2025 SPRAYFOAM Convention & Expo
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Development of an Evaluation Protocol for Closed-Cell SPF

PART II TEST RESULTS

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Mary Bogdan
Research Fellow - Honeywell

Mary Bogdan is a Research Fellow for Honeywell and is the Technology Lead for the Blowing Agent Technical Sales and Service Group. She earned a bachelor's degree in Chemistry/Biochemistry and an MBA from Canisius University. Since joining Honeywell in 1989, Mary has held numerous positions in research and development. She currently supports the global fluorine products blowing agent business.

Over her career, she has worked on the introduction of Honeywell's HCFC, HFC and HFO technology across many applications. She is a Six Sigma Black belt. She has more than 30 U.S. patents and has numerous published technical articles on the development and use of fluorocarbons as foam blowing agents. She has co-authored and presented several CPI papers receiving the CPI Best paper awards for 12 of her presentations. She has received a Distinguished leadership award from ACC CPI and a Heroes in Chemistry Award from the ACS.

She is on the Board of Directors for SPFA and actively represents Honeywell on several Trade Association (including ACC- CPI committees), ASTM and Building Code committees.

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Rick Duncan
Technical Consultant - SPFA

Rick brings more than 25 years of experience in technical marketing, building science, and product/business development delivering 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 technical director of SPFA from 2008-2020, and as executive director from 2020 to 2024. As a technical consultant to SPFA, he oversees all technical activities for the organization. He holds a Ph.D. in Engineering Science and Mechanics Penn State, MSME from Bucknell and a BSME from the University of Maryland. Rick is a Registered Professional Engineer in Pennsylvania.

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Overview

Task Group

Evaluation Protocol (Current Research)

Frame Testing

- Exotherm Data
- Frame Load Data
- Change in Foam Thickness

Box testing:

- Density
- % Closed cell content
- Vol % Dimensional stability

Conclusions

Recommendations

SPFA High-Lift Foam Task Group

Formed under the SPFA BEC

Small group of SPFA Consultants, Suppliers, and Contractors only

Initially to evaluate installation performance of high-lift foams

Correlate application techniques with foam quality

Members:

- Mary Bogdan, Honeywell
- Tom Harris, Tom Harris PUR Consulting
- Mac Sheldon, Sheldon Consulting
- Shawn Wate, TruTeam
- George Spanos, SPI
- Rick Duncan, SPFA
- Patrick Stehley, Honeywell

SPFA High-Lift Foam Task Group

Honeywell Buffalo Research Lab Staff

Recognized for the work and dedication to completing this project

Commercial	TSS Foam Lab	Refrigeration Lab	Site Services
Stephanie Madara	Mary Bogdan	Elizabet Vera Becerra	Randy Speed
	Patrick Stehley		Tom Canti
	Molly Bartz		Brian Duke
	Matt Bennett		Gerald Mangus
	David Decker		
	David Gorski		

Test Protocol Variables

METHOD	
Pass Thickness x Number	Time Between Passes
1” x 6	30 sec
2” x 3 non-vertical	30 sec
2” x 3 vertical	30 sec, plus <100°F surface, 30 min*
3” x 2	30 sec
5” x 1	N/A

X

SPRAY DIRECTION
Vertical
Horizontal

X

SPRAY TECHNIQUE
Picture Frame
No Picture Frame

= 22

Focus Of Study- Impact of Application Variables

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Test Protocol Constant

MANPOWER
Applicator: Jeremy Ramer - TruTeam
Honeywell Lab Personnel

MATERIALS
HFO Medium Density ccSPF (non-high lift)
Wood Frames
Cardboard Liner

MACHINE
Material Temperature = 80°F
Graco H40, 10/50 ft hose
AP Fusion Gun with 4242 Mixing Chamber
Temperature A/B = 120°F
Pressure = 1200 psi

METHODS
30 sec between passes (except two controls)
Substrate Moisture Probe/ Temperature Heat Gage
Crane Digital Load Gage
Frame Release Time = 30 min
Wood Moisture – Pin Gage
Ambient Temp/Humidity – 65-70°F, 25-50% RH

MEASUREMENT
Fram Moisture
Room Temperature / Humidity
Exotherm – 3 pts using TC @ 10 sec intervals for 48h
Frame Load - 15 min first hour, then hourly for 24h+
Foam Property Testing
Frame Testing

What We Sprayed

22 Frame & Box Samples Prepared

Spray Technique/Lift Configurations			A	B	C	D	Control
	Picture Frame	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
1	Yes	Side-side	✓	✓	✓	✓	
2	No	Side-side	✓	✓	✓	✓	
3	Yes	Vertical	✓	✓	✓	✓	
4	No	Vertical	✓	✓	✓	✓	
5	Yes	Rising Foam		✓	✓		
6	No	Rising Foam		✓	✓		
7	No	Vertical <100F					(1)
8	No	Vertical 30 min					(2)

- **Non-High Lift HFO medium-density closed-cell foam applied**
- Lift configuration D was limited to 5” to avoid exothermic scorching
- Control Foam – Sprayed in No Picture Frame and Vertical Method
  (1) Waiting until surface temperature of foam reaches 100°F before next pass
  (2) Waiting 30 minutes between each pass

Frame Test

Frame Testing Timeline

Testing on 22 Sample Frames

Property	Test Method	Timeline
Exothermic Temperatures	Thermocouples with automated data acquisition	10 second intervals for up to 48 hours after spraying
Frame Load	Frame with load cell (manually recorded)	<1 hour: 15-min intervals after release 1-8 hours: 1-hr intervals 24 hours 2, 3, 4, 5, 7 or 30 days after release
Change in Thickness	Pin Probe	8, 24 and 45 days after spraying

Frame Test

Exotherm vs Application Technique

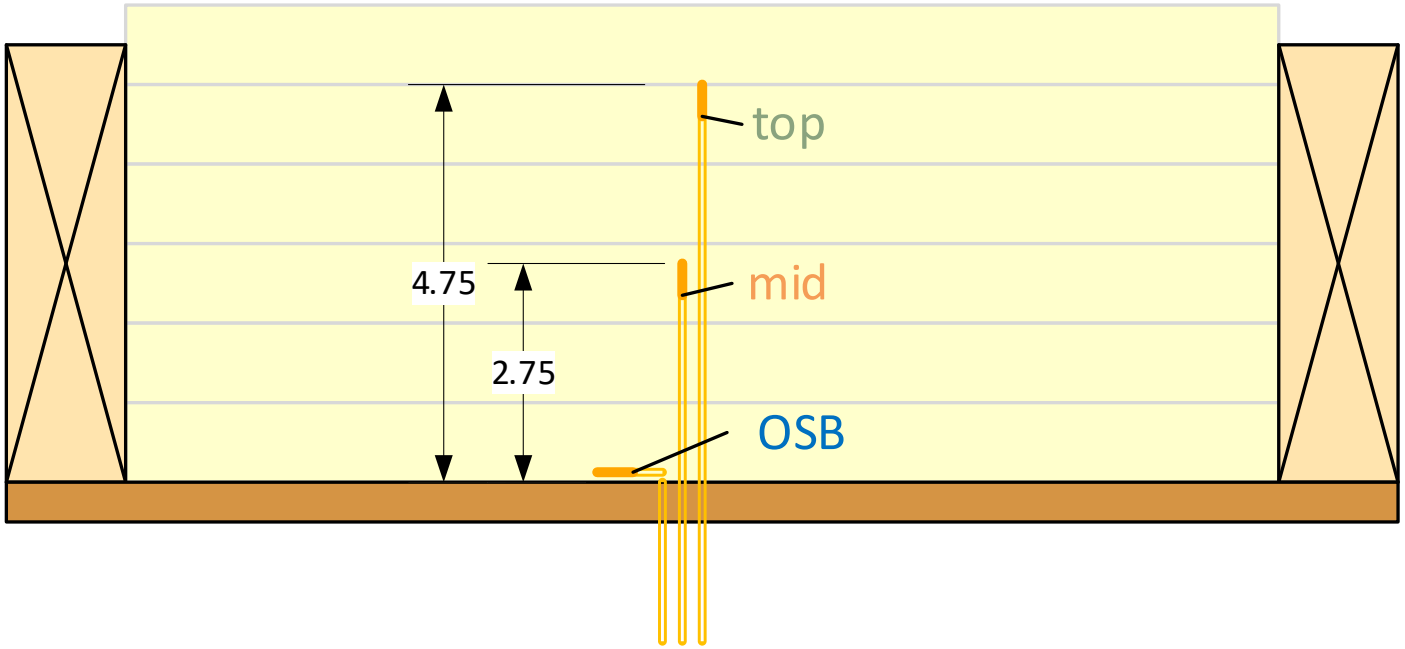
Exothermic Temperature Test

- Data: Exotherm Temperature vs. Time
- Location: top/middle/bottom of Frame
- Frequency: 10 second intervals
- Duration: 48 hours

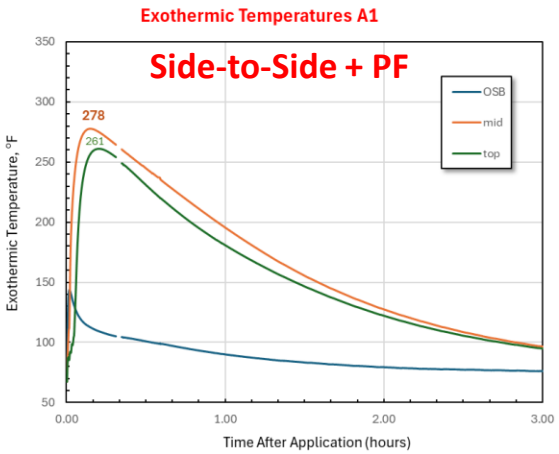
900,000 + Data Points

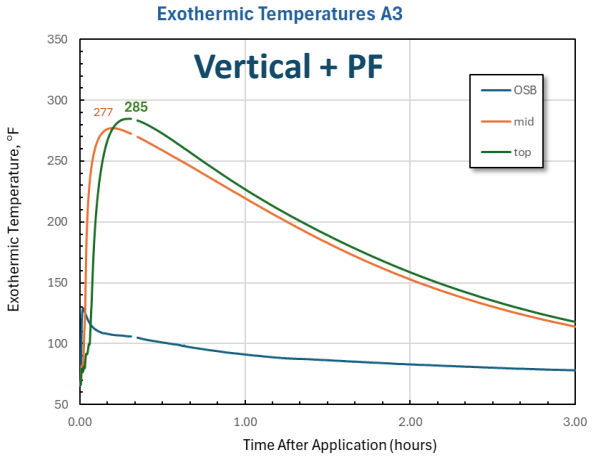
Thermocouple Placement

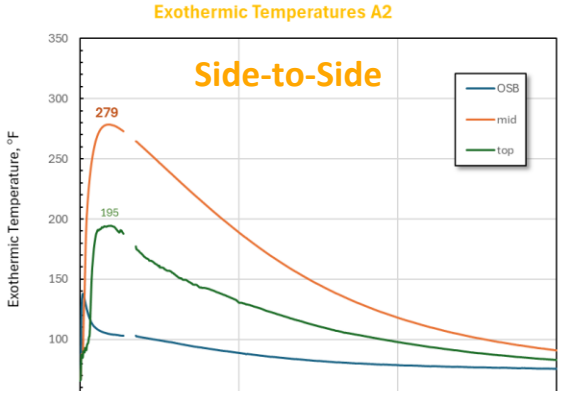
Illustration of thermocouple placement in spray frame

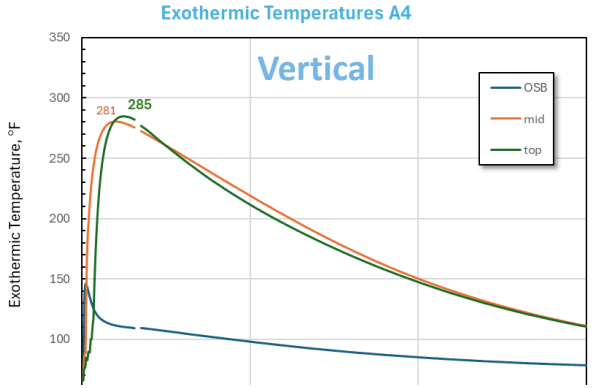


Exotherm vs Time: 6 x 1” Lifts









OSB minimal impact, Side-to-Side bigger upper layer difference

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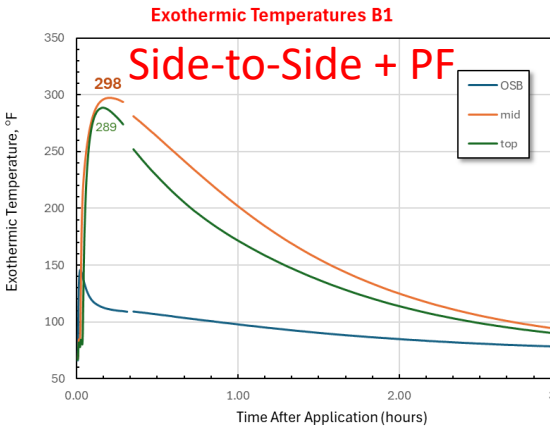
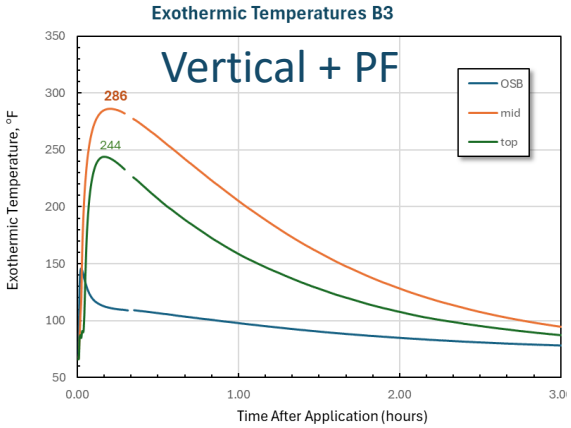
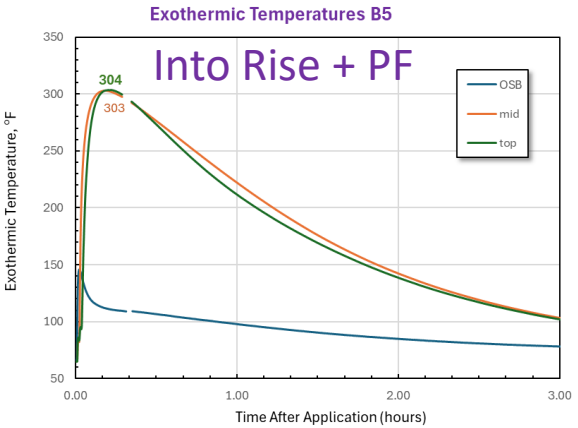
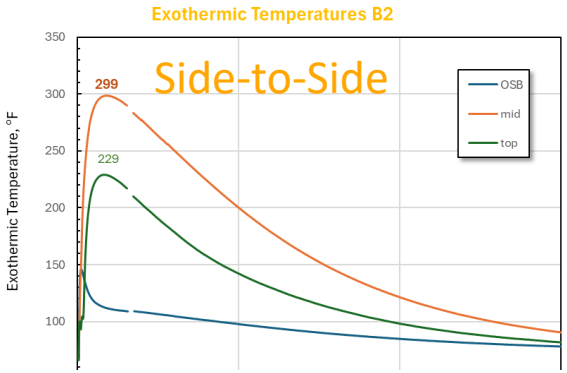
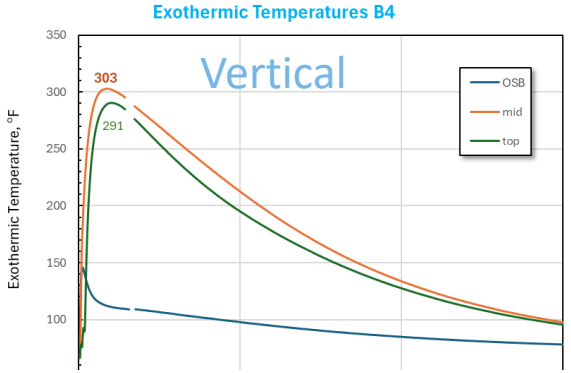
Exotherm vs Time: 3 x 2” Lifts

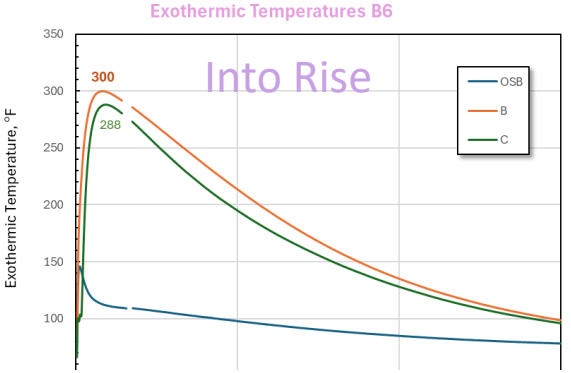












OSB minimal impact, Side-to-Side bigger upper layer difference

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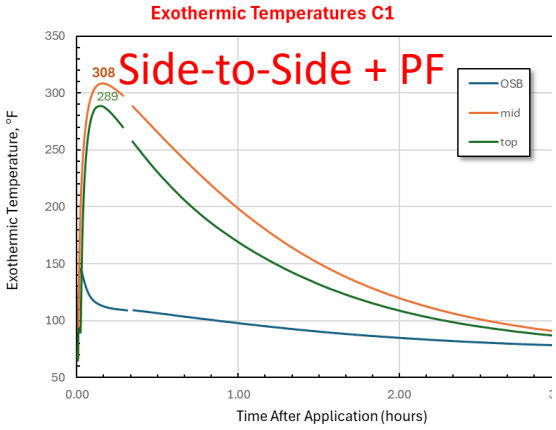
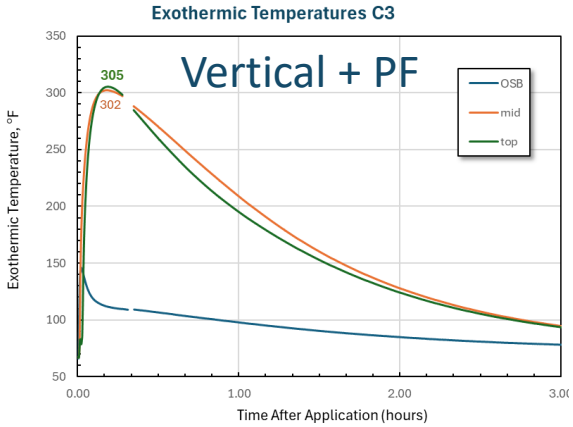
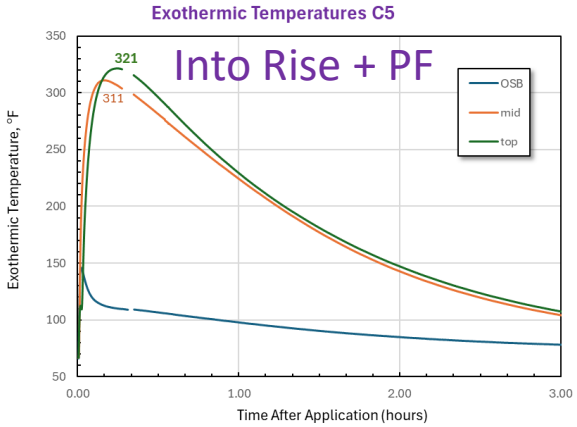
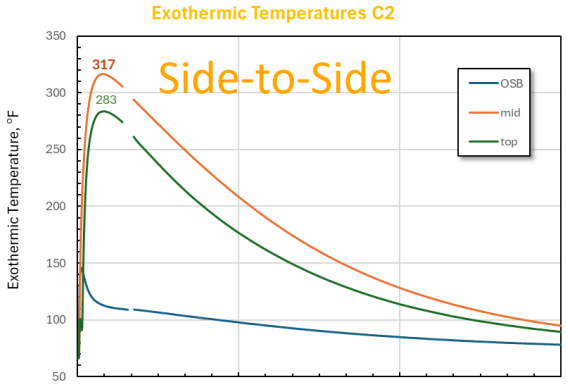
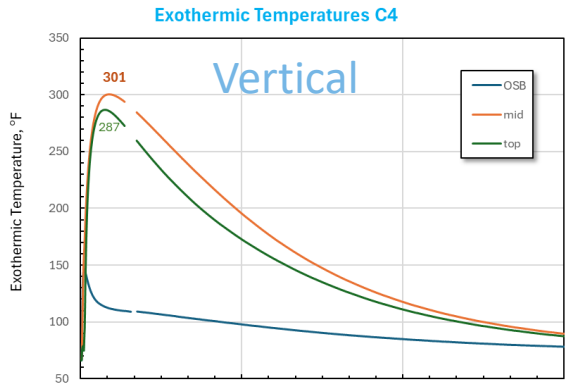
Exotherm vs Time: 2 x 3” Lifts

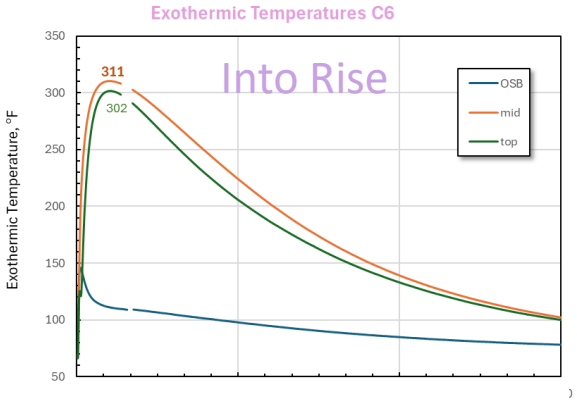












OSB minimal impact, Min upper layer differences

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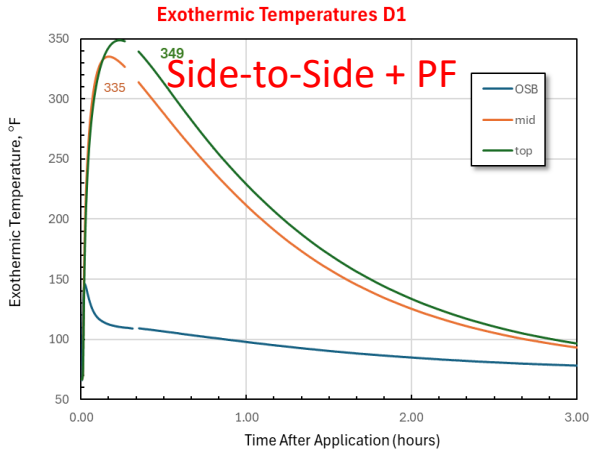
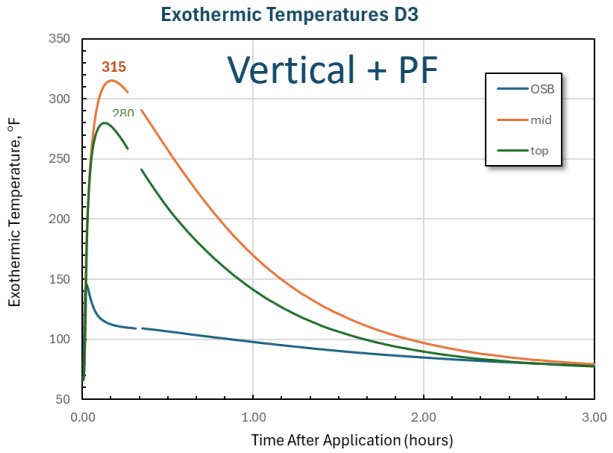
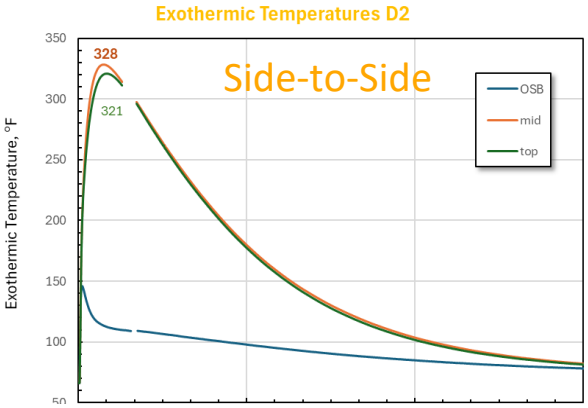
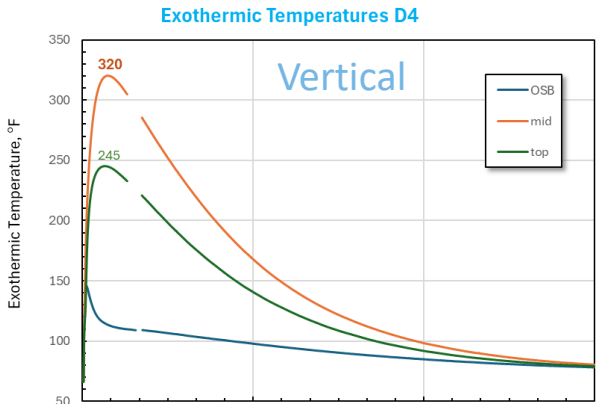
Exotherm vs Time: 1 x 5” Lift









OSB minimal impact, Vertical bigger upper layer difference

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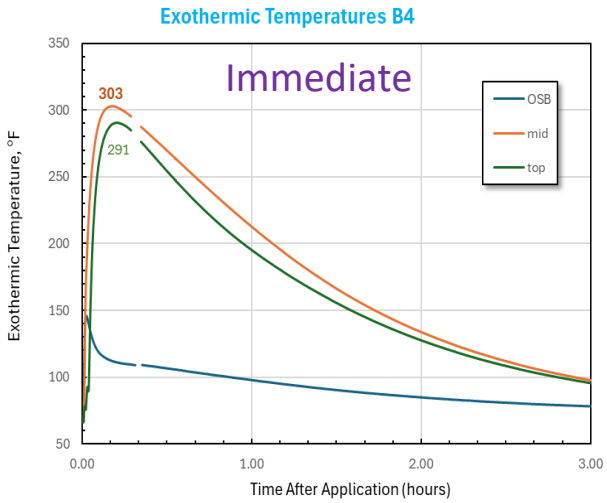
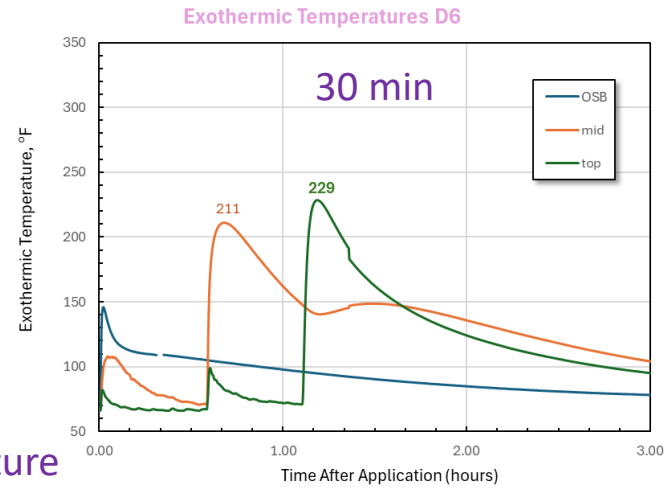
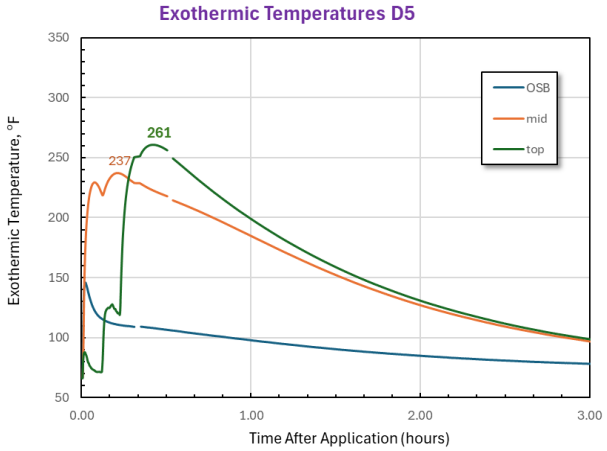
Exotherm vs Time vs Time Between Pass





<100°F Surface Temperature



3 x 2” Lift
Vertical Spray

Time between passes significant, Longer lower exotherm

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Exotherm Summary Data

Peak Exothermic Temperature (°F)		Lift Configurations				
Spray Technique		A	B	C	D	C
Picture Frame	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
Yes	Side-side	278	298	308	349	
No	Side-side	279	299	317	328	
Yes	Vertical	284	286	305	315	
No	Vertical	285	302	301	320	
Yes	Rising Foam		304	321		
No	Rising Foam		300	311		
No	Vertical <100					261
No	Vertical 30 min					229
	Average	**282**	**298**	**311**	**328**	**245**

OBSERVATIONS FOR PEAK EXOTHERMIC TEMPERATURES:

- Picture Framing has no visible impact on max temperature
- Mildly dependent on spray direction
- Heavily dependent on lift thickness
- Installation per Manufacturers Installation Instructions (MII) provide lowest peak temperatures

Application vs Time to Reach <80°F (Hr: Min)

Spray Technique		Lift Configurations				
		A	B	C	D	Control
Picture Frame	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
Yes	Side-side	5:08	4:28	4:24	4:55	
No	Side-side	4:32	4:20	4:52	3:20	
Yes	Vertical	6:14	4:49	4:51	3:26	
No	Vertical	5:48	4:39	4:28	3:34	
Yes	Rising Foam		4:31	5:41		
No	Rising Foam		5:05	5:20		
No	Vertical < 100°F surface					4:54
No	Vertical 30 min					4:20

- 6 x 1” pass took the longest time to drop below 80°F
- 1 x 5” pass took the least amount of time to drop below 80°F
- Comparing 30 second wait time to MII wait time shows insignificant difference in time to drop below 80°F

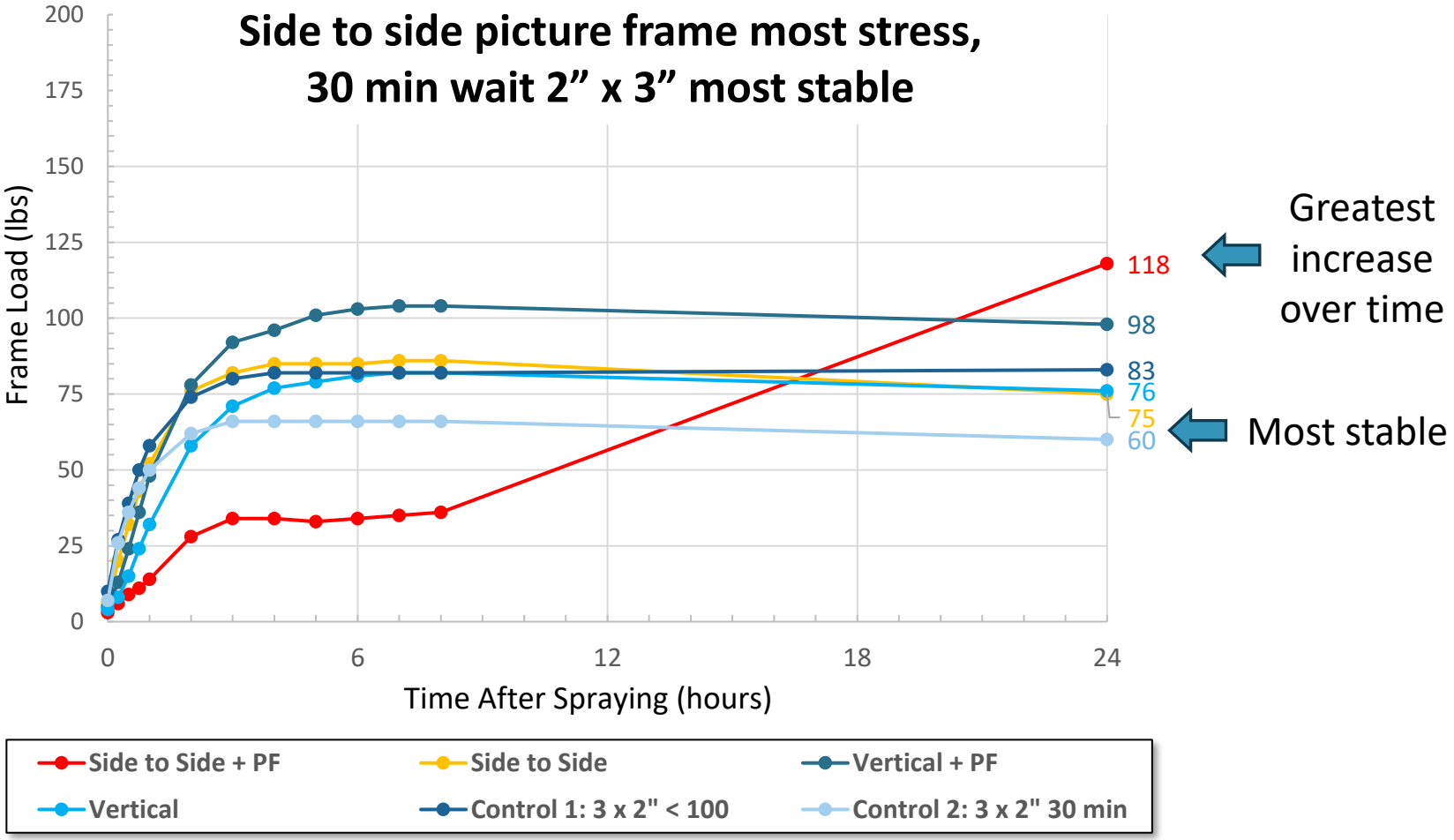
Frame Test

Frame Pressure vs Application

Frame Load Data Collection

Time	Measurement Interval
<1 hour	15 min
1-8 hour	1 hr
> 24 hours	1,2,3,4,5,7,30 Days

Frame Load vs Application (6 x 1”)



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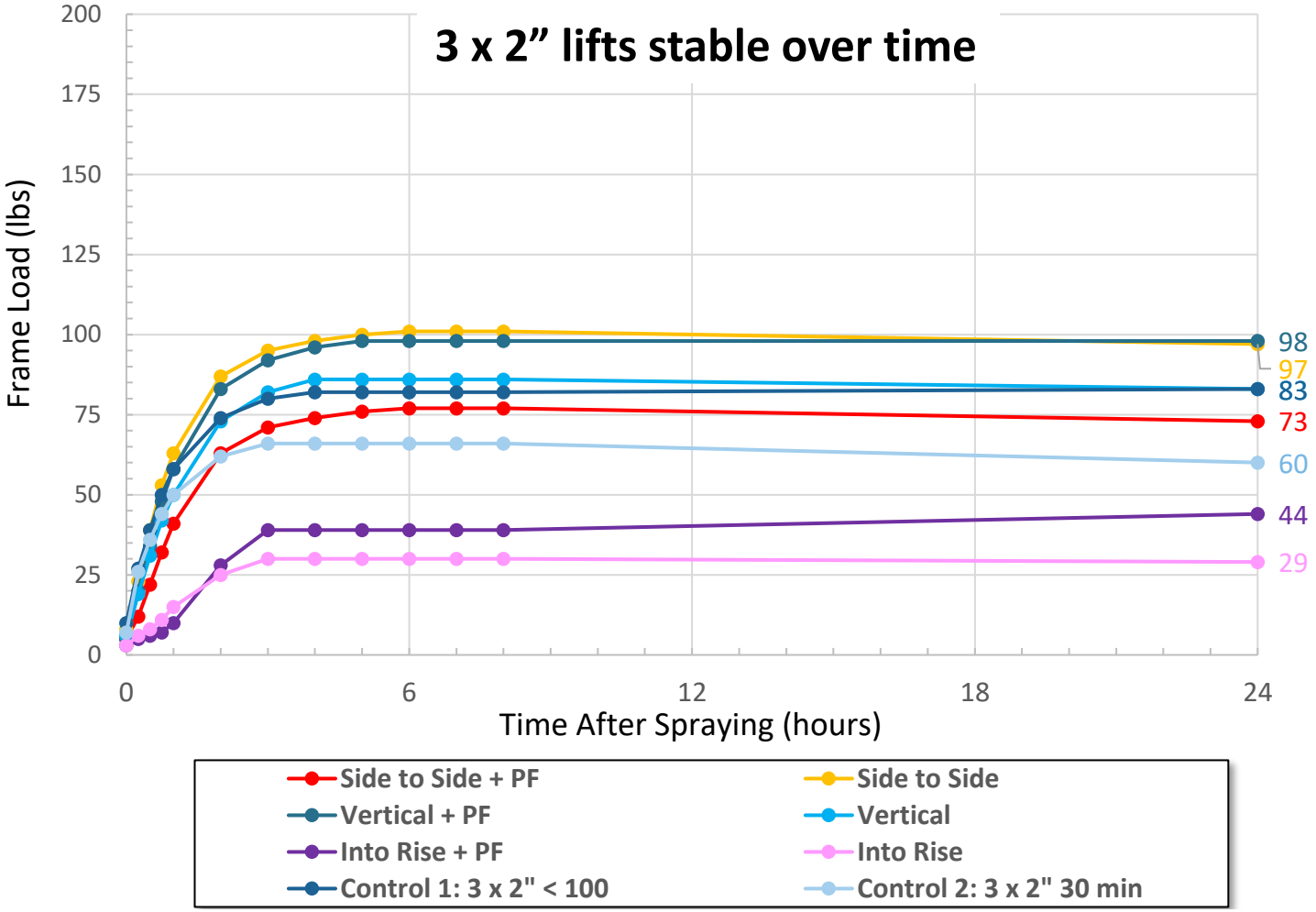
Frame Load vs Application (3 x 2”)



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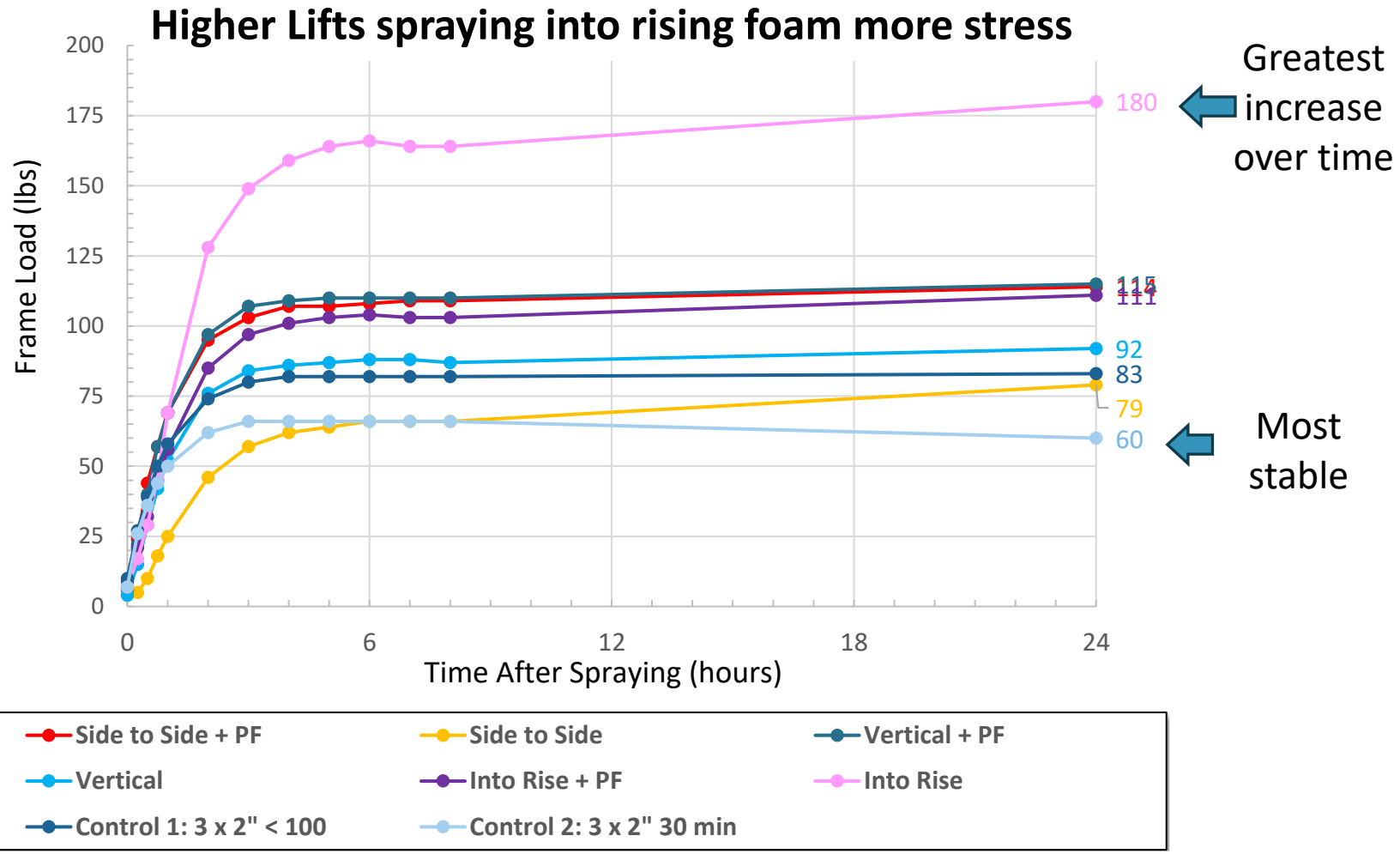
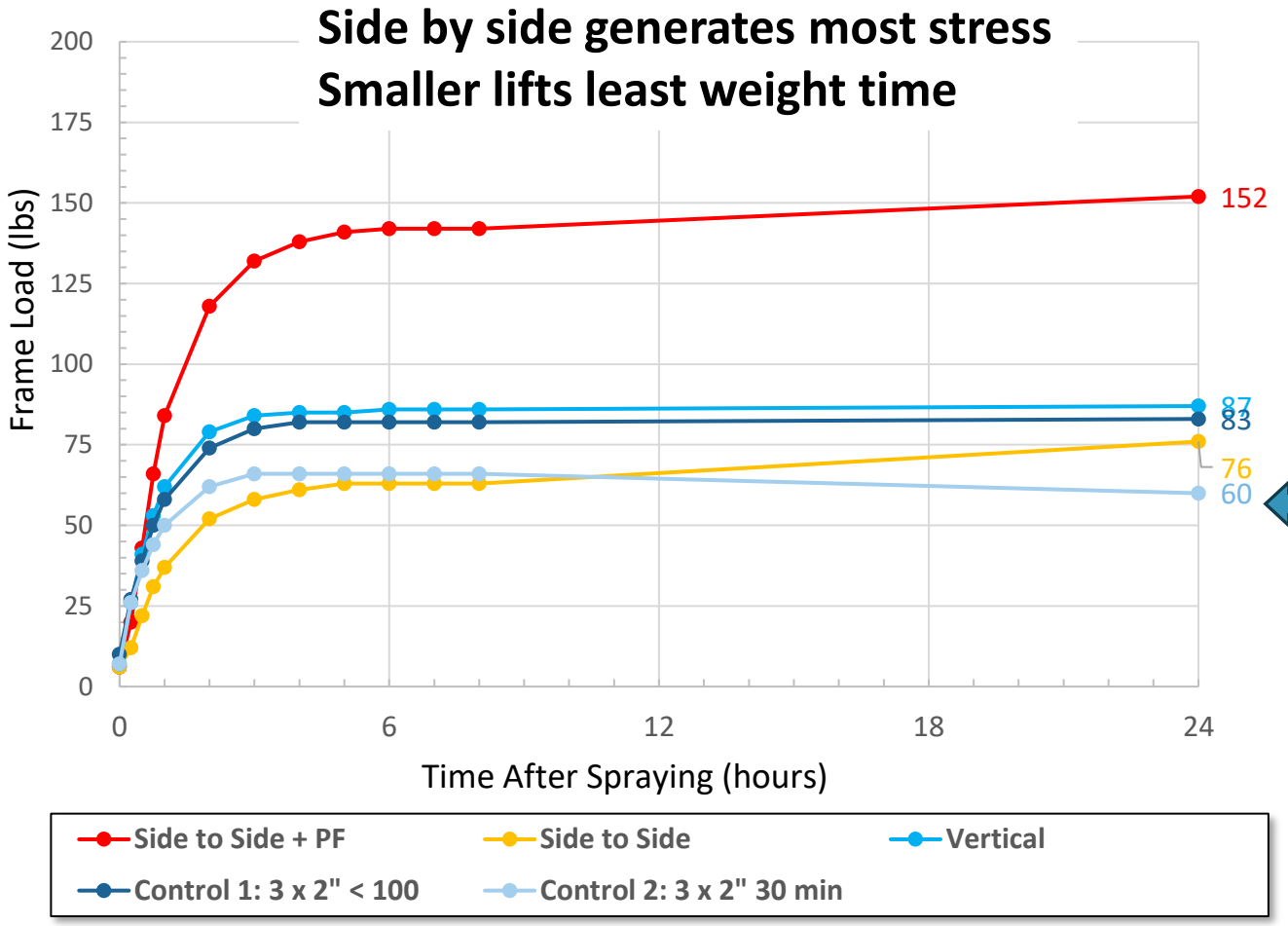
Frame Load vs Application (2 x 3”)



SPRAY POLYURETHANE FOAM ALLIANCE

Frame vs Load vs Application (1 x 5”)



Greatest increase over time

Most stable

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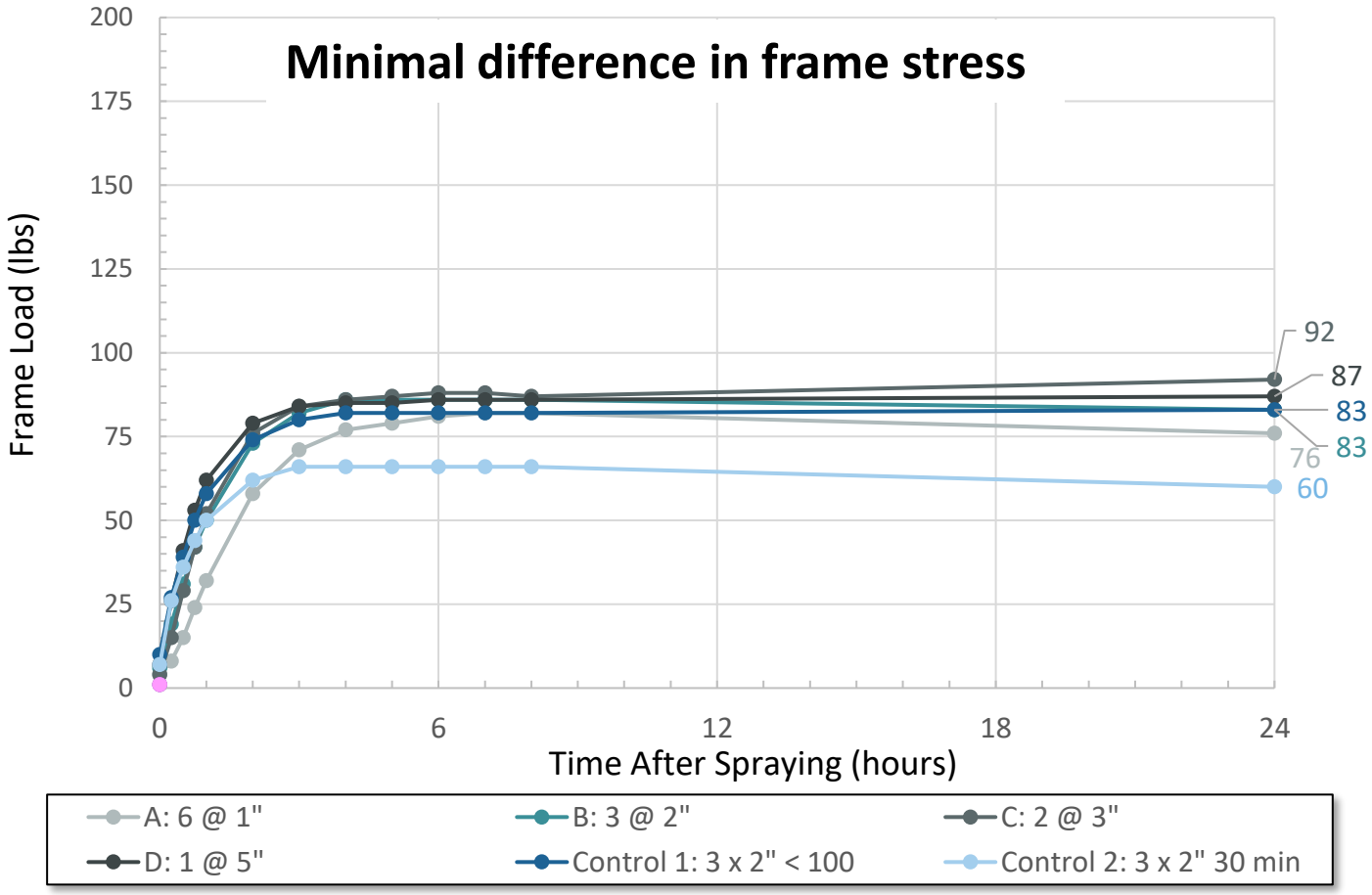
Frame Load vs Application (Vertical)



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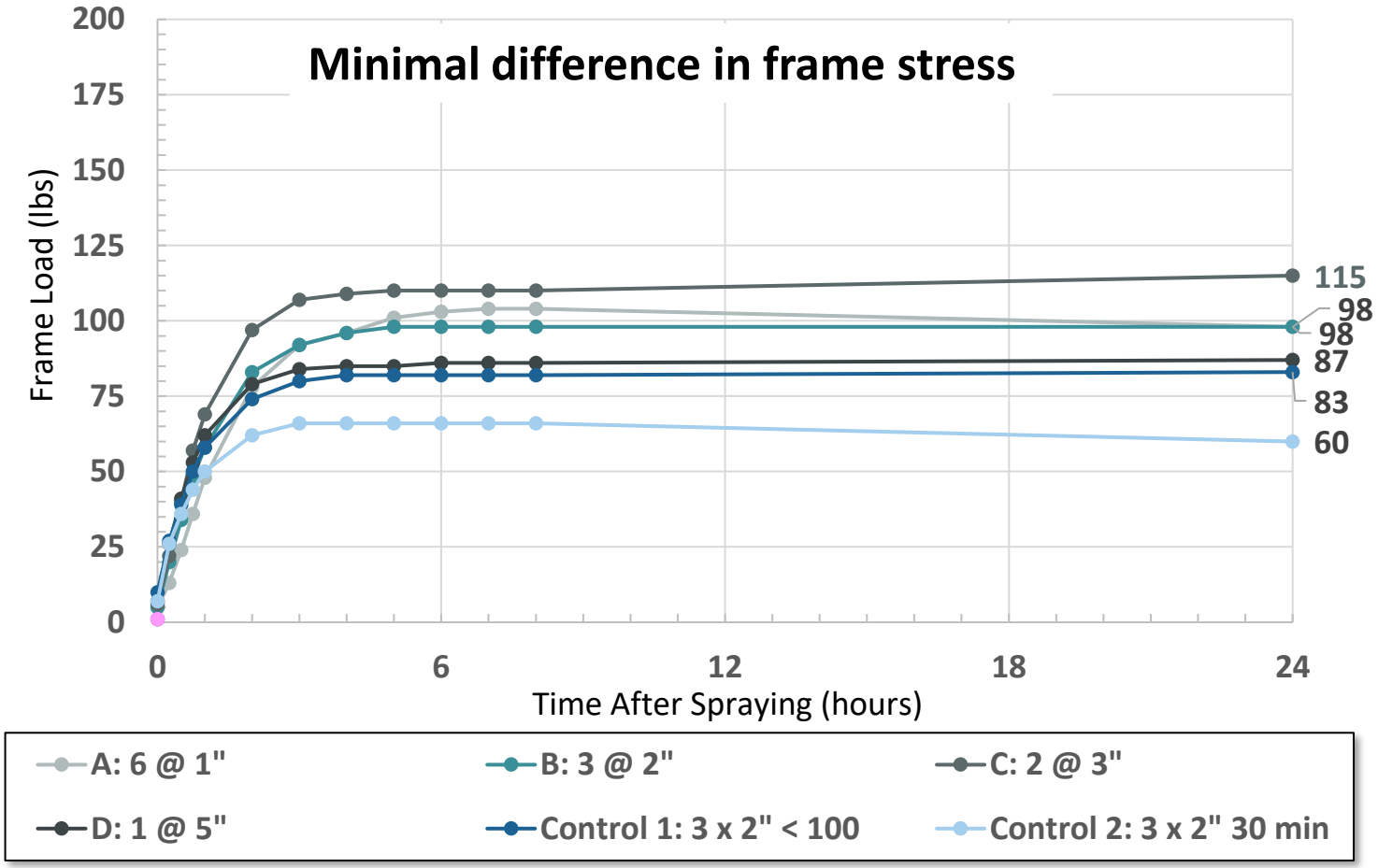
Frame Load vs Application (Vertical + PF)



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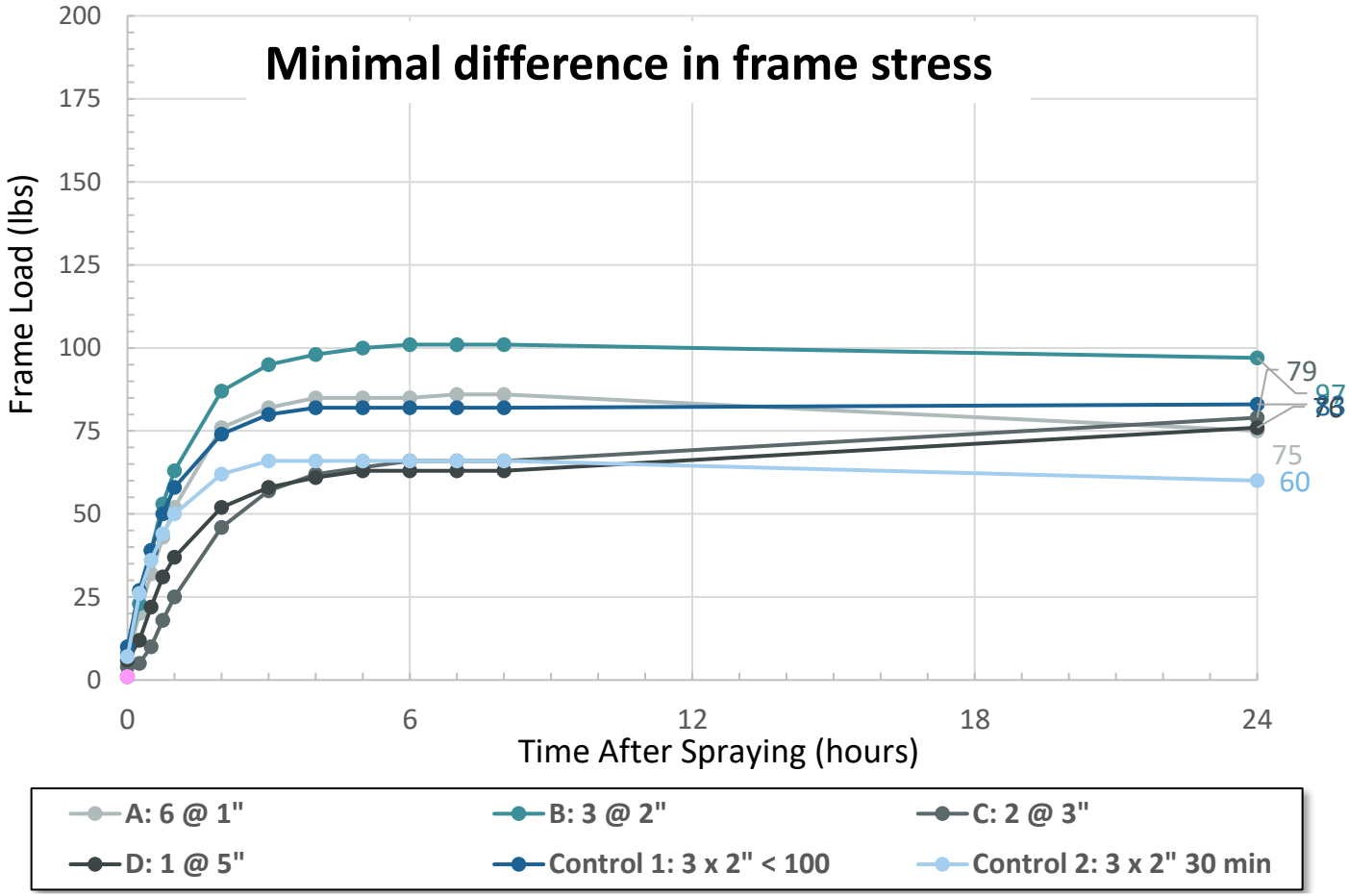
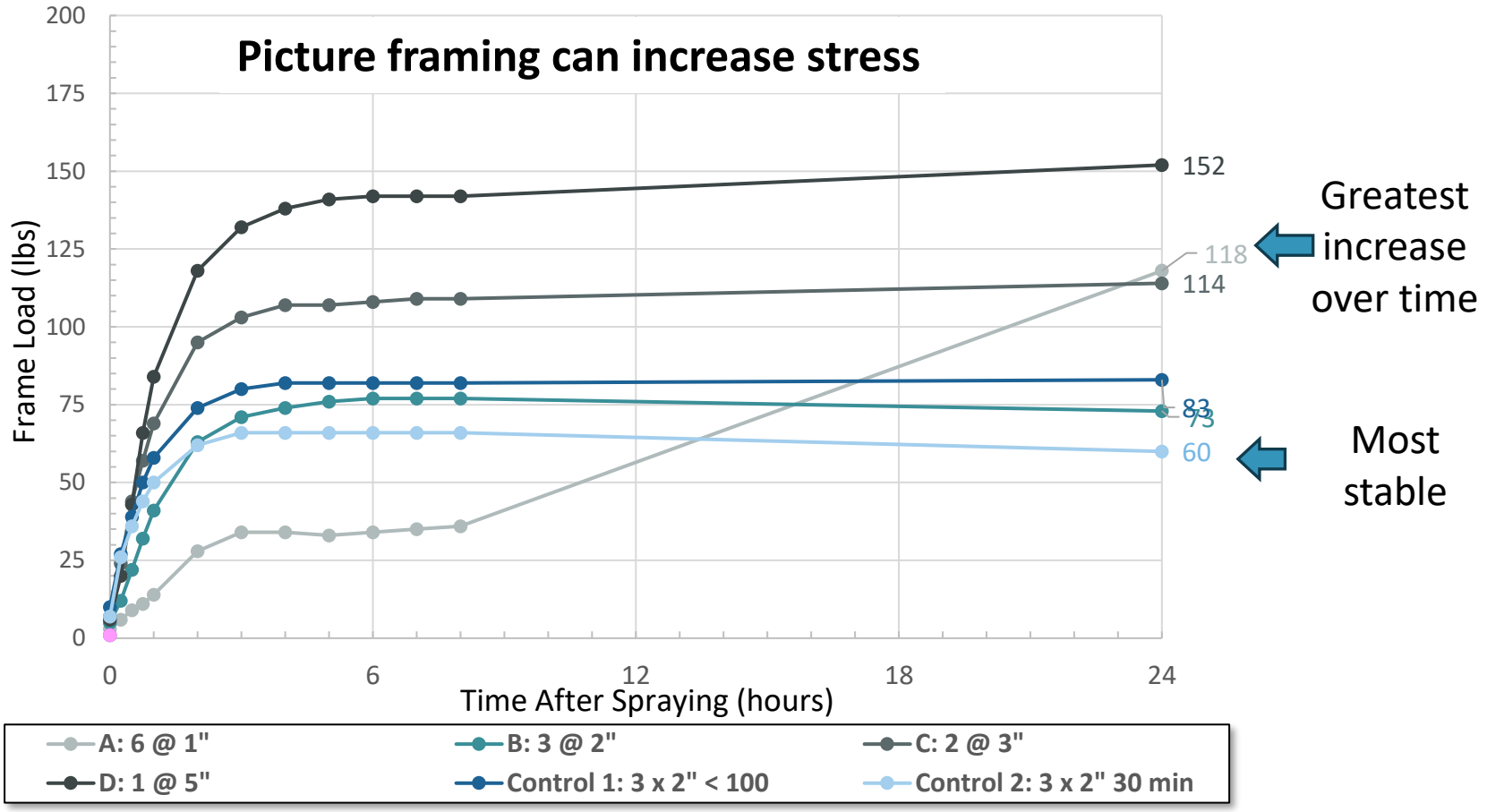
Frame Load vs Application (Side by Side)



SPRAY POLYURETHANE FOAM ALLIANCE

Frame Load vs Application (Side by Side + PF)



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Frame Pressure Vs Application Summary (lbs)

Frame Load after 24 hours		Lift Configurations				
Spray Technique		A	B	C	D	Control
Picture Frame	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
Yes	Side-side	118	73	114	152	
No	Side-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 (Control 1)					83
No	Vertical (Control 2)					60
	Average	**92**	**71**	**115**	**54**	**72**

OBSERVATIONS :

- Picture-framing appears to increase frame load in most cases
- Waiting 30 minutes between each pass (Control 2) samples using MII have lowest frame loads
- Long-term frame load can increase or decrease depending on lift thickness and spray technique

Frame Load Over Extended Time

Measured Fixture load from 3 to 30 days after spraying

Note:

"Day X" refers to data taken on the shown in the Day X column.

Due to staffing availability, loads were taken 3, 4, 5,6, 8, 28 or 31 days after application

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

Large continued load decrease

Large continued load increase relative to others with same lift configuration

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Frame Test

Change in Thickness vs Application

Change in Thickness

Background:

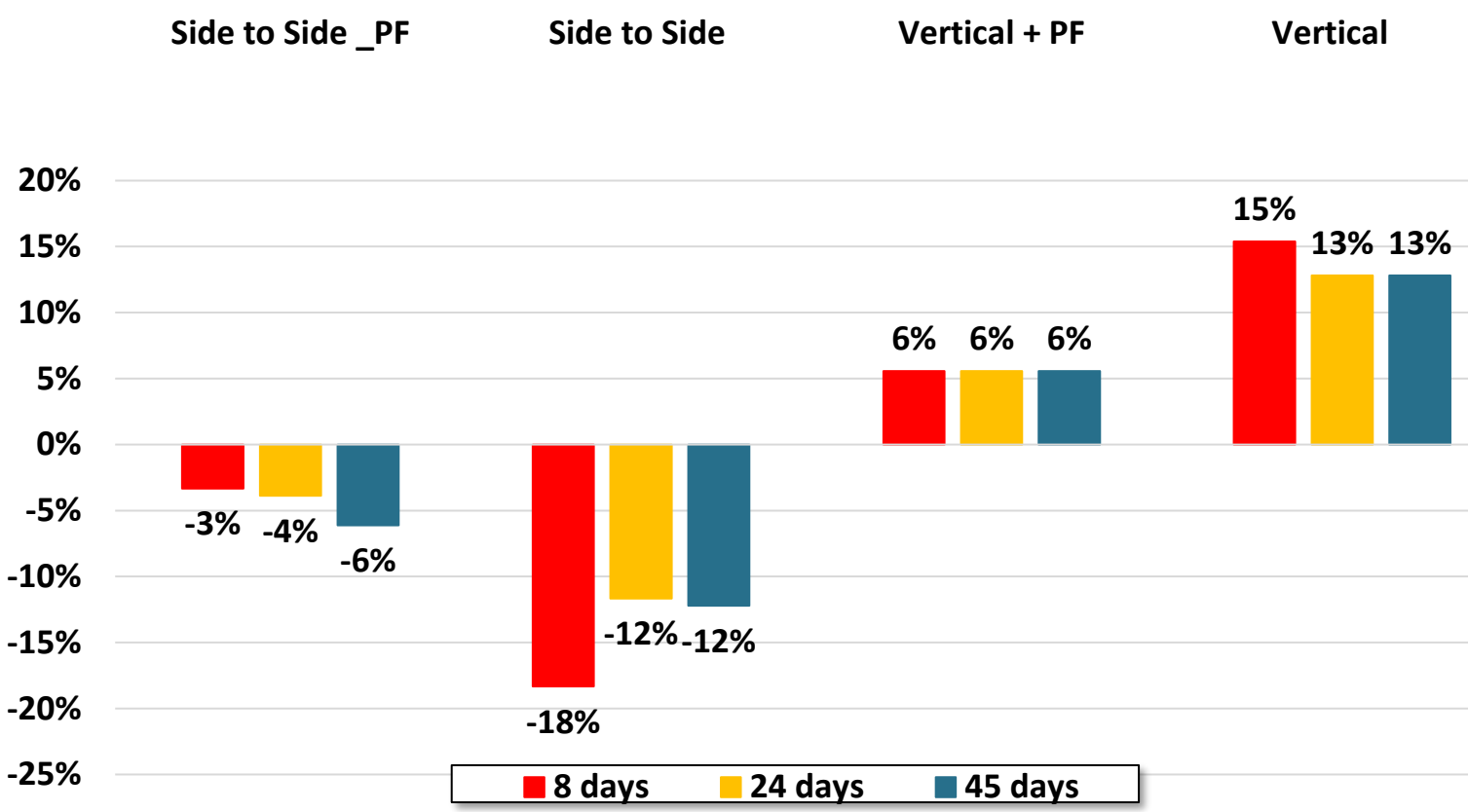
Closed-cell foam can shrink over time
Sometimes called reversion

Most prevalent in thickness direction

Test:

- Pass thickness was measured for each pass while spraying the frames.
- After the frames are sprayed, overall foam thickness of the Fram was measured at intervals of 8, 24, and 45 days.
- Data was recorded and compared to the initial sprayed final thickness measurements.

% Change in Thickness vs Time (6 x 1”)



Side to Side Greatest Loss of Thickness,
Vertical Greatest Post Growth

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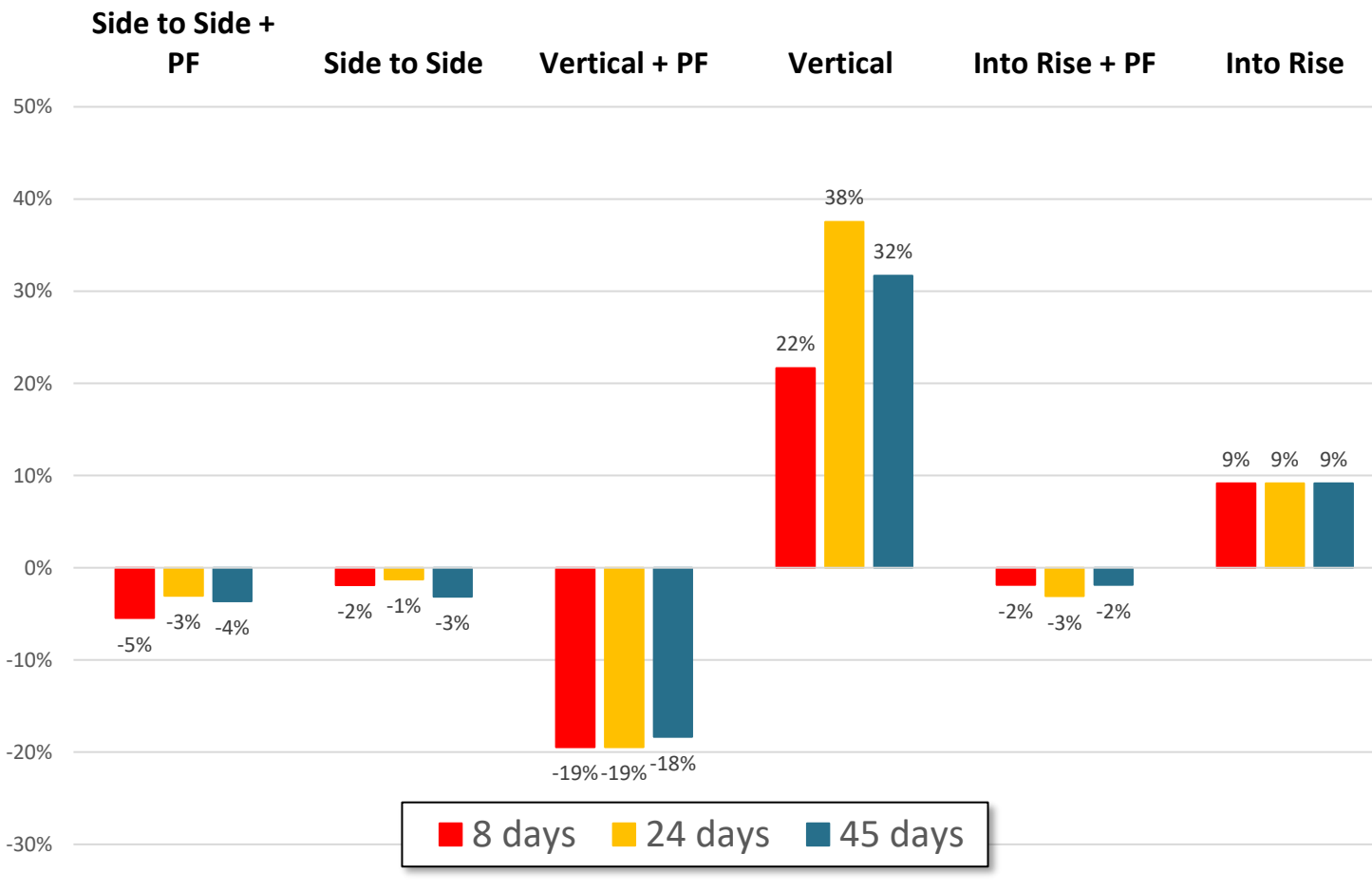
% Change in Thickness vs Time (3 x 2”)



Vertical + PF Greatest Loss of Thickness, Vertical Greatest Post Growth

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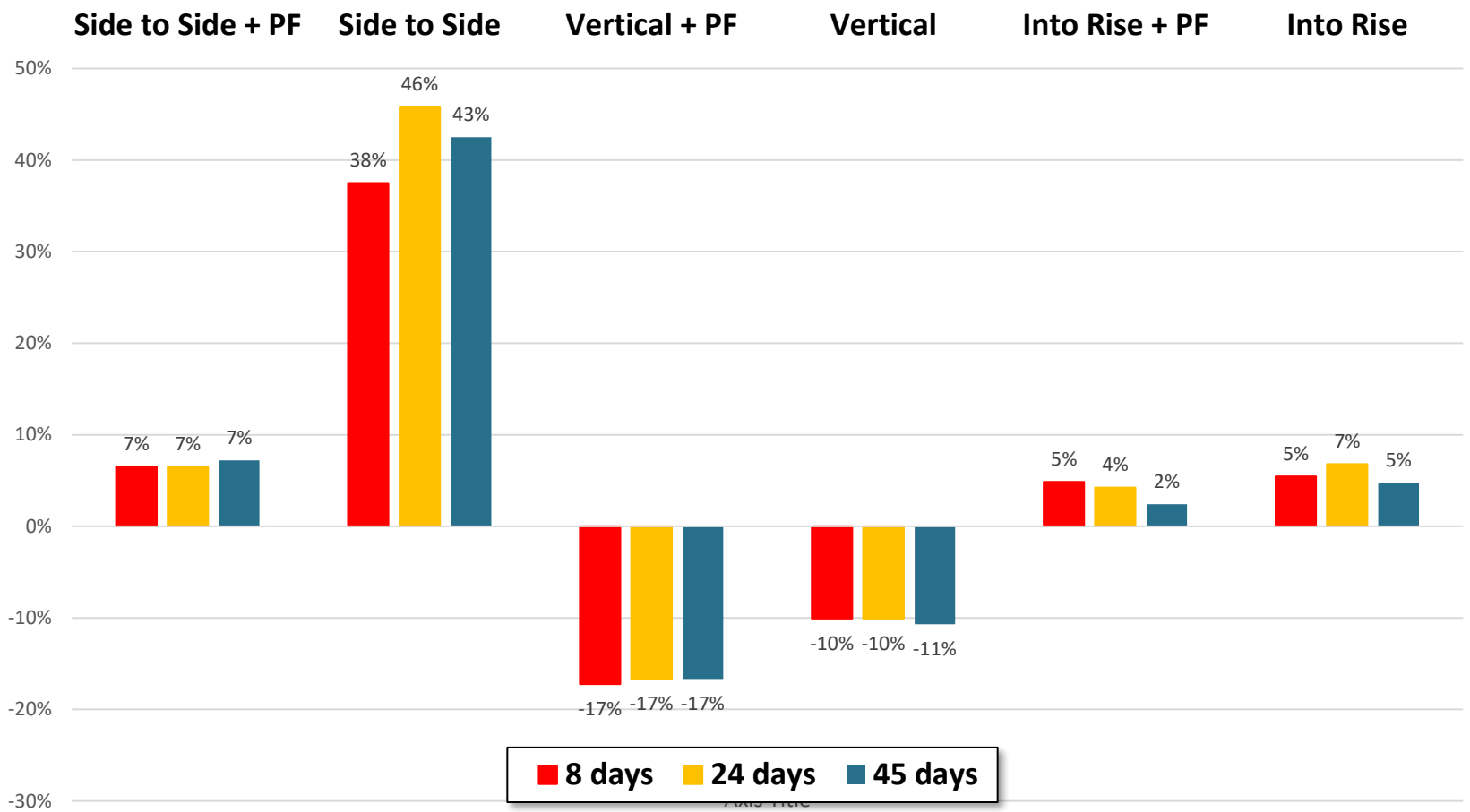
% Change in Thickness vs Time (2 x 3”)



Vertical + PF Greatest Loss of Thickness, Side to Side Greatest Post Growth

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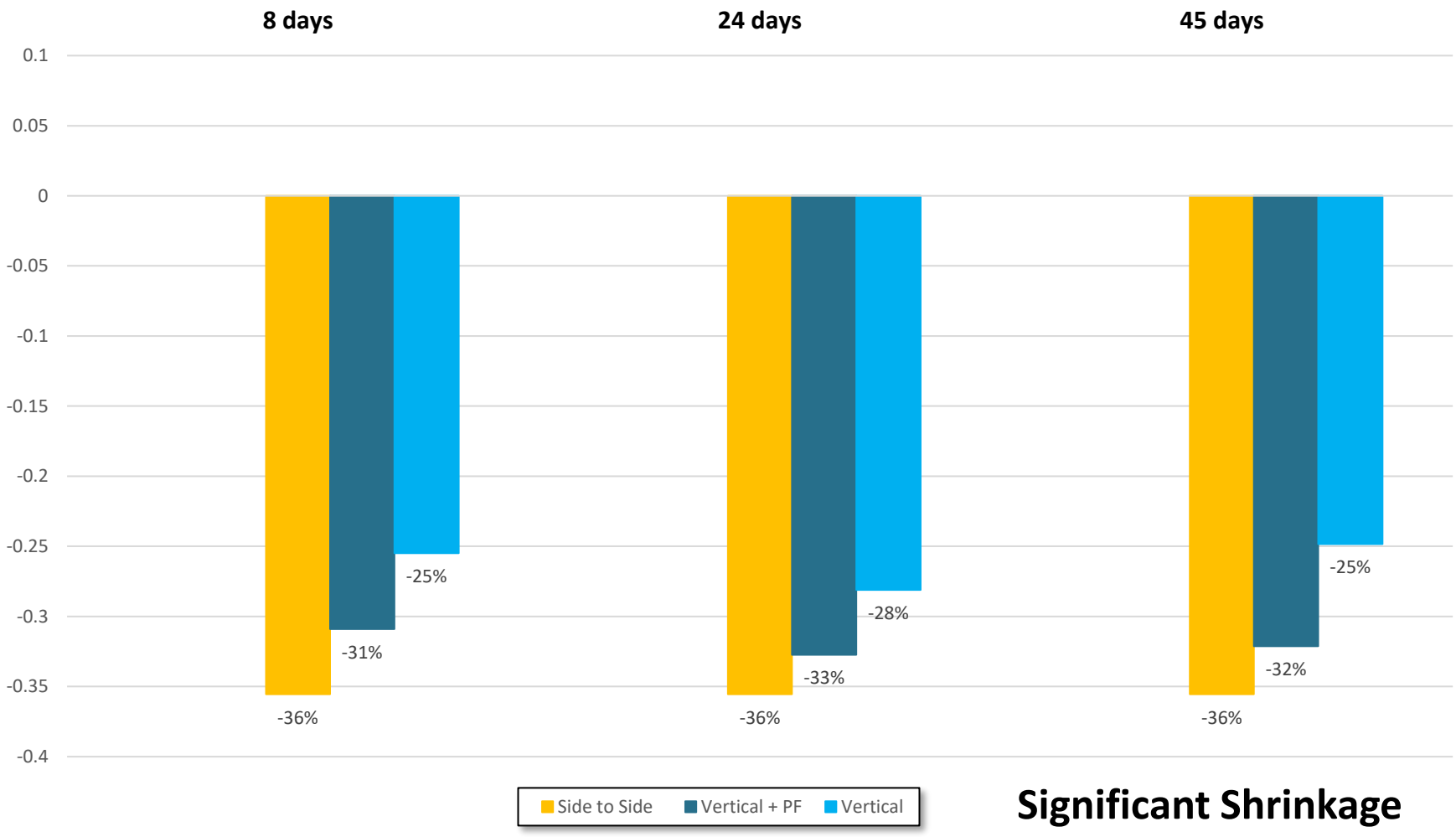
Change in Thickness vs Time (1 x 5”)



Significant Shrinkage

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Change in Thickness 1 x 5”

Side to Side +PF

Side to Side

Vertical +PF

Vertical

Significant Shrinkage

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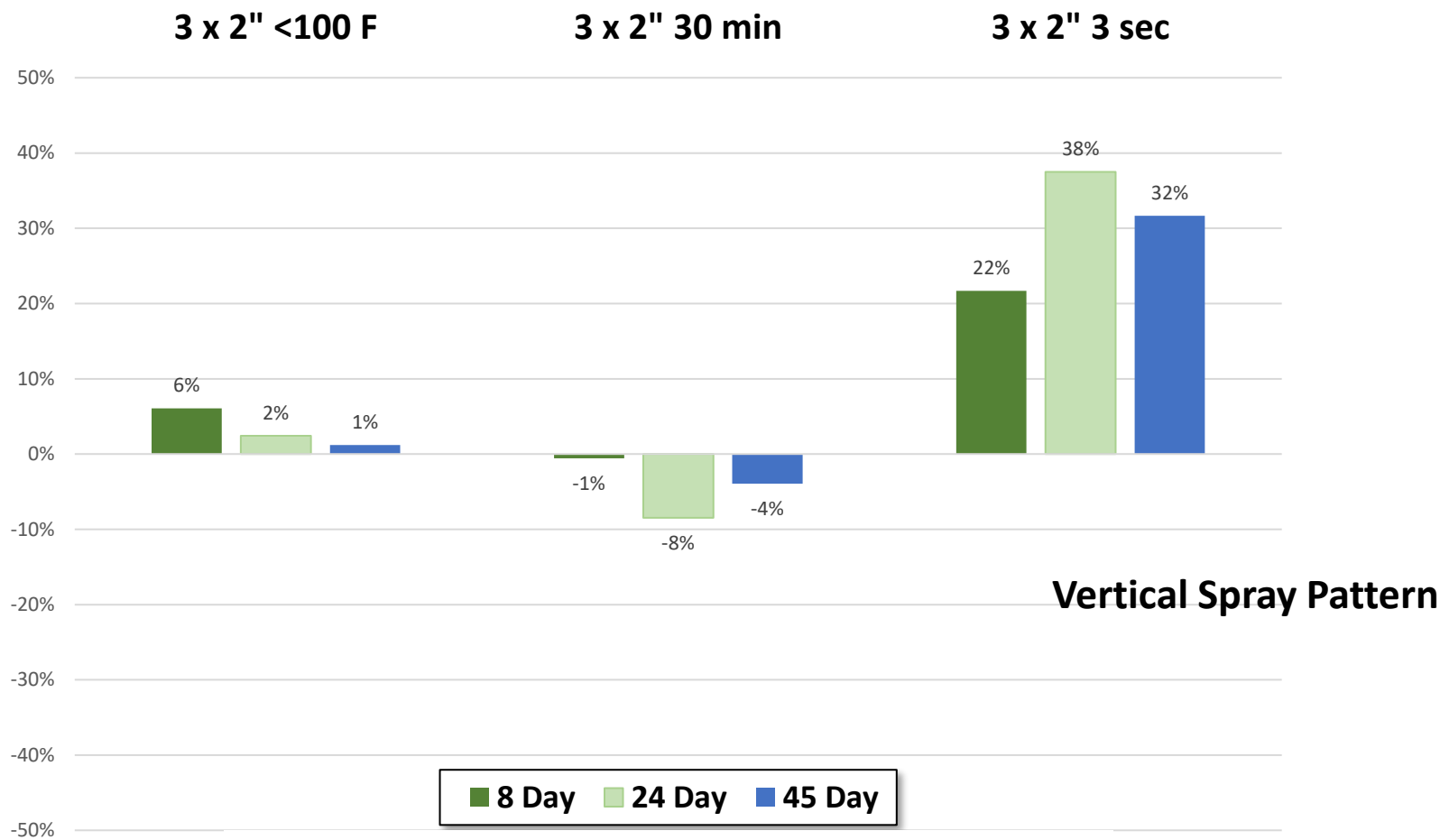
Change in Thickness vs Time (Controls)



Vertical Spray Pattern

3x 2” 3 Second Wait Greatest Post Growth

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% Change in Thickness vs Control Summary

% Change from initial		Lift Configurations														
Spray Technique		6 x 1"			3 x 2"			2 x 3"			1 x 5"			Control		
Picture Frame	Spray Direction	8 Days	24 Days	45 Days	8 Days	24 Days	45 Days	8 Days	24 Days	45 Days	8 Days	24 Days	45 Days	8 Days	24 Days	45 Days
Yes	Side-side	-3%	-4%	-6%	-5%	-3%	-4%	7%	7%	7%						
No	Side-side	-18%	-12%	-12%	-2%	-1%	-3%	38%	46%	43%	-36%	-36%	-36%			
Yes	Vertical	6%	6%	6%	-19%	-19%	-18%	-17%	-17%	-17%	-31%	-33%	-32%			
No	Vertical	15%	13%	13%	22%	38%	32%	-10%	-10%	-11%	-25%	-28%	-25%			
Yes	Rising Foam				-2%	-3%	-2%	5%	4%	2%						
No	Rising Foam				9%	9%	9%	5%	7%	5%						
No	Vertical (Control 1)													6%	2%	1%
No	Vertical (Control 2)													-1%	-8%	-4%

- 1 – 2” passes using side to side technique showed most consistent performance
- 5” passes showed largest amount of shrinkage
- Controls showed consistent low change vs time

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SPRAY POLYURETHANE FOAM ALLIANCE

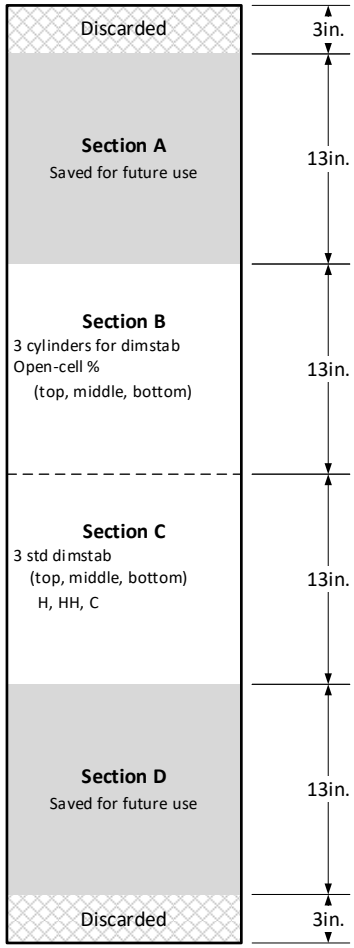
Box Test
Foam Quality

Box Testing Timeline

Testing on 22 Box Sample

Property	Test Method/ Conditions	Frequency	Timeline
Density - Core - Top - Middle - Bottom - Cylinder	ASTM D1622	Once	2-5 days after spraying
% Closed Cell - Top - Middle - Bottom	ASTM D6226	Once	19-27 days after spraying
Dimensional Stability - Top - Middle - Bottom	ASTM D2126 Hot (90°C) Cold (-40°C) Hot and Humid (70°C/90% RH)	Initial, 1,7,14 days	3-5 days after spraying
Dimensional Stability - Cylinder	Hot (90°C) Cold (-40°C) Hot and Humid (70°C/90% RH)	Initial, 1,7,14 days	3-5 days after spraying

Box Testing Diagram



Box Test

Foam Quality

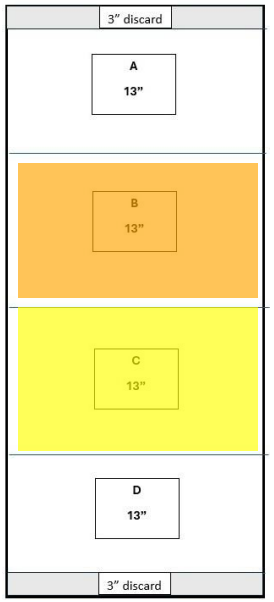
Application Technique vs Density

Density

D1622/D1622M Test Method for Apparent Density of Rigid

Measured 2 to 5 days after spraying

Density samples cut from cavity inserts as follows:



- Block, Top, Middle, and Bottom samples are cut from Section C
- Average dimensions of Block sample:
  3.5"H x 20" Long x 12" Wide
- Block density was measured then split into 3 samples:
  - Top (closest to surface)
  - Middle
  - Bottom (closest to first pass sprayed)
- Cylinder Densities are taken from Section B with a 3" foam core extractor.
- Densities were measured on the whole cored sample

Density vs Application Technique Summary

Density (lb/ft^3)		Lift Configurations				
Spray Technique		A	B	C	D	D'
Picture Fixture	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
Yes	Side-side	2.29	2.17	1.89	1.75	
No	Side-side	2.29	2.09	1.90	1.81	
Yes	Vertical	2.45	2.28	2.11	2.00	
No	Vertical	2.44	2.16	2.24	2.06	
Yes	Rising Foam		2.31	2.23		
No	Rising Foam		2.36	2.19		
No	Vertical (<100)					2.28
No	Vertical (30 min)					2.31
	Average	**2.37**	**2.23**	**2.09**	**1.90**	**2.30**

- **No impact from picture framing**
- **Dependent on spray direction (rising foam highest, side-to-side worst)**
- **Dependent on lift thickness – 5” pass produces lowest density**
- **1” to 2” lifts are best (except for spraying into rising foam) are most consistent with manufacturer specifications**

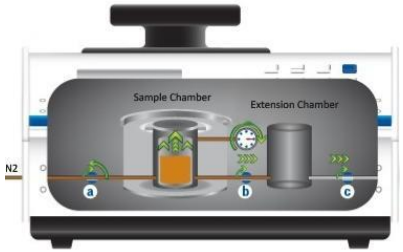
Box Test

Foam Quality

Application Technique vs % Closed Cell Content

How a Pycnometer works…

% Closed-Cell Method



Before testing begins the Pycnometer is calibrated with a ball bearing standard.

Foam samples are weighed and measured for volume and the data is entered into the pycnometer. The foam sample is then placed into the sample chamber.

The Pycnometer pushes nitrogen into the Sample Chamber and measures the volume of the gas that is displaced into the Extension Chamber. (ex. OC foam will have lower volume displaced than CC foam because there is more space in the foam for the gas to sit.)

Results are recorded in % closed cell and all 5 samples tested are averaged and reported.

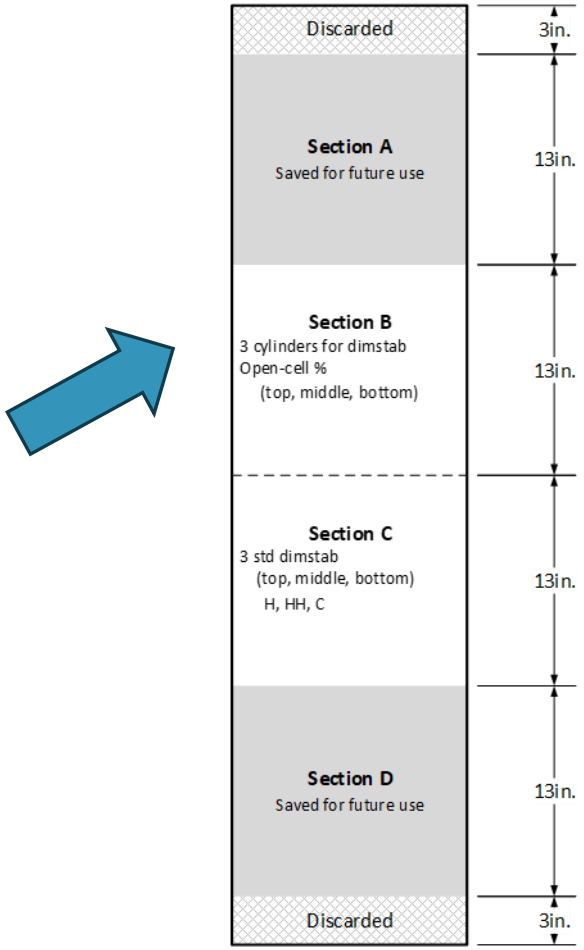
https://www.anton-paar.com/us-en/products/details/ultrapyc/?sku=231520

% Closed-Cell Content Test

D6226 Test Method for Open Cell Content of Rigid Cellular Plastics

Measured 20 to 28 days after spraying

Closed-cell content samples cut from cavity insert Section B



SPRAY POLYURETHANE FOAM ALLIANCE

% Closed Cell vs Application Technique Data Summary

Closed-Cell			Lift Configurations				
Spray Technique			A	B	C	D	D'
	Picture Fixture	Spray Direction	6 @ 1”	3 @ 2”	2 @ 3”	1 @ 5”	3 @ 2”
1	Yes	Side-side	89	88	59	67	
2	No	Side-side	90	89	65	65	
3	Yes	Vertical	92	92	83	72	
4	No	Vertical	92	91	83	83	
5	Yes	Rising Foam		86	75		90
6	No	Rising Foam		87	77		91
		Average	**91**	**89**	**74**	**72**	**90**

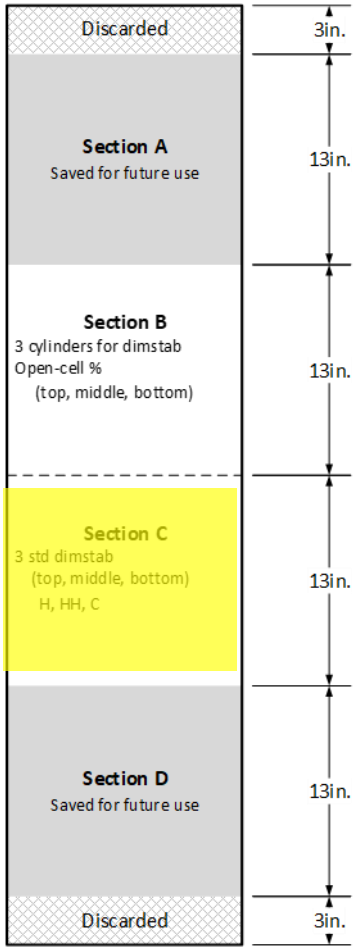
- Thicknesses greater than 2” have lower % closed cell content
- Side-side lower % closed cell than vertical
- Picture framing no impact on % closed cell

Box Test

Foam Quality

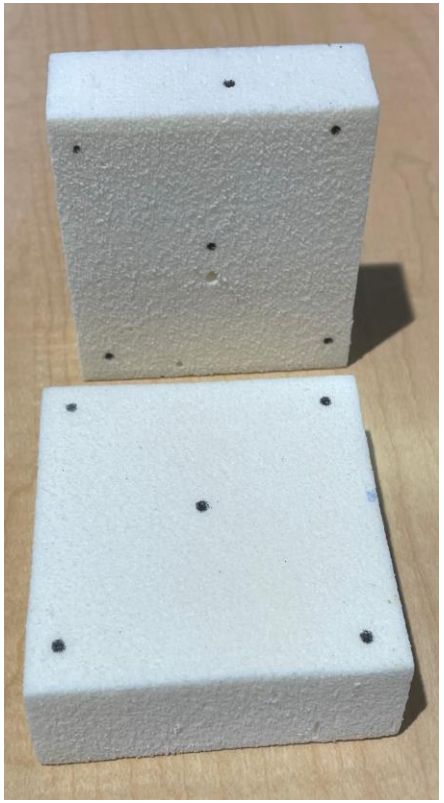
Application Technique vs ASTM Dimensional Stability

Dimensional Stability



D2126 Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging

- Samples were taken from section C of the box
- Started measurement 3 to 5 days after spraying
- Large core sample split into 3 sections Top, Middle, Bottom
- Sample size is 3”x3”x1 and ran in triplicate
- Conditions were Hot (90°C), Hot & Humid (70°C – 95% Relative Humidity), and Cold (-29°C)
- Sample dimensions were measured Initial (after cut) then placed in their conditions. Then measured at 24hrs, 10 days, and 17 days.
- Results are recorded as % Volume Change



SPRAY POLYURETHANE FOAM ALLIANCE

ASTM
Dimensional Stability @ 14 Days- vol % Change

14- Day Dimensional Stability (% Volume Change)		Lift Configuration					
Spray Technique			A	B	C	D	Control
Picture Frame	Spray Direction	Conditioning	6x1"	3x2"	2x3"	1x5"	3x2"
Yes	Side-Side	Cold (-40°C)	-0.4	-0.6	-17.4	-20.2	
		Hot (90°C)	9.9	13.4	6.1	22.4	
		Hot-Humid (70°C/90% RH)	6.9	9.3	4.2	0.7	
No	Side-Side	Cold (-40°C)	-0.4	-0.6	-4.6	-17.0	
		Hot (90°C)	6.2	15.0	17.1	9.5	
		Hot-Humid (70°C/90% RH)	5.0	4.7	1.7	0.0	
Yes	Vertical	Cold (-40°C)	-0.3	-0.5	-0.6	-6.9	
		Hot (90°C)	1.6	2.4	18.4	9.7	
		Hot-Humid (70°C/90% RH)	4.5	3.4	1.6	2.6	
No	Vertical	Cold (-40°C)	-0.4	-0.5	-0.7	-4.6	
		Hot (90°C)	4.5	4.9	17.2	10.7	
		Hot-Humid (70°C/90% RH)	3.5	3.3	1.2	1.6	
Yes	Into Rising Foam	Cold (-40°C)		2.0	-1.6		
		Hot (90°C)		3.8	1.2		
		Hot-Humid (70°C/90% RH)		0.3	-1.9		
No	Into Rising Foam	Cold (-40°C)		-0.7	1.5		
		Hot (90°C)		2.2	1.6		
		Hot-Humid (70°C/90% RH)		2.3	-0.2		
No	Control (< 100F)	Cold (-40°C)					-0.6
		Hot (90°C)					12.8
		Hot-Humid (70°C/90% RH)					4.5
No	Control (30 min)	Cold (-40°C)					-0.8
		Hot (90°C)					10.3
		Hot-Humid (70°C/90% RH)					4.9

ASTM Specification
< 15 % change

Aging in Cold Environment: Shrinks Foam

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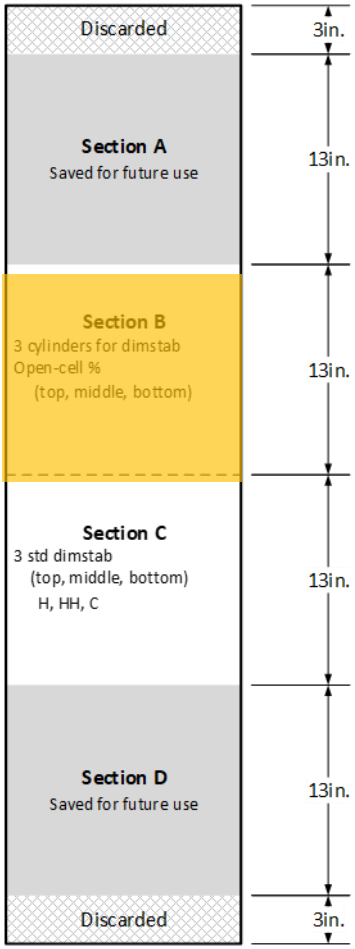
Box Test

Foam Quality

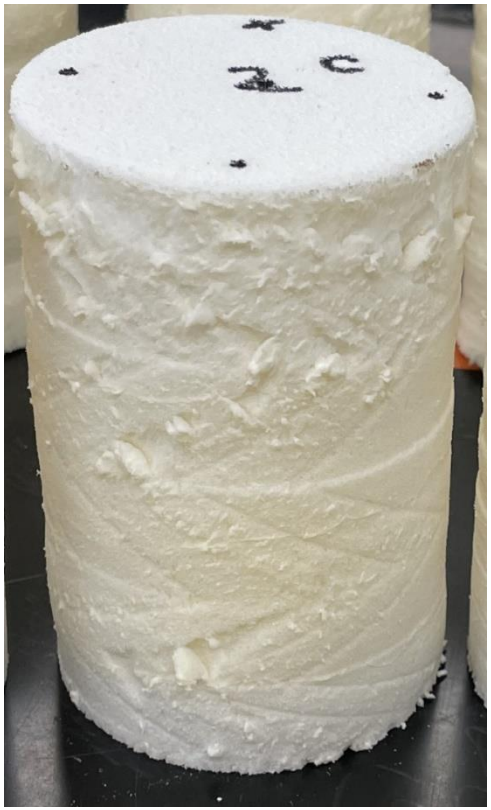
Application Technique vs Dimensional Stability

Cylinder

Cylinder
Dimensional Stability @ 14 Days- vol % Change



- Samples were taken from section B of the box
- Started measurement 3 to 5 days after spraying
- Sample size is 3” diameter cylinder and ran in triplicate
- Conditions were Hot (90°C), Hot & Humid (70°C – 95% Relative Humidity), and Cold (-29°C)
- Sample dimensions were measured Initial (after cut) then placed in their conditions. Then measured at 24hrs, 10 days, and 17 days.
- Results are recorded as % Volume Change



SPRAY POLYURETHANE FOAM ALLIANCE

Cylinder
Dimensional Stability @ 14 Days- vol % Change

14- Day Dimensional Stability (% Volume Change)		Lift Configuration					
Spray Technique			A	B	C	D	Control
Picture Frame	Spray Direction	Conditioning	6x1"	3x2"	2x3"	1x5"	3x2"
Yes	Side-Side	Cold (-40°C)	-1.5	-0.5	-29.6	-17.6	
		Hot (90°C)	2.3	-6.2	11.7	17.6	
		Hot-Humid (70°C/90% RH)	-5.3	-9.8	-11.1	-14.8	
No	Side-Side	Cold (-40°C)	-0.2	-0.1	-4.3	-18.6	
		Hot (90°C)	1.9	-7.5	8.1	16.9	
		Hot-Humid (70°C/90% RH)	-0.5	-3.9	-11.0	-16.7	
Yes	Vertical	Cold (-40°C)	0.3	-0.3	-0.5	-14.7	
		Hot (90°C)	-3.7	-3.7	12.0	14.8	
		Hot-Humid (70°C/90% RH)	-2.7	-1.5	-4.1	-18.3	
No	Vertical	Cold (-40°C)	-1.1	-0.3	-3.2	-0.8	
		Hot (90°C)	-0.7	-6.8	16.1	13.5	
		Hot-Humid (70°C/90% RH)	-5.0	-5.6	-5.1	-15.6	
Yes	Into Rising Foam	Cold (-40°C)		0.0	-1.4		
		Hot (90°C)		-15.9	3.7		
		Hot-Humid (70°C/90% RH)		-7.7	-11.9		
No	Into Rising Foam	Cold (-40°C)		-1.2	-1.9		
		Hot (90°C)		-13.5	6.6		
		Hot-Humid (70°C/90% RH)		-9.9	-13.3		
No	Control (< 100F)	Cold (-40°C)					-1.5
		Hot (90°C)					8.4
		Hot-Humid (70°C/90% RH)					0.9
No	Control (30 min)	Cold (-40°C)					-0.6
		Hot (90°C)					5.3
		Hot-Humid (70°C/90% RH)					-17.7

Conclusions:
5” foam samples show dimensional stability issues

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SPRAY POLYURETHANE FOAM ALLIANCE

Conclusions: General

Extensive study designed to demonstrate impact application methods have on foam quality

- two sample types (Box, Frame), total 484 tests, >1M data points

Limited variables:

- Spray lifts, Spray pattern, Spray techniques

Control samples meet manufacturer published criteria when sprayed per TDS

Conclusion: Frame Testing- Exotherm

Exotherm (peak):

- Picture Framing has no visible impact on peak temperature
- Dependent on spray direction
- Dependent on lift thickness
- MII provide lowest peak temperatures
- Increasing lift thickness increases exothermic temperatures from 225°F to about 245°F

Exotherm Cooling Time to Room Temperature (<80°F):

- 6 x 1” pass took the longest time to drop below 80°F
- 1 x 5” pass took the least amount of time to drop below 80°F
- Comparing 30 second wait time to MII wait time shows insignificant difference in time to drop below 80°F

Conclusion: Frame Testing- Load

Sample Thickness

- Picture-framing appears to increase frame load in most cases
- Waiting 30 minutes between each pass (Control 2) samples using MII have lowest frame loads
- Long-term frame load can increase or decrease depending on lift thickness and spray technique

Conclusion: Frame Testing- Thickness

Sample Thickness

- 1 – 2” passes using side to side technique showed most consistent performance
- 5” passes showed largest amount of shrinkage
- Controls showed consistent low change vs time

Conclusion: Box Testing- Foam Quality

Density:

- No major impact from picture framing
- Strongly dependent on spray direction (rising foam highest, side-to-side worst)
- Strongly dependent on spray direction (rising foam highest, side-to-side worst)
- Heavily dependent on lift thickness – 5” pass produces lowest density
- 1” to 2” lifts are best (except for spraying into rising foam) are most consistent with manufacturer specifications

% Closed Cell Content:

- Thicknesses greater that 2” have lower % closed cell content
- Side-side lower % closed cell than vertical
- Picture framing no impact on % closed cell

Conclusion: Box Testing- Foam Quality

Dimensional Stability ASTM:

- Thicker lift more failures
- Side by side with picture frame issues with cold conditions
- Samples sprayed side by side 2 x 3” Hot humid failures
- 1 x 5 “ more failures

Dimensional Stability Cylinder :

- 6 x 1” pass took the longest time to drop below 80°F Failures 1 x 5” side by side with and without picture frames have issues under all conditions

Recommendations/ Suggestions

Suggested improvements to the load frame apparatus

- Better pressure gauges for frames- digital feed
- Automatic measurement for thickness
- Is use of tape at seam restricting foam movement?
- Balance feet for base of frame
- Thermocouple placement at lift lines