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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 use outside buildings. For specific projects, a thorough review of these guides 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.

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 to the extent applicable. Those pipe standards followed by (*a*) are outside diameter-controlled pipes. Those followed by (*b*) are inside 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*)	D 1785
Poly(Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR) (*a*)	D 2241
Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	D 2464
Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40	D 2466
Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80	D 2467
Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings	D 2564
Bell-End Poly(Vinyl Chloride) (PVC) Pipe (*a*)	D 2672
Poly(Vinyl Chloride) (PVC) Plastic Tubing (*a*)	D 2740
Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Line Couplings	D 3036
Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals	D 3139
Elastomeric Seals (Gaskets) for Joining Plastic Pipe	F 477
PVC and ABS Injected Solvent Cemented Plastic Pipe Joints (Note 1)	F 545

NOTE 1—Only PVC cements should be used to make joints with PVC pipe and PVC fittings. Only ABS cements should be used to make joints with ABS pipe and ABS fittings. Joining PVC pipe to ABS fittings and vice versa is not recommended for pressure piping systems.

1.3.2 *For polyethylene (PE) plastic piping components*:

Title of Specification	ASTM Designation
Polyethylene (PE) Plastic Pipe, Schedule 40 (*b*)	D 2104
Polyethylene (PE) Plastic Pipe, (SDR-PR) (*b*)	D 2239
Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter (*a*)	D 2447
Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe	D 2609
Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe (*a*)	D 2683
Polyethylene (PE) Plastic Tubing (*a*)	D 2737
Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter (*a*)	D 3035
Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing	D 3261

1.3.3 *For polybutylene (PB) plastic piping components*:

Title of Specification	ASTM Designation
Polybutylene (PB) Plastic Pipe (SDR-PR) (*b*)	D 2662
Polybutylene (PB) Plastic Tubing (*a*)	D 2666
Polybutylene (PB) Plastic Pipe (SDR-PR) Based on Outside Diameter (*a*)	D 3000

1.3.4 *For acrylonitrile-butadiene-styrene (ABS) plastic piping components*:

Title of Specification	ASTM Designation
Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80 (*a*)	D 1527
Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings	D 2235
Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR) (*a*)	D 2282
Threaded Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80	D 2465
Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40	D 2468
Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80	D 2469
PVC and ABS Injected Solvent Cemented Plastic Pipe Joints (Note 1)	F 545

1.3.5 *For poly(vinyl chloride) (PVC) and polyethylene (PE) Plastic Piping Components Issued By the American Water Works Association*:

C900-75 Poly(Vinyl Chloride) (PVC) Pressure Pipe, 4-inch through 12-inch, for Water (*a*)
C901-78 Polyethylene (PE) Pressure Pipe, Tubing and Fittings, ½-inch through 3-inch, for Water

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

[1] This guide is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.61 on Water Systems.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 1527 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[3]

D 1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120[2]

D 2104 Specification for Polyethylene (PE) Plastic Pipe, Schedule 40[2]

D 2235 Specification for Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings[2]

D 2239 Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter[2]

D 2241 Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)[2]

D 2282 Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR)[2]

D 2447 Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80 Based on Outside Diameter[2]

D 2464 Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80[2]

D 2466 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40[2]

D 2467 Specification for Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80[2]

D 2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems[2]

D 2662 Specification for Polybutylene (PB) Plastic Pipe (SDR-PR)[2]

D 2666 Specification for Polybutylene (PB) Plastic Tubing[2]

D 2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement[2]

D 2737 Specification for Polyethylene (PE) Plastic Tubing[2]

D 2740 Specification for Poly(Vinyl Chloride) (PVC) Plastic Tubing[2]

D 2749 Symbols for Dimensions of Plastic Pipe Fittings[2]

D 2774 Practice for Underground Installation of Thermoplastic Pressure Piping[2]

D 2855 Practice for Making Solvent-Cemented Joints With Poly(Vinyl Chloride) (PVC) Pipe and Fittings[2]

D 3000 Specification for Polybutylene (PB) Plastic Pipe (SDR-PR) Based on Outside Diameter[2]

D 3035 Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter[2]

D 3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals[2]

F 412 Terminology Relating to Plastic Piping Systems[2]

F 477 Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe[2]

F 545 Specification for PVC and ABS Injected Solvent Cemented Plastic Pipe Joints[2]

2.2 *American Water Works Association Standards:*

C 601-68 Disinfecting Water Mains[4]

C 900-75 Poly(Vinyl Chloride) (PVC) Pressure Pipe, 4-Inch Through 12-Inch, for Water[4]

C 901-78 Polyethylene (PE) Pressure Pipe, Tubing and Fittings, ½-Inch Through 3-Inch, for Water[4]

2.3 *Plastics Pipe Institute Report:*

PPI-TR 4 Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Pipe and Fittings Compounds[5]

2.4 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials[6]

Standard No. 61 for Drinking Water Systems Components—Health Effects[6]

3. Terminology

3.1 Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600 and Symbols D 2749, unless otherwise specified.

3.2 *dimension ratio (DR)*—the average specified diameter of the pipe in millimetres or inches divided by the minimum specified wall thickness (*t*) in millimetres or inches. If pipe is outside diameter (OD) controlled, use OD requirements; if the pipe is inside diameter (ID) controlled, use ID requirements. If the wall thickness calculated in this way is less than 1.50 mm (0.060 in.) it should be arbitrarily increased to 1.50 mm. The DR values should be rounded to the nearest 0.5.

3.3 *standard thermoplastic pipe dimension ratio (SDR and SIDR)*—a selected series of numbers in which the dimension ratios are constants for all sizes of pipe for each standard dimension ratio and which are the ANSI Preferred Number Series 10 modified by +1 or −1. If the outside diameter (OD) is used, the modifier is +1 and the designation is SDR. If the inside diameter (ID) is used, the modifier is −1 and the designation is SIDR. They are calculated by dividing the average diameter of the pipe in millimetres or in inches by the minimum wall thickness in millimetres or in inches. If pipe is OD controlled, use OD requirement; if pipe is ID controlled, use ID requirement. If the wall thickness calculated by this formula is less than 1.50 mm (0.060 in.), it should be arbitrarily increased to 1.50 mm.

3.4 *long-term hydrostatic strength (LTHS)*—the estimated tensile stress in the wall of the pipe in the circumferential orientation that when applied continuously will cause failure of the pipe at 100 000 h.

[2] *Annual Book of ASTM Standards*, Vol 08.04.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] Available from American Water Works Association, 6666 W. Quincy Ave., Denver, CO 80235.

[5] Available from Plastics Pipe Institute, 355 Lexington Ave., New York, NY 10017.

[6] Available from NSF International, P.O. Box 130140, Ann Arbor, MI 48113-0140.

3.5 *hydrostatic design basis (HDB)*—one of a series of established stress values for a compound. See applicable product standard.

3.6 *service (design) factor*—a number less than 1.00 (which takes into consideration all the variables and degree of safety involved in a thermoplastic pressure piping installation) which is multiplied by the HDB to give the HDS.

3.7 *hydrostatic design stress (HDS)*—the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure, that can be applied continuously with a high degree of certainty that failure of the pipe will not occur. The HDS is obtained by multiplying the HDB by the service (design) factor.

3.8 *pressure rating (PR)*—the estimated maximum pressure that water in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur. (See 3.9).

3.9 *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:

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

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. (See 2.3.)
d = average inside diameter, mm (or in.)—substitute d for D in equations and change minus sign to plus.

3.10 *standard thermoplastic pipe materials designation code*—The pipe materials designation code consists of the abbreviation for the type of plastic, followed by four digits indicating the specific compound and the HDB divided by 200. When the HDB divided by 200 is less than two digits, a cipher is used before the number. A complete material code consists of two or three letters and four figures.

4. Sizes

4.1 This guide covers nominal pipe sized ½, ¾, 1, 1¼, 1½, 2, 2½, 3, 3½, 4, 5, 6, 8, 10, and 12 in. and nominal tubing sized ½, ⅝, ¾, 1, 1¼, 1½, and 2 in.

5. System Pressure Design

5.1 The maximum pressure ratings in Tables 1-14 make allowance for normal operating conditions, reasonable installation procedures, good handling, good jointing 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). The normal pressure rating for the tubing covered in the referenced specifications is 160 psi (Note 2).

NOTE 2—See Marking section and appendix of applicable pipe specification for marking pipe with pressure ratings lower than the maximum values given in Tables 1-14.

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.

TABLE 1 Maximum Water Pressure Ratings at 23°C (73°F) for Schedule 40 PVC Plastic Pipe (Specification D 1785)

Nominal Pipe Size, in.	PVC 1120 PVC 1220	Pressure Rating, psi[A]		
		PVC 2116	PVC 2110	PVC 2112
½	600	450	300	370
¾	480	390	240	300
1	450	260	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.

5.3 The maximum pressure ratings in Tables 1-14 make some allowance for surge and water hammer. However, when excessive surges and water hammer are likely to be encountered, extra allowance should be made or protective devices installed. The surge or water hammer resulting from rapid flow stoppage may be calculated by means of the following equation:

$$p = V\sqrt{\frac{3960}{\left(\frac{1 + 300\,000d}{Et}\right)}} \qquad ()$$

where:

p = peak water surge pressure, psi,
E = modulus of elasticity of the pipe material, psi,
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 is the same as the pipe joined after reasonable time for cure of the joint. The pressure rating of well-made heat-fused joints is the same as the pipe joined, after the material in the joint has cooled to the pipe temperature. The pressure rating of well-made threaded and insert fitting joints is the same as that of the pipe joined (5.5).

5.5 PVC and ABS threaded pipe shall be pressure rated at 50 % of that of nonthreaded pipe. Pipe with wall thicknesses less than those of Schedule 80 pipe shall not be threaded. PE and PB pipe shall not be threaded.

5.6 Joints and the allied fittings made by means other than

TABLE 2 Maximum Water Pressure Ratings at 23°C (73°F) for Schedule 80 PVC Plastic Pipe (Specification D 1785)

Nominal Pipe Size in.	Pressure Rating, psi[A]							
	PVC 1120 and PVC 1220		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. 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 D 1785)

Nominal Pipe Size, in.	Pressure Rating, psi[A]							
	PVC 1120 and PVC 1220		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.

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 should also be considered (See Specification D 3139.)

5.7 Allowance shall be made for operating conditions in which the water will be above 27°C (80°F) under normal service conditions. Hydrostatic design stresses for thermoplastic pipe materials are given in PPI-TR4, 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 1-14 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, and (*7*) similar factors or combinations of (1) through (6). This will result in using pipe and fittings with heavier walls. Consult manufacturers for specific recommendations. Operating temperatures above 23°C (73°F) will make the pipe more flexible and will lower both the short-term and long-term hydrostatic strengths; for a temperature of 38°C (100°F) a pressure rating of 80 % of the 23°C (73°F) values has been found to be adequate for most thermoplastic piping materials covered in current ASTM standards. The designer of the piping system shall use any additional design (safety) factors that are deemed necessary to cover any unusual or special conditions that may be encountered on a specific job. When long-term factors are translated to short-term pressure loadings, the corresponding short-term factors are 2 to 4 times greater, depending on the kind and type of plastic; for example, a 2.0 long-term factor for PVC 1120 gives a 4.0 short-term factor; a 2.0 long-term factor for PE 3306 gives a 5.0 short-term factor.

5.9 Pressure surges may affect adversely the long-term performance of system components and shall be kept to the absolute minimum practical. Where surges are anticipated due to the action of pressure regulating valves, pumps, and other