

Development of Test Procedure to Assess Horizontal Strain in SPF Wall Assemblies

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ABSTRACT

Spray polyurethane foam (SPF) is installed in the field. The advantage of this product is the fact that it adheres to the structure and expands to create an airtight seal. In this process it not only provides insulation and air sealing but also increases the racking strength of the structure. Buildings are “living” structures. They are impacted by the environment. As temperatures rise, building materials expand, and as temperatures drop, they contract. This puts strain on the structure that can be visible by cracks in all plaster or concrete. At this point in time, there is no method that allows SPF system houses or applicators to assess the stress load on a building assembly that spray foam has been applied to.

Building Insulation materials such as SPF are tested for dimensional stability via ASTM D2126 over a period under different environmental test conditions. This is often used by specifiers and architects to compare building materials when designing a structure. It is important to note that these tests are done under laboratory conditions and do not necessarily reflect field conditions.

This paper discusses the development of a method to measure the stress in the horizontal direction on a wooden building assembly over time. A test “fixture” was developed that allows for stress measurements over time. The key of this work is to ensure that this method developed has the required sensitivity to detect stress differences when application techniques and processing conditions vary.

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INTRODUCTION

In recent years with the increases in building energy codes, spray polyurethane foam (SPF) has grown in popularity among building designers due to its superior thermal properties and its ability to seal the building enclosure. An often-overlooked benefit of SPF is its ability to enhance a building's structural integrity. However, as weather conditions fluctuate and building materials naturally expand and contract, there is currently no effective means to assess the stress load that a building assembly will experience and the performance of the SPF. Traditional testing methodologies, such

as ASTM D2126, are used to understand the performance of the foam in a controlled environment. However, these samples are typically smaller and do not illustrate the overall foam performance or interaction with the substrate (e.g., sheathing and framing of a wall assembly) to which they are applied. In this paper the development of a testing methodology utilizing a test "fixture" to provide data from a series of experiments will be discussed to determine what impact application method and lift thickness have on horizontal strain. The answer to the following questions will be determined based on the results of this work:

1. Can the test fixture detect differences in stress when foam is sprayed within and outside the manufacturer's recommendations?
2. Does spray application method impact frame stress?
3. Is there any correlation between the test fixture stress results and changes in foam thickness over time?

Finally, it will be explained in this paper how the test fixture is constructed and how the testing was performed for this study.

BACKGROUND

Hydrofluoroolefin (HFO) blown spray polyurethane foam was introduced to the market in 2014. By 2017, several manufacturers increased the maximum pass thickness of the new HFO foams from 2 inches to between 3 to 6 inches. The introduction of these "high-lift" foams led to a rise in reported field issues, including shrinkage, poor cell structure, delamination and cracking, reduced core density, decreased compression strength, and inconsistencies in yield. In response to these challenges, the Spray Polyurethane Foam Alliance (SPFA), published a TechTip article addressing high-lift closed cell spray foam insulations. During this period, a test fixture was developed to simulate high-lift foam stress on a building assembly structure. Furthermore, In January 2022, SPFA established a high-lift task group to assess the performance of high-lift foams and to correlate application techniques to building assembly stress. In November 2024, the high-lift task group conducted experiments with the aim of developing an evaluation protocol to simulate assembly stress.

TEST FIXTURE

With the introduction of high lift foam formulations, a new test fixture was developed to assess the stress of foam in a building assembly. The test fixture was created to help identify potential issues, such as shrinkage, and the foam pulling away from the substrate before the foam was applied in real-world conditions.

To streamline the spraying process and mimic actual field applications a test fixture was developed. The overall dimensions of the frame features a spraying cavity resembling a 16" on-center stud wall, with an internal width of 14½" and length of 44 ½". During spraying, the frame will be positioned on its side to simulate real wall studs. The frame is primarily constructed from 2" x 6" nominal lumber, with its overall dimensions increased to 47 ¾" x 36 ½". The floating board, to which the crane scale is attached, measures 2" x 6" x 44 ¼". Instead of using cardboard for the spraying substrate, ½" Oriented Strand Board are employed. The OSB is secured in place, except for at the floating board. The floating board is initially screwed into the sides of the frame. All gaps are masked to prevent foam from seeping underneath adhering the OSB to the floating board.

Picture 1. Large test fixture



Picture 2. Large test fixture with 1/2" OSB Backing Board



Picture 3. Large test jig after being sprayed



A crane scale is a specialized device designed for weighing loads suspended from cranes or other lifting mechanisms. The mini crane scales used in this context measure the force in pounds exerted by the foam on the floating board. The crane scale is suspended between the upper part of the frame and the floating board with an inverted J-hook, which is threaded and bolted through the boards. Before testing, the crane scales are zeroed, and the hooks are tightened until a force of 5 lbs. is displayed on the crane scale. After the frame is sprayed and before the floating board is released, the crane scale is zeroed again to ensure that any force detected on the floating board reflects the actual force exerted as the foam is curing.

Picture 4. Mini crane scale



TESTING METHOD

The high-lift foam task group, which was formed under the SPFA Building Envelope Committee, consists of a small group of SPFA consultants, spray foam suppliers, and spray foam contractors. The initial premise of the study was to evaluate the installation performance of high-lift foams and then correlate application techniques with foam quality. Before the testing was performed, the task group devised testing protocols of what variables would be tested along with a list of test protocol constants. Since the primary purpose of this work is to evaluate the sensitivity of this method/fixture to variances in stress, it was decided to use a non-high-lift formulation. This allows the team to assess whether the test fixture could detect changes that the variables, such as spray pattern, pass thickness, and pass count, might cause in assembly stress.

Table 1. Test Protocol Constants

Manpower		Methods	
Applicator: Jeremy Ramer -TruTeam		30 sec between passes (except 2 controls)	
Honeywell Lab Personnel		Substrate Moisture Probe/Temperature Heat Guage	
Materials		Crane Digital Load Gage	
HFO Medium Density Closed Cell Spray Foam (Non-High Lift)		Frame Release Time = 30 min	
Wooden Test Jigs		Wood Moisture – Pin Gauge	
Cardboard Liner		Ambient Temperature/Humidity – Standard	
Machine		Measurement	
Graco H40, 10/50ft hose		Frame Moisture	
AP Fusion Gun with 4242 Mixing Chamber		Room Temperature/Humidity	
Material Temp= 80°F		Exotherm – 3 pts using Thermocouples @ 10 second intervals for 48hr	
Temperature A/B = 120°F		Foam Property Testing	
Pressure 1200 psi		Frame Testing	

Testing being done adhered to a predetermined plan of spray techniques and lift configurations established by the task group. All tests were sprayed with a 30-second wait time between each lift, except for the two control samples. For control 1, each lift was sprayed after waiting until the surface temperature of the previous lift reached 100°F. For control 2, each lift was sprayed 30 minutes after the previous lift. Each fixture would sit in the spray hood for 15 minutes from the time after the final lift was applied. The test fixture was then relocated to a secondary curing room and at 30 minutes from the first lift application (except in the case of the 2 controls where it was 30 minutes from the last lift applied). The floating board was then released from both sides of the fixture simultaneously through removing the support screws.

Table 2. High Lift Study Spray Plan

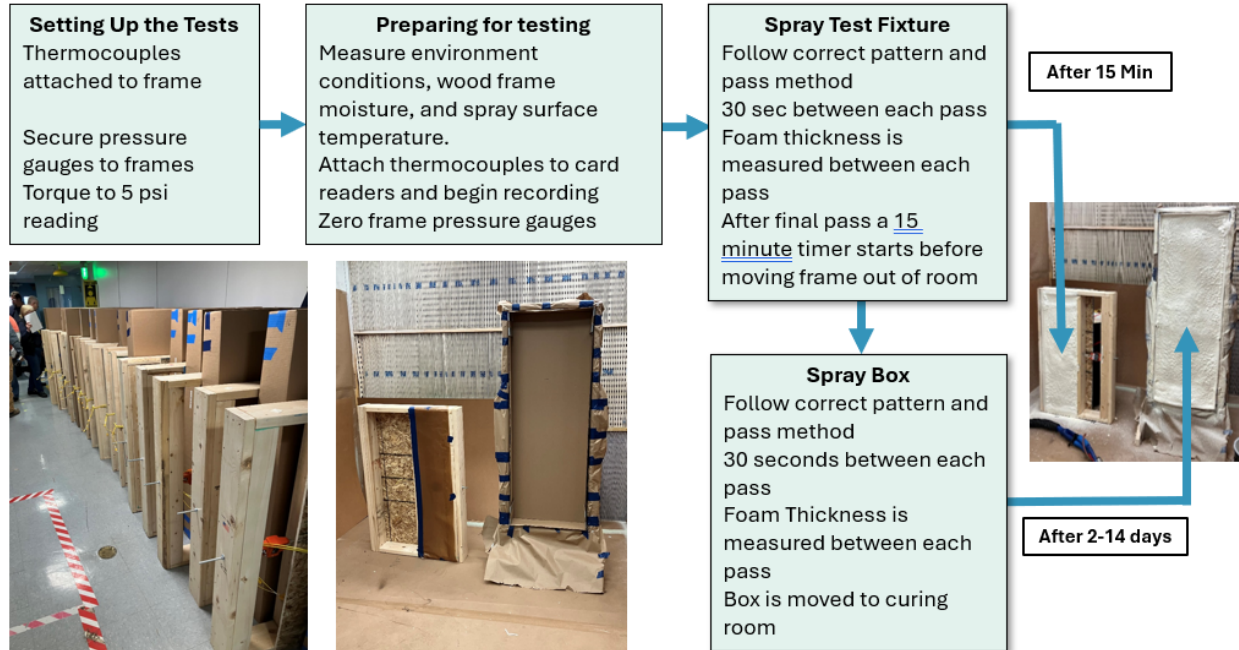
Picture Frame (PF)	Spray Direction	# Passes @ Pass thickness				Control
		6 @ 1"	3 @ 2"	2 @ 3"	1 @ 5"	
Yes	Side to Side	✓	✓	✓	✓	-
No	Side to Side	✓	✓	✓	✓	-
Yes	Vertical	✓	✓	✓	✓	-
No	Vertical	✓	✓	✓	✓	-
Yes	Rising Foam	-	✓	✓	-	-
No	Rising Foam	-	✓	✓	-	-
No	Vertical	-	-	-	-	(1)
No	Vertical	-	-	-	-	(2)

*Non-High Lift HFO medium-density closed cell foam applied
 -Control Foam – Sprayed without picture frame in Vertical Direction
 (1) Waiting until surface temperature reaches 100°F before next pass
 (2) Waiting 30 minutes between passes

Once the floating board was released, scale readings were taken every 15 minutes for the first hour. Following that, readings were recorded hourly for the next 48 hours. For the subsequent 7 days, measurements were taken 3 times a day. On Day 10 and Day 11, readings were recorded twice a day. From Day 12, measurements were taken 3 times a week for as long as the scale maintained battery life.

In addition to spraying each test fixture, a cardboard box configured to represent a 24" on-center wall stud was also sprayed by the same technique. This allows the foams to be tested for physical properties. These test results will be presented in a different paper¹.

Picture 5. Program Timeline¹



Picture 6. Cardboard box sprayed for physical testing

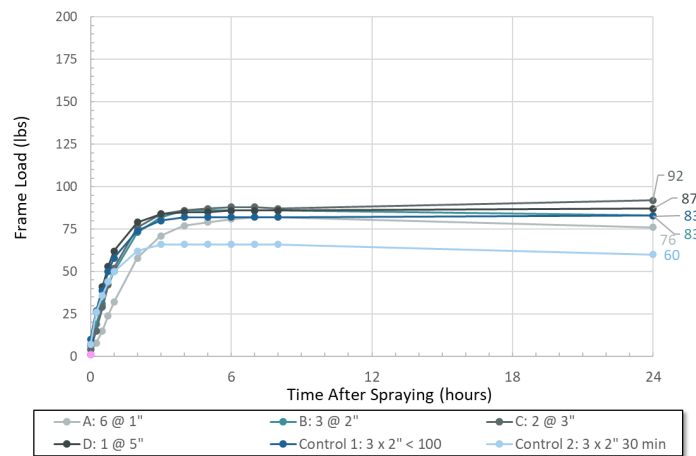


DATA AND DISCUSSION

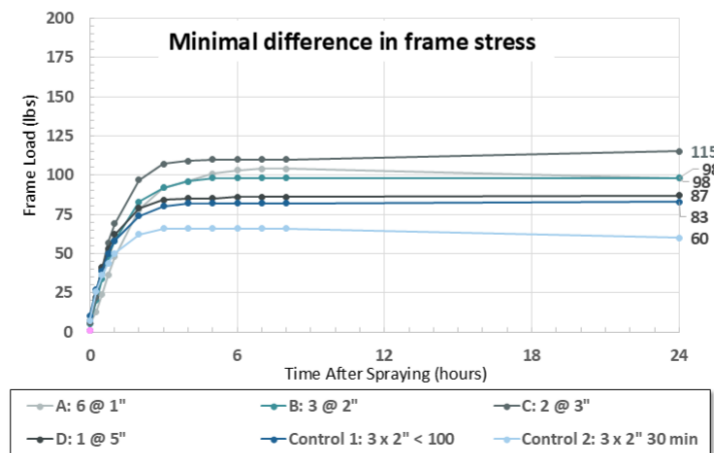
Can the test fixture detect differences in stress when foam is sprayed within and outside the manufacturer's recommendations?

Since it is well documented that spraying outside manufacturers recommended conditions can yield poor quality foam and potentially result in field failures, a non-high lift medium density HFO spray system was chosen for this testing. This allows the team to determine if the test fixture can detect any impact on horizontal strain from the spray method or pass thickness. The results will illustrate what impact spraying outside of the manufacturers specifications have on building assembly stress. Shown below are the different spray patterns and lift configurations versus the frame load (lbs), measured by the crane scale on the floating board when released, over 24 hours.

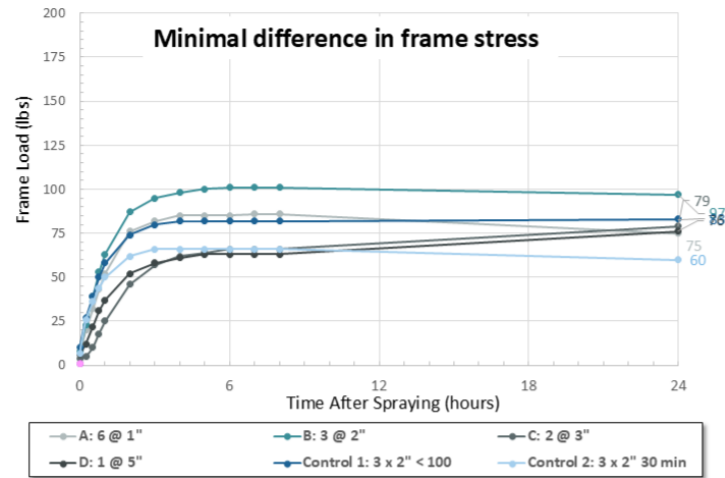
Graph 1. Frame Load vs Application Method (Vertical Spray Pattern)¹



Graph 2. Frame Load vs Application Method (Vertical Spray Pattern + Picture Framing)¹



Graph 3. Frame Load vs Application Method (Side to Side Spray pattern)¹



Graph 4. Frame Load vs Application Method (Side to Side pattern + Picture Framing)¹

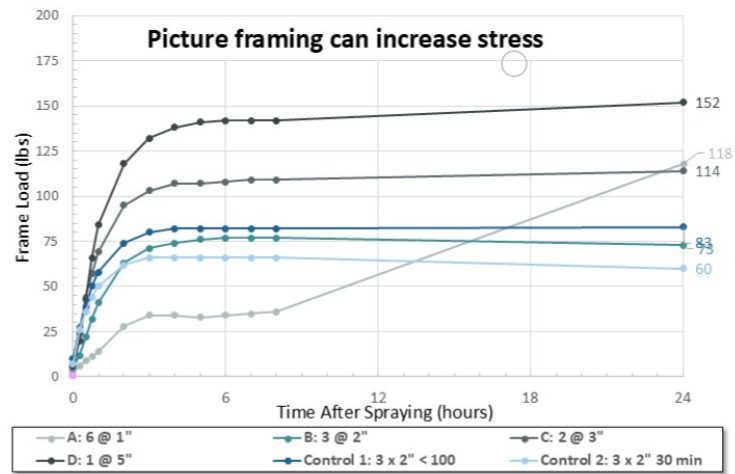


Table 3. Test Fixture Load (lbs) Vs Application after 24 hours

Spray Technique		Lift Configurations (lbs) (# Passes @ Pass Thickness)				
Picture Frame	Spray Direction	6 @ 1"	3 @ 2"	2 @ 3"	1 @ 5"	Control 3 @ 2"
Yes	Side to Side	118	73	114	152	-
No	Side to Side	75	97	79	76	-
Yes	Vertical	98	98	115	93	-
No	Vertical	76	83	92	87	-
Yes	Rising Foam	-	44	111	-	-
No	Rising Foam	-	29	180	-	-
No	Vertical	-	-	-	-	83
No	Vertical	-	-	-	-	60

Table 4. Test Fixture Load (lbs) over Extended time

Lift Thickness	Spray Technique	Day	Day 1 Load (lbs)	Day X*	Day X Load (lbs)	Δ Change	% Change@
6 x 1"	Side to Side + PF	1	118	8	61	-57	-48%
	Side to Side		75	5	77	2	3%
	Vertical + PF		98	5	107	9	9%
	Vertical		76	5	84	8	11%
3 x 2"	Side to Side + PF	1	73	5	84	11	15%
	Side to Side		97	6	107	10	10%
	Vertical + PF		93	6	94	1	1%
	Vertical		83	31	132	49	59%
	Into Rising Foam + PF		44	5	57	13	30%
	Into Rising Foam		29	5	33	4	14%
2 x 3"	Side to Side + PF	1	114	5	113	-1	-1%
	Side to Side		79	8	96	17	22%
	Vertical + PF		115	31	116	24	1%
	Vertical		92	31	116	24	26%
	Into Rising Foam + PF		111	31	118	7	6%
	Into Rising Foam		180	3	176	-4	-2%
1 x 5"	Side to Side + PF	1	152	28	175	23	15%
	Side to Side		76	4	85	9	12%
	Vertical + PF		93	31	110	17	18%
	Vertical		87	4	85	-2	-2%
Controls	Control 1 [^]	1	83	31	71	-12	-14%
	Control 2 [#]	1	60	8	47	-13	-22%

* It should be noted that battery life of each crane scale was not consistent resulting with varying Day X values. Future testing will address this

@ Percent Difference equation $((\text{Day 1} - \text{Day x}) / \text{Day 1}) = \text{Percent Difference}$

[^] Control 1 – No Picture frame, Vertical pass method, waiting to spray next lift until surface temperature reads 100°F

[#] Control 2 – No Picture frame, Vertical pass method, waiting 30 minutes between spraying each lift.

Conclusion:

The manufacturers specification for spraying dictates no larger than a 3" pass and waiting until the surface temperature at least reaches 100°F before spraying the next pass. As a result, both control 1 and control 2 have a lower 24 hour frame pressure as well as lower frame load over time. In most cases, an increase in frame load values was observed over extended time when spraying outside of the 2" lift. However, given that all samples, except the controls, were sprayed with only 30 seconds between each pass, they were all outside of manufacturer specifications. Aside from a few outliers, most samples shown an increase in frame load after the initial 24 hours. The two control samples, which both had relatively lower initial numbers, demonstrate decreases in frame load over extended time as illustrated by having a large negative percent change.

Does spray application method impact frame stress?

According to the manufacturer's specifications, the system should be sprayed vertically from a distance of 18 inches above the surface. Prior to spraying, the surface temperature and moisture content were measured and found to be within the manufacturer's guidelines. It was determined that spraying into rising foam negatively impacts cell structure and since it was sprayed to demonstrate the negative effects of this application method the results obtained from that testing will not be discussed here. Testing variations were conducted using four different application configurations: picture frame with side-to-side application, no picture frame with side-to-side application, picture frame with vertical application, and no picture frame with vertical application.

Table 5. Test fixture load (lbs) comparing picture frame (PF) and non-picture frame side to side application

Lift Thickness	Spray Technique	Day 1 Load (lbs)	Spray Technique	Day 1 Load (lbs)	% Difference
6 x 1"	Side to Side + PF	118	Side to Side	75	36%
3 x 2"	Side to Side + PF	73	Side to Side	97	-33%
2 x 3"	Side to Side + PF	114	Side to Side	79	31%
1 x 5"	Side to Side + PF	152	Side to Side	76	50%

Table 6. Test fixture load (lbs) comparing picture frame (PF) and non-picture frame vertical application

Lift Thickness	Spray Technique	Day 1 Load (lbs)	Spray Technique	Day 1 Load (lbs)	% Difference
6 x 1"	Vertical + PF	98	Vertical	76	22%
3 x 2"	Vertical + PF	93	Vertical	83	11%
2 x 3"	Vertical + PF	115	Vertical	92	20%
1 x 5"	Vertical + PF	93	Vertical	87	6%

Table 7. Test fixture load (lbs) comparing picture frame (PF) side to side and vertical results

Lift Thickness	Spray Technique	Day 1 Load (lbs)	Spray Technique	Day 1 Load (lbs)	% Difference
6 x 1"	Side to Side + PF	118	Vertical + PF	98	17%
3 x 2"	Side to Side + PF	73	Vertical + PF	93	-27%
2 x 3"	Side to Side + PF	114	Vertical + PF	115	-1%
1 x 5"	Side to Side + PF	152	Vertical + PF	93	39%

Table 8. Test fixture load (lbs) comparing non-picture frame side to side and vertical application

Lift Thickness	Spray Technique	Day 1 Load (lbs)	Spray Technique	Day 1 Load (lbs)	% Difference
6 x 1"	Side to Side	75	Vertical	76	-1%
3 x 2"	Side to Side	97	Vertical	83	14%
2 x 3"	Side to Side	79	Vertical	92	-16%
1 x 5"	Side to Side	76	Vertical	87	-14%

Conclusion:

It is important to understand that many of these samples were not sprayed according to the manufacturer specifications. However, the data in Tables 5 and Table 6 illustrate that employing the picture framing application alongside either spray application method typically results in higher test fixture loading values after 24 hours. Meanwhile, the data from Tables 7 and Table 8 reveal varying differences when comparing the side-to-side and vertical spray application methods. Generally, the picture framing variations of these methods exhibit higher values; while the comparison between the side-to-side and vertical iterations demonstrates inconsistent differences. The standard side-to-side and vertical application results indicate only minimal or slight variations in load pressure after 24 hours.

Is there any correlation between the test fixture stress results and changes in foam thickness over time?

A total of 22 variations in application methods were tested throughout the study. For each application method (refer to Table 2), one test fixture was sprayed. The use of the test fixture for assessing assembly stress has been extensively discussed. When foams physically change, they can change in both vertical and horizontal directions. The test fixtures load gauge measures stress in the horizontal direction. Another test conducted on the test fixture involved measuring changes in material thickness. During the application process, lift thickness was measured after each pass. Overall foam thickness of the test fixture was recorded initially and again at 8, 24, and 45 days. These data are listed in Table 9.

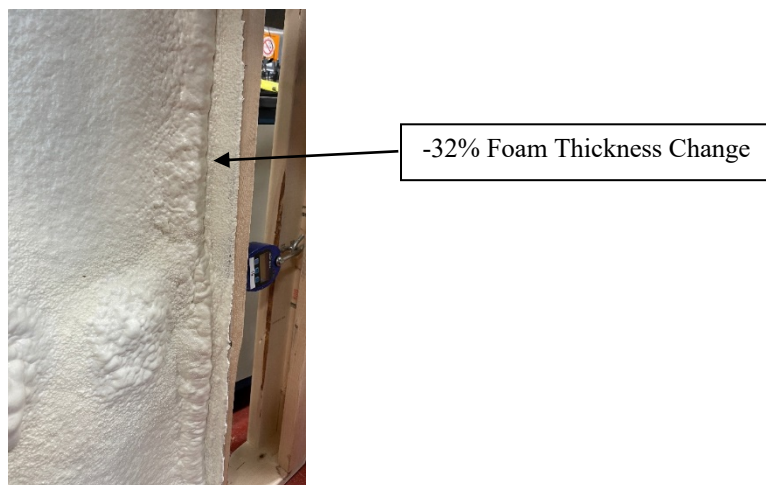
Table 9. Comparing Test frame Load on Day X to changes in foam thickness

Application Method		Frame Load (lbs)		Frame Foam Thickness Change		
Lift Technique	Spray Technique	Day X	Day X Load	8 Day	24 Days	45 Days
6 x 1"	Side to Side + PF	8	61	-3%	-4%	-6%
	Side to Side	5	77	-18%	-12%	-12%
	Vertical + PF	5	107	6%	6%	6%
	Vertical	5	84	15%	13%	13%
3 x 2"	Side to Side + PF	5	84	-5%	-3%	-4%
	Side to Side	6	107	-2%	-1%	-3%
	Vertical + PF	6	94	-19%	-19%	-18%
	Vertical	31	132	-16%	-5%	-9%
	Into Rising Foam +PF	5	57	-2%	-3%	-2%
	Into Rising Foam	5	33	9%	9%	9%
2 x 3"	Side to Side + PF	5	113	7%	7%	7%
	Side to Side	8	96	-8%	-3%	-5%
	Vertical + PF	31	116	-17%	-17%	-17%
	Vertical	31	116	-10%	-10%	-11%
	Into Rising Foam +PF	31	118	5%	4%	2%
	Into Rising Foam	3	176	-4%	-3%	-5%
1 x 5"	Side to Side	4	85	-36%	-36%	-36%
	Vertical + PF	31	110	-31%	-33%	-32%
	Vertical	4	85	-25%	-28%	-25%
Controls	Control 1 [^]	31	71	6%	2%	1%
	Control 2 [#]	8	47	-1%	-8%	-4%

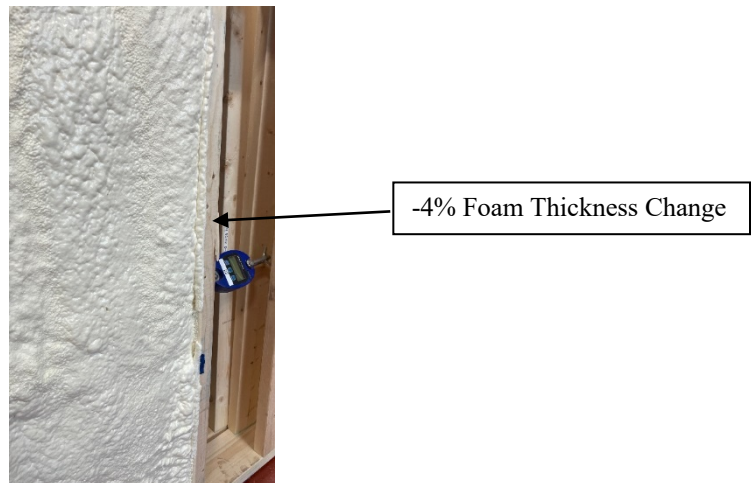
[^] Control 1 – No Picture frame, Vertical pass method, waiting to spray next lift until surface temperature reads 100°F

[#] Control 2 – No Picture frame, Vertical pass method, waiting 30 minutes between spraying each lift.

Picture 7. Frame Foam Thickness – Frame 19 1 x 5" Vertical + PF



Picture 8. Frame Foam Thickness – Frame 22 3 x 2” Vertical - Control 2 – 30min between passes



Conclusion:

Foam application impacts stress in both the vertical and horizontal directions. Significant changes in foam thickness may reduce stress, which is reflected in the fixture load measurements. Analyzing the 3 x 2” vertical samples with and without picture frame, it was observed that while previous results indicated that samples with picture frame exhibit higher initial assembly stress, the picture frame specimen shows a greater loss in foam thickness, leading to a reduction in frame assembly stress. This trend is also evident in the 2 x 3” vertical samples with and without picture frame, as well as between the two control samples. Therefore, any method developed to determine assembly stress should incorporate measurements in both the horizontal and vertical directions.

Conclusions

The primary goal of this paper was to introduce a new test method for spray applied polyurethane foam. There are certain foam characteristics that ASTM testing methods cannot predict for field applied materials. However, new test methods introduced should be thoroughly vetted and results should be analyzed to ensure the value and accuracy of this new methodology.

In this paper, there were three questions asked:

- ***Can the test fixture detect differences in stress when foam is sprayed within and outside the manufacturer’s recommendations?***
- ***Does spray application method impact frame stress,***
- ***Is there any correlation between the test fixture stress results and changes in foam thickness over time?***

All three questions have been answered, and the relevance of each question and answer must now be understood.

It has been shown that the test fixture does show the differences between spraying within and outside of manufacturers specifications. The relevance is when spray foam manufacturers are bringing new materials to market, they will have a new method for testing the extremes of their systems. With the advent of high lift foam systems, this testing methodology provides system houses with a means to assess the limits of their systems. It allows them to evaluate the impact of factors, such as pass thickness and the time between passes, on foam performance.. This test method will help the industry to understand the amount of stress and strain that spraying foam between rafters or stud walls may cause. It may also help prevent issues such as foam pulling away from the studs and shrinkage, both of which will break the thermal and moisture barriers, which can lead to larger problems in the building.

The second question addressed whether the spray application method impacts the building assembly stress measured by the test fixture. It is important to remember that this test was conducted with a system sprayed outside the recommended manufacturer application guidelines. Also, that this is a single data point. The data shows that the most significant impact on horizontal stress observed resulted from picture framing the interior stud cavity before applying

either spray method. While some manufacturers provide recommendations on spray techniques, they primarily focus on substrate and material conditions. The relevance of our findings lies in the fact that picture framing the interior stud cavity increases horizontal stress, which could lead to separation from the stud wall or delamination issues if the substrate or material conditions are not within manufacturers specifications during application. Although the choice of application method is often based on the personal preferences of the spray foam applicator, further investigation suggests that the use of picture framing may want to be reconsidered by the industry, as future complications could be posed by this approach.

The final question considered whether there is any correlation between the test fixture stress results and changes in foam thickness direction over time. The data suggests that if there is significant foam thickness loss over time the frame stress is reduced. This is anticipated. As a result, both foam thickness vs time and vs frame stress need to be measured in any test procedure adopted.

While additional testing is necessary to fully validate this new testing method, this paper demonstrates that the test fixture provides valuable data which may help to determine material application specifications and enhance our understanding of stress in building assemblies under the real-world conditions.

REFERENCES

¹ “Development of an Evaluation Protocol for Closed-Cell SPF”, Mary Bogdan and Rick Duncan; 2025 Spray Foam Convention and Expo – Daytona Beach, FL February 12, 2025

Patrick Stehley



Patrick Stehley is a Sr. Advanced R&D Scientist for Honeywell. He holds a B.S. in Environmental Science with a Minor in Chemistry from Lock Haven University. Patrick started his career in October 2000 at Air Products and Chemicals as a technician helping develop catalysts and surfactants. In 2005 he joined Bayer (now Covestro) working with Elastomers and later would join the Flexible Foam Raw Material group performing research and technical service on polyols and Isocyanates. He joined Honeywell in May 2022 in the Technical Sales and Service group working with Fluorinated Blowing Agents in Buffalo, NY.

Mary Bogdan



Mary Bogdan is a Fellow 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 30 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. In 2022 she was presented with the CPI Distinguished Leadership Award. In 2023 she was named “Hero in Chemistry” by ACS for her work in development of HFO blowing agents.

Rick Duncan



Rick brings nearly 30 years of experience in technical marketing, building science, and product/business development to deliver new materials and applications to the construction market. Drawing from his prior teaching experience, Rick simplifies complex building envelope issues and clearly describes solutions for construction and design professionals. Rick served as new product development director for CertainTeed/Saint-Gobain Insulation from 1997-2006, Marketing Manager with Honeywell Specialty Materials. More recently Rick served as technical director of the Spray Polyurethane Foam Alliance from 2008-2020, and as executive director from 2020 until his retirement in 2024. As a current technical consultant to SPFA, he oversees all technical activities for the organization. He holds a Ph.D. in Engineering Science and Mechanics Penn State University, MSME from Bucknell University and a BSME from the University of Maryland. Rick is a Registered Professional Engineer in Pennsylvania.

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