Update on Compatibility Testing of Spray Polyurethane Foam with CPVC

Part II – Final Results

Polyurethanes 2009 Technical Conference
October 5-7, 2009
Gaylord Conference Center
National Harbor, MD

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Honeywell

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AGENDA

1. CPVC background
2. Goal of Program
3. Test Procedure
4. Test Results
5. Summary
6. Acknowledgements

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What is CPVC ?

- First produced by Lubrizol Advanced Materials, Inc. (formerly BF Goodrich Performance Materials) in the late 1950's.
- PVC homopolymer subjected to chlorination reaction
- Chlorine atoms surrounding the carbon backbone help protect the chain from attack, improving the plastic's
  - Temperature
  - Chemical resistance

Where is CPVC used?

Most commonly used to manufacture pipe and pipe fittings for fire suppression systems, potable water distribution, as well as corrosive fluid handling . Use is recognized by all model building codes.

Covered by:

–NFPA 13D/ NFPA 13R: Standard for the Installation of Sprinkler Systems in One-and Two-Family Dwellings and Manufactured Homes

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Where is CPVC used?

2009 IRC Code Change
SECTION R313
FIRE SPRINKLER SYSTEMS

R313.1 General. 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.

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Where is CPVC used?

CPVC and Polyurethane Foam Today

As pour foam…

One product includes a layer of rigid polyurethane foam insulation, bonded directly to the entire pipe surface.

As spray foam…

Applied directly to the surface of CPVC pipe and fittings as insulation, construction gap filler and, in some cases, a fire block/retardant

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How does CPVC fail?

Environmental Stress Cracking (ESC)

By chemical attack under loading

- A mechanism by which certain organic chemicals cause extremely localized weakening at the surface of a part that permits the propagation of a crack. The crack exhibits glossy fractured surfaces occuring in regions of mechanical stress (e.g., pressure loads)

- Organic fluids, such as natural or synthetic ester oils, nonionic surfactants, alcohols, glycols may cause ESC

How does CPVC fail?

Mechanical Stress Cracking (MSC)

Results when piping is installed under high loading/stress

- Presence of external or internal cracks in a plastic can cause failure by tensile stresses less than that of its short-term mechanical strength
- Compounded by exposure to elevated temperatures.
  - The polyurethane chemical reaction is exothermic, which depending upon foam thicknesses, can reach temperatures in excess of 200 °F

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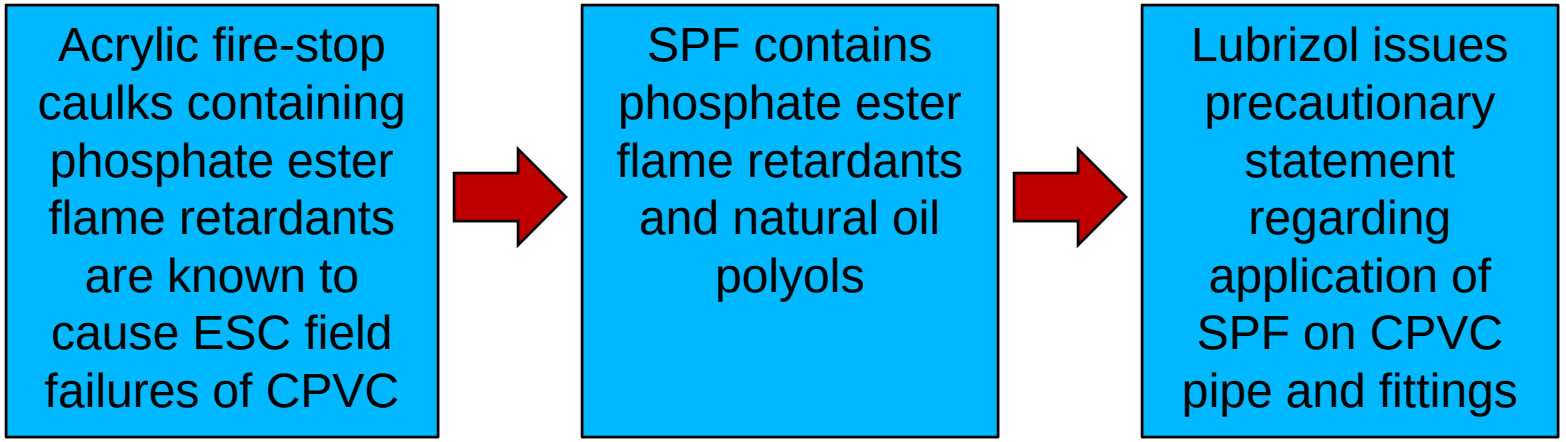
What is the present concern?

Chain of Events



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What is the present concern?

Chain of Events

Lubrizol 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***."

Lubrizol issues precautionary statement regarding application of SPF on CPVC pipe and fittings

Several jurisdictions ban SPF installation over CPVC piping and fittings

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Industry Research Program Begins

Goal of the Program:

Demonstrate the chemical/physical impact on the performance and longevity of CPVC piping and fittings when it is in contact with spray polyurethane foam.

How?

- Evaluate the chemical, thermal and physical compatibility of SPF with CPVC piping and fittings
- Hire independent consultant to review data and issue summary report
- Develop an appropriate test procedure for SPF products that reflect field installation conditions

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Review of Test Methods

Current chemical compatibility tests for CPVC:

ISO 22088
Determination of resistance to environmental stress cracking (ESC)

ASTM D543
Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents

Limitations
Both involve continuous immersion or direct application in possible chemical materials

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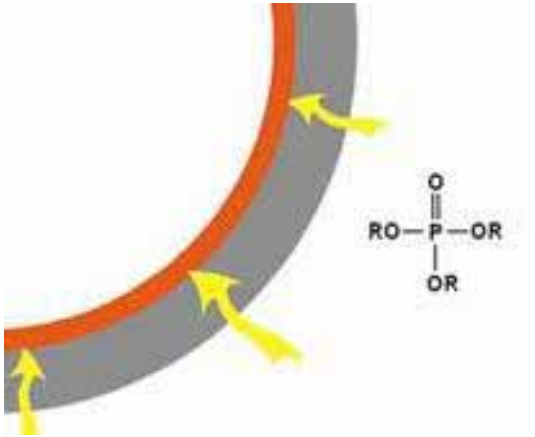
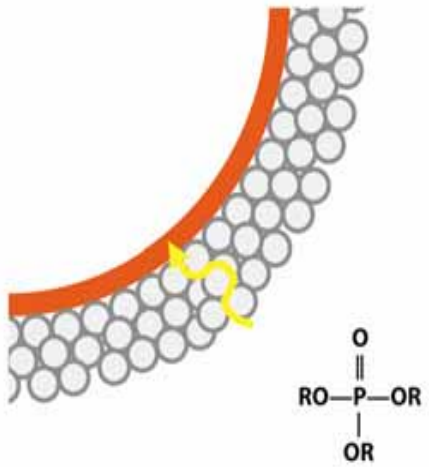
Review of Test Methods

Do these methods accurately reflect interaction or predict compatibility?





Current method		***Spray foam application***
involves significant level of exposure	→	Limited contact surface area
Lengthy duration of liquid content	→	Short duration of liquid contact
Clear migration pathway	→	Blocked migration pathway
Designed for homogeneous material	→	Non-homogeneous

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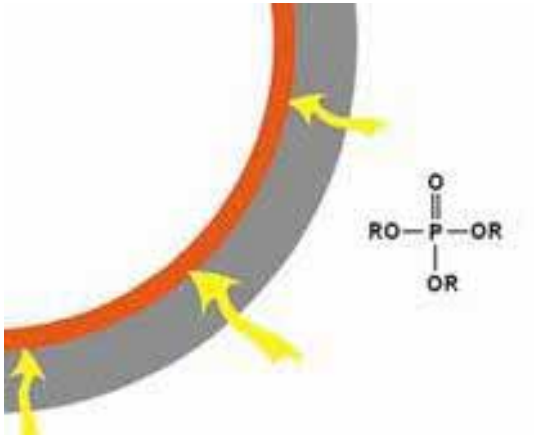
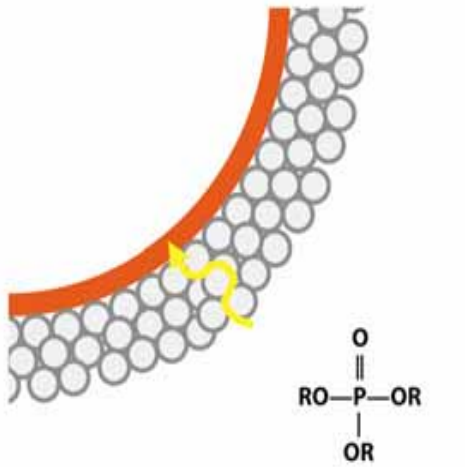
Review of Test Methods

Do these methods accurately reflect interaction or predict compatibility?





Current method
involves significant level of exposure
Lengthy duration of liquid content
Clear migration pathway
Designed for homogeneous material

Spray foam application
Limited contact surface area
Short duration of liquid contact
Blocked migration pathway
Non-homogeneous

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Development of Field Test Method

Alternative Test Procedure:

- Duplicated field conditions and compared to standard performance
  - Encased a pipe/fitting setup in minimum of 1 inch of polyurethane foam.
  - Placed under hydrostatic pressure @ 150 °F
  - Monitor pipe and fittings for stress cracking, pipe rupture, or leakage
- Accelerated testing
  - Samples tested under range of conditions simulating 6000 hrs service
- Analyzed impact on piping
  - Inspect pipe surface & analyze foam for phosphate migration or concentration

Duration in Chamber (hrs)	Pipe Pressure (psi)
3000	210
6000	210

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Development of Field Test Method

Test Program Resources and Funding:

- SPFA provided $23k for research program
- CPI provided grant of $10k through Rigid Foams Committee
- SPFA supplier members provided lab services and raw materials
- Lubrizol provided testing, piping, laboratory equipment for program

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Development of Field Test Method

Test Variables:

- Type of foam: ***Prepared from industry generic formulations***
  - Medium density (MD) Closed Cell Spray Foam
  - Low density (LD) Open Cell Spray Foam
  - Closed cell One Component
- Soy and non-soy polyol based-***Two commercial systems included***
  - Natural oil polyols (NOP) are gaining widespread use in the polyurethanes industry. NOPs are fully reacted products and chemically do not resemble the agricultural products they are derived from.
- Type of flame retardant: ***Based upon industry survey***
  - TCPP -(Tris(2-chloroisopropyl)phosphate)-***Most widely used***
  - TEP -(Triethyl phosphate)-***Most aggressive in soak test***
  - TDCPP -(Tris (1,3-dichloroisopropyl) phosphate blend) -***Used in one component foams only***
- Flame retardant concentration: ***Use levels based upon industry survey***
- Thickness of the foam –***Ranges based upon application from 1 inch to 4 inches***

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Good eye Clarence. Now that you mention it, I do see the applicator's T-shirt through the coveralls. We saw at least one helper using a breather suit during our

Development of Field Test Method

Test Variables:

Foam Type	Medium Density (MD) Closed-Cell Spray Foam (2 pcf)	Low Density (LD) Open-Cell Spray Foam (0.5 pcf)	One- Component Foam (OCF)	Natural-oil polyol (NOP) spray foam
Variables	• Thickness • FR Type (TCPP/TEP) • FR Conc.	• FR Type (TCPP/TEP) • FR Conc.	• FR Type (TCPP/TDCPP) • FR Conc.	• Thickness • Soy-Based Polyol

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Samples:

- DoX -Utilizing partial factorials
- High and low point variables
- Single analysis per condition
- Testing pipe controls without foam

Foam Type	Flame Retardant (FR) Type	FR Conc. (W% polyol side)	Foam Thickness (in)	Sample Test Duration			
				Init.	1 mo	3000 hrs**	6000 hrs**
MD	TCPP	10	4	X	X	X	X
	TCPP	10	2	X	X	X	X
	TCPP	4	4	X	X	X	X
	TCPP	4	2	X	X	X	X
	TEP	10	4	X	X	X	X
	TEP	10	2	X	X	X	X
	TEP	4	4	X	X	X	X
LD	TCPP	50		X	X	X	X
	TCPP	15		X	X	X	X
	TEP	50		X	X	X	X
	TEP	15		X	X	X	X
OCF	TCPP	5*	¾" +/-	X	X	X	X
	TCPP	10*	¾" +/-	X	X	X	X
	TDCPP	10*	¾" +/-	X	X	X	X
	No PhosEster	0*	¾" +/-	X	X	X	X
NOP	LD BioBased			X	X	X	X
	MD Demilec			X	X		X

* concentration of FR on complete product for OCF (single package products)

** actual test durations were 4500 and 6200 hours, the time at which specimens were removed from test chambers

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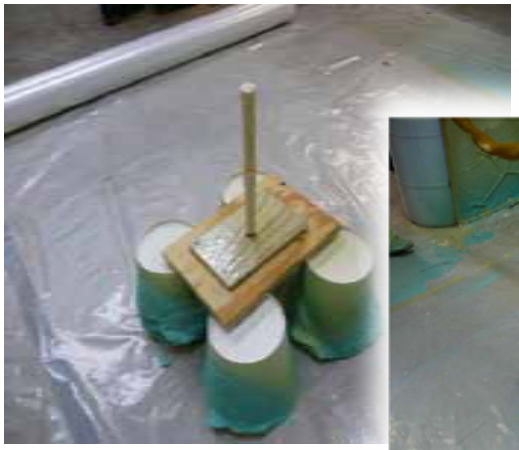
Development of Field Test Method

Sample Preparation:

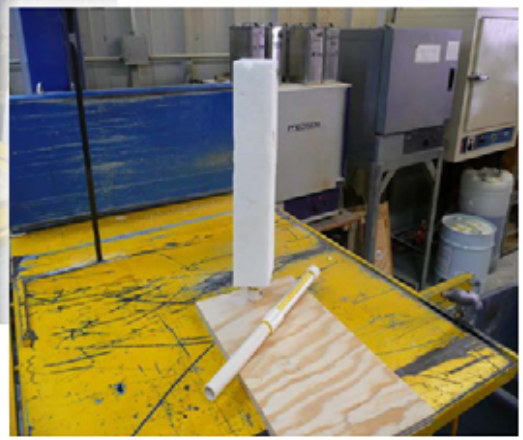
OCF



Setup

Spray

Trim



Complete

Development of Field Test Method

Sample Preparation:

Foam Type	# Initial Testing	# in Test Chamber	# for Shipment Damage	# for application improvement	TOTAL
MD	28	21	14	14	**56**
LD	16	12	8	8	**32**
OCF	16	12	8	8	**32**
NOP LD	4	3	3	3	**10**
NOP MD	3	2	3	3	**9**
TOTAL	**57**	**50**	**36**	**36**	**139**

Thanks to Demilec USA LLC, BioBased Insulation®, NCFI Polyurethanes, and Convenience Products of Clayton Corp for providing laboratory services

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Development of Field Test Method

Samples in Chamber:

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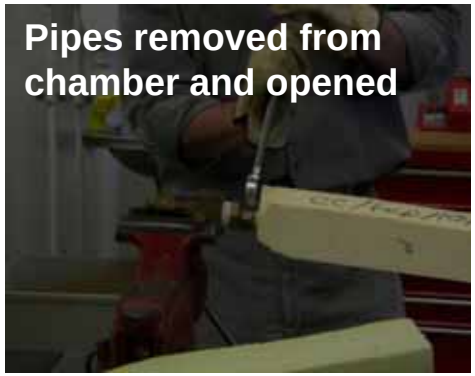
Development of Field Test Method

Sample Removal:

- Samples removed after ~3000 hrs and ~6000 hrs of exposure
- Four tests performed on removed samples
  1. Phosphate detection in foam
  2. Phosphate detection in pipe
  3. Visual/microscopic inspection of outer surface
  4. Rupture testing and microscopic inspection


Pipes removed from chamber and opened


Water drained out


Fittings cut from pipe


Foam cut from pipe retained for testing.

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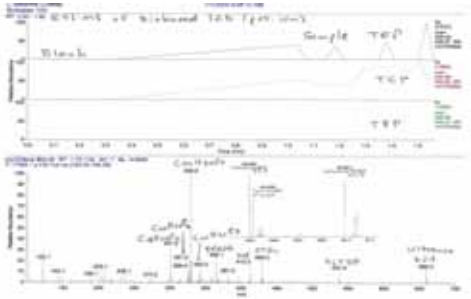
Development of Field Test Method

1. Phosphate Detection in Foam:

- Foam removed from pipe
- Foam material prepared and analyzed using GC method for FR identification
- Inductively Coupled Plasma analysis (ICP) was used to determine %P in the foam

Chromatogram



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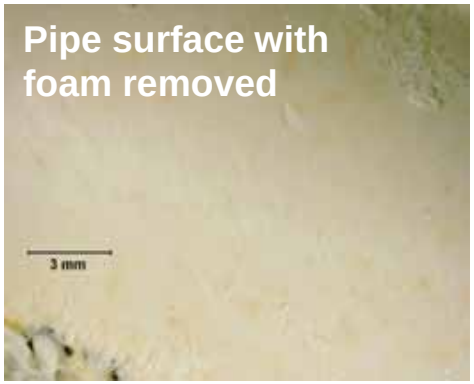
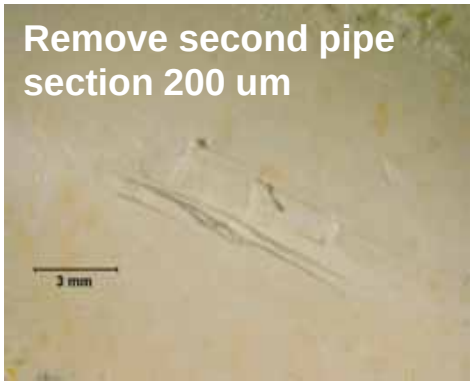
Development of Field Test Method

2. Phosphate Detection in Pipe:

- CPVC material taken from outer surface of pipe
- Extracted with ~1ml of methanol on hot plate for 15 minutes
- Solvent reduced to ~0.5ml by evaporation and extract separated from CPVC particles
- ~0.5ml of tetrahydrofuran added to methanol extract identification
- Analyzed by positive ion electroscopy (ESI-MS)





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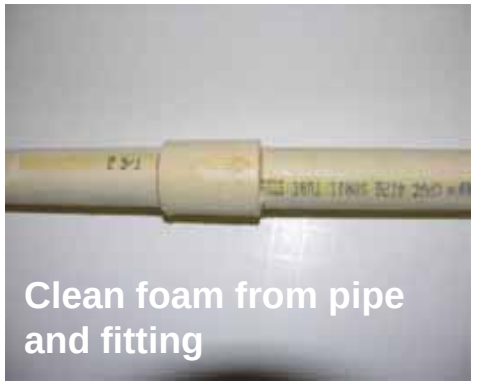
Development of Field Test Method

3. Microscopic Evaluation of Pipe:

- Foam carefully removed from pipe surface using coping saw and utility knife
- Cleaned using razor blade
- Surfaces examined visually and microscopically for indications of ESC
- None of the specimens exhibited any indications of ESC along the outer surface



Clean foam from pipe and fitting

Cut pieces from pipe and fitting

Perform microscopic evaluation of pipe and fitting

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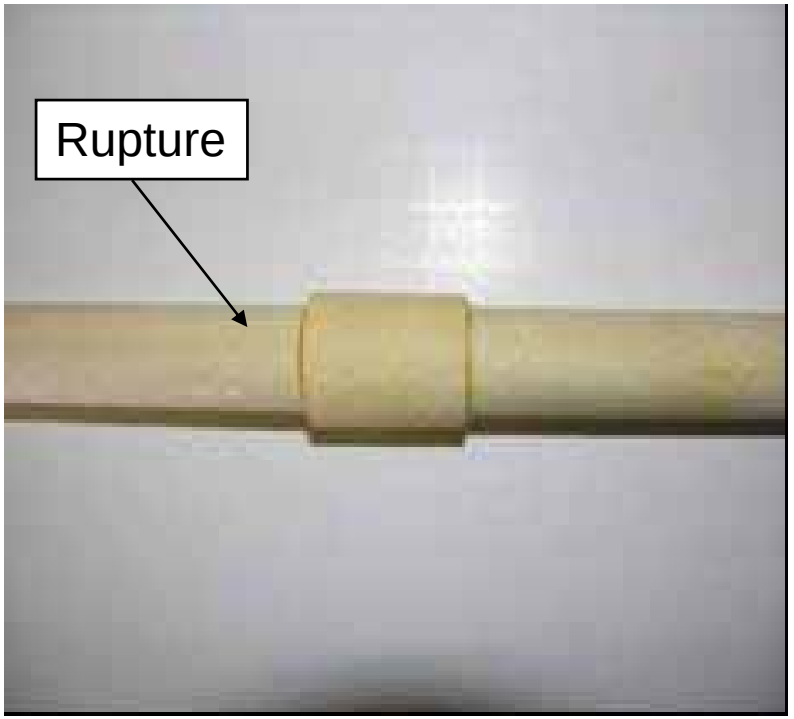
Development of Field Test Method

4. Rupture-Testing of Pipe:

- ESC may be overlooked by visual and microscopic inspection in some cases
- ESC may be opened and specimens failed by over-pressurization of the piping
- All specimens ruptured at 1300-1600 psi
- Ruptured specimens were sectioned and microscopically inspected for ESC



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Test Results

3000 hr:

- FR detected in foam and in pipe
- **NO ESC found in any samples**
- **All samples passed rupture test**

Foam Type	Actual Test Duration (hrs)	Flame Retardant (FR) Type	FR Conc. (W% polyol side)	Foam Thickness (in)	Test Results			
					P in Foam	P in Pipe	ESC	Rupture
MD	4506	TCPP	10	4	YES	YES	NO	PASS
	4506	TCPP	4	2	YES	YES	NO	PASS
	4506	TEP	10	4	YES	YES	NO	PASS
LD	4506	TCPP	50		YES	YES	NO	PASS
	4580	TCPP	15		YES	YES	NO	PASS
	4506	TEP	50		YES	YES	NO	PASS
	4506	TEP	15		YES	YES	NO	PASS
OCF	4506	TDCPP	10*	¾" +/-	YES	NO	NO	PASS
NOP LD	3695				YES	YES	NO	PASS

* concentration of FR on complete product for OCF (single package products)

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Test Results

6000 hr:

- FR detected in foam and in pipe
- **NO ESC found in any samples**
- **All samples passed rupture test**

FOOTNOTES:

† 3000 hr test shows FR, no testing done at 6000 hr.
† † Testing in progress
† † † Confirming test results

Foam Type	Actual Test Duration (hrs)	Flame Retardant (FR) Type	FR Conc. (W% polyol side)	Foam Thickness (in)	Test Results			
					P in Foam	P in Pipe	ESC	Rupture
MD	6092	TCPP	10	4	YES	†	NO	PASS
	6092	TCPP	10	2	YES	YES	NO	PASS
	6092	TCPP	4	4	YES	YES	NO	PASS
	6092	TCPP	4	2	YES	YES	NO	PASS
	6092	TEP	10	4	YES	†	NO	PASS
	6092	TEP	10	2	YES	YES	NO	PASS
	6092	TEP	4	4	YES	YES	NO	PASS
LD	6092	TCPP	50		YES	†	NO	PASS
	6092	TCPP	15		YES	†	NO	PASS
	6092	TEP	50		YES	†	NO	PASS
	6092	TEP	15		YES	†	NO	PASS
OCF	6092	TCPP	5*	¾" +/-	YES	YES	NO	PASS
	6092	TCPP	10*	¾" +/-	YES	YES	NO	PASS
	6092	TDCPP	10*	¾" +/-	YES	YES	NO	PASS
	6092	No PhsEstr	10*	¾" +/-	NO	†††	NO	PASS
NOP LD	††				††	††	††	††
NOP MD	6092				YES	YES	NO	PASS

* concentration of FR on complete product for OCF (single package products)

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Communication Plan

Final Report

Test protocol and study report 3rd party reviewed

Jim Paschal, PE

James Paschal Engineering and Forensic Consulting, Inc.

Chairperson of ASTM Committee on CPVC Testing

20 years

Peer review of study by plastics and foam industry

Independent evaluation of the data

External Communication

CPI paper on program

Letter for building inspectors

Publication in Spray Foam Magazine

Publication on SPFA website

Preparation of industry white paper for use with trades and CPVC industry

Proposed modification to ASTM test method to incorporate this procedure as an alternative to testing raw components

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Summary

- CPVC and SPF are used extensively and in combination within the building envelope
- Lubrizol issued cautionary statement based on concerns over specific raw materials used in SPF formulations
- Current test protocol used by CPVC industry does not adequately apply to SPF
- Alternative test protocol developed by plastics and SPF industry consensus

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Summary

- Initial and Accelerated aging studies after more than 6000 hrs show:
  - Measureable levels of FR in foam and CPVC
  - No indications of ESC by visual or microscopic inspection or by rupture testing
- Communications
  - Final Report
  - CPI Paper
  - Dissemination of results in presentations, magazine articles, websites and whitepapers

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Acknowledgements

SPFA Supplier Sponsors

BASF The Chemical Company

BaySystems

BioBased Insulation

SWD
Corbond
FOMO

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