Thermoplastic Piping Applications for Utility Distribution Systems– Part 2

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In the first part of this series on thermoplastic piping, a discussion was presented focused on the use thermoplastic piping systems in buildings. In the following discussion we review the use of thermoplastic piping in site distribution system, with specific emphasis on HDPE (High Density Polyethylene) and PE-RT (Polypropylene of Raised Temperature resistance) piping systems. We will share our opinions, key takeaways, and lessons learned from recent projects.

The Proliferation of Plastic Piping

As discussed in Part 1, thermoplastic piping systems has been used successfully for hydronic systems for decades. In pressurized distribution systems, PVC (polyvinyl chloride) and HDPE are commonly used as a carrier pipe. The selection of thermoplastic systems is largely a result of their relative lower material costs, reduced transport and installation costs, and corrosion resistance, as compared to ductile iron pipe (DIP) welded carbon steel pipe, and concrete cylinder / prestressed concrete piping systems. While the selection of piping systems should be evaluated based on site-specific design criteria, one of the limitations associated with thermoplastic pipe is the working pressure rating at elevated temperatures. Typically, the working pressure rating thermoplastic piping systems is reduced when the operating fluid temperature exceeds 73-degrees (F).

Figure 1 – Pre-insulated PE-RT pipe. Banner Medical Center, Tucson AZ

This article will focus on the HDPE and PE-RT family of thermoplastic piping which are suitable for Chilled Water and Hot Water distribution systems. The primary variation between the two piping systems is that the PE material used in PE-RT systems allows for a significantly improved processability and long-term strength at higher temperatures.

Definitions

“Thermoplastic” - a plastic material that becomes pliable or moldable at a certain elevated temperature and hardens upon cooling. This process is repeatable and during this process the physical properties are retained.

“HDPE” – High Density Polyethylene, family piping features extruded pipe and injection molded or fabricated fittings.

“PE-RT”– Polypropylene of Raised Temperature resistance, having a unique molecular structure and crystalline substructure which provides long term hydraulic strength at high temperatures without the need for cross-linking the material. This family of piping features extruded pipe and injection molded or fabricated fittings.

General Applications

HDPE and PE-RT piping distribution systems can be utilized in applications including: Potable Water, Hydronic Systems, Chilled Water Systems, Condenser Water, and Reclaimed Water. PE-RT piping system can be used in distribution system applications operating at higher temperatures including Hot Water systems. Both systems are available un-insulated or pre-insulated.

Design Considerations

HDPE and PE-RT pipe are manufactured as an outside diameter (OD) controlled product, and available with an outside diameter equivalent to iron pipe size (IPS) or ductile pipe (DIP) size. The pipe is manufacture with varying dimension ratios (DR), which is ratio of the pipe outside diameter to the pipe minimum wall thickness. Typical dimension ratios range from DR-7 to DR-21 for most pressurized systems. The smaller the DR, the thicker the wall. In comparison with PVC, ductile iron and carbon steel piping systems, the wall thickness of the PE pipe is substantially thicker, reducing the cross- sectional flow area of the pipe. As indicated in Figure 2, this variation is most pronounced with larger diameter pipes with a low DR. For example, an 18-inch, DR-11 HDPE pipe has a cross-sectional area of 166 sq-inches, and the cross-sectional area of an 18-inch, pressure class 250 ductile iron pipe is 280 sq-inches.

Nominal Pipe Size	ID HDPE (1) DR 11	ID HDPE (1) DR 13.5	ID DIP (2)	ID Carbon Steel (3)
8"	6.96"	7.27"	8.55"	7.98"
12"	10.29"	10.75"	12.64"	11.94"
18"	14.53"	15.17"	18.88"	17.25"
24"	19.37"	20.23"	25.14"	23.25"

(1) IPS outside diameter controlled.
(2) DIP – 8" and 12" pressure class 350, 18" pressure class 250, 24" pressure class 200
(3) Carbon Steel – 8" and 12" Sch 40, 18" and 24" STD weight

Figure 2 – Inside Diameter Comparison for Different Pipe Material, Size, and DR

The variation in the flow area is partially offset by a lower friction coefficient for HDPE and PE-RT pipe, however it emphasizes the need to calibrate hydraulic models for the flow area of the pipe, rather than utilizing nominal pipe sizes.

Pressure and Temperature Rating

Pressure and temperature ratings are inversely related in thermoplastic piping systems. In general, as piping service temperature requirements increase, the allowable pipe working pressure decreases. When the operating fluid temperature exceeds 73-degrees (F), the allowable design pressure for HDPE and PE-RT piping are reduced, by a temperature design factor. The maximum design temperature for HDPE is 140-degrees (F). PE-RT systems extends the operating temperatures to 180-degree (F). which is more consistent with hot water distribution systems.

Design Pressures							
Operating Temperatures							
Application	Dimensional Ratio	73^0F	100^0F	120^0F	140^0F	160^0F	180^0F
Water, Brine Alcohols, Glycols, and Dry Natural Gas (non 49CFR192 applications)	DR 7	333 psig	280 psig	244 psig	210 psig	187 psig	167 psig
	DR 9	250 psig	210 psig	183 psig	158 psig	141 psig	125 psig
	DR 11	200 psig	168 psig	146 psig	126 psig	112 psig	100 psig
	DR 13.5	160 psig	134 psig	117 psig	101 psig	90 psig	80 psig
	DR 17	125 psig	105 psig	91 psig	79 psig	70 psig	63 psig
	DR 21	100 psig	84 psig	73 psig	63 psig	56 psig	50 psig

Figure 3 – PE-RT Design Pressure Ratings versus Permissible Service Temperatures - Courtesy of ISCO Industries

Thermal Expansion

The coefficient of thermal expansion (a) for PE pipe is significantly larger than the coefficient of thermal expansion for metallic piping. For example, for PE pipe a= 80 x 10^{-6} in/in/°F, and for carbon steel a=6.1 x 10^{-6} in/in/°F. However, elastic modulus (E) for PE (0.065 x 10^{6} psi) is considerably less than carbon steel (29 x 10^{6} psi). The force to restrain the thermal expansion is function of the coefficient of thermal expansion, the elastic modulus, the cross-sectional area of the pipe wall, and the change in temperature; the resultant force generated by the thermal expansion is considerably less for HDPE pipe than carbon steel pipe.

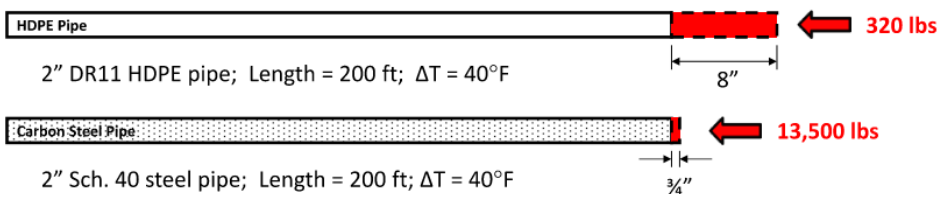

Figure 4 – HDPE Thermal Expansion versus Force Axial Force to Restrain Expansion Courtesy of Performance Pipe

In direct buried HDPE piping systems, the soil friction along the exterior of the pipe is generally adequate to resist dimensional change and resist the forces generated by thermal expansion. Connection to unrestrained systems and appurtenances may require thrust blocking to avoid pull-out from push-on joints in the existing piping. However, with a reduced axial force resulting from thermal expansion, the thrust block is typically smaller that the requirements for metallic piping systems.

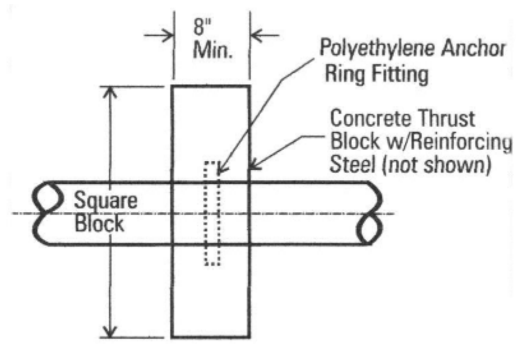

Figure 5 – HDPE Thrust Block

Joint Methodology

Joints in HDPE and PE-RT piping systems are generally made with butt fusion, electrofusion, and saddle fusion techniques. These processes use a combination of heat and pressure fuse the sections of the pipe together, creating a continuous pipeline. Molded fittings are available in a variety of configuration for smaller pipe diameters. Fabricated fittings are generally utilized for large pipe diameters.

Mechanical and transition fitting are available for connection to valves and appurtenances, and for connections to existing piping systems. Thermoplastic tends to creep when subject to pressure induced by the fittings, thus backing rings and stiffeners should be evaluated at mechanical joints.

Figure 6 – Butt Fusion, Banner Medical Center Tucson AZ

HDPE and PE-RT systems also allow for the pipeline to be installed in a curvilinear alignment, potentially reducing the requirement for bends in the system. The allowable bending radius is a function of the DR, and the OD of the pipe. The allowable bend radius generally ranges from 20 times the OD of the pipe for DR less than 7, to 27 times the OD of the pipe for DR-21. The allowable bending radius enhance the options for the vertical alignments associated with horizontal boring.

Installation Techniques

HDPE and PR-RT distributions systems can be installed using traditional open cut trenches, jack and bore, or directional boring techniques. In directional boring applications the stresses on the pipe during installation must be evaluated to mitigate the potential to overstress the pipe. Additionally, in directional borings with per-insulated pipe, the thickness of the jacketing should be increased to prevent it from being damaged during installation.

Figure 7 – Pull in of Pre-insulated PE-RT Pipe in Horizontal Bore

Another unique aspect associated with HDPE pipe is the testing requirements. Unlike ridged pipelines, the HDPE pipe expands while under pressure. Testing includes an initial pressurization of the system to allow for the initial expansion of the piping to stabilize. After the initial phase, the hydrostatic test occurs, and an allowance for makeup water is calculated based on the pipe diameter. This volume of makeup water reflects minor expansion of the piping and not leakage out of the piping.

Lessons Learned

Each piping system must be fully evaluated based on the system and site-specific criteria. Only a full understating of the piping advantages and limitations will lead to a successful project. The development of resins for thermal plastic piping systems have enabled improved pressure and temperature ratings, but as with all systems there are limitations. Additionally, the installation of the system should be closely monitored. A few of the lessons learned include:

- In large diameter distribution systems, flushing of the system at adequate velocities is difficult. Enforce cleanliness of the pipe during Storage and installation.
- Establish and maintain a rigorous quality control procedure for fusion welding.
- The use of PE-RT systems allows for an elevated working temperature in the system. The anticipated working temperature of the system should be coordinated with the hot water generation system. Appropriate digital temperature and pressure limits with hard-wired safeties to prevent overtempt/overpressure excursions that may manifest due system error, creating damage to the pipe.
- In directional boring applications, the selection of the piping must be consistent with the working parameters of the system and the stresses developed during installation.
- Modeling of the distribution system must be based on the actual inside diameter of the HDPE or PE-RT pipe and not nominal pipe size.

Summary

Specifying and installing thermoplastic, ductile iron, carbon steel or other traditional hydronic piping systems are applicable, provided that the design criteria is met. However, developments in thermoplastic piping technology makes HDPE and PE-RT a legitimate alternative. This is largely due to the fact that HDPE and PE-RT can meet most hydronic distribution system temperature and pressure requirements while offering many other advantages (installation options, corrosion resistance, etc.).

Additional Piping Resources

American Water Works Association - https://www.awwa.org
Plastics Pipe Institute - https://plasticpipe.org/
Chevron Phillips, Performance Pipe https://www.cpchem.com/what-we-do/solutions/performance-pipe
ISCO Industries - https://isco-pipe.com/
JM Eagle - https://www.jmeagle.com/

Authored by John C. McGann. John has been with GLHN since 1986 and is Director of Civil Engineering. He has worked on master planning, design, and construction of underground utility distribution systems his entire career. GLHN's utility infrastructure resume and John's resume are synonymous; his civil utilities group has been responsible for well over $500 million in utility infrastructure work since 2000. John's engineering expertise extends to water and wastewater systems analysis and design, structures, grading, roadway design, and traffic control plans. Previous experience also includes specialization in hydraulics and hydrology engineering.

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