
8	8.625	7.625	0.500	12	80	69
10	10.750	9.750	0.500	15	60	109
12	12.750	11.750	0.500	18	●‡	157
14	14.000	13.000	0.500	21	●‡	202
16	16.000	15.000	0.500	24	40	265
18	18.000	17.000	0.500	27	●‡	338
20	20.000	19.000	0.500	30	30	419
22	22.000	21.000	0.500	33	30	508
24	24.000	23.000	0.500	36	●‡	606
26	26.000	25.000	0.500	39	20	713
28	28.000	27.000	0.500	42	20	829
30	30.000	29.000	0.500	45	20	953
32	32.000	31.000	0.500	48	20	1090
34	34.000	33.000	0.500	51	20	1230
36	36.000	35.000	0.500	54	20	1380
42	42.000	41.000	0.500	63	●‡	1880
			Schedule 160†			
1	1.315	0.815	0.250	1½	160	0.6
1¼	1.660	1.160	0.250	1⅞	160	1.0
1½	1.900	1.338	0.281	2¼	160	1.4
2	2.375	1.689	0.343	3	160	2.9
2½	2.875	2.125	0.375	3¾	160	4.9
3	3.500	2.624	0.438	4½	160	8.3
4	4.500	3.438	0.531	6	160	17.6
5	5.563	4.313	0.625	7½	160	32.2
6	6.625	5.189	0.718	9	160	53
8	8.625	6.813	0.906	12	160	117
10	10.750	8.500	1.125	15	160	226
12	12.750	10.126	1.312	18	160	375

TABLE A2.11 Dimensions of Typical Commercial 90° Long-Radius Butt-Welding Elbows (ASME B16.9-1993) (*Continued*)

Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to face *A*	Pipe schedule number*	Weight (approx) (lb†)
			Double extra strong			
¾	1.050	0.434	0.308	1⅛	●‡	0.4
1	1.315	0.599	0.358	1½	●‡	0.7
1¼	1.660	0.896	0.382	1⅞	●‡	1.2
1½	1.900	1.100	0.400	2¼	●‡	1.8
2	2.375	1.503	0.436	3	●‡	3.4
2½	2.875	1.771	0.552	3¾	●‡	6.5
3	3.500	2.300	0.600	4½	●‡	10.7
3½	4.000	2.728	0.636	5¼	●‡	15.4
4	4.500	3.152	0.674	6	●‡	21.2
5	5.563	4.063	0.750	7½	●‡	37.2
6	6.625	4.897	0.864	9	●‡	61
8	8.625	6.875	0.875	12	●‡	114

* Pipe schedule numbers in accordance with ASME B36.10M.
† Weights are not tabulated in ASME B16.9.
‡ This size and thickness does not correspond with any schedule number.

Wrought-Steel Butt-Welding Fittings

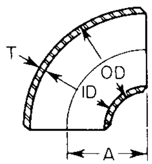
Wrought-steel welding fittings include elbows, tees, crosses, reducers, laterals, lap-joint stub ends, caps, and saddles.

Wrought-steel fittings are made to the dimensional requirements of ASME B16.9 in sizes NPS ½ (DN 15) through NPS 48 (DN 1200). Also, short-radius elbows and returns are produced in accordance with ASME B16.28 in sizes NPS ½ (DN 15) through NPS 24 (DN 600). The wrought fitting materials conform to ASTM A234, A403, or A420, the grades of which have chemical and physical properties equivalent to that of the mating pipe. ASME B16.9 requires that the pressure-temperature rating of the fitting equal or exceed that of the mating pipe of the same or equivalent material, same size, and same nominal wall thickness. The pressure-temperature rating may be established by analysis or by proof testing. Short-radius elbows and returns (fitting centerline bend radius is equal to the fitting NPS) manufactured under ASME B16.28 are rated at 80 percent of the rating calculated for seamless straight pipe of the same size and nominal thickness and same or equivalent material. Therefore, both standards require that, in lieu of specifying any pressure rating, the pipe wall thickness and pipe material type with which the fittings are intended to be used be identified on the fitting.

Pressure testing of the fittings is not required by either standard. However, the fittings are required to be capable of withstanding, without leakage, a test pressure equal to that prescribed in the specification of the pipe with which the fitting is recommended to be used.

Both ASME B16.9 and B16.28 prescribe dimensions and manufacturing tolerances of wrought butt-welded fittings. The standards establish laying dimensions,

TABLE A2.12 Dimensions of Typical Commercial 90° Short-Radius Elbows (ASME B16.28-1994)



Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to face *A*	Pipe schedule number*	Weight (approx) (lb†)
			Standard			
1	1.315	1.049	0.133	1	40	0.3
1¼	1.660	1.380	0.140	1¼	40	0.4
1½	1.900	1.610	0.145	1½	40	0.6
2	2.375	2.067	0.154	2	40	1.0
2½	2.875	2.469	0.203	2½	40	1.9
3	3.500	3.068	0.216	3	40	3.0
3½	4.000	3.548	0.226	3½	40	4.2
4	4.500	4.026	0.237	4	40	5.7
5	5.563	5.047	0.258	5	40	9.7
6	6.625	6.065	0.280	6	40	15.2
8	8.625	7.981	0.322	8	40	30.5
10	10.750	10.020	0.365	10	40	54
12	12.750	12.000	0.375	12	•‡	79
14	14.000	13.250	0.375	14	30	102
16	16.000	15.250	0.375	16	30	135
18	18.000	17.250	0.375	18	•‡	171
20	20.000	19.250	0.375	20	20	212
22	22.000	21.250	0.375	22	•‡	256
24	24.000	23.250	0.375	24	20	305
26§	26.000	25.250	0.375	26	•‡	359
28	28.000	27.250	0.375	28	•‡	415
30	30.000	29.250	0.375	30	•‡	480
32	32.000	31.250	0.375	32	•‡	546
34	34.000	33.250	0.375	34	•‡	617
36	36.000	35.250	0.375	36	•‡	692
42	42.000	41.250	0.375	48	•‡	1079

TABLE A2.12 Dimensions of Typical Commercial 90° Short-Radius Elbows (ASME B16.28-1994) (*Continued*)

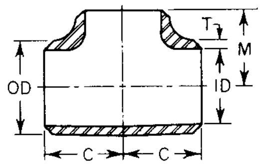
Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to face *A*	Pipe schedule number*	Weight (approx) (lb†)
			Extra strong			
1½	1.900	1.500	0.200	1½	80	0.7
2	2.375	1.939	0.218	2	80	1.3
2½	2.875	2.323	0.276	2½	80	2.5
3	3.500	2.900	0.300	3	80	4.0
3½	4.000	3.364	0.318	3½	80	5.7
4	4.500	3.826	0.337	4	80	7.8
5	5.563	4.813	0.375	5	80	13.7
6	6.625	5.761	0.432	6	80	22.6
8	8.625	7.625	0.500	8	80	45.6
10	10.750	9.750	0.500	10	60	72
12	12.750	11.750	0.500	12	●‡	104
14	14.000	13.000	0.500	14	●‡	135
16	16.000	15.000	0.500	16	40	177
18	18.000	17.000	0.500	18	●‡	225
20	20.000	19.000	0.500	20	30	278
22	22.000	21.000	0.500	22	30	333
24	24.000	23.000	0.500	24	●‡	404
26§	26.000	25.000	0.500	26	20	474
28	28.000	27.000	0.500	28	20	581
30	30.000	29.000	0.500	30	20	634
32	32.000	31.000	0.500	32	20	722
34	34.000	33.000	0.500	34	20	817
36	36.000	35.000	0.500	36	20	913
42	42.000	41.000	0.500	42	●‡	1430

* Pipe schedule numbers in accordance with ASME B36.10M.
† Filling weights are not tabulated in ASME B16.28.
‡ This size and thickness has no corresponding schedule number.
§ Dimensional data for pipe sizes NPS 26 and larger are not included in ASME B16.28.

which remain fixed for each size and type of fitting irrespective of the fitting wall thickness. Tables A2.11, A2.12, A2.13, A2.14, and A2.15 list the laying dimensions and approximate weights for selected fitting sizes, pipe schedules, and configurations.

Laterals are not governed by any national standard. However, dimensions of laterals commonly used are given in Table A2.16. Working pressures are rated at 40 percent of the allowable working pressure established for pipe from which laterals are made. Where full allowable pipe pressures must be met, the laterals are generally made from heavier pipe with ends machined to match standard pipe dimensions. Dimensional tolerances of laterals vary not more than ±1/32 in (1.0 mm) for sizes up to and including NPS 8 (DN 200) and ±1/16 in (2.0 mm) for sizes NPS 10 (DN 250) through NPS 24 (DN 600).

TABLE A2.13 Dimensions of Typical Commercial Straight Butt-Welding Tees (ASME B16.9-1993)



Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to end *C*	Center to end *M*	Pipe schedule number*	Weight (approx) (lb†)
Standard							
½	0.840	0.622	0.109	1	1	40	0.3
¾	1.050	0.824	0.113	1⅛	1⅛	40	0.4
1	1.315	1.049	0.133	1½	1½	40	0.8
1¼	1.660	1.380	0.140	1⅞	1⅞	40	1.3
1½	1.900	1.610	0.145	2¼	2¼	40	2.0
2	2.375	2.067	0.154	2½	2½	40	2.9
2½	2.875	2.469	0.203	3	3	40	5.2
3	3.500	3.068	0.216	3⅜	3⅜	40	7.4
3½	4.000	3.548	0.226	3¾	3¾	40	9.8
4	4.500	4.026	0.237	4⅛	4⅛	40	12.6
5	5.563	5.047	0.258	4⅞	4⅞	40	19.8
6	6.625	6.065	0.280	5⅝	5⅝	40	29.3
8	8.625	7.981	0.322	7	7	40	53
10	10.750	10.020	0.365	8½	8½	40	91
12	12.750	12.000	0.375	10	10	●‡	132
14	14.000	13.250	0.375	11	11	30	172
16	16.000	15.250	0.375	12	12	30	219
18	18.000	17.250	0.375	13½	13½	●‡	282
20	20.000	19.250	0.375	15	15	20	354
22	22.000	21.250	0.375	16½	16½	20	437
24	24.000	23.250	0.375	17	17	20	493
26	26.000	25.250	0.375	19½	19½	●‡	634
28	28.000	27.250	0.375	20½	20½	●‡	729
30	30.000	29.250	0.375	22	22	●‡	855
32	32.000	31.250	0.375	23½	23½	●‡	991
34	34.000	33.250	0.375	25	25	●‡	1136
36	36.000	32.250	0.375	26½	26½	●‡	1294

TABLE A2.13 Dimensions of Typical Commercial Straight Butt-Welding Tees (ASME B16.9-1993) (*Continued*)

Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to end *C*	Center to end *M*	Pipe schedule number*	Weight (approx) (lb†)
Extra strong							
½	0.840	0.546	0.147	1	1	80	0.3
¾	1.050	0.742	0.154	1⅛	1⅛	80	0.5
1	1.315	0.957	0.179	1½	1½	80	0.9
1¼	1.660	1.278	0.191	1⅞	1⅞	80	1.6
1½	1.900	1.500	0.200	2¼	2¼	80	2.4
2	2.375	1.939	0.218	2½	2½	80	3.7
2½	2.875	2.323	0.276	3	3	80	6.4
3	3.500	2.900	0.300	3⅜	3⅜	80	9.4
3½	4.000	3.364	0.318	3¾	3¾	80	12.6
4	4.500	3.826	0.337	4⅛	4⅛	80	16.4
5	5.563	4.813	0.375	4⅞	4⅞	80	26.4
6	6.625	5.761	0.432	5⅝	5⅝	80	42.0
8	8.625	7.625	0.500	7	7	80	76
10	10.750	9.750	0.500	8½	8½	60	118
12	12.750	11.750	0.500	10	10	•‡	167
14	14.000	13.000	0.500	11	11	•‡	203
16	16.000	15.000	0.500	12	12	40	271
18	18.000	17.000	0.500	13½	13½	•‡	351
20	20.000	19.000	0.500	15	15	30	442
22	22.000	21.000	0.500	16½	16½	30	548
24	24.000	23.000	0.500	17	17	20	607
26	26.000	25.000	0.500	19½	19½	20	794
28	28.000	27.000	0.500	20½	20½	20	910
30	30.000	29.000	0.500	22	22	20	1065
32	32.000	31.000	0.500	23½	23½	20	1230
34	34.000	33.000	0.500	25	25	20	1420
36	36.000	35.000	0.500	26½	26½	20	1610
Schedule 160*							
½	0.840	0.466	0.187	1	1	160	0.4
¾	1.050	0.614	0.218	1⅛	1⅛	160	0.6
1	1.315	0.815	0.250	1½	1½	160	1.1
1¼	1.660	1.160	0.250	1⅞	1⅞	160	1.9
1½	1.900	1.338	0.281	2¼	2¼	160	3.0
2	2.375	1.689	0.343	2½	2½	160	4.9
2½	2.875	2.125	0.375	3	3	160	7.8
3	3.500	2.626	0.438	3⅜	3⅜	160	12.2
4	4.500	3.438	0.531	4⅛	4⅛	160	22.8
5	5.563	4.313	0.625	4⅞	4⅞	160	38.5
6	6.625	5.189	0.718	5⅝	5⅝	160	59
8	8.625	6.813	0.906	7	7	160	120
10	10.750	8.500	1.125	8¼	8½	160	222
12	12.750	10.126	1.312	10	10	160	360

TABLE A2.13 Dimensions of Typical Commercial Straight Butt-Welding Tees (ASME B16.9-1993) (*Continued*)

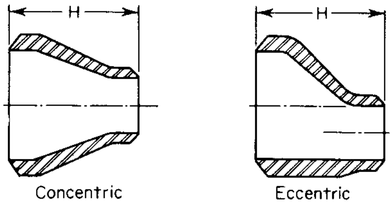
Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Center to end *C*	Center to end *M*	Pipe schedule number*	Weight (approx) (lb†)
			Double extra strong				
½	0.840	0.252	0.294	1	1	●‡	0.4
¾	1.050	0.434	0.308	1⅛	1⅛	●‡	0.6
1	1.315	0.599	0.358	1½	1½	●‡	1.3
1¼	1.660	0.896	0.382	1⅞	1⅞	●‡	2.4
1½	1.900	1.100	0.400	2¼	2¼	●‡	3.7
2	2.375	1.503	0.436	2½	2½	●‡	5.7
2½	2.875	1.771	0.552	3	3	●‡	9.8
3	3.500	2.300	0.600	3⅜	3⅜	●‡	14.8
3½	4.000	2.728	0.636	3¾	3¾	●‡	20.2
4	4.500	3.152	0.674	4⅛	4⅛	●‡	26.6
5	5.563	4.063	0.750	4⅞	4⅞	●‡	43.4
6	6.625	4.897	0.864	5⅝	5⅝	●‡	68
8	8.625	6.875	0.875	7	7	●‡	118

* Pipe schedule numbers in accordance with ASME B36.10M. Other thicknesses available.
† Fitting weights are not tabulated in ASME B16.9.
‡ This size and thickness does not correspond with any schedule number.

Forged Branch Fittings

Under the various pressure piping codes, branch connections may be made by welding the branch pipe or a welding outlet fitting to the run pipe, provided sufficient reinforcement is available to compensate for the material removed from the run pipe to create the branch opening. The reinforcement may be in the form of excess material already available in the run and branch pipes, or it may be added. At the writing of this book, national standards governing the dimensions, tolerances, and manufacture of welding outlet fittings had not been issued. However, MSS-SP-97, 1995, has been developed to cover forged-carbon-steel 90° branch outlet fittings in butt-welding, socket-welding, and threaded outlet ends. The standard provides essential dimensions, finish, tolerances, and testing requirements. Because of the absence of strict standards, manufacturers produce welding outlet fittings of their own proprietary designs. These fittings must comply with the codes governing the systems in which the fittings are to be installed. The fittings, when installed in accordance with the manufacturers' recommendations, include the required reinforcement. The dimensions of these fittings vary; standardized dimensions and properties must be obtained from the manufacturers. Also, designers must consider the appropriate parameters (e.g., stress intensification factors). Figure A2.4 shows several types of welding fittings, which are proprietary; the terminology used varies with the manufacturer. The fittings are produced in carbon and alloy steels under the ASTM specifications for forgings permitted by applicable codes.

TABLE A2.14 Dimensions of Typical Commercial Concentric and Eccentric Butt-Welding Reducers (ASME B16.9-1993)

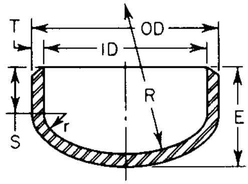


Nominal pipe size	Length *H*	Weight (approx), lb (concentric or eccentric)			
		Standard	Extra strong	Schedule 160	Double extra strong
¾ × ⅜	1½	0.2	0.3	0.3	. . .
¾ × ½	1½	0.2	0.3	0.3	0.4
1 × ⅜	2	0.3	0.4	0.4	0.4
1 × ½	2	0.3	0.4	0.5	0.5
1 × ¾	2	0.3	0.4	0.5	0.5
1¼ × ½	2	0.5	0.5	0.6	0.7
1¼ × ¾	2	0.5	0.5	0.6	0.7
1¼ × 1	2	0.5	0.6	0.7	0.8
1½ × ½	2½	0.5	0.6	0.8	1.0
1½ × ¾	2½	0.5	0.6	0.9	1.0
1½ × 1	2½	0.6	0.7	0.9	1.0
1½ × 1¼	2½	0.6	0.8	1.0	1.2
2 × ¾	3	0.8	1.0	1.4	1.7
2 × 1	3	0.9	1.0	1.4	1.6
2 × 1¼	3	0.9	1.1	1.4	1.8
2 × 1½	3	0.9	1.2	1.6	1.9
2½ × 1	3½	1.3	1.7	2.3	3.0
2½ × 1¼	3½	1.4	1.7	2.2	3.1
2½ × 1½	3½	1.5	1.8	2.2	3.0
2½ × 2	3½	1.6	2.0	2.7	3.3
3 × 1¼	3½	1.7	2.2	3.1	4.1
3 × 1½	3½	1.8	2.1	3.1	4.0
3 × 2	3½	2.0	2.6	3.4	4.0
3 × 2½	3½	2.1	2.8	3.7	4.6
3½ × 1¼	4	2.3	3.2	. . .	5.8
3½ × 1½	4	2.5	3.1	. . .	5.8
3½ × 2	4	2.7	3.5	. . .	5.7
3½ × 2½	4	2.9	3.8	. . .	5.9
3½ × 3	4	3.0	4.0	. . .	6.8

TABLE A2.14 Dimensions of Typical Commercial Concentric and Eccentric Butt-Welding Reducers (ASME B16.9-1993) (*Continued*)

Nominal pipe size	Length *H*	Weight (approx), lb (concentric or eccentric)			
		Standard	Extra strong	Schedule 160	Double extra strong
4 × 1½	4	2.7	3.8	5.6	6.6
2	4	3.1	3.9	5.6	6.6
2½	4	3.3	4.4	5.5	6.3
3	4	3.5	4.7	6.5	7.7
3½	4	3.6	4.8	. . .	8.2
5 × 2	5	5.0	6.6	10.6	12.2
2½	5	5.5	7.2	10.2	11.7
3	5	5.7	7.8	10.2	11.1
3½	5	5.8	8.0	. . .	13.3
4	5	5.9	8.3	12.4	14.2
6 × 2½	5½	7.6	9.9	15.8	18.8
3	5½	8.0	11.1	15.1	18.5
3½	5½	8.1	11.6	. . .	17.3
4	5½	8.1	12.0	17.2	19.1
5	5½	8.6	12.6	18.8	21.4
8 × 3½	6	12.8	16.1	. . .	27.9
4	6	13.1	18.6	26.9	25.7
5	6	13.4	19.5	29.6	29.2
6½	6	13.9	20.4	32.1	32.7
10 × 4	7	21.1	25.3	50	
5	7	21.8	28.7	48	
6	7	22.3	29.8	50	
8	7	23.2	31.4	58	
12 × 5	8	30.5	39.1	78	
6	8	31.1	40.6	75	
8	8	32.1	37.4	86	
10	8	33.4	43.6	94	
14 × 6	13	55	74		
8	13	57	76		
10	13	60	79		
12	13	63	83		

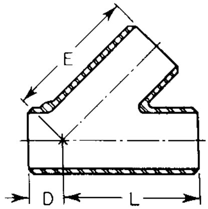
TABLE A2.15 Dimensions of Typical Commercial Butt-Welding Standard Caps (ASME B16.9-1993 Except as Noted)



Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Length *E*	Tangent *S*	Dish radius *R*	Knuckle radius *r*	Pipe schedule number*	Weight (approx) (lb)
½	0.840	0.622	0.109	1	0.74	0.54	0.10	40	0.1
¾	1.050	0.824	0.113	1¼	0.93	0.72	0.14	40	0.2
1	1.315	1.049	0.133	1½	1.10	0.92	0.17	40	0.3
1¼	1.660	1.380	0.140	1½	1.02	1.35	0.23	40	0.4
1½	1.900	1.610	0.145	1½	0.95	1.41	0.27	40	0.4
2	2.375	2.067	0.154	1½	0.83	1.81	0.34	40	0.6
2½	2.875	2.469	0.203	1½	0.68	2.15	0.41	40	0.9
3	3.500	3.068	0.216	2	1.02	2.69	0.51	40	1.4
3½	4.000	3.548	0.226	2½	1.39	3.11	0.59	40	2.1
4	4.500	4.026	0.237	2½	1.26	3.52	0.67	40	2.5
5	5.563	5.047	0.258	3	1.48	4.42	0.84	40	4.2
6	6.625	6.065	0.280	3½	1.70	5.31	1.01	40	6.4
8	8.625	7.981	0.322	4	1.68	6.98	1.33	40	11.3
10	10.750	10.020	0.365	5	2.13	8.77	1.67	40	20.0
12	12.750	12.000	0.375	6	2.62	10.50	2.00	▲†	29.5
14	14.000	13.250	0.375	6½	2.81	11.60	2.21	30	35.3
16	16.000	15.250	0.375	7	2.81	13.34	2.54	30	44.3
18	18.000	17.250	0.375	8	3.31	15.08	2.88	▲†	57
20	20.000	19.250	0.375	9	3.81	16.84	3.21	20	71
22	22.000	21.250	0.375	10	4.31	18.60	3.54	20	86
24	24.000	23.250	0.375	10½	4.31	20.35	3.88	20	102
26	26.000	25.250	0.375	10½	3.81	22.10	4.21	▲†	110
28	28.000	27.250	0.375	10½	3.31	23.85	4.54	▲†	120
30	30.000	29.250	0.375	10½	2.81	25.60	4.88	▲†	125
32	32.000	31.250	0.375	10½	2.31	27.35	5.21	▲†	145
34	34.000	33.250	0.375	10½	1.81	29.10	5.54	▲†	160
36	36.000	35.250	0.375	10½	1.31	30.85	5.88	▲†	175
42	42.000	41.250	0.375	12	1.31	36.10	6.88	▲†	230

* Pipe schedule numbers in accordance with ASME B36.10M.
† This size and thickness does not correspond with any schedule number.

TABLE A2.16 Dimensions of Typical Commercial Butt-Welding Laterals



Nominal pipe size	Standard		Weight (approx) (lb)	Extra strong		Weight (approx) (lb)
	L and *E*	*D*		*L* and *E*	*D*	
			Straight			
1	5¾	1¾	1.7	6½	2	2.5
1¼	6¼	1¾	2.4	7¼	1¼	3.8
1½	7	2	3.2	8½	2½	5.4
2	8	2½	5.0	9	2½	7.7
2½	9½	2½	9.2	10½	2½	13.5
3	10	3	12.6	11	3	18.8
3½	11½	3	17.2	12½	3	25.6
4	12	3	20.8	13½	3	32.8
5	13½	3½	31.4	15	3½	49.8
6	14½	3½	42.4	17½	4	79
8	17½	4½	76	20½	5	140
10	20½	5	124	24	5½	202
12	24½	5½	180	27½	6	273
14	27	6	218	31	6½	340
16	30	6½	275	34½	7½	433
18	32	7	326	37½	8	526
20	35	8	396	40½	8½	628
24	40½	9	544	47½	10	882

TRAPS

Steam Traps

The function of a steam trap is to discharge condensate from steam piping or steam heating equipment without permitting live steam to escape. Some principal types of steam traps are:

- Float
- Thermostatic
- Thermodynamic
- Inverted bucket

The float type (Fig. A2.5) consists of a chamber containing a float-and-arm mechanism which modulates the position of a discharge valve. As the level of condensate in the trap rises, the valve is opened to emit the condensate. This type of valve tends to discharge a steady stream of liquid since the valve position is proportional to the rate of incoming condensate. Because the discharge valve is below the waterline, float-type steam traps must employ a venting system to discharge noncondensable gases. This is generally accomplished with a thermostatic element which opens a valve when cooler noncondensable gases are present but closes the valve in the presence of hotter steam. The thermostatic steam trap (Fig. A2.6) contains a thermostatic element which opens and closes a valve in response to fluid temperature. Condensate collected upstream of the valve is subcooled, cooling the thermostat, which, in turn, exposes the discharge port. When the cooler condensate is discharged and the incoming condensate temperature approaches the saturation temperature, the thermostat closes the discharge port. Because of its principle of operations, the thermostatic trap operates intermittently under all but maximum condensate loads.

The *inverted bucket* steam trap (Fig. A2.7) consists of a chamber containing an inverted bucket (the opening at the bottom) which actuates a discharge valve through a linkage. The valve is open when the bucket rests at the bottom of the trap. This allows air to escape during warm-up until the bottom of the bucket is sealed by rising condensate. The valve remains open as long as condensate is flowing, and trapped air bleeds out through a small vent in the top of the bucket. When steam enters the trap, it fills the bucket, causing the bucket to float so it rises and closes the valve. The steam slowly escapes through the bucket vent and condenses, thus allowing the bucket to sink and reopen the valve for condensate flow. Small amounts of air and noncondensable

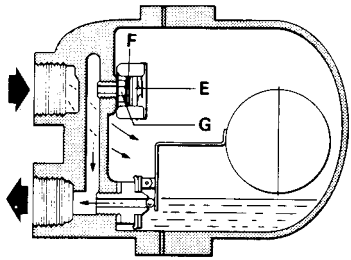
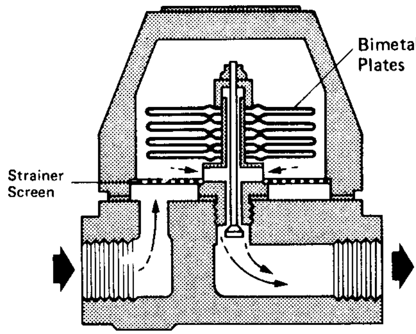
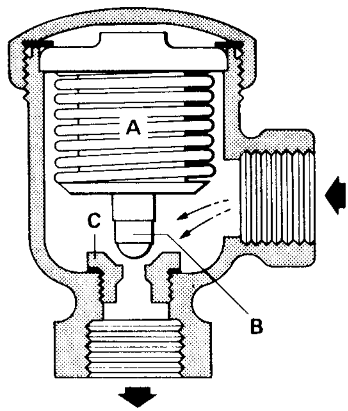


FIGURE A2.5 Float steam trap. (*Spirax Sarco Inc.*)



Trap Strainer Unit



Balanced Pressure Thermostatic Trap

FIGURE A2.6 Thermostatic steam trap. (*a*) Trap strainer unit; (*b*) balanced pressure thermostatic trap. (*Spirax Sarco Inc.*)

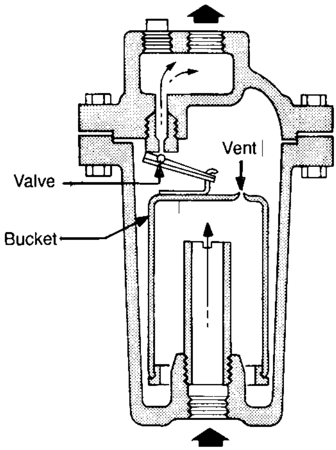


FIGURE A2.7 Inverted bucket steam trap. (*Spirax Sarco Inc.*)

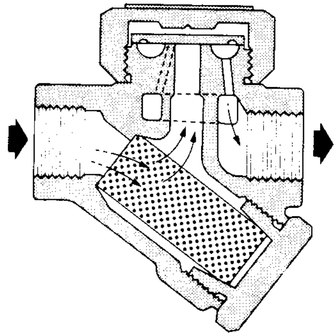


FIGURE A2.8 Thermodynamic steam trap (with integral strainer). (*Spirax Sarco Inc.*)

gases (such as carbon dioxide) that enter the trap during normal operation are also vented through the small opening in the top of the bucket, which prevents the trap from becoming air-bound.

The *thermodynamic steam* trap is illustrated in Fig. A2.8. In this type of trap, flashing of the hot condensate tends to force a small piston into the discharge opening when the temperature of the condensate approaches within about 30°F (15°C) of the saturation temperature. As soon as the condensate collected in the drain system cools sufficiently below the flash temperature, the trap opens and discharges the accumulated water until the temperature of the condensate once more approaches the saturation temperature and flashes, thereby closing the trap and again repeating the cycle. A small orifice permits a continuous discharge of steam, flashed vapor, or noncondensable gas when the trap is closed.

Single orifices are sometimes used to remove condensate from high-pressure, high-temperature steam lines. Where the drains are required only in bringing the line up to temperature, the use of orifices, in conjunction with valves, is particularly desirable.

Air (drain) traps are used to discharge condensed liquid—from a gas system. The drain trap operates on the same principle as the float steam trap does, except that the drain trap does not contain a thermostatic clement.

STRAINERS

Strainers are used in piping systems to protect equipment sensitive to dirt and other particles that may be carried by the fluid. During system start-up and flushing, strainers may be placed upstream of pumps to protect them from construction debris that may have been left in the pipe. Figure A2.9 depicts a typical start-up strainer. Permanent strainers may be installed upstream of control valves, traps, and instrutments to protect them from corrosion products that may become dislodged and carried throughout the piping system.

Strainers are available in a variety of styles, including wye and basket.

The *wye strainer* (Fig. A2.10) is generally used upstream of traps, control valves, and instruments. The wye strainer resembles a lateral branch fitting with the strainer element installed in the branch. The end of the lateral branch is removable, to permit servicing of the strainer. Also, a blow-off connection may be provided in the end cap to flush the strainer.

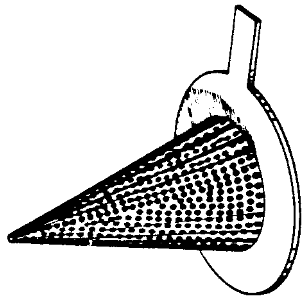


FIGURE A2.9 Conical start-up strainer.

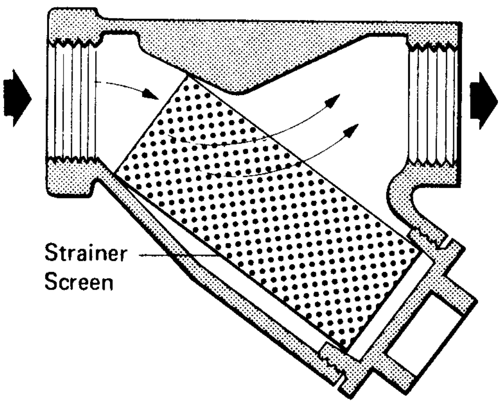


FIGURE A2.10 Wye strainer.

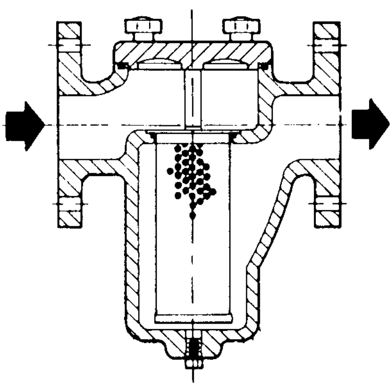


FIGURE A2.11 Basket strainer.

Basket strainers (Fig. A2.11) are generally used where high flow capacity is required. The basket strainer is serviced by removing the cover, which yields access to the basket. Basket strainers are also available in a duplex style which consists of two parallel basket strainers and diverting valves, which permit diversion of the flow through one of the strainer elements while the other element is being serviced—an essential feature where flow cannot be interrupted.

EXPANSION JOINTS

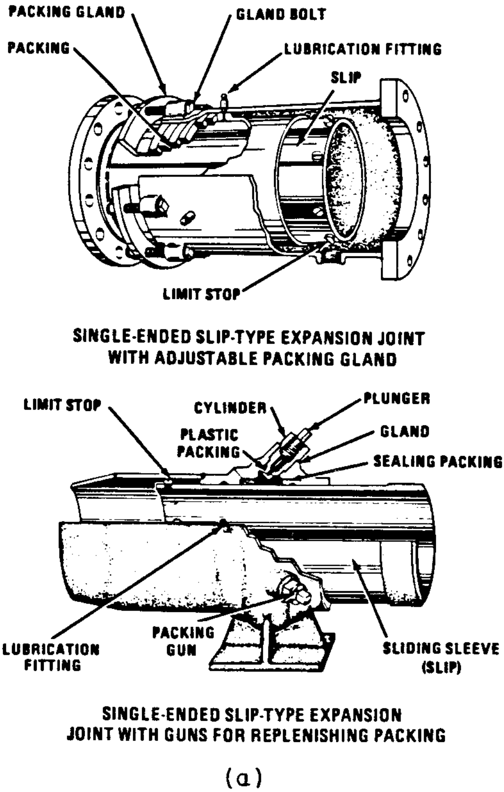
Expansion joints are used in piping systems to absorb thermal expansion where the use of expansion loops is undesirable or impractical. Expansion joints are available in slip, ball, metal bellows, and rubber bellows configurations.

Slip-type expansion joints (Fig. A2.12a) have a sleeve that telescopes into the body. Leakage is controlled by packing located between the sleeve and the body. Leakage is minimal and can be near zero in many applications. A completely leak-free seal cannot be ensured; thus these expansion joints are ruled out where zero leakage is required. The packing is subject to wear due to cyclic movement of the sleeve when connected piping expands and contracts. Thus, these joints require periodic maintenance, either to compress the packing by tightening a packing gland or to replace or replenish the packing. Replacement of the packing rings is necessary when leakage develops in a joint that has an adjustable packing gland which has been tightened to its limit. Some designs provide for packing replenishment rather than replacement. These are usually called *gun-packed* or *ram-packed* slip joints. Since the packing can wear away, some packing material may be picked up in the line fluid. This rules out the use of slip joints in systems, where such contamination of fluid cannot be tolerated.

Slip-type expansion joints are particularly suited for lines having straight-line (axial) movements of large magnitude. Slip joints cannot tolerate lateral offset or angular rotation (cocking) since this would cause binding, galling, and possibly leakage due to packing distortion. Therefore, the use of proper pipe alignment guides is essential.

Ball expansion joints (Fig. A2.12b) consist of a socket and ball with a sealing mechanism placed between them. The seals are of rigid materials, and in some designs a pliable sealant may be injected into the cavity located between the ball and socket. The joints are capable of absorbing angular and axial rotation; however, they cannot accommodate movement along the longitudinal axis of the joint. Therefore, an offset must be installed in the line to absorb pipe axial movement.

Bellows-type expansion joints (Fig. A2.13) do not have packing; thus they do not have the potential leakage or fluid contamination problems sometimes associated with slip joints. Likewise, they do not require the periodic maintenance (lubrication and repacking) that is associated with slip joints. Bellows joints absorb expansion and contraction by means of a flexible bellows that is compressed or extended. They can also accommodate direction changes by various combinations of compression on one side and extension on an opposing side. Thus, they can adjust to lateral offset and angular rotation of the connected piping. However, they are not capable of absorbing torsional movement. Typically, the bellows is corrugated metal and is welded to the end pieces. To provide the requisite flexibility, the metal bellows is considerably thinner than the associated piping. Thus these expansion joints are especially susceptible to rupture by overpressure. A bellows can also fail because of metal fatigue if the accumulated flexing cycles exceed the designed fatigue life



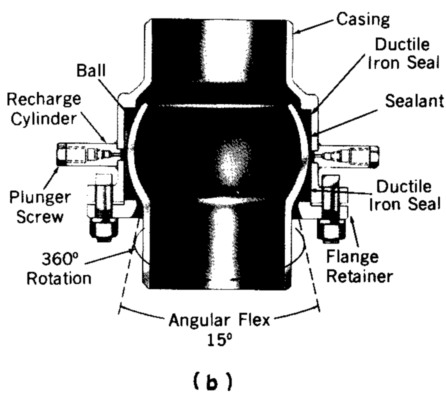


FIGURE A2.12 (*a*) Slip-type expansion joint. (*Yarway Co.*) (*b*) Typical ball expansion joint. (*Barco Co.*)

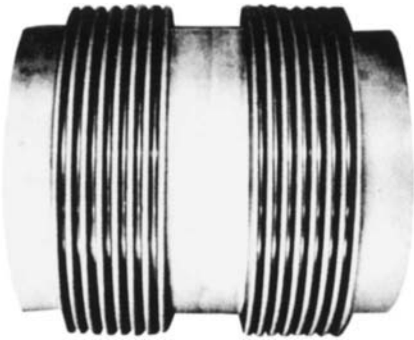


FIGURE A2.13 Metal bellows expansion joint.

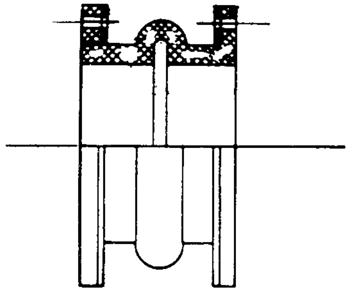


FIGURE A2.14 Rubber expansion joint.

(cyclic life) of the bellows or if the flexing extremes exceed the designed compression and extension limits.

Rubber expansion joints (Fig. A2.14) are similar in design to metal bellows expansion joints except that they are constructed of fabric and wire-reinforced elastomers. They are most suitable for use in cold water service where large movements must be absorbed (e.g., condenser circulating water).

THREADED JOINTS

Threaded joints are normally used in low-pressure small-bore, nonflammable service, although threaded iron pipe is commonly used in domestic gas piping and threaded joints up to NPS 12 (DN 300) have been used in low-pressure liquid service.

For quality joints, it is essential to have smooth, clean threads. A proper form for a pipe threading die is shown in Fig. A6.27. Because cut-thread surfaces are somewhat imperfect, thread sealants (pipe dope) and lubricants are often used to ensure a leak-tight joint. Lubricants such as linseed oil or a compound containing powdered zinc or nickel are sufficient to produce a leak-tight joint in well-made threads. Imperfect threads may require white lead or plumber's tape to provide a good seal. In high-pressure piping where leakage cannot be tolerated, the threaded joints may be seal-welded. Where seal welding is employed, all exposed threads should be covered to prevent cracking in the weld.

Dimensional Standards. Dimensional standards for threads are established in ASME Standard B1.20.1. This standard specifies dimensions, tolerances, and gauging for tape and straight pipe threads, including certain special applications. The normal type of pipe joint employs a tapered external and tapered internal thread. But straight pipe threads are used to advantage for certain types of pipe couplings, grease cup, fuel and oil fittings, mechanical joints for fixtures, and conduit and hose couplings.

Pressure-Tight Joints

Pressure-tight joints for low-pressure service are sometimes made with straight internal threads and the American standard taper external threads. The ductility of the coupling enables the straight thread to conform to the taper of the pipe thread. In commercial practice, straight-tapped couplings are furnished for standard-weight (schedule 40) pipe NPS 2 (DN 50) and smaller. If taper-tapped couplings are required for standard-weight pipe sizes NPS 2 (DN 50) and smaller, line pipe in accordance with API 5L should be ordered. The thread lengths should be in accordance with the American Standard for Pipe Threads, ASME B1.20.1. Taper-tapped couplings are furnished on extra-strong (schedule 80) pipe in all sizes and on standard-weight NPS 2½ (DN 65) and larger.

Dry-seal pipe threads machined in accordance with ASME B1.20.3 are also employed for pressure-tight joints, particularly where the presence of a lubricant or sealer would contaminate the flow medium. Threads are similar to the pipe threads covered by ASME B1.20.1; the essential difference is that, in dry-seal pipe threads, the truncation of the crest and root is controlled to ensure metal-to-metal contact coincident with or prior to flank contact, thus eliminating spiral leakage paths. Dry-seal pipe threads are used in refrigerant systems and for fuel and hydraulic control lines in aircraft, automotive, and marine service. Thread sizes up to NPS 3 (DN 75) are covered by ASME B1.20.3.

Hose Nipples and Couplings. Hose coupling joints are ordinarily used with a gasket and made with straight internal and external loose-fitting threads. There are several standards of hose threads having various diameters and pitches, one of which is based on the American standard pipe thread. With this thread series, it is possible to join small hose sizes ½ to 2 in, inclusive, to ends of standard pipe having American standard external taper pipe threads, by using a gasket to seal the joint. ASME B1.20.7 applies to the threaded parts of hose couplings, valves, nozzles, and all other fittings used in direct connection with hose intended for fire protection or for domestic and industrial general services. However, fire hose coupling dimensions and threads vary with fire districts, and the local fire authority must be consulted. Figure A2.15 illustrates a typical fire hose coupling.

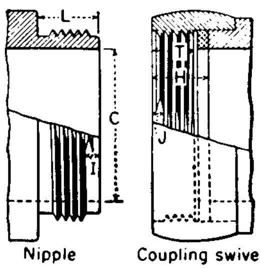


FIGURE A2.15 Typical fire hose coupling.

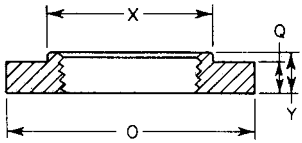
Bolted Joints

The use of bolted joints is advantageous in the following circumstances:

- The components cannot be serviced in line.
- The components being joined are not capable of being welded.
- Quick field assembly is required.
- The component or pipe section must be frequently removed for service.

Bolted piping components are manufactured in accordance with several national standards. Also, several manufacturers produce proprietary bolted connections

TABLE A2.17 Dimensions of Typical Commercial Cast-Iron Companion Flanges Manufactured in Accordance with ASME B16.1-1989



Companion flange, class 125

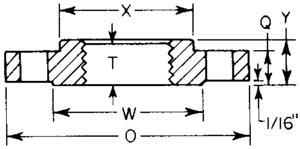
Size (in)	Diameter of flange *Q* (in)	Thickness of flange* (min.) *Q* (in)	Diameter of hub (min.) *X* (in)	Length through hub* (min.) *Y* (in)	Weight (approx) each (lb)	
					Cast iron	Malleable†
1	4¼	7/16	1 15/16	11/16	1.75	
1¼	4⅝	½	2 5/16	13/16	2.00	
1½	5	9/16	2 9/16	⅞	2.25	2.25
2	6	⅝	3 1/16	1	4.00	4.00
2½	7	11/16	3 9/16	1⅛	6.00	6.00
3	7½	¾	4¼	1 3/16	7.63	7.63
3½	8½	13/16	4 13/16	1¼	9.00	9.00
4	9	15/16	5 5/16	1 5/16	11.75	11.75
5	10	15/16	6 7/16	1 7/16	14.00	14.00
6	11	1	7 9/16	1 9/16	16.50	16.50
8	13½	1⅛	9 11/16	1¾	26.00	26.00
10	16	1 3/16	11 15/16	1 15/16	37.75	
12	19	1¼	14 1/16	2 3/16	50.50	
14 OD	21	1⅜	15⅜	2¼	80.00	
16 OD	23½	1 7/16	17½	2½	100.00	
18 OD	25	1 9/16	19⅝	2 11/16	106.00	
20 OD	27½	1 11/16	21¾	2⅞	128.00	
24 OD	32	1⅞	26	3¼	202.00	

which offer cost and time savings over conventional flanged connections. However, proprietary designs must be used within the limitations of the applicable codes.

Ductile and Cast-Iron Flanges. Cast-iron flanges are produced in accordance with ASME B16.1. The standard establishes dimensional requirements, pressure ratings, materials, and bolting requirements. The pressure-temperature ratings and materials requirements for cast-iron flanges are the same as those for cast-iron flanged fittings. The pressure-temperature ratings are given in Table A2.6. The dimensions for Class 125 and Class 250 cast-iron flanges are listed in Table A2.17. XDimensions for bolting are listed in Table A2.18. Note that the Class 125 and Class 250 flanges can be mated with ASME B16.5 Class 150 and Class 300 steel flanges, respectively. When a Class 150 flange is bolted to a Class 125 cast-iron flange (a flat-faced flange), the steel flange should be flat-faced.

Ductile iron flanges and flanged fittings are manufactured in conformance with

TABLE A2.17 Dimensions of Typical Commercial Cast-Iron Companion Flanges Manufactured in Accordance with ASME B16.1-1989 (*Continued*)



Companion flange, class 250

Size (in)	Diameter of flange *O* (in)	Thickness of flange (min.) *Q* (in)	Diameter of hub (min.) *X* (in)	Length through hub‡ (min.) *Y* (in)	Length of threads (min.) *T* (in)	Diameter of raised face *W* (in)	Weight (approx) each (lb) Cast iron	Malleable†
1½	6⅛	13⁄16	2¾	1⅛	0.87	3 9⁄16	5.75	
2	6½	⅞	3 5⁄16	1¼	1.00	4 3⁄16	6.50	6.50
2½	7½	1	3 15⁄16	1 7⁄16	1.14	4 15⁄16	9.50	9.50
3	8¼	1⅛	4⅝	1 9⁄16	1.20	5 11⁄16	12.33	12.33
3½	9	1 3⁄16	5¼	1⅝	1.25	6 5⁄16	16.00	
4	10	1¼	5¾	1¾	1.30	6 15⁄16	20.00	20.00
5	11	1⅜	7	1⅞	1.41	8 5⁄16	24.00	24.00
6	12½	1 7⁄16	8⅛	1 15⁄16	1.51	9 11⁄16	32.00	32.00
8	15	1⅝	10¼	2 3⁄16	1.71	11 15⁄16	51.00	51.00
10	17½	1⅞	12⅝	2⅜	1.92	14 1⁄16	77.00	
12	20½	2	14¾	2 9⁄16	2.12	16 7⁄16	103.00	

* All 125-lb cast-iron standard flanges have a plain face.

† Dimensional standards have not been established for malleable-iron companion flanges; they are generally produced to the same dimensions as cast-iron flanges of the same class.

‡ Minimum thickness of Class 250 flanges includes 1⁄16-in raised face.

the following standards:

ASME B16.42 — Ductile Iron Pipe Flanges and Flanged Fittings—Class 150 and 300.

ANSI/AWWA — C110/A21.10, C115/A21.15 and C153/A21.53, are listed earlier under ductile and cast iron fittings.

Steel and Nickel-Alloy Flanges. Steel and nickel-alloy flanges up to NPS 24 are produced in accordance with ASME B16.5. Steel flanges NPS 26 (DN 650) through NPS 60 (DN 1500) are produced in accordance with ASME B16.47. Also, orifice flanges are produced in accordance with ASME B16.36. The standards specify materials, dimensions, pressure-temperature ratings, and recommendations for bolting and gasketing. Flanges manufactured to ASME B16.5 and B16.47 may be cast or forged. Also, blind flanges may be fabricated from specific plate materials. The most commonly used materials are forged carbon steel (ASTM A105) and forged low-alloy and stainless steel (ASTM A182). The standards cover seven pressure classes (Classes 150, 300, 400, 600, 900, 1500, and 2500) in a variety of styles and materials. Figures A2.16 and A2.17 show typical flange styles. The dimensions of each style within each pressure class are held constant irrespective of the material. Therefore, within each pressure class, the pressure-temperature rating varies with the material properties (see Figs. A2.1, A2.2, and A2.3).

TABLE A2.18 Bolting Dimension for Cast-Iron Flanges

Size (in)	Diameter of bolt circle	Number of bolts	Diameter of bolts	Diameter of bolt holes	Length of bolts
Class 125					
1	3⅛	4	½	⅝	1¾
1¼	3½	4	½	⅝	2
1½	3⅞	4	½	⅝	2
2	4¾	4	⅝	¾	2¼
2½	5½	4	⅝	¾	2½
3	6	4	⅝	¾	2½
3½	7	8	⅜	¾	2¾
4	7½	8	⅝	¾	3
5	8½	8	¾	⅞	3
6	9½	8	¾	⅞	3¼
8	11¾	8	¾	⅞	3½
10	14¼	12	⅞	1	3¾
12	17	12	⅞	1	3¾
14	18¾	12	1	1⅛	4¼
16	21¼	16	1	1⅛	4½
18	22¾	16	1⅛	1¼	4¾
20	25	20	1⅛	1¼	5
24	29½	20	1¼	1 4⁄8	5½

Size (in)	Diameter of bolt circle	Diameter of bolt holes	Number of bolts	Size of bolts	Length of bolts
Class 250					
1½	4½	⅞	4	¾	2¾
2	5	¾	8	⅝	2¾
2½	5⅞	⅞	8	¾	3¼
3	6⅝	⅞	8	¾	3½
3½	7¼	⅞	8	¾	3½
4	7⅞	⅞	8	¾	3¾
5	9¼	⅞	8	¾	4
6	10⅝	⅞	12	¾	4
8	13	1	12	⅞	4½
10	15¼	1⅛	16	1	5¼
12	17¾	1¼	16	1⅛	5½

Proprietary Bolted Connections. There are various proprietary bolted pipe joining systems produced that are not formally addressed by any standard. Under the various piping codes, pressure-retaining components not covered by standards specifically cited as acceptable for use under the "Code" may be used provided their design is proved by analysis or proof testing or a combination of both.

Flange Types

Flanges differ in method of attachment to the pipe, i.e., whether they are screwed, welded, or lapped. Contact surface facings may be plain, serrated, grooved for ring joints, seal-welded, or ground and lapped for metal-to-metal contact. Some common types of joints and facings are shown in Fig. A2.18. In Section VIII, Unfired Pressure Vessels, of the ASME Boiler and Pressure Vessel Code, three types of circular flanges are defined, and these are designated as loose-type (Fig. A2.17), integral-type (Fig. A2.16), and optional-type flanges. Under the code, the welds and other details of construction shall satisfy the dimensional requirements stated therein.

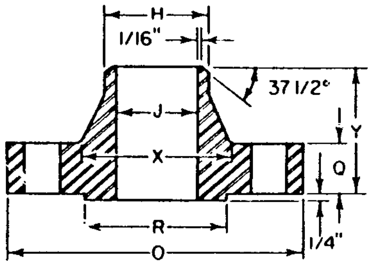


FIGURE A2.16 Typical integral flange (welding neck flange).

Loose-Type Flanges. This (slip-on) type covers those designs in which the flange has no direct connection to the nozzle neck or the vessel or pipe wall and those designs where the method of attachment is not considered to give the mechanical strength equivalent of integral attachment.

Integral-Type Flanges. This type covers designs in which the flange is cast or forged integrally with the nozzle neck or the vessel or pipe wall, butt-welded thereto, or attached by other forms of arc or gas welding of such a nature that the flange and nozzle neck or vessel or pipe wall is considered to be the equivalent of an integral structure. In welded construction, the nozzle neck or the vessel or pipe wall is considered to act as a hub.

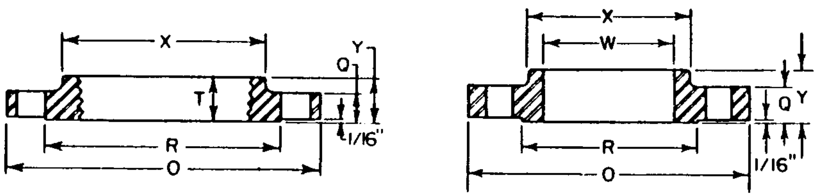


FIGURE A2.17 Typical loose flanges (threaded and slip-on).

Optional-Type Flanges. This type covers designs where the attachment of the flange to the nozzle neck or the vessel or pipe wall is such that the assembly is considered to act as a unit, which shall be calculated as an integral flange, except that for simplicity the designer may calculate the construction as a loose-type flange, provided that stipulated load values are not exceeded.

It is important in flange design to select materials and to proportion dimensions of bolts, flanges, and gaskets to ensure that the necessary compression will be maintained on the joint faces over the expected life of the equipment.

Several distinct phases of the problem are involved: (1) type of flange facing, (2) finish of contact surfaces, (3) gasket type and proportions, (4) bolt load required to secure and maintain a tight joint, and (5) proportions of flange needed to support the bolt load.

Types of Flange Facing. There are numerous types of contact facings for flanges, the simplest of which is the plain face provided with a "smooth tool finish." Class 125 cast-iron flanged fittings are provided with this type of facing. For steel flanges

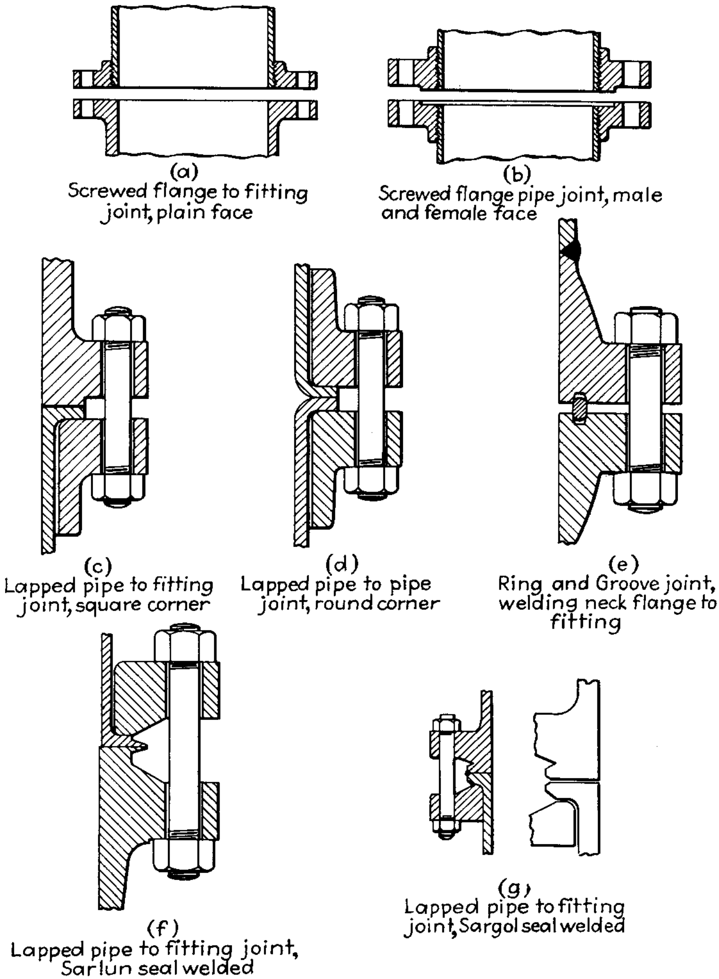


FIGURE A2.18 Commonly used flanged joints. (*a*) Screwed flange to fitting joint, plain face; (*b*) screwed flange pipe joint, male-and-female face; (*c*) lapped pipe to fitting joint, square corner; (*d*) lapped pipe to pipe joint, round corner; (*e*) ring and groove joint, welding neck flange to fitting; (*f*) lapped pipe to fitting joint, Sarlun seal welded; and (*g*) lapped pipe to fitting joint, Sargol seal welded.

and fittings, the typical facings (Fig. A2.19) are taken from the American Standard for Steel Pipe Flanges and Flanged Fittings, ASME B16.5 and ASME B16.47. The raised face, the lapped, and the large male-and-female facings have the same dimensions, which provide a relatively large contact area. Where metal gaskets are used with these facings, the gasket area should be reduced to increase the gasket compression.

The flange-facing types illustrated in Fig. A2.19 range in size and contact area in the following order: large tongue-and-groove, small tongue-and-groove, small

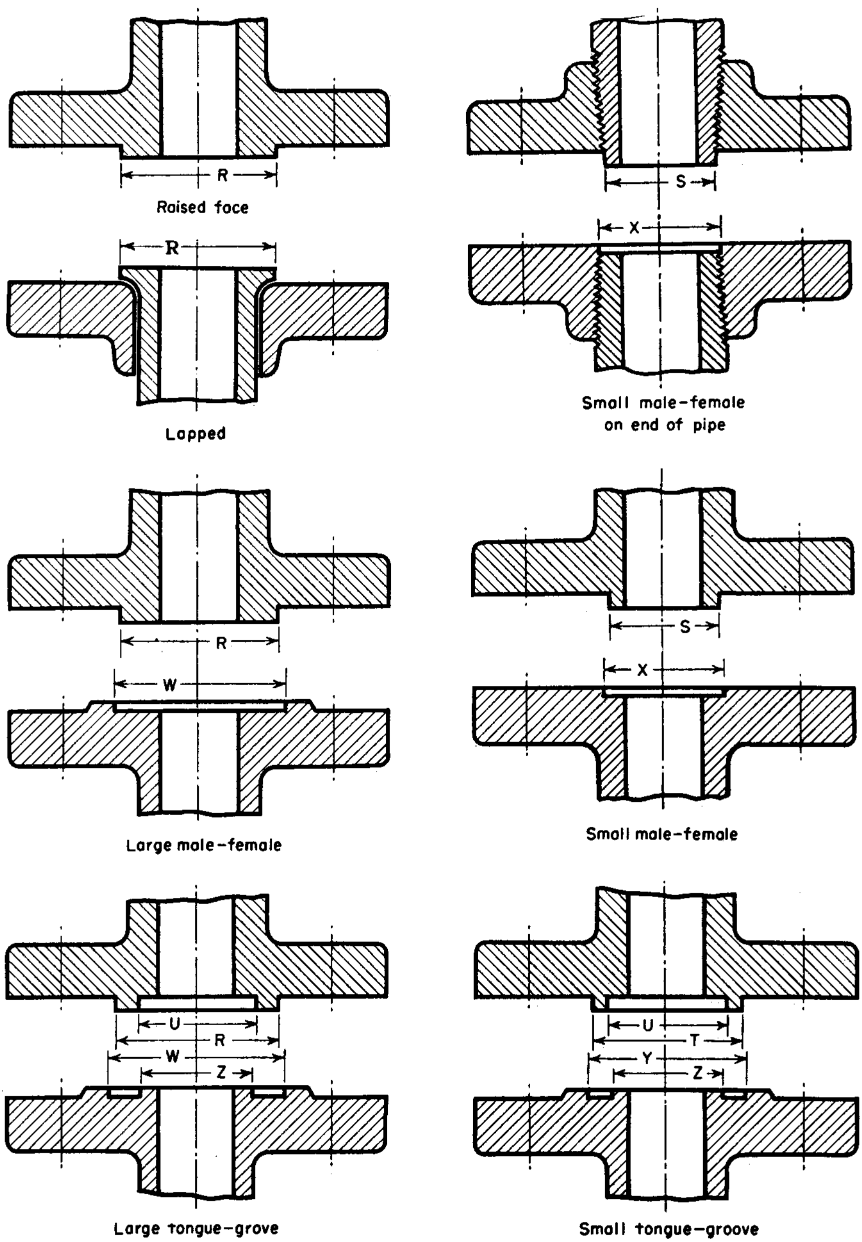
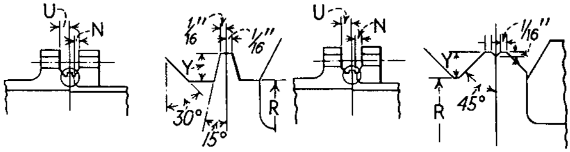


FIGURE A2.19 Typical flange facings (for dimensions, see ASME B16.5).



Nominal pipe size	Basic raised-face, outside diameter *R*	Height of face		Height of front hub		Height of welding projections	
		Sargol* *U*	Sarlun† *U*	Sargol* *N*	Sarlun† *N*	Sargol* *Y*	Sarlun† *Y*
2½	4⅛	½	11⁄16	¼	5⁄16	⅛	5⁄16
3	5	⅝	11⁄16	5⁄16	5⁄16	3⁄16	5⁄16
4	6 3⁄16	¾	¾	7⁄16	13⁄32	5⁄16	5⁄16
5	7 5⁄16	⅞	⅞	½	½	⅜	⅜
6	8½	1	1	9⁄16	9⁄16	⅜	⅜
8	10⅝	1⅛	1⅛	⅝	⅝	⅜	⅜
10	12¾	1¼	1¼	⅝	¾	⅜	⅜
12	15	1 5⁄16	1 5⁄16	⅝	13⁄16	⅜	⅜
14	16½	1⅜	1⅜	⅝	⅞	⅜	⅜
16	18½	1⅜	1⅜	⅝	⅞	⅜	⅜

All dimensions in inches.
* Dimensions of modified Sargol joint.
† Dimensions of Sarlun facings recommended by Sargent and Lundy, Inc.

FIGURE A2.20 Typical facing dimensions for Sargol and Sarlun joints, Class 150 to 2500 flanges (see footnotes).

male-and-female, and ring joint. Because of the small gasket contact area, a tight joint may be secured with the ring-type facing using low bolting loads, thereby resulting in lowered flange stresses (ASME B16.5). The Sargol and Sarlun facings, which have lips for seal welding, are used frequently for severe service conditions. Seal welding is not always performed since, if it is properly made, a tight joint often can be maintained without the welded seal, thus facilitating disassembly. Typical facing dimensions for Sarlun and Sargol joints are shown in Fig. A2.20. Special types of facing of individual design intended for a specific service are numerous. Economic considerations generally make it desirable to use a standard facing wherever possible.

Selection of the type of facing depends to a considerable extent on the nature of the service. However, it is not possible to determine exactly which facing should be used. Prior experience is usually relied on as a guide. Plain-face joints with red rubber gaskets have been found satisfactory for temperatures up to 220°F (105°C), whereas serrated raised-face joints with graphite-steel-composition gaskets are commonly used for temperatures up to 750°F (400°C). For high temperatures and pressures, faces giving a high contact pressure for a given bolt load are customary, such as the tongue-and-groove and ring joints. However, with high contact pressures, the gasket load must be checked to ensure that the gasket is not overcompressed.

An equally successful joint for most types of service can be made by using a profile-serrated metal gasket contacting the flange facing, which may be the plain male-to-male raised-face type.

Contact Surface Finish. The surface finish is an important factor in determining the extent to which a gasket must flow to secure an impervious seal. Bolting that results in adequate gasket flow to form a satisfactory seal with a smooth contact surface may be inadequate to secure a tight joint with a rough surface. The finish may vary from that produced by rough casting surfaces to that produced by grinding and lapping. Less gasket flow will be necessary for the latter than for the former. The finish most frequently provided on cast-iron and steel pipe flanges is the smooth tool finish. A serrated finish frequently is provided for steel flanges, particularly when using a graphite-composition gasket with a wide contact area such as is furnished on raised, lapped, or large tongue-and-groove facings. The serrated finish consists of spiral or concentric grooves, usually about 1/64 in (0.4 mm) deep with 12.5 serrations per cm (32 serrations per inch). Where metal gaskets are used, a smooth surface produced by grinding or lapping is usually provided. The Sargol and Sarlun facings mate metal to metal without a gasket, in which case a mirrorlike finish is necessary. This is usually produced by grinding and lapping. It is evident that the surface finish varies with the type of contact face and gasket used and, therefore, should be specified accordingly.

Gaskets

Since it is expensive to grind and lap joint faces to obtain fluid-tight joints, a gasket of some softer material is usually inserted between contact faces. Tightening the bolts causes the gasket material to flow into the minor machining imperfections, resulting in a fluid-tight seal. A considerable variety of gasket types are in common use. Soft gaskets, such as cork, rubber, vegetable fiber, graphite, or asbestos, are usually plain with a relatively smooth surface. The semimetallic design combines metal and a soft material, the metal to withstand the pressure, temperature, and attack of the confined fluid and the soft material to impart resilience. Various designs involving corrugations, strip-on-edge, metal jackets, etc., are available. In addition to the plain, solid, and flat-surface metal gaskets, various modified designs and cross-sectional shapes of the profile, corrugated, serrated, and other types are used. The object in general has been to retain the advantage of the metal gasket but to reduce the contact area to secure a seal without excessive bolting load. Effective gasket widths are given in various sections of the ASME Boiler and Pressure Vessel Code.

Gasket Materials. Gasket materials are selected for their chemical and pressure resistance to the fluid in the pipe and their resistance to deterioration by temperature. Gasket materials may be either metallic or nonmetallic. Metallic ring-joint gasket materials are covered by ASME Standard B16.20, Ring-Joint Gaskets and Grooves for Steel Pipe Flanges. Nonmetallic gaskets are covered in ASME Standard B16.21, Nonmetallic Gaskets for Pipe Flanges. Typical selections of gasket materials for different services are shown in Table A2.19.

Gasket Compression. In the usual type of high-pressure flange joint, a narrow gasket face or contact surface is provided to obtain higher unit compression on the gasket than is obtainable on full-face gaskets used with low-pressure joints. The compression on this surface and on the gasket if the gasket is used, before internal

TABLE A2.19 Selections of Gasket Materials for Different Services

Fluid	Application	Gasket material*
Steam (high pressure)	Temp up to 1000°F (538°C)	Spiral-wound comp. asbestos or graphite
	Temp up to 1000°F (538°C)	Steel, corrugated, or plain
	Temp up to 1000°F (538°C)	Monel, corrugated, or plain
	Temp up to 1000°F (538°C)	Hydrogen-annealed furniture iron
	Temp up to 1000°F (538°C)	Stainless steel 12 to 14 percent chromium, corrugated
	Temp up to 1000°F (538°C)	Ingot iron, special ring-type joint
	Temp up to 750°F (399°C)	Comp. asbestos, spiral-wound
	Temp up to 600°F (316°C)	Woven asbestos, metal asbestos
	Temp up to 600°F (316°C)	Copper, corrugated or plain
Steam (low pressure)	Temp up to 220°F (105°C)	Red rubber, wire inserted
Water	Hot, medium, and high pressures	Black rubber, red rubber, wire inserted
	Hot, low pressures	Brown rubber, cloth inserted
	Hot	Comp. asbestos
Water	Cold	Red rubber, wire inserted
	Cold	Black rubber
	Cold	Soft rubber
	Cold	Asbestos
	Cold	Brown rubber, cloth inserted
Oils (hot)	Temp up to 750°F (399°C)	Comp. asbestos
	Temp up to 1000°F (538°C)	Ingot iron, special ring-type joint
Oils (cold)	Temp up to 212°F (100°C)	Cork or vegetable fiber
	Temp up to 300°F (149°C)	Neoprene comp. asbestos
Air	Temp up to 750°F (399°C)	Comp. asbestos
	Temp up to 220°F (105°C)	Red rubber
	Temp up to 1000°F (538°C)	Spiral-wound comp. asbestos
Gas	Temp up to 1000°F (538°C)	Asbestos, metallic
	Temp up to 750°F (399°C)	Comp. asbestos
	Temp up to 600°F (316°C)	Woven asbestos
	Temp up to 220°F (105°C)	Red rubber
Acids	(Varies; see section on corrosion)	Sheet lead or alloy steel
	Hot or cold mineral acids	Comp. blue asbestos
		Woven blue asbestos
Ammonia	Temp up to 1000°F (538°C)	Asbestos, metallic
	Temp up to 700°F (371°C)	Comp. asbestos
	Weak solutions	Red rubber
	Hot	Thin asbestos
	Cold	Sheet lead

* Several gasket manufacturers have introduced nonasbestos, nonmetallic gasket materials for use in high-temperature service. These materials are proprietary, and therefore the manufacturers should be consulted for specific applications.

pressure is applied, depends on the bolt loading used. In the case of standard raised-face joints of the steel-flange standards, these gasket compressions range from 28 to 43 times the rated working pressure in the Class 150 to 400 standards, and from 1 to 28 times in the Class 600 to 2500 standards for an assumed bolt stress of 60,000 psi (4200 kg/cm^2). For the lower-pressure standards, using composition gaskets, a bolt stress of 30,000 psi (2100 kg/cm^2) usually is adequate. The effect of applying the internal pressure is to decrease the compression on the contact surface, since part of the bolt tension is used to support the pressure load.

The initial compression required to force the gasket material into intimate contact with the joint faces depends upon the gasket material and the character of the joint facing. For soft-rubber gaskets, a unit compression stress of 4000 psi (280 kg/cm^2) to 6000 psi (420 kg/cm^2) usually is adequate. Laminated asbestos gaskets in serrated faced joints perform satisfactorily if compressed initially at 12,000 psi (850 kg/cm^2) to 18,000 psi (1260 kg/cm^2). Metal gaskets such as copper, Monel, and soft iron should be given initial compressions considerably in excess of their yield strengths. Unit pressures of 30,000 psi (2100 kg/cm^2) to 60,000 psi (4200 kg/cm^2) have been used successfully with metal gaskets. Various forms of corrugated and serrated metal gaskets are available which enable high unit compression to be obtained without excessive bolt loads. These are designed to provide a contact area that will flow under initial compression of the bolts so as to make an initially pressure-tight joint, but at the same time the compressive stresses in the body of the gasket are sufficiently low as to be comparable to the long-time load-carrying ability of the bolting and flange material at high temperatures.

The residual compression on the gasket necessary to prevent leakage depends on how effective the initial compression has been in forming intimate contact with the flange joint faces. Tests show that a residual compression on the gasket of only 1 to 2 times the internal pressure, with the pressure acting, may be sufficient to prevent leakage where the joint is not subjected to bending or to large and rapid temperature changes. Since joints in piping customarily must withstand both these disturbing influences, minimum residual gasket compressions of 4 to 6 times the working pressure should be provided for in the design of pipe joints.

Relation of Gaskets to Bolting. There is a tendency, as indicated in the ASME Rules for Bolted Flanged Connections, to assign lower residual contact-pressure ratios ranging from about 1 for soft-rubber gaskets to 6 or 7 for solid-metal gaskets. Whereas these are said to have proved satisfactory service for heat-exchanger and pressure-vessel flanges, the more severe service encountered by pipe flanges due to bending moments and large temperature changes is considered by many to warrant designing on the basis of the larger residual gasket compression ratios recommended in the previous paragraph. The lack of understanding of the mechanics of gasket action, the variety of gasket materials, shapes, widths, and thicknesses; the variety of facings used; the variation in flange stiffness; and the uncertainties in bolt pull-up are among the factors that render difficult a precise solution to the problem of gasket design.

Rules for bolting and flange design are contained in Sections III and VIII of the ASME Boiler and Pressure Vessel Code.

Bolting

Bolting material for cast-iron flanges is listed in ASME B16.1. Generally, ASTM A307, grade B material is suitable. For steel flanges, acceptable bolting material is listed in ASME B16.5.

Threading. Bolts and nuts normally are threaded in accordance with ASME B1.1 Standard for Unified Screw Threads. In diameters 1 in and smaller, Class 2A fits on the bolt or stud and Class 2B on the nut applies with the coarse thread series. In diameters 1⅛ in and larger, the eight-pitch-thread series applies with the same fit. Grade 7 bolts are threaded by roll threading after heat treatment. Roll threading cold-works the surface uniformly. The resulting compressive stresses provide substantially increased fatigue strength at the thread root, which is usually the weakest point. The thread root is the weakest point because it is the smallest cross-sectional area in the bolt. The stressed area A of a bolt is computed from

$$A = \frac{0.7854(D - 0.9743)^2}{N}$$

where D is the nominal bolt diameter and N represents the threads per inch.

Bolts with fine threads will exhibit a slightly higher proof strength (about 10 percent) than bolts with coarse threads (as illustrated in Fig. A2.21), provided that the length of engagement with the mating internal thread is sufficient to guarantee a tensile failure through the bolt rather than failure by thread stripping.

In practical bolt assemblies, fine threads are considered weaker because of reduced thread height. Fine threads have limited application for threaded assemblies. They should be used for adjustment rather than as a clamping force.

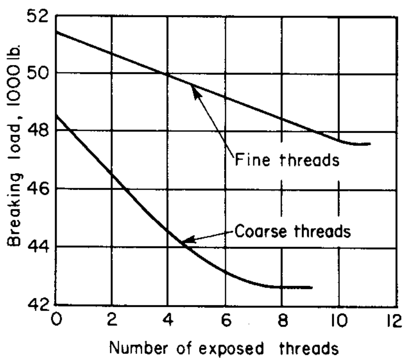


FIGURE A2.21 Comparison of proof strength of fine and coarse threads, SAE Grade 5, ¾-in bolts.

Dimensions

The dimensions applicable to bolting materials are given in ASME B16.5, American Standard Pipe Flanges and Flanged Fittings.

Securing and Tightening. For the average low- and medium-pressure installations, bolts are made in staggered sequence with wrenches which will usually result in adequately tight joints. For the high-pressure and -temperature joints, it becomes increasingly important to make up each stud to a definite tension. Torque wrenches are sometimes used for this purpose.

In exceptional cases where a more positive method is desired, the studs may be tightened until a definite elongation has been attained. For this condition, an initial cold tension of 30,000 psi (2100 kg/cm^2) to 35,000 psi (2460 kg/cm^2) in each stud is recommended. Since the modulus of elasticity of stud material is about 30×10^6 psi (2.1×10^6 kg/cm^2), a tension of 30,000 psi (2100 kg/cm^2) would result in an elongation 0.1% of effective length. The effective length is the distance between nut faces plus one nut thickness. Special studs with ground ends are required to make micrometer measurements for this purpose. After the joint has been in service, periodic checks of the actual cold lengths as compared with the tabulated lengths will detect any permanent elongation of the studs. Permanent elongation will indicate

TABLE A2.20 Turning Efforts to Tighten Eight-Pitch-Thread Bolts

Nominal diameter of bolt (in)	Number of threads per inch	Tensile stress area A_s	Stress* 30,000 psi Torque (ft·lb)	Stress* 30,000 psi Force per bolt (lb)	Stress* 60,000 psi Torque (ft·lb)	Stress* 60,000 psi Force per bolt (lb)
½	13	0.1419	30	4,257	60	8,514
9⁄16	12	0.182	45	4,560	90	10,920
⅝	11	0.226	60	6,780	120	13,560
¾	10	0.334	100	10,020	200	20,040
⅞	9	0.606	160	18,180	320	36,360
1	8	0.462	245	13,860	490	27,720
1⅛	8	0.790	355	23,700	710	47,400
1¼	8	1.000	500	30,000	1,000	60,000
1⅜	8	1.233	680	36,990	1,360	73,980
1½	8	1.492	800	44,760	1,600	89,520
1⅝	8	1.78	1,100	53,400	2,200	106,800
1¾	8	2.08	1,500	62,400	3,000	124,800
1⅞	8	2.41	2,000	72,300	4,000	144,600
2	8	2.77	2,200	83,100	4,400	166,200
2¼	8	3.56	3,180	106,800	6,360	213,600
2½	8	4.44	4,400	133,200	8,800	266,400
2¾	8	5.43	5,920	162,900	11,840	325,800
3	8	6.51	7,720	195,300	15,440	390,600
3¼	8	7.69	.....	230,700	.....	461,400
3½	8	8.96	.....	268,800	.....	537,600
3¾	8	10.34	.....	310,300	.....	620,400
4	8	18.11	.....	354,300	.....	708,600

* Stress has been calculated on the basis of stressed area A_s where $A_s = 0.7854\,(D - 0.9743/N)^2$ in which D is the nominal bolt diameter and N is threads per inch.

overstressing, relaxation, and creep. When these conditions become severe, new studs may be required to maintain the joint properly.

Special thread lubricants are available for temperatures both below 500°F (260°C) and from 500°F (260°C) to 1000°F (540°C). Such lubricants not only facilitate initial tightening but also permit easier disassembly after service.

Table A2.20 illustrates the turning effort required for tightening well-lubricated threads and bearing surfaces. Tests with no lubricant on threads and bearing surfaces may increase torque requirements by 75 to 100 percent to secure a given bolt stress.

For more information on bolted joints, see Chap. A7.

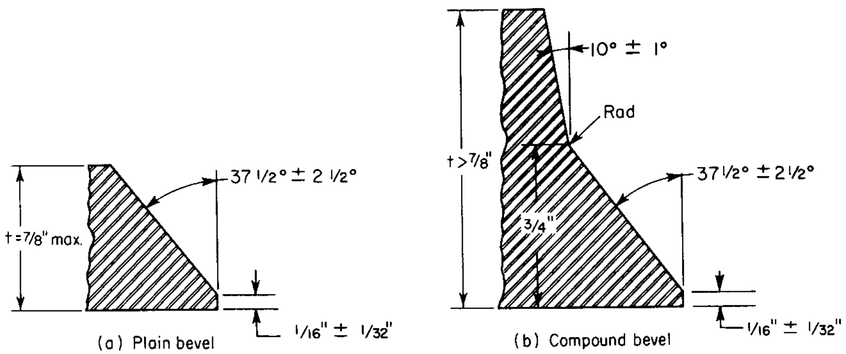
WELDED AND BRAZED JOINTS

Welded and brazed joints are the most commonly used methods for joining piping components because these joints are stronger and more leak-tight than threaded and flanged joints. Furthermore, they do not add weight to the piping system as flanges do, and they do not require an increase in pipe wall thickness to compensate for threading, as threaded joints do.

Pipe-Weld Joint Preparation and Design

Butt Welds. The most common type of joint employed in the fabrication of welded pipe systems is the circumferential butt joint. It is the most satisfactory joint from the standpoint of stress distribution. Its general field of application is pipe to pipe, pipe to flange, pipe to valve, and pipe to fitting joints. Butt joints may be used for all sizes, but fillet-welded joints can often be used to advantage for pipe NPS 2 (DN 50) and smaller.

The profile of the weld edge preparations for butt welds may be any configuration the welding organization deems suitable for making an acceptable weld. However, to standardize the weld edge preparation on butt-welded commercial piping components, standard weld edge preparation profiles have been established in ASME B16.25. These weld edge preparation requirements are also incorporated into the standards governing the specific components (e.g., B16.9, B16.5, B16.34). Figures



Nominal pipe wall thickness t	End preparation
Less than x*	Cut square or slightly chamfer, at manufacturer's option
x* to ⅞ incl.	Plain bevel as in (a) above
More than ⅞	Compound bevel as in (b) above
x* = 3⁄16" for carbon steel, ferritic alloy steel, or wrought iron; ⅛" for austenitic alloy steel	

FIGURE A2.22 Basic welding bevel for all components (without backing ring, or with split ring).

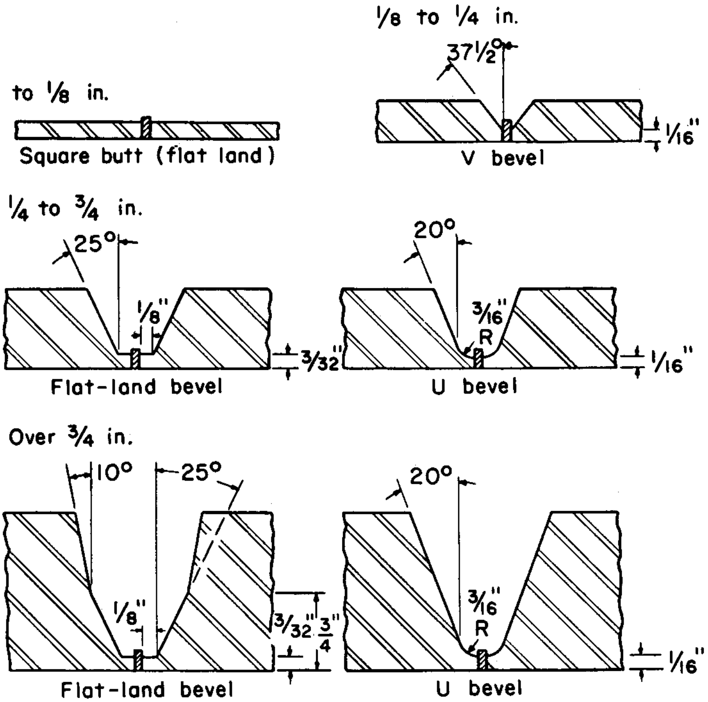


FIGURE A2.23 Typical end preparations for pipe which is to be welded by the inert-gas tungsten-arc welding process.

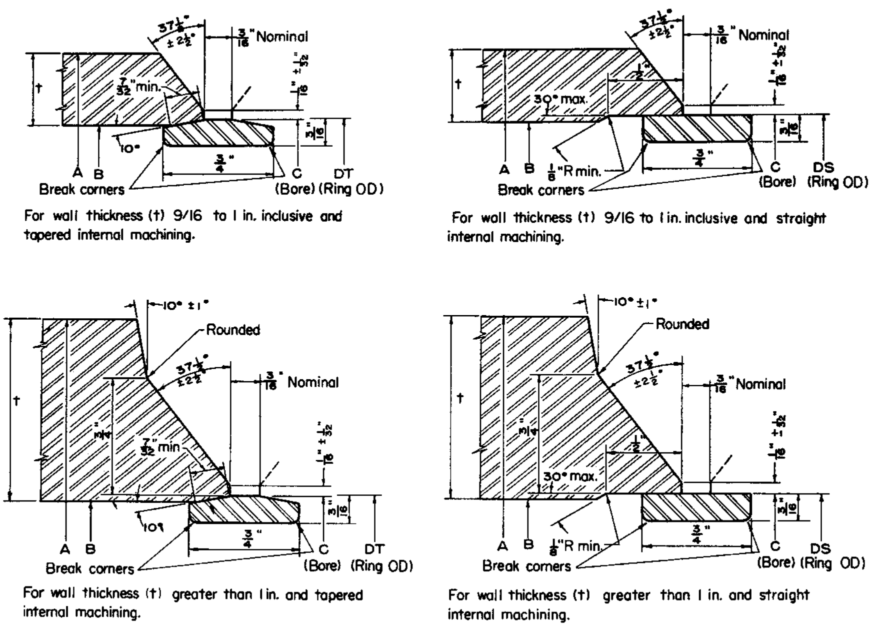


FIGURE A2.24 End preparation and backing-ring requirements for critical-service applications employing flat or taper-machined solid backing rings. See Table A2.21 for dimensional data.

TABLE A2.21 Dimensions for Internal Machining and Backing Rings for Heavy-Wall Pipe in Critical Applications

Nominal pipe size	Schedule no. or wall	Nominal OD *A*	Nominal ID *B*	Nominal wall thickness *t*	Machined ID of pipe *C* tolerance +0.010 −0.000	OD of backing ring: Tapered ring *DT* tolerance +0.010 −0.000	OD of backing ring: Straight ring *DS* tolerance +0.000 −0.010
3	XXS	3.500	2.300	0.600	2.409	2.419	2.409
4	XXS	4.500	3.152	0.674	3.279	3.289	3.279
5	160	5.563	4.313	0.625	4.428	4.438	4.428
	XXS	5.563	4.063	0.750	4.209	4.219	4.209
6	120	6.625	5.501	0.562	5.600	5.610	5.600
	160	6.625	5.187	0.719	5.326	5.336	5.326
	XXS	6.625	4.897	0.864	5.072	5.082	5.072
8	100	8.625	7.437	0.594	7.546	7.554	7.544
	120	8.625	7.187	0.719	7.326	7.336	7.326
	140	8.625	7.001	0.812	7.163	7.173	7.163
	XXS	8.625	6.875	0.875	7.053	7.063	7.053
	160	8.625	6.813	0.906	6.998	7.008	6.998
10	80	10.750	9.562	0.594	9.671	9.679	9.669
	100	10.750	9.312	0.719	9.451	9.461	9.451
	120	10.750	9.062	0.844	9.234	9.242	9.232
	140	10.750	8.750	1.000	8.959	8.969	8.959
	160	10.750	8.500	1.125	8.740	8.750	8.740
12	60	12.750	11.626	0.562	11.725	11.735	11.725
	80	12.750	11.374	0.688	11.507	11.515	11.505
	100	12.750	11.062	0.844	11.234	11.242	11.232
	120	12.750	10.750	1.000	10.959	10.969	10.959
	140	12.750	10.500	1.125	10.740	10.750	10.740
	160	12.750	10.126	1.312	10.413	10.423	10.413
14 OD	60	14.000	12.812	0.594	12.921	12.929	12.919
	80	14.000	12.500	0.750	12.646	12.656	12.646
	100	14.000	12.124	0.938	12.319	12.327	12.317
	120	14.000	11.812	1.094	12.046	12.054	12.044
	140	14.000	11.500	1.250	11.771	11.781	11.771
	160	14.000	11.188	1.406	11.498	11.508	11.498

TABLE A2.21 Dimensions for Internal Machining and Backing Rings for Heavy-Wall Pipe in Critical Applications (*Continued*)

Nominal pipe size	Schedule no. or wall	Nominal OD *A*	Nominal ID *B*	Nominal wall thickness *t*	Machined ID of pipe *C* tolerance +0.010 −0.000	OD of backing ring	
						Tapered ring *DT* tolerance +0.010 −0.000	Straight ring *DS* tolerance +0.000 −0.010
16 OD	60	16.000	14.688	0.656	14.811	14.821	14.811
	80	16.000	14.312	0.844	14.484	14.492	14.482
	100	16.000	13.938	1.031	14.155	14.165	14.155
	120	16.000	13.562	1.219	13.826	13.836	13.826
	140	16.000	13.124	1.438	13.442	13.452	13.442
	160	16.000	12.812	1.594	13.171	13.179	13.169
18 OD	40	18.000	16.876	0.562	16.975	16.985	16.975
	60	18.000	16.500	0.750	16.646	16.656	16.646
	80	18.000	16.124	0.938	16.319	16.312	16.317
	100	18.000	15.688	1.156	15.936	15.946	15.936
	120	18.000	15.250	1.375	15.553	15.563	15.553
	140	18.000	14.876	1.562	15.225	15.235	15.225
	160	18.000	14.438	1.781	14.842	14.852	14.842
20 OD	40	20.000	18.812	0.594	18.921	18.929	18.919
	60	20.000	18.376	0.812	18.538	18.548	18.538
	80	20.000	17.938	1.031	18.155	18.165	18.155
	100	20.000	17.438	1.281	17.717	17.727	17.717
	120	20.000	17.000	1.500	17.334	17.344	17.334
	140	20.000	16.500	1.750	16.896	16.906	16.896
	160	20.000	16.062	1.969	16.515	16.523	16.513
22 OD	. . .	22.000	20.750	0.625	20.865	20.875	20.865
	60	22.000	20.250	0.875	20.428	20.438	20.428
	80	22.000	19.750	1.125	19.990	20.000	19.990
	100	22.000	19.250	1.375	19.553	19.563	19.553
	120	22.000	18.750	1.625	19.115	19.125	19.115
	140	22.000	18.250	1.875	18.678	18.688	18.678
	160	22.000	17.750	2.125	18.240	18.250	18.240
24 OD	30	24.000	22.876	0.562	22.975	22.985	22.975
	40	24.000	22.624	0.688	22.757	22.765	22.755
	60	24.000	22.062	0.969	22.265	22.273	22.263
	80	24.000	21.562	1.219	21.826	21.836	21.826
	100	24.000	20.938	1.531	21.280	21.290	21.280
	120	24.000	20.376	1.812	20.788	20.798	20.788
	140	24.000	19.876	2.062	20.350	20.360	20.350
	160	24.000	19.312	2.344	19.859	19.867	19.857

A2.22, A2.23, and A2.24 illustrate the various standard weld edge profiles for different wall thickness.

On piping, the end preparation is normally done by machining or grinding. On pipe of heavier wall thicknesses, machining is generally done on post mills. On carbon and low-alloy steels, oxygen cutting and beveling are also used, particularly on pipe of wall thicknesses below ½ in (12 mm). However, the slag should be removed by grinding prior to welding.

Because of fairly broad permissible eccentricity and size tolerances of pipe and fittings, considerable mismatch may be encountered on the inside of the piping. Limitations on fit-up tolerances are included in several piping codes. For severe service applications, internal machining may be required to yield proper fit-up. When one is machining the inside diameter, care should be taken to ensure that minimum wall requirements are not violated. Table A2.21 lists the counterbore dimensions typically specified.

When piping components of unequal wall thickness are to be welded, care should be taken to provide a smooth taper toward the edge of the thicker member. The length of the taper desirable is normally 3 times the offset between the components, as outlined in ASME Boiler and Pressure Vessel Code Sections-I and III, and ASME B31.1, Power Piping Code. The two methods of alignment which are recommended are shown in Fig. A2.25.

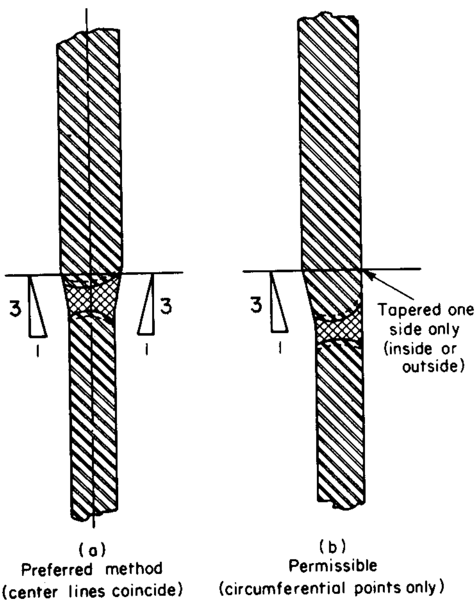


FIGURE A2.25 Recommended welding-end sections for pipe, valves, and fittings of unequal thickness. (*a*) Preferred method (centerlines coincide); (*b*) permissible (circumferential points only).

The wall thickness of cast-steel fittings and valve bodies is normally greater than that of the pipe to which they are joined. To provide a gradual transition between piping and components, the ASME Boiler and Pressure Vessel Code and the ASME

Code for Pressure Piping permit the machining of the cylindrical ends of fittings and valve bodies to the nominal wall thickness of the adjoining pipe. However, in no case is the thickness of a valve permitted to be less than $0.77t_{min}$ at a distance of $1.33t_{min}$ from the weld end, where t_{min} is the minimum valve thickness required by ASME B16.34. The machined ends may be extended back in any manner, provided that the longitudinal section comes within the maximum slope line indicated in Fig. A2.25. The transition from the pipe to the fitting or valve end at the joint must be such as to avoid sharp reentrant angles and abrupt changes in slope.

End Preparation for Inert-Gas Tungsten-Arc Root-Pass Welding. The pipe end bevel preparations shown in Fig. A2.24 are considered adequate for shielded metal-arc welding, but they pose some problems in inert-gas tungsten-arc welding. When this process is used, extended U or flat-land bevel preparations are considered more suitable since the extended land reduces the heat sink, thereby affording better weld penetration. The end preparations apply to inert-gas tungsten-arc welding of carbon- and low-alloy steel piping, stainless-steel piping, and most nonferrous piping materials. On aluminum piping, the flat-land bevel preparations are preferred by some fabricators.

Backing Rings. Backing rings are employed in some piping systems, particularly where pipe joints are welded primarily by the shielded metal-arc welding process with covered electrodes. For example, a significant number of pipe welds for steam power plants and several other applications are made with the use of backing rings. On the other hand, in many applications backing rings are not used, since they may restrict flow, provide crevices for the entrapment of corrosive substances, enhance susceptibility to stress corrosion cracking, or introduce still other objectionable features. Thus, there is little, if any, use made of backing rings in most refinery piping, radioactive service piping, or chemical process piping.

The use of backing rings is primarily confined to carbon- and low-alloy steel and aluminum piping. Carbon-steel backing rings are generally made of a mild carbon steel with a maximum carbon content of 0.20 percent and a maximum sulfur content of 0.05 percent. The latter requirement is especially important since high sulfur in deposited weld metal (which could be created by an excessive sulfur content in such rings) may cause weld cracks. Split backing rings are satisfactory for service piping systems. For the more critical service applications involving carbon- and low-alloy steel piping, solid flat or taper-machined backing rings are preferred in accordance with the recommendations shown in Pipe Fabrication Institute Standard ES1 and illustrated in Fig. A2.24 and Table A2.21.

When a machined backing ring is desired, it is a general recommendation that welding ends be machined on the inside diameter in accordance with the Pipe Fabrication Institute standard for the most critical services—and then only when pierced seamless pipe that complies with the applicable specifications of the American Society for Testing and Materials is used. Such critical services include high-pressure steam lines between boiler and turbines and high-pressure boiler feed discharge lines, as encountered in modern steam power plants. It is also recommended that the material of the backing ring be compatible with the chemical composition of the pipe, valve, fitting, or flange with which it is to be used. Where materials of dissimilar composition are being joined, the composition of the backing ring may be that of the lower alloy.

On turned-and-bored and fusion-welded pipe, the design of the backing ring and internal machining, if any, should be a matter of agreement between the customer and the fabricator. Regardless of the type of backing rings used, it is recommended that the general contour of the welding bevel shown in Fig. A2.24 be maintained.

When machining piping for backing rings, the resulting wall thickness should be not less than that required for the service pressure. Wherever internal machining for machined backing rings is required on pipe and welding fittings in smaller sizes and lower schedule numbers than those listed in Table A2.21, weld metal may have to be deposited on the inside of the pipe in the area to be machined. This is to provide satisfactory contact between the machined surface on the pipe inside and the machined backing ring. For such cases, the machining dimension should be a matter of agreement between the fabricator and the purchaser.

Whenever pipe and welding fittings in the sizes and schedule numbers listed in Table A2.21 have plus tolerance on the outside diameter, it also may be necessary to deposit weld metal on the inside of the pipe or welding fitting in the area to be machined. In such cases, sufficient weld metal should be deposited to result in an ID not greater than the nominal ID given in Table A2.21 for the particular pipe size and wall thickness involved.

Experience indicates that machining to dimension *C* for the pipe size and schedule number listed in Table A2.21 generally will result in a satisfactory seat contact of 7/32 in (5.5 mm) minimum (approximately 75 percent minimum length of contact) between pipe and the 10° backing ring. Occasionally, however, it will be necessary to deposit weld metal on the inside diameter of the pipe or welding fitting in order to provide sufficient material for machining a satisfactory seat.

In welding butt joints with backing rings, care should be exercised to ensure good fusion of the first weld pass into the backing ring in order to avoid lack of weld penetration or other types of stress-raising notches.

Consumable Insert Rings.. The chemical composition of a piping base metal is established primarily to provide it with certain mechanical, physical, or corrosion resisting properties. Weldability characteristics, if considered at all, are of secondary concern. On the other hand, the chemical composition of most welding filler metals is determined with primary emphasis on producing a sound, high-quality weld. The steelmaking process employed in the manufacture of welding filler metals permits closer control of the composition range, which is usually considerably narrower than would be practical for the piping base metal where much larger tonnages of steel are involved. On some base metals, the welding together by fusion of only the base-metal compositions may lead to such welding difficulties as cracking or porosity. The addition of filler metal tends to improve weld quality. However, in inert-gas tungsten-arc welding, the addition of welding filler metal from a separate wire, which the welder feeds with one hand while manipulating the tungsten-arc torch with the other, is a cumbersome process and interferes with welding ease. The welder may leave areas with lack of penetration, which generally are considered unacceptable as can be seen, e.g., in the rules of the ASME Boiler and Pressure Vessel Code. Since some types of serious weld defects are detected only with difficulty during inspection (if they are detected at all), it is extremely important to provide the easiest welding conditions for the welder to produce quality welds. One technique to produce high-quality welds is to employ consumable insert rings of proper composition and dimensions. Consumable insert rings which are available commercially are shown in Fig. A2.26. The three primary functions of consumable insert rings are to (1) provide the easiest welding conditions and thereby minimize the effects of undesirable welding variables caused by the ‘‘human’’ element, (2) give the most favorable weld contour to resist cracking resulting from weld-metal shrinkage and hot shortness, or brittleness, in hot metal, and (3) produce metallurgically the soundest possible weld-metal composition of desirable strength, ductility, and toughness properties.

The best welding conditions are obtained where the flat-land and extended U-bevel preparations are used. These joint preparations are particularly helpful where welding is done in the horizontal fixed pipe position (5G), since they ensure a flat or slightly convex root contour and provide by far the greatest resistance to weld cracking in those alloys particularly susceptible to microfissuring.

The weld-root contour conditions to be expected from different bevel preparations and consumable insert rings are illustrated in Fig. A2.27. Where sink is not acceptable, it is considered obligatory to use consumable insert rings with the special flat-land or extended U-bevel preparation. In horizontal-rolled (IG) and vertical-position (2G) welding, the insert ring should be placed concentrically into the beveled pipe.

In horizontal fixed-position (5G) welding, the insert ring should be placed eccentric to the centerline of the pipe (as shown in Fig. A2.28). In this position, the insert ring compensates for the downward sag of the molten weld metal and aids in obtaining smooth, uniform root contour along the inner diameter and the joint.

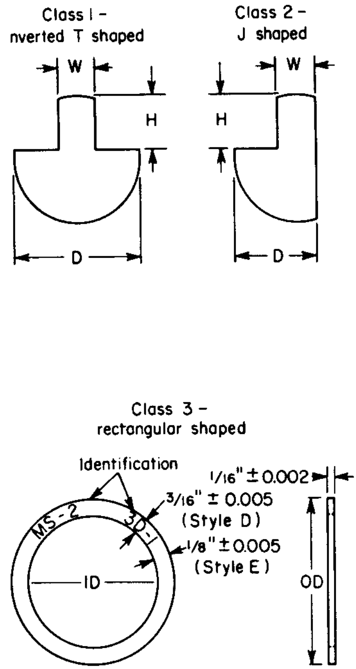


FIGURE A2.26 Commercial consumable insert rings used in pipe welding (MIL-I-23413). Style D: for NPS 2 and larger. On Schedule 5 for NPS 5 and larger; style E: for NPS less than 2. On Schedule 5 for NPS less than 5.

Fillet Welds

Circumferential fillet-welded joints are generally used for joining pipe to socket joints in sizes NPS 2 (DN 50) and smaller. Figure A2.29 illustrates three typical fillet-welded joints. These types of welds are subjected to shearing and bending stresses, and adequate penetration of the pieces being joined is essential. This is particularly important with the socket joint, since the danger of washing down the end of the hub may obscure, by reason of fair appearance, the lack of a full and sound fillet weld. This condition is one which cannot be detected in the finished weld by the usual visual inspection. Additionally, a 1/16-in (1.5-mm) gap (before welding) must be maintained between the pipe end and the base of the fitting to allow for differential expansion of the mating elements.

There are service applications in which socket welds are not acceptable. Piping systems involving nuclear or radioactive service or corrosive service with solutions which promote stress corrosion cracking or concentration cell action generally

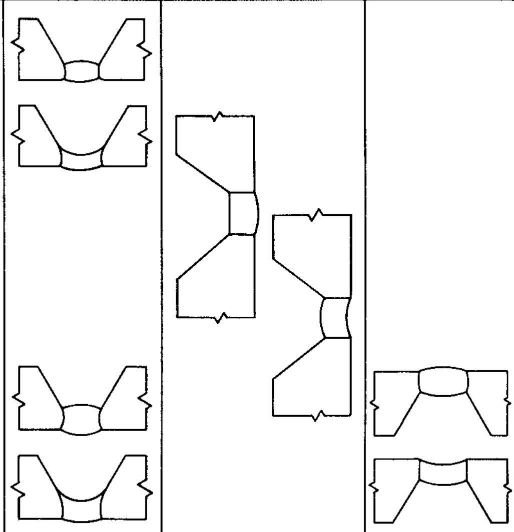
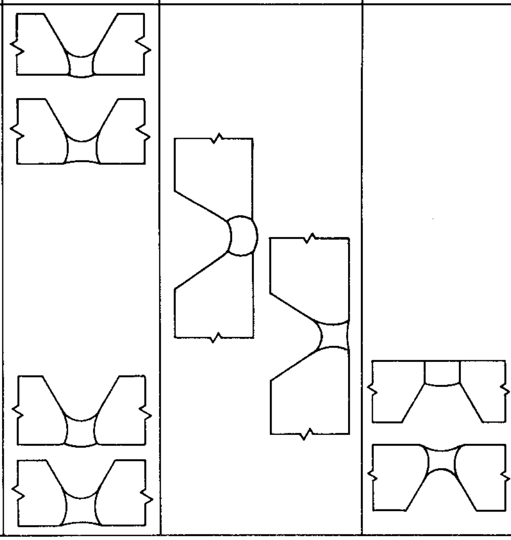
Welding conditions	Consumable insert ring	Position	Inside pipe contour: Top	Inside pipe contour: Side	Inside pipe contour: Bottom	Permissible concavity at inside of pipe
"Flat-land" bevel	Yes	1G				0
	No	1G				0
	Yes	2G				0
	No	2G				1/32"
	Yes	5G				0
	No	5G				1/32"
37 1/2	Yes	1G				0
	No	1G				1/32"
	Yes	2G				1/64"
	No	2G				1/16"
	Yes	5G				1/8"
	No	5G				1/16"

FIGURE A2.27 Root-contour conditions which can be expected as the result of normal pipe welding with the gas tungsten-arc welding process. In 5G (horizontal-fixed) position welding the insert ring is positioned eccentric to the centerline of the pipe, as illustrated in Fig. A2.28.

require butt welds in all pipe sizes with complete weld penetration to the inside of the piping.

Brazed Joints

Lap or shear-type joints generally are necessary to provide capillary attraction for brazing of connecting pipe. Square-groove butt joints may be brazed, but the results are unreliable unless the ends of the pipe or tube are accurately prepared, plane and square, and the joint is aligned carefully, as in a jig. High strengths may be obtained with butt joints if they are properly prepared and brazed. However, owing to the brittleness of the brazing alloy, they are not normally applicable.

The alloys generally used in brazing exhibit their greatest strength when the thickness of the alloy in the lap area is minimal. Thin alloy sections also develop the highest ductility. For brazing ferrous and nonferrous piping with silver- and copper-base brazing alloys, the thickness of the brazing alloy in the joint generally should not be more than 0.006 in (0.15 mm) and preferably not more than 0.004 in (0.1 mm). Thicknesses less than 0.003 in (0.07 mm) may make assembly difficult, while those greater than 0.006 in (0.15 mm) tend to produce joints having lowered strength. The brazing of certain aluminum alloys is similar in most respects to the brazing of other materials. However, joint clearances should be greater because of a somewhat more sluggish flow of the brazing alloys. For aluminum, a clearance of 0.005 to 0.010 in (0.12 to 0.25 mm) will be found satisfactory. Care must be exercised in fitting dissimilar metals, since the joint clearance at brazing temperature is the controlling factor. In these cases, consideration must be given to the relative expansion rates of the materials being joined.

The length of lap in a joint, the shear strength of the brazing alloy, and the average percentage of the brazing surface area that normally bonds are the

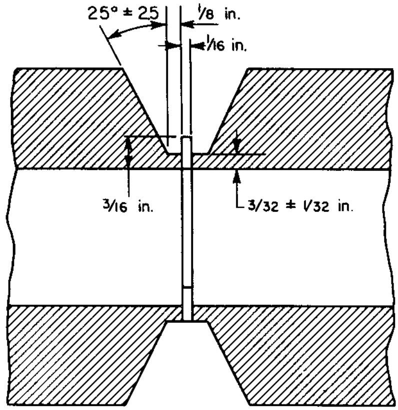


FIGURE A2.28 Eccentric insertion of consumable insert ring in pipe welded in the fixed horizontal pipe position.

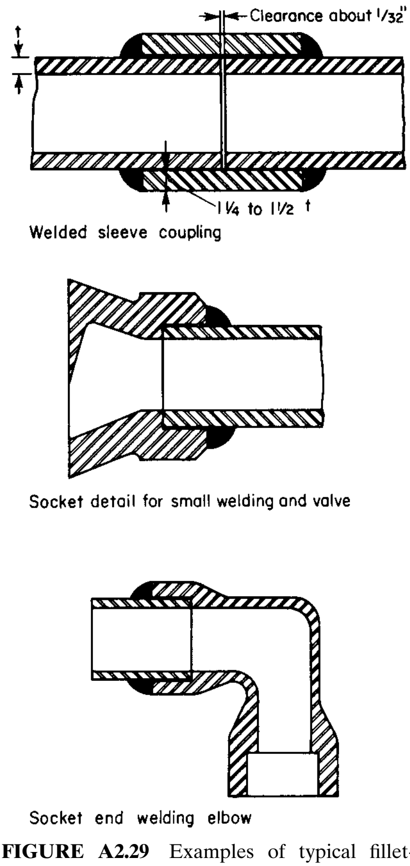
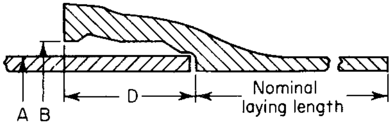


FIGURE A2.29 Examples of typical fillet-welded joints.

TABLE A2.22 Standard Dimensions of Bell-and-Spigot Joints for Pipe Centrifugally Cast in Metal Molds



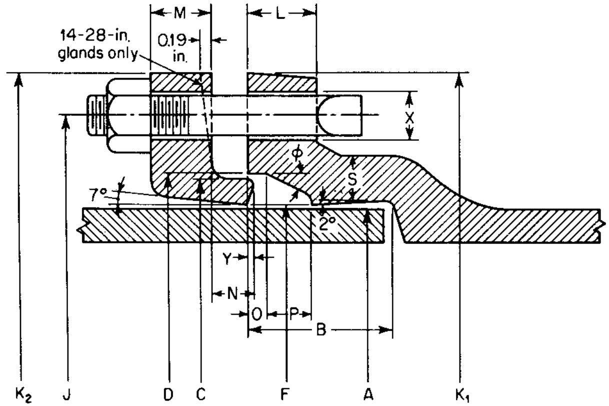
Nominal pipe size	Class	Thickness designation	Thickness of pipe	OD of pipe *A*	Diameter of socket *B*	Depth of socket *D*	Weight (approx) (lb)			Joint compound, (lb per 2½-in depth)	Jute (lb per joint)	Lead (lb per 2½-in depth)
							Barrel per foot	Bell	18-ft laying length*			
3	Through 350	22	0.32	3.96	4.76	3.30	11.4	11	215			
4	Through 350	22	0.35	4.80	5.60	3.30	15.3	14	290	2.00	0.21	8.00
6	Through 350	22	0.38	6.90	7.70	3.88	24.3	25	460	3.00	0.31	11.25
8	Through 350	22	0.41	9.05	9.85	4.38	34.7	41	665	4.00	0.44	14.50
10	Through 250	22	0.44	11.10	11.90	4.38	46.0	54	880			
	300	23	0.48	11.10	11.90	4.38	50.0	54	955	5.00	0.53	17.50
	350	24	0.52	11.10	11.90	4.38	53.9	54	1025			
12	Through 200	22	0.48	13.20	14.00	4.38	59.8	66	1140			
	250, 300	23	0.52	13.20	14.00	4.38	64.6	66	1230	6.00	0.61	20.50
	350	24	0.56	13.20	14.00	4.38	69.4	66	1315			

TABLE A2.22 Standard Dimensions of Bell-and-Spigot Joints for Pipe Centrifugally Cast in Metal Molds (*Continued*)

Nominal pipe size	Class	Thickness designation	Thickness of pipe	OD of pipe *A*	Diameter of socket *B*	Depth of socket *D*	Weight (approx) (lb)			Joint compound, (lb per 2½-in depth)	Jute (lb per joint)	Lead (lb per 2½-in depth)
							Barrel per foot	Bell	18-ft laying length*			
14	50	21	0.48	15.30	16.10	4.50	69.7	78	1335			
	100	22	0.51	15.30	16.10	4.50	73.9	78	1410			
	150	22	0.51	15.30	16.10	4.50	73.9	78	1410	7.00	0.81	24.00
	200	23	0.55	15.30	16.10	4.50	79.5	78	1510			
	250, 300	24	0.59	15.30	16.10	4.50	85.1	78	1610			
	350	25	0.64	15.30	16.10	4.50	92.0	78	1735			
16	50, 100	22	0.54	17.40	18.40	4.50	89.2	96	1700			
	150	22	0.54	17.40	18.40	4.50	89.2	96	1700			
	200	23	0.58	17.40	18.40	4.50	95.6	96	1815	8.25	0.94	33.00
	250	24	0.63	17.40	18.40	4.50	103.6	96	1960			
	300, 350	25	0.68	17.40	18.40	4.50	111.4	96	2100			
18	50	21	0.54	19.50	20.50	4.50	100.4	114	1920			
	100	22	0.58	19.50	20.50	4.50	107.6	114	2050			
	150	22	0.58	19.50	20.50	4.50	107.6	114	2050			
	200	23	0.63	19.50	20.50	4.50	116.5	114	2210	9.25	1.00	36.90
	250	24	0.68	19.50	20.50	4.50	125.4	114	2370			
	300	25	0.73	19.50	20.50	4.50	134.3	114	2530			
	350	26	0.79	19.50	20.50	4.50	144.9	114	2720			
20	50	21	0.57	21.60	22.60	4.50	117.5	133	2250			
	100	22	0.62	21.60	22.60	4.50	127.5	133	2430			
	150	22	0.62	21.60	22.60	4.50	127.5	133	2430			
	200	23	0.67	21.60	22.60	4.50	137.5	133	2610	10.50	1.25	40.50
	250	24	0.72	21.60	22.60	4.50	147.4	133	2785			
	300	25	0.78	21.60	22.60	4.50	159.2	133	3000			
	350	26	0.84	21.60	22.60	4.50	170.9	133	3210			
24	50	21	0.63	25.80	26.80	4.50	155.4	179	2975			
	100	22	0.68	25.80	26.80	4.50	167.4	179	3190			
	150	23	0.73	25.80	26.80	4.50	179.4	179	3410	13.00	1.50	52.50
	200, 250	24	0.79	25.80	26.80	4.50	193.7	179	3665			
	300	25	0.85	25.80	26.80	4.50	207.9	179	3920			
	350	26	0.92	25.80	26.80	4.50	224.4	179	4220			

* Includes weight of bell.

TABLE A2.23 Standard Dimensions of Mechanical (Gland-Type) Joints (ANSI/AWWA C111/A21.11-1985)



Nominal pipe size	A‡ Plain end	B	C	D	F	ϕ deg	X†	J	K_1§ Centrifugal pipe	K_1§ Pit cast pipe and fittings	K_2§	L	M	N	O	P	S* Centrifugal pipe	S* Pit cast pipe and fittings	Y	Bolts¶ No	Bolts¶ Size	Bolts¶ Length
2	±0.05 2.50	2.50	±0.05 3.39	±0.05 3.50	±0.05 2.61	28°	+0.06 −0.0 ¾	±0.05 4.75	−0.05 6.00	−0.10 6.25	−0.10 6.25	−0.05 0.75	−0.05 0.62	0.50	0.31	0.63	−0.05 0.37	−0.07 0.44	0.08	2	⅝	2½
2½	±0.05 2.75	2.50	±0.05 3.64	±0.05 3.75	±0.05 2.86	28°	+0.06 −0.0 ¾	±0.05 5.00	−0.05 6.25	−0.10 6.50	−0.10 6.50	−0.05 0.75	−0.03 0.62	0.50	0.31	0.63	−0.05 0.37	−0.07 0.44	0.08	2	⅝	2½
3	±0.06 3.96	2.50	±0.04 4.84	±0.06 −0.04 4.94	±0.07 −0.03 4.06	28°	+0.06 −0.0 ¾	±0.06 6.19	−0.06 7.62	−0.12 7.69	−0.12 7.69	−0.06 0.94	−0.06 0.62	0.75	0.31	0.63	−0.05 0.47	−0.10 0.52	0.12	4	⅝	3
4	±0.06 4.80	2.50	±0.04 5.92	+0.06 −0.04 6.02	+0.07 −0.03 4.90	28°	+0.06 −0.0 ⅞	±0.06 7.50	−0.06 9.06	−0.12 9.12	−0.12 9.12	−0.06 1.00	−0.06 0.75	0.75	0.31	0.75	−0.05 0.55	−0.10 0.65	0.12	4	¾	3½
6	±0.06 6.90	2.50	±0.04 8.02	+0.06 −0.04 8.12	+0.07 −0.03 7.00	28°	+0.06 −0.0 ⅞	±0.06 9.50	−0.06 11.06	−0.12 11.12	−0.12 11.12	−0.06 1.06	−0.06 0.88	0.75	0.31	0.75	−0.05 0.60	−0.10 0.70	0.12	6	¾	3½
8	±0.06 9.05	2.50	±0.04 10.17	+0.06 −0.04 10.27	+0.07 −0.03 9.15	28°	+0.06 −0.0 ⅞	±0.06 11.75	−0.06 13.31	−0.12 13.37	−0.12 13.37	−0.08 1.12	−0.08 1.00	0.75	0.31	0.75	−0.05 0.66	−0.12 0.75	0.12	6	¾	4

TABLE A2.23 Standard Dimensions of Mechanical (Gland-Type) Joints (ANSI/AWWA C111/A21.11-1985) (*Continued*)

Nominal pipe size	A‡ Plain end	B	C	D	F	ϕ deg	X†	J	K_1§		K_2§	L	M	N	O	P	S*		Y	Bolts¶		
									Centrifugal pipe	Pit cast pipe and fittings							Centrifugal pipe	Pit cast pipe and fittings		No	Size	Length
10	±0.06 11.10	2.50	+0.06 −0.04 12.22	+0.06 −0.04 12.34	+0.07 −0.03 11.20	28°	+0.06 −0.0 ⅞	±0.06 14.00	−0.06 15.62	−0.12 15.69	−0.12 15.62	−0.08 1.19	−0.08 1.00	0.75	0.31	0.75	−0.06 0.72	−0.12 0.80	0.12	8	¾	4
12	±0.06 13.20	2.50	+0.06 −0.04 14.32	+0.06 −0.04 14.44	+0.07 −0.03 13.30	28°	+0.06 −0.0 ⅞	±0.06 16.25	−0.06 17.88	−0.12 17.94	−0.12 17.88	−0.08 1.25	−0.08 1.00	0.75	0.31	0.75	−0.06 0.79	−0.12 0.85	0.12	8	¾	4
14	+0.05 −0.08 15.30	3.50	+0.07 −0.05 16.40	+0.07 −0.05 16.54	+0.06 −0.07 15.44	28°	+0.06 −0.0 ⅞	±0.06 18.75	−0.08 20.25	−0.12 20.31	−0.12 20.25	−0.12 1.31	−0.12 1.25	0.75	0.31	0.75	−0.08 0.85	−0.12 0.89	0.12	10	¾	4
16	+0.05 −0.08 17.40	3.50	+0.07 −0.05 18.50	+0.07 −0.05 18.64	+0.06 −0.07 17.54	28°	+0.06 −0.0 ⅞	±0.06 21.00	−0.08 22.50	−0.12 22.56	−0.12 22.50	−0.12 1.38	−0.12 1.31	0.75	0.31	0.75	−0.08 0.91	−0.12 0.97	0.12	12	¾	4½
18	+0.05 −0.08 19.50	3.50	+0.07 −0.05 20.60	+0.07 −0.05 20.74	+0.06 −0.07 19.64	28°	+0.06 −0.0 ⅞	±0.06 23.25	−0.08 24.75	−0.15 24.83	−0.15 24.75	−0.12 1.44	−0.12 1.38	0.75	0.31	0.75	−0.08 0.97	−0.15 1.05	0.12	12	¾	4½
20	+0.05 −0.08 21.60	3.50	+0.07 −0.05 22.70	+0.07 −0.05 22.84	+0.06 −0.07 21.74	28°	+0.06 −0.0 ⅞	±0.06 25.50	−0.08 27.00	−0.15 27.08	−0.15 27.00	−0.12 1.50	−0.12 1.44	0.75	0.31	0.75	−0.08 1.03	−0.15 1.12	0.12	14	¾	4½
24	+0.05 −0.08 25.80	3.50	+0.07 −0.05 26.90	+0.07 −0.05 27.04	+0.06 −0.07 25.94	28°	+0.06 −0.0 ⅞	±0.06 30.00	−0.08 31.50	−0.15 31.58	−0.15 31.50	−0.12 1.62	−0.12 1.56	0.75	0.31	0.75	−0.08 1.08	−0.15 1.22	0.12	16	¾	5
30	+0.08 −0.06 32.00	4.00	+0.08 −0.06 33.29	+0.08 −0.06 33.46	+0.08 −0.06 32.17	20°	+0.06 −0.0 1⅛	±0.06 36.88	−0.12 39.12	−0.18 39.12	−0.18 39.12	−0.12 1.81	−0.12 2.00	0.75	0.38	1.00	−0.10 1.20	−0.15 1.50	0.12	20	1	6
36	+0.08 −0.06 38.30	4.00	+0.08 −0.06 39.59	+0.08 −0.06 39.76	+0.08 −0.06 38.47	20°	+0.06 −0.0 1⅛	±0.06 43.75	−0.12 46.00	−0.18 46.00	−0.18 46.00	−0.12 2.00	−0.12 2.00	0.75	0.38	1.00	−0.10 1.35	−0.15 1.80	0.12	24	1	6
42	+0.08 −0.06 44.50	4.00	+0.08 −0.06 45.79	+0.08 −0.06 45.96	+0.08 −0.06 44.67	20°	+0.06 −0.0 1⅜	±0.06 50.62	−0.12 53.12	−0.18 53.12	−0.18 53.12	−0.12 2.00	−0.12 2.00	0.75	0.38	1.00	−0.10 1.48	−0.15 1.95	0.12	28	1¼	6
48	+0.08 −0.06 50.80	4.00	+0.08 −0.06 52.09	+0.08 −0.06 52.26	+0.08 −0.06 50.97	20°	+0.06 −0.0 1⅜	±0.06 57.50	−0.12 60.00	−0.18 60.00	−0.18 60.00	−0.12 2.00	−0.12 2.00	0.75	0.38	1.00	−0.10 1.61	−0.15 2.20	0.12	32	1¼	6

* The thickness of the bell S shall in all instances be equal to, and generally exceed by at least 10 percent, the nominal wall thickness of the pipe or fitting of which it is a part.

† Cored holes may be tapered an additional 0.06 in in diameter.

‡ In the event of ovalness of the plain end outside diameter, the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in the table. The minor acis shall not be less than the above minimum diameter plus an additional minus tolerance of 0.04 in for NPS 8–12, 0.07 in for NPS 14–24, and 0.10 in for NPS 30–48.

§ K_1 and K_2 are the dimensions across the bolt holes. For sizes 2 and 2¼ in, both flange and gland may be oval shaped. For NSP 3–48, the gland may be polygon shaped.

¶ Mechanical joints require the use of specially designed bolts. See ANSI/AWWA C111/A21.11-1985.

principal factors determining the strength of brazed joints. The shear strength may be calculated by multiplying the width by the length of lap by the percentages of bond area and by taking into consideration the shear strength of the alloy used. An empirical method of determining the lap distance is to take it as twice the thickness of the thinner or weaker member joined. Normally this will provide adequate strength, but in cases of doubt, the fundamental calculations should be employed.

Such detailed determinations are generally unnecessary for brazed piping, since commercial brazing fittings are available in which the length of lap is predetermined at a safe value. For brass and copper pipe, cast or wrought bronze and wrought copper fittings are available. A bore of correct depth to accept the pipe is provided, and midway down this bore may be a groove into which, at the time of manufacture, a ring of brazing alloy is inserted. Since the alloy is preplaced in fittings with such a groove, separate feeding of brazing alloy by hand is generally unnecessary.

JOINING DUCTILE OR CAST-IRON PIPE

Bell-and-Spigot Joint

This joint for underground cast-iron pipe was developed as long ago as 1785. Standard dimensions are shown in Table A2.22.

The joint may be made up with lead and oakum, sulfur compounds, or cement. Lead and oakum constitute the prevailing joint sealer for sanitary systems. Bell-and-spigot joints are usually reserved for sanitary sewer systems. These joints are not used in ductile iron pipe.

Mechanical (Gland-Type) Joint

This modification of the bell-and-spigot joints, as designated in Federal Specification WW-P-421 and ANSI/AWWA C111/A21.11, is illustrated in Table A2.23. This joint is commonly used for low and intermediate-pressure gas distribution systems, particularly those conveying natural gas or dry manufactured gas. Mechanical joints are also used for water lines, sewage, and process piping. In the mechanical (gland-type) joint shown in Fig. A2.30, the lead and oakum of the conventional bell-and-spigot joint are supplanted by a stuffing box in which a rubber or composition packing ring, with or without a metal or canvas tip or canvas backing, is compressed by a ductile cast-iron follower ring drawn up with bolts. In addition to making an inherently tight joint even under considerable pressure, this arrangement has the advantage of permitting relatively large lateral deflections (3½° to 7°), as well as longitudinal expansion or contraction. For more details, refer to AWWA C600, Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances.

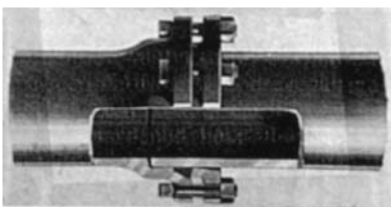


FIGURE A2.30 Mechanical (gland-type) joint for cast-iron pipe.

Tyton Joint

The Tyton joint is designed to contain an elongated grooved gasket. The inside contour of the socket bell provides a seat for the circular rubber in a modified bulb-shaped gasket. An internal ridge in the socket fits into the groove of the gasket. A slight taper on the plain end of the pipe facilitates assembly.

Standard dimensions are given in Table A2.24. The maximum joint deflection angle is 5° for sizes through NPS 12 (DN 300), 4° for NPS 14 (DN 350) and NPS 16 (DN 400), and 3° for NPS 18 (DN 450), NPS 20 (DN 500), and NPS 24 (DN 600). Either all-bell U.S. standardized mechanical joint fittings or bell-and-spigot all-bell fittings with poured or cement joints can be used with Tyton joint pipe.

Mechanical Lock-Type Joint

For installations where the joints may tend to come apart owing to sag or lateral thrust in the pipeline, a mechanical joint having a self-locking feature is used to resist end pull. This joint is similar to the gland-type mechanical joint except that in the locked joint the spigot end of the pipe is grooved or has a recess to grip the gasket. Although only slight expansion or contraction can be accommodated in this type of joint, it does allow the usual 3½° to 7° angular deflection. The lock-type joint finds application aboveground in the process industries and in river crossings on bridges or trestles, as well as in submarine crossings or in unusually loose or known marshy soils. Where the locking feature is on the spigot rather than on the bell, this type of pipe can be used with the regular line of mechanical joint fittings.

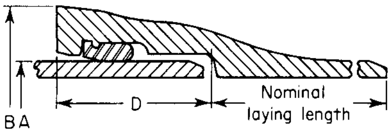
Mechanical Push-On-Type Joint

Where a low-cost mechanical joint is desired, the roll-on type can be used. In this joint, a round rubber gasket is placed over the spigot end and is pulled into the bell by mechanical means, thus pulling the ring into place in the bottom of the bell. Outside the rubber gasket, braided jute is wedged behind a projecting ridge in the bell. This serves to confine the gasket under pressure in the joint. A bituminous compound is used to seal the mouth of the bell and to aid in retaining the hemp and the rubber gasket. Either bell-and-spigot or mechanical (gland-type) fittings are used with this line of pipe. Push-on joints are made in accordance with ANSI/AWWA C111/A21.11.

Mechanical Screw-Gland-Type Joint

This type of mechanical joint for cast-iron pipe makes use of a coarse-threaded screw gland drawn up by means of a spanner wrench to compress a standard rubber or composition packing gasket. The joint allows from 2° to 7° angular deflection, as well as expansion or contraction without danger of leaks. A lead ring, inserted in the bell ahead of the gasket, seals off the contents of the line from the gasket. The ring also provides an electric circuit through the joint for thawing out frozen underground mains and service lines by the electrical method. The screw-gland joint is used in piping which conveys water, gas, oil, and other fluids at considerable pressure. The gaskets and lead rings are interchangeable with those used in equivalent lines of mechanical joints of the bolted-gland type. A full line of fittings is available for use with screw-gland pipe.

TABLE A2.24 Standard Dimensions of Tyton Joints



Nominal pipe size	Class	Thickness designation	Thickness of pipe, in	OD of pipe *A*	OD of bell *B*	Depth of socket *D*	Weight (approx) (lb)		
							Barrel per foot	Bell	18-ft length*
3	Through 350	22	0.32	3.96	6.08	3.00	11.4	11	215
4	Through 350	22	0.35	4.80	7.22	3.15	15.3	14	290
6	Through 350	22	0.38	6.90	9.47	3.38	24.3	25	460
8	Through 350	22	0.41	9.05	12.00	3.69	34.7	41	665
10	Through 250	22	0.44	11.10	14.20	3.75	46.0	54	880
	300	23	0.48				50.0		955
	350	24	0.52				53.9		1025
12	Through 200	22	0.48	13.20	16.35	3.75	59.8	66	1140
	250, 300	23	0.52				64.6		1230
	350	24	0.56				69.4		1315
14	50	21	0.48	15.30	19.15	5.00	69.7	78	1335
	100, 150	22	0.51				73.9		1410
	200	23	0.55				79.5		1510
	250, 300	24	0.59				85.1		1610
	350	25	0.64				92.0		1735
16	Through 150	22	0.54	17.40	21.36	5.00	89.2	96	1700
	200	23	0.58				95.6		1815
	250	24	0.63				103.6		1960
	300, 350	25	0.68				111.4		2100
18	50	21	0.54	19.50	23.56	5.00	100.4	114	1920
	100, 150	22	0.58				107.6		2050
	200	23	0.63				116.5		2210
	250	24	0.68				125.4		2370
	300	25	0.73				134.3		2530
	350	26	0.79				144.9		2720
20	50	21	0.57	21.60	25.80	5.00	117.5	133	2250
	100, 150	22	0.62				127.5		2430
	200	23	0.67				137.5		2610
	250	24	0.72				147.4		2785
	300	25	0.78				159.2		3000
	350	26	0.84				170.9		3210
24	50	21	0.63	25.80	30.32	5.00	155.4	179	2975
	100	22	0.68				167.4		3190
	150	23	0.73				179.4		3410
	200, 250	24	0.79				193.7		3665
	300	25	0.85				207.9		3920
	350	26	0.92				224.4		4220

* Includes weight of bell.

Ball-and-Socket Joints

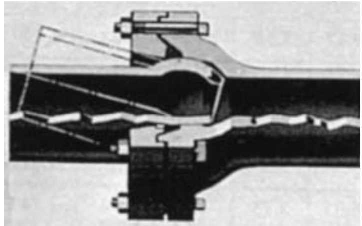


FIGURE A2.31 Ball-and-socket mechanical joint for cast-iron pipe.

For river crossings, submarine lines, or other places where great flexibility is necessary, ductile cast-iron pipe can be obtained with ball-and-socket joints of the mechanical-gland types, as shown in Fig. A2.31. Provision is made for longitudinal expansion and contraction, and a positive stop against disengagement of the joint is a feature of the design. As much as 15° angular deflection can be accommodated without leakage. This pipe is heavy enough to remain underwater where laid without requiring river clamps or anchorage devices. The pipe may be pulled across streams with a cable, since the joints are positively locked against separating, or it may be laid directly from a barge, bridge, or pontoons, without the services of a diver. The mechanical ball-and-socket joint is suitable for use with water, sewage, air, gas, oil, and other fluids at considerable pressure. Either bell-and-spigot or mechanical (gland-type) fittings can be used with this line of pipe, although the integral ball present on the spigot end of some designs has to be cut off before the pipe can be inserted in a regular bell.

Universal Pipe Joints

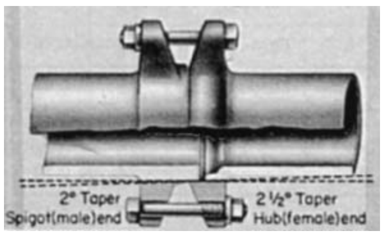


FIGURE A2.32 Universal cast-iron pipe joint.

This type of cast-iron pipe joint (shown in Fig. A2.32) has a machined taper seat which obviates the need for caulking or for a compression gasket. The joint is pulled up snugly with two bolts, after which the nuts are backed off slightly, thus enabling the lock washers to give enough to avoid overstressing the socket or lugs. Pipe is made in 12- to 20-ft (3.5- to 6-m) lengths to the usual pressure classes and can be bought as Type III under Federal Specification WW-P-421. Universal-joint fittings are available for use with the pipe. This type of joint is used to some extent in pipe diameters of NPS 4 (DN 100) to NPS 24 (DN 600) for underground water supply systems; but it is not considered suitable for gas service, and it does not permit much angular displacement or expansive movement.

Compression-Sleeve Coupling

The type of joint shown in Fig. A2.33 is used with plain-end pipe of either cast iron or steel. It is widely known under the trade names of Dresser coupling and Dayton coupling. Compression sleeve couplings are used extensively for air, gas, oil, water, and other services above- or underground. With a joint of this type, it is necessary to anchor or brace solidly at dead ends or turns to prevent the line from pulling apart. Compression couplings and fittings with screwed packing glands are available for use with small-size cast-iron or steel pipe. In welded transmission lines for oil or gas where any significant change in temperature is expected, a certain

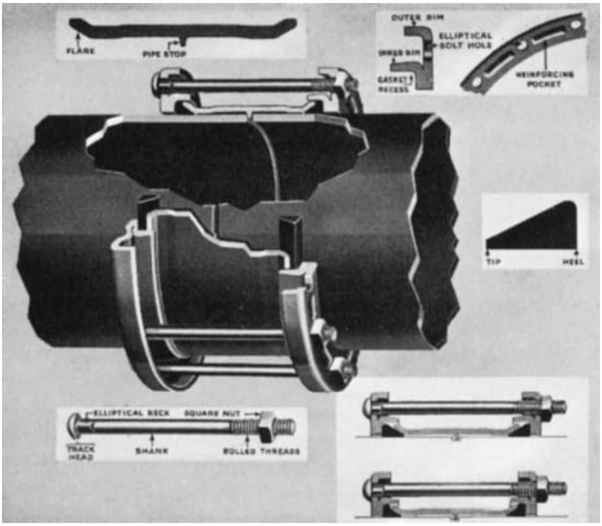


FIGURE A2.33 Compression sleeve (Dresser) coupling for plain-end cast-iron or steel pipe.

percentage of the joints may be made up with compression couplings instead of welding in order to allow for expansion.

Grooved Segmented-Ring Coupling

The type of split coupling shown in Fig. A2.34 is used with either ductile cast-iron or steel pipe that has grooves near the ends which enable the coupling to grip the pipe, in order to prevent disengagement of the joint. The couplings are manufactured in a minimum of two segments for small pipe sizes and several segments for large pipe sizes. Grooved-end fittings are available for use with the couplings. With proper

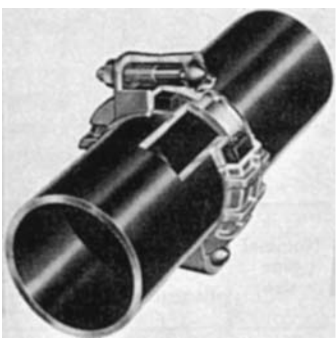


FIGURE A2.34 Victualic coupling for grooved-end cast-iron or steel pipe.

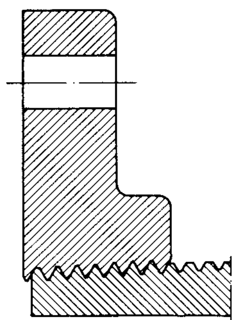


FIGURE A2.35 Screwed-on cast-iron flange.

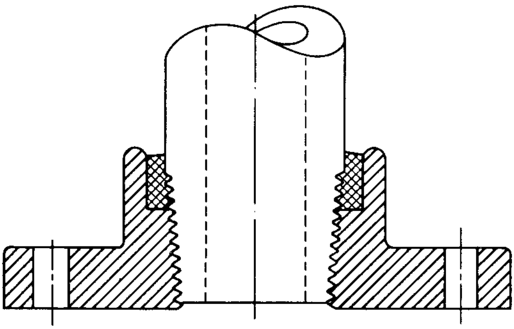


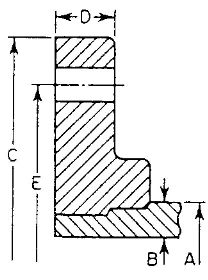
FIGURE A2.36 High-hub cast-iron flanges with bitumastic to protect the exposed threads.

choice of gasket material, the joint is suitable for use above- or underground with nearly any fluid or gas. The joint's advantages are its

- Ability to absorb minor angular and axial deflections
- Ability to increase gasket sealing force with increased system pressure

Refer to AWWA C.606, Standard for Grooved and Shouldered Joints.

TABLE A2.25 Standard Dimensions of Class 125 Flanged Joints for Silver Brazing with Centrifugally Cast Pipe



Nominal pipe size	Pipe	Flanges				Bolts	
	Outside diameter *A*	Outside diameter *C*	Thickness* *D*	Bolt circle *E*	Weight each (lb)	Number	Diameter
2	2.50	6	¾	4¾	4	4	⅝
3	3.96	7½	1	6	7	4	⅝
4	4.80	9	1⅛	7½	13	8	⅝
6	6.90	11	1¼	9½	17	8	¾
8	9.05	13½	1⅜	11¾	27	8	¾
10	11.10	16	1½	14¼	38	12	⅞
12	13.20	19	1½	17	58	12	⅞

* Thickness *D* is slightly heavier than for standard cast-iron flanges in ASME B16.1-1989.

- Simplicity for rapid erection or dismantling for systems requiring frequent disassembly.

The coupling is also available in a style where grooving of the pipe ends is not required. Joint separation is prevented by the use of hardened steel inserts (teeth) which grab the mating pipe ends.

Flanged Joints

Flanged ductile or cast-iron pipe is used aboveground for low and intermediate pressures in water-pumping stations, gas works, power and industrial plants, oil refineries, booster stations for water, and gas and oil transmission lines. Cast iron flanges usually are faced and drilled according to ASME B16.1. For flanged joints in a ductile iron pipe, refer to ASME B16.42, ANSI/AWWA C110/A21.10, C111/A21.11, C115/A21.15, and C153/A21.53. Cast-iron pipe is made both with integrally cast flanges and with threaded companion flanges for screwing onto the pipe (as shown in Figs. A2.35 and A2.36). In the latter case, the outside diameter of the pipe conforms to iron pipe size (IPS) dimensions to allow for the threads provided. It is available in sizes NPS 3 (DN 50) through NPS 24 (DN 600) and in length to 18 ft (5.5 m). For lengths less than 3 ft (1 m), in sizes NPS 3 (DN 50) through NPS 12 (DN 300), the flanges may be cast integrally with the pipe, rather than screwed on the pipe, at the manufacturer's option.

Standard dimensions of flanged joints for silver brazing are shown in Table A2.25.

CONCRETE, CEMENT, AND CEMENT-LINED PIPE

Nonreinforced Concrete Pipe

Nonreinforced concrete pipe for the conveyance of sewage, industrial waste, and storm water is made in sizes from NPS 4 to NPS 36 (DN 100 to DN 900). It is produced in accordance with ASTM Specification C14, Standard Specifications for Concrete Sewer Storm Drain and Culvert Pipe.

Nonreinforced-concrete drain tile is used for land drainage and for subsurface drainage of highways, railroads, airports, and buildings. It is made in sizes from NPS 4 through 36 (DN 100 through 900) in accordance with ASTM Specification C412, Standard Specification for Concrete Drain Tile, and AASHO M178, Standard Specification for Concrete Drain Tile. Drain tile is available in the standard quality, extra-quality, and special-quality classifications.

Perforated concrete pipe used for under-drainage is made in accordance with ASTM Specification C444, Specifications for Perforated Concrete Pipe. This pipe is also made in sizes NPS 4 through 36 (DN 100 through 900) and is available in the standard-strength and extra-strength classification.

Concrete irrigation pipe, used for the conveyance of irrigation water under low hydrostatic heads and for land drainage, is made in sizes NPS 4 through 24 (DN 100 through 600) in accordance with ASTM Specification C118, Standard Specifications for Concrete Pipe for Irrigation or Drainage.

Nonreinforced-concrete irrigation pipe for use with rubber-type gasket joints is made for conveyance of irrigation water at water pressures of 1 bar (35 ft of head) or higher depending on the diameter. Such pipe is made in sizes NPS 6 through 24 (DN 100 through 600) in accordance with ASTM Specification C505, Specifications for Nonreinforced Concrete Irrigation Pipe with Rubber Type Gasket Joints. Physical and dimensional requirements of standard-strength bell-and-spigot nonreinforced-concrete sewer pipe are tabulated in Table A2.26.

Jointing. Rubber-gasketed joints for C14 and C76 pipe are covered by ASTM Specification C443, Joints for Circular Concrete Sewer and Culvert Pipe, Using Flexible, Watertight, Rubber-Type Joints.

Reinforced-Concrete Pipe

Reinforced-concrete pipe for the conveyance of sewage, industrial wastes, and storm water and for the construction of culverts is made in sizes from NPS 12 to 144 (DN 300 through 3600). Reinforced-concrete pipe may or may not be manufactured for use with rubber gaskets to seal the joints. It is usually manufactured in accordance with the following specifications:

- ASTM C76, Specifications for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe
- AASHO M170, Specifications for Reinforced Concrete Culvert, Storm Drain and Sewer Pipe
- Federal SS-P-375-Pipe, Concrete (Reinforced, Sewer)

Reinforced-concrete pipe may be made with either tongue-and-groove or bell-and-spigot joints. When made for use with rubber gaskets, the joints must conform to ASTM Specification C443 or AASHO Specification M198, Specifications for Joints for Circular Concrete Sewer and Culvert Pipe, Using Flexible Watertight, Rubber-Type Gaskets.

Concrete pipe is available also in both an arch and an elliptical cross section. These pipes are made in accordance with the following specifications:

- ASTM C506, Specifications for Reinforced Concrete Arch Culvert, Storm Drain and Sewer Pipe
- ASTM C507, Specifications for Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe

In each of the standards covering reinforced-concrete pipe, five strength classes are defined in terms of minimum three-edge bearing load at a crack width of 0.01 in (0.25 mm) and at the ultimate strength of the pipe.

The strength class required for a given installation is determined by computing the earth load and live load which will be transferred to the pipe under the conditions anticipated. This load is then converted to an equivalent three-edge bearing load by dividing it by a bedding factor. The bedding factor depends upon installation conditions and is always greater than 1.0.

Reinforced and Prestressed-Concrete Pressure Pipe

Reinforced-concrete pressure pipe is discussed in detail in Chap. A8.

Cement-Lined Steel, Ductiles, and Cast-Iron Pipe

Refer to Chap. B9 of this handbook.

Cement-lined pipe is well established for use in cold-water lines. Substantial

TABLE A2.26 Physical and Dimensional Requirements of Class 1, Bell-and-Spigot Nonreinforced Concrete Sewer Pipe (ASTM C1488; for Class 2 and Class 3 refer to ASTM C14)

Internal diameter (in) (1)	Min thickness of barrel T (in) (2)	Min laying length*§ L (ft) (3)	Inside diameter at mouth of socket† D_s (in) (4)	Depth of socket L_s (in) (5)	Min. taper of socket HL_s (6)	Min. thickness of socket‡ T_s (7)	Minimum strength (lb/lin ft) Three-edge bearing method (8)	Minimum strength (lb/lin ft) Sand-bearing method§ (9)	Max. absorption (%) (10)
4	⅝	2½	6	1½	1:20	$3T/4$, all sizes	1500	1500	8
6	⅝	2½	8¼	2	1:20		1500	1650	8
8	¾	2½	10¾	2¼	1:20		1500	1950	8
10	⅞	3	13	2½	1:20		1600	2100	8
12	1	3	15¼	2½	1:20		1300	2250	8
15	1¼	3	18¾	2½	1:20		2000	2620	8
18	1½	3	22¼	2¾	1:20		2200	3000	8
21	1¾	3	25¾	2¾	1:20		2400	3300	8
24	2⅛	3	29½	3	1:20		2600	3600	8

* Shorter lengths may be used for closures and specials.

† When pipe is furnished having an increase in thickness over that given in column 2, the diameter *at the inside* of the socket shall be increased by an amount equal to twice the increase of the barrel.

‡ This measurement shall be taken ¼ in from the outer end of the socket.

§ Not included in ASTM Specification C14.

quantities of cement-lined steel pipe are used for other applications where corrosion is more of a problem. The largest user, by far, is the petroleum industry in oil field flow lines, pipelines, tubing, and casing. Cement-lined pipe is particularly suitable for these applications because of the presence in the oil fields of saltwater, hydrogen sulfide, carbon dioxide, and other corrosive material. Other applications include lines in salt works for handling brine, discharge lines in coal mines for carrying highly corrosive sulfur water, lines in paper and pulp mills for handling diluted acids and corrosive waste liquids, and lines in process plants where water or other liquids must be kept free from iron contamination or rust.

Cement-lined pipe is generally joined with screwed seal rings which prevent the corrosive liquid from coming in contact with steel. Flanged joints are also extensively used. Some prefabrication is done of piping assemblies involving welding of the steel joints. Field joining of the preassembled welded assemblies is then done with flanged ends. Cement of course must not be at the pipe ends being welded. After welding, these ends are filled with mortar.