Institute For Research in Construction

International Symposium 2011

Air Intrusion and Its Impact on Moisture Transport in Mechanically Attached Roofing Systems

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Presenter: Peter Kalinger

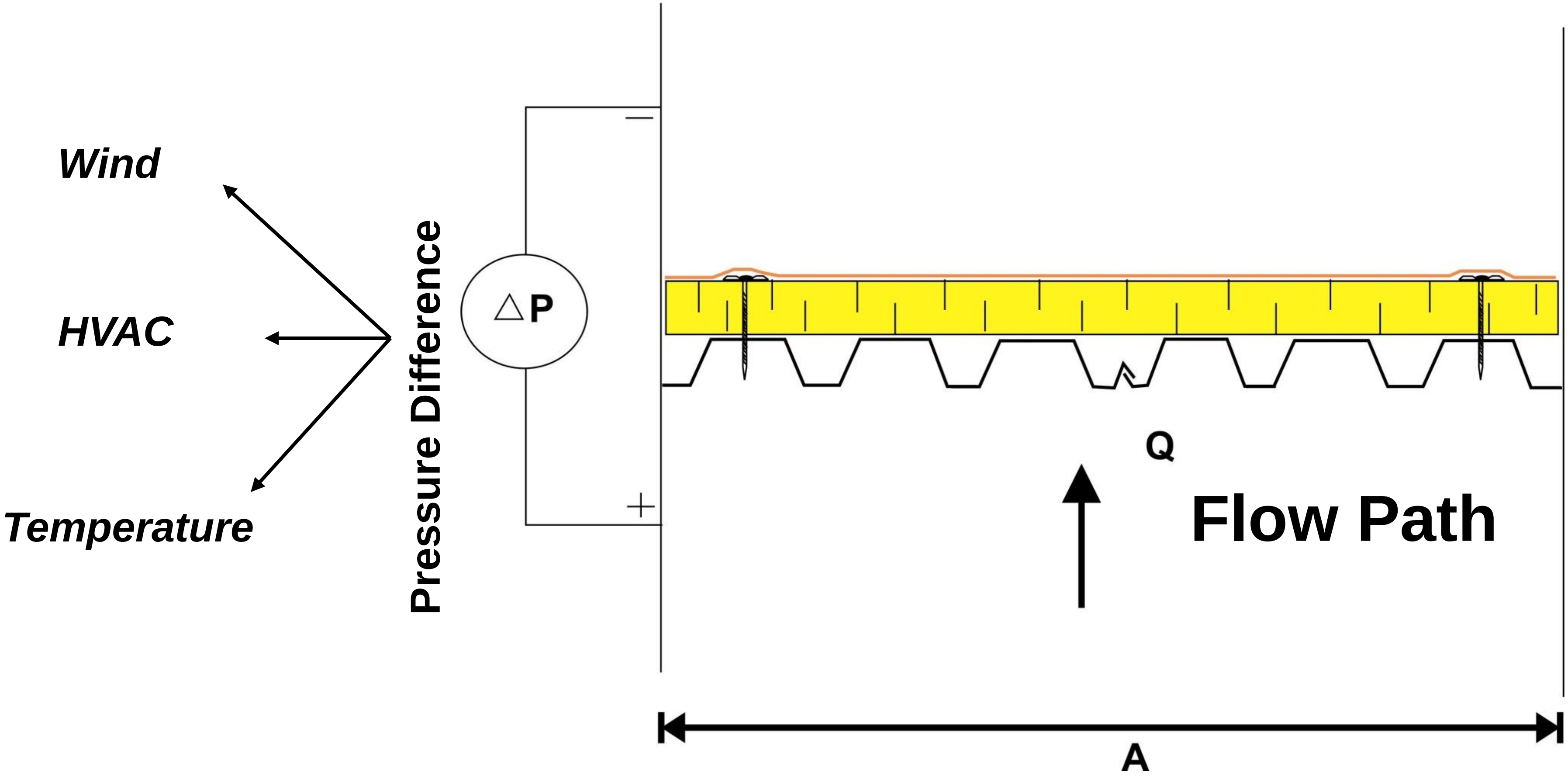
National Research Council Canada
Conseil national de recherches Canada

Canada

Outline

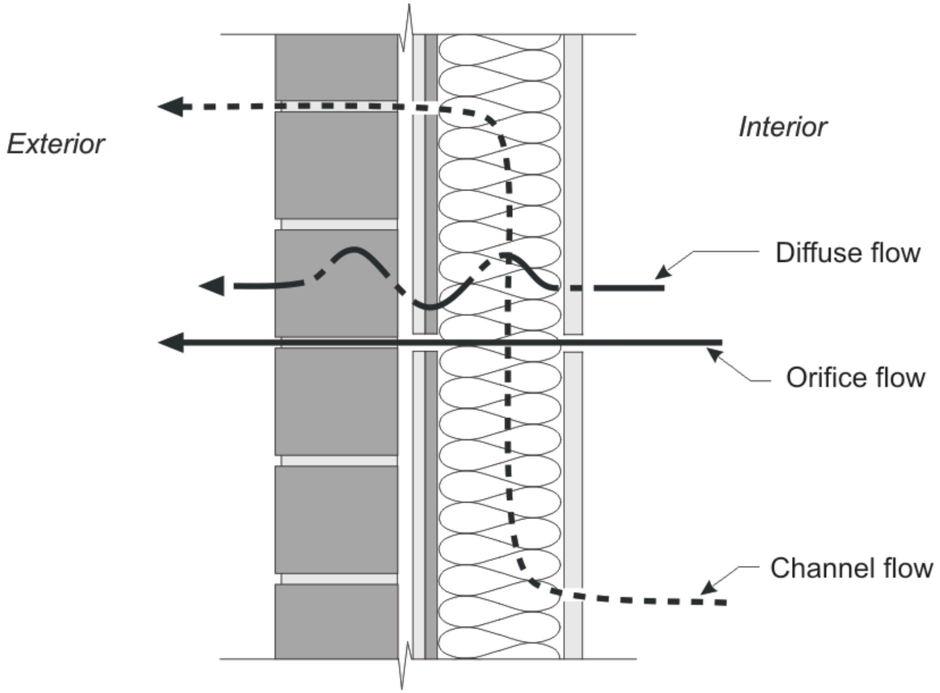
- Overview of Air Intrusion
- Quantification of Air Intrusion – Experimental Testing
- Impact of Air Intrusion on Moisture Transport – Experimental Testing
- Conclusions

SCIENCE BEHIND AIR MOVEMENT



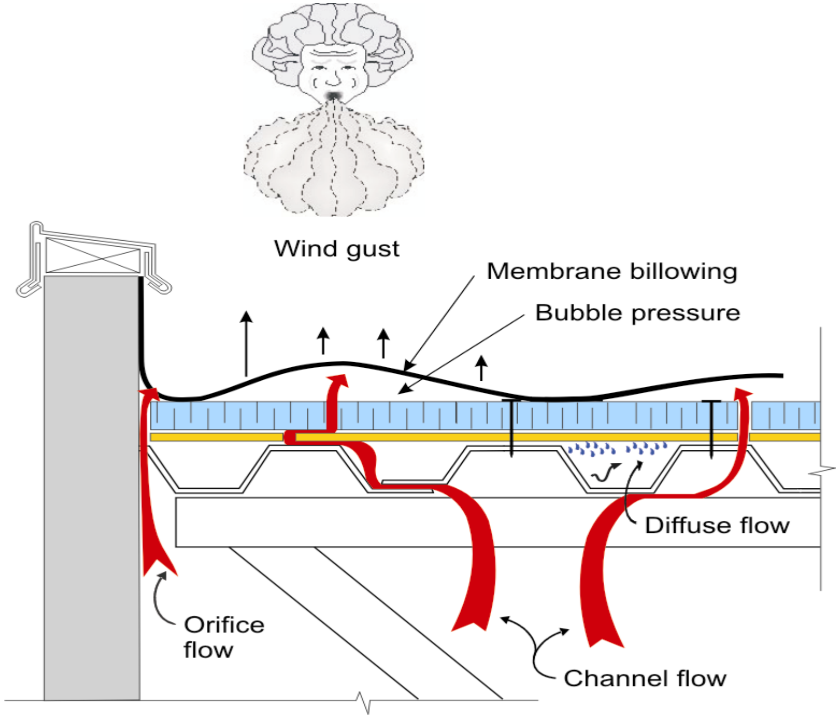
AIR LEAKAGE

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 INTRUSION

When conditioned indoor air enters into a building envelope assembly but cannot escape to the exterior environment, it is termed as "Air Intrusion".



AIR LEAKAGE VS. AIR INTRUSION

AIR INTRUSION vs. AIR LEAKAGE:

THE DILEMMA FOR LOW-SLOPED, MECHANICALLY ATTACHED MEMBRANE ROOFS

By Bas A. Baskaran, PhD, and Suda Molleti, PhD

The majority of low-sloped roofs are constructed as conventional membrane roofing assemblies (membrane above insulation). Currently, four types of conventional assemblies are typically in use:

- Mechanically attached assembly,
- Loose-laid, ballasted assembly,
- Fully bonded assembly (insulation-fastened and membrane-adhered), and
- Adhesive-applied assembly (all components fully adhered).

Approximately one fourth of North American low-slope/commercial buildings are roofed with mechanically attached assemblies (NRCA 2004), and their popularity continues to grow. This paper differentiates the air intrusion and air leakage performance of the mechanically attached assembly.

The waterproofing membrane, the key component of mechanically attached roofs, is available in three different types:

- Modified bituminous membranes (mod bit), i.e., asphaltic-based, with a width of 3.3 ft (1 m),
- Thermosets, including the commonly used ethylene propylene diene monomer (EPDM), also known as ethylene propylene diene terpolymer, and
- Thermoplastics, encompassing a wider variety of roofing membranes, the most common of which are polyvinyl chloride (PVC) and thermoplastic olefin (TPO).

Both thermoset and thermoplastic membranes employ different seaming techniques due to their different chemical,

Figure 1A – Billowing of mechanically attached TPO membrane in the field (Photo courtesy of Hans Gerhardt).

Figure 1B – Billowing of mechanically attached TPO membrane in the lab.

4 • INTERFACE NOVEMBER 2009

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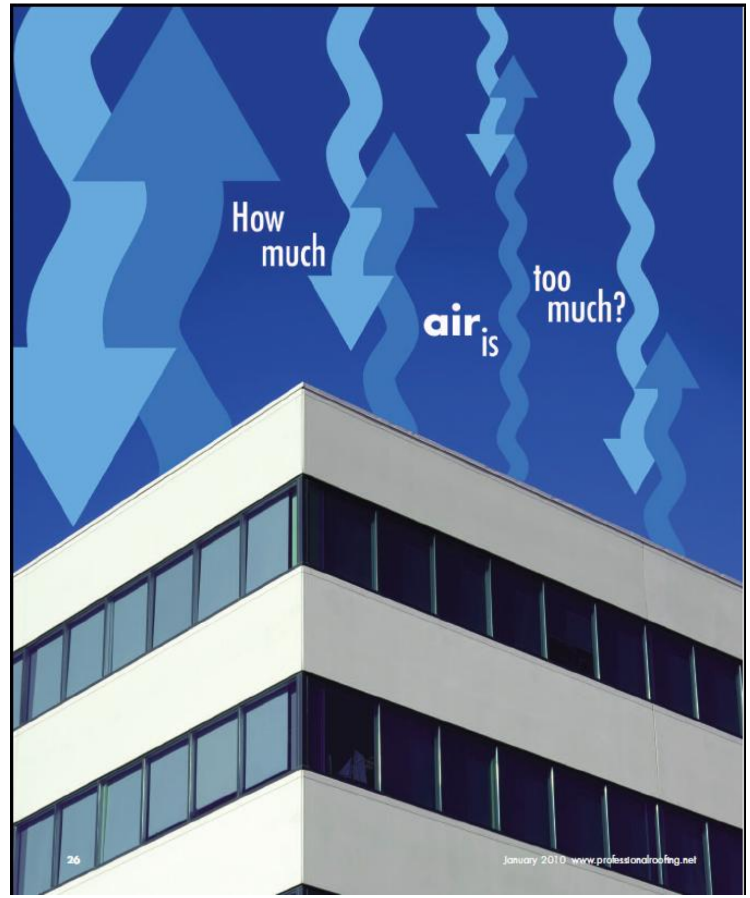
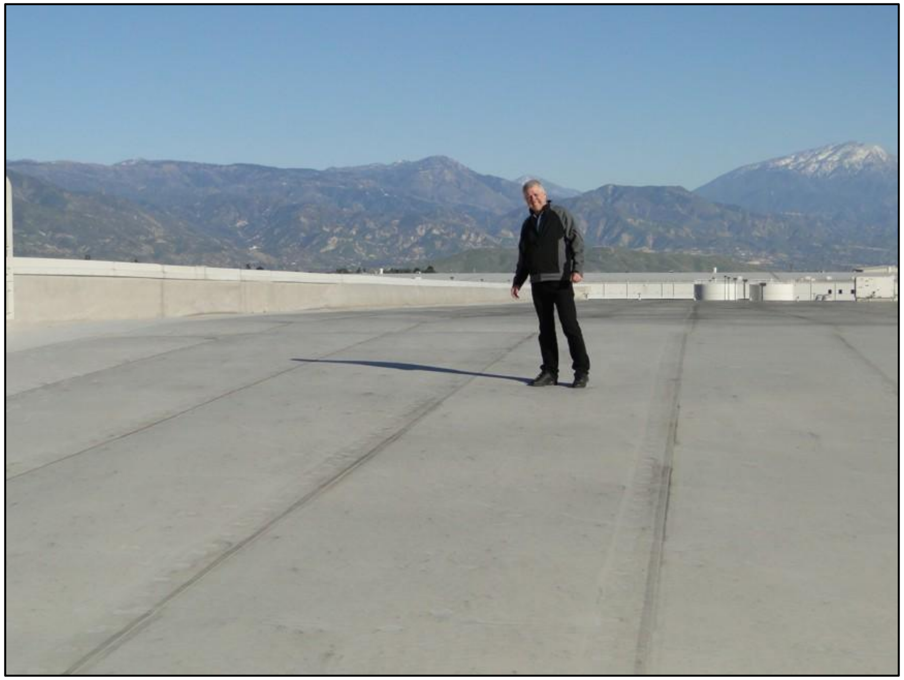


PROFESSIONAL ROOFING– JANUARY 2010

WIND UPLIFT ACTION OF MECHANICALLY ATTACHED ROOFING SYSTEM

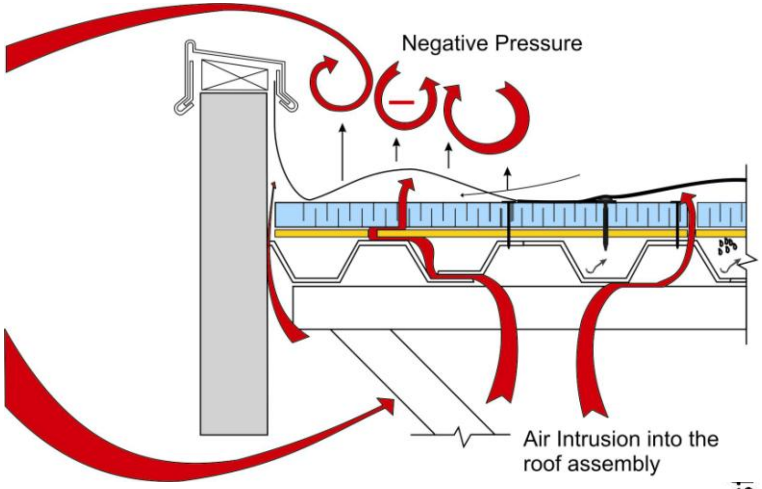


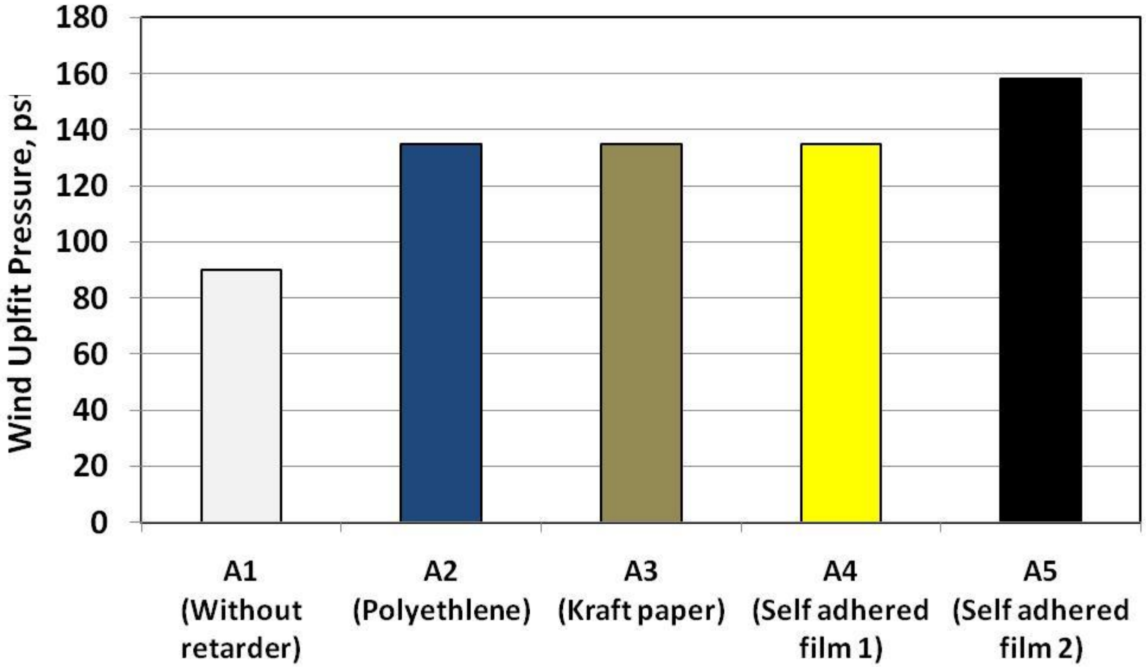
RIALTO, CALIFORNIA

WIND SPEEDS > 50 mph

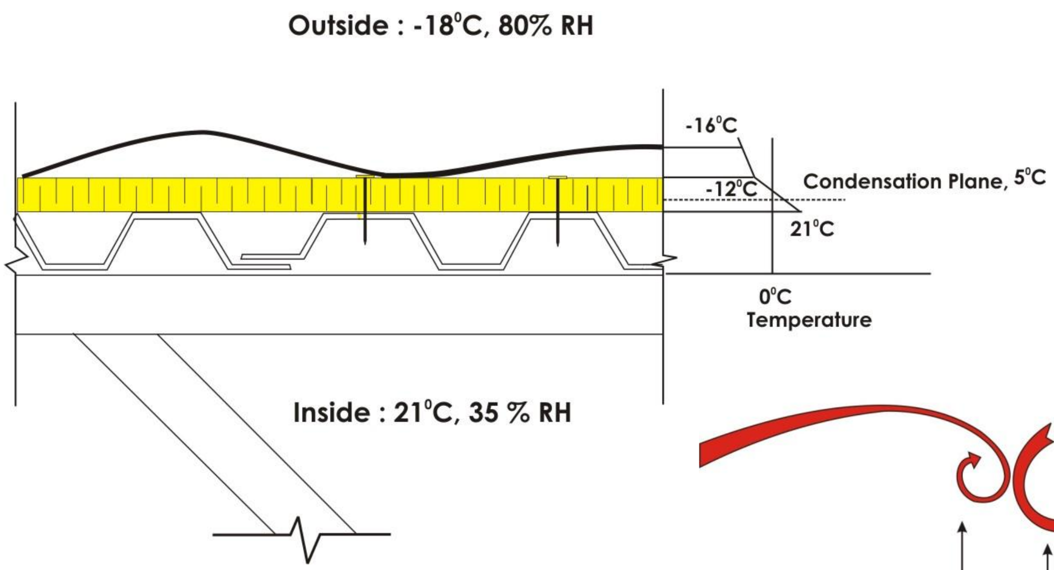
MEASURED PRESSURES > 30 psf

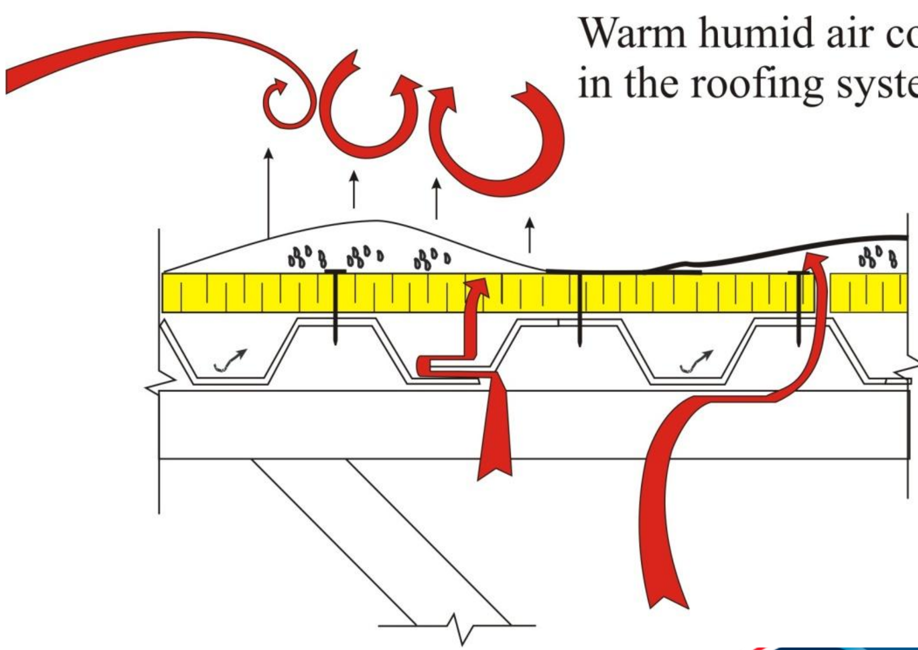
AIR INTRUSION IMPACT ON WIND UPLIFT RESISTANCE





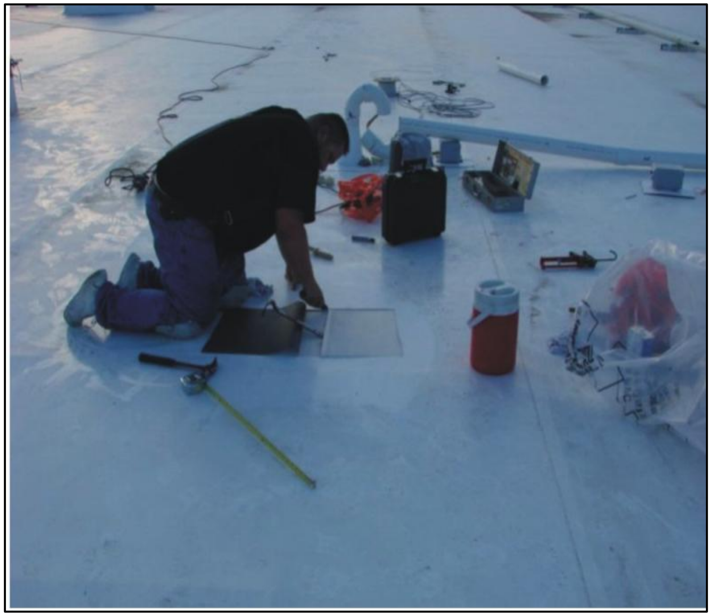
AIR INTRUSION IMPACT ON MOISTURE TRANSPORT

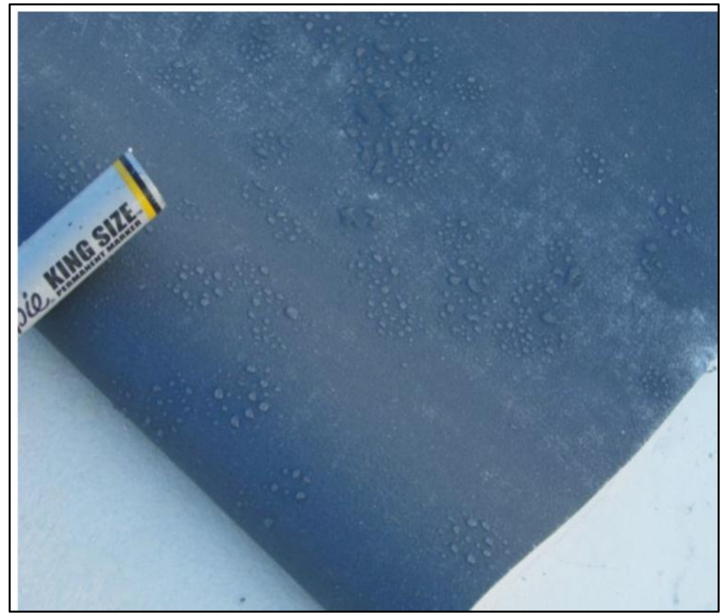




Warm humid air condensing in the roofing system

AIR INTRUSION IMPACT ON MOISTURE TRANSPORT

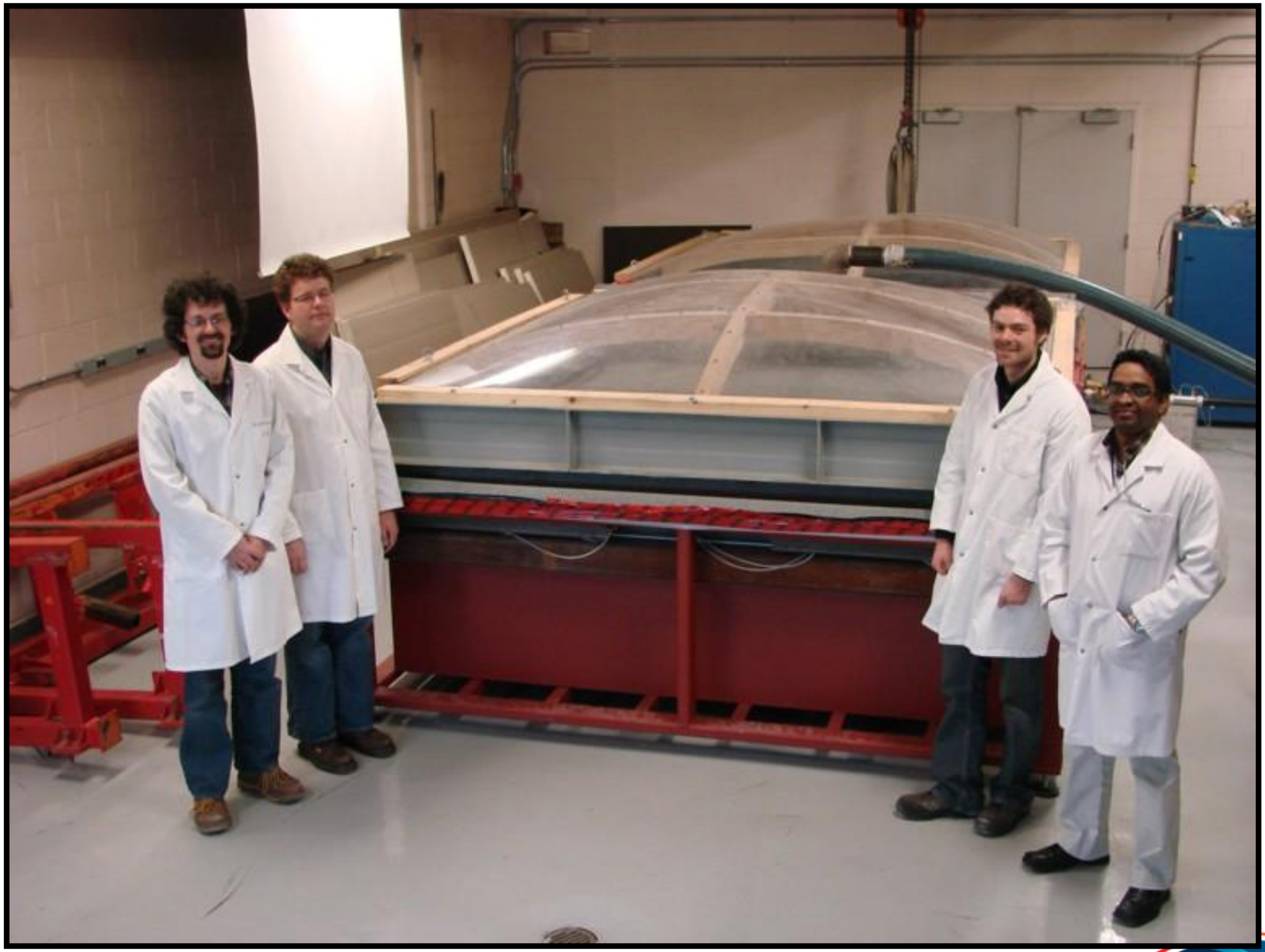




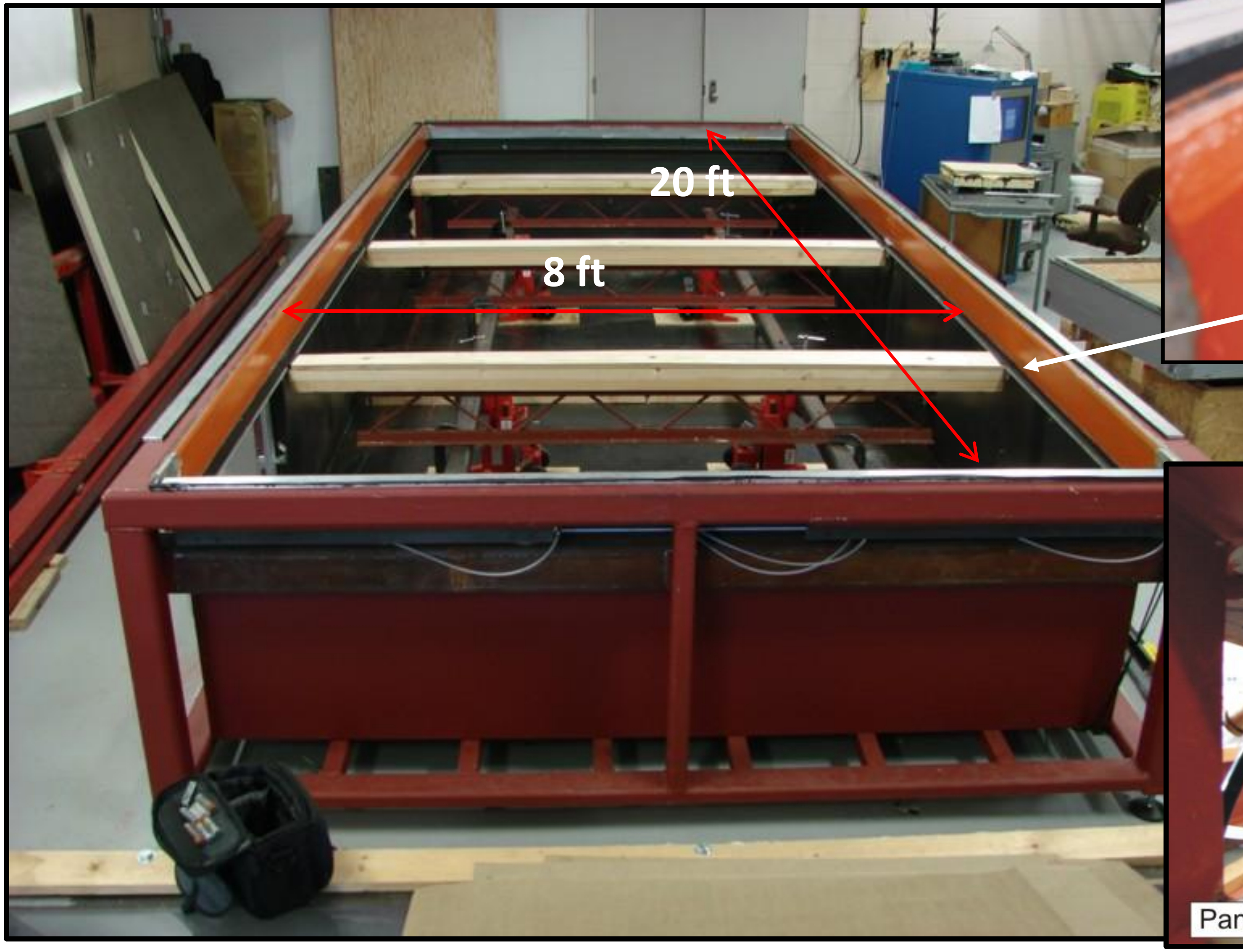
What is the relation between air intrusion and moisture transport and what are the limits for potential condensation ?

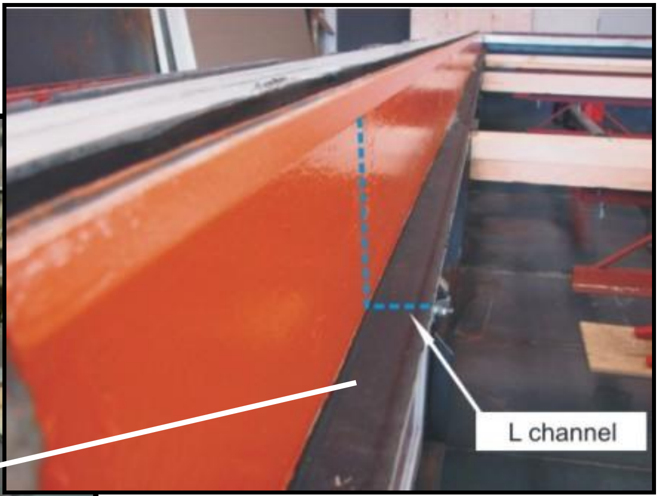
AIR INTRUSION RESEARCH
NRC/IRC

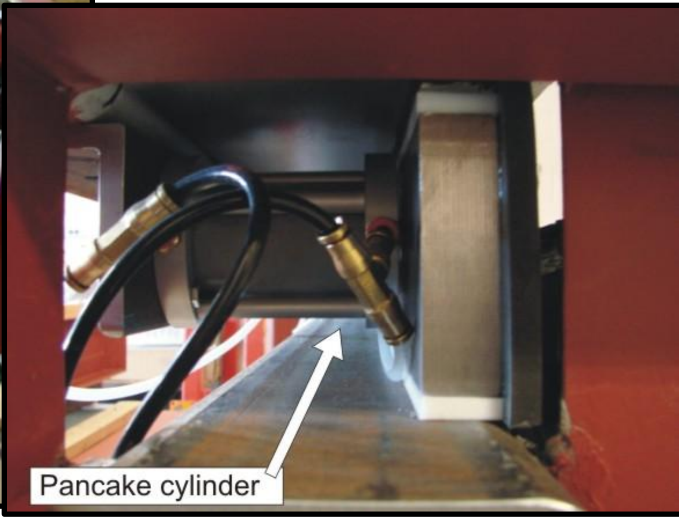
DYNAMIC ROOFING FACILITY AIR INTRUSION TEST FACILITY (DRF-AI)



BOTTOM CHAMBER

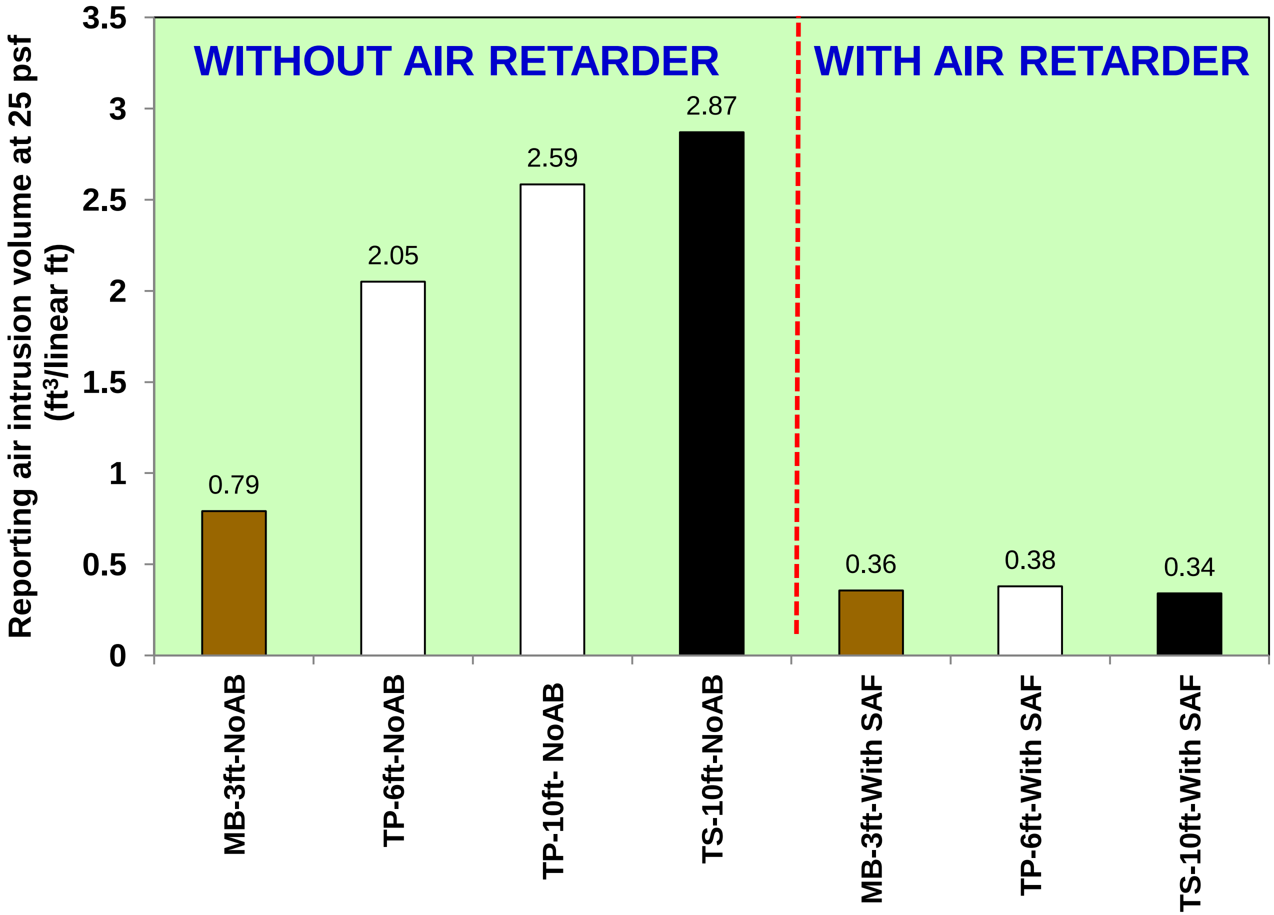






DECK INSTALLATION

SIGDERS DEVELOPED CONTROL DATA FOR AIR INTRUSION



NRCA/CRCA

Additional tests to fill the data

CRCA-NRCA RESEARCH PROJECT

MEMBERS

NATIONAL ROOFING CONTRACTORS ASSOCIATION

CANADIAN ROOFING CONTRACTORS' ASSOCIATION

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Carlisle SynTec Incorporated

DOW ROOFING SYSTEMS

Firestone BUILDING PRODUCTS

Sika

Sarnafil

RESEARCH TASKS

Task 1 – System Evaluation: Quantify air intrusion of the common roofing assembly configurations

Task 2 –Develop a relation between air intrusion and risk for moisture condensation

Project Duration : August 2009 - August 2012

TASK 1:
AIR INTRUSION QUANTIFICATION

EXPERIMENTAL LAYOUT

3 SYSTEMS TESTED

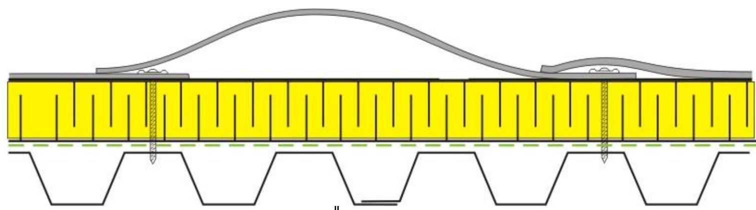
1.Kraft Paper

2.Polyethylene

3.HD Cover Board

PVC **EPDM**

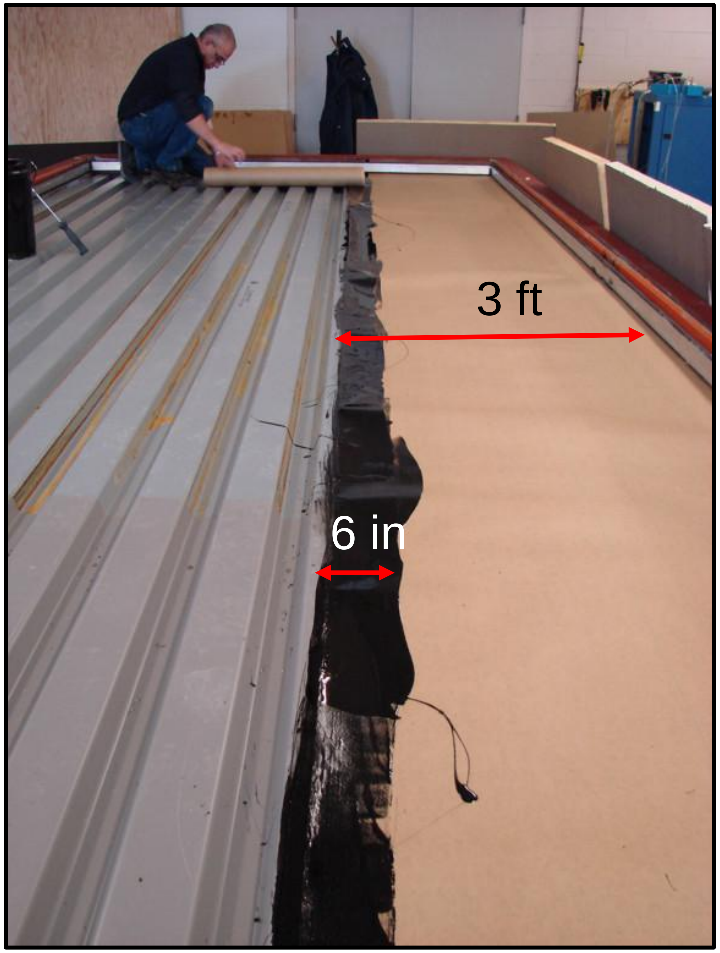
Membrane



4 ft x 4 ft x 2 in. ISO

Deck : 22 Ga -80 ksi

AIR RETARDER INSTALLATION



S1: KRAFT PAPER

AIR RETARDER INSTALLATION

S2: POLYETHYLENE

INSULATION INSTALLATION : S1 AND S2

10 boards
of
48 x 48 x 2 in

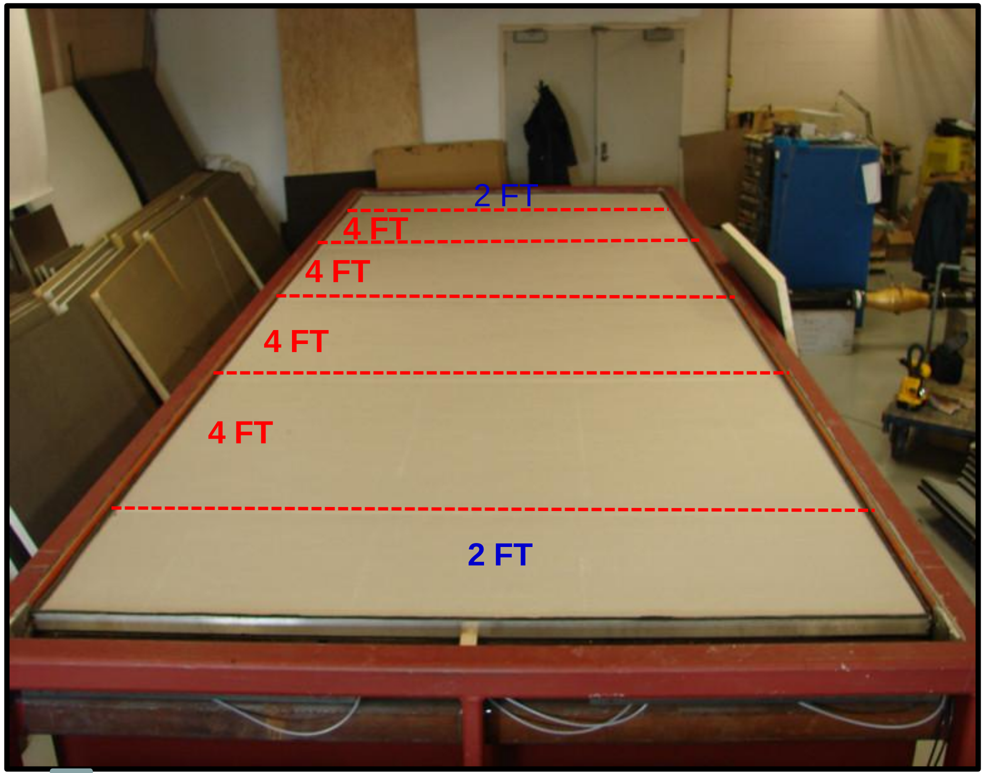
Mechanical
fastened
5/board = 50 fasteners

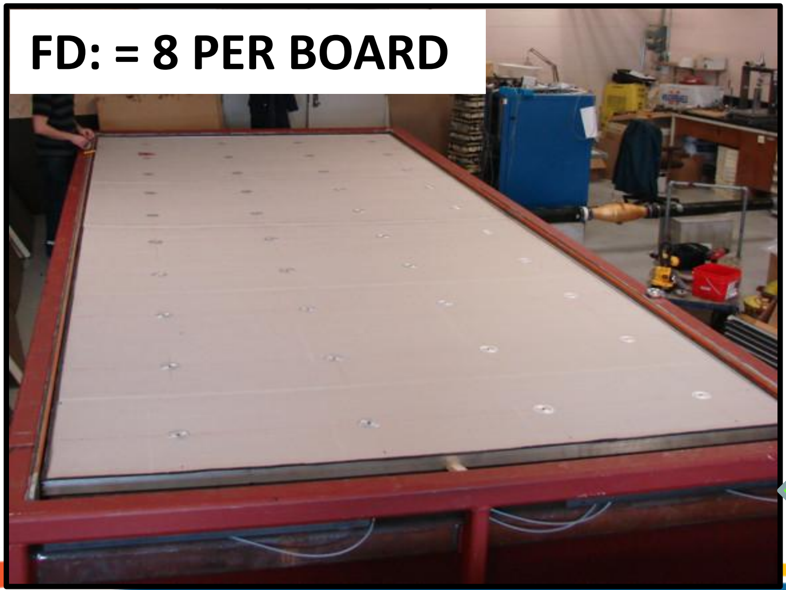
ISO
seals
along
the
width

ISO
seals
along
the
length

S3 : HD COVER BOARD(NO AIR RETARDER ON DECK)

HD: = 4 FT X 8 FT X 0.5 IN

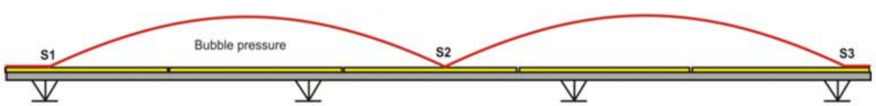


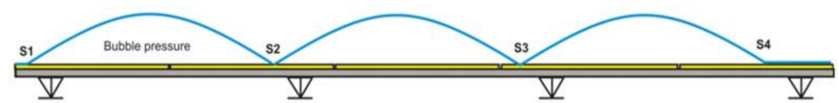


MEMBRANE LAYOUT

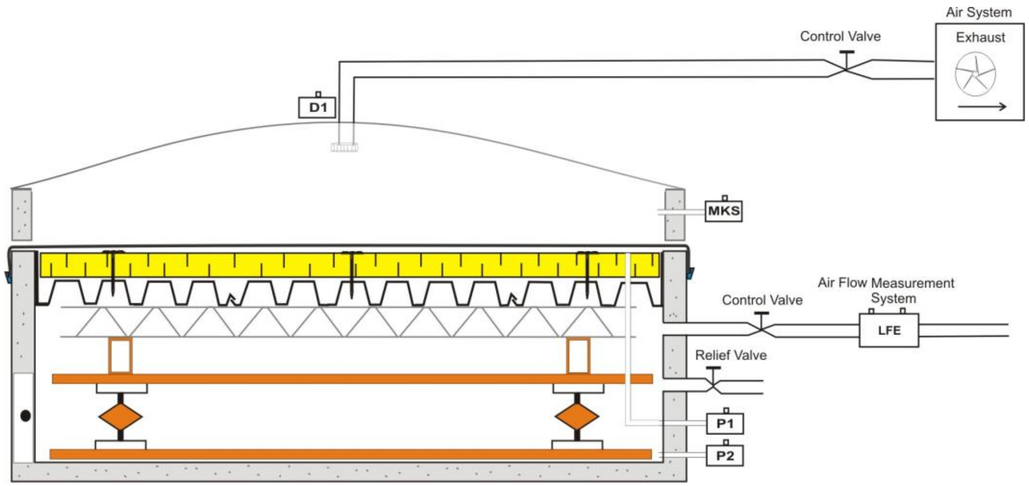
S1, S3: TS: FR = 114 IN FS = 12 IN.

S2: TP: FR = 66 IN FS = 12 IN.





DRF-AI : INSTRUMENTATION



MKS= Membrane pressure

P1= Insulation pressure (top of insulation)

P2= Bottom Chamber pressurer (below deck)

D1= Deflection Sensor

LFE= Laminar Flow Element

TEST PROCEDURE : ASTM D7586 / D7586M – 11

ASTM D7586 / D7586M - 11

INTERNATIONAL

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

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 SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The 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.

9. Test Procedure

9.1 With the membrane assembly specimen constructed in the bottom chamber and covered with the removable top chamber, the test procedure comprises of measuring the extraneous leakage of the bottom chamber and air intrusion of the test specimen.

9.2 Ensure that the top chamber is tightly fixed to the bottom chamber during the test to make sure that no membrane slippage occurs.

Note 3: Clamping devices or gaskets may be used for tightening the top chamber to the bottom chamber.

9.3 To measure the extraneous leakage, connect the air system and the airflow measurement system as shown in Figure 2. With the relief valve closed, measure the extraneous leakage of the bottom chamber at the negative air pressure differences of 75 Pa (1.5 psf), 120 Pa (2.5 psf), 240 Pa (5.01 psf), 360 Pa (7.5 psf), 480 Pa (10 psf) and 600 Pa (12.5 psf).

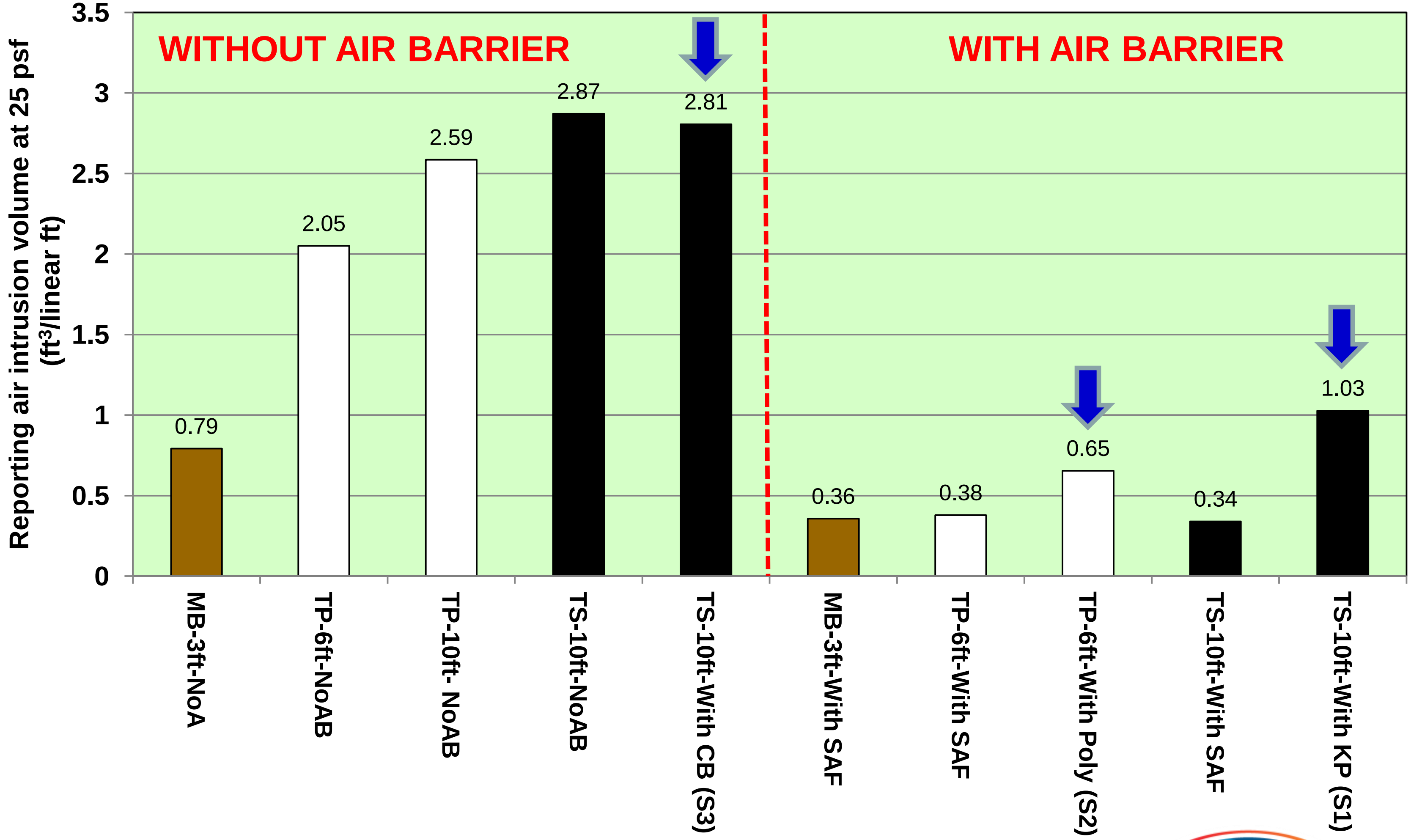
9.4 Express the measured extraneous leakage of the bottom chamber in terms of flow at standard conditions and plot the relationship between the air flow and pressure difference as per equation (1) as described in 8.7

9.4 To measure the air intrusion of the test specimen, connect the air system's pipe network along with control valve to the opening of the top chamber, and connect the airflow measurement system with the control valve to the opening on the bottom chamber as shown in Figure 3.

9.5 The air intrusion quantification of the test specimen shall be determined by following the below procedure of depressurization technique:

9.5.1 Close the relief valve on the bottom chamber and open the control valve on the airflow measurement system.

REPORTING AIR INTRUSION VOLUME AS PER THE ASTM D7586-11

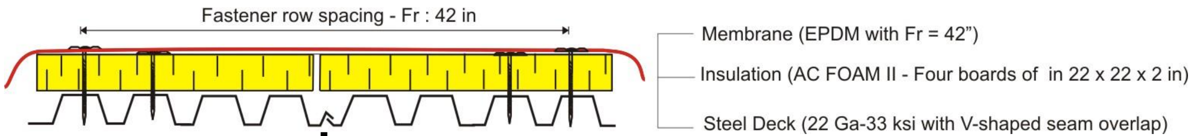


TASK2:
AIR INTRUSION - MOISTURE TRANSPORT

EXPERIMENTAL STUDY WITH DYNAMIC PRESSURES AND DIFFERENT RELATIVE HUMIDITY

TEST SPECIMENS AND CONDITIONS

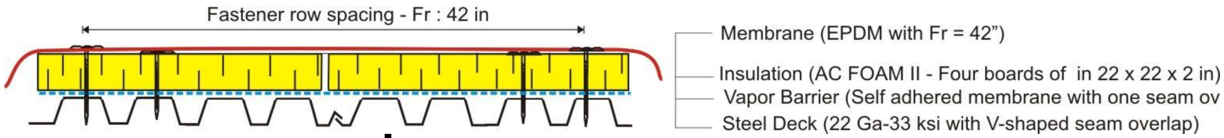
THERMOSET SYSTEM WITHOUT AIR RETARDER



S1: No Suction Pressure (Vapor Drive)

S2: With Suction Pressure

THERMOSET SYSTEM WITH AIR RETARDER



S3: No Suction Pressure (Vapor Drive)

S4: With Suction Pressure

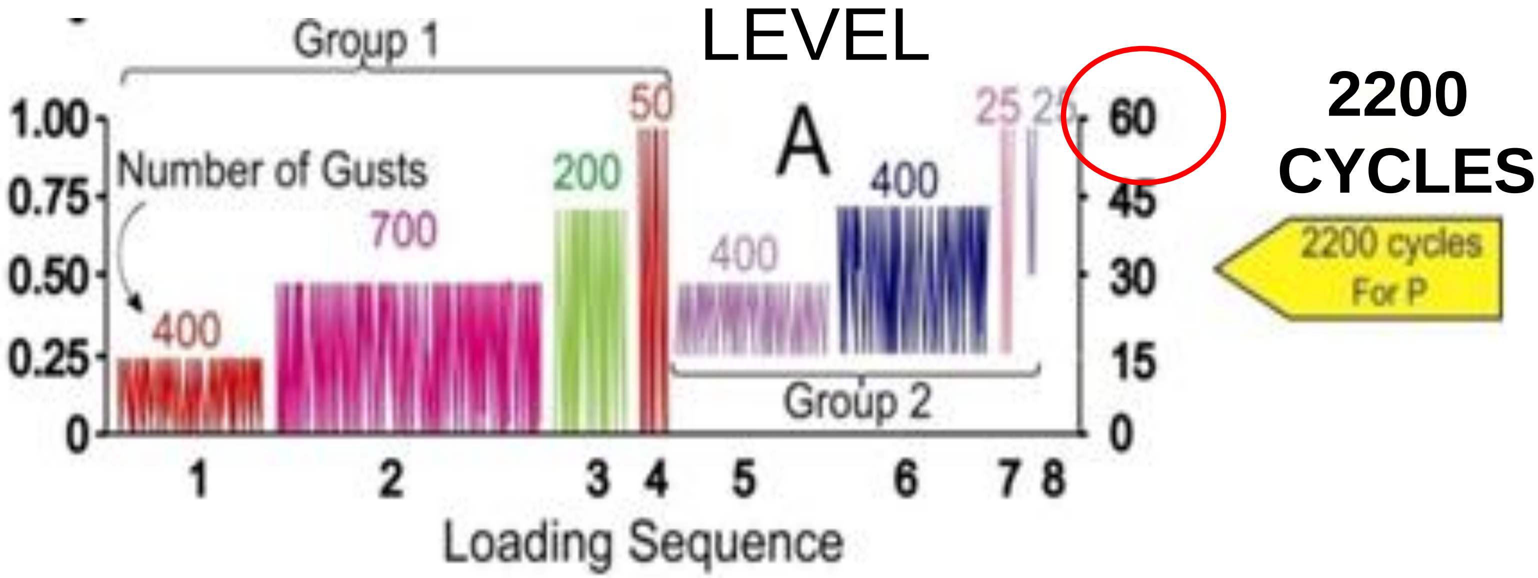
Outdoor Target Temperature: -5^{0}C (23^{0}F)

Indoor Target Temperature: 22^{0}C (72^{0}F)

Relative Humidity
25%
35%
50%
65%

SUCTION PRESSURE

CSA A123.21 –DYNAMIC LOADING CYCLE

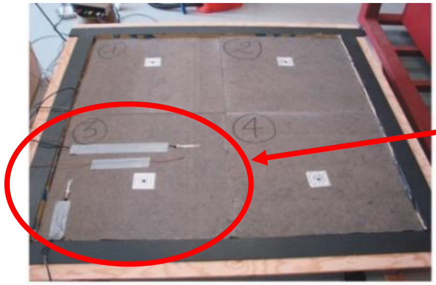


Target Pressure: 60 psf
15 psf: 800 cycles
30 psf: 1100 cycles
45 psf: 225 cycles
60 psf: 75 cycles

TYPICAL TEST SPECIMEN CONSTRUCTION

1. Installation of the Deck

2. Installation of theVapor Barrier



3. Insulation installed and instrumented

Temperature
And RH
sensors

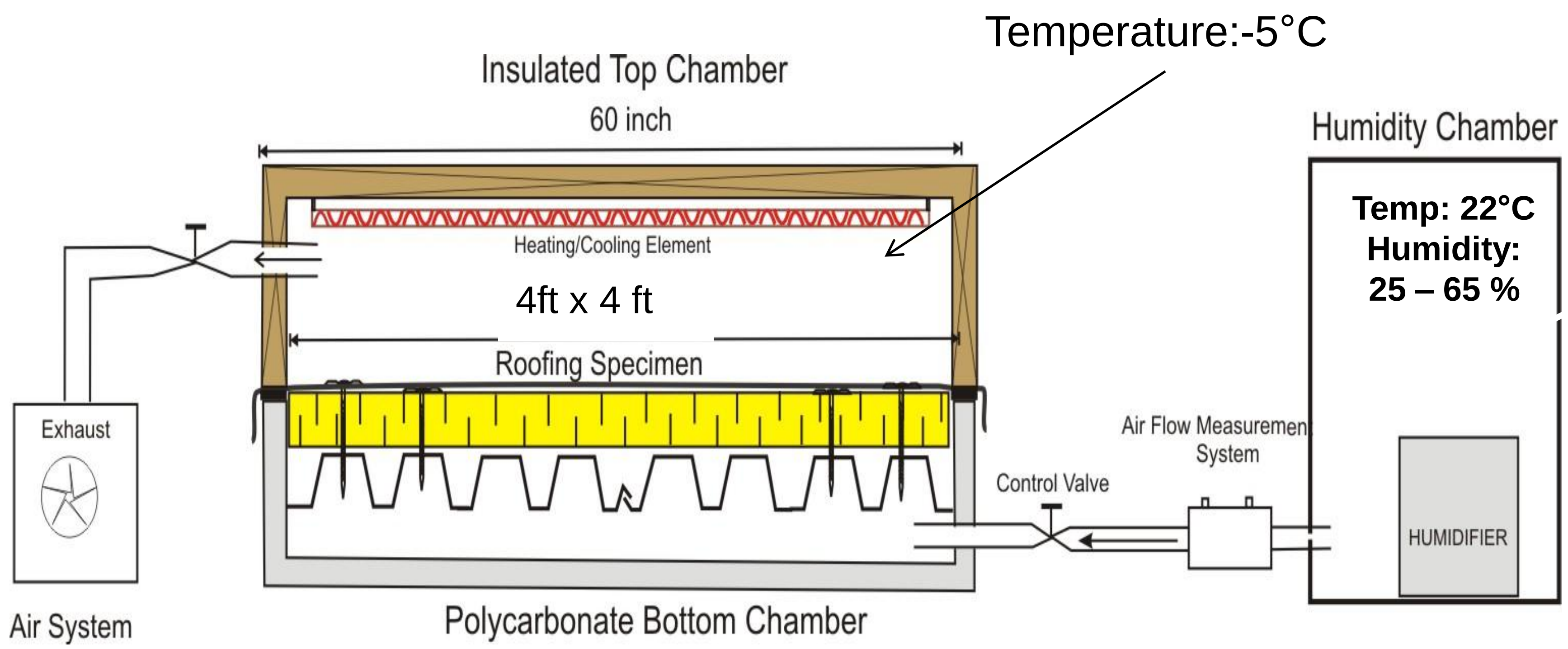
4. EPDM Membrane mechanically fastened with batten bars at the seams

5. Applying adhesive primer on the seam

6. Applying seam tape

7. System instrumented and ready for test

EXPERIMENTAL APPARATUS



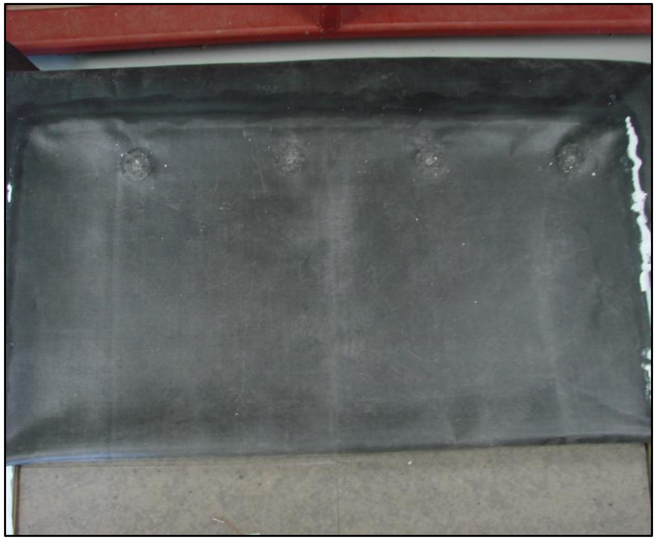
TEST PROCEDURE

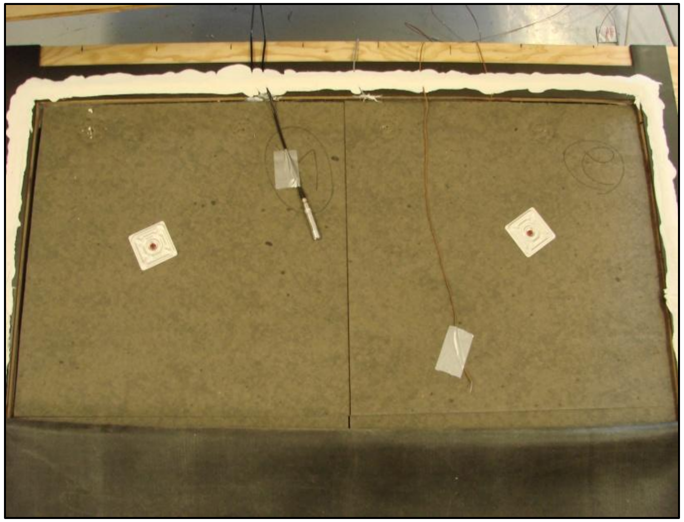
- ❑ Insulation boards pre weighed and the specimen constructed
- ❑ Test chamber set to a target temperature of -5^0 C (23^{0}F)
- ❑ Temperature and relative humidity set to 22^{0}C (72^{0}F) and 25% in the humidity chamber.
- ❑ After temperature and relative humidity stabilization, specimen subjected to CSA A123.21-10 dynamic pressures for a duration of 5 hrs
- ❑ Test stopped for visual inspections of condensation and insulation boards weighed to measure the moisture content
- ❑ Insulation boards put back and specimen reconstructed for testing at next humidity level
- ❑ With above outdoor and indoor temperatures, each specimen is subjected to four different humidity levels of 25%, 35%, 50% and 65% and with dynamic pressure application at each humidity level
- ❑ Each specimen subjected to four days of testing (One humidity condition /day)

S1:NO AIR RETARDER - NO SUCTION PRESSURE

VAPOR DRIVE

25%



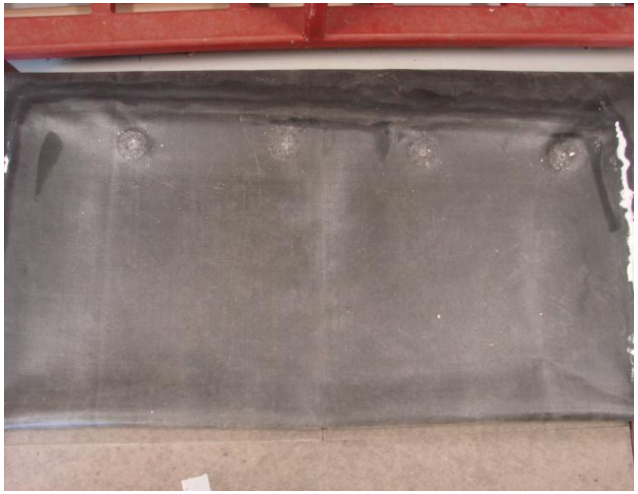


35 %

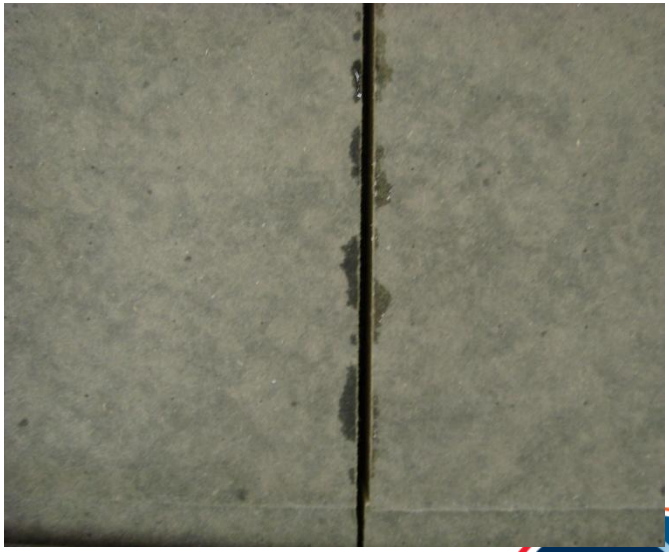
S1:NO AIR RETARDER- NO SUCTION PRESSURE

VAPOR DRIVE

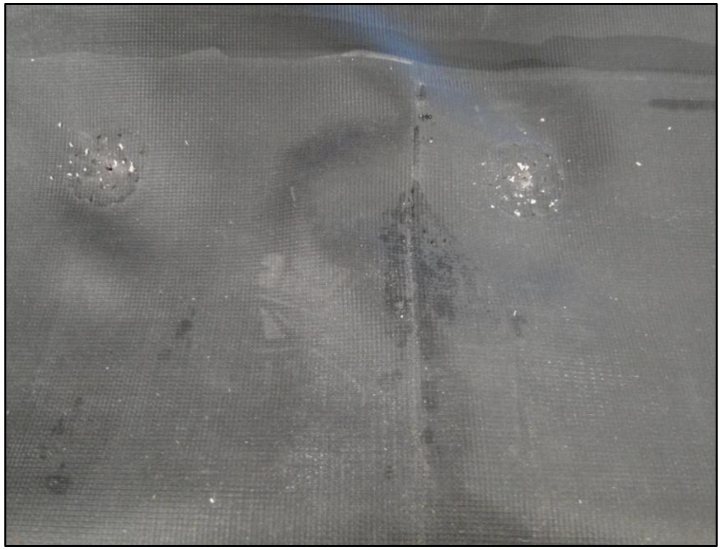
50%

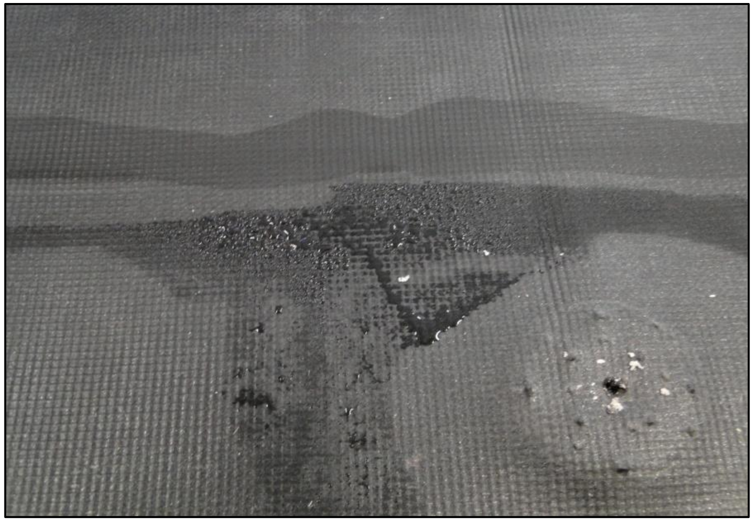


65 %



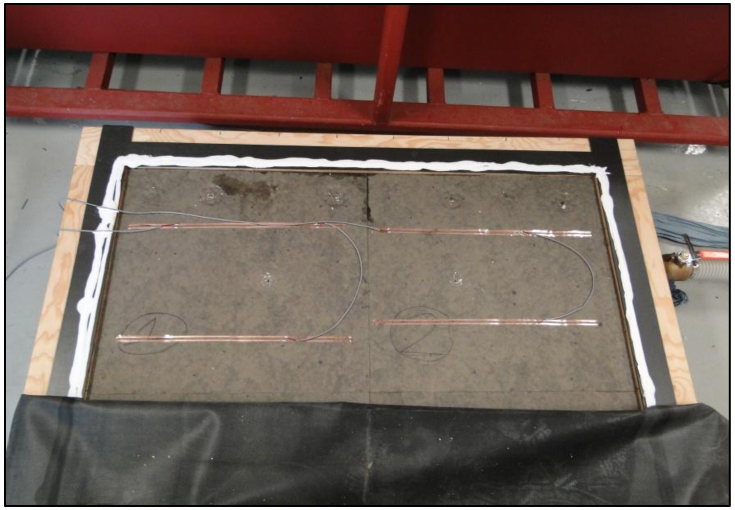
S2:NO AIR RETARDER-WITH SUCTION PRESSURE

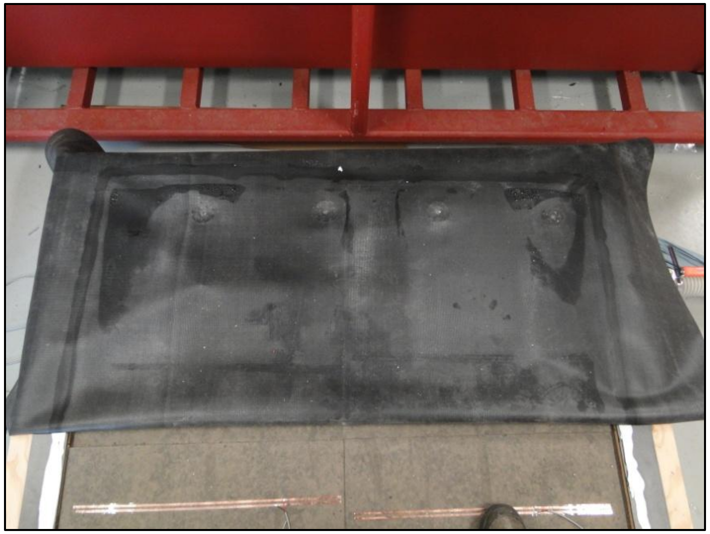


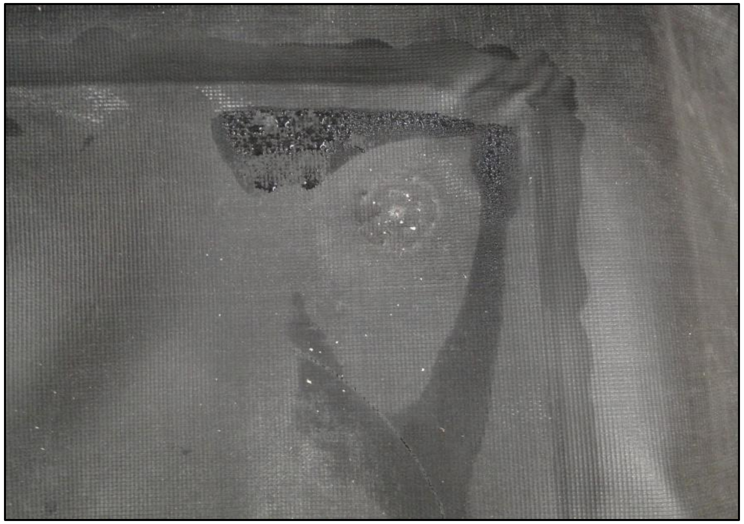


35% RH

S2:NO AIR RETARDER-WITH SUCTION PRESSURE

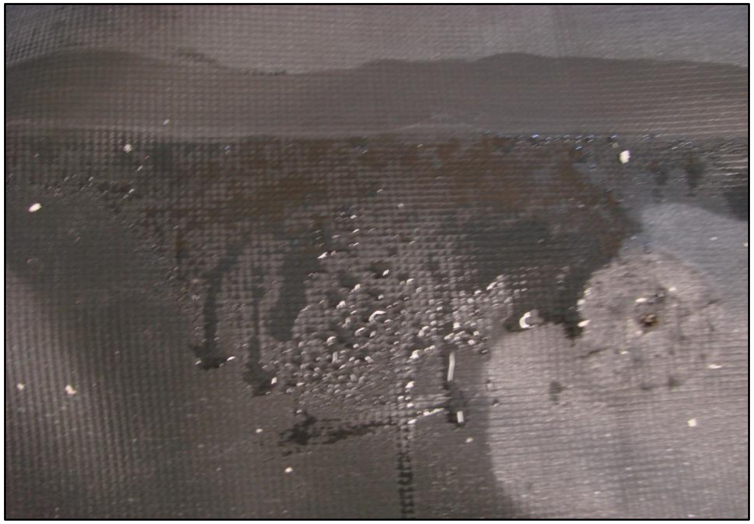


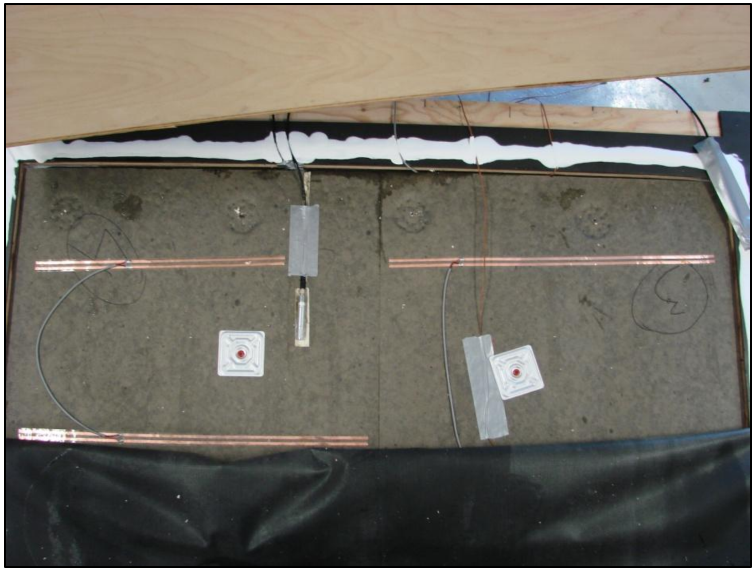


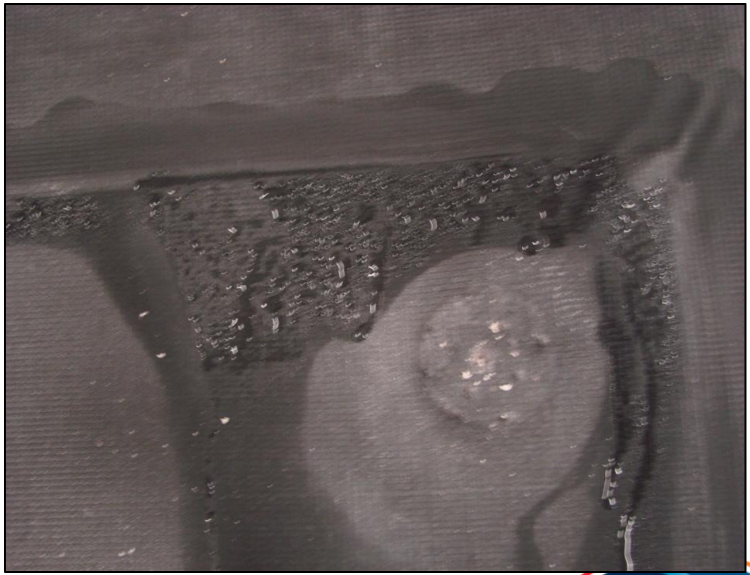


50% RH

S2:NO AIR RETARDER-WITH SUCTION PRESSURE



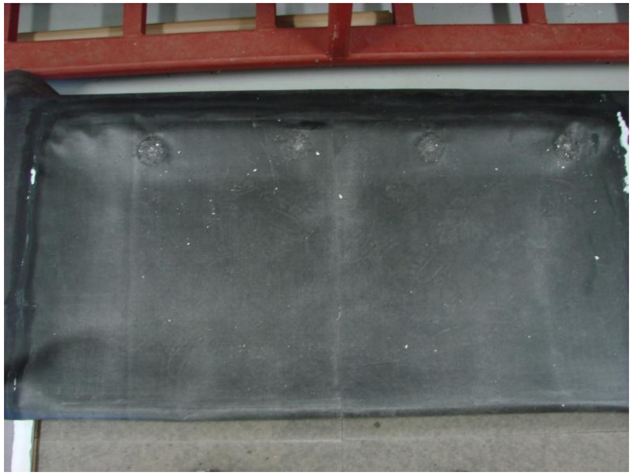


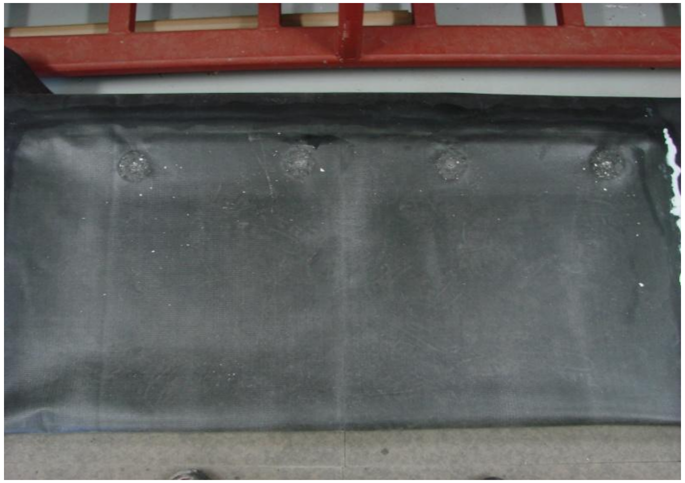


65% RH

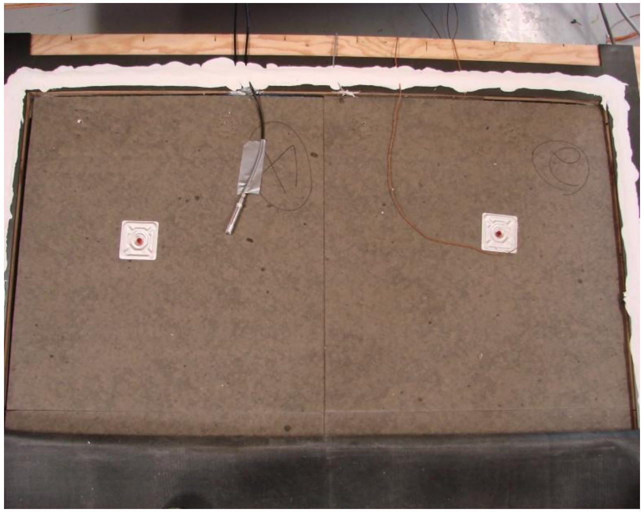
S3:WITH AIR BARRIER-NO SUCTION PRESSURE

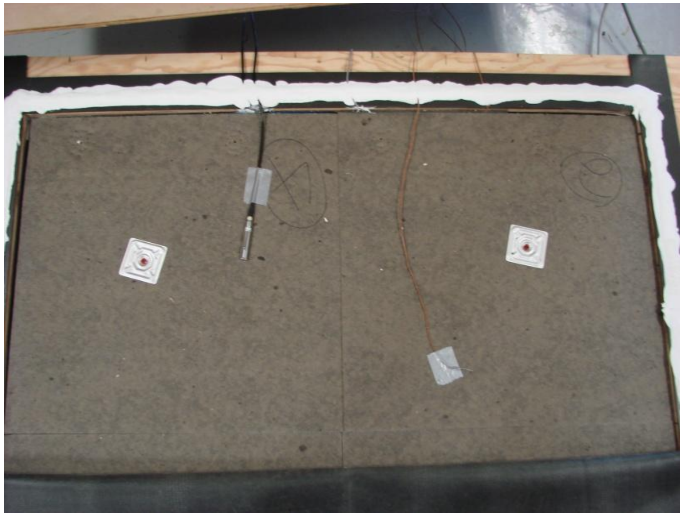
VAPOR DRIVE





50%

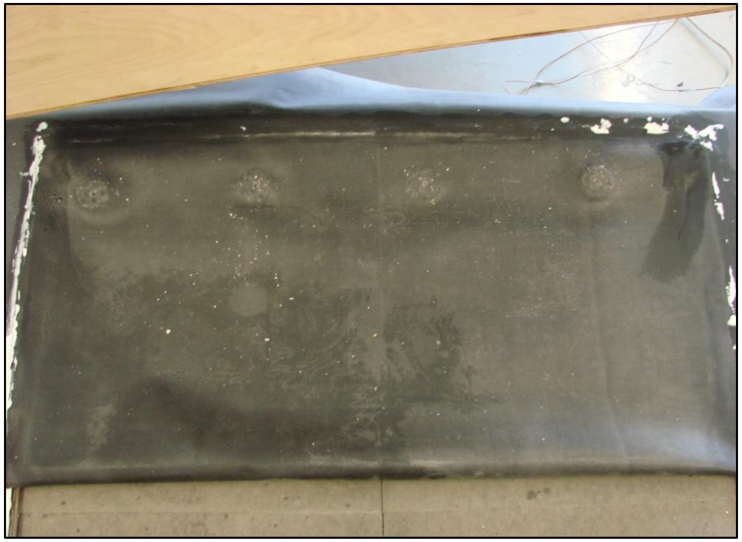


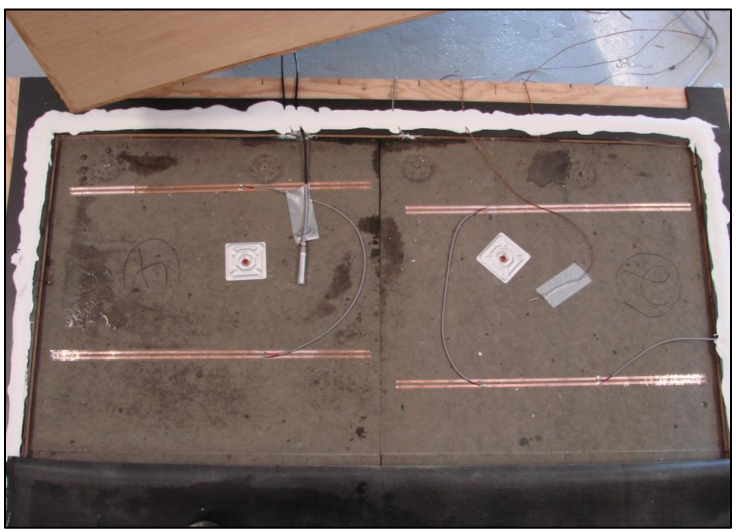


65 %

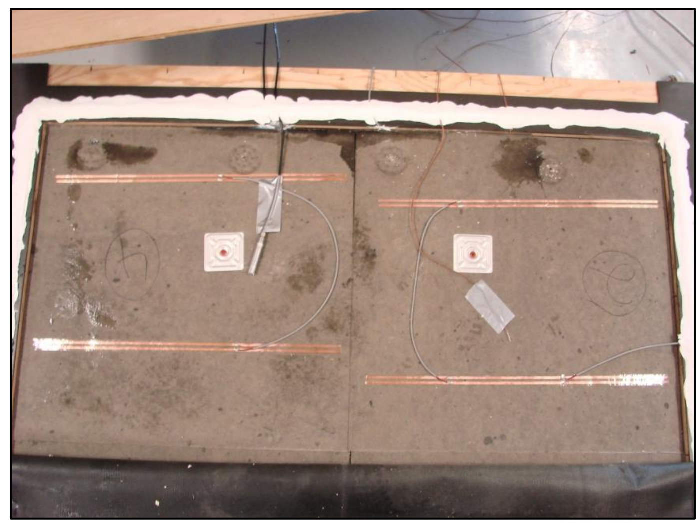
S4:WITH AIR RETARDER-WITH SUCTION PRESSURE

50% RH





65% RH

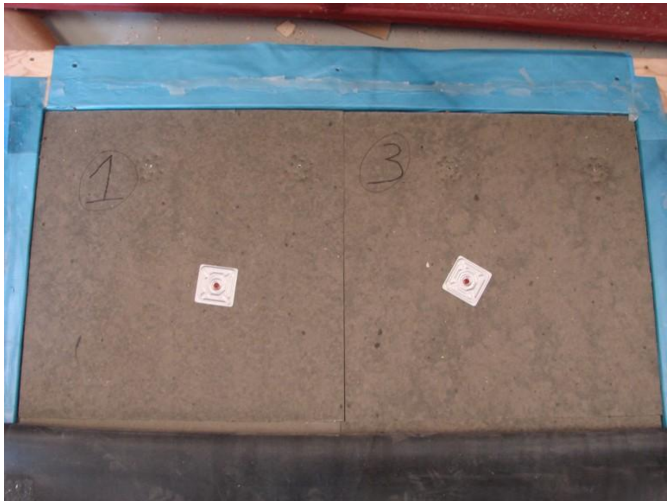


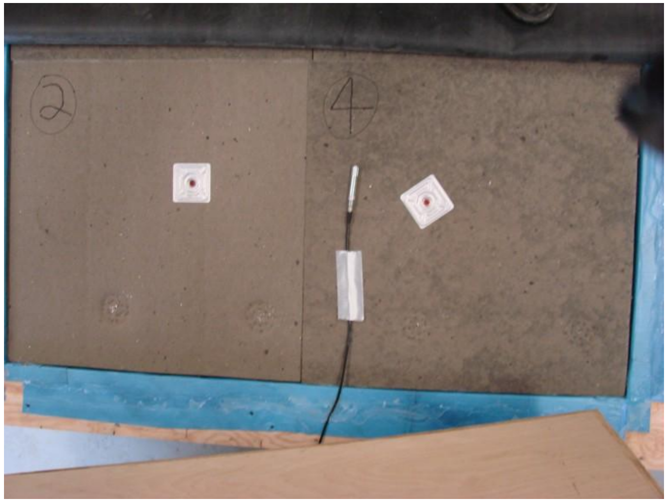
S4:WITH AIR RETARDER-WITH SUCTION PRESSURE

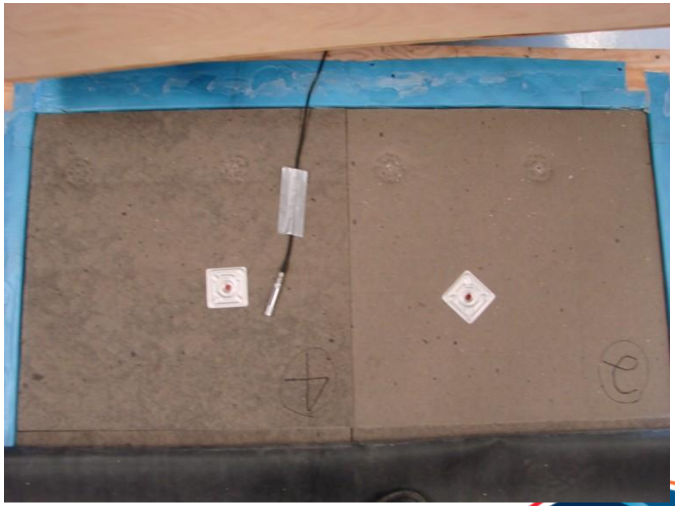
BREACH IN THE AIR RETARDER DURING INSTALLTION

S4:WITH AIR RETARDER-WITH SUCTION PRESSURE RETESTED

50% RH

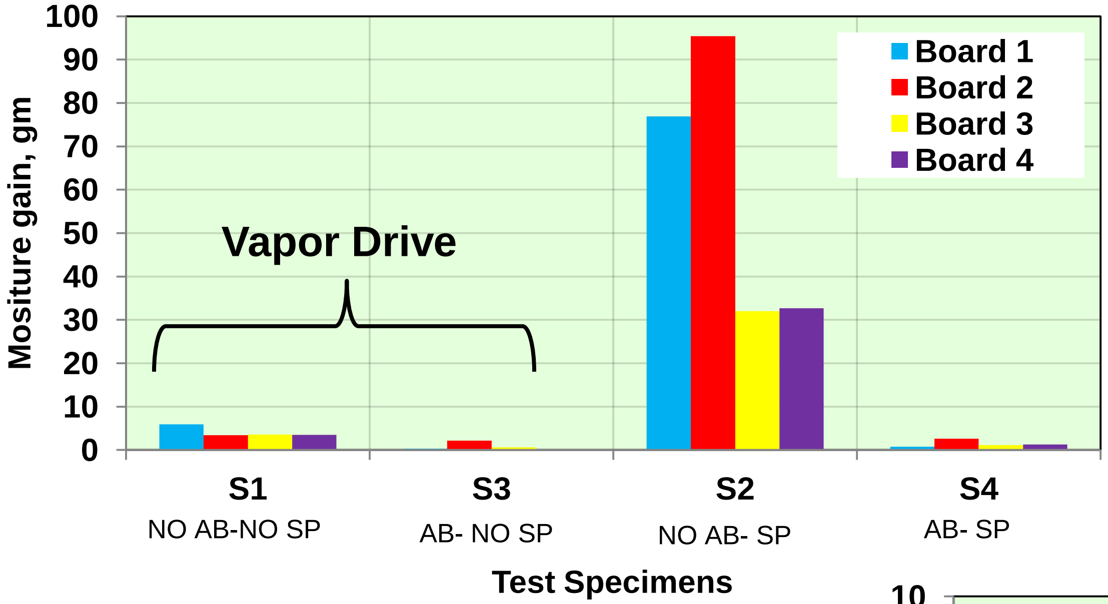


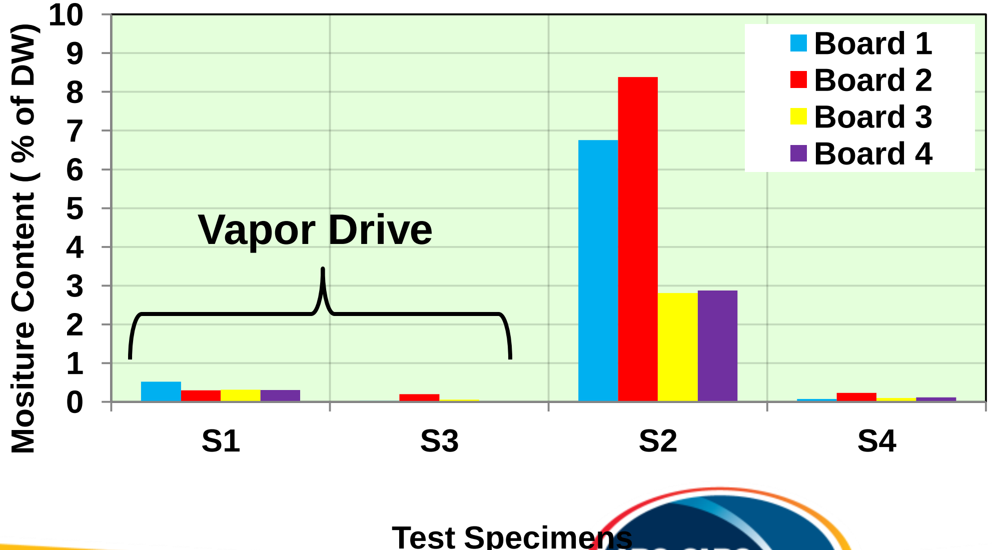




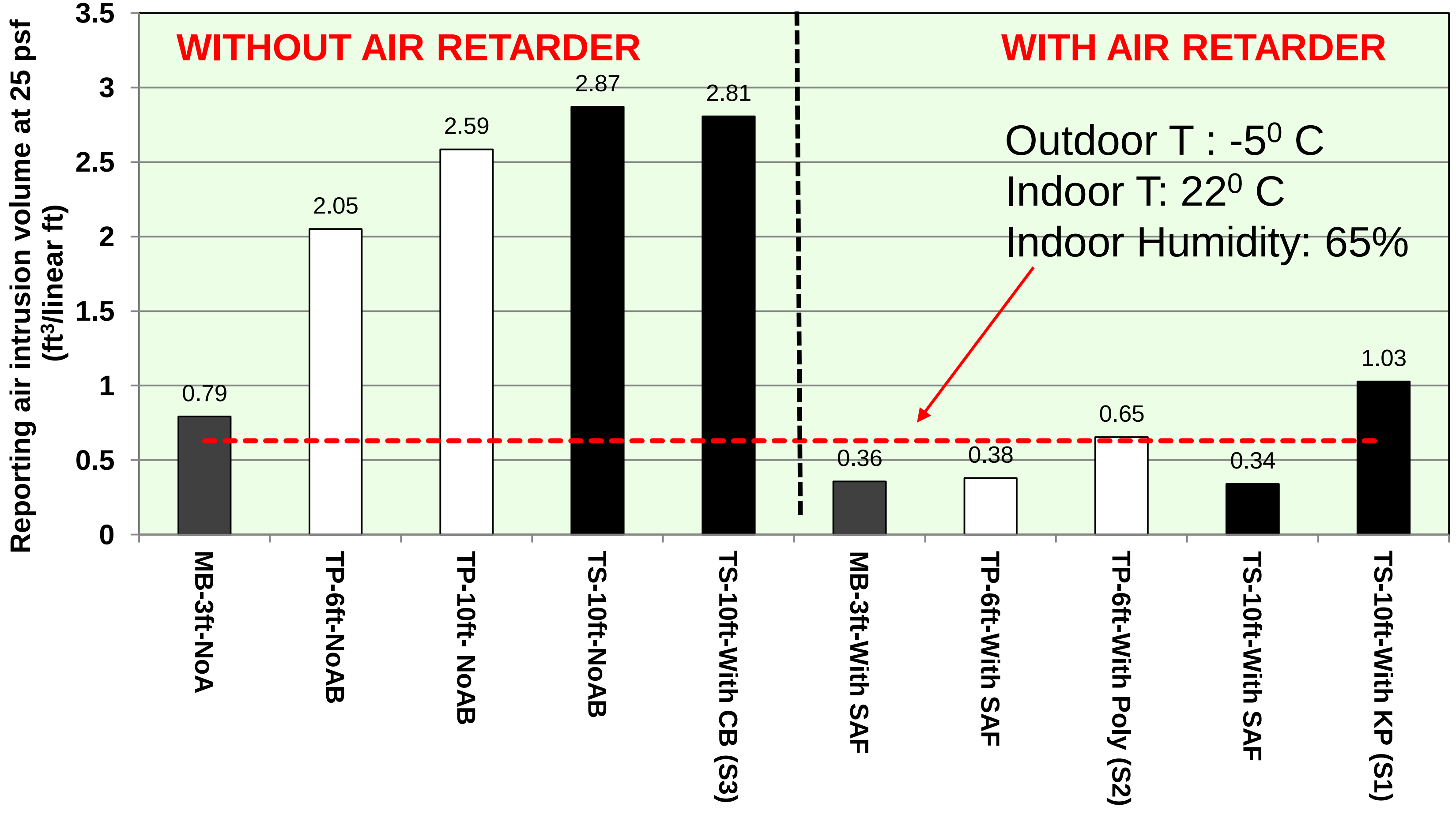
65% RH

MOISTURE GAIN : COMPARISON





AIR INTRUSION LIMIT FOR POTENTIAL CONDENSATION



CONCLUSIONS

- In collaboration with CRCA, NRCA and four major roofing manufacturers, a research project focussing on air intrusion quantification and its impact on the moisture transport was started.
- The kraft paper and polyethylene sheet did minimize the air intrusion into however both underperformed compared to the self adhered film as air retarders.
- Installing HD cover boards on top of the insulation provided no resistance to air intrusion as the cover boards do not seal the primary flow paths of the steel deck.
- The risk for potential condensation and increased moisture gain within the system from air intrusion is considerably higher than the potential moisture gain due to vapour transmission.

CONCLUSIONS

- Air retarder at the deck level can minimize the moisture gain in the roof systems both due to vapor transmission and air intrusion. However, trapped air due to air intrusion between the air retarder and air barrier (membrane) within the roof system can cause condensation.

- At an outside temperature of -5^0 C (23^{0}F) and indoor conditions of 23^{0}C (72^{0}F) with 65% relative humidity, an air intrusion volume of 0.63 ft^3/ linear ft (17 L / linear m) could be said to be the critical volume for potential condensation in mechanically attached roofing systems.

- Further study is needed to investigate and develop the limits for potential condensation at different outdoor and indoor conditions, and at different humidity levels.

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