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An American National Standard

Standard Guide for Selection, Design, and Installation of Thermoplastic Water-Pressure Piping Systems[1]

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1. Scope*

1.1 This guide is intended for use in the selection, design, and installation of thermoplastic water-pressure piping systems. For specific projects, a thorough review of this guide is recommended for the purpose of selecting specific materials, methods of joining, system design factor, and any special procedures deemed necessary to assure a satisfactory system.

NOTE 1—Comprehensive information on the selection, design, joining, system design factors, installation and special products and piping systems for pressurized water and other specialized applications is available in the PPI Handbook of Polyethylene Pipe and from other domestic and International sources such as PE compound and product manufacturers and trade associations.

1.2 It is recommended that governing codes and project specifications be consulted prior to the use of this guide. Nothing in this guide should be construed as recommending practices or systems at variance with governing codes and project specifications.

1.3 The pipe, fittings, and joining materials shall meet the requirements of one or more of the following component product standards listed in 1.3.1 through 1.3.4 to the extent applicable. In 1.3.1, 1.3.2, and 1.3.4 the pipe standards followed by (*a*) are outside diameter-controlled pipes.

1.3.1 *For poly(vinyl chloride) (PVC) plastic piping components:*

Title of Specification	ASTM Designation
Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120 (*a*)	D1785
Poly(Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR) (*a*)	D2241
Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	D2464
Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40	D2466
Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	D2467
Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings	D2564
Bell-End Poly(Vinyl Chloride) (PVC) Pipe (*a*)	D2672
Poly(Vinyl Chloride) (PVC) Plastic Tubing (*a*)	D2740
Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Line Couplings	D3036
Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals	D3139
Elastomeric Seals (Gaskets) for Joining Plastic Pipe	F477
PVC and ABS Injected Solvent Cemented Plastic Pipe Joints	F545

1.3.2 *For Chlorinated Poly(Vinyl chloride) (CPVC) plastic piping components:*

Title of Specification	ASTM Designation
Chlorinated Poly(Vinyl chloride) (CPVC) Plastic Pipe, Schedules 40 and 80 (a)	F441/F441M
Chlorinated Poly(Vinyl chloride) (CPVC) Plastic Pipe Fittings, Schedule 80	F439
Solvent Cements for Chlorinated Poly(Vinyl chloride) (CPVC) Plastic Pipe and Fittings	F493

1.3.3 *Standards for polyethylene (PE) plastic piping:*

ASTM Standard	Designation

[1] This guide is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water.

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

Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter	D2239
Standard Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe	D2609
Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing	D2683
Standard Specification for Polyethylene (PE) Plastic Tubing	D2737
Standard Practice for Underground Installation of Thermoplastic Pressure Piping	D2774
Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing	D3261
Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter	D3035
Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter	F714
Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing	F1055
Standard Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings	F1056
Standard Practice for Electrofusion Joining Polyolefin Pipe and Fittings	F1290
Standard Specification for Deformed Polyethylene (PE) Liner	F1533
Standard Guide for Construction Procedures for Buried Plastic Pipe	F1668
Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure	F2164
Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE)	F2206
Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings	F2620
Standard Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method	F2634
Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)	F2786
Standard Specification for Lap-Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes ¾ in. to 65 in.	F2880
Standard Practice for Specimens and Testing Conditions for Testing Polyethylene (PE) Pipe Butt Fusions Using Tensile and Hydrostatic Test Methods	F2928
Standard Specification for Billets made by Winding Molten Extruded Stress-Rated High Density Polyethylene (HDPE)	F3034
Standard Specification for Metric Outside Diameter Polyethylene (PE) Plastic Pipe (DR-PN)	F3123
Standard Practice for Data Recording the Procedure used to Produce Heat Butt Fusion Joints in Plastic Piping Systems or Fittings	F3124
Standard Practice for Guided Side Bend Evaluation of Polyethylene Pipe Butt Fusion Joint	F3183
Standard Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethylene (PE) and Polyamide (PA) Pipe and Fittings	F3190
AWWA Standards	
Standards Polyethylene (PE) Pressure Pipe and Tubing, 1/2 in. (13 mm) Through 3 in. (76 mm), for Water Service	C901
Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 65 In. (100 mm Through 1,650 mm), for Waterworks	C906
CSA Standards	
Standards Definitions, general requirements, and methods of testing for thermoplastic pressure piping	B137.0
Polyethylene (PE) pipe, tubing, and fittings for cold water pressure services	B137.1

1.3.4 *For poly(vinyl chloride) (PVC) Plastic Piping Components Issued By the American Water Works Association:*

C900 Poly(Vinyl Chloride) (PVC) Pressure Pipe, 4-inch through 12-inch, for Water (a)	

1.3.5 Pipes with wall thicknesses less than 1.50 mm (0.06 in.) are not recommended.

1.4 *Other Joining Devices*—Joining devices other than those covered by the listed standards may be selected by the user on the basis of his own engineering evaluation and service experience.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D638 Test Method for Tensile Properties of Plastics
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
D2239 Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
D2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
D2464 Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
D2467 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
D2609 Specification for Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
D2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement
D2683 Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
D2737 Specification for Polyethylene (PE) Plastic Tubing
D2740 Specification for Poly(Vinyl Chloride) (PVC) Plastic Tubing (Withdrawn 1989)[3]
D2774 Practice for Underground Installation of Thermoplastic Pressure Piping
D2855 Practice for the Two-Step (Primer and Solvent Cement) Method of Joining Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Pipe and Piping Components with Tapered Sockets
D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
D3036 Specification for Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Line Couplings (Withdrawn 1985)[3]
D3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
D3261 Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing
F412 Terminology Relating to Plastic Piping Systems
F439 Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
F441/F441M Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
F477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
F493 Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
F545 Specification for PVC and ABS Injected Solvent Cemented Plastic Pipe Joints (Withdrawn 2001)[3]
F714 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter
F1055 Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene and Crosslinked Polyethylene (PEX) Pipe and Tubing
F1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings
F1290 Practice for Electrofusion Joining Polyolefin Pipe and Fittings
F1498 Specification for Taper Pipe Threads 60° for Thermoplastic Pipe and Fittings
F1533 Specification for Deformed Polyethylene (PE) Liner (Withdrawn 2018)[3]
F1668 Guide for Construction Procedures for Buried Plastic Pipe

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

F2164 Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure
F2206 Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE)
F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
F2634 Test Method for Laboratory Testing of Polyethylene (PE) Butt Fusion Joints using Tensile-Impact Method
F2786 Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Gaseous Testing Media Under Pressure (Pneumatic Leak Testing)
F2880 Specification for Lap-Joint Type Flange Adapters for Polyethylene Pressure Pipe in Nominal Pipe Sizes ¾ in. to 65 in.
F2928 Practice for Specimens and Testing Conditions for Testing Polyethylene (PE) Pipe Butt Fusions Using Tensile and Hydrostatic Test Methods
F3034 Specification for Billets made by Winding Molten Extruded Stress-Rated High Density Polyethylene (HDPE)
F3123 Specification for Metric Outside Diameter Polyethylene (PE) Plastic Pipe (DR-PN)
F3124 Practice for Data Recording the Procedure used to Produce Heat Butt Fusion Joints in Plastic Piping Systems or Fittings
F3183 Practice for Guided Side Bend Evaluation of Polyethylene Pipe Butt Fusion Joint
F3190 Practice for Heat Fusion Equipment (HFE) Operator Qualification on Polyethylene (PE) and Polyamide (PA) Pipe and Fittings

2.2 *American Water Works Association Standards:*[4]:
C651 Disinfecting Water Mains
C900 Poly(Vinyl Chloride) (PVC) Pressure Pipe, 4-Inch Through 12-Inch, for Water
C901 Polyethylene (PE) Pressure Pipe and Tubing, ½ in. (13 mm) Through 3 in. (76 mm), for Water Service
C906 Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 65 In. (100 mm Through 1,650 mm), for Waterworks

2.3 *Plastics Pipe Institute Report:*[5]
PPI-TR 4 HDB/SDB/PDB/MRS Listed Materials
PPI-TR 9 Recommended Design Factors and Design Coefficients for Thermoplastic Pressure Pipe
PPI Handbook of Polyethylene Pipe

2.4 *NSF Standards:*
NSF/ANSI Standard No. 14 for Plastic Piping Components and Related Materials[6]
NSF/ANSI Standard No. 61 for Drinking Water Systems Components—Health Effects[6]

2.5 *Uni-Bell PVC Pipe Association*[7]
Uni-Bell Handbook of PVC Pipe , Chapter VIII, Table 8.7

2.6 *CSA Standards:*[8]
B137.0 Definitions, general requirements, and methods of testing for thermoplastic pressure piping
B137.1 Polyethylene (PE) pipe, tubing, and fittings for cold water pressure services

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600 and Symbols unless otherwise specified.

3.2 *relation between standard dimension ratio, hydrostatic design stress, and pressure rating*—the following expression is used in this guide to relate standard dimension ratio, hydrostatic design stress, and pressure rating:

$$2S/P = R - 1 \text{ or } 2\,S/P = (D/t) - 1 \quad (1)$$

where:

S = hydrostatic design stress, MPa (or psi),
P = pressure rating, MPa (or psi),
D = average outside diameter, mm (or in.),
t = minimum wall thickness, mm (or in.), and
R = standard thermoplastic pipe dimension ratio also known as SDR or SIDR, whichever is applicable.
d = average inside diameter, mm (or in.)—substitute d for D in equations and change minus sign to plus.

4. Significance and Use

4.1 The requirements of this specification are intended to provide information to select, design and install thermoplastic, water-pressure piping systems. Materials covered in this specification are Poly(Vinyl Chloride) (PVC), Chlorinated Poly(Vinyl Chloride) (CPVC) and Polyethylene (PE) plastic pipe fittings.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.
[5] Available from Plastics Pipe Institute (PPI), 105 Decker Court, Suite 825, Irving, TX 75062, http://www.plasticpipe.org.
[6] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48113-0140, http://www.nsf.org.
[7] Available from UNI-BELL PVC Pipe Association, 711 LBJ Freeway, Suite 1000, Dallas, TX 75234, http://www.uni-bell.org
[8] Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON M9W 1R3, Canada, http://www.csagroup.org.

5. System Pressure Design

5.1 The maximum pressure ratings in Tables 1-4 make allowance for normal operating conditions, reasonable installation procedures, good handling, good joining workmanship, operating temperatures below 27°C (80°F), and surges likely to be encountered at water flow velocities up to 5 ft/s (1.5 m/s). For operating conditions at or above 27°C(80°F), temperature ~~correction~~derating factors for stress and modulus of elasticity for PVC are listed in Table 6 and CPVC in Table 9. Tubing Sizes with pressure ratings less than 160 psi are listed in the tables. (Note 1). Pressure capabilities for PE piping products are addressed in the PE standards listed in 1.3.3.

NOTE 2—Pressure capabilities for PE piping products vary significantly depending on the PE material (such as PE2406, PE2708, PE3408, PE4710), the long-term stress rating system (HDB or MRS), and whether the standard uses pressure class (PC), pressure rating (PR), or nominal pressure (PN), and operational conditions such as internal and external environment, temperature, and chemical compatibility. Refer to these standards and to the comprehensive design information sources identified in Note 1 for PE product pressure capabilities for water and other special design applications.

NOTE 3—See Marking section and appendix of applicable pipe specification for marking pipe with pressure ratings lower than the maximum values given in Tables 1-4.

5.2 The maximum safe water velocity in a thermoplastic piping system depends on the specific details of the system and the operating conditions. In general, 5 ft/s (1.5 m/s) is considered to be safe. Higher velocities may be used in cases where the operating conditions can be controlled or a higher design factor than 2.0 is used, or both. The total pressure in the system at any time (operating plus surge or water hammer) due to surges or water hammers shall not exceed 150 % of the pressure rating of the system.

5.3 The maximum pressure ratings in Tables 1-4 make some allowance for surge or water hammer. However, when excessive surges or water hammer are likely to be encountered, extra allowance shall be made or protective devices installed. The surge or water hammer pressure resulting from rapid flow stoppage shall be calculated by means of the following equation:

$$p = V\sqrt{\frac{4{,}033}{\left(1+\frac{300\,000d}{Et}\right)}} \tag{2}$$

where:

p = peak water surge pressure, psi,
~~E = modulus of elasticity of the pipe material, psi, (Temperature Correction Factors, Table 6 PVC or Table 9 CPVC)~~
$\underline{E}$ = modulus of elasticity of the pipe material, psi, (Temperature Derating Factors, Table 6 PVC or Table 9 CPVC)
d = inside diameter of the pipe, inclusive, in.,
t = wall thickness, in., and
V = water velocity, ft/s.

5.4 The pressure rating of properly solvent-cemented joints made in accordance with 8.2.1 is the same as the pipe joined after reasonable time for cure of the joint. The pressure rating of well-made heat-fused joints made in accordance with 8.2.1 is the same as the pipe joined, after the material in the joint has cooled to the pipe temperature.

TABLE 1 Maximum Water Pressure Ratings at 23°C (73°F) for Schedule 40 PVC Plastic Pipe (Specification D1785)

Nominal Pipe Size, in.	PVC 1120 PVC 1220 PVC 2120	Pressure Rating, psi[A]		
		PVC 2116	PVC 2110	PVC 2112
½	600	480	300	370
¾	480	390	240	300
1	450	360	220	280
1¼	370	290	180	230
1½	330	260	170	210
2	280	220	140	170
2½	300	240	150	190
3	260	210	130	160
3½	240	190	120	150
4	220	180	110	140
5	190	160	100	120
6	180	140	90	110
8	160	120	80	100
10	140	110	NPR[B]	90
12	130	110	NPR	80

[A] These maximum pressure ratings apply only to unthreaded pipe. The industry recommends against the use of threaded PVC plastic pipe in Schedule 40 wall thickness in nominal pipe sizes 6 in. and smaller. See applicable ASTM standard for code designation, for example, PVC 1120. Pipe with pressure ratings less than 0.34 MPa (50 psi) is not recommended for use in pressure systems.
[B] NPR = not pressure rated.

TABLE 2 Maximum Water Pressure Ratings at 23°C (73°F) for Schedule 80 PVC Plastic Pipe (Specification D1785)

Nominal Pipe Size in.	Pressure Rating, psi[A]							
	PVC 1120, PVC 1220, and PVC 2120		PVC 2116		PVC 2110		PVC 2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
¼	850	420	680	340	420	210	530	260
¾	690	340	550	280	340	170	430	210
1	630	320	500	250	320	160	390	200
1¼	520	260	420	210	260	130	320	160
1½	470	240	380	190	240	120	290	150
2	400	200	320	160	200	100	250	130
2½	420	210	340	170	210	110	260	130
3	370	190	300	150	190	90	230	120
3½	350	170	280	140	170	90	220	110
4	320	160	260	130	160	80	200	100
5	290	140	230	120	140	NPR[B]	180	90
6	280	140	220	110	140	NPR	170	90
8	250	120	200	100	120	NPR	150	80
10	230	120	190	90	120	NPR	150	NPR
12	230	110	180	90	110	NPR	140	NPR

[A] See applicable ASTM standard for code designation, for example, PVC 1120. Pressure ratings are lower at elevated temperatures. Pipe with pressure ratings less than 0.34 MPa (50 psi) is not recommended for use in pressure systems.
[B] NPR, not pressure rated.

TABLE 3 Maximum Water Pressure Ratings at 23°C (73°F) for Schedule 120 PVC Plastic Pipe (Specification D1785)

Nominal Pipe Size,	Pressure Rating, psi[A]							
	PVC 1120, PVC 1220, PVC 2120		PVC 2116		PVC 2110		PVC 2112	
	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded	Unthreaded	Threaded
½	1010	510	810	410	510	250	630	320
¾	770	390	620	310	390	190	480	240
1	720	360	570	290	360	180	450	220
1¼	600	300	480	240	300	150	370	190
1½	540	270	430	210	270	130	340	170
2	470	240	380	190	240	120	290	150
2½	470	230	370	190	230	120	290	150
3	440	220	360	180	220	110	280	140
3½	380	190	310	150	190	100	240	120
4	430	220	340	170	220	110	270	130
5	400	200	320	160	200	100	250	120
6	370	190	300	150	190	90	230	120
8	380	180	290	140	180	90	230	110
10	370	180	290	140	180	90	230	110
12	340	170	270	140	170	80	210	110

[A] See applicable ASTM standard for code designation, for example, PVC 1120. Pressure ratings are lower at elevated temperatures.

5.5 PVC and CPVC threaded pipe shall be pressure rated at 50 % of that of nonthreaded pipe (see Specification F1498). Pipe with wall thicknesses less than those of Schedule 80 pipe shall not be threaded. PE pipe shall not be threaded.

5.6 Joints and the allied fittings made by means other than those covered above shall be pressure-rated by engineering evaluations and service experience by either the design engineer or user, or both. The recommendations of the manufacturers shall also be considered (see Specification D3139).

5.7 Allowance shall be made for operating conditions in which the water temperature will be above 27°C (80°F) under normal service conditions. Elevated temperature ~~correction~~derating factors, design stresses and modulus of elasticity for PVC are listed in Table 6 and CPVC in Table 9. Hydrostatic design stresses for thermoplastic pipe materials are given in PPI-TR 4, Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Pipe and Fittings Compounds, a report issued at intervals by the Plastics Pipe Institute.

5.8 In piping system design the selection of a design or safety factor depends on the operating conditions that will be encountered. It may be necessary to use pressure ratings lower than the pressure ratings listed in Tables 1-4 when the following are likely to be encountered: (*1*) surges or water hammer, (*2*) cyclic pressure oscillations, (*3*) air pockets, (*4*) quick-closing valves, (*5*) pumps with more capacity than the lines can deliver, (*6*) flow velocities more than 5 ft/s *(7)* operating conditions at or above 27 °C(80 °F), and (*8*) similar factors or combinations of (1) through (7). This will result in using pipe and fittings with heavier