Liquid Process Piping - *Part 3: Miscellaneous Piping Design*

Course No: M02-037
Credit: 2 PDH

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This course was adapted from the United States Army of Corps of Engineers (USACE), Publication Number EM 1110-1-4008, Chapters 5, 6 and 7 of the "Liquid Process Piping" engineering manual, which is in the public domain.

Chapter 5
Plastic Piping Systems

5-1. General

Thermoplastic piping systems, commonly referred to as plastic piping systems, are composed of various additives to a base resin or composition. Thermoplastics are characterized by their ability to be softened and reshaped repeatedly by the application of heat. Table 5-1 lists the chemical names and abbreviations for a number of thermoplastic piping materials. Because of the slightly different formulations, properties of plastic piping materials (for example, polyvinyl chloride - PVC) may vary from manufacturer to manufacturer[1]. Therefore, designs and specifications need to address specific material requirements on a type or grade basis, which may have to be investigated and confirmed with manufacturers.

a. Corrosion

Unlike metallic piping, thermoplastic materials do not display corrosion rates[2]. That is, the corrosion of thermoplastic materials is dependent totally on the material™s chemical resistance rather than an oxide layer, so the material is either completely resistant to a chemical or it deteriorates. This deterioration may be either rapid or slow. Plastic piping system corrosion is indicated by material softening, discoloration, charring, embrittlement, stress cracking (also referred to as crazing), blistering, swelling, dissolving, and other effects. Corrosion of plastics occurs by the following mechanisms:

- absorption;
- solvation;
- chemical reactions such as oxidation (affects chemical bonds), hydrolysis (affects ester linkages), radiation, dehydration, alkylation, reduction, and halogenation (chlorination);

Table 5-1
Abbreviations for Thermoplastic Materials

Abbreviation	Chemical Name
ABS	Acrylonitrile-Butadiene-Styrene
CPVC	Chlorinated Poly(Vinyl Chloride)
ECTFE	Ethylene-Chlorotrifluoroethylene
ETFE	Ethylene-Tetrafluoroethylene
FEP	Perfluoro(Ethylene-Propylene) Copolymer
PE	Polyethylene
PFA	Perfluoro(Alkoxyalkane) Copolymer
PP	Polypropylene
PTFE	Polytetrafluoroethylene
PVC	Poly(Vinyl Chloride)
PVDC	Poly(Vinylidene Chloride)
PVDF	Poly(Vinylidene Fluoride)

Sources: ASTM D 1600.
ASME B31.3 (Used by permission of ASME).

[1] Schweitzer, Corrosion-Resistant Piping Systems, p. 17.
[2] Ibid., p. 18.

- thermal degradation which may result in either depolymerization or plasticization;
- environmental-stress cracking (ESC) which is essentially the same as stress-corrosion cracking in metals;
- UV degradation; and - combinations of the above mechanisms.

For plastic material compatibility with various chemicals, see Appendix B. If reinforcing is used as part of the piping system, the reinforcement is also a material that is resistant to the fluid being transported. Material selection and compatibility review should consider the type and concentration of chemicals in the liquid, liquid temperature, duration of contact, total stress of the piping system, and the contact surface quality of the piping system. See Appendix A, paragraph A-4 - Other Sources of Information, for additional sources of corrosion data.

b. Operating Pressures and Temperatures

The determination of maximum steady state design pressure and temperature is similar to that described for metallic piping systems. However, a key issue that must be addressed relative to plastic piping systems is the impact of both minimum and maximum temperature limits of the materials of construction.

c. Sizing

The sizing for plastic piping systems is performed consistent with the procedures of Paragraph 3-3. However, one of the basic principles of designing and specifying thermoplastic piping systems for liquid process piping pressure applications is that the short and long term strength of thermoplastic pipe decreases as the temperature of the pipe material increases.

Thermoplastic pipe is pressure rated by using the International Standards Organization (ISO) rating equation using the Hydrostatic Design Basis (HDB) as contained in ASTM standards and Design Factors (DFs). The use of DFs is based on the specific material being used and specific application requirements such as temperature and pressure surges. The following is the basic equation for internal hydraulic pressure rating of thermoplastic piping:

$$P_R = 2(HDS)(t/D_m)$$

where:

P_R = pipe pressure rating, MPa (psi)
t = minimum wall thickness, mm (in)
D_m = mean diameter, mm (in)
HDS = (HDB)(DF)

The minimum pipe wall thickness can also be determined using the requirements of ASME B31.3 as described in Paragraph 3-3b. This procedure is not directly applicable to thermoplastic pipe fittings, particularly in cyclic pressure operations due to material fatigue. Therefore, it should not be assumed that thermoplastic fittings labeled with a pipe schedule designation will have the same pressure rating as pipe of the same designation. A good example of this is contained in ASTM D 2466 and D 2467 which specify pressure ratings for PVC schedule 40 and 80 fittings. These ratings are significantly lower than the rating for PVC pipe of the same designation. For thermoplastic pipe fittings that do not have published pressure ratings information similar to ASTM standards, the fitting manufacturer shall be consulted for fitting pressure rating recommendations.

d. Joining

Common methods for the joining of thermoplastic pipe for liquid process waste treatment and storage systems are contained in Table 5-2. In selecting a joining method for liquid process piping systems, the advantages and disadvantages of each method are evaluated and the manner by which the joining is accomplished for each liquid service is specified. Recommended procedures and specification for these joining methods are found in codes, standards and manufacturer procedures for joining thermoplastic pipe. Table 5-3 lists applicable references for joining thermoplastic pipe.

e. Thermal Expansion

When designing a piping system where thermal expansion of the piping is restrained at supports, anchors, equipment nozzles and penetrations, large thermal stresses and loads must be analyzed and accounted for within the design. The system PFDs and P&IDs are analyzed to determine the thermal conditions or modes to

Table 5-2
Thermoplastic Joining Methods

Joining Method	ABS	PVC	CPVC	PE	PP	PVDF
Solvent Cementing	X	X	X			
Heat Fusion				X	X	X
Threading*	X	X	X	X	X	X
Flanged Connectors**	X	X	X	X	X	X
Grooved Joints***	X	X	X	X	X	X
Mechanical Compression****	X	X	X	X	X	X
Elastomeric seal	X	X	X	X	X	X
Flaring				X		

Notes:
X = applicable method
* Threading requires a minimum pipe wall thickness (Schedule 80).
** Flanged adapters are fastened to pipe by heat fusion, solvent cementing, or threading.
*** Grooving requires a minimum pipe wall thickness (material dependent).
**** Internal stiffeners are required.
Source: Compiled by SAIC, 1998.

Table 5-3
Thermoplastic Joining Standards

Reference	Key Aspects of Reference
ASTM D 2657	Recommended practice for heat fusion.
ASTM D 2855	Standard practice for solvent cementing PVC pipe and fittings.
ASTM D 3139	Elastomeric gasketed connections for pressure applications.
ASTM F 1290	Recommended practice for electrofusion.

Source: Compiled by SAIC, 1998.

which the piping system will be subjected during operation. Based on this analysis, the design and material specification requirements from an applicable standard or design reference are followed in the design.

A basic approach to assess the need for additional thermal stress analysis for piping systems includes identifying operating conditions that will expose the piping to the most severe thermal loading conditions. Once these conditions have been established, a free or unrestrained thermal analysis of the piping can be performed to establish location, sizing, and arrangement of expansion loops, or expansion joints (generally, bellows or slip types).

If the application requires the use of a bellow or piston joint, the manufacturer of the joint shall be consulted to determine design and installation requirements.

When expansion loops are used, the effects of bending on the fittings used to install the expansion loop are considered. Installation of the loop should be performed in consultation with the fitting manufacturer to ensure that specified fittings are capable of withstanding the anticipated loading conditions, constant and cyclic, at the design temperatures of the system. Terminal loadings on equipment determined from this analysis can then be used to assess the equipment capabilities for withstanding the loading from the piping system. It should also be noted that this termination analysis at equipment and anchor terminations should consider the movement and stress impacts of the cold condition.

o rigid or restraining supports or connections should be made within the developed length of an expansion loop, offset, bend or brand. Concentrated loads such as valves should not be installed in the developed length. Piping support guides should restrict lateral movement and should direct axial movement into the compensating configurations. Calculated support guide spacing distances for offsets and bends should not exceed recommended hanging support spacing for the maximum temperature. If that occurs, distance between anchors will have to be decreased until the support guide spacing distance equals or is less than the recommended support spacing. Use of the rule of thumb method or calculated method is not recommended for threaded Schedule 80 connections. Properly cemented socket cement joints should be utilized.

Expansion loops, offsets and bends should be installed as nearly as possible at the mid point between anchors.

Values for expansion joints, offsets, bends and branches can be obtained by calculating the developed length from the following equation.

$$L = n_1 \left(\frac{3\ E\ D_o\ e}{S} \right)^{1/2}$$

where:

= developed length, m (ft)
n_1 = conversion factor, 10^{-3} m/mm (1/12 ft/in)
E = tensile modulus of elasticity, MPa (psi)
D_o = pipe outer diameter, mm (in)
e = elongation due to temperature rise, mm (in)
S = maximum allowable stress, MPa (psi)

In determining the elongation due to temperature rise information from the manufacturer on the material to be used should be consulted. For example, the coefficient of expansion is 6.3 x 10^{-5} mm/mm/°C (3.4 x 10^{-5} in/in/°F) for Type IV rade I CPVC and 5.4 x 10^{-5} mm/mm/°C (2.9 x 10^{-5} in/in/°F) for Type I rade I PVC. Other sources of information on thermal expansion coefficients are available from plastic pipe manufacturers.

PVC and CPVC pipe does not have the rigidity of metal pipe and can flex during expansion, especially with smaller diameters. If expansion joints are used, axial guides should be installed to ensure straight entrance into the expansion joint, especially when maximum movement of the joint is anticipated. eakage at the seals can occur if the pipe is cocked. Independent anchoring of the joint is also recommended for positive movement of expansion joints.

f. Piping Support and Burial

Support for thermoplastic pipe follows the same basic principles as metallic piping. Spacing of supports is crucial for plastic pipe. Plastic pipe will deflect under load more than metallic pipe. Excessive deflection will lead to structural failure. Therefore, spacing for plastic pipe is closer than for metallic pipe. Valves, meters, and fittings should be supported independently in plastic pipe systems, as in metallic systems.

In addition, plastic pipe systems are not located near sources of excessive heat. The nature of thermoplastic pipe is that it is capable of being repeatedly softened by increasing temperature, and hardened by decreasing temperature. If the pipe is exposed to higher than design value ambient temperatures, the integrity of the system could be compromised.

Contact with supports should be such that the plastic pipe material is not damaged or excessively stressed. Point contact or sharp surfaces are avoided as they may impose excessive stress on the pipe or otherwise damage it.

Support hangers are designed to minimize stress concentrations in plastic pipe systems. Spacing of supports should be such that clusters of fittings or concentrated loads are adequately supported. Valves, meters, and other miscellaneous fittings should be supported exclusive of pipe sections.

Supports for plastic pipe and various valves, meters, and fittings, should allow for axial movement caused by thermal expansion and contraction. In addition, external stresses should not be transferred to the pipe system through the support members. Supports should allow for axial movement, but not lateral movement. When a pipeline changes direction, such as through a 90° elbow, the plastic pipe should be rigidly anchored near the elbow.

Plastic pipe systems should be isolated from sources of vibration, such as pumps and motors. Vibrations can negatively influence the integrity of the piping system, particularly at joints.

Support spacing for several types of plastic pipe are found in Tables 5-4 through 5-6. Spacing is dependent upon the temperature of the fluid being carried by the pipe.

The determining factor to consider in designing buried thermoplastic piping is the maximum allowable deflection in the pipe. The deflection is a function of the bedding conditions and the load on the pipe. The procedure for determining deflection is as follows[3]:

$$\%\ deflection = \frac{100\ \Delta Y}{D_o}$$

where:
- ΔY = calculated deflection
- D_o = outer pipe diameter, mm (in)

$$\Delta Y = \frac{(K_x)(d_e)(\Gamma)}{[0.149(PS) + 0.061(E')]}$$

where:
- ΔY = calculated deflection
- K_x = bedding factor, see Table 5-7
- d_e = deflection lag factor, see Table 5-8
- Γ = weight per length of overburden, N/m (lb/in)
- PS = pipe stiffness, MPa (psi)
- E' = soil modulus, MPa (psi), see Table 5-9

$$\Gamma = \frac{(H)(D_o)(\gamma)}{144} = (\Omega)(D_o)$$

where:
- Γ = weight per length of overburden, N/m (lb/in)
- H = height of cover, m (ft)
- D_o = outer pipe diameter, mm (in)
- γ = density of soil N/m^3 (lb/ft^3)
- Ω = soil overburden pressure, MPa (psi)

$$PS = \frac{(E)(I_a)}{0.149\ (R)^3}$$

where:
- PS = pipe stiffness, MPa (psi)
- E = modulus of elasticity of pipe, MPa (psi)
- I_a = area moment of inertia per unit length of pipe, mm^4/mm (in^4/in)
- R = mean radii of pipe, MPa (psi)

$$R = \frac{(D_o - t)}{2}$$

where:
- R = mean radii of pipe, MPa (psi)
- D_o = outer pipe diameter, mm (in)
- t = average wall thickness, mm (in)

$$I_a = \frac{t^3}{12}$$

where:
- I_a = area moment of inertia per unit length of pipe, mm^4/mm (in^4/in)
- t = average wall thickness, mm (in)

Proper excavation, placement, and backfill of buried plastic pipe is crucial to the structural integrity of the system. It is also the riskiest operation, as a leak in the system may not be detected before contamination has occurred. A proper bed, or trench, for the pipe is the initial step in the process. In cold weather areas, underground pipelines should be placed no less than one

[3] ASTM D 2412, Appendices.

Table 5-4
Support Spacing for Schedule 80 PVC Pipe

Nominal Pipe Size, mm (in)	Maximum Support Spacing, m (ft) at Various Temperatures				
	16°C (60°F)	27°C (80°F)	38°C (100°F)	49°C (120°F)	60°C (140°F)*
25 (1)	1.83 (6.0)	1.68 (5.5)	1.52 (5.0)	1.07 (3.5)	0.91 (3.0)
40 (1.5)	1.98 (6.5)	1.83 (6.0)	1.68 (5.5)	1.07 (3.5)	1.07 (3.5)
50 (2)	2.13 (7.0)	1.98 (6.5)	1.83 (6.0)	1.22 (4.0)	1.07 (3.5)
80 (3)	2.44 (8.0)	2.29 (7.5)	2.13 (7.0)	1.37 (4.5)	1.22 (4.0)
100 (4)	2.74 (9.0)	2.59 (8.5)	2.29 (7.5)	1.52 (5.0)	1.37 (4.5)
150 (6)	3.05 (10.0)	2.90 (9.5)	2.74 (9.0)	1.83 (6.0)	1.52 (5.0)
200 (8)	3.35 (11.0)	3.2 (10.5)	2.90 (9.5)	1.98 (6.5)	1.68 (5.5)
250 (10)	3.66 (12.0)	3.35 (11.0)	3.05 (10.0)	2.13 (7.0)	1.83 (6.0)
300 (12)	3.96 (13.0)	3.66 (12.0)	3.2 (10.5)	2.29 (7.5)	1.98 (6.5)
350 (14)	4.11 (13.5)	3.96 (13.0)	3.35 (11.0)	2.44 (8.0)	2.13 (7.0)

Note: The above spacing values are based on test data developed by the manufacturer for the specific product and continuous spans. The piping is insulated and is full of liquid that has a specific gravity of 1.0.
* The use of continuous supports or a change of material (e.g., to CPVC) is recommended at 60°C (140°F).
Source: Harvel Plastics, Product Bulletin 112/401 (rev. 10/1/95), p. 63.

Table 5-5
Support Spacing for Schedule 80 PVDF Pipe

Nominal Pipe Size, mm (in)	Maximum Support Spacing, m (ft) at Various Temperatures			
	20°C (68°F)	40°C (104°F)	60°C (140°F)	80°C (176°F)
25 (1)	1.07 (3.5)	0.91 (3.0)	0.91 (3.0)	0.76 (2.5)
40 (1.5)	1.22 (4.0)	0.91 (3.0)	0.91 (3.0)	0.91 (3.0)
50 (2)	1.37 (4.5)	1.22 (4.0)	0.91 (3.0)	0.91 (3.0)
80 (3)	1.68 (5.5)	1.22 (4.0)	1.22 (4.0)	1.07 (3.5)
100 (4)	1.83 (6.0)	1.52 (5.0)	1.22 (4.0)	1.22 (4.0)
150 (6)	2.13 (7.0)	1.83 (6.0)	1.52 (5.0)	1.37 (4.5)

Note: The above spacing values are based on test data developed by the manufacturer for the specific product and continuous spans. The piping is insulated and is full of liquid that has a specific gravity of 1.0.
Source: Asahi/America, Piping Systems Product Bulletin P-97/A, p. 24.

Table 5-6
Support Spacing for Schedule 80 CPVC Pipe

Nominal Pipe Size, mm (in)	Maximum Support Spacing, m (ft) at Various Temperatures					
	23°C (73°F)	38°C (100°F)	49°C (120°F)	60°C (140°F)	71°C (160°F)	82°C (180°F)
25 (1)	1.83 (6.0)	1.83 (6.0)	1.68 (5.5)	1.52 (5.0)	1.07 (3.5)	0.91 (3.0)
40 (1.5)	2.13 (7.0)	1.98 (6.5)	1.83 (6.0)	1.68 (5.5)	1.07 (3.5)	0.91 (3.0)
50 (2)	2.13 (7.0)	2.13 (7.0)	1.98 (6.5)	1.83 (6.0)	1.22 (4.0)	1.07 (3.5)
80 (3)	2.44 (8.0)	2.44 (8.0)	2.29 (7.5)	2.13 (7.0)	1.37 (4.5)	1.22 (4.0)
100 (4)	2 59 (8.5)	2 59 (8.5)	2 59 (8.5)	2.29 (7.5)	1.52 (5.0)	1.37 (4.5)
150 (6)	3.05 (10.0)	2.90 (9.5)	2.74 (9.0)	2.44 (8.0)	1.68 (5.5)	1.52 (5.0)
200 (8)	3.35 (11.0)	3.20 (10.5)	3.05 (10.0)	2.74 (9.0)	1.83 (6.0)	1.68 (5.5)
250 (10)	3.51 (11.5)	3.35 (11.0)	3.20 (10.5)	2.90 (9.5)	1.98 (6.5)	1.83 (6.0)
300 (12)	3.81 (12.5)	3.66 (12.0)	3.51 (11.5)	3.20 (10.5)	2.29 (7.5)	1.98 (6.5)

Note: The above spacing values are based on test data developed by the manufacturer for the specific product and continuous spans. The piping is insulated and is full of liquid that has a specific gravity of 1.0.
Source: Harvel Plastics, Product Bulletin 112/401 (rev. 10/1/95), p. 63.

Table 5-7
Bedding Factor, K_x

Type of Installation	K_x
Shaped bottom with tamped backfill material placed at the sides of the pipe, 95% Proctor density or greater	0.083
Compacted coarse-grained bedding and backfill material placed at the side of the pipe, 70-100% relative density	0.083
Shaped bottom, moderately compacted backfill material placed at the sides of the pipe, 85-95% Proctor density	0.103
Coarse-grained bedding, lightly compacted backfill material placed at the sides of the pipe, 40-70% relative density	0.103
Flat bottom, loose material placed at the sides of the pipe (not recommended); <35% Proctor density, <40% relative density	0.110

Source: Reprinted from Schweitzer, Corrosion-Resistant Piping Systems, p. 49, by courtesy of Marcel Dekker, Inc.

Table 5-8
Deflection Lag Factor, d_e

Installation Condition	d_e
Burial depth <5 ft. with moderate to high degree of compaction (85% or greater Proctor, ASTM D 698 or 50% or greater relative density ASTM D-2049)	2.0
Burial depth <5 ft. with dumped or slight degree of compaction (Proctor > 85%, relative density > 40%)	1.5
Burial depth >5 ft. with moderate to high degree of compaction	1.5
Burial depth > 5 ft. with dumped or slight degree of compaction	1.25

Source: Reprinted from Schweitzer, Corrosion-Resistant Piping Systems, p. 49, by courtesy of Marcel Dekker, Inc.

Table 5-9
Values of E′ Modulus of Soil Reaction for Various Soils

Soil Type and Pipe Bedding Material	E′ for Degree of Compaction of Bedding, MPa (lb/ft²)			
	Dumped	Slight <85% Proctor >40% rel. den.	Moderate 85-95% Proctor 40-70% rel. den.	High >90% Proctor >70% rel. den.
Fine-grained soils (LL >50) with medium to high plasticity CH, MH, CH-MH	No data available - consult a soil engineer or use E′ = 0			
Fine-grained soils (LL <50) with medium to no plasticity CL, ML, ML-CL, with <25% coarse-grained particles	0.35 (50)	1.38 (200)	2.76 (400)	6.90 (1000)
Fine-grained soils (LL <50) with no plasticity CL, ML, ML-CL, with >25% coarse-grained particles.	0.69 (100)	2.76 (400)	6.90 (1000)	13.8 (2000)
Coarse-grained soils with fines GM, GC, SM, SC contains >12% fines.	0.69 (100)	2.76 (400)	6.90 (1000)	13.8 (2000)
Coarse-grained soils with little or no fines GW, SW, GP, SP contains <12% fines (or any borderline soil beginning with GM-GC or GC-SC)	1.38 (200)	6.90 (1000)	13.8 (2000)	20.7 (3000)
Crushed rock	6.90 (1000)	20.7 (3000)	20.7 (3000)	20.7 (3000)

Notes: LL = liquid limit
Sources: AWWA C900, Table A.4., p.17.
Schweitzer, Corrosion-Resistant Piping Systems, p. 48, (by courtesy of Marcel Dekker, Inc.).

foot below the frost line. The trench bottom should be relatively flat, and smooth, with no sharp rocks that could damage the pipe material. The pipe should be bedded with a uniformly graded material that will protect the pipe during backfill. Typical installations use an American Association of State Highway Transportation Officials (AASHTO) #8 aggregate, or pea-gravel for six inches below and above the pipe. These materials can be dumped in the trench at approximately 90-95% Proctor without mechanical compaction. The remainder of the trench should be backfilled with earth, or other material appropriate for surface construction, and compacted according to the design specifications.

5-2. Polyvinyl Chloride (PVC)

Polyvinyl chloride (PVC) is the most widely used thermoplastic piping system. PVC is stronger and more rigid than the other thermoplastic materials. When specifying PVC thermoplastic piping systems particular attention must be paid to the high coefficient of expansion-contraction for these materials in addition to effects of temperature extremes on pressure rating, viscoelasticity, tensile creep, ductility, and brittleness.

a. PVC Specifications

PVC pipe is available in sizes ranging from 8 to 400 mm (1/4 to 16 in), in Schedules 40 and 80. Piping shall conform to ASTM D 2464 for Schedule 80 threaded type; ASTM D 2466 for Schedule 40 socket type; or ASTM D 2467 for Schedule 80 socket type.

Maximum allowable pressure ratings decrease with increasing diameter size. To maintain pressures ratings at standard temperatures, PVC is also available in Standard Dimension Ratio (SDR). SDR changes the dimensions of the piping in order to maintain the maximum allowable pressure rating.

b. PVC Installation

For piping larger than 100 mm (4 in) in diameter, threaded fittings should not be used. Instead socket welded or flanged fittings should be specified. If a threaded PVC piping system is used, two choices are available, either use all Schedule 80 piping and fittings, or use Schedule 40 pipe and Schedule 80 threaded fittings. Schedule 40 pipe will not be threaded. Schedule 80 pipe would be specified typically for larger diameter pipes, elevated temperatures, or longer support span spacing. The system is selected based upon the application and design calculations.

The ranking of PVC piping systems from highest to lowest maximum operating pressure is as follows: Schedule 80 pipe socket-welded; Schedule 40 pipe with Schedule 80 fittings, socket-welded; and Schedule 80 pipe threaded. Schedule 40 pipe provides equal pressure rating to threaded Schedule 80, making Schedule 80 threaded uneconomical. In addition, the maximum allowable working pressure of PVC valves is lower than a Schedule 80 threaded piping system.

5-3. Polytetrafluoroethylene (PTFE)

Polytetrafluoroethylene (PTFE) is a very common thermoplastic material used in many other applications in addition to piping systems. PTFE is chemically resistant and has a relatively wide allowable temperature range of -260°C (-436°F) to 260°C (500°F). Furthermore, PTFE has a high impact resistance and a low coefficient of friction and is often considered fiself-lubricating.fl The most common trade name for PTFE is Teflon, registered trademark of E.I Dupont Company.

5-4. Acrylonitrile-Butadiene-Styrene (ABS)

Acrylonitrile-Butadiene-Styrene (ABS) is a thermoplastic material made with virgin ABS compounds meeting the ASTM requirements of Cell Classification 4-2-2-2-2 (pipe) and 3-2-2-2-2 (fittings). Pipe is available in both solid wall and cellular core wall, which can be used interchangeably. Pipe and fittings are available in size 32 mm (1-1/4 in) through 300 mm (12 in) in diameter. The pipe can be installed above or below grade.

a. ABS Standards

ASTM D 2282 specifies requirements for solid wall ABS pipe. ASTM D 2661 specifies requirements for solid wall pipe for drain, waste, and vents. ASTM F 628 specifies requirements for drain, waste, and vent pipe and fittings with a cellular core. Solid wall ABS fittings conform to ASTM D 2661. The drainage pattern for fittings is specified by ASTM D 3311.

ABS compounds have many different formulations that vary by manufacturer. The properties of the different formulations also vary extensively. ABS shall be specified very carefully and thoroughly because the acceptable use of one compound does not mean that all ABS piping systems are acceptable. Similarly, ABS compositions that are designed for air or gas handling may not be acceptable for liquids handling.

b. ABS Limitations

Pigments are added to the ABS to make pipe and fittings resistant to ultraviolet (UV) radiation degradation. Pipe and fittings specified for buried installations may be exposed to sunlight during construction, however, and prolonged exposure is not advised.

ABS pipe and fittings are combustible materials; however, they may be installed in noncombustible buildings. Most building codes have determined that ABS must be protected at penetrations of walls, floors, ceilings, and fire resistance rated assemblies. The method of protecting the pipe penetration is using a through-penetration protection assembly that has been tested and rated in accordance with ASTM E 814. The important rating is the "F" rating for the through penetration protection assembly. The "F" rating must be a minimum of the hourly rating of the fire resistance rated assembly that the ABS plastic pipe penetrates. Local code interpretations related to through penetrations are verified with the jurisdiction having authority.

5-5. Chlorinated Polyvinyl Chloride (CPVC)

Chlorinated polyvinyl chloride (CPVC) is more highly chlorinated than PVC. CPVC is commonly used for chemical or corrosive services and hot water above 60°C (140°F) and up to 99°C (210°F). CPVC is commercially available in sizes of 8 to 300 mm (1/4 to 12 in) for Schedule 40 and Schedule 80. Exposed CPVC piping should not be pneumatically tested, at any pressure, due to the possibility of personal injury from fragments in the event of pipe failure; see Paragraph 3-8d for further information.

ASTM specifications for CPVC include: ASTM F 437 for Schedule 80 threaded type; ASTM F 439 for Schedule 80 socket type; and ASTM F 438 for Schedule 40 socket type. However, note that Schedule 40 socket may be difficult to procure.

5-6. Polyethylene (PE)

Polyethylene (PE) piping material properties vary as a result of manufacturing processes. Table 5-10 lists the common types of PE, although an ultra high molecular weight type also exists. PE should be protected from ultraviolet radiation by the addition of carbon black as a stabilizer; other types of stabilizers do not protect adequately[4]. PE piping systems are available in sizes ranging from 15 to 750 mm (½ to 30 in). Like PVC, PE piping is available in SDR dimensions to maintain maximum allowable pressure ratings.

5-7. Polypropylene (PP)

Polypropylene (PP) piping materials are similar to PE, containing no chlorine or fluorine. PP piping systems are available in Schedule 40, Schedule 80, and SDR dimensions. With a specific gravity of 0.91, PP piping systems are one of the lightest thermoplastic piping systems.

5-8. Polyvinylidene Fluoride (PVDF)

Polyvinylidene fluoride (PVDF) pipe is available in a diameter range of 15 to 150 mm (½ to 6 in); Schedules 40 and 80; and pressure ratings of 1.03 MPa (150 psig) and 1.59 MPa (230 psig). Use of PVDF with liquids above 49°C (120°F) requires continuous support. Care must be taken in using PVDF piping under suction. PVDF does not degrade in sunlight; therefore, PVDF does not require UV stabilizers or antioxidants. PVDF pipe is chemically resistant to most acids; bases and organics; and can transport liquid or powdered halogens such as chlorine or bromine. PVDF should not be used with strong alkalies, fuming acids, polar solvents, amines, ketones or esters[5]. Trade names for PVDF pipe include Kynar by Elf Atochem, Solef by Solvay, Hylar by Ausimont USA, and Super Pro 230 by Asahi America.

Fusion welding is the preferred method for joining PVDF pipe. Threading can only be accomplished on Schedule 80 pipe.

[4] Schweitzer, Corrosion-Resistant Piping System, p. 39.
[5] Ibid., p. 43.

Table 5-10
Polyethylene Designations

Type	Standard	Specific Gravity
Low Density (LDPE)	ASTM D 3350, Type I	0.91 to 0.925
Medium Density (MDPE)	ASTM D 3350, Type II	0.926 to 0.940
High Density (HDPE)	ASTM D 3350, Type III and ASTM D 1248 Type IV	0.941 to 0.959

Source: Compiled by SAIC, 1998

Chapter 6
Rubber and Elastomer Piping Systems

6-1. General

The diverse nature of the chemical and physical characteristics of rubber and elastomeric materials makes these material suited for many chemical handling and waste treatment applications. The most common elastomeric piping systems are comprised of hoses. These hoses are constructed of three components: the tube, the reinforcement, and the cover. The tube is most commonly an elastomer and must be suitable for the chemical, temperature, and pressure conditions that a particular application involves. Table 6-1 lists several elastomers used in piping systems and the chemical identifications of the polymers. Physical and chemical characteristics of elastomers used in hose manufacturing are specified in ASTM D 2000. Hose reinforcement is designed to provide protection from internal forces, external forces, or both. Reinforcement usually consists of a layer of textile, plastic, metal, or a combination of these materials. Hose covers are designed to provide hoses with protection from negative impacts resulting from the environment in which the hose is used. Covers are also typically composed of textile, plastic, metal, or a combination of these materials.

6-2. Design Factors

In selecting and sizing a rubber or elastomeric piping system, four factors must be considered: service conditions, (pressure and temperature); operating conditions (indoor/outdoor use, vibration resistance, intermittent of continu ous service, etc.); end connections; and environment requirements (flame resistance, material conductivity, labeling requirements, etc.).

a. Service Conditions

For applications requiring pressure or vacuum service reinforcement can improve the mechanical properties of the hose. The maximum recommended operating pressure in industrial applications utilizing Society of Automotive Engineers (SAE) standards hose designations is approximately 25% of the rated bursting pressure of the specific hose. Table 6-2 lists common SAE hose standards.

In determining the maximum operating conditions, special consideration must be given to the operating temperatures. Rubber and elastomer materials are temperature sensitive, and both the mechanical qualities and chemical resistance properties of the materials are effected by temperature. Appendix B provides information regarding the effects of temperature on chemical resistance, and Table 6-1 provides information

Table 6-1
Common Materials Used in Rubber/Elastomer Piping Systems

Elastomer	ASTM D 1418 Class	Common or Trade Name	Minimum Service Temperature - Continuous Operations	Maximum Service Temperature - Continuous Operations
Fluoroelastomer	FKM	FKM, Viton, Fluorel	-23°C (-10°F)	260°C (500°F)
Isobutylene Isoprene	IIR	Butyl	-46°C (-50°F)	148°C (300°F)
Acrylonitrile Butadiene	NBR	Buna-N, Nitrile	-51°C (-60°F)	148°C (300°F)
Polychloroprene	CR	Neoprene	-40°C (-40°F)	115°C (240°F)
Natural Rubber or Styrene Butadiene	NR or SBR	Gum Rubber; Buna-S	-51°C (-60°F)	82°C (180°F)

Source: Compiled by SAIC, 1998.

Table 6-2
Rubber and Elastomer Hose Standards

SAE Designation	Tube	Reinforcement	Cover
100R1A		one-wire-braid	synthetic-rubber
100RIT		one-wire-braid	thin, nonskive
100R2A		two-wire-braid	synthetic rubber
100R2B		two spiral wire plus one wire-braid	synthetic rubber
100R2AT		two-wire-braid	thin, nonskive
100R2BT		two spiral wire plus one wire-braid	thin, nonskive
100R3		two rayon-braided	synthetic rubber
100R5		one textile braid plus one wire-braid	textile braid
100R7	thermoplastic	synthetic-fiber	thermoplastic
100R8	thermoplastic	synthetic-fiber	thermoplastic
100R9		four-ply, light-spiral-wire	synthetic-rubber
100R9T		four-ply, light-spiral-wire	thin, nonskive

Source: Compiled by SAIC, 1998.

on the temperature limitations of the mechanical properties of rubber and elastomeric materials. As the operating temperature increases, the use of jacketed or reinforced hose should be considered to accommodate lower pressure ratings of the elastomeric materials.

Like plastic piping systems, rubber and elastomer systems do not display corrosion rates, as corrosion is totally dependent on the material's resistance to environmental factors rather than on the formation of an oxide layer. The corrosion of rubbers and elastomers is indicated by material softening, discoloring, charring, embrittlement, stress cracking (also referred to as crazing), blistering, swelling, and dissolving. Corrosion of rubber and elastomers occurs through one or more of the following mechanisms: absorption, solvation, chemical reactions, thermal degradation, and environmental stress cracking.

General compatibility information for common elastomer is listed in Table 6-3. Information regarding the compatibility of various elastomers with specific chemicals can be found in Appendix B. In addition, standards for resistance to oil and gasoline exposure have been developed by the Rubber Manufacturer's Association (RMA). These standards are related to the effects of oil or gasoline exposure for 70 hours at 100 °C (ASTM D 471) on the physical/mechanical properties of the material. Table 6-4 summarizes the requirements of the RMA oil and gasoline resistance classes.

b. Operating Conditions

In most cases, the flexible nature of elastomers will compensate for vibration and thermal expansion and contraction in extreme cases. However, designs should incorporate a sufficient length of hose to compensate for the mechanical effects of vibration and temperature.

Table 6-3
General Chemical Compatibility Characteristics of Common Elastomers

Material	Good Resistance	Poor Resistance
Fluoroelastomer	Oxidizing acids and oxidizers, fuels containing <30% aromatics	Aromatics; fuels containing >30% aromatics
Isobutylene Isoprene	Dilute mineral acids, alkalies, some concentrated acids, oxygenated solvents	Hydrocarbons and oils, most solvents, concentrated nitric and sulfuric acids
Acrylonitrile Butadiene	Oils, water, and solvents	Strong oxidizing agents, polar solvents, chlorinated hydrocarbons
Polychloroprene	Aliphatic solvents, dilute mineral acids, salts, alkalies	Strong oxidizing acids, chlorinated and aromatic hydrocarbons
Natural Rubber or Styrene Butadiene	Non-oxidizing acids, alkalies, and salts	Hydrocarbons, oils, and oxidizing agents

Notes: See Appendix B for more chemical resistance information.
Source: Compiled by SAIC, 1998.

Table 6-4
RMA Oil and Gasoline Resistance Classifications

RMA Designation	Maximum Volume Change	Tensile Strength Retained
Class A (High oil resistance)	+25%	80%
Class B (Medium-High oil resistance)	+65%	50%
Class C (Medium oil resistance)	+100%	40%

Source: RMA, "The 1996 Hose Handbook," IP-2, p. 52.

c. End Connections

Hose couplings are used to connect hoses to a process discharge or input point. Methods for joining elastomeric hose include banding/clamping, flanged joints, and threaded and mechanical coupling systems. These methods are typically divided into reusable and non-reusable couplings. Table 6-5 lists common types of couplings for hoses. Selection of the proper coupling should take into account the operating conditions and procedures that will be employed.

d. Environmental Requirements

Hose is also manufactured with conductive, non-conductive, and uncontrolled electrical properties. Critical applications such as transferring aircraft hose or transferring liquids around high-voltage lines, require the electrical properties of hose to be controlled. Unless the hose is designated as conducting or nonconducting, the electrical properties are uncontrolled. Standards do not currently exist for the prevention and safe dissipation of static charge from hoses. Methods used to control electrical properties include designing contact between a body reinforcing wire and a metal coupling to provide electrical continuity for the hose or using a conductive hose cover. ASTM D 380 describes standard test methods for the conductivity of elastomeric hoses. For a hose to be considered non-conductive, it should be tested using these methods.

6-3. Sizing

The primary considerations in determining the minimum acceptable diameter of any elastomeric hose are design flow rate and pressure drop. The design flow rate is based on system demands that are normally established in the process design phase of a project and which should be

Table 6-5
Typical Hose Couplings

Class	Description
Reusable with clamps	1. Short Shank Coupling 2. Long Shank Coupling 3. Interlocking Type 4. Compression Ring Type
Reusable without clamps	1. Screw Type 2. Push-on Type
Non-reusable couplings	1. Swaged-on 2. Crimped-on 3. Internally Expanded Full Flow Type 4. Built-in Fittings
Specialty couplings	1. Sand Blast Sleeves 2. Radiator and Heater Clamps 3. Gasoline Pump Hose Couplings 4. Coaxial Gasoline Pump Couplings 5. Welding Hose Couplings 6. Fire Hose Couplings

Source: Compiled by SAIC, 1998.

fully defined by this stage of the system design. Pressure drop through the elastomeric hose must be designed to provide an optimum balance between installed costs and operating costs. Primary factors that will impact these costs and system operating performance are internal diameter (and the resulting fluid velocity), materials of construction and length of hose.

6-4. Piping Support and Burial

Support for rubber and elastomer piping systems should follow similar principles as metallic and plastic pipe. However, continuous piping support is recommended for most applications due to the flexible nature of these materials. Also due to its flexible nature, elastomer piping is not used in buried service because the piping is unable to support the loads required for buried service.

When routing elastomer hose, change in piping direction can be achieved through bending the hose rather than using fittings. When designing a rubber or elastomer piping system, it is important to make sure that the bend radius used does not exceed the maximum bend radius for the hose used. If the maximum bend radius is exceeded, the hose may collapse and constricted flow or material failure could occur. As a rule of thumb, the bend radius should be six times the diameter of a hard wall hose or twelve times the diameter of a soft wall hose.

6-5. Fluoroelastomer

Fluoroelastomer (FKM) is a class of materials which includes several fluoropolymers used for hose products. Trade names of these materials include Viton and Fluorel. Fluoroelastomers provide excellent high temperature resistance, with the maximum allowable operating temperatures for fluoroelastomer varying from 232 to 315°C (450 to 600°F), depending upon the manufacturer. Fluoroelastomers also provide very good chemical resistance to a wide variety of chemical classes.

6-6. Isobutylene Isoprene

Isobutylene isoprene (Butyl or II R) has excellent abrasion resistance and excellent flexing properties. These characteristics combine to give isobutylene isoprene very good weathering and aging resistance. Isobutylene isoprene is impermeable to most gases, but provides poor resistance to petroleum based fluids. Isobutylene isoprene is also not flame resistant.

6-7. Acrylonitrile Butadiene

Acrylonitrile butadiene (nitrile, Buna-N or NBR) offers excellent resistance to petroleum oils, aromatic hydrocarbons and many acids. NBR also has good elongation properties. However, NBR does not provide good resistance to weathering.

6-8. Polychloroprene

Polychloroprene (neoprene or CR) is one of the oldest synthetic rubbers. It is a good all-purpose elastomer that is resistant to ozone, ultraviolet radiation, and oxidation. Neoprene is also heat and flame resistant. These characteristics give neoprene excellent resistance to aging and weathering. Neoprene also provides good chemical resistance to many petroleum based products and aliphatic hydrocarbons. However, neoprene is vulnerable to chlorinated solvents, polar solvents, and strong mineral acids.

6-9. Natural Rubber

Natural rubber (styrene butadiene, gum rubber, Buna-S, NR, or SBR) has high resilience, good tear resistance, and good tensile strength. It also exhibits wear resistance and is flexible at low temperatures. These characteristics make natural rubber suitable for general service outdoor use. However, natural rubber is not flame resistant and does not provide resistance to petroleum based fluids.

Chapter 7
Thermoset Piping Systems

7-1. General

Thermoset piping systems are composed of plastic materials and are identified by being permanently set, cured or hardened into shape during the manufacturing process. Thermoset piping system materials are a combination of resins and reinforcing. The four primary thermoset resins are epoxies, vinyl esters, polyesters, and furans. Other resins are available.

a. Thermoset Piping Characteristics

Advantages of thermoset piping systems are a high strength-to-weight ratio; low installation costs; ease of repair and maintenance; hydraulic smoothness with a typical surface roughness of 0.005 mm (0.0002 in); flexibility, since low axial modulus of elasticity allows lightweight restraints and reduces the need for expansion loops; and low thermal and electrical conductivity. Disadvantages of thermoset piping systems are low temperature limits; vulnerability to impact failure; increased support requirements, a drawback of the low modulus of elasticity; lack of dimensional standards including joints since pipe, fittings, joints and adhesives are generally not interchangeable between manufacturers; and susceptibility to movement with pressure surges, such as water hammer. Table 7-1 lists applicable standards for thermoset piping systems.

b. Corrosion Resistance

Like other plastic materials, thermoset piping systems provide both internal and external corrosion resistance. For compatibility of thermoset plastic material with various chemicals, see Appendix B. Due to the different formulations of the resin groups, manufacturers are contacted to confirm material compatibility. For applications that have limited data relating liquid services and resins, ASTM C 581 provides a procedure to evaluate the chemical resistance of thermosetting resins.

c. Materials of Construction

Fiberglass is the most common reinforcing material used in thermoset piping systems because of its low cost, high tensile strength, light weight and good corrosion resistance. Other types of commercially available reinforcement include graphite fibers for use with fluorinated chemicals such as hydrofluoric acid; aramid; polyester; and polyethylene. The types of fiberglass used are E-glass; S-glass for higher temperature and tensile strength requirements; and C-glass for extremely corrosive applications.

Most thermoset piping systems are manufactured using a filament winding process for adding reinforcement. This process accurately orients and uniformly places tension on the reinforcing fibers for use in pressure applications. It also provides the best strength-to-weight ratio as compared to other production methods. The other main method of manufacturing is centrifugal casting, particularly using the more reactive resins.

Thermoset piping can be provided with a resin-rich layer (liner) to protect the reinforcing fibers. The use of liners is recommended for chemical and corrosive applications. Liners for filament wound pipe generally range in thickness from 0.25 to 1.25 mm (0.01 to 0.05 in), but can be custom fabricated as thick as 2.8 mm (0.110 in) and are often reinforced. Liner thickness for centrifugally cast thermoset piping generally ranges from 1.25 to 2.0 mm (0.05 to 0.08 in); these liners are not reinforced. If not reinforced, liners may become brittle when exposed to low temperatures. Impacts or harsh abrasion may cause failure under these conditions.

Fittings are manufactured using compression molding, filament winding, spray-up, contact molding and mitered processes. Compression molding is typically used for smaller diameter fittings, and filament winding is used for larger, 200 to 400 mm (8 to 16 in), fittings. The spray-up, contact molding and mitered processes are used for complex or custom fittings. The mitered process is typically used for on-site modifications.

d. Operating Pressures and Temperatures

Loads; service conditions; materials; design codes and standards; and system operational pressures and temperatures are established as described in Chapters 2 and 3 for plastic piping systems. Table 7-2 lists recommended temperature limits for reinforced thermosetting resin pipe.

Table 7-1
Thermoset Piping Systems Standards (As of Nov. 1997)

Standard	Application
ASTM D 2310	Machine-made reinforced thermosetting pipe.
ASTM D 2996	Filament wound fiberglass reinforced thermoset pipe.
ASTM D 2997	Centrifugally cast reinforced thermoset pipe.
ASTM D 3517	Fiberglass reinforced thermoset pipe conveying water.
ASTM D 3754	Fiberglass reinforced thermoset pipe conveying industrial process liquids and wastes.
ASTM D 4024	Reinforced thermoset flanges.
ASTM D 4161	Fiberglass reinforced thermoset pipe joints using elastomeric seals.
ASTM F 1173	Epoxy thermoset pipe conveying seawater and chemicals in a marine environment.
AWWA C950	Fiberglass reinforced thermoset pipe conveying water.
API 15LR	Low pressure fiberglass reinforced thermoset pipe.

Source: Compiled by SAIC, 1998.

Table 7-2
Recommended Temperature Limits for Reinforced Thermosetting Resin Pipe

Materials		Recommended Temperature Limits			
		Minimum		Maximum	
Resin	Reinforcing	°F	°C	°F	°C
Epoxy	Glass Fiber	-20	-29	300	149
Furan	Carbon	-20	-29	200	93
Furan	Glass Fiber	-20	-29	200	93
Phenolic	Glass Fiber	-20	-29	300	149
Polyester	Glass Fiber	-20	-29	200	93
Vinyl Ester	Glass Fiber	-20	-29	200	93

Source: ASME B31.3, p. 96, Reprinted by permission of ASME.

e. Thermoset Piping Support

Support for thermoset piping systems follow similar principles as thermoplastic piping systems. Physical properties of the materials are similar enough that the same general recommendations apply. Spacing of supports is crucial to the structural integrity of the piping system. Valves, meters, and other miscellaneous fittings are supported independently of pipe sections. Separate supports are provided on either side of flanged connections. Additionally, anchor points, such as where the pipeline changes direction, are built-up with a rubber sleeve at least the thickness of the pipe wall. This provides protection for the pipe material on either side of the anchor.

Reinforced polyester pipe requires a wide support surface on the hanger. It also calls for a rubber or elastomeric cushion between the hanger and the pipe to isolate the pipe from point loads. This cushion is approximately 3 mm ($^1/_8$ in) thick. Table 7-3 summarizes the maximum support spacing at various system pressures for reinforced epoxy pipe.

Table 7-3
Support Spacing for Reinforced Epoxy Pipe

Nominal Pipe Size, mm (in)	Maximum Support Spacing, m (ft) at Various Temperatures					
	24°C (75°F)	66°C (150°F)	79°C (175°F)	93°C (200°F)	107°C (225°F)	121°C (250°F)
25 (1)	3.20 (9.9)	2.99 (9.8)	2.96 (9.7)	2.87 (9.4)	2.83 (9.3)	2.65 (8.7)
40 (1.5)	3.54 (11.6)	3.47 (11.4)	3.44 (11.3)	3.35 (11.0)	3.29 (10.8)	3.08 (10.1)
50 (2)	3.99 (13.1)	3.93 (12.9)	3.90 (12.8)	3.78 (12.4)	3.72 (12.2)	3.47 (11.4)
80 (3)	4.57 (15.0)	4.51 (14.8)	4.45 (14.6)	4.33 (14.2)	4.27 (14.0)	3.96 (13.0)
100 (4)	5.09 (16.7)	5.03 (16.5)	4.97 (16.3)	4.82 (15.8)	4.75 (15.6)	4.42 (14.5)
150 (6)	5.76 (18.9)	5.67 (18.6)	5.61 (18.4)	5.46 (17.9)	5.36 (17.6)	5.00 (16.4)
200 (8)	6.10 (20.0)	6.10 (20.0)	6.04 (19.8)	5.88 (19.3)	5.79 (19.0)	5.39 (17.7)
250 (10)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	5.73 (18.8)
300 (12)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.00 (19.7)
350 (14)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)	6.10 (20.0)

Note: The above spacing values are based on long-term elevated temperature test data developed by the manufacturer for the specific product. The above spacing is based on a 3-span continuous beam with maximum rated pressure and 12.7 mm (0.5 in) deflection. The piping is assumed to be centrifugally cast and is full of liquid that has a specific gravity of 1.00.
Source: Fibercast, Centricast Plus RB-2530, p. 2.

The same principles for pipe support for reinforced polyester apply to reinforced vinyl ester and reinforced epoxy thermoset pipe. Span distances for supports vary from manufacturer to manufacturer. The design of piping systems utilizing reinforced vinyl ester or reinforced epoxy pipe reference the manufacturer™s recommendations for support spacing.

Each section of thermoset piping has at least one support. Additionally, valves, meters, flanges, expansion joints, and other miscellaneous fittings are supported independently. Supports are not attached to flanges or expansion joints. Supports allow axial movement of the pipe.

f. Thermoset Piping Burial

Reinforced polyester, vinyl ester, and epoxy pipe may be buried. The same basic principles which apply to burying plastic pipe also apply for thermoset pipe regarding frost line, trench excavation, pipe installation, and backfill. For operating pressures greater than 689 kPa (100 psi), the internal pressure determines the required wall thickness. For operating pressures less than 689 kPa (100 psi), the vertical pressure on the pipe from ground cover and wheel load dictates the required wall thickness of the pipe.

g. Joining

Common methods for the joining of thermoset pipe for liquid process waste treatment and storage systems include the use of adhesive bonded joints, over wrapped joints, and mechanical joining systems. The application requirements and material specification for these fittings are found in various codes, standards, and manufacturer procedures and specifications, including:

- ASME B31.3 Chapter VII;
- ASME B31.1 Power Piping Code;
- The Piping Handbook, 6th Edition; and
- Fibercast Company Piping Design Manual.

h. Thermal Expansion

When designing a piping system in which thermal expansion of the piping is restrained at supports, anchors, equipment nozzles, and penetrations, thermal stresses and loads must be analyzed and accounted for within the design. The system PFDs and P&IDs are analyzed to determine the thermal conditions or modes to which the piping system will be subjected during operation. Based on this analysis, the design and material specification requirements are determined from an applicable standard or design reference.

The primary objective of the analysis is to identify operating conditions that will expose the piping to the most severe thermal loading conditions. Once these conditions have been established, a free or unrestrained thermal analysis of the piping can be performed to establish location, sizing, and arrangement of expansion joints or loops. Due to the cost of thermoset piping, the use of loops is not normally cost-effective.

The following procedure can be used to design expansion joints in fiberglass piping systems. The expansion joint must be selected and installed to accommodate the maximum axial motion in both expansion and contraction. This typically requires that some amount of preset compression be provided in the expansion joint to accommodate for all operating conditions. In addition, suitable anchors must be provided to restrain the expansion joint; guides must be installed to assure that the pipe will move directly into the expansion joint in accordance with manufacturer requirements; and pipe supports, which allow axial movement, prevent lateral movement, and provide sufficient support to prevent buckling, must be included in the design.

Step 1: Determine Required Preset

$$Length\ of\ Preset = \frac{R(T_i - T_{\min})}{T_{\max} - T_{\min}}$$

where:

R = rated movement of expansion joint, mm (in)
T_i = installation temperature, °C (°F)
T_{min} = minimum system temperature, °C (°F)
T_{max} = maximum system temperature, °C (°F)

Step 2: Design expansion loops using the equation provided in Paragraph 4-6, or consult with the piping manufacturer; for example, see Table 7-4.

Table 7-4
Loop Leg Sizing Chart for Fibercast RB-2530 Pipe

D_o mm (in)	Thermal Expansion, mm (in), versus Minimum Leg Length, m (ft)					
	25.4 mm (1 in)	**50.8 mm (2 in)**	**76.2 mm (3 in)**	**127 mm (5 in)**	**178 mm (7 in)**	**229 mm (9 in)**
33.40 (1.315)	1.22 m (4 ft)	1.52 m (5 ft)	1.83 m (6 ft)	2.44 m (8 ft)	2.74 m (9 ft)	3.05 m (10 ft)
48.26 (1.900)	1.83 m (6 ft)	2.44 m (8 ft)	2.74 m (9 ft)	3.66 m (12 ft)	4.27 m (14 ft)	4.88 m (16 ft)
60.33 (2.375)	2.13 m (7 ft)	3.05 m (10 ft)	3.66 m (12 ft)	4.88 m (16 ft)	5.79 m (19 ft)	6.40 m (21 ft)
88.90 (3.500)	2.74 m (9 ft)	3.96 m (13 ft)	4.88 m (16 ft)	6.10 m (20 ft)	7.32 m (24 ft)	8.23 m (27 ft)
114.3 (4.500)	3.66 m (12 ft)	4.88 m (16 ft)	6.10 m (20 ft)	7.62 m (25 ft)	9.14 m (30 ft)	10.4 m (34 ft)
168.3 (6.625)	4.57 m (15 ft)	6.40 m (21 ft)	7.62 m (25 ft)	9.75 m (32 ft)	11.6 m (38 ft)	13.1 m (43 ft)
219.1 (8.625)	5.18 m (17 ft)	7.01 m (23 ft)	8.84 m (29 ft)	11.3 m (37 ft)	13.1 m (43 ft)	14.9 m (49 ft)
273.1 (10.75)	5.79 m (19 ft)	7.92 m (26 ft)	9.75 m (32 ft)	12.5 m (41 ft)	14.6 m (48 ft)	16.8 m (55 ft)
323.9 (12.75)	6.10 m (20 ft)	8.53 m (28 ft)	10.4 m (34 ft)	13.4 m (44 ft)	15.8 m (52 ft)	18.0 m (59 ft)
355.6 (14.00)	5.79 m (19 ft)	7.92 m (26 ft)	9.75 m (32 ft)	12.5 m (41 ft)	14.9 m (49 ft)	16.8 m (55 ft)

Notes: D_o = outside diameter of standard Fibercast pipe. D_o may be different for other manufacturers.
Thermal expansion characteristics and required loop lengths will vary between manufacturers.
Source: Fibercast, Piping Design Manual, FC-680, p. 6.

7-2. Reinforced Epoxies

Although epoxies cure without the need for additional heat, almost all pipe is manufactured with heat-cure. Reinforced epoxy piping systems are not manufactured to dimensional or pressure standards. Therefore, considerable variation between manufacturers exist in regard to available size, maximum pressure rating and maximum temperature rating. Performance requirements, including manufacturing, conforms to ASTM standards in order to not sole-source the piping system.

7-3. Reinforced Polyesters

Reinforced polyester thermoset piping systems are the most widely used due to affordability and versatility. The maximum continuous operating temperature for optimum chemical resistance is 71°C (160°F). Like the epoxies, reinforced polyester piping systems are not manufactured to dimensional or pressure standards. Variation of available piping sizes, maximum pressure rating, and maximum temperature ratings exist between manufacturers. Performance requirements, including manufacturing, conform to ASTM standards in order to not sole-source the piping system.

[1] Schweitzer, Corrosion-Resistant Piping Systems, p. 102.

7-4. Reinforced Vinyl Esters

The vinyl ester generally used for chemical process piping systems is bisphenol-A fumarate due to good corrosion resistance[1]. Reinforced vinyl ester piping systems vary by manufacturer for allowable pressures and temperatures. Performance requirements, including manufacturing, conforms to ASTM standards in order to not sole-source the piping system.

7-5. Reinforced Furans

The advantage of furan resins is their resistance to solvents in combination with acids or bases[2]. Furans are difficult to work with and should not be used for oxidizing applications. Maximum operating temperatures for furan resins can be 189°C (300°F). Furan resin piping is commercially available in sizes ranging from 15 to 300 mm (½ to 12 in) standard.

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[2] Schweitzer, Corrosion-Resistant Piping Systems, p. 96.