## *Staying Out of Trouble with SPF*

Summer Camp 2018

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## Copyright Materials



## Introduction to Staying Out of Trouble with SPF

1. We are interpreting the "SPF" in this title as meaning all field-processed polyurethane products used in construction.

2. We have included 1-part and 2-part kit polyurethanes because they are accessory to, or alternates to bulk "SPF" projects.

## Overview

Foam is a versatile product that can do things other products can't

- Closed-cell polyurethane foam can provide a continuous air barrier, insulation, and moisture control, in one application*
- Open-cell polyurethane foam can provide a continuous air barrier and insulation**

*Water Vapor Permeance (ASTM E 96) 0.97 perm at 1.5"

**Water Vapor Permeance at 5 ½" (ASTM E 96) 11 perm

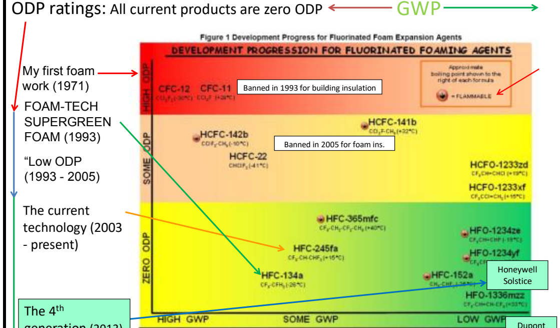
## Overview

There are several types of polyurethane foam available to meet various project requirements

- Foam sealant (FS)
- Spray-applied polyurethane foam (SPF)
- Injected polyurethane foam (IPF)
- Open and closed-cell foams
- Seasonal formulations

## Closed-cell bulk polyurethane foam blowing agents

ODP ratings: All current products are zero ODP ← GWP →




Original source: Dupont Formacel 1100 paper

## Field-processed polyurethane products used in construction

1. Urethane Caulks
2. **One-component foam sealants (FS)**
3. **Two-component kits (SPF, IPF)**
4. **Bulk field-applied polyurethane foam (SPF, IPF)**
5. SPF used as a part of a roofing system

Not covering these:

- Rigid foam board
- Urethane caulk
- SPF used as part of an exterior roofing systems (Roof foam)
- Note that SPF not used as roofing, is often called Wall foam

## Spray foam and coating roof systems




Courtesy: SPFA AND RCMA

**Polyurethane products and quality assurance/control**

| Polyurethane Product | Use (Does not include adhesive products) | Closed-cell foam | Open-cell foam | QA - Verify parameters before and during processing | QA - Verify preparation parameters | QA - Verify parameters during the installation | QC - Verify parameters after the installation |
|---|---|---|---|---|---|---|---|
| **Single-component caulk/sealant** | Seal cracks < 1/8" | NA | NA | Product temperature | Ambient and subtrate temp.; substrate dry; compatable | Technique; bead thickness, push vs. pull bead | Visual inspection* |
| **Single-component foam** (comes in colors) | | | | | Ambient and subtrate temperature; substrate clean and dry; verify compatability | | |
| Expanding | Seal cracks 1/8" to 3/4" | Y | NA | Chemical temperature, well mixed | | Full depth; any required bracing; moisten between lifts > 3/4"; technique | Visual inspection* |
| Non-expanding | Seal cracks 1/8" to 3/4" | Y | NA | Chemical temperature, well mixed | | Full depth; moisten between lifts > 3/4"; technique | Visual inspection* |
| **Two-part slow-rise foam kit** | Seal cracks > 1/4" or fill cavities | Y | Y | Chemical temp., equal pressures, component weight; test shots | Ambient subtrate temperature and RH; substrate clean and dry (wood moisture content or metal and masonry surface moisture); verify compatability | Maintain preparation conditions; sheathing integrity and fastening | No pass thickness limit; use infrared to verify fill; maintain prep. conditions thru cure period |
| **Two-part spray foam kit** | Seal cracks > 1/4" or build up on open surfaces in lifts | Y | Y | Chemical temp., equal pressures, component weight; test shots | | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain preparation conditions thru cure period |
| **Injected two-part bulk foam** | Fill closed cavities | Y | Y | chemical temperature, pressure, ratio; test shots | Ambient subtrate temperature and RH; substrate clean and dry (wood moisture content or metal and masonry surface moisture); verify compatability | Maintain preparation conditions during installation; sheathing integrity and fastening | no pass thickness limit; infrared to verify fill; maintain prep. conditions thru cure period |
| **Spray-applied two-part bulk foam** | Build up on open surfaces in lifts | Y | Y | Chemical temperature, pressure, ratio; test shots | | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain prep. conditions thru cure period |
| **Spray-applied two-part bulk roofing foam** | Build up on open surfaces in lifts | Y | Y | Chemical temperature, pressure, ratio; test shots | Same as bulk wall foam above | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain prep. conditions thru cure period |

* Assess cell color, uniformity, size, shape, odor, friability, strength, lift thickness, etc.

## 1-part foam sealant

(low-pressure FS)




## Intro to 1-part Foam Sealant (FS)

- Straw and gun-type dispensing systems

## Intro to 1-part Foam Sealant (FS)

- Foam sealant (FS) is cost effective in lieu of bulk foam in small (< 1/2”) cracks and gaps.

## Intro to 1-part Foam Sealant (FS)

- Use the right 1-part product for the application!
  - Expanding, low-expansion, and non-expanding
  - Adhesives
  - Fire rated products for sealing at fire separations
  - Various colors and sizes
  - Some manufacturers have seasonal formulations

## One-part foam products

Expanding FS

There is a variety of one-part products

Low-expansion FS

| Product | Information |
|---|---|
| | Pur Fill 1G<br>Our most versatile foam |
| | Pur Fill 1G 600<br>Same benefits as 1G, smaller size |
| | Pur Stick<br>Professional gun foam adhesive system |
| | Pur Black<br>Developed for outdoor use |
| | IPF Foam<br>Designed for pest control professionals |
| | EZ Flo Gun Foam<br>Stops passage of air, gases, water, etc. |
| | Pur Fill Cold Weather<br>Same benefits of 1G, smaller size |
| | Pur Fill Window Foam<br>Formulated to seal out drafts |
| | Pur Fill Fireblock Foam<br>Moisture-curing, fire-blocking foam. |

## Intro to 1-part FS

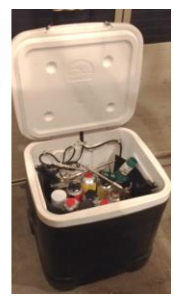
Straw Foams

| WINDOW FOAM | EZ FLO | DUO FILL 400 | PUR FILL NF 12 | PUR BLACK NF | PUR FILL NF 24 | GUN CLEANER |
|---|---|---|---|---|---|---|
| WP01 | EZ01 | DF01 | NF12 | BF16 | NF01 | GC01 |
| 24 oz, 600ml | 27 oz, 675ml | 13 oz, 400ml | 12 oz, 250ml | 16 oz, 400ml | 24 oz, 600ml | 20 oz, 500ml |
| 12 cans/case | 12 cans/case | 15 cans/case | 12 cans/case | 12 cans/case | 12 cans/case | 12 cans/case |
| 100 cases/pallet | 80 cases/pallet | 84 cases/pallet | 75 cases/pallet | 140 cases/pallet | 80 cases/pallet | 80 cases/pallet |
| 1.6 lbs/can | 1.9 lbs/can | 1.2 lbs/can | 1 lb/can | 1.25 lbs/can | 1.6 lbs/can | 1.2 lbs/can |
| 23 lbs/case | 27 lbs/case | 18 lbs/case | 13 lbs/case | 15 lbs/case | 22 lbs/case | 14 lbs/case |
| 10 gallons | 11 gallons | 3 gallons | 4 gallons | 5 gallons | 9 gallons | |
| 1/2" bead=960 lin. ft. | 1/2" bead=1080 lin. ft. | | | | | |
| 2200 cu. in. | 2400 cu. in. | 600 cu. in. | 960 cu. in. | 1060 cu. in. | 2200 cu. in. | |
| 5.9 R factor | 5.9 R factor | Light blue in color | UL listed | | | |
| 1.3 cu. ft. | 1.5 cu. ft. | Rigid dispensing | .6 cu. ft. | | | Flushes out uncured foam |
| 15 board ft. | 17 board ft. | | | | | Fits all dispensing guns |

ALWAYS LEAVE A CAN ON THE GUN

## Preconditioning one-part FS

1. Shake the cans well
2. Warm the cans to the proper temperature
   - Minimum ambient is 40F
   - Recommended between 60F and 80F
3. How do you warm them?
   - Slowly with a low-flux heat source
   - Never allow the cans to get above 122F
   - They will explode
4. Swap them out during the work if the weather is cold



## The misting mystery

FS is a water-cured product. It will not set up if water is not available to the reaction.

Manufacturer's instructions:
"With a misting bottle, mist the area with water on the area to be foamed. If you are foaming in large sections, stop every two inches, mist water on the earlier foam and add another two inches."

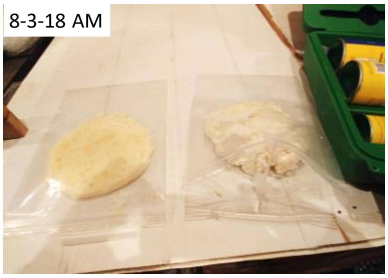
## One-component foam sealant

8-2-18

Without moisture

With moisture

## One-component foam sealant

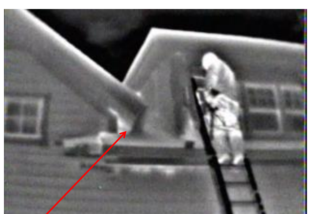



Without moisture With moisture

## One-component foam sealant


Without moisture With moisture

## Cold chemicals without moisture



Infrared and daylight frost patterns – failed panel joint air sealing

## Cold chemicals without moisture

Frost due to air leakage

## Keys to one-part FS quality

1. Select the right product for the application
2. Require the installer to meet the manufacturer's requirements
    - Warm the chemicals
    - Shake the cans
    - Moisten if the air is dry or foaming thick cross sections
    - Close the gun valve when not in use
3. Require the installer to certify that the manufacturer's requirements have been met.

# 2-part kits

(low pressure)

- These come in open and closed-cell formulations
- They also come in spray and slow-rise formulations

## Low-pressure refillable systems

Pressure vessel systems come in all sizes (up to tank car size)

The larger ones are all "refillables"
Some small PVs are sold as "disposable" or "portable" kits

## Product selection – 2-part kits

- Most of these products are comparably priced.
- None of the products are using the fourth-generation blowing agent yet.

## Product selection – 2-part kits

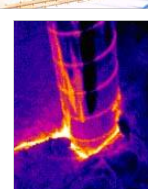
- Most of the fast-rise systems are E84 compliant
- Only some of the slow-rise products are E84 compliant

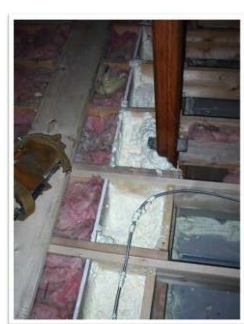
## Product selection – 2-part kits

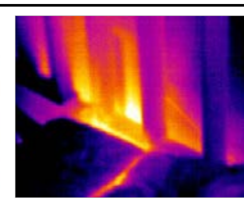
- Most of the guns are variable flow ("metered flow").
- One product has colored the chemicals so that the foam comes out green. If it turns blue or yellow, it is off ratio.
- The slow-rise products have different "push" distances.

## Select the right product

This project required thousands of pounds of foam, but bulk foam was not an option due to access



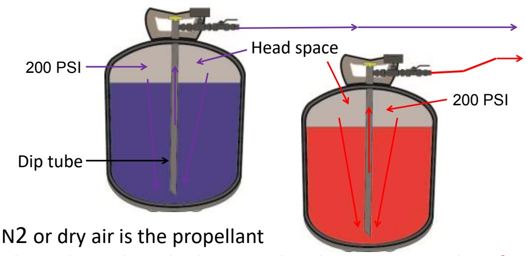




# How do they work?

## How do kits and cans work?

Two sealed disposable one-component systems are combined to make a two-component kit



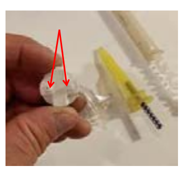

N2 or dry air is the propellant

Always keep the cylinders upright when you are making foam!

## How do kits and cans work?

1. In disposables, the A to B ratio relies on fixed-orifice flow control at very specific temperatures, viscosities, and pressures.
2. The fixed orifice may be in the gun or the disposable mixers





## Calibrating kits

**CALIBRATION PROCEDURE**

**Acceptable ratios are 1.08 to 1.16.**

**Always calibrate the spray foam system prior to the start of spraying.**
**Recalibrate the spray foam system if the foam:**

- is off color
- is too rubbery, crunchy or runny
- runs off the substrate
- does not cure

**CALIBRATION INSTRUCTIONS**

*Equipment needed: Scale capable of weighing in grams, paper lunch bags, calibration nozzles, calculator, pen or pencil.*

1. Ensure chemical temperature in tanks and hoses are 70°F (21°C) or higher.
2. Set nitrogen regulator pressures at 150 PSI and open all system valves.
3. Remove nozzle from foam applicator, disengage the foam applicator safety and dispense chemicals in an appropriate container to verify proper chemical flow while purging air from the hoses.
4. Weigh each empty bag and mark its weight on the bag so that its weight may be deducted

A. Purging

## Calibrating kits

from the total weight of the filled paper bags.

5. Clean front of spray applicator barrel and engage safety. Place calibration nozzle on the foam applicator.
6. Hold the two bags together, place one tube in each bag, disengage the foam applicator safety and engage trigger for six to eight seconds.
7. Engage foam applicator safety.
8. Weigh and record individual bag weights. Always divide the weight of bag B into the weight of bag A. If the ratio is too high increase the pressure of the B tank, and if the ratio is too low increase the pressure of the A tank. **Acceptable ratios are 1.08 to 1.16.**

*Example*
*A: 208g (weight) – 8g (bag weight) = 200g*
*B: 190g (weight) – 8g (bag weight) = 182g*
*Ratio: 200 ÷ 182 = 1.10*

*NOTE: If verification of readings of the regulator is necessary, install pressure gauges in line with the regulator. Verify both sides. To verify corresponding pressures of tanks, install pressure gauges in line with each tank. Perform this task on the nitrogen inlet valve. Should pressure need to be reduced in a tank, slowly bleed off pressure. Never bleed any tank below 120 psi. For best results, perform pressure adjustments in 10 psi increments.*

If at anytime during dispensing foam quality is suspect, first replace the nozzle. If nozzle replacement does not solve the problem, repeat the calibration process.

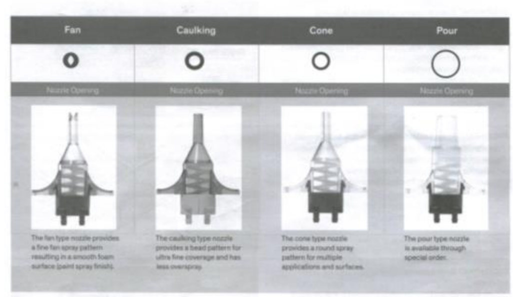
*NOTE: If spraying has stopped more than 30 seconds, foam in the nozzle will begin to cure and clog. System performance will be compromised. Replace the used nozzle with an unused nozzle. Higher temperatures speed curing, while lower temperatures slow curing.*

B. Weighing


C. Calibrating

## Mixer options

Anti-crossover Nozzles



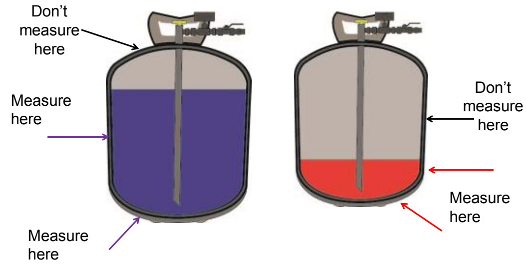
## Two-part tricks

Most mixers and guns can be cleaned and reused. Soak the mixers at the site and blow them out with air later.

You can buy extra mixers and guns separately from the kit manufacturers.

## Quality Control - temperature

- Measure the metal containers where the liquid is in contact with the metal.




## Kits and Cans – Pre-conditioning

Foam conditioning "hot box" for 200 board-foot kits

Temperature control

Heater

Water bed heater with controller ($62)

Igloo 60-Quart Ice Cube Roller Cooler ($27)

## Quality Control - temperature

Foam conditioning "hot box" for 600 board-foot kits

Temperature control

Heater(s)

1 sheet of Thermax and foil tape ($30)

Water bed heater with controller ($62)

Husky Roller tool box ($69)

## Kits and Cans - temperature

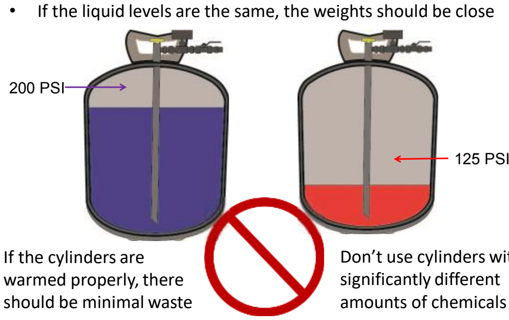
Verifying temperatures remotely

The probes can be down in the bottom of the hot box or taped to the tanks with the read-outs on top where they can be seen without lifting the tanks or opening the lid

Battery operated digital probe Thermometers ($18.00 for two)

## Quality Control - weights

- Liquid levels need to be about the same for the pressures to be close
- If the liquid levels are the same, the weights should be close




If the cylinders are warmed properly, there should be minimal waste

Don't use cylinders with significantly different amounts of chemicals

## Quality Control

Verify tank weights. They are typically within 10% to be sure pressures and flows are the same. Ask the manufacturer. Some kits start out at different weights – not 1:1.

Small luggage scales are quick and easy to use one at a time or in pairs ($14/pair)

Weighing a 600 board feet kit
14.8 lbs. to 17.2 lbs.
14% off ratio or 1 : 1.16

## Calibrating kits

**CALIBRATION PROCEDURE**

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- runs off the substrate
- does not cure

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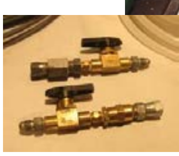
4. Weigh each empty bag and mark its weight on the bag so that its weight may be deducted

A. Purging

## Quality Control - pressures

If you want to talk about trans-filling tanks and/or about balancing pressures, this is at least a two beer discussion



A & B valve sets - #4 JIC

Pressure gauge isolator

## Ask Terry about this one!

## Structural tubes at the wall line

Warm the tanks and do test shots for QA

## Quality Control – kit foam test shots

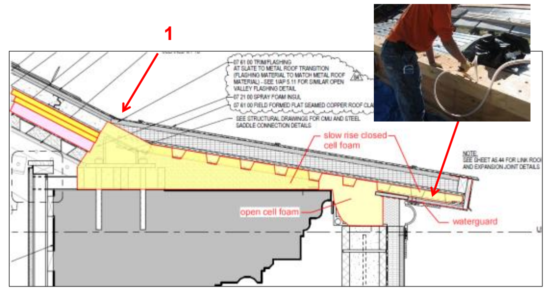
Uniform cells and not friable – should “snap” when it is broken

Good foam test shots

Exterior showing the roof frame ready for the cement plank roof deck




Detail – lower slope over original cornice




Finished cornice enclosure & overhang

Field tests related to assuring product quality

My finger goes right through the test shot. Mottled and friable – chemicals too cold

Un-mixed and friable – chemicals too cold

## Keys to two-part kit quality

1. Select the right product for the application
2. Require the installer to meet the manufacturer's requirements
   - Warm the chemicals
   - Shake or roll the cans (200 vs. 600 bd. ft. kits)
   - Use matched cylinders (same product and weight)
   - Verify ratio (not always 1:1) with calibration tests
   - Verify startup with test shots
   - Close the valves when not in use
3. Require the installer to certify that the manufacturer's requirements have been met

# 2-part bulk foam installations

(high pressure)

## The processing system

The foam industry relies on this state of the art equipment to provide processing quality

Courtesy: Graco

## Bulk SPF

Think about how many times the technician pulls the trigger and how long each lasts

## How do we stay out of trouble with bulk SPF?

Make sure the project requirements are right

1. Select the right product
2. Address the building science implications of SPF/IPF in the assembly design
3. Make sure there is a good fit between the building enclosure and the HVAC system

## Product choice

1. Select the right product. There are a lot of choices!
   - Is the product appropriate for the volume of foam being required ("8 inches of Purfil spray foam" in an 8" metal stud wall cavity*)?
     - Purfil is a 1-part foam sealant, not wall insulation
   - Can the R-value "fit" within the available framing thickness? (R-49 in a 2x12 rafter) (3" of foam in a 2.5" brick cavity)

## Product choice

3" SPF on metal stud and Densglas backup wall

## Product choice

1. SPF or IPF in closed cavities?
   - Product pass thickness parameters for most SPF products are 2" to 4". This prevents burn out due to concentrated heat of reaction due to high catalyst levels.
   - IPF has no pass thickness limits due to its slow-rise chemistry

## Field tests related to assuring product quality

Scorching or burn-out

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Product choice

1976 Venturi Gallery – Allen Memorial Museum

- R-value before and after – R-3 before vs. R-38 after
- Foam product/system used – Closed-cell froth IPF
- Techniques used – Drill and fill, open slots
- Quantity used – 4,600 lbs.

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Product choice

Moisture damage to signature masonry cladding

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Product choice


Venturi Gallery – Oberlin College

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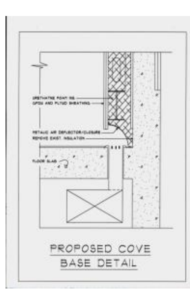
Product choice




Art Museum

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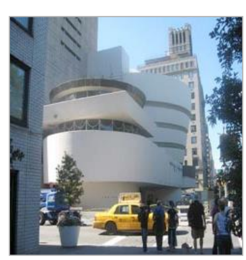
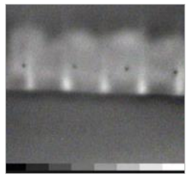
Polyurethane foam isn't just insulation

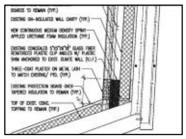


Closed-cell foamed-in-place insulation

## Polyurethane foam isn't just insulation

Infrared QC of foamed-in-place insulation behind 1" plaster – effective year-round (240F)





## Product choice

1. Select the right product
   - Is the product appropriate for the vapor control requirements? (open-cell vs. closed-cell foam)
   - Is the product appropriate for the environmental conditions that the installation requires?
   - Does the product meet the requirements for the application? (Coast Guard certified for marine flotation)

## Product choice

### Infrastructure

### Frozen-earth retaining system

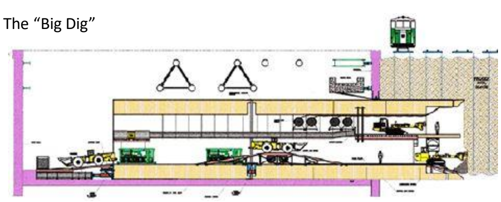
- Specialty foam product: 2.0# SPF formulation for -5F substrate
- Specialty installation requirements: Develop pass thickness and dwell time requirements for -5F substrate
- Diagnostic and/or QA requirements: Measure effluent
- Specialty coating: Thermal barrier paint
- Specialty accessory product: Chicken wire attachment system

## Product choice

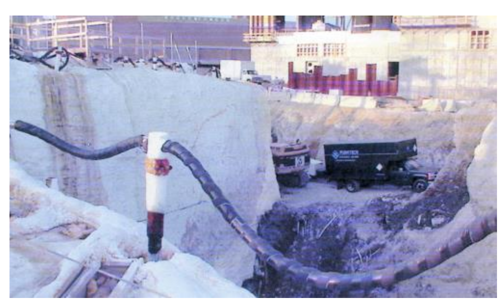
The "Big Dig"

## Product choice

The "Big Dig"



## Product choice



The "Big Dig"

## Product choice

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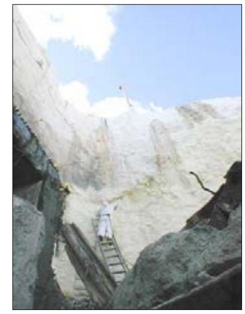

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## Product choice

Injected over 7,000 pounds on the first day

- Description – Erie Canal maintenance barges ~75' X 25' X 5'-6"
- Lockwood, NY - Project date: 2016 – ($.25 Million in five days)
- Problem addressed with IPF – Marine Flotation for ©1930 barges
- IPF was the best solution – Specified by the engineer – the only field-applied flotation product available that met the Coast Guard specs.

## Product choice

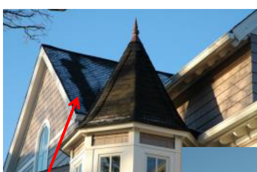
## Building enclosure planning

2. Address the building science implications of SPF in the assembly design
   - Hybrid assemblies
   - Vented vs. unvented slopes

## Building Science issue – mixed/hybrid insulation

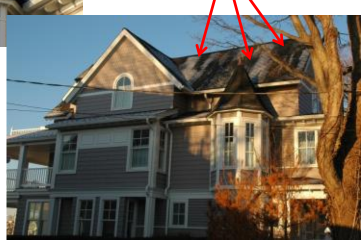
- Improper ratio of R-values and a vapor-open and air-open support system
- Condensation has led to mold and mildew in some areas of this project

## Vented vs. unvented



Melt patterns before the repair

Melt from gaps around ducts in the vented roof slopes



## BE vs. HVAC

3. Make sure there is a good fit between the building enclosure and the HVAC system
   - Sequencing
   - Conflicts in the use of space in the assembly
   - Vented vs. unvented

## Preventing problems

Require trades in the right sequence to avoid this problem

No insulation in the wall cavity

Boxed out the wall cavity, but the insulation was after the HVAC

## Preventing problems

HVAC and insulation both need this space

Result

## How do we stay out of trouble with bulk SPF?

Make sure the project requirements are right

4. Verify foam-to-substrate material compatibility
5. Require installer qualifications
6. Require complete processing and installation parameters in the product documentation (50 plus LEED if required)

## Material compatibility

4. Verify foam-to-substrate material compatibility

- Adhesion – (Foam won't stick to ice)
  - Eliminate or plan for known material incompatibilities
  - Verify material bond strength with a pull test if the substrate is unknown

## Compatibility

**Substrate material compatibility for foamed-in-place polyurethanes**

| Substrate Materials - General Description | Product/Brand name | Adhesion rating | Preparation | Maximum moisture content allowed |
|---|---|---|---|---|
| **Plastics / membranes** | | | | |
| Polyethylene films and membranes | | Poor | N/A | N/A |
| Polytetrafluoroethylene (PTFE) products | | Poor | N/A | N/A |
| Polypropelyne products | Tyvek, Typar, etc. | Moderate | N/A | N/A |
| | | | | |
| Glass fiber reinforced products | | | | |
| Reinforced plastic membranes (Poly, TPO, PVC, etc.) | Reinforced polyethylene (many brands) | Varies with plastics (see this list for the plastic film to assess compatibility) | | N/A |
| Reinforced bituminous membranes | Many | Varies with membrane - note that most bituminous-based product can soften or melt from the heat of reaction - this can temporarilly compromise bond strength of the substrate | | N/A |
| Reinforced in paper membranes (Scrim) | Many | Good | Verify paper is not coated with a plastic or wax that may reduce bond strength | Value unknown, but integrity of the paper is important |
| Polyester resin sheet goods with integral glass fibers (Corvettes, tub-showers units, translucent roofing, etc.) | Fiberglas | Moderate | Clean and dry* | N/A |
| Peel-and-stick membranes | | | | |
| Products with polyethylene film finish | Ice and Water Shield | Poor | Torch | N/A |
| Products modified to accept foam | Blueskin, Perm-A-Barrier | Moderate | Clean and dry* | N/A |
| Polyurethane and Isocyanurate board stock | Tuff-R, Thermax | Good | Clean and dry* | N/A |
| Polystyrene foam | | | | |
| Expanded | Styrofoam EPS | Good | Clean and dry* | N/A |
| Extruded | Styrofoam XPS | Good | Clean and dry* | N/A |

*Update on Compatibility Testing of Spray Polyurethane Foam with CPVC, originally presented at Polyurethanes 2008

## Compatibility

Known materials

**Substrate material compatibility for foamed-in-place polyurethanes**

| Substrate Materials - General Description | Product/Brand name | Adhesion rating | Preparation | Maximum moisture content allowed |
|---|---|---|---|---|
| **Wood products** | | | | |
| Construction grade spruce | Many | Good | Clean and dry* | < 11% |
| Pressure treated lumber | Many | Varies | Clean and dry*, free of preservative buildup | < 11% |
| Wood boards | Rough-sawn and planed | | | |
| Glue-laminated beams & joists | | | | < 11% |
| Natural wood face layer | Many | Good | Clean and dry* | < 11% |
| Waxed finish | Many | Poor | Apply bonding material | < 11% |
| Plywood | | | | < 11% |
| Standard wood | Many | Good | Clean and dry* | < 11% |
| Pressure treated | Many | Varies | Clean and dry*, free of preservative buildup | < 11% |
| OSB | | | | < 11% |
| Smooth side | Many | Moderate | Sand and/or prime | < 11% |
| Rough side | Many | Good | Clean and dry* | < 11% |
| High and medium-density composite wood panels | | | | < 11% |
| MDO | Many | Moderate | Sand and/or prime | < 11% |
| Particle board | Many | | | < 11% |

This document is available upon request

## Compatibility

Known materials

**Substrate material compatibility for foamed-in-place polyurethanes**

| Substrate Materials - General Description | Product/Brand name | Adhesion rating | Preparation | Maximum moisture content allowed |
|---|---|---|---|---|
| | | | | |
| **Metals** | | | | |
| Steel | | | | |
| Mill-finish cold rolled sections | Many | Moderate | Clean and apply etching agent/primer | |
| Mill-finish coil stock | Many | Poor | Clean and apply etching agent/primer | |
| Primed and/or painted | Many | Good | Clean and dry | |
| Galvanized steel - Spangled | Many | Poor | Apply etching agent | |
| Galvanized steel - Hot dipped | Many | Moderate | Prime | |
| Galvanized steel - Cold coated | Many | Moderate | Prime | |
| Galvanized steel - with paint-prep. galvanization process | Galvalume | Good | Clean, dry, free of oil and grease, or uncured solvent-based materials | |
| Aluminum | | | | |
| Mill-finish | | Poor | Etching & prime | |
| Primed and/or painted | | Good | Clean and dry* | |
| Galvanized - Galvalume | | Moderate | Clean and dry* | |
| Aluminum foil facers on RFB | | Moderate | Clean and dry* | |
| **Coatings** | | | | |
| Bituminous coatings | Tar, foundation coatings, vapor barrier coatings | Poor | May delaminate from heat of reaction | |
| Water-based coatings | Foundation coatings, vapor barrier coatings | Varies by product - verify with manufacturer | As directed by manufacturer | |
| Polyurea | Many | Good | Clean and dry | |
| Oil and water-based paints | Many | Good | Clean and dry | |
| | | | | |

This document is available upon request

## Compatibility

Known materials

**Substrate material compatibility for foamed-in-place polyurethanes**

| Substrate Materials - General Description | Product/Brand name | Adhesion rating | Preparation | Maximum moisture content allowed |
|---|---|---|---|---|
| **Masonry/glass** | | | | |
| Aged poured-in-place or pre-cast concrete | Many | Good | Clean and dry* | |
| Fresh poured-in-place or pre-cast concrete | Many | Varies | Clean and dry* | |
| Concrete block | Many | Good | Clean and dry* | |
| Brick | Many | Good | Clean and dry* | |
| Stone | | Good | Clean and dry* | |
| Ceramic clay block | Many | Good | Clean and dry* | |
| Ceramic tile - natural | Many | Good | Clean and dry* | |
| Ceramic tile - glazed | Many | Moderate | Clean and dry* | |
| Glass fiber products | Open mesh | Good | Clean and dry* | N/A |
| | Woven roving | Good | Clean and dry* | N/A |
| Paper faced gypsum board | Standard gypsum wall board | Good | | |
| | Exterior gypsum board (Densglas) | Moderate | | |
| Plaster | | Good | | |
| Window glass | Many | Moderate | Clean and dry* | |
| Foam glass board stock | Many | Moderate | Clean and dry* | |

This document is available upon request

## Compatibility

Known materials

Prepare substrates properly
- Clean, dry, warm
- Prime, etch, mechanical fastening, physical support



## Material compatibility

4. Verify foam-to-substrate material compatibility and connections to the structure
   - Consider heat-of-reaction (250 F) bond release (hot tar will delaminate)
   - Consider cure pull of “fully-adhered” substrate layers in combination with increased temperatures and lack of mechanical attachment (substrate bonding to the structure)

## Compatibility

Foam and food-grade T-B coating system rated for exposure in occupied spaces



Before and After

## Compatibility

Slow-rise foam to the rescue

Bituminous VR melts with heat of reaction at full thickness

## The existing conditions

Brick and metal studs after removing the wet sheathing and mold. Brick ties were preserved where possible.


Copper through-wall flashing was found at the base of the wall

## Cure lift

Differential cooling



***Specialty Field-Applied Foam Applications***

Goal: Install an air and vapor tight insulation system

The drainage plane was sealed with SPF during the insulation installation

## Cure lift

The substrate has to be attached to the structure

## Installer qualifications

5. Require the following:
   - Experience and training
   - Certifications – State and local
   - Require adequate insurance

## Installer qualifications

### Bid phase document requirements

1. Manufacturers' certifications for the Installer
2. SPFA CERTIFICATION that the Installation Contractor meets the SPFA Professional Certification Program or the Installed Building Products Training Program Certification (optional)
3. Written certification that the foam installer has been in the business of performing foam installations for at least five years
4. Installer State and County Compliance Certificate or license (where required)

## Installer qualifications

### Bid phase document requirements

Certificates of insurance

1. Installer must have insurance provided by "Admitted Insurance companies" from Standard, not Excess markets. This must be stated on the insurance company's form.
2. Exclusions must not include "Interior and exterior insulation."
3. Must provide verification of full environmental/pollution coverage.

## Product documentation

6. Require complete documentation
   - Processing parameters (25)
   - Installation parameters (25)
   - Safety documentation (Site protection)
     - Written safety plan (required by law – only covers employees)
     - Air quality management plan (not required by law, but protects the Owner and the property)
     - SDSs

## Product documentation

Typical industry documentation:

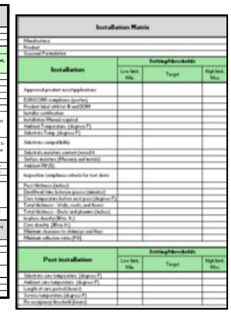
- Product/Tech. Data Sheets
- Evaluation Service Reports
- Installation Instructions
- Safety Data Sheets
- Application Guides
- Sample CSI specifications
- Marketing documents
- Hundreds of pages of information in each set

## SOLUTIONS – Require and verify parameters

Coincidentally, there are 25 parameters on each matrix. They are all critical

Many installers only use one brand of foam, so one set of lists would work for all projects

| Processing Matrix | | | |
|---|---|---|---|
| Manufacturer | | | |
| Product | | | |
| Seasonal formulation | | | |
| Chemical Processing | Setting/thresholds | | |
| | Low limit, Min. | Target | High limit, Max. |
| A Storage Temperature (degrees F) | 50 | In this range | 75 |
| B Storage Temperature (degrees F) | 65 | In this range | 85 |
| A Conditioning Temperature (F) | 50 | 80 | 90 |
| B Conditioning Temperature (F) | 50 | 80 | 90 |
| A Supply Temperature (degrees F) | 50 | 80 | 90 |
| B Supply Temperature (degrees F) | 50 | 80 | 90 |
| A Recirculation/ mixing | Not required - Can recirculate to increase temperature - Do not set heaters above 85F | | |
| B Recirculation/ mixing | | | |
| A Transfer rate | Minimum 2:1 on the A side. Minimum 1:1 on the B side. Minimum ½-inch supply hoses. Pumps sized to supply adequate volume to the proportioner. | | |
| B Transfer rate | | | |
| A Pressures (PSI) | 800 | 1,400 | 2,000 |
| B Pressures (PSI) | 800 | 1,400 | 2,000 |
| Pressure difference (PSI) | Any pressure difference less than the high limit | | 50 |
| A Flow proportion (by volume) | +2% | 1:1 | +2% |
| B Flow proportion (by volume) | | | |
| A Flow proportion (by weight) | 1:1 - Must be adjusted from weight to volume using the specific gravity at the test temperature | | |
| B Flow proportion (by weight) | | | |
| | Ambient 30 to 65 | Ambient 65 to 80 | Ambient > 80 |
| A Temperature (degrees F) | N/A | 120 | 118 |
| B Temperature (degrees F) | N/A | 120 | 118 |
| A Temperature (degrees F) | N/A | 120 | 115 |
| B Temperature (degrees F) | | | |
| A Temperature (degrees F) | N/A | 120 | 115 |
| B Temperature (degrees F) | | | |
| Reactivity profile - Rise (Seconds) | Cream Time 4, tack free 34 | | |
| Reactivity profile - cure time (hours) | Initial Cure Time <1 (See TDS for details) | | |




These documents are available upon request

## How do we stay out of trouble with bulk SPF?

Make sure the project requirements are right

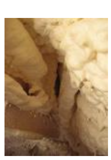
7. Set performance standards for the SPF/IPF and verify
8. Require matching material and labor guarantees
9. Require written certification that all parameters have been met

## Performance Standards

7. Set performance standards for the SPF/IPF and verify
   - Make sure the R-value intent is clear. (R-value vs. thickness – require "average with a minimum.")
   - Require that an air barrier performance standard be met. This brings the SPF into the air barrier system. (It isn't just insulation.)

## Performance Standards

- Which of these installations will have better R-value performance?
- The average of zero and 12" is 6", right?
- How would you verify how thick this is?
- How would you install a uniform coating on this work?



## Performance Standards

7. Set performance standards for the SPF/IPF and verify
   - Make sure the R-value intent is clear. (R-value vs. thickness – require "average with a minimum.")
   - Require that an air barrier performance standard be met. This brings the SPF into the air barrier system. (It isn't just insulation)

## Performance Standards

Mobile building enclosure

## Performance Standards

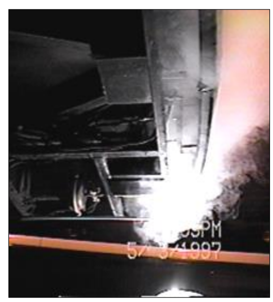
## Performance Standards



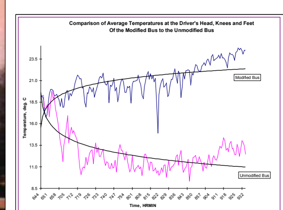



If you can see the fog, you can seal it!

## Performance Standards



Before and after remediation



## Performance Verification

- Prepare for and oversee the compliance test (cost)
- Perform whole-building airtightness test to confirm compliance with the standard

Five fans were set up, only three were required = .10 CFM50/SF shell

Compliance Test – No masking of Mechanicals

## Performance Standards

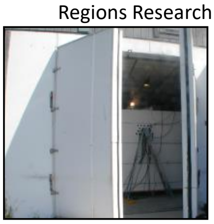
New Hampshire High School
high performance vs. conventional construction cost*
Guaranteed 50% of ASHRAE Number

| | | |
|---|---|---|
| The Addition and Renovation | 90,000 sq. ft. | |
| Total campus | 255,000 sq. ft. | |
| BE installation & commissioning | | $112,000. |
| Reduction in air leakage | 50% less | |
| The HVAC system savings | 25% less | |
| Construction savings (net) | | $945,806 |
| The first winter fuel cost (2007-2008) | $21,000 ~ | $.10/sq. ft. |
| Comments: | | |
| Standard insulation values | R=38 roof, R=21 walls | |
| Local conventional school heating cost | | $.86/sq. ft. |

**Bill Root, GWR Engineering*

## Performance Standards

The first ARRO Project being tested at the U.S. Cold Regions Research Environmental Laboratory



R-value = an average of 70 for ~ 2 watts per square foot of footprint

~200 watts total energy for –70F outside, +70F inside

Air leakage test ARRO 2 = .03 CFM50/SF shell = net zero

## Performance Standards

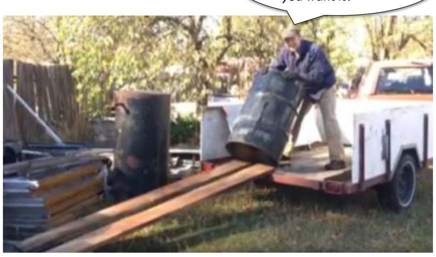
ARRO 1 at McMurdo in Antarctica


ARRO 2 deployed in Antarctica – first autonomous station to send weather data over an entire winter

## Product choice

8. Require matching material and labor warranties.

*Here's your warranty spray foam. Where do you want it?*



## Verification and reporting

8. Require written certification that all parameters have been met
   - Processing parameters (use the parameter checklist as the report form)
   - Installation parameters (use the parameter checklist as the report form)

## SOLUTIONS - Processing

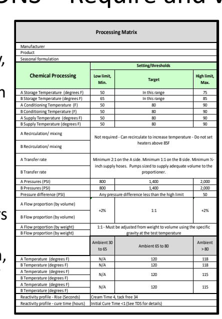
6. Processing
   a. Require and approve complete documentation so that one of the responsible parties can verify that the processing has been performed properly
   b. Use third-party commissioning (manual fault protection)
   c. Use automatic full-time fault-protection process monitoring, control, and reporting

85% of the foam problem projects I have worked on were caused by processing issues

## SOLUTIONS – Require and verify parameters

Coincidentally, there are 25 parameters on each matrix. They are all critical

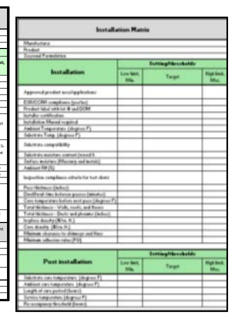
Many installers only use one brand of foam, so one set of lists would work for all projects



Processing Matrix

Manufacturer
Product
Seasonal formulation

| Chemical Processing | Setting/thresholds: Low limit, Min. | Target | High limit, Max. |
|---|---|---|---|
| A Storage Temperature (degrees F) | 50 | In this range | 75 |
| B Storage Temperature (degrees F) | 65 | In this range | 85 |
| A Conditioning Temperature (F) | 50 | 80 | 90 |
| B Conditioning Temperature (F) | 50 | 80 | 90 |
| A Supply Temperature (degrees F) | 50 | 80 | 90 |
| B Supply Temperature (degrees F) | 50 | 80 | 90 |
| A Recirculation/ mixing | Not required - Can recirculate to increase temperature - Do not set heaters above 85F | | |
| B Recirculation/ mixing | | | |
| A Transfer rate | Minimum 2:1 on the A side. Minimum 1:1 on the B side. Minimum ½-inch supply hoses. Pumps sized to supply adequate volume to the proportioner. | | |
| B Transfer rate | | | |
| A Pressures (PSI) | 800 | 1,400 | 2,000 |
| B Pressures (PSI) | 800 | 1,400 | 2,000 |
| Pressure difference (PSI) | Any pressure difference less than the high limit | | 50 |
| A Flow proportion (by volume) | +2% | 1:1 | +2% |
| B Flow proportion (by volume) | | | |
| A Flow proportion (by weight) | 1:1 - Must be adjusted from weight to volume using the specific gravity at the test temperature | | |
| B Flow proportion (by weight) | | | |
| | Ambient 30 to 65 | Ambient 65 to 80 | Ambient > 80 |
| A Temperature (degrees F) | N/A | 120 | 118 |
| B Temperature (degrees F) | N/A | 120 | 118 |
| A Temperature (degrees F) | N/A | 120 | 115 |
| B Temperature (degrees F) | | | |
| A Temperature (degrees F) | N/A | 120 | 115 |
| B Temperature (degrees F) | | | |
| Reactivity profile - Rise (Seconds) | Cream Time 4, tack free 34 | | |
| Reactivity profile - cure time (hours) | Initial Cure Time <1 (See TDS for details) | | |



Installation Matrix

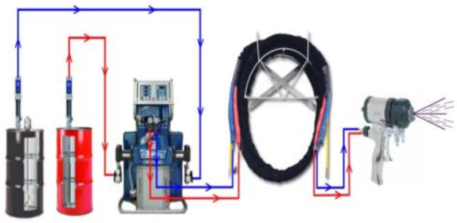
Installation

Post installation

These documents are available upon request

## Why only a small percentage (<1%) of projects have product quality problems

- Sophisticated processing equipment: positive-displacement equipment normally performs within an acceptable tolerance



## Verification and reporting

This could have been avoided by verifying temperature, ratio, and mix before starting the installation

This was not a technique issue

## SOLUTIONS - Processing

6. Processing
   a. Require and approve complete documentation so that one of the responsible parties can verify that the installation has been performed properly
   b. Use third-party commissioning (manual fault protection)
   c. Use automatic full-time fault-protection process monitoring, control, and reporting

## Field tests required to assure product quality

Ratio is the first test because it is the most frequent cause of serious foam failures

- Processing tests
  - Verify ratio
  - Test shots – verify mix
- Installation tests
  - Verify pass thickness
  - Verify dimensional stability
  - Verify density
- IAQ tests
  - Re-entry tests

Ratio testing is key to assuring that the chemicals are completely reacted during the mixing event that takes place at the gun. The steps are:

- Verify supply chemical temperatures
- Verify pressures are balanced
- Perform a high-stall test
- Calibrate the proportioner

## Field tests required to assure product quality

55 Gallon Drum

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outdoor ambient | | | 21.0 | 25.0 | | | |
| Inside ambient | | | 65/72 inside the truck | One hour later with the door open | | | |
| Difference | 1.0 | 73.0 | 72.0 | 72.0 | 53.8 | -19.0 | Difference |
| Difference | 2.0 | 67.0 | 65.0 | 65.0 | 42.2 | -22.8 | Difference |
| Difference | 2.0 | 60.0 | 58.0 | 58.0 | 43.0 | -17.0 | Difference |
| | | | Top to bottom diff. = 14F | Top to bottom diff. = 14F | | | |

IR gun surface temperatures

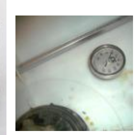
Core temperatures

Verify supply chemical temperatures near the bottom in the core of the supply chemicals

These are 36" long to measure the core temperature near the pump inlet

## Field tests required to assure product quality

Measurements of chemical temperatures should be taken in the core of the material (near the transfer pump inlet)



250 gallon tote

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outdoor ambient | | | 21.0 | 25.0 | | | |
| Inside ambient | | | 65/72 inside the truck | One hour later with the door open | | | |
| | | | Not full | | | | Difference |
| Difference | 0.0 | 65.0 | 65.0 | 66.0 | 53.4 | -12.6 | Difference |
| Difference | -0.3 | 60.2 | 60.5 | 60.5 | 40.6 | -19.9 | Difference |
| | | | Middle to bottom diff. = 4.5F | Middle to bottom diff. = 5.5F | | | |

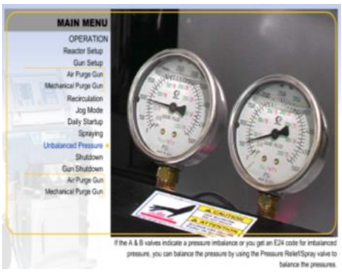
Side away from the door

IR gun surface temperatures

Side near the door

Core temperatures

## Field tests required to assure product quality




A 100 psi differential is best practice. Most manufacturers recommend 50 PSI.

A 200 psi differential approaches where you could have a cross over in the gun.

Verify and balance the initial pressures if required

Always require a high-stall test

## Field tests required to assure product quality

Calibration can identify restrictions

One type of restriction

Calibration test should be 1:1

## Field tests required to assure product quality

Supply-side restrictions

This system was off ratio about 14%, but within 3% after fixing the hoses

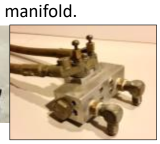
## Field tests required to assure product quality

Manual calibration – by volume

These Installers removed the gun manifold to perform their ratio tests

## Field tests required to assure product quality

This test was done with an adapter that bolts onto the manifold.



## Field tests required to assure product quality

Manual calibration – by volume

This is a snap shot in time, but a worthwhile QA check for equipment performance

This test was off by less than 1%

This test was originally off by more than the manufacturer's tolerance of 2% because the chemical temperature was too low.

After heating the chemicals, the test result was less than 2%.

## Field tests required to assure product quality

Cold chemicals

## Field tests required to assure product quality

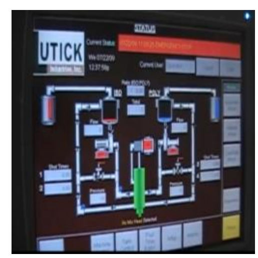
This test was performed on two trucks on 6-23-18 in 15 minutes. This JMT proportioner was within 1%.

## SOLUTIONS - Processing

6. Processing
   a. Require and approve complete documentation so that one of the responsible parties can verify that the installation has been performed properly
   b. Use third-party commissioning (manual fault protection)
   c. Use automatic full-time fault-protection process monitoring, control, and reporting

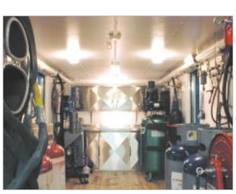
## SOLUTIONS - full-time fault-protection process monitoring, control, and reporting

QA monitors have been in use in OEM applications since 1954



## SOLUTIONS - full-time fault-protection process monitoring, control, and reporting

This is industry-standard off-the-shelf quality control equipment used in OEM manufacturing.
This ratio monitor can eliminate most foam processing failures.



Aftermarket flow ratio, usage totalizer, and temperature monitor system with auto shut-off added to standard proportioning equipment.

## SOLUTIONS - full-time fault-protection process monitoring, control, and reporting

Flow meters provide accurate ratio data. Stroke counters do not.

These are the two main components of a temperature and ratio monitoring system.

SOLUTIONS - full-time fault-protection process monitoring, control, and reporting

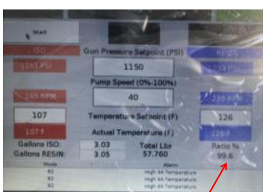
Flow meters provide accurate ratio data. Stroke counters do not.

This type of equipment could eliminate up to 85% of the problem projects


SOLUTIONS - full-time fault-protection process monitoring, control, and reporting

- The flowmeters produce about 10,000 pulses per gallon, so the resolution of the measurement of each chemical is about 0.0001 gallons.
- Over the course of a job spraying one set of foam, this gives a measurement accuracy of about +/- 0.02% (ASTM C1848 requires +/- 2.0%)
- +10%

SOLUTIONS - full-time fault-protection process monitoring, control, and reporting




The readout is 99.6% - The manufacturer and ASTM C1848 (SPF) allow plus or minus 2% from the 1:1 theoretical ratio

**Daily Report & Job Summary**

Job #: 15
Customer: Sprayfoam Inc
Address: 21 East Rd.
Chemical Used: Chemical/Manufacturer
Applicator Name: John Doe

| Spray Dates | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-13-17 | 42.85 | 42.87 | 99.95 |
| 09-14-17 | 30.21 | 30.23 | 99.93 |
| 09-15-17 | 17.89 | 17.93 | 99.78 |
| 09-18-17 | 11.61 | 11.63 | 99.88 |
| 09-19-17 | 2.86 | 2.89 | 98.86 |
| Total Gallons | 105.42 | 105.55 | 99.88 |

Field tests required to assure product quality

- Processing tests
  - Verify ratio
  - Test shots – verify mix
- Installation tests
  - Verify pass thickness
  - Verify dimensional stability
  - Verify density
- IAQ tests
  - Re-entry tests

Field tests required to assure product quality

- Strip tests – verify performance at the gun

Perform test shots

Field tests required to assure product quality

“Surfboard” strip tests

## Field tests required to assure product quality

Always do test shots before starting the installation, if for no other reason than to clear the cold material from the whip. This type of material could put the entire project's quality in question.

Strip tests can show lead and lag, poor mix, and cold material.

## Field tests required to assure product quality

Cut cross-sections and confirm cell size, shape, and color uniformity

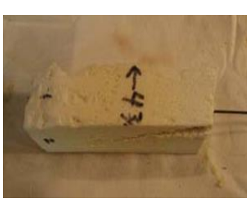
## Field tests required to assure product quality

Uniform cells and not friable – should "snap" when it is broken

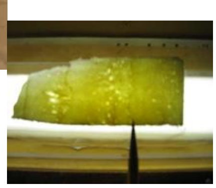
## Field tests required to assure product quality

- Processing tests
  - Verify ratio
  - Verify mix – test shots
- Installation tests
  - Verify pass thickness
  - Verify dimensional stability
  - Verify density
- IAQ tests
  - Re-entry tests

## Field tests required to assure product quality



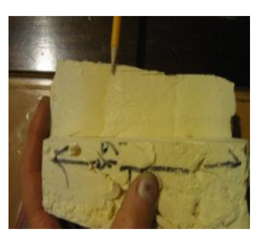
Pass thickness test



## Field tests required to assure product quality

Pass thickness

1. Installing to the Manufacturer's pass thickness specification
2. Pass vs. "total" and "daily total" insulation thickness
3. Theoretical variations for acceptable non-compliance



## Field tests required to assure product quality

Ratio is the first test because it is the most frequent cause of serious foam failures

- Processing tests
  - Verify ratio
  - Test shots – verify mix
- Installation tests
  - Verify pass thickness
  - Verify density
  - Verify dimensional stability
- IAQ tests
  - Re-entry tests

## Verify density

1. Make sure the average density matches the manufacturer’s published density (ASTM D2126)
2. Test the density of the top, middle, and bottom thirds
3. Important: Make sure the core density isn’t too low (dimensional stability)

## Field tests related to assuring product quality

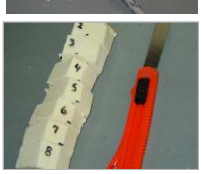




## Field tests related to assuring product quality


- QA included ratio check – 1/day
- Strip test shots – one per set
- Density checks – three per day

## Field tests related to assuring product quality

Both of these samples were the same product installed at the same time – different pass thicknesses

Density Profiles

Properly applied sample

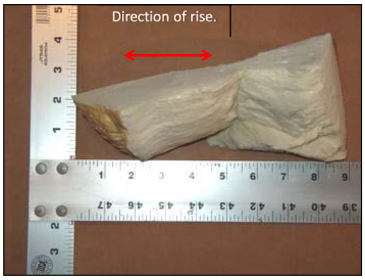
| | Sample 10A | Sample 5B |
|---|---|---|
| Pass thicknesses | 1.5" - 7" | 1.5" - 2" |
| Percent change | 6% | 25% |
| Average density for entire sample | ~1.8 | ~2.2 |
| Slice #1 | 2.95 | 2.56 |
| Slice #2 | 1.94 | 2.15 |
| Slice #3 | 1.69 | 2.14 |
| Slice #4 | 1.56 | 2.35 |
| Slice #5 | 1.77 | 2.47 |
| Slice #6 | 1.78 | 2.32 |
| Slice #7 | 1.95 | 2.15 |
| Slice #8 | - | 2.13 |

Improperly applied sample

3 layers is probably enough, the core (middle third) is the critical one

## Field tests related to assuring product quality

## Field tests related to assuring product quality



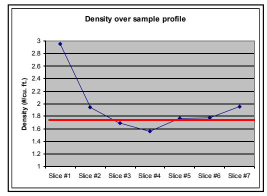

Density affects dimensional stability

Elongated cells are weaker perpendicular to the grain and thermal shock causes the material to shrink laterally.

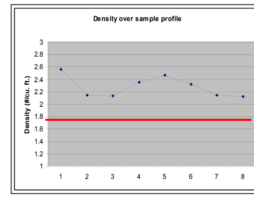
## Field tests related to assuring product quality

Density Profiles

Blue line: Incorrect pass thickness

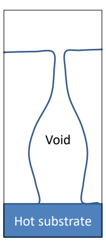



Blue line: Correct pass thickness




Red line indicates minimum density (1.75#/cu. ft.) for good dimensional stability for a nominal 2# SPF

## Field tests related to assuring product quality




## Field tests required to assure product quality

- Processing tests
  - Verify ratio
  - Test shots – verify mix
- Installation tests
  - Verify pass thickness
  - Verify density
  - Verify dimensional stability
- IAQ tests
  - Re-entry tests

## Field tests required to assure product quality

Slit test that opened up – sounded like a gun shot when the slit caused it to open! Excessive pass thickness on a hot substrate was the cause.

Slit test that didn't open up – dimensionally stable product

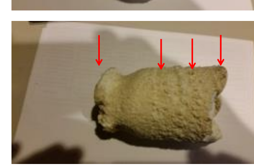
## Field tests required to assure product quality

Processing affects dimensional stability

Before an ASTM D 2126 test


Only one of the three passes was significantly off ratio.

After the test

## Keys to two-component bulk foam quality

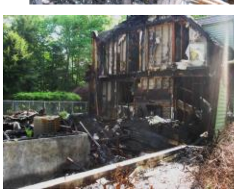
1. Select the right product for the application
2. Require the installer to meet the manufacturer's requirements
   - Warm (or cool) the chemicals
   - Mix the chemicals if stratified
   - Verify the ratio (requires balanced pressures and adequate supply)
   - Verify startup mix/quality with test shots
   - Monitor pass thickness
   - Follow industry standard safety protocols for site protection
3. Require the installer to certify that the manufacturer's requirements have been met

## Safety First!

- Personal protection (95%)
- Site protection
  - Evacuation (5%)
  - Ventilation (balanced) (<1%)
  - CAZ safety (<1%)

Who is this?

## Ventilate, but check the CAZ



Air sealing plus unbalanced ventilation can cause back-drafted combustion appliances

**Thank you for your time!**

**QUESTIONS??**

By: Henri Fennell, CSI/CDT


www.polyurethanefoamconsulting.com
Cell: 802-222-7740

## Introducing "TECH-FORMS"

**Case Study**

*By: Henri C. Fennell, CSI/CDT*
*H C Fennell Consulting, LLC*

## Introducing "TECH-FORMS"

**System Overview**

1. A system that combines the insulation, sheathing, and roofing into a "composite" structural cladding system.

## Introducing "TECH-FORMS"

**Project goals**

1. Evaluate the feasibility of using TECH-FORMS as an alternative to Quonset Huts : Avoid the additional cost of a redundant structure that is typically required to insulate and finish that type of low-cost building enclosure system.
2. Daylighting: develop and test a more energy-efficient method in a low-cost enclosure design.
3. Fabric-covered structures: Provide a more energy-efficient enclosure system than fabric-only systems.

## Introducing "TECH-FORMS"

**How to meet these goals**

1. This composite system spans over lightweight, structurally-efficient tubular or truss frames that can be bent or fabricated to create a virtually unlimited number of linear or curved architectural shapes. This allows complete design flexibility, limited only by the shape of any combination of framing elements.
2. Fast construction of high-performance, energy-efficient structures is made possible.

## Introducing "TECH-FORMS"

**Advantages vs. other comparable structures:**

1. Meets the current industry-wide need to meet sustainability goals. Increased energy performance will reduce fossil fuel use and emissions.
2. The high-performance nature of the product will make it a system of choice for the new "net-zero energy" market where quick, open-plan structures for moderate to long-term use are required.

## Introducing "TECH-FORMS"

**The composite system**

The components that make up this system are:

1. A proven roof membrane system
2. A light tubular or trussed steel framing system
3. A custom, field-applied polyurethane foam insulation system
4. A field-applied interior finish system

## Introducing “TECH-FORMS”

### CASE STUDY

1. This small prototype structure uses conventional greenhouse framing elements arranged to allow the inclusion of efficient, double-glazed vertical windows high on the structure. (are not blocked by snow cover).
2. The building is approximately 30’ by 32’, creating a second level on the original low-pitched roof, single-story building.
3. This structure has been in place for fifteen years in harsh Vermont winter conditions; there is no sign of deterioration in the structure or its energy performance.

## Introducing “TECH-FORMS”

The Design

1. Raise the roof of an existing garage
2. Demonstrate day-lighting with insulating glass
3. Demonstrate the structural composite design

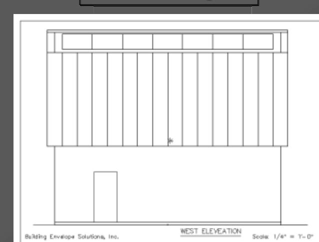
## Introducing “TECH-FORMS”

### Drawings


Cross-section through the structure

## Introducing “TECH-FORMS”

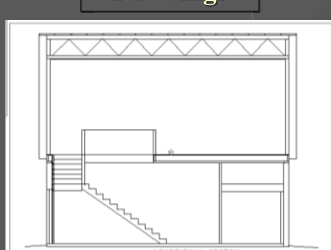
### Drawings




West Elevation

## Introducing “TECH-FORMS”

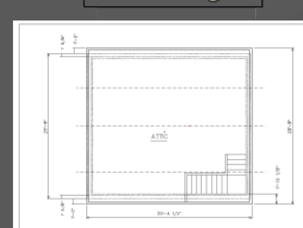
### Drawings




Longitudinal Section

## Introducing “TECH-FORMS”

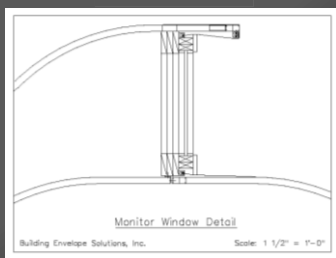
### Drawings




Floor Plan

## Introducing “TECH-FORMS”

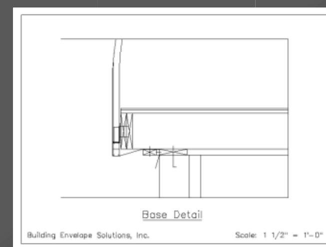
### Drawings




Section at Monitor window

## Introducing “TECH-FORMS”

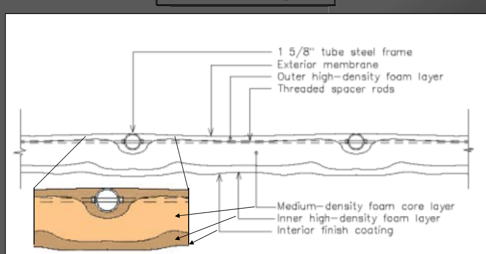
### Drawings




Section at base of bows

## Introducing “TECH-FORMS”

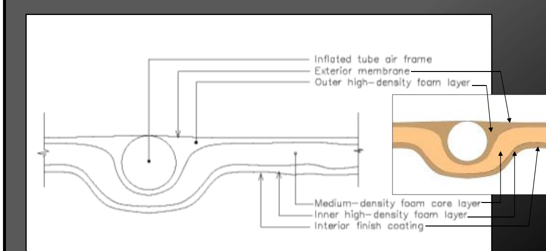
### Drawings




Section through composite wall/roof assembly

## Introducing “TECH-FORMS”

### Drawings




Alternate section for inflated air tube structure

## Introducing “TECH-FORMS”

### CASE STUDY

For this project, a Unistrut base detail was used to support the greenhouse bows.

## Introducing “TECH-FORMS”

### CASE STUDY

Unistrut frame at the top of the bows

Bows being set on the Unistrut base frame

## Introducing “TECH-FORMS”

### CASE STUDY

All bows in place

Lower side bows in place

## Introducing “TECH-FORMS”

### CASE STUDY

Preparing to install the roofing membrane on the lower-side bows

Fabric installed - before stretching

## Introducing “TECH-FORMS”

### CASE STUDY

Installing the membrane below the monitor windows

Wrapping the fabric at the gable end prior to stretching

## Introducing “TECH-FORMS”

### CASE STUDY

Completed installation

## Introducing “TECH-FORMS”

### CASE STUDY

Completed installation

## Introducing “TECH-FORMS”

### CASE STUDY

Daylighting

After the interior finish coating

## Introducing "TECH-FORMS"

### CASE STUDY

Like new ten years later

Snow slides off quickly – minimizes roof loads

## Introducing "TECH-FORMS"

No sign of roof membrane wear, deterioration, or problems with the seams after 15 years

Composite roof easily carries someone climbing or sitting on it – mid span

## Introducing "TECH-FORMS"

### Larger structures that can use this approach

There are a number of commercially available frame and cover systems for larger structures that could use this system.

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There are a number of commercially available frame and cover systems for larger structures that could use this system.

## Introducing "TECH-FORMS"

### Conclusion

Working together, these materials create a synergetic system that is ideal for high-performance, moderate-duration structures.

Speed of construction and the efficient use of materials provides a cost-effective, energy-efficient system for enclosing space.

# ENTERING THE SPF ROOFING MARKET

For the SPF Insulation Contractor

SPRAYFOAM CONVENTION & EXPO

January 26-29, 2014

Palm Springs, California

2014

The comments and opinions in this presentation do not necessarily represent or reflect those of SPFA.

# ENTERING THE SPF ROOFING MARKET

- Overview of the Roofing Market
- History of SPF Roofing in the US
- Advantages of SPF Roofing
- Spray Polyurethane Foam for Roofing Applications
- SPF Roof Coating Systems
- Primers
- SPF Roofing Equipment
- SPF Roof Application
  - Surface prep, substrates, details, foam and coating application, granules, and what to look out for
- Bidding a project.
- Warranties and Applicator Programs

# US ROOFING MARKET

- US demand for roofing is projected to rise 3.5 percent annually to 268 million squares in 2017, valued at $27.2 billion. Asphalt shingles will remain the dominant product and will offer the best growth opportunities, to be outpaced only by the much smaller segments of roofing tile and other roofing materials. The West will lead gains by region.
- SPF low slope roofing remains at 2-3% of the commercial market.

SPRAYFOAM CONVENTION & EXPO
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2014

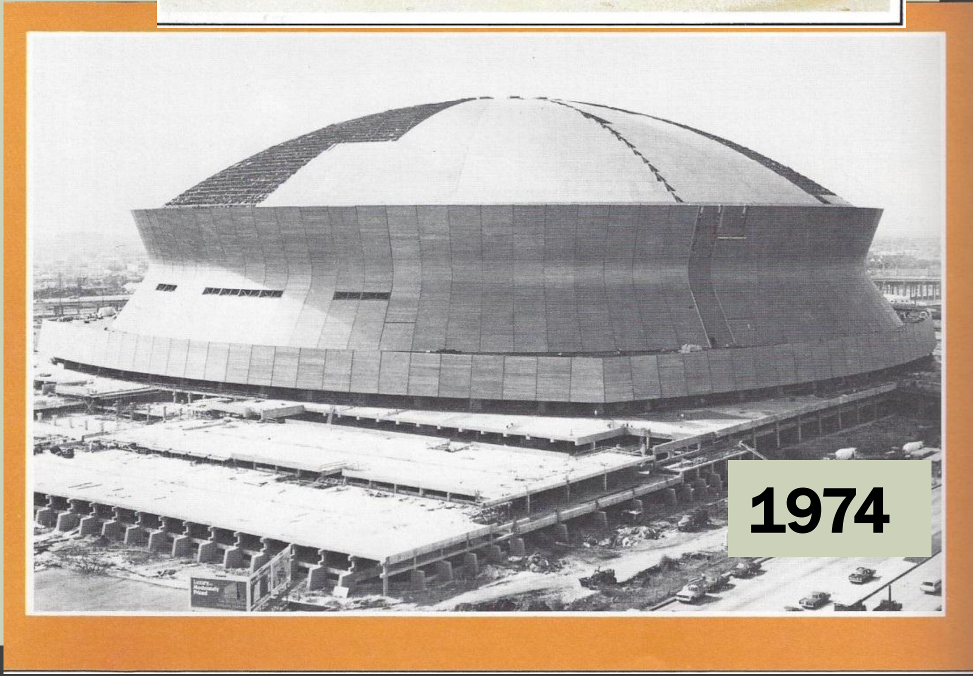
# SPF ROOFING - FROM THE BEGINNING

- In 1937 Otto Bayer discovered the basic polyurethane chemistry in Germany.
- In 1953 Walter Baughman created the “Blendometer” which allowed for the strategic mix of chemicals to create a plastic expanding foam. Applied as a liquid and expanded into a thick foam which eventually hardened upon curing.
- In 1963 Fred Gusmer invented the first dedicated spray technology machine, the FF; named for Fred Werner his partner and Fred Gusmer.  Similar equipment by Binks and others soon followed allowing the application of spray polyurethane foams and opening roofing and insulation markets to this new foam plastic material.

# SPF ROOFING FROM THE BEGINNING

- The energy crisis of the 1970's created a demand for the economical and energy saving spray polyurethane foam (SPF) roofing system. The SPF roofing system could be spray applied over a variety of existing roof systems with excellent adhesion. Silicone, Acrylic, Hypalon, Asphaltic and Urethane coatings were used to coat over the SPF insulation to form the system. The blowing agent commonly used in the SPF supplied was "Freon" or CFC-11. Many of these roofs are still in place today although with new top layers or coating systems. The SPF systems on these roofs are 35-40 years old.

1979



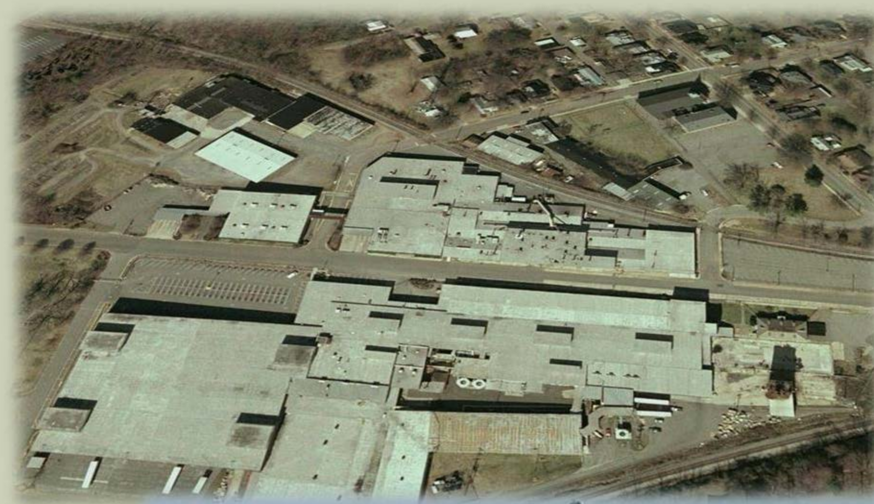
1974

# SPF ROOFING FROM THE BEGINNING

- In the 1980's, Energy Savings from Spray Foam roofing systems were beginning to be documented.  Some of the first recoats and renewal of SPF roofing was completed. New spray equipment, new products and technologies made the application of the polyurethane foam easier and more efficient.  Studies were done at Oakridge laboratories, Texas A&M University and by the US Navy that indicated SPF roofing systems were sustainable and saved money and energy.

# SPF ROOFING FROM THE BEGINNING

- The 1990's SPF products meet challenges of compliance with the Montreal protocol causing changes in the blowing agent and rounds of new testing. Robotic application was developed. A study was done by the National Roofing Foundation of many in place SPF roofs validating the viability of the system.  In 1997 NRCA inserted a section on SPF roofing into their Roofing Manual further validating the system.



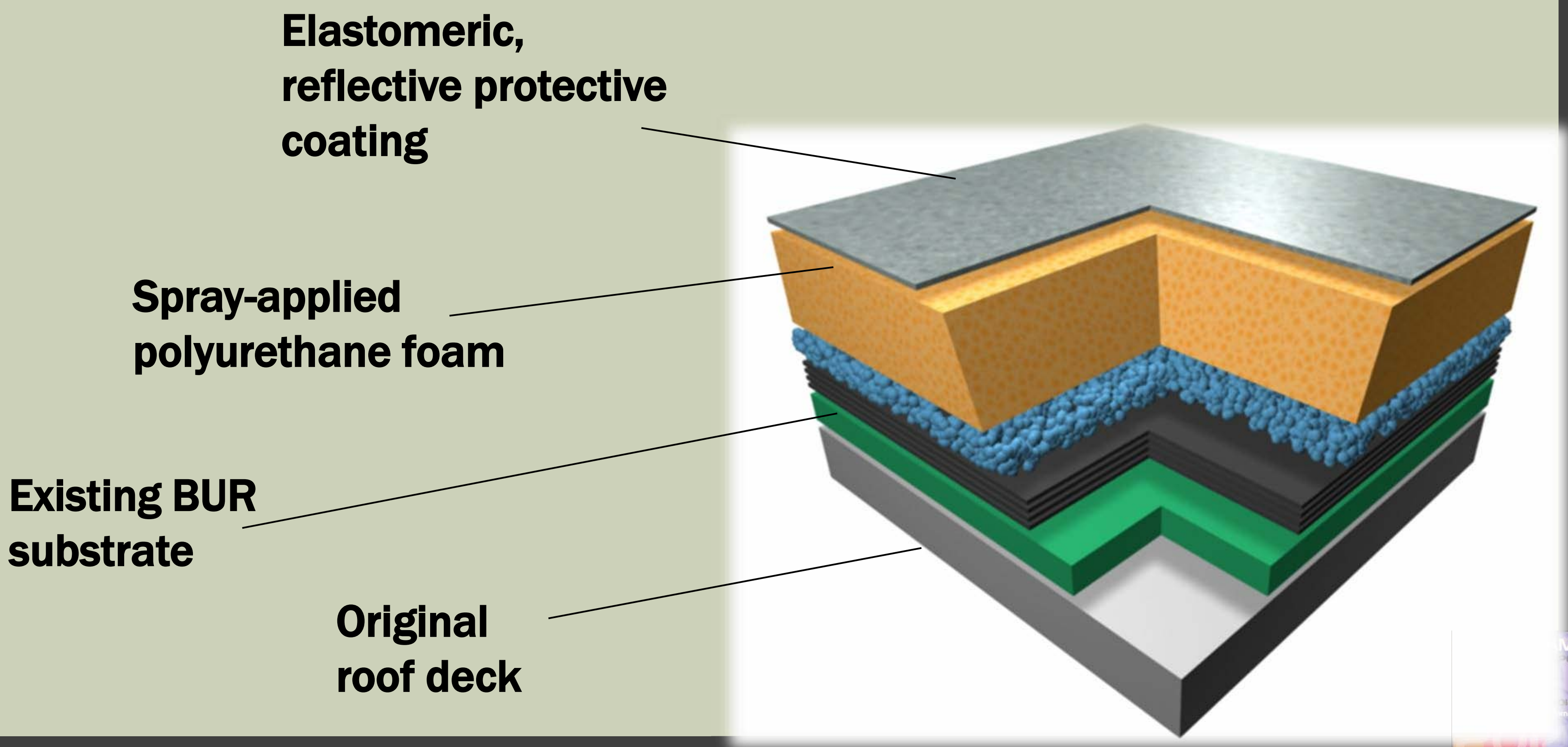
# SPF ROOFING FROM THE BEGINNING

- In the 21st century, some SPF roofs, recoated, are still performing very well at 35 to 40 years of age. SPF roofing has now been installed in the U.S. for over 45 years compared with 11 years for TPO and 28 years for EPDM membrane roofing. Another blowing agent change to HFC 245fa so that the ozone layer would not be diminished. Other legislative challenges are presenting themselves as we move forward and aesthetics remain a challenge as well.


# WHY SPF SYSTEMS FOR YOUR ROOF

- Seamless
- Self Flashing
- Durable
- Energy Efficient
- Sustainable
- Proven Performance
- Stands up to the elements
- Lightweight

# Coated Polyurethane Foam Roofing System



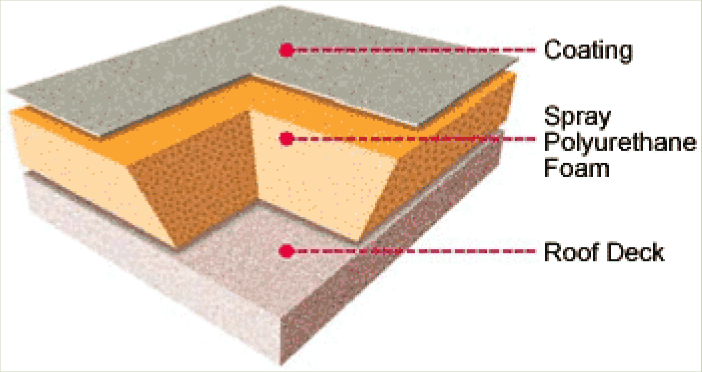
# SEAMLESS

# SELF FLASHING

# SELF FLASHING

# DURABLE

- Superior hail and impact resistance
- No fasteners
- Highest wind uplift resistance
- Seamless and Monolithic



# ENERGY EFFICIENT

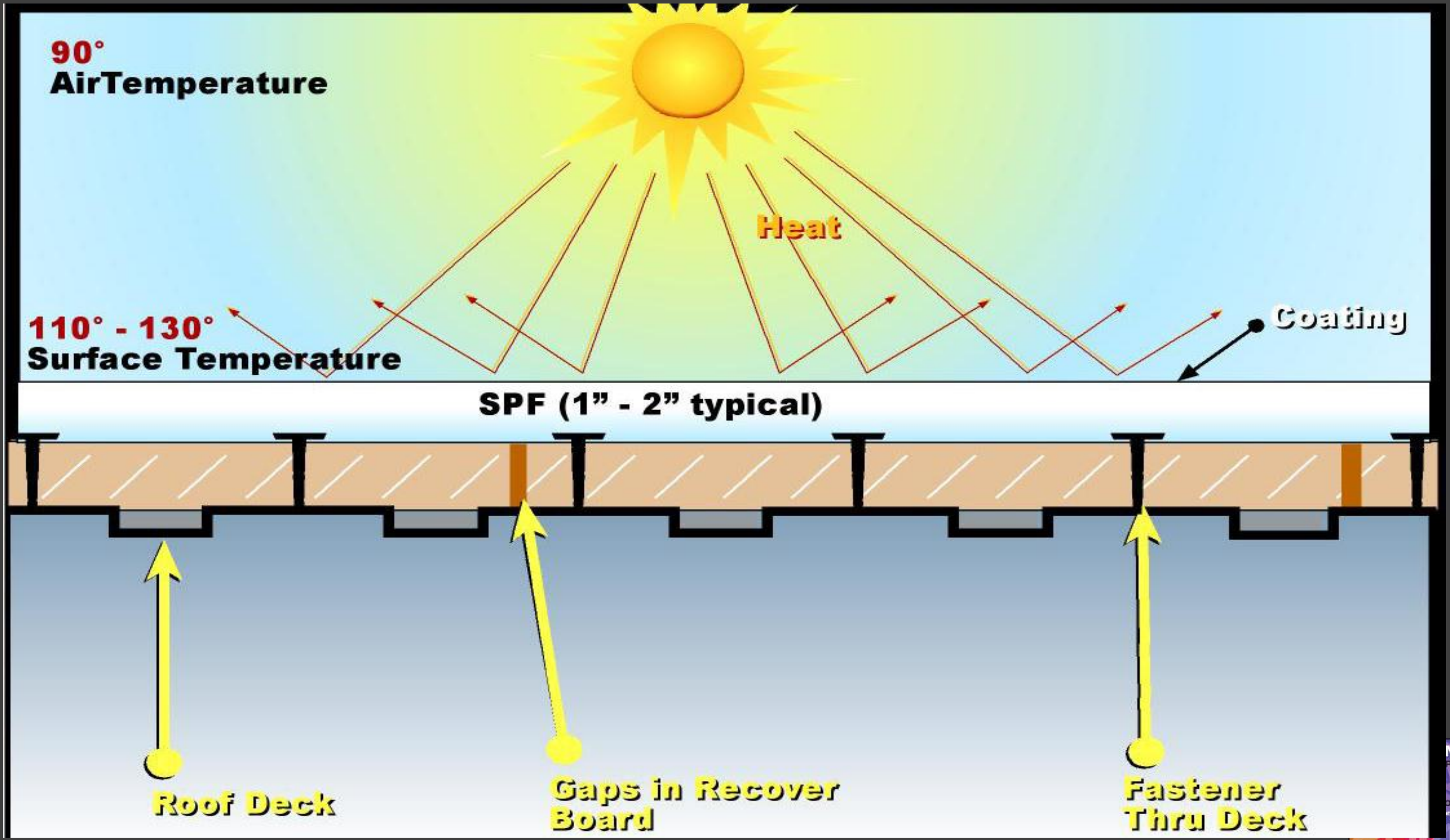
## You are already familiar with it!!

- Wherever you need the most effective insulation:

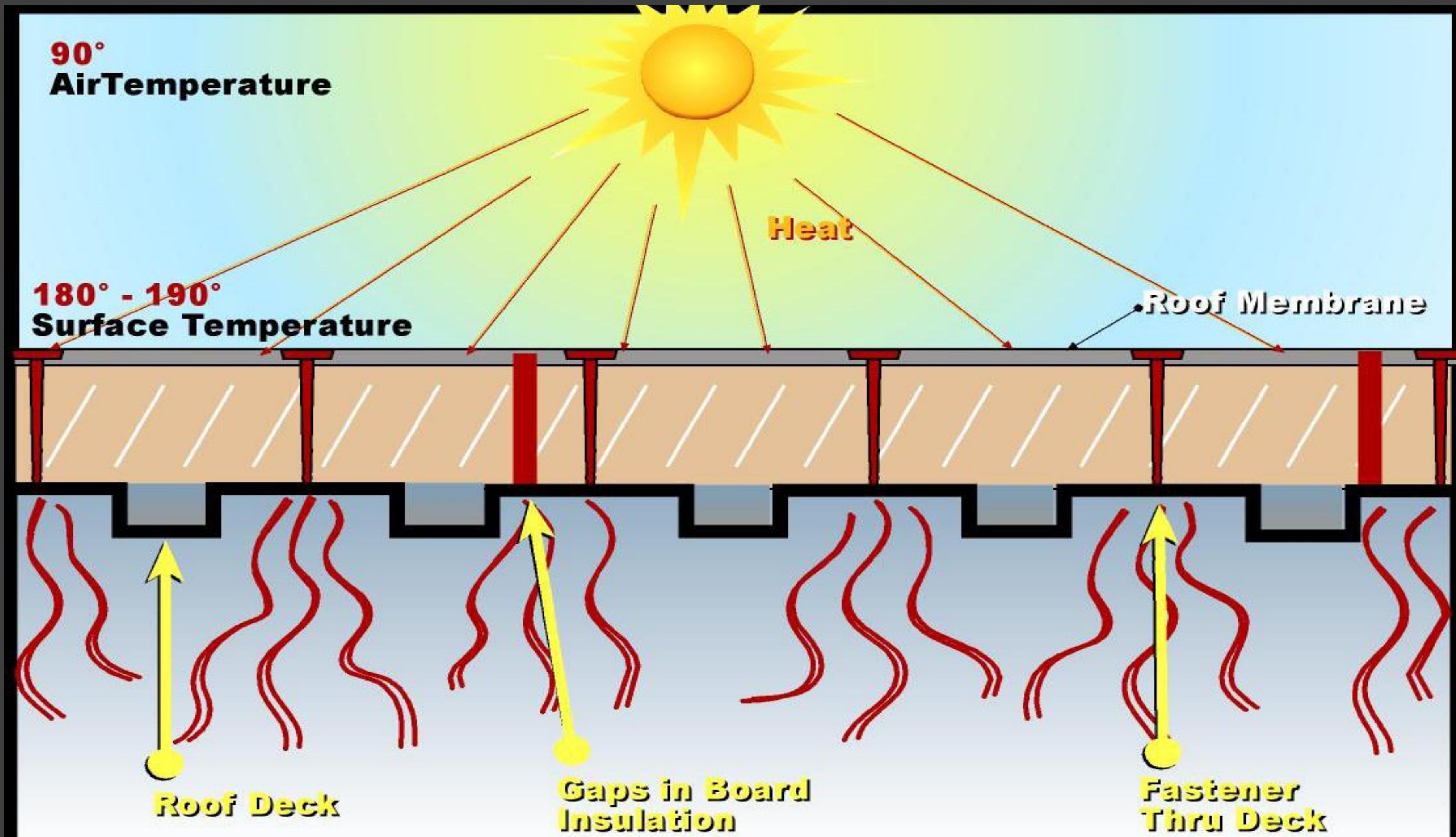
# SPF VS. SINGLE PLY ROOFING

Easy to note the thermal shorts
From the fasteners and the superior
insulation value of the spray foam

# REFLECTIVE SPF ROOF SYSTEM



# CONVENTIONAL ROOF SYSTEM



# SUSTAINABLE

# 600,000+SF IN TEXAS
# 26 YEARS OLD – RECOATED ONCE

# PROVEN PERFORMANCE

- National Roofing Foundation Study
  - 143 randomly chosen SPF roofs
  - Average age 12.3 years
  - Only 3 recorded any leaks
  - None deemed failures
  - Roof granules noted by Dr Dupuis as creating the “most aesthetically pleasing SPF roof

# STANDS UP TO ELEMENTS

- Wind Resistant
- Many Pass FM and UL High Impact Hail Test
- Adaptable to many irregular configurations

# RICOWI COMMENTS:

*"Hurricane Andrew proved the old adage of the weak link. The performance of sprayed polyurethane foam in high-wind conditions showed there was no weak link."*

Charles Brandt Goldsmith, AIA

Chairman, Roofing Industry Committee on Wind Issues

# NRCA COMMENTS:

*"The performance of the spray-applied polyurethane foam roofs that were inspected was found to be outstanding. If the substrate is adequately anchored, these systems appear to offer great wind resistance. They do not exhibit a tendency to progressively fail after being impacted by missiles, and they appear to be quite resistant to water leakage after missile impact."*

Thomas Lee Smith, AIA, CRC
National Roofing Contractor's Assoc.

# Adapts to Even the Most Challenging Roofs

# AESTHETICS AND GOOD WORKMANSHIP ARE IMPORTANT

# INEXPERIENCE CAN CAUSE POOR APPLICATIONS

# INEXPERIENCE CAN CAUSE POOR APPLICATIONS

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# INEXPERIENCE CAN CAUSE POOR APPLICATIONS

# INEXPERIENCE CAN CAUSE POOR APPLICATIONS

# SPRAY POLYURETHANE FOAM FOR ROOFING

Closed Cell SPF

ASTM C 1029 Type III-IV

Density

- 2.7-2.8 lb./cu ft
- 3.0 lb./cu ft

Compressive Strength

>40 psi

# SELECTION OF A POLYURETHANE FOAM

- Selecting the SPF System and the proper reactivity
  - Predicted Ambient Temperature
  - Anticipated Substrate Temperatures
  - Equipment Requirements

- Code  and Specification Requirements

# CODE REQUIREMENTS

- Must pass ASTM E 108 Fire tests

FM APPROVED

UL

# SURFACE BURNING CHARACTERISTICS

- **Flammability** **ASTM E 84**
- Flame Spread index <75
- Smoke Dev. Index Not Required

Code requires foam plastics used in roofing to have less than 75 flame spread index per ASTM E84

# PROTECTING ROOFING SPF

- Why a protective covering?
  - UV degradation
  - Improve resistance to mechanical damage
  - Flammability and/or code ratings

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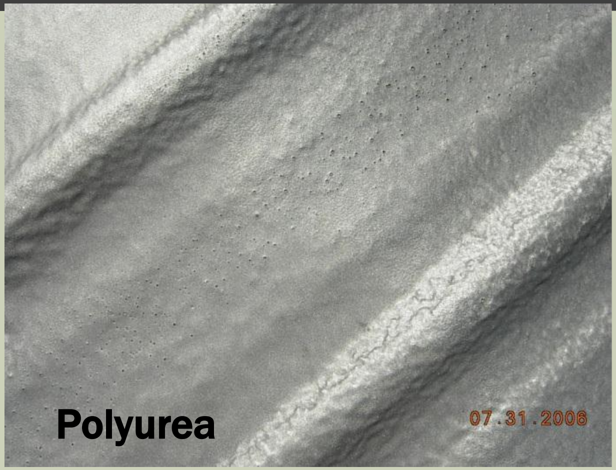
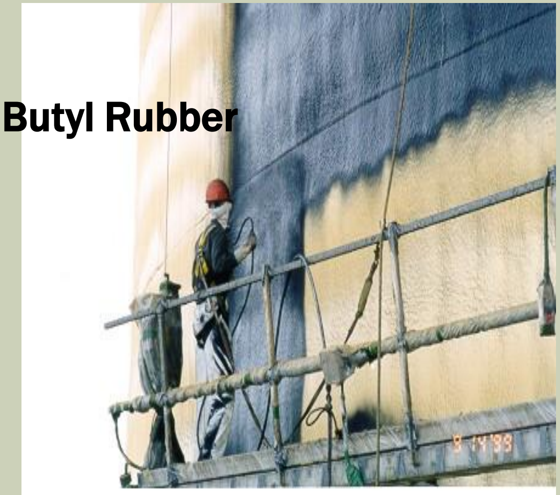
# COATINGS FOR SPF ROOFING

- Acrylic
- Butyl Rubber
- Silicone
- Polyurethane
- Polyurea









# SELECTION OF ELASTOMERIC COATINGS

- SPF's closed cell structure is water resistant
- Must be protected with a covering to prevent surface degradation caused by UV exposure
  - Deteriorate due by UV approx. 1/8"/year
- Elastomeric coatings correctly specified and applied will protect polyurethane foam from surface degradation.

# SELECTION OF ELASTOMERIC COATINGS

- **Influencing Factors:**
  - Flammability and Code Requirements
  - Aesthetic Considerations
  - Expected Longevity
  - Life Cycle Cost
  - More Mils = Longer Life
  - Slope or Not

# SELECTION OF ELASTOMERIC COATINGS

- **Influencing Factors:**
  - Purpose of Building- Cold Storage, Office, etc.
    - Vapor Drive
  - Roof Top Activity- Impact of mechanical damage
  - Environment- chemical resistance
    - Caustic mfg. environment
    - Coastline
    - Airports
  - Geographic Location and Time of Year
    - Weather
    - Temperature
    - Humidity

# PRIMERS

Primers are used to:

- Enhance adhesion between a substrate and SPF or coating.
- Enhance adhesion between layers of SPF or coating.
- Bind small amounts of dirt or seal the substrate.
- Help seal porous substrates.
- Darken a substrate to increase solar gain to increase the performance of the SPF.
- Inhibit corrosion of metal substrates.
- Darken substrates to reduce small amounts of residual moisture.
- Darken substrates to allow application in less than optimum ambient temperatures.
- make his/her job easier and more accurate.
- AY-143 Primers: Why, When and How to Use Them

# EQUIPMENT FOR SPF ROOFING

# SURFACE PREP TOOLS

# SPRAY FOAM EQUIPMENT


# SPRAY FOAM EQUIPMENT FOR ROOFING APPLICATIONS

- Larger output – 30-40 Lbs. per minute
- Larger capacity material heaters
- Longer hose – 310- 410 ft.
- ½” diameter heated hose
- Power supply

# SPRAY GUNS

- Most SPF roofing applicators use a larger volume output chamber in their plural component spray gun.


# COATING EQUIPMENT

# COATING EQUIPMENT

3000-7500 psi fluid pressure
Gun rated for pressure
Tip Extension
.031 - .042 tip size
300-400 ft or ½” to 3/4” Hose rated for pressure
Moisture locked
Feed pump

# GRANULE APPLICATION

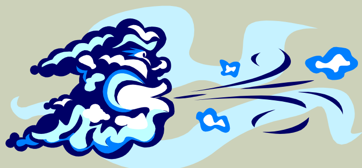
- Commercial Grit blasting pot hose and tip are usually the equipment required for roofing granule application.

# SAFETY AND FALL PROTECTION

- Fall protection systems are required for most roofing applications.
- Air purifying respirators are required.
- Company Safety plan

# CONTROL OF THE ENVIRONMENT

- Wind
- Overspray
- Precipitation
- Pollen and Debris



# SPF ROOFING APPLICATION

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# The Details are Important

# INSPECTION AND PREPARATION

Prior to making a bid or proposal

- Inspect the roof deck, existing roof system and flashings.
  - **Clean**
  - Dry
  - Sound and Secure

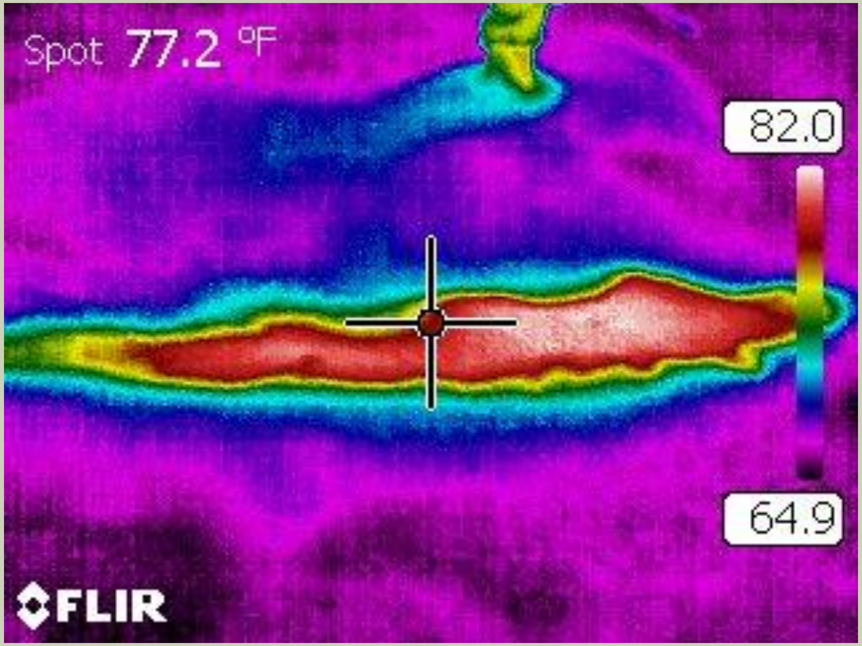
# RETROFIT OR RECOVER ROOFING

- Inspect or test for moisture
  - Wet materials and insulation must be removed
- Inspect for adhesion between membrane, insulation and deck

# CLEAN AND DRY SURFACE

# CHECK FOR POOR DRAINAGE

# Moisture Survey





Roofs should be evaluated by sampling, infrared moisture survey and visual inspection to ensure your substrate is “dry”

# If the roofing system is wet removal or tear off is required

# METAL DECKS

- **Direct Application**
  - Fill the flutes
  - Cover with adhesive mesh
- **COVERING**
  - Underlayment Boards
    - Urethane board stock (faced) Poly-iso
    - Fiberboard
    - GP Densdeck
    - US Gypsum Securock




# WOOD SUBSTRATES

- **Tongue & Groove, Planking**
  - Due to the frequency of joints, varying openings and effects of expansion/contraction
  - Must be overlaid with a minimum of ¼" thick sheeting
- **Joints in excess of ¼" must be sealed**
  - Caulking compatible with SPF (before priming)

# CONCRETE SUBSTRATES

- Surface free of laitance and release agents
- Remove loose dirt, dust and debris
- Prime per Manufacturers' Recommendations

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# CONCRETE SUBSTRATES

- Do <u>NOT</u> apply SPF < 28 day cure period or until Concrete has met design strength
- Cracks and joints over ¼” grouted or caulked
- Lightweight insulating concrete <u>cannot</u> be sprayed onto

# BUILT-UP ROOFING (BUR)

- Remove loose gravel, dust by way of:
  - Power Vac
  - Power Sweeper
  - Air Blow
  - Hand Blow
  - Wet Vac

# SPF Application over Smooth BUR

# SPF/SILICONE COATING OVER BUR

# METAL ROOFS

- Joints correctly lapped, sealed and fastened.
- Clean using air jet, power wash, vacuum equipment.
- Grease or oil removed with proper cleaning solutions or steam cleaning.
- Priming may be required as dictated by the substrate




# SPF APPLICATION OVER SINGLE-PLY SYSTEM

# CORRUGATED METAL ROOF WITH SPF AND ACRYLIC COATING

# CORRUGATED METAL ROOF WITH SPF AND SILICONE COATING

# PRIMERS

Scarified SPF must always be primed

Aged, degraded or "rusted" SPF should be primed

# PRIMER APPLICATION

- Since primers are usually lower in viscosity they can be sprayed through most smaller airless spray equipment with tip sizes from 0.15-0.21.
- The can also be roller or brush applied

# SPRAY POLYURETHANE FOAM APPLICATION

# APPLICATION CONDITIONS

- Many of the parameters for insulation and roofing application of SPF are similar.
  - Substrate must be dry, clean and well adhered.
  - Environmental conditions must be suitable.
  - Other trades must be done with their work and out of the area.

# Ventilation and Air Intakes Must be Closed

# WIND CONDITIONS

Use wind screen when wind is above 15 mph or in sensitive areas

# Wind Screens

# WIND CONDITIONS

- Protect items not movable
- Move items movable

# APPLICATION

- ¼" Slope required

- The Definition of Ponding:
  - 100 sq. Ft. or more
  - ½" or more of water
  - 24 hours after rain

- Eliminate or minimize ponding with correct placement or slope towards drains or scuppers

# APPLICATION GUIDELINES

- Minimum pass thickness of ½”.
- Total thickness of SPF should be a minimum of 1”
  (or more if specified)
- Apply uniformly plus ¼”
  per inch, minus 0”
- Maximum pass of 1.5”

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# APPLICATION GUIDELINES

- The SPF must be applied in a minimum pass thickness of ½”.

# APPLICATION GUIDELINES

- The FULL specified thickness of SPF should be applied in any area the same day.
- SPF surface should be allowed to cure before applying the selected coating.

# APPLICATION GUIDELINES

- If more than 24 hours elapse before the coating is applied, the SPF must be inspected for:
  - UV degradation
  - moisture contamination
- Primer option

# Robotics

Robotic application Can yield very Consistent results

# SMOOTH SURFACE - "IDEAL"

**Acceptable**

# ORANGE PEEL - "FINE TEXTURE" (EXTERIOR SKIN OF AN ORANGE)

**Acceptable**

# COURSE ORANGE PEEL - " NODULES ARE LARGER THAN VALLEYS, VALLEYS RELATIVELY CURVED"

Acceptable

# POPCORN - "COURSE TEXTURE, VALLEYS FORM SHARP ANGLES"

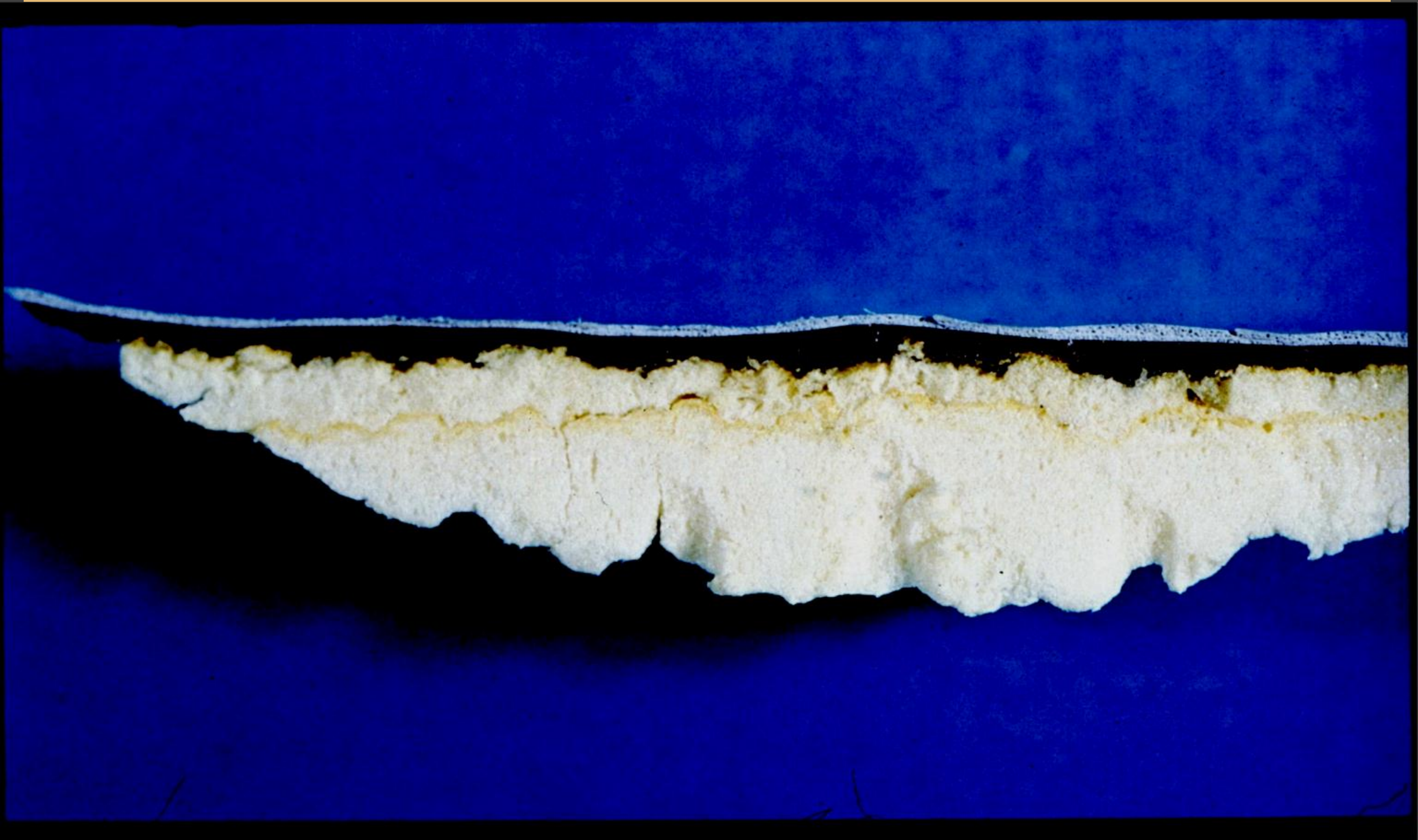
**Unacceptable**

# TREE BARK - "COARSE TEXTURE, VALLEYS FORM SHARP ANGLES"

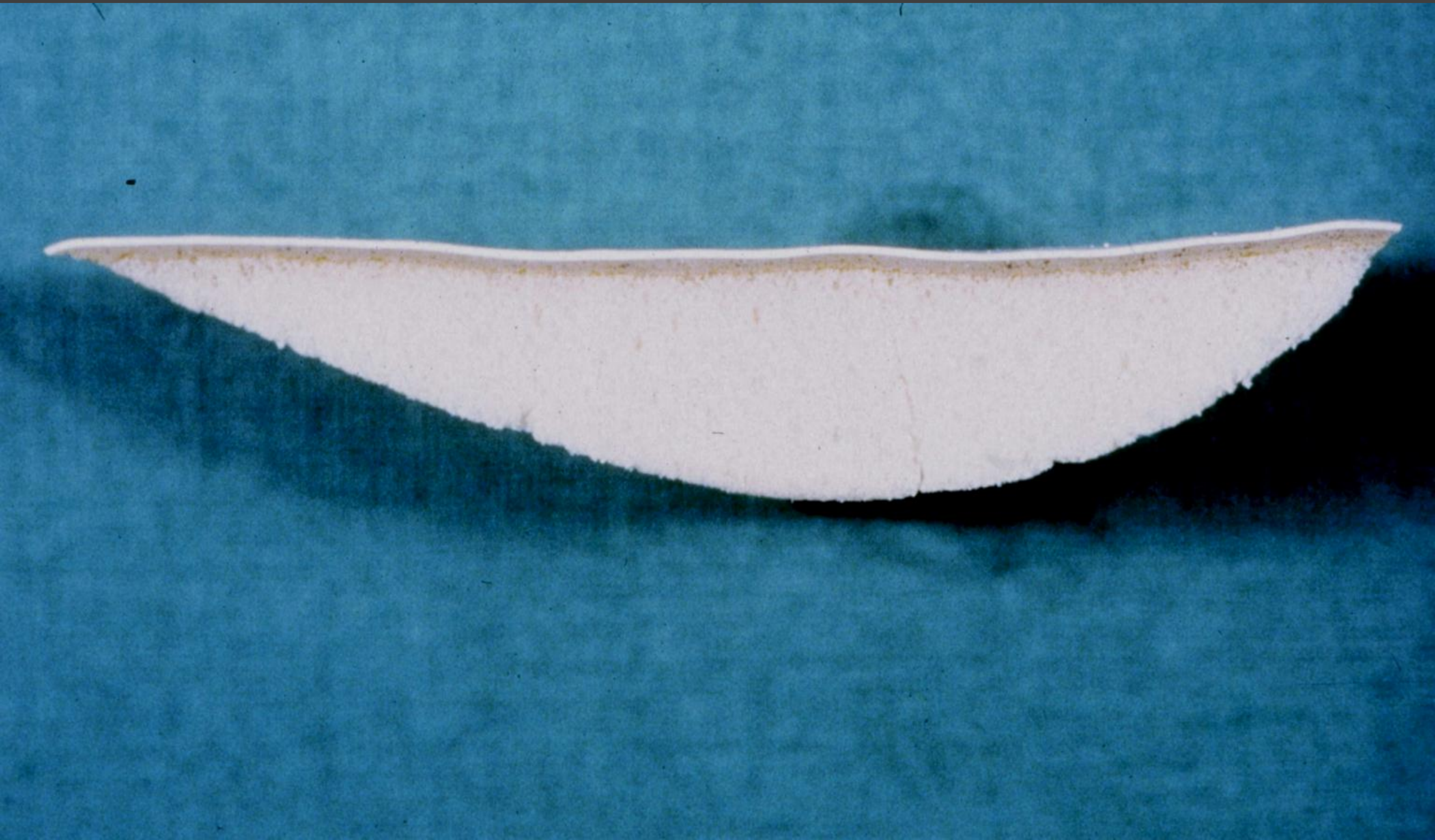
Unacceptable

# SURFACE TEXTURE

# Slit Sample with SPF rough Surface Texture



# Slit Sample with SPF smooth Surface Texture



# PRE-COATING APPLICATION GUIDELINES

- Inspect the SPF surface and correct all:
  - voids
  - pinholes
  - rough foam
  - blisters
- Small areas can be caulked.

# ACRYLIC COATINGS

- Organic coating based on acrylic polymers
- Water-borne
- Cure by coalesance
- Breathable- not a vapor barrier
- Apply over 50°F or higher
- Keep from freezing
- UV resistant
- Single component

# ACRYLIC COATINGS

- White and light grey are the most common colors.  Can be tinted to match any color
- Good color retention
- Do not use under standing water or cold storage/freezer applications without a vapor barrier
- Do not apply when rain is imminent

# SILICONE COATINGS

- Inorganic coatings derived from silicone polymers
- Solvent based
- Excellent weatherability and UV resistance
- Breathable, not a vapor barrier
- Single component

# URETHANE COATINGS

- Organic coatings based on an isocyanate and polyol reaction
- Single and plural component
- Different speeds of reactivity
- Two types:
  - **Aromatic**- moderate to high tensile strength and elongation, usually used as a base coat

# URETHANE COATINGS

- **Aliphatic-** similar properties as aromatic coatings, generally not as high solids content.
  - Excellent UV resistance
  - Usually used as a top coat.
- Breathers as well as vapor retardant

# URETHANE COATING TYPES

## Polyurethane Coatings

**Single Components**

- Moisture cured
- Breathable (vapor retarder types available)
- Medium to high solids
- Aromatic and aliphatic
- Vapor retarder or breathable

**Plural Components**

- Reaction of polyol and iso cure
- Mix “A” and “B”
- Curing - standard to fast
- Require care in mixing
- High tensile strength
- Resist mechanical damage
- Aromatic or aliphatic

# BUTYL RUBBER COATINGS

- Derived from polymerization of isobutylene
- Best vapor retarder of all coatings
- Recommended for high vapor drive applications such as cold storage
- Poor UV stability, must be top coated
- Most are two component

# COATING APPLICATION

# PROTECTIVE COATINGS/COVERINGS

- Application:
  - Even application technique
  - Extra coating at rough surface, pass lines, cants, etc.
  - Ground SPF must receive extra coating
  - Terminate past SPF
  - Back roll where necessary

# MINIMUM DRY FILM THICKNESS

- Spray foam is not a glass like finish.
- Spray foam is textured with peaks and valleys
- Foam texture influences the amount of coating required to meet specified mil thickness.

# APPLIED ELASTOMERIC COATING COVERAGE REQUIREMENTS

- Factors that effect dry film thickness (DFT):
  - Foam surface texture
  - Wind over spray loss
  - Container residue
  - Equipment characteristics/maintenance

# COATING APPLICATION TECHNIQUES

- Rolling -use if over spray is a problem or wind conditions prevail.
- Brushing- use when trimming out parapets, HVAC units, Stacks, etc.

# APPLICATION CONSIDERATIONS ACRYLIC

- Application conditions
- Sloped roof only………breathable coating
  - Above 50°F with no inclement weather imminent
    - *Caution…*Freezing is possible
    - *Caution…exudation* – water can cool substrate temperatures of liquid coating causing condensation which may result in the secretion of substances from the uncured membrane when materials lack adequate time to cure before falling temperatures, in high humidity or due to lack of direct sunlight to the roof in moderate temperatures.
    - Mud Cracking – Applied at too thick a pass

# APPLICATION CONSIDERATIONS
# TWO COMPONENT URETHANES

- Application conditions
  - Above 50°F with no inclement weather imminent
    - *Caution…*Surface moisture can cause un-reacted B component, resulting in a off-ratio coating

# APPLICATION CONSIDERATIONS
## SILICONES AND SINGLE COMPONENT URETHANES

- Application conditions
  - Above 40°F with no inclement weather imminent
  - Silicone and single component urethanes are *moisture cure*
  - Moisture cure materials draw moisture out of the atmosphere to create a chemical reaction. Areas of low humidity will extend the time needed for cure or an require the addition of a catalyst to assist the chemical reaction

# GRANULE APPLICATION

- Usually applied with high volume low pressure sandblast equipment.
- Typical application is 30-50 lbs../100 sq. Ft.
- Can be used as walkways.

# GRANULE APPLICATION ADDED FOR:

- Fire ratings
- Aesthetics
- Durability
- Traffic walkways

# JOB SITE QUALITY CONTROL

- Check your coating application equipment frequently

- Be sure material is stored properly

- Use thinners only as recommended

# JOB SITE QUALITY CONTROL

- If a problem occurs stop immediately, check equipment or material for defects or improper techniques.
- Retain batch numbers and areas where applied in case of problems

# DETAILS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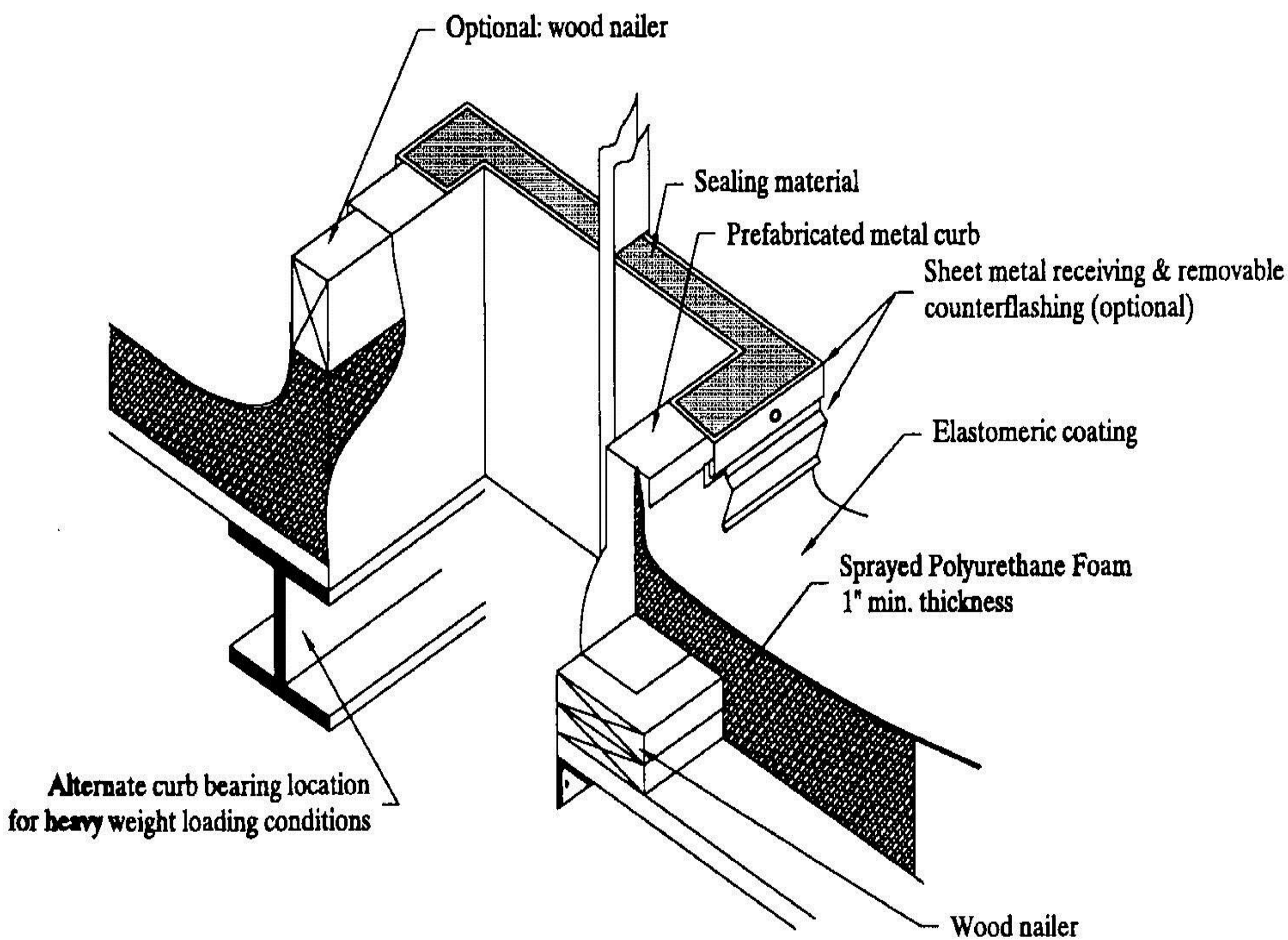
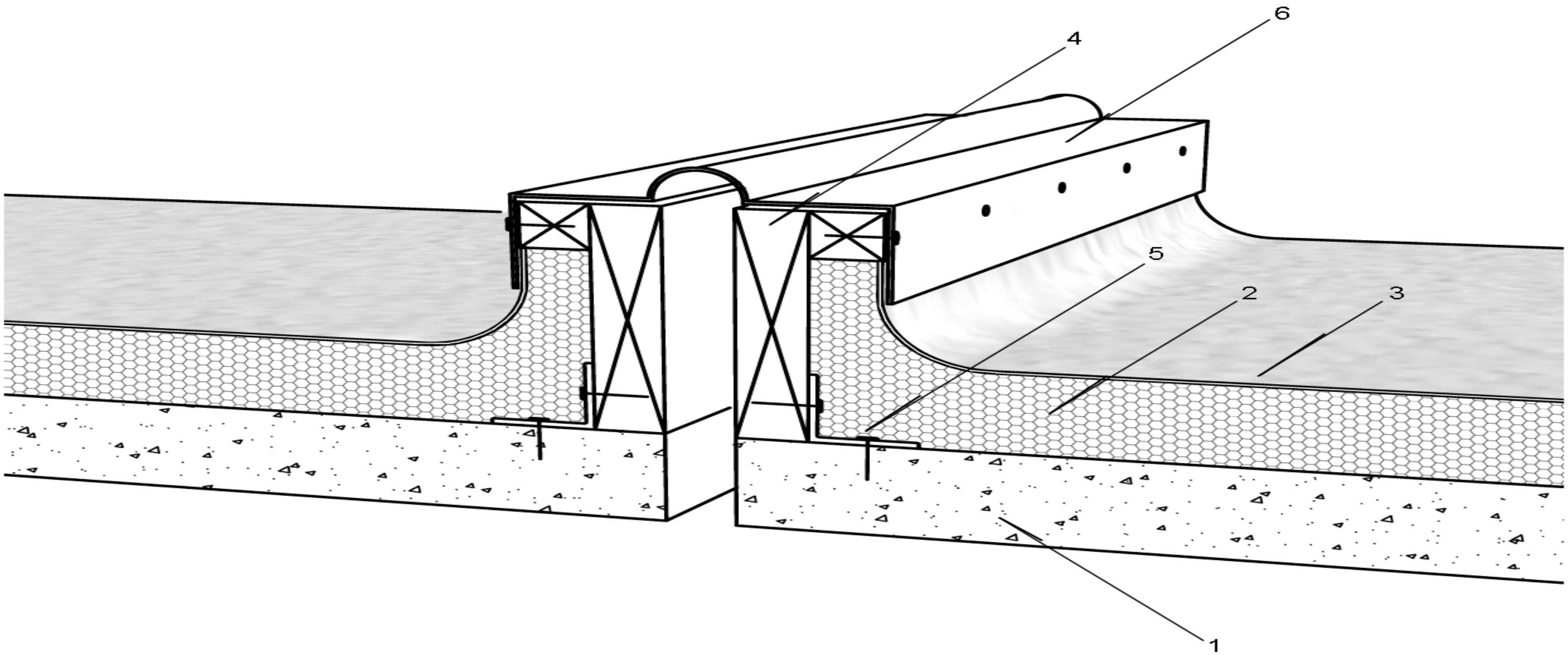
# RAISED CURB DETIAL FOR ROOFTOP AIR HANDLING UNITS & DUCTS (PREFABRICATED METAL CURB)



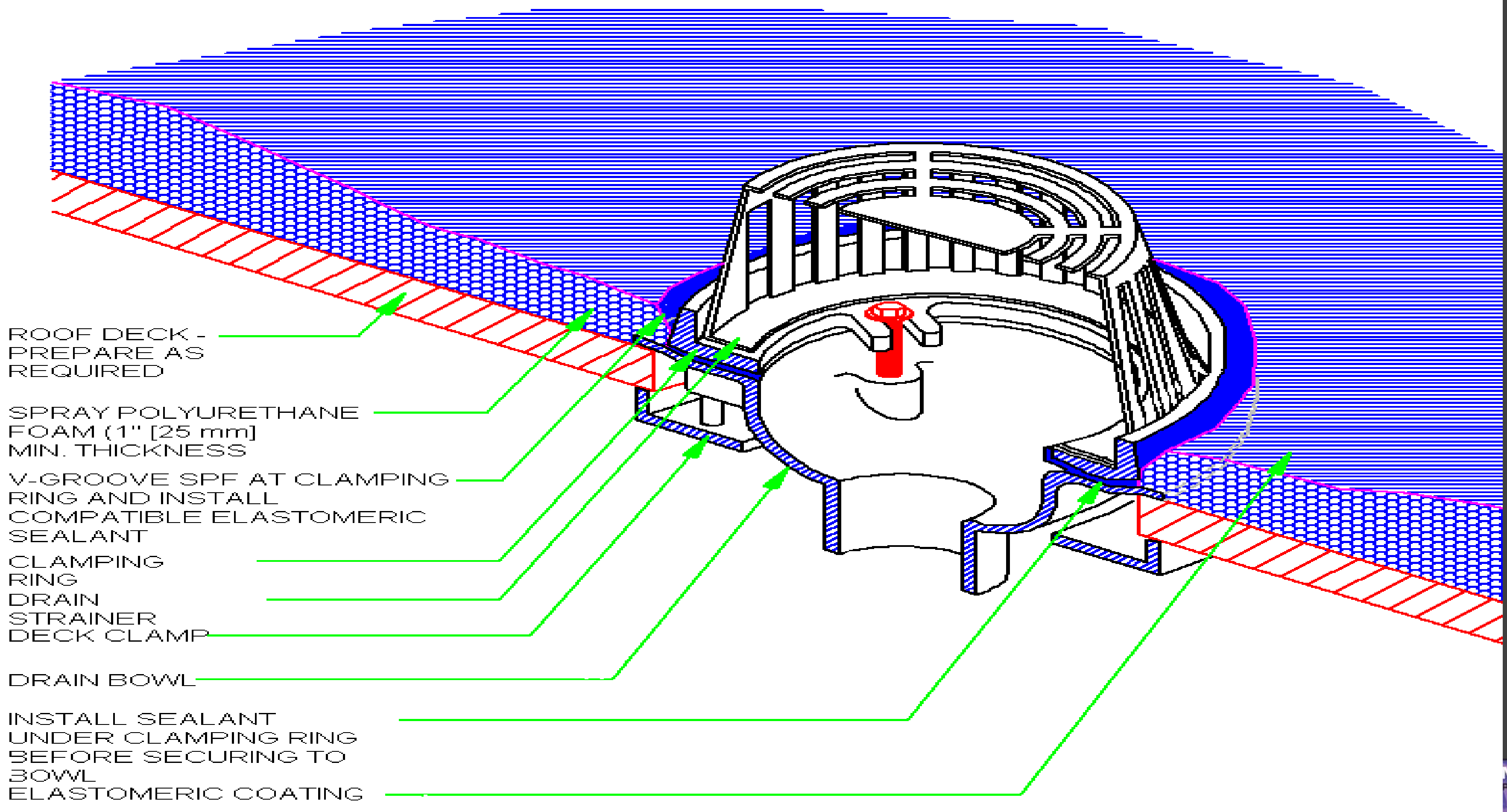

NOV 10 2006

# 12. BUILDING EXPANSION JOINT



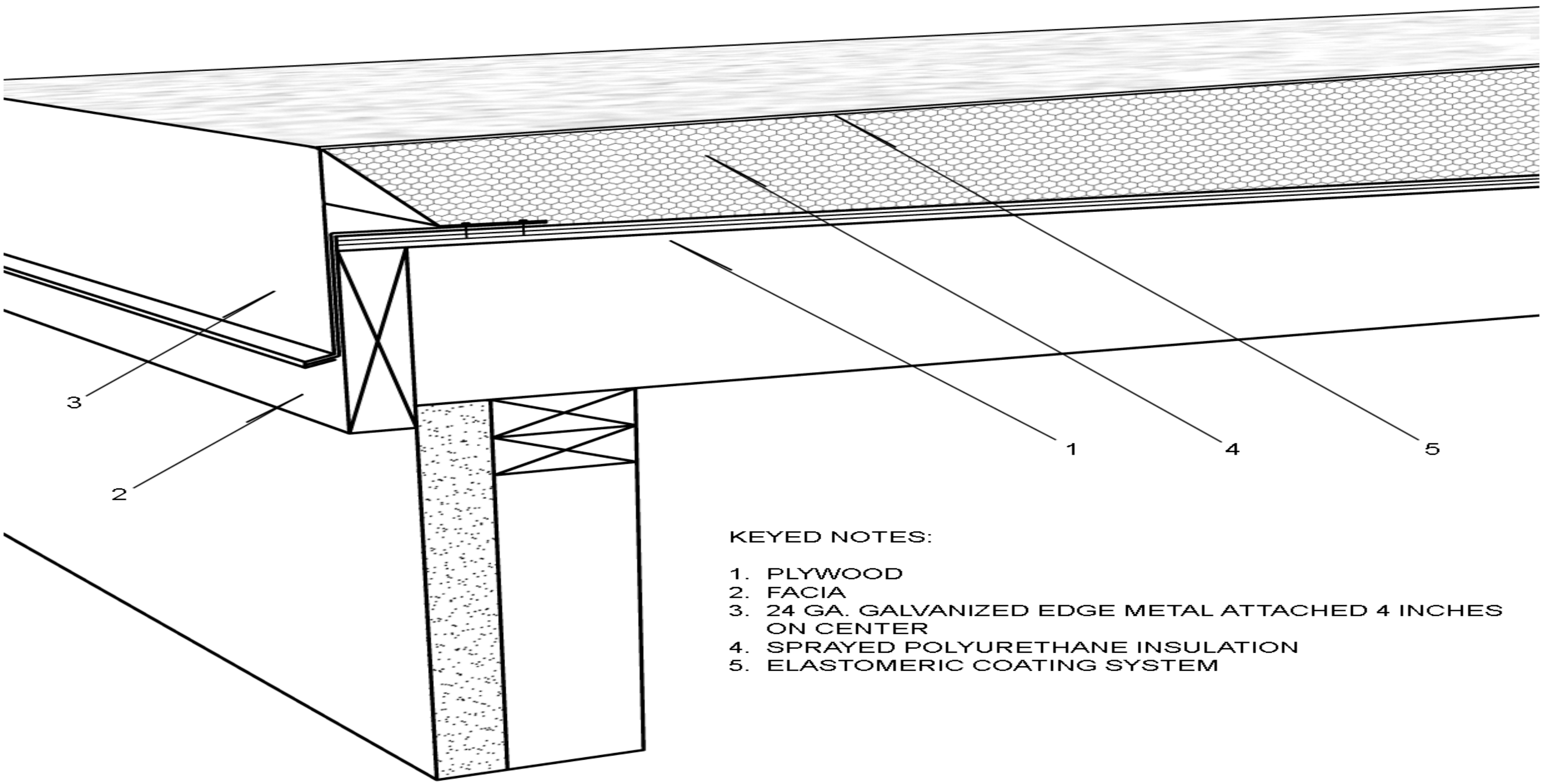

KEYED NOTES:

1. SUBSTRATE
2. SPRAYED POLYURETHANE INSULATION
3. ELASTOMERIC COATING SYSTEM
4. MINIMUM 2" X 10" CURB
5. ANGLE BRACKET SECURES CURB TO SUBSTRATE WITH MECHANICAL FASTENERS
6. RUBBER EXPANSION JOINT COVER


ROOF DECK - PREPARE AS REQUIRED
SPRAY POLYURETHANE FOAM (1" [25 mm] MIN. THICKNESS
V-GROOVE SPF AT CLAMPING RING AND INSTALL COMPATIBLE ELASTOMERIC SEALANT
CLAMPING RING
DRAIN STRAINER
DECK CLAMP
DRAIN BOWL
INSTALL SEALANT UNDER CLAMPING RING BEFORE SECURING TO BOWL
ELASTOMERIC COATING




# 16. STANDARD PERIMETER EDGE METAL FLASHING




KEYED NOTES:

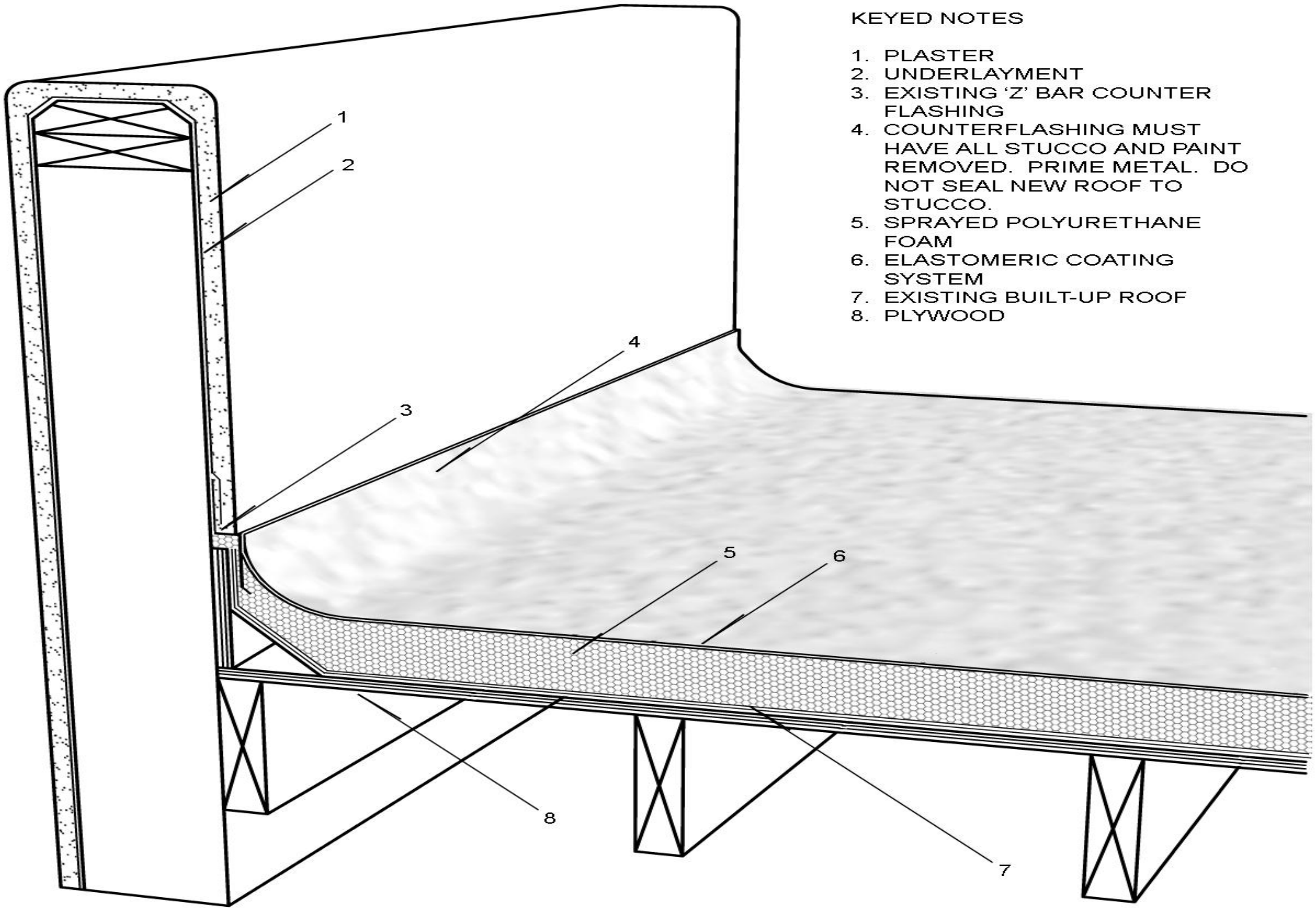
1. PLYWOOD
2. FACIA
3. 24 GA. GALVANIZED EDGE METAL ATTACHED 4 INCHES ON CENTER
4. SPRAYED POLYURETHANE INSULATION
5. ELASTOMERIC COATING SYSTEM





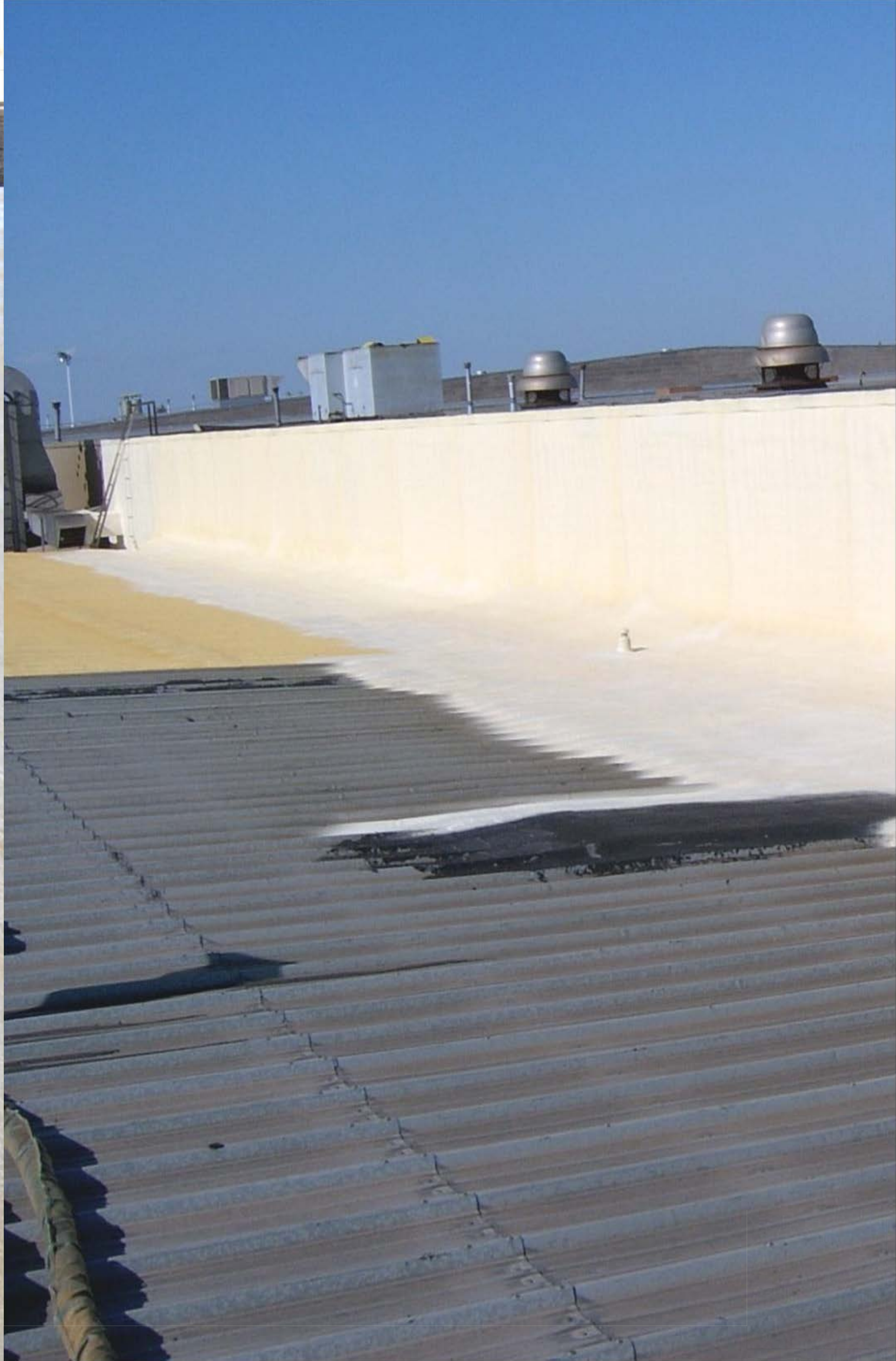
Holiday Inn
www.hiexpress.com

# 30. EXISTING STUCCO PARAPET W/ 'Z' BAR COUNTERFLASHING

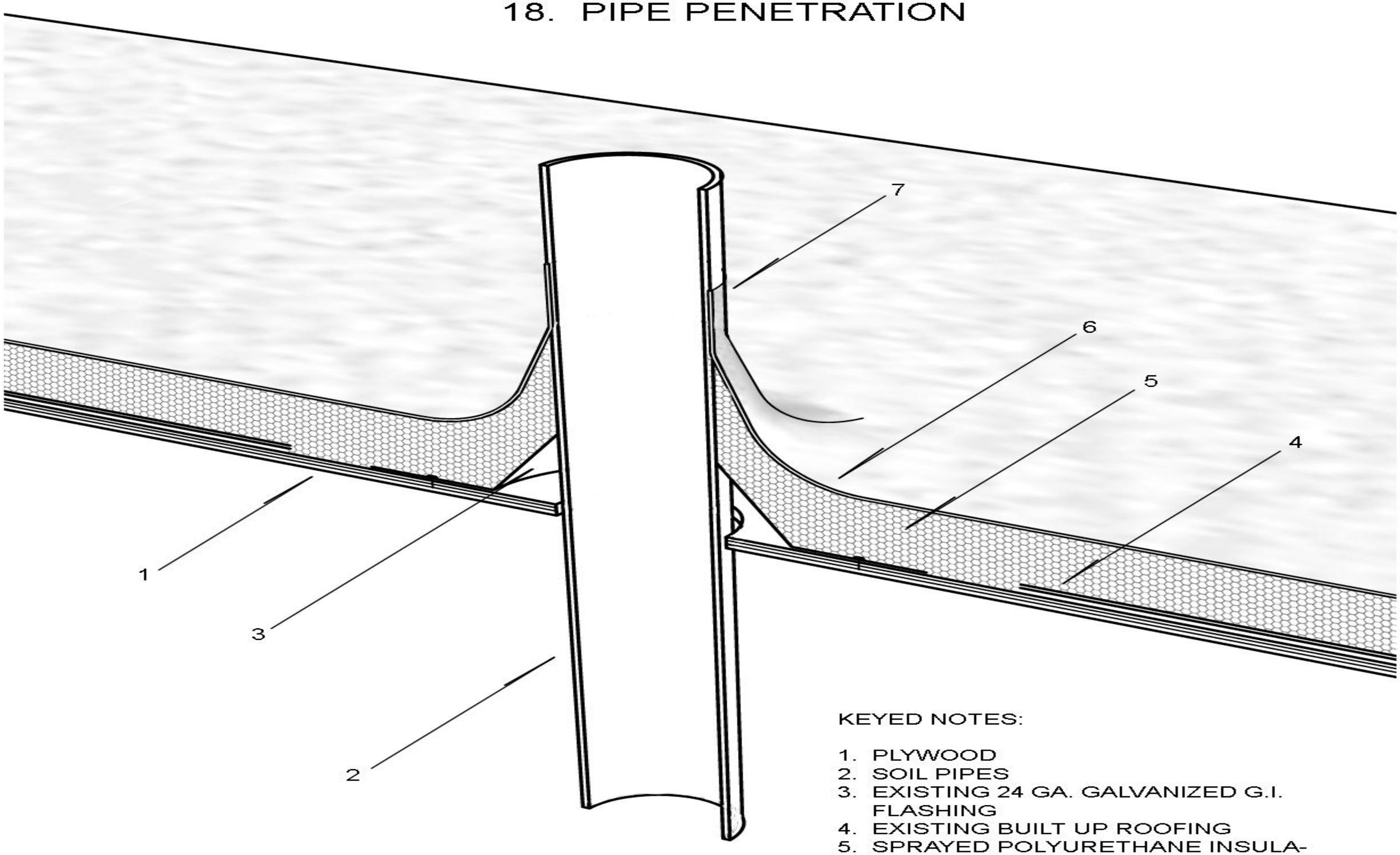



KEYED NOTES

1. PLASTER
2. UNDERLAYMENT
3. EXISTING 'Z' BAR COUNTER FLASHING
4. COUNTERFLASHING MUST HAVE ALL STUCCO AND PAINT REMOVED. PRIME METAL. DO NOT SEAL NEW ROOF TO STUCCO.
5. SPRAYED POLYURETHANE FOAM
6. ELASTOMERIC COATING SYSTEM
7. EXISTING BUILT-UP ROOF
8. PLYWOOD

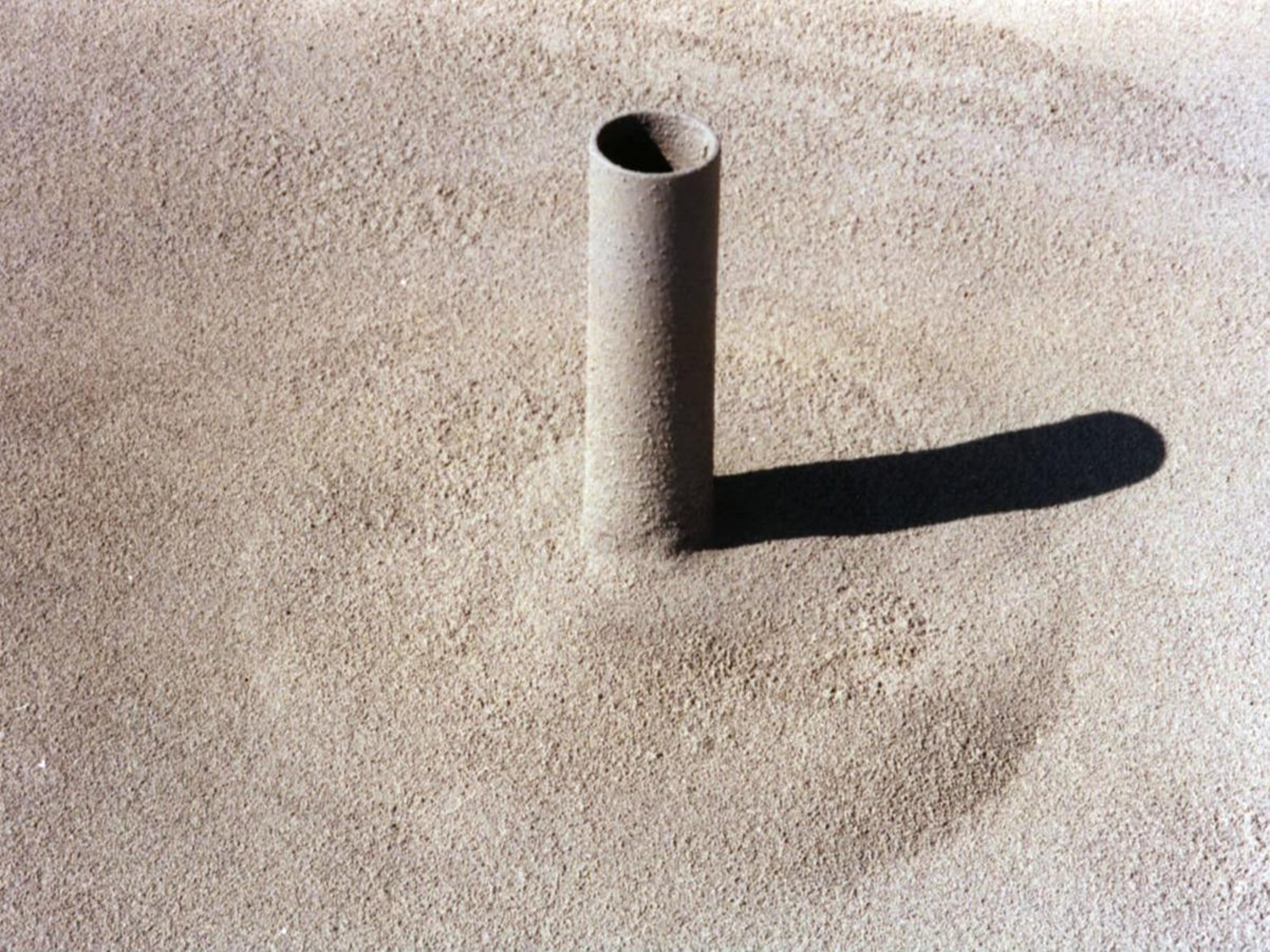



# 18. PIPE PENETRATION




KEYED NOTES:

1. PLYWOOD
2. SOIL PIPES
3. EXISTING 24 GA. GALVANIZED G.I. FLASHING
4. EXISTING BUILT UP ROOFING
5. SPRAYED POLYURETHANE INSULATION
6. ELASTOMERIC COATING SYSTEM
7. PROTECTIVE COATING TO EXTEND A MINIMUN 2 INCHES BEYOND INSULATION TERMINATION




Sharpie
Permanent Marker

# ROOF MOUNTED EQUIPMENT DETAILS

# EVALUATE ESTIMATE PROPOSAL PROJECT

# DURING THE ESTIMATE

## Design Considerations

- SPFA Documents Available:
  - AY 104  New and Remedial Roofing
  - AY 102  Guide for Protective Coatings
  - AY 110  Guide for Aggregate Systems

  ASTM Standards available as well from ASTM

# DURING THE ESTIMATE

## Design Considerations

- Substrate and SPF Thickness
  - Minimum 1-inch thickness on any substrate including foam stop flashings, walls, drains, etc.
  - Minimum 1.5-inches on gravel and metal decks
  - Consult with Manufacturers and Specifier

# DURING THE ESTIMATE

## Design Considerations

- Coatings / Coverings application
  - Acrylic, Silicone, Urethane, Polyurea, butyl and rock
  - Elongation, tensile strength, permeability, and weathering
  - Cure Time; solvent based, water based, 100% solids
  - Performance history in local area, and immediate environment on the roof

# DURING THE ESTIMATE

- If there is Roof Traffic
  - Higher density SPF
  - Choice of coatings
  - Walkways
  - Platforms

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# DURING THE ESTIMATE

Design Considerations

- Building Use:
  - Insulation requirements
  - Interior operations and schedules
  - Vapor Drive: cold storage, swimming pools, etc.
  - Ventilation (i.e. clean rooms)

# DURING THE ESTIMATE

**Design Considerations**

- **Drainage:**
  - **Fill low areas**
  - **Create slope to drain**

# DURING THE ESTIMATE
# COST ANALYSIS

- **Key Estimating Tips** - At the Job Walk

  - Logistics: set ups, parking lots, access
  - Interior or exterior usage to affect production
  - Local weather: time of year, wind conditions, temperature at night, amount of shaded area on roof
  - Amount of roof mounted equipment
  - Core sample to determine roof layers

# DURING THE ESTIMATE COST ANALYSIS

- **Key Estimating Tips** - On the estimate document

  - Knowledge of materials

  - Scheduling: seasonal, weekends

  - Codes and regulations: tear off, fire ratings, etc.

  - Allow slack in materials and labor

  - Do not use unit pricing, price all materials and apply labor to each task

# Jobsite Storage Considerations

# SPRAY POLYURETHANE FOAM ROOF WARRANTIES

Contractor vs. Manufacturer Warranties

# Roof Warranties

This aspect is a bit different in roofing projects versus insulation projects.

Most owners or specifier are going to want a 5, 10, 15, 20 maybe 50 year warranty.

The roofing market is such that either the contractor or the system manufacturer is asked for a limited warranty on the completed roof system.

Payment may be withheld until the warranty is delivered.

# Roof Warranties

- NDL and Non-prorated.
- Limited Warranties and your responsibilities
- Inspections by third parties
- Labor and Material Warranties
- Product Only Warranties
- Maintenance Agreements
- No Leak Warranties

# SPFA TECHNICAL DOCUMENTS

- AY-102 A Guide for Selection of Elastomeric Protective Coatings Over Sprayed Polyurethane Foam
  A 19 page guideline covering the generic types of elastomeric coatings, the why and how to achieve the best performance for the life of a warranty.
- AY-104 Spray Polyurethane Foam Systems for New and Remedial Roofing
  There are 26 Illustrated design details included in this 46-page document, which is the most important guideline for the SPF roofing contractor or his/her applicator.
- AY-107 Spray Polyurethane Foam Blisters
  What causes blisters? How can blisters be prevented? Different types of blisters are discussed and repair procedures are spelled out in this 6-page document.
- AY-110 Spray Polyurethane Foam Aggregate Systems for New and Remedial Roofing
  This is an 18-page document that details considerations dealing with SPF aggregate systems and new and remedial roofing.
- AY-122 The Renewal of Spray Polyurethane Foam and Coating Roof Systems
  A 16-page document covering roof preparation, procedures and considerations including maintenance procedures.
- AY-124 Wind Uplift
  A four color, four-page brochure with photos showing the staying power of SPF during hurricanes Andrew and Hugo and a tornado in Plainfield, Illinois. An excellent handout and advertising sales tool.
- AY-125 P-Rating Brochure
  A color brochure consisting of two pages of an underside roof assembly fire-rated and tested for Building Code compliance by Underwriters Laboratories, Inc.

# SPFA TECHNICAL DOCUMENTS

- AY-127 Maintenance Manual for Spray Polyurethane Foam Roof Systems
  This nine-page manual, with photos, provides the building owner and maintenance personnel with a basic guideline for the maintenance and repair of SPF roof systems. This is the brochure that you leave with the building owner/manager when your project is finalized.
- AY-130 What is Sustainable Low-Slope Roofing?
  When it comes to roofing, SPF is the answer and this colored brochure explains why. Good for the initial sales approach and makes a good mailer.
- AY-137 Spray Polyurethane Equipment Guidelines
  For those entering the SPF business in the selection of application equipment. Listed are the five equipment elements necessary to spray polyurethane foam.
- AY-138 Guideline for Roof Assembly Evaluation for Spray Polyurethane Foam Roof System
  8-pages including roof surface assembly considerations. What is an acceptable substrate surface for SPF application? Criteria for recover, re-roof, and tear-off.
- AY-139 Recommendations for Repair of Spray Polyurethane Foam Roof Systems due to Hail and Wind Driven Damage
  This document provides a means to evaluate information collected from the investigation of an SPF roof system after damage has occurred and to make recommendations for the rehabilitation and/or repair of the damaged areas.
- AY-142 A Guideline for Securing Roofing Components with SPF Adhesives

Colored photos of typical jobs including single and dual component adhesives and how to apply them

- **Thank you**

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

---

| Spray Date | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-13-17 | 42.85 | 42.87 | 99.95 |

---

**Final Settings 09-13-17**

| | Temperature | Pressure | Motor Speed |
|---|---|---|---|
| Setpoint | 106/112 | 900 | 70% |
| ISO | 80 | 957 | 284 RPM |
| RESIN | 79 | 964 | 260 RPM |

---

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

---

| Spray Date | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-14-17 | 30.21 | 30.23 | 99.93 |

---

**Final Settings 09-14-17**

| | Temperature | Pressure | Motor Speed |
|---|---|---|---|
| Setpoint | 106/112 | 900 | 70% |
| ISO | 80 | 962 | 284 RPM |
| RESIN | 79 | 964 | 246 RPM |

---

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

---

| Spray Date | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-15-17 | 17.89 | 17.93 | 99.75 |

---

**Final Settings 09-15-17**

| | Temperature | Pressure | Motor Speed |
|---|---|---|---|
| Setpoint | 106/112 | 900 | 70% |
| ISO | 81 | 954 | 284 RPM |
| RESIN | 80 | 964 | 274 RPM |

---

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

---

| Spray Date | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-18-17 | 11.61 | 11.63 | 99.88 |

---

**Final Settings 09-18-17**

| | Temperature | Pressure | Motor Speed |
|---|---|---|---|
| Setpoint | 106/112 | 900 | 70% |
| ISO | 92 | 952 | 284 RPM |
| RESIN | 88 | 957 | 274 RPM |

---

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

---

| Spray Date | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-19-17 | 2.86 | 2.89 | 98.86 |

---

**Final Settings 09-19-17**

| | Temperature | Pressure | Motor Speed |
|---|---|---|---|
| Setpoint | 106/112 | 900 | 70% |
| ISO | 79 | 937 | 284 RPM |
| RESIN | 77 | 942 | 274 RPM |

---

# Daily Report & Job Summary

**Job #: 15**

**Customer: Sprayfoam Inc**

**Address: 21 East Rd.**

**Chemical Used: Chemical/Manufacturer**

**Applicator Name: John Doe**

| Spray Dates | Gallons A | Gallons B | Ratio % |
|---|---|---|---|
| 09-13-17 | 42.85 | 42.87 | 99.95 |
| 09-14-17 | 30.21 | 30.23 | 99.93 |
| 09-15-17 | 17.89 | 17.93 | 99.75 |
| 09-18-17 | 11.61 | 11.63 | 99.88 |
| 09-19-17 | 2.86 | 2.89 | 98.86 |
| Total Gallons | 105.42 | 105.55 | 99.88 |

## Polyurethane products and quality assurance/control

| Polyurethane Product | Use (Does not include adhesive products) | Closed-cell foam | Open-cell foam | QA - Verify parameters before and during processing | QA - Verify preparation parameters | QA - Verify parameters during the installation | QC - Verify parameters after the installation |
|---|---|---|---|---|---|---|---|
| **Single-component caulk/sealant** | Seal cracks < 1/8" | NA | NA | Product temperature | Ambient and subtrate temp.; substrate dry; compatable | Technique; bead thickness, push vs. pull bead | Visual inspection* |
| **Single-component foam** (comes in colors) | | | | | Ambient and subtrate temperature; substrate clean and dry; verify compatability | | |
| Expanding | Seal cracks 1/8" to 3/4" | Y | NA | Chemical temperature, well mixed | | Full depth; any required bracing; moisten between lifts > 3/4"; technique | Visual inspection* |
| Non-expanding | Seal cracks 1/8" to 3/4" | Y | NA | Chemical temperature, well mixed | | Full depth; moisten between lifts > 3/4"; technique | Visual inspection* |
| **Two-part slow-rise foam kit** | Seal cracks > 1/4" or fill cavities | Y | Y | Chemical temp., equal pressures, component weight; test shots | Ambient subtrate temperature and RH; substrate clean and dry (wood moisture content or metal and masonry surface moisture); verify compatability | Maintain preparation conditions; sheathing integrity and fastening | No pass thickness limit; use infrared to verify fill; maintain prep. conditions thru cure period |
| **Two-part spray foam kit** | Seal cracks > 1/4" or build up on open surfaces in lifts | Y | Y | Chemical temp., equal pressures, component weight; test shots | | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain preparation conditions thru cure period |
| **Injected two-part bulk foam** | Fill closed cavities | Y | Y | chemical temperature, pressure, ratio; test shots | Ambient subtrate temperature and RH; substrate clean and dry (wood moisture content or metal and masonry surface moisture); verify compatability | Maintain preparation conditions during installation; sheathing integrity and fastening | no pass thickness limit; infrared to verify fill; maintain prep. conditions thru cure period |
| **Spray-applied two-part bulk foam** | Build up on open surfaces in lifts | Y | Y | Chemical temperature, pressure, ratio; test shots | | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain prep. conditions thru cure period |
| **Spray-applied two-part bulk roofing foam** | Build up on open surfaces in lifts | Y | Y | Chemical temperature, pressure, ratio; test shots | Same as bulk wall foam above | Lift thickness; time between passes; maintain prep. conditions; cure-lift prevention | Visual inspection*; pass thickness limit; thump test; maintain prep. conditions thru cure period |

* Assess cell color, uniformity, size, shape, odor, friability, strength, lift thickness, etc.

# 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.

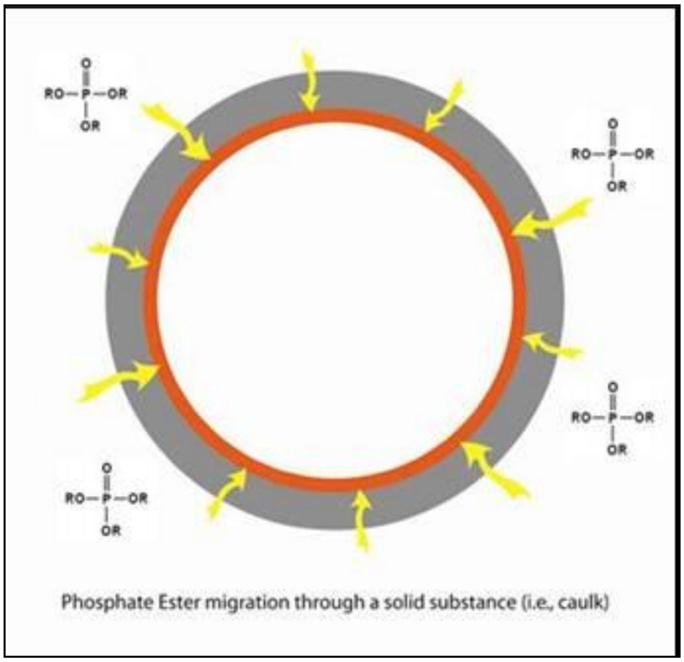


***Figure 1.*** *Simulate phosphate ester migration through solid substance*

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.

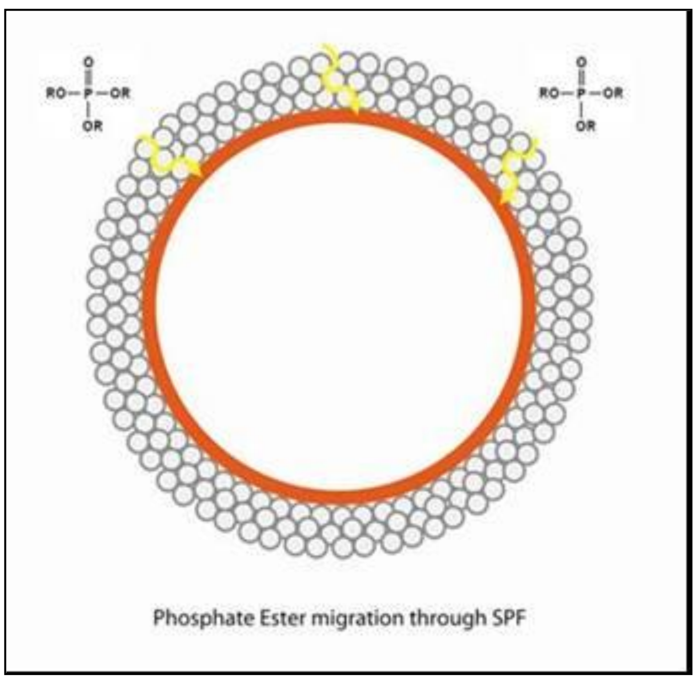


***Figure 2.*** *Simulate phosphate ester migration in foam*

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.

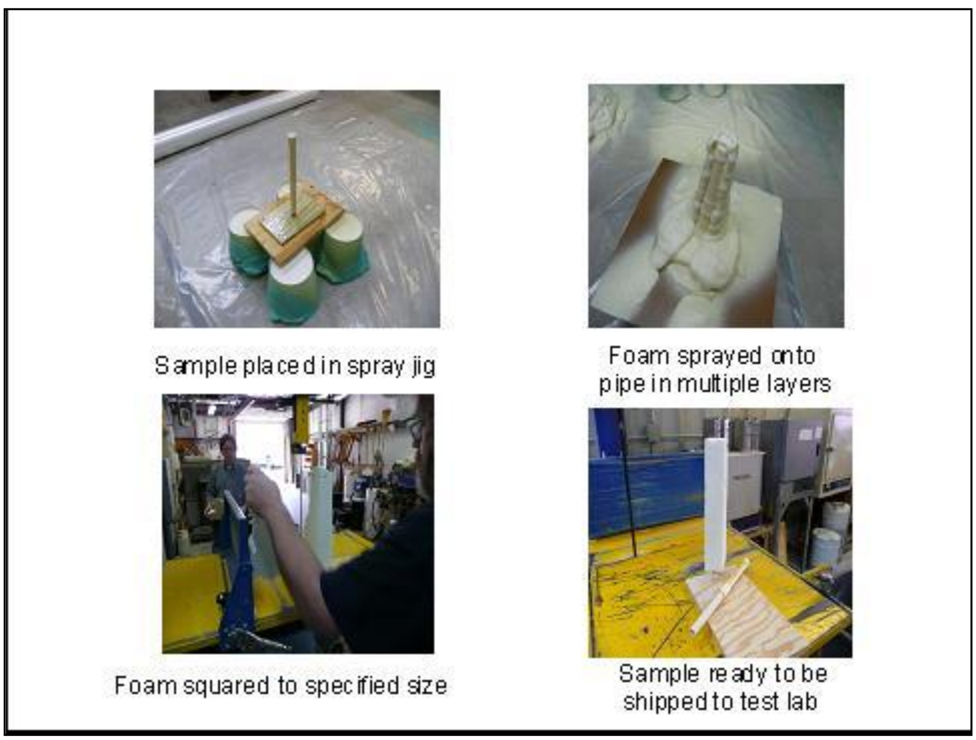


***Figure 5.*** *Preparation of open-cell foam samples*

**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*

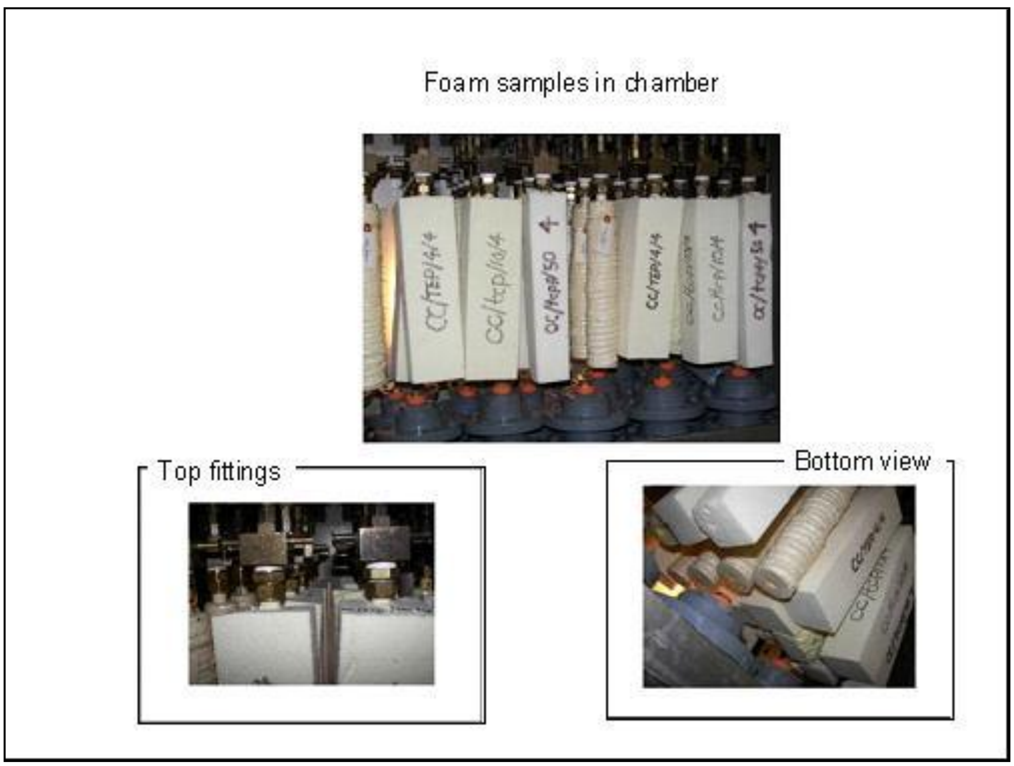


***Figure 7.*** *Samples in test chamber*

## 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.

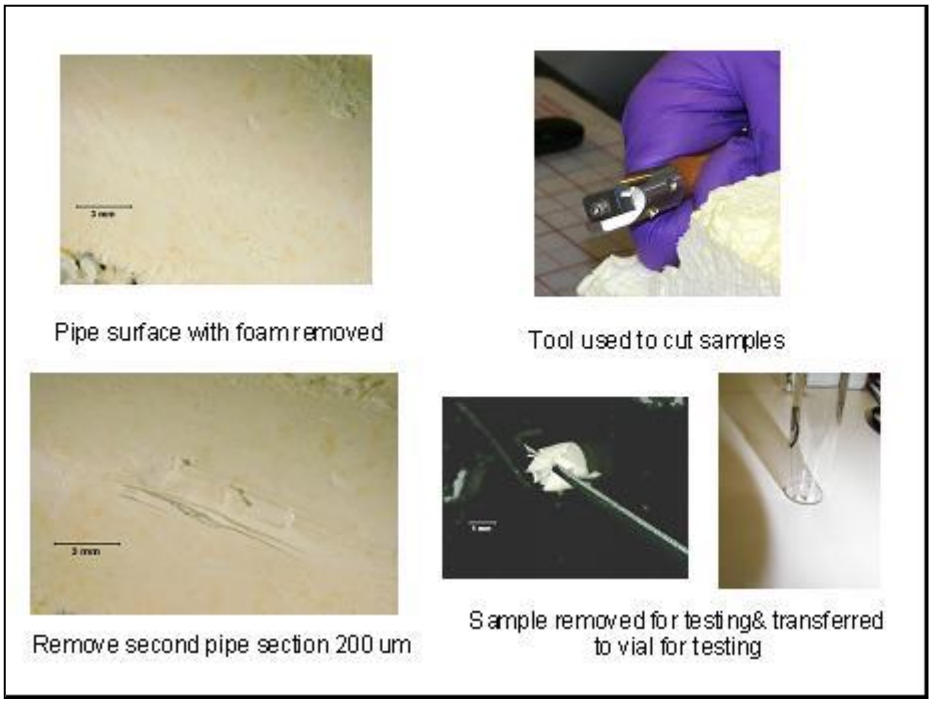


***Figure9.*** *Sampling pipe surface*

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).

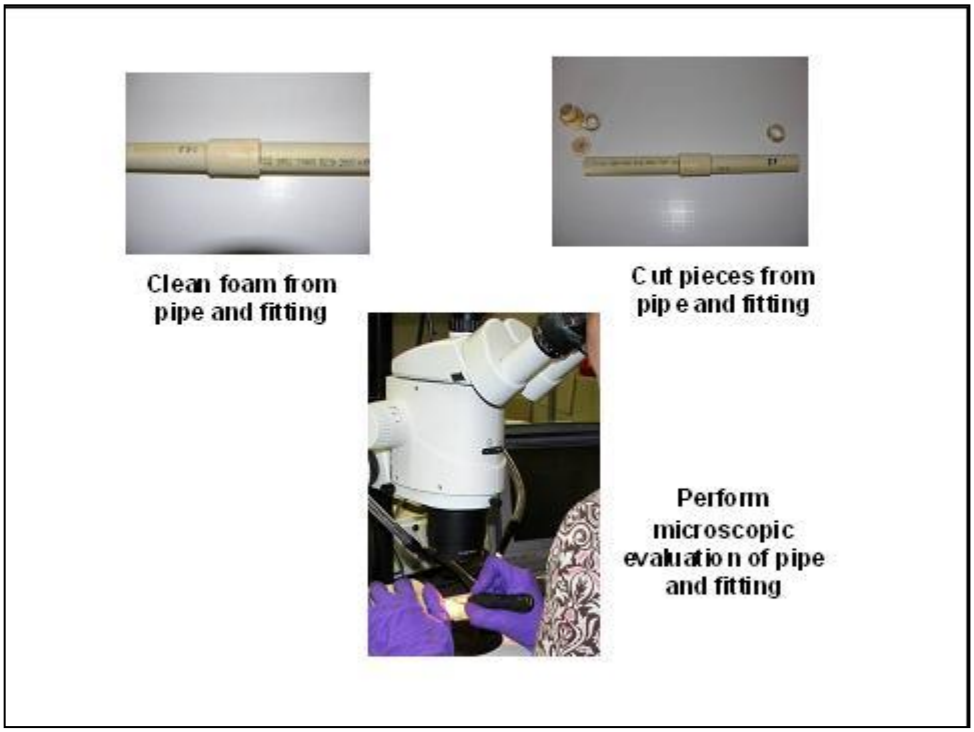


***Figure 10.*** *Samples analyzed for ESC microscopically*

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.

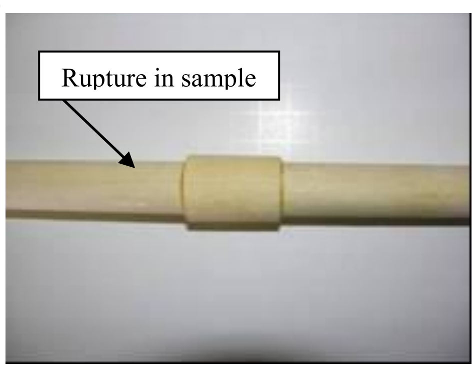


***Figure 11.*** *Ruptured sample*

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.

Contributing companies include:

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

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Finally the authors would like to thank Michelle Knight and Kevin Daugherty of Lubrizol Advanced Materials, Inc. and James Paschal of James Paschal Engineering and Forensic Consulting, LLC who assisted with the research program and preparation of the paper.

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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.

SUBMITTALS CHECKLIST – BIDDER QUALIFICATION REQUIREMENTS

A. Provide the following submittals with the bid form
    1. Certificates of insurance
        a. Installer must have insurance provided by "Admitted Insurance companies" from Standard, not excess markets. This must be stated on the insurance company's form
        b. Exclusions must not include "Interior and exterior insulation"
        c. Must provide verification of full environmental/pollution coverage
    2. Installer qualification information
        a. Manufacturer's installer certification for the Installer
        b. Written safety plan (including a complete Site Protection plan with an Air Quality Management Protocol including a re-occupancy certification requirement)
        c. SPFA CERTIFICATION that the Installation Contractor meets the SPFA Professional Certification Program or the Installed Building Products Training Program certification
        d. Written certification that the foam installer has been in the business of performing foam installations for at least five years.
        e. Installer State and County compliance Certificate (where required)
    3. Manufacturer's Product Information
        a. ICC, or other approved third-party Evaluation Service Agency's ESR or Compliance Label
        b. Technical Data Sheet(s) for each type of material that will be installed, to include all technical and tested physical and performance properties.
        c. Manufacturer's Product safety information
            i. SDS for all foam products that will be installed
            ii. SDS for all coating products that will be installed
            iii. SDS for all other related products that will be installed
        d. Manufacturers' printed installation requirements and instructions for all foam products, coatings, and other related materials that will be installed, including evaluating, preparing, and treating substrates, temperature and other limitations of installation conditions. Processing and installation requirements must include tolerances for compliance for specifications that include expected variations.
    4. Written guarantee that the Installer will not sub-contract any portions of the work
    5. Written guarantee that the Installer will only use matched A and B components
    6. Manufacturers' certification of compatibility for all project substrates
    7. Proposed materials and methods for sealants required in cracks and joints too small for SPF
B. Provide the following submittals prior to the Installation
    1. A building enclosure system sequencing plan, including quality assurance testing requirements and milestones.
    2. Participation in the construction and testing of a mockup, if one is required.

C. Provide the following closeout submittals prior to final acceptance
   1. Completed air barrier air leakage test compliance test reports and certifications
   2. Certification that the Project meets the specified energy performance requirements
   3. Product Warranty(s) for all foam products, coatings, and other related materials that will be installed as part of the work
   4. Installation Warranty(s) for all foam products, coatings, and other related materials that will be installed (must be at least for the duration of the product manufacturer's warranty, and at least for the minimum project requirements and term)
   5. Completed and signed SPFA "Spray Polyurethane Foam Installation Certificate" form
   6. Processing reports, including samples, photos and written reports
      a. Processing Quality assurance testing (required except for pre-work installations)
         i. Supply chemical core temperature report
         ii. Supply chemical pressure report
         iii. Manual flow ratio calibration report for all proportioners – at least once per day
         iv. Strip test shot report (until a minimum of one quality test per is achieved for each spray session)
      b. Installation Quality assurance testing (required except for pre-work installations)
         i. Substrate moisture test report
         ii. Ambient and substrate temperature report
         iii. Unreacted isocyanate rub test report
         i. Density check report (one test per 2,000 square feet of building enclosure)
         ii. Pass thickness test report
   2. Written report/letter certifying satisfactory completion of the installation
   3. A written certification that the premises are safe for re-occupancy
   4. All information required from the Installer to attain a Certificate of Occupancy from the local code authority
   5. Project documentation: photographs of all phases of the work

Description:

The “post-work submittals” are reports that are to be provided by the Contractor describing and certifying that his work has been completed as required in the Remediation Recommendations (the remediation plan specifications will have a list of submittals required before, during, and after the work – these are after the work). Some of these reports are for you, for example a re-occupancy certificate and product warranties, some for the building inspector, for example they may require certification that the insulation is up to the local standards, and some may be a certificate that gets posted near the electric panel about the work that is required by code, etc. My role is to verify that the submittals are turned in or posted and contain the required information. This line item states that my receipt of a report does not mean that the work indicated in the report has been completed as required, only that the report has been provided.  If my scope of work includes inspecting the Contractor's work and reporting on the work he has completed, I would be able to attest that the work has been completed and that it was done properly. One of the reasons for requiring submittals is to bolster our intent that the work be performed properly, and that we will be checking it and it will be documented.  A condition of final payment is that we have to receive and approve the submittals.  Without submittal requirements, things like warranties may never be delivered.

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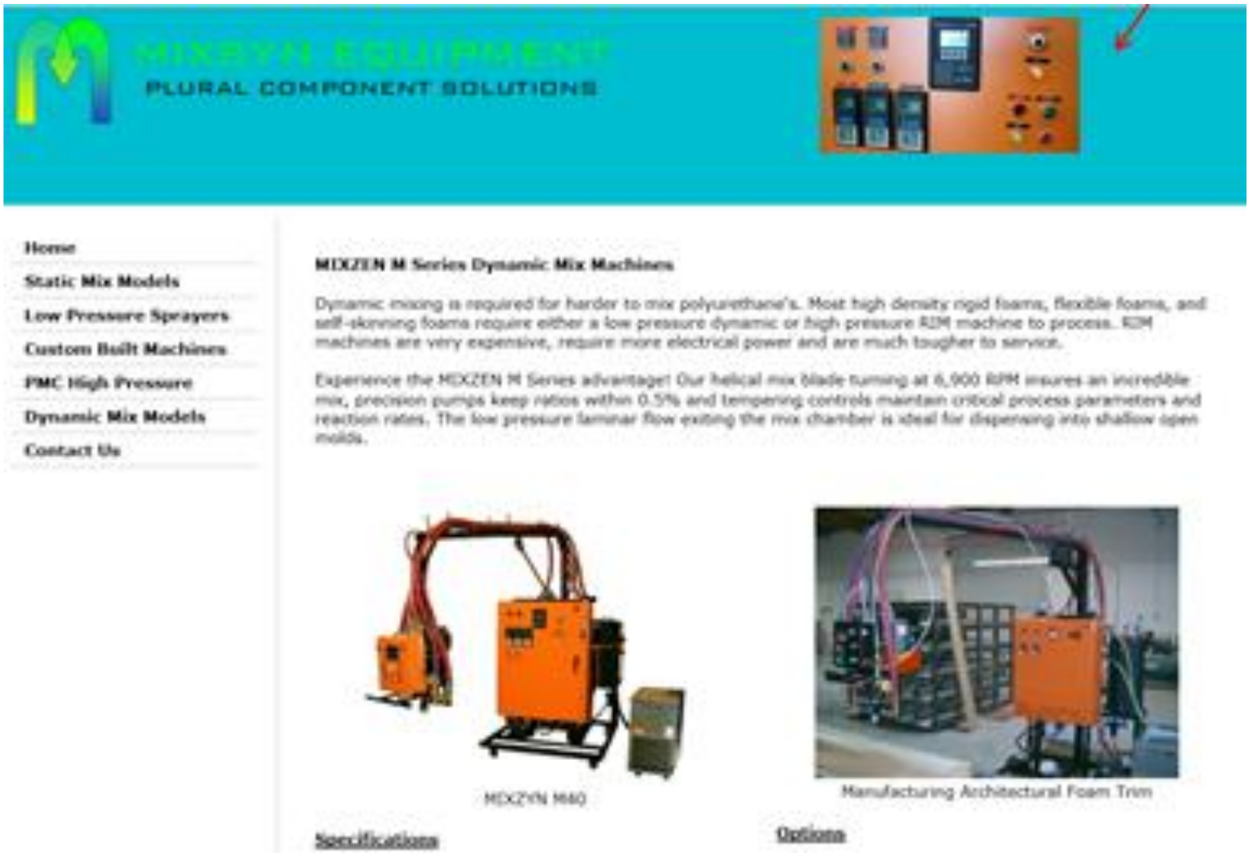
## The case for foam process monitoring

A member of one of the largest foam manufacturers commented to me when we were discussing industry developments that he believes the biggest threat to the industry is the fact that installers can process foam off ratio (meaning that the two chemicals involved are not mixed in the proper proportion).


I would expand that general processing problem to include processing foam at the wrong temperatures, which often creates off-ratio material. My recommendation to the industry is mandating the use of monitoring equipment that would eliminate this problem. I used this type of equipment in my business for twenty years, and it allowed me to work on high-need, high-profile projects like the Guggenheim Museum.

This type of QA monitoring equipment has been in use for many years by OEM foam molding companies throughout the industry.  The equipment is easily adaptable to on-site spray foam processing equipment, which is very simple compared to automatic high production RIM molding equipment.

## Standard OEM QA Equipment




Temperature sensors and controllers are inexpensive, easy to implement, and reliable, even at the remote gun location. Flow meters are more expensive, but more than pay for themselves by avoiding off-ratio events. Shut-off switches and/or valves are also inexpensive, easy to implement, and reliable. Eighty percent of the real (not perceived) foam problems I see are caused by equipment-related issues.

Restrictions in the hoses (upstream and down), improper daily machine setup, improper temperatures, and empty supply-side reservoirs cause most of the problems. Basic temperature and flow ratio monitors would detect out-of-spec processing parameters and immediately shut down the processing equipment, thus preventing poor quality material from being installed.

Difficulties can still arise if the operator over-rides the lock-out functions built into these systems. However, most processing problems can be still be avoided by requiring digital or paper reports generated by the monitors themselves in the submittals. This documentation would identify installers who do not use the QA equipment properly.

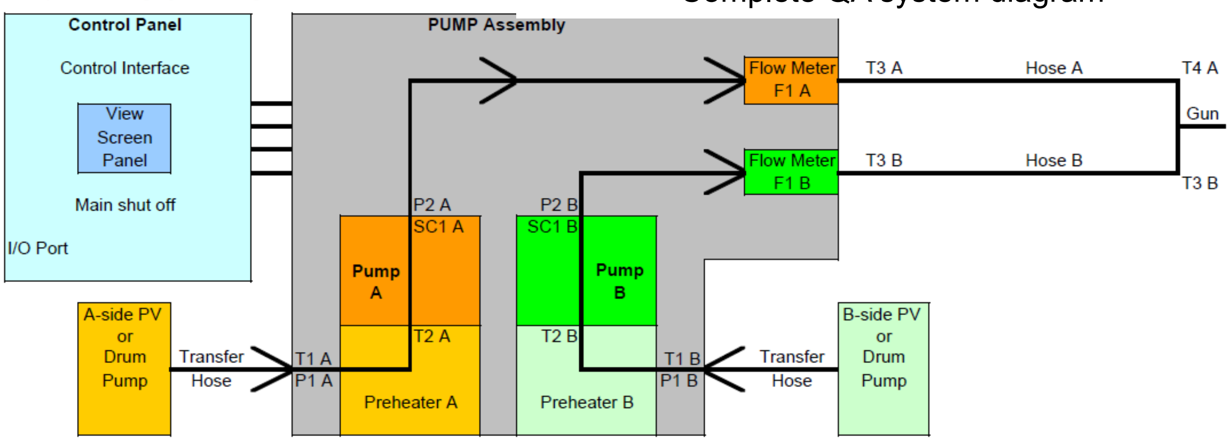
These reports would document out-of-spec. operations, allowing the specifier or consumer to identify improper processing quickly. This would discourage installers from over-riding the QA controls, and encourage proper maintenance. These monitoring systems have the computing power, data logging capabilities, and output interfaces necessary to generate reports for all of the processing parameters on a full-time basis.

Requiring this type of QA documentation will also serve to pre-qualify foam installers. A major qualifier to use when choosing an installer is does he possess the equipment capability of monitoring temperature and ratio. Those installers who do understand proper processing, or do not have the proper

QA equipment, will not be able to meet the bid requirements included in solicitations that require confirmation of this type of QA control equipment and reporting in the bid submissions.

The following information about ratio monitoring shows what the equipment looks like, and everything an installer needs to assure he is meeting the requirements set forth in the SPFA Equipment Guidelines. Ideal QA equipment would operate as indicated in this diagram:

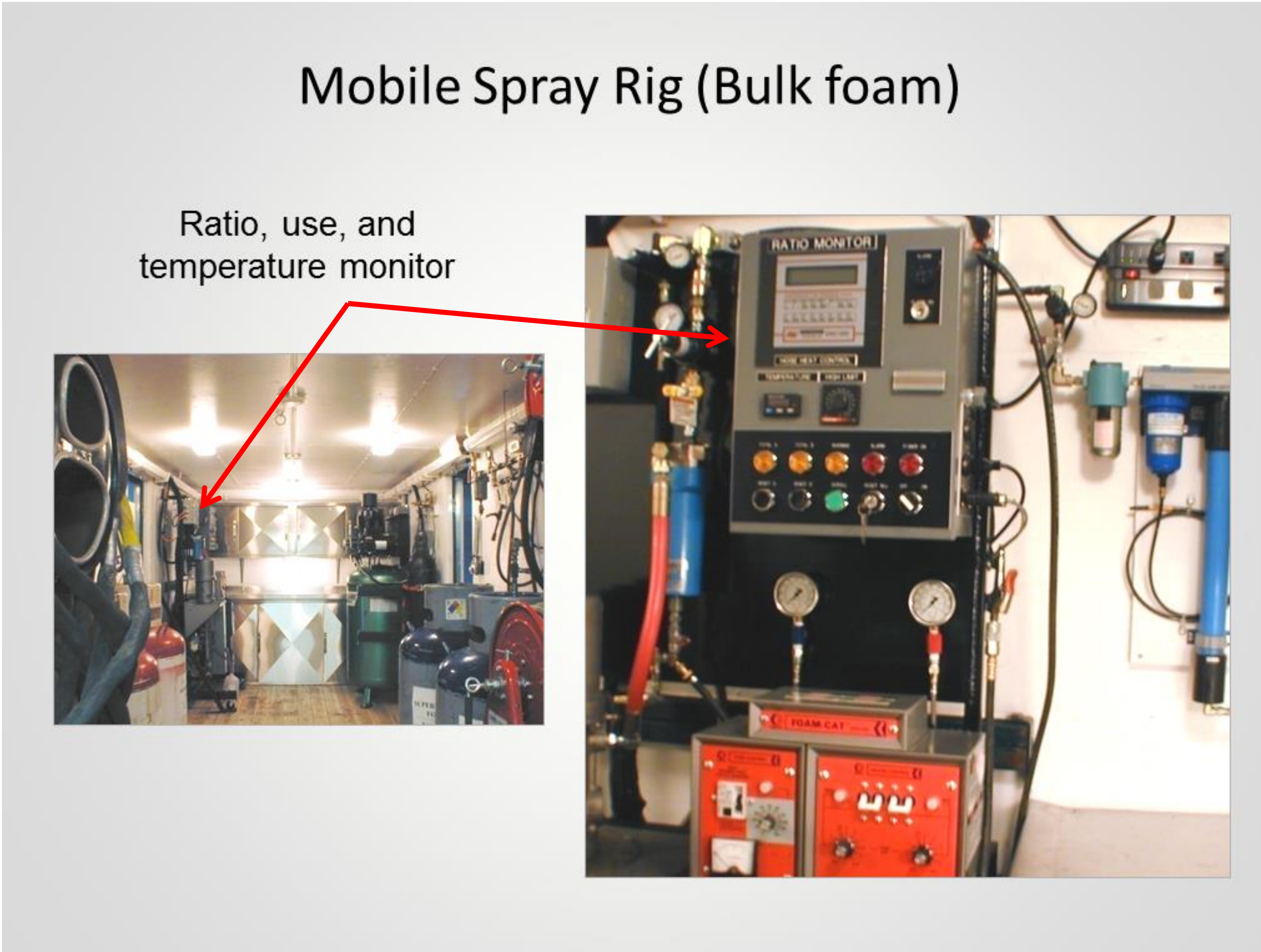
**Pump Monitoring System Diagram** Complete QA system diagram




| | | | |
|---|---|---|---|
| T1 A | Temperature at inlet from transfer hoses (A) | 0 to 200 degrees F | Shut down if below set point |
| T1 B | Temperature at inlet from transfer hoses (B) | 0 to 200 degrees F | Shut down if below set point |
| T2 A | Temperature at oulet from preheater (A side) | 0 to 200 degrees F | Shut down if below set point |
| T2 B | Temperature at oulet from preheater (B side) | 0 to 200 degrees F | Shut down if below set point |
| T3 A | Temperature in first section of hose (A side) | 0 to 200 degrees F | Shut down if above high limit set point |
| T3 B | Temperature in first section of hose (B side) | 0 to 200 degrees F | Shut down if above high limit set point |
| T4 A | Temperature at gun end of hoses (A side) | 0 to 200 degrees F | Shut down if below set point |
| T4 B | Temperature at gun end of hoses (B side) | 0 to 200 degrees F | Shut down if below set point |
| P1 A | Pressure at outlet of Transfer hose (A side) | 0 to 500 psi | Shut down if below set point |
| P1 B | Pressure at outlet of Transfer hose (B side) | 0 to 500 psi | Shut down if below set point |
| P2 A | Pressure at outlet of pump (A side) | 0 to 3,000 psi | Shut down if below set point<br>Alarm, then shut down if A - B difference exceeds preset limits |
| P2 B | Pressure at outlet of pump (B side) | 0 to 3,000 psi | Shut down if below set point<br>Alarm, then shut down if A - B difference exceeds preset limits |
| F1 A | Flow rate (A side) | 0 to 5 GPM | Alarm, then shut down if A - B difference exceeds preset limits |
| F1 B | Flow rate (B side) | 0 to 5 GPM | Alarm, then shut down if A - B difference exceeds preset limits |
| SC1 A | Stroke counter (A side) | 0 to 100,000 | Record only |
| SC1 B | Stroke counter (B side) | 0 to 100,000 | Record only |
| PV A | Pressure vessel (A - Side) | | |
| PV B | Pressure vessel (B - Side) | | |

Graco manufactures more than 90% of the pump systems that are used for in-field foam processing. Graco makes ratio monitoring systems for manufacturing, but only offers pressure monitors for field applications.


**What a temperature and ratio monitor looks like installed in the rig:**

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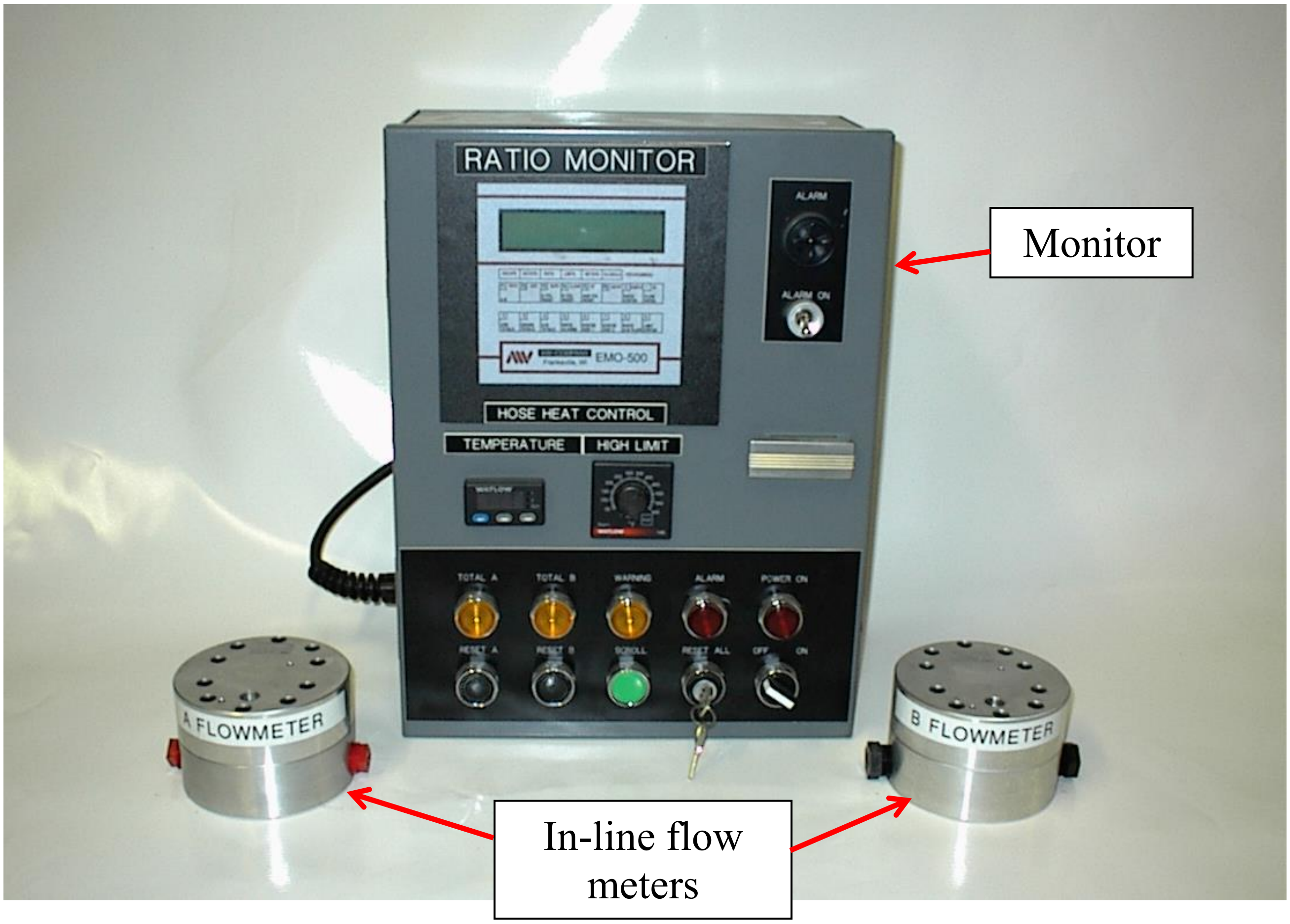
**Pieces – parts**

These are the two main components of a temperature and ratio monitoring system.




Miscellaneous accessories needed for a complete monitoring system include the following:

1. Thermistors and wire to locate at the gun, in the hoses, and right after the primary heaters.
2. In line air valve to shut off pump if electrical lock-out is not easily available
3. Electrical outlet with surge/overload protector at monitor plug in
4. Remote alarm or warning light if used in addition to built-in alarm

The incentive for the industry to use monitors, in conjunction with other quality control methods, is to avoid problem foam installations. In the absence of ANSI standards, it is up to the industry to mandate this type of quality control equipment. Architects can specify this as a quality control method, and foam manufacturers, who suffer the most from poor quality installations, should mandate that monitors be used by everyone who buys their material. This would have to be a universal mandate. If only one or two manufacturers require the use of monitors it would effectively raise the price of their products in what is already a very competitive marketplace.