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CCBST 15TH CANADIAN CONFERENCE ON BUIDLING SCIENCE AND TECHNOLOGY

Impact of Air Intrusion on Moisture Performance of Seam-Fastened Mechanically Attached Roofing Systems

** Sudhakar Molleti & Bas Baskaran*	*NRCC*
Peter Kalinger	*CRCA*
Mark Graham	*NRCA*
J.F. Cote, Joe Malpezzi and Joe Schwetz	*SPRI*

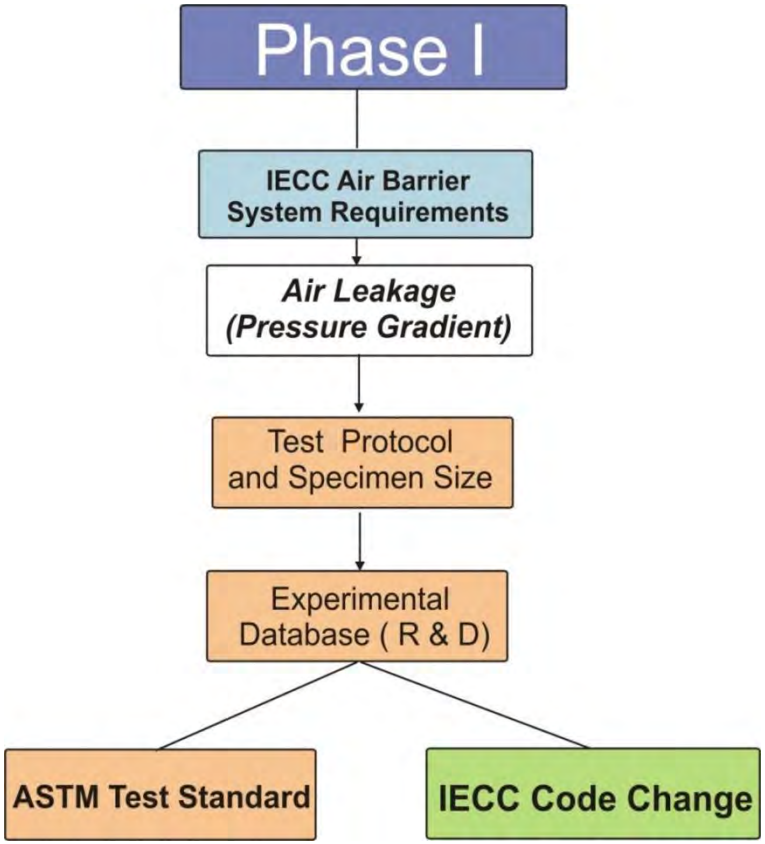
Presentation Outline

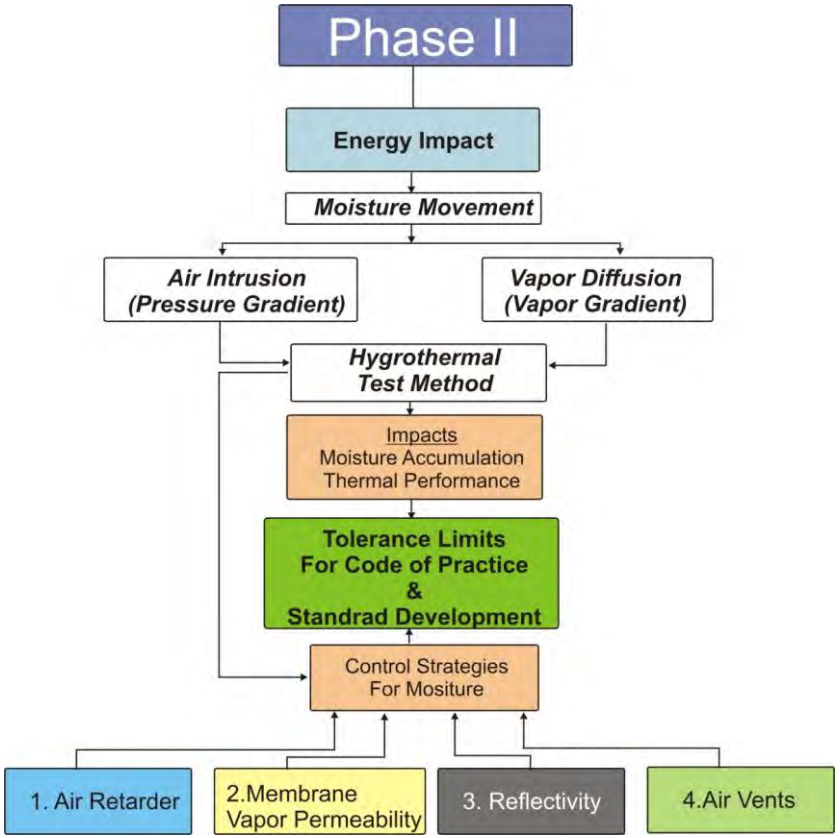
- Background
- Experimental Approach
- Results
- Conclusions and Future Work

AIR

Air Movement
Impacts On
Roofing Systems

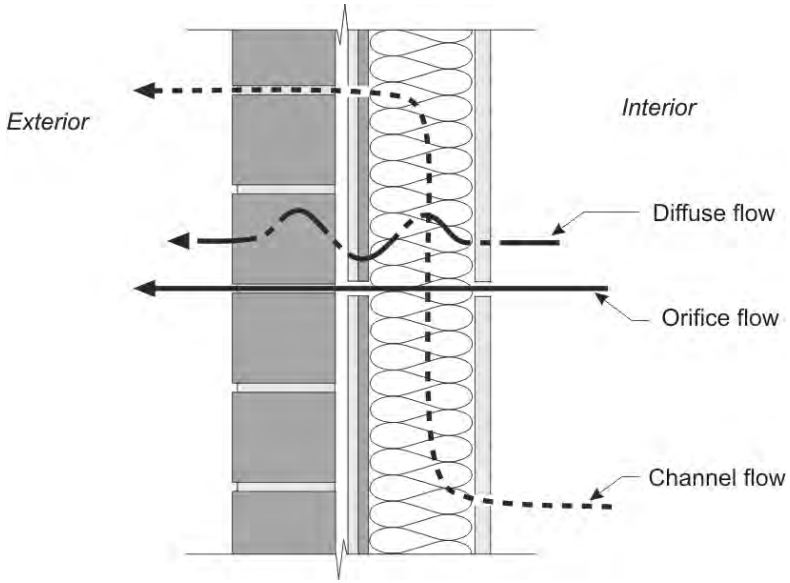
AIR Program


Phase I
IECC Air Barrier System Requirements
Air Leakage (Pressure Gradient)
Test Protocol and Specimen Size
Experimental Database (R & D)
ASTM Test Standard
IECC Code Change

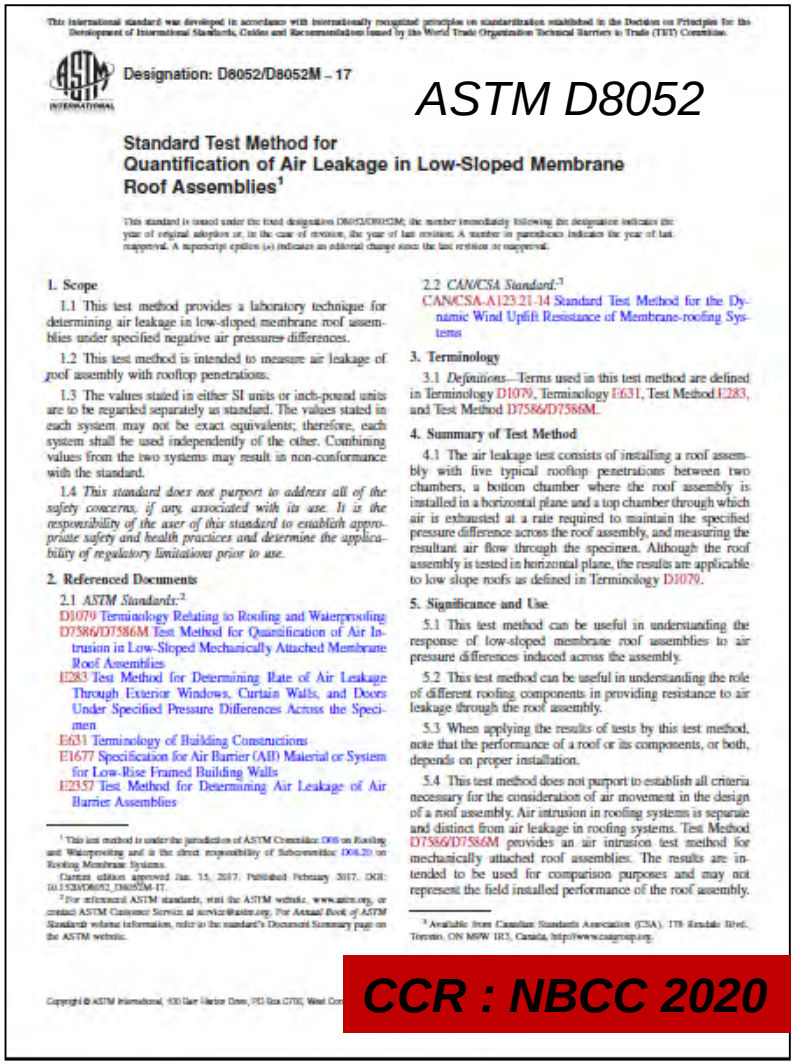

Phase II
Energy Impact
Moisture Movement
Air Intrusion (Pressure Gradient)
Vapor Diffusion (Vapor Gradient)
Hygrothermal Test Method
Impacts
Moisture Accumulation
Thermal Performance
Tolerance Limits For Code of Practice & Standrad Development
Control Strategies For Mositure
1. Air Retarder
2.Membrane Vapor Permeability
3. Reflectivity
4.Air Vents

Phase 1 : Air Leakage

When air enters or leaves from one environmental condition to the other environmental condition through the building envelope assembly, it is termed as **“Air Leakage”**.



AIR Phase 1 Outcomes



This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D8052/D8052M – 17

ASTM D8052

Standard Test Method for Quantification of Air Leakage in Low-Sloped Membrane Roof Assemblies[1]

This standard is issued under the fixed designation D8052/D8052M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides a laboratory technique for determining air leakage in low-sloped membrane roof assemblies under specified negative air pressure differences.

1.2 This test method is intended to measure air leakage of roof assembly with rooftop penetrations.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1079 Terminology Relating to Roofing and Waterproofing

D7586/D7586M Test Method for Quantification of Air Intrusion in Low-Sloped Mechanically Attached Membrane Roof Assemblies

E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

E631 Terminology of Building Constructions

E1677 Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls

E2357 Test Method for Determining Air Leakage of Air Barrier Assemblies

2.2 *CAN/CSA Standard:*[3]

CAN/CSA-A123.21-14 Standard Test Method for the Dynamic Wind Uplift Resistance of Membrane-roofing Systems

3. Terminology

3.1 *Definitions*—Terms used in this test method are defined in Terminology D1079, Terminology E631, Test Method E283, and Test Method D7586/D7586M.

4. Summary of Test Method

4.1 The air leakage test consists of installing a roof assembly with five typical rooftop penetrations between two chambers, a bottom chamber where the roof assembly is installed in a horizontal plane and a top chamber through which air is exhausted at a rate required to maintain the specified pressure difference across the roof assembly, and measuring the resultant air flow through the specimen. Although the roof assembly is tested in horizontal plane, the results are applicable to low slope roofs as defined in Terminology D1079.

5. Significance and Use

5.1 This test method can be useful in understanding the response of low-sloped membrane roof assemblies to air pressure differences induced across the assembly.

5.2 This test method can be useful in understanding the role of different roofing components in providing resistance to air leakage through the roof assembly.

5.3 When applying the results of tests by this test method, note that the performance of a roof or its components, or both, depends on proper installation.

5.4 This test method does not purport to establish all criteria necessary for the consideration of air movement in the design of a roof assembly. Air intrusion in roofing systems is separate and distinct from air leakage in roofing systems. Test Method D7586/D7586M provides an air intrusion test method for mechanically attached roof assemblies. The results are intended to be used for comparison purposes and may not represent the field installed performance of the roof assembly.

[1] This test method is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.20 on Roofing Membrane Systems.

Current edition approved Jan. 15, 2017. Published February 2017. DOI: 10.1520/D8052_D8052M-17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON M9W 1R3, Canada, http://www.csagroup.org.

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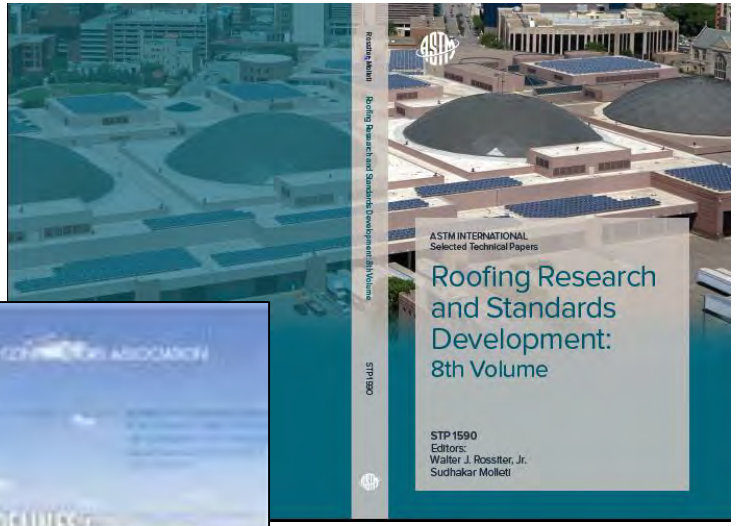
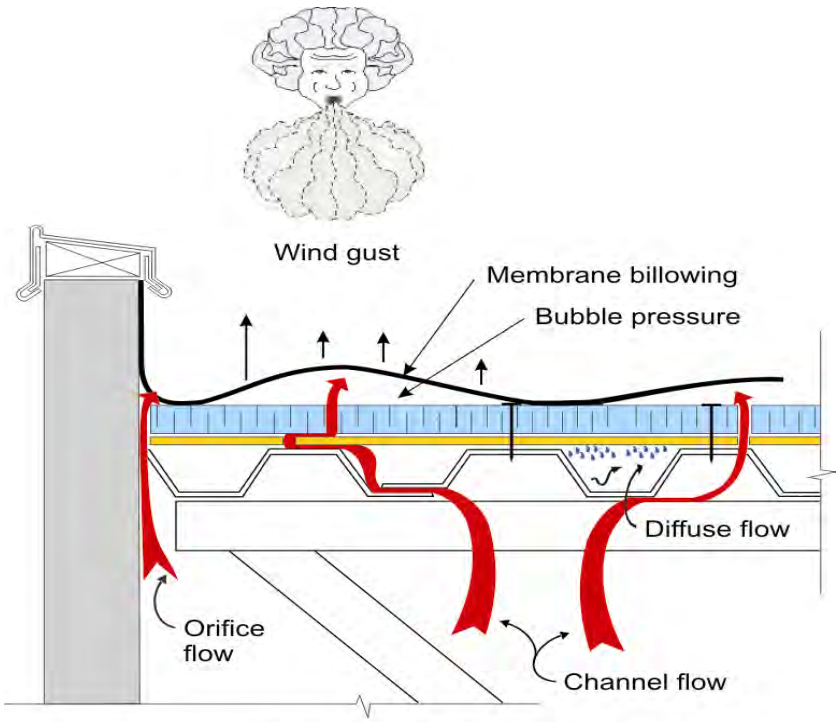
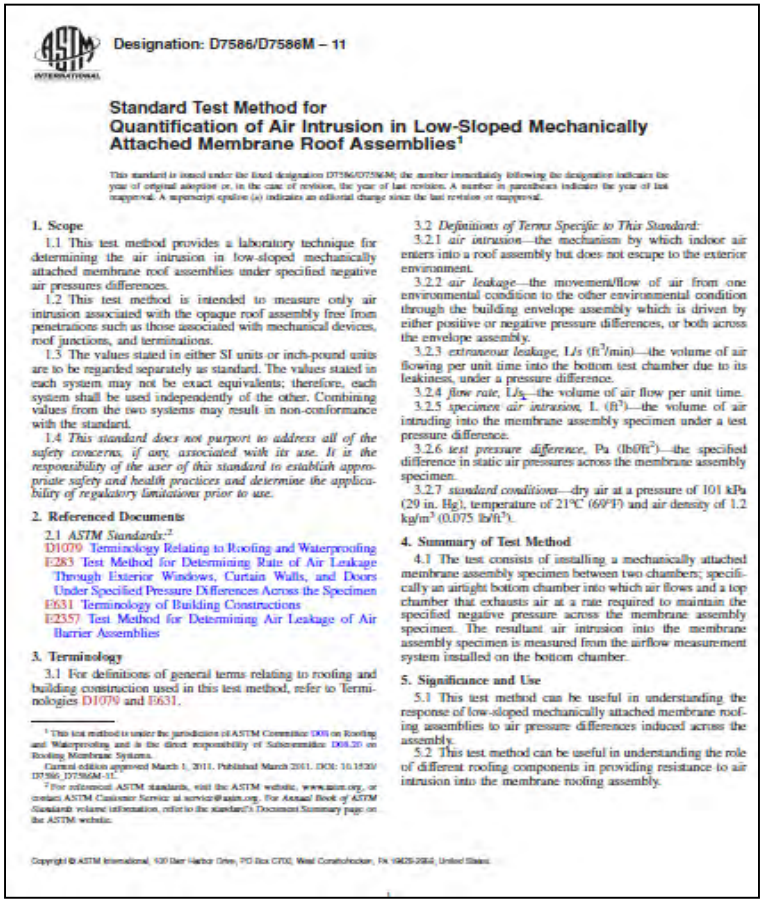


Phase 2 : Air Intrusion

AIR INTRUSION :the mechanism by which indoor air enters into a roof assembly but does not escape to the exterior environment.



Indoor air intruding into the asembly



Designation: D7586/D7586M – 11

Standard Test Method for Quantification of Air Intrusion in Low-Sloped Mechanically Attached Membrane Roof Assemblies[1]

This standard is issued under the fixed designation D7586/D7586M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides a laboratory technique for determining the air intrusion in low-sloped mechanically attached membrane roof assemblies under specified negative air pressures differences.

1.2 This test method is intended to measure only air intrusion associated with the opaque roof assembly free from penetrations such as those associated with mechanical devices, roof junctions, and terminations.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen

E631 Terminology of Building Constructions

E2357 Test Method for Determining Air Leakage of Air Barrier Assemblies

3. Terminology

3.1 For definitions of general terms relating to roofing and building construction used in this test method, refer to Terminologies D1079 and E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *air intrusion*—the mechanism by which indoor air enters into a roof assembly but does not escape to the exterior environment.

3.2.2 *air leakage*—the movement/flow of air from one environmental condition to the other environmental condition through the building envelope assembly which is driven by either positive or negative pressure differences, or both across the envelope assembly.

3.2.3 *extraneous leakage*, L/s (ft^3/min)—the volume of air flowing per unit time into the bottom test chamber due to its leakiness, under a pressure difference.

3.2.4 *flow rate*, L/s_a—the volume of air flow per unit time.

3.2.5 *specimen air intrusion*, L (ft^3)—the volume of air intruding into the membrane assembly specimen under a test pressure difference.

3.2.6 *test pressure difference*, Pa (lbf/ft^2)—the specified difference in static air pressures across the membrane assembly specimen.

3.2.7 *standard conditions*—dry air at a pressure of 101 kPa (29 in. Hg), temperature of 21°C (69°F) and air density of 1.2 kg/m^3 (0.075 lb/ft^3).

4. Summary of Test Method

4.1 The test consists of installing a mechanically attached membrane assembly specimen between two chambers; specifically an airtight bottom chamber into which air flows and a top chamber that exhausts air at a rate required to maintain the specified negative pressure across the membrane assembly specimen. The resultant air intrusion into the membrane assembly specimen is measured from the airflow measurement system installed on the bottom chamber.

5. Significance and Use

5.1 This test method can be useful in understanding the response of low-sloped mechanically attached membrane roofing assemblies to air pressure differences induced across the assembly.

5.2 This test method can be useful in understanding the role of different roofing components in providing resistance to air intrusion into the membrane roofing assembly.

[1] This test method is under the jurisdiction of ASTM Committee D08 on Roofing and Waterproofing and is the direct responsibility of Subcommittee D08.20 on Roofing Membrane Systems.

Current edition approved March 1, 2011. Published March 2011. DOI: 10.1520/D7586_D7586M-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

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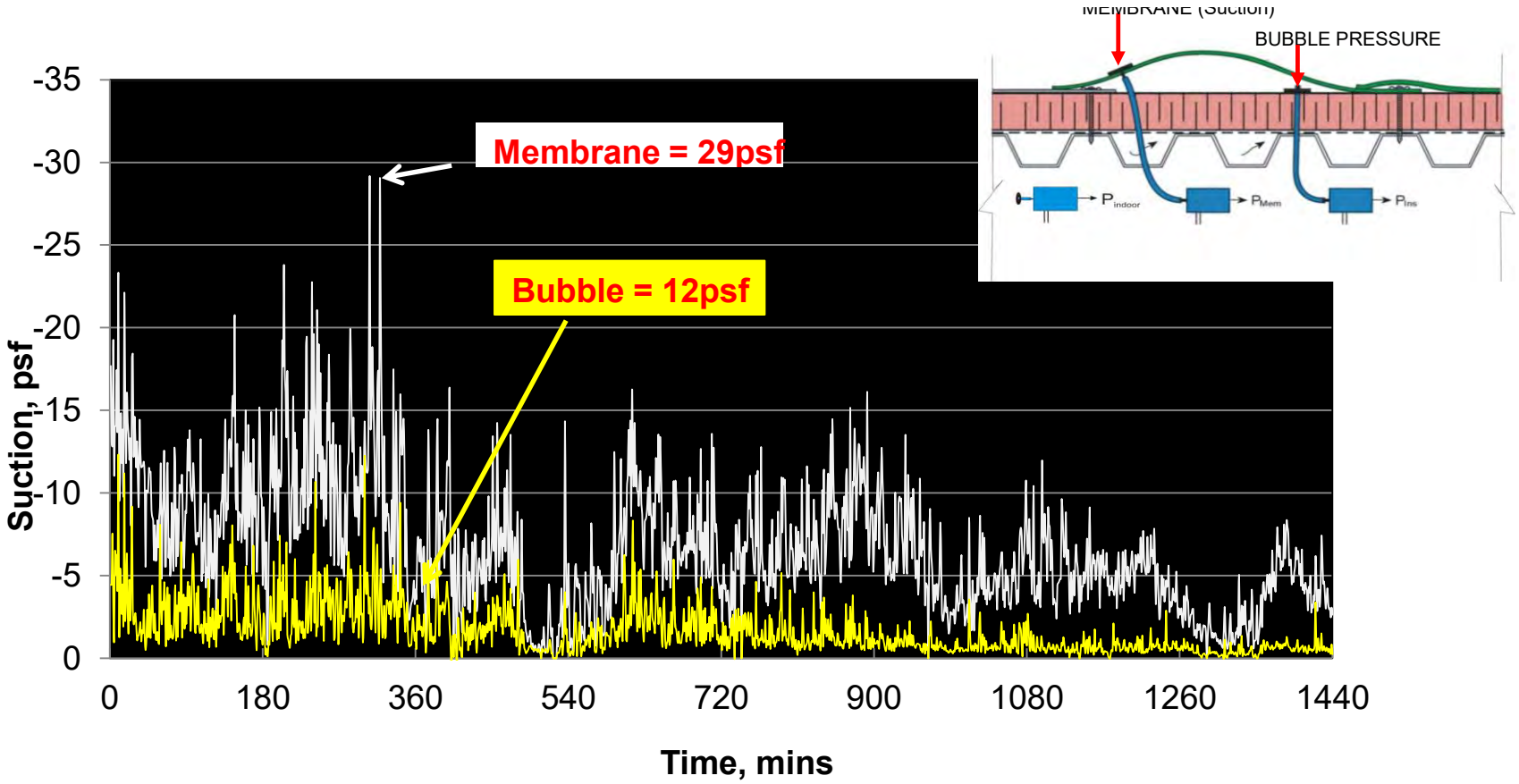
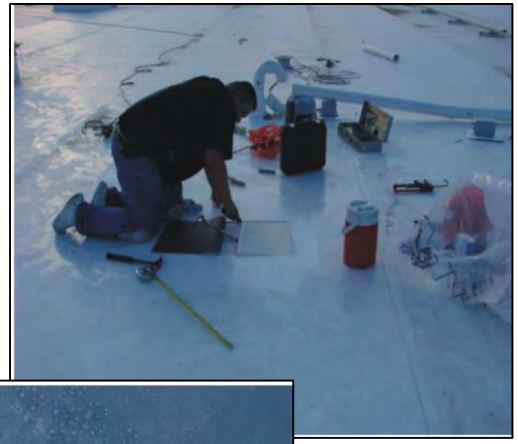
Wind Performance of Seam Fastened Mechanically Attached Roofing System

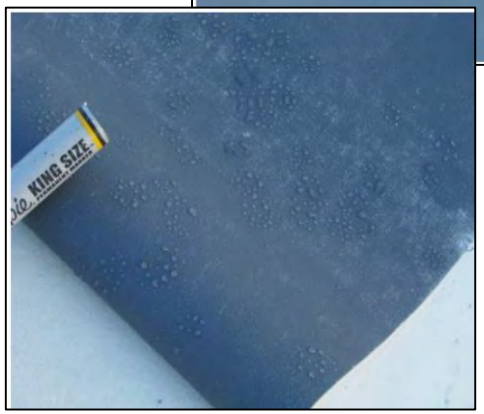
Bubble Pressure

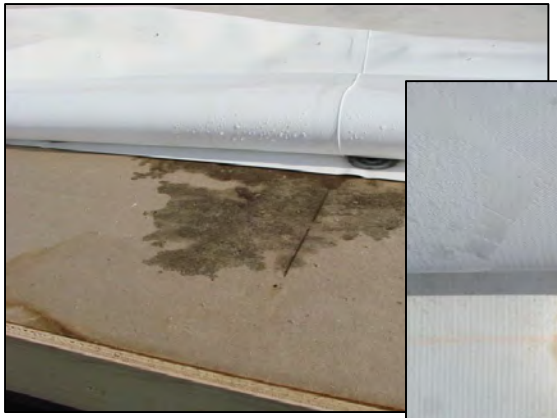
BUBBLE PRESSURE VARIES FROM 25 to 35 % of SUCTION [FR = 6 FT, FS = 12 IN]

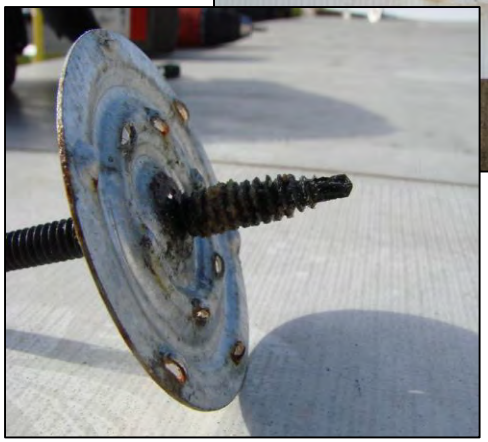


Impact of Air Intrusion

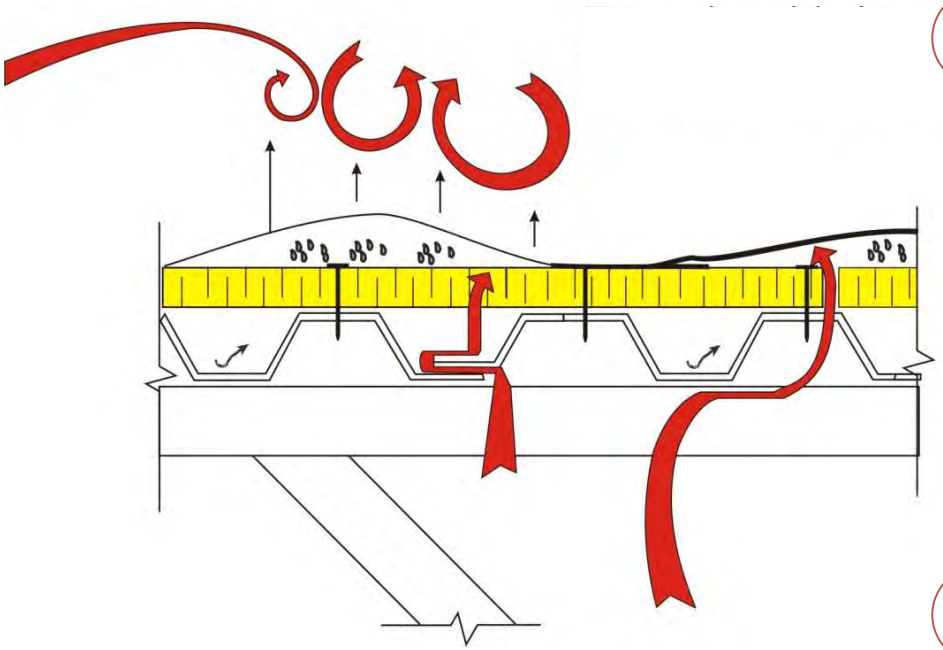








Phase 2: Air Intrusion Impact On Moisture Transport



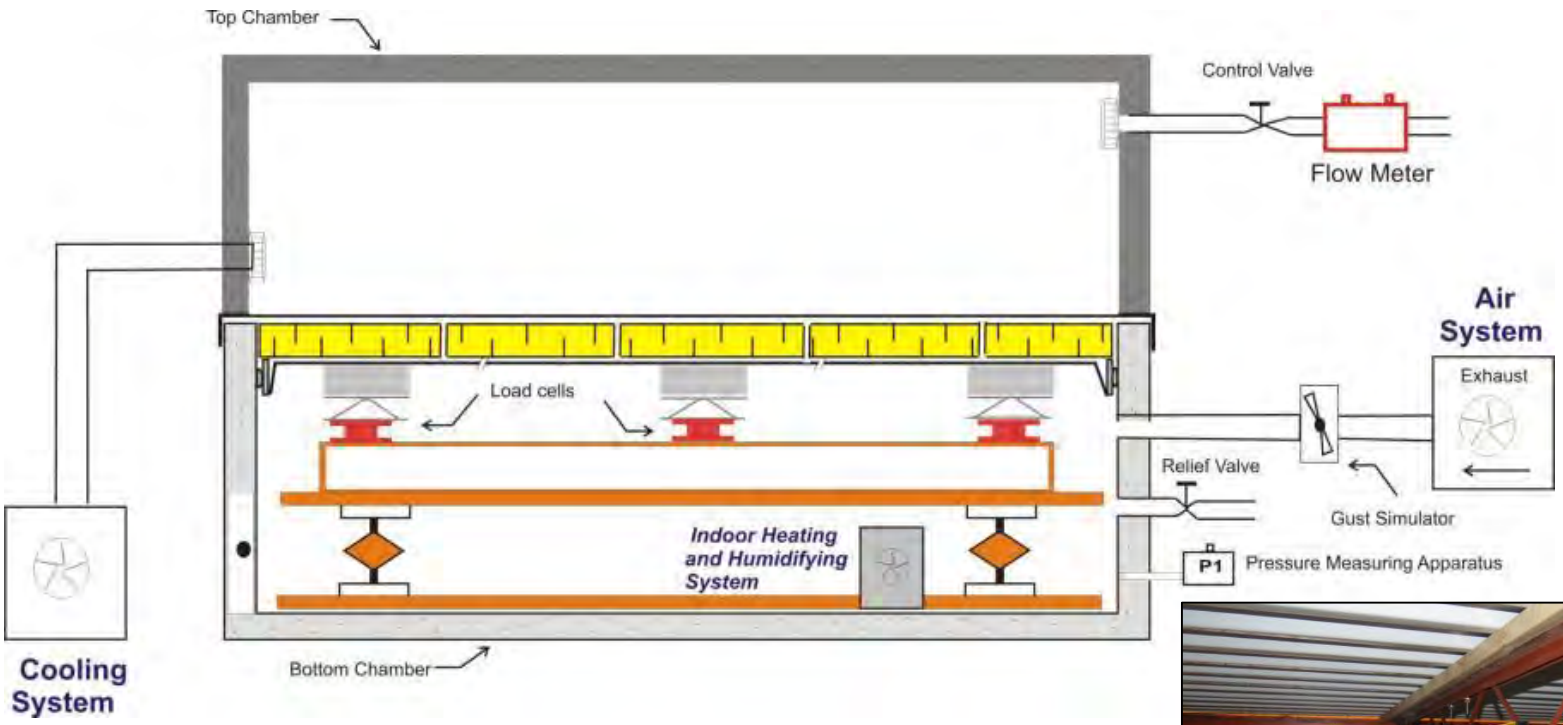
- Quantify air intrusion
- Moisture accumulation
- Effect of insulation layout
- Effect of vapor barrier/air retarder
- Solar absorptance of the membrane
- Air Intrusion vs. Vapor Drive

What is the relation between air intrusion and moisture transport and the limits for potential condensation ?

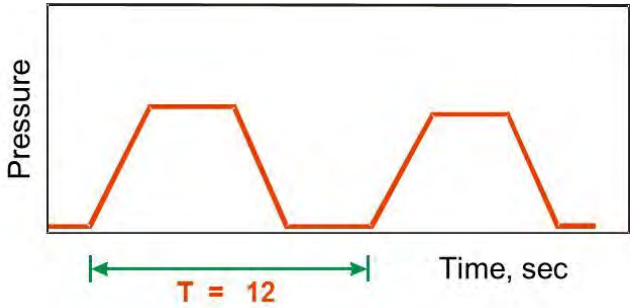
Experimental Approach
Energy Efficient Roof Testing Facility

- Air Intrusion
- Air Leakage
- Hygrothermal Performance
- Effective Thermal Resistance

Test Setup


Top Chamber
Control Valve
Flow Meter
Air System
Exhaust
Load cells
Relief Valve
Gust Simulator
Indoor Heating and Humidifying System
P1
Pressure Measuring Apparatus
Cooling System
Bottom Chamber

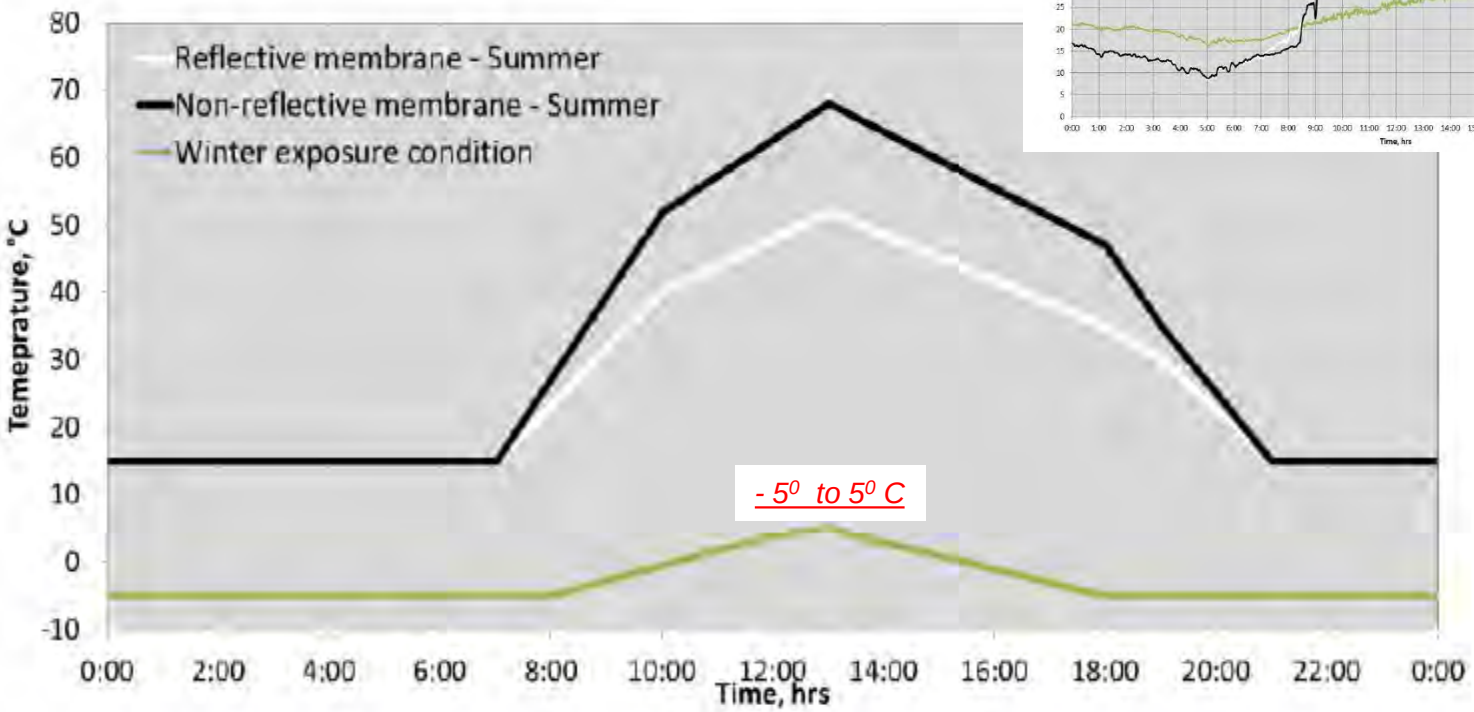
Test Protocol

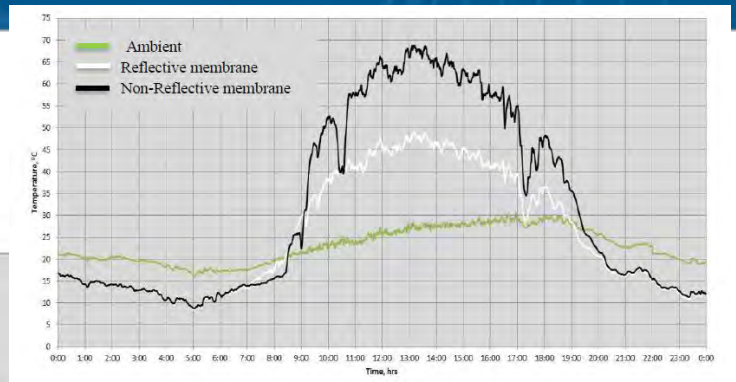


Test Parameters

- Pressure: 5 psf
- Gust Duration: 12 sec
- Temperature:
  - Winter: - 5 to 5^{0}C
  - Summer: Thermoplastic : 15 to 48^0±C; Thermoset and Mod-Bit: 15 to 68^0± C
- Relative Humidity: 40 %
- Test Duration: 24 hrs

Test Parameter : Temperature



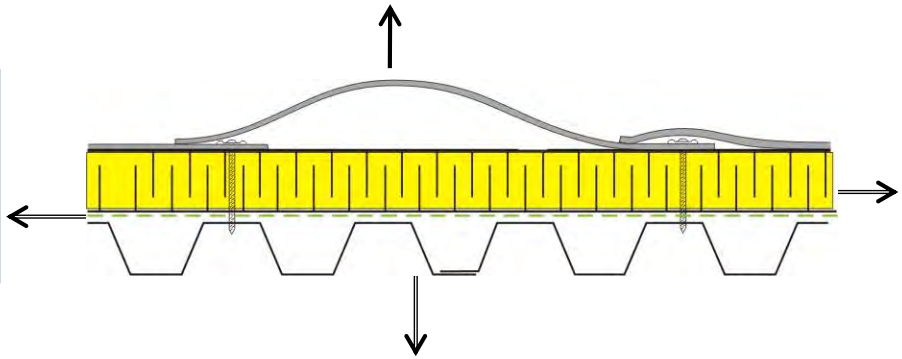


Tested Systems

Label	System details	Label	System details
S1	Thermoplastic (6ft) – 2 inch ISO	S7	Thermoplastic (10ft) – 2 inch staggered ISO
S2	Thermoplastic (6ft) – 4 inch ISO	S8	Thermoplastic (6ft) – 2 inch ISO, kraft paper adhesive seam
S3	Thermoplastic (10ft) – 2 inch ISO	S9	Thermoplastic (6ft) – 2 inch ISO, kraft paper seam tape
S4	Thermoset (10ft) – 2 inch ISO	S10	Thermoplastic (6ft) – 2 inch ISO, polyethylene seam tape
S5	Modified Bituminous (3ft) – 2 inch ISO	S11	Thermoplastic (6ft) – 2 inch ISO, self-adhered sheet
S6	Thermoplastic (6ft) – 2 inch staggered ISO	S12	Thermoplastic (6ft) Vapor Diffusion – 2 inch ISO

Membrane
Mod-Bit, Thermoplastic, Thermoset
Fr= 12 in

No VB, Kraft paper, Polyethylene, Self adhered sheet



4 ft x 4 ft x 2 in.
4 ft x 4 ft x 4 in

Deck : 22 Ga -80 ksi

System Installation

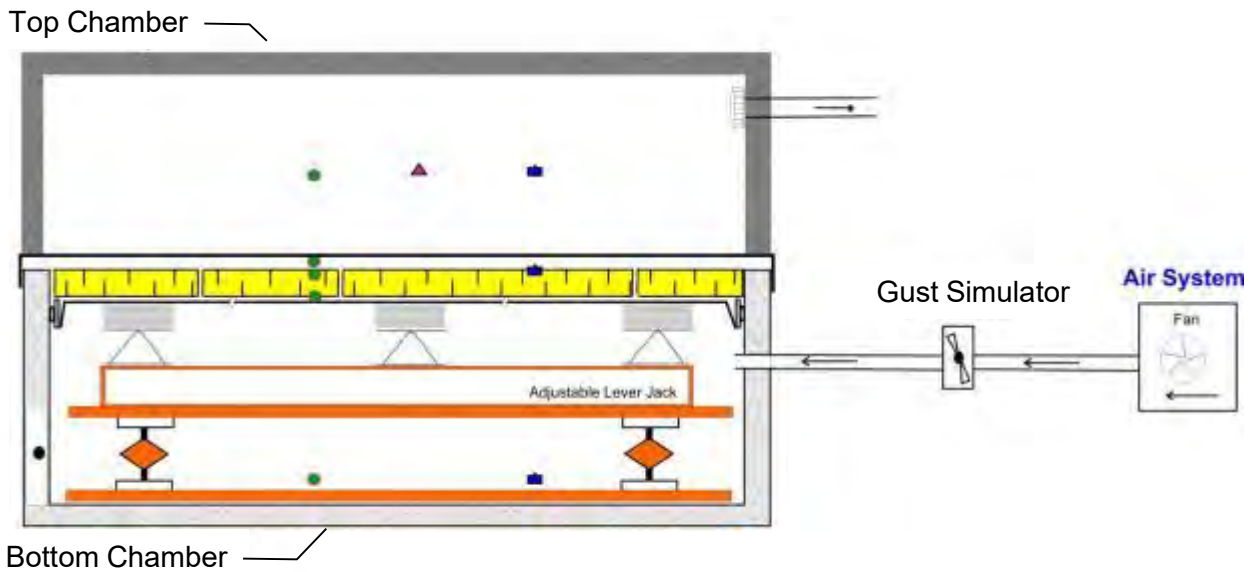
Steel deck installation

Vapor barrier/air retarder installation

Insulation installation

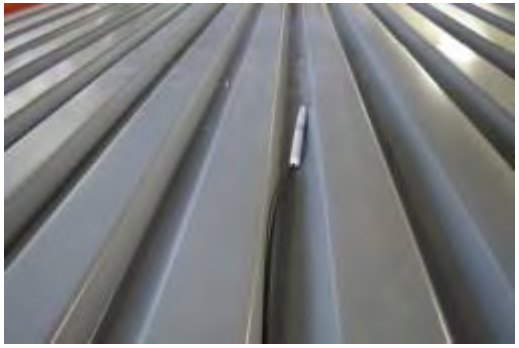
Reflective (left) and non-reflective (right) membrane installation

Instrumentation



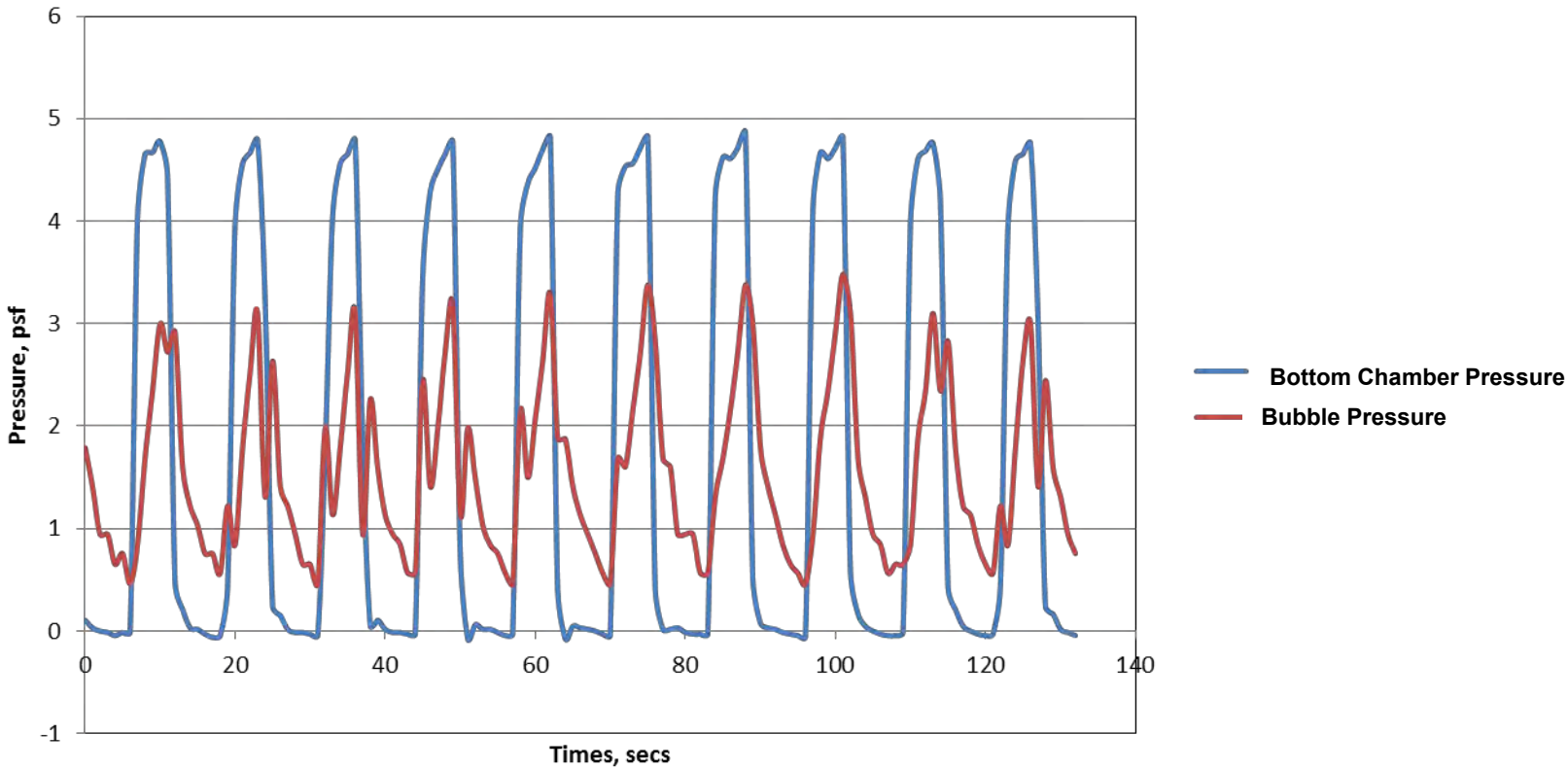
Legend

- ***Pressure Transducers***
- ***Relative Humidity and Temperature Sensors***
- ***Deflection Sensor***



Completed System Ready for Testing

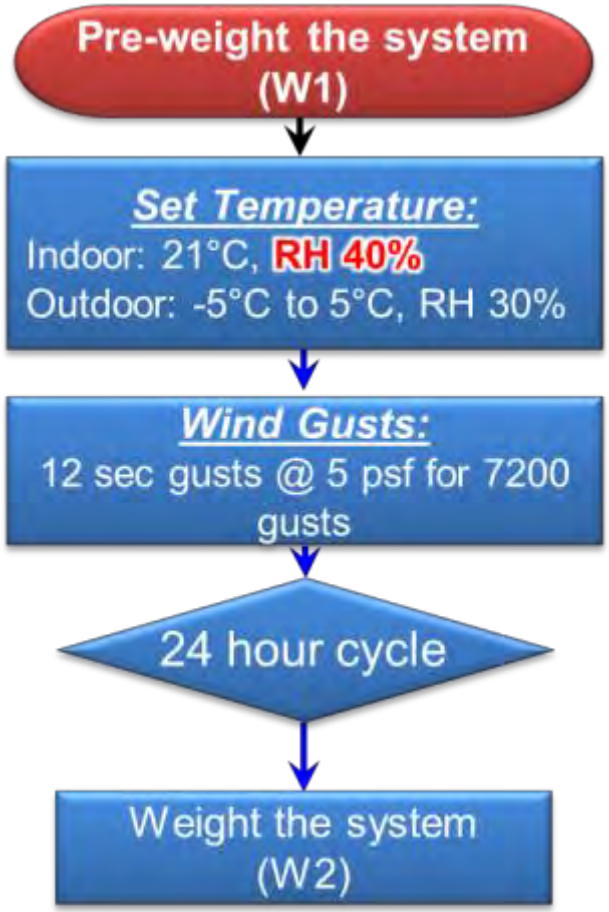
Step 1 : Air Intrusion Quantification



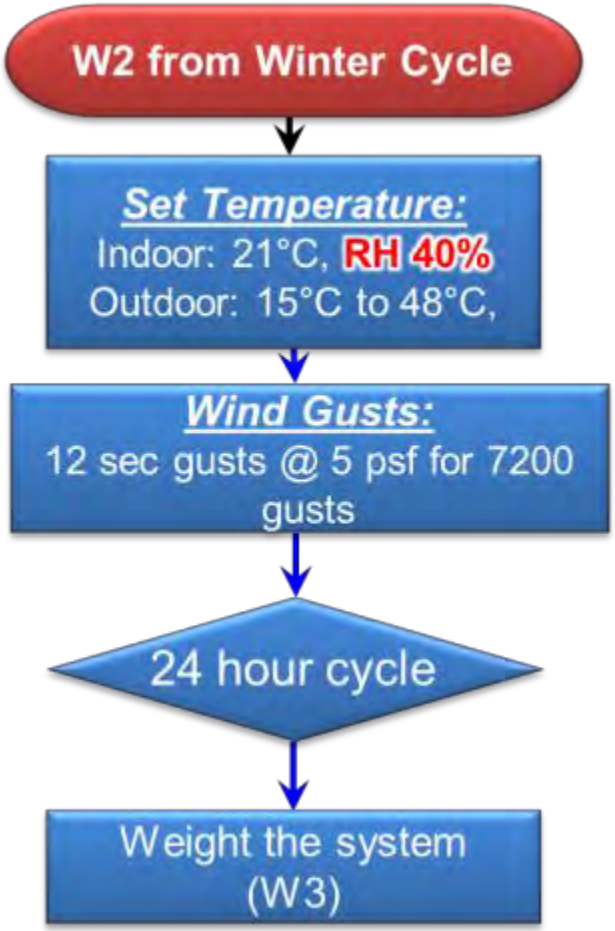
Air Intrusion per GUST = 3.37 ft^3 (95.61 Litres)

Step 2 : Dynamic Wind – Temperature Testing

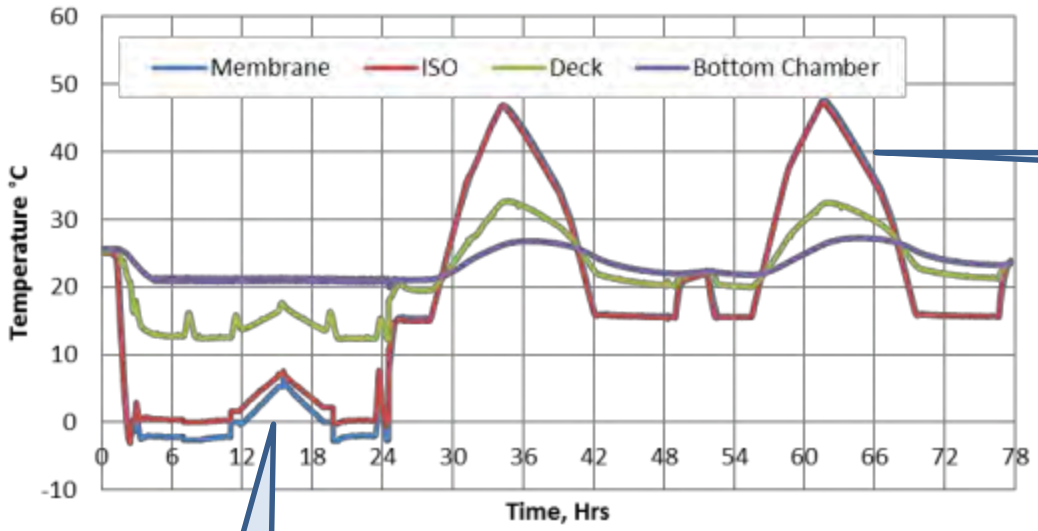
2.1 Winter Cycle



2.2 Summer Cycle

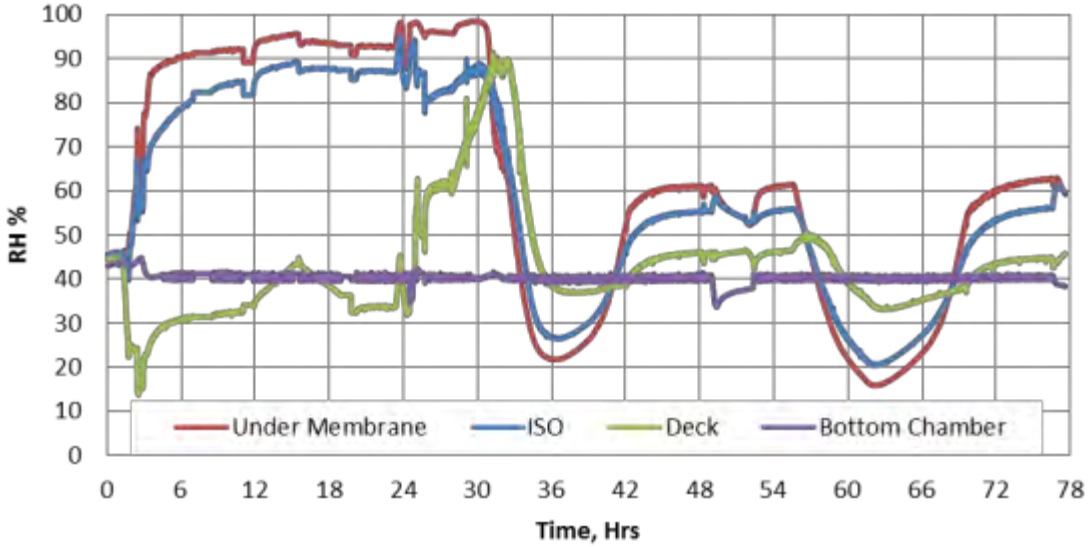


Results
S1: Time History Plots

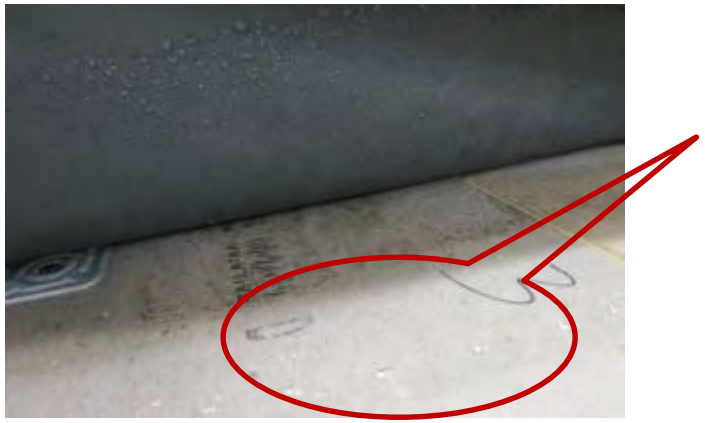


Two Summer Cycles

Winter Cycle



S1-System Condition after Winter Cycle



S1 : System Condition after Winter and Summer Cycle

After 24 Hrs Summer Cycle

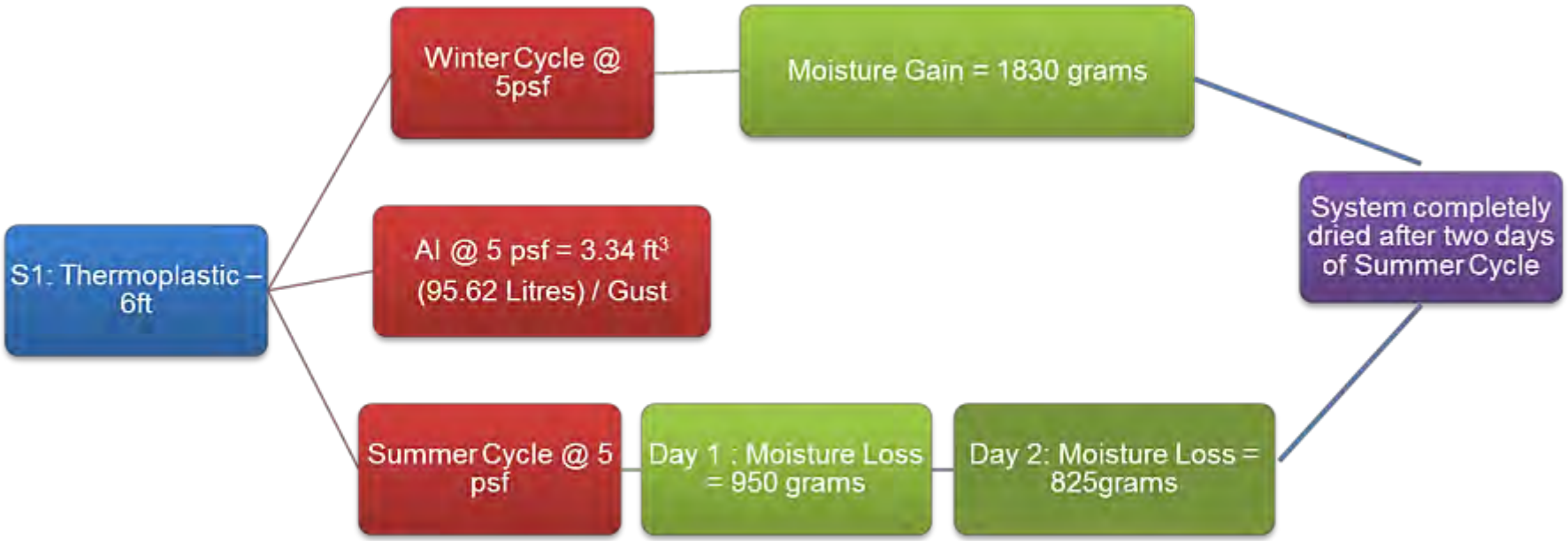
After 48 Hrs Summer Cycle

S1 - Weight Observations – after One Winter & Two Summer Cycles

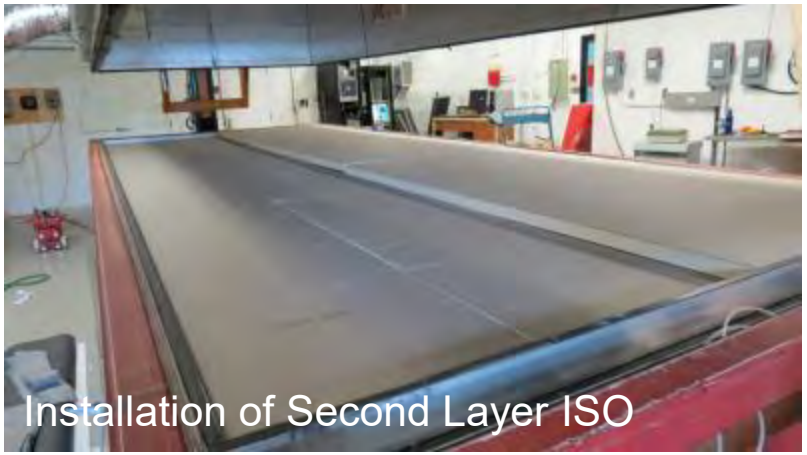
Condition	Weight (gm)
Initial (W1)	396580
After Winter Cycle (W2)	398410
W2- W1 (Moisture Gain) – a	**1830**
After One Summer Cycle (W3)	397460
W3-W2 (Moisture Loss) – b	**-950**
After Second Summer Cycle (W4)	396735
W3-W4 (Moisture Loss) – c	**-825**
Moisture in the System [a – (b+c)]	**55**

System dried completely

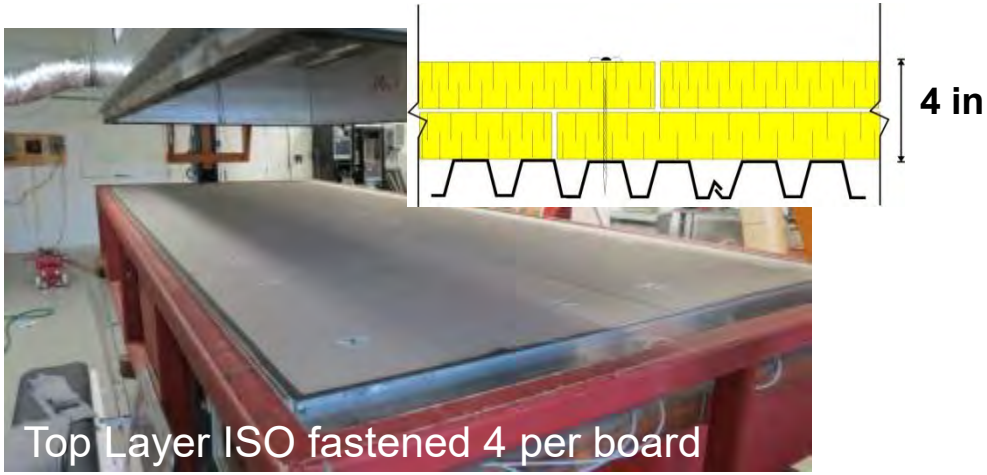
S1 – Summary


S1: Thermoplastic – 6ft
Winter Cycle @ 5psf
Moisture Gain = 1830 grams
Al @ 5 psf = 3.34 ft3 (95.62 Litres) / Gust
Summer Cycle @ 5 psf
Day 1 : Moisture Loss = 950 grams
Day 2: Moisture Loss = 825grams
System completely dried after two days of Summer Cycle

S6 : Thermoplastic – 6ft – Two layer Staggered Insulation Construction



Installation of Second Layer ISO



Top Layer ISO fastened 4 per board

Membrane Installation – System Ready for Testing

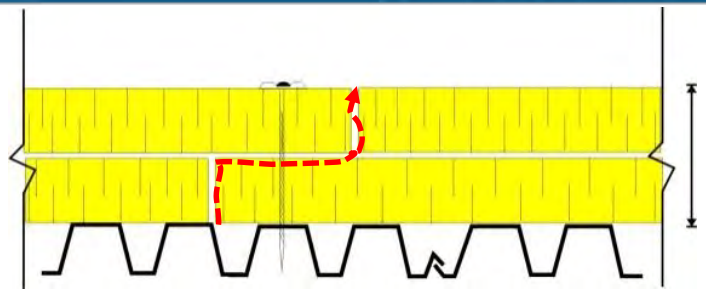
S6 : Thermoplastic – 6ft – Two layer Staggered Insulation – System Condition After Winter and Summer Cycle

Winter Cycle

Summer Cycle

No Insulation Shrinkage

S6 : Thermoplastic – 6ft – Two layer Staggered Insulation – Moisture Performance

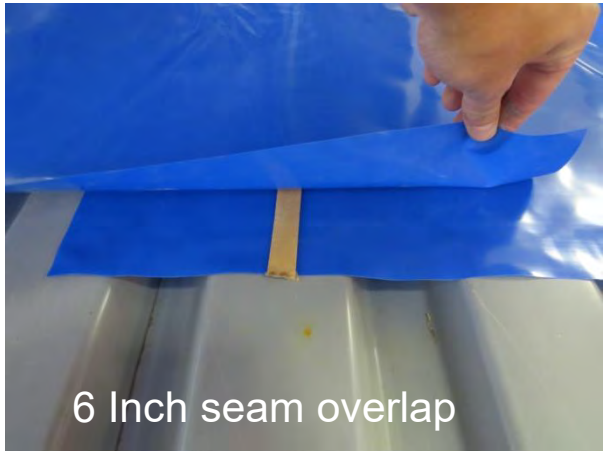


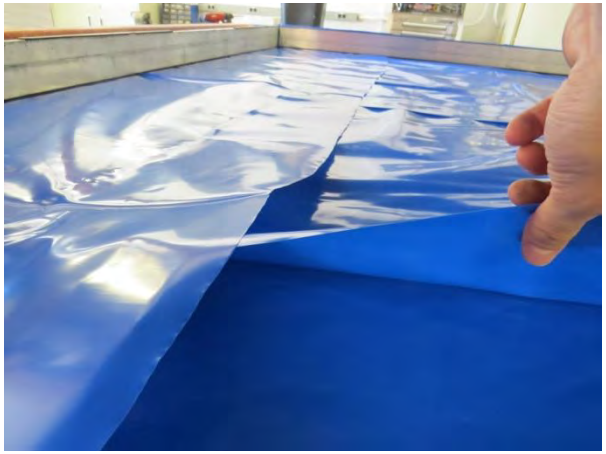
S6: Thermoplastic Staggered Layout

- Winter Cycle @ 5 psf → Moisture Gain = 610 grams
- Al @ 5 psf = 2.29 ft^3 (64.85 Litres) / Gust
- Summer Cycle @ 5 psf → Moisture Loss = 610 grams

→ System completely dried after one Summer Cycle

S10 : Thermoplastic System – 6ft with 10mil Poly as AR System Construction



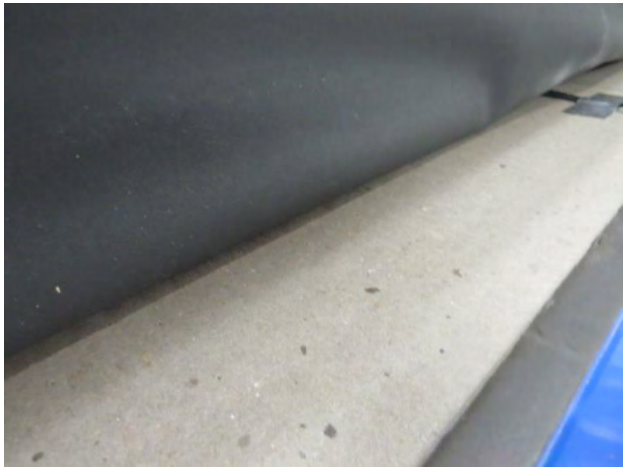


Seam Location

S10 : Thermoplastic System – 6ft with 10mil Poly as AR System Condition After Winter and Summer Cycle

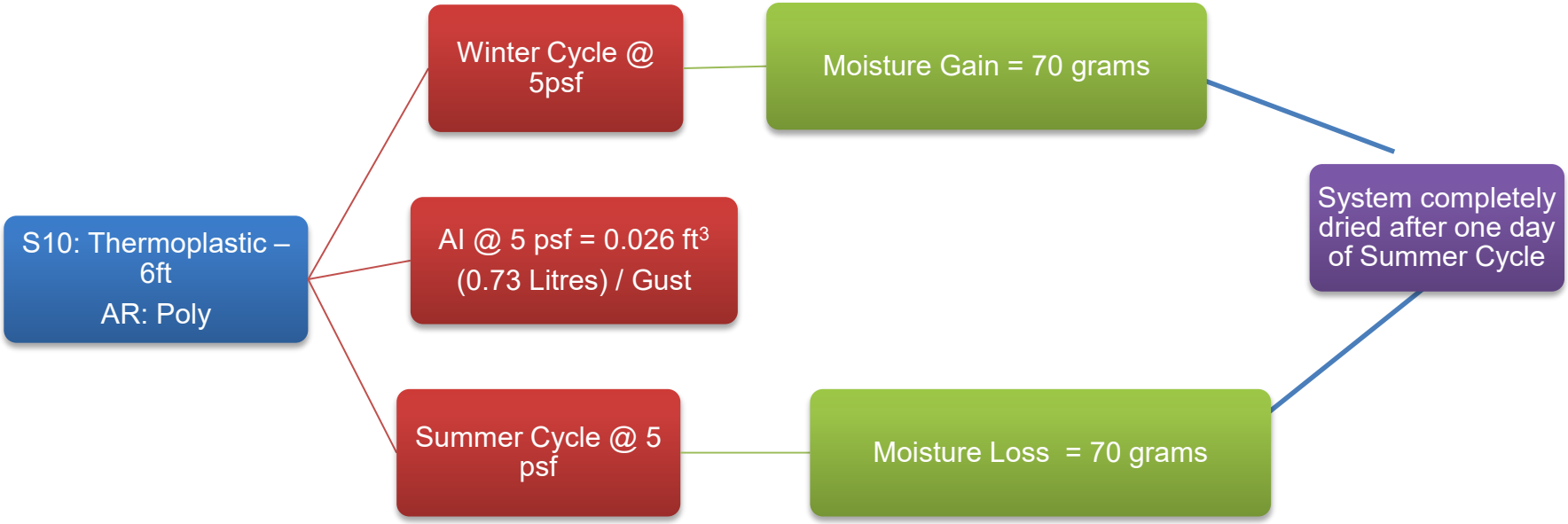
Winter Cycle

Summer Cycle

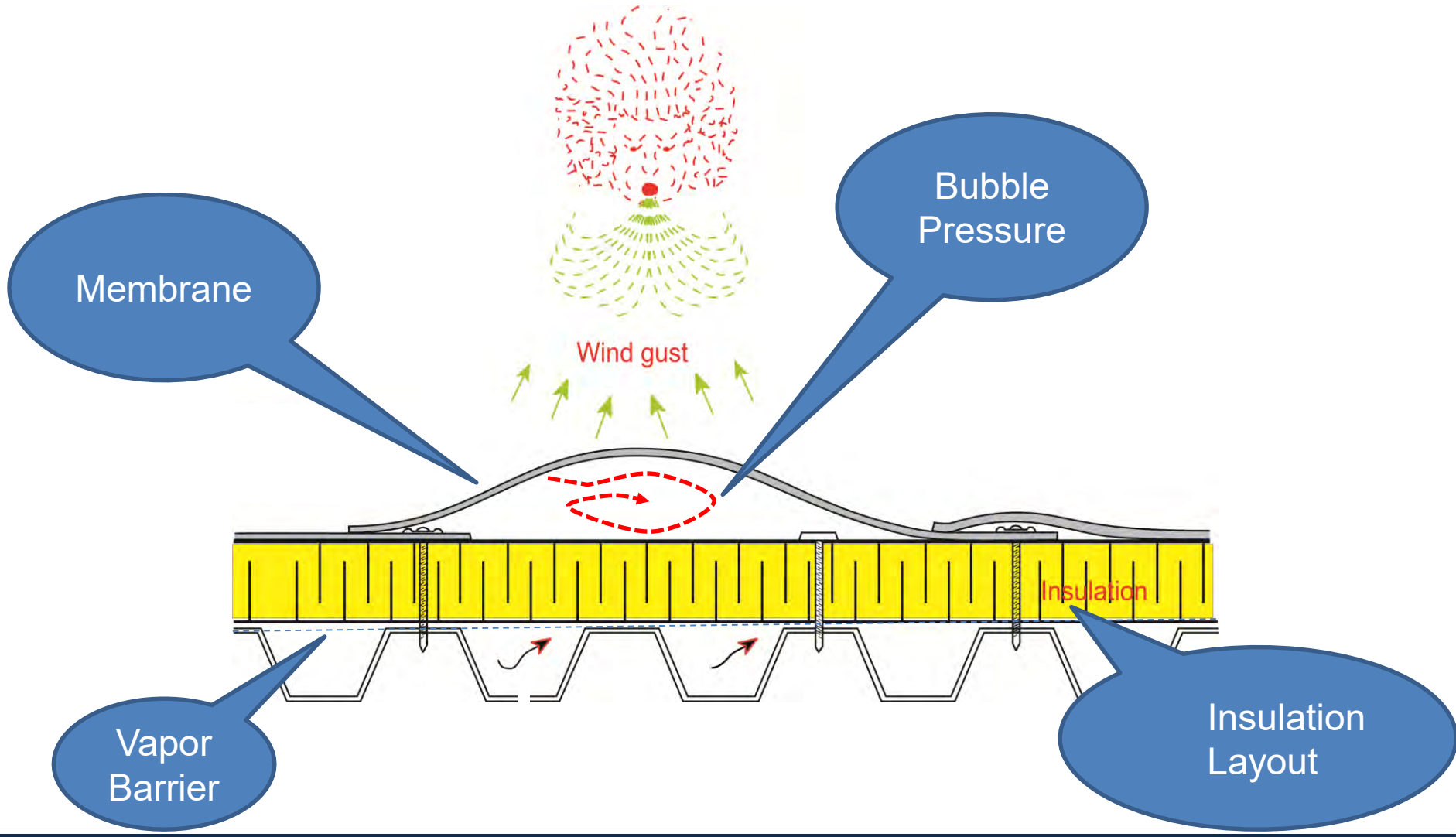


No Insulation Shrinkage

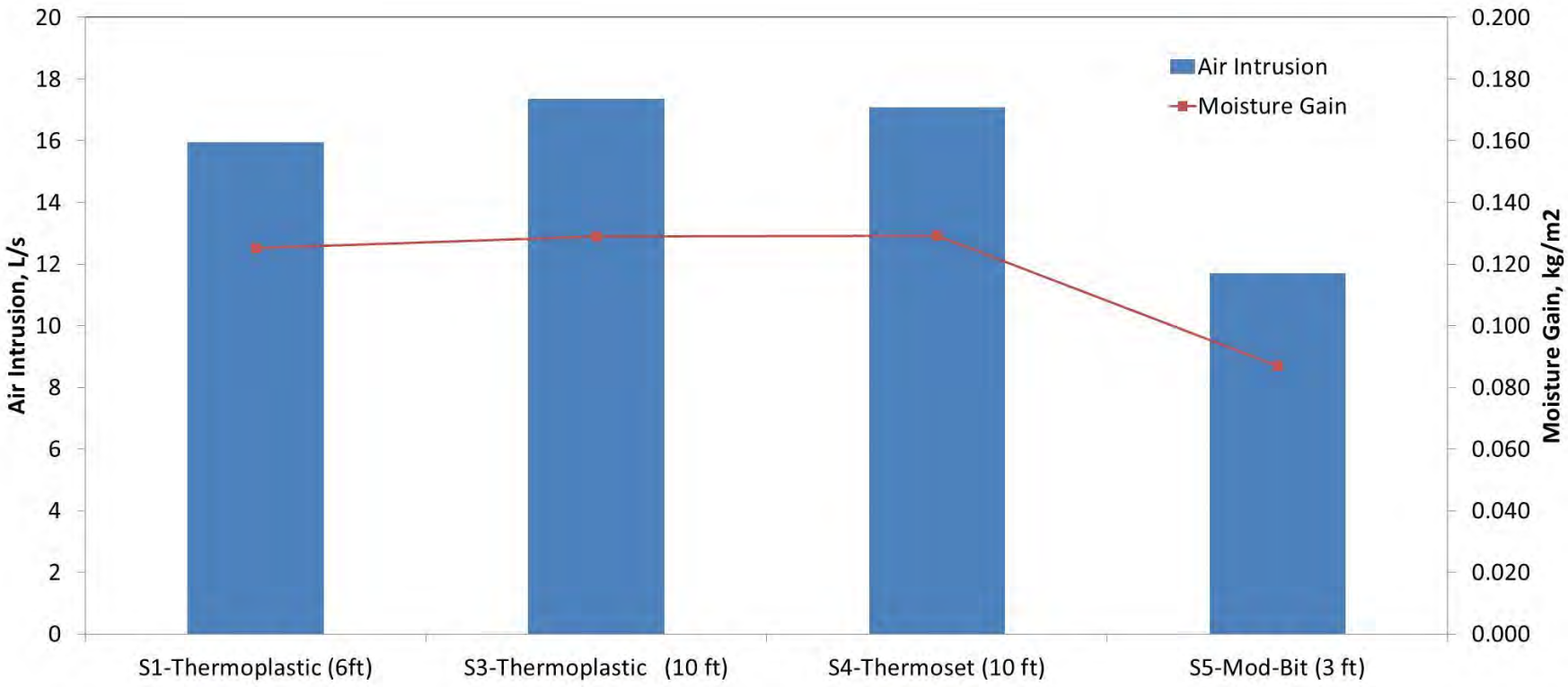
S10 : Thermoplastic System– 6ft with 10mil Poly as AR Moisture Performance



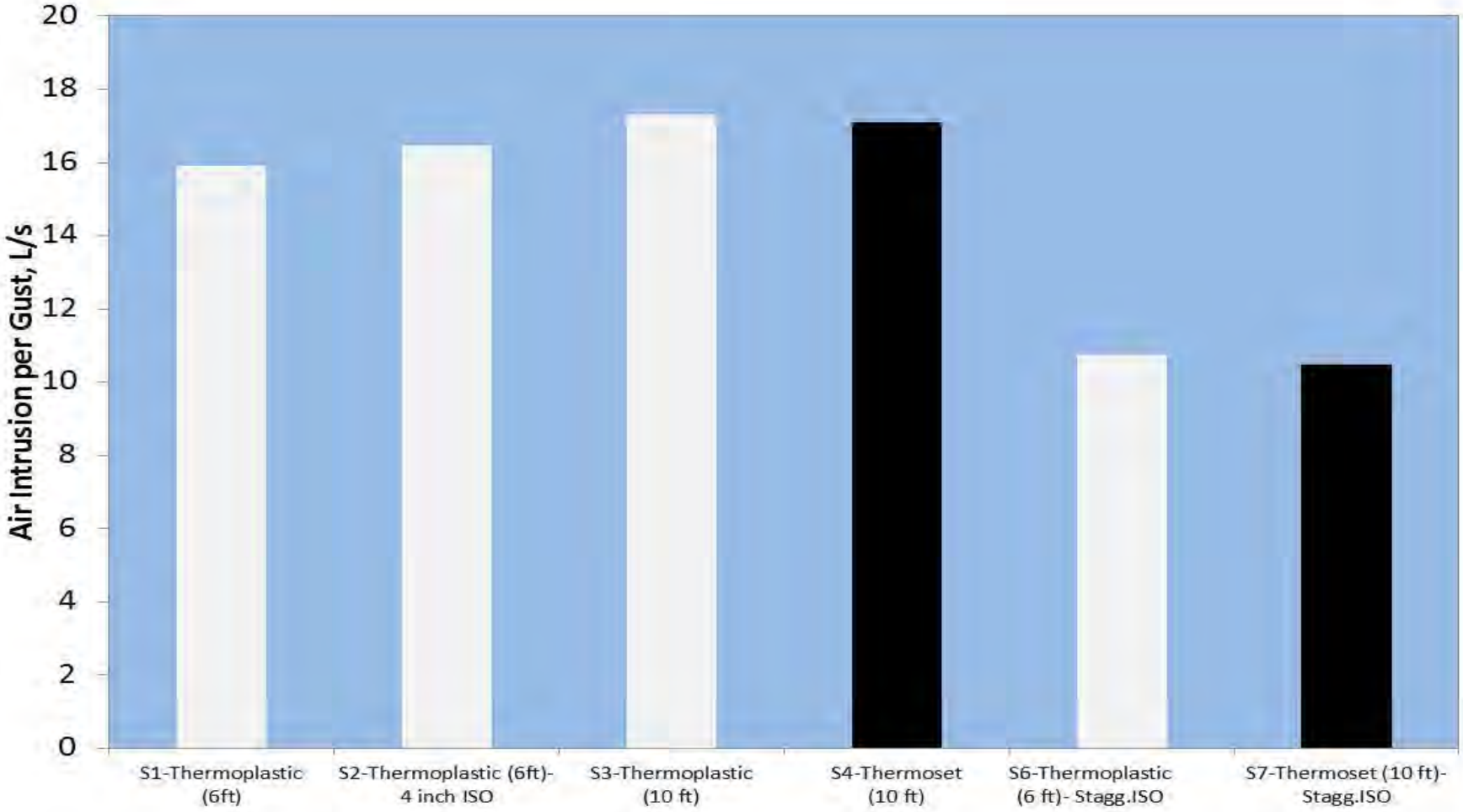
Results (Cont'd…_)



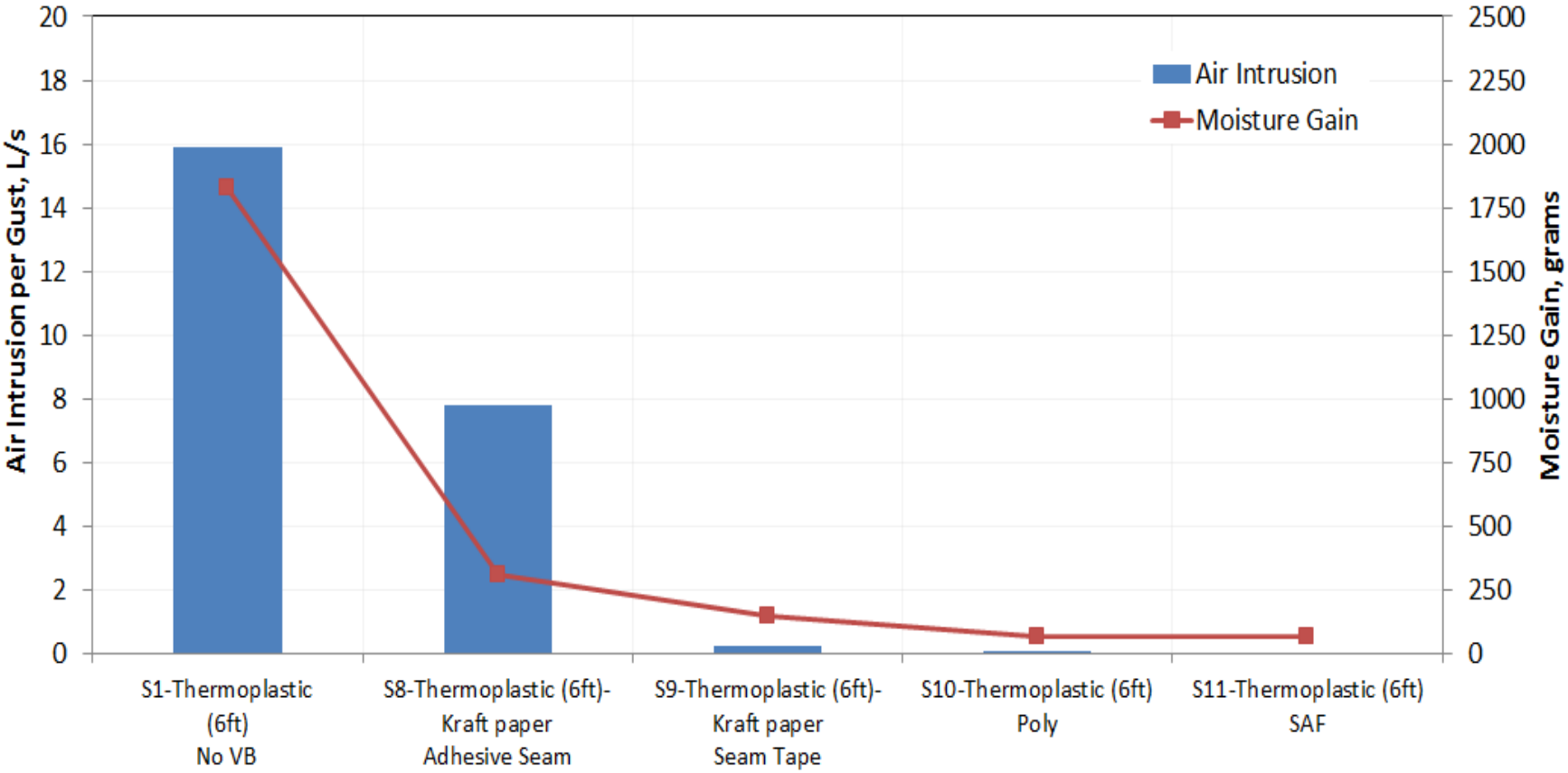
Effect of Membrane



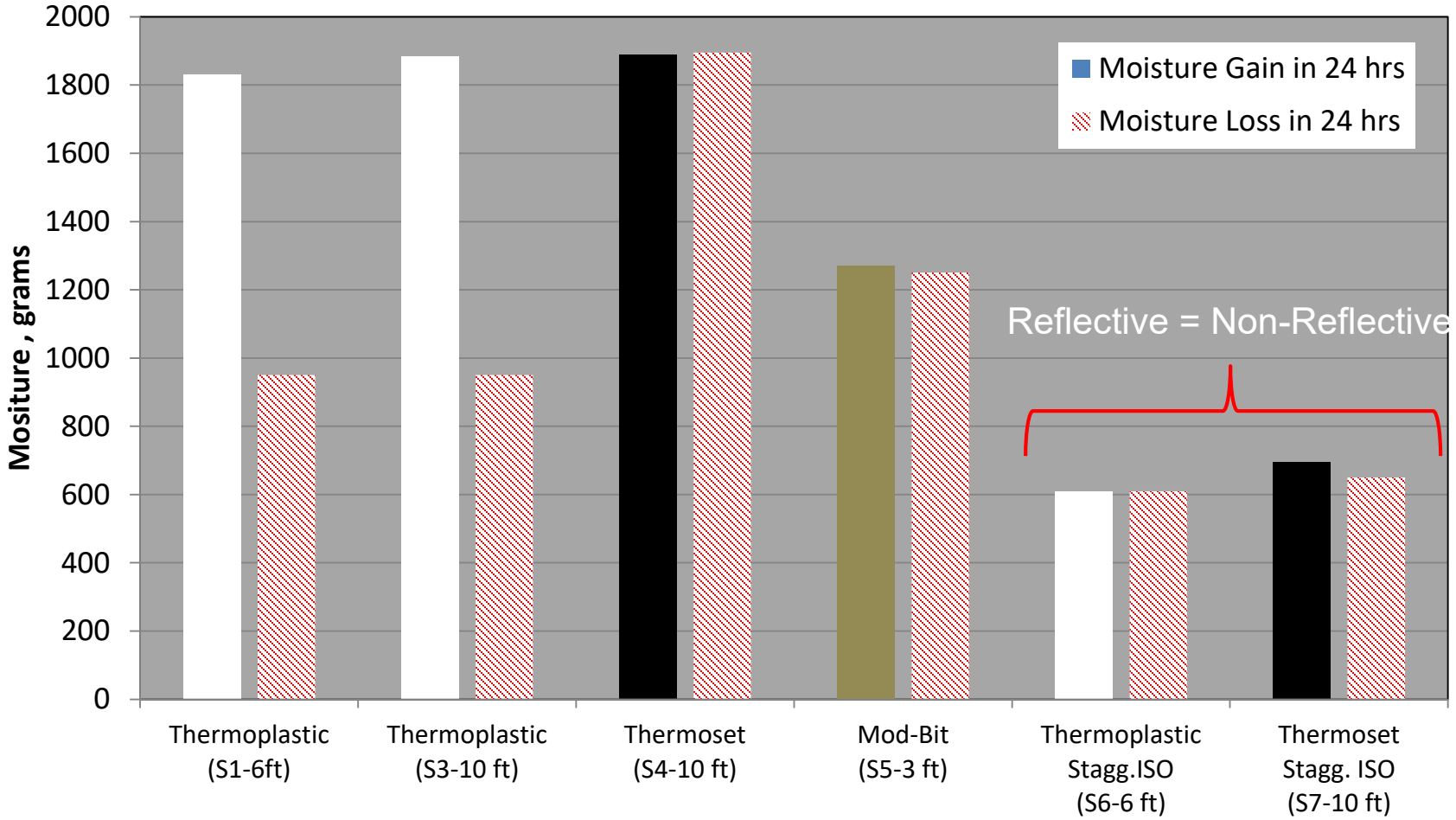
Effect of Insulation Layout



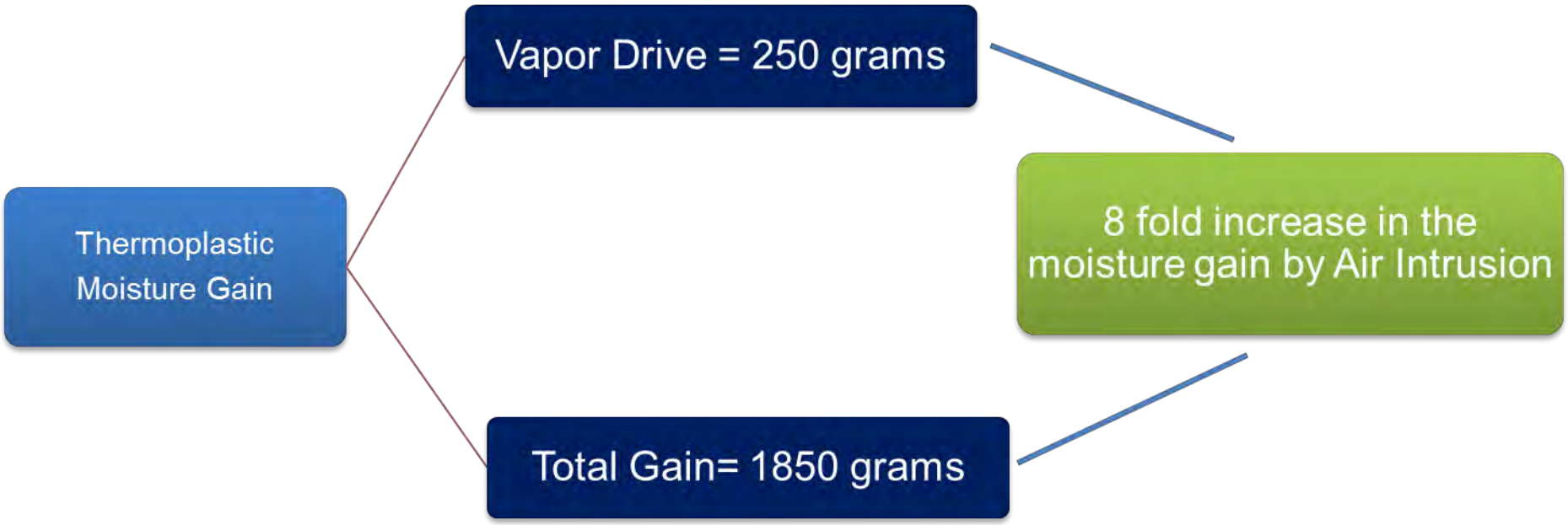
Effect of Vapor Barrier



Effect of Solar Absorptance



Air Intrusion vs. Vapor Drive : Moisture Gain



Air Intrusion vs. Vapor Drive : Drying Rate

Thermoplastic
@ 5psf in winter cycle
gained moisture of 1850 grams

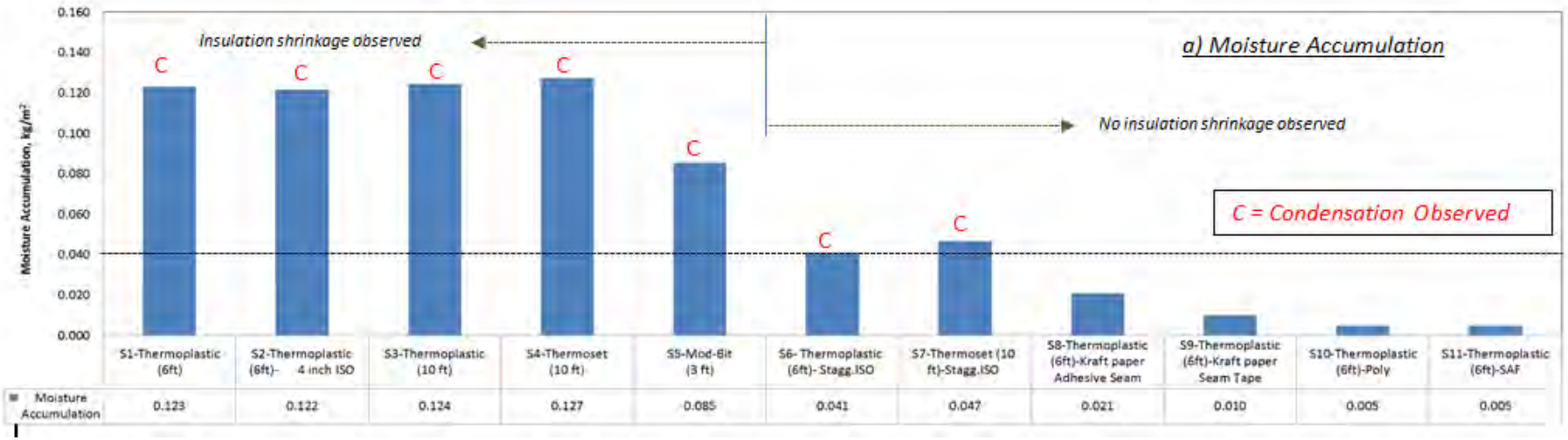
Moisture Loss through Vapor Drive in 24 hrs = 270 grams

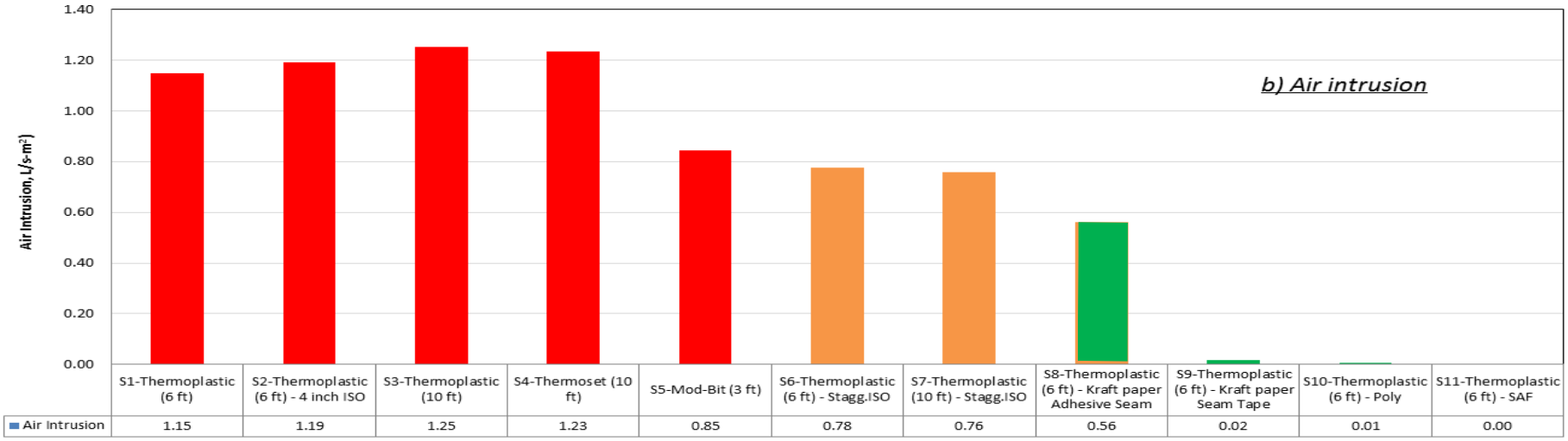
Vapor Drive contributed to 13% drying

Moisture Loss through Air Intrusion in 24 hrs = 970 grams

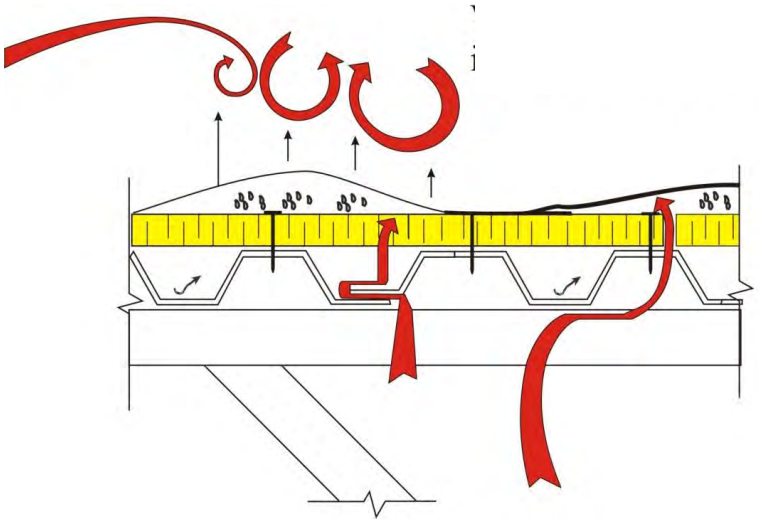
Air Intrusion contributed to 52 % drying

Air Intrusion Limits





Phase 2: Air Intrusion Impact On Moisture Transport - Conclusions



- Quantify air intrusion
- Moisture accumulation
- Effect of insulation layout
- Effect of vapor barrier/air retarder
- Solar absorptance of the membrane
- Air Intrusion vs. Vapor Drive