

How to Avoid CPVC System Failure

As a forensic engineer, I frequently work on several types of parts and systems. In other words, some parts and systems have a higher failure rate than other similar systems. Often the failures are related to problems in a part or component as produced by the manufacturer. In other cases, the problems are due to the design and/or installation.

One type of system on which I have worked is CPVC-based systems. Chlorinated polyvinyl chloride (CPVC) is a thermoplastic produced by the chlorination of polyvinyl chloride (PVC) resin. CPVC pipe can be rated for use in fire suppression systems, among others.

The chlorine content varies per product; however, the increase of the chlorine content raises the glass transition temperature. In addition, manufacturers include additives such as stabilizers and pigments based on the various listings, applications, and process needs. While blend and manufacturing defects can result in failures, they are not addressed herein. This article focuses on improper design and installation of CPVC-based systems.

LACK OF KNOWLEDGE LEADS TO DESIGN DEFICIENCIES

Several years ago, I provided design analysis and expert testimony on a Denver District Court case (*Regency v. Cleary*, 06CV9367) concerning the improper design and installation of a CPVC-based fire suppression system. This case illustrated several troubling issues related to fire protection systems that may be installed throughout the United States.

First, the system as designed was faulty. The code requires systems to comply with the installation instructions for CPVC systems. The designer in *Regency v. Cleary* stated that he had not seen the manufacturer's installation instructions until the day before his deposition. In addition, he had not referenced them in the design, so the system was not installed in compliance with the manufacturer's instructions. It was further revealed that the manufacturer's instructions had not been followed on as many as 100 other systems that he had designed.

Second, it did not appear that anyone involved in the design, installation, review, or approval of this system knew the installation instructions or the requirements for the specific CPVC system. When the deficiencies were identified, the designer, installer, and authority having jurisdiction (AHJ) were unaware of the deficiencies. Even more troubling, they failed to understand the implications of these deficiencies.

Further, they argued (unsuccessfully) that the system was not deficient.

The specific deficiencies in the subject system included the following:

- Installation and gluing of joints occurred at ambient temperatures below the manufacturer's listed minimums.
- The several-hundred-foot lengths of main floor pipe had no method to account for thermal expansion.
- In some areas, pipe was installed too close to heat-producing devices (see Figure 1).
- Wall penetrations had insufficient clearances.

The intent of a fire suppression system (to suppress a fire) can be compromised significantly if thermal expansion causes system failure, preventing the proper automatic operation of the system during a fire event. Failure of a fire suppression system greatly increases the risk of injury to building occupants and to responders tasked with putting out the fire. In addition, regardless of the ability of the system to properly suppress a fire, the system in this case as installed was prone to systemic leaks and failures as the system pipe began to fracture due to forces exceeding the creep capacity of the CPVC material. The system in this case had not failed yet, but it was compromised. Thus, the system was removed and replaced with an associated large price tag.



Figure 1 This installation demonstrates a CPVC pipe system and sprinkler in the direct path of a unit heater, which is a direct code violation that can lead to CPVC pipe fracture and burst.



Figure 2 This failure was due to environmental stress cracking created by the application of a caulk with a hydrocarbon base.

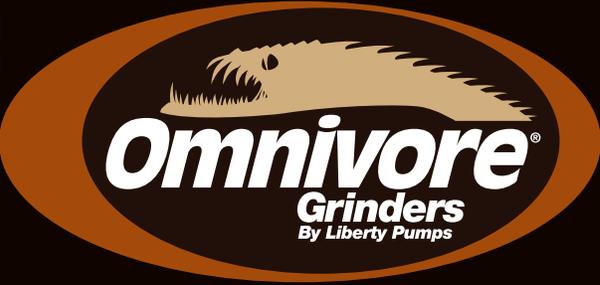
POOR DECISIONS LEAD TO CRACKING

I also have worked on numerous CPVC systems that were charged with glycol. CPVC systems are listed to be used with only glycerin. **The use of glycol results in environmental stress cracking (ESC) that degrades the pipe's strength from the interior. Fractures develop inside the pipe, unobservable from the exterior.**

In reference, NFPA 13R: *Standard for the Installation of Sprinkler Systems in Residential Occupancies Up to and Including Four Stories in Height* Section A-1-6.2 states: "Listed CPVC sprinkler pipe and fittings should be protected from freezing only with glycerin. **The use of diethylene, ethylene, or propylene glycols is specifically prohibited. Laboratory testing shows the glycol-based antifreeze solutions present a chemical environment detrimental to CPVC.**"

The coatings used to protect black fire suppression pipe (steel or iron components used in mains and standpipes) from corrosion can contain chemicals that result in ESC. The addition of solvents or cutting oils during the installation process also can introduce ESC-producing chemicals. The wet side of the iron pipes and fittings must be free of any of these compounds prior to connection within a CPVC system. Manufacturer instructions typically contain information related to the proper cleaning of metal components used in a system containing CPVC material. I have worked on several cases in which the first horizontal section of CPVC pipe in

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Figure 3 The longitudinal fracture was the result of a deep gouge in the pipe.

a system failed due to ESC caused by oils and solvents in the system. Typically, as the distance from the black pipe increases, the amount of ESC is reduced.

Exterior ESC issues have been observed as well. While no evidence of ESC was observed, the pipe in the Denver case had been painted in conflict with the manufacturer's listing. CPVC pipe must not be coated with any unapproved material, or the listing, and thus the warranty, will be voided. Exposure to many hydrocarbons and pesticides also will result in ESC and may result in exterior crack formation (see Figure 2).

RUPTURES DUE TO SUNLIGHT EXPOSURE

CPVC pipe is also notch and sunlight sensitive. From the time of production through its useable service life, a CPVC pipe system must be protected from this potential damage.

In a case in Utah, several sections of CPVC pipe had degraded and failed due to exposure to sunlight for many weeks. The pipes that were on the top exterior of the bundle had obvious bleaching of the surface, but it was installed anyway. Several years after installation, leaks started to develop.

In most cases, the manufacturer's instructions identify and warn of these issues, but some designers, installers, and users don't read the manufacturer's manual or instructions. Scrapes, gouges, and impact will create a stress concentration that can result in rupture. Laboratory testing resulted in

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illustrating a significant reduction in burst strength when the pipe was scratched with an awl (see Figure 3).

IMPROPER INSTALLATION CAUSES FAILURE

A variety of installation practice deficiencies commonly are observed during failure analysis of these systems. The following deficiencies typically are not observed in metal pipe-based systems.

Excessive glue in pipe joints can result in weakening of the pipe wall, which results in a reduced evaporation rate of the solvents in the glue and also provides a location for contaminants to lodge, resulting in ESC.

Use of a non-listed glue also has been observed. The joints do not bond completely, and the glue fractures, allowing the pipe to separate from the socket or fracture (see Figure 4).

Improper insertion of the pipe into the socket can result in bending, which results in differential glue thickness often with no adhesion at the thinned section. Also, if the pipe is not fully inserted and held as the manufacturer's instructions state, the full strength of the joint will not be realized, making the joint prone to failure. If the glue had partially dried, fractures and channels in the glue would form, which will allow eventual leakage and/or separation.

Improper support of the pipe is also a common observation in failed systems. CPVC pipe should not be clamped, as this reduces its ability to flex for thermal expansion. Also, the applied stress can result in fracture at the clamp locations. Hangers with a large span can result in fracture at the stress points.

A COORDINATED EFFORT TO GUARD AGAINST FAILURE

In summary, the majority of the failures in CPVC pipe systems are related to installation deficiencies, ESC due to sunlight, incompatible chemicals, and scratches or impact abuse. In recent years, manufacturers have made efforts to ensure compliance with their instructions by offering training and certifications to installers. However, in some cases, improper information has been disseminated in these courses.

Designers should stress the importance of the sensitivity of CPVC to installation practices and take steps to make sure their designs are being installed properly. Installers own the responsibility to understanding and following the manufacturer's installation instructions as mandated by the codes. Finally, owners must understand the systems and take steps to ensure that listings and installations are not compromised by their actions or neglect. **PSD**



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Figure 4 This failure was the result of an improperly glued joint.

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