

TECHNICAL NOTE

Suitability and Fitness of Chlorinated Polyvinyl Chloride (CPVC) Piping Systems for Commercial Building Applications



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Foreword

This document 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 document is to discuss the suitability and fitness of CPVC piping systems for commercial building applications.

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1. Introduction

Chlorinated polyvinyl chloride (CPVC) is a versatile thermoplastic and member of the vinyl family and is a high-temperature plastic pressure piping system introduced for potable plumbing applications in 1959. In certain countries, the acronym PVC-C is used.

CPVC tubing is produced in nominal tubing sizes (NTS) ranging from 1/2 to 2 in. SDR 11 wall thickness. CPVC pipe is produced in nominal pipe sizes (NPS) ranging from 1/2 to 24 in. Schedule 40 and 80 and several SDR (e.g., SDR 11, SDR 13.5) wall types, with iron pipe size (IPS) outside diameters.

Note 1: The terms “pipe” and “piping” as well as “tube” and “tubing” may be used interchangeably within this document.

Advantages of CPVC piping systems include:

- Safety of potable water and long-term reliability
- Resistance to corrosion, tuberculation, deposits
- Elevated temperature capability
- Long-term hydrostatic strength
- Resistance to potable water disinfectants chlorine, chloramine, and chlorine dioxide
- Lightweight, easy to transport
- Speed and ease of installation
- Available in wide range of sizes
- Noise and water hammer resistance (surge pressure absorption)
- Minimal scrap value, avoiding jobsite theft
- Durability and toughness to survive jobsite installations
- No flame used for joining; solvent cement and/or mechanical joints
- Standardized pipe and fitting dimensions
- Professional installed appearance
- Cost effectiveness

CPVC tubing and pipe are typically available in 10 ft. and 20 ft. straight lengths for use with molded fittings. See [Figure 1](#) and [Figure 2](#).



Figure 1 - CPVC pipe



Figure 2 - CPVC molded fittings

This Technical Note will explain material properties and capabilities that should be considered when designing CPVC systems for commercial building applications. The content in this document may be used to apply to applications such as hot- and cold-water distribution (potable water plumbing), fire protection, chilled water, and hydronic heating and cooling systems.

CPVC piping materials are also used in various process piping and industrial applications, which are outside the scope of this document.

Topics discussed in this document include:

- **Section 2:** CPVC Material Definition
- **Section 3:** Suitability for high-temperature applications
- **Section 4:** Effects of potable water disinfectants on CPVC piping materials
- **Section 5:** Mixed-material systems that contain both copper materials (i.e. tubing, fittings, valves) and CPVC
- **Section 6:** Other Design and Installation Considerations

This Technical Note is not a design manual. Engineers, designers, and installers should refer to CPVC pipe, tubing and fitting manufacturer's technical data and design manuals for detailed design and installation information.

2. CPVC Material Definition

CPVC is polyvinyl chloride (PVC) that has been chlorinated via a free radical chlorination reaction. CPVC material is produced by adding chlorine to PVC in a water slurry or fluidized bed chlorination process. The chlorination reaction is initiated by ultraviolet light. The chlorinated PVC is compounded with ingredients necessary for the desired properties for further processing.

The chlorine added to PVC gives CPVC higher temperature performance and improved fire and corrosion resistance. The increased chlorine content also improves the material's resistance to chemical attack. CPVC pressure pipe is a distinct material from PVC pressure pipe, with additional capabilities, and is accepted in all model plumbing and mechanical codes for applications such as hot- and cold-water distribution (potable water plumbing), fire protection, chilled water, and hydronic heating and cooling systems.

CPVC pipe and fitting compounds adhere, at a minimum, to **ASTM D1784** for CPVC cell class 23447 meeting mechanical strength, heat resistance, and flammability.

2.1 Standards and Publications

- **ASME B31.3** *Process Piping*
- **ASTM D1784** *Standard Classification System and Basis for Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds*
- **ASTM D2837** *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products*
- **ASTM D2846** *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems*

- **ASTM F441/F441M** *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedule 40 and 80*
- **ASTM F442/F442M** *Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe (SDR-PR)*
- **ASTM F437** *Standard Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*
- **ASTM F438** *Standard Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40*
- **ASTM F439** *Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80*
- **ASTM F493** *Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings*
- **ASTM F1970** *Special Engineered Fittings, Appurtenances or Valves for use in Poly (Vinyl Chloride) (PVC) OR Chlorinated Poly (Vinyl Chloride) (CPVC) Systems*
- **CSA B137.6** *CPVC Pipe, Tubing and Fittings for Hot and Cold Water Distribution Systems*
- **NSF/ANSI 14** *Plastics Piping System Components and Related Materials*
- **NSF/ANSI/CAN 61** *Drinking Water System Components – Health Effects*
- **PPI TR-4** *PPI HSB Listing of Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Strength Design Basis (SDB), Pressure Design Basis (PDB) and Minimum Required Strength (MRS) Ratings For Thermoplastic Piping Materials or Pipe*
- **UL 1821** *Standard for Thermoplastic Sprinkler Pipe and Fittings for Fire Protection Service*

3. CPVC Suitability for High Temperature Applications

Chlorinated polyvinyl chloride piping systems are pressure-rated for operation up to 200°F (93°C), according to the procedures found within the industry standards listed in **Section 2.1**. Actual pressure ratings depend upon wall type (e.g., SDR 11, SDR 13.5, Schedule 80) which dictates the actual wall thickness.

For SDR 11 CPVC tubing, standard hydrostatic pressure ratings are 400 psi at 73°F (2,750 kPa at 23°C) and 100 psi at 180°F (690 kPa at 82°C).

Note 1: Consult the specific CPVC pipe and fitting manufacturer's literature and listings, as well as the solvent cement manufacturer's literature and listings, for appropriate temperature and pressure ratings and limitations.

Years of experience, combined with long-term hydrostatic testing per **ASTM D2837** and as listed in **PPI TR-4**, have proven the resistance of CPVC to continuous operation at elevated temperatures such as found in hydronic heating systems and certain commercial plumbing systems.

For all thermoplastic piping products, operating pressures are dependent on the operating temperatures – the higher the temperature, the lower the pressure rating. As per **ASTM F441/F441M** and **F442/F442M**, Temperature Derating Factors as shown in **Table 1** for CPVC pipes conveying fluid at elevated temperatures must be applied.

Table 1: Temperature Derating Factors for CPVC Pipe

| Temperature | | Pipe Derating Factor | |
|-------------|----------|---------------------------|---------------------------|
| °F | °C | CPVC 4120-05 ^a | CPVC 4120-06 ^a |
| 73 to 80 | 23 to 27 | 1.00 | 1.00 |
| 90 | 32 | 0.91 | 0.91 |
| 100 | 38 | 0.82 | 0.83 |
| 120 | 49 | 0.65 | 0.70 |
| 140 | 60 | 0.50 | 0.57 |
| 160 | 71 | 0.40 | 0.44 |
| 180 | 82 | 0.25 | 0.31 |
| 200 | 93 | 0.20 | ^b |

^a See ASTM F441/F441M and F442/F442M for material descriptions and requirements related to pipe material designation codes CPVC 4120-05 and CPVC 4120-06.

^b Consult with specific product or component manufacturer for temperature derating factors above 180°F (82°C)

To determine an elevated temperature rating, multiply the 73°F pressure rating by the derating factor from the appropriate column in **Table 1**.

Example: Per ASTM F442, SDR 11 CPVC pipe is rated at 400 psi at 73°F. Calculate the pressure rating for a pipe made from CPVC 4120-05 material at 160°F.

Answer: 400 psi x 0.40 = 160 psi at 160°F

Occasionally, designs for domestic hot-water plumbing systems specify that the minimum hot-water temperature shall be 140°F (60°C) to prevent the potential growth of water pathogens such as Legionella. This range of water temperature is also found in certain commercial plumbing systems. Rated for operation under pressure at temperatures up to 200°F (93°C), CPVC piping systems are suitable for such applications.

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 CPVC pipe manufacturer's published ratings and product standards such as **ASTM D2846**, **F441/F441M**, **F442/F442M**, or **CSA B137.6** for specific information about pressure ratings at various temperatures.

4. Effects of Potable Water Disinfectants on CPVC

Chlorinated polyvinyl chloride systems are immune to chlorine degradation and will not be affected by systems operating continuously at temperatures up to 200°F (93°C), even when used in conjunction with high levels of chlorine for disinfection purposes.

In some instances, such as the process of thermal disinfection of commercial plumbing systems, which may be intended to prevent or kill the growth of water pathogens such as Legionella, plumbing systems may be exposed to water temperatures of 160°F (70°C) or higher, combined with high levels of disinfectants such as chlorine, chloramines, or chlorine dioxide for short periods of time. CPVC piping systems are suitable for such exposures.

Thanks to its smooth wall surfaces, CPVC pipes are also less likely than metallic pipes to host the growth of biofilms, which can harbor bacteria as well as potential food sources for the bacteria.

5. Mixed-Material Systems that Contain Both Copper Materials (i.e. Tubing, Fittings, Valves) and CPVC

Plumbing and mechanical 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. These requirements are often based on Copper Development Association guidelines, such as **CDA Publication A4015-14/23 *The Copper Tube Handbook***.

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, such as:

- The chemistry of the water (i.e., “aggressiveness”),
- Water temperature,
- Water velocity, and/or
- Cavitation where changes in flow direction occur.

When it occurs, this type of attack on the copper tubing components can release dissolved copper into the water while simultaneously corroding the copper tubing, which will eventually lead to failure of the copper tubing. This effect has been reported in various regions of the world, including North America.

As published in **PPI TN-57 *Proper Integration PP-R Piping Materials with Copper Tubing and Components for Plumbing Applications***: “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”.

Due to its amorphous structure and high glass transition temperature, CPVC is resistant to oxidizers and metal ions and is not susceptible to copper ion catalyzed oxidation degradation.

6. Other Design and Installation Considerations

CPVC piping is inherently ductile, allowing it to be deflected within permissible limits, around or away from objects during installation, which can reduce installation time. This ductility allows for greater freedom of design and lower installed cost.

With all piping systems, proper design and installation is critical. Building codes, industry manuals, and the pipe and fitting manufacturers’ design and installation instructions and training content should always be reviewed in detail prior to installing a CPVC system.

A maximum design velocity for hot- and cold-water distribution systems of 8 feet per second (2.4 m/s) is typically utilized for CPVC tubing systems and for CPVC pipe NPS 4 and smaller, while a maximum

design velocity of 5 feet per second (1.5 m/s) is typically used for CPVC pipe water distribution systems larger than NPS 4. Contact the pipe manufacturer for velocity limitations for specific design situations.

In addition to the topics discussed in this Technical Note, the following design and installation topics should also be considered for any CPVC piping project:

- Safety, handling, and storage
- Hydraulic design (e.g., pipe sizing)
- Permeation of oxygen through the pipe wall
- Thermal expansion and contraction (e.g., expansion arms and loops)
- Cutting and joining procedures
- Hangers and supports
- Heat transfer / insulation
- Chemical compatibility of ancillary products (e.g., firestops, thread sealants)
- **ASME B31.3** Bonder Qualification (see solvent cement manufacturer)

7. Summary

Based on the information provided in this Technical Note, it is demonstrated that chlorinated polyvinyl chloride (CPVC) piping materials are suitable for high-temperature applications, are resistant to potable water disinfectants, and are suitable for mixed-material piping systems (e.g., metal, plastic), even those that contain both copper materials (i.e., tubing, fittings, valves) and CPVC where dissolved copper ions may occur.

The life expectancy of CPVC piping materials, when specified correctly and installed according to industry and manufacturers' guidelines, is typically well in excess of fifty (50) years. Long-term pressure ratings for these piping materials are developed based on testing in accordance with **ASTM Test Method D2837** and the materials are listed according to **PPI TR-3**.

Therefore, CPVC piping systems are suitable for many commercial building applications, including hot- and cold-water distribution (potable water plumbing), fire protection, chilled water, and hydronic heating and cooling systems and are considered fit for those purposes.