Henri Fennell, CSI/CDT

Henri is an architect and building envelope specialist with over forty years of experience in the construction industry. He was a pioneer in the solar industry, introduced the installation technique for field-applied closed-cell cavity-fill polyurethane foam, developed a pressurized theatrical fog quality assurance technique and protocol, and has designed and constructed a net-zero energy research structure in Antarctica. He has four energy-related U.S. patents.

HCF foam experience

1. First spray foam project was in 1971
2. Foam manufacturing from 1973 to 1979
3. Foam contracting and BE consulting from 1979 to 2009
   - Developed the method for injecting closed-cell foam on site
   - Installed ~ 5 million pounds of foam
4. Foam and BE commissioning from 2009 to present
5. Noteworthy foam projects include:
   - 1977 net-zero solar project in Boston, The Big Dig, Four American Ski Grande Hotels in the Northeast, 2005 Net-zero energy weather station in Antarctica, The Guggenheim Museum
6. Two US patents and numerous technical papers related to foam & foam QA




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Safely Installing SPF in Occupied Buildings – Preparation and Testing

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Will Wade, Environmental Health & Engineering (EH&E)

Tuan Trong, Environmental Health & Engineering

Sarah Mack, Enthalpy Analytical Laboratories

Introduction

- Best practice for SPF installers is to not do spray foam in occupied buildings. The best practice is to evacuate the occupants!
- An apartment property manager's need for the Spray Polyurethane Foam (SPF) installers to perform installations in the attics of a 104-unit complex while maintaining resident occupancy was a situation where an alternate method was needed.

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The Project Scope

A project came along…

- Two apartment complexes with three buildings at each complex
- Low-income housing with typical occupancy
- Originally Built in 1977
- Complex #1 – 20,600 sq. ft. for top floor and the attics
- Complex #2 – 18,000 sq. ft. for top floor and the attics
- Each dwelling approx. 650-800 sq. ft.

The Project Scope

- Closed-cell SPF insulation was to be installed on the underside of all of the roof slopes.
- Foam to be installed in the attics which are directly above the occupied units and some common spaces.
- Project duration was September through December 2021 – too long for evacuation.
- The cost of a four-month relocation of the occupants would have prevented this energy-upgrade project altogether.

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Evacuation is the industry standard

- As we all should know, evacuation is always the only guaranteed way to protect occupants of a building during an SPF installation. However, in some retrofit situations, evacuating the occupants is not practicable, especially in projects where the work will take an extended amount of time and/or there are a lot of occupants.
- The key is to know how to install SPF while protecting the occupants and being able to prove that it is done safely.

- This protects the occupants from IAQ issues.
- This also avoids the potential for legal issues for the Installer. Some occupants may want to get a windfall, and some may imagine a problem where none exists.

Evacuation is the industry standard

1. Moving the hundred-plus families out of the building for several weeks would have been too expensive.
2. No SPF installers would bid the project because they didn't know how to safely do the installation without evacuating the premises.
3. The General Contractor contacted me because they knew I had performed major SPF installations safely in occupied buildings before.

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Why does spray foam require occupant protection?

1. Standard spray foam vapors are produced during a normal installation.
   a. Listed SDS chemicals are released (MDI, fire retardant, blowing agent, polyol, surfactant, catalysts, recycled fillers, dyes, etc.).
   b. Short-term exposures only occur for the installers during the spray work, but they use PPE and engineering controls to protect themselves.
   c. Ventilation is always recommended during the installation to clear out the vapors before they contaminate surfaces and HVAC equipment.
2. Long-term exposure issues can occur if SPF is misapplied.

Off ratio – fluctuations look like this

Layers of A-rich, good quality, and B-rich foam

This is rare, but misapplied foam can produce off gassing

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HCFC's experience with installing SPF in occupied buildings includes several types of safety workarounds

1. Performed the work at night - Daycare Centers, schools, businesses.
2. Closed the Guggenheim Museum briefly and managed the ventilation system for localized work.
3. Isolated the Roswell Flower Museum attic and managed the ventilation system – a short-term project.
4. Physically isolated and depressurized attics and crawl spaces in an occupied multi-family and hotel/condo buildings.
5. Physically isolated and depressurized 80,000 sq. ft. of attics in an occupied independent and assisted living facility.

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Isolate the work zone - Protect adjoining spaces

Pressurization and depressurization via the blower window!

Isolate the work zone - Protect adjoining spaces

Pressurization and
depressurization

HCFC's experience with installing SPF in occupied buildings includes several types of workarounds:

1. These projects all used variations of a proven Indoor Air Quality Management Protocol, which was developed for projects performed with full occupancy as part of our OSHA-required Written Safety Plan (Hazard Communication Plan).
2. The goal was always to completely isolate the occupied space from the work zones. Isolation included physical separation, signage, lock-out protocols, and other hazard communication means and methods, including depressurization.

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What are the Safety Concerns?

- Vapors released during the spray installation and cure period can be hazardous without PPE.
- This method answers the question – “Has the SPF been properly processed and installed?”
- Combustion Appliance Zone (CAZ) considerations were also addressed.

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What are the Safety Concerns?

- A-Side (Isocyanate) – Inhalation can cause 1) irritation of the nose, throat, and lungs, causing runny nose, sore throat, coughing, tightness in the chest, and shortness of breath, and 2) respiratory tract sensitization (e.g., the development of asthma) with symptoms of chest tightness, shortness of breath, coughing, and/or wheezing. An asthma attack can be life-threatening.
- Fortunately, isocyanates are water reactive and are gone from the air in hours or a day or two if the workspace is properly ventilated (at least two air changes per hour).
- Only the Installer has to be protected with PPE if the work zone is properly isolated by barriers and/or depressurization and ventilated (engineering controls).

What are the Safety Concerns?

- B-Side – Inhalation can cause irritation of the respiratory tract, causing cough, sore throat, and runny nose. Irritation of the eyes (liquid or vapor) and skin (liquid) are also possible. Cardiac arrhythmia (irregular heartbeat) is a symptom of overexposure to certain blowing agents. In addition, the vapors of some amine catalysts can temporarily cause vision to become foggy or blurry, and halos may appear around bright objects and lights.
- Long-term B-side exposure can cause sensitivity and respiratory issues.

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Building complex – Affordable Housing

Year Built: 1977

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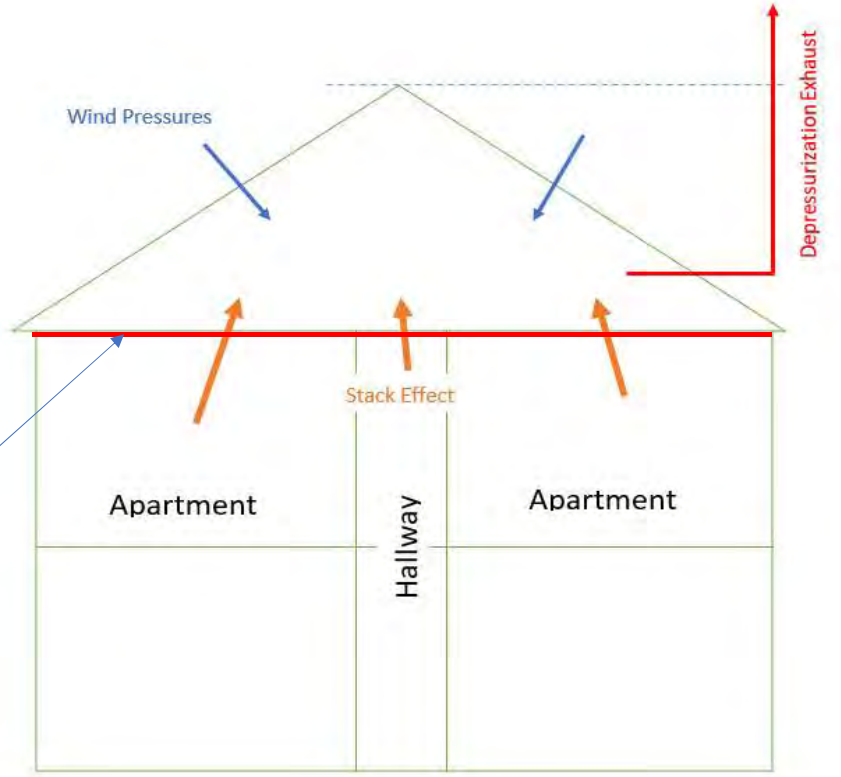
Building Layout

The attic depressurization pressure (ventilation isolation) was based on measured stack effect and wind pressures (about -15 pascals to exceed the baseline in a typical one or two-story buildings).

Attic boundary (physical isolation)



Must be greater than all other pressures combined

Mechanical systems can create localized negative pressures below the attic floor.

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How to isolate the Work Zone from the occupied spaces

1. Tighten the physical boundaries.
2. Depressurize the work zone with fans to further isolate the work zone from the occupants.
3. Use manometers to verify that the work zone pressure is far enough below the occupied space pressure to assure that no vapors flow into the occupied units from the attics.
4. Quantify and record the pressure differences across the isolation boundaries and verify that the isolation pressures and flow rates are adequate by testing the indoor air quality in the occupied spaces.

Manometers

Differential pressure meter

- Pressure and flow multi-channel gauge for a TEC blower door set-up or other manometer
- One channel measures the attic work zone pressure
- The other channel measures the pressure in an occupied unit or a common space below to assure that the attic is lower than either occupied space

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Isolating the attics

Plastic was installed on the attic floors to isolate the attics from the common spaces.

The contractor could have used air sealing to accomplish this physical isolation if the ceiling was relatively continuous so that only small gaps and cracks needed to be air sealed.

Depressurizing the attics

Exhaust fans blow upward to prevent vapors from re-entering the building

Exhaust-only fans use depressurization to isolate the attics from the common spaces

The pressure difference across the boundary was verified with continuous datalogging manometers

The Building's Systems

- No central HVAC systems were in use in any of the occupied units. There were mini-split heat pumps in each unit. No ducts to seal!
- Fresh air ventilation was not specified but it should meet the ASHRAE 62.2 standard.
- All of the units had operable windows and doors that opened to the interior hallway (common space) and to the outdoors. All of these access points were able to be used during the work with the isolation protocols in place.

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How to isolate the Work Zone from occupied spaces

Use physical separation between the work zone and the occupants as much as possible – this reduces the ventilation requirements

1. Seal any ducts and air handlers so the vapors cannot be circulated
2. Seal any recessed lights
3. Seal around any chimneys and flues
4. Install plastic on the attic floor sheathing to seal top plates, elevation transitions, and penetrations (wiring, pipes, etc.)
5. Seal along the fire walls between sections of large attics or crawl spaces

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How to isolate the Work Zone from the occupied spaces

Depressurize the work zone with respect to the occupied spaces

1. Exhaust air from the work zone (attic, room, etc.).
2. Verify that the flow rate is adequate to maintain at least a ten pascal larger negative pressure than the stack effect (baseline P) in the work zone (attic, room, etc.).
3. Depressurize the work zone (WZ) during the work in addition to for the length of the cure period.
4. Test the WZ air to verify that all vapors in the air have been cleared out.

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The Original Plan

- The General Contractor was not aware of why or how to manage air pressures.
- The SPF Installer didn't include any air quality management protocols in their written safety plan (Hazard Communication Plan) or service agreement. They had never used IAQ testing.
- The General Contractor and SPF Installer were not aware of how to monitor and record work zone pressures or verify the air quality in the occupied spaces during the work to protect against legal suits.

The New HCFC Plan

- Hazard communication
  - Notification for the occupants
  - Distribution of documentation – SDSs, warnings, and access protocols for the residents
  - Signage – Keep out!, Respirator Required!, etc.
  - Lock-outs if necessary
- Work zone isolation
  - Physical isolation and verification
  - Pressure isolation and verification
- IAQ Verification – lab testing
- Work zone ventilation
  - Make-up air for the exhaust fans
  - Ventilation at the required rates for safe isolation
  - CAZ safety

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HCFC's Role

- Planned and oversaw the site protection portion of this project
- Required and approved an OSHA-compliant safety plan for the General Contractor and the Foam Installer, including consideration and implementation of Combustion Appliance Zone Best Practices from DOE-WAP and the Building Performance Institute, Inc.
- Provided guidance for an Air Quality Management system
- Provided guidance for Foam Waste and Container Disposal/Recycling
- Provided guidance for the IAQ and bulk foam laboratory testing protocols
- Provided a qualified laboratory that is familiar with SPF and its chemistry
- Provided guidance for verifying foam product quality during and after the installation

EH&E's Role

EH&E is a local environmental testing agency that provided the following:

- Daily site assessment including monitoring and recording the pressure differences across the boundaries
- Environmental testing
  - Collected air and bulk foam samples
  - Sent the samples to, and communicated with the lab and the GC
- Data analysis & reporting
  - Recorded on-site observations and laboratory results
  - Communicated findings and recommendations so any fan flow rate changes were made in a timely fashion

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Preparing For Spray

- IAQ tests were performed daily leading up to the spray work to establish baseline values for the first and second floors in each building.
- Bulk foam off-gas lab tests were performed prior to starting the attic work to provide a complete list of compounds to look for in the air.
- The fire walls were sealed to separate attic areas with gasketed passage doors at each boundary between the work zones. The attics were too large to complete all at once while maintaining adequate ventilation. Attic halves for the 8-unit buildings (6,000 sq. ft. each) and attic thirds for the 10-unit buildings (7,300 sq. ft. each) were sprayed.
- Pressures were checked (by manometer) and recorded each day prior to spraying – ensuring correct flows and isolation requirements were present. 6-8 negative-air machines were used to achieve appropriate (~ 15 pascals) negative air pressures in the attics.

Spray Day Activities

- Confirm the depressurization levels and ensure proper operation of the manometers that were checking the pressure differences hourly during the installation and cure period.
- Thermal desorption tubes were installed and collected daily after the WZ has been cleared out to assess potential IAQ exposures for the occupants.
- Samples were collected:
  - Starting 30 minutes after the start of the spray work
  - Each test ran for a full 2-hours @ 200 ml/min.
- These samples were collected in the common hallway of the buildings and/or in the living units and overnighted to the lab. (A one-day TAT)

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SPF installed on the roof deck

Joseph Lstiburek, Medford, MA, 1997

Post-Spray Day Activities

- Continue ventilation in each work zone until after the cure period.
- Continue testing the IAQ daily during the work and after the cure period in each work zone.
- Install a code-required insulation certificate in any building that has received an air barrier upgrade.

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Data To Prove It

- Samples were received by the Lab daily for rush analysis.
- The lab assessed the samples for all VOCs with special focus on any related to the SPF. The turn around time for these lab tests was one day!
  - The first contact with the lab for pricing this type of work - Sept 10th
  - The first foam and air samples were received by the lab on Sept 28th
  - The last air sample set was collected on Dec 30th
- The building performance of the energy upgrade was verified with blower door and infrared testing and met the state energy code and project requirements.

BETTER BUILDING BY DESIGN

- Enthalpy has a comprehensive list of all compounds found in SPF.
- The off-gas test on the first bulk sample verified that all of the SPF compounds were on the list.
- Only one SPF product was used for this project.

Why and What?

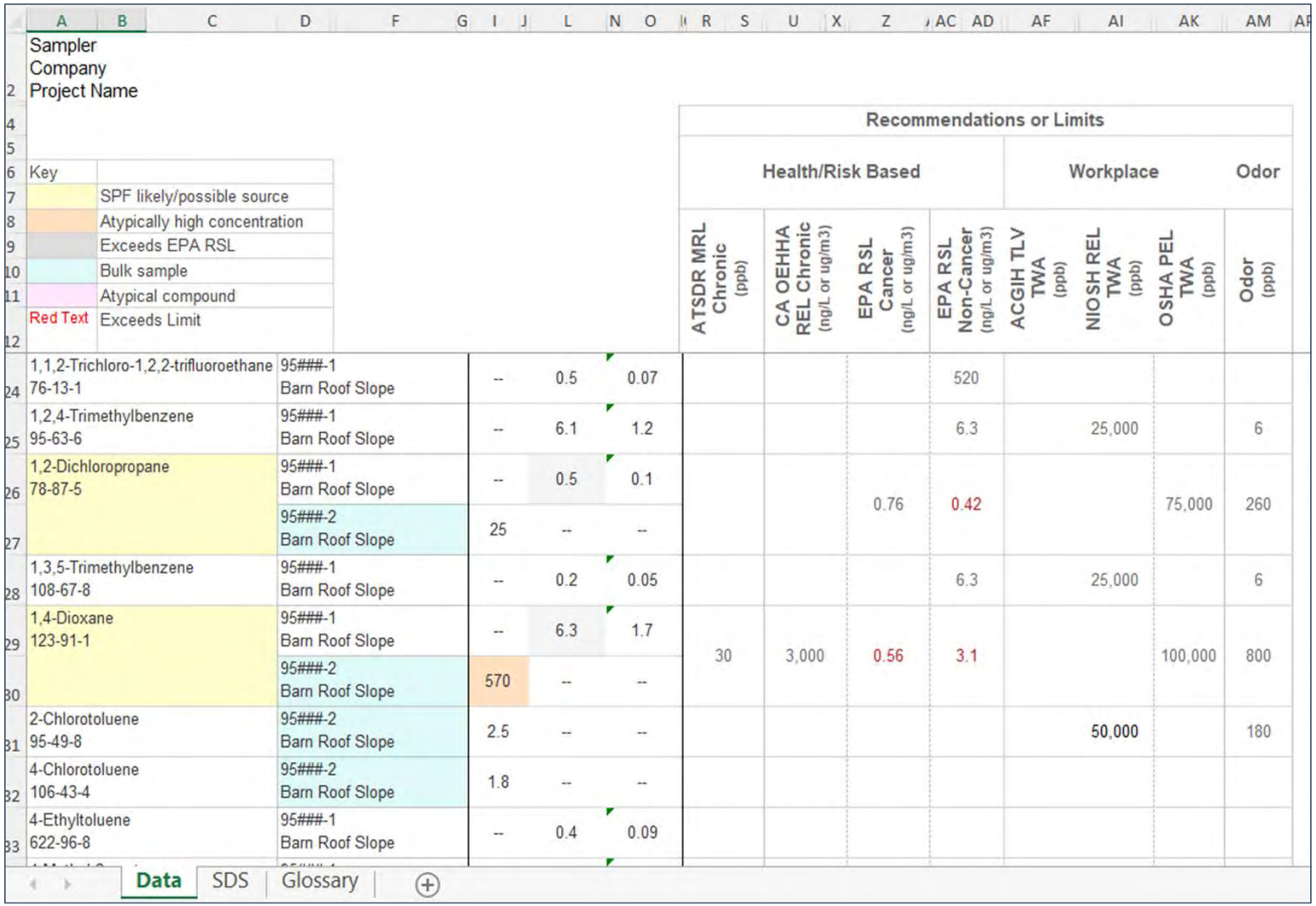
- Proof that little to no vapor-laden air from the attic space was making its way to the living space
- Which compounds – the SPF Target list plus a full VOC scan while there is spray work happening

Key	
	SPF Target Compound
	Atypically high concentration
	Bulk sample

Health/Risk Based			Workplace			Odor
ATSDR MRL Chronic (ppb)	CA OEHHA REL Chronic (ng/L or ug/m3)	EPA RfC (ng/L or ug/m3)	ACGIH TLV TWA (ppb)	NIOSH REL TWA (ppb)	OSHA PEL TWA (ppb)	Odor (ppb)

ATSDR MRL = Screening levels; estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse health effects, **ppb** = parts per billion, **OEHHA** = Screening levels; for conducting health risk assessments of airborne emissions from stationary sources, **ng/L** = nanograms per liter, **ug/m3** = micrograms per cubic meter, **EPA Rfc** = EPA 's Reference Concentration for no risk, **ACGIH** = Screening levels; estimates of workplace exposure that these exposure at or below these levels does not create an unreasonable risk of disease or injury, **TWA** = Time weighted average, **REL** = NIOSH Recommended Exposure Limit, **PEL** = Permitted exposure level.

Typical EDD data report



Sampler
Company
Project Name

Key	
	SPF likely/possible source
	Atypically high concentration
	Exceeds EPA RSL
	Bulk sample
	Atypical compound
Red Text	Exceeds Limit

						Recommendations or Limits								
						Health/Risk Based				Workplace			Odor	
						ATSDR MRL Chronic (ppb)	CA OEHHA REL Chronic (ng/L or ug/m3)	EPA RSL Cancer (ng/L or ug/m3)	EPA RSL Non-Cancer (ng/L or ug/m3)	ACGIH TLV TWA (ppb)	NIOSH REL TWA (ppb)	OSHA PEL TWA (ppb)	Odor (ppb)	
24	1,1,2-Trichloro-1,2,2-trifluoroethane 76-13-1	95###-1 Barn Roof Slope	--	0.5	0.07				520					
25	1,2,4-Trimethylbenzene 95-63-6	95###-1 Barn Roof Slope	--	6.1	1.2				6.3		25,000		6	
26	1,2-Dichloropropane 78-87-5	95###-1 Barn Roof Slope	--	0.5	0.1			0.76	0.42			75,000	260	
27		95###-2 Barn Roof Slope	25	--	--									
28	1,3,5-Trimethylbenzene 108-67-8	95###-1 Barn Roof Slope	--	0.2	0.05				6.3		25,000		6	
29	1,4-Dioxane 123-91-1	95###-1 Barn Roof Slope	--	6.3	1.7	30	3,000	0.56	3.1			100,000	800	
30		95###-2 Barn Roof Slope	570	--	--									
31	2-Chlorotoluene 95-49-8	95###-2 Barn Roof Slope	2.5	--	--						50,000		180	
32	4-Chlorotoluene 106-43-4	95###-2 Barn Roof Slope	1.8	--	--									
33	4-Ethyltoluene 622-96-8	95###-1 Barn Roof Slope	--	0.4	0.09									

Data | SDS | Glossary

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What the Data shows

- Effectiveness of the HCFC protocol
- That the foam was of good quality
- If different foams were used or were off ratio
- All of the reds were below the EPA exposure limits

	Compounds-->	THF	D4	Triethylamine
Sample Date	Sample #			
27-Sep-21	1	0.4	-	-
	2	0.4	-	-
	3	0.5	-	-
	4	-	-	-
6-Oct-21	1	200	4	-
	2	210	5	-
	3	140	-	-
	4	0.3	-	-
25-Oct-21	1	40	4	-
	2	40	4	-
	3	39	4	-
	4	0.6	-	-
3-Nov-21	1	0.6	8	55
	2	0.6	8	170
	3	0.6	8	20
	4	0.2	-	-
9-Nov-21	1	7.9	-	-
	2	8.3	-	-
	3	9.6	-	-
	4	0.3	-	-
3-Dec-21	1	2.6	4	-
	2	2.4	5	-
	3	2.3	4	-
	4	0.1	-	-
15-Dec-21	1	9.6	4	-
	2	9	4	-
	3	14	4	-
	4	-	-	-
30-Dec-21	1	620	-	-
	2	590	-	-
	3	880	-	-
	4	3.3	-	-
		C4	C8	C6
		Solvent, adhesive	De-foamer, solvent, viscosity controller	Ammonia/Fish-like odor, catalytic solvent
				EPA HAP

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Sampling Event #1

Compound	CAS	1	2	3	4	5	6
Acetone	67-64-1	67	62	57	9.7		3.1
Pentane	109-66-0	300	290	280	12		
3-Methylhexane	591-76-4	27	25	23			
Heptane	142-82-5	22	22	21			
2-Methyl-1-propanol	78-83-1	25	22				
Isobutane	75-28-5			26			
TVOC		950	760	890	<200	<200	<200

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How can air test and bulk foam sample test results be used to verify that the occupants are safe?

1. Compare the list of off-gas compounds to the list of air compounds to determine if any SPF target or off-gas compounds are present.
2. Check the level of health risk for any matching compounds by seeing whether their concentrations are above or below the known EPA exposure limits (PEL = permissible exposure limits).
3. If there are no SPF compounds in the comparison, or they are all at safe levels, there is no safety issue for the project.

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Follow-up

- Continue isolation, ventilation, and air testing for at least as long as the cure period of the SPF after the work is complete.

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Conclusions

- This project provided safe IAQ without evacuating the buildings.
- It was different for the lab to be working on the front end of an SPF insulation installation – typically they are asked to test afterward when there are complaints.
- EH&E – gained experience in overseeing installers/remediation teams with expertise in terms of pressurizations and developing/maintaining and recording them for this type of project.
- The EDD data package was helpful for fast review of data by EH&E.
- EH&E reported that the test equipment was easy to use.

Conclusions (cont.)

- The industry standard is to evacuate a building or any adjacent spaces that are being sprayed or injected with polyurethane foam.
- This is not always possible in some high-density building occupancies.
- The intent of the industry standard for evacuation is to protect the occupants from exposure to SPF vapors that could cause health issues.
- There are other ways to provide safe protection, but they all require an understanding of isolation methods and how to constantly verify that adequate isolation is being maintained.
- Every building and every occupancy is different, so isolation methods will be different in every application.
- This complexity and additional cost is why evacuation is the standard, but in this situation, a lot of money was saved by using the alternate HCFC method.

Conclusions (cont.)

- Evacuation is always the right approach unless the installer and his laboratory are qualified to use this alternate method safely! Isolating the work, Laboratory air quality testing and recording the isolation pressure data must be part of the process.
- Just because the HCFC method has been used successfully for this project does not mean that it is safe to spray polyurethane foam without evacuating the occupants.

Thank you for your time!

QUESTIONS??

Safely Installing SPF in Occupied Buildings – Preparation and Testing (2025)

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