NUTS & BOLTS

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SPRINKLER PIPE FAILURES

Sprinkler Pipe Failures

Failures by the orange CPVC sprinkler pipes that run around the ceilings of our buildings can get us into at best, an expensive replacement program, and at worst considerable expense in damaged equipment, stores and furnishings. These pipe failures are occurring all too often. We have completed failure analyses on pipe that flooded a computer room in a high school, failed in a hospital putting rooms out of service for decontamination, destroyed electronics, caused loss of finished flooring and carpeting in a multistory residential condo, and more.

Manufacturing Defects One form of manufacturing defect we see arises in the extrusion process. The CPVC granules are extruded through a die that includes a mandrel. The mandrel is supported by three or four vanes. The plastic flows around the vanes that support the mandrel and the plastic is expected to knit together as the divided flow rejoins to form the pipe. Failure to knit results in long, straight, axial cracks. We have observed that more often than not the crack is more open on the inside than on the outside. Unlike other failure modes, traces of the weak knit line can be seen where the pipe runs inside the sockets of fittings.

Another form of manufacturing defect is failure of the CPVC granules to fully fuse during extrusion.

Using a stereomicroscope we see this defect as granularity on the fracture surfaces.

Defects traceable to resin chemistry are reported in the literature however, as yet, we have not observed them. We are always concerned about the amount and purity of regrind additions to the resin and about the amount of moisture carried in by the regrind.

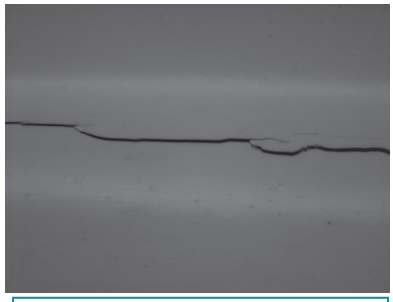


Figure 1: Axial crack in CPVC sprinkler pipe to due preservative oil washed in with the water 100x

We have not yet encountered pipe that failed to satisfy the ASTM specifications for roundness and variability in wall thickness.

Stress During cool down after leaving the extrusion die the outside of the pipe cools first, both shrinking and becoming stiffer sooner than the inside pipe wall. This applies a differential hoop stress that ends up being compressive on the outside wall and tensile on the inside wall. This residual stress is superimposed on the stress due to internal water pressure. Additionally, because the pipe is relatively thick compared to its diameter, mathematical analysis tells us that the hoop stress due to internal pressure is higher at the ID than it is at the OD.

Accordingly, even if a flaw starts out as uniform across a pipe's wall thickness, with the higher stress at the ID, stress-related cracks usually initiate at the ID and, after failure, are more open at the ID.

Strength During extrusion there is a tendency for the molecules of the polymers making up CPVC to become aligned in the direction of plastic flow. It is normal for the extruded product to be weaker in the transverse direction and stronger in the axial direction.

While it is possible in theory for badly hung CPVC pipe to be subjected to axial tensile strength, we have not seen such failures. We have seen bending stress failures in elbows where the pipe was badly fitted and hung.

Stress Cracks These are called ESC, environmental stress cracks. ESC occurs when CPVC that is under tensile stress is attacked by specific organic chemicals. Without listing the actual chemicals, in the sprinkler environment those chemicals are found in the glue used to join the CPVC pipe, in soldering flux used when making up copper fittings, in the cutting fluids used in threading steel pipe, badly chosen cleaning solvents, anti-corrosion linings in steel pipe, anti-bacterial coatings in supply lines, lubricants used in manufacturing steel pipe and fittings, and the drawing lubricants used in making copper tubing.

In general, in flowing water situations the organics causing ESC are carried away over time so there are fewer problems. Also, if the particular organic is water soluble it gets diluted so it is less likely to cause problems. The worst problems arise when the organic chemical is insoluble in water and the water is not flowing.

ESC cracks tend to be axial. As they appear in figure 1, they are zig zag. Sometimes they are branched and sometimes stop-and-go. Usually they have surprisingly uniform crack openings on the ID, and crack initiation is usually on the ID. Sometimes they are at the top of the pipe where an insoluble contaminant has floated. ESC cracks frequently stop adjacent to cemented joints.

We also see crazing such as figure 2.

Installation Defects Failure to adequately clean and then to adequately rinse steel and copper pipe and fittings in the supply line can lead to ESC.

Inserting antibacterial coated metal pipe (ABF) in a static sprinkler line will crack the CPVC.

When assembling CPVC, incomplete insertion at a fitting can leave a blob of glue that can cause ESC. Similarly, excess glue can leave a blob that starts CPVC, figure 2.

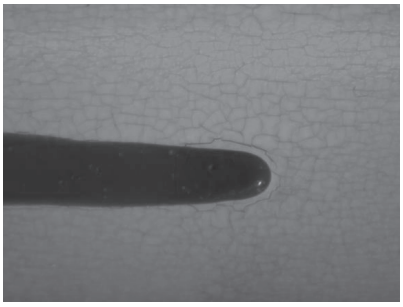


Figure 2: ESC surrounds an adhesive drip inside a CPVC pipe. Crazing is due to vapor from the adhesive.

Some Incompatible Chemicals:

- Ethylene & propylene glycol antifreeze
- Chlorinated hydrocarbons such as methylene chloride, chloroform and ethylene chloride.
- Most aromatics. These are molecules that include a benzene ring such as benzene and toluene.
- Most esters such as methyl and ethyl acetate
- Most ethers such as petroleum ether and ethyl ether
- Most phthalates
- Most amines such as diethyl and hydrazine.
- Most ketones such as MEK and acetone.
- Most unsaturated hydrocarbons such as cyclohexane, mineral oil, motor oil

A Few Usually Compatible Chemicals

- Most alcohols if diluted in water
- Most saturated hydrocarbons

NHML Services Cracked CPVC pipe cut open and examined using a stereomicroscope so as to assign the failure to the appropriate category. Organics on the ID are collected with high purity solvents and analyzed by GCMS. A crack is broken open for direct examination of the fracture surface. The question put to us is usually “what is the cause of failure and is there a manufacturing defect or an installation defect or a service defect? We usually analyze a segment about six inches long with any remaining pipe returned to you in its as received condition. The work on the six inch segment is necessarily destructive. Put to us this question and you can expect to receive a report in about five working days for a fixed price that is presently $1200.00. The fixed price changes to a per-hour rate if we need to accommodate observers, if additional segments need to be tested, if on-site examinations become appropriate, or if we need to confer with your attorneys.

Also, we will get back to you if additional analysis needs to be done to nail down the answers.

FH 6/27/08

NHML STAFF BIO

Senior Chemist: Jeff Masse

We are fortunate to have long time employee Jeff Masse as our Senior Chemist. He has been with NHML since 1992. Jeff has his Masters degree from UCLA and has a very strong background in Physical and Organic Chemistry as well as Analytical.

What does he do here at NHML? Analysis of plastics, liquids and contaminates using Energy Dispersive Spectroscopy (EDS), Fourier Transfer Infrared Spectroscopy (FTIR), Gas Chromatography/Mass Spectroscopy (GC/MS) and Differential Scanning Calorimeter (DSC) instrumentation.

Jeff and his wife currently reside in East Waterboro, Maine with their 4 children. One of his favorite hobbies is hunting.

Recent Case Studies From the Chemistry Lab

Case History: Medical Device Manufacturer

Customer problem: Manufactures a medical device for use in the uterine cavity and needs to verify that no trace of mineral spirits have remained on the devices.

What NHML did to solve problem: We performed a solvent extraction on the devices and then analyzed the extract by Gas Chromatography—Mass Spectrometry. The resulting chromatogram showed conclusively that no hydrocarbon residue from mineral spirits remained on the devices.

Benefit to customer: QC department has proof as to the cleanliness of their medical devices.

Case History: Manufacturer of insulin pump

Customer problem: Connector needle on personal insulin pump was clogged with an unknown clear solid substance.

What NHML did to solve problem: We analyzed the clear substance by FTIR and by the absorption peaks in the spectrum. We concluded that the clear obstruction was a hydrated protein. We ruled out the possibility that the obstruction was Loctite (used in the construction of the pump), and also the possibility that the obstruction was dried or coagulated insulin.

Benefit to customer: Complaint technician had some good data with which to write a report on this particular complaint.

Case History: Manufacturer of stents for surgical implants

Customer problem: Manufactures of stents for surgical implantation. During manufacture a surfactant is used at one point but is later “flashed off” at 340° C. Customer needs to verify that all of the surfactant has been successfully removed by this procedure, and that stents are clean and ready for implantation.

What NHML did to solve problem: We performed a solvent extraction on the stents and then analyzed the extract by Gas Chromatography-Mass Spectrometry. The resulting chromatograms showed surfactant peaks for all positive controls, no surfactant peaks for negative controls or for any of the actual test samples, thus verifying that all of the surfactant is removed by the 340° C flash off procedure.

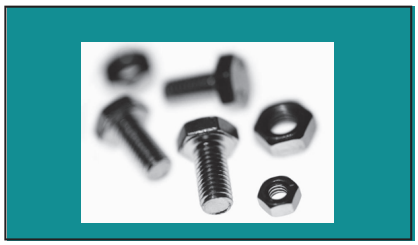
Benefit to customer: QC department has proof as to the cleanliness of their medical devices.

Your Problem Solving Partner

Our Philosophy

New Hampshire Materials Laboratory has one goal - to help you solve your technical problems at a reasonable cost. Tests help, but are not always enough. Our team of dedicated and experienced professionals have the skills and the backup facilities to serve in the following:

- Failure Analysis
- Material Certification/Compliance
- New Product Testing
- Mechanical Properties
- Tensile/Compression Testing



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New Hampshire MATERIALS LABORATORY, INC.

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FAILURE ANALYSIS

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MATERIAL ID & CERTIFICATION

THERMAL ANALYSIS

CONTAMINATION ID

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