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	EF	EC	EF	EC
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**					
	24EC (75EF)	**66EC (150EF)**	**79EC (175EF)**	**93EC (200EF)**	**107EC (225EF)**	**121EC (250EF)**
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 71EC (160EF). 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.

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[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 189EC (300EF). Furan resin piping is commercially available in sizes ranging from 15 to 300 mm (½ to 12 in) standard.

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