Piping Development Process

1. Establish applicable system standard(s)
2. Establish design conditions
3. Make overall piping material decisions
   - Pressure Class
   - Reliability
   - Materials of construction
4. Fine tune piping material decisions
   - Materials
   - Determine wall thicknesses
   - Valves
5. Establish preliminary piping system layout & support configuration
6. Perform flexibility analysis
7. Finalize layout and bill of materials
8. Fabricate and install
9. Examine and test
15. Nonmetallic Piping

- General
- Design, Fabrication, and Installation for
  - Thermoplastics
  - Reinforced thermosetting resins
  - Reinforced concrete
  - Vitrified clay
  - Borosilicate glass
  - Piping lined with nonmetals
- Limitations

The Material in This Section is Addressed by B31.3 in:

- Chapter VII - Nonmetallic Piping and Piping Lined with Nonmetals
- Appendix B - Stress Tables and Allowable Pressure Tables for Nonmetals
General

➢ Chapter VII has requirements for
  ▪ Thermoplastics
  ▪ Reinforced thermosetting resins
  ▪ Reinforced concrete
  ▪ Vitrified clay
  ▪ Borosilicate glass
  ▪ Piping lined with nonmetals

General

➢ Trend toward the use of nonmetals is increasing
➢ Nonmetals are used when the metallic alternative is judged to be too expensive
➢ Allowances for variations of pressure and temperature described in Chapter II are not permitted for nonmetallic piping
➢ Increased allowable stresses for occasional loads described in Chapter II are not permitted
Thermoplastics

- Materials that can be repeatedly softened by heating and hardened by cooling
- Pipe is extruded
- Fittings are usually injection molded, but sometimes fabricated
- Valve parts are usually injection molded

Commonly used thermoplastics

- ABS Acrylonitrile-butadiene-styrene
- CPVC Chlorinated polyvinyl chloride
- FEP Perfluoro ethylene propylene
- (HD)PE (High density) polyethylene
- PFA Polypolymers
- PP Polypropylene
- PVC Polyvinyl chloride
- PVDF Polyvinylidene fluoride

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Nonmetallic Piping - 7

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Nonmetallic Piping - 8
Thermoplastics

### B31.3 recommended temperature limits:

<table>
<thead>
<tr>
<th>Material</th>
<th>Min (F)</th>
<th>Max (F)</th>
<th>Min (C)</th>
<th>Max (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>-40</td>
<td>176</td>
<td>-40</td>
<td>80</td>
</tr>
<tr>
<td>CPVC</td>
<td>0</td>
<td>210</td>
<td>-18</td>
<td>99</td>
</tr>
<tr>
<td>FEP</td>
<td>-325</td>
<td>400</td>
<td>-198</td>
<td>204</td>
</tr>
<tr>
<td>PE</td>
<td>-30</td>
<td>180</td>
<td>-34</td>
<td>82</td>
</tr>
<tr>
<td>PFA</td>
<td>-40</td>
<td>450</td>
<td>-40</td>
<td>250</td>
</tr>
<tr>
<td>PP</td>
<td>30</td>
<td>210</td>
<td>-1</td>
<td>99</td>
</tr>
<tr>
<td>PVC</td>
<td>0</td>
<td>150</td>
<td>-18</td>
<td>66</td>
</tr>
<tr>
<td>PVDF</td>
<td>0</td>
<td>275</td>
<td>-18</td>
<td>135</td>
</tr>
</tbody>
</table>

---

**Thermoplastics Characteristics**

- High coefficient of thermal expansion
  - 4\" in 100\' (3 mm/m) of expansion for 50°F (25°C) temperature change [HDPE]
  - More in some thermoplastics, less in others
- Creep at room temperature
- Low elastic modulus
- Longitudinal strain due to internal pressure can be significant
Thermoplastics

Allowable Stress

Hydrostatic design stress (HDS) is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a suitable design factor (usually 0.5)

<table>
<thead>
<tr>
<th>Material</th>
<th>Short-term (ksi)</th>
<th>HDS* (ksi)</th>
<th>Short-term (MPa)</th>
<th>HDS* (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>7.53</td>
<td>2.00</td>
<td>51.9</td>
<td>13.8</td>
</tr>
<tr>
<td>PE</td>
<td>2.96</td>
<td>0.80</td>
<td>20.4</td>
<td>5.5</td>
</tr>
<tr>
<td>PVC</td>
<td>7.53</td>
<td>2.00</td>
<td>51.9</td>
<td>13.8</td>
</tr>
</tbody>
</table>

* HDS at 23°C (73°F)

Thermoplastics

Allowable Stress – US Customary Units

![Chart showing allowable stress vs. temperature in F for CPVC and PE.](chart.png)
Thermoplastics

**Allowable Stress – Metric Units**

<table>
<thead>
<tr>
<th>Temperature (C)</th>
<th>CPVC</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>-20</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>40</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Thermoplastics**

**Pressure Design – Straight Pipe**

\[ t = \frac{PD}{2(S + P)} \]

**Where:**

- \( t \) = pressure design thickness
- \( P \) = design pressure
- \( D \) = outside diameter of pipe
- \( S \) = HDS value for material from Appendix B

No specific rules for external pressure design.
Thermoplastics

Support

Because of the low modulus and low allowable stress, thermoplastics require more support than similar sized metallic pipe. For 68°F (20°C):

<table>
<thead>
<tr>
<th>NPS</th>
<th>PP (Asahi)</th>
<th>Typical Metallic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>1</td>
<td>3.5</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>1.4</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
<td>1.8</td>
</tr>
<tr>
<td>6</td>
<td>7.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Fabrication – Butt fusion fittings are joined to the pipe using a butt fusion welding process. (PE, PP, PVDF, others)
Thermoplastics

Fabrication – Socket fittings can be joined to the pipe using a socket fusion welding process. (PE, PP, PVDF, others)

(Spears) (Asahi)
Thermoplastics

Fabrication – Piping can also be joined using a hot gas welding process. (PE, PP, PVDF, others)

Bonders are required to use a qualified bonding procedure specification. The BPS shall specify

- Procedure for making the bonds
- Materials, including storage requirements
- Tools, including proper care and handling
- Environmental requirements (clean, dry, warm)
- Joint preparation
- Dimensional requirements, including tolerances
- Cure time
- Protection of work
- Acceptance criteria

[A328.2].

**Thermoplastics**

**Fabrication**
- A warm, dry and clean environment is required for fabrication
- A leak at an elbow requires
  1. Cutting out the elbow and adjacent pipe
  2. Fabricating a piece with an elbow and two couplings
  3. And installing it, hoping none of the six new joints leak

---

**Reinforced Thermosetting Resins**

- Materials that harden when heated and cannot be re-melted
- Pipe is filament wound, contact molded, or centrifugally cast
- Fittings are molded, filament wound or fabricated
- Few RTR valves are available
Reinforced Thermosetting Resins

Commonly used resins
- Polyester
- Vinylester
- Epoxy
- Furan

Commonly used reinforcements
- Glass fiber
- Carbon fiber

Filament wound
(Smith Fibercast)
Reinforced Thermosetting Resins

Contact Molded

Reinforced Thermosetting Resins

Centrifugally Cast
Reinforced Thermosetting Resins

Reinforced plastic mortar pipe
- Has aggregate (usually sand) in addition to fiber reinforcement to stiffen the wall of the pipe
- Is used mostly underground
- Usually has bell and spigot joints, but may have socket joints like other RTR piping

Vendor recommended temperature limits
- Range from 180 to 275°F (82 to 135°C)
- Are somewhat dependent on the resin
- But are more dependent on the construction of the pipe and fittings…amount of reinforcement in the liner and structural layers
- Can be significantly lowered depending on the chemical being handled
Reinforced Thermosetting Resins

Characteristics

- Higher coefficient of thermal expansion…about twice that of steel, but 1/5 of thermoplastics
- Creep at room temperature
- Low elastic modulus (3 to 10% of steel), but 3 to 10 times thermoplastics

Reinforced Thermosetting Resins

Allowable Stress – Filament Wound and Centrifugally Cast

*Hydrostatic design stress (HDS)* is the hoop stress that when applied continuously, will cause failure of the pipe at 100,000 hours multiplied by a design factor. The design factor is:

- Not more than 1.0 if stress is determined using the pressure cycling method
- Not more than 0.5 if stress is determined using the static pressure method

Typical HDS values are 8,000 to 13,000 psi (55 to 90 MPa)
Reinforced Thermosetting Resins

**Allowable Stress** – Contact Molded

*Design stress (DS)* is 1/10 of the minimum tensile strength

Pressure Design – Same as for thermoplastic pipe

---

**Support**

Because of the lower modulus and lower allowable stress, RTR pipe requires more support than similar sized metallic pipe. For 75°F (24°C):

<table>
<thead>
<tr>
<th>NPS</th>
<th><strong>Green Thread (Smith Fibercast)</strong></th>
<th><strong>Typical Metallic</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>1</td>
<td>10.9</td>
<td>3.3</td>
</tr>
<tr>
<td>2</td>
<td>14.1</td>
<td>4.3</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>5.2</td>
</tr>
<tr>
<td>6</td>
<td>20.5</td>
<td>6.2</td>
</tr>
</tbody>
</table>
Reinforced Thermosetting Resins

Support – Support elements must be designed to provide low concentrated stresses and protect the piping from abrasion.

(Typical guide and anchor – Conley)

Fabrication - Butt fittings are joined to the pipe using a butt wrapping process.

(Smith Fibercast)
Reinforced Thermosetting Resins

Fabrication – Doing it in a warm, clean, dry environment is sometimes a challenge.

Socket fittings are joined to the pipe using an adhesive.

(Conley)
Reinforced Thermosetting Resins

Fabrication
A leak at an elbow requires
1. Cutting out the elbow and adjacent pipe
2. Fabricating a piece with an elbow and two couplings
3. And installing it, hoping none of the six new joints leak

Reinforced Thermosetting Resins

BPS and Bonder Qualification Tests are required as for thermoplastic piping, except test pressure is 3 times manufacturer’s rating
Reinforced Concrete

- Typically 15 to 250 psi (1 to 17 bar) ambient temperature water service
- Made to ASTM and AWWA standards with specific B31.3 pressure ratings

Vitrified clay

- Manufactured from clay fired in furnaces
- Joined with
  - Rubber seals
  - Caulking
  - Mortar
- B31.3 mentions, but has no specific requirements
Borosilicate Glass

- Manufactured from molten glass
- Joined with clamps, rubber seals

Piping Lined with Nonmetals

Common liners include
- Fluoropolymer
- Polypropylene
- PVDF
- Glass

Glass Lined (Estrella)

Polypropylene Lined (Resistoflex)
Piping Lined with Nonmetals

- Thermoplastic liners can be “locked-in” or loose
- PTFE and FEP lined systems require vent holes
- Thermoplastic lined pipe and fittings are usually ductile iron and steel
- Glass lined pipe and fittings are steel
- Systems usually have many flanged joints

Typical Fittings

- Concentric Reducer
- 90° Elbow
- Tee
Piping Lined with Nonmetals

Untypical Fittings

Common Thermoplastic Liners

- Fluoropolymer
  - FEP Perfluoro ethylene propylene
  - PTFE Polytetrafluorethylene
  - PFA Polyperfluoroalkoxy Alkane
- Polypropylene
- PVDF
Piping Lined with Nonmetals

B31.3 recommended temperature limits for liners:

<table>
<thead>
<tr>
<th>Material</th>
<th>Min (F)</th>
<th>Max (F)</th>
<th>Min (C)</th>
<th>Max (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEP</td>
<td>-325</td>
<td>400</td>
<td>-198</td>
<td>204</td>
</tr>
<tr>
<td>PTFE</td>
<td>-325</td>
<td>500</td>
<td>-198</td>
<td>260</td>
</tr>
<tr>
<td>PFA</td>
<td>-325</td>
<td>500</td>
<td>-198</td>
<td>260</td>
</tr>
<tr>
<td>PP</td>
<td>0</td>
<td>225</td>
<td>-18</td>
<td>107</td>
</tr>
<tr>
<td>PVDF</td>
<td>0</td>
<td>275</td>
<td>-18</td>
<td>135</td>
</tr>
<tr>
<td>Glass</td>
<td>Limited by the metal.</td>
<td>Limited by the metal.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Piping Lined with Nonmetals

- The metallic portions of piping lined with nonmetals for
  - Design
  - Fabrication
  - Examination, and
  - Testing
  shall conform to the rules of Chapters I through VI

- Liners must be qualified for external pressure in order to prevent liner collapse
### Piping Lined with Nonmetals

Failures frequently occur at the flange joints. Following the ASME PCC-1 bolt-up procedure greatly improves the chances of success:
- Snug up bolting
- Tighten to 20% of target torque using cross pattern
- Tighten to 50 to 70% of target torque using cross pattern
- Tighten to 100% of target torque using cross pattern
- Continue tightening to 100% target torque using rotational pattern until no movement
- Wait 4 hours or longer and repeat rotational pattern to 100% target torque until no movement

### Limitations

**Thermoplastic Piping**
- may not be used in above ground flammable fluid service unless
  - NPS 1 and smaller
  - Owner approves
  - The piping is safeguarded, and
  - The following are considered
    - The possibility of exposure of piping to fire
    - The susceptibility to brittle failure or failure due to thermal shock when exposed to fire
    - The ability of thermal insulation to protect the piping when exposed to fire
- shall be safeguarded when used in other than Category D fluid service
Limitations

- PVC and CPVC may not be used in compressed gas service
- RPM Piping shall be safeguarded when used in other than Category D fluid service
- RTR Piping shall be safeguarded when used in toxic or flammable fluid services
- Borosilicate Glass Piping
  - Shall be safeguarded when used in toxic or flammable fluid services
  - Shall be safeguarded against large, rapid temperature changes