Thermoplastic Industrial Piping Systems Workbook

Prepared by:
TIPS Product Line Committee of the PPFA
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All text, charts, and photos were prepared and edited by Chasis Consulting, Inc.

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Introduction
What is the PPFA?
The Plastic Pipe and Fittings Association (PPFA) is composed of dozens of companies involved in the manufacturing of products for plastic piping systems. PPFA has been a major force in educating the American market for decades in thermoplastic residential, commercial and industrial piping products design and installation. For further information, log on to www.ppfahome.org.

What is TIPS?
TIPS is the acronym for Thermoplastic Industrial Piping Systems; it also is the name of a product line committee (plc) of the PPFA. TIPS/plc is made up of several prestigious manufacturers in the industry whose goals are to educate and promote to the market place the many benefits of thermoplastic industrial piping systems. For further information, log on to www.ppfahome.org/tips.

What does TIPS exclude?
For purposes of this presentation, TIPS includes only thermoplastic piping materials used mostly in aboveground commercial and industrial applications. Residential applications such as hot and cold water distribution and drain-waste-vent are covered in other PPFA publications. Glass-reinforced resin, tubing, plastic-lined and composite piping are not included in the presented material.

Presentation Objectives
This presentation is to provide knowledge, proficiency and a comfort level in designing, specifying, installing, and maintaining TIPS. For maximum educational benefit, the joint use of the one-day PPFA PowerPoint CD and workbook is recommended.

Definitions and History

Plastic
A material that contains organic, polymeric substances of large molecular weight, is solid in its finished state, and at some stage in its manufacture or processing into a finished article, can be shaped by flow.

Monomer
A relatively simple compound that can react to form a polymer. Examples are: vinyl chloride, ethylene, and propylene.

Polymer
A substance consisting of molecules characterized by the repetition of one or more types of monomeric units. Examples are: polyvinyl chloride, polyethylene, and polypropylene.
**Copolymer**
A polymer formed by the polymerization of two chemically different monomers. Examples are: polyethylene and polypropylene copolymer; and polyvinyl chloride and ABS copolymer.

**Thermoplastic**
A plastic that can be repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the plastic, and that in the softened state, can be shaped by flow into an article by molding or extrusion.

*Water analogy: Thermoplastics, similar to water, can be heated and cooled repeatedly without any change in the material's basic properties. (i.e., recyclable)*

**Thermoset**
A plastic that, when cured by application of heat or by chemical means, changes into a substantially infusible product.

*Egg analogy: Thermosets, similar to eggs, can be processed only once with changes occurring in the material's basic properties.*

**Resin**
Broadly stated, the term designates any polymer or copolymer that is the basic material for a plastic.
Additives

Chemical ingredients incorporated in the resin or added during the manufacturing process to give desired product performance characteristics. These can include the following:

- Heat Stabilizers - Protect against thermal degradation
- Antioxidants - Protect against oxidation
- Ultraviolet Stabilizers - Protect against ultraviolet degradation
- Lubricants - Improve manufacturing processing
- Pigments - Add a distinctive color and aid in UV protection
- Fillers - Reduce cost and may also increase stiffness
- Property Modifiers - Enhance a particular material property
- Processing Aids - Assist material mixing/fusion during processing

Compound

A mixture of a thermoplastic resin with other additives or ingredients

Extrusion

Virtually all thermoplastic pipe is extruded. Extrusion is a process whereby heated plastic forced through a shaping orifice becomes one continuously formed piece.
**Injection Molding**

Most voluminous thermoplastic non-pipe products are injection molded. Injection molding is the process of forming a material by forcing it, under pressure, from a heated cylinder through a sprue (runner) into the cavity of a closed mold.

---

**History of Thermoplastic Piping Materials**

<table>
<thead>
<tr>
<th>Estimated Year Plastic Discovered</th>
<th>Plastic Material*</th>
<th>Estimated Year of Piping Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1868</td>
<td>Cellulose Nitrate (Celluloid)</td>
<td>First semi-synthetic plastic</td>
</tr>
<tr>
<td>1907</td>
<td>Phenol Formaldehyde (Bakelite)</td>
<td>First all-synthetic plastic</td>
</tr>
<tr>
<td>1927</td>
<td>Polyvinyl Chloride (PVC)</td>
<td>1935</td>
</tr>
<tr>
<td>1933</td>
<td>Polyethylene (PE)</td>
<td>1948</td>
</tr>
<tr>
<td>1938</td>
<td>Cellulose Acetate Butyrate (CAB)</td>
<td>1940</td>
</tr>
<tr>
<td>1938</td>
<td>Polytetrafluoroethylene (PTFE)</td>
<td>1960</td>
</tr>
<tr>
<td>1943</td>
<td>Chlorinated Polyvinyl Chloride (CPVC)</td>
<td>1960</td>
</tr>
<tr>
<td>1948</td>
<td>Acrylonitrile Butadiene Styrene (ABS)</td>
<td>1952</td>
</tr>
<tr>
<td>1948</td>
<td>Polyvinylidene Fluoride (PVDF)</td>
<td>1964</td>
</tr>
<tr>
<td>1955</td>
<td>Ethylene Chlorotrifluoroethylene (ECTFE)</td>
<td>1966</td>
</tr>
<tr>
<td>1956</td>
<td>Fluorinated Ethylenepropylene (FEP)</td>
<td>1965</td>
</tr>
<tr>
<td>1957</td>
<td>Polypropylene (PP)</td>
<td>1958</td>
</tr>
<tr>
<td>1960</td>
<td>Cross-Linked Polyethylene (PEX)**</td>
<td>1965</td>
</tr>
<tr>
<td>1962</td>
<td>Polybutylene (PB)</td>
<td>1971</td>
</tr>
<tr>
<td>1968</td>
<td>Perfluoroalkoxy (PFA)</td>
<td>1972</td>
</tr>
</tbody>
</table>

* Items in bold print are plastic materials included in this presentation. ** A thermoset material
Material Characteristics

Plastic Material Designations

ASTM is the standards development organization that classifies plastic piping materials by common physical characteristics categories. Over the past decade, there has been a movement to refine the classifications in a more meaningful way; however, the old designations are still in use.

Old ASTM Designations: Material Designation
- First Digit = Type
- Second Digit = Grade
- Third / Fourth Digit = Hydrostatic design stress divided by 100
- Example: PVC 1120

New ASTM Designation Called Cell Classification
- First Digit = Material
- Second Digit = Impact Strength
- Third Digit = Tensile Strength
- Fourth Digit = Modulus of Elasticity
- Fifth Digit = Heat Deflection Temperature
- Example: PVC 12454 (Similar to PVC 1120)

This presentation will include the following materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>ASTM Specification</th>
<th>Cell Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>ASTM D1784-11</td>
<td>23447-24448</td>
</tr>
<tr>
<td>HDPE</td>
<td>ASTM D3350-12e1</td>
<td>345464C/E</td>
</tr>
<tr>
<td>PP</td>
<td>ASTM D4101-11</td>
<td>Type I</td>
</tr>
<tr>
<td>PVC</td>
<td>ASTM D1784-11</td>
<td>Cell Classification 12454</td>
</tr>
<tr>
<td>PVDF</td>
<td>ASTM D3222-05 (R2010)</td>
<td>Type I Grade 2</td>
</tr>
</tbody>
</table>

*Notes:
1. Thermoplastic compounds can be reformulated to accentuate certain properties. Check with product manufacturers for latest compound usage and cell classification.
2. ABS and PEX piping/tubing systems—except for some unique applications—have not been included in the presentation since most of these plastic systems are used in residential drain, waste, and vent systems (ABS) and hot and cold-water distribution systems (PEX).
3. For detailed information on ABS and PEX piping/tubing materials, go to the PPFA website; www.ppfahome.org.
4. Recently, ASTM approved revisions to ASTM F441 and F442 defining two classifications of CPVC materials—CPVC 4120-05 and CPVC 4120-06. CPVC 4120-05 has an HDS of 500 psi at 180°F/82°C, and 4120-06 has an HDS of 625 psi at 180°F/82°C. Both CPVC materials will be listed in the temperature correction tables shown in the Engineering Design Considerations section.
**Physical Characteristics**

The physical values listed may differ slightly due to variations of manufacturer’s resins and compounds.

### Specific Gravity

The ratio of the density of a material to the density of water at standard temperature (ASTM D792 Test Method). The lower the value, the lighter the weight. *Note: Water = 1.0*

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>0.91</td>
</tr>
<tr>
<td>PE</td>
<td>0.92</td>
</tr>
<tr>
<td>PVC</td>
<td>1.38</td>
</tr>
<tr>
<td>CPVC</td>
<td>1.55</td>
</tr>
<tr>
<td>PVDF</td>
<td>1.76</td>
</tr>
</tbody>
</table>

PE Piping Lighter than Water

### Tensile Strength

The pulling force necessary to break a specimen, divided by the cross-section area at the point of failure. (ASTM D638 Test Method) (psi @ 73°F/23°C)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVDF</td>
<td>8000</td>
</tr>
<tr>
<td>CPVC</td>
<td>7500</td>
</tr>
<tr>
<td>CPVC</td>
<td>7300</td>
</tr>
<tr>
<td>PP</td>
<td>4600</td>
</tr>
<tr>
<td>PE</td>
<td>3500</td>
</tr>
</tbody>
</table>

Tensile Testing Machine  Tensile Plastic Specimen Test

### Modulus of Elasticity

The ratio of the stress to the elongation per inch due to this stress, in a material that deforms elastically. (ASTM D638 Test Method) (psi @ 73°F[23°C] x 105) The lower the value, the more the elasticity.

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus of Elasticity (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>4.2</td>
</tr>
<tr>
<td>CPVC</td>
<td>3.6</td>
</tr>
<tr>
<td>PVDF</td>
<td>2.1</td>
</tr>
<tr>
<td>PP</td>
<td>2.0</td>
</tr>
<tr>
<td>PE</td>
<td>1.2</td>
</tr>
</tbody>
</table>

### Flexural Strength

The strength of a plastic material in bending as expressed by the tensile stress of the outermost fibers of a bent test sample at the instant of failure. (ASTM D790 Test Method) (psi)

<table>
<thead>
<tr>
<th>Material</th>
<th>Flexural Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>14500</td>
</tr>
<tr>
<td>CPVC</td>
<td>13400</td>
</tr>
<tr>
<td>PVDF</td>
<td>9700</td>
</tr>
<tr>
<td>PP</td>
<td>7000</td>
</tr>
<tr>
<td>PE</td>
<td>3000</td>
</tr>
</tbody>
</table>

Flexural Plastic Specimen Test
Izod Impact Strength

The resistance a notched test specimen has to a sharp blow from a pendulum hammer. (ASTM Test D256) (ft-lb/in) The lower the value, the lower the impact strength.

<table>
<thead>
<tr>
<th>Material</th>
<th>Impact Strength (ft-lb/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>7.0</td>
</tr>
<tr>
<td>PVDF</td>
<td>3.8</td>
</tr>
<tr>
<td>CPVC</td>
<td>2.0</td>
</tr>
<tr>
<td>PVC</td>
<td>1.1</td>
</tr>
<tr>
<td>PP</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Coefficient of Thermal Expansion

The fractional change in a length of a specimen due to a unit change in temperature. (ASTM D6960 Test Method) (in./in./°F x 10-5) The lower the value, the lower the expansion rate.

<table>
<thead>
<tr>
<th>Material</th>
<th>Coefficient of Thermal Expansion (in./in./°F x 10^-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>3.0</td>
</tr>
<tr>
<td>CPVC</td>
<td>3.8</td>
</tr>
<tr>
<td>PP</td>
<td>5.0</td>
</tr>
<tr>
<td>PVDF</td>
<td>7.3</td>
</tr>
<tr>
<td>PE</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Thermal Conductivity

The time rate of transferring heat by conduction through a material of a given thickness and area for a given temperature difference. (ASTM C177 Test Method) (Btu in./hr/ft²/°F) The lower the value, the less conductive.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity (Btu in./hr/ft²/°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>0.95</td>
</tr>
<tr>
<td>PVDF</td>
<td>1.18</td>
</tr>
<tr>
<td>PVC</td>
<td>1.20</td>
</tr>
<tr>
<td>PP</td>
<td>1.20</td>
</tr>
<tr>
<td>PE</td>
<td>2.60</td>
</tr>
</tbody>
</table>

Heat Resistance

The general maximum allowable temperature of a piping system in which 20-psi working pressure or less may be used (°F/°C)

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature (°F/°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>140°F/60°C</td>
</tr>
<tr>
<td>PE</td>
<td>160°F/71°C</td>
</tr>
<tr>
<td>PP</td>
<td>180°F/82°C</td>
</tr>
<tr>
<td>CPVC</td>
<td>210°F/99°C</td>
</tr>
<tr>
<td>PVDF</td>
<td>285°F/141°C</td>
</tr>
</tbody>
</table>
Abrasión Resistencia

Al usar el Test Taber Abração, la pérdida de peso de un material se mide después de estar expuesto a un rodillo abrasivo durante 1000 ciclos. (mg) El valor más bajo es el más abrasion resistente.

*Note: Stainless Steel is 50.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>5</td>
</tr>
<tr>
<td>PVDF</td>
<td>5-10</td>
</tr>
<tr>
<td>PP</td>
<td>15-20</td>
</tr>
<tr>
<td>PVC</td>
<td>15-20</td>
</tr>
<tr>
<td>CPVC</td>
<td>20</td>
</tr>
</tbody>
</table>

Flash Ignición de Temperatura

La temperatura más baja de un material a la que se puede ignitar gas combustible suficiente. (°F/°C)

*Note: Wood products ignite at 500°F/260°C and lower.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>900°F/482°C</td>
</tr>
<tr>
<td>PVDF</td>
<td>790°F/412°C</td>
</tr>
<tr>
<td>PVC</td>
<td>730°F/388°C</td>
</tr>
<tr>
<td>PE</td>
<td>660°F/349°C</td>
</tr>
<tr>
<td>PP</td>
<td>N/A/N/A</td>
</tr>
</tbody>
</table>

Calificación de Combustibilidad

Un prueba Underwriter Laboratories para medir la resistencia de un material a la ignición, el derretimiento, la emisión de luz y la combustión de la superficie. El 94V-0 es la calificación más resistente a la combustión; 94HB es la más resistente a la combustión.

*Fire retardant grades can increase value to 94V-2.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVDF</td>
<td>94V-0</td>
</tr>
<tr>
<td>CPVC</td>
<td>94V-0</td>
</tr>
<tr>
<td>PVC</td>
<td>94V-0</td>
</tr>
<tr>
<td>PP*</td>
<td>94HB</td>
</tr>
<tr>
<td>PE</td>
<td>94V-2</td>
</tr>
</tbody>
</table>

Índice de Oxígeno Limitante

El porcentaje de oxígeno necesario en un ambiente para la combustión (Método ASTM D2863). Cuanto más alto el valor, mayor la resistencia a la combustión. (%)

<table>
<thead>
<tr>
<th>Material</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>60</td>
</tr>
<tr>
<td>PVDF</td>
<td>44-75</td>
</tr>
<tr>
<td>PVC</td>
<td>43</td>
</tr>
<tr>
<td>PP</td>
<td>18</td>
</tr>
<tr>
<td>PE</td>
<td>17</td>
</tr>
</tbody>
</table>
Flame Spread / Smoke Development Indices

Flame spread and smoke development indices are material characteristics of plastic piping systems determined by various tests such as ASTM E84, UL 723, CAN/ULC S102.2, and/or UBC 8-1. Most North American building and mechanical codes require combustible piping in return air plenums to have a maximum flame spread value of 25 and a maximum smoke development value of 50. The pipe testing results are often listed by third party companies and should be available from manufacturers of the piping system. Some manufacturers offer specialty products that can improve flame spread and smoke development indices.

TIPS are...

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
Features & Benefits
TIPS products have decades of proven performance. In some applications, testing has shown that plastic piping materials can last for over a century or more.

### Proven & Tested Performance

<table>
<thead>
<tr>
<th>Piping Material</th>
<th>Years in Usage (as of 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>78</td>
</tr>
<tr>
<td>PE</td>
<td>64</td>
</tr>
<tr>
<td>PP</td>
<td>55</td>
</tr>
<tr>
<td>CPVC</td>
<td>53</td>
</tr>
<tr>
<td>PVDF</td>
<td>49</td>
</tr>
</tbody>
</table>

### Chemical Resistance

Plastics handle many exterior and interior environments without protective coatings:
- Handles most fluids at temperatures below 285°F/141°C and pressures up to 235 psi
- Eliminates interior and exterior protective surface finishing
- Longevity of piping system is unsurpassed

### Corrosion Resistance

Plastics are basically non-conductive and are therefore immune to galvanic or electrolytic corrosion attack.
- No expensive corrosion prevention equipment is required
- No expensive coatings required in acid or alkaline and wet or dry soils
- Most thermoplastics have no known end-life
**Optimum Flow Characteristics**

Because of their smooth surfaces, all plastic pipes have a Hazen and William C Factor of 150 or higher.
- Less turbulent flow and lower velocities for most plastic piping systems
- Less Horsepower is required to transfer fluid
- May be able to downsize piping size compared to other piping materials

**Light Weight**

Plastic piping is lighter in weight than any other piping material.
- Lower transportation costs
- Easier installation in close quarters
- Less costly material-handling equipment
- Less individual safety concerns
- Less costly pipe hangers
- Polyolefin (PB / PE / PP) piping is lighter than water and may be cost-effectively installed in water environments

**Abrasion Resistance**

Most plastics are more abrasion resistant than non-plastic pipe (as measured using the Taber Abrasion Test).
- Less wear on pipe
- Ideal for most slurry applications
- Outlasts most non-plastic piping materials in handling solids
Low Thermal Conductivity
All plastic piping materials have low thermal conductance resulting in less heat loss through the wall of the pipe.
- May eliminate or greatly reduce the need for pipe insulation
- May minimize or eliminate dripping condensation in plant interiors
- May reduce the energy needed to maintain fluid temperatures

Variety of Joining Methods
Every plastic piping system has three or more joining options.
- Allows easy joining of plastics and transition to other piping systems
- Allows pre-fabricated or field-joined systems
- Allows joining in a variety of environmental conditions
- Heat fusion and solvent cemented joints are normally stronger than the pipe

Variety of Colors
The plastic piping process allows color to be an integral part of the piping system.
- Easy to identify different piping applications and piping materials
- Visual safety factor in critical underground piping applications
- Various colored valve handles can identify fluids being handled
Flexibility / High-Deformation Capacity

Plastic piping is relatively flexible and has high-deformation capacity ("strainability") compared to other piping materials.

- Plastic pipe is inserted as a liner to repair other piping systems
- May reduce the need for fittings in some piping applications
- In trenches, plastic piping can activate support from the surrounding soil by minor deformation. This allows greater burial depths and surface live loads
- May reduce damage to piping caused by earth movement

Weather Resistance

With the use of proper compound additives, plastic piping is a superb material in any natural environment.

- Plastic piping can be impervious to sunlight with inexpensive protective coverings
- PVDF is so weather resistant it is used in the finish coating for roofing and siding
- Most plastic piping working pressures are not affected in outdoor use; however, some loss of impact properties can occur
- Some polyolefins are highly resistant to damage by freezing and thawing of liquids

Nontoxic / Odorless

Most plastic piping systems are odorless and nontoxic.

- Many plastic piping systems are approved by the NSF (for potable water contact) and the FDA (for food processing)
- When piping systems are properly purged, plastics do not affect beverage/food odor or taste

Biological Resistance

Modern thermoplastic resins and compounds have no documented records of any fungi, bacteria, or termite attacks. Due to its inertness, thermoplastic piping is the preferred material in deionized and other high and ultra-high-purity water systems.
Code Acceptance

There are dozens of plastic piping standards referenced in plumbing and mechanical codes.

- With dimensional uniformity, many piping products may be interchanged
- Third-party organizations certify conformance to consensus standards
- Standard certification agencies’ markings are on most plastic piping products

Integrated Piping Systems

Most plastics offer complete systems of fluid-handling products allowing complete systems of one plastic material to be in contact with all fluid-wetted parts.

- Ease of product selection
- Reduces the possibility of chemical attack of dissimilar piping materials
- Non-plastic materials are minimized or not required

Ease of Fabrication

Thermoplastic piping materials can be easily fabricated into many diverse fluid-handling products due to ease of construction.

- Basically, “If you can draw it, a good plastics fabricator can make it!”
- Piping and ducting systems are constructed to customer’s requirements
- Short delivery times for most fabrications
Ease of Product Identification

Most plastic piping products have surface markings showing manufacturing country of origin, material, pipe size, pressure rating, product manufacturer, applicable certification or listing agency and manufacturing process cycle.

- Local code officials can easily determine product acceptability
- Installers can easily contact manufacturers for field data and information
- Maintenance crews can determine product identity for replacements or repairs

Environmental Soundness

Thermoplastics materials can be recycled and used in the manufacturing processes. Also, the cumulative energy requirements to manufacture, install, and transport plastic piping systems are much less than most non-plastic piping systems.

- Less damage to the Earth's ecology
- Less kilowatt energy to manufacture products
- Less energy to transfer fluids and piping products
- No direct flame used to join pipe; no fires or burns to installers
- All thermoplastics are recyclable
Product Availability
Manufacturers and local distributors inventory standard plastic piping products extensively to ensure timely deliveries.
  • Reduces the installer’s or end-user’s inventory requirements
  • Construction completion dates are not compromised
  • Plastic piping products can be interchanged with other manufacturers’ products

Cost Comparisons of Installed Plastic versus Metal Piping Systems
The following aboveground piping systems have been selected to compare thermoplastic piping systems on an installed basis. The comparison cost ratios include material and labor costs. PVC Schedule 80 piping is used as the base ratio of 1.00; all other cost ratios are compared to PVC Sch. 80. The cost data is taken from blending a Chemical Processing article and the cost data in the book “Plastic Piping Systems” by David A. Chasis. The cost ratios are estimates only and will vary with regional and changing labor costs as well as changes in piping material prices.

Estimates for 6-inch Aboveground Piping System Installed Cost Comparisons¹

<table>
<thead>
<tr>
<th>Materials</th>
<th>Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Sch. 40</td>
<td>0.93</td>
</tr>
<tr>
<td>PVC Sch. 80</td>
<td>1.00</td>
</tr>
<tr>
<td>PP Sch. 80</td>
<td>1.11</td>
</tr>
<tr>
<td>CPVC Sch. 80</td>
<td>1.42</td>
</tr>
<tr>
<td>Carbon Steel Sch. 40</td>
<td>1.59</td>
</tr>
<tr>
<td>Aluminum Sch. 40</td>
<td>2.11</td>
</tr>
<tr>
<td>Stainless Steel-304- Sch. 40</td>
<td>2.83</td>
</tr>
<tr>
<td>Stainless Steel-316 Sch. 40</td>
<td>3.03</td>
</tr>
<tr>
<td>Copper Type L</td>
<td>3.08</td>
</tr>
<tr>
<td>PVDF Sch. 80</td>
<td>4.22</td>
</tr>
<tr>
<td>Titanium Sch. 40</td>
<td>6.11</td>
</tr>
</tbody>
</table>

Note 1: Using this table, one can see that 6-inch diameter carbon steel piping is almost 60% more costly to install than PVC 80 piping.

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Secondary Cost Savings
Not only does TIPS have lower installation costs than other piping materials, it also provides significant secondary cost savings.

- Reduced insurance premiums for many installations due to less on-site accidents
- Reduced freight costs
- Reduced job-site thefts of piping materials
- Reduced maintenance costs

TIPS are...

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
General Design Piping Practices

Follow generally accepted engineering practices when designing with thermoplastic piping. These include:

- Selecting the proper material for the application
- Controlling pressure surges and velocities
- Identifying standards for piping components
- Selecting and proper sizing of pipe, valves and fittings
- Proper pipe supports, anchors, and guides
- Proper underground design considerations
- Selecting the most cost-effective system for required service life
- Following all applicable codes and standards

Plastic Piping Design Practices

Plastic piping has several unique engineering properties compared to non-plastic materials. To ensure an effective and long lasting piping installation, the design engineer needs to be aware of these properties:

- Chemical Resistance
- Pipe and System Pressure Ratings
- Temperature Limits
- Temperature/Pressure Relationship
- Expansion/Contraction
- Pipe Support
- Underground Pipe Flexibility

Chemical Resistance

Plastics in general have excellent chemical resistance; however, there are certain chemical environments that affect the properties of plastics in the following ways:

- Chemical Attack: An environment that attacks certain active sites on the polymer chain.
- Solvation: Absorption of a plastic by an organic solvent.
- Plasticization: Results when a liquid hydrocarbon is mixed with a polymer but unable to dissolve it.
- Environmental Stress-Cracking: A failure that occurs when tensile stresses combined with prolonged exposure to certain fluids generate localized surface cracks.

Chemical Resistance Tables

Many manufacturers have tested hundreds of reagents to determine their affect on plastics. These lists are readily available and act as a guide for the user and design engineer. Listed is a rather broad chemical resistance table of chemical groups and piping material. A recommended fluid is based on performance and safety factors.

### General Chemical Resistance Tables

<table>
<thead>
<tr>
<th>Chemical – Inorganics</th>
<th>CPVC</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids, dilute</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Acids, concentrated</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Acids, oxidizing</td>
<td>R</td>
<td>NR</td>
<td>NR</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Alkalis</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Acid gases</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>
### Chemical Resistance Detailed Partial Chart

Shown is a partial chemical resistance table adapted from a manufacturer’s detail listing of hundreds of reagents. These and similar tables are compiled from years of testing and research, however, if involved with a critical application and conflicting chemical resistance information, self-testing is advised.

<table>
<thead>
<tr>
<th>Chemical – Inorganics</th>
<th>PVC</th>
<th>CPVC</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia gases</td>
<td>NR</td>
<td>R</td>
<td>R</td>
<td>L</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Halogen gases</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Salts</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Oxidizing salts</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical – Organics</th>
<th>PVC</th>
<th>CPVC</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Acid anhydrides</td>
<td>NR</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Alcohols-glycols</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>NR</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Esters / ketones / ethers</td>
<td>NR</td>
<td>L</td>
<td>L</td>
<td>NR</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>Hydrocarbons – aliphatic</td>
<td>R</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Hydrocarbon – aromatic</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>R</td>
</tr>
<tr>
<td>Hydrocarbons - halogenated</td>
<td>L</td>
<td>NR</td>
<td>NR</td>
<td>L</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Natural gas</td>
<td>L</td>
<td>R</td>
<td>R</td>
<td>L</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Synthetic gas</td>
<td>NR</td>
<td>L</td>
<td>L</td>
<td>NR</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Oils</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>R</td>
</tr>
</tbody>
</table>

R = Recommended  L = Limited Use  NR = Not Recommended

### Operating Pressure Determination

Thermoplastic piping’s pressure ratings are determined by ASTM and PPI standards and requirements. Pipe pressure ratings are calculated using the following ISO equation:

\[
PR = 2(HDS) \times \frac{t}{D_m}
\]

where:
- \(PR\) = Pressure rating, psi (MPa)
- \(t\) = Minimum wall thickness, in (mm)
- \(D_m\) = Mean diameter, in (mm)
- \(HDS\) = Hydrostatic design stress = HDB** (hydrostatic design basis) \times DF*** (design factor)

* Most values of HDS for water @ 73°F/23°C or 180°F/82°C are specified by ASTM and other standards.

** Hydrostatic design basis is determined by long-term hydrostatic strength testing as defined by ASTM and PPI standards. Each thermoplastic pressure piping material has an established HDB @ 73°F/23°C or 180°F/82°C for water and hot water applications, respectively.
Maximum HDS for water uses a pipe design factor (DF) of 0.5. For natural gas pipe, the DF is 0.32. Most thermoplastic piping manufacturers list product pressure ratings in their technical literature.

**Schedule Pipe**

Schedule pipe is IPS (Iron Pipe Size) OD (outside diameter) pipe with a wall thickness that matches the wall thickness of the same size and schedule steel pipe. Most vinyl pipe is available in Schedules 40, 80, and 120. (The higher the Schedule number, the thicker the pipe wall for each size.) Pipe pressure ratings decrease as pipe diameter increases for most schedules.

**Standard Dimension Ratio (SDR)**

SDR pipe is based on the IPS OD system and lists several standard pressure ratings. SDR is the pipe OD divided by the wall thickness. For a given SDR, the pressure ratings are constant for all pipe sizes for each plastic material. Non-standard DRs (dimension ratios) can be computed for any pipe OD and wall thickness.

**Metric/Bar Rating**

Metric or Bar Rated pipe is similar to SDR piping ratings in that all sizes of a single SDR and the same material have the same pressure rating. In the Metric system, one bar = one atmosphere = 14.7 psi. A bar rating of 16 = (14.7 x 16) = 235.2 psi.

<table>
<thead>
<tr>
<th>SDR Rating</th>
<th>Pressure Rating (psi)</th>
<th>Bar Rating (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.5</td>
<td>315</td>
<td>21.4</td>
</tr>
<tr>
<td>17.0</td>
<td>250</td>
<td>17.0</td>
</tr>
<tr>
<td>21.0</td>
<td>200</td>
<td>13.6</td>
</tr>
<tr>
<td>26.0</td>
<td>160</td>
<td>10.9</td>
</tr>
<tr>
<td>32.5</td>
<td>125</td>
<td>8.5</td>
</tr>
<tr>
<td>41.0</td>
<td>100</td>
<td>6.8</td>
</tr>
</tbody>
</table>

**Fittings**

Pressure ratings of molded fittings are similar to that of pipe as shown in the listed tables. However, some molded fitting manufacturers have lowered the pressure capability of their products in comparison to pipe. For pressure capabilities of molded and fabricated fittings, consult the manufacturer’s recommendations.

**Other**

Other plastic piping systems have differing outside diameter dimensions and pressure ratings such as Copper Tube Size (CTS), Cast Iron (CI) and Sewer & Drain. Plastic piping made to most of these piping diameters is used for non-industrial applications.

**Temperature and Design Pressure Ratings of Plastic Piping**

Thermoplastic piping materials decrease in tensile strength as temperature increases, and increase in tensile strength as temperature decreases. This characteristic must be considered when designing TIPS. The correction factor for each temperature and material is calculated. To determine the maximum suggested design pressure at a particular temperature, multiply the base pressure by the correction factor.
Comparison of Schedule 80 Pipe Pressure Ratings (psi) at 73°F/23°C

<table>
<thead>
<tr>
<th>Nominal Pipe Size (in.)</th>
<th>PVC/CPVC</th>
<th>PE (SDR 11*)</th>
<th>PP**</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>850</td>
<td>160</td>
<td>410</td>
<td>580</td>
</tr>
<tr>
<td>¾</td>
<td>690</td>
<td>160</td>
<td>330</td>
<td>470</td>
</tr>
<tr>
<td>1</td>
<td>630</td>
<td>160</td>
<td>310</td>
<td>430</td>
</tr>
<tr>
<td>1 ½</td>
<td>470</td>
<td>160</td>
<td>230</td>
<td>320</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>160</td>
<td>200</td>
<td>270</td>
</tr>
<tr>
<td>3</td>
<td>370</td>
<td>160</td>
<td>190</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>320</td>
<td>160</td>
<td>160</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>280</td>
<td>160</td>
<td>140</td>
<td>190</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
<td>160</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>10</td>
<td>230</td>
<td>160</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>12</td>
<td>230</td>
<td>160</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* PE is not Schedule 80.
** Pipe pressure ratings shown are piping manufacturer’s values.
PPI, as of yet, does not publish PP HDB or HDS ratings.

Temperature Correction Factors for Piping

<table>
<thead>
<tr>
<th>Operating Temperature °F / °C</th>
<th>CPVC1</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<td>.84</td>
<td>.91</td>
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<td>.82</td>
<td>.83</td>
<td>.78</td>
<td>.85</td>
<td>.62</td>
</tr>
<tr>
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<td>.74</td>
<td>.74</td>
<td>.80</td>
<td>.50</td>
</tr>
<tr>
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<td>.70</td>
<td>.63</td>
<td>.75</td>
<td>.40</td>
</tr>
<tr>
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<td>.62</td>
<td>.57</td>
<td>.68</td>
<td>.30</td>
</tr>
<tr>
<td>130 / 54</td>
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<td>.57</td>
<td>.50</td>
<td>.65</td>
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<td>.48</td>
<td>*</td>
<td>.57</td>
<td>NR</td>
</tr>
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<td>*</td>
<td>.50</td>
<td>NR</td>
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<tr>
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<td>*</td>
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<td>NR</td>
<td>NR</td>
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<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>.25</td>
</tr>
</tbody>
</table>

*Drainage Only   NR = Not Recommended   CM = Check with Manufacturer

*Note: The first correction factors are for CPVC 4120-05 material.
The second correction factors are for CPVC 4120-06 material.

Example

What is the maximum pressure rating of 3” PP Sch. 80 pipe @ 120°F/49°C? Looking at the previous tables:

Maximum Pressure Rating: 0.75(190) = 142.5 psi

Operating Pressure of Valves, Unions, and Flanges

One of the limiting pressure ratings of TIPS and other piping systems is the 150-psi pressure rating of many valves, unions and flanges (some manufacturers list valves and unions at higher pressure ratings). As in pipe, as the temperature goes up, the working pressure rating goes down.
### Maximum Operating Pressure (psi) of Valves*/Unions*/Flanges

<table>
<thead>
<tr>
<th>Operating Temperature °F / °C</th>
<th>CPVC</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-100 / 25-38</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
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<tr>
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<td>135</td>
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<td>150</td>
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<tr>
<td>130 / 54</td>
<td>120</td>
<td>118</td>
<td>75</td>
<td>150</td>
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<td>105</td>
<td>50</td>
<td>150</td>
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<td>140</td>
</tr>
<tr>
<td>160 / 71</td>
<td>90</td>
<td>80</td>
<td>NR</td>
<td>133</td>
</tr>
<tr>
<td>170 / 77</td>
<td>80</td>
<td>70</td>
<td>NR</td>
<td>125</td>
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<td>50</td>
<td>NR</td>
<td>115</td>
</tr>
<tr>
<td>190 / 88</td>
<td>60</td>
<td>NR</td>
<td>NR</td>
<td>106</td>
</tr>
<tr>
<td>200 / 99</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>97</td>
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<tr>
<td>220 / 104</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>67</td>
</tr>
<tr>
<td>240 / 116</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>52</td>
</tr>
</tbody>
</table>

* Valve and union pressure ratings may vary with each manufacturer. Consult manufacturer’s published information. NR = Not Recommended

### Operating Pressure of Directly Threading Pipe

Direct threading of thermoplastic piping is accomplished using only proper threading equipment. However, it is not recommended to thread pipe below the thickness of a Schedule 80 pipe. Threading vinyl pipe reduces operating pressures by 50%. With most other Schedule 80 thermoplastic piping materials, threading reduces operating pressure for all pipe sizes to 20-psi or less. If threaded connections must be used, increased working pressure could be obtained using transition fittings such as molded unions and adapters.

### Vacuum Collapse Rating and Underground Loading

Most industrial thermoplastic piping systems can handle a vacuum as low as 5 microns. With atmospheric pressure at 14.7 psi and a perfect vacuum, most plastic piping cannot be brought to collapse unless the pipe is brought to a partial out-of-round condition or an external radial pressure is added. If a vacuum line is to be installed underground, special care must be taken to assure a minimum of deformation. Contact the pipe manufacturer for assistance if this condition is encountered.

### Pressure Losses in Plastic Piping Systems

As fluid flows through a piping system, it experiences head loss that is determined by fluid velocity, pipe wall smoothness and internal pipe surface area. Pipe and fitting manufacturers, using the Hazen-Williams formula, have calculated and have readily available the friction loss and velocity data for all their products. Valve manufacturers have calculated liquid sizing constants (C values) for each type and size of valve in determining the pressure drop for a given condition. To determine the pressure drop through a valve, the following equation is used:

\[
\Delta P = \frac{Q^2 \cdot \text{S.G.}}{C_v^2}
\]

where:
- \(\Delta P\) = Pressure drop across the valve (psi)
- \(Q\) = Flow through the valve (gpm)
- \(\text{S.G.}\) = Specific gravity of the liquid
- \(C_v\) = Flow coefficient
Example

Find the pressure drop across a 1½ PVC ball check valve with a water flow rate of 50 gpm:

\[ \Delta P = \frac{Q^2 \cdot \text{S.G.}}{C_v^2} = \frac{(50)^2 \cdot 1.0}{(56)^2} = 0.797 \text{ psi} \]

\( C_v \) for valve = 56 (from manufacturer's manual)

Sample Partial Listing of Flow Capacity and Friction Loss for Sch. 80 PVC per 100 ft.

<table>
<thead>
<tr>
<th>GPM</th>
<th>1&quot; Pipe</th>
<th>1½&quot; Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity (ft/sec)</td>
<td>Friction Head (ft)</td>
</tr>
<tr>
<td>7</td>
<td>3.26</td>
<td>4.98</td>
</tr>
<tr>
<td>10</td>
<td>4.66</td>
<td>9.65</td>
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<tr>
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<td>9.32</td>
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<tr>
<td>25</td>
<td>11.66</td>
<td>52.64</td>
</tr>
<tr>
<td>30</td>
<td>13.99</td>
<td>78.78</td>
</tr>
<tr>
<td>35</td>
<td>16.32</td>
<td>98.16</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
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<tr>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example

Find the velocity and friction head loss of 1½ PVC Sch. 80 pipe @ 25 gpm:

Using table:
Velocity = 4.69 ft/sec
Head loss = 5.74 ft or 2.49 psi

C Factors for Common Piping Materials

<table>
<thead>
<tr>
<th>Constant (C)</th>
<th>Type of Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>All Thermoplastics / New Steel</td>
</tr>
<tr>
<td>140</td>
<td>Copper / Glass / New Cast Iron / Brass</td>
</tr>
<tr>
<td>125</td>
<td>Old Steel / Concrete</td>
</tr>
<tr>
<td>110</td>
<td>Galvanized Steel / Clay</td>
</tr>
<tr>
<td>100</td>
<td>Old Cast Iron</td>
</tr>
</tbody>
</table>

Hydraulic Shock

Hydraulic shock or water hammer is a momentary pressure rise resulting when the velocity of the liquid flow is abruptly changed. The longer the line and higher the liquid velocity, the greater the shock load from the surge. For the piping system to maintain its integrity, the surge pressure plus the pressure existing in the piping system must not exceed 1½ times the recommended working pressure rating of the operating system.
The following formula determines the surge pressure:

\[ P = v \left( \frac{S.G. - 1}{2} \right) C + C \]

where:
- \( P \) = Maximum surge pressure (psi)
- \( v \) = Fluid velocity (ft/sec)
- \( C \) = Surge wave constants
- \( S.G. \) = Specific gravity of the liquid

**Example**

What would the surge pressure be if a valve were suddenly closed in a 2” PVC Sch. 80 pipe carrying fluid with a S.G. of 1.2 at a rate of 30 gpm and a line pressure of 160 psi@ 70°F/21°C?

\( C = 24.2 \) (from Surge Wave Constant Table)

\( v = 3.35 \) (from Flow Capacity & Friction Loss Table)

\[ P = v \left( \frac{S.G. - 1}{2} \right) C + C = 3.35 \left( \frac{1.2 - 1}{2} 24.2 + 24.2 \right) = 3.35 (26.6) = 90 \text{ psi} \]

Total line pressure = 90 + 160 = 250 psi

*Note: 2” PVC Sch. 80 pipe has a pressure rating of 400 psi at 73°F/23°C; therefore, 2” PVC Sch. 80 pipe is acceptable for this application.*

**Avoiding Hydraulic Shock**

- Fluid velocity < 5 ft/sec
- Actuated valves with specific closing times
- Start pump with partially closed valve in discharge line
- Install check valve near the pump discharge to keep line full
- Vent all air out of system before start-up

**Thermal Expansion & Contraction**

Thermoplastics compared to non-plastic piping have relatively higher coefficients of thermal expansion. For this reason, it is important to consider thermal elongation and contraction when designing thermoplastic piping systems.

Use the following formula to calculate the expansion/contraction of plastic pipe:

\[ \Delta L = y \left( \frac{T_1 - T_2}{10} \right) \cdot \frac{L}{100} \]

where:
- \( \Delta L \) = Expansion of the pipe (in.)
- \( y \) = Constant factor (in./10°F/100ft)
- \( T_1 \) = Maximum temperature (°F)
- \( T_2 \) = Minimum temperature (°F)
- \( L \) = Length of pipe run (ft)

**Example**

How much expansion will result in 300 ft of PVC pipe installed at 50°F/10°C and operating at 125°F/52°C? (\( y \) for PVC = 0.360)
ΔL = y (T₁ − T₂) / 10 • \[ \frac{L}{100} = 0.36 \left( \frac{125 - 50}{10} \right) \cdot \frac{300}{100} = 8.1 \text{ in.} \]

**Values of y for Specific Plastics**

<table>
<thead>
<tr>
<th>Material</th>
<th>y Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>0.360</td>
</tr>
<tr>
<td>CPVC</td>
<td>0.456</td>
</tr>
<tr>
<td>PP</td>
<td>0.600</td>
</tr>
<tr>
<td>PVDF</td>
<td>0.948</td>
</tr>
<tr>
<td>PE</td>
<td>1.000</td>
</tr>
</tbody>
</table>

**Managing Expansion / Contraction in Piping System**

Forces which result from thermal expansion and contraction can be reduced or eliminated by providing piping offsets, expansion loops, or expansion joints. The preferred method of handling expansion/contraction is to use offset and/or expansion loops. Expansion joints require little space but are limited in elongation length and can be a maintenance and repair issue. As a rule-of-thumb, if the total temperature change is greater than 30°F/17°C, compensation for thermal expansion should be considered.

**Expansion Loops and Offsets**

Expansion Loop Formula:

\[ \phi = \sqrt{\frac{3ED(ΔL)}{2S}} \]

where:

- \( \phi \) = Loop length (in.)
- E = Modulus of elasticity at maximum temperature (psi)
- S = Working stress at maximum temperature (psi)
- D = Outside diameter of pipe (in.)
- ΔL = Change in length due to change in temperature (in.)
Example
What would the loop length be to compensate for 4" of expansion of 3" CPVC Sch. 80 pipe with a minimum temperature of 110°F/43°C? (Outside diameter of 3" pipe = 3.5 in., E = 371,000, S = 1500)

\[
\Delta L = \frac{3 \cdot ED \cdot (\Delta L)}{2S} = \frac{3 \cdot 371,000 \cdot 3.5 \cdot 4}{2 \cdot 1,500} = \frac{15,582,000}{3,000} \approx 72 \text{ in.}
\]

Thermal Stress
If provisions are not made for expansion/contraction, the resulting forces will be transmitted to the pipe, fittings and joints. Expansion creates compressive forces and contraction creates tensile forces.

To calculate the induced stress of restrained pipe, use the formula:

\[
St = EC\Delta T
\]

where:
- \(St\) = Stress (psi)
- \(E\) = Modulus of elasticity (psi x 10^6)
- \(C\) = Coefficient of thermal expansion (in/in/°F x 10^5)
- \(\Delta T\) = Temperature change between the installation temperature and max/min temperature, whichever produces the greatest differential (°F)

Example
What is the induced stress developed in 2" Schedule 80 PVC pipe with the pipe restricted at both ends? Assume the temperature extremes are from 70°F to 100°F (21°C to 38°C).

\[
St = EC\Delta T = (3.60 \times 10^5) \times (3.0 \times 10^5) \times (100-70) = 324 \text{ psi}
\]

Note: Steel pipe stress is approximately 15 – 20 times higher than most plastic piping.

Longitudinal Force
Longitudinal force is that pressure asserted against fixed restraining structures. To determine the magnitude of the longitudinal force, multiply the stress by the cross sectional area of the plastic pipe. The formula is:

\[
F = St \cdot A
\]

where:
- \(F\) = Force (lbs.)
- \(St\) = Stress (psi)
- \(A\) = Cross-sectional area (in²)

Example
With the stress as shown in the previous example, calculate the total amount of force developed in the 2" Schedule 80 PVC pipe? (cross-sectional area of 2" pipe = 1.556 in²)

\[
F = St \cdot A = 324 \text{ psi} \times 1.556 \text{ in}^2 = 504 \text{ lbs.}
\]
Support Spacing

The tensile and compressive strengths of plastic pipe are less than those of metal piping. Consequently, plastics require additional pipe support. In addition, as temperature increases, tensile strength decreases requiring additional support. At very elevated temperatures, continuous support may be required.

Support Spacing of Schedule 80 Pipe (ft)

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter (in.)</th>
<th>CPVC 60°F/16°C</th>
<th>CPVC 100°F/38°C</th>
<th>CPVC 140°F/60°C</th>
<th>PP 60°F/16°C</th>
<th>PP 100°F/38°C</th>
<th>PP 140°F/60°C</th>
<th>PVC 60°F/16°C</th>
<th>PVC 100°F/38°C</th>
<th>PVC 140°F/60°C</th>
<th>PVDF 60°F/16°C</th>
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<td>3 ½</td>
<td>11</td>
<td>9 ½</td>
<td>5 ½</td>
<td>9 ½</td>
<td>7 ½</td>
<td>7</td>
</tr>
</tbody>
</table>

* Listings show spacing (ft) between supports. Pipe is normally in 20-ft lengths. Use continuous support for spacing under three feet.

Pipe Support Spacing with Fluid Specific Gravities Greater Than 1.0

<table>
<thead>
<tr>
<th>Specific Gravity</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.00</td>
</tr>
<tr>
<td>1.1</td>
<td>0.98</td>
</tr>
<tr>
<td>1.2</td>
<td>0.96</td>
</tr>
<tr>
<td>1.4</td>
<td>0.93</td>
</tr>
<tr>
<td>1.6</td>
<td>0.90</td>
</tr>
<tr>
<td>2.0</td>
<td>0.85</td>
</tr>
<tr>
<td>2.5</td>
<td>0.80</td>
</tr>
</tbody>
</table>

* Above data are for un-insulated piping. For insulated piping, reduce spans to 70% of values shown.

Pipe Hangers

Use hangers that have a large bearing area to spread out the load over the largest practical area. The basic rules for hanging plastic pipe are:

- Avoid point contact or concentrated bearing loads.
- Avoid abrasive contact.
- Use protective shields to spread the loads over large areas.
- Do not have the pipe support heavy valves or specialty fittings.
- Do not use hangers that “squeeze” the pipe.
Typical Pipe Hangers

- Wrought Clevis
- Riser Clamp
- Adjustable Solid Ring
- Double-belt Pipe Clamp
- Single Pipe Roll
- Roller Hanger
- Pipe Roll & Plate

Pipe & Valve Supports

- Continuous Support with Structural Angle
- Overhead Support for Valve
- Supporting Plastic Pipe Vertically
- Shoe Support
- Hanger with Protective Sleeve
- Valve Support from Below
- Trapeze Support
Anchors & Guides

Anchors direct movement of pipe within a defined reference frame. At the anchoring point, there is no axial or transverse movement. Guides allow axial movement of pipe but prevent transverse movement. Use guides and anchors whenever expansion joints are utilized and on long runs and directional changes in pipe.

Anchoring & Guide Design Diagrams
Insulation of Plastic Piping

To calculate heat loss or gain through plastic piping, the following equation is used:

\[ Q = \frac{K t A \Delta T}{x} \]

where:
- \( Q \) = Heat gain or loss (Btu)
- \( K \) = Thermal conductivity of the pipe (Btu-in./ft²-hr-°F)
- \( \Delta T \) = Temperature difference of inside and outside pipe walls (°F/°C)
- \( A \) = Surface area (ft²)
- \( x \) = Wall thickness (in.)
- \( t \) = Time (hrs.)

Example

What is the heat loss over 1 hour of a 1-foot long section of 2” PVC Sch. 80 pipe with a temperature difference of 80°F/27°C?

- \( K = 1.2 \text{ Btu-in./ft}^2\text{-hr-°F (for PVC)} \)
- \( D = 2.375 \text{ in. for 2" pipe} \)
- \( A = \pi DL = (3.141)(2.375 \text{ in.})(1\text{ft/12in.})(1\text{ ft}) = 0.621 \text{ ft}^2 \)
- \( x = 0.218 \text{ in.} \)

\[ Q = \frac{K t A \Delta T}{x} = \frac{1.2 \times 1 \times 0.621 \times 80}{0.218} = 273.47 \text{ Btu} \]

Example

What is the heat loss over 1 hour of a 1-foot long section of 2” Carbon Steel Sch. 80 pipe with a temperature difference of 80°F/27°C?

- \( K = 321.4 \text{ Btu-in./ft}^2\text{-hr-°F (for PVC)} \)
- \( D = 2.375 \text{ in. for 2" pipe} \)
- \( A = \pi DL = (3.141)(2.375 \text{ in.})(1\text{ft/12in.})(1\text{ ft}) = 0.621 \text{ ft}^2 \)
- \( x = 0.218 \text{ in.} \)

\[ Q = \frac{K t A \Delta T}{x} = \frac{321.4 \times 1 \times 0.621 \times 80}{0.218} = 73243.8 \text{ Btu} \]

Other Above-ground Design Considerations

Cold Environments

Most plastic piping systems handle temperatures below 0°F/-18°C if the system liquid does not freeze. However, in most cases, the pipe flexibility and the impact resistance decrease, cause the pipe to become brittle. Protect the pipe from impact if this condition can occur. To prevent liquid freezing or crystallization in piping, electric heat tracing may be used and applied directly on the pipe within the insulation. The heat tracing must not exceed the temperature-pressure system design.
**Hot Environments**

When pressure-piping applications exceed 285°F/141°C, the use of thermoplastic piping is limited. Make sure, in temperatures above 100°F/38°C, that expansion/contraction, reduced working pressures and support spacing are considered in the system design.

**Outdoor Environments**

Most TIPS are formulated for protection against the harmful ultraviolet rays from the sun. However, long periods of exposure to direct sunlight can oxidize the surface of the piping, causing discoloration and reduced impact resistance. To prevent these phenomena, opaque tape or paint can be applied. Be sure to use approved acrylic or water based paints. Do not use oil-based paints as they may cause harm to some plastic piping.

**Compressed Air**

EXCEPT FOR SPECIALLY DESIGNED AND DESIGNATED PLASTIC PIPING SYSTEMS, MOST MANUFACTURERS DO NOT RECOMMEND THEIR PRODUCT FOR HANDLING OF OR TESTING WITH ANY COMPRESSED GASES.

**Below-ground Considerations**

**Below-ground Design**

Plastic pipe in most instances is considered a flexible pipe rather than a rigid piping material. Flexible pipe is pipe that is able to bend without breaking and uses the pipe wall and buried medium to sustain external loads. When installed properly, plastic pipe develops support from the surrounding soil.

Pipe deflection or compression depends on any one or a combination of three factors:
- Pipe stiffness
- Soil stiffness (soil density along the sides of the pipe)
- Load on the pipe (earth/static/live)

**Pipe Stiffness**

Pipe stiffness is the force in psi divided by the vertical deflection in inches. An arbitrary data point of 5% deflection is used as a comparison of pipe stiffness values in flexible piping. Each pressure piping material has a different pipe stiffness value that is based on the material's flexural modulus. For any given SDR, the pipe stiffness remains constant for all sizes.

**Soil Stiffness**

Soil stiffness is the soil's ability to resist compaction. There is a formula (Spangler's) to determine the "E" values or deflection of buried flexible pipe in terms of soil stiffness independent of pipe size. The "E" value is also referred to as the modulus of soil reactions. The soil backfill type and amount of compaction directly affect these values.
Pipe Loading

Earth loads may be calculated using Marston’s load formula. Static loads are calculated using Boussinesq’s Equation. Live or dynamic loads are also calculated using Boussinesq’s Equation, by multiplying the superimposed load (W) by 1½. There are many existing tables available from pipe manufacturers for various piping materials listing soil conditions, soil compaction, pipe stiffness values, maximum height of cover recommendations and other useful data to design underground plastic piping systems.

Trench Design

Trenches should be of adequate width to allow the proper bedding and backfilling of plastic pipe, while being as narrow as practical. A trench width of two or three times the piping diameter is a good rule of thumb in determining the trench width. Following is a table listing minimum trench widths for various pipe sizes and a cross-section showing pipe trench terminology.

<table>
<thead>
<tr>
<th>Nom. Pipe Sizes (Diameter in.)</th>
<th>Number of Pipe Diameters</th>
<th>Trench Width (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.3</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>2.9</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>2.9</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>2.5</td>
<td>26</td>
</tr>
<tr>
<td>12</td>
<td>2.4</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>2.0</td>
<td>30</td>
</tr>
<tr>
<td>18</td>
<td>1.8</td>
<td>32</td>
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<tr>
<td>21</td>
<td>1.6</td>
<td>34</td>
</tr>
<tr>
<td>24</td>
<td>1.5</td>
<td>36</td>
</tr>
<tr>
<td>27</td>
<td>1.5</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>1.4</td>
<td>42</td>
</tr>
<tr>
<td>33</td>
<td>1.4</td>
<td>46</td>
</tr>
<tr>
<td>36</td>
<td>1.4</td>
<td>50</td>
</tr>
<tr>
<td>40</td>
<td>1.4</td>
<td>56</td>
</tr>
<tr>
<td>48</td>
<td>1.3</td>
<td>62</td>
</tr>
</tbody>
</table>

Minimum Cover of Buried Pipe

The following guidelines may be used when burying plastic pipe:
- Locate pipe below the frost line
- A minimum cover of 18 in. or one pipe diameter (whichever is greater) when there is no overland traffic
- A minimum cover of 36 in. or one pipe diameter (whichever is greater) when truck traffic may be expected
- A minimum cover of 60 in. when heavy truck or locomotive traffic is possible

For more detailed information on belowground plastic piping systems, refer to the Plastic Pipe Institute (PPI) for polyolefins (PE and PP) and PVC Pipe Association for PVC piping.

TIPS are...

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
Joining, Installation, Testing & Repairing Methods
General Piping Practices

There are some distinctive differences between plastic and non-plastic installation, testing, and repairing techniques. However, always use good piping practices similar to other piping materials. For example:

- Always have a slow opening valve at the pump discharge
- Provide for proper air relief and vacuum break at high points
- Follow specific manufacturer’s installation and safety manual
- Train installers if handling piping material for the first time
- Use appropriate piping joining tools and accessories
- Piping should be installed as stress-free as possible
- Eliminate air from the piping system before testing & start-up

Joining Methods

Before joining any plastic piping products, always make certain of the following:

- Inspect the products to be joined to ensure no cracks (normal molding “knit” lines not included), gouges, warping or other imperfections are present
- Make certain the fitting socket and outside pipe diameter fit as described by the manufacturer
- All pipe should be cut squarely, deburred and where applicable beveled (especially above 2-inch diameter)
- Thoroughly clean all piping products before joining
- Keep piping products to be joined at similar temperatures when solvent cementing or heat fusing
- Be knowledgeable of the manufacturer’s products and installation procedures

Inspection

Before joining any plastic pipe, inspect the pipe surface for deep gouges and cracks. If suspect areas are found, cut out the damaged section at least 12 inches beyond the ends of the gouge or crack. Also, make certain that the component socket and outside pipe diameter fit correctly.

Cutting / Cleaning

Cut, deburr, and bevel (when applicable) plastic pipe with specialty-designed tools. Using a clean, dry cloth, remove any dirt, grease, and/or water from joining surfaces. If the cloth is unsuccessful at removing surface dirt, follow the Manufacturer’s recommendations on cleaners or use an emery cloth or fine sand paper. Do not use mechanical sanding tools to clean or bevel pipe.
Flanging

Materials Applicable: All

Advantages
- Excellent for transitioning plastics to non-plastic materials in all pipe diameters
- Other advantages similar to threading

Concerns
- High initial cost
- Dissimilar material contacting fluid being handled (gaskets)
- Not compact dimensionally
- Limited to 150 psi working pressure
- Installer abuse

Bottom Line: An excellent method for joining dissimilar piping materials and facilitates the installation of large diameter fittings in restricted-space areas

Use soft, full-face gaskets comparable with handled fluid and thermoplastic material.

Install the flange making sure the pipe is bottomed-out to the flange stop. Use lubricated bolts and flat washers to join.

Cut pipe with appropriate pipe cutting tools.

Remove all burrs inside and outside of pipe.

Remove dirt, grease, and moisture with clean, dry rag before joining.

Bevel pipe ends where applicable (solvent cementing).
Tighten down each bolt in a manner diametrically opposite each other (see bolt pattern sequence).

Points to Remember
- Make certain the system pressure does not exceed 150 psi.
- Use a torque wrench and follow manufacturers’ bolting pattern and torque requirements when tightening nuts / bolts.
- Heavy flat washers should be used on flanges to be joined.
- Use lubricated bolts (lubricant to be material-compatible).
- Do not use ring gaskets; use chemically compatible full-face gaskets with a 55-80 durometer.
- Avoid using metal flanges with excessively raised inner lip.
- Do not bury flanged connections.

Solvent Cementing

Materials Applicable: ABS / CPVC / PVC

Advantages
- Joint is as strong or stronger than the pipe and fitting
- No foreign substance contacting fluid being handled
- No expensive special tools required

Concerns
- Once joined, cannot be taken apart
- Time delay before testing
- Needs ventilated environment to join
- Leaks not easily fixed
- Difficult to join in poor weather conditions

Bottom Line: The preferred joining system for ABS, CPVC & PVC piping systems due to joint integrity and low labor costs especially when compared to welding and brazing of metallic piping

Use a proper applicator sized for the pipe diameter to be joined.
Liberally coat twice the primer to pipe outside wall.
Liberally coat twice the primer to fitting socket.
Before the primer is dried, apply two coats of cement to pipe outside wall.

Before the primer is dried, apply two coats of cement to fitting socket.

Without delay and while cement is wet, push pipe into fitting, twisting a quarter turn until pipe bottoms out.

After assembly, joint should have a solid ring or bead of cement around the joint interface. If voids are present, joint may be suspect. Hold pipe and fitting together for about 15-30 seconds to avoid push out.

Using a rag, remove excess cement from pipe and fitting.

### Points to Remember

- Pipe, fittings and cement should be exposed to the same temperature for at least one hour prior to cementing.
- Use only natural bristle brushes (brush width should be one-half of pipe diameter), approved daubers, rollers and/or swabs to apply cement and primer.
- Some pipe system joints may be cementable without a primer. Check manufacturers’ instructions.
- When joining in temperatures below 40°F/4.4°C or above 90°F/32°C, carefully follow cement manufacturers’ instructions.
- Use the appropriate cement for the piping material and wall thickness.
- Observe the “use prior to” date on cement containers.
- Discard cements if they become lumpy and stringy.
- Cement in well ventilated environments.
- Keep cements and primers away from any open flame (no smoking in joining area).
- Appropriate joint-drying time should elapse before moving or testing the cemented pipe system (see manufacturers’ guidelines).
- Don't be stingy using cement and primer.
- When cementing ball valves, carefully cement the pipe into the valve with the ball open at a 45° angle.
- Do not take shortcuts…follow manufacturers’ instructions completely (or review ASTM D2855).

### Butt Fusion (Conduction Heating)

**Materials Applicable:** PE / PP / PVDF

**Advantages**

- No foreign materials contacting fluid being handled
- Joint is as strong as the pipe and fitting
- Once the tool is prepared, a quick-joining system
- Can test the system immediately
- Ideal for large-diameter installations

**Concerns**

- Normally requires a source of electricity
- Requires expensive tools
- May require an independent installer to operate the fusion tool
- Cannot be taken apart once the joint is made
- Difficult to assemble in poor weather conditions
- Difficult to use in close-quarter installations
- Possible electrical-shock hazards in wet environments

**Bottom Line:** The preferred method for joining heat fusible piping due to joint integrity, ability to handle all sizes of pipe diameters and the low labor costs compared to non-plastic piping materials

Assemble all required tools and set temperature of heater plate to manufacturer’s recommendation.

Squared cut, deburred, and cleaned piping ends are placed and secured in the joining device clamping shells.

The pipe is then properly aligned with enough space between pipe ends to place the heating plate.

After the heating plate is removed, the soften pipe ends are butted together at the recommended pressure rating. Relieve the pipe joining pressure and “heat soak” the pipe joint for seconds or minutes depending on size of the pipe and the weather conditions.

Visually inspect the welded pipe to ensure a uniform radial weld. Then unclamp and carefully remove the piping from the machine after the joint is cool enough to be comfortably hand-touched.

**Points to Remember**
- Keep the heater plate faces clean.
- Wear insulated gloves and avoid contact with the heater plates and any hot, melted material.
- When joining long lengths of piping, keep the fusion machine stationary and move the pipe.
- During the winter and excessively windy days, shelter the heater plates and entire joining process.
- When in doubt about the quality of a joint, cut it out and redo.
**Infrared Radiant Butt Fusion (Radiant Heating - Non Contact)**

**Materials Applicable:** PE / PP / PVDF

**Advantages**
- Cleaner, less contaminated weld
- More repeatable
- Smaller bead size
- Other advantages similar to butt fusion

**Concerns**
- More labor-intensive
- Expensive joining machine
- Greater possibility of cold welds
- Other concerns similar to butt fusion

**Bottom Line:** If ultra-high purity fluid systems are of concern, the best heat fusion system available

**Points to Remember**
- Similar to standard butt fusion
Bead & Crevice-Free Fusion

Materials Applicable: PE / PP / PVDF

Advantages
- Eliminates any significant friction loss
- Minimizes any bacteria build-up
- Perhaps the ultimate piping system for ultra-high purity systems
- Other advantages similar to butt fusion

Concerns
- Very labor intensive
- Need expertise
- Limited to small-diameter piping
- Other concerns similar to electric fusion

Bottom Line: The ultimate joining system for small-diameter, heat-fusible piping systems requiring minimum turbulence and smooth bore
Socket Fusion

Materials Applicable: PE / PP / PVDF

Advantages
- Socket joint could be stronger than butt type
- Easier to use in close-quarter installations
- Other advantages similar to butt fusion

Concerns
- Limited in size to a 6-inch diameter maximum
- Other concerns similar to butt fusion

Cut and deburr pipe ends after installing correct size of male and female tool pieces on heating tool.

Clean pipe and fittings with cloth after adjusting the tool thermostat to the desired joining temperature.

Place the proper size depth gage over the pipe end.

Attach the depth gage clamp to the pipe, locking it into place. Then, remove the depth gage.

Simultaneously place the pipe and fitting squarely and fully on the heat tool pieces so that the ID of the fitting and the OD of the pipe are in contact with the heating surfaces.

Simultaneously remove the pipe and fitting from the tool pieces and immediately insert the pipe, squarely and fully, into the socket of the fitting. (Do not rotate.) Hold the completed joint in place for at least 15 seconds. Remove the clamp after completion.

Hold the pipe and fitting on the tool pieces for the prescribed amount of time.
**Bottom Line:** An excellent system of joining heat-fusible plastics in smaller pipe diameters. Much lower labor costs than welding or brazing of non-plastic piping.

**Points to Remember**
- Clean tool pieces by removing residue after each joint.
- Spray tool contact surfaces with silicone after each joint.
- Use heat-resistant gloves and avoid contact with hot surfaces.
- Join in well ventilated environment.
- If joining in inclement weather, protect the installation area.
- Do not test the joint until fully cooled to ambient temperature.
- Do not turn the pipe when inserting into the fitting or valve.

**Electric Fusion (Wire Resistance Heating)**

**Materials Applicable:** PE / PP / PVDF

**Advantages**
- Can “dry-fit” the entire system before joining
- Relatively quick installation time
- Minor leaks can be fixed easily
- Can make multiple joints simultaneously

**Concerns**
- Need an electrical source
- Possibility of contamination of fluid by socket resistance coil
- Once joined cannot take apart
- Expensive joining tool
- Mostly used in non-pressure applications

---

<table>
<thead>
<tr>
<th>Mark the pipe at the notch on depth gage that corresponds with size pipe being used.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take nut off fitting, placing fusion coil into fitting socket.</td>
</tr>
<tr>
<td>Place nut onto fitting and hand-tighten. Bend leads of coil away from center of fitting to allow room for pipe to be fitted.</td>
</tr>
<tr>
<td>Place end of pipe into fitting until the mark is flush with top of nut.</td>
</tr>
</tbody>
</table>
Bottom Line: Due to their cost and quality effectiveness, thermoplastics have replaced glass and ductile iron as the preferred chemical waste drainage system.

Points to Remember
- Leave the pigtails as-is until the joint has been tested.
- Do not tighten compression clamps excessively.
- Adjust the power unit without a coil connected to the terminal block.
- On large projects, dry-fit the entire system and then begin the joining process, marking each finished joint.
- In temperatures below 60°F/16°C, it may be necessary to increase voltage times.
Mechanical Pressure Cut / Rolled-Grooved with Metal Gasket Coupler

Materials Applicable: PVC / PE (Other plastic materials may be joined; check with pipe and coupler manufacturers)

Advantages
- Easy to assemble and disassemble
- Can prefabricate a system for field installation
- Can test the system immediately
- Allows for some misalignment in piping systems
- Pipe diameters up to 24-inch

Concerns
- Expensive tools may be required
- Foreign material in contact with liquid being handled and thermoplastic compatibility
- May reduce pressure rating of pipe
- Can only be used with certain plastic materials (check with manufacturer)
- Exterior corrosion or chemical attack possible with coupling

Bottom Line: Usually preferred over threaded and flanged plastic systems by most pipe-fitters familiar with the joining technique

After cutting, deburring, and cleaning the pipe end, place the pipe into the grooving tool and follow the manufacturer’s grooving instructions. The photo shown depicts a rolled grooved pipe end.

Next, select the proper coupler-gasket assembly. The selection is based on pipe material type, coupler-gasket design, and job site conditions. (Confirm with pipe and coupler manufacturer in selection process.)

Place lubricated gasket to grooves of both pipe ends. Place compression coupling over gasket then tighten bolts to the desired torque.
Points to Remember

- Not all plastic piping can use this joining method.
- Check pipe OD tolerances before grooving.
- Use pipe supports whenever possible in grooving pipe.
- Maintain grooving tools for cleanliness and sharpness.
- Rolled grooves are normally stronger than cut grooves.
- Periodically check groove dimensions to comply with groove coupler manufacturer’s specifications.
- Pipe wall thickness could affect whether to use cut or roll groove.

Mechanical Pressure Cut-Groove with Plastic & Spline Coupler

Materials Applicable: PVC

Advantages

- Similar coupler material as piping to prevent corrosion and chemical attack
- No expensive equipment required
- Other advantages similar to metal coupler cut-groove system

Concerns

- Limited to piping materials and diameter sizes
- Other concerns similar to metal coupler cut-groove system

Bottom Line: An excellent joining system for tough services requiring a quick connection and disconnection feature

Points to Remember

- Similar to metal coupler cut-groove system
Mechanical Chemical Drainage Cut-Groove

Materials Applicable: PP / PVDF

Advantages
- No expensive tool required
- Easy to install
- Can take apart after joined
- No electric source needed
- Easy to repair and maintain
- Ideal for under sink trap
- Installation not effected by inclement weather

Concerns
- Limited size range
- Cannot be buried
- Seal needs to be compatible with liquid
- Can leak due to repetitive expansion & contraction
- Used for drainage systems only

Bottom Line: For labor savings and maintenance, there is no better under-sink joining system

After cutting and deburring pipe, use pipe tool to groove pipe.

Cut groove in pipe by rotating tool counter-clockwise.

Place compression nut on pipe, then put on seal until it clicks into the groove.

Insert pipe into fitting.

Tighten nut one quarter-turn past hand-tight using a plastic spanner wrench.
Points to Remember
- Do not over tighten compression nuts.
- Do not bury or put behind enclosed walls.
- Elastomeric seal needs to be compatible with liquid handled.

Mechanical Quick Connect
Materials Applicable: PP (Glass Filled) / PVDF

Advantages
- Easy to assemble and disassemble
- Can test the system immediately
- Easy to fix leaks
- No expensive tools required

Concerns
- Limited in size to 4 inches
- Limited in pressure rating
- Limited to PP / PVDF
- Expensive fittings

Bottom Line: Easy and quick to join using no tools

Points to Remember
- Square cut and deburr pipe
- Bottom out pipe when inserting into socket

Mechanical Transition
Materials Applicable: All

Advantages
- Eliminates plastic threading directly to metal piping
- Other advantages similar to Threaded

Concerns
- System may be limited to 150-psi working pressure
- Limited in size up to 3-inch diameter
- Metal-plastic unions can be expensive

Bottom Line: An excellent method to join smaller diameter plastic piping to non-plastic piping systems

Angle Transition Fitting
Transition Fitting on Compressed Air System
Points to Remember
- Use Teflon tape or approved sealant on threaded joints when joining.
- Plastic male thread may transition into metal female thread, provided working temperature is to be at or above installed temperature.
- Do not thread male metal threads into plastic female threads.
- Metal connectors should be chemically compatible with the handled liquid.
- Do not over tighten threaded connections.

Direct Threading of Plastic Piping

Materials Applicable: All

Advantages
- Can disassemble
- Can fix leaks easily
- Can join dissimilar materials
- Can prefabricate a system for field installation
- Can test the system immediately

Concerns
- Requires more expertise assembling sizes larger than 2-inch diameter
- Reduces the working pressure of the system 50% or more depending on pipe material
- Threads are the weakest part of the piping system
- Special tools required
- Thicker pipe is required
- Compatibility of thread sealants
- May not be suitable for some plastic to non-plastic transitions

Insert plug into pipe end to prevent distortion of pipe walls.

Turn threading dies slowly, keeping speed constant. Use an approved thread-cutting lubricant.

After threading pipe, use Teflon tape or approved sealer/lubricant (mfg. instructions).

Screw fittings onto pipe and tighten with strap wrench. Avoid excessive torque. One to two threads past hand-tight is adequate.
Bottom Line: For industrial applications, use threaded plastic joints only if necessary

Points to Remember
- Use only schedule 80 pipe or heavier.
- Threading dies must be clean and sharp.
- Use strap wrenches or other non-metal tightening device.
- Threaded pipe can reduce the working pressure of the system 50% or more.
- Do not bury threaded connections.
- Do not subject threaded joints to repeated or severe strain.
- Use Teflon tape or a manufacturer's approved thread sealant for threads.
- Do not thread male metal piping into plastic female connection.
- For industrial applications, use threaded plastic joints only if necessary.

Installing Plastic Pipe

Installation practices for plastic piping system differ very little from those of installing other piping systems. Novice installers should contact an experienced plastic piping representative of either a manufacturer or distributor to educate the installing crew in proper joining techniques. In large critical projects, it may be advisable to certify the competency of each pipe fitter.

The size of the work crews depends on the following:
- Size and length of piping system
- Atmospheric temperature
- Construction conditions
- Construction schedule
- Type of joining method
- Local union requirements

<table>
<thead>
<tr>
<th>Pipe Diameter (in.)</th>
<th>Joining Work Crew (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ - 2</td>
<td>1</td>
</tr>
<tr>
<td>2 ½ - 3</td>
<td>2</td>
</tr>
<tr>
<td>4 - 8</td>
<td>3</td>
</tr>
<tr>
<td>10 and above</td>
<td>4</td>
</tr>
</tbody>
</table>

Storage and Handling of Plastic Pipe

Storage

Plastics have excellent resistance to weathering and may be stored outside for short periods of time. However, for prolonged outside storage, it is recommended that the pipe and fittings be kept under a light tarpaulin or in a well-ventilated shed to prevent the excessive heat build-up and possible surface ultraviolet degradation.

Summary of Points to Remember:
- For prolonged outside storage, put pipe and fittings under an opaque, light-colored tarpaulin or in a well-ventilated shed. This will minimize warpage and possible surface ultraviolet degradation.
- Some pipe manufacturers ship pallets of pipe with an opaque wrap. Leave wrap on until ready to use.
- Loose pipe stacks should not exceed 3 feet in height, to prevent excessive deflection.
- Bundled pipe may be double-stacked.
- Pipe rack storage should be free from sharp metallic burrs and edges and away from heat sources such as radiator steam pipes. Pipe racks should have appropriate support to prevent pipe from sagging.
- Bellied pipe, if stored for extended periods, should have alternate rows of bells be inverted so the loading on the bell is minimized.

**Handling**

Excessively rough handling of plastic piping may cause damage. Dragging the free end of pipe off a truck and allowing it to crash to a hard surface can mar or split the pipe ends. A deep scratch or gouge in the pipe can reduce its pressure rating. Most thermoplastic piping becomes brittle in low temperatures. Be especially careful not to drop or impact the pipe when this condition occurs.

**Summary of Points to Remember:**
- Do not carelessly drop pipe from truck when unloading.
- Use a load distributor when moving small diameter pipe.
- Protect piping from impact abuse, especially in cold weather.
- Use soft pads on truck bottoms that have metal edges.
- Use 3- or 4-inch-wide nylon or rope slings for pipe lifting.
- Do not use piping that has been run-over by vehicles.

**Above-ground Installations**

Good piping design techniques are recommended for all piping materials. Anchoring, support spacing and hanger design are somewhat unique in plastics and have been addressed in the Engineering Section. Another factor to consider with plastics aboveground is to prevent impact damage from exterior sources such as forklifts. This can be accomplished by using protective metal, concrete, or wooden shields.

**Summary of Points to Remember:**
- Have a knowledgeable crew handling and joining plastic piping systems.
- Handle and store the plastic pipe properly.
- Be aware of expansion/contraction considerations.
- Use proper support spacing and hangers.
- Keep hangers and anchors close to elbows.
- Use anchors and guides when necessary.
- Properly support plastic valves.
- Protect pipe from being damaged by moving vehicles.
- Protect pipe from UV degradation if continuously exposed to sunlight

**Below-ground Installations**

Because of its light weight, its corrosion resistance to all types of soil, and its easy joining methods, plastics are ideal for buried pipe applications. In fact, well over 70% of all PVC and PE piping installations are for belowground uses such as water mains, irrigation, sewers, water service lines, and natural gas distribution (PE only).
Summary of Points to Remember:
- Use as narrow a trench as possible and use trench supports to protect workers when necessary.
- Do not bury mechanical connected piping (threaded, flanged, or grooved).
- Make certain the trench depth is a minimum of 12 inches below the frost line.
- Snake all small diameter pipe in trenches.
- Soil surrounding pipe and backfill should be free of any rocks or sharp objects (sand bedding may be necessary).
- Be sure that solvent-welded joints are dry before handling or creating other pipe movement.
- If thrust blocking is required, use only poured-in-place concrete into undisturbed soil. Do not use wood or precast concrete blocks.
- Record precisely or lay conductive wire abutting pipe to be able to accurately locate underground plastic pipe.

Testing Plastic Piping Systems
Test all plastic piping systems hydrostatically prior to full service. (There are a few specially formulated plastic piping systems designed to transport compressed air/gas that may be air-tested.)

Summary of Points to Remember:
- Test all piping systems before putting into service.
- **Do not test plastic pipe with compressed air or other gases unless manufacturer approves.**
- Make sure when testing plastic piping that air is removed from lines to be tested.
- When testing solvent-welded piping, make certain the solvent-welded joints are cured before testing.
- Test both carrier and containment pipe in dual-containment pipe. In some cases, the containment pipe may be air tested @ 5 psi (check with manufacturer).
- Minimize surge pressures when filling system to be tested.
- The test pressure should be no more than 1 ½ times the designed maximum system operating pressure, or at the rating of the lowest rated system component (whichever is lower).
- Test below-ground piping systems before completely backfilling (leave all joints exposed during testing).
- If testing at high pressures, only the personnel required for the test should be at the test site.

Repairing Plastic Piping Systems
The successful installation and testing of plastic piping systems very rarely require any repairs or maintenance. For mechanically joined piping systems using threading and flanging techniques, repairs are similar to those used in non-plastic piping systems.
Remove excess cement residue at pipe joint and make sure the joint is moisture-free.

Cut welding rod of similar piping material at 45° angle.

Using an appropriate hot-air welding gun and maintaining uniform heat and pressure on the rod, weld a root bead into the prepared area.

Apply additional weld beads; number of beads depends on pipe size.

**Back Welding**

If minute leaks do occur in cemented or fused low-pressure piping systems, back welding may be of use. If the leak is a steady stream, cut out and replace the joint. If the leak does not occur at the joint, cut out the entire section and replace. Before repairing a leak, the joint to be welded must be completely dry. Only skilled plastic welders should repair joint leaks. Adhesive-type repair kits are also available. (Check with cement or other manufacturers.)

**Points to Remember When Repairing Plastic Pipe**

- To minimize repairs, do not take shortcuts when installing plastic piping systems, and follow manufacturers’ instructions.
- Use plastic threaded joining as a last resort.
- Tighten threaded plastic components a maximum of 1½ to 2 threads past finger-tight.
- Male plastic thread into female metal thread is allowable if temperatures do not fall below installation temperature.
- Do not thread metal male thread into plastic female thread.
- Do not over torque bolts on plastic flanges.
- Use full-face gaskets 1/8” thickness.
- Hot-air weld solvent-cemented/heat-fused joints, the piping system must be dry.
- An experienced welder should repair plastic piping.

**TIPS are...**

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
Product Availability
Product Availability

Thermoplastic piping systems offer a broad range of materials, products, sizes, and geometries. Most of these products are readily available. Listed is a summary of various product groupings.

**Pressure Pipe & Fittings**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Size Range* (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>¼ - 24</td>
</tr>
<tr>
<td>PE</td>
<td>½ - 120</td>
</tr>
<tr>
<td>PP</td>
<td>½ - 24</td>
</tr>
<tr>
<td>PVC</td>
<td>1/8 – 24</td>
</tr>
<tr>
<td>PVDF</td>
<td>½ - 12</td>
</tr>
</tbody>
</table>

* Pipe may be Schedule, SDR and/or Metric. Larger pipe sizes may be available for import and may be extruded in the USA in the future.

**Chemical Waste Drainage Systems**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Size Range* (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPVC</td>
<td>1 ½ - 12</td>
</tr>
<tr>
<td>PP</td>
<td>1 ½ - 12</td>
</tr>
<tr>
<td>PVDF</td>
<td>1 ½ - 6</td>
</tr>
</tbody>
</table>

* Larger sizes are available by fabrication.
Compressed Air Piping

<table>
<thead>
<tr>
<th>Materials</th>
<th>Size Range* (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>½ - 4</td>
</tr>
<tr>
<td>PE</td>
<td>½ - 4</td>
</tr>
</tbody>
</table>

* Specially formulated compounds. Do not use other thermoplastic piping for compressed air or other gases.

Double Containment Piping Systems

<table>
<thead>
<tr>
<th>Size range (common usage)</th>
<th>Carrier Pipe (in.)</th>
<th>Containment Pipe (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>½</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>¾</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1 ½</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>24</td>
</tr>
</tbody>
</table>

Materials: All combinations of carrier and containment piping are used (including plastic and non-plastic materials).
## Valves

<table>
<thead>
<tr>
<th>Type</th>
<th>Materials &amp; Size Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPVC</td>
</tr>
<tr>
<td>Angle</td>
<td>1/4 - 1/2</td>
</tr>
<tr>
<td>Ball</td>
<td>1/2 - 4</td>
</tr>
<tr>
<td>Butterfly</td>
<td>1 1/2 - 12</td>
</tr>
<tr>
<td>Check</td>
<td>1/2 - 24</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>1/2 - 6</td>
</tr>
<tr>
<td>Float</td>
<td>N/A</td>
</tr>
<tr>
<td>Foot</td>
<td>1/2 - 4</td>
</tr>
<tr>
<td>Gate</td>
<td>1/2 - 8</td>
</tr>
<tr>
<td>Globe</td>
<td>N/A</td>
</tr>
<tr>
<td>Goose Neck</td>
<td>1/4 - 1/2</td>
</tr>
<tr>
<td>Laboratory</td>
<td>1/4 - 3/8</td>
</tr>
<tr>
<td>Multiport</td>
<td>1/2 - 4</td>
</tr>
<tr>
<td>Needle</td>
<td>1/4 - 1/2</td>
</tr>
<tr>
<td>Pressure Relief</td>
<td>1/2 - 4</td>
</tr>
<tr>
<td>Pressure Regulator</td>
<td>N/A</td>
</tr>
<tr>
<td>Solenoid</td>
<td>1/2 - 3</td>
</tr>
</tbody>
</table>
Strainers

<table>
<thead>
<tr>
<th>Type</th>
<th>Materials &amp; Size Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPVC</td>
</tr>
<tr>
<td>Wye</td>
<td>3/8 – 4</td>
</tr>
<tr>
<td>Basket</td>
<td>½ - 12</td>
</tr>
</tbody>
</table>

Filters

<table>
<thead>
<tr>
<th>Type</th>
<th>Filter Housing Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPVC</td>
</tr>
<tr>
<td>Bag</td>
<td>yes</td>
</tr>
<tr>
<td>Cartridge</td>
<td>yes</td>
</tr>
</tbody>
</table>

Pumps

<table>
<thead>
<tr>
<th>Type</th>
<th>Materials &amp; Size Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPVC</td>
</tr>
<tr>
<td>Barrel/Drum</td>
<td>no</td>
</tr>
<tr>
<td>Diaphragm</td>
<td>no</td>
</tr>
<tr>
<td>Flexible Liner</td>
<td>yes</td>
</tr>
<tr>
<td>Horizontal Centrifugal</td>
<td>yes</td>
</tr>
<tr>
<td>Magnetic Drive</td>
<td>yes</td>
</tr>
<tr>
<td>Metering</td>
<td>no</td>
</tr>
<tr>
<td>Peristaltic</td>
<td>no</td>
</tr>
<tr>
<td>Submersible</td>
<td>yes</td>
</tr>
<tr>
<td>Vertical Centrifugal</td>
<td>yes</td>
</tr>
</tbody>
</table>
Sheet / Rod

- **Materials**: All

- **Products**:
  - Self-priming Centrifugal Pumps
  - Flexible Liner Pump
  - Diaphragm Pump
  - Submersible Vertical Centrifugal Pump
  - Horizontal Centrifugal Pump
  - Magnetic Drive Centrifugal Pump
  - Drum Pumps
  - Metering Pump
  - Sheet & Rod (Fluorocarbons)
  - Plastic Extruded Profiles
  - Sheet, Machining Shapes and Duct
Ducting / Fans

- Materials: CPVC / PP / PVC / PVDF
- Size Range: 2” through 36” Duct (Rectangular & Circular) / Centrifugal Fans

Scrubbers / Packing

- Materials: CPVC / PP / PVC / PVDF

Tanks / Adapters / Vacuum Breakers

- Molded Tanks: PE / PP
- Fabricated Tanks: All Materials
- Tank Adapters: CPVC / PP / PVC (½ - 4”)
- Vacuum Breakers: PP / PVC / PVDF
Fabrications

- All materials and configurations
Flow Monitoring Equipment

- Vortex Sensors: CPVC / PP / PVC / PVDF
- Rotor Sensors: PP / PVDF
- Conductivity/Resistivity Sensors: PVDF
- Temperature Sensors: PVDF
- Pressure Sensors: PVDF
- Level Sensors: PVDF
- Gage Guards: CPVC / PP / PVC / PVDF
- Sight Glasses: CPVC / PP / PVC / PVDF

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Heat Exchangers

- Immersion: PE / PP / PVDF
- Tube Plate: PE / PP / PVDF
- Gas/Liquid: PE / PP / PVDF

Accessories

- Cements / Primers: CPVC / PVC
- Cement Applicators: Daubers / Rollers / Swabs / Natural Hair Brushes
- Cutting / Beveling Tools: Band Saw / Miter Saw / Wheeled Pipe Cutter / Cone Beveller / Flat Beveller
- Expansion Joints: CPVC / PVC / Bellows
- Flange Gaskets / O-rings: Neoprene / Buna / Viton / Teflon-envelope / Others
- Joining Tools: Fusion Equipment / Come-a-long / Strap Wrench / Grooving Equipment / Threader & Dies
- Nuts / Bolts / Washers: Metal and Plastic
- Pipe Hangers: All Types
- Thread Sealants: Teflon Tape & Approved Thread Sealant
- Welders / Welding Rod: Hand Held / All Rod Materials

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TIPS are...

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
Selecting the Proper Plastic Piping Material
Selecting the Proper Plastic Piping Material

To select the proper plastic piping material, conditions of service for the liquid to be handled and the suitability of the materials for those service conditions must be known. Listed is a summary and example of selecting the proper plastic piping material.

Service Conditions Check List

- Type Application
- Type Fluid(s)
- Working Pressure (min/max)
- Working Temperature (min/max)
- Velocity (max)
- Specific Gravity
- Viscosity
- Particulates
- Pipe Size Range
- Above- or Below-ground Installation
- Interior / Exterior Exposure
- Specific Code Agencies / Approvals
- Fluid-handling Products in Fluid Contact

TIPS Material Selection

- Chemical Compatibility
- Pressure/Temperature Capability
- Piping Size and Product Availability
- Piping System Joining Method
- Price Comparability

Example – Service Conditions

<table>
<thead>
<tr>
<th>Application:</th>
<th>Metal Ore Smelting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid:</td>
<td>Sulfuric Acid, 70% concentration</td>
</tr>
<tr>
<td>Working Pressure:</td>
<td>50-105 psi</td>
</tr>
<tr>
<td>Working Temperature:</td>
<td>70-130°F / 21-54°C</td>
</tr>
<tr>
<td>Velocity:</td>
<td>Less than 3 ft/sec</td>
</tr>
<tr>
<td>Specific Gravity:</td>
<td>1.57</td>
</tr>
<tr>
<td>Viscosity:</td>
<td>60 ssu</td>
</tr>
<tr>
<td>Particulates:</td>
<td>minimal</td>
</tr>
<tr>
<td>Piping Sizes:</td>
<td>½ - 6-inch</td>
</tr>
<tr>
<td>Installation:</td>
<td>Above ground</td>
</tr>
<tr>
<td>Exposure:</td>
<td>Interior</td>
</tr>
<tr>
<td>Code Agencies:</td>
<td>Standard</td>
</tr>
<tr>
<td>Required Fluid handling Equipment:</td>
<td>Pipe / Fitting / Valve / Pump</td>
</tr>
</tbody>
</table>

*Conditions depicted in bold are major selection criteria for this application.*
### Example – Chemical Compatibility

<table>
<thead>
<tr>
<th>Chemical</th>
<th>PVC</th>
<th>CPVC</th>
<th>PP</th>
<th>PVDF</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature (°F/°C)</strong></td>
<td>70/21</td>
<td>140/60</td>
<td>140/60</td>
<td>185/85</td>
<td>70/21</td>
</tr>
<tr>
<td>Sulfuric acid, 50% R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sulfuric acid, 60% R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sulfuric acid, 70% R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sulfuric acid, 80% R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sulfuric acid, 90% R</td>
<td>R</td>
<td>NR</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Sulfuric acid, 93% R</td>
<td>R</td>
<td>NR</td>
<td>R</td>
<td>R</td>
<td>NR</td>
</tr>
<tr>
<td>Sulfuric acid, 100% NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

R = Recommended  — = No information available  NR = Not Recommended

### Example – Pressure Capability

<table>
<thead>
<tr>
<th>Nominal Pipe Size (in.)</th>
<th>PVC / CPVC</th>
<th>PE (SDR 11)</th>
<th>PP</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>370</td>
<td>160</td>
<td>190</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>320</td>
<td>160</td>
<td>160</td>
<td>220</td>
</tr>
<tr>
<td>6</td>
<td>280</td>
<td>160</td>
<td>140</td>
<td>190</td>
</tr>
</tbody>
</table>

### Temperature Correction Factors for Piping

<table>
<thead>
<tr>
<th>Operating Temp. (°F/°C)</th>
<th>CPVC</th>
<th>PE</th>
<th>PP</th>
<th>PVC</th>
<th>PVDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>110/43</td>
<td>.77</td>
<td>.74</td>
<td>.80</td>
<td>.50</td>
<td>.75</td>
</tr>
<tr>
<td>120/49</td>
<td>.70</td>
<td>.63</td>
<td>.75</td>
<td>.40</td>
<td>.68</td>
</tr>
<tr>
<td>130/54</td>
<td>.62</td>
<td>.57</td>
<td>.68</td>
<td>.30</td>
<td>.62</td>
</tr>
</tbody>
</table>

✓ CPVC: 0.62(280) = 174 psi

✗ PVC: 0.30(280) = 84 psi

(System max. is 105 psi)

✓ PVDF: 0.62(190) = 118 psi

### Example – Product Availability and Joining System

CPVC and PVDF Availability: ✓

CPVC Joining System: Solvent Cementing

PVDF Joining System: Heat Fusion
Example – Cost Comparison

<table>
<thead>
<tr>
<th>Materials</th>
<th>Piping Costs ($)</th>
<th>Ratio CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC Sch. 80</td>
<td>11,499</td>
<td>0.50</td>
</tr>
<tr>
<td>CPVC Sch. 80</td>
<td>18,932</td>
<td>0.83</td>
</tr>
<tr>
<td>Carbon Steel Sch. 40</td>
<td>22,789</td>
<td>1.00</td>
</tr>
<tr>
<td>St. Steel 304L Sch. 40</td>
<td>45,835</td>
<td>2.01</td>
</tr>
<tr>
<td>Aluminum alloy 303 Sch. 40</td>
<td>48,134</td>
<td>2.11</td>
</tr>
<tr>
<td>St. Steel 316L Sch. 40</td>
<td>49,355</td>
<td>2.17</td>
</tr>
<tr>
<td>Copper</td>
<td>50,473</td>
<td>2.21</td>
</tr>
<tr>
<td>PVDF Sch. 80</td>
<td>63,945</td>
<td>2.81</td>
</tr>
<tr>
<td>Titanium Sch. 40</td>
<td>132,804</td>
<td>6.11</td>
</tr>
<tr>
<td>Alloy 200 Sch. 40</td>
<td>150,188</td>
<td>6.59</td>
</tr>
<tr>
<td>Zirconium Sch. 40</td>
<td>159,382</td>
<td>6.99</td>
</tr>
</tbody>
</table>

*Adapted from Chemical Processing, June 1999

Example – Results

Selected Material: CPVC

Example Addendum

- If sulfuric acid concentration were 93%, only PVDF would be selected.
- If sulfuric acid concentration were 60% and the maximum temperature were 120°F/49°C, both CPVC and PP would be considered.
- If maximum temperature did not exceed 110°F/43°C, both PE and PVC would be considered.

TIPS are...

- Durable
- Easy and safe to install
- Environmentally sound
- Cost-effective
Applications
**Acid/Chemical Waste Drainage**

- **Commonly Used Materials:** CPVC / PE / PP / PVDF
- **Process Piping:** Waste / Drain / Vent / Neutralization / Double Containment

**Air and Fume Pollution Control**

- **Commonly Used Materials:** All
- **Process Piping:** Cooling & Washing Tower / Absorption Tower / Sulfuric Acid Mist Elimination / Waste Liquor / Waste Lye / Neutralization / Calcium Sulfate / Cleaning Agent / Absorbed Liquid Thickener/Ducting/Scrubbers and Packing
Amusement / Theme Parks

- **Commonly Used Materials:** CPVC / PE / PVC
- **Process Piping:** Water Rides / Fountains / Water Supply & Waste Water Treatment

Aquariums

- **Commonly Used Materials:** CPVC / PVC / PE (ABS & PE include specially formulated compounds for compressed air)
- **Process Piping:** Fresh Water / Salt Water / Aeration

Plastic is the preferred piping material in most aquariums.
Chemical Process

- **Commonly Used Materials:** All
- **Process Piping:** Most Chemically Compatible Process Piping below 275°F/135°C and 150 psi / Waste & Water Treatment / Air Pollution / Double Containment

![CPVC Chemical Tank Piping Outdoors](image1)

![Packaged De-ionized Water System](image2)

![PP Chemical Process Piping](image3)

![CPVC Chemical Process Piping](image4)

Chlor-Alkali

- **Commonly Used Materials:** CPVC / PVC / PVDF
- **Process Piping:** Wet Chlorine / Sodium Hydroxide / Brine / Sulfuric Acid / Sodium Hypochlorite / Hydrochloric Acid / Demineralized & Deionized Water / Steam Condensate

![CPVC in Ion Membrane Process](image5)

![CPVC Chlorine Gas Scrubber](image6)

![CPVC with FRP Overwrap](image7)

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Commercial / Institutional

- **Commonly Used Materials**: All
- **Process Piping**: Large Diameter Hot Water / Drains / Neutralization Systems / Acid Waste Drainage / Hot and Cold Water Distribution

Compressed Air / Gases

- **Commonly Used Materials**: ABS / PE (specially formulated compounds)
  
  *(Note: Other thermoplastic piping is not suitable for compressed air/gases.)*
- **Piping**: All piping 24 inches from the compressed air storage source to the air tool
Desalination

- **Commonly Used Materials**: All
- **Process Piping**: Seawater Water Intake & Outlet / Fresh Water / Reverse Osmosis / Electro-dialysis / Concentrated Salt Water

![Electro-dialysis Desalination Plastic Piping](image1)

![Reverse Osmosis Desalination Plastic Piping](image2)

Double Containment

- **Commonly Used Materials**: All
- **Process Piping**: Prevents any harmful fluids from harming the environment and/or personnel. Systems can include various combinations of plastic and metal carrier and containment piping.

![PP Double Containment Piping Products](image3)

![PVC Stainless Steel Double Contained Piping Systems](image4)

Electronics / Semiconductors

- **Commonly Used Materials**: CPVC / PP / PVC / PVDF
- **Process Piping**: Deionized Water / Etching Solutions / Plating Solutions / High & Ultra High Purity Water / Water & Waste Treatment / Acid Drain / Air Pollution Control / Double Containment
Environmental Protection (Land Fills / Toxic Waste)

- **Commonly Used Materials**: All
- **Process Piping**: Methane Release / Double Containment / Acid Accumulation / Pond Liners / Odor Control / Zebra Mussel Treatment / Landfill Leachate / Reclaimed Water

- Circuit Board Production Using PVC & CPVC Plastic Piping
- PVDF High Purity Water Piping System in Semiconductor Plant
- PP Work Station for Semiconductor Processing
- PVC Piping for Gray-water Usage
- PE Double Containment Tanking
- 72" PE Fabricated Man-hole for Landfill
- PE & PVC Odor Control Piping in Landfill
Fire Sprinkler Systems

- **Commonly Used Materials**: CPVC/PEX
- **Process Piping**: Use in residential and commercial applications. Installations are available in either stand-alone or multipurpose systems

![CPVC Fire Sprinkler System](image1)

![PEX Fire Sprinkler System](image2)

Fire Water Mains (Industrial)

- **Commonly Used Materials**: PE / PVC
- **Process Piping**: Buried Fire Water Mains for Plant Perimeter / Dry Systems

![PVC Piping for Fire Hydrant & Drinking Water in Marine Operation](image3)

![PE Piping in Underground Industrial Fire Hydrant System](image4)

![PVC Dry Fire Hydrant System](image5)
Fish Hatcheries / Farms

- **Commonly Used Materials**: PE / PVC
- **Process Piping**: Fresh Water / Salt Water / Feed / Circulation

Food / Beverage

- **Commonly Used Materials**: ABS / CPVC / PP / PVC / PVDF
- **Process Piping**: Brine / Vinegar / Auxiliary Water / Air / Chemical Bleaching / Citrus Acid / Low-temperature Process / Corn Syrup / Hot Corn Liquors / Acidic Juices / Hot Sauce
Geothermal Energy

- **Commonly Used Materials**: CPVC / PE / PVC
- **Process Piping**: Well Water / Transmission / Injection / Reinjection

![Binary Geothermal Plant](image1)

![Geothermal Plant Using PE Piping](image2)

Closed PE Loop Geothermal System

PE Loops in Geothermal System

Heavy Construction

- **Commonly Used Materials**: CPVC / PE / PVC
- **Process Piping**: Bridge & Overhead / Drains / Dewatering / Dredging / Temporary Bypass Pumping

![PVC Mechanical Piping for Emergency Flooding Relief](image3)

![Slip Lining of Concrete Piping with PE](image4)

![Trenchless Insulation of PE Piping](image5)

![Relining of Concrete Pipe with PE](image6)
Heating / Ventilating / Air Conditioning (HVAC)

- **Commonly Used Materials**: ABS / CPVC / PE / PVC
- **Process Piping**: Chilled Water / Condenser Water / Condensate Return / Solar

Marine

- **Commonly Used Materials**: CPVC / PE / PP / PVC
- **Process Piping**: Salt Water / Air Lines / Refrigeration / Fresh Water Supply

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Mining

- **Commonly Used Materials**: All
- **Process Piping**: Slurries / Leaching / Air Pollution / Acids / Chemical Mineral Extraction / Decant / Tailings / Impoundment / Water Supply

![](PE_Piping_for_Tailings_in_Copper_Mine.png)

PE Piping for Tailings in Copper Mine

![](CPVC_Used_in_Smelting_Operation.png)

CPVC Used in Smelting Operation

![](PE_De-watering_Lines.png)

PE De-watering Lines

Oil / Gas Gathering

- **Commonly Used Materials**: PE / PVC
- **Process Piping**: Natural Gas Gathering / Water Flooding / Supply Water / Main Lines / Crude Oil Flow / Saltwater Disposal / Fuel Transfer / Natural Gas Distribution

![](PE_Piping_for_Oil_&_Natural_Gas_Collection.png)

PE Piping for Oil & Natural Gas Collection

![](56"OD_x_4"_Thick_PE_Pipe_for_Handling_Crude_Oil.png)

56"OD x 4" Thick PE Pipe for Handling Crude Oil

![](Multiple_Uses_for_Plastic_Piping_in_Off-shore_Rigs.png)

Multiple Uses for Plastic Piping in Off-shore Rigs
Original Equipment Manufacturing (OEM)

- **Commonly Used Materials**: All
- **Process Piping**: Desalination Units / Pure Water Units / Paper Process Machines / Laboratory Work Bench Stations / Pump & Filtration Units / Deionized Water Units / Many Others

Pharmaceutical

- **Commonly Used Materials**: CPVC / PVC / PP / PVDF
- **Process Piping**: Process / QC Lab / Production Water / Equipment Cleaning Water / Waste & Water Treatment / Double Containment
Power Plants

- **Commonly Used Materials**: CPVC / PE / PVC
- **Process Piping**: Intake / Cooling / Condenser / Water Treatment / Fly Ash / Bottom Ash

Pulp / Paper

- **Commonly Used Materials**: All
Refrigeration

- **Commonly Used Materials**: ABS / PE / PVC
- **Process Piping**: Brine / Recirculation / Ice-making / Ethylene Glycol / Secondary Cooling / Condensate Drains

Steel Processing

- **Commonly Used Materials**: All
- **Process Piping**: Coke / Galvanizing / Pickling / Tin / Wire Drawing / Waste & Water Treatment / Air Pollution / Double Containment
Surface Finishing / Plating

- **Commonly Used Materials**: CPVC / PP / PVC / PVDF
- **Process Piping**: Transfer Feed / Rinse / Brass, Cadmium, Chrome, Copper, Gold, Lead, Nickel, Rhodium, Silver, Tin and Zinc Salt Plating Solutions / Waste & Water Treatment / Air Pollution Control / Double Containment / Galvanizing

Swimming Pools (Municipal / School)

- **Commonly Used Materials**: PE / PVC
- **Process Piping**: Filtration / Backwash / Main Drain / Chlorine / Inflow / Outflow
**Water / Waste Treatment**

- **Commonly Used Materials:** All
- **Process Piping:** Chemical Feed / Batch Treatment Neutralization / Filter Press / VOC Removal / Diatomaceous Earth Cleaning / Waste Water / Neutralized Water / Clean Water

**TIPS are...**

- **Durable**
- **Easy and safe to install**
- **Environmentally sound**
- **Cost-effective**
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