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A Green Alternative to Pressure Pipe



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The magazine for plumbing engineers, designers, specifiers, code officials, contractors, manufacturers, master plumbers, and plumbing professionals

What do domestic hot water piping for King County prisons in Washington, the chilled water piping for Fort Hood Army Base in Texas, water-source heat pump piping at the University of Maine, fan coil (hot and chilled water) piping serving a Florida retirement home, process piping at an Idaho cheese factory, and compressed air piping at a Rocky Mountain titanium plant all have in common?

2
things

- 1 The choice of piping material was extremely important to the owners or administrators of these buildings.
- 2 After rigorous evaluation of the material options, the decision was made to flat spec polypropylene-random (PP-R).

The driving factor on these projects was the need for a long-term, reliable system. Cost was secondary. This is a radical change in an industry not normally known for radical change.

While polypropylene (PP) was virtually ignored for potable and pressure pipe applications in North America until the last few years, plumbing engineers are not unfamiliar with its benefits.

A Green Alternative to Pressure Pipe

chemistry lesson

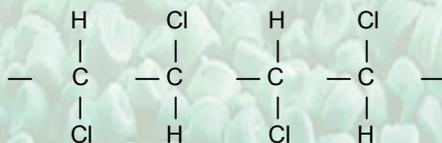
At first glance, plastic materials look pretty much the same, and let's face it: How many of us really learned enough back in chemistry class to look at the chemical names and fully understand a material's chemical properties? Thus, we have a tendency to lump polymers in one group and to minimize or ignore the significance of which material you select.

In reality, there is a tremendous difference between plastics in terms of their composition. These differences begin at the basic molecular level and result in substantial differences in their toxicity, life safety, brittleness, chemical sensitivities, expected life, and recyclability.

The focus of this sidebar is on plastics used for large pipes for distributing potable water in institutional and commercial buildings, specifically chlorinated polyvinyl chloride (CPVC) and polypropylene-random (PP-R).

Chlorinated Polyvinyl Chloride

CPVC is produced by chlorination of polyvinyl chloride (PVC) resin. As the name suggests, CPVC is about two-thirds by weight chlorine. As part of the PVC family, it carries all of the same concerns raised regarding the environmental and health impacts of PVC.

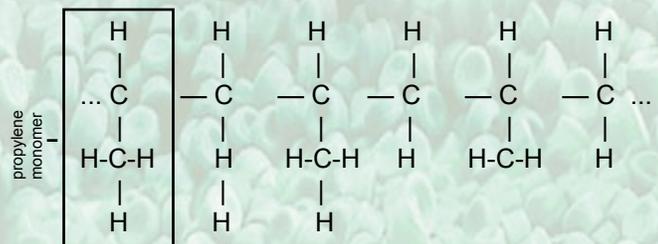


In addition to the general concerns raised about PVC, there are additional concerns about the use of CPVC for pressure piping systems. Any product that can be glued together must have a high degree of chemical sensitivity, leaving it vulnerable to attack by a number of common household and jobsite chemicals. Contact with even trace amounts of many lubricants, sealants, fire stops, paints, and other com-

mon materials will cause stress cracks and pinhole leaks in CPVC. Posing a significant threat are the polyolester (POE) oils used with modern, environmentally friendly refrigerants. A trace amount of POE in a CPVC piping system will result in complete system failure.

Polypropylene-random

In contrast, the building blocks for polypropylene (PP) are hydrogen and carbon. PP is a linear structure based on the monomer C_3H_6 . It is manufactured from propylene gas, a by-product of oil-refining processes.



These chains of propylene monomers average thousands of monomers long, with some longer and some shorter, giving it the characteristics of both strength and flexibility.

Following are the properties of PP-R:

- Resistance to stress and cracking (i.e., high tensile and compressive strength)
- Low thermal conductivity
- High operational temperatures
- Excellent dielectric properties
- Resistance to most alkalis and acids, organic solvents, degreasing agents, and electrolytic attack
- Less resistance to aromatic, aliphatic, and chlorinated solvents and UV
- Nontoxic
- Easy to produce and assemble
- Recyclable



Figure 1 The small pieces of a fiber material running longitudinally with the run of the three-layered PP-R pipe are highlighted in the circle. These fibers reduce thermal expansion by 75 percent.



Figure 2 Socket fusion procedure



Figure 3
Once fused, the fitting and pipe become one piece, with no leak path or weak point

Acid waste pipe often is made from polypropylene due to its extremely high resistance to most chemicals because the long chains of polymers do not provide a weak point for chemicals to attack. Also, PP often is used in deionized, or ultra-pure, water systems.

Why the sudden adoption of polypropylene into potable and hydronic applications by such venerable and conservative engineering organizations as the U.S. Army Corps of Engineers? This article explores seven factors that have contributed to this change in the market. Three factors have to do with advances in PP technology, one with economics, one with today's liability-wary climate, and one with the green movement in general. Last, but not least, many of the North American plumbing codes now recognize polypropylene as a safe and effective piping system.

ADVANCES IN PP TECHNOLOGY

Development of High-temperature and High-pressure Polypropylene

Basic polypropylene has many features that make it a suitable piping material. It is resistant to corrosion and abrasion, and it does not support scale formation. However, for use in hot, pressurized fluid systems, it has two serious limitations:

1. The temperature and pressure rating is not high enough for boiler or domestic hot water heating applications.
2. The thermal expansion is excessive.

The physical strength of polypropylene pipe is affected by the polymers' chain lengths. PP-H (long polymer chains) is a tough material that can be inflexible and brittle. PP-S (short polymer chains) has short chains resulting in a more flexible pipe, but it is not as strong. A blending of short and long polymer chains called PP-R (random) offers the best of both worlds, resulting in a tough, yet flexible, material. With the addition of trace amounts of the right property enhancing compounds, the performance of PP-R is increased further. The result is a PP-R piping system that has twice the pressure rating of standard PP. This engineered piping material can handle 180°F boiler water at 100 pounds per square inch (psi) for 50 years.

Control of Thermal Expansion

For decades, the natural linear expansion rate of plastic pipe was a major source of frustration for piping engineers. Its growth rate of 10 inches per 100 feet per 100°F was simply too much for most applications.

German engineering solved this problem. The PP-R pipe is extruded in three layers, and the middle layer contains small pieces of a fiber product running longitudinally with the run of the pipe (see Figure 1). These pieces restrict the thermal expansion of the pipe by 75 percent and bring it to the same order of magnitude as metal pipe.

Since PP does not exert the large forces that metal pipes do when they expand or contract, the remaining amounts of expansion or contraction can be addressed easily. The pipe can be rigidly supported every 10 feet to limit the remaining expansion, or the pipe can be operated at its design operating temperature before fixing the supports. Thus, when the pipe is allowed to cool to the ambient temperature, it will contract and put the pipe under tension. With most types of pipe joining systems, tension could present issues, but as discussed in the next section, fusion connections are the strongest part of the system and are not a concern.

Development of Socket Fusion Connection Technology

The weak link in most piping systems exists at the connection. Mankind has experimented with dozens of methods to connect pipes and fittings, with varying degrees of failure. Methods that use a foreign material, like glues, solders, gaskets, or pipe tape, increase the possible number of failure modes. Mechanical fasteners can come loose. Chemical bonds require a degree of chemical sensitivity that can result in failures. Welding can make a great connection that is as strong as the pipe itself, when done properly by skilled craftsmen.

Socket fusion (see Figure 2) offers the same level of connection as welding without being as labor intensive. The procedure is as follows:

1. Insert the pipe and fitting onto the welding device.
2. Heat the pipe and fitting for the specified time.
3. Gently join the pipe and fitting for a lifetime connection.

Heat fusion connections are simple, quick, and reliable. By forming a connection that has the same physical properties as the pipe and fitting, systematic weaknesses are eliminated. Eliminating the addi-



polypropylene-random

tion of foreign materials (such as gaskets and glues) to the piping system reduces the potential of chemical or mechanical failures. Socket fusion also prevents blowouts at the joints, which are common in other socket or mechanical-type connections. The result is a connection without a potential leak path or failure mode (see Figure 3). Thus, the connections are the strongest part of the piping system instead of the weakest link.

Proper fusion connections won't leak or fail over time, so maintenance or repair concerns are alleviated.

ECONOMIC FACTORS

Historically, a premium was paid for polypropylene piping, and it was considered too expensive to use for applications such as domestic water and hydronics. In North America, its usage generally has been limited to acid waste, deionized water, and pharmaceutical applications. Again, thanks to German engineering in the 1980s and 1990s, the cost of PP pipe was reduced to where it competed favorably with metal pipes. That was back when copper was \$1 per pound. Now, with copper costing two to three times that price, it is possible to upgrade and save money. Projects bidding against copper have reported material savings of 25 percent and higher.

Copper prices swing widely based on numerous factors, which makes bidding a job difficult since the price can go up substantially between the bid date and the actual installation. It even has reached the point where jobsite theft is a real issue. Polypropylene, on the other hand, is a by-product of the petroleum industry that must be put to use and is therefore fairly stable in price. It also offers little incentive for theft.

Other cost factors should be considered to get the whole picture. Although a rigid pipe, PP-R requires closer hanger spacing than metal pipes. Also, PP pipe requires the use of firestopping systems listed for these applications, which may limit competition. When installed in a return air plenum, the pipe may require insulation to give it the required smoke and flame ratings. However, there are ways to offset these costs. The pipe has a very high, natural R value, meaning that pipe insulation may be reduced or eliminated. Insulating domestic cold water is not needed to avoid condensation when the pipe is in a conditioned space. Insulating chilled water return pipe is not beneficial with paybacks beyond the life of the building. Some energy codes are being amended to allow the elimination of the wasteful practice of over-insulating. It also may be possible to eliminate corrosion-inhibiting chemicals that would be required to protect ferrous pipes.

WARRANTY IN PLACE OF LIABILITY

An engineer once told me that a high-rise building was simply "vertical housing for lawyers." A leaky pipe nowadays can land you in court, and going to court can be disastrous for your business.

Pipes seem to be failing more quickly than in the past. Why? An explanation provided by Mike Dodson, director of engineering for Virginia Mason Hospital in Seattle, points to more aggressive water treatment, which renders water that does not support the microbiological film that used to line the inside of pipes. Without this lining, the metal ions are exposed to the aggressive water molecules looking for anything to attack. The resulting failure of the piping system leaves the plumbing engineer whose name is on the drawings just as exposed legally as the bare pipe is physically. When the accepted practice can result in failure, it also might result in litigation.

A meaningful warranty for a pipe system must cover more than the material and labor to replace the pipe or fitting. It must cover the incidental damage caused by the leak. The choice of PP-R and fu-

sion along with precise quality control makes such a warranty possible, not merely for the first year, but even for as long as 10 years. This warranty protects the building owner and design engineer long after the installing contractor's one-year warranty has expired. In today's litigious environment, owners, designers, and installers all benefit from this kind of warranty. Of course, the plumbing engineer is responsible for ensuring that the pipe manufacturer has approved the application before specifying PP-R for any fluids besides water and glycol.

SUSTAINABLE CONSTRUCTION MOVEMENT

In the past, we typically accepted that the products we purchased were engineered to fail. We called this "planned obsolescence." In five or 10 years, we would throw it away and buy a new one. This way of thinking now looks foolish on a number of levels, but it is particularly crazy for piping systems. When pipe systems fail, they can cause extensive damage, and replacing a failed pipe costs far more than the cost of the pipe. Thus, buildings and the pipes in them need to last for 50 years, not 15. According to Dodson, copper pipes in the Pacific Northwest are now failing in as little as five to seven years. When pipes fail, they often damage many other building systems, and the replacement of piping systems often impacts other components of a structure. The environmental impact of replacing a failed piping system before the building needs to be replaced is substantial.

The first leak is rarely the last leak. A piping system that is leaking has failed and becomes an ongoing expense for building management. Terry Smith, director of engineering for Marriott International, says that leaking pressure pipes is the company's number one maintenance expense. Thus, choosing a piping system that will outlast the building should be the driving factor in specifying a green piping system.

Another environmental advantage of polypropylene is that it is made of just carbon and hydrogen and contains no toxins, PVCs, or heavy metals. PP can be recycled, and the manufacturing process has a low carbon footprint.

CODE ACCEPTANCE

As little as five years ago, none of the North American plumbing codes recognized PP-R as an accepted material for plumbing. Since then, PP-R has been added to most of the model codes, with the exception of the Uniform Plumbing Code and some municipal codes. However, in such areas, the authority having jurisdiction often approves its use after evaluating the considerable evidence of its international track record.

SUMMARY

Being a plumbing engineer means being an expert on pipes. As such, you are obligated to yourself and your clients to learn all you can about every piping system that could benefit the projects you design. Polypropylene is a viable solution for some of the challenges you face and deserves to be added to your arsenal of engineering answers.



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