Proper Integration of Copper Tubing and Components with PP-R Piping Materials for Plumbing Applications

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Foreword

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WITH PP-R PIPING MATERIALS FOR PLUMBING APPLICATIONS

This technical note was developed and published with the technical help and financial support of the members of the Plastics Pipe Institute (PPI). These members have shown their commitment to developing and improving quality products by assisting standards development organizations in the development of standards, and also by developing design aids and reports to help engineers, code officials, specifying groups, contractors and users.

The purpose of this technical note is to provide information regarding proper integration of copper tubing and components with random copolymerized polypropylene (PP-R) piping materials for plumbing applications. While this technical note is specific to PP-R piping materials, the recommendations regarding proper design, sizing, and operation of systems with copper tubing and components may also be applicable to other plastic piping materials approved for plumbing applications.

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1.0 INTRODUCTION

Random copolymerized polypropylene (PP-R) is a high-temperature plastic pressure piping system used for plumbing and hydronic heating and cooling applications. PP-R was launched in the 1980s in Europe, then introduced to North America in the 2000s.

PP-R product standards include:

- ASTM F2389 *Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems,* first published in 2004 www.astm.org
- CSA B137.11 *Polypropylene (PP-R) pipe and fittings for pressure applications,* first published in 1993 www.shopcsa.ca

This Technical Note will explain how 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.

These concerns do not apply to copper alloy materials, such as brass or bronze, or to cold-water plumbing, hydronic systems, closed-loop geothermal systems or industrial piping systems.

This Technical Note will explain the conditions that can result in premature failure of copper or PP-R piping materials, and how to avoid these problems through proper design, sizing and balancing of plumbing systems.

Note 1: While this technical note is specific to PP-R piping materials, the recommendations regarding proper sizing of and intergrating with copper tubing and components may also be applicable to other plastic piping materials approved for plumbing applications.

Note 2: For more information about proper sizing of copper plumbing systems and the potential for corrosion of copper, see the *Copper & Copper Alloy Corrosion Resistance Database* available from the Copper Development Association at www.copper.org and the Canadian Copper & Brass Development Association at http://en.coppercanada.ca/.

2.0 TECHNICAL DEFINITIONS

Corrosion: Chemical attack on the surface of a metal forming a more stable ionic material, most commonly the electrochemical oxidation of metal through attack by oxygen, chlorine, sulfur, or other oxidizing agents.

Erosion: The process of gradual destruction of a material or surface through wear or surface abrasion, sometimes caused by excessive flow velocities in piping systems.

Erosion Corrosion: Degradation of a surface due to mechanical action coupled with a secondary corrosion element. Often caused by abrasion from suspended solids, cavitation, or turbulent fluid flow wearing away the passivation layer protecting an underlying material and causing rapid damage to the material through both physical wear of the material and further chemical attack.

Flow-accelerated Corrosion: A corrosion mechanism occurring when fast flowing fluid dissolves the passivation layer on metal surfaces and the metal again creates a passivation layer which is subsequently dissolved and the cycle repeats, resulting in rapid damage to the metal through bulk dissolution in the fluid stream.

Oxidative Attack: A type of attack on a polymer material where oxygen combines with the carbon atoms of the polymer chain to create new species that decompose leading to chain scission. With plastic pipe, this can lead to failure in the pipe or tubing wall characterized by a large number of cracks emanating from the interior surface of the pipe or tubing wall.

Passivation Layer: A thin coating of protective material found in metal pipes due to the formation of metal oxide on the surface of the material. This layer protects the pipe surface from damage due to corrosion, but not necessarily offering protection from erosion. In copper tubing, this is often referred to as the “patina”.

PPM: Parts per million, a measurement used to express the concentration of chemicals in a solution such as water. Sometimes, the equivalent unit of measure “mg/L” is used.

3.0 OXIDATIVE ATTACK OF PP-R PIPING MATERIALS INFLUENCED BY DISSOLVED COPPER

Plumbing codes adopted throughout Canada and USA contain requirements which limit the flow velocity through copper tubing and components to help prevent various types of erosion and corrosion of the copper material.

When such limits are not adhered to, copper components can suffer from “flow-accelerated” or “flow-induced” corrosion. The speed and degree of such corrosion is dependent upon several factors, discussed below. When it occurs, this type of attack on the copper tubing components can release dissolved copper into the water. This effect has been reported in various regions of the world, including North America.

In certain circumstances, dissolved copper can greatly accelerate an oxidative reaction between the chlorine (added as a water disinfectant) or dissolved oxygen in the water, or both, and the PP-R piping material, degrading the PP-R material over time. The result can be premature failure of the PP-R piping components, especially in locations of external physical pressure, such as with high clamping force of brackets.

Situations where pipes are clamped incorrectly to accommodate thermal expansion and contraction can also contribute. Even a small amount of dissolved copper in the plumbing water can contribute to the problem, if specific aggressive factors all exist in the same system.

To help prevent such oxidative attack, *metal deactivators* can be used as part of the stabilization or antioxidant additive package used in pipe formulations. Such metal deactivators are designed and tested to resist oxidative attack of the piping material for decades of normal operation. However, the most aggressive combinations of water chemistry, temperature and flow velocity have been shown to result in field problems in PP-R piping systems, in limited situations.

The application where such instances have occurred are mixed-material commercial plumbing systems that combine copper and PP-R materials. In a mixed-material plumbing system, copper components are typically used for mechanical room piping between equipment and hot-water recirculation return lines, and PP-R piping material is used for distribution piping throughout the building.

In such circumstances, premature failure of the copper components is also present, requiring repair or replacement of copper components and often other equipment in the system as well.

The root cause of such failures is excessive velocities through the copper tubing components, combined with certain water chemistries, high chlorination of the water, and high operating water temperatures above 140°F (60°C).

In fact, research has shown that the following conditions must be present for this “flow-induced” copper corrosion issue to occur:

- Constant replenishment of chlorine and oxygen in the water,
- High circulation water temperatures, in excess of 140°F,
- Excessive flow rates in the associated copper tubing or components, and
- Water chemistry that is specifically aggressive to copper

Many unintended field issues are caused by improper balancing of piping legs or segments within commercial plumbing systems, whereby some piping legs receive excessive flow rates while others are often underserved (too low flow). This situation can encourage building owners or operators to increase hot-water temperatures throughout the system for the apparent benefit of delivering more hot-water to the portions of the building being underserved by inadequate flow.

This issue does not occur in cold-water plumbing, hydronic systems, closed-loop geothermal systems or industrial piping systems. This is because in those types of systems, there is typically not the high-velocity flow rate combined with constant replenishment of chlorine and oxygen in the water.

As proven by successful operation of PP-R piping systems in commercial plumbing applications around the world, including North America, this type of oxidative attack of PP-R piping materials is rare. Steps can be taken to prevent it.

Note 3: Damage caused by dissolved copper in the water resulting from erosion corrosion or other degradation of copper components in a plumbing system may void any system warranty offered by the PP-R pipe manufacturer.

4.0 DESIGN OF DOMESTIC HOT-WATER RECIRCULATION PLUMBING

The most important factor in preventing this type of flow-accelerated corrosion in copper components, and the subsequent chemical oxidative attack of connected PP-R components, is the design and control of proper flow rates within the copper components to prevent the corrosion of the copper.

When utilizing copper tubing or fittings in domestic hot-water recirculation (DHWR) systems, PPI recommends following Copper Development Association guidelines such as CDA Publication A4015-14/16: *The Copper Tube Handbook* for specifications and limitations regarding sizing, temperature and flow velocity in copper tubing.

The following design recommendations apply to mixed-material commercial plumbing systems using copper and PP-R:

4.1 Copper Levels in Drinking Water

Copper is a regulated substance with potential health risks for consumers of drinking water if levels are excessive. This guidance of the CDA *Copper Tube Handbook* should help ensure that the copper levels in the water do not approach the regulatory action levels recommended by independent institutions. Examples of such regulations include:

- U.S. Environmental Protection Agency (EPA) *Lead and Copper Rule* https://www.epa.gov/dwreginfo/lead-and-copper-rule
- World Health Organization (WHO) *Guidelines for Drinking Water Quality* http://www.who.int/water_sanitation_health/publications/copper/en/

4.2 Hot-Water Temperatures

Accordingly, and as mandated by various regulations and codes for domestic hot-water recirculation (DHWR) systems, it is considered good design and operational practice to ensure that the maximum hot-water temperature within any part of the system, including recirculation loops, does not exceed 140°F (60°C). Not only does this help prevent corrosion of the copper, but also typically results in a much more energy-efficient system with greater safety for users of the water, and lower risk of scalding. Some regulations and codes further restrict the temperature at any fixture to a maximum of 120°F (50°C) for safety reasons related to scalding.

There are some exceptions to this temperature setting, such as the process of thermal disinfection of commercial plumbing systems intended to prevent or kill growth of water pathogens such as legionella. In some cases, plumbing systems are operated at temperatures of 160°F (70°C) or higher, combined with high levels of disinfectants such as chlorine, for short periods of time for disinfection purposes.

Importantly, the maximum temperature of water during a high-temperature disinfection process must not exceed the rating of the pipe or any piping components at the operating pressure of the building’s plumbing system. Refer to the PP-R pipe manufacturer’s published ratings and product standards such as ASTM F2389 and CSA B137.11 for information about pressure ratings at various temperatures.

4.3 Water Flow Velocity

According to certain regulations and codes, flow velocity in plumbing and DHWR systems should not exceed 5 ft/sec (1.5 m/s) at temperatures up to 140°F. Where water temperatures may exceed 140°F, CDA Publication A4015-14/16 - *The Copper Tube Handbook* limits the velocity in plumbing systems to 2 to 3 ft/sec (0.6 to 0.9 m/s).

However, depending on factors such as “local aggressive water conditions”, many commercial plumbing designers limit flow velocities through copper tubing to 1.5 ft/sec (0.5 m/s) anywhere in the system. An exception may be where velocities up to 3 ft/sec (0.9 m/s) are needed to achieve proper flow temperature throughout the length of longer piping legs.

4.4 Connecting to Existing Copper Systems

When re-piping an existing DHWR-system originally installed in copper tubing, it is recommended that all copper tubing and components are replaced. Otherwise, special attention is required to ensure that remaining components will not be exposed to excessive flow velocities, water temperatures or aggressive water conditions. This level of design knowledge about existing components may be difficult to ascertain.

Before adding PP-R piping to an existing copper system or replacing copper with PP-R piping in a DHWR-application, the level of dissolved copper in the hot water should first be tested. The level should not exceed 0.1 ppm (mg/L). Higher levels of total copper indicate that the copper pipe is corroding due to water velocity or other conditions. Protection of the copper tubing using on-site phosphate or sodium silicate water treatment systems, or reduction in flow velocity or temperature, or both, may be necessary to properly control copper levels in the water, before connecting new PP-R piping.

Brass components such as valves, adapters, pressure-reducing valves (PRV), and backflow prevention devices will generally not cause an issue and are routinely used with PP-R piping in plumbing systems.

Water treatment and quality can change in the future, making it critical to follow these guidelines.

Note 4: Limited experience has shown that dissolved copper levels below 0.1 ppm will not adversely affect PP-R piping materials, but that levels above 0.5 ppm may have a significant effect. The effects of dissolved copper levels within the range of 0.1 to 0.5 ppm is dependent on conditions such as water temperature, total chlorine, pH, ORP, and dissolved oxygen content.

4.5 Other Design Issues

Precise design of a commercial plumbing system may require various sizes of piping or circulating pumps or both for various segments of a building to meet the required occupant water demands without exceeding stated flow velocities. If the exact demands and conditions are not known during design, then the use of pressure balancing valves may be required.

To hydraulically balance a DHWR-system and ensure the required flow rate for each area of the building will be met, it may be necessary to install balancing valves in every circulating loop throughout the complete plumbing system. This practice can maintain the flow velocity in the smaller return piping at or below the designer's or CDA's recommendations while meeting flow demands.

In addition to sizing the piping components and pumps to the correct flow velocity, care must also be taken to avoid excessive surge pressures (water hammer) during operation. Pump systems operating with on/off cycling, or pumps which are over-sized for the piping, can create excessive pressures and stress the piping material, while also creating noise, vibrations and wasting pumping energy.

Cavitation can also be a concern in areas of the piping where excessive turbulence and flow velocity may occur. The level of dissolved air/oxygen in the water can also significantly affect whether cavitation occurs in the piping. Cavitation can lead to excessive system noise and, more importantly, can lead to erosion and degradation of pipes, fittings and other components. PP-R piping is not known to be susceptible to erosion corrosion, as compared to copper tubing. The pump total dynamic head (TDH) must also be matched to the flow requirements, piping layout, and operating conditions to avoid cavitation for all components throughout the system.

Properly sized variable-speed (i.e. ECM[1], VFD[2]) constant-pressure pumping systems and pressure-sustaining valves can help alleviate these issues. The pumps should be sized to operate at maximum efficiency with the lowest energy usage for the required flow rate.

In some situations, the DHWR system is also used to provide hot water to the mechanical heating system. Additional consideration and care must be given for this type of combined system, as the mechanical components may not be compatible with the more aggressive water conditions and flow velocity limitations of DHWR systems, and these components may be not suitable for potable water contact.

See *PPI RECOMMENDATION E: Recommendation Against Mixing Hydronic Heating Water with Potable Water* for more information on this topic.

[1] Electronically commutating motor
[2] Variable frequency drive

5.0 SUMMARY

In mixed-material plumbing systems which combine copper with PP-R piping materials, it is critically important to limit flow velocities through each copper component to ensure that flow-accelerated corrosion of said copper components will not result. The maximum flow velocities for the specific water temperature and water chemistry of the system, as published by the Copper Development Association and listed within Section 4 of this Technical Note, must be adhered. This is important for the longevity of both the copper and the PP-R piping materials.

A system that is constructed utilizing only PP-R materials will not suffer from flow-accelerated copper corrosion. Therefore, when adequate control of water chemistry, water velocities or water temperatures cannot be assured over the lifetime of the plumbing system, it is recommended to avoid mixed-material piping systems by utilizing only PP-R materials, or other approved polymer materials, in place of copper tubing and fittings.