Update on Compatibility Testing of Spray Polyurethane Foam with CPVC

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ABSTRACT

In response to the growing use of the combination of CPVC and spray polyurethane foam products (SPF) the Center for the Polyurethane Industry (CPI) and the Spray Polyurethane Foam Alliance (SPFA), along with Lubrizol Advanced Materials, Inc., a leading CPVC resin manufacturer, have conducted a study which assesses the compatibility of generic SPF and CPVC pipe and fittings. This research program has allowed the industry to assess the chemical, physical, and thermal compatibility of soy and non-soy based closed-cell polyurethane foam, soy and non-soy based open-cell polyurethane foam, and one component foam with CPVC pipe and fittings. Industry testing and current ASTM test protocols involve soaking the CPVC pipe in a liquid or solvent material. Foam presents an interesting challenge for compatibility testing since CPVC/foam compatibility does not involve the long term liquid contact of materials. Instead, the contact point is multi-cellular foam on a smooth plastic surface. This paper discusses the outcome of sample testing and includes a physical and analytical assessment of the foam and CPVC. Of particular interest, is the interaction between phosphate ester flame retardants, which have been linked to CPVC pipe failures due to contact with other substances, the long term and short term effects of variables such as foam exotherm, phosphate ester type and concentration, as well as soy polyols. This program will provide a basis for an ongoing industry program to evaluate SPF products with plastic building materials.

DISCLAIMER

INTRODUCTION

This paper is second of two papers on this subject, where the first of which was presented at Polyurethanes 2008. In this paper the results of the two year program are presented and discussed.

WHAT IS CPVC?

"At its most basic level, CPVC is a PVC homopolymer that has been subject to a chlorination reaction. In PVC, a chlorine atom occupies 25 percent of the bonding sites on the backbone, while the remaining sites are filled with hydrogen. CPVC differs from PVC in that approximately 40 percent of the bonding sites on the backbone are filled with strategically place chlorine, while the remaining 60 percent available sites are filled with hydrogen. The chlorine atoms surrounding the carbon backbone of CPVC are large atoms which protect the chain from attack. Access to the CPVC carbon chain is restricted by the chlorine on the molecule. It is the additional chlorine that provides CPVC with its superior temperature and chemical resistance." (1)

WHERE IS IT USED?

Chlorinated Poly Vinyl Chloride (CPVC) Pipe & Fitting compounds are designed and manufactured to ASTM D 1784 *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds*. These pipes and fittings are used for fire suppression systems, potable water distribution, as well as corrosive fluid handling and are recognized by all model building codes. CPVC compounds were first produced by Lubrizol Advanced Materials, Inc. (formerly BF Goodrich Performance Materials) in the late 1950's. (1) Since that time, CPVC it has been successfully installed in residential, commercial, and industrial applications and continues to gain popularity due to the many benefits that it offers as well as its lower cost and ease of installation when compared with steel or copper pipe and tubing. When installed per manufacturer's recommendations, CPVC pipe can perform very well. Manufacturers report that more than a billion feet of CPVC sprinkler piping have been successfully installed in accordance with NFPA 13D Standard for the Installation of Sprinkler Systems in One- and Two-Family Dwellings and Manufactured Homes and 13R Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and including four stories in height. In 2009 there was a change adopted to the IRC code Section R313. The change states that effective January 1, 2011, an approved automatic fire sprinkler system shall be installed in new one and two-family dwellings and townhouses in accordance with NFPA 13D.

WHAT ARE THE LIMITATIONS FOR CPVC PIPING?

As with any plastic, CPVC has limitations as to where it can be installed and under what physical environments it can successfully be used in. CPVC piping and fittings have primarily two routes of failure: physical and chemical. These modes of failure are often manifested in installations as mechanical stress cracking and environmental stress cracking. Mechanical stress cracking is the result of the piping being installed under high stress situations. Mechanical stress cracking is defined as the external or internal cracks in a plastic caused by tensile stresses in excess of the local short-term mechanical strength. (2) CPVC pipe failures can stem from two mechanical failure modes: improper installation or excessive pressure. This is not the focus of this paper.

Environmental stress is often the result of variables that impact the chemical resistance of the CPVC pipe and/or fittings. This includes "chemical concentration, temperature, pressure, external stress and final product quality. This can exhibit itself in several different ways with the most common problems being softening, degradation and cracking. Environmental stress cracking (ESC) is a mechanism by which organic chemicals achieve an extremely localized weakening at the surface of the part which permits the propagation of a crack. It generally presents itself as a crack with glossy fracture surfaces that occur in regions of high mechanical stress. Potential ESC agents for CPVC include natural or synthetic ester oils, nonionic surfactants, alcohols and glycols" (1)

WHAT ABOUT CPVC AND SPF?

The use of polyurethane foam has grown dramatically in the commercial and residential market. Often SPF is applied directly, as insulation, or crack filler, to the surface of CPVC pipe and fittings. SPF is made in the field from a reaction of a diisocyanate and a resin blend containing polyols, surfactants, amine catalyst, blowing agents and flame retardants (including phosphate esters). The polyols used in the resin blends can be petroleum based or soy or other agricultural feedstock based. The polyurethane chemical reaction is exothermic, which depending upon foam thicknesses can reach temperature in excess of 200° F. Based upon the use of phosphate esters as flame retardants in spray foam and recent field failures related to other materials containing phosphate esters, CPVC resin manufacturers including Lubrizol have issued cautionary statements about the use of their products in conjunction with SPF. It is important to note that foam plastics containing phosphate esters have not resulted in any documented ESC related failures. Since no qualified research exists today to support that there is no impact, Lubrizol issued the following cautionary statement:

> "We are currently investigating chemical compatibility of polyurethane foams with our CPVC brands. This process will take several months to investigate. Thus, at this time, we cannot say whether such products are compatible with CPVC. While we are not aware of a CPVC failure that was the result of chemical incompatibility with properly applied polyurethane foams, when polyurethane foams are not properly applied there is the potential for excess heat that can lead to ballooning of the pipe and a subsequent failure."(3)

A number of other manufacturers have followed suit. The goal of this co-sponsored research work is to demonstrate that there is no chemical/physical impact to the performance and longevity of CPVC piping and fittings when they are in contact with spray polyurethane foam. This program will include evaluation of the chemical, thermal and physical compatibility of spray foam with CPVC piping/fittings and have the data reviewed and a summary report issued by an independent third party.

HOW DOES ONE TEST CHEMICAL COMPATIBILITY WITH CPVC?

Two test procedures ISO 22088 *Determination of Resistance to Environmental Stress Cracking (ESC)* and ASTM D543 *Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents* are used by the industry to test method for evaluating the resistance of plastics to chemical reagents. The current methods used to test chemical compatibility with CPVC pipe are not appropriate for foam plastics. There are some clear limitations defined in the ASTM test procedure.

> "The limitations of the results obtained from these practices should be recognized. The choice of types and concentrations of reagents, duration of immersion or stress, or both, temperature of the test, and properties to be reported is necessarily arbitrary. The specification of these conditions provides a basis for standardization and serves as a guide to investigators wishing to compare the relative resistance of various plastics to typical chemical reagents. Correlation of test results with the actual performance or serviceability of plastics is necessarily dependent upon the similarity between the testing and the end-use conditions. For applications involving continuous immersion, the data obtained in short-time tests are of interest only in eliminating the most unsuitable materials or indicating a probable relative order of resistance to chemical reagents." (3)

Two of the main problems that have been identified with the applicability of this test method to foam plastics are the physical characteristics of the foamed plastic and the short duration of liquid chemical contact with CPVC.

ISO 22088 and ASTM D 543 are very relevant tests for solids, liquids, gels, or adhesives containing phosphate esters. Figure 1, below depicts phosphate ester migration from a fire rated caulk into a CPVC fire sprinkler pipe. When installed around CPVC pipe, phosphate esters contained within these caulks have a significant level of exposure with a clear migration pathway to the CPVC pipe.

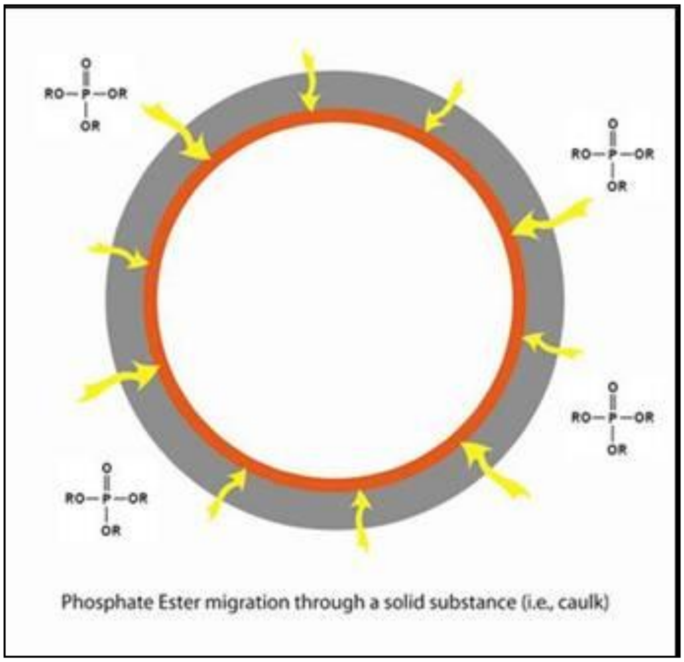


Figure 1. *Simulate phosphate ester migration through solid substance*

However, *Figure 2* represents SPF when applied over the surface of CPVC pipe. The cellular structure of SPF and other foam plastics limit the amount of surface area contact between the CPVC and SPF. The pathway for the migration of phosphate esters is reduced in many ways. Unlike other solid homogeneous products, SPF is non homogeneous. The cellular nature of the product requires that any phosphate esters traverse a tortuous pathway along cell wall boundaries.

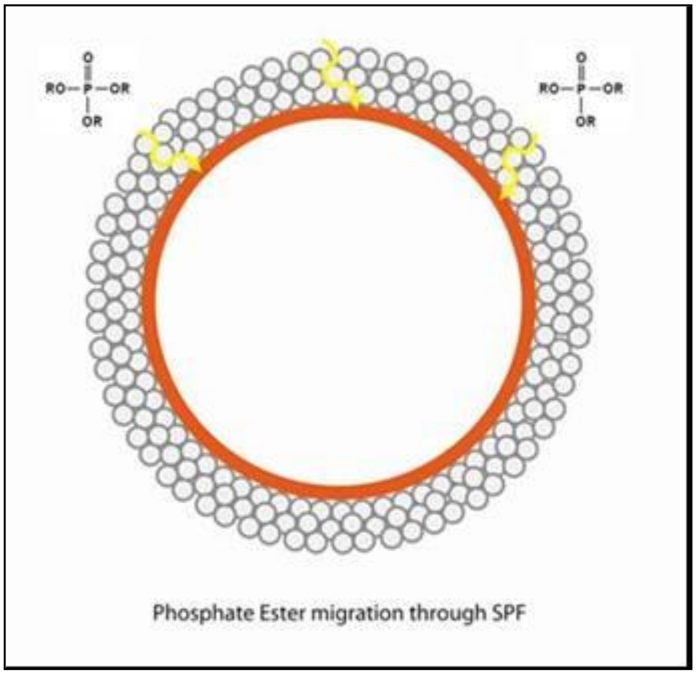


Figure 2. *Simulate phosphate ester migration in foam*

Once reacted, most SPF products are substantially cured in a matter of minutes depending on the catalysts used. Some SPF products suggest that the chemical reaction in which the resin blend (“B” side) and the diisocyanate (“A” side) is completed and results in a solidified polyurethane foam product in a few seconds. ASTM C 1029 *Standard Specification for Spray-Applied Rigid Cellular Polyurethane Thermal Insulation* allows for all spray applied polyurethane products to be fully cured and cut for physical properties testing after 72 hours. This relatively short cure time and short term contact with SPF in its liquid form suggests that any chemical incompatibility between liquid components and CPVC resins will not result in a substantial risk of pipe failure.

ALTERNATIVE TEST PROCEDURE

Since the current test procedures do not adequately represent the exposure mode, development of an alternative test scenario that more accurately depicts the exposure scenario was necessary. It was agreed that the most reasonable test scenario should involve encasing a pipe/fitting setup in polyurethane foam. This would duplicate field conditions. The pipe fitting assembly would be placed under hydrostatic pressure. Since it is important to get this information in a timely manner the test specimens in addition to being under pressure would be placed at an elevated temperature to accelerate exposure conditions.

***Figure 3**. CPVC test pipe with fitting*

Numerous test conditions were considered and the following conditions were selected as the final industry test protocol.

- Each pipe/fitting assembly was encased in a minimum of 1 inch foam
- The foamed pipe test specimens were placed in the environmental chamber at 150°F and _ambient relative humidity
- Every specimen was subjected to a constant hydrostatic pressure of 210 psi
- The pipes were removed at approximately 3000 hr, and 6000 hr.
- Throughout the test period the pipe pressure was monitored for signs of pipe rupture or leakage.
- When removed after 3000 hrs, samples with the highest flame retardant concentrations were tested and compared to pipe without foam subjected to the same conditions:
    - Pipe
        - Visual and microscopic examination for signs of stress cracking
        - Surface analyzed for phosphate content
    - Foam
        - Samples analyzed phosphate migration via positive ion electrospray (ESI-MS) using a Thermo Scientific LTQ Orbitrap XL FTMS and concentration via ICPOES (Inductively Coupled Plasma Optical Emission Spectroscopy). When removed after 6000 hrs, all samples not having measureable phosphate levels after 3000 hrs were tested as described above. After examination and analysis, all samples were destructively pressure tested to detect non-visible signs of stress cracking.

The combination of pressure and temperature used are consistent with CPVC ..performance testing. The results will be compared to Lubrizol standard samples. A 97.5% (one-sided) confidence level will be utilized.

TEST VARIABLES AND CONDITIONS

Based upon the causative factors for environmental stress cracking (ESC), it was agreed that there were 5 variables that should be included in this study: type of foam, type of flame retardant, flame retardant concentration, soy and non-soy polyol based and thickness of the foam. A design experiment utilizing a partial factorial was constructed utilizing a high and low point for each of the variables within each of the foam types. Each experiment was run only once. The constraint of the experimentation was 50 samples, the capacity of the test chamber.

Types of foam

There are a variety of polyurethane foams used in buildings. The applications range from one component foams used as a fire stop, gap filler or adhesive to wall foam insulation. In order to accurately evaluate the chemical exposure a medium density closed-cell, low density open-cell and closed-cell one component foam were included in the study. Since the focus of this study is flame retardants it was decided to utilize a generic foam system vs commercial system to minimize variation within each test. The spray polyurethane industry came to a consensus on three generic formulations to be used in the study.

Type and quantity of flame retardants

As stated earlier environmental stress is often the result of variables that impact the chemical resistance of the CPVC pipe and/or fittings. Chemicals in contact with the CPVC and the concentration of them can result in environmental stress cracking. Phosphate esters are the chemical of concern in this investigation. There are a large variety of flame retardants (phosphate esters) available for use in the SPF industry. SPFA surveyed its membership to identify what types and concentrations of phosphate ester flame retardants are used. The goal was to identify the most commonly used flame retardants.

In addition the industry conducted chemical soak compatibility testing with the flame retardants listed to identify the most aggressive flame retardant. This test involved placing CPVC pipe samples in containers containing full strength TCPP and TEP. The samples were observed for two months. The difference was marked. The TEP seemed to dissolve CPVC very quickly. The TCPP sample had no visible etching or solvation after two months. Figure 4 illustrates the results after only three weeks exposure.

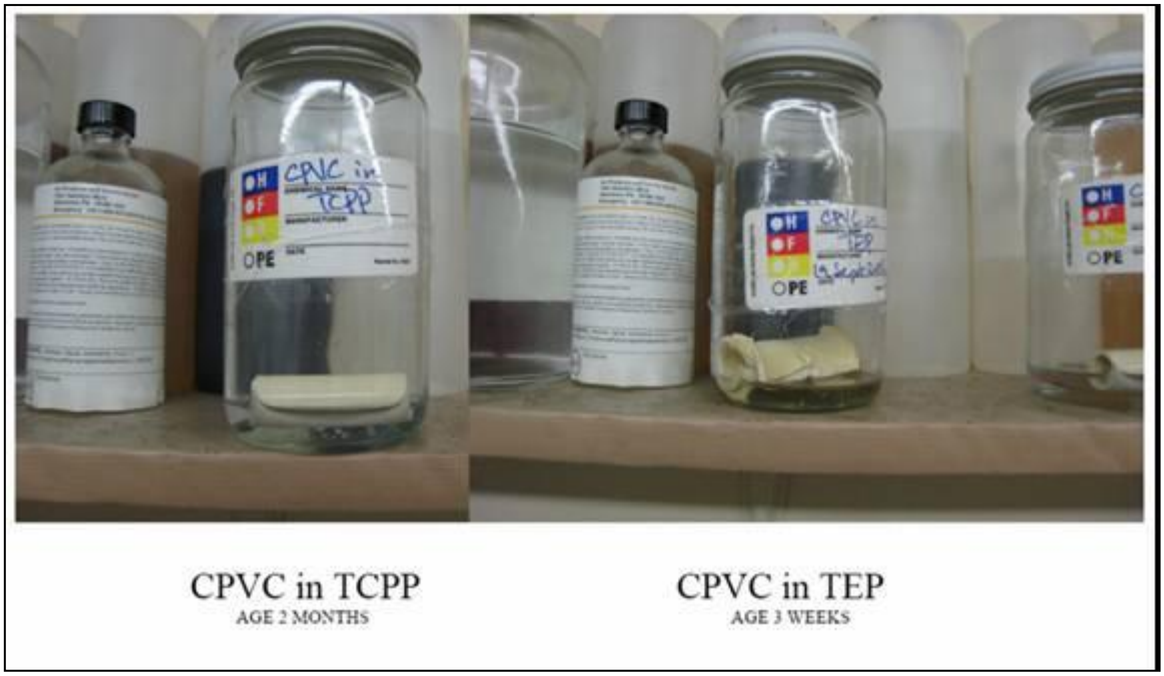


Figure 4. *Soak test CPVC in phosphate ester flame retardants*

Based on the industry survey, three primary flame retardants were identified for use in the study, TCPP- (Tris(2-chloroisopropyl)phosphate), TDCP- (Tris (1,3-dichloroisopropyl) phosphate blend) (for one component foam)and TEP (Triethyl phosphate). The soak test allowed us to rank the materials based upon the reaction with the CPVC piping. TEP being considered the most aggressive.

Type of polyol

It has been long acknowledged by the CPVC industry that CPVC is not chemically resistant to vegetable oils. The polyurethane industry has begun to formulate polyurethane foams which are prepared not only with petroleum based polyols but also polyols derived from agricultural materials such as soy oils and sucrose. These vegetable oil polyols are fully reacted products and chemically do not resemble the starting materials. However, there has been concern raised in the building community around these foams and the potential for ESC. To address this, a commercial open and closed-cell vegetable based spray foam were added to the experimental design. These materials are prepared with the flame retardant TCPP within the concentration levels utilized in the other experiments.

Thickness

Temperature or thermal exposure of the pipe or fitting has been identified as a key variable in ESC. The spray polyurethane foam reaction is exothermic. Although the exothermic temperature for a polyurethane reaction can exceed 200°F it is often for a very short period of time. Since polyurethane foam is a good insulator the retention of the exothermic heat is dependent upon the thickness of the foam application. CPVC fire sprinkler pipe is typically pressure rated for 175 psi at 150°F. It is not usually derated for higher temperatures. CPVC plumbing pipe is typically pressure rated for 100 psi at 180°F and can be derated to 80 psi at 200 °F. However; most CPVC manufacturers do not rate pipe or fittings for pressure service above 200°F.

The heat deflection temperature or heat distortion temperature (HDT) is the temperature at which a polymer or plastic sample deforms under a specified load. For CPVC Pipe, the HDT is approximately 220°F. The exotherm created and the presence of the liquid components before, during, and immediately after the reaction takes place may act as a catalyzing agent and increase the possibility of ESC. In order to address the result of the elevated temperature and its initial effect on the pipe and the migration of phosphates, all pipe samples were sprayed at thicknesses > 1 inch and > 4 inch. This creates the variation in internal foam temperatures. Prior to testing the samples are then trimmed down to 1 inch so that they will fit inside the test chamber.

The completed experimental design and samples with testing schedule are listed in Table 1

Table 1. Sample test schedule

Type of foam	Flame Retardant (FR)	Concentration FR, wt% polyol side	Thickness Foam, in	Sample Test Schedule	
				~3000 hr	~6000 hr
Closed-cell	TCPP	10	4	X	X
	TCPP	10	2	*	X
	TCPP	4	4	*	X
	TCPP	4	2	X	X
	TEP	10	4	X	X
	TEP	10	2	*	X
	TEP	4	4	*	X
Open-Cell	TCPP	50	[redacted]	X	X
	TCPP	15	[redacted]	X	X
	TEP	50	[redacted]	X	X
	TEP	15	[redacted]	X	X
OCF	TCPP	5[a]	¾" +/-	*	X
	TCPP	10[a]	¾" +/-	*	X
	TDCPP	10[a]	¾" +/-	X	X
	No phosphate ester	0	¾" +/-		X
BIO-POLYOL	Open-cell	[redacted]	[redacted]	X	X
	Closed-cell	[redacted]	[redacted]	[redacted]	X

* Not tested at 3000 hours to reduce cost of study

[a] Concentration FR, wt% Total

SAMPLE PREPARATION

A total of 139 samples were prepared for this study. The specific quantities for each study are listed in Table 2. The pipe posed a challenge to the labs because traditionally the pipe is secured to a wall assembly and the spray foam is put around the sample. How this challenge was met for each technology is described below. After the samples were prepared they were shipped via ground to Lubrizol's Test Facility in Brecksville Ohio.

Table 2. Samples prepared for test program

Type	# For testing including initial	# In test chamber	# Extra for shipment damage	# Extra for application improvement	Total #
Closed-Cell Foam	28	21	14	14	**56**
Open-Cell Foam	16	12	8	8	**32**
One Component	16	12	8	8	**32**
Soy – Open	4	3	3	3	**10**
Soy – Closed	3	2	3	3	**9**
Total	**67**	**50**	**36**	**36**	**139**

Closed-cell/ Open-cell foams

Spraying of the CPVC pipe external to a wall assembly presented a challenge. It needed to be encapsulated in foam and the open end needed to be left clean of foam to allow for attachment of the sample to the test chamber. The pictures in Figure 5 illustrate the steps taken to prepare the open-cell foam samples. A similar procedure was used for preparation of the closed-cell foam samples. Standard industry equipment and raw materials were utilized to prepare the formulations and spray the samples.

Sample placed in spray jig

Foam sprayed onto pipe in multiple layers

Foam squared to specified size

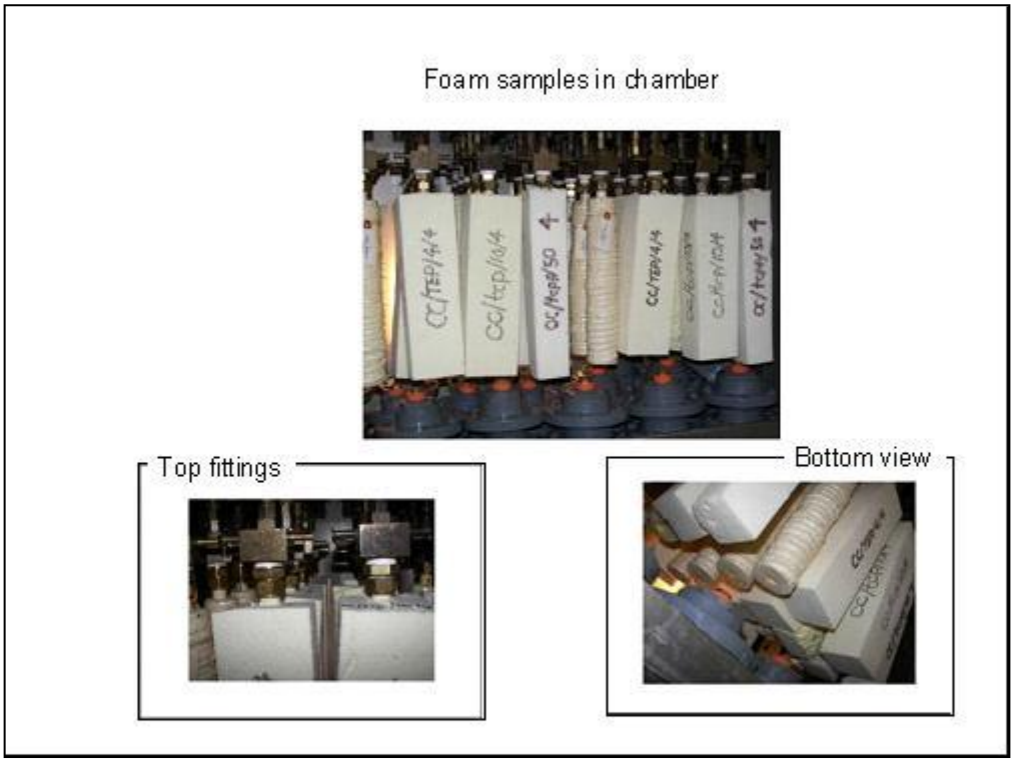
Sample ready to be shipped to test lab

Figure 5. *Preparation of open-cell foam samples*

One Component Foam Samples

Traditionally one component foam has limited contact with a CPVC pipe surface because it is used to seal or fill gaps. Because of the elevated temperature of the test it was agreed that the test pipe would be covered with one component foam. However, it would only be applied at 1 inch thickness. In order to insure that the foam exposure resembled traditional building practices the pipe was placed in a jig. It was rotated as a continuous bead of foam was applied to the pipe. Figure 6. Illustrates what the final sample looked like.

Figure 6. *One Component foam sample*



Foam samples in chamber

Top fittings

Bottom view

Figure 7. *Samples in test chamber*

TESTING

The testing was divided into 3 phases. The first was chemical in nature. It looked to detect the presence of phosphorus (i.e. flame retardants). The second was microscopic in nature. It looked to detect ESC on the pipe and fitting surfaces. The final was physical in nature. This test ruptured the pipes and fittings via excessive pressure looking to detect weak points and signs of non visible ESC.

Sample Preparation

The pipe was depressurized and removed from the sample chamber. The water was drained form the pipe and the fittings were sawed off. The sample was than transferred to the analytical labs microscopic and physical property lab for analysis.

PHOSPHATE DETECTION IN THE FOAM

A section of foam was removed from the pipe assembly and transferred to the analytical lab for testing. The foam samples were prepared and analyzed using the GC method for FR identification. In the next step ICPOES (Inductively Coupled Plasma Optical Emission Spectroscopy) was used to determine the % P level in the foam.

FR Identification by GC

FR Identification by GCThe rigid foam sample is cut into small (1/4 -1/2 inch) pieces and placed into an 8 dram glass vial (polyseal capped only), 20-mL of methylene chloride is added via auto pipette, and then shaken vigorously for a minimum of 1 hr using an auto shaker. The foam plus solvent is allowed to sit for 2 hrs, after which the solvent is decanted and analyzed using GC/FID. The FR type is determined using an optimum set of instrument parameters and known FR calibration standards. The extraction efficiency of the method has not been determined for rigid foam samples, therefore this method is used only to identify the FR type.

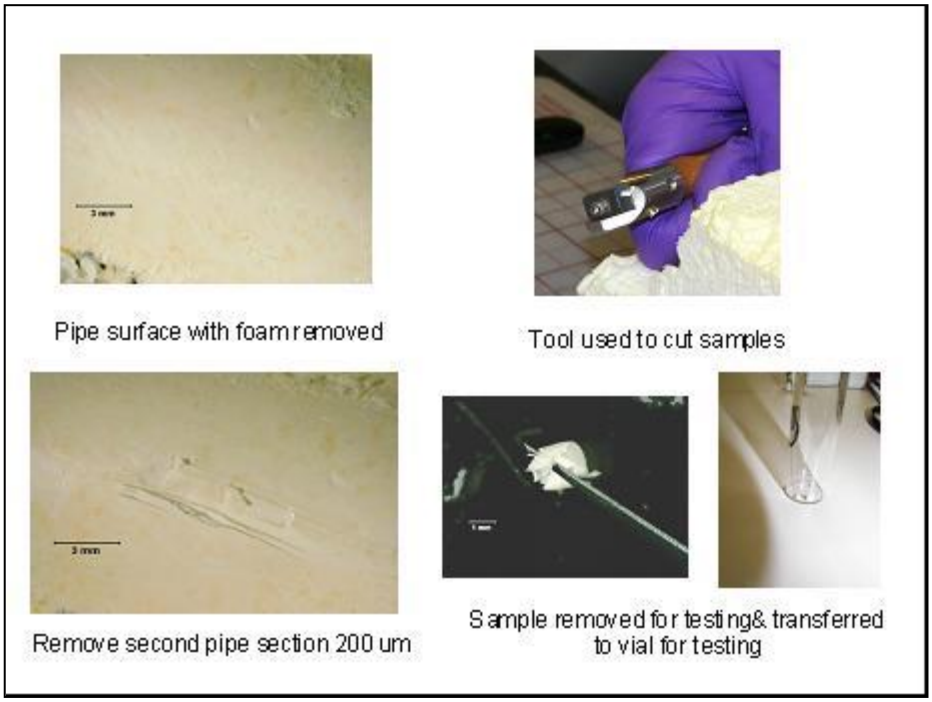
% Phosphorus in Foam

For the total phosphate analysis (% P level) in the foam a known weight of foam was digested with a known volume of concentrated nitric acid in a closed microwave digestion vessel. The microwave digestion program slowly ramps the Teflon digestion vessels to 230°C, holds for 10 minutes and then allows the vessels to cool down to room temperature. The foam samples are completely digested following this program. The vessels are then opened, contents transferred to a volumetric flask and diluted to volume with DI water. The digested samples are analyzed for total phosphorus content by ICPOES (Inductively Coupled Plasma Optical Emission Spectroscopy). Calibration standards covering the range of the samples are made up to match the acid concentration of the samples. A nitric acid blank sample that was carried through the digestion procedure is also analyzed.

Figure 8. *Foam sample removed for testing*

PHOSPHATE DETECTION IN THE PIPE

The foam was than carefully removed from the pipe surface. A scarfer was sued to remove layers from the pipe surface. The first 200um of the pipe surface was removed and than a sample of pipe were placed in a vial and ready for chemical analysis.



Pipe surface with foam removed

Tool used to cut samples

Remove second pipe section 200 um

Sample removed for testing& transferred to vial for testing

Figure9. *Sampling pipe surface*

The pipe samples were than extracted with ~1 ml of methanol on a hot plate for ~15 minutes each. The solvent is reduced to ~0.5mL by evaporation, was separated from the CPVC particles. About 0.5 mL tetrahydrofuran was added to the methanol extract to make ~1mL of solution.

The sample solution was analyzed by positive ion electrospray (ESI-MS), using the Thermo Scientific LTQ Orbitrap XL FTMS instrument. A solvent background was run first, followed by the sample solution.

MICROSCOPIC EVALUATION

The initial examination consisted of removing the foam from the specimen using a combination of coping saw and utility knife. Once the bulk of the foam was removed, the pipe and fitting surfaces were cleaned of residual foam using a razor blade.

Once the surfaces were exposed, the pipe, coupling, endcap, and joint areas were examined visually and microscopically for indications of environmental stress cracking (ESC).

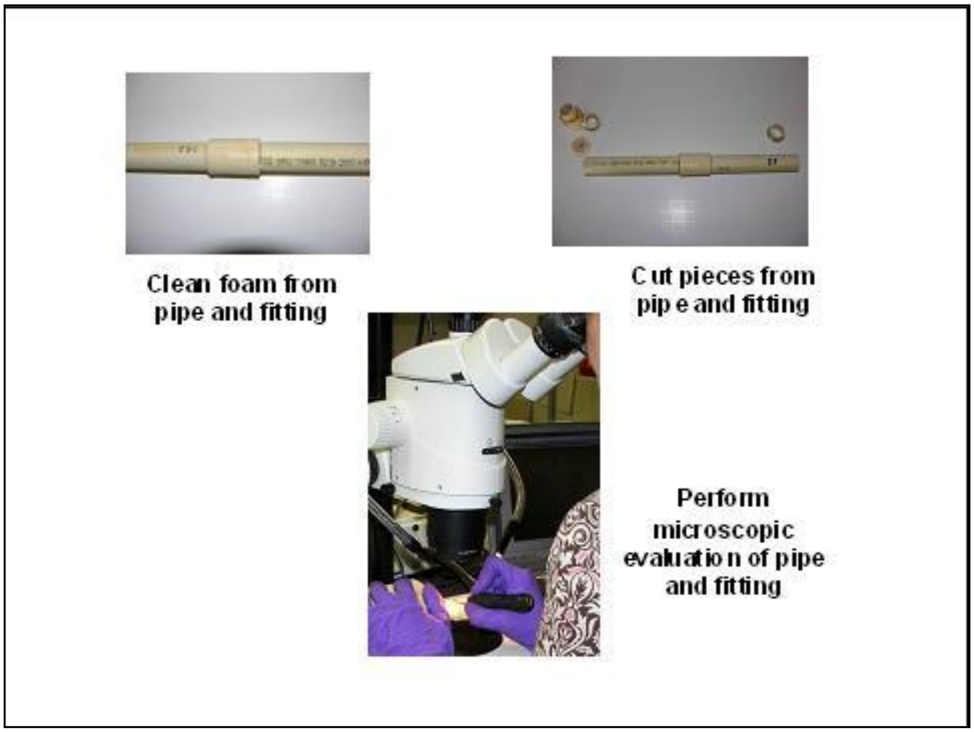


Figure 10. *Samples analyzed for ESC microscopically*

None of the specimens exhibited any indications of environmental stress cracking along the outer surfaces

RUPTURE TESTING

In some cases ESC can initiate in the CPVC but not be observable until the crack is opened by applying a hoop stress to the pipe/fitting. This was done using hydrostatic pressure on the specimen assembly. The pressure was increased slowly until final rupture of the specimen. Had ESC initiated in the wall of the pipe or fitting, the specimen would fail at that weakened area, and the resulting fracture surface would show signs of ESC.

The final rupture pressure for the specimens was approximately 1300-1600 psi. The actual pressure was not recorded other than by observation on a pressure gage. This allowed the testing to proceed more quickly, reducing the program costs. The actual final rupture pressure was not significant to the testing being done. The purpose of the burst test was to fracture the specimen to allow examination of the resulting fracture surfaces.

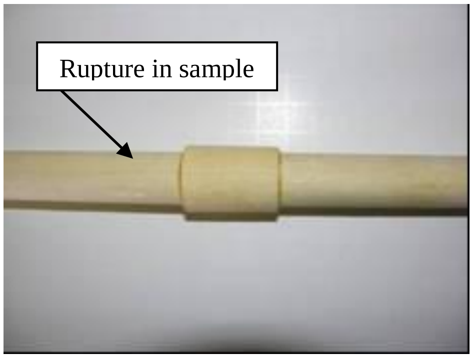


Figure 11. *Ruptured sample*

The burst specimens were then sectioned and the fracture surfaces examined microscopically.

DATA

Table 3. ~3000 Hour Test Results

Type of foam	Actual test hours	Flame Retardant (FR)	Concentration FR, wt% polyol side	Thickness Foam, in	Phosphorus in Foam	Phosphorus in Pipe	Microscopic analysis ESC Detected	Rupture test
Closed-cell	4506	TCPP	10	4	Yes	Yes	No	Pass
	4506	TCPP	4	2	Yes	Yes	No	Pass
	4506	TEP	10	4	Yes	Yes	No	Pass
Open-Cell	4506	TCPP	50	[redacted]	Yes	Yes	No	Pass
	4580	TCPP	15	[redacted]	Yes	Yes	No	Pass
	4506	TEP	50	[redacted]	Yes	Yes	No	Pass
	4506	TEP	15	[redacted]	Yes	Yes	No	Pass
OCF	4506	TDCPP	10 [a]	¾" +/-	Yes	Not detected	No	Pass
Bio Based Open-cell	3695	[redacted]	[redacted]	[redacted]	Yes	Yes	No	Pass

[a] Concentration FR, wt% Total

Table 4. ~6000 Hour Test Results

Type of foam	Actual test hours	Flame Retardant (FR)	Concentration FR, wt% polyol side	Thickness Foam, in	Phos-phorus in Foam	Phos-phorus in Pipe	Microscopic analysis ESC Detected	Rupture test
Closed-cell	6092	TCPP	10	4	Yes	*	Pass	Pass
	6092	TCPP	10	2	Yes	Yes	Pass	Pass
	6092	TCPP	4	4	Yes	Yes	Pass	Pass
	6092	TCPP	4	2	Yes	Yes	Pass	Pass
	6092	TEP	10	4	Yes	*	Pass	Pass
	6092	TEP	10	2	Yes	Yes	Pass	Pass
	6092	TEP	4	4	Yes	Yes	Pass	Pass
Open-Cell	6092	TCPP	50	[redacted]	Yes	*	Pass	Pass
	6092	TCPP	15	[redacted]	Yes	*	Pass	Pass
	6092	TEP	50	[redacted]	Yes	*	Pass	Pass
	6092	TEP	15	[redacted]	Yes	*	Pass	Pass
OCF	6092	TCPP	5[a]	¾" +/-	Yes	Yes	Pass	Pass
	6092	TCPP	10[a]	¾" +/-	Yes	Yes	Pass	Pass
	6092	TDCPP	10[a]	¾" +/-	Yes	Yes	Pass	Pass
	6092	No phosphate ester	0	¾" +/-	No	***	Pass	Pass
BIO-POLYOL	**	Open-cell	[redacted]	[redacted]	**	**	**	**
	6092	Closed-cell	[redacted]	[redacted]	Yes	Yes	Pass	Pass

** Tested at 3000 hours and flame retardant found in pipe so testing was not repeated.*

*** Test still in progress*

**** Confirming test results*

[a] Concentration FR, wt% Total

CONCLUSIONS

Although final analysis indicated that traces of all types of tested flame retardants were found on the CPVC pipes and fittings, there were no signs of ESC detected. Nor did rupture testing of the pipe identify any signs of ESC.

Based on these findings, it appears that SPF systems containing the tested types and tested maximum levels of flame retardants are compatible with CPVC piping systems. This finding is equally applicable to open- and closed-cell, sealant, and natural oil-based SPFs.

The test methodology developed as a result of this study appears to be a satisfactory protocol for the testing of SPF and polymeric piping systems.

ACKNOWLEDGEMENTS

When the issues with CPVC products were first identified, the Spray Polyurethane Foam Alliance’s (SPFA) Technical Committee went into action. SPFA members with backgrounds ranging from contractors to suppliers to SPF consultants came together to seriously look at the issue.

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5 Star Performance Insulation, Inc.
Albemarle Corporation
BASF Polyurethane Foam Enterprises, LLC
Bayer MaterialScience
BaySystems North America, LLC
BioBased® Insulation
Convenience Products
Mason Knowles Consulting
Fomo Products, Inc.
Gaco Western
Honeywell
Houlden Contracting Inc.
Huntsman Polyurethanes
Icynene Inc
Insulated Roofing Contractors
Resin Technologies/ Henry Company
ICL Industrial Products (Supresta)
SWD Urethane Company
The Insulation Man
NCFI Polyurethanes
Demilec (USA) LLC
Corbond Corporation

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BIOGRAPHIES

Chris Porter


Chris Porter, of BioBased Insulation, has been involved in spray foam insulation since 2004. First, as President of CPR Thermal Solutions, a spray foam insulation company, and more recently as Building Science and Code Manager for BioBased Insulation, Chris has helped break new ground in the area sustainable construction techniques. He holds a Bachelors degree in Business Administration from University of Central Arkansas. He has a diverse background and is experienced in the field of spray foam insulation as well as being a certified Home Energy Rater. Chris is an active member in the Spray Polyurethane Foam Alliance, and sits on several committees including the Technical, Building Envelope, and Code Development. Chris attributes much of his success to his practical approach to issues, diverse technical experience, and willingness to listen to guidance from multiple sources including Jesus Christ.

Richard S. Duncan, Ph.D., P.E.


Since September 2008, Rick has served as Technical Director of SPFA. Prior to that he was a for Senior Marketing Manager for Honeywell Spray Foam Insulation group and spent more than 10 years at CertainTeed/Saint-Gobain Corporation, where he was the Director of Laboratory Services for CertainTeed Insulation and Global Program Manager for Saint-Gobain Insulation's New Materials and Applications Program. Prior to joining Saint-Gobain, Rick was a Visiting Assistant Professor of Mechanical Engineering at Bucknell University. He holds a Ph.D. in Engineering Science and Mechanics from Penn State, Masters in Mechanical Engineering from Bucknell University and a Bachelor of Science in Mechanical Engineering from the University of Maryland. Rick is a Registered Professional Engineer in Pennsylvania, Colorado and Utah.

Mary Bogdan


Mary Bogdan is a Sr. Principal Scientist for Honeywell. She earned a bachelor's degree in Chemistry/Biochemistry and an MBA from Canisius College. Since joining Honeywell in 1989, Mary has held numerous positions in research and development. She currently supports the fluorine products blowing agent business leading application research projects and providing technical service to the global spray foam industry. She is a Six Sigma Black belt. She has over 20 US patents and has numerous published technical articles on the development and use of fluorocarbons as foam blowing agents. She is currently a member of the SPFA Board of Directors and in addition she has received industry recognition for leadership and excellence in presentation of technical papers.