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# CHAPTER A9

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## GROOVED AND PRESSFIT PIPING SYSTEMS

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The use of mechanical joints in the design and construction of piping systems is rapidly becoming a general practice. This chapter discusses two types of mechanical pipe joints. The first is a mechanically pressed joint called Pressfit®\* that is designed to join light-wall carbon steel and stainless steel pipe. The second joint is generically termed a grooved joint. This type of joint is designed for joining any type of pipe, metallic or nonmetallic, that is capable of being cut or roll grooved.

Both types of joints rely on a mechanical interlock with the pipe end for pressure and structural integrity and an elastomeric gasket for the pressure boundary seal.

### **PRESSFIT®**

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#### **Introduction**

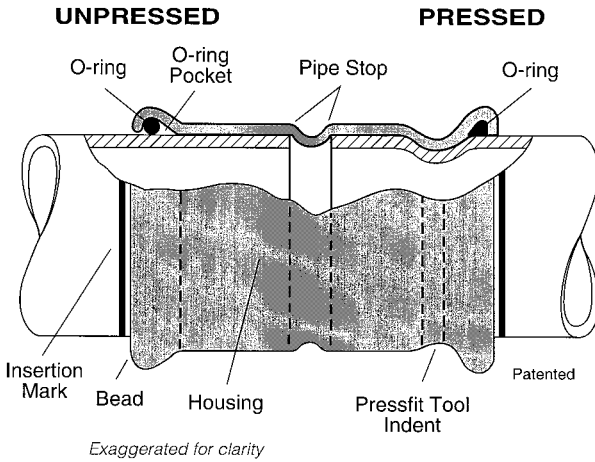
The Pressfit piping system is an innovative, rigid, self-restrained mechanical joining method for schedule 5 or lighter weight lightweight stainless steel and carbon steel pipe. This proprietary mechanical pipe joint is designed for use in small-bore piping systems, NPS ½ (DN15) to NPS 2 (DN50). The Pressfit system may be applied to any service that is compatible with the piping materials, the gasket material, and the temperature range of the system, unless prohibited by the manufacturer's instructions. Typical applications would include building-services piping, potable water, fire protection, heating and cooling, industrial processes, process cooling and heating systems, plant utilities, and vacuum systems.

#### **Joint Concept**

The Pressfit joining system concept is illustrated in Fig. A9.1 The left side of Fig. A9.1 shows the pipe fully inserted into the Pressfit fitting in the “unpressed” condi-

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\* Pressfit® is a registered trademark of Victaulic Company of America.



**FIGURE A9.1** Pressfit joint.

tion. The right side of Fig. A9.1 shows a cross-sectional view of the Pressfit joint in the “pressed” condition. Note that the pressing operation indents the Pressfit fitting and pipe, thus providing the mechanical restraint required to resist pressure and external loads that try to separate the pipe. The O-ring seal has also been compressed to provide the pressure-boundary seal of the joint. Additionally, the final pressed shape of the Pressfit joint provides resistance to torsional movement.

### Industry Specification, Codes and Product Testing

Pressfit fittings and pipe meet the requirements of the following specifications, codes, and standards:

- Pressfit carbon steel products meet the requirements of ASTM A53 Grade A and A135 Grade A. Pressfit stainless steel products meet the requirements of ASTM A312 Grade 316/316L and ASTM A269 Grade 304/304L.
- Pressfit products meet the requirements for use in piping systems designed to comply with ASME B31.1, B31.3 and B31.9 piping codes. Pressfit products are qualified for use in these systems by the following paragraphs:
  - ASME B31.1, Power Piping, Paragraphs 104.1.2, 104.7(c), and 118
  - ASME B31.3, Process Piping, Paragraphs 304.1, 304.7.2(a), and 304.7.2
  - ASME B31.9, Building Services Piping, Paragraphs 904.7, 904.7.2, and 913
- Codes and standards that have approved or listed Pressfit products are
  - Underwriters’ Laboratories—UL Listed
  - Underwriters’ Laboratories Canada—ULC Listed
  - Factory Mutual—FM Approval
  - Southern Building Code Congress International, Public Safety Testing, Evaluation Service Inc.—SBCCI, PST, and ESI Report No. 9535

International Conference of Building Official and Uniform Mechanical Code—  
UMC, ICBO-ES Report No. 5079

Building Officials and Code Administrators—BOCA Evaluation Services Inc.  
Listed Report No. 93–3 Cat. 22 and Cat. 15

National Fire Protection Association—NFPA 13

Underwriters' Laboratories—ANSI/NSF-61 listed for stainless steel potable wa-  
ter service

### System Pressure and Temperature Rating

The Pressfit pipe joining system, when installed in accordance with the manufactur-  
er's instructions, is rated as follows:

- Pressfit joints are rated for 300 psi (2065 kPa) when used in general service or process systems.
- Pressfit joints are rated for 175 psi (1200 kPa) for all fire protection services.
- The maximum and minimum continuous service temperatures for Pressfit joints are defined by the selection of the O-ring seal which is compatible with the system fluid. Thermal service conditions are shown in Table A9.1 A comparison of the maximum allowable design pressure of the Pressfit joint to an ASME Class 150 joint over the temperature range from ambient to the maximum continuous service temperature of the Pressfit joint is shown in Figs. A9.2, A9.3 and A9.4.

### Joint Installation

Pressfit pipe fittings are designed to be installed on square cut, plain-end pipe. No special pipe-end preparations are needed. Pressfit joints are made using generally accepted pipe fitting techniques with the addition of the following requirements:

- Each pipe end must be marked by measuring back from the end to establish an insertion or witness mark. This mark should be highly visible and extend for at least 180° of the pipe circumference. The insertion depth should be measured and marked as shown in Table A9.2.
- The marked pipe end should be fully inserted into the Pressfit fitting completely to the pipe stop. The insertion or witness mark should be adjacent to the end of

**TABLE A9.1**

Elastomer	Minimum temperature	Maximum temperature
EPDM (Grade "E")*	-30°F/-34°C	+230°F/+110°C
Nitrile (Grade "T")*	-20°F/-29°C	+180°F/+82°C
Fluoroelastomer (Grade "O")*	-20°F/-7°C	+300°F/+149°C

\* Grade designations "E," "T," and "O" are commercial designations assigned by Victaulic Company of America for product identification purposes only.

### 316/316L STAINLESS STEEL PRESSFIT

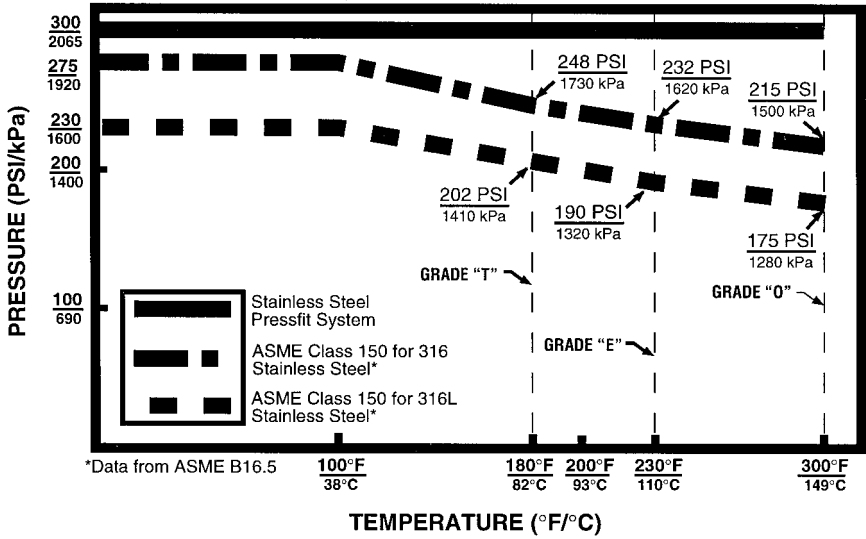


FIGURE A9.2

### STAINLESS STEEL VIC-PRESS 304

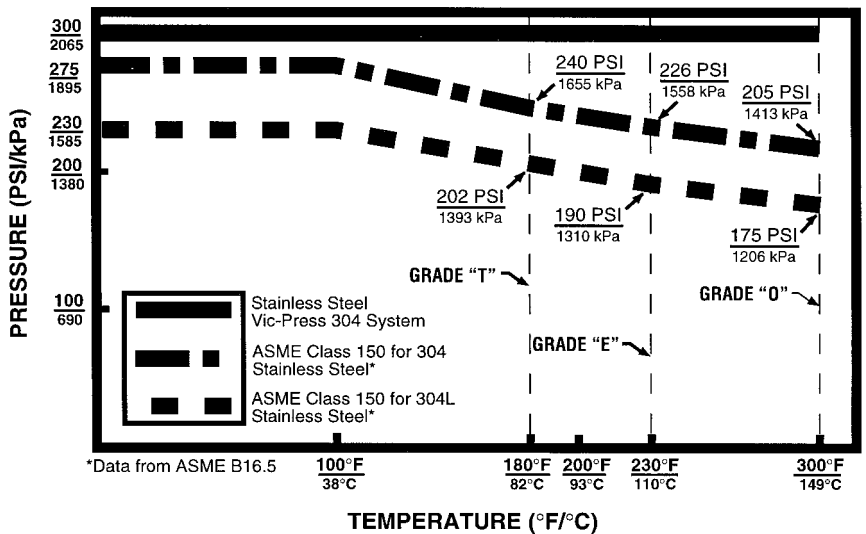


FIGURE A9.3

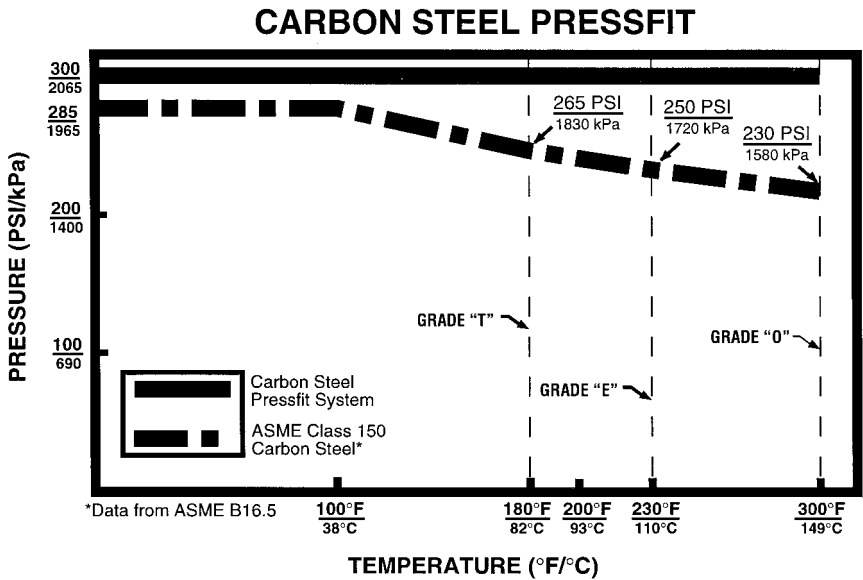


FIGURE A9.4

the Pressfit fitting. The Pressfit pipe fitting should be squared to the pipe and pressed onto the pipe using the proper pressing jaw and Pressfit tool.

### System Installation

As with all piping systems, a Pressfit system must be properly installed to provide the system performance envisioned by the piping designer. At minimum, the following installation requirements should be considered:

- *System Support:* Like all other piping systems, pipe joined with Pressfit joints requires support to carry the weight of the piping system, system fluid, and other system equipment. As in other methods of joining pipes, the support or hanging method must be adequate to eliminate undue stresses on joints, piping, and other

TABLE A9.2

Pressfit insertion mark depth—In (mm)						
Size	NPS ½ DN 15	NPS ¾ DN 20	NPS 1 DN 25	NPS 1¼ DN 32	NPS 1½ DN 40	NPS 2 DN 50
Depth	⅞ (22)	1 (25)	1 (25)	1¼ (32)	1½ (40)	1⅞ (48)

TABLE A9.3

Nominal pipe size	Suggested maximum span between supports—approved Pressfit pipe ft (m)				
	Water service			Gas/air service	
	UL/ULC/FM*	B31.1	B31.9	B31.1	B31.9
NPS ¾ DN 20	— —	7 (2.1)	8 (2.4)	9 (2.7)	8 (2.4)
NPS 1 DN 25	12 (3.7)	7 (2.1)	9 (2.7)	9 (2.7)	9 (2.7)
NPS 1¼ DN 32	12 (3.7)	7 (2.1)	11 (3.4)	9 (2.7)	11 (3.4)
NPS 1½ DN 40	12 (3.7)	7 (2.1)	12 (3.7)	9 (2.7)	13 (4.0)
NPS 2 DN 50	12 (3.7)	10 (3.1)	13 (4.0)	13 (4.0)	15 (4.6)

\* Carbon steel only

system components. The suggested maximum span between supports for Pressfit piping systems is shown in Table A9.3.

- Thermal Expansion and Contraction:** As with all rigid piping systems, piping installed utilizing Pressfit joints must be reviewed by the piping designer to assure proper allowances are incorporated into the piping system design to eliminate undue stresses from thermal expansion or contraction. The use of flexible mechanical coupling-type expansion joints is highly recommended for this service. If installation of flexible mechanical joints is not possible or desired, the designer is encouraged to use single-leg (Z-shaped) or dual-leg (U-shaped) expansion compensation loops as shown in Figs. A9.5 and A9.6 For calculated piping movement,  $\Delta l$ , the minimum expansion compensate leg length  $L$  may be determined by using Figs. A9.7 and A9.8 As a result of thermal expansion and contraction of pipe, Pressfit joints may be subjected to torsional or rotational movement. Rotational angles must be limited to a maximum of 5°.

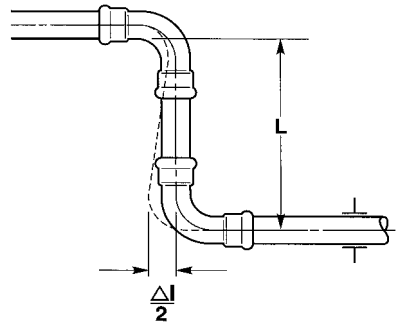
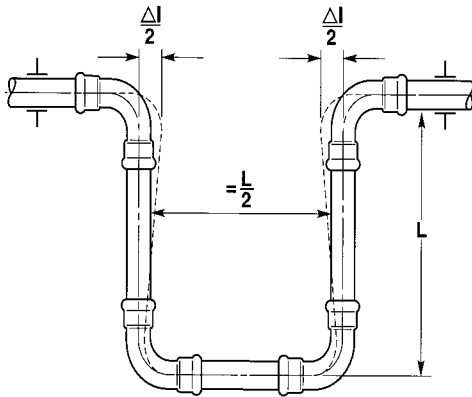


FIGURE A9.5 Z-shaped expansion compensator.

### Advantages of Pressfit

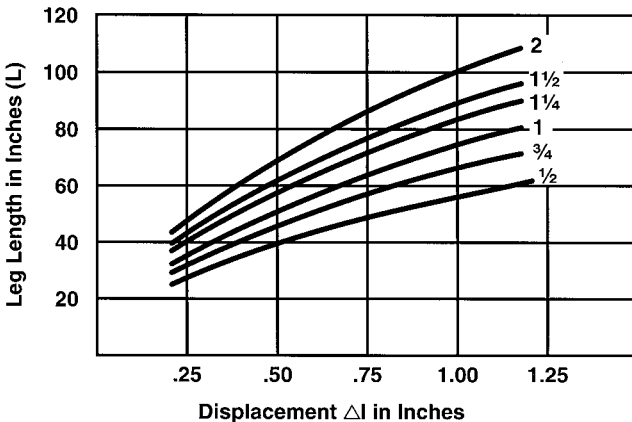
The Pressfit pipe joint was conceived to provide a fast, clean, and cool method of installing lightweight carbon and stainless steel piping systems. Advantages provided by using Pressfit are listed as follows:



**FIGURE A9.6** U-shaped expansion compensator pipe with fittings.

- The Pressfit piping system, with its lower weight, lack of required pipe-end preparation, along with ease and speed of pressing joints, will provide a lower final cost installation to the contractor and owner than the same size carbon or stainless steel system installed by threading, flanging, or welding.
- Due to the design of the Pressfit fitting, piping designers can take advantage of the full-rated pressure capability of the Pressfit fitting across the allowed temperature range of the selected O-ring material. Pressure derating with an increase in metal temperature is not a factor in Pressfit systems as compared to a flanged system. Refer to Figs. A9.2, A9.3, and A9.4 for comparison.
- Pipe used in piping systems utilizing Pressfit joints has thinner nominal wall thickness than Schedule 40 pipe used in most applications where Pressfit should

**Z-Shaped Expansion Compensator**



**FIGURE A9.7**

U-Shaped Expansion Compensator

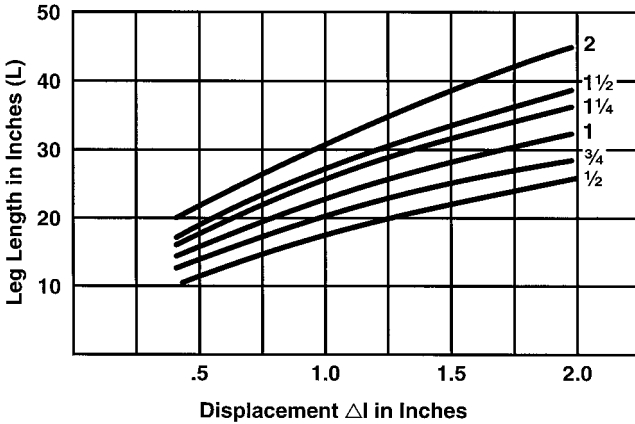


FIGURE A9.8

be considered. This difference results in significant increases of flow area and less pressure drop in Pressfit piping systems, compared to systems designed utilizing Schedule 40 pipe. A tabulation of these factors is shown in Tables A9.4 and A9.5.

- When considering carbon steel Pressfit and Schedule 40 piping from an internal corrosion perspective, the Pressfit system provides adequate performance when used in closed-loop service where water treatment is maintained or introduction of oxygen into the system is limited to periodic testing or system makeup. In Table A9.6 and Fig. A9.9, the corrosion resistance ratio (CRR) of Schedule 5 and Schedule 40 carbon-steel Pressfit pipe are compared. The corrosion resistance ratio (CRR) is a method, established by Underwriters' Laboratories in 1970, by which to compare the effective wall thicknesses for various pipes. The effective

TABLE A9.4 Friction Loss

NPS (DN)	Flow rate (GPM)	Friction loss (psi per ft) C = 120				
		Schedule 5	Schedule 10		Schedule 40	
			psi	Higher	psi	Higher
½ (15)	15	0.500	0.643	22%	0.951	90%
¾ (20)	25	0.3713	0.4510	21%	0.6351	71%
1 (25)	40	0.2584	0.3773	46%	0.4691	82%
1¼ (32)	100	0.4062	0.5426	34%	0.6721	66%
1½ (40)	120	0.2800	0.3592	28%	0.4445	59%
2 (50)	150	0.1330	0.1616	22%	0.1989	50%

**TABLE A9.5** Flow Area

NPS (DN)	Available flow area (sq in)				
	Schedule 5	Schedule 10		Schedule 40	
		Flow area	Less	Flow area	Less
½ (15)	0.396	0.357	10%	0.304	23%
¾ (20)	0.655	0.614	8%	0.533	20%
1 (25)	1.103	0.945	14%	0.864	22%
1¼ (32)	1.839	1.633	11%	1.496	19%
1½ (40)	2.461	2.222	10%	2.036	17%
2 (50)	3.960	3.650	8%	3.360	15%

wall thickness is the minimum thickness remaining at any point within a system which has exposure to both internal and external corrosion. For Schedule 5 pipe, the effective wall thickness is the minimum allowed by the applicable ASTM standard and for threaded Schedule 40, it is the minimum remaining thickness under the first exposed thread. Threaded Schedule 40 is used as the baseline and has a CRR of 1. Piping with a CRR greater than 1 will have an effective wall thickness greater than threaded Schedule 40. As can be seen in the table above, Schedule 5 Pressfit pipe has an effective wall thickness greater than threaded Schedule 40 in sizes up through NPS 1½ (DN 40). This is normally adequate to assure long system life.

**TABLE A9.6**

Nominal size pipe NPS (DN)	Corrosion resistance ratio carbon-steel pipe	
	Schedule 5 Pressfit	Schedule 40 threaded
¾ (20)	3.38	1.00
1 (25)	2.17	1.00
1¼ (32)	1.40	1.00
1½ (40)	1.11	1.00
2 (50)	0.90	1.00

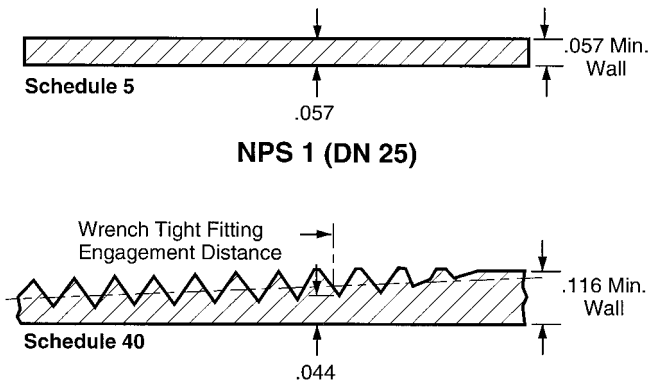


FIGURE A9.9

## GROOVED MECHANICAL PIPE JOINTS

### Introduction

The grooved piping method for mechanically joining pipe is recognized as the fast, easy, economical, and reliable method of joining pipe for many services. With over 70 years of service experience, the grooved piping method is now accepted along with the pipe joining methods, such as welding, flanging, and threading.

The grooved system provides a self-restrained pipe connection which can withstand the full-pressure thrust loads at the maximum-rated working pressure of the coupling. Easy assembly also allows easy disassembly. This, in combination with a union at every joint, permits easy system access for maintenance, repair, component replacement, and retrofits. Also, fittings can be loosely assembled and rotated to line up with mating components before the couplings are tightened. This eases work in tight places and around existing pipe, structures, or equipment. Features such as easy assembly, system access, and installation in confined spaces are not available with other joining methods.

### Reference Codes, Standards, and Specifications

Grooved joints consist of grooved pipe ends and grooved pipe couplings. The pipes themselves may meet many various industry specifications. The pipe ends and couplings meet the requirements of the following:

Pipe Grooves—ANSI/AWWA C606–87 Grooved and Shouldered Joints

Pipe Couplings—ASTM F1476–93 Standard Specification for Performance of Gasketed Mechanical Couplings for use in Piping Applications

Grooved couplings may meet the requirements or be listed by the following codes or agencies. The designer should check with the coupling manufacturer to verify compliance or listing:

American Bureau of Shipping (ABS)

American National Standards Institute (ANSI)

American Petroleum Institute (API)—API Std. 5L Sect. 7.5

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

American Society of Mechanical Engineers (ASME) Pressure Piping Code, B31; B31.1, Power Piping; B31.3, Process Piping; B31.5, Refrigeration Piping; B31.9, Building Services Piping; B31.11, Slurry Pipelines

Building Officials and Code Administrators (BOCA)

Canadian Standards Association—B242 (CSA)

Factory Mutual Research Corp. (FM)—Approved for fire protection services

International Association of Plumbing & Mechanical Officials (IAPMO)

National Fire Protection Association (NFPA)

New York Materials and Equipment Acceptance (NY-MEA)

Southern Building Code Congress International (SBCCI)—Standard Plumbing and Mechanical Code

Underwriters' Laboratories, Inc. (UL)—Listed for fire protection services

Underwriters' Laboratories of Canada (ULC)—Listed for fire protection services

Underwriters' Laboratories Inc. Listed (ANSI/NSF-61)

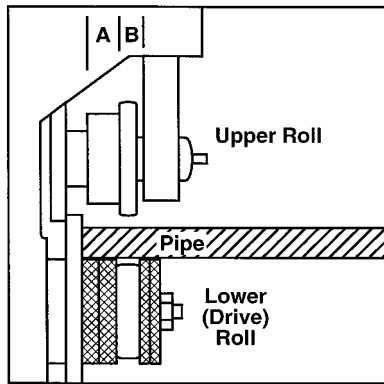
## Joint Concept

The grooved pipe-joining method is simple and reliable. The coupling housing performs several functions as an integral part of the pipe joint. It contains the fully enclosed gasket and reinforces and secures it in position for a proper seal. The housing also engages the pipe grooves around the full pipe circumference and creates a unified joint while it provides the advantages of mechanical joining. The leak-tight joint is created without exposing workers and property to the fire, smoke, and health hazards associated with welded joints or with welding flanges onto pipe.

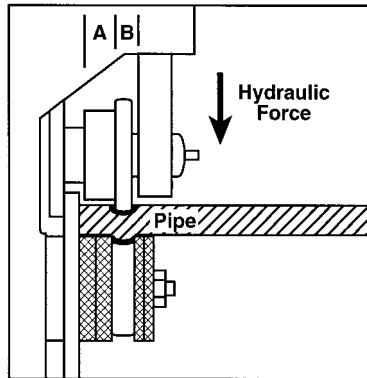
## Types of Grooves

**Cut Groove.** Grooved piping systems normally use two types of grooves. The first type, cut groove, is achieved by machining a groove in the pipe end. This type of groove may be used for standard weight and heavier pipe walls, cast ductile iron pipe, and other pipe materials that do not lend themselves to mechanical deformation, such as fiberglass reinforced plastic. Cut grooving removes material from the pipe wall and therefore should not be used for grooves in pipes with walls thinner than standard weight.

**Rolled Groove.** The second type, roll groove, is achieved by placing the pipe end in a roll grooving machine and rolling (mechanically deforming) a groove into the pipe. This grooving is accomplished by pressing a grooving roll into the pipe wall as the pipe is rotated by the machine. The resultant groove does not remove any pipe material. Fig. A9.10 shows the roll grooving process.



Roll grooving tools cold form groove into pipe – maintains dimensions

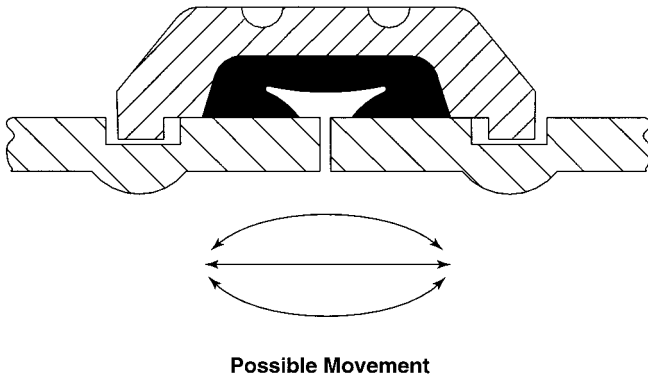


Roll grooving removes no metal from pipe

FIGURE A9.10 Roll grooving process.

## Types of Couplings

**Flexible Couplings.** As with grooves, there are two basic types of pipe couplings. The first type is defined as a flexible coupling. Flexible couplings allow for controlled pipe movement within the coupling while maintaining a positive seal and a self-restrained joint. Such performance is achieved through the combination of the elastomeric gasket, which seals the joint, with the housing, which engages the groove without clamping rigidly onto the pipe. The design allows for expansion, contraction, and deflection generated by thermal changes, building or ground settlement, and seismic activity. Pipe movement accommodation with flexible couplings will minimize the stresses that can be generated by this movement. Figure A9.11 is an exaggerated illustration of a flexible coupling. A welded system requires additional components such as expansion loops and expansion joints, since it consists solely



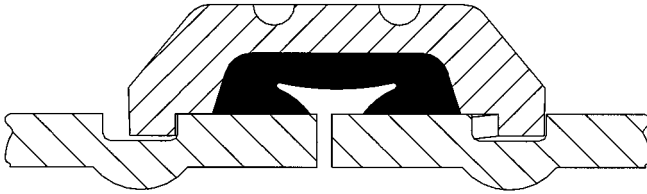
**FIGURE A9.11** Flexible coupling.

of rigid connections and has no inherent characteristics to prevent the buildup of thermal and mechanical stresses.

In order to ensure that the flexible behavior is available when required, it is necessary to support a flexible system in such a manner as to direct all motion to the preferred location. For example, to accommodate piping expansion in a long piping run, pipe lengths should be in axial alignment joined by properly gapped pipe couplings between two opposing anchors. When used in mechanical equipment rooms and on pump connections, flexible couplings will characteristically provide greater piping deflections than those generated by traditional piping methods when adequate additional support is provided.

Flexible couplings do not clamp rigidly onto the pipe. Therefore, every joint minimizes noise and vibration transmission to the piping system generated by pumps or other equipment (in contrast to other joining methods). Independent laboratory tests have confirmed that three flexible couplings connected in a series reduce more vibration than do elastomeric-arch or corrugated flexible-metal hose-type vibration isolators. Welded, flanged, or threaded joints offer no vibration attenuation, so additional costly vibration control devices are required.

**Rigid Coupling.** The second type of coupling is defined as rigid coupling. Rigid couplings positively clamp the pipe to create a rigid joint, so axial movement and deflection are eliminated. They are particularly useful on risers, mechanical rooms, horizontal runs with numerous branches, and other areas where flexibility is not desired. Proper rigid coupling installation provides system behavior characteristics similar to those of other rigid systems, so that all piping remains in strict alignment and is not subject to axial or angular movement during operation. Figure A9.12 is an exaggerated illustration of a rigid coupling. For this reason, systems installed with rigid couplings utilize support techniques similar to those used in traditional flanged and welded systems and do not require additional support as in a flexible system. ASME Pressure Piping Code Section B31.1, Power Piping, and B31.9, Building Services Piping, may be used as guidelines for supporting rigid systems. Risers consisting entirely of rigid couplings can be treated similarly to welded piping systems, and where thermal movement is required, expansion joints or offsets will be necessary to prevent piping system movement and damage to components. The piping systems using rigid couplings are obviously advantageous where rigidity is



**No Movement**

**FIGURE A9.12** Rigid coupling.

desired, as in mechanical equipment rooms, long straight runs, and similar applications.

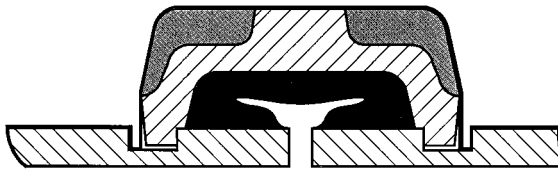
**Using Flexible and Rigid Couplings in a Piping System.** When both flexible and rigid couplings are utilized, the system designer can optimize hanger spacing, eliminate expansion loops and flex connectors, and incorporate rigidity and flexibility where desired. An example of such a system would be a pumping system which bridges two buildings via an underground line. At the pump end, rigidity may be desirable in the mechanical room to control piping motion, whereas within the straight piping run between buildings, flexible couplings are the most desirable to accommodate anticipated settlements or thermal movements. In the adjoining building for the distribution system, it may be advantageous to use a rigid system, as a high-joint intensity may require an extensive support system when flexible couplings are used. By designing risers and long straight runs with rigid and flexible couplings, the designer can make use of the rigidity of rigid couplings to reduce guiding requirements and the flexibility of flexible couplings to accommodate thermal movement as required.

The use of flexible and rigid couplings provides a variety of benefits to the system designer, installer, and owner, which results in the most reliable system for most applications and makes the grooved method an excellent choice for joining pipe.

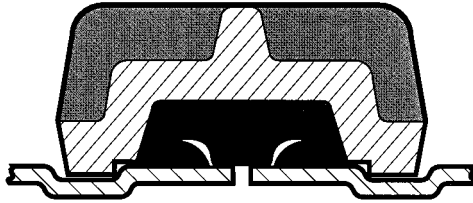
### Grooved Joint Gaskets

Many factors must be considered in determining the optimum gasket for a specific service. The foremost consideration is temperature, along with concentration of product, duration of service, and continuity of service. Temperatures beyond the recommended limits have a degrading effect on the polymer. Therefore, there is a direct relationship between temperature, continuity of service, and gasket life.

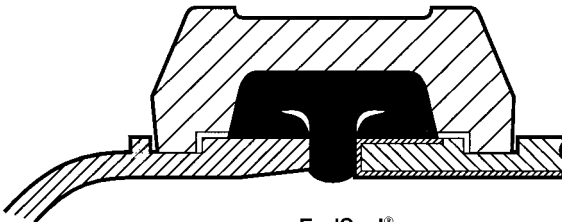
The piping system designer should also consider the gasket style that will provide the desired system performance. Three basic styles are shown in Fig. A9.13. The standard gasket style is suitable for most piping system applications. The FlushSeal® style is designed with a centrally located lip that seals the internal gasket cavity and minimizes the entrapment of system fluids or debris. The EndSeal® seals the pipe ends to virtually eliminate entrapment of system fluids and debris. The piping system designer should review the grooved joint manufacturer's gasket styles and select the style most suited to his system design.



Standard



FlushSeal®



EndSeal®

FIGURE A9.13 Gasket styles.

### Gasket Selection

A variety of synthetic rubber gaskets are available to provide the option of grooved piping products for the widest range of applications. To assure the maximum life for the service intended, proper gasket selection and specification is essential.

The compounding of synthetic rubbers is both a science and an art form. There are many gasket materials available from the various manufacturers of grooved pipe joints. The piping system designer should consult the manufacturer for gasket material recommendations about the grooved joint he has specified. The designer is further cautioned that in instances where a gasket is not affected by several substances used alone, their combination could adversely affect the gasket. Where possible, these materials should be subjected to simulated service conditions to determine their suitability.

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FlushSeal® and EndSeal® are registered trademarks of Victaulic Company of America.

**TABLE A9.7** Maximum Working Pressure

Rigid coupling (Victaulic style 97)		Flexible coupling (Victaulic style 77)	
Nominal pipe size NPS (DN)	Maximum work Pressfit psi (kPa)	Nominal pipe size NPS (DN)	Maximum work Pressfit psi (kPa)
1 (25)	750 (5175)	¾ (20)	1,000 (6900)
1¼ (32)	750 (5175)	1 (25)	1,000 (6900)
1½ (40)	750 (5175)	1¼ (32)	1,000 (6900)
2 (50)	750 (5175)	1½ (40)	1,000 (6900)
2½ (65)	750 (5175)	2 (50)	1,000 (6900)
3 O.D.	750 (5175)	2½ (65)	1,000 (6900)
3 (80)	750 (5175)	3 O.D.	1,000 (6900)
4 (100)	750 (5175)	3 (80)	1,000 (6900)
4¼ O.D.	750 (5175)	3½ (90)	1,000 (6900)
5 (125)	750 (5175)	4 (100)	1,000 (6900)
5¼ O.D.	700 (4825)	4¼ O.D.	1,000 (6900)
5½ O.D.	700 (4825)	5 (125)	1,000 (6900)
6 (150)	700 (4825)	5¼ O.D.	1,000 (6900)
6¼ O.D.	700 (4825)	5½ O.D.	1,000 (6900)
6½ O.D.	700 (4825)	6 (150)	1,000 (6900)
8 (200)	600 (4130)	6¼ O.D.	1,000 (6900)
10 (250)	500 (3450)	6½ O.D.	1,000 (6900)
12 (300)	400 (2750)	8 (200)	800 (5500)
14 (350)	300 (2065)	10 (250)	800 (5500)
16 (400)	300 (2065)	12 (300)	800 (5500)
18 (450)	300 (2065)	14 (350)	300 (2065)
20 (500)	300 (2065)	15 (375)	300 (206)
24 (600)	250 (1725)	16 (400)	300 (2065)
		18 (450)	300 (2065)
		20 (500)	300 (2065)
		22 (550)	300 (2065)
		24 (600)	250 (1725)

**Source:** Courtesy of Victaulic Company of America.

**TABLE A9.8** Gasket Temperature Rating

Gasket grade*	Temperature range*	Compound
<b>E</b>	-30°F to +230°F -34°C to +110°C	EPDM
<b>T</b>	-20°F to +180°F -29°C to +82°C	Nitrile
<b>E</b> (Type A)	Ambient	EPDM
<b>M-2</b>	-40°F to +160°F -40°C to +71°C	Epichlorohydrin
<b>V</b>	+30°F to +180°F -1°C to +82°C	Neoprene
<b>O</b>	+20°F to +300°F -7°C to 149°C	Fluoro- elastomer
<b>L</b>	-30°F to +350°F -34°C to +177°C	Silicone #
<b>A</b>	+20°F to +180°F -7°C to +82°C	White nitrile
<b>T</b> (EndSeal)	-20°F to +150°F -29°C to +66°C	High modulus nitrile

\* The gasket grades and temperature ranges shown in this table are for gaskets as manufactured by Victaulic Company of America. Other manufacturers' products may not be rated as shown here. Consult the gasket manufacturer for exact temperature range.

**Pressure-Temperature Ratings.** Couplings used in grooved mechanical pipe joints are proprietary designs offered by their various manufacturers. The piping system designer should review the manufacturer's literature to determine pressure and temperature ratings. Pressure ratings for flexible and rigid coupling are shown in Table A9.7, and temperature ratings of gasket materials are shown in Table A9.8, courtesy of Victaulic Company of America.

**Piping System Design Considerations.** Grooved mechanical-joint piping systems have some specific characteristics that are different from conventional threaded, welded, and flanged systems. When understood and properly utilized, the piping system designer can achieve well-designed, economical piping systems. As always, professional piping design practice must prevail. The following considerations should be reviewed during the piping system design.

In all piping systems designs, piping system thermal growth must be considered. Common methods of accommodating grooved piping system movement are 1) to allow the system to free float. This design method allows the pipe to move in a desired direction through the use of anchoring or guidance; or 2) utilize the linear movement-deflection capabilities of flexible grooved couplings.

The selection of either of these methods is dependent on the type of piping system and the designer's preference. Since it is difficult to predict all system designs,

it is the intent here to call attention to the mechanical advantages of the grooved piping method and how it can be used to the piping system designer's benefit. These examples are presented to stimulate thought and should not be considered as recommendations for a specific system.

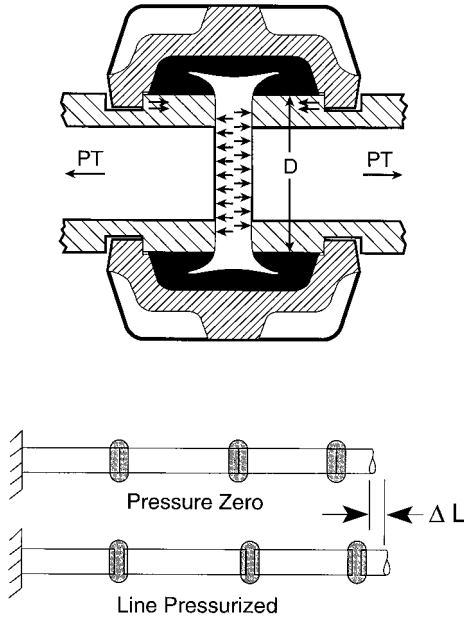


FIGURE A9.14

### Free-Floating System

Free-floating systems are piping systems which are allowed to thermally expand or contract without the use of expansion joints, provided that this movement does not cause bending-moment stresses at branch connections or is not harmful to joints and changes in direction or to parts of structures or other equipment. This can be accomplished by randomly installing joints or, if desired, by installing guides to control the direction of movement. The effects of pressure thrusts must be taken into account when utilizing flexible grooved couplings, as the pipe may move to the full extent of the available pipe end gaps when allowed to float. See Fig. A9.14 for pressure-thrust example.

$$PT = \frac{\pi}{4} D^2 P \quad (\text{A9.1})$$

PT = Pressure thrust (lb) (newtons)

D = Outside diameter of pipe (in) (mm)

P = Internal pressure (psi) (kPa)

The system designer should ensure that branch connections and offsets are sufficiently long so that the maximum angular deflection of the coupling is never exceeded and that it can accommodate the anticipated total movement of the pipes. Otherwise, the designer must anchor the system and direct movements. See Table A9.9 for recommended pipe alignment guide spacing.

### Flexible Grooved Couplings Utilizing Their Linear Movement and Deflection Capabilities

When designing piping joined with flexible mechanical grooved type couplings, it is necessary to give consideration to certain characteristics of these couplings. These characteristics distinguish flexible groove-type couplings from other types and methods of pipe joining. When this is understood, the designer can utilize the many advantages that these couplings provide.

Linear and angular movement available at flexible grooved pipe joints is published for each coupling manufacturer. These values are theoretical maximums. For design purposes, these figures should be reduced by the following factors to allow for coupling and pipe groove tolerances.

#### *Linear and Angular Movement Tolerance*

NPS  $\frac{3}{4}$ – $3\frac{1}{2}$  (DN20-90)—Reduce published figures by 50 percent

NPS 4 (DN100) and larger—Reduce published figures by 25 percent

Standard roll grooved pipe will provide  $\frac{1}{2}$  the expansion-contraction or deflection capabilities of the same size standard cut grooved pipe

The angular deflection available at a flexible grooved pipe joint is useful in simplifying and speeding system design and installation.

Angular deflection or misalignment is calculated

$$\begin{aligned} Y &= L \sin \diamond \\ \Theta &= \sin^{-1} \frac{G}{D} \end{aligned} \tag{A9.2}$$

$$Y = \frac{G \times L}{D}$$

$Y$  = deflection of misalignment (in) (mm)

$G$  = allowable pipe end movement (in) (mm)

$\diamond$  = allowable deflection (degrees) from centerline of pipe  
reduced by angular movement tolerance

$D$  = pipe outside diameter (in) (mm)

$L$  = pipe length (in) (mm)

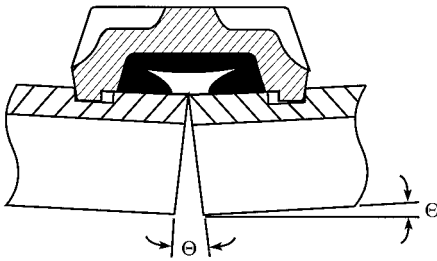
Reference Fig. A9.15 for sample diagram.

Flexible grooved-type couplings allow angular flexibility and rotational movement to take place at joints. These features provide advantages in installing and

**TABLE A9.9** Recommended Pipe Alignment Guide Spacing

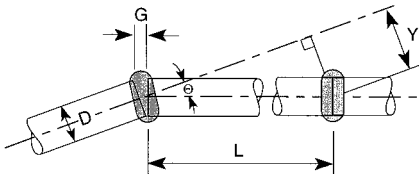
Nominal pipe size NPS (DN)	Maximum distance to first guide or anchor in (mm)	Approximate distance between first to second guide in (mm)
1 (25)	4" (101.6)	1'-4" (406.4)
1¼ (32)	5" (127.0)	1'-5" (431.8)
1½ (40)	6" (152.4)	1'-9" (533.4)
2 (50)	8" (203.2)	2'-4" (711.2)
2½ (65)	10" (254.0)	2'-11" (889.0)
3 (80)	1'-0" (304.8)	3'-6" (1066.8)
3½ (90)	1'-2" (355.6)	4'-1" (1244.6)
4 (100)	1'-4" (406.4)	4'-8" (1422.4)
5 (125)	1'-8" (508.0)	5'-8" (1727.2)
6 (150)	2'-0" (609.6)	7'-0" (2133.6)
8 (200)	2'-8" (812.8)	9'-4" (2844.8)
10 (250)	3'-4" (1016.0)	11'-8" (3556.0)
12 (300)	4'-0" (1219.2)	14'-0" (4267.2)
14 (350)	4'-8" (1422.4)	16'-4" (4978.4)
16 (400)	5'-4" (1625.6)	18'-8" (5689.6)
18 (450)	6'-0" (1828.8)	21'-0" (6400.8)
20 (500)	6'-8" (2032.0)	23'-4" (7112.0)
24 (600)	8'-0" (2438.4)	28'-0" (8534.4)

**Source:** Courtesy of Victaulic Company of America.



$\frac{3}{4}$  -  $3\frac{1}{2}$ " (20 - 90 mm) – Reduce published figures by 50%  
 4" (100 mm) and larger – Reduce published figures by 25%

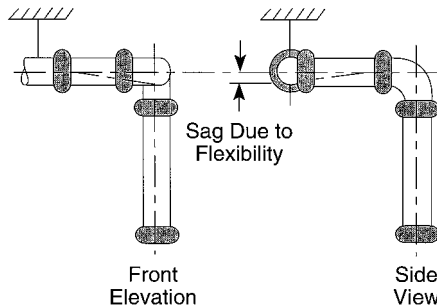
Standard roll grooved pipe will provide one-half the expansion/contraction or deflection capabilities of the same size standard cut groove pipe.



**FIGURE A9.15** Angular movement.

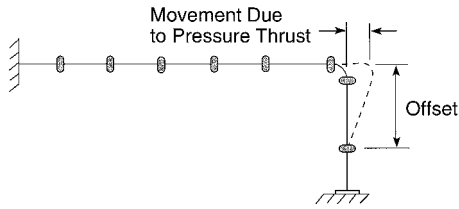
engineering piping systems but must be considered when determining hanger and support spacing. As illustrated in Fig. A9.16, it is obvious that this system would require further hangers (or use of rigid couplings) to eliminate the drooping of the pipes that may occur. Hanger positions must be considered in relation to the angular rotational movement that may occur at joints.

flexible couplings allow linear movement, therefore consideration must be given to pressure thrusts which would move the pipe ends to the maximum extent allowed by the coupling. This movement will accumulate at the end of system runs. Offsets at the ends of system runs as illustrated in Fig. A9.17 are to be capable of deflecting sufficiently to prevent harmful bending moments which would be induced at the ends of the offset. It should be noted that if the pipes were to expand due to thermal changes, then further growth of pipes would also take place at the



**FIGURE A9.16** Support requirement.

angular deflection at butted or fully spaced joints is not possible unless the ends of the pipes can shorten and grow as required. Unrestrained deflected joints will tighten up under the action of axial pressure thrusts or other forces acting to



**FIGURE A9.17** Pressure thrust movement.

pull pipes apart. If joints are to be maintained deflected, then lines must be anchored to restrain pressure thrusts and end pull forces, otherwise sufficient lateral force must be exerted to keep joint deflected. Lateral forces will always act on deflected joints due to internal pressure. A fully deflected joint will no longer be capable of providing the full linear movement normally available at the joint.

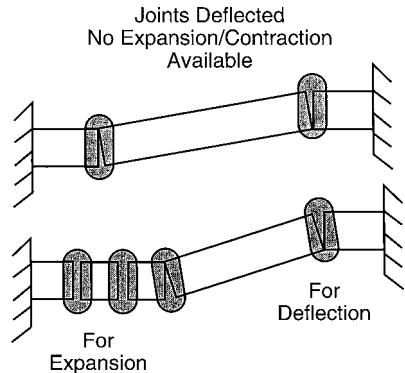
The grooved piping method will not allow maximum linear and angular movement simultaneously at the same joint. If linear and angular movement are expected simultaneously, systems should be designed with sufficient joints to accommodate both, including allowance for recommended tolerances. Figure A9.18 shows a typical arrangement used to accommodate simultaneous linear and angular movement.

For anchored systems, where pressure thrusts do not act to hold the joints in tension, or in systems where the joints have been intentionally deflected (e.g., curves), lateral restraint should be provided to prevent movement of the pipes due to pressure thrusts acting at deflections. Lightweight hangers are not adequate in preventing sideways movement of pipes.

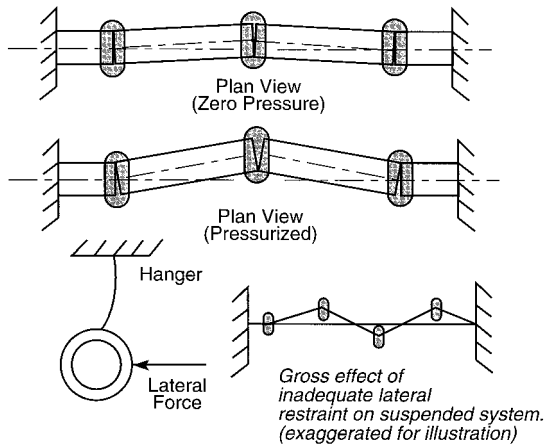
It should be anticipated that small deflections will occur in all straight lines, and side thrusts will be exerted on the joints. An example of inadequate lateral restraint is shown in Fig. A9.19.

Flexible couplings do not automatically provide for expansion or contraction of piping. In anchored systems, gaps must be set to handle combinations of expansion and contraction. In free-floating systems, offsets of sufficient length must be used to accommodate movement without overdeflecting joints. Design anchors to direct movement away from or to protect critical changes in direction, branch connections, and structure. Spacing and suitable types of supports should be considered in accommodating anticipated pipe movements. Refer to Table A9.10 for suggested support spacing for flexible and rigid coupled systems.

Movement in piping systems due to thermal changes can be accommodated with the grooved piping method. Sufficient flexible joints must be available to accommodate anticipated movement, including movement tolerance. If anticipated movement will be greater than provided by the total number of joints in the system, additional expansion in the form of an expansion joint should be considered. The



**FIGURE A9.18** Accommodating piping expansion and deflection.



**FIGURE A9.19** Inadequate lateral restraint.

first step in accommodating thermal movement is to compute the exact change in the linear length of the piping system over the distance of interest. The actual expansion of 100 ft and 100 m pipe lengths has been computed at different temperatures for the most common piping materials (carbon steel, stainless steel, and copper tubing) and are shown in Table A9.11. These values should not be applied to pipe of other materials, as they will vary. Expansion coefficients may vary 5 percent or more when obtained from different sources. This variation should be taken into account. Example A9.1 illustrating the use of Table A9.11 follows:

### **Example A9.1**

**Given:** 240-ft (75-m)-long carbon-steel pipe

Maximum operating temperature = 220°F (104°C)

Minimum operating temperature = 40°F (4°C)

Temperature at time of installation = 80°F (26°C)

**Calculation:** From Table A9.11, carbon-steel pipe expansion

220°F (104°C) 1.680 in per 100 ft of carbon-steel pipe

40°F (4°C) 0.300 in per 100 ft of carbon-steel pipe

Difference: 1.380 in per 100 ft of carbon-steel pipe for temperature 40°F (4°C) to 220°F (104°C)

Therefore, 240-ft of pipe =  $\frac{240(1.380)}{100} = 3.312$  in (8.41 cm)

### **Example A9.2 A Simplified Calculation for a Long Straight Piping System.**

400-ft (122-m)-long, straight piping system; NPS 6 (DN 150); 20-ft (6-m) random lengths; installed at 60°F (+16°C) (also lowest operating temperature; maximum

**TABLE A9.10** Suggested Support Spacing for Rigid and Flexible Coupled Piping Systems

**Rigid systems**

NPS (DN)	Suggested maximum span between supports ft (m)						NPS (DN)	Suggested maximum span between supports ft (m)					
	Water service			Gas or air service				Water service			Gas or air service		
	*	†	‡	*	†	‡		*	†	‡	*	†	‡
1 (25)	7 (2.1)	9 (2.7)	12 (3.7)	9 (2.7)	9 (2.7)	12 (3.7)	10 (250)	19 (5.8)	21 (6.4)	15 (4.6)	24 (7.3)	31 (9.5)	15 (4.6)
1¼ (32)	7 (2.1)	11 (3.4)	12 (3.7)	9 (2.7)	11 (3.4)	12 (3.7)	12 (300)	23 (7.0)	21 (6.4)	15 (4.6)	30 (9.1)	33 (10.1)	15 (4.6)
1½ (40)	7 (2.1)	12 (3.7)	15 (4.6)	9 (2.7)	13 (4.0)	15 (4.6)	14 (350)	23 (7.0)	21 (6.4)	15 (4.6)	30 (9.1)	33 (10.1)	15 (4.6)
2 (50)	10 (3.1)	13 (4.0)	15 (4.6)	13 (4.0)	15 (4.6)	15 (4.6)	16 (400)	27 (8.2)	21 (6.4)	15 (4.6)	35 (10.7)	33 (10.1)	15 (4.6)
3 (80)	12 (3.7)	15 (4.6)	15 (4.6)	15 (4.6)	17 (5.2)	15 (4.6)	18 (450)	27 (8.2)	21 (6.4)	15 (4.6)	35 (10.7)	33 (10.1)	15 (4.6)
4 (100)	14 (4.3)	17 (5.2)	15 (4.6)	17 (5.2)	21 (6.4)	15 (4.6)	20 (500)	30 (9.1)	21 (6.4)	15 (4.6)	39 (11.9)	33 (10.1)	15 (4.6)
6 (150)	17 (5.2)	20 (6.1)	15 (4.6)	21 (6.4)	25 (7.6)	15 (4.6)	24 (600)	32 (9.8)	21 (6.4)	15 (4.6)	42 (12.8)	33 (10.1)	15 (4.6)
8 (200)	19 (5.8)	21 (6.4)	15 (4.6)	24 (7.3)	28 (8.5)	15 (4.6)							

A.440

\* Spacing corresponds to ASME B31.1 Power Piping Code.

† Spacing corresponds to ASME B31.9 Building Services Piping Code.

‡ Spacing corresponds to NFPA 13 Sprinkler Systems.

Flexible systems: maximum support spacing for straight runs without concentrated loads and where full linear movement is required.

**Flexible systems**

NPS (DN)	Pipe length in ft (m)										NPS (DN)	Pipe length in ft (m)									
	7 (2.1)	10 (3.0)	12 (3.7)	15 (4.6)	20 (6.1)	22 (6.7)	25 (7.6)	30 (9.1)	35 (10.7)	40 (12.2)		7 (2.1)	10 (3.0)	12 (3.7)	15 (4.6)	20 (6.1)	22 (6.7)	25 (7.6)	30 (9.1)	35 (10.7)	40 (12.2)
	*Average hangers per pipe length evenly spaced											*Average hangers per pipe length evenly spaced									
¾-1 (20-25)	1	2	2	2	3	3	4	4	5	6	10-12 (250-300)	1	1	1	2	2	2	2	3	3	3
1¼-2 (32-50)	1	2	2	2	3	3	4	4	5	5	14-16 (350-400)	1	1	1	2	2	2	2	3	3	3
2½-2 (65-100)	1	1	2	2	2	2	2	3	4	4	18-24 (450-600)	1	1	1	2	2	2	2	3	3	3
5-8 (125-200)	1	1	1	2	2	2	2	3	3	3	28-42 (700-1050)	1	1	1	1	2	2	2	3	3	3

\* No pipe length should be left unsupported between any two couplings.

\* No pipe length should be left unsupported between any two couplings.

Maximum support spacing for straight runs without concentrated loads and where full linear movement is not required.

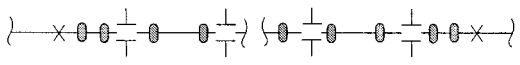
NPS (DN)	Suggested maximum span between supports ft (m)	NPS (DN)	Suggested maximum span between supports ft (m)
¾-1 (20-25)	8 (2.4)	10-12 (250-300)	16 (4.9)
1¼-2 (32-50)	10 (3.0)	14-16 (350-400)	18 (5.5)
2½-4 (65-100)	12 (3.7)	18-30 (450-750)	20 (6.1)
5-8 (125-200)	14 (4.3)	32-42 (800-1050)	21 (6.4)

**TABLE A9.11** Thermal Expansion of Pipe

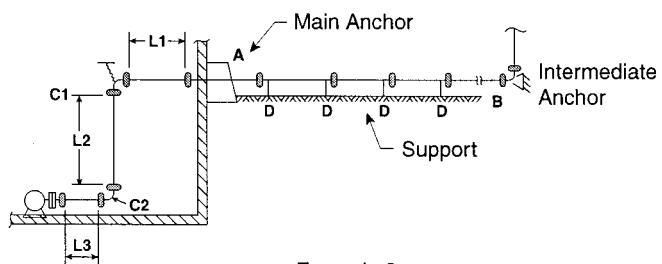
Temperature °F (°C)	In per 100 ft (mm per 100 m)			Temperature °F (°C)	In per 100 ft (mm per 100 m)		
	Carbon steel	Copper	Stainless steel		Carbon steel	Copper	Stainless steel
-40 (-40)	-0.288 (-24.0)	-0.421 (-35.1)	-0.461 (-38.4)	180 (82)	1.360 (113.2)	2.051 (170.9)	2.074 (172.9)
-20 (-28)	-0.145 (-12.1)	-0.210 (-17.4)	-0.230 (-19.0)	200 (93)	1.520 (126.6)	2.296 (191.3)	2.304 (191.9)
0 (-17)	0 (0)	0 (0)	0 (0)	212 (100)	1.610 (134.2)	2.428 (202.4)	2.442 (203.4)
20 (-6)	0.148 (12.5)	0.238 (19.7)	0.230 (19.0)	220 (104)	1.680 (140.1)	2.516 (209.7)	2.534 (211.3)
32 (0)	0.230 (19.0)	0.366 (30.5)	0.369 (30.8)	230 (110)	1.760 (146.7)	2.636 (219.8)	2.650 (220.8)
40 (4)	0.300 (24.9)	0.451 (37.7)	0.461 (38.4)	260 (126)	2.020 (168.3)	— —	— —
60 (15)	0.448 (37.4)	0.684 (57.1)	0.691 (57.7)	280 (137)	2.180 (181.8)	— —	— —
80 (26)	0.580 (48.2)	0.896 (74.8)	0.922 (76.8)	300 (148)	2.350 (195.9)	— —	— —
100 (37)	0.753 (62.7)	1.134 (94.5)	1.152 (96.1)	320 (160)	2.530 (211.0)	— —	— —
120 (48)	0.910 (75.8)	1.366 (113.9)	1.382 (115.2)	340 (171)	2.700 (225.1)	— —	— —
140 (60)	1.064 (88.6)	1.590 (132.6)	1.613 (134.5)	350 (176)	2.790 (232.6)	— —	— —
160 (71)	1.200 (100.1)	1.804 (150.3)	1.843 (153.6)				

operating temperature of 180°F [+82°C]. Table A9.11 shows this system will give 3.7, in (9.4 cm) total anticipated movement. Reference Fig. A9.20 for a sketch of Example 1 piping system.

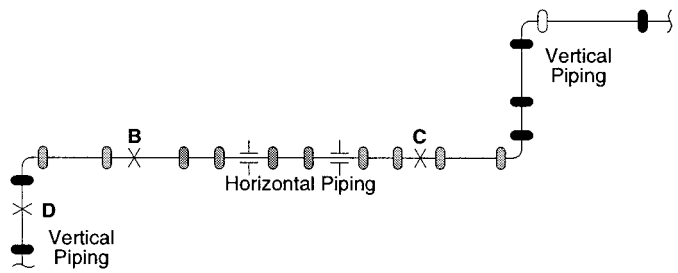
- 20 Joints between anchor points
- × 1/4 in Movement per coupling (cut grooved pipe with Victaulic Style 77 couplings performance data)
- 5 in (12.7 cm) available movement
- 25% Movement tolerance
- 3.75 in (9.52 cm) Total linear movement available
- 3.7 in (9.4 cm) Required movement



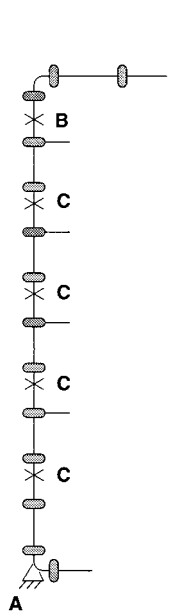
Example 1 & 2



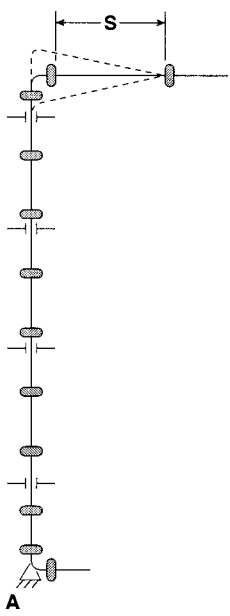
Example 3



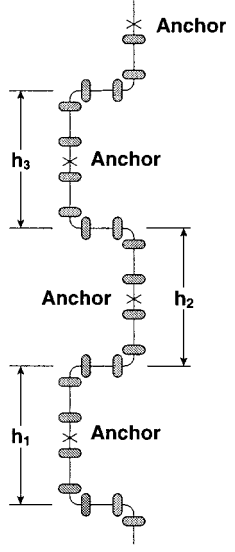
Example 4



Example 5



Example 6



Example 7

FIGURE A9.20 Example piping systems.

## Expansion Loops Utilizing Flexible Couplings and Fittings

Grooved piping offers the designer the advantage of using flexible couplings and fittings in expansion loops without inducing stresses in the pipes, elbows, or joints. The deflection capability of flexible couplings allows for thermal growth-contraction to be absorbed within the couplings at the elbows as the thermal forces induce deflection. It is important that rigid couplings are not used on expansion loops, as these couplings are not designed to accommodate angular deflection.

As shown in Fig. A9.21a, a total of eight flexible couplings, four grooved 90° elbows, and three pipe spools are required to complete each expansion loop. As system temperature decreases and the pipe run contracts (see Fig. A9.21b), the loop expands, and the deflection capability of the couplings accommodates this movement. As system temperature increases (see Fig. A9.21c), the opposite effect occurs as the pipe run expands and the loop contracts with the couplings accommodating the deflection in the opposite direction.

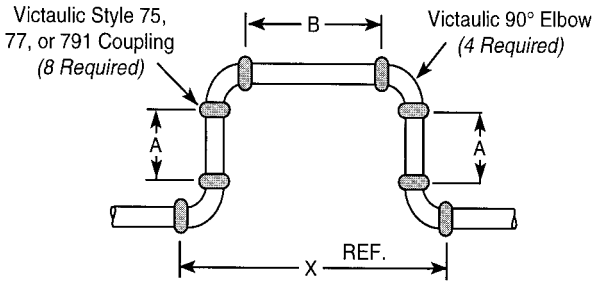
The amount of thermal expansion and contraction,  $\Delta X$ , should be determined by the system designer based on the length of pipe run between anchors and the anticipated temperature changes from the installation temperature (see Table A9.11 for details). The angular deflection available at each coupling is a design characteristic inherent to the coupling size, style, and the type of groove—cut or roll grooved. The length of the perpendicular branches of the loop dimension  $A$  (see Figure A9.21a) is determined by the amount of expected pipeline expansion or contraction,  $\Delta X$ , and the deflection available per joint. Dimension  $A$  should be the same on both sides of the loop. The length of the parallel branch of the expansion loop, Dimension  $B$ , is determined by  $\Delta X$ , and it must be sufficiently long enough to prevent the elbows at the pipe run from butting during thermal expansion. It is recommended that Dimension  $B$  be at least 2 in (50.8 mm) larger than  $\Delta X$ .

The designer can use Fig. A9.22, Expansion Loop Design, to aid in the design of expansion. These loops incorporate all the design information for each size of Victaulic Flexible Coupling, including the angular movement tolerance. The nominal pipe size and either the design thermal expansion,  $\Delta X$ , or the length of perpendicular branches, dimension  $A$ , must be known, and the other can be determined. It is essential for a properly functioning expansion loop that it be installed without any coupling deflection and that the pipeline be properly anchored and guided. Whenever possible, the expansion loop should be located adjacent to an anchor within four pipe diameters. The first and second alignment guides on the opposite side of the expansion loop should be located a maximum distance of 4 and 14 pipe diameters, respectively. Additional intermediate guides may be required throughout the system for pipe alignment. Refer to Table A9.9 for recommended spacing. If the expansion loop cannot be located adjacent to an anchor, guides should be installed on both sides of the unit, as mentioned.

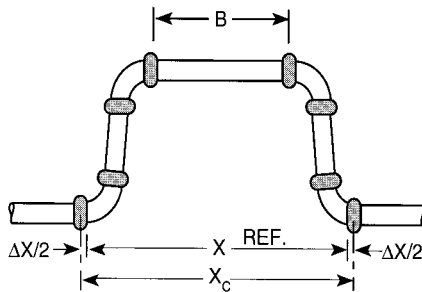
**Example A9.3 Expansion Loop Calculation.** Using the parameters established in Example A9.2, NPS 6 (DN 150) nominal pipe size and 3.75 in (95.2 mm) of total anticipated movement, refer to Fig. A9.22 to determine the length of perpendicular loop branches for both cut and roll groove pipe. Reference Fig. A9.20 for a sketch of Example 2 piping system.

$$\Delta X = 3.75 \text{ in (95.2 mm)}$$

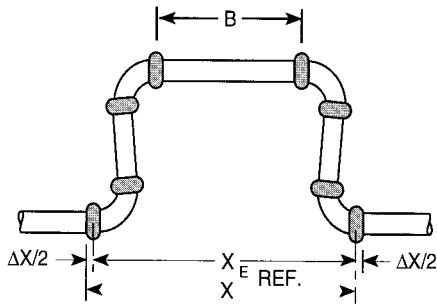
$$\text{Pipe size} = \text{NPS 6 (DN 150)}$$



**A**  
Expansion Loop



**B**  
Thermal Contraction  
Pipeline Shrinks – Loop Expands



**C**  
Thermal Expansion  
Pipeline Grows into Loop – Loop Contracts

**FIGURE A9.21** Thermal expansion loop.

## Expansion Loop Design Utilizing Victaulic Flexible Couplings and Fittings\* VICTAULIC CUT GROOVED PIPE

A.446

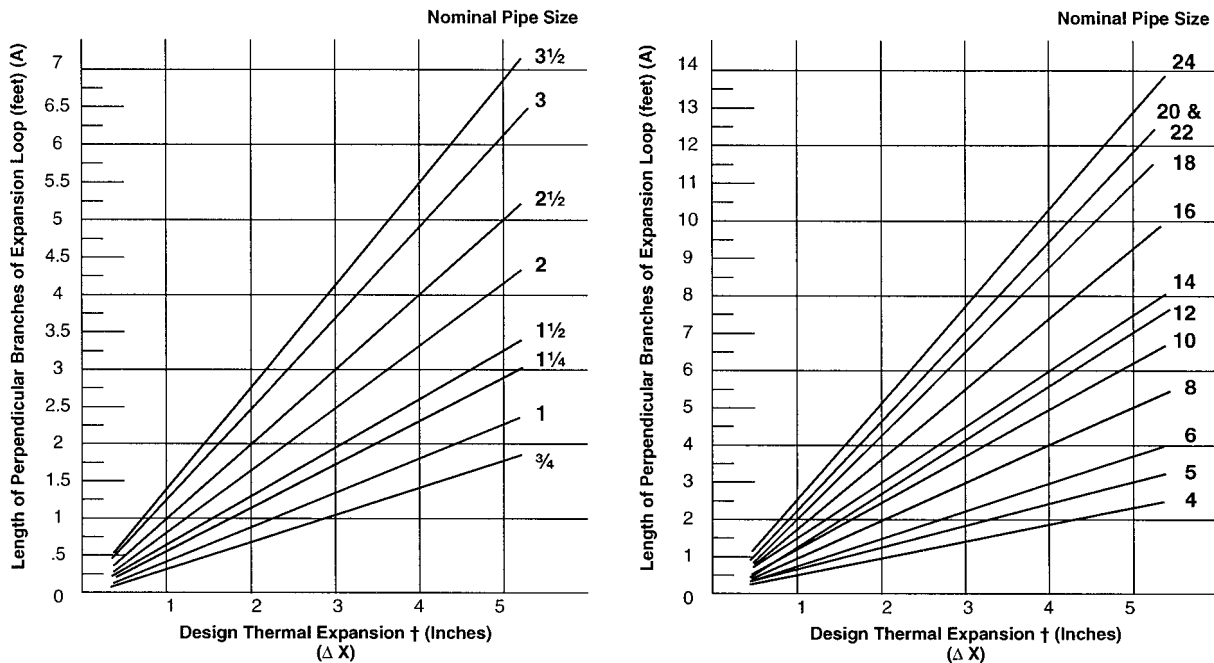
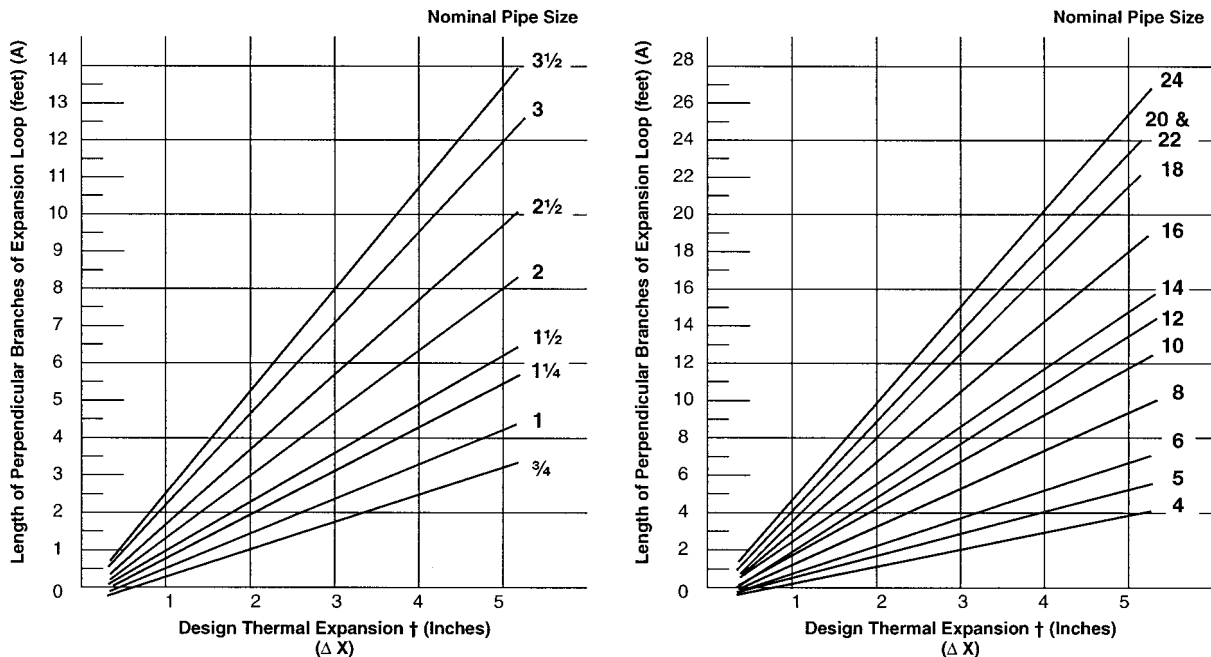


FIGURE A9.22 Expansion loop design.

## Expansion Loop Design Utilizing Victaulic Flexible Couplings and Fittings\* VICTAULIC ROLL GROOVED PIPE



\* Based on pipe grooved in accordance with Victaulic specifications.

† Valves include design tolerances: 50% reduction for sizes below 4"/25% reduction for sizes 4" and larger.

**FIGURE A9.22** (Continued) Expansion loop design.

For cut groove pipe (Fig. A9.22)

$$A = 2.7 \text{ ft (0.82 m) minimum}$$

For roll groove pipe (Fig. A9.22)

$$A = 5.4 \text{ ft (1.65 m) minimum}$$

To provide an expansion loop for the described system, the two branches must be a minimum of 2.7 ft (0.82 m) and 5.4 ft (1.65 m) long for cut and roll groove pipe, respectively. The parallel branch of the expansion loop must be at least 2 in (50.8 mm) larger than  $\Delta X$ .

$$B = \Delta X + 2$$

$$B = 3.75 \text{ in} + 2 \text{ in} = 5.75 \text{ in minimum (95.25 mm} + 50.8 = 146.05 \text{ mm)}$$

The simple system described in Example A9.2 and above accommodated thermal expansion through the use of flexible couplings and an expansion loop. We must also discuss the application of flexible couplings and rigid couplings with the use of main anchors, intermediate anchors, and guides to accommodate thermal movement and pressure thrust.

## Anchors

Anchors can be used to prevent movement due to pressure thrust and thermal growth. There are two types of anchors which are commonly used:

**A.** Main anchors

**B.** Intermediate anchors

Main anchors are installed at or near terminal points and changes of direction of a pipe line. The forces acting on a main anchor will result from internal pressure thrust and thermal growth. These forces can generate substantial loads which may require structural analysis. Intermediate anchors divide a long pipe run, with main anchors at each end, into individual expanding sections. The pressure thrust on the intermediate anchors cancel each other out. Where there is a change in pipe diameter, there will be a differential pressure thrust acting on an intermediate anchor. Typical examples of main and intermediate anchors are shown in Fig. A9.23.

The following examples illustrate the mechanical advantages of the grooved piping method and how they can be utilized to the piping systems designer's benefit. These are presented to stimulate thought and should not be considered as recommendations for a specific system. The grooved piping method, when used in a piping system, should always be utilized in designs consistent with good piping practice.

**Example A9.4 Anchor Locations.** To properly restrain this system, reference Fig. A9.20 for Example 3 piping system sketch. It would be necessary to provide a pressure thrust anchor at "A" to prevent the piping outside the structure from being forced inside by the pressure thrust acting at the elbow "B." Inside, it would be necessary to provide a hanger at point C1, or a base support at point C2. No

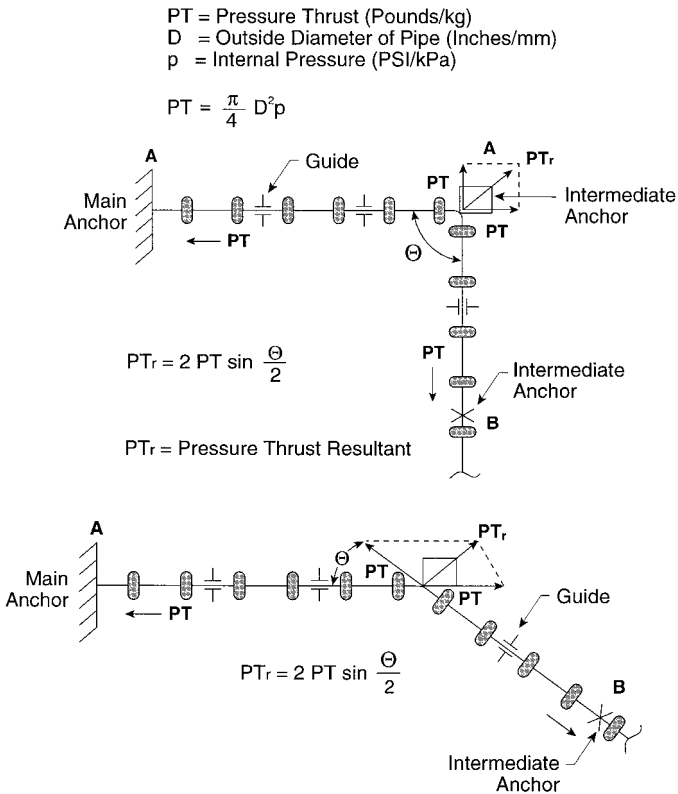


FIGURE A9.23

anchoring would be required, and the self-restraining feature of the joints would hold the piping securely together. Outside, it would be necessary to ensure that the maximum end load of the joints was not exceeded due to thermal movement of the pipes. Intermediate anchors may be required. The pipe must be properly supported and guided. Refer to Tables A9.9 and A9.10. Where flexible couplings are not required to accommodate thermal movement, rigid couplings can reduce supports and offsets.

**Example A9.5 Anchor and Guide Locations.** Anchor at location D to support weight of pipe. Use hangers to support weight of piping. Anchors as well as guides may be required at B and C if flexible couplings are used as expansion joints. Refer to Fig. A9.20 for Example 4 piping system sketch.

**Example A9.6 Treatment of Risers with Branch Connections.** Free-moving risers can cause shear forces at branch connections due to pressure thrusts or thermal movement. The pipe should be anchored at or near the base with a main pressure thrust anchor, A, capable of supporting the full pressure thrust and local weight of pipe and fluids. Any movement of horizontal pipe at the bottom of the riser must

be considered independently, with adequate provision for movement. Refer to Fig. A9.20 for Example 5 piping system sketch.

When flexible couplings are used, the system can be anchored at the top, B, with an anchor capable of withstanding full pressure thrust at the top of the riser plus local weight of pipe. The use of this upper anchor prevents any possibility of closed flexible joints opening under pressure and causing movement at the riser top. This method is often used for fire standpipe or similar systems where movement would cause shearing of intermediate components or branches.

Piping between upper, B, and lower, A, anchors should be supported by intermediate anchors, C, capable of supporting local pipe weight and preventing lateral movement. Intermediate anchors should be placed a minimum of every other random length of pipe.

The system can be anchored at A also, and intermediate anchors at C can be used to support local pipe weight. Allowance for thermal movement should be considered, depending on application.

**Example A9.7 Treatment of Risers Without Branch Connection for Flexible Couplings.** Reference Fig. A9.20 for Example 6 piping system sketch. With this method, a main thrust anchor is again needed at the bottom of the riser, A, which supports the total weight of pipe and fluids. Guidance is necessary at suitable intervals to prevent buckling of the riser. It is necessary that the pipe length, S, at the top of the stack be long enough to accommodate the total vertical movement. This movement is the result of the combined effect of pipe being moved to the full extent of the available pipe linear movement due to pressure thrusts and thermal growth.

Rigid couplings also could be used to prevent linear movement due to pressure thrust. For offset S at the top of the riser to accommodate thermal growth, it would be necessary to use the proper number of flexible couplings to provide the angular deflection.

**Example A9.8 Treatment of Risers to Eliminate Concentrated Anchor Loads.** Refer to Fig. A9.20 for Example 7 piping system sketch. When structural requirements dictate that base anchor load or upper anchor load must be minimized, then the use of a *looped* system should be considered. In the system illustrated, each anchor carries the local weight of pipe. This method is often considered in tall buildings where high anchor loads would be generated. The offsets must be long enough to accommodate movement in the pipes due to flexible-coupling linear movement due to pressure thrust plus any thermal or other movements of pipes or supports. The use of rigid couplings could be considered to prevent linear movement due to pressure thrust.

## Offsets and Differential Settlement

In many piping system designs, offsets or differential settlement must be considered. This is particularly important, as pipes pass from one structure to another. Flexible couplings offer the designer a method to accommodate offsets of pipe runs due to misalignment or building settlement. The offset transition can be achieved only with flexible couplings, as they allow for angular deflection at each joint.

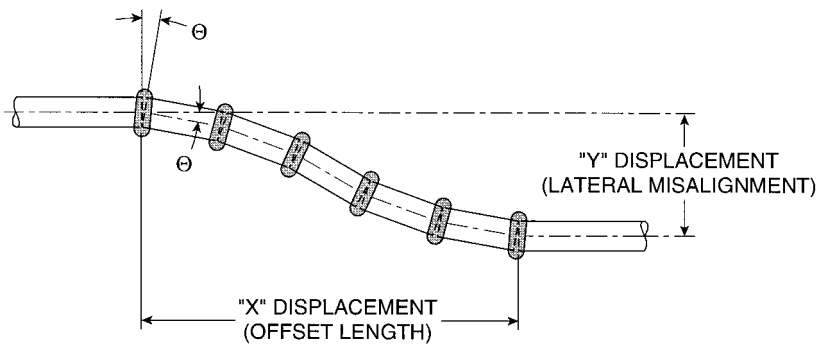


FIGURE A9.24 Pipe displacement.

Offsets are determined by the amount of lateral misalignment on the particular pipe run and the length along the pipe run that is required for the parallel shift of the run. In Fig. A9.24, these two parameters are shown as the Y-Displacement, lateral misalignment, and the X-Displacement, offset length, respectively.

The pipe spools are first deflected in the direction of the misalignment until the midpoint of a particular pipe spool is more than half the required Y-Displacement. This spool then becomes a transition spool, as an equal number of couplings and pipe spools are required on either side of the transition spool to deflect the pipeline back to its original direction.

A major objective in designing for a misalignment is to achieve the required Y-Displacement, using the minimum number of couplings. To this end, because of symmetry around a transition point, as explained earlier, the point of inflection is a pipe spool and not a coupling. Therefore, for all calculations and results in this section, an even number of couplings and an odd number of pipe spools have been used. Also, to maximize the deflection at each joint, cut-groove pipe should be considered. Should roll-grooved joints be used, then the deflection available will be one-half that of a cut-grooved joint.

The number of couplings and the length of the pipe spools are the two variables that can be altered to obtain the desired misalignment. Other factors, such as the maximum angle of deflection at each coupling and the maximum pipe-end separation are a function of the size and style coupling being used.

The following is a technical explanation of the formulas derived to calculate the number of couplings, spool length, X- and Y-Displacements.

The geometric derivation to accommodate offsets starts with the deflection on one pipe spool from the pipe run at the angle,  $\Theta$  (see Fig. A9.24). The Y-Displacement from the pipe-run centerline after the first deflected spool is shown as  $\Delta Y_1 = (L + a) \sin \Theta$ , where  $L$  is the length of the pipe spool and  $a$  is one-half the maximum pipe-end separation for the particular coupling to be used. As the second spool is connected and deflected, also at the angle,  $\Theta$ , the total angle of deflection from the pipe run is  $\Theta + \Theta$ , or  $2\Theta$  (see Fig. A9.25). The Y-Displacement due to the second coupling and pipe spool is  $\Theta Y_2 = (L + a) \sin 2\Theta$ .

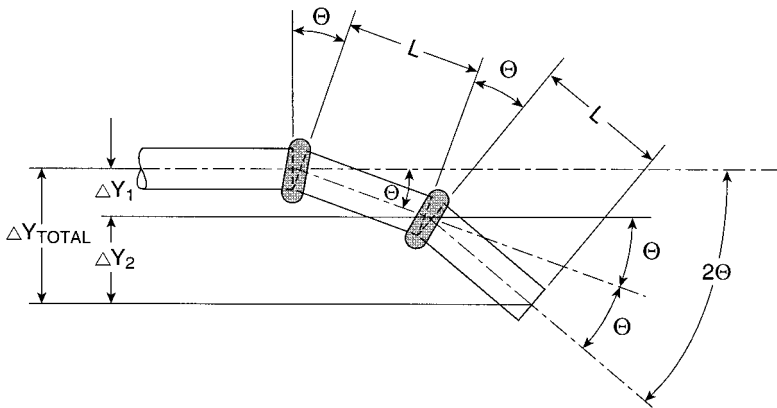


FIGURE A9.25 Deflection of pipe.

Since the length of each pipe spool is equal, then the total Y-Displacement to the end of the second pipe spool from the pipe run is the sum of each spool or

$$\Delta Y_{TOTAL} = \Delta Y_1 + \Delta Y_2 = (L + a) (\sin \Theta) + \sin 2\Theta). \tag{A9.3}$$

When the value of  $\Delta Y_{TOTAL}$  is at least half of the required Y-Displacement, then the last calculated pipe length up to that point becomes the point of transition. Geometrical symmetry about this point allows that the actual Y-Displacement of the completed misalignment will be equal to two times the  $\Delta Y_{TOTAL}$  up to the transition spool piece plus the Y-Displacement of the spool piece itself, or

$$\begin{aligned} \text{Y-Displacement} = & (L + a)[2(\sin \Theta) + 2(\sin \Theta) + \dots \\ & 2(\sin(P - 1)\Theta) + (L + a)[\sin P\Theta] \end{aligned} \tag{A9.4}$$

where  $P$  is the number of spool pieces to achieve the transition and is equal to one-half of the number of couplings involved in the total misalignment.

This expression is mathematically simplified to:

$$\begin{aligned} & P - 1 \\ \text{Y-Displacement} = & (L + a)[\sin P\Theta + 2 \sin n\Theta] \\ & n = 1 \end{aligned}$$

When  $n$  = the total number of couplings in the misalignment, and  $P = n/2$ .

By using the same geometric and trigonometric relations, the distance in the  $X$  direction required for the misalignment is as follows:

$$X\text{-Displacement} = (L + a)[\cos P\Theta + 2e\tau \cos n\Theta] \quad (A9.5)$$

$$n = 1$$

**Example A9.9 Pipe Misalignment.** A designer wants to connect a NPS 6 (DN150) feed main from an existing building to a new structure. There is 66 in (1676 mm) of pipe run between the connection points, and it is expected that a settlement of 3 in (76.2 mm) will occur. To utilize the maximum deflection available from flexible coupling, cut grooved-pipe nipples will be used.

### Requirements

Y-Displacement = 3 in (76.2 mm)

X-Displacement = less than 66 in (1676 mm)

Maximum pipe-end separation = 0.25 in (6.4 mm) (from coupling manufacturer performance data for flexible coupling)

Design pipe-end separation\* = 0.188 in (4.8 mm)

1/2 pipe-end separation,  $a = 0.094$  in (2.4 mm)

Maximum angle of deflection =  $2^\circ 10' = 2.167^\circ$  (from coupling manufacturer performance data for flexible coupling)

Design angle of deflection,  $\Theta = 1^\circ 38' = 1.625^\circ$

\*Maximum values reduced by 25% for design and installation purposes. The published maximum pipe-end separation and angular deflection figures should be reduced by 50% for NPS  $3/4$ –NPS  $3 1/2$  (DN 20–DN 90) sizes, and 25% for NPS 4 and larger sizes.

Try: 4 couplings ( $n = 4$ )  $P = n/2 = 2$

Spool lengths,  $L = 12$  in

$a = 0.094$  in

$\Theta = 1.625^\circ$

$$P - 1$$

$$Y\text{-Displacement} = (L + a)[\sin P\Theta + 2 \sin n\Theta]$$

$$n = 1$$

$$= (12 + 0.094)\{\sin(2 \times 1.625) + 2$$

$$\quad [\sin(1 \times 1.625)]\}$$

$$= 12.094 \{0.057 + 2(0.028)\} = 1.37 \text{ in}$$

Not enough; Y-Displacement of 3 in (76.2 mm) is required, so try 6 couplings:

$$n = 6$$

$$P = n/2 = 3$$

$$L = 12 \text{ in}$$

$$a = 0.094 \text{ in}$$

$$\Theta = 1.625^\circ$$

$$\begin{aligned} \text{Y-Displacement} &= (12 + 0.094) \{ \sin(3 \times 1.625) + 2 \\ &\quad [ \sin(1 \times 1.625) + \sin(2 \times 1.625) ] \} \\ &= 12.094 \{ 0.085 + 2[0.028 + 0.057] \} = 3.08 \text{ in} \end{aligned}$$

Y-Displacement is sufficient (exceeds 3 in requirement).

Check: X-Displacement

$$P = 1$$

$$\text{X-Displacement} = (L + a) [ \cos P\Theta + 2e\tau \cos n\Theta ]$$

$$n = 1$$

$$n = 6$$

$$P = n/2 = 3$$

$$L = 12 \text{ in}$$

$$a = 0.094 \text{ in}$$

$$\Theta = 1.625^\circ$$

$$= 12.094 \{ \cos(3 \times 1.625) + 2[ \cos(1 \times 1.625) + \cos(2 \times 1.625) ] \}$$

$$\text{X-Displacement} = 60.38 \text{ in (1533.7 mm)}$$

X-Displacement is sufficient [less than 66 in (1676 mm) requirement]

With six NPS 6 (DN150) flexible couplings and five 12 in (300 mm) cut-groove pipe spools, the misalignment can be accommodated, attaining the required Y-Displacement in the limited X-Displacement.

### Earthquake Design Considerations

Piping systems designed for earthquake prone areas must be analyzed for the movements and loads associated with these events. The grooved system provides many mechanical design features useful in systems subject to earthquake conditions. The inherent flexibility of flexible couplings acts to reduce the transmission of stresses throughout the piping system, and the resilient gasket aids to further reduce

the transmission of vibration. Where flexibility is not desired, rigid couplings can be used.

As a general practice, seismic bracing and piping supports are utilized in piping systems to prevent excessive movement by controlling and directing system movement during a seismic occurrence which would result in overstressing the piping system. In a similar manner, piping supports for a grooved piping system must limit pipe movements such that they do not exceed the recommended allowable deflections and end loads. An excellent reference source, which covers these piping systems, is NFPA 13 Installation of Sprinkler Systems. This standard requires sprinkler systems to be protected to minimize or prevent pipe breakage where subject to earthquakes.

This is accomplished by using two techniques:

- Making the piping flexible where necessary by use of flexible couplings
- Affixing the piping to the building structure for minimum relative movement by using sway bracing

Flexibility is provided by using flexible couplings joining grooved end pipe and swing joints. “Rigid-Type” mechanical couplings, which do not permit movement at the grooved connection, are not considered flexible couplings. Rigid couplings are used in horizontal piping for purposes other than the requirements of earthquake protection. Where large pipe movements are anticipated, seismic swing joints are made up using flexible grooved couplings, pipe nipples and grooved elbows, as shown in Fig. A9.26.

## Product Applications

The use of grooved piping systems has become widespread throughout the world. Applications of these joints come from all commercial, industrial, and municipal areas. Grooved joints are being used from NPS  $\frac{3}{4}$  (DN 20) to NPS 100 (DN 2500). Applications are limited by the pressure, temperature, and system media. Each manufacturer of grooved piping joints has published pressure and temperature ratings of their various style couplings and gaskets. The piping system designer should consult this information to assure proper systems design.

The piping system designer can expect to find joints and gaskets available to accommodate temperatures from  $-30^{\circ}\text{F}$  ( $-34^{\circ}\text{C}$ ) to  $300^{\circ}\text{F}$  ( $140^{\circ}\text{C}$ ) and pressures of up to 1000 psi (6900 kPa) and above. Materials of construction are normally ductile cast iron; however, couplings are also available in stainless steel, aluminum, and other castable materials, as special applications may require. Grooved systems can utilize pipe made of steel, stainless steel, aluminum, PVC, fiberglass, ductile iron and lined ductile iron, and steel, or any metallic or nonmetallic material that can be grooved.

## Benefits of Grooved Piping Systems

Grooved piping systems offer a number of benefits when designed and installed properly.

- Grooved systems provide the designer the choice of flexible and rigid joints. The system can be designed to be flexible, allowing for expansion, contraction, and

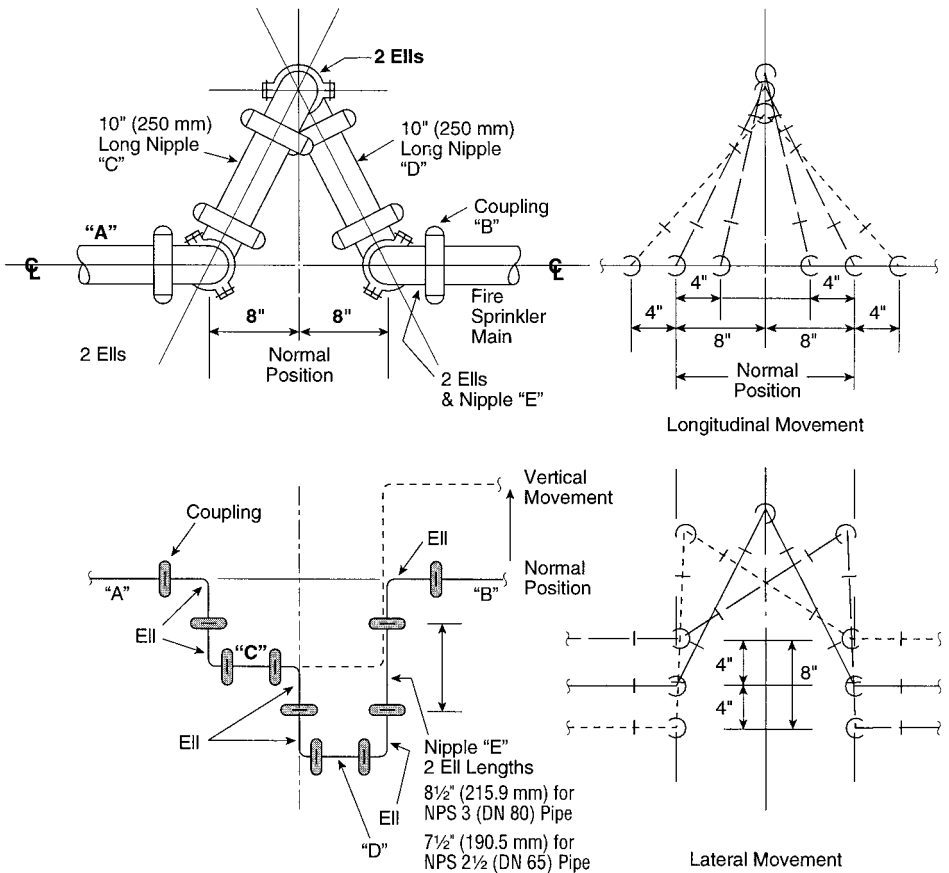


FIGURE A9.26 Seismic swing joint.

structure settlement. Rigid couplings can be included in the system design to provide rigidity to minimize pipe supports.

- Grooved piping systems provide dampening of system vibration. The prevention of the transmission of objectionable vibration induced by piping systems to the building structure has become increasingly crucial, as vibration induced noise is a major complaint by building occupants.
- A properly designed grooved piping system will normally result in a lower installation cost to the facility owner. Piping is prepared rapidly through roll grooving. Installation is accomplished with simple hand tools and standard pipe-fitting techniques. Takeout dimensions for fittings and valves are consistent, thus pipes can be roll grooved at ground level and then lifted into place and coupled into the system. Where the designer chooses, piping can be prefabricated off site. In either case, installation is much more rapid when compared to welding or threading. In most cases, this speed of installation will result in a more cost-effective system.

- Where piping must be removed for replacement or maintenance, the grooved system should be the system of choice. With each joint becoming a *union*, a grooved system is the easiest and quickest piping system to service. Flanges for the same size pipe have many more bolts to remove and replace, and a new gasket is always needed. A grooved coupling is removed more rapidly because it has fewer bolts. The bolts and gasket are readily reusable unless they have been damaged.