Plastic Pressure Piping Materials for Plumbing & Mechanical Applications

A presentation by the Plastics Pipe Institute

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The Plastics Pipe Institute

**PPI Represents All Sectors of the Plastic Pipe Industry**
- PPI was formed in 1950 to develop test methods for plastic pressure pipes
- Today: Non-profit trade association serving North America

**PPI Mission:** To advance the acceptance and use of plastic pipe systems through research, education, technical expertise and advocacy

**Members:** PPI members share a common interest in broadening awareness and creating opportunities that expand market share and extend the use of plastics pipe in all of its many applications

**2020:** Over 170 members firms involved with the plastic pipe industry around the world

**Website:** [www.plasticpipe.org](http://www.plasticpipe.org)
The Plastics Pipe Institute

PPI Represents All Sectors of the Plastic Pipe Industry
- PPI’s five divisions focus on solutions for multiple applications:
  - Building & Construction Division (BCD)
  - Drainage
  - Energy Piping Systems
  - Municipal & Industrial
  - Power & Communications

BCD Materials: PEX, CPVC, PE-RT, PEX-AL-PEX, PP, HDPE (Geothermal)
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PPI’s Building & Construction Division (BCD)
BCD is focused on plastic pressure pipe and tubing systems used within buildings and on building premises for applications such as plumbing, water service, fire protection, hydronic heating and cooling, snow and ice melting, district heating and cooling, and ground source geothermal piping systems.

BCD involvement with industry groups:
Course Introduction – Part I

Specifiers and designers of plumbing and mechanical systems have options when selecting the optimal pipe material for each application.

- Considerations include availability, cost, durability, convenience of handling and joining, safety for drinking water, and long-term reliability, which includes factors such as resistance to corrosion, mineral build-up, and disinfectants.

- Other selection factors include sound, vibration, and heat transfer.

- This course will demonstrate that there is an affordable and reliable plastic pressure pipe and fitting material for practically every plumbing and mechanical piping application.
Course Introduction – Part II

This course will also describe the proper use of plastic pressure pipe systems for various applications:

- Plumbing distribution (hot- and cold-water supply)
- Fire protection (sprinklers)
- Hydronic heating and cooling (including radiant heating & cooling)
- Snow & ice melting (for outdoor surfaces)
- Geothermal ground loops (geothermal)
- District heating applications (buried pipelines)
Course Introduction – Part III

This course will show how to access tools for plastic pipe systems:
- PPI Website
- Other industry websites
- Plastic Pressure Pipe Design Calculator www.plasticpipecalculator.com
Course Outline

By the end of this course, you will be able to:

1. Describe the piping materials CPVC, HDPE, PEX, PE-RT & PP in terms of material properties, capabilities, joining systems, applications, standards, and code compliance.

2. Indicate where and how to use these materials in applications such as plumbing distribution, fire protection, hydronic heating and cooling, snow & ice melting, geothermal ground loop, and district heating applications.

3. Discuss the design of piping materials in terms of sizing for flow, pressure loss, thermal expansion/contraction, etc. using a publicly-available software program.

4. Explain how to access industry resources related to selecting and specifying the right piping material(s) for various applications.
1. Plastic Pressure Piping Solutions

This Learning Objective will describe piping materials in terms of material properties, joining systems, applications, standards, and code compliance.

Prologue  Universal requirements
1.a CPVC  chlorinated polyvinyl chloride
1.b HDPE  high-density polyethylene
1.c PEX  crosslinked polyethylene
1.d PE-RT polyethylene of raised temperature resistance
1.e PP polypropylene
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Universal Requirements: Drinking Water Safety

- **All** plastic tubing, pipes and fittings intended for potable (drinking) water shall meet the requirements of **NSF/ANSI/CAN Standard 61 Toxicological Evaluation for Materials in Contact with Drinking Water (“Health Effects”)**

1.1 **Purpose** “This Standard establishes minimum health effects requirements for the chemical contaminants and impurities that are indirectly imparted to drinking water from products, components, and materials used in drinking water systems.”
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Universal Requirements: Lead-free components
- All plastic tubing, pipes and fittings intended for potable (drinking) water shall meet the requirements of NSF/ANSI Standard 372: Drinking Water System Components, Lead Content

1.1 Purpose “This Standard establishes procedures for the determination of lead content based on the wetted surface area of products.”

1.2 Scope “The standard applies to any drinking water system component that conveys or dispenses water for human consumption through drinking or cooking.”
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Universal Requirements: Dimension Ratios
- **Most** plastic pipe and tubing uses a *Standard Dimension Ratio (SDR)*
- *Standard Dimension Ratio* - the ratio of outside diameter to wall thickness, calculated by dividing the average outside diameter of the tubing by the minimum wall thickness
- Examples:
  - PEX tubing is **SDR 9** (wall thickness is 1/9 of the OD)
  - CPVC tubing is **SDR 11** (wall thickness is 1/11 of the OD)
- Within a *Standard Dimension Ratio*, each diameter of the pipe type has the same pressure capability & rating (e.g. ½, ¾, 1, 2, etc.)

*Exception: Pipes that follow **Schedule 40/80** dimension schemes*
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Universal Requirements: Design Factor / Safety Factor
- **All** plastic tubing, pipes and fittings have inherent safety factors for the intended applications based on prescribed Design Factors listed within product standards

- Pressure-Temperature ratings are based on an extrapolated time-to-failure prediction using a **0.50* Design Factor** on pressure
  - Actual capability is typically **2 times** the listed (i.e. labeled) pressure rating

- Plastic systems demonstrate Long-term Hydrostatic Strength (LTHS) through established test methods such as **ASTM D2837** and listings according to **PPI TR-3 Policies and Procedures for Developing Hydrostatic Design Basis (HDB) and Hydrostatic Design Stresses (HDS) for Thermoplastic Piping Materials**

*Certain HDPE materials utilize a 0.63 design factor*
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Universal Requirements: Flame and Smoke Ratings
- If plastic pipe is to be installed within a return air plenum that requires “non-combustible materials”, then the materials must demonstrate a flame spread rating ≤ 25 and a smoke spread rating ≤ 50

- These values are generated in standardized testing in accordance with ASTM E84 test method using the “Steiner Tunnel” test

- 2018 Uniform Mechanical Code requires ASTM E84 testing

- Details of fire-test chamber from UL 2846
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Universal Requirements: Flame and Smoke Ratings
- If plastic pipe is to be installed within a return air plenum that requires “non-combustible materials”, then the materials must demonstrate a peak optical density \( \leq 0.50 \), an average optical density \( \leq 0.15 \), and a flame spread distance not greater than \( 5 \) feet.

- These values are generated in standardized testing in accordance with UL 2846 test method using the “Steiner Tunnel” test.

- 2018 International Mechanical Code requires UL 2846 or ASTM E84 testing.

- Steiner Tunnel at UL LLC.
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Universal Benefits: Plastic Piping Systems are Sustainable and Safe
- No mining operations for the ore
- Lower cost to the environment for production
- Much lower energy cost to produce plastic as compared with metal pipes
- Smooth wall, excellent flow characteristics reduce pumping costs
- Flexibility can dampen water hammer, reducing pressure spikes
- Materials do not add minerals to drinking water, do not support biofilm growth
- Proven long life and durability provides value and reliability
- Light weight reduces transportation volume and costs
- Plastic systems protect health, safety & welfare!

- Steel pipe with corrosion and build-up
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1.a Chlorinated Polyvinyl Chloride: CPVC
- A high-temperature pressure piping system; up to 200°F (93°C)
- Introduced for potable plumbing in 1959
- Introduced for fire protection in 1985
- Also used for hydronic heating & cooling, industrial and process piping applications

Common types:
- CPVC 4120-05, CPVC 4120-06 (material designation codes)
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CPVC: Advantages
- Safety of potable water and long-term reliability
- Corrosion resistance, no mineral build-up
- Resistant to disinfectants chlorine and chloramines
- No flame used for joining; solvent cement or mechanical joints
- Ease of installation with professional appearance
- Universal compatibility of pipes/fittings
- Lightweight, easy to transport
- Lower installed cost than metal pipes
- No scrap value; avoid jobsite theft

Courtesy Lubrizol
Plastic Pressure Piping Solutions

**CPVC: Configurations**
- CPVC is provided in straight lengths
- Available in Copper Tube Size (CTS), Iron Pipe Size (IPS) – different ODs and IDs
- Fittings are molded in both CTS and IPS sizes
- Specific compounds for plumbing, hydronics and fire protection applications
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CPVC: Fittings/Joining
- CPVC pipe & fittings are joined via: i. Solvent Cement; ii. Grooved mechanical fittings

i. Solvent Cement joints use liquid cement that “welds” pipes to fittings for secure joints
- Available in nominal sizes from 1/2 in. to 12 in.
- Specific processes are described in material standards and installation manuals

Courtesy Lubrizol (x3)
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**CPVC: Fittings/Joining**
- CPVC pipe & fittings are joined via: i. Solvent Cement; ii. Grooved mechanical fittings

ii. Grooved mechanical fittings connect pipes to fittings, once pipe ends are prepared
- Specific processes are described in material standards and installation manuals

*Courtesy Victaulic x2*
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CPVC: Product Standards
- **ASTM D2846**: CTS tubing & fittings for potable water; sizes ¼ to 2 in. nominal
- **ASTM F437**: Schedule 80 Threaded CPVC fittings
- **ASTM F438**: Schedule 40 Socket-type CPVC fittings
- **ASTM F439**: Schedule 80 Socket-type CPVC fittings
- **ASTM F441**: Schedule 40 and 80 pipe sizes; sizes ¼ to 16 in. nominal
- **ASTM F442**: IPS pipe sizes; sizes ¼ to 12 in. nominal
- **ASTM F493**: Solvent Cements for CPVC pipe and fittings
- **CSA B137.5**: All sizing types; sizes ¼ to 12 in. nominal
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**CPVC: Properties**
- Product standards establish capabilities and test requirements, such as:
  - Materials
  - Workmanship
  - Dimensions and tolerances
  - Quick burst pressures
  - Long-term (sustained) pressure ratings
  - Thermocycling resistance
  - Solvent Cement and Adhesives
  - Test Methods
  - Marking requirements
  - More…
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CPVC: Short-term Burst Pressure
- Product standards have requirements for short-term burst pressure at 73°F (23°C)

- CPVC Pipe Minimum Requirements:
  - ASTM F442: 1,250 psi for SDR 11 wall thickness; 1,000 psi for SDR 13.5; etc.

<table>
<thead>
<tr>
<th>SDR</th>
<th>Minimum Burst Pressure^\text{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>psi</td>
</tr>
<tr>
<td>11</td>
<td>1250</td>
</tr>
<tr>
<td>13.5</td>
<td>1000</td>
</tr>
<tr>
<td>17</td>
<td>800</td>
</tr>
<tr>
<td>21</td>
<td>630</td>
</tr>
<tr>
<td>26</td>
<td>500</td>
</tr>
<tr>
<td>32.5</td>
<td>400</td>
</tr>
</tbody>
</table>

^\text{a} The fiber stress used to derive these test pressures is 6400 psi [44.1 MPa].
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CPVC: Long-term (Sustained) Pressure
- Product standards have requirements for long-term (sustained) pressure ratings:

- CPVC Tubing & Fitting Assembly, Minimum Requirements:
  - ASTM D2846: 364 psig at 180°F for SDR 11 wall thickness

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Test Duration</th>
<th>Water Bath</th>
<th>Air Bath</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6 min</td>
<td>521 psi [3590 kPa]</td>
<td>551 psi [3800 kPa]</td>
</tr>
<tr>
<td>B</td>
<td>4 h</td>
<td>364 psi [2510 kPa]</td>
<td>403 psi [2780 kPa]</td>
</tr>
</tbody>
</table>
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CPVC: Code Compliance
- **Plumbing**: CPVC pipe and fittings are listed within model codes such as the *International Plumbing Code (IPC)*, *Uniform Plumbing Code (UPC)*, and *National Standard Plumbing Code (NSPC)* for plumbing distribution.

- **Mechanical**: CPVC pipe and fittings are listed within model codes such as the *International Mechanical Code (IMC)*, *Uniform Mechanical Code (UMC)*, and *Uniform Solar, Hydronics, and Geothermal Code (USHGC)* for hydronic piping.
1.b High Density Polyethylene: HDPE
- A medium-temperature pressure piping system; up to 140°F (60°C)
- Introduced for potable water in the 1960s
- Bimodal materials introduced in the 2000s – third generation of HDPE
- Used for municipal water/sewer; geothermal ground loop pipes, low-temperature (chilled water) district cooling

Common types:
- PE 3608, PE 4710 (material designation codes)
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**HDPE: Advantages**
- Safety of potable water and long-term reliability
- Corrosion resistance, no mineral build-up
- Resistant to disinfectants chlorine and chloramines
- No flame used for joining; heat fusion or mechanical joints
- Lightweight, easy to transport
- Lower installed cost than metal pipes
- No scrap value; avoid jobsite theft
- Strong and tough material
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**HDPE: Configurations**
- HDPE tubing is available in coils or straight lengths, depending on the customer preference, the diameter, and the application
- HDPE tubing is Copper Tube Size (CTS); typical for water service
- HDPE pipe is Iron Pipe Size (IPS); typical for geothermal ground loops
- Typically black for long-term UV resistance

![Image of HDPE tubing and pipe](image_url)
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HDPE: Fittings/Joining
- HDPE connections are typically via heat fusion
  1. Butt fusion (pipe-to-pipe or fitting-to-fitting) joints according to ASTM Standard D3261
  2. Socket fusion (pipe-to-fitting) joints according to ASTM Standard D2683
  3. Electrofusion (pipe-to-fitting) joints according to ASTM Standard F1055
- Fusion joints shall be installed in accordance with ASTM Practice F2620
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HDPE: Fittings/Joining

- ASTM F2620 Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings
- First published in 2006, latest edition 2019

![Image of HDPE pipe and fittings](Image)

Courtesy McElroy
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**HDPE: Fittings/Joining**
- Geothermal U-bends can be fabricated from elbows, or
- Molded from the same polymer as the pipe material

**U-bend fabricated with butt-fused elbows**

**Molded HDPE U-bend already fused to pipe ends**

**Coil of HDPE pipe with U-bend**
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HDPE: Fittings/Joining
- Grooved mechanical fittings connect pipes to fittings
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HDPE: Code Compliance

- **Plumbing**: HDPE pipe and fittings are listed within model codes such as the *International Plumbing Code (IPC)*, *Uniform Plumbing Code (UPC)*, and *National Standard Plumbing Code (NSPC)* for water service pipes.

- **Mechanical**: HDPE pipe and fittings are listed within model codes such as the *International Mechanical Code (IMC)*, *Uniform Mechanical Code (UMC)*, and *Uniform Solar, Hydronics, and Geothermal Code (USHGC)* for hydronic piping.
1.c Crosslinked Polyethylene: PEX
- A flexible high-temperature pressure piping system; up to 200°F (93°C)
- Introduced for radiant heating in the early 1970s in Europe
- Introduced to USA and Canada in early 1980s for heating and plumbing
- Today, PEX tubing systems are used for water service lines, hot- and cold-water distribution, radiant heating and cooling, outdoor snow and ice melting, residential fire protection, geothermal ground loops, district heating & cooling, and other demanding applications

Common types:
- PEX 1006, PEX 3206, PEX 5106 (material designation codes*)

*For PEX, the 1st digit refers to chlorine resistance, the 2nd digit refers to UV resistance, and the 3rd and 4th digits refer to hydrostatic strength
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PEX: Formal Definition
- “Crosslinked Polyethylene is a polyethylene material which has undergone a change in molecular structure using a chemical or a physical process whereby the polymer chains are chemically linked.

Source: PPI Technical Note 17 “Crosslinked Polyethylene Pipe & Tubing”
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PEX: Advantages
- Safety of potable water and long-term reliability
- Corrosion resistance, no mineral build-up
- Resistant to disinfectants chlorine and chloramines
- No flame used for joining; compression-style fittings
- Ease of installation with professional appearance
- Noise and water hammer resistance
- Many fitting and joining options
- Lightweight, easy to transport
- Lower installed cost than metal pipes
- No scrap value; avoid jobsite theft

Courtesy Viega
Plastic Pressure Piping Solutions

PEX: Configurations
- PEX tubing is available in coils or straight lengths, depending on the customer preference, the diameter, and the application
- PEX tubing is Copper Tube Size (CTS); PEX pipe is Iron Pipe Size (IPS) or DN size
- PEX is available in natural, white, or colors such as red, white, blue, black, orange
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PEX: Oxygen Diffusion Barrier
- Oxygen (O₂) from the atmosphere can permeate or diffuse (pass through) the wall of plastic pipes and be absorbed into the heating system water
- Polyolefin materials (HDPE, PEX, PE-RT, PP, etc.) can allow oxygen to permeate
- This may cause corrosion of iron or steel components or certain aluminum heat exchangers (causes no harm to the tubing itself)

Solution:
- Certain PEX tubing has an oxygen diffusion barrier (layer) to resist permeation
- This oxygen diffusion barrier is required when pipes are used in most closed-loop hydronic systems with ferrous components
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PEX: Fittings/Joining
- There are several types of “compression” fittings designed for use with PEX tubing
- PEX fittings are produced from lead-free brass alloys and engineered polymers
- Lead-free brass alloy fittings are in compliance with latest SDWA
- Polysulfone (PLS) and polyphenylsulfone (PPSU) are thermoplastic polymers known for their toughness, stability at high temperatures, and chlorine resistance
- These are the typical polymers used for fittings and manifolds as part of PEX systems
- HDPE Electrofusion fittings can also be used with some PEX materials
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**ASTM F1807 Crimp ring fitting**
Available in lead-free brass

**ASTM F1807 copper crimp ring** (not to scale!)

**ASTM F2159 polymer crimp fitting**

**Typical Crimp ring fitting assembly tool**

**ASTM F1807 Crimp Assembly**
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ASTM F1960 Cold-expansion fitting using a PEX ring
Available in polymer and lead-free brass

Courtesy Uponor
Plastic Pressure Piping Solutions

**ASTM F3347/F3348 Press fittings using stainless steel sleeve.**
Available in polymer and lead-free brass.
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ASSE 1061 Push-fit fittings
Available in polymer and lead-free brass

Courtesy Reliance Worldwide Corp.
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**ASTM F1055 Electrofusion fitting**
Molded HDPE fitting with embedded wire
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PEX: Product Standards
- **ASTM F876**: CTS sizes; nominal diameters ¼ to 6 in.
- **ASTM F877**: CTS “systems” – fittings, manifolds, assemblies, etc.
- **ASTM F2788**: IPS sizes in nominal diameters 3 to 54 in.; DN sizes 16 to 1,000 mm
- **ASTM F3253**: CTS PEX tubing with oxygen diffusion barrier
- **CSA B137.5**: CTS sizes; nominal diameters ¼ to 6 in. (harmonized with F876)
- More than ten ASTM standards for various fitting designs
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PEX: Product Standards
- Product standards establish capabilities and test requirements, such as:
  - Materials
  - Workmanship
  - Dimensions and tolerances
  - Degree of Crosslinking
  - Quick burst pressures
  - Long-term (sustained) pressure ratings
  - Thermocycling resistance
  - Chlorine resistance
  - UV resistance
  - Excessive pressure-temperature capability
  - Hot-bend and cold-bend tests
  - Marking requirements
  - More…
PEX: Short-term Burst Pressure

- Product standards have requirements for short-term burst pressure

- **PEX Tubing & Fitting Assembly Minimum Requirements:**
  - **ASTM F876**: 475 psig at 73°F; 210 psig at 180°F (for tubing)
  - **ASTM F877**: 475 psig at 73°F; 210 psig at 180°F (for connections)

- Fittings/connections must have same capabilities as the tubing
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PEX: Long-term (Sustained) Pressure
- Product standards have requirements for long-term (sustained) pressure ratings:

- PEX Tubing & Fitting Assembly Minimum Requirements:
  - ASTM F876: 160 psig at 73°F, 100 psig at 180°F (for tubing)
  - ASTM F877: 160 psig at 73°F, 100 psig at 180°F (for connections)

- Fittings/connections must have same capabilities as the tubing
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PEX: Oxidative Resistance Testing
- All PEX intended for use with potable water must have a minimum extrapolated lifetime of **50 years** when tested in accordance with ASTM Test Method F2023

- **ASTM F2023 Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Chlorinated Hot Water**

- “Extrapolated time-to-failure” of tubing at each end-use condition (1, 3, 5) is calculated using Miner’s Rule formula based on end-use conditions of **80 psig @ 140°F**

- See PPI TN-53 *Guide to Chlorine Resistance Ratings*… for more information
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PEX: Code Compliance
- **Plumbing**: PEX pipe and fittings are listed within model codes such as the *International Plumbing Code (IPC)*, *Uniform Plumbing Code (UPC)*, and *National Standard Plumbing Code (NSPC)* for plumbing distribution

- **Mechanical**: PEX pipe and fittings are listed within model codes such as the *International Mechanical Code (IMC)*, *Uniform Mechanical Code (UMC)*, and *Uniform Solar, Hydronics, and Geothermal Code (USHGC)* for hydronic piping
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1.d Polyethylene of Raised Temperature: PE-RT
- A high-temperature flexible pressure piping system; up to 180°F (82°C)
- First used for warm-water radiant heating in the 1990s in Europe
- Introduced to North America in the 2000s
- Today, PE-RT systems are used for hot- and cold-water plumbing, water service lines, radiant heating and cooling, outdoor snow and ice melting, district heating & cooling, and other demanding applications

Courtesy Dow
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PE-RT: Advantages
- Safety of potable water and long-term reliability
- Corrosion resistance, no mineral build-up
- Resistant to disinfectants chlorine and chloramines
- No flame used for joining; compression-style fittings
- Ease of installation with professional appearance
- Noise and water hammer resistance
- Many fitting and joining options
- Lightweight, easy to transport
- Lower installed cost than metal pipes
- No scrap value; avoid jobsite theft
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**PE-RT: Configurations**
- PE-RT tubing is available in coils or straight lengths, depending on the customer preference, diameter, and the application
- **PE-RT tubing** is Copper Tube Size (CTS); **PE-RT pipe** is Iron Pipe Size (IPS)
- PE-RT is available in white or colors such as red, white, blue, black, orange
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PE-RT: Oxygen Diffusion Barrier
- Oxygen (O₂) from the atmosphere can permeate or diffuse (pass through) the wall of plastic pipes and be absorbed into the heating system water
- Polyolefin materials (HDPE, PEX, PE-RT, PP, etc.) can allow oxygen to permeate
- This may cause corrosion of iron or steel components or certain aluminum heat exchangers (causes no harm to the tubing itself)

Solution:
- Certain PE-RT tubing has an oxygen diffusion barrier (layer) to resist permeation
- This oxygen diffusion barrier is required when pipes are used in most closed-loop hydronic systems with ferrous components
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PE-RT: Fittings/Joining
- PE-RT tubing has same dimensions as PEX tubing, works with most of the same fittings
- PE-RT fittings are produced from lead-free brass alloys and engineered polymers
- Lead-free brass alloy fittings are in compliance with latest SDWA
- Polysulfone (PLS) and polyphenylsulfone (PPSU) are thermoplastic polymers known for their toughness, stability at high temperatures, and chlorine resistance
- These are the typical polymers used for fittings and manifolds as part of PE-RT systems
- PE-RT may also be joined using heat fusion or grooved mechanical fittings
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PE-RT: Fittings/Joining
- As an HDPE material, PE-RT pipe can also be joined using heat fusion (welding)
  - Butt fusion HDPE fittings
  - Socket fusion HDPE fittings
  - Electrofusion HDPE fittings
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PE-RT: Fittings/Joining
- PE-RT pipe is also available in large diameters for hydronic applications
- Can be joined using grooved mechanical fittings
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PE-RT: Product Standards
- ASTM F2623: CTS sizes; nominal diameters ¼ to 6 in. for hydronic applications
- ASTM F2769: CTS sizes; nominal diameters ¼ to 6 in for potable applications
- CSA B137.18: CTS sizes; nominal diameters ¼ to 6 in. (harmonized with F2769)
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PE-RT: Product Standards
- Product standards establish capabilities and test requirements, such as:
  - Materials
  - Workmanship
  - Dimensions and tolerances
  - Quick burst pressures
  - Long-term (sustained) pressure ratings
  - Thermocycling resistance
  - Excessive pressure-temperature capability
  - Hot-bend and cold-bend tests
  - Marking requirements
  - More…
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PE-RT: Short-term Burst Pressure
- Product standards have requirements for short-term burst pressure

- PE-RT Tubing & Fitting Assembly Minimum Requirements:
  - **ASTM F2623**: 475 psig at 73°F; 180 psig at 180°F (for hydronic systems)
  - **ASTM F2769**: 475 psig at 73°F; 265 psig at 180°F (for potable systems)

- Fittings/connections must have same capabilities as the tubing
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PE-RT: Long-term (Sustained) Pressure
- Product standards have requirements for long-term (sustained) pressure ratings:

- PE-RT Tubing & Fitting Assembly Minimum Requirements:
  - ASTM F2623: 325 psig at 73°F; 165 psig at 180°F (for hydronic systems)
  - ASTM F2769: 325 psig at 73°F; 190 psig at 180°F (for potable systems)

- Fittings/connections must have same capabilities as the tubing
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PE-RT: Oxidative Resistance Testing
- All PE-RT intended for use with potable water must have a minimum extrapolated lifetime of **50 years** when tested in accordance with **ASTM Test Method F2023**

- **ASTM F2023 Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Chlorinated Hot Water**

- “Extrapolated time-to-failure” of tubing at each end-use condition (1, 3, 5) is calculated using Miner’s Rule formula based on end-use conditions of **80 psig @ 140°F**
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PE-RT: Code Compliance
- **Plumbing**: PE-RT pipe and fittings are listed within model codes such as the *International Plumbing Code (IPC)*, *Uniform Plumbing Code (UPC)*, and *National Standard Plumbing Code (NSPC)* for plumbing distribution

- **Mechanical**: PE-RT pipe and fittings are listed within model codes such as the *International Mechanical Code (IMC)*, *Uniform Mechanical Code (UMC)*, and *Uniform Solar, Hydronics, and Geothermal Code (USHGC)* for hydronic piping
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1.e Polypropylene Pressure Pipes (PP)
- High-temperature rigid pressure piping systems; up to 180°F (82°C)
- First used in the 1970s in Europe for hydronic heating, then in the 1990s for plumbing
- Introduced to North America in the 2000s
- Two types or grades of PP material available: PP-R and PP-RCT
- PP pressure piping systems are used for hot- and cold-water plumbing, hydronic heating and cooling, industrial and food-grade piping and other demanding applications
- PP pipes also provide resistance to highly acidic and basic solutions
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**PP: Advantages**
- Safety of potable water and long-term reliability
- Corrosion resistance, no mineral build-up
- Resistant to disinfectants chlorine and chloramines
- Heat-fused or mechanical joints; no flame used for joining
- Ease of installation with professional appearance
- Lightweight, easy to transport
- Lower installed cost than metal pipes
- No scrap value; avoid jobsite theft
Plastic Pressure Piping Solutions

**PP: Configurations**
- PP is provided in straight lengths
- Available in Iron Pipe Size (IPS), multiple SDRs depending on pressure requirements
- Fittings are molded to match pipe sizes
- Solid wall pipe is used when thermal expansion/contraction is not a concern
- Fiber-core layer pipe is used when thermal expansion/contraction is a concern

*Solid wall pipe on far left and far right*

*Fiber-core layer pipe inside left and inside right*
Plastic Pressure Piping Solutions

**PP: Fittings/Joining**
- PP pipe & fittings are joined via: i. Heat fusion; ii. Electrofusion; iii. Grooved mechanical fittings

  i. **Heat Fusion joints** are “welded” under pressure to form continuous piping systems
  - Specific processes are described in material standards and installation manuals

*Courtesy McElroy*
Plastic Pressure Piping Solutions

**PP: Fittings/Joining**
- PP pipe & fittings are joined via: i. Heat fusion; ii. Electrofusion; iii. Grooved mechanical fittings

  ii. **Electrofusion joints** have embedded copper wires that heat the fitting, welding it to pipe ends; computerized machine controls the process
Plastic Pressure Piping Solutions

PP: Fittings/Joining
- PP pipe & fittings are joined via: i. Heat fusion; ii. Electrofusion; iii. Grooved mechanical fittings

ii. Grooved mechanical fittings connect pipes to fittings
Plastic Pressure Piping Solutions

PP: Product Standards
- **ASTM F2389**: IPS pipe & fittings; DN sizes 16 - 355 mm nominal (similar to ½ - 14 in.)
- **CSA B137.11**: All sizing types; sizes 3/8 - 28 in. nominal

*Courtesy Aquatherm*
Plastic Pressure Piping Solutions

PP: Properties
- Product standards establish capabilities and test requirements, such as:
  - Materials
  - Workmanship
  - Dimensions and tolerances
  - Quick burst pressures
  - Long-term (sustained) pressure ratings
  - Thermal stability
  - Oxidative stability
  - Thermocycling resistance
  - Test Methods
  - Marking requirements
  - More…
Plastic Pressure Piping Solutions

PP: Long-term (Sustained) Pressure
- Product standards have requirements for long-term (sustained) pressure ratings:
  - PP materials follow ISO methodology for long-term pressure ratings
  - See PPI TN-28 for details
Plastic Pressure Piping Solutions

PP: Long-term (Sustained) Pressure
- Product standards have requirements for long-term (sustained) pressure ratings:

- **PP Pipe, Minimum Requirements:**
  - **PP-R:** 2,320 psi Hoop stress at 68°F; 510 psi Hoop stress at 203°F
  - **PP-RCT:** 2,175 psi Hoop stress at 68°F; 551 psi Hoop stress at 203°F

**TABLE 11 Hydrostatic Test Conditions**

<table>
<thead>
<tr>
<th>Material</th>
<th>Hoop Stress, psi (MPa)</th>
<th>Temperature, °F (°C)</th>
<th>Time, h</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP-R</td>
<td>2320 (16.0)</td>
<td>68 (20)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>510 (3.5)</td>
<td>203 (95)</td>
<td>1000</td>
</tr>
<tr>
<td>PP-RCT</td>
<td>2175 (15.0)</td>
<td>68 (20)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>551 (3.8)</td>
<td>203 (95)</td>
<td>1000</td>
</tr>
</tbody>
</table>
Plastic Pressure Piping Solutions

PP: Compatibility with dissolved Copper
- PPI TN-57 *Proper Integration of Copper Tubing and Components with PP-R Piping Materials for Plumbing Applications*
- Improper or excessive flow rates within mixed-material plumbing systems that contain both copper materials (i.e. tubing, fittings, valves) combined with PP-R piping materials can result in premature failure of both the copper components and the PP-R materials, potentially resulting in plumbing system leaks
Plastic Pressure Piping Solutions

PP: Code Compliance
- **Plumbing**: PP pipe and fittings are listed within model codes such as the *International Plumbing Code (IPC)*, *Uniform Plumbing Code (UPC)*, and *National Standard Plumbing Code (NSPC)* for plumbing distribution.

- **Mechanical**: PP pipe and fittings are listed within model codes such as the *International Mechanical Code (IMC)*, *Uniform Mechanical Code (UMC)*, and *Uniform Solar, Hydronics, and Geothermal Code (USHGC)* for hydronic piping.
Plastic Pressure Piping Solutions

Summary: Piping materials in terms of material properties, joining systems, applications, standards, and code compliance

Prologue  Universal requirements
1.a CPVC  chlorinated polyvinyl chloride
1.b HDPE  high-density polyethylene
1.c PEX  crosslinked polyethylene
1.d PE-RT  polyethylene of raised temperature resistance
1.e PP  polypropylene
2. Plumbing & Mechanical Applications

This Learning Objective focuses on plastic pipes in applications:

2.a Plumbing distribution (hot- and cold-water supply)
2.b Fire protection (sprinklers)
2.c Hydronic heating and cooling (including radiant heating & cooling)
2.d Snow & ice melting (for outdoor surfaces)
2.e Geothermal ground loops (geothermal)
2.f District heating applications (buried pipelines)
Plumbing & Mechanical Applications

2.a Hot- and Cold-Water Plumbing Distribution
- PEX, PE-RT and CPVC are used for residential plumbing supply pipes
- CPVC, PEX and PP are commonly used in commercial applications
- Some systems use both flexible (PEX, PE-RT) and rigid (CPVC, PP) pipes

**System Benefits:**
- Plastic piping systems save costs and last longer
- Plastic pipes are corrosion-resistant, no build-up
- Pipes are quieter and transfer less heat
- Optimized designs can save water
  - Hot-water recirculation reduces waste
  - Design tools help to optimize flowrates
Plumbing & Mechanical Applications

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- Design tools help to optimize flowrates
Plumbing & Mechanical Applications

2.a Hot- and Cold-Water Plumbing Distribution

Case Study:
- High-rise residential towers, 300,000 ft²
- 78,000 feet of PEX tubing for hot- and cold-water plumbing distribution
- Corrosion-resistant
- Faster installation
- Reduced heat transfer
- Quieter
Plumbing & Mechanical Applications

2.b Fire Protection
- Piping materials CPVC and PEX have been listed for residential fire sprinkler systems since the 1980s and 1990s, respectively

- According to installation standard NFPA 13D, where the intent is to provide an affordable sprinkler system in homes while maintaining a high level of life safety, CPVC and PEX fire sprinkler systems that are listed to system standard UL 1821 are approved to supply water to fire sprinklers for one- and two-family dwellings

- UL 1821 is the system performance standard for plastic fire protection systems
2.b Fire Protection

- UL 1821 *Thermoplastic Sprinkler Pipe and Fittings for Fire Protection Service*

- 1.2 “Thermoplastic pipe and fittings covered by these requirements are intended for use in sprinkler systems in any of the following types of occupancies:
  a) Light hazard occupancies as defined in the Standard for Installation of Sprinkler Systems, NFPA 13;
  b) Residential occupancies as defined in the Standard for Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes, NFPA 13D; and
  c) Residential occupancies as defined in the Standard for Installation of Sprinkler Systems in Low-Rise Residential Occupancies, NFPA 13R.”
Plumbing & Mechanical Applications

2. b Fire Protection
- CPVC, when listed, can be used for NFPA 13D, NFPA 13R, and NFPA 13 light hazard fire protection applications built according to codes
- Each brand / pipe must be tested and third-party certified for FP applications

System Benefits:
- Plastic piping systems save costs and last longer
- Plastic pipes are corrosion-resistant, no build-up
- Plastic systems are joined without flame
- No hot-work permits required

Courtesy Lubrizol
2.b Fire Protection
- **CPVC**, when listed, can be used for **NFPA 13D**, **NFPA 13R**, and **NFPA 13 light hazard** fire protection applications built according to codes
- Each brand / pipe must be tested and third-party certified for FP applications

**System Benefits:**
- Plastic piping systems save costs and last longer
- Plastic pipes are corrosion-resistant, no build-up
- Plastic systems are joined without flame
  - No hot-work permits required

Courtesy Lubrizol
Plumbing & Mechanical Applications

2.b Fire Protection
- PEX is used for residential fire protection applications built according to NFPA 13D
- Each brand / pipe must be tested and third-party certified for FP applications

System Benefits:
- Plastic piping systems save costs and last longer
- Plastic pipes are corrosion-resistant, no build-up
- Plastic systems are joined without flame
  - No hot-work permits required
Plumbing & Mechanical Applications

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System Benefits:
- Plastic piping systems save costs and last longer
- Plastic pipes are corrosion-resistant, no build-up
- Plastic systems are joined without flame
  - No hot-work permits required
Plumbing & Mechanical Applications

2.b Fire Protection

Case Study:
- Dormitory retrofit, University of Notre Dame (IN)
- 750,000 ft² in 12 buildings
- 8,000 sprinkler heads
- Installed during winter & summer breaks, 7 months
- Chosen due to speed, no hot work, resistance to corrosion and MIC
Plumbing & Mechanical Applications

2.c Hydronic Heating & Cooling
- Water (R718) is the optimal heat transfer medium or fluid
- Typical hydronic systems actually outperform VRF (variable refrigerant flow) systems by 30 to 40 percent thanks mainly to lower pumping costs
- Hydronic distribution systems do not distribute refrigerants throughout buildings
Plumbing & Mechanical Applications

2.c Hydronic Heating & Cooling
- All plastic piping materials in this presentation are suitable for hydronic heating & cooling distribution throughout buildings

Courtesy Uponor x 4
Plumbing & Mechanical Applications

2.c Hydronic Heating & Cooling
- The chart below compares the energy used by various systems to distribute heating or cooling capacity throughout a building
- Source: HIA-C
- [www.iapmo.org/hiac](http://www.iapmo.org/hiac)
Plumbing & Mechanical Applications

2.c Hydronic Heating & Cooling
- Information from DOD on VRF systems
- Source: HIA-C

1. For Air Force facilities, do not use VRF systems.
2. For Army facilities, VRF systems are strongly discouraged.
3. For Navy facilities, request for approval from the Facilities Engineering Command (FEC) for the use of VRF systems.
Plumbing & Mechanical Applications

2.c Hydronic Heating & Cooling
- Information from DOD on VRF systems
- Source: HIA-C

---

**ENGINEERING AND CONSTRUCTION BULLETIN**

**No.** 2017-7  
**Issuing Office:** CECW-CE  
**Issued:** 22 Mar 17  
**Expires:** 22 Mar 19

**SUBJECT:** Changes to UFC 3-410-01, Heating, Ventilating and Air Conditioning Systems, with Change 3

**CATEGORY:** Directive and Guidance

**REFERENCES:**

a. Unified Facilities Criteria (UFC) 3-410-02, Lonworks® Direct Digital Control for HVAC and other Local Building Systems, with Change 1

b. Unified Facilities Criteria (UFC) 3-410-01, Heating, Ventilating and Air Conditioning Systems, with Change 3

1. The following changes to the HVAC Systems UFC were recently completed.

2. A paragraph on Variable Refrigerant Flow (VRF) Systems has been added to the HVAC Systems UFC (Par 3-5.16). VRF Systems will no longer be permitted in Air Force facilities. The Army will allow VRF Systems; however, they will be strongly discouraged. The Navy is not restricting VRF systems as long as they comply with ASHRAE 15 Safety Standard for Refrigeration Systems.
Plumbing & Mechanical Applications

2.c Hydronic Radiant Heating, Radiant Heating & Cooling
- PEX or PE-RT tubing is typically embedded in floors, walls or ceilings
- Heated or chilled water is circulated through the tubing for energy transfer
- The most comfortable and efficient method to heat or cool any space

System Benefits:
- Improved thermal comfort, silent
- Architectural freedom, invisible
- Energy flexibility, controllability
- Reduced temperature stratification
- Higher overall system efficiency
- Radiant systems help to achieve compliance with ASHRAE Standard 55

*Thermal Conditions for Human Occupancy*

Courtesy REHAU
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Thermal Conditions for Human Occupancy
Plumbing & Mechanical Applications

2.c Hydronic Radiant Heating, Radiant Heating & Cooling
- In cooling mode, radiant surfaces are regulated, temperatures stay above the dew point
- Radiant designers are well aware of how to design and control these systems

Case Study:
- San Francisco Pier 15 Exploratorium
- 330,000 ft², Net-Zero, LEED® Gold
- 200,000 feet of PEX tubing embedded in concrete floor
- System operates in radiant heating or radiant cooling mode
2.d Snow and Ice Melting (SIM)
- SIM systems augment the removal of snow and ice by circulating a heat transfer fluid through plastic pipes

System Benefits:
- Convenience
- Increased safety and reduced liability
- Minimized environmental impact
- Lower operating costs
- Long-lasting reliability
Plumbing & Mechanical Applications

2.d Snow and Ice Melting (SIM)
- PEX or PE-RT tubing is embedded in or below outdoor surfaces
- Outdoor moisture sensors can detect when operation is needed
- Heated antifreeze (glycol + water) is circulated through the tubing for energy transfer

Courtesy REHAU x3
Plumbing & Mechanical Applications

2.d Snow and Ice Melting (SIM)
- Typical applications (residential, commercial, institutional, industrial)
  - Sidewalks
  - Steps
  - Pool decks
  - Driveways
  - Ramps
  - Roads
  - Parking garages
  - Train stations
  - Hangers
  - Aviation surfaces
2.d Snow and Ice Melting (SIM)
- ASHRAE HVAC Applications “Ch. 51 Snow Melting and Freeze Protection” provides guidance to designers

## Table 1  Frequencies of Snow-Melting Surface Heat Fluxes at Steady-State Conditions

<table>
<thead>
<tr>
<th>Location</th>
<th>Snowfall Hours per Year</th>
<th>Snow-Free Area Ratio, $A_r$</th>
<th>75%</th>
<th>90%</th>
<th>95%</th>
<th>98%</th>
<th>99%</th>
<th>100%</th>
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<tr>
<td>Albany, NY</td>
<td>156</td>
<td>1</td>
<td>89</td>
<td>125</td>
<td>149</td>
<td>187</td>
<td>212</td>
<td>321</td>
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<td>0.5</td>
<td>60</td>
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<td>138</td>
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<td>276</td>
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<td>Albuquerque, NM</td>
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<td>61</td>
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<td>Amarillo, TX</td>
<td>64</td>
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<td>113</td>
<td>150</td>
<td>168</td>
<td>212</td>
<td>228</td>
<td>318</td>
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<td>71</td>
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<td>62</td>
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<td>Billings, MT</td>
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<td>Bismarck, ND</td>
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<td>30</td>
<td>39</td>
<td>60</td>
<td>73</td>
<td>180</td>
</tr>
</tbody>
</table>

*Source: 2015 ASHRAE Handbook—HVAC Applications*
Plumbing & Mechanical Applications

2.d Snow and Ice Melting (SIM)
- Operating costs are often 50% less expensive (or better) than typical contracting costs for mechanical snow removal, plus frequent sanding and salting (and the inconvenience and cost of snow banks left behind)
- Plus, the SIM system is automatic and is always on time

- Example: National Museum of the American Indian, Washington, DC
Plumbing & Mechanical Applications

2.d Snow and Ice Melting (SIM)
- Operating costs are often 50% less expensive (or better) than typical contracting costs for mechanical snow removal, plus frequent sanding and salting

Case Study:
- Solara development, Vail, Co
- 60,000 ft² of outdoor surfaces melted
- 200,000 feet of PEX tubing installed outdoors
- Sidewalks, steps, street, parking areas
- Multiple sensors, multiple zones
Plumbing & Mechanical Applications

2.e Ground Source Geothermal
- Ground source heat pumps are the most efficient source of heating and cooling energy for any type of building (vs. VRF, boilers, chillers, etc.)
- HDPE, PEX, PE-RT and PP piping materials are used for ground loop piping

System Benefits:
- Systems exchange heat with the Earth (“geoexchange”)
- Geothermal heat pumps can have efficiencies (COP) greater than 450% when operating in heating mode
- Heat is rejected to the earth when cooling (high EER)
- Heat pumps are indoors, out of sight, no noise
- Low operating costs, high reliability, economical
Plumbing & Mechanical Applications

2.e Ground Source Geothermal

- Ground source heat pumps are the most efficient source of heating and cooling energy for any type of building (vs. VRF, boilers, chillers, etc.)

- HDPE, PEX, PE-RT and PP piping materials are used for ground loop piping
Plumbing & Mechanical Applications

2.6 District Heating & Cooling Pipelines
- For transferring heated or chilled fluids from one location to another, buried pipelines of plastic piping materials are often ideal.
- **HDPE, PEX, PE-RT** and PP piping materials are used for district heating & cooling energy transfer pipelines.

**System Benefits:**
- Lower costs, faster installation, no corrosion
- With pre-insulated pipes, insulation is factory-made, watertight, and consistent in R-value
- Flexible pre-insulated pipes install in long lengths with fewer joints, faster installation
Plumbing & Mechanical Applications

2.f District Heating & Cooling Pipelines
- See ASTM F2165-19 Standard Specification for Flexible Pre-insulated Plastic Piping

Designation: F2165 – 19

Standard Specification for Flexible Pre-Insulated Plastic Piping

This standard is issued under the fixed designation F2165; the number immediately following the designation indicates the year of original adoption; i.e., in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superceding edition (â) indicates an editorial change since the last revision or reapproval.

1. Scope
1.1 This specification covers flexible, pre-insulated plastic piping systems commonly used to convey hot and cold fluids, including piping systems that are supplied complete with plastic carrier pipe, thermal insulation, and outer jacket manufactured as an integrated system, and are supplied in a coil or as a straight length. Both bonded and non-bonded insulation types are included. Included are requirements and test methods for material, workmanship, dimensions, and end seal testing. Requirements for markings are also given. The components covered by this specification are intended for use in, but not limited to, residential and commercial, hot- and cold-potable water distribution systems, reclaimed water, fire protection, municipal water service lines, radiant heating and cooling systems, hydronic distribution systems, snow and ice melting

2. Referenced Documents
2.1 ASTM Standards:
C168 Terminology Relating to Thermal Insulation
Plumbing & Mechanical Applications

2.f District Heating & Cooling Pipelines
- HDPE, PEX, PE-RT and PP piping materials are used for district heating & cooling energy transfer pipelines

Case Study:
- Four Seasons Resort, Napa Valley, CA
- 5,000 feet HDPE in sizes 2 in. to 8 in.
- Grooved mechanical connections

Case Study: Four Seasons Resort, Napa Valley, CA
5,000 feet HDPE in sizes 2 in. to 8 in. Grooved mechanical connections

Courtesy Victaulic
Plumbing & Mechanical Applications

Summary: Plastic pipes are used in multiple applications

2.a Plumbing distribution (hot- and cold-water supply)
2.b Fire protection (sprinklers)
2.c Hydronic heating and cooling (including radiant heating & cooling)
2.d Snow & ice melting (for outdoor surfaces)
2.e Geothermal ground loops (geothermal)
2.f District heating applications (buried pipelines)
3. Design of Plastic Piping Systems

This Learning Objective will show tools for sizing and designing systems

3.a Sizing pipes for flow rates / calculating pressure loss (head loss)
3.b Addressing hydraulic shock to prevent pressure surges
3.c Determining pipe weights and volumes (empty and full)
3.d Predicting longitudinal thermal expansion / contraction
3.e Sizing expansion arms & legs (for thermal expansion)
Design of Plastic Piping Systems

3.a Sizing pipes for flow rates / calculating pressure loss (head loss)
- Sizing pipe seems easy enough – make it large enough to carry the required fluid

- Priority #1: Keep friction low to reduce pumping costs
- Priority #2: Do not exceed allowable velocities (noise, vibration, erosion)
- Priority #3: Keep fluid moving fast enough to prevent stagnation of water, mineral build-up, possible biofilm growth (plumbing)
Design of Plastic Piping Systems

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- Priority #3: Keep fluid moving fast enough to prevent stagnation of water, mineral build-up, possible biofilm growth (plumbing)
- Priority #4: Keep fluid moving fast enough to have turbulent flow for heat transfer (where heat transfer through the pipe wall is needed; e.g. radiant piping, geothermal)
- Priority #5: Cost (material and labor), space
Design of Plastic Piping Systems

3.a Sizing pipes for flow rates / calculating pressure loss (head loss)
- In reality, designers of hydronic heating/cooling, geothermal and other piping systems need to know several factors to make good decisions for sizing pipes:

1. Required flow rate (GPM)
2. Specific fluid type (water or glycol mix)
3. Fluid temperature (affects viscosity)
4. Pipe length and associated fittings
5. Pipe type and inside diameter
6. Fluid chemistry, etc.

Note: Certain data is still being added to BCD Calculator
Final updates going live in 2020
Design of Plastic Piping Systems

3.a  Sizing pipes for flow rates / calculating pressure loss (head loss)
- Plastic Pressure Pipe Design Calculator www.plasticpipecalculator.com
- Data for all types of plastic pressure pipes

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Head loss calculation with PEX tubing nominal size 2
Design of Plastic Piping Systems

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- Data for all types of plastic pressure pipes

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Head loss calculation with PEX tubing nominal size 2

<table>
<thead>
<tr>
<th>Flow Rate:</th>
<th>33 USGPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Pipe:</td>
<td>99 ft</td>
</tr>
<tr>
<td>Fluid Type (Water or % Glycol):</td>
<td>100% Water</td>
</tr>
<tr>
<td>Average Fluid Temperature*:</td>
<td>73 °F</td>
</tr>
</tbody>
</table>

*This calculation uses the Darcy Weisbach equation which includes temperature as a variable. As a result, tables using the Hazen-Williams equation with a standard temperature may show different results.
Design of Plastic Piping Systems

3.a Sizing pipes for flow rates / calculating pressure loss (head loss)
- Plastic Pressure Pipe Design Calculator www.plasticpipecalculator.com
- Data for all types of plastic pressure pipes

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Head loss calculation with PEX tubing nominal size 2

<table>
<thead>
<tr>
<th>Results</th>
<th>Turbulent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Drop</td>
<td>2.5 Psi (17.3 kPa)</td>
</tr>
<tr>
<td>Head Loss</td>
<td>5.8 ft water</td>
</tr>
<tr>
<td>Velocity*</td>
<td>5.1 ft/s (1.5 m/s)</td>
</tr>
</tbody>
</table>

* Values shown above are not an indication that the flow velocity is acceptable for your application. Always refer to and follow the pipe manufacturers recommended velocity limits.
Design of Plastic Piping Systems

3.b Addressing hydraulic shock (surge pressures)
- NAHB report “Surge Pressure in Plumbing Pipe Materials”
- Plastic pipes can significantly reduce surge pressures & water hammer

Figure 7: Comparison of Piping Pressure Response to Quick-Acting Valve with Cold Water Flows
3.b Addressing hydraulic shock (surge pressures)
- NAHB report “Surge Pressure in Plumbing Pipe Materials”
- Plastic pipes can significantly reduce surge pressures & water hammer

### Table 3: Peak Pressure Comparison – 2.5 GPM Cold Water Flow, 54°F Water
(See Figure 4b)

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Peak 1 (psig)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>½” Type L Copper</td>
<td>239</td>
<td>0</td>
</tr>
<tr>
<td>½” CPVC</td>
<td>173</td>
<td>28</td>
</tr>
<tr>
<td>½” PEX-1</td>
<td>168</td>
<td>30</td>
</tr>
<tr>
<td>½” PEX-2</td>
<td>150</td>
<td>37</td>
</tr>
</tbody>
</table>

### Table 4: Peak Pressure Comparison – 2.5 GPM Hot Water Flow, 130°F Water
(see Figure 5b)

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Peak 1 (psig)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>½” Type L Copper</td>
<td>181</td>
<td>0</td>
</tr>
<tr>
<td>½” CPVC</td>
<td>149</td>
<td>18</td>
</tr>
<tr>
<td>½” PEX-1</td>
<td>113</td>
<td>38</td>
</tr>
<tr>
<td>½” PEX-2</td>
<td>109</td>
<td>40</td>
</tr>
</tbody>
</table>
Design of Plastic Piping Systems

3.b Addressing hydraulic shock (surge pressures)
- NAHB report “Surge Pressure in Plumbing Pipe Materials”
- Plastic pipes can significantly reduce surge pressures & water hammer

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Hydraulic shock calculation with CPVC pipe nominal size 12
3.b Addressing hydraulic shock (surge pressures)
- NAHB report “Surge Pressure in Plumbing Pipe Materials”
- Plastic pipes can significantly reduce surge pressures & water hammer

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Hydraulic shock calculation with CPVC pipe nominal size 12
3.c Determining pipe weights and volumes (empty and full)
- Data is necessary when selecting glycol, for instance
- Data for all types of plastic pressure pipes

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

*Example: Pipe weight/volume calculation with CPVC pipe nominal size 4*
Design of Plastic Piping Systems

3.c Determining pipe weights and volumes (empty and full)
- Data is necessary when selecting glycol, for instance
- Data for all types of plastic pressure pipes

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Pipe weight/volume with CPVC pipe nominal size 4

<table>
<thead>
<tr>
<th></th>
<th>Dry Weight:</th>
<th>Filled Weight:</th>
<th>Volume Of Fluid In Pipe:</th>
<th>Volume Of Mixture Fluid:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>372.3 lb</td>
<td>820.1 lb</td>
<td>53.9 US Gallons</td>
<td>0.0 US Gallons</td>
</tr>
<tr>
<td></td>
<td>168.9 kg</td>
<td>372.0 kg</td>
<td>203.8 L</td>
<td>0.0 L</td>
</tr>
</tbody>
</table>
3.d Longitudinal thermal expansion/contraction
- Longitudinal thermal expansion/contraction is higher for plastics than metals
- This is accommodated in proper design

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Thermal expansion/contraction calculation with PP pipe nominal size 75
Design of Plastic Piping Systems

3.d Longitudinal thermal expansion/contraction
- Longitudinal thermal expansion/contraction is higher for plastics than metals
- This is accommodated in proper design

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Thermal expansion/contraction calculation with PP pipe nominal size 75

| Initial Temperature: | 70 °F |
| Final Temperature:   | 140 °F |
| Length of Pipe:      | 100 ft |

Results

| Length of Tube Expansion: | 1.6 in | 41 mm |

Calculation Details
3.e Sizing expansion arms & legs
- Longitudinal thermal expansion/contraction is higher for plastics than metals
- This is accommodated in proper design

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Expansion arm design with PEX pipe nominal size 6

<table>
<thead>
<tr>
<th>Expansion Arm/Loop Design</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion Type: Arm Loop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is this a Geothermal Application?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe/Tubing Selection¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe/Tubing Material: PEX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sizing Type (CTS/IPS/Metric): IPS (ASTM F2788)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall Type (SDR/Schedule): SDR 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal Pipe/Tubing Size²: 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Design of Plastic Piping Systems

3.e Sizing expansion arms & legs
- Longitudinal thermal expansion/contraction is higher for plastics than metals
- This is accommodated in proper design

Five Sets of Functions:
- Pressure/Head Loss
- Hydraulic Shock
- Pipe Weight/Volume
- Thermal Expansion/Contraction
- Expansion Arm/Loop Design

Example: Expansion arm design with PEX pipe nominal size 6
Design of Plastic Piping Systems

Summary: Tools to assist with sizing and designing

3.a Sizing pipes for flow rates / calculating pressure loss (head loss)
3.b Addressing hydraulic shock to prevent pressure surges
3.c Determining pipe weights and volumes (empty and full)
3.d Predicting longitudinal thermal expansion / contraction
3.e Sizing expansion arms & legs (for thermal expansion)
4. Industry Resources

This Learning Objective will suggest industry resources to assist with selecting & specifying pipes and systems

4.a HIA-C
4.b IGSHPA
4.c RPA
4.d PPI
Industry Resources

4.a Hydronics Industry Alliance-Commercial (HIA-C)

- “The Hydronic Industry Alliance-Commercial (HIA-C) is a non-profit alliance of hydronic equipment manufacturers and partners operating in North America.”
- “Operating under the principle that water is the most efficient and greenest energy transfer medium on the planet, the alliance serves as a resource within the HVAC and Service Water Heating industry.”

Water: THE NATURAL CHOICE

The Most Comfortable HVAC System
The Most Efficient HVAC System
Safe and Sustainable

best

Before you build, learn what the Department of Defense, building owners, and others have learned through their experience with VRF systems.

VRF REJECTED
Industry Resources

4.a Hydronics Industry Alliance-Commercial (HIA-C)

- Building Efficiency System Tool (BEST) for commercial system HVAC design
- “BEST provides annual energy consumption and lifecycle cost comparisons, based on actual system performance data, for your building’s HVAC system in just minutes!
- “BEST uses AHRI-certified performance data and building energy efficiency ratings to model the HVAC system as it will operate in real life – not the test lab.”
Industry Resources

4.a Hydronics Industry Alliance-Commercial (HIA-C)

- **Building Efficiency System Tool (BEST)** for commercial system HVAC design
- [www.iapmo.org/hiac](http://www.iapmo.org/hiac)
Industry Resources

4.b International Ground Source Heat Pump Association (IGSHPA)

- “For more than three decades, the International Ground Source Heat Pump Association (IGSHPA) has worked to advance ground source heat pump (GSHP) technology on local, state, national, and international levels.”
- [www.igshpa.org](http://www.igshpa.org)
Industry Resources

4.b International Ground Source Heat Pump Association (IGSHPA)

IGSHPA provides multiple tools to the industry, as well as training programs
- Guides, manuals
- Technical explanations
- Conferences
- Access to “accredited installers” through website
- Most comprehensive Geothermal “code”
  is ANSI/CSA/IGSHPA C448
- www.igshpa.org

Courtesy IGSHPA
Industry Resources

4.c Radiant Professionals Alliance (RPA)

- “The RPA is an international trade association comprised of individuals and companies dedicated to increasing the use of radiant heating and cooling technologies through education and the development of codes and standards language reflecting best practices.”
- “Guiding the future of the radiant and hydronics industry through technical expertise for code development, professional certification, and industry advocacy.”

- Adaptability, Architectural freedom, Control, Efficiency, Invisibility, Longevity, Reduced maintenance, Safety – the Advantages of Hydronic Radiant Systems
Industry Resources

4.c Radiant Professionals Alliance (RPA)

- Education at conferences (E.g. AHR)
- Radiant Comfort Guide
- Webinars, manuals
- ASSE 19210, Hydronics Heating and Cooling Installer Professional Qualification Standard
- www.radiantpros.org
Industry Resources

4.c Radiant Professionals Alliance (RPA)

- Education at conferences (E.g. AHR)
- Radiant Comfort Guide
- Webinars, manuals
- ASSE 19210, Hydronics Heating and Cooling Installer Professional Qualification Standard
- www.radiantpros.org
Industry Resources

4.d The Plastic Pipe Institute (PPI)

- “PPI is a 501(c)(6) non-profit trade association representing all sectors of the plastic pipe industry across North America.
- “Based in Irving, TX, PPI’s five divisions provide expertise about piping materials, design, applications, standards requirements, and code compliance.”
Industry Resources

4.d The Plastic Pipe Institute (PPI): Building & Construction Division

- Webpage for each piping material
- Technical Publications & Guides
- Plastic Pressure Pipe Design Calculator
- Webpages on all major Applications
- Magazine articles
- Educational videos
- Case studies
- Presentations and recorded webinars
- Lists of Members and Producers
- www.plasticpipe.org
Industry Resources

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CROSSLINKED POLYETHYLENE (PEX)

PEX tubing comes in nominal sizes ranging from 1/4 to 3 in. copper tube size (CTS), and pipe sizes in both inch and metric sizes. PEX tubing is SDR9 with standard hydrostatic pressure ratings of 160 psi at 72°F (1105 kPa at 23°C) and 100 psi at 180°F (690 kPa at 82°C). Consult the specific PEX manufacturer’s literature and listings for appropriate pressure ratings. PEX tubing and pipe are sold in coils and straight lengths.

Definition: PEX is a polyethylene material which has undergone a chemical or a physical process whereby the polymer chains are chemically linked. Crosslinking of polyethylene into PEX for pipes results in improved properties such as elevated temperature strength and performance, chemical resistance and resistance to slow crack growth.

Overview: PEX is a high-temperature flexible plastic pressure pipe with over 40 years of successful use in the European market, including extensive testing for durability and material performance. It was first introduced in North America in the early 1980s and is widely used for plumbing, water service, fire protection, hydronic heating and cooling, snow and ice melting and ground source geothermal piping systems. PEX is approved in all model plumbing and mechanical codes across the United States and Canada, and some PEX pipe is listed for use in fire sprinkler systems as defined in NFPA standard 13D.

PEX Advantages

- Safety of potable water and long-term reliability
- Resistance to corrosion, tuberculation, deposits
- Chlorine and chloramine resistance
- Flexibility to speed installations
- Freeze-break resistance
- Lightweight, easy to transport
- Noise and water hammer resistance
- No scrap value, avoiding job site theft
- Durability and toughness to survive job site installations
- No flame used for joining, with many fitting and joining options
Industry Resources

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BUILDING & CONSTRUCTION RELATED LITERATURE

Statements
- PPI Technical Response to "Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems"
- Statement A - Relative Oxidative Aggressiveness of Chloramines and Free Chlorine Disinfectants on Crosslinked Polyethylene (PEX) Pipes Used in Treated Potable Water
- Statement Y - Taste and Odor of Drinking Water from Plastic Piping Systems

Recommendations
- Recommendation E - Recommendation Against Mixing Hydronic Heating Water with Potable Water
- Recommendation F - Testing PEX Pipe and Tubing Systems with Air
- Recommendation G - Epoxy Pipe Coatings

Position Papers
- Installation of CPVC Fittings Within and Under Concrete Slabs
- Installation of PEX Fittings Within and Under Concrete Slabs

Technical Notes
- TN-17 - Crosslinked Polyethylene (PEX) Pipe & Tubing
- TN-26 - Erosion Study of Brass Insert Fittings used in PEX Piping Systems
- TN-31 - Difference Between PEX and PP Piping Systems for Potable Water Applications
- TN-32 - UV Labeling Guidelines for PEX Pipes
- TN-39 - Recommended Practices Regarding Application of Pesticides and Termicides near PEX Pipes
- TN-52 - Guide to High-Temperature Applications of Non-Potable PEX Pipe and Tubing Systems
- TN-53 - Guide to Chlorine Resistance Ratings of PEX Pipes and Tubing for Potable Water Applications
- TN-55 - Plastic Piping Materials for Gas Applications
- TN-56 - Plastic Piping Materials Near Recessed Lighting Fixtures
- TN-57 - Proper Integration of Copper Tubing and Components with PP-R Piping Materials for Plumbing Applications
- TN-62 - Suitability and Fitness of CPVC Piping Systems for Commercial Building Applications

Technical Reports
- PPI Technical Response to AWWA Journal Paper 11-17
- TR-11 - Resistance of Thermoplastic Piping Materials to Micro- and Macro-Biological Attack
- TR-48 - R-Value and Thermal Conductivity of PEX and PE-RT
- Fixture Flow Rate Comparison Cross-Linked Polyethylene (PEX) Piping and Copper Tubing
- NASHRC Surge Pressure in Plumbing Pipe Materials
- Janya Report 05-1039 - Proposal for the Evaluation of the Chlorine Resistance of UV Exposed PEX Pipe
- Janya Report 09-1190 - Usage and Effects of Chlorine Dioxide on PEX Plumbing
- Janya Report - Chlorine Resistance Testing of PEX Piping Materials
Industry Resources

4.d The Plastic Pipe Institute (PPI): Building & Construction Division

- Webpage for each piping material
- Technical Publications & Guides
- Example: *Handbook of Polyethylene Pipe, 2nd Edition*
Industry Resources

4.d The Plastic Pipe Institute (PPI): Building & Construction Division

- Webpage for each piping material
- Technical Publications & Guides
- Example: DESIGN GUIDE - Residential PEX Water Supply Plumbing Systems
Industry Resources

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- Lists of Members and Producers
- [www.plasticpipe.org](http://www.plasticpipe.org)

**BCD APPLICATIONS**

PPI's Building & Construction Division (BCD) is focused on plastic pressure pipe and tubing systems used in buildings and on building premises for a wide variety of applications:

- Fire protection
- Geothermal ground loops
- Hot- and cold-water plumbing distribution
- Outdoor snow and ice melting
- Radiant heating and cooling systems
  - Radiant Control Systems
  - Thermal Comfort - Radiant Heating & Cooling
- Reclaimed water piping
- Turf conditioning
- Water service lines
- Chilled water piping
- District heating and cooling
- Flexible pre-insulated piping
- Hydronic piping and distribution
Industry Resources

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CASE STUDIES

Hydronic Piping
- Mechanical Joining System Benefits New Napa Valley Resort
- Three Pipes Make HVAC Systems Run More Efficiently

Plumbing
- Boston Area "Quiet House" Offers Unique Selection of Noise-Reducing Features
- Prestigious Westgate Building in Austin Save Over 1 Million In Replacing 50 Years Old Plumbing System
- Psychiatric Hospital Preserves Patient Comfort and Safety While Replacing Failed Plumbing in Main Care Facility
- Delta-Base 2210 Plumbing Calculator Reduces Substantial Savings with Installation of Flowguard Gold CPVC Pipe and Fittings
- Award-Winning Custom Builder Solves Aggressive Water and Noise Problems with High-Performance CPVC Pipe System
- Award Winning Building (H&H)
- Homeowners Frustrated by Pitting Leaks in Copper Plumbing, Find Relief with PEX
- Uponor PEX Saves Money and Time for Residential High Rise
- Uponor Plumbing Systems Overcome Re-pipe Challenges

Radiant Heating & Cooling
- PEX Pipe Helps Zoo Provide Comfort to Animals and Visitors While Reducing Energy Use and Costs
- FedEx Air Hanger - Radiant Heating System
- Harley Davidson, Lorette, WI - Heating Cooling System
- LUMENHAUS at Farnsworth House - Geothermal Ground Loop Heat Exchanger
- Mercedes Benz Burlington - Heating and Snow and Ice Melt System
- Pier One - Radiant Heating and Cooling System
- Spring Creek Mountain Village - Radiant Heating
- YWCA Toronto Elm Center - Radiant Heating & Cooling
- Color This Radiant Home GREEN - Bramson, MD
- Clean Heat and Comfortable Warmth Make Breathing Easier
Industry Resources

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### BCD Members

#### Pipe and Fittings Manufacturers

- Aquatechnik North America
- Aquatherm
- Asahi-America
- Auray Managing S.L.
- Bow Plumbing Group
- Centennial Plastics, Inc.
- Charter Plastics, Inc.
- Flying W Plastics
- Golan Plastic Products LTD
- Heatlink Group Inc
- IPEX USA LLC
- Legend Valve
- Mercury Plastics LLC
- Mr. PEX Systems
- NUPI Americas

- Poloplast
- REHAU Inc.
- Reliance Worldwide Corp.
- Rifeng Systems Co., LTD
- Teel Plastics
- Uponor, Inc.
- Versaprofiles Products Inc.
- Victaulic
- Viega LLC
- Watts Water Technologies
- WL Plastics Corp
- WRW Westfälische Rohrwerke GmbH
- YogaPipeACR
- Zum PEX, Inc.
Industry Resources

Summary: Resources to assist with selecting & specifying piping systems

4.a HIA-C
4.b IGSHPA
4.c RPA
4.d PPI
Summary

At this time, participants should be able to:

1. Describe the piping materials CPVC, HDPE, PEX, PE-RT & PP in terms of material properties, capabilities, joining systems, applications, standards, and code compliance

2. Indicate where and how to use these materials in applications such as plumbing distribution, fire protection, hydronic heating and cooling, snow & ice melting, geothermal ground loop, and district heating applications

3. Discuss the design of piping materials in terms of sizing for flow, pressure loss, thermal expansion/contraction, etc. using a publicly-available software program

4. Explain how to access industry resources related to selecting and specifying the right piping material(s) for various applications
Conclusion

Plastic piping systems can deliver the optimum combination of performance, efficiency, cost and longevity

When applied correctly, plastic piping systems can improve buildings’ comfort, efficiency, and operating costs
Plastic Pressure Piping Materials for Plumbing & Mechanical Applications

Thank you!

Contact
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lmacnevin@plasticpipe.org Tel (469) 499-1057