OWENS CORNING

INNOVATIONS FOR LIVING®

BUILDING SCIENCE
INSIGHTS
Physics to the Field™

The Next Frontier of Building Science: Air Leakage

Achilles Karagiozis

Global Director Building Science, Sustainability

Owens Corning

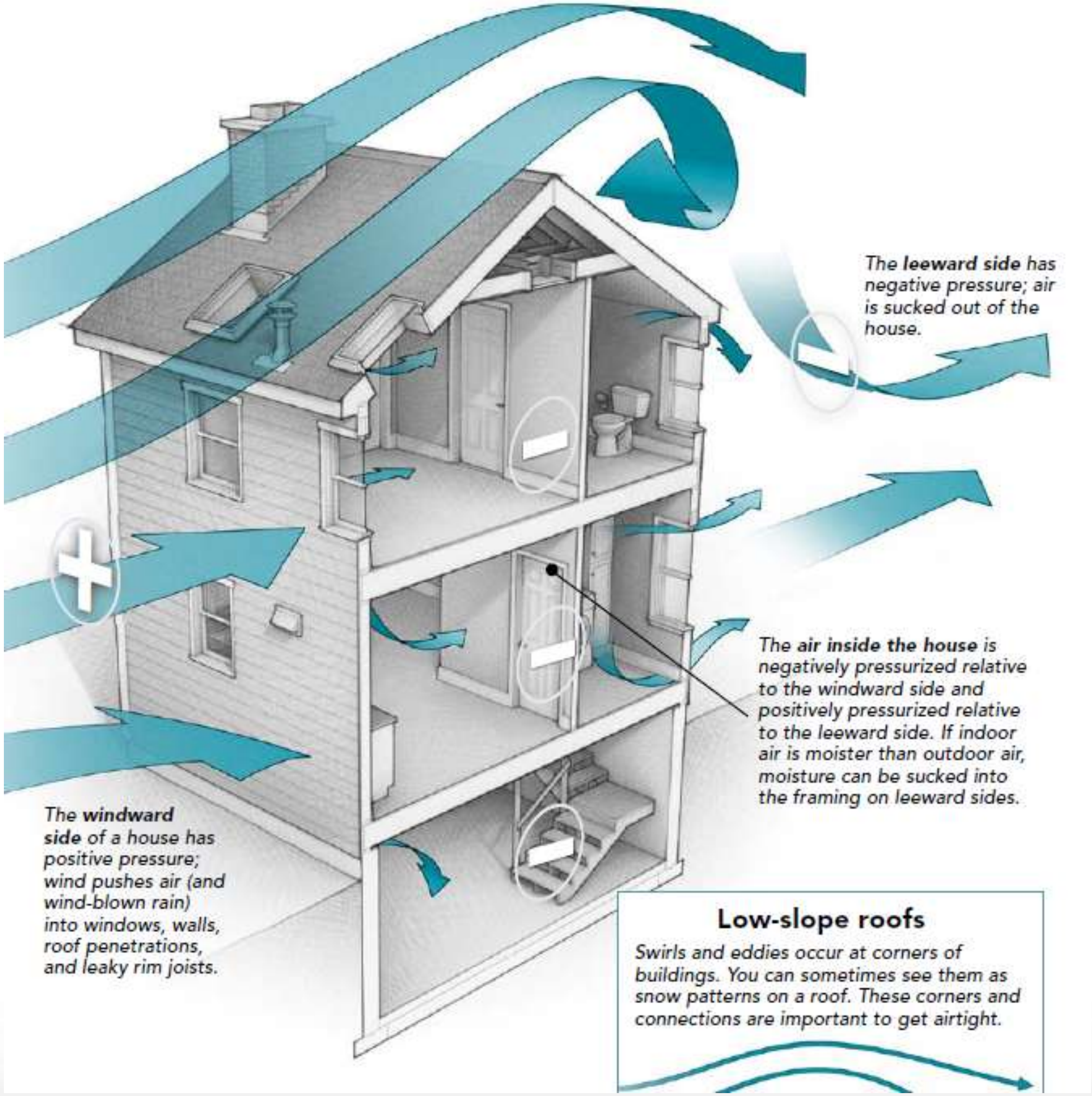
Acknowledgements

- Mikael Salonvaara, Owens Corning
- Andre Desjarlais,   Oak Ridge National Laboratory
- Laverne Dagleish, ABAA
- Dave Wolf, Owens Corning
- Department of Energy, DOE
- Diana Hun, Oak Ridge National Laboratory
- Hartwig Kuenzel, Fraunhofer Institute of Building Physics

Presentation Layout

- Objectives (Short Term and Long Term)
- Simplification of the Physics
- Air Leakage performance structure
- Passive House wall Heat-Air-Moisture analysis
- Implementation of a approach for Design

Air flow



JStraube

Motivations

BUILDING SCIENCE INSIGHTS
Physics to the Field™

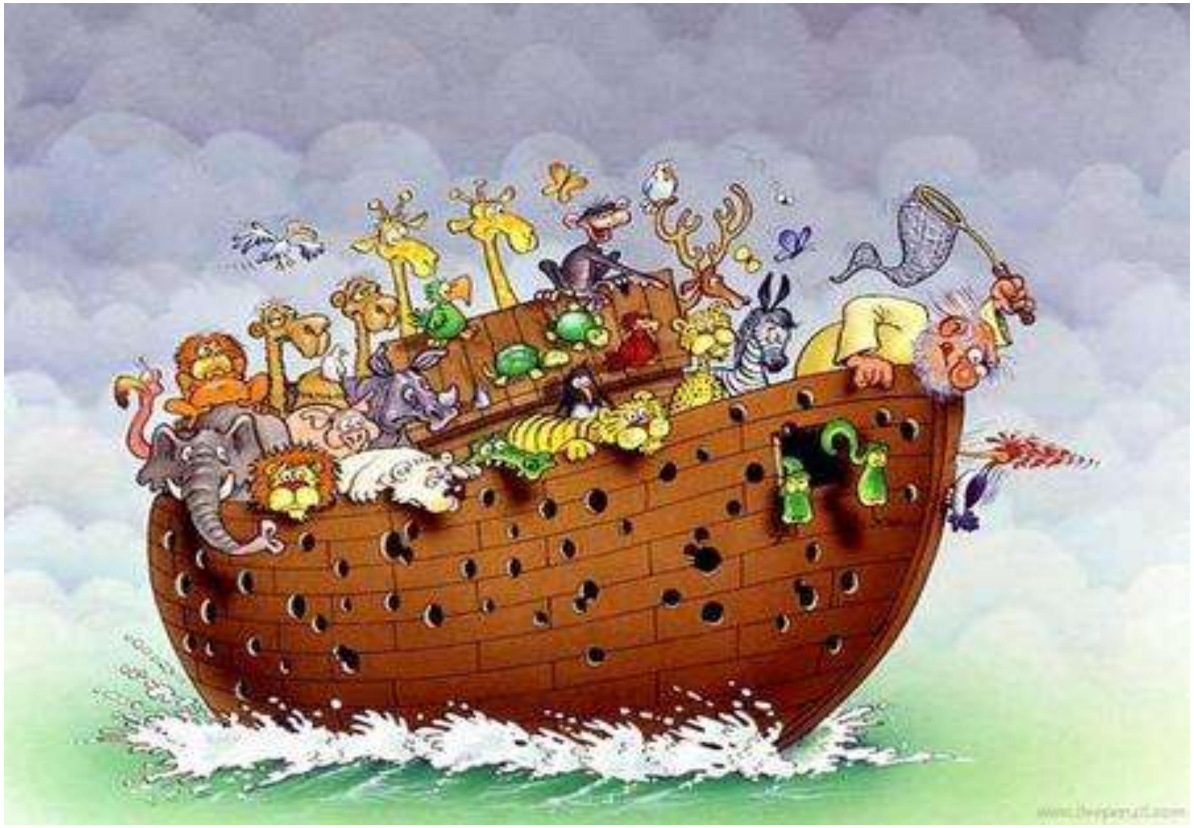
- My Motivation – Owens Corning wants to provide higher performance level analysis (quantification) to building community

- ORNL/DOE Motivation – Increase awareness and upgrade in performance goals for USA

It is **important** for Building Science to get a better grip on this topic

- ABAA/Industry Motivation- Increase air tightness, understand impact and create a design approach

Current Status



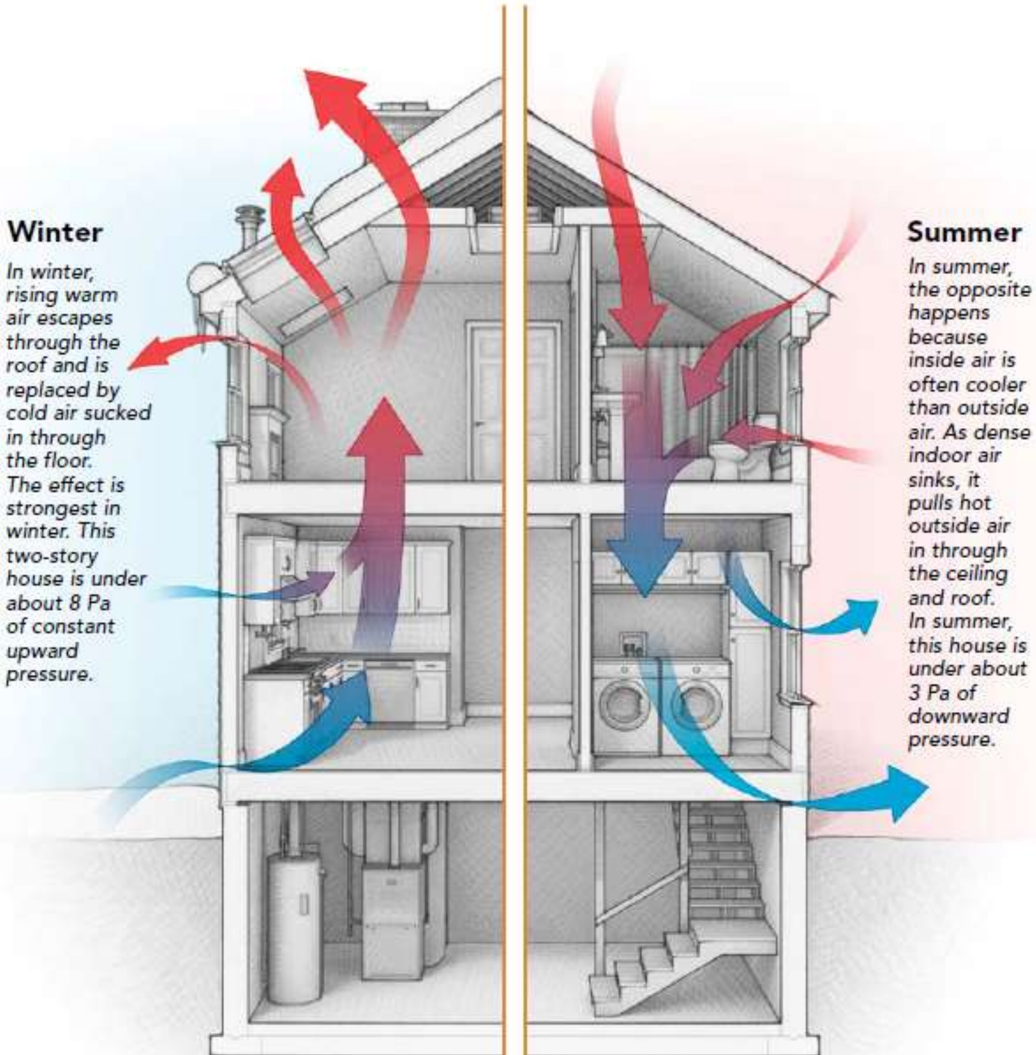
Question :

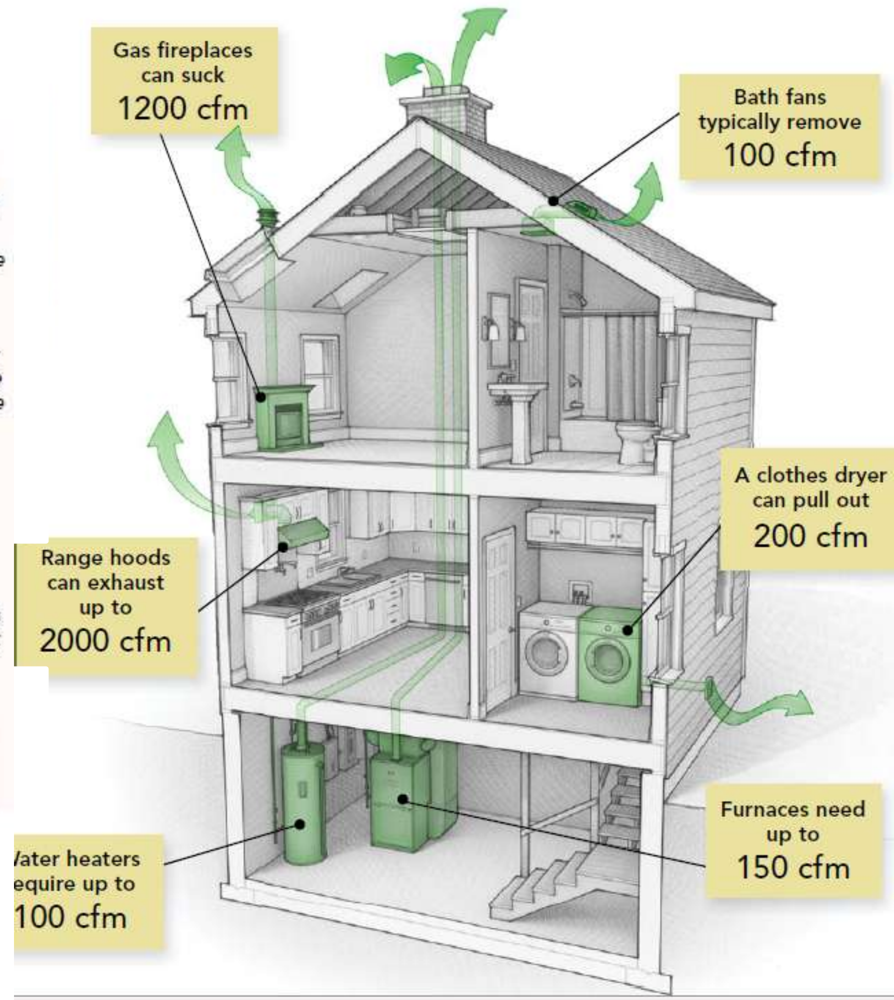
How much air Leakage does this woodpecker cause ?

Building science is lacking…. Need Quantification

Air Flow

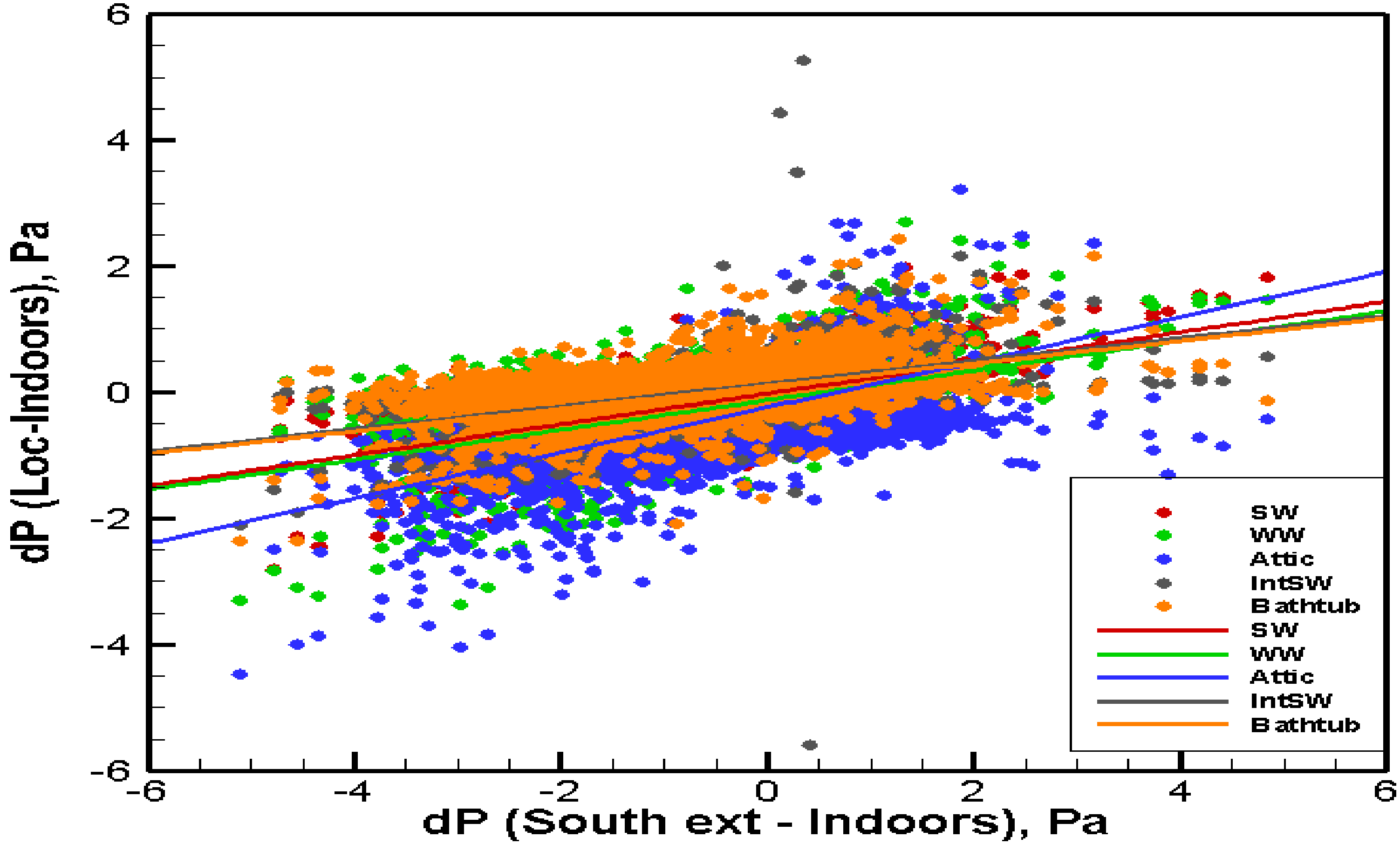
BUILDING SCIENCE INSIGHTS
Physics to the Field™





Actual Measurements

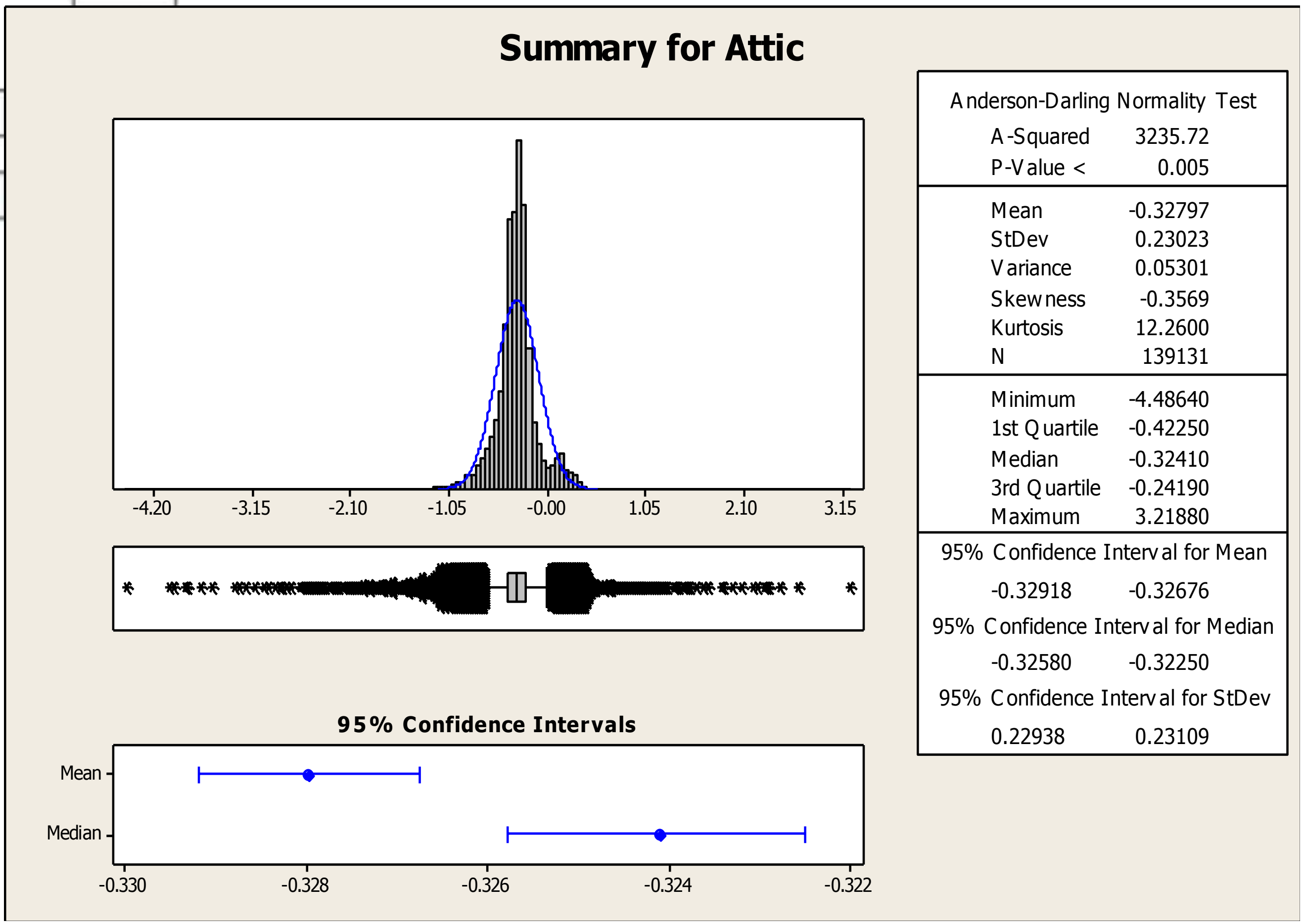
Fresh off the press… Mika's House Atlanta Aug 1-3



Actual Measurements

SW

Out

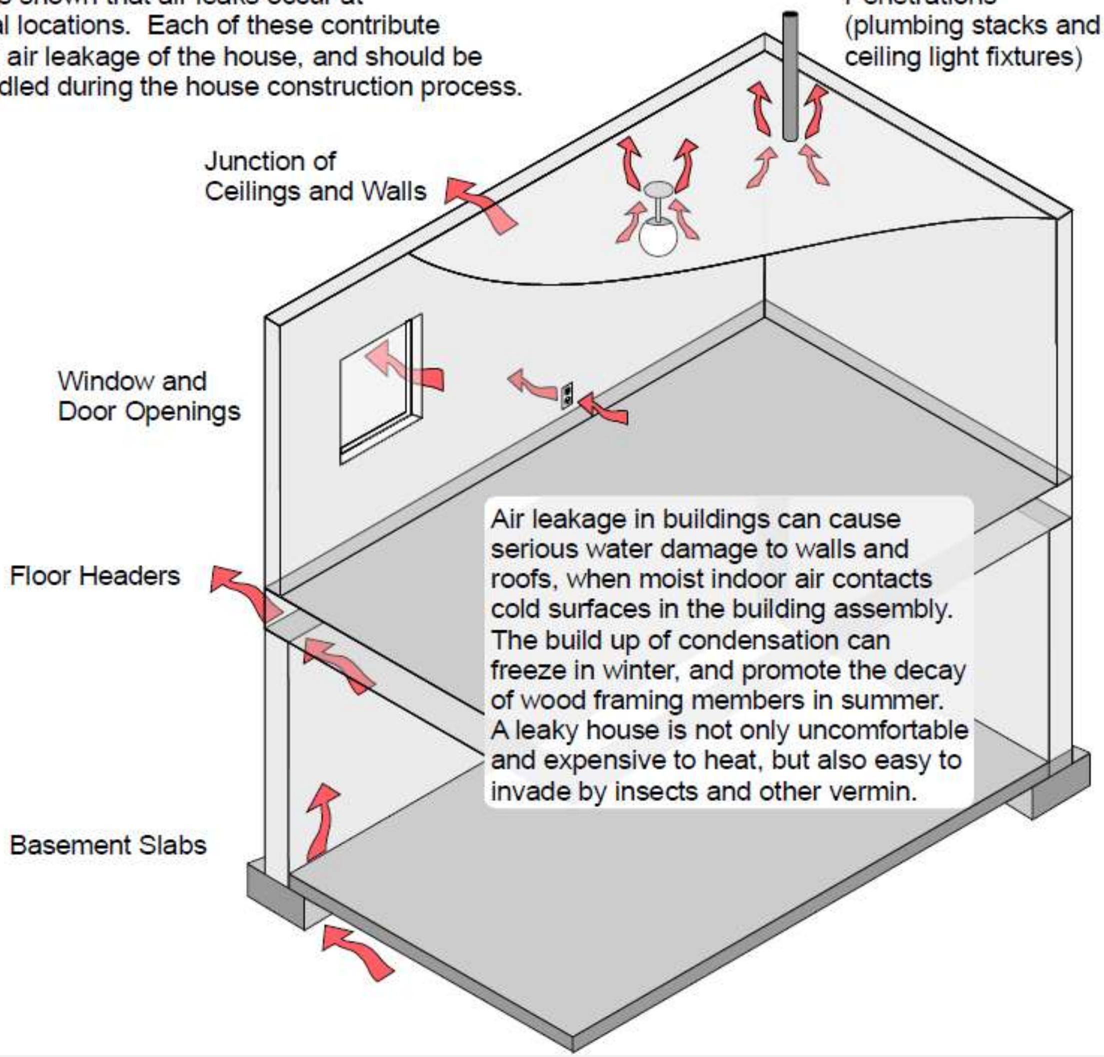


S
T
A
T
I
S
T
I
C
S

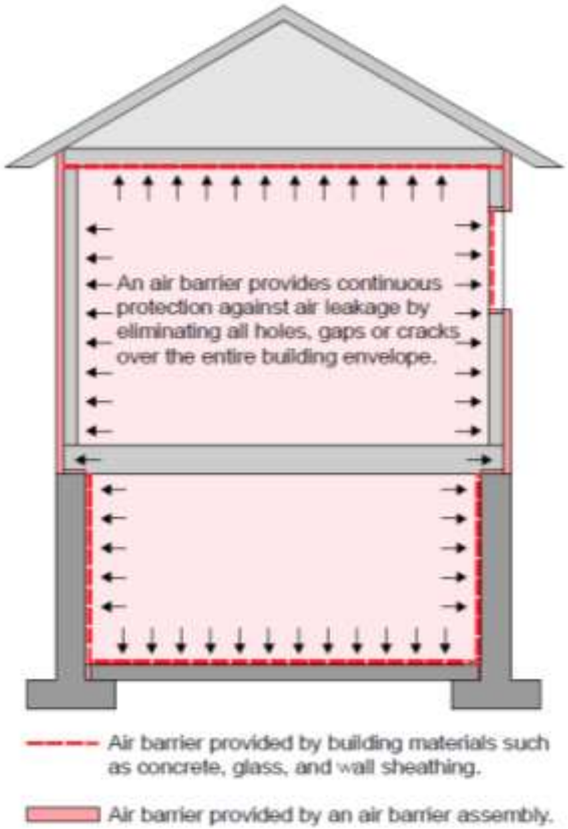
Air Leakage Path

TYPICAL AIR LEAKAGE PATHS

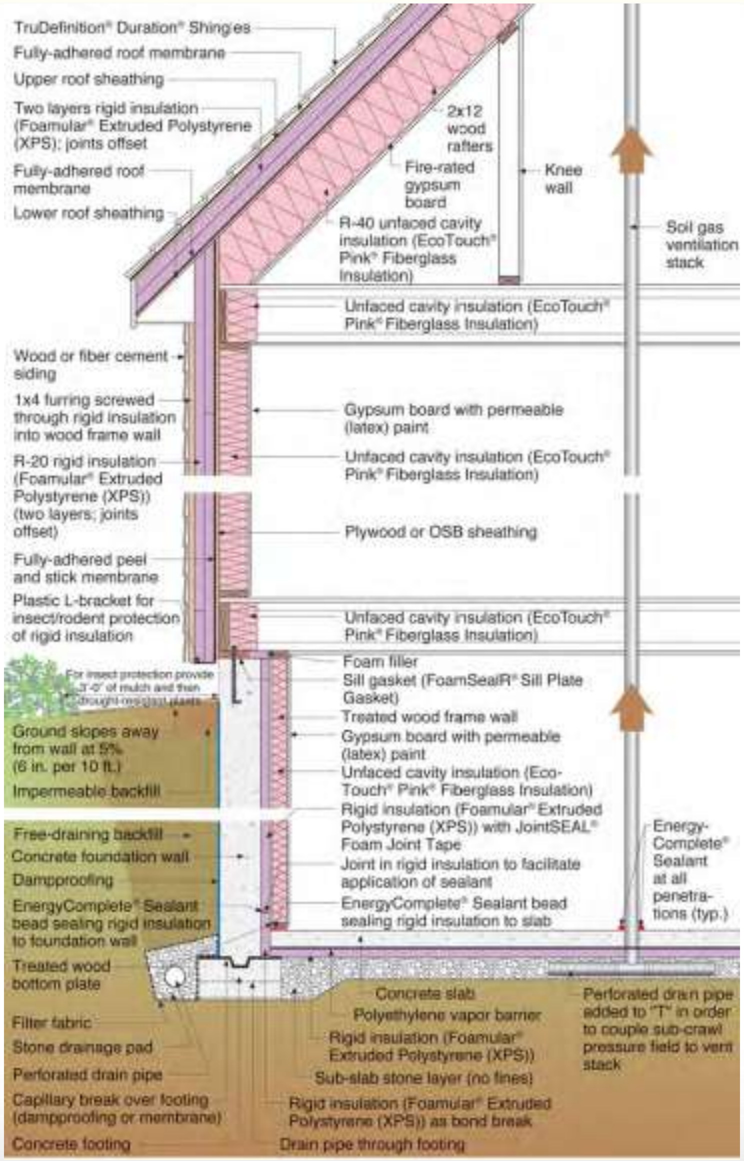
Research has shown that air leaks occur at certain typical locations. Each of these contribute to the overall air leakage of the house, and should be carefully handled during the house construction process.



Air leakage in buildings can cause serious water damage to walls and roofs, when moist indoor air contacts cold surfaces in the building assembly. The build up of condensation can freeze in winter, and promote the decay of wood framing members in summer. A leaky house is not only uncomfortable and expensive to heat, but also easy to invade by insects and other vermin.

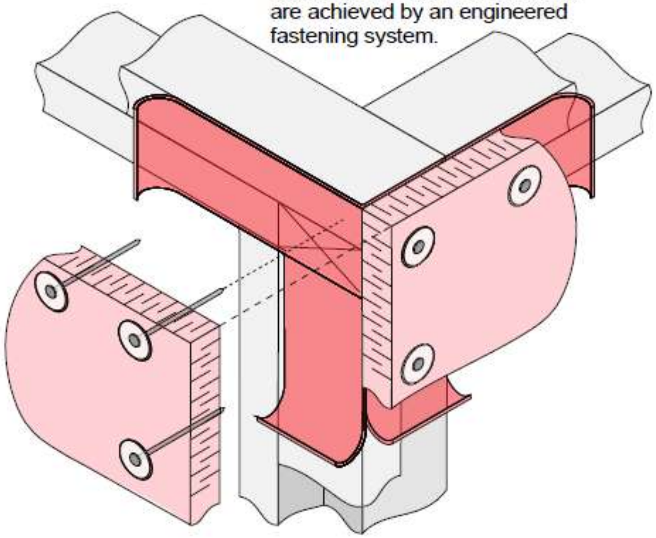


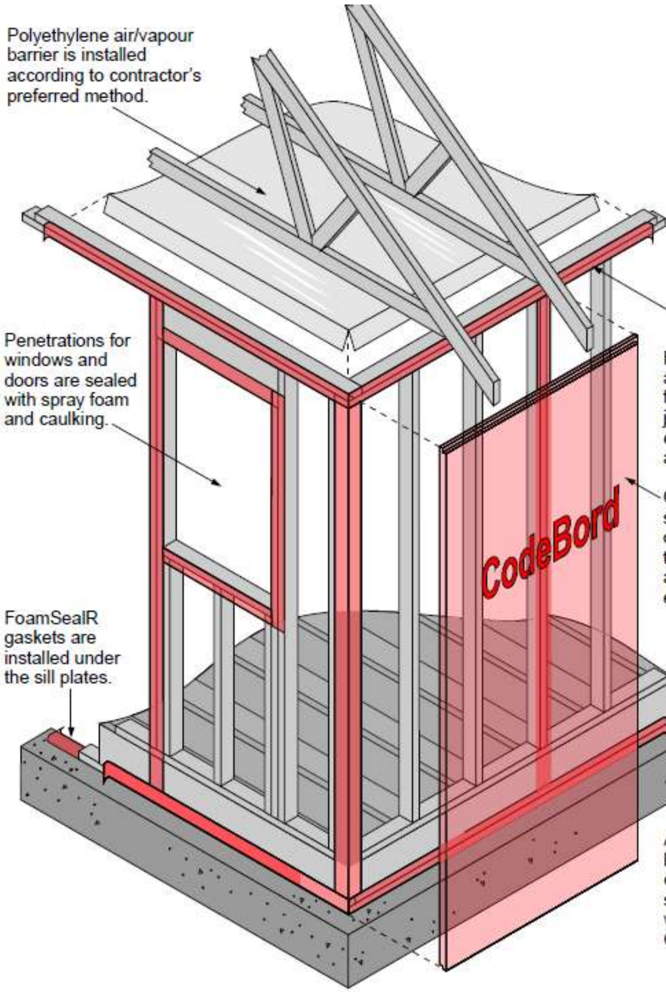
Attention to all construction Details are a Must !!

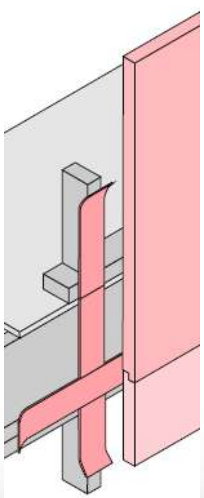


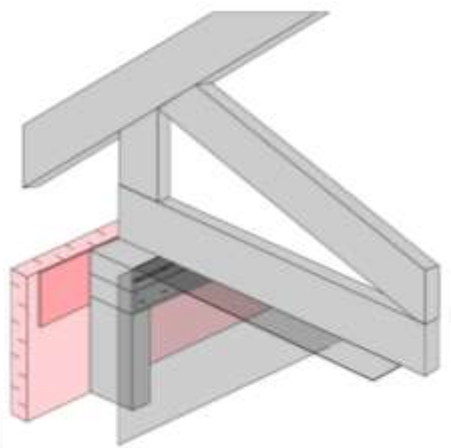
Specifying the details…and then training our contractors to do-it-right!

Exterior Air Sealing Strategies



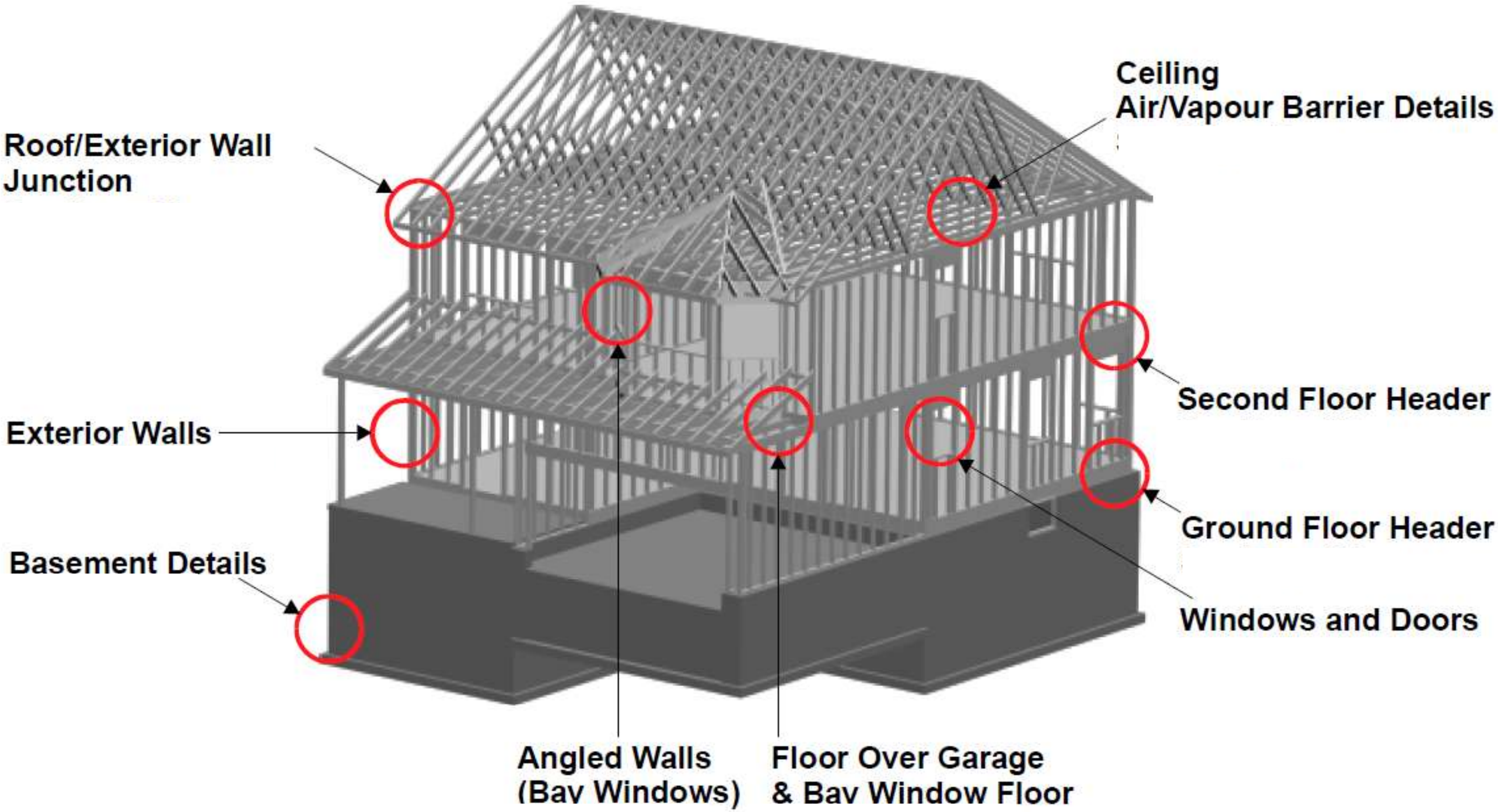






Interior Air Sealing Strategies

Systems Approach to Air Leakage



Objectives

Short-Term

- Include air leakage thermal losses in envelope calculations
- Include the impact of air leakage in moisture flow calculations
- Be able to address durability design analysis

1-D WUFI Analysis

Long-Term

- Incl
- Full leakage

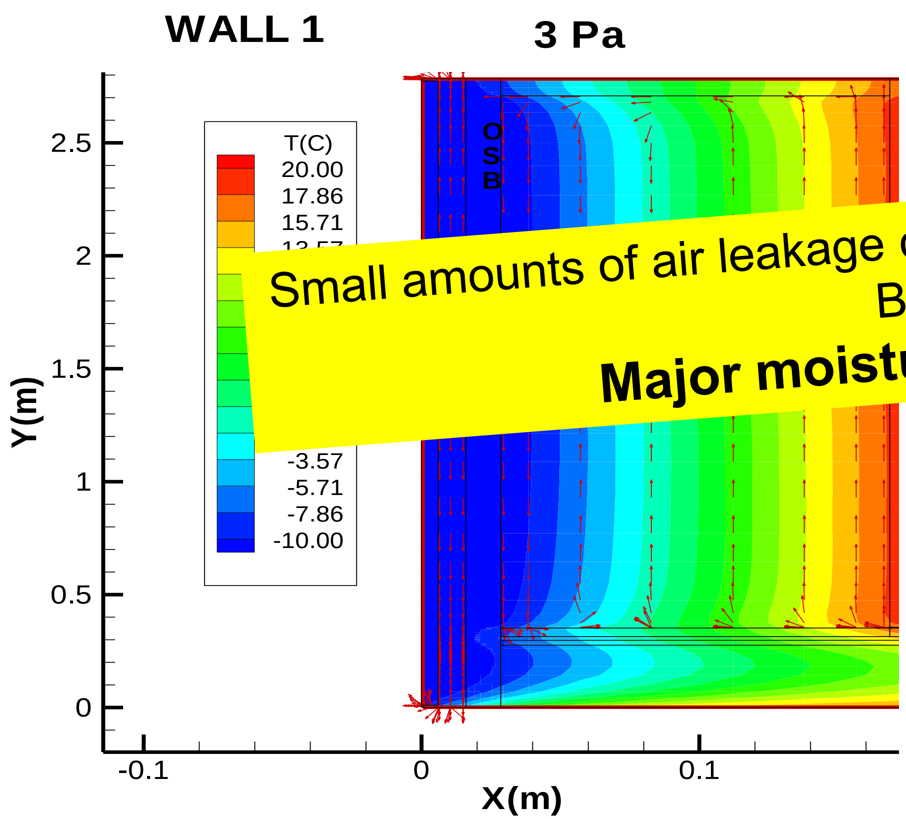
2-D, 3-D WUFI Analysis
WUFI+Passive

Create the basic understanding

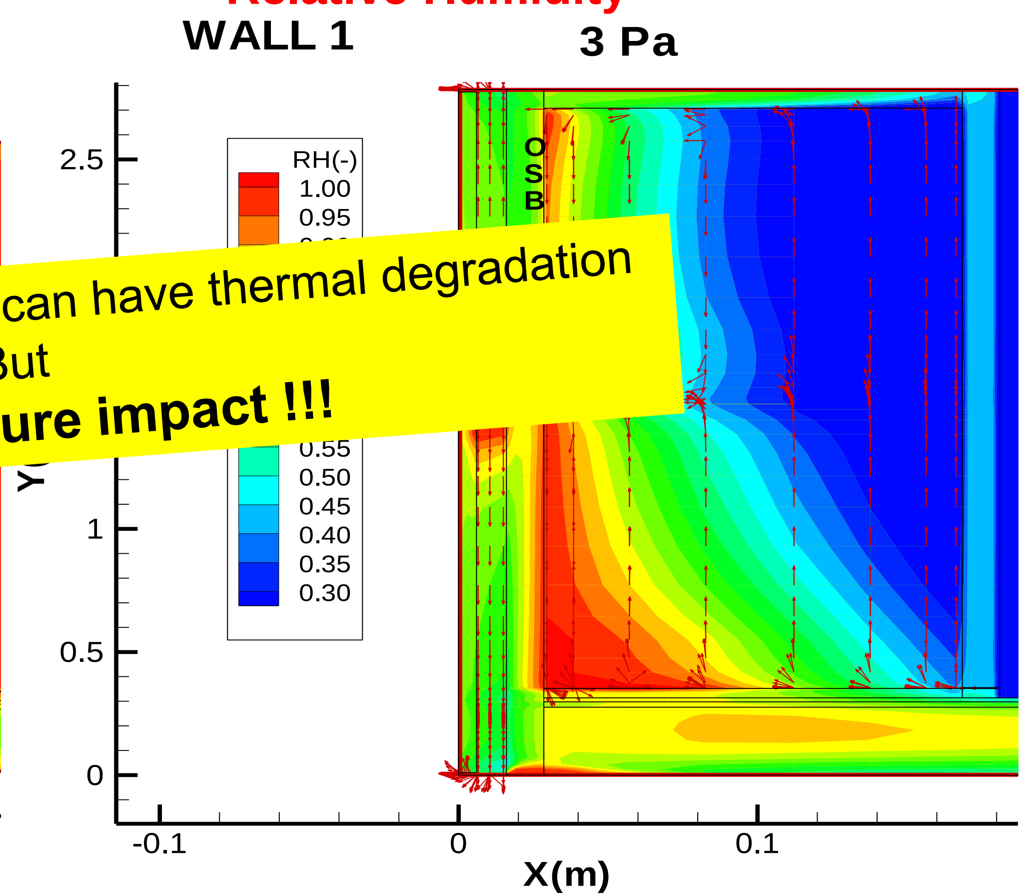
BUILDING SCIENCE INSIGHTS
Physics to the Field™

Intentionally Leaky… added holes

Temperature



Relative Humidity



Small amounts of air leakage can have thermal degradation

But

Major moisture impact !!!

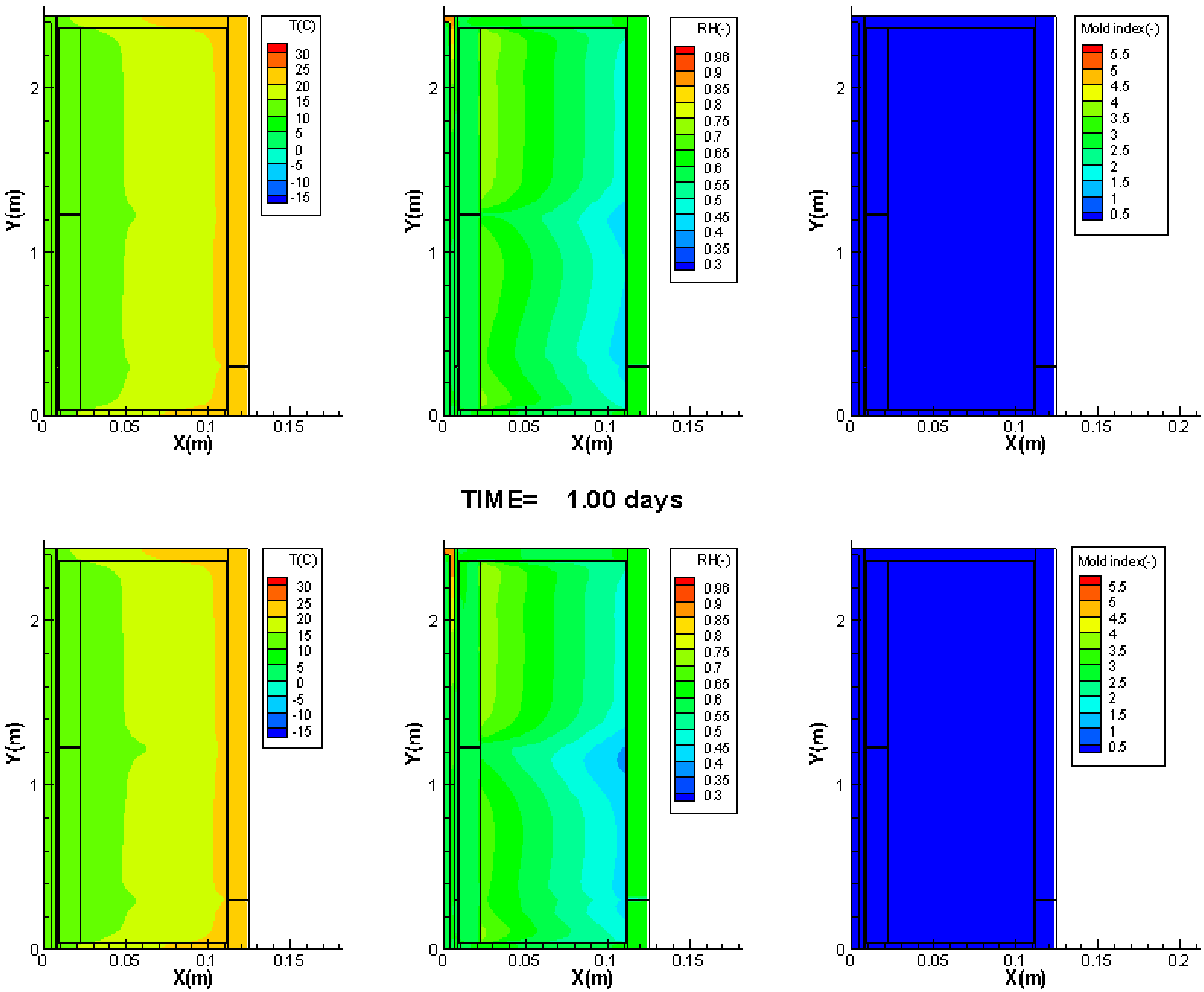
Minneapolis: Study by ORNL and BSC

Air leaks through walls

- Explain the basics needed to be captured in WUFI model
- Show the process
- Take science data to the field (**From an academic exercise to reality**)

What is future ?

Neutral Plane



2 Storey Building

For a particular joint

Air Barrier system

Air leakage modes

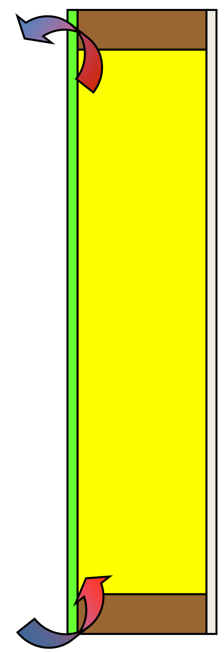
- **Air flow through the wall**
  - Through insulated wall cavity
  - Between components (where the majority of the leakage flow happens)

- **Wind-washing**
  - No flow through – flow in and out (insulation)

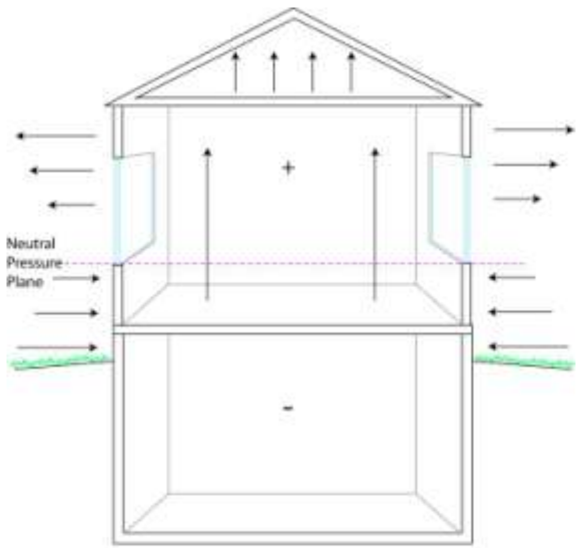
Roles of Air Barriers

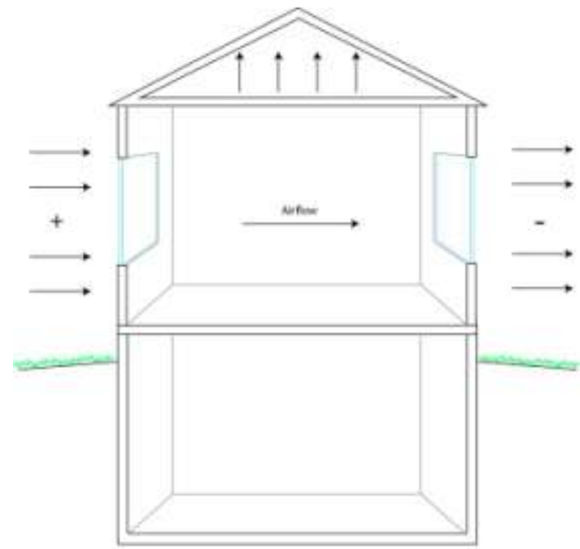
Terminology Session: Where is Professor Eric Burnett ?

- **Wind barrier**
  - Prevent “wind-washing” of insulated cavity
- **Air barrier** or
  - Prevent air flows <u>through</u> the wall



Forces causing airflow through envelope parts



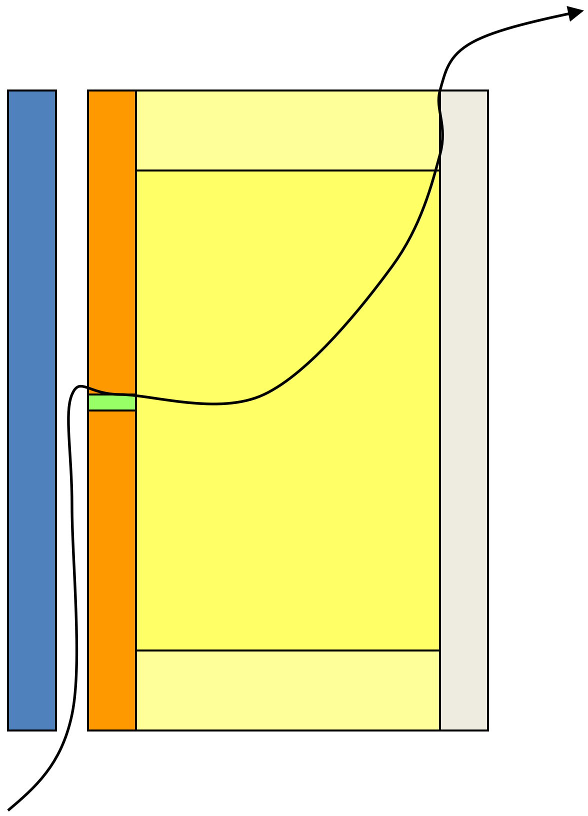


Stack + mechanical ventilation (+/- ΔP) **Wind**

Infiltration/Exfiltration is the unwanted air movement through a building and is caused by a pressure difference (air moves from high pressure to a lower pressure).

Multi-dimensional flows to 1D

- Add heat and moisture source to
  - Exterior cavity (air from outdoors/ins. cavity)
  - Insulated cavity (air from ext. cavity/indoors)



Linear Transport Laws

- **Fourier's Law –** Heat is transferred from a region of higher temperature to a region of lower temperature

$$Q = -kA\frac{dT}{dx}$$

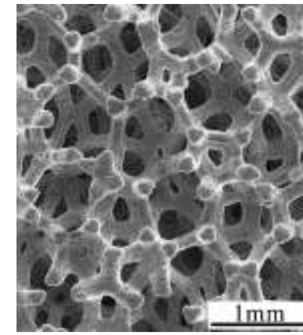
- **Fick's law** – Mass is transferred from a region of higher concentration to a region of lower concentration

$$J = -DA\frac{dC}{dx}$$

Governing Equations

Mass Balance

$$\frac{\partial \rho_a(T)}{\partial t} + \nabla.\left(\rho_a(T)\vec{v}_a\right) = 0$$



Momentum Balance

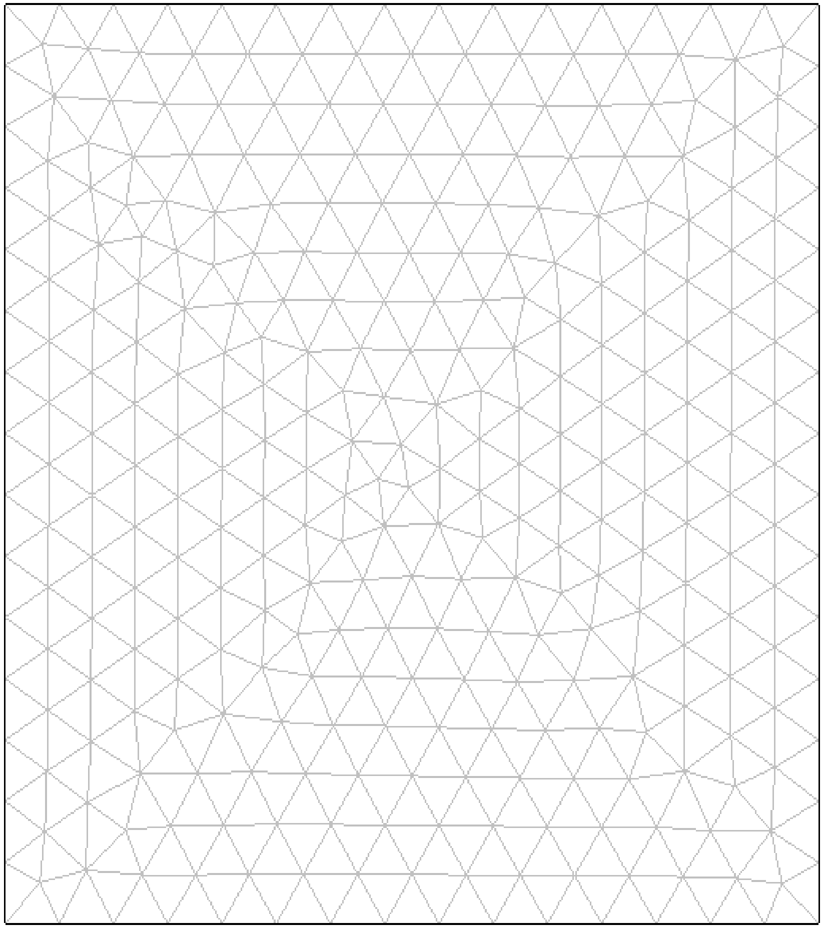
$$\frac{\partial\left(\rho_a(T)\vec{v}_a\right)}{\partial t} + \nabla\left(\rho_a(T)\vec{v}_a ; \vec{v}_a\right) = -\Delta P_a + \frac{\mu_a(T)}{K_a}\vec{v}_a + \rho_a(T)\vec{g}$$

Energy balance

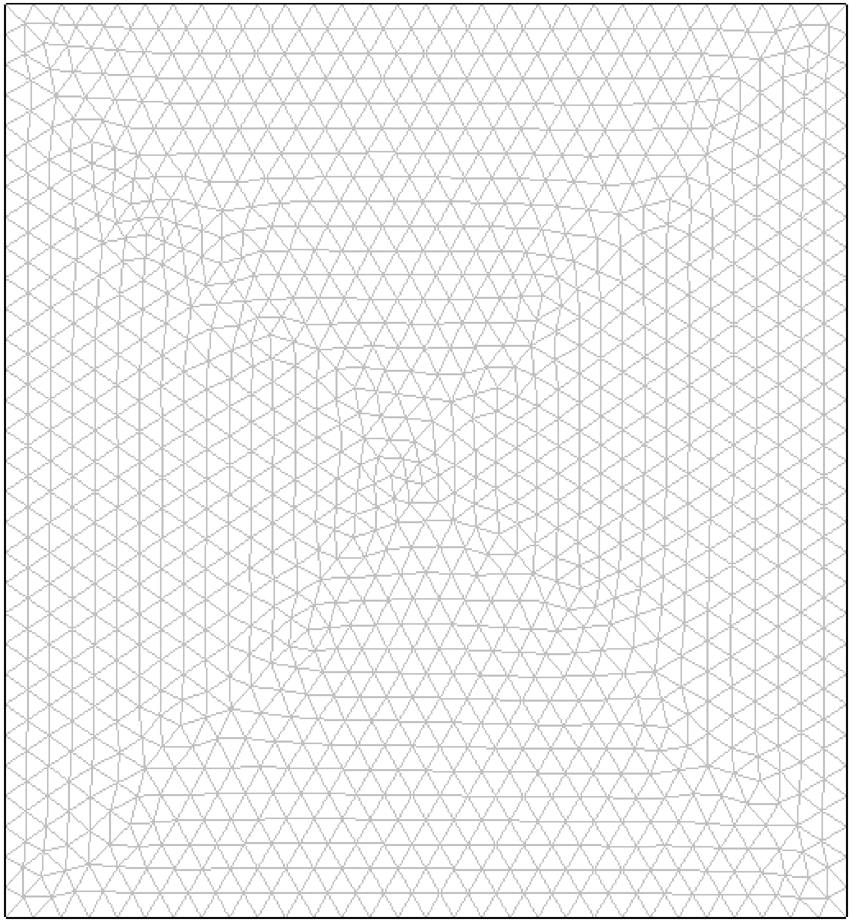
$$\rho_m(u,T)C_p(u,T)\frac{\partial T}{\partial t} = \underbrace{-\nabla.\left(\rho_a C_p(T)\vec{V}_a T\right)}_{Convection} + \underbrace{\nabla.\left(k(u,T)\Delta T\right)}_{Conduction} + \underbrace{L_v.\left(\delta_p(u,T)\nabla P_v\right)}_{Evaporation}$$

$$+ \underbrace{L_{ice}.\rho_m(u,T)u\frac{\partial f_l(T)}{\partial t}}_{Condensation}$$

Solve each equation/element



Mesh containing 590 elements



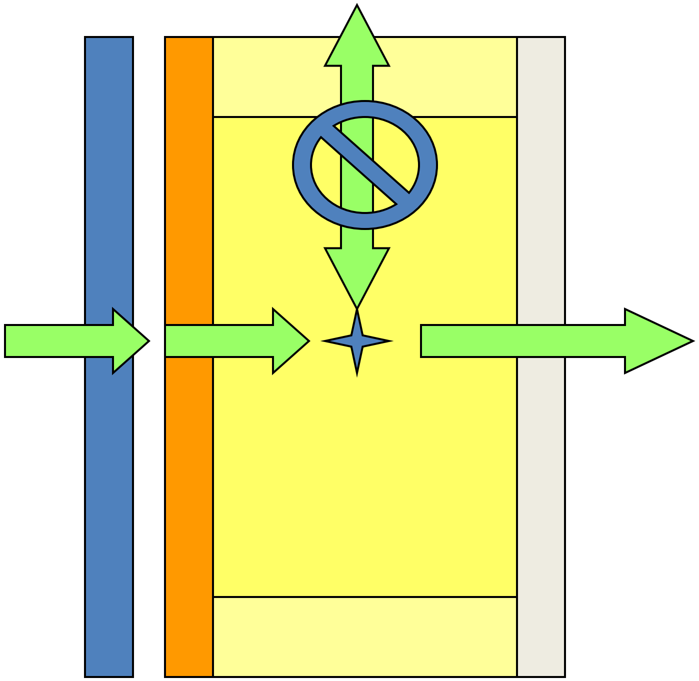
Mesh containing 2360 elements

Flow balance

OWENS CORNING
INNOVATIONS FOR LIVING

BUILDING SCIENCE INSIGHTS
Physics to the Field™

- Air can leak one-dimensionally all the way through, or some of the air may be lost (or added!)
- Initially, let's assume that all flow will go through and there are no leaks
  - Flow direction would cause problems in assigning the source (attic, etc.)



Procedure to Calculate Sources and Sinks

- **Calculate pressures P**
  - **Wind**
    - Wind pressure coefficients and locations
    - Wind speed and direction
  - **Stack**
    - Neutral pressure plane
  - **M**echanical **v**entilation and **b**uilding **p**ressure **b**alance

- **Calculate flow through**
  - Air leakage characteristics

Wind pressure on buildings

- ASHRAE Fundamentals 2005
  - Bernoulli's equation

$$p_v = \frac{\rho_a U_H^2}{2}$$

where

U_H = approach wind speed at upwind wall height H, m/s
ρ_a = ambient (outdoor) air density, kg/m^3

- Wind pressure coefficient on the wall Cp

The proportional relationship is shown in the following equation, in which the difference p_s between the pressure on the building surface and the local outdoor atmospheric pressure at the same level in an undisturbed wind approaching the building is

$$p_s = C_p p_v \quad (3)$$

where C_p is the local wind pressure coefficient for the building surface.

Wind speed at the building (wall) height

- Location affects the wind speed

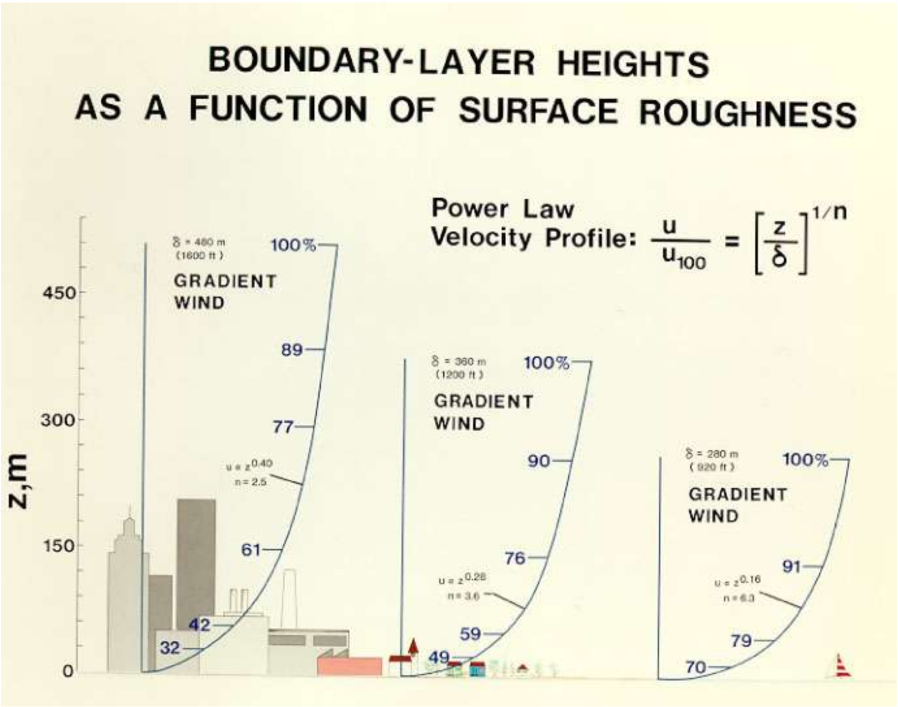


Table 1 Atmospheric Boundary Layer Parameters

Terrain Category	Description	Exponent a	Layer Thickness δ, m
1	Large city centers, in which at least 50% of buildings are higher than 21.3 m, over a distance of at least 0.8 km or 10 times the height of the structure upwind, whichever is greater	0.33	460
2	Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger, over a distance of at least 460 m or 10 times the height of the structure upwind, whichever is greater	0.22	370
3	Open terrain with scattered obstructions having heights generally less than 9.1 m, including flat open country typical of meteorological station surroundings	0.14	270
4	Flat, unobstructed areas exposed to wind flowing over water for at least 1.6 km, over a distance of 460 m or 10 times the height of the structure inland, whichever is greater	0.10	210

$$U_H = U_{met}\left(\frac{\delta_{met}}{H_{met}}\right)^{a_{met}}\left(\frac{H}{\delta}\right)^{a} \quad (4)$$

Local wind pressure coefficient C_p – need to simplify

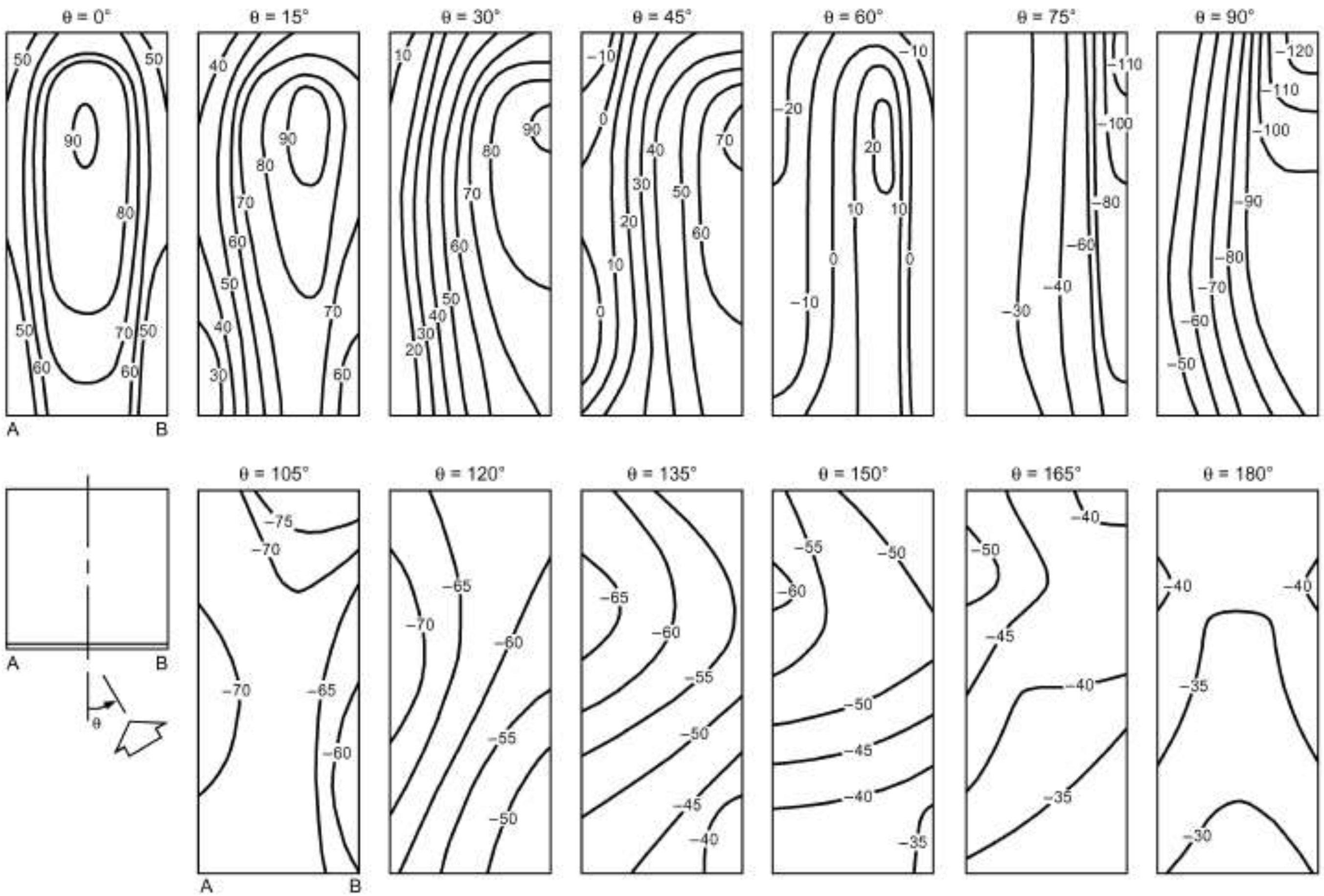


Fig. 4 Local Pressure Coefficients ($C_p \times 100$) for Tall Building with Varying Wind Direction
(Davenport and Hui 1982)

Simplified wind pressure coefficients

- Default value: assume average wall coefficient (tall buildings)

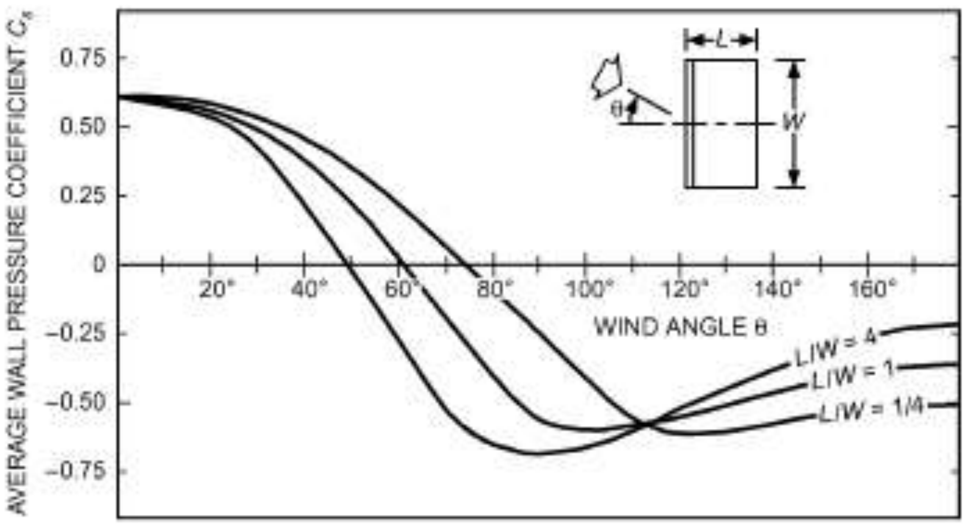


Fig. 7 Surface-Averaged Wall Pressure Coefficients for Tall Buildings
(Akins et al. 1979)

Simplified wind pressure coefficients

- Default value: assume average wall coefficient (low-rise)

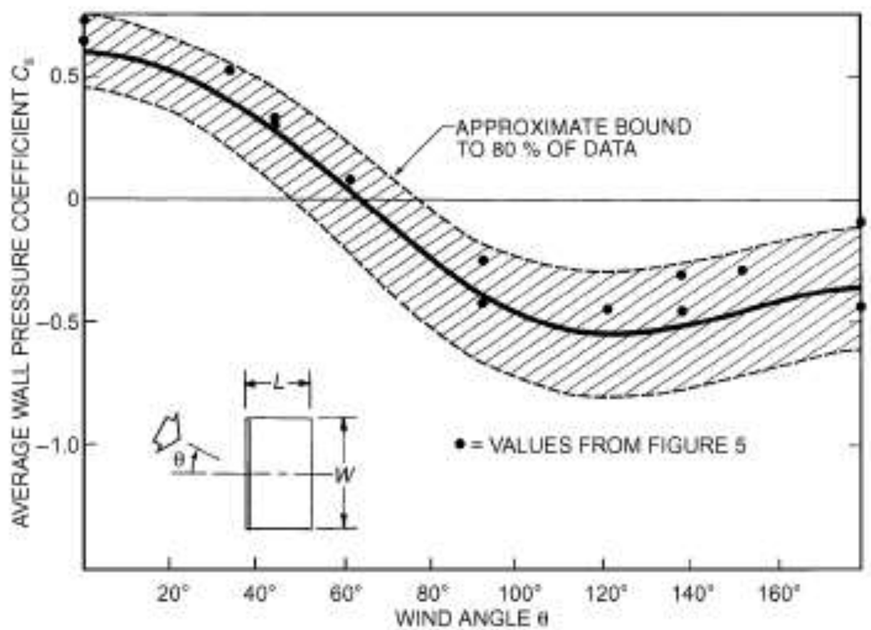


Fig. 6 Variation of Surface-Averaged Wall Pressure Coefficients for Low-Rise Buildings
Courtesy of Florida Solar Energy Center
(Swami and Chandra 1987)

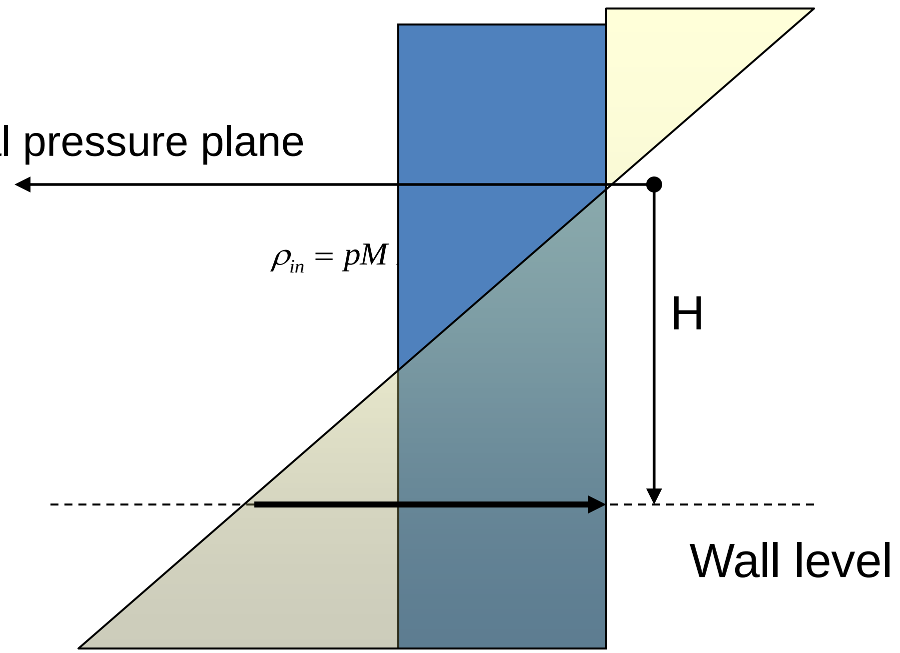
Stack pressure

- Buoyancy effect: Density difference of air outdoors and indoors

$$\Delta P = \frac{pM}{R}\left(\frac{1}{T_{out}} - \frac{1}{T_{in}}\right) \cdot g \cdot H$$

Dense, cold, heavy air

$\rho_{out} = pM / RT_{out}$



$\rho_{in} = pM$

Light, warm air

Zone pressures

- Building pressure calculations

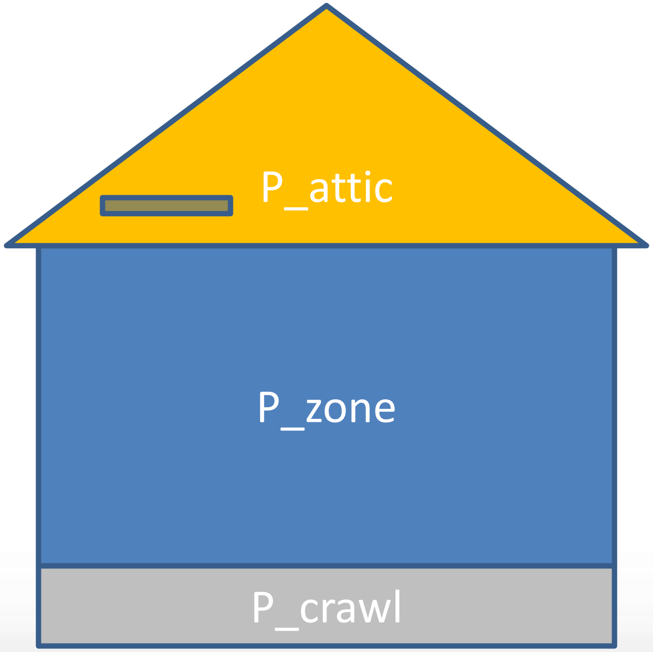
- Building zones
  - Room to room balance
  - Stratification (bottom to top)
    - Location of the leak in the building and in the element matters!

- Have an attic zone, and a crawlspace zone

Total pressure difference

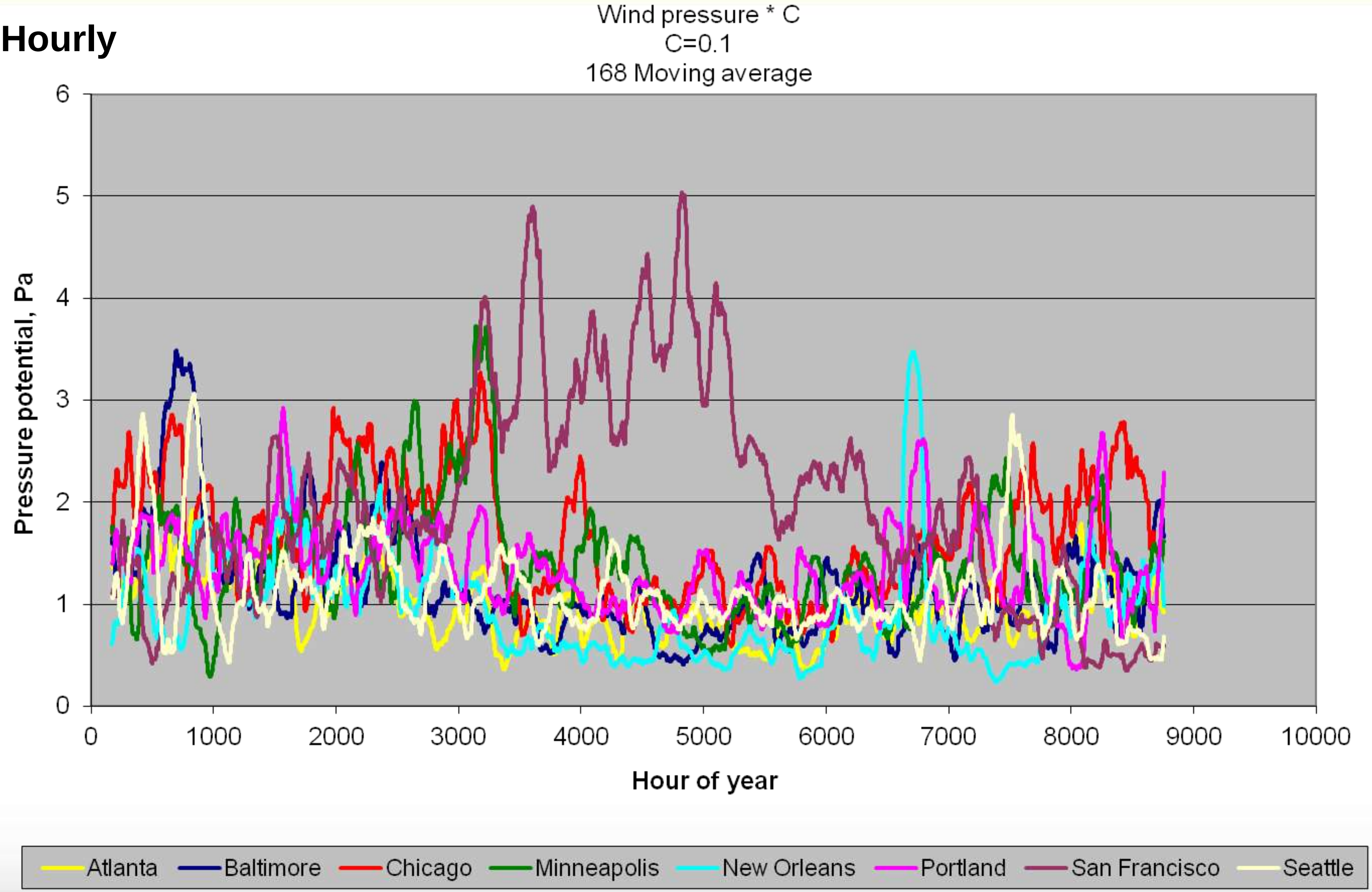
$$\Delta P = \Delta P_{wind} + \Delta P_{Stack} + \Delta P_{Mechanical}$$

$$\Delta P = \Delta C_p \cdot \tfrac{1}{2} \rho U^2 + \frac{pM}{R}\left(\frac{1}{T_{out}} - \frac{1}{T_{in}}\right) \cdot g \cdot H + \Delta P_{Mechanical}$$



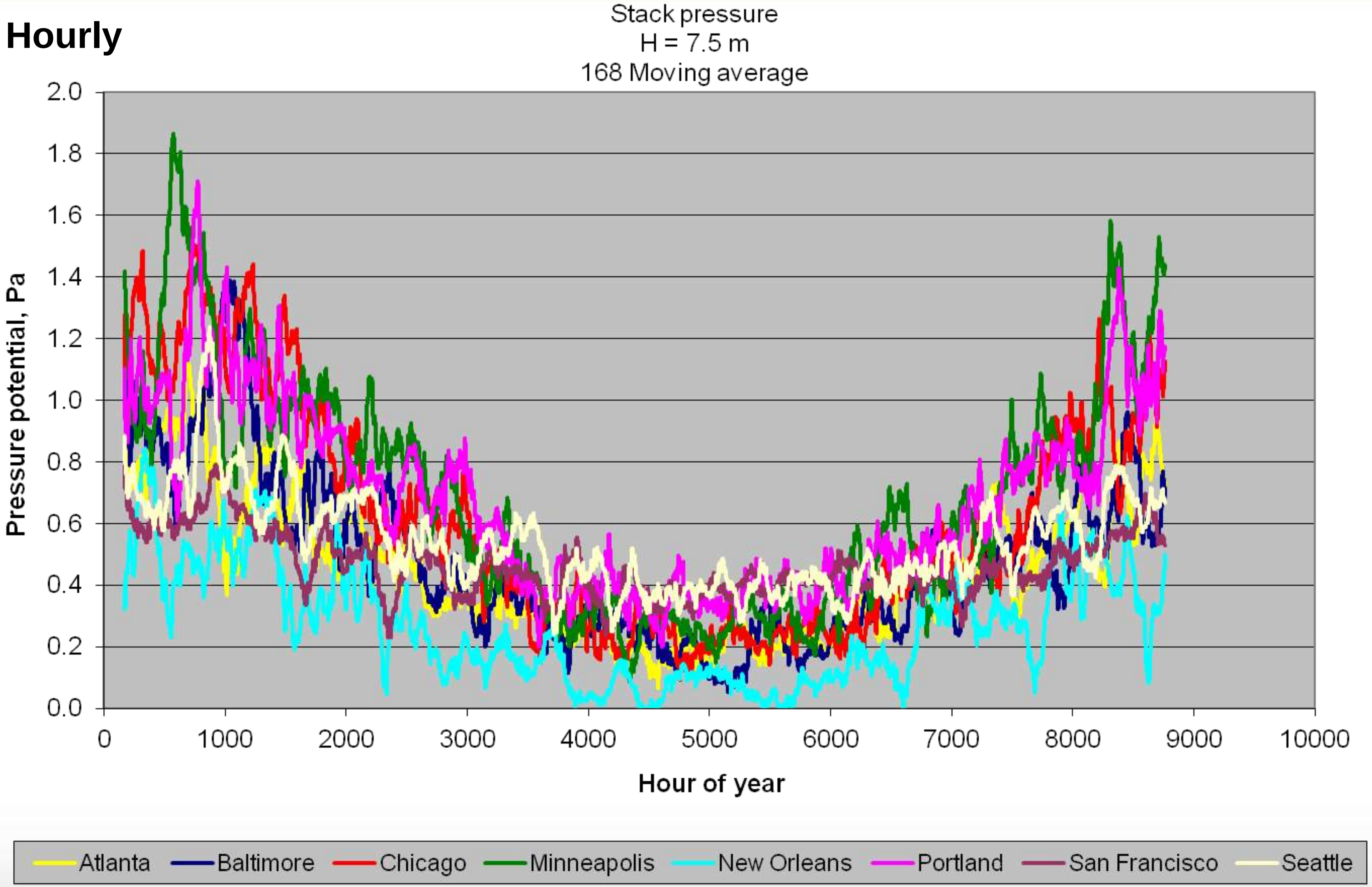
Climate Effects

Hourly



Climate Stack Pressure

Hourly



Equations for sinks/sources

- In addition to exterior cavity, we have now air leaks in and through insulation layer
- Wind Pressure Difference and Thermal Buoyancy result in a pressure difference across the wall.

$Q = C\Delta p^n$ — Wall assembly air leakage characteristics

Q[m³/h-m²] — Volume Flow Rate through the wall per m²

Δp[Pa] — Pressure difference across the wall

- Heat source:

$$S_h = \rho_{in} \cdot Q \cdot C_{p,Air} \cdot (T_{in} - T)$$

S_h: Heat Source [W/m²]
ρ_{in}: Density of the incoming Air [kg/m³]
Q: Air Flow Rate through the Wall [m³/h-m²]
$C_{p,Air}$: Spec. Heat Capacity of Air [J/kg K]
T_{in}: Temperature; Incoming air [K]
T: Temperature in the Layer [K]

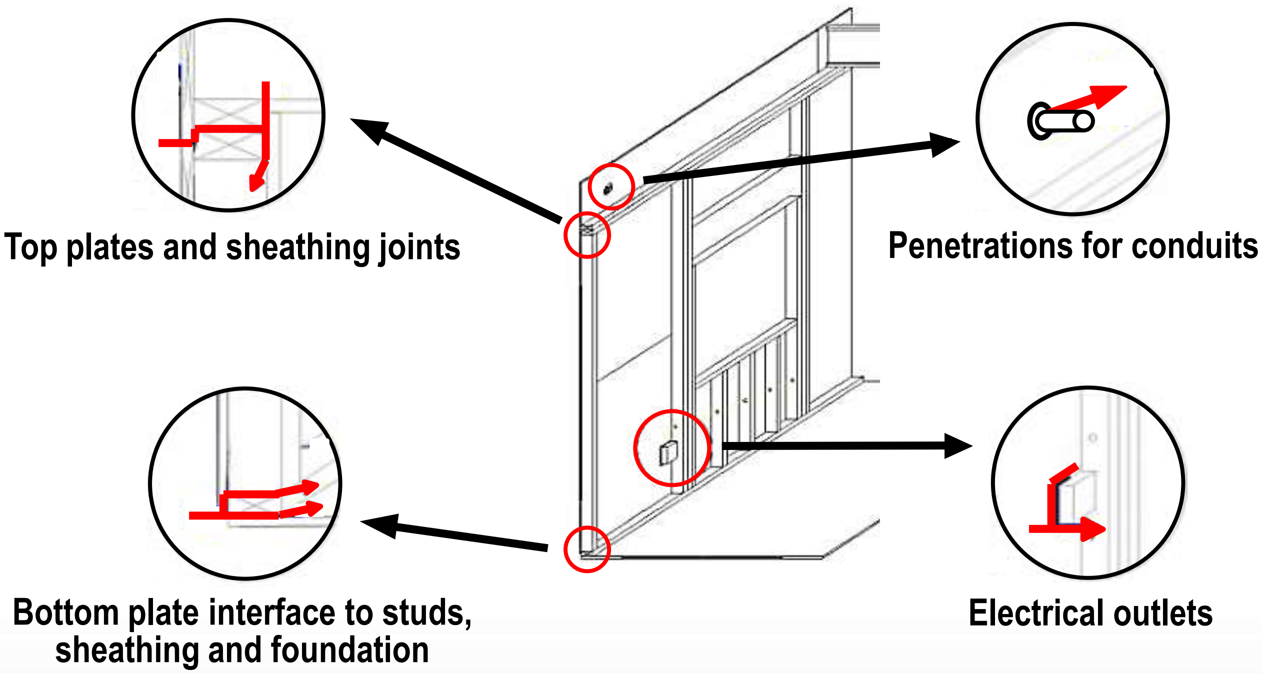
- Moisture source:

$$S_w = Q(c_{source} - c)$$

S_w: Moisture Source [kg/m²s]
c_{source}: Water Vapor Concentration in the incoming Air; [kg/m³]
c: Water Vapor Concentration in the air in Layer [kg/m³]

Sub-Assembly Tests

- Characterize and identify major air leakage paths in walls
- Assess methods to seal significant sources of leakage



Joints/Openings

All joints/openings in the building envelope should be air sealed.

But, some joints/openings must be more important than others.

Which ones?

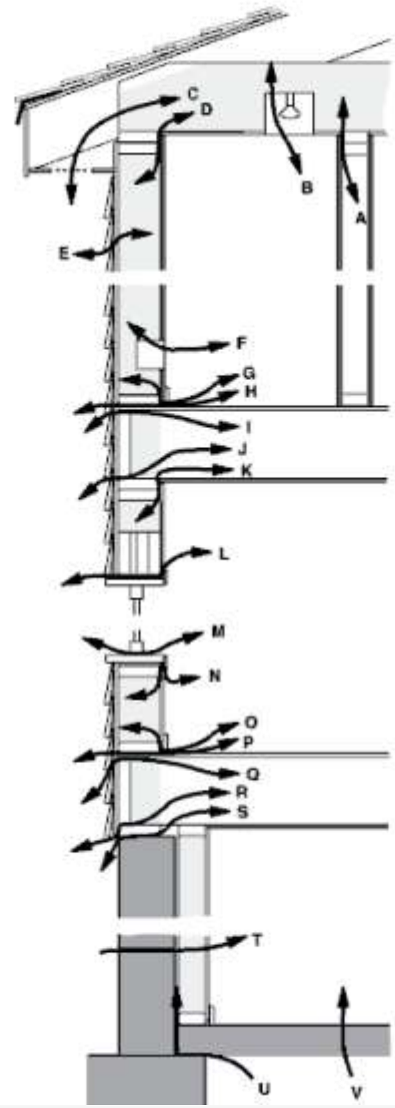


Image from Conservation Technology

Joints/Openings

Which ones?

- A good question, but …

Not so easy to answer.

- Lots of different types of joints
- Differing levels of construction quality
- Not easy to isolate and measure
- Then there's this thing called "coupling", where other things around the joints affect its leakage

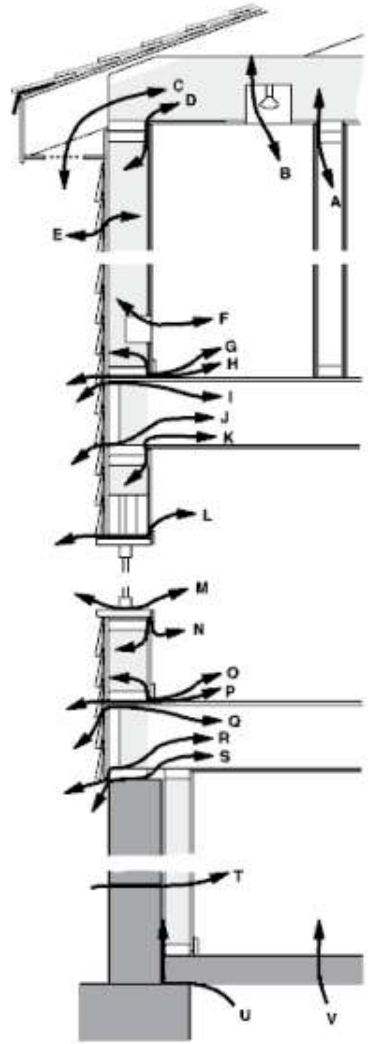


Image from Conservation Technology

DOE/ORNL/Tremco's ABAA

Tim Maddox

ASTM 2357 Cycling Pressures

Phase 3 (2012 – 2013): Critical Tests

- **Each of the 8 Air Barrier Systems will be tested at least 5 to 15 different attachments each !**


Interior

Spray-applied foam


Mechanically fastened


Non-insulating board stock

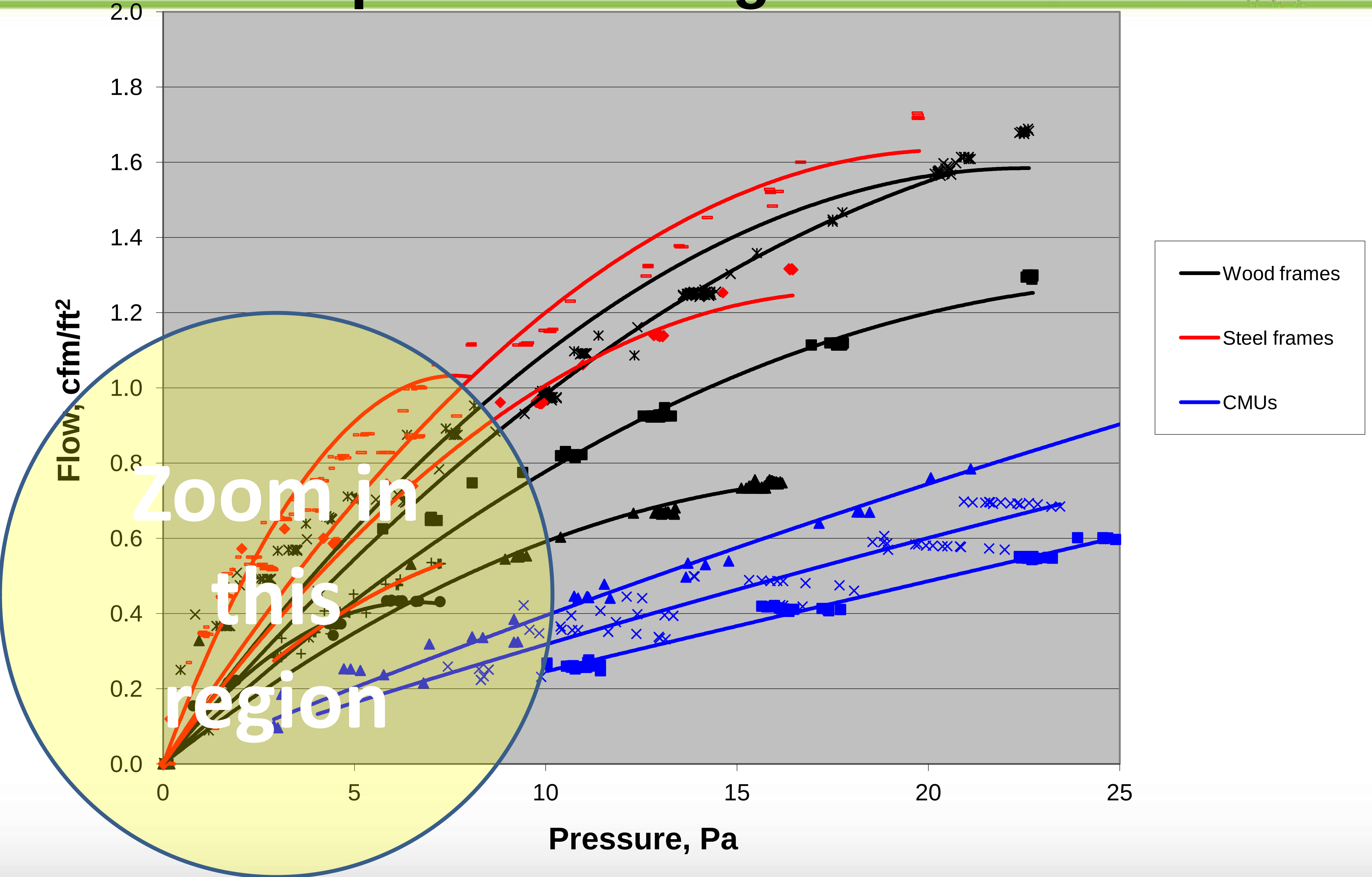

Insulating board stock


Sealers w/ backup structure


Self-adhered


Fluid-applied non-foaming

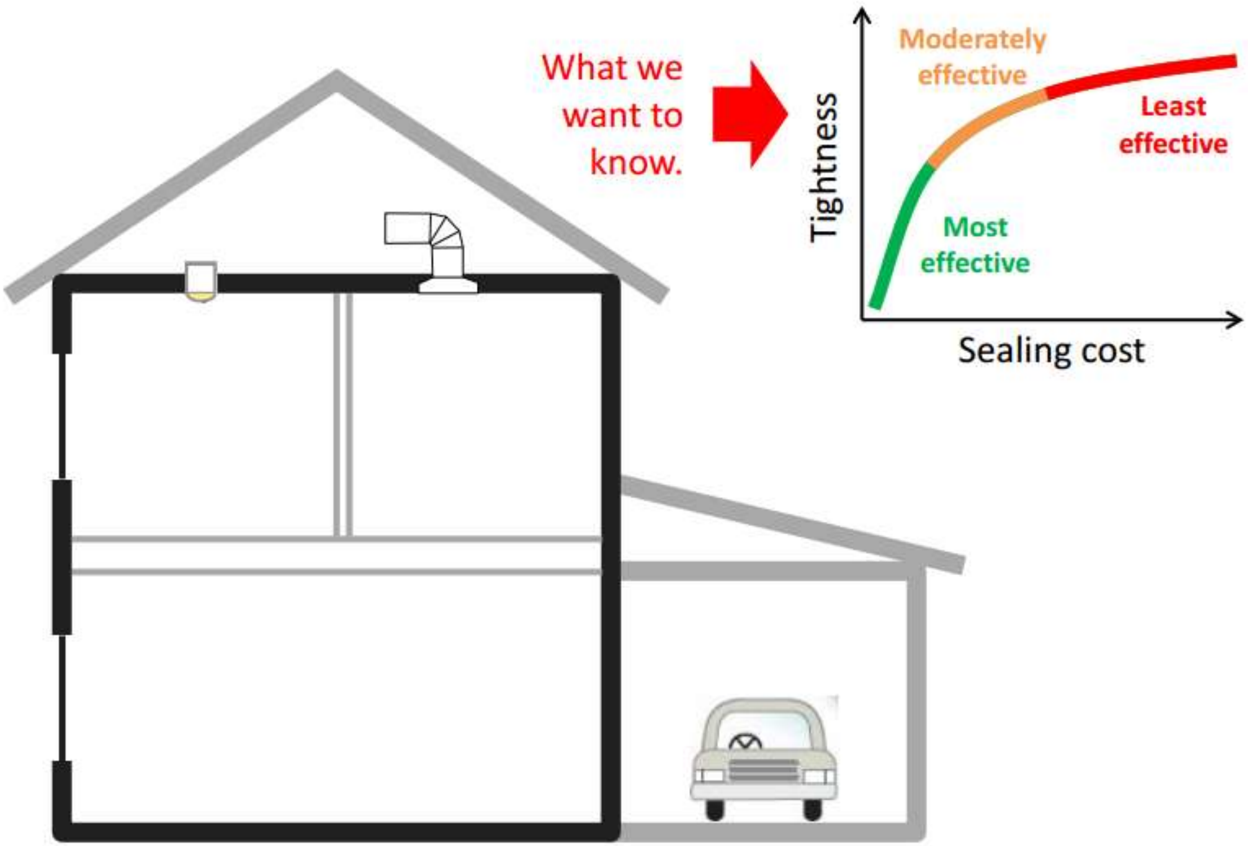
Example of Component leakage



Residential Application

BUILDING SCIENCE INSIGHTS
Physics to the Field™

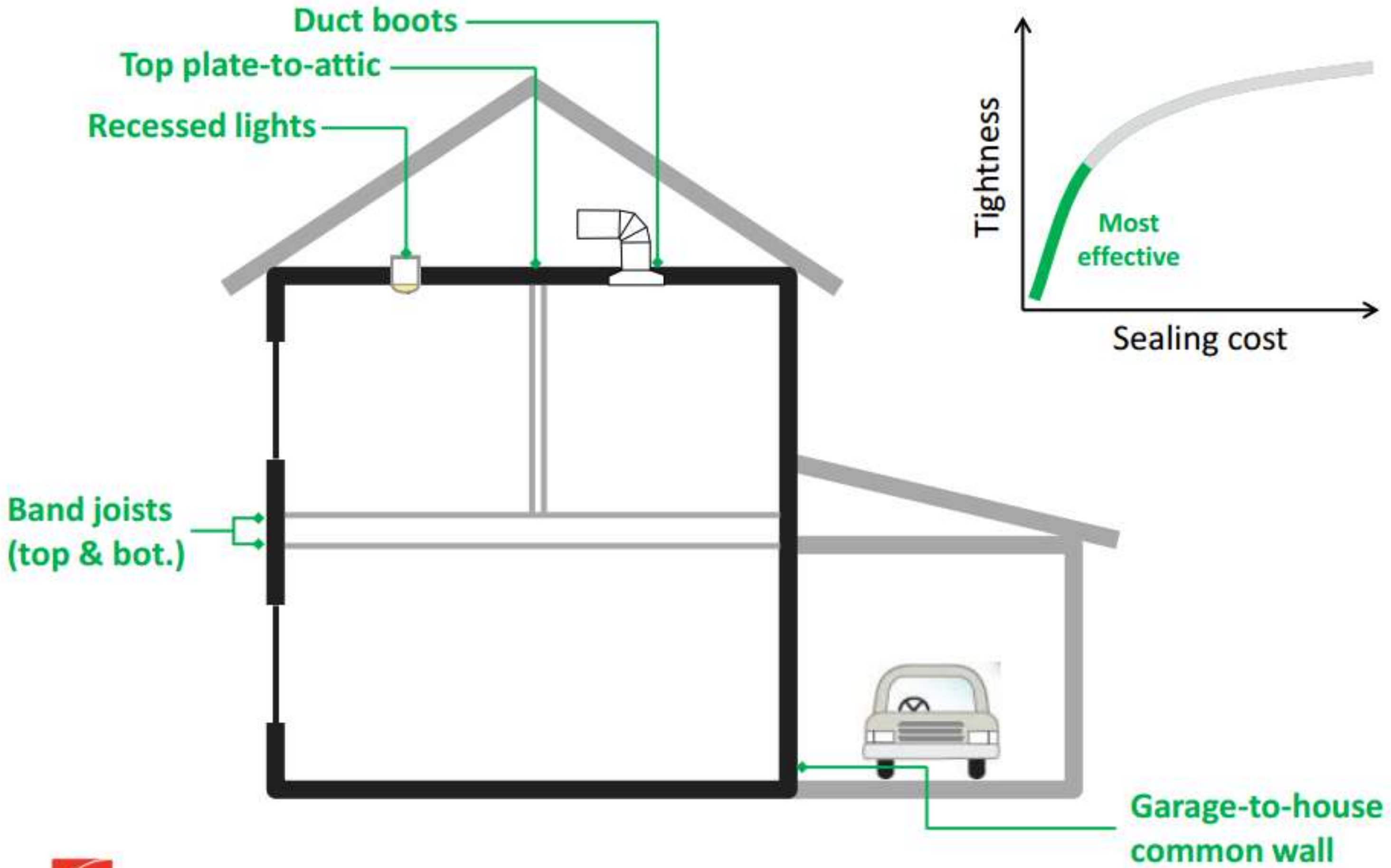
Typical House | Biggest Bang for the Buck



Wolf ,Salonvaara & Tyler; Owens Corning 2012

Interior Air Sealing

Most Effective Joints to Seal



Wolf ,Salonvaara & Tyler; Owens Corning 2012

Ranking for Particular Air Barrier & Housing Project

Really nice to have **blower door** data

But what does ACH50 mean ?

We **need** the actual loading between Housing Zones

At Minimum ATTIC-MAIN-BASEMENT

Equations for sinks/sources… cont'd

- Remember the serial order of sources/sinks
  - Insulated cavity gets air from exterior cavity or indoors (light weight wood frame wall, for example)
  - Relate to three leakage classes (Envelope):

1 ACH50	3 ACH50	5 ACH50
Good	Acceptable	High
0.2 L/s m^2	0.6 L/s m^2	1 L/s m^2

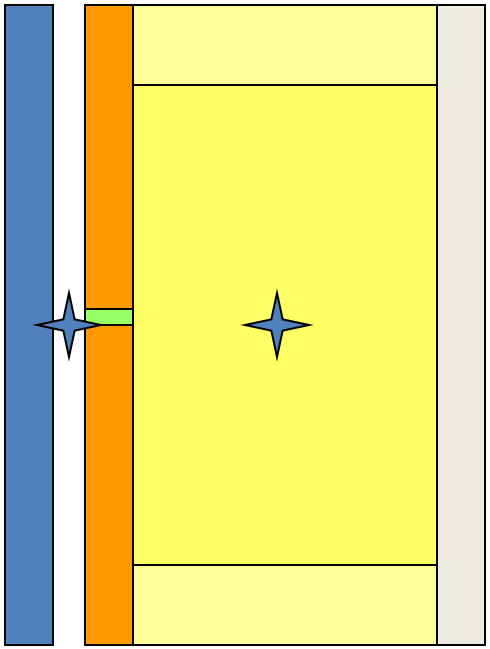
No air sealing

Band Joist
Top Plate to sheathing
Bottom Plate to Sheathing
Bottom Plate to Slab
Corners

Example: One to Two sources

- $Q = C\Delta p^n$

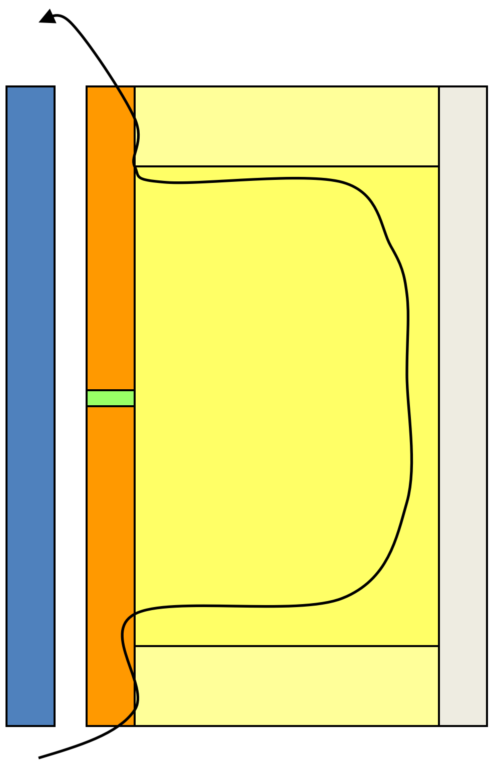
- No diffuse seeping flow through materials
  - Only sources and sinks
    - Exterior cavity (maybe, depends on flow path def.)
    - Insulated cavity



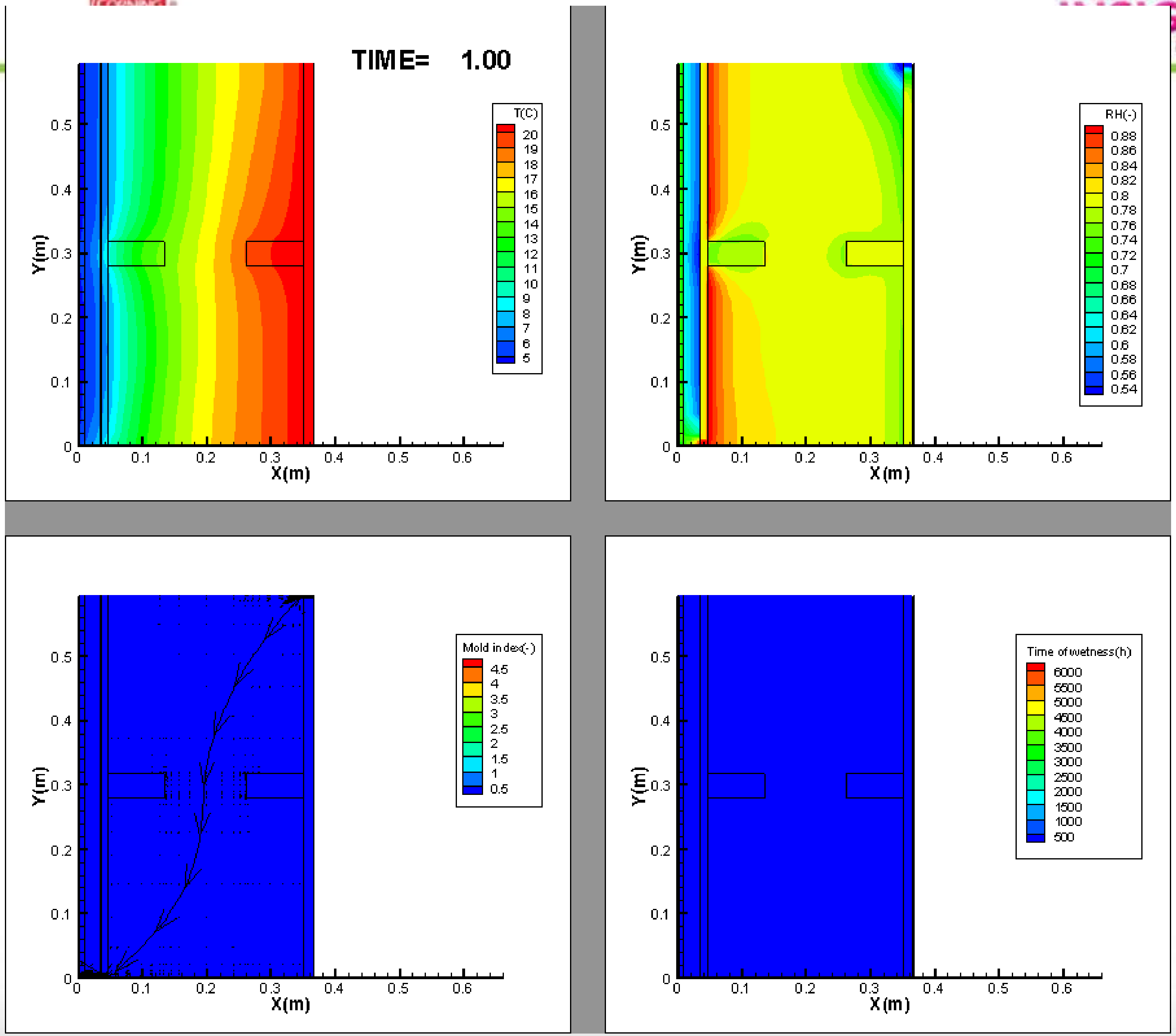
Source assigned to this layer.
No sources to ‘impermeable’ that are bypassed by airflow.

Wind washing - sources/sinks

- Add heat and moisture source to
  - Insulated cavity (air from outdoors)
  - Flow mostly on the interior side of the insulated cavity (natural convection as a force)
  - Air tightness to be defined for cavity
  - Force for flow is stack (wind can be added with C_{bottom}, C_{top})



Capture and understand



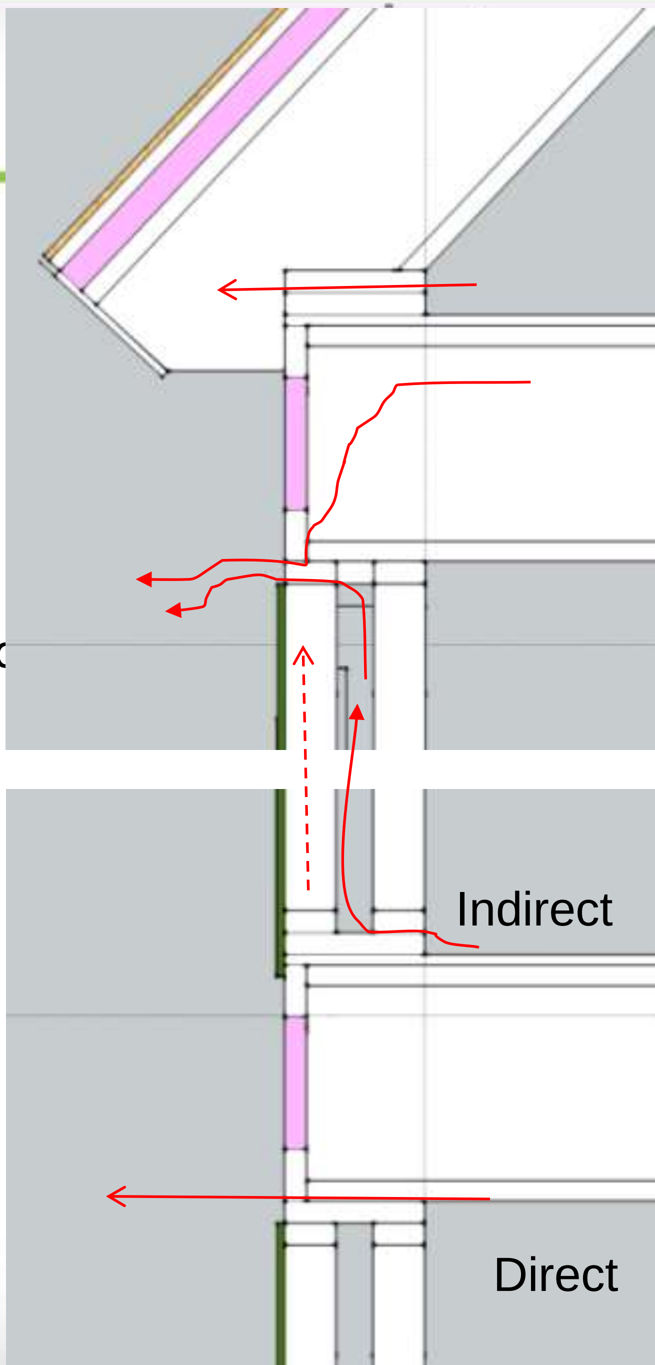
Double stud
Walls
With cellulose
insulation

Passive House
Air Leakage Study
Independent of Insulation Type

Passive House Technical Committee

Air Leakage Paths

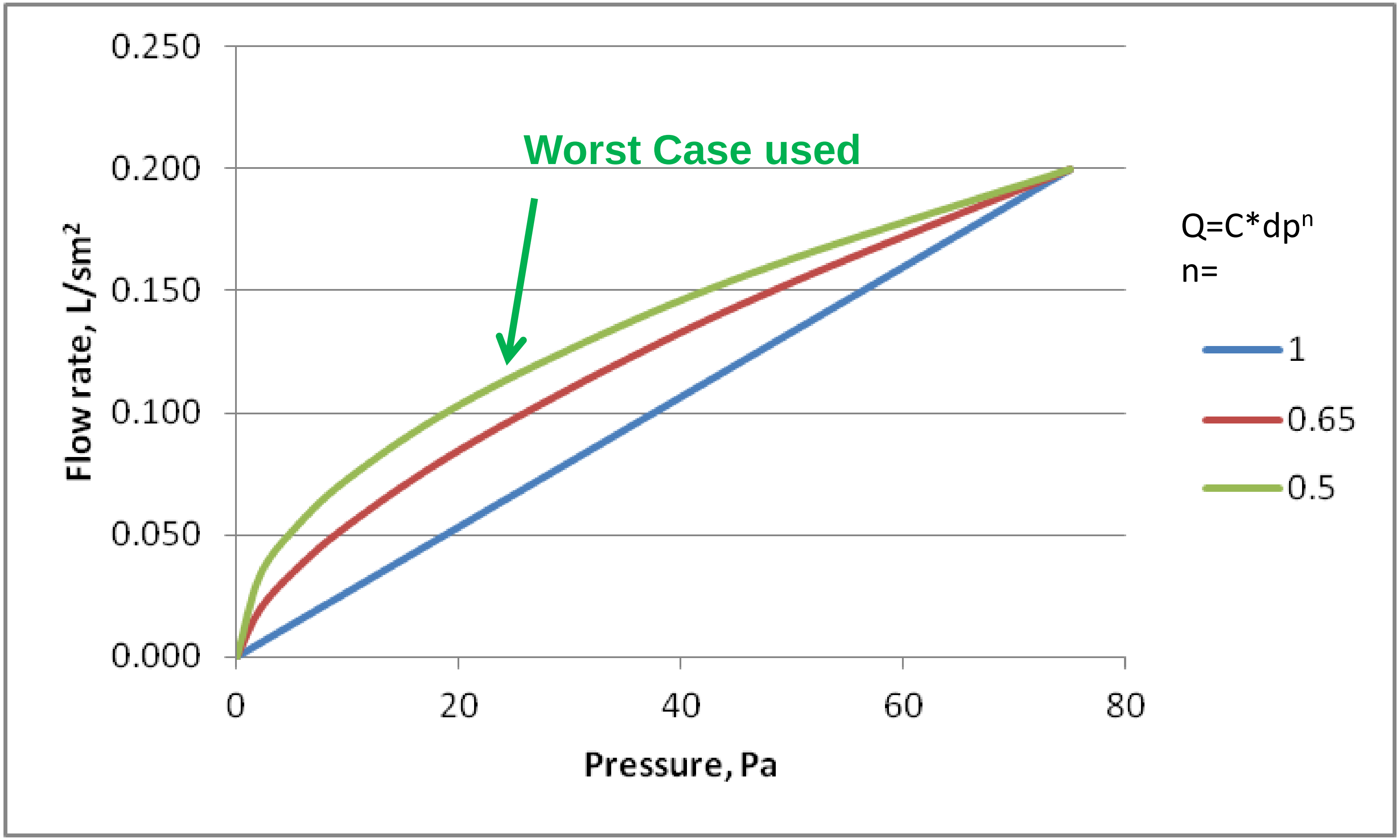
- Short Direct Paths
  - By-pass insulated cavity
  - Most of whole house BE leakage
  - Effects: Thermal > Moisture
    - If any air moves into the insulated cavity, mo multiplied
- Long Indirect Paths
  - Flow through insulated cavity
  - Less flow than through direct paths
  - Effects: Moisture > Thermal



Air Leakage Rated at 75Pa

- Air barrier
  - Materials 0.02 L/sm^2 @75Pa
  - Assemblies 0.2 L/sm^2 @75Pa
  - Systems 2.0 L/sm^2 @75Pa
- Exponent n=?
  - Needed for estimating the flow at building pressures
- These simulations used n=0.5 which gives the highest flow rates at low pressures (safety factor for design)

Flow Characteristic: Exponent n



Assembly Leakage to Whole Building

- Assume
  - 30ft x 40ft two story building
  - Average ceiling height 8.5ft
  - Walls and roofs leak the same 0.2 L/sm^2@75Pa
  - Flow characteristic n=0.65 or n=0.5 ($Q=C*dp^n$)

L/sm^2 @75	0.2	0.4	0.6
cfm/ft^2 @75	0.04	0.08	0.16
n=0.65			
cfm/ft^2 @50	0.031	0.061	0.123
L/sm^2 @50	0.154	0.307	0.461
ach50	0.32	0.64	0.95
n=0.50			
cfm/ft^2 @50	0.033	0.065	0.131
L/sm^2 @50	0.163	0.327	0.490
ach50	0.34	0.68	1.01

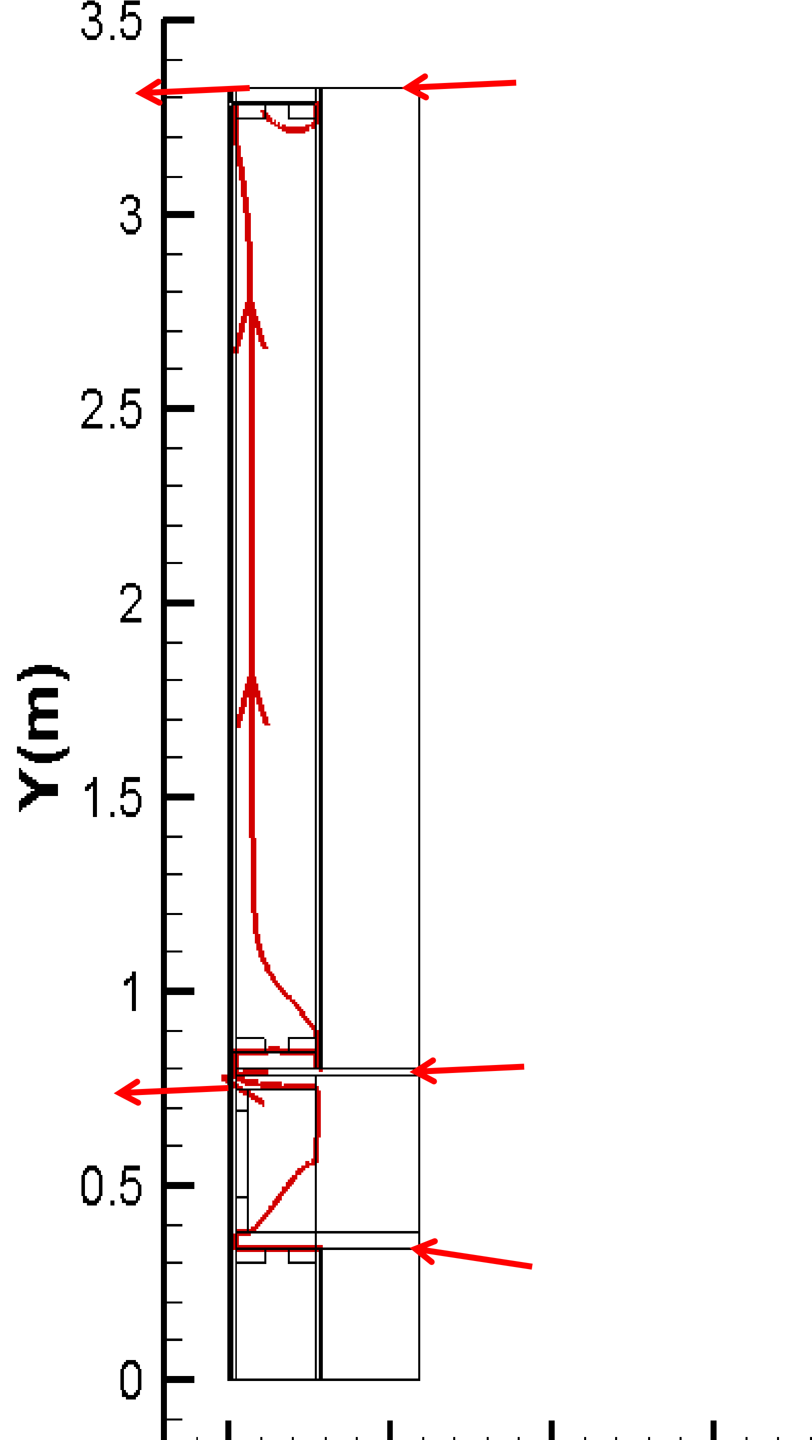
For all the **worldy units**

Airflow Paths

Vinyl
19 mm cavity
WRB
OSB
10 in Insulation
Gypsum
Paint 10 perms

North Orientation… mostly exfiltration

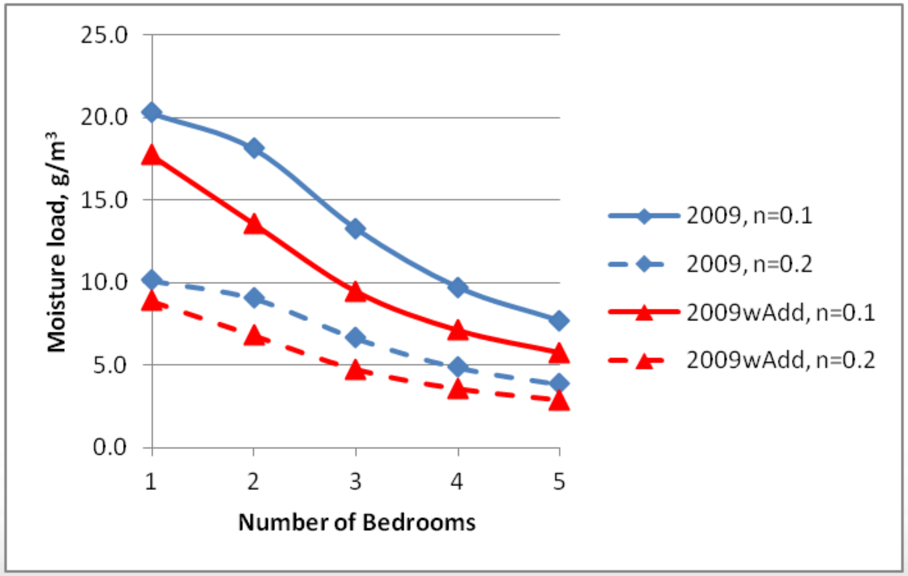
Start Time 1 Oct. 2075



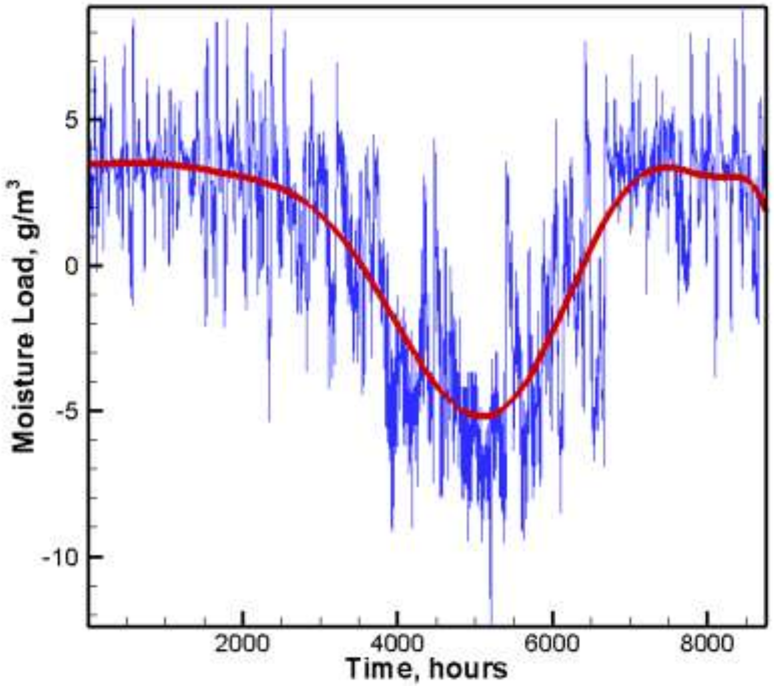
Indoor Moisture Loads

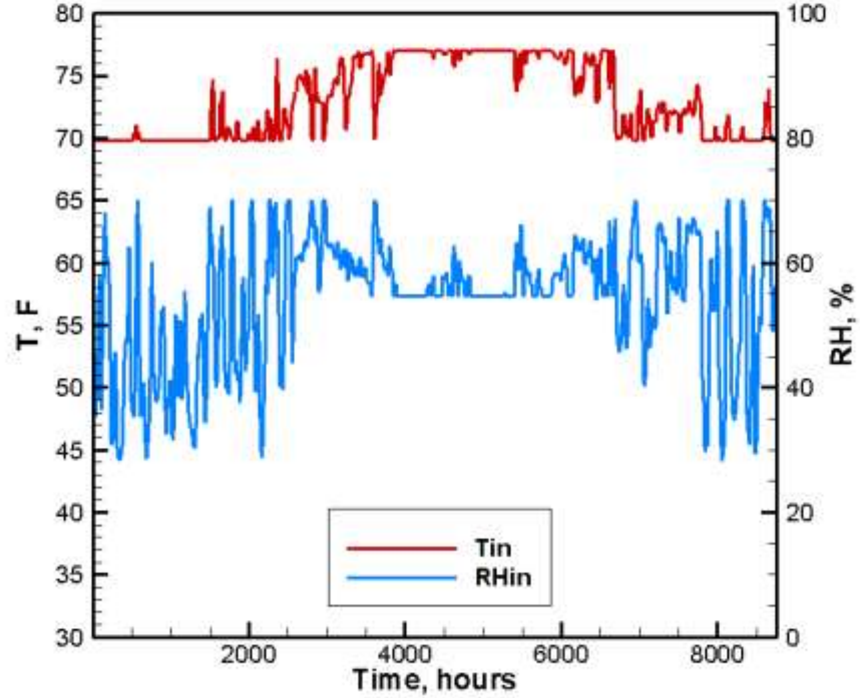
- Loads were calculated assuming
  - 9 L/d moisture production (20 lb/d) (SPC160, 2 bdr)
  - 500 m^3 house volume (17553 cf)
  - ach=0.25 (leakage and occupancy effects)
- These result in moisture load of +3 g/m^3 when no dehumidification by cooling system

Old and new SPC160 moisture loads.
Average house size f(#bdr) considered.

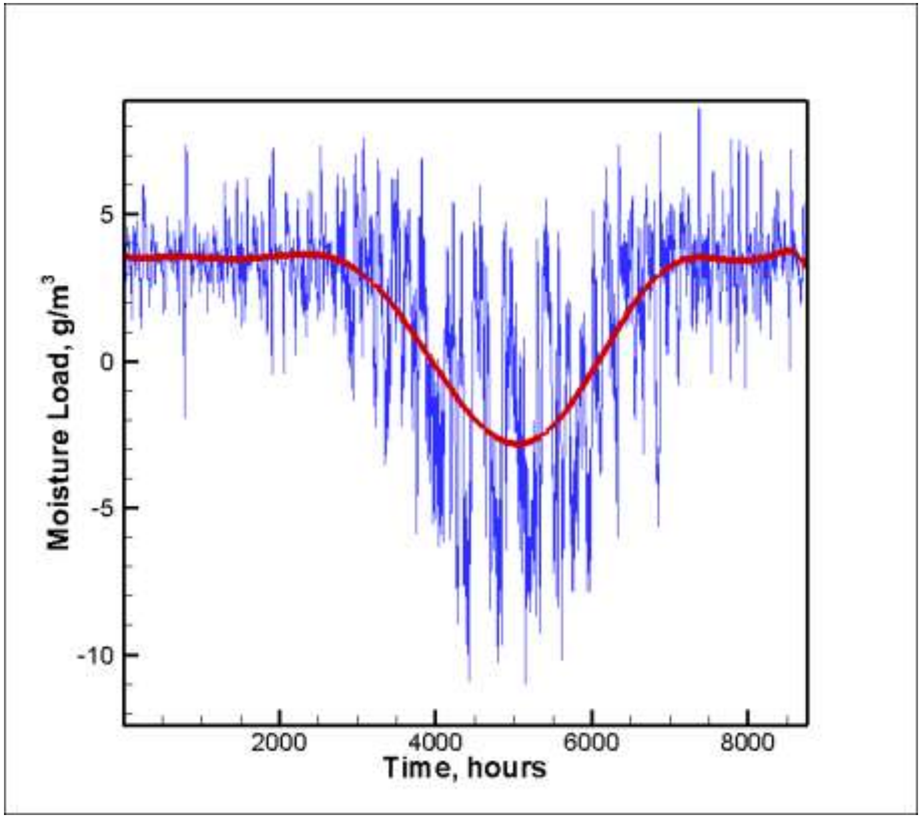


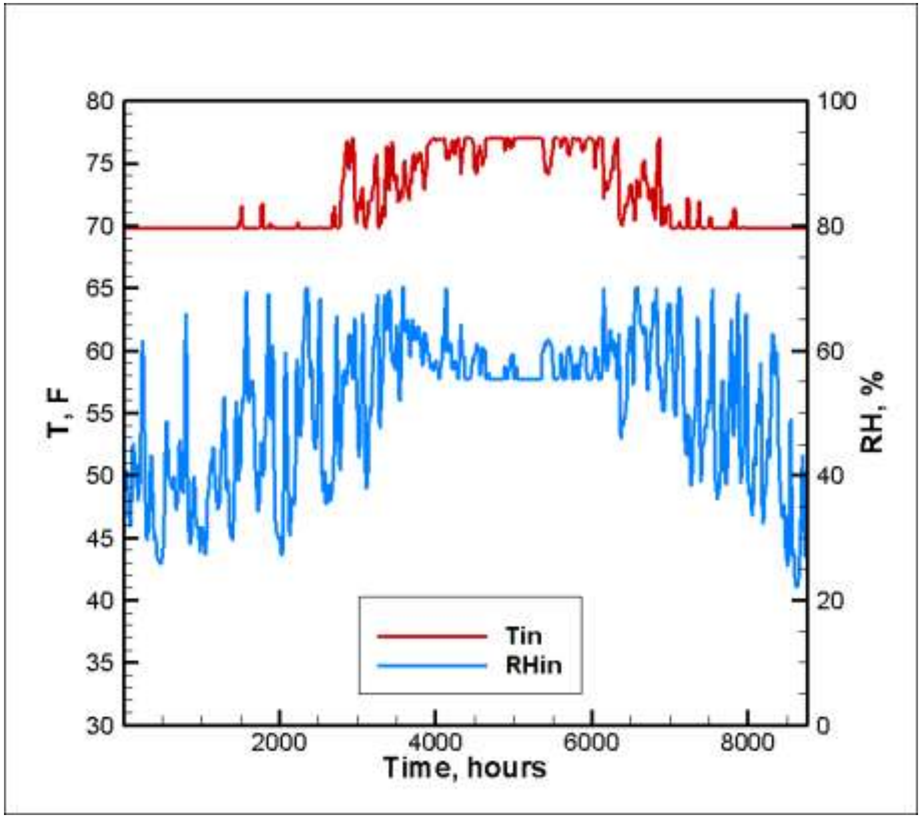
Atlanta - Indoors



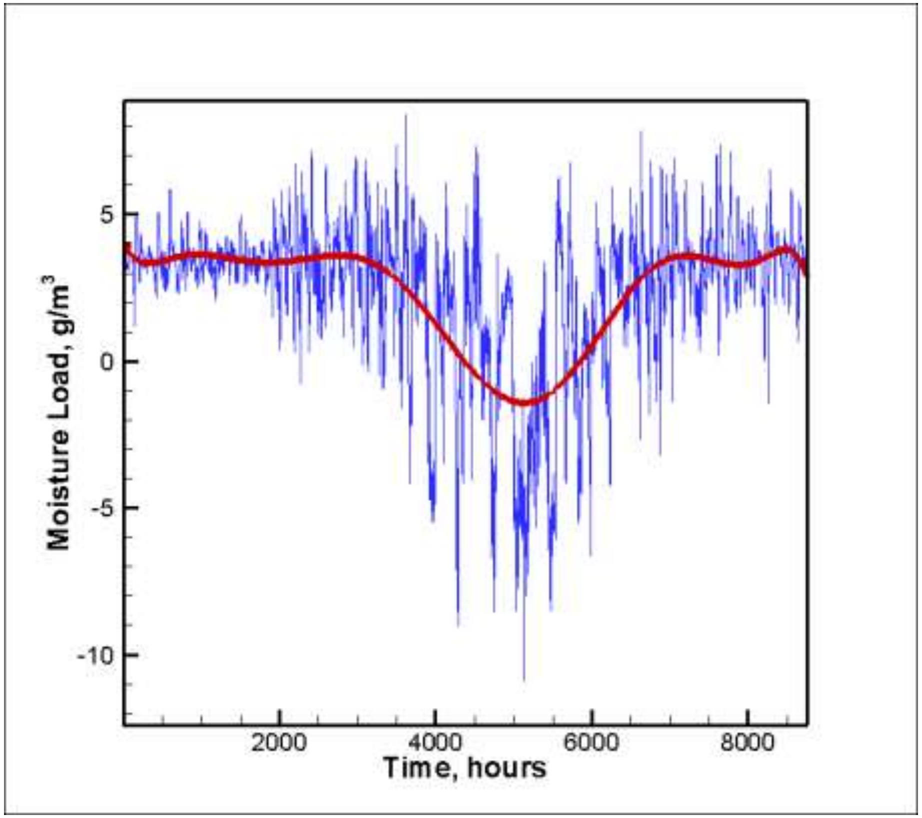


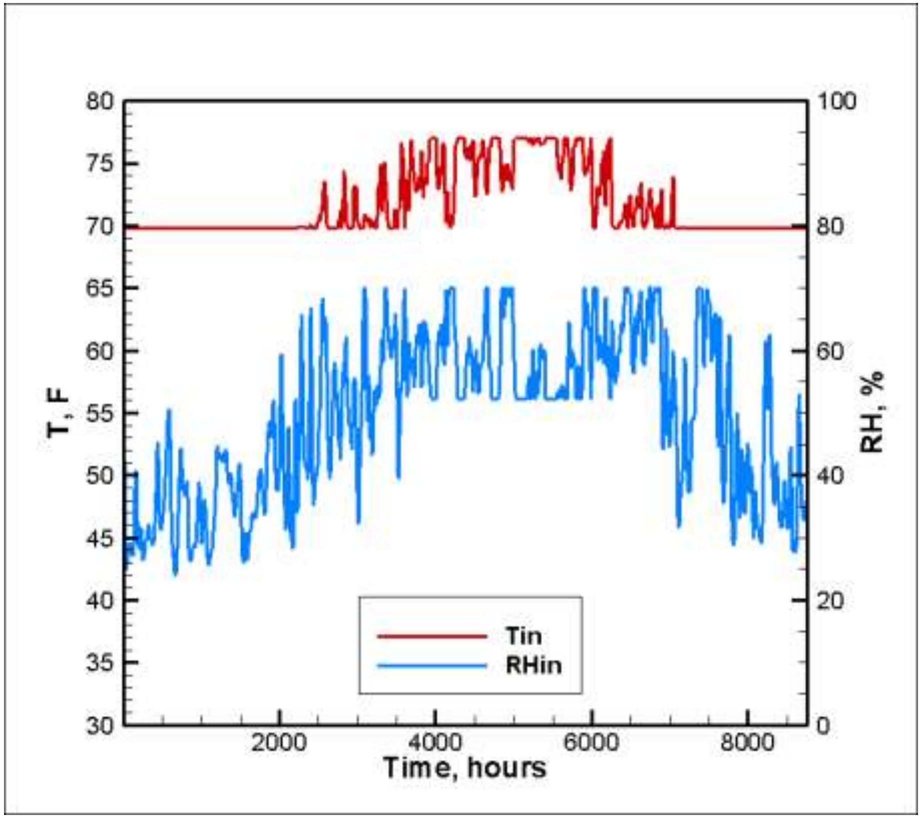
Baltimore - Indoors



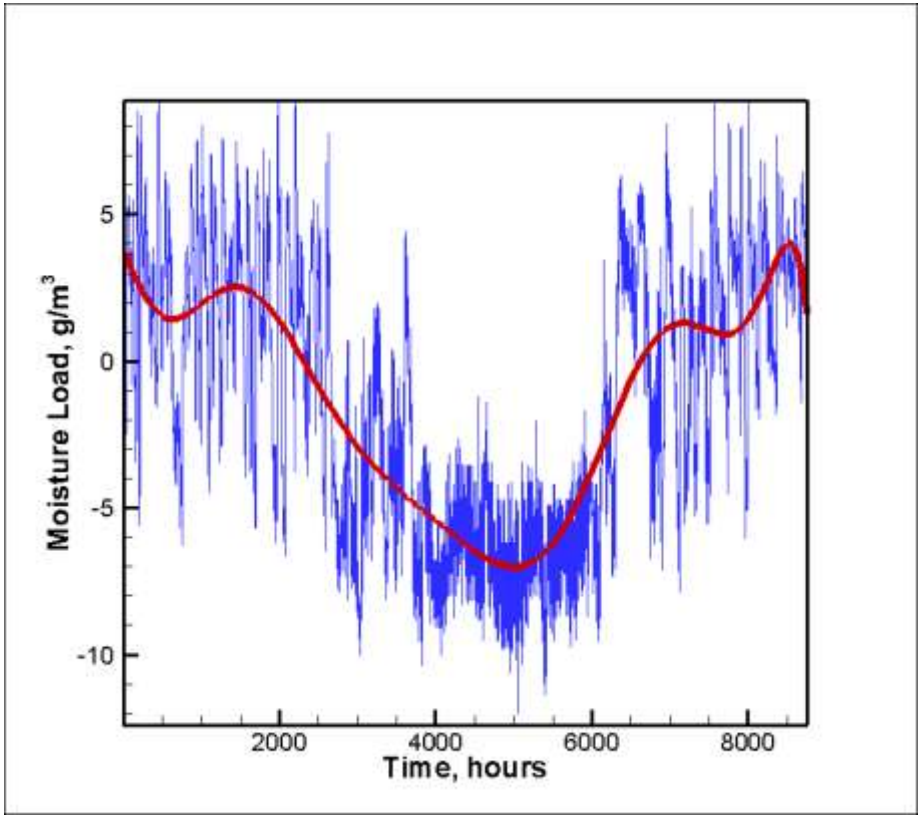


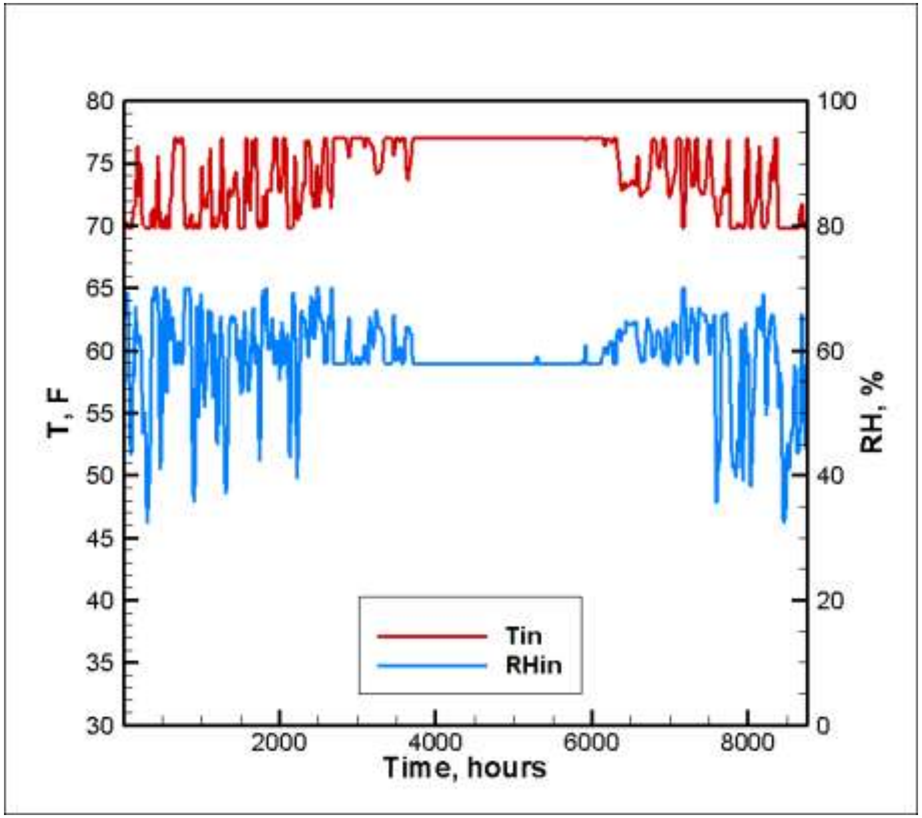
Boston - Indoors



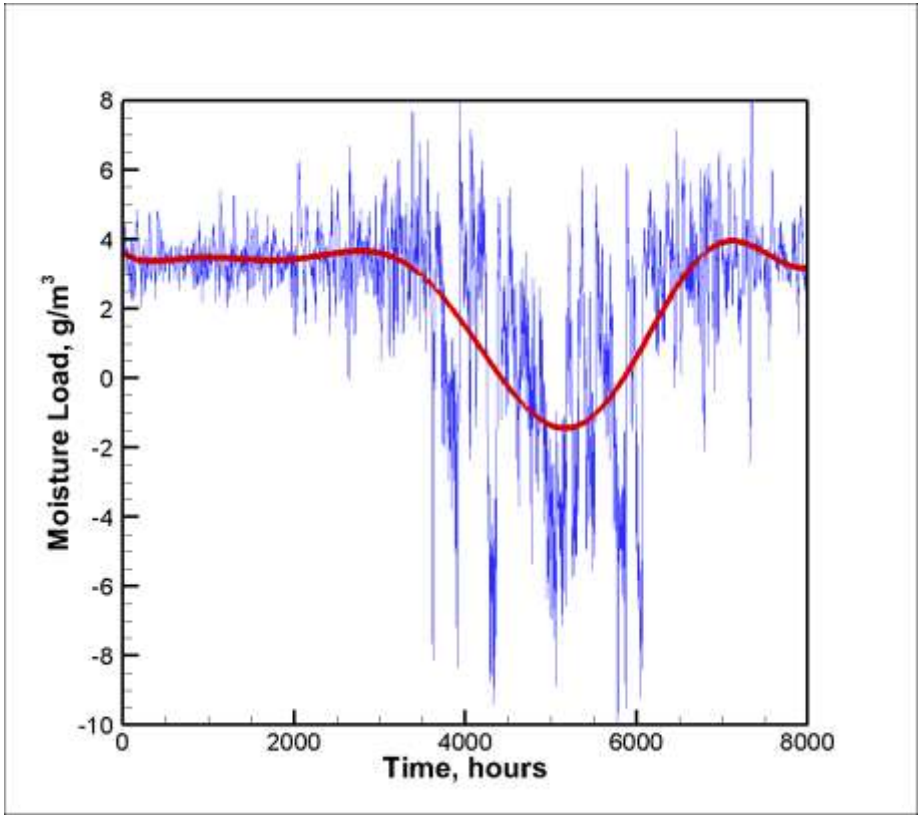


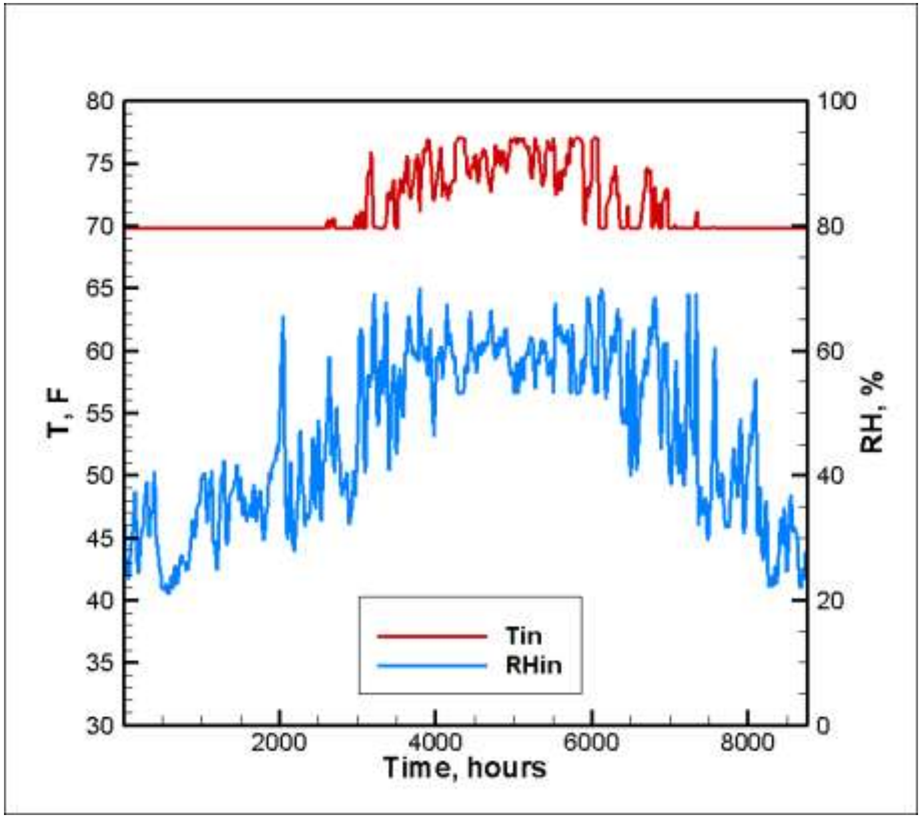
Houston - Indoors



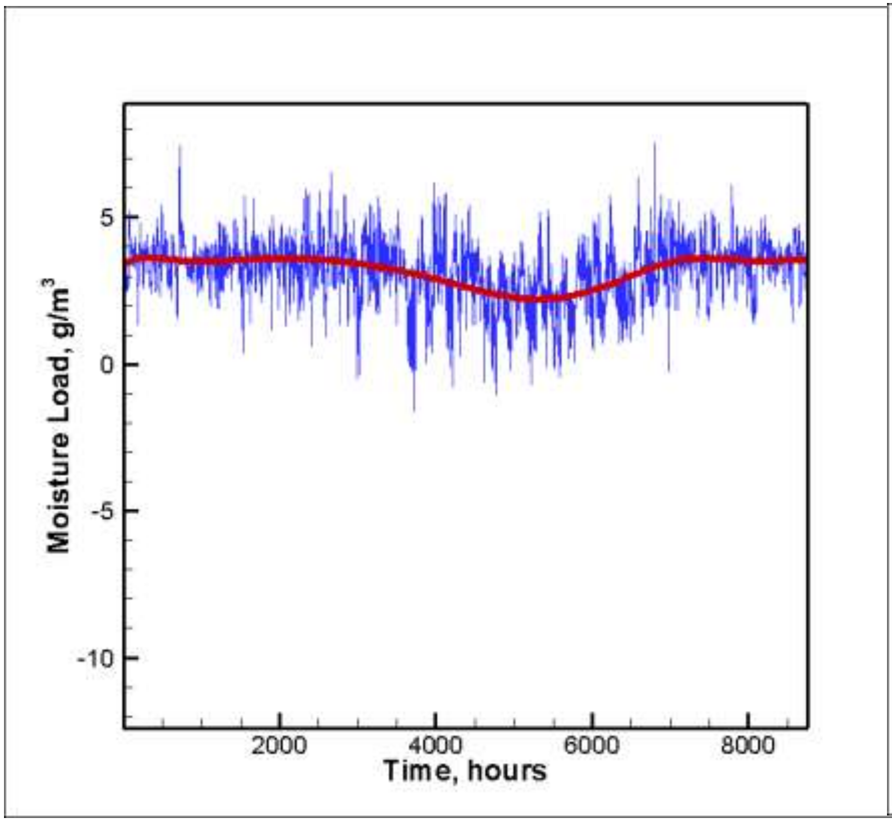


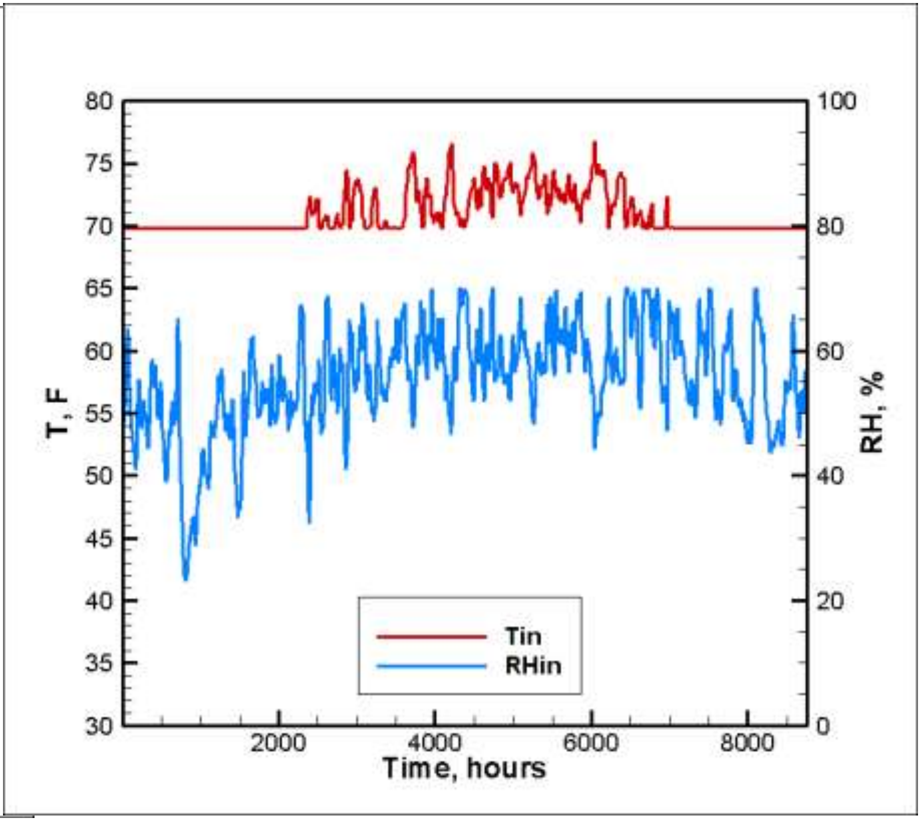
Minneapolis - Indoors





Seattle - Indoors



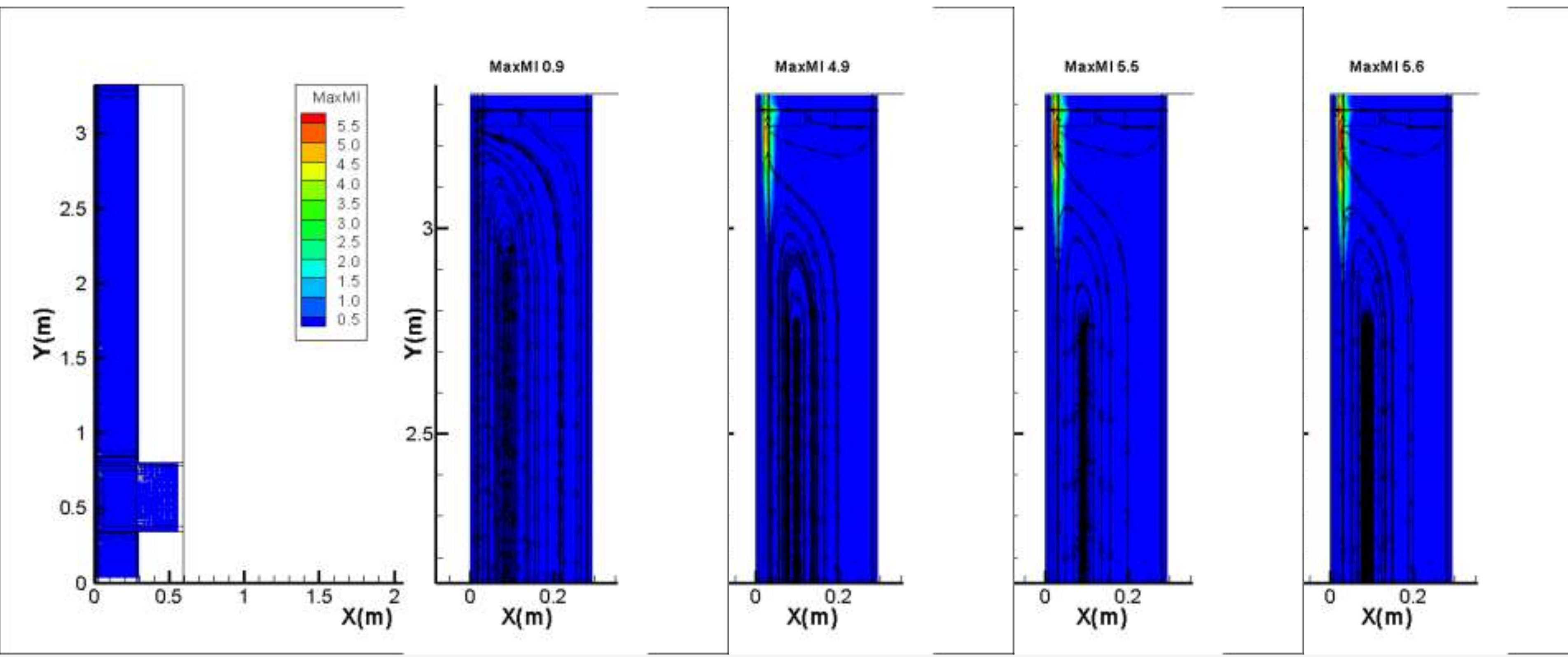


Mold Growth Estimates

- Predicted maximum Mold Growth Index after exposure to indoor/outdoor weather
  - Layers included: WRB and everything inwards

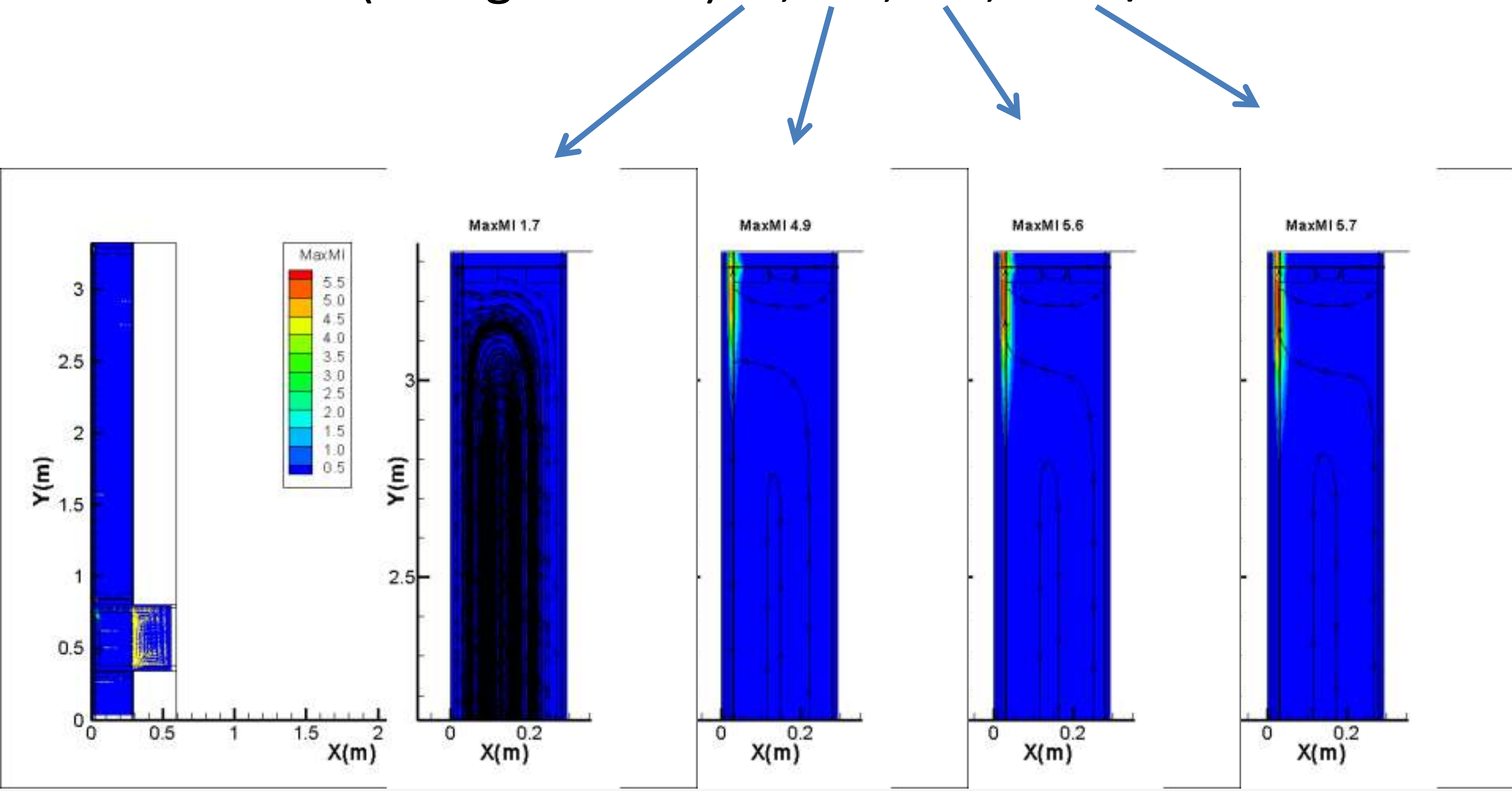
Results – Atlanta – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2



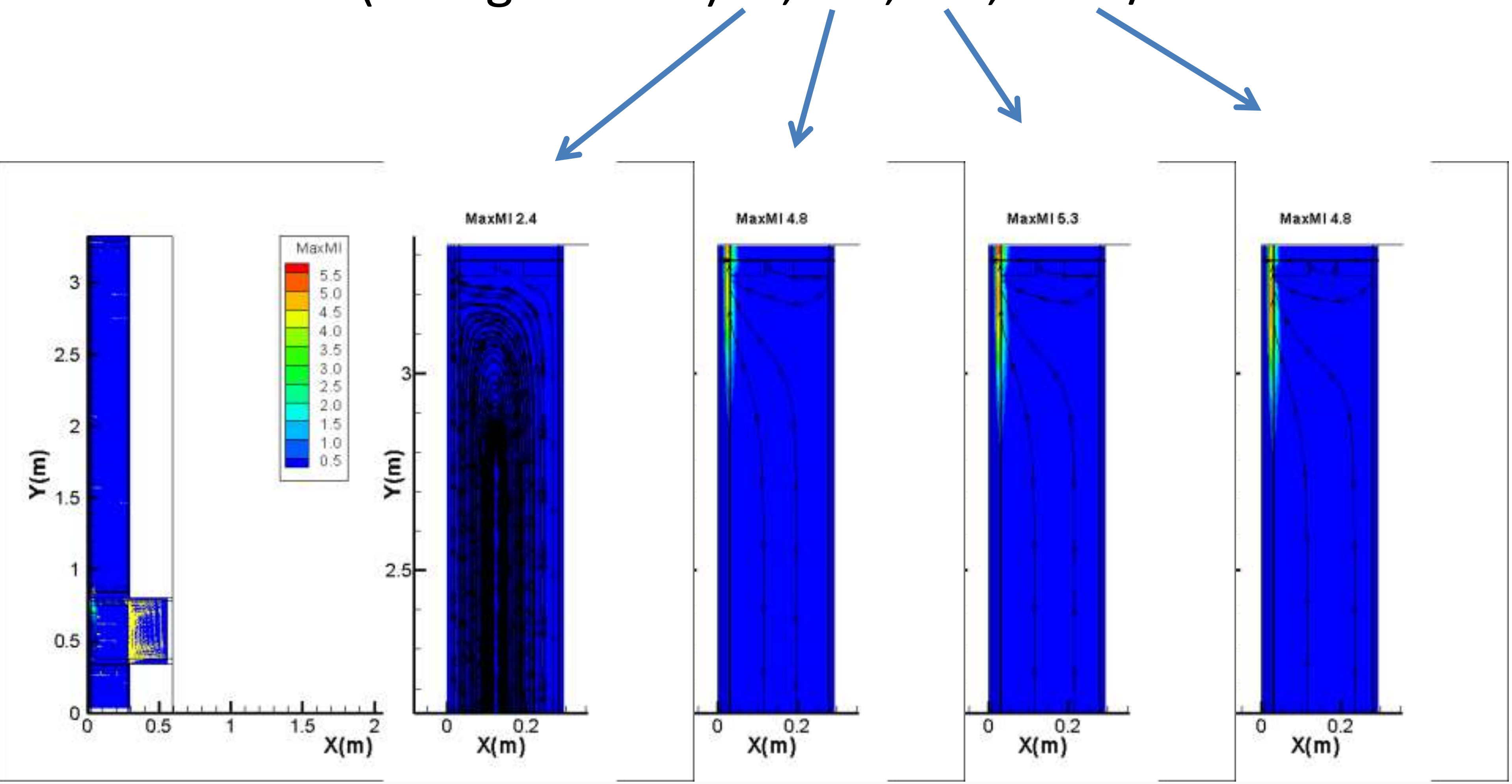
Results – Baltimore – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2



Results – Boston – Max Mold

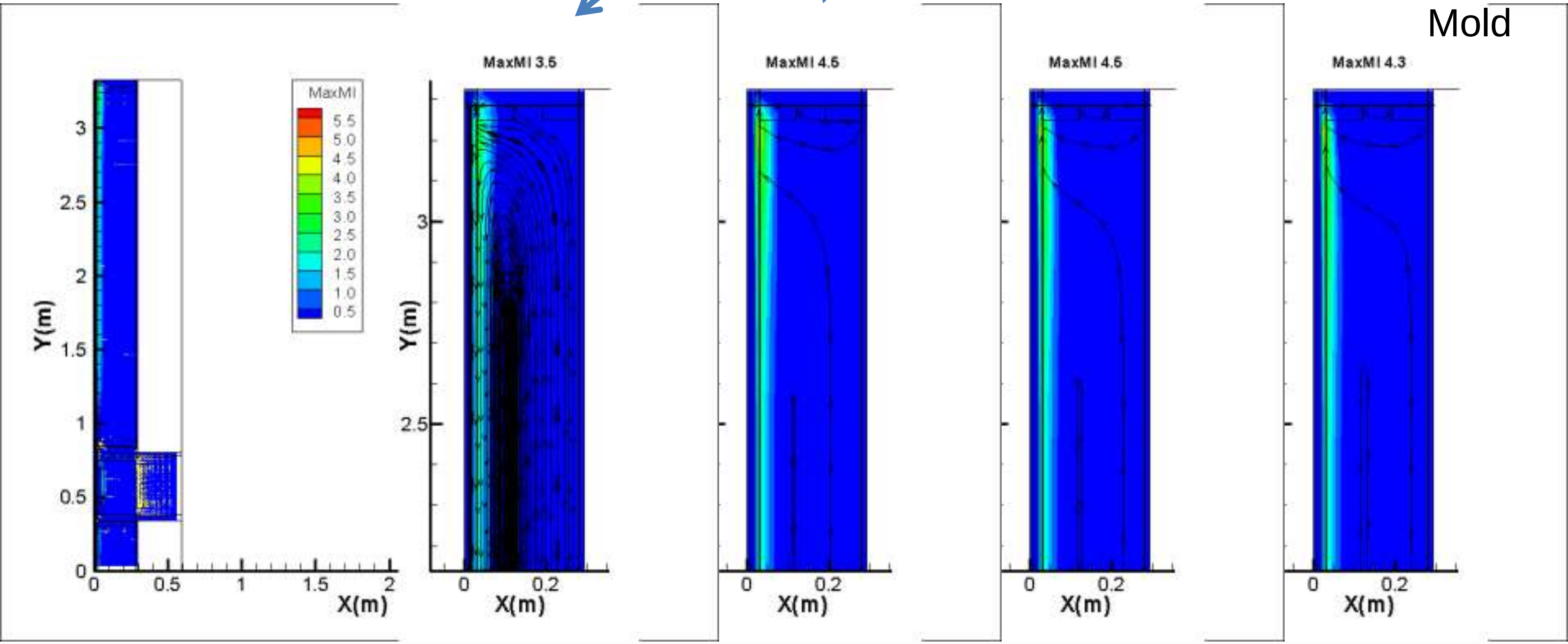
- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2



Results – Houston – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2

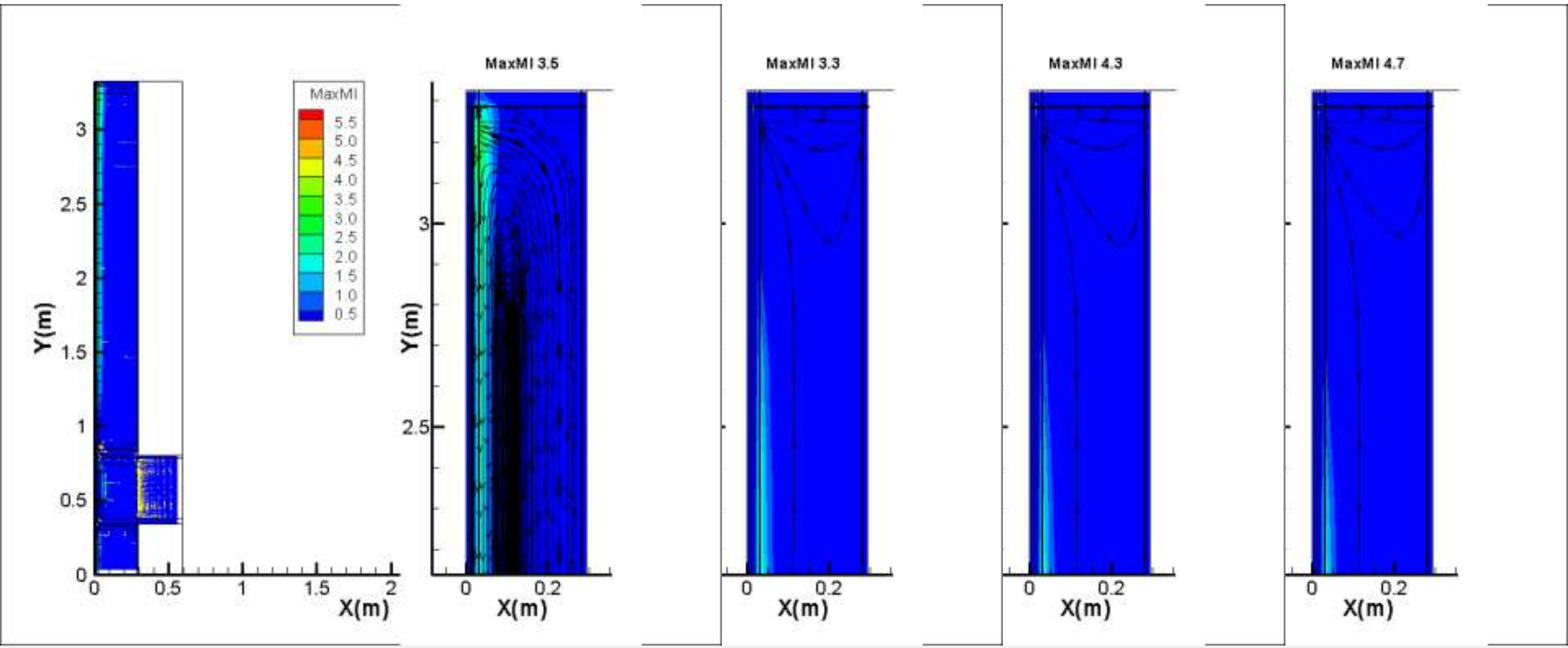
Peak, then: More air, lower Mold



Results – Houston (-5Pa) – Max Mold

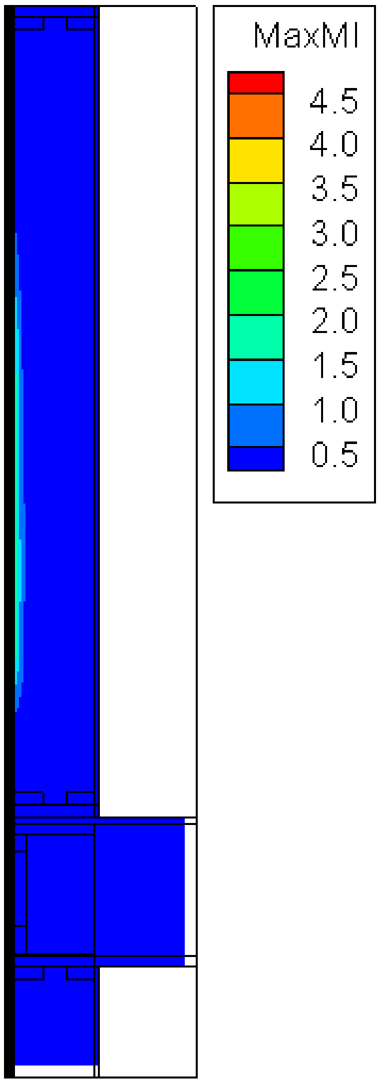
- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2
- Mechanical underpressure 5 Pa
  - Note: No vapor retarder in Houston

More air, higher Mold



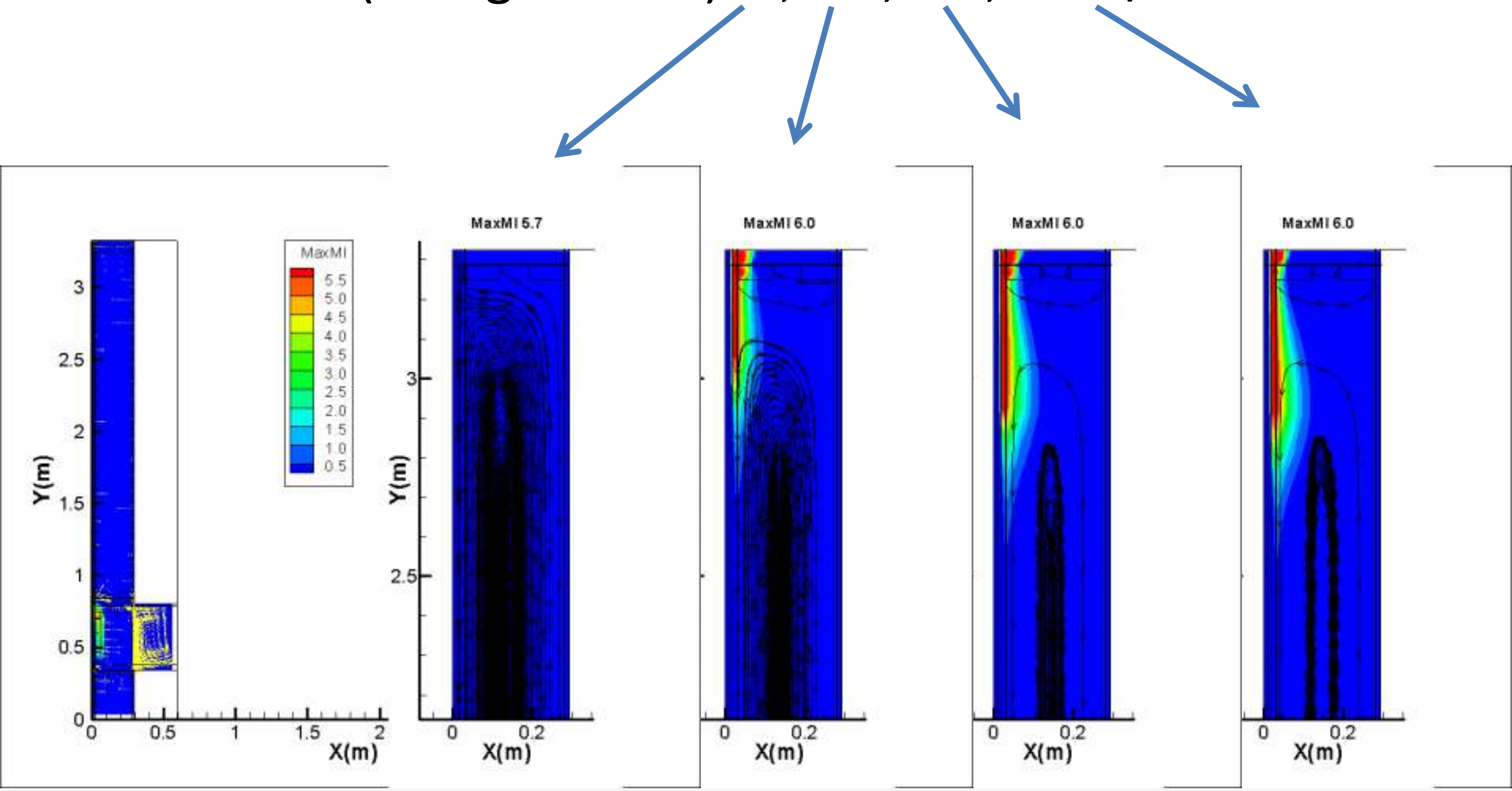
Results – Houston (-5Pa) – Max Mold

- Flow rate (rating at 75Pa): 0.6 L/sm^2
- Mold growth mostly not at the flow path



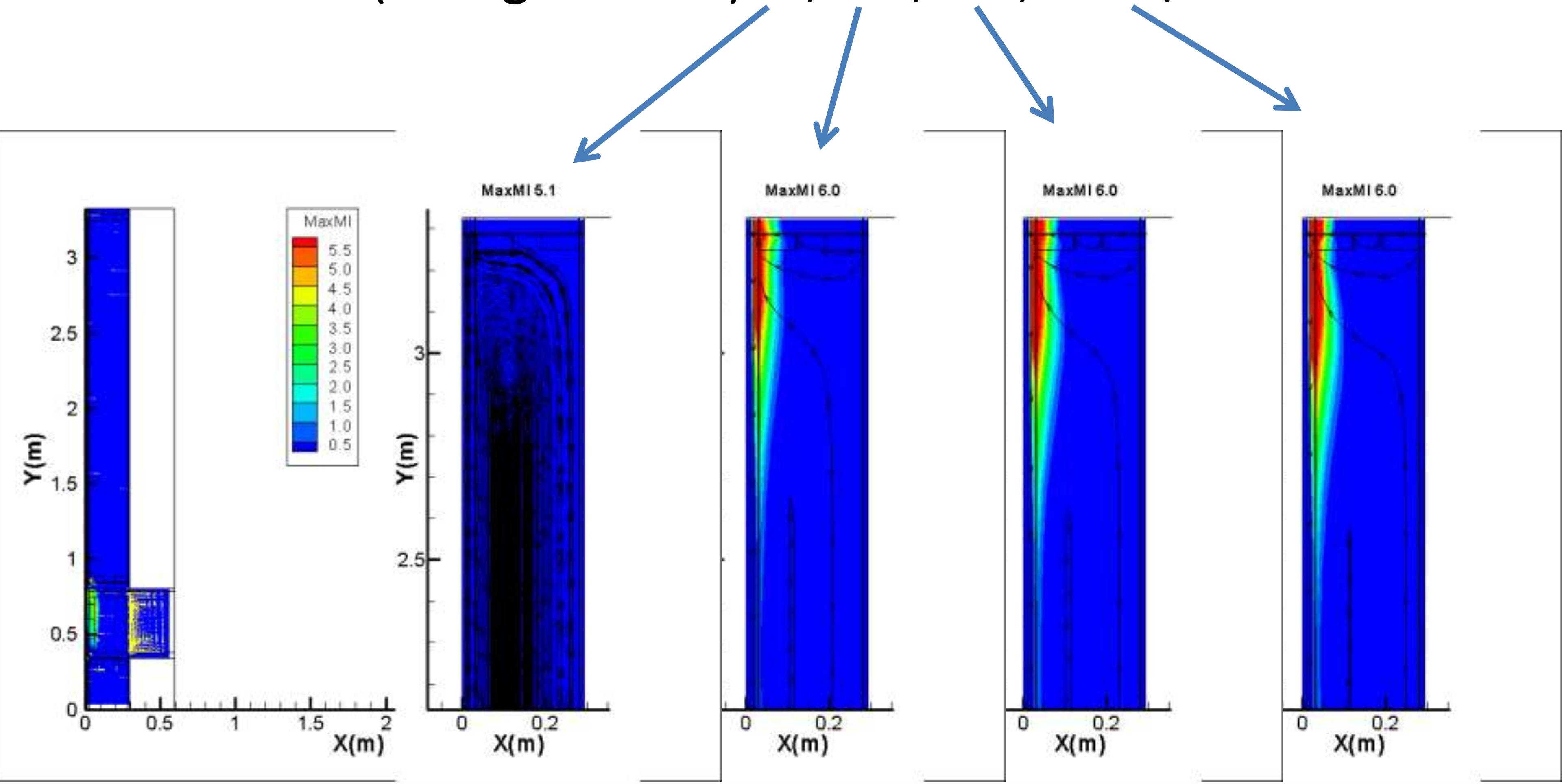
Results – Minneapolis – Max Mold

- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm^2



Results – Seattle – Max Mold

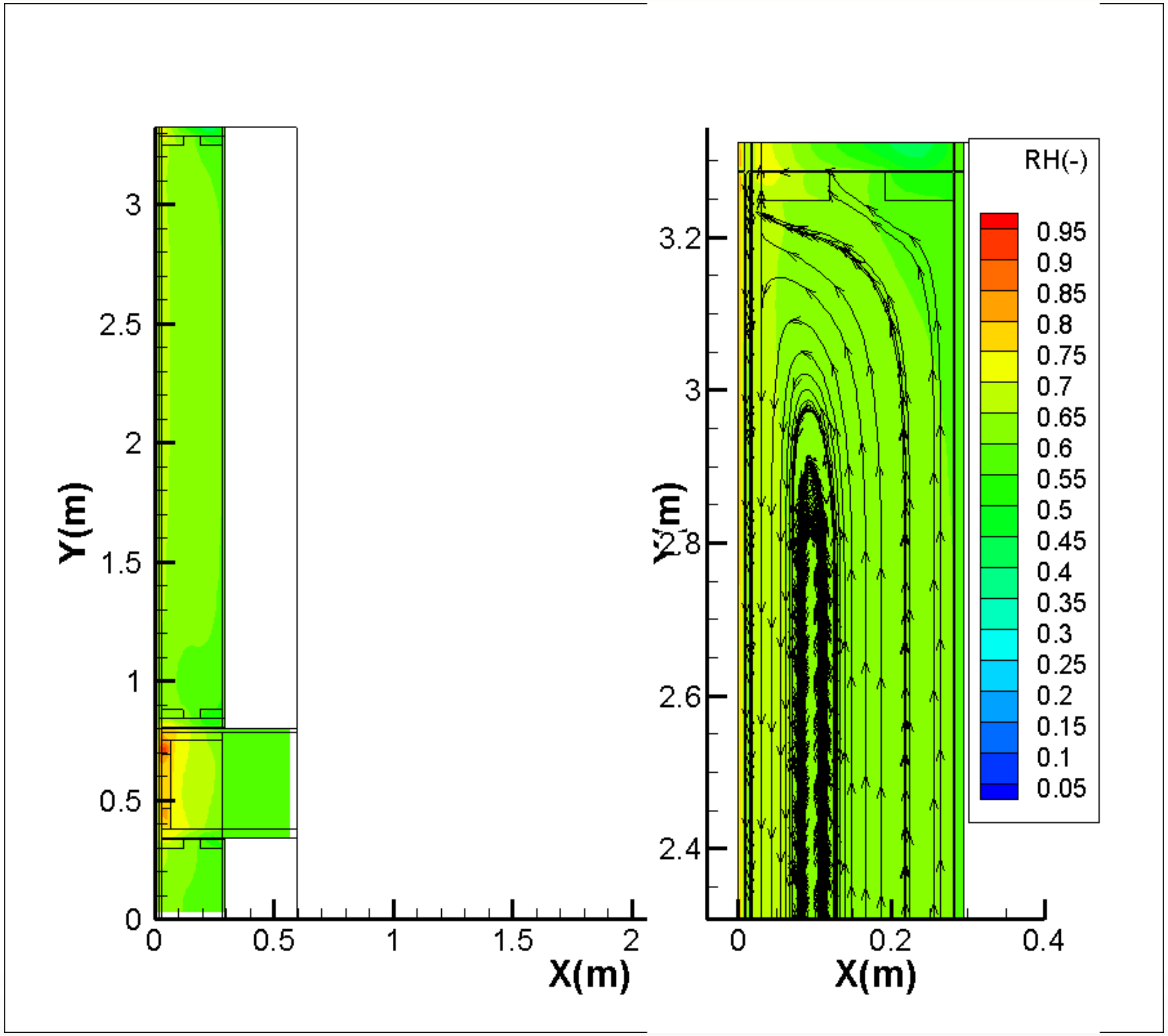
- Flow rate (rating at 75Pa): 0, 0.2, 0.4, 0.6 L/sm²



Results - RH

- Examples of airflow effect on relative humidity inside the wall

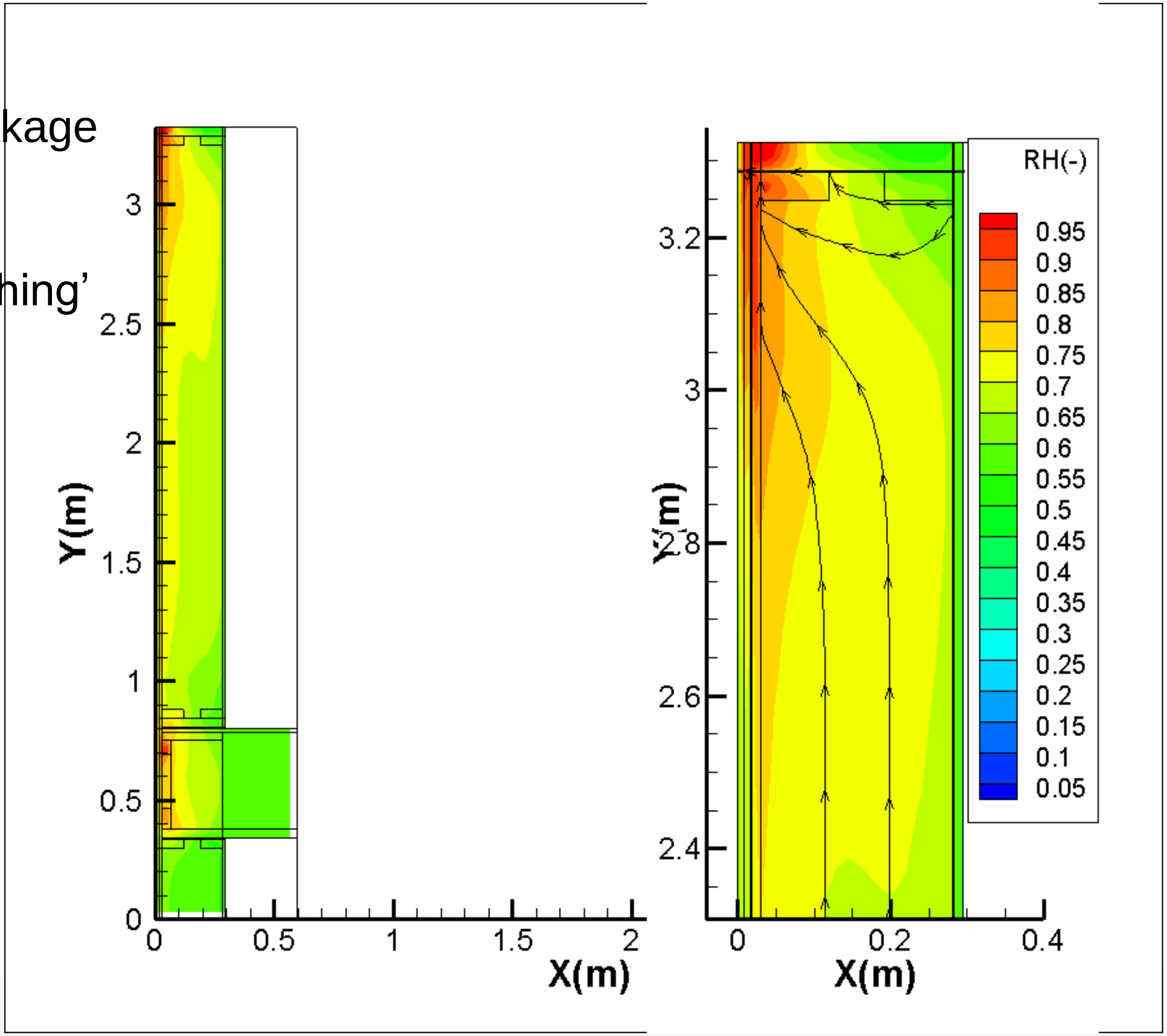
Results – Minneapolis - RH



Full wall (left) and top only (right)

Results - Minneapolis - RH

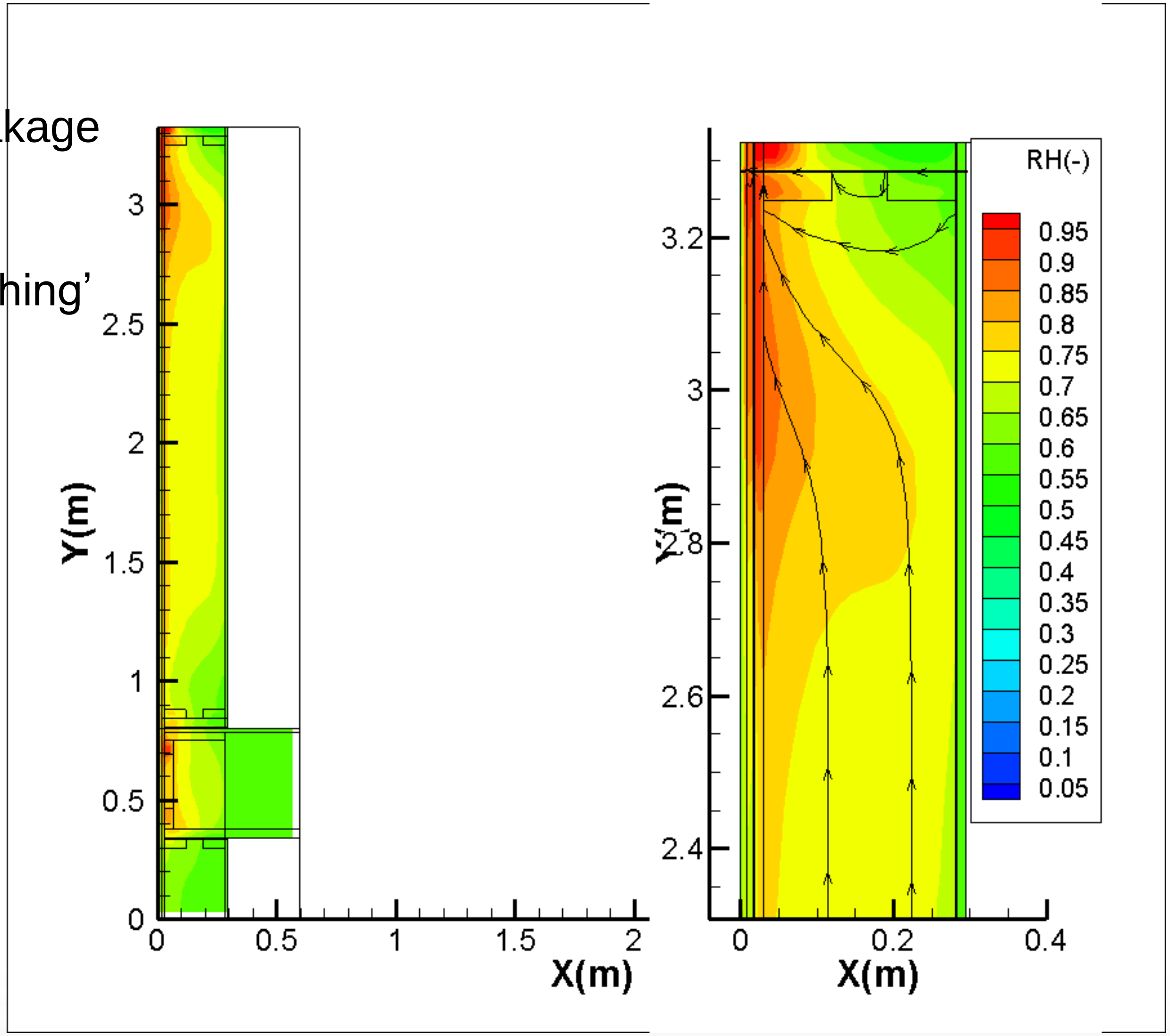
0.2 rated air leakage through interior surface (interior air 'flushing' at rim joist)



Full wall (left) and top only (right)

Results - Minneapolis - RH

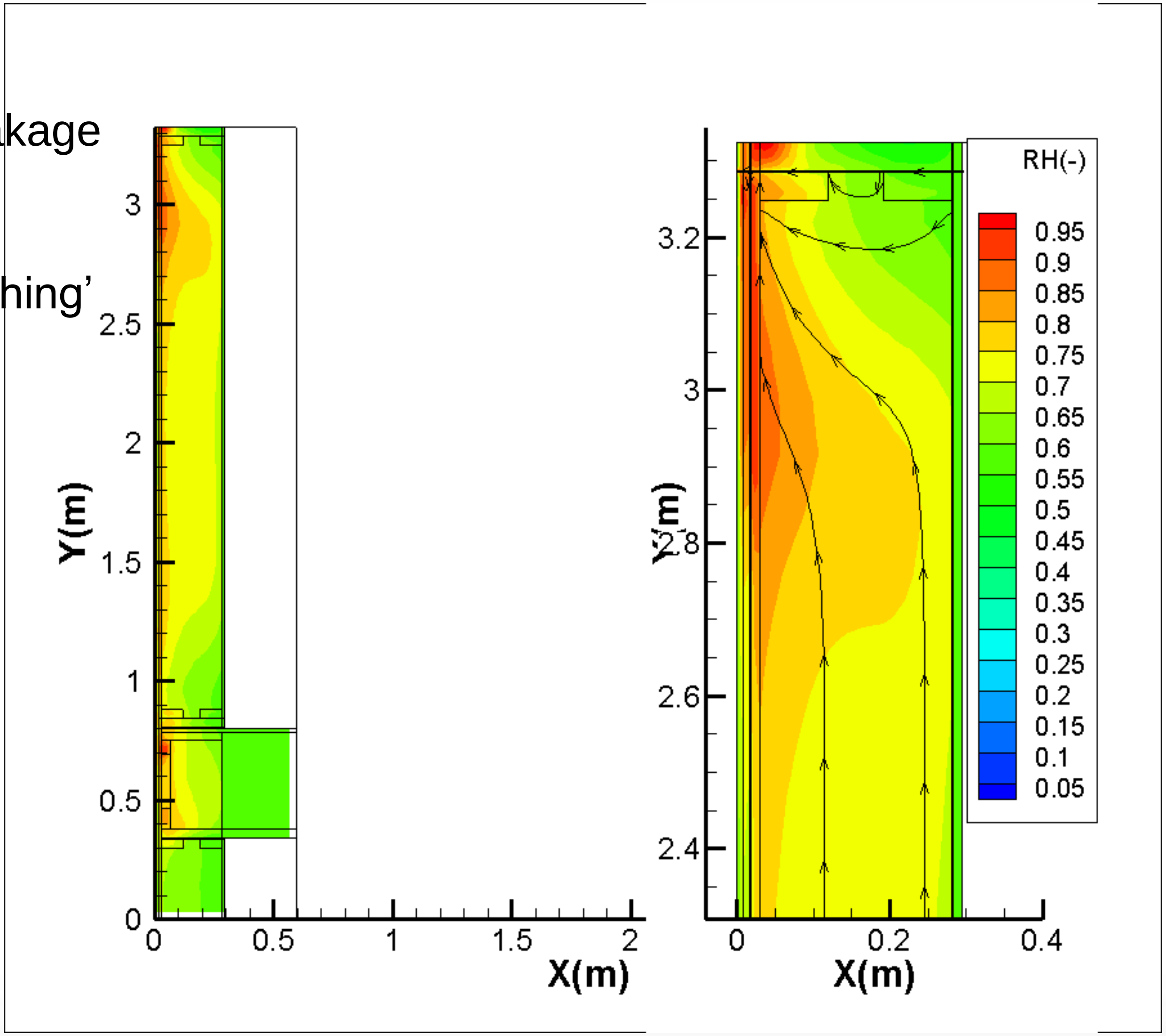
0.4 rated air leakage through interior surface (interior air 'flushing' at rim joist)



Full wall (left) and top only (right)

Results - Minneapolis - RH

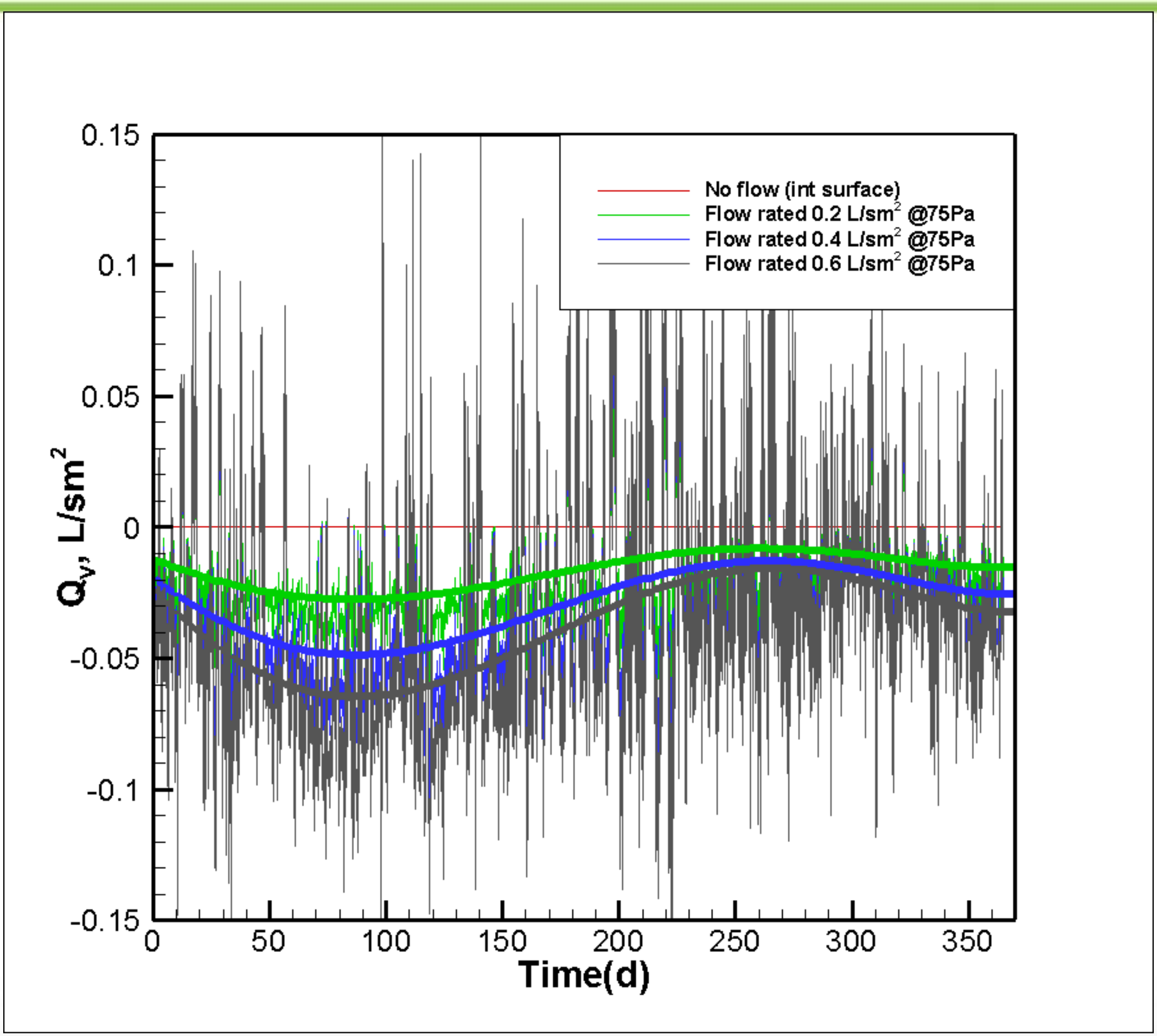
0.6 rated air leakage through interior surface (interior air 'flushing' at rim joist)



Full wall (left) and top only (right)

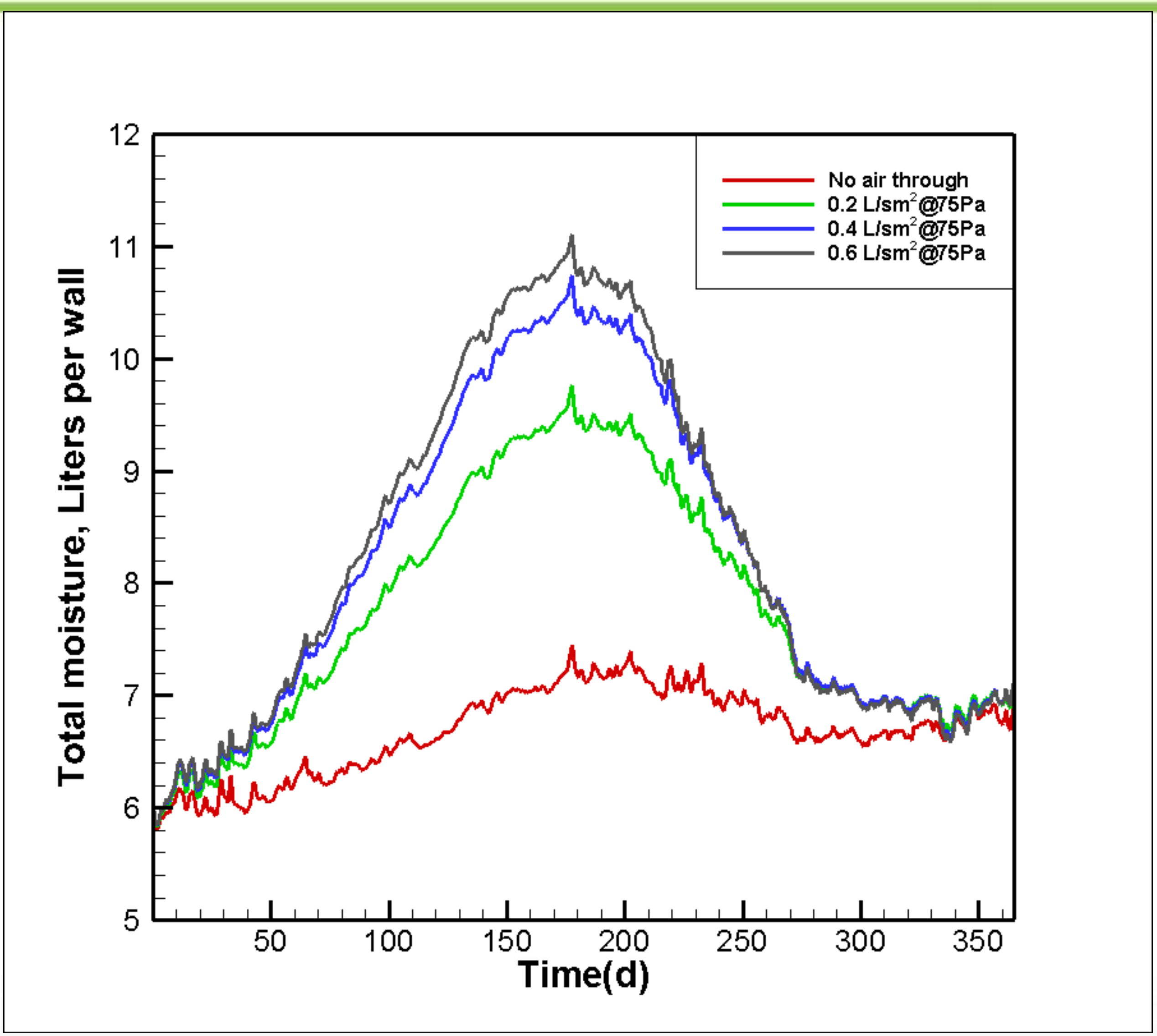
Results - Minneapolis

Air leakage comparison



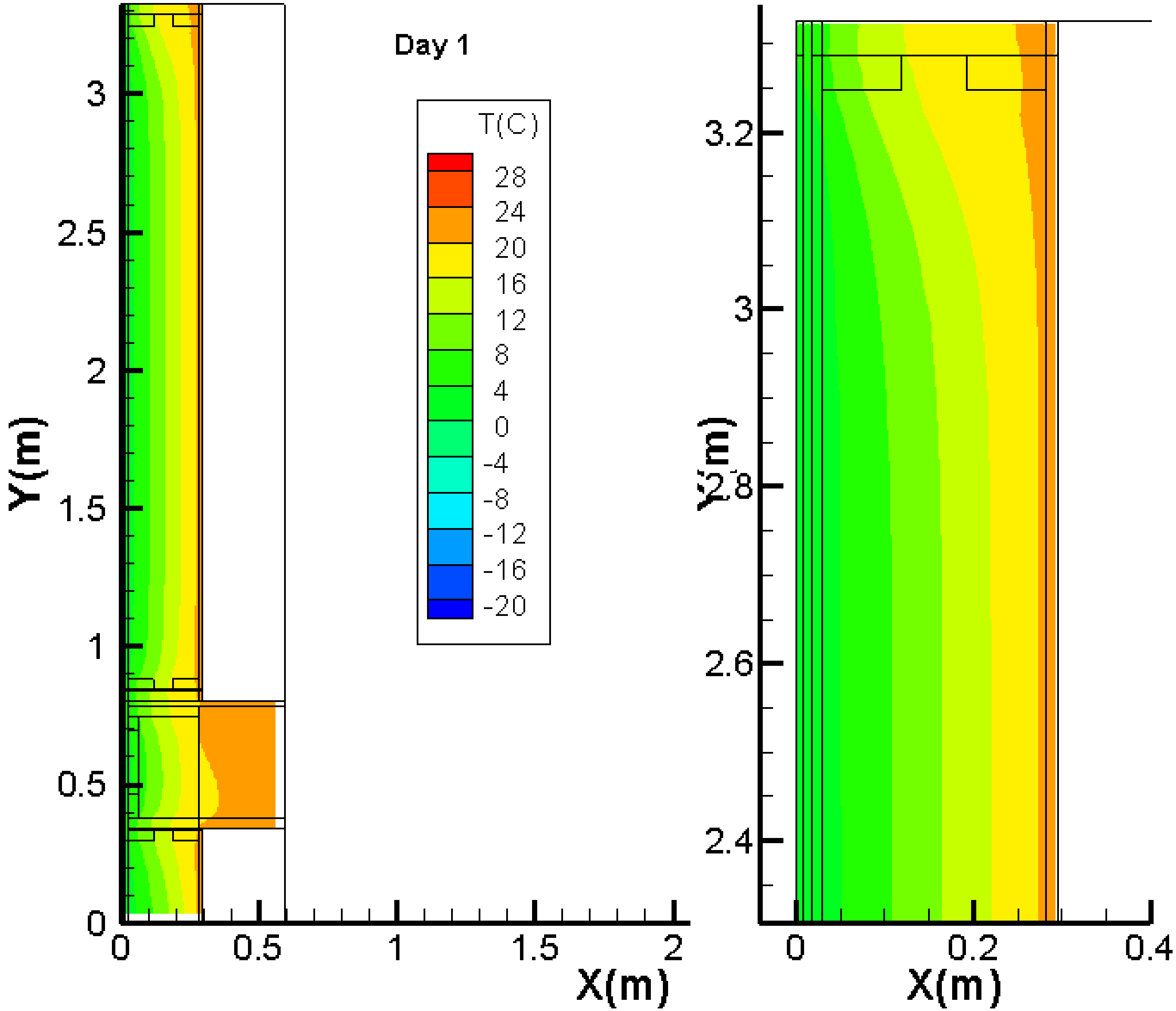
Stack neutral plane at the bottom of the wall below rim joist

Total Moisture Minneapolis

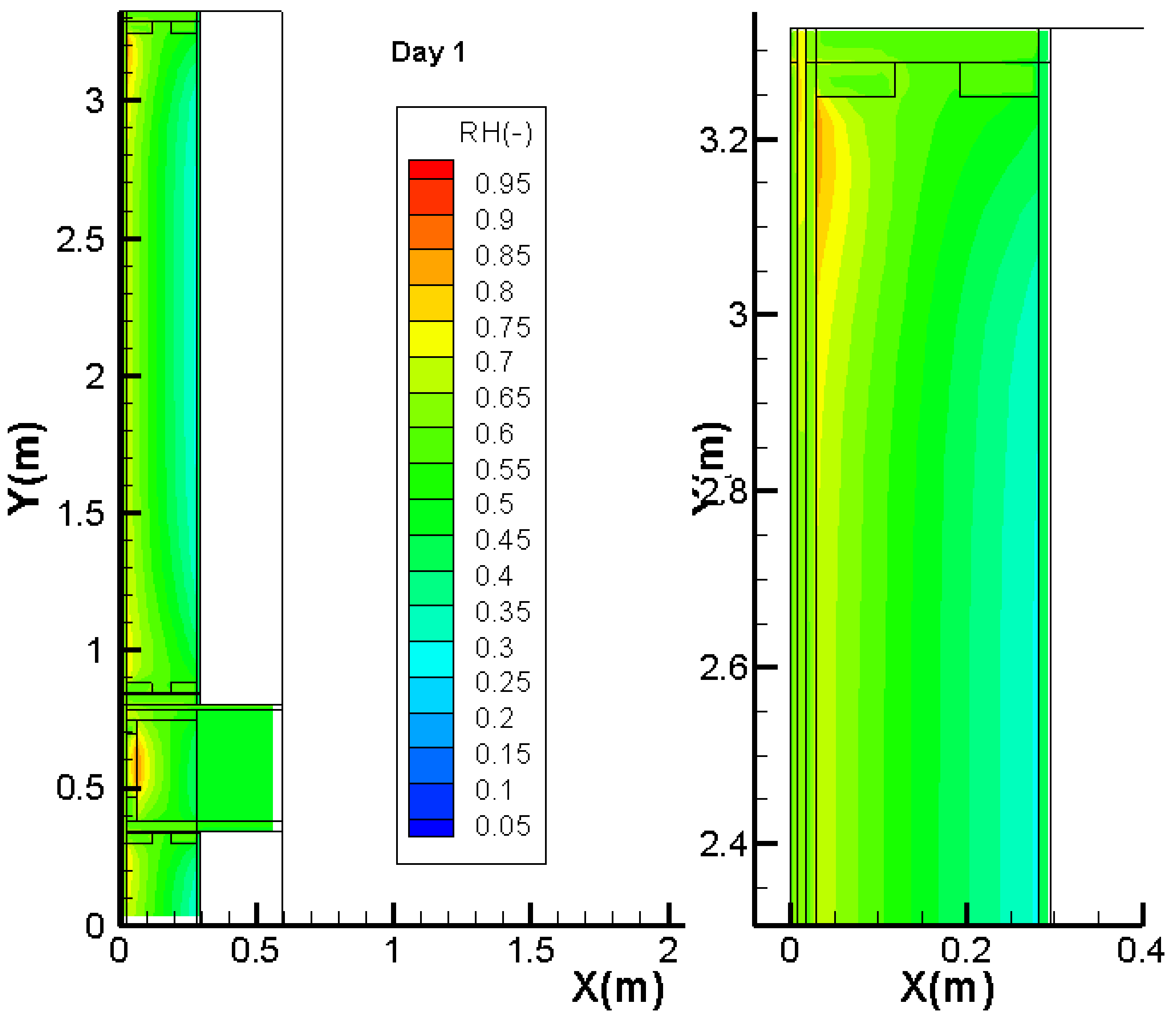


Time starting

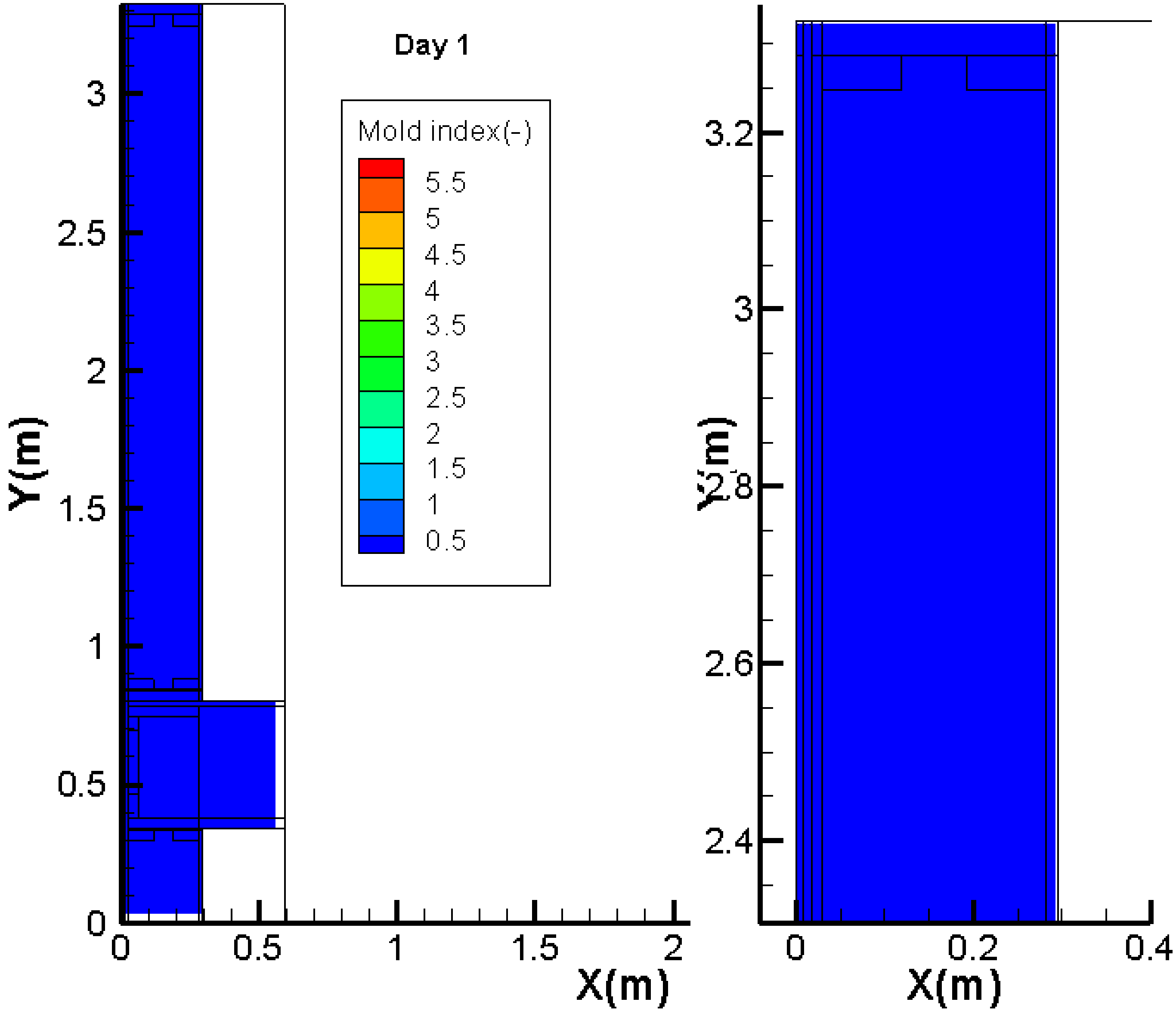
Minneapolis



Minneapolis



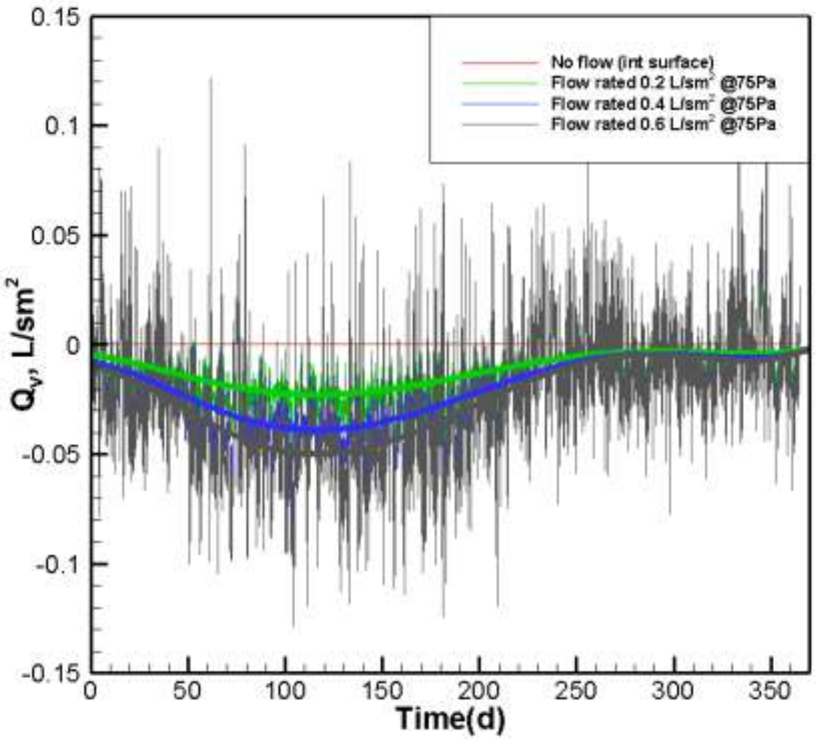
Minneapolis



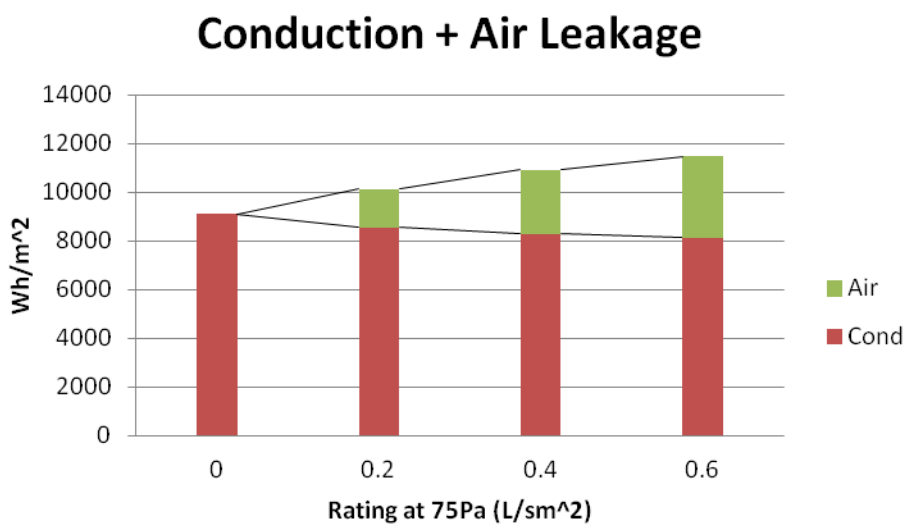
Energy Impact - Assumptions

- Airflow exfiltrates or infiltrates through the wall
- Heat loss due to air flow
  - $E = Qv * rho * cp * \Delta T$ where
    - ΔT = Tin-Tout, if exfiltrating
    - ΔT = Tin-Tair@surface, if infiltrating
  - Tair@surface = air temperature at entrance to indoors at the wall surface
  - Airflow affect the conduction heat loss by exchanging heat with the wall
- Yearly sum of conduction heat loss and air heat loss

Atlanta

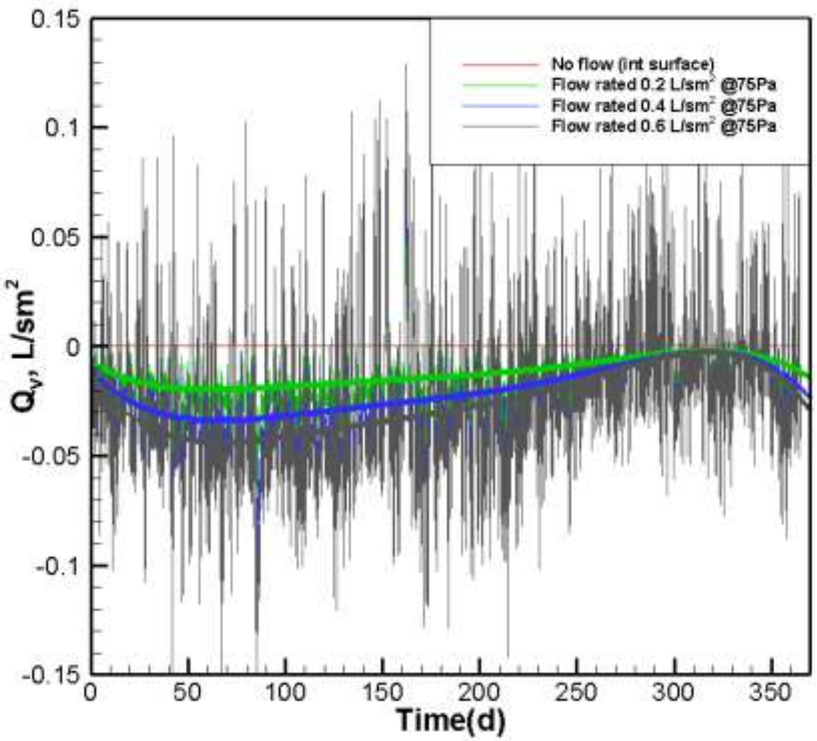


No flow (int surface)
Flow rated 0.2 L/sm² @75Pa
Flow rated 0.4 L/sm² @75Pa
Flow rated 0.6 L/sm² @75Pa
Qy, L/sm²
Time(d)
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
50
100
150
200
250
300
350

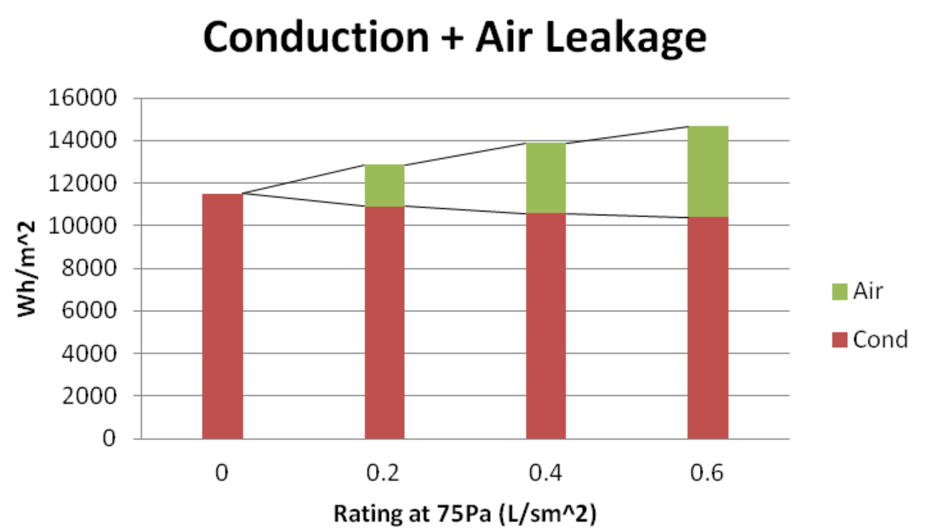


Conduction + Air Leakage
Wh/m^2
14000
12000
10000
8000
6000
4000
2000
0
0
0.2
0.4
0.6
Rating at 75Pa (L/sm^2)
Air
Cond

Baltimore

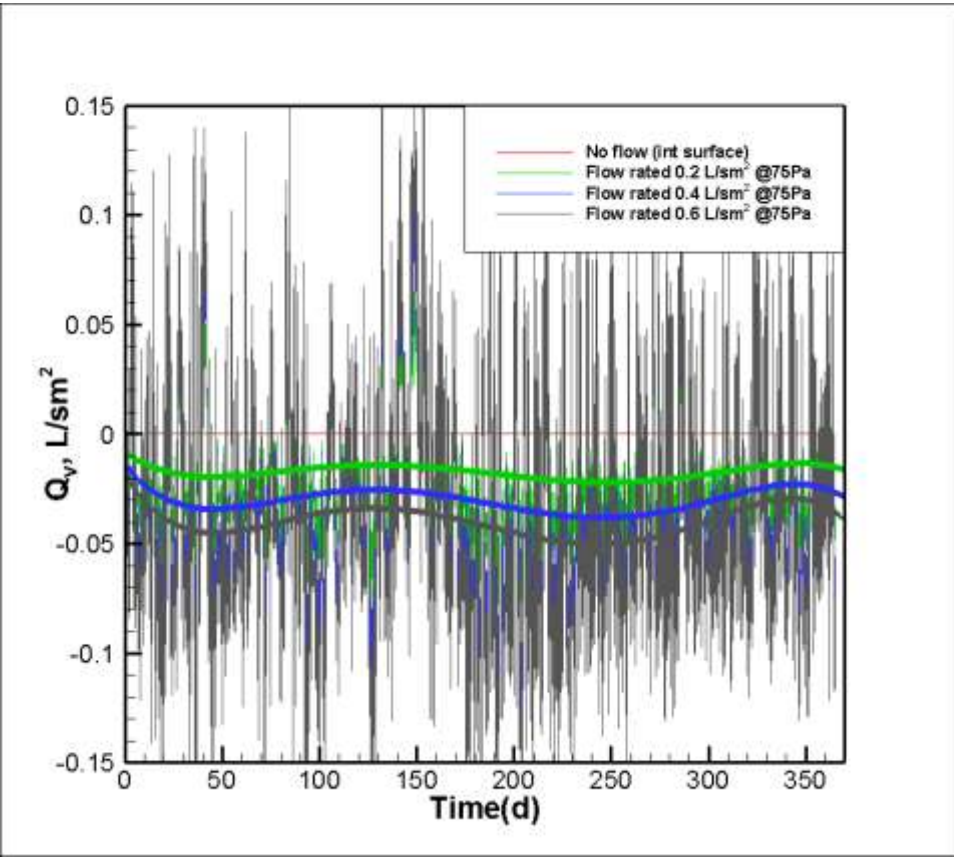


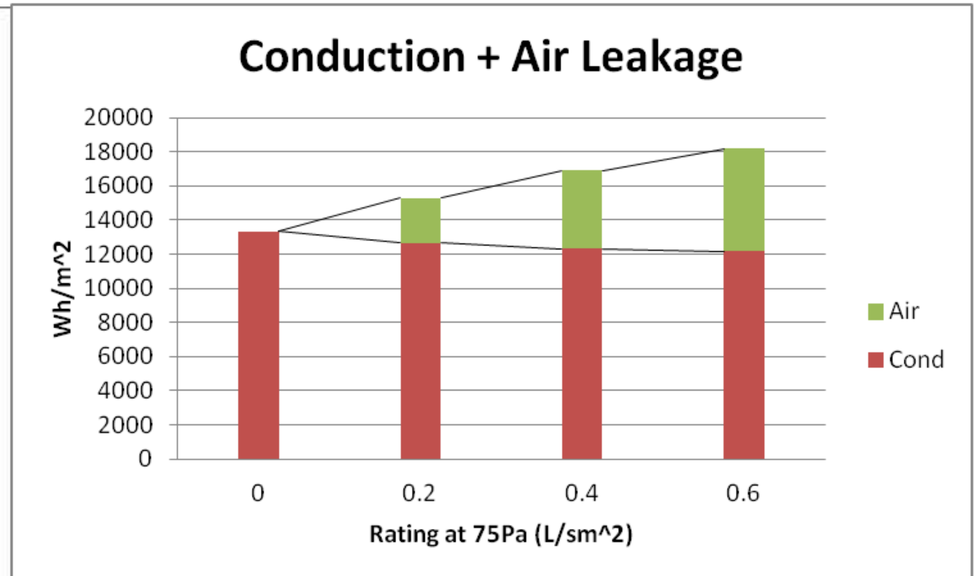
No flow (int surface)
Flow rated 0.2 L/sm² @75Pa
Flow rated 0.4 L/sm² @75Pa
Flow rated 0.6 L/sm² @75Pa
Qv, L/sm²
Time(d)



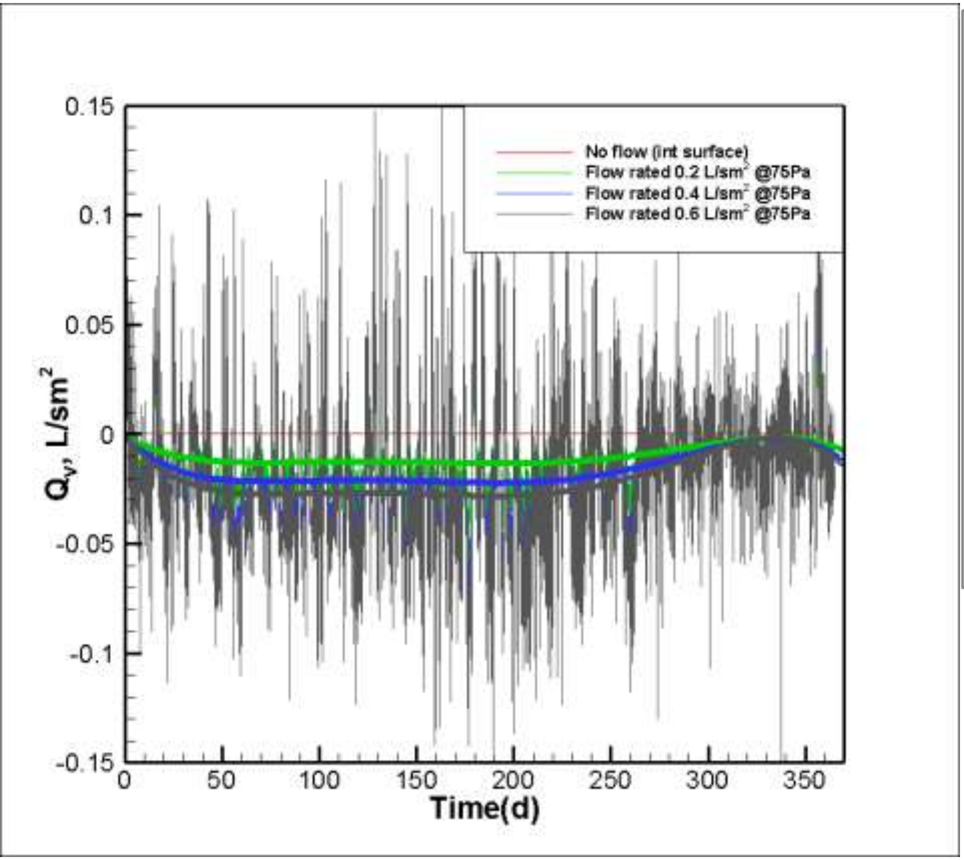
Conduction + Air Leakage
Wh/m^2
Air
Cond
Rating at 75Pa (L/sm^2)

Boston

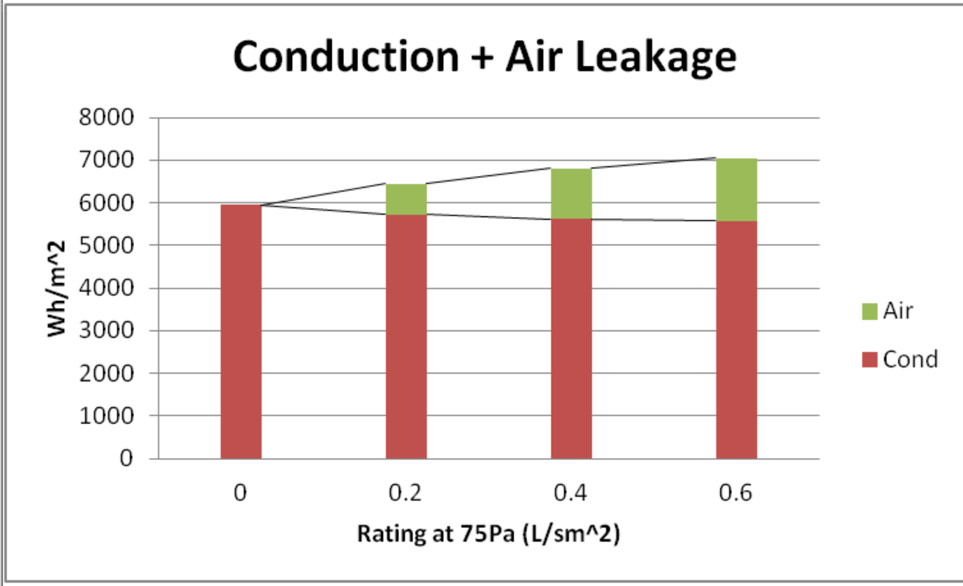

No flow (int surface)
Flow rated 0.2 L/sm² @75Pa
Flow rated 0.4 L/sm² @75Pa
Flow rated 0.6 L/sm² @75Pa
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
Qy, L/sm²
0
50
100
150
200
250
300
350
Time(d)


Conduction + Air Leakage
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Wh/m^2
0
0.2
0.4
0.6
Rating at 75Pa (L/sm^2)
Air
Cond

Houston

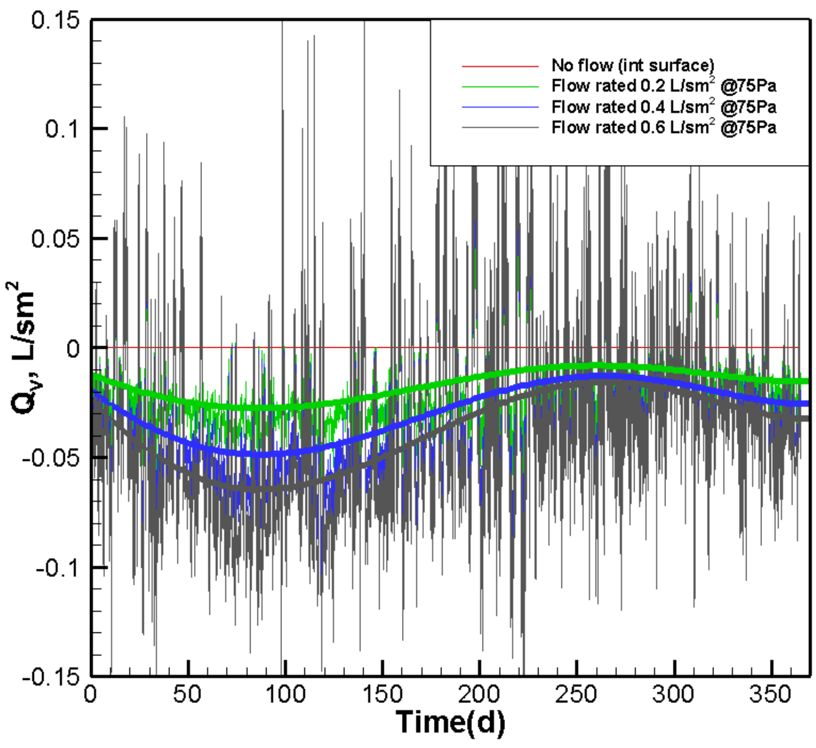


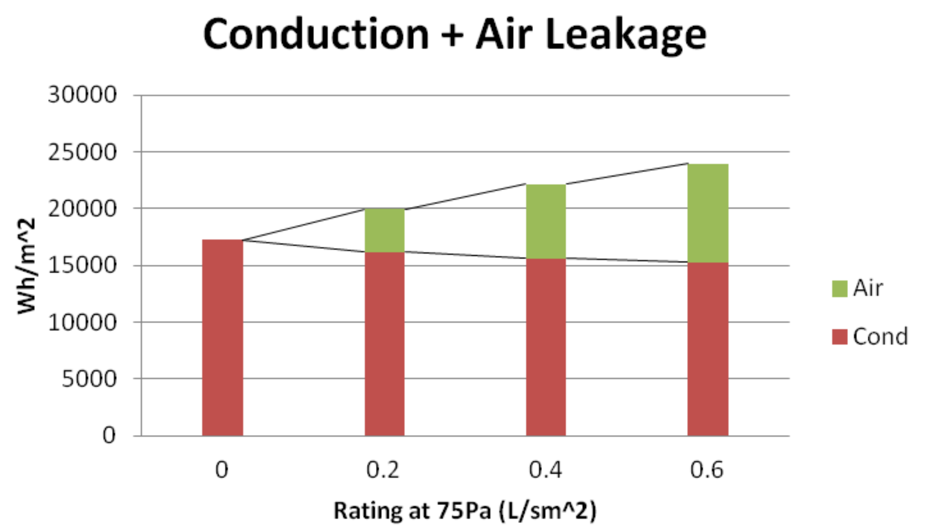
No flow (int surface)
Flow rated 0.2 L/sm² @75Pa
Flow rated 0.4 L/sm² @75Pa
Flow rated 0.6 L/sm² @75Pa
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0 50 100 150 200 250 300 350
Time(d)
Qv, L/sm²



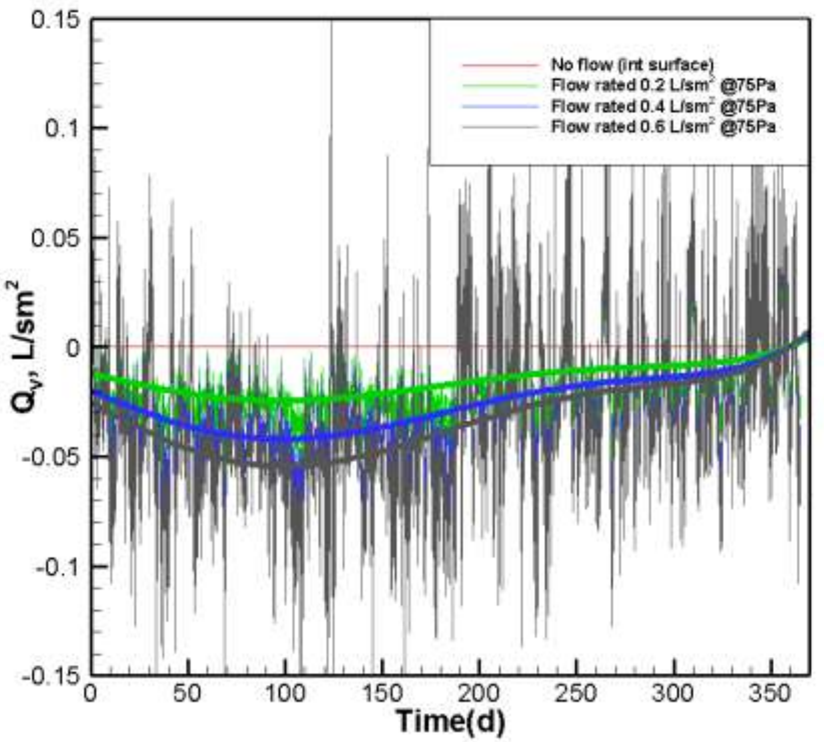
Conduction + Air Leakage
8000
7000
6000
5000
4000
3000
2000
1000
0
Wh/m^2
0 0.2 0.4 0.6
Rating at 75Pa (L/sm^2)
Air
Cond

Minneapolis

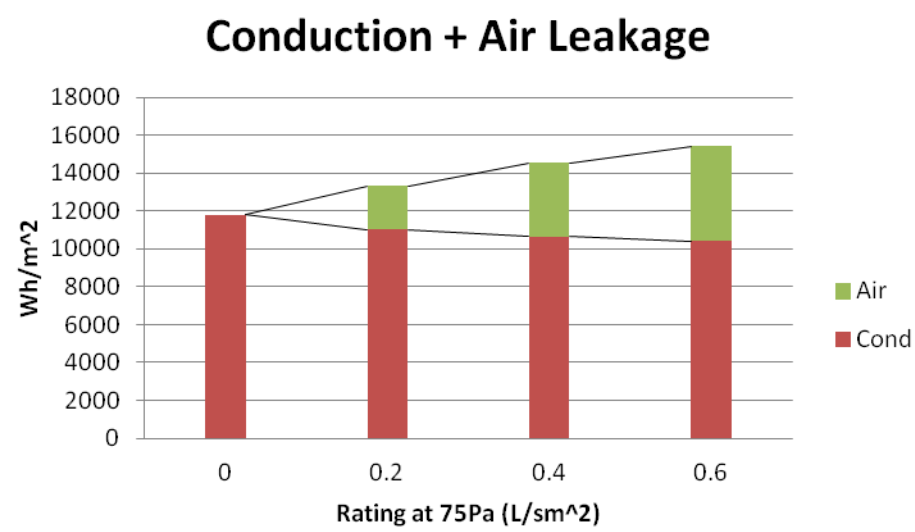




Seattle



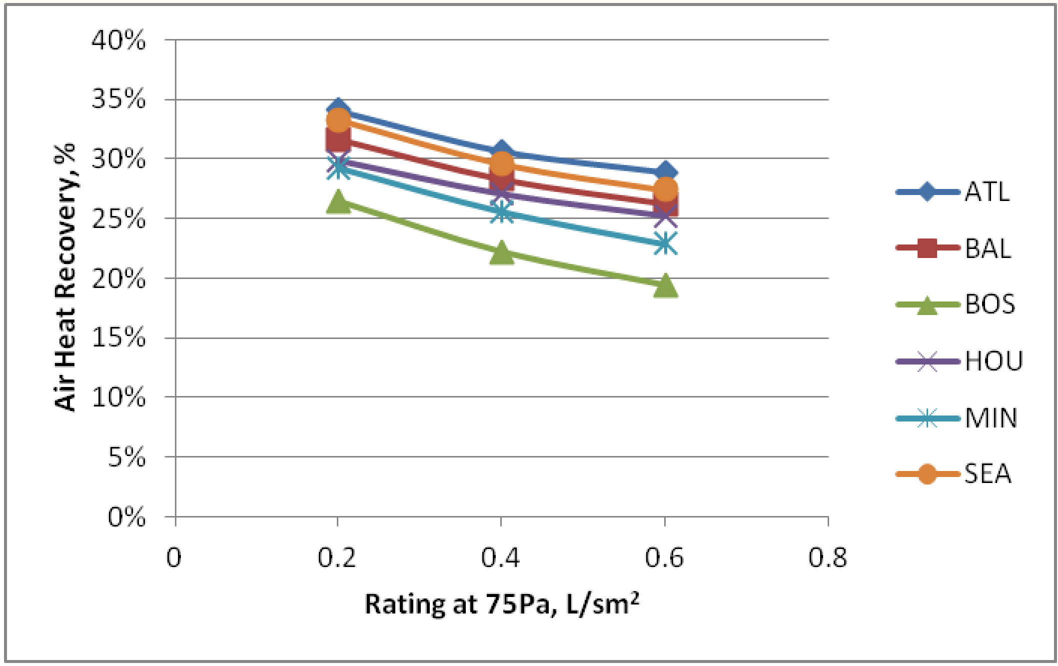
No flow (int surface)
Flow rated 0.2 L/sm² @75Pa
Flow rated 0.4 L/sm² @75Pa
Flow rated 0.6 L/sm² @75Pa
Qv, L/sm²
Time(d)



Conduction + Air Leakage
Wh/m^2
Rating at 75Pa (L/sm^2)
Air
Cond

Air Heat Recovery

- **The wall is a heat exchanger**
  - Air flow through the wall gives a small heat recovery
- Compare total heat loss
  1. Walls with air leakage
  2. Airtight walls with the same air flow rate taken directly from outside
     - No HRV
     - With HRV (efficiency=?)



- What air heat recovery efficiency does case (2) need in order to provide the same heat loss as case (1)?

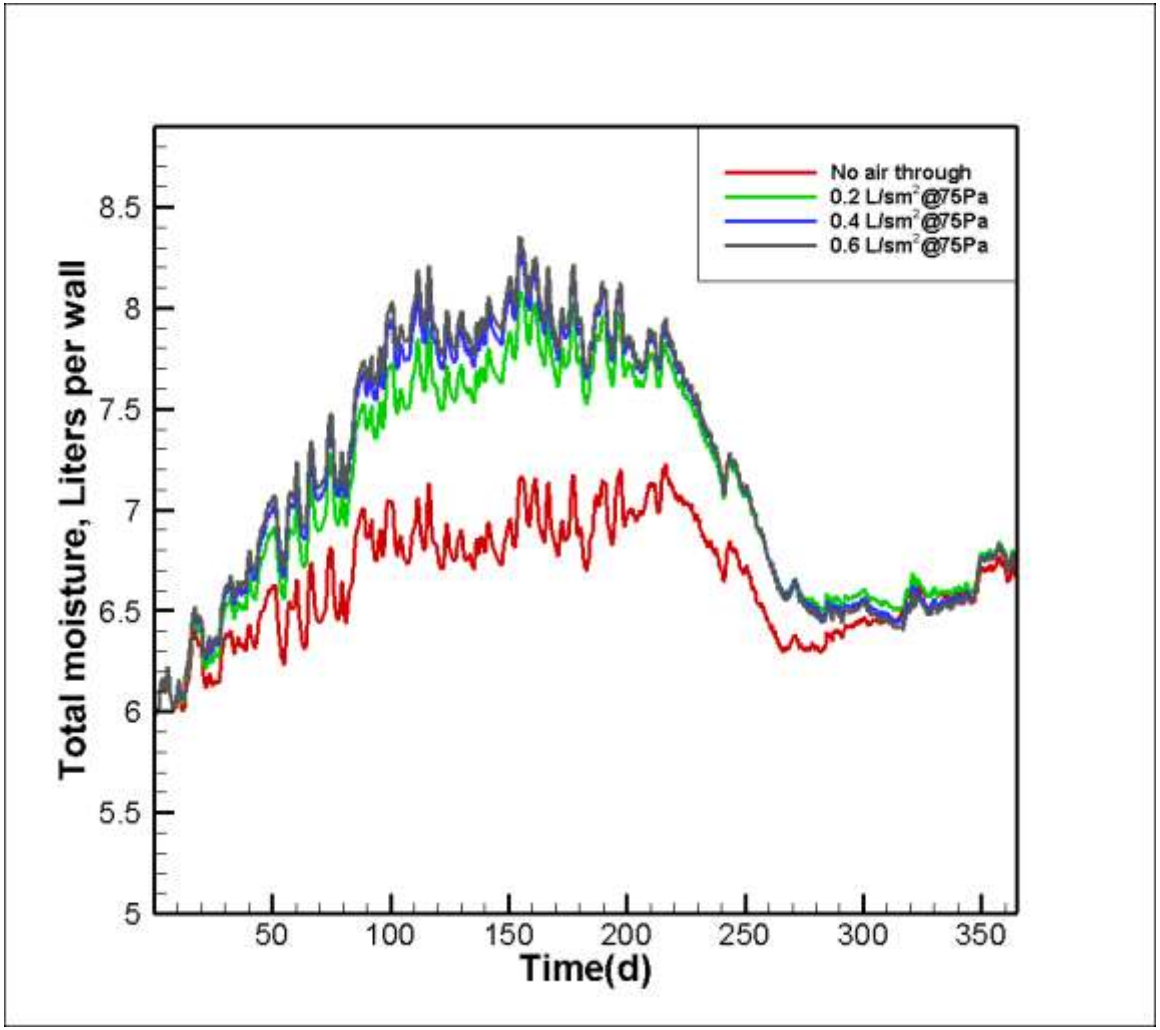
Filtrating Air Heat Recovery

- More airflow means more heat flow
  - The question is whether the air flow is part of designed ventilation or uncontrolled (unwanted) air exchange
    - Uncontrolled flow not wanted and causes extra heat loss
    - If considered part of the house ventilation: Does the house have a HRV/ERV?
- Air that filtrates slowly through the insulating parts provides heat recovery benefits
- The higher the airflow rate per wall U-value, the lower the relative benefits (heat recovery)
- Air flow going through short cracks or openings provides low heat recovery effects

Total Moisture in Walls

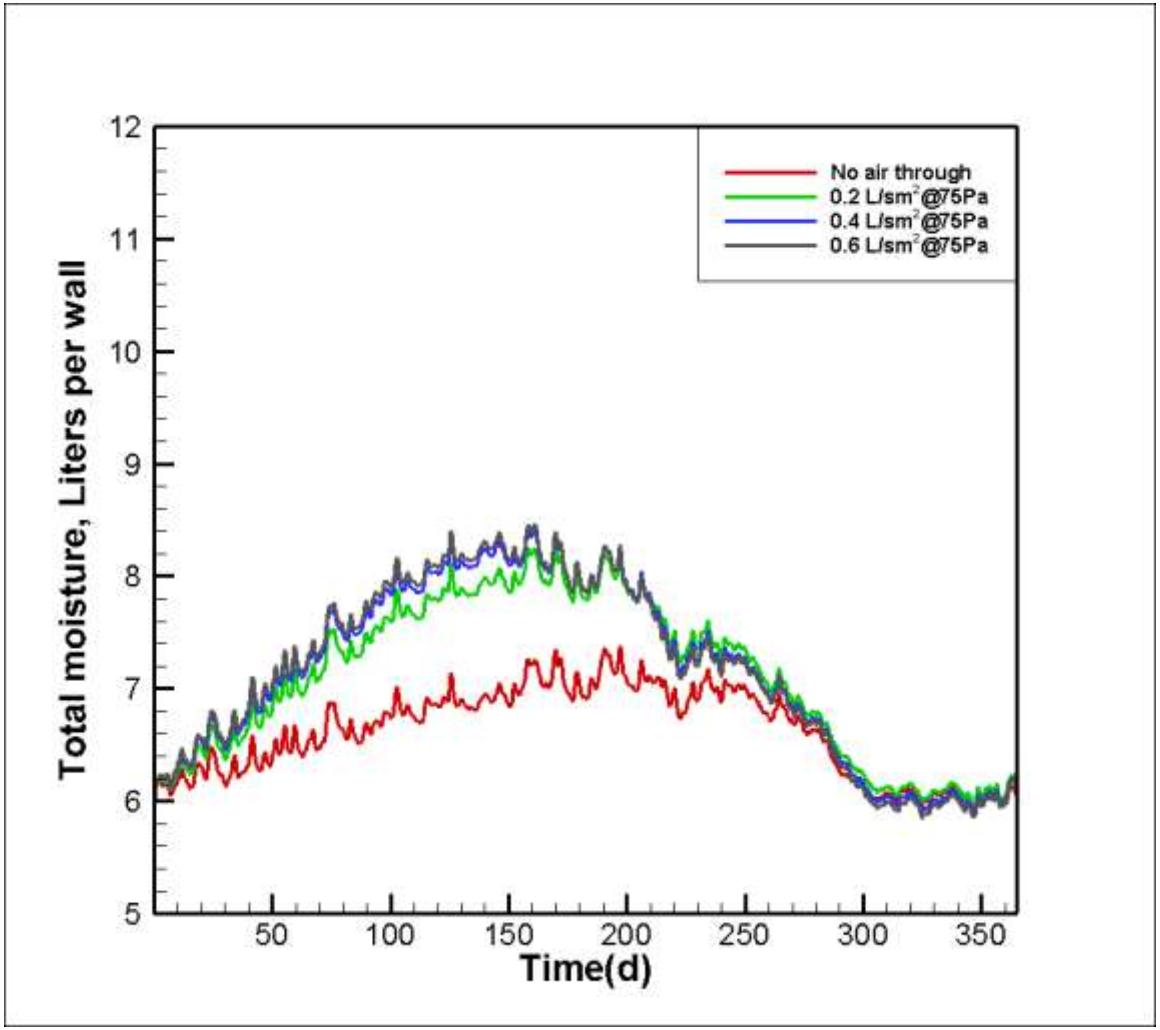
- All layers included
- Only difference is the air leakage rate

Atlanta



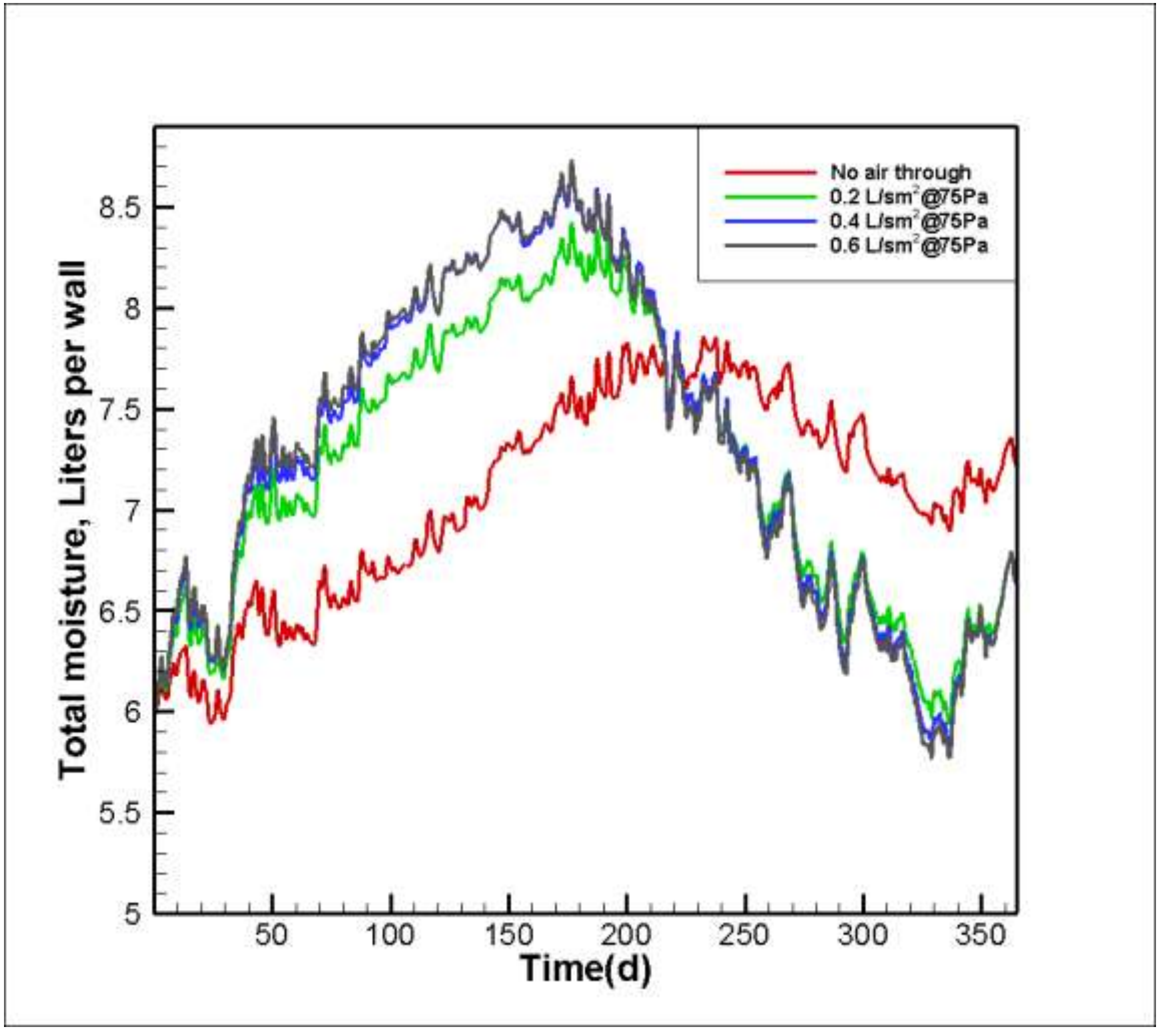
No air through
0.2 L/sm²@75Pa
0.4 L/sm²@75Pa
0.6 L/sm²@75Pa
Total moisture, Liters per wall
8.5
8
7.5
7
6.5
6
5.5
5
50
100
150
200
250
300
350
Time(d)

Baltimore

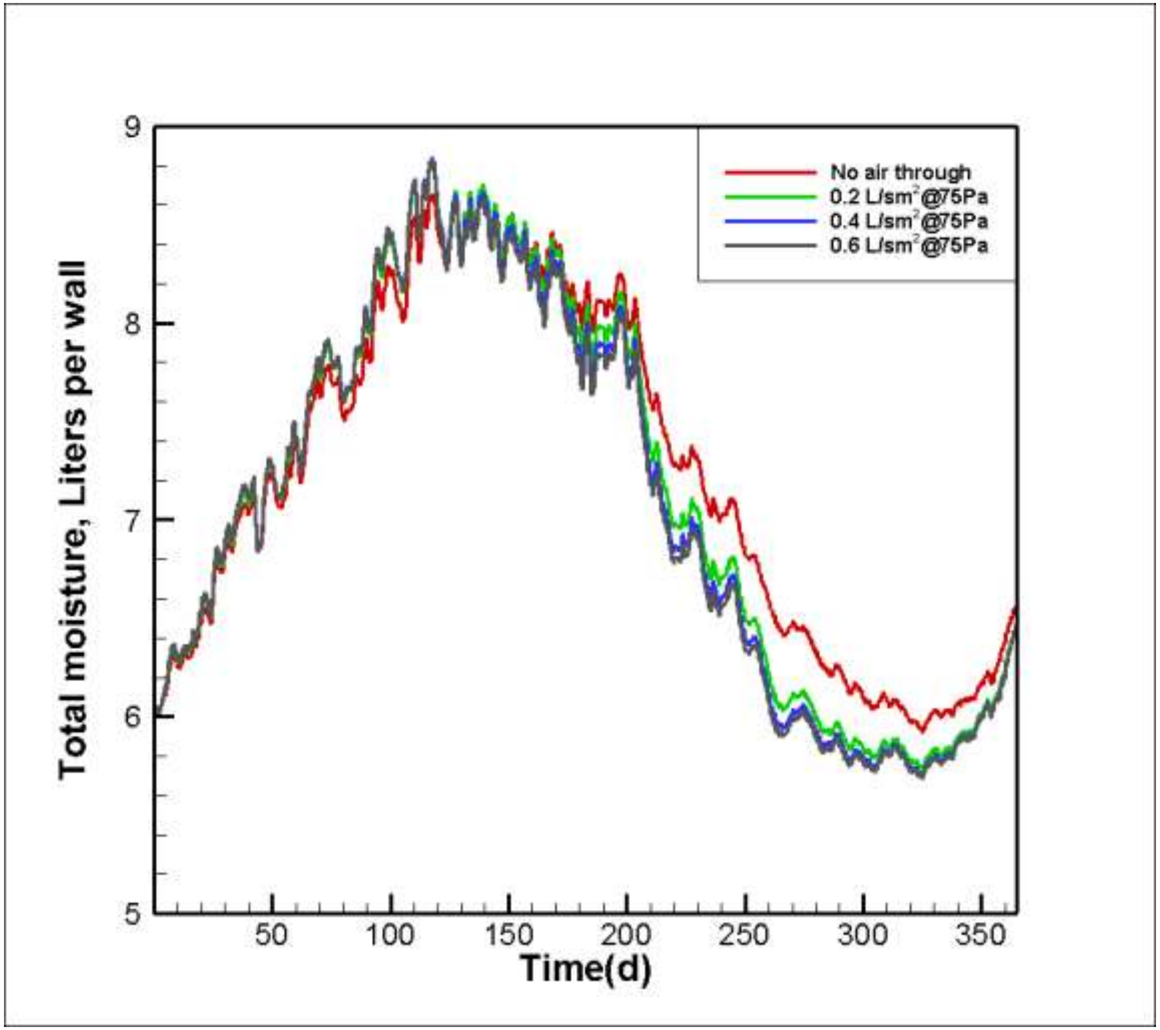


No air through
0.2 L/sm²@75Pa
0.4 L/sm²@75Pa
0.6 L/sm²@75Pa
Total moisture, Liters per wall
Time(d)
12
11
10
9
8
7
6
5
50
100
150
200
250
300
350

Boston

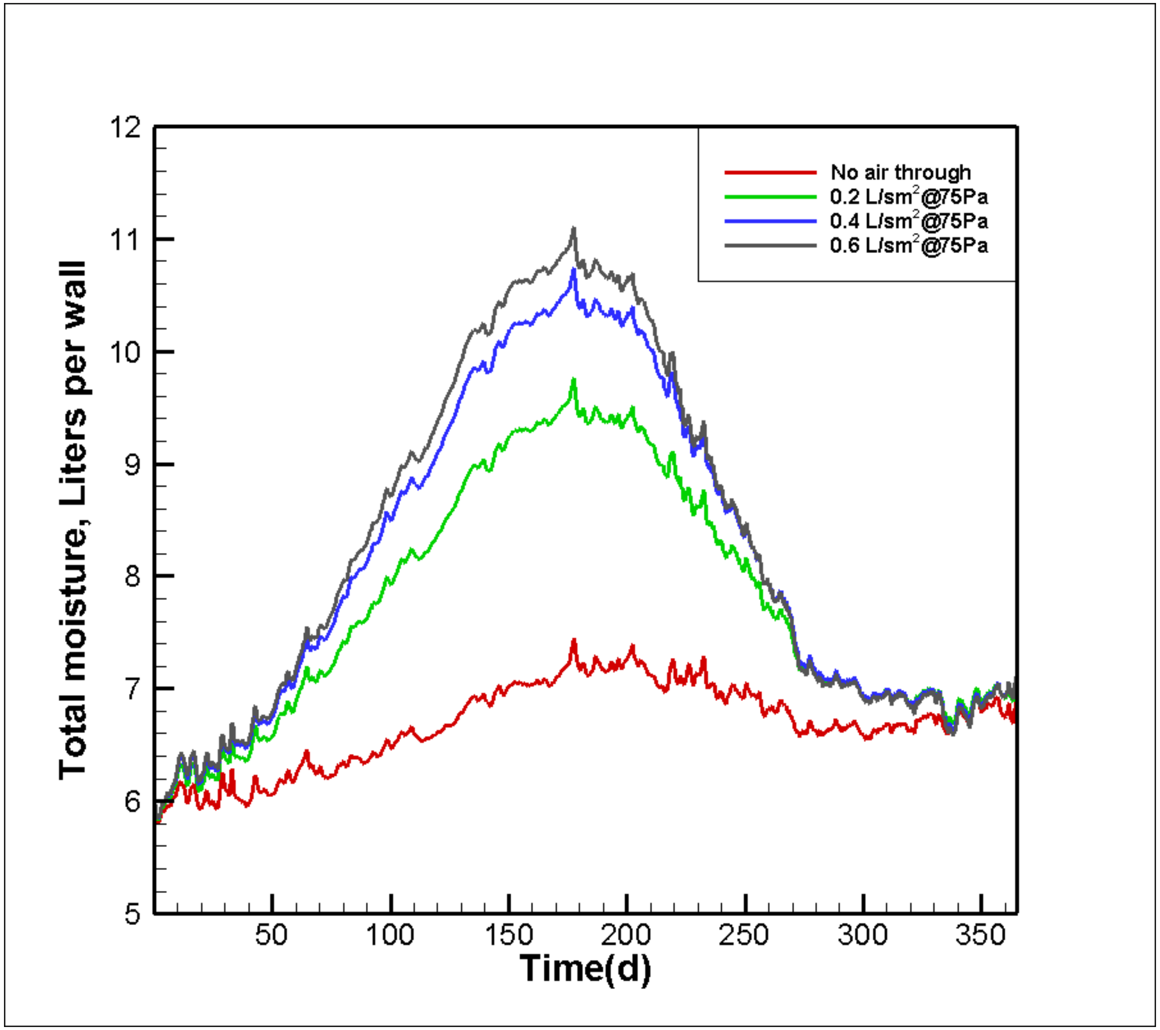

No air through
0.2 L/sm²@75Pa
0.4 L/sm²@75Pa
0.6 L/sm²@75Pa
Total moisture, Liters per wall
Time(d)
5
5.5
6
6.5
7
7.5
8
8.5
50
100
150
200
250
300
350

Houston

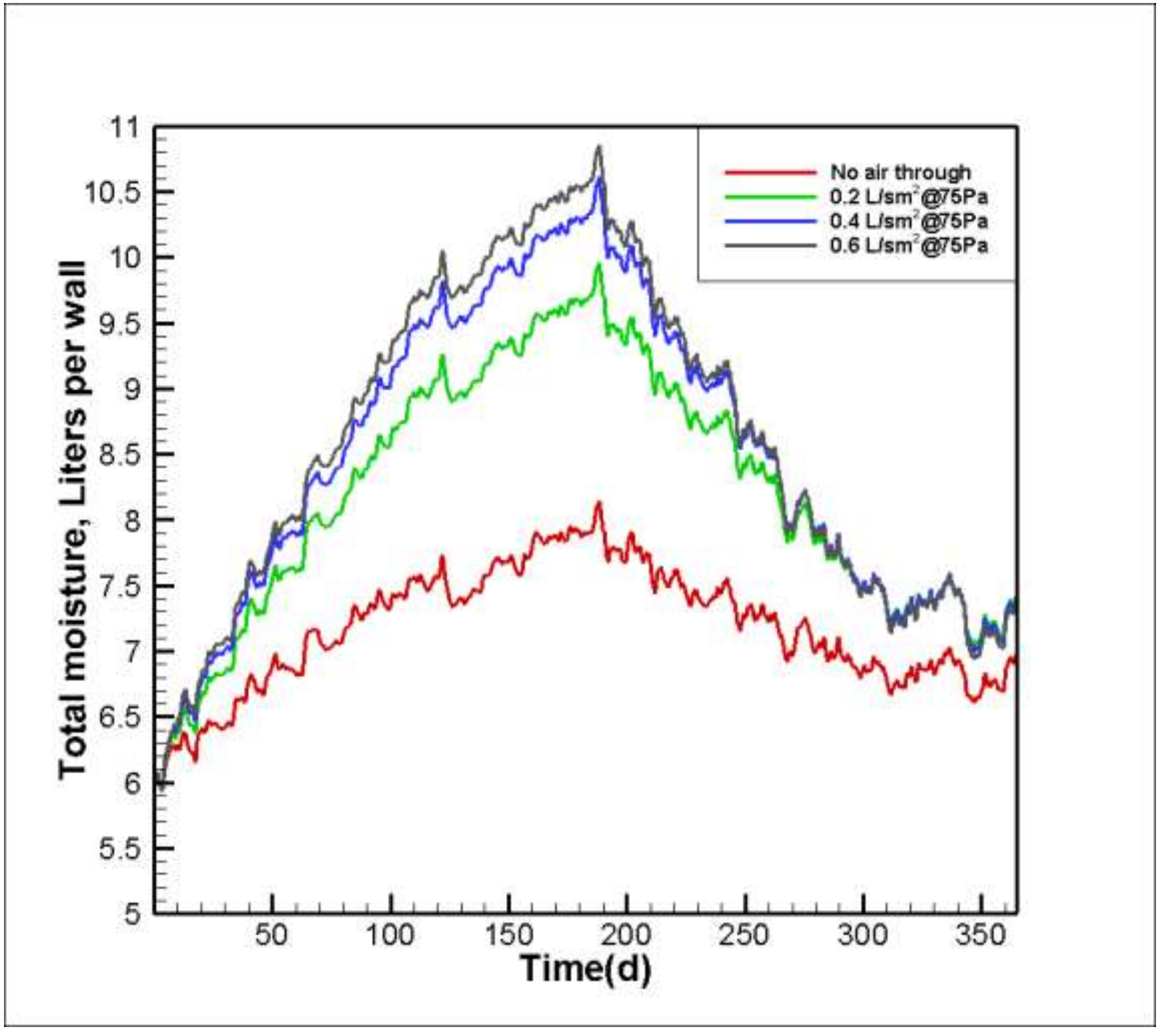


No air through
0.2 L/sm²@75Pa
0.4 L/sm²@75Pa
0.6 L/sm²@75Pa
Total moisture, Liters per wall
Time(d)
5
6
7
8
9
50
100
150
200
250
300
350

Minneapolis



Seattle



Total moisture, Liters per wall
Time(d)
No air through
0.2 L/sm²@75Pa
0.4 L/sm²@75Pa
0.6 L/sm²@75Pa
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
50
100
150
200
250
300
350

Conclusions

- Moisture performance (mold)
  - Standard walls (OSB exterior sheathing) have to be airtight at or below current assembly air tightness requirements (0.2 L/sm^2 / 0.04 cfm/sqft @ 75Pa) to reduce risk for mold growth
- Energy performance
  - At 0.2 L/sm^2@75Pa rating the airflow through the walls increases the heat loss (combined conduction plus air) by roughly 25%
  - Flow through insulated cavities can provide some heat recovery, however
    - Flow path cannot be controlled, short circuiting will not provide heat recovery

Disclaimer: Results are not to be generalized and are valid only for the simulated structures

Next Steps

- Study the impact of low air leakage rates on the moisture performance of alternative wall structures such as with exterior continuous insulation
  - Risk reduction factors

Conclusions

- A big step forward in our analysis capability for air flow. Never done before to this level.
- Component air leakage testing with STATISTICS (mean values and spread) would be very useful to create libraries were each air sealing system would be documented.
- New testing apparatus like Owens Corning, TREMCO, ORNL and BSC can provide hard core data to create series and parallel resistance models for airflow calculations in envelopes.
- Revisit the analysis with OC measured data.

Final Thought

Just think about what we can do !!!