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Heat, Air & Moisture Management in Commercial Buildings

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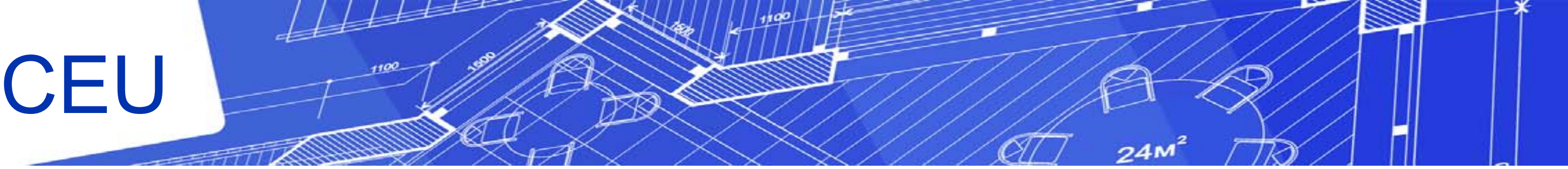

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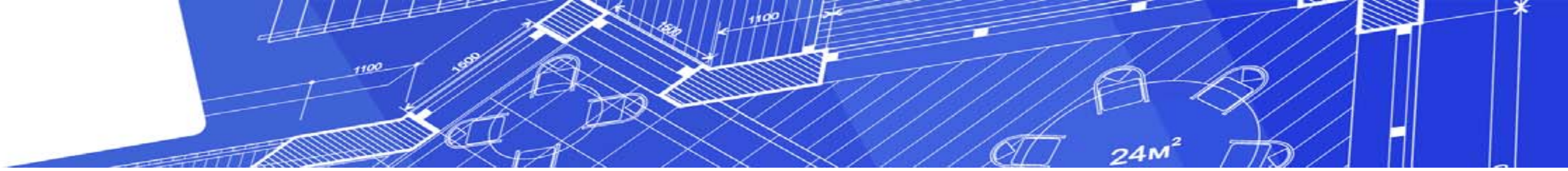
Heat, Air & Moisture Management in Commercial Buildings



Outline

1. Physics of Heat, Air and Moisture Transport *through* the Building Enclosure: *The 4 Control Layers*

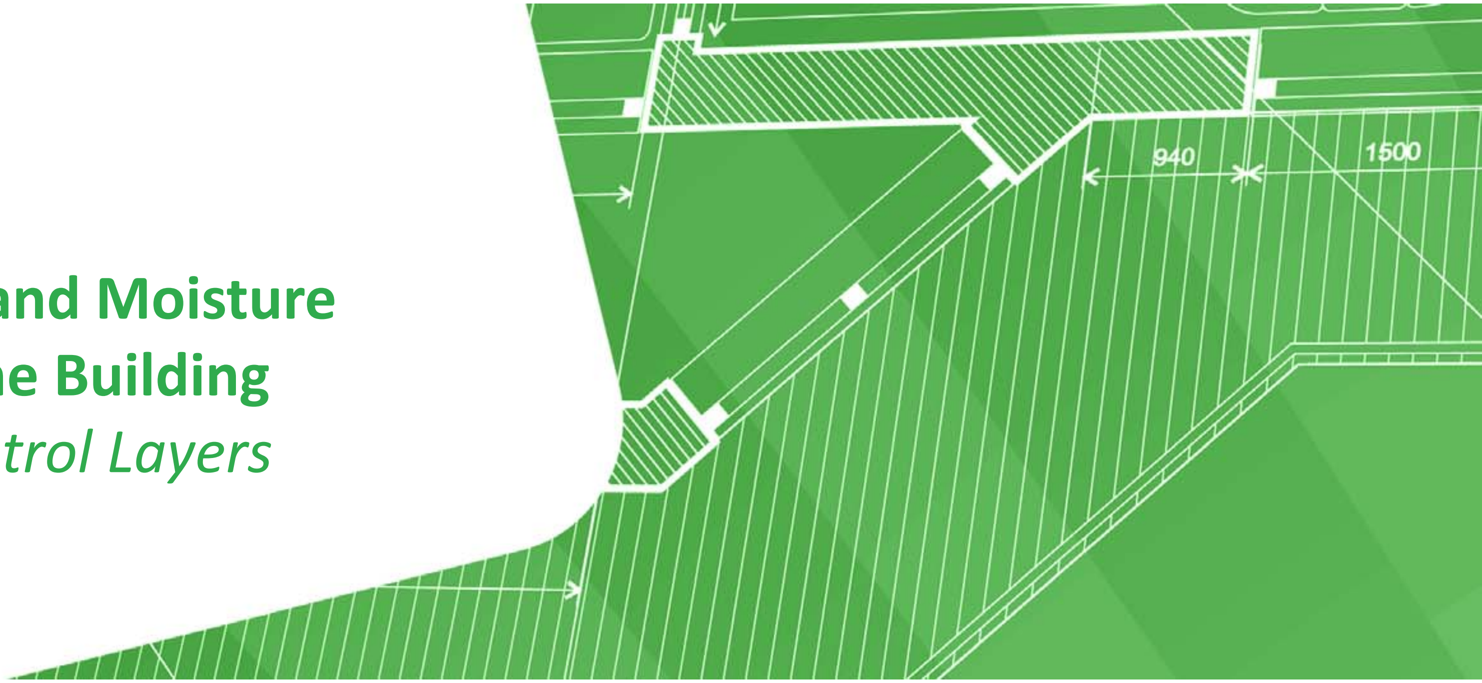
2. Moisture Management Principles for the Building Enclosure: *The Balance of Wetting vs. Drying*

3. Climate-specific Design Considerations for Building Enclosure

4. Condensation Analysis Tools

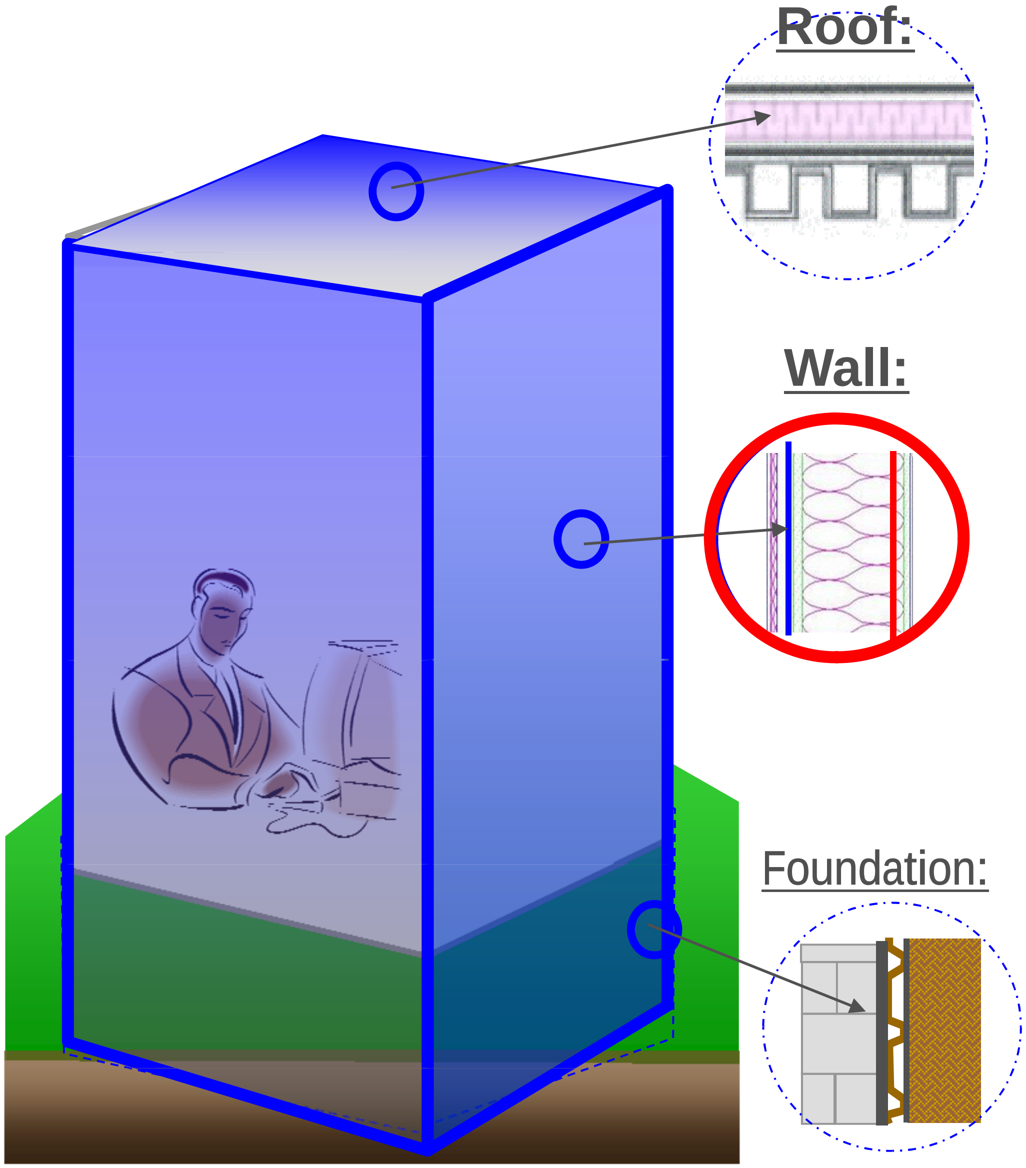
Section 1

Physics of Heat, Air and Moisture Transport *through* the Building Enclosure: *The 4 Control Layers*



The Building Enclosure (Building Envelope[1])

- **Separates the interior and exterior environments**
- **Primary functions: control the *flow of energy* (heat, sound, light, etc.) and *flow of mass* (air, moisture, etc.)**
  - » *Today's focus: Heat-Air-Moisture (HAM)*
- **The building envelope includes roof, wall and foundation**
  - » *Today's focus: walls*



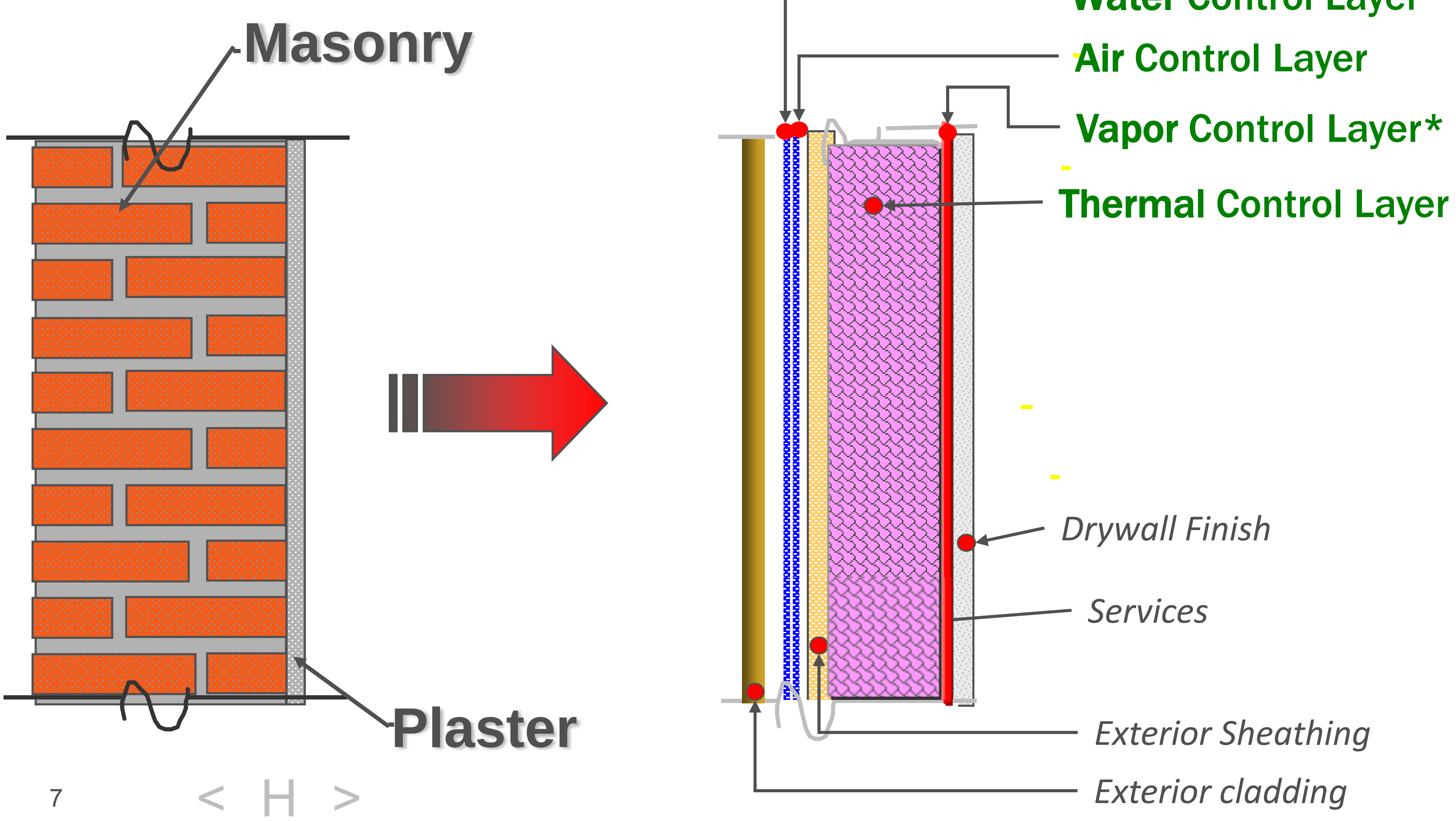
Source[1]: Joe Lstiburek, Insight Vocabulary (Insight – 24): "Building Enclosures, not Building Envelope. You put letters in an envelope not people"

Wall Evolution …

Heat-Air-Moisture

Then

Now



Masonry

Plaster

Water Control Layer

Air Control Layer

Vapor Control Layer*

Thermal Control Layer

Drywall Finish

Services

Exterior Sheathing

Exterior cladding

**Vapor Control Layer use and location in the wall is climate specific*

Heat Flow and Heat Management

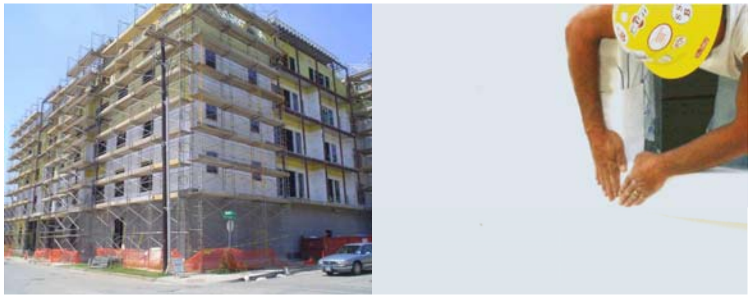
Conduction

- Heat flow through materials

Thermal Insulation

Convection

- Heat flow through air currents



Air Barriers

Radiation

- Heat flow through space

Radiant Barriers

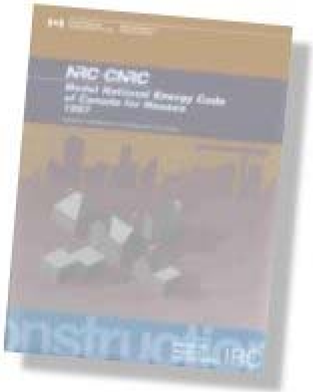
Cool Roof

Energy Codes & Standards: Canada


NRC·CNRC
Model National Energy Code of Canada for Buildings
1997
IRC

MNECB: ***The Model National Energy Code of Canada for Buildings***

- Last Version: **MNECB 1997**
- Sets minimum requirements for energy efficiency in buildings, taking into account regional construction costs, regional heating fuel types and costs and regional climatic differences; focuses on airtightness
- The MNECB applies to all buildings, other than houses of three storeys or less, and to additions of more than 10 m^2 to such buildings


NRC·CNRC
Model National Energy Code
IRC

- **MNECH:** ***The Model National Energy Code of Canada for Houses***
  - Last version: **MNECH 1997**
  - The MNECH applies to residential buildings of three storeys or less, and additions of more than 10 m^2. It refers to the RSI values that guide home building and focuses on airtightness.

NBC-2005

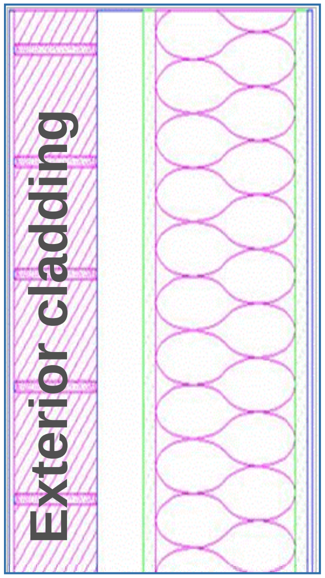
- **NBC -- Section 5 – Environmental Separation**

Energy Codes Updates: Canada

- **The MNECB 1997 referenced ASHRAE 90.1 - 1989**
- **The Canadian Commission on Building and Fire Codes (CCBFC) has created the Standing Committee on Energy Efficiency in Buildings (SCEEB) to update the technical provisions of the MNECB 1997**
- **The updated MNECB is scheduled to be published in 2011.**

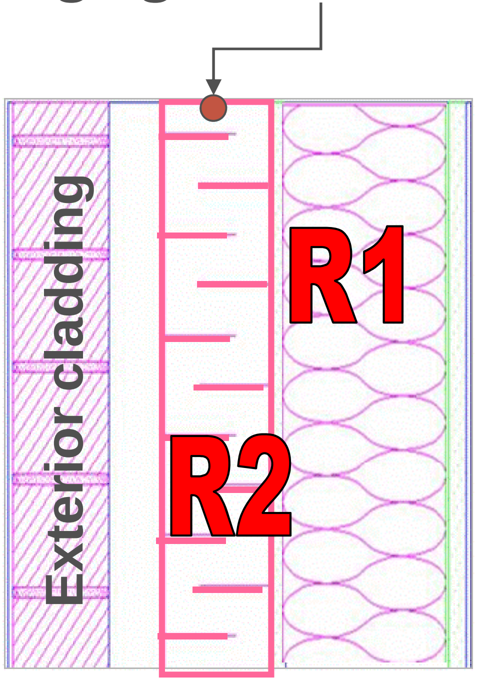
Energy Code Trends – Framed Construction

Traditional Wall Design



Cavity *Insulation*

Exterior insulation to address thermal bridging and increase R-value



- R1/R2 will determine dew point location
- Moisture Management considerations

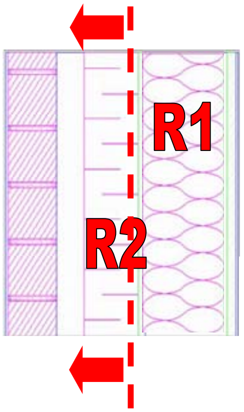
Hybrid *Insulation System*

(Frame Construction: Steel / wood studs)

NBC -2005

Table 9.25.1.2. Ratio of Outboard to Inboard Thermal Resistance

Heating Degree-Days of Building Location(1), Celsius degree-days	Minimum Ratio (R2/R1), Total Thermal Resistance Outboard of Material's Inner Surface to Total Thermal Resistance Inboard of Material's Inner Surface
up to 4,999	0.20
5,000 to 5,999	0.30
6,000 to 6,999	0.35
7,000 to 7,999	0.40
8,000 to 8,999	0.50
9,000 to 9,999	0.55
10,000 to 10,999	0.60
11,000 to 11,999	0.65
12,000 or higher	0.75



Dew Point outside Water Control Layer

Quiz # 1

Thermal insulation controls flow of heat by:

___ Convection

✓___ Conduction

___ Radiation

Quiz #2

Continuous insulation (c.i.) in framed walls is:

___ Insulation placed within the stud cavity

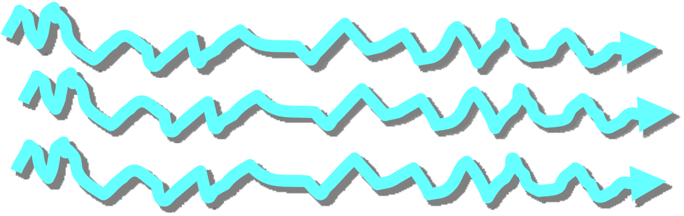
✓___ Insulation uninterrupted by framing

___ Insulation with taped joints

Air and Moisture Transport

H-A-M

Air Transport

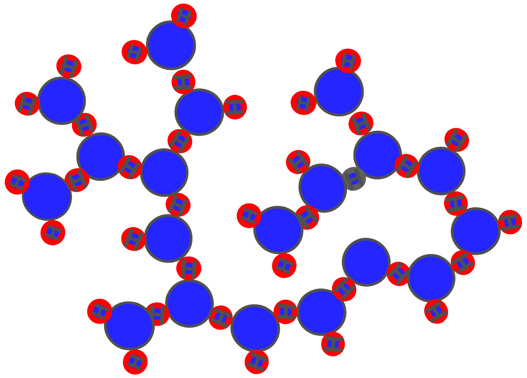


ΔP

Moisture Transport

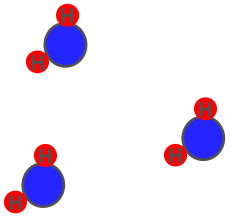
Liquid Water

- Main source: Rain



Water Vapors

- Air transported
- Diffusion

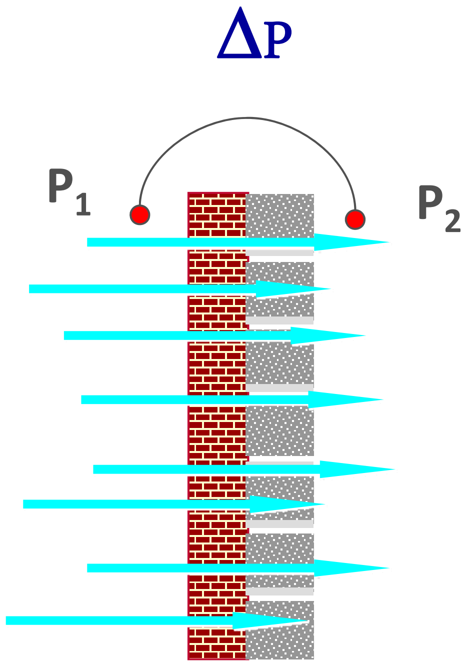


Air Leakage

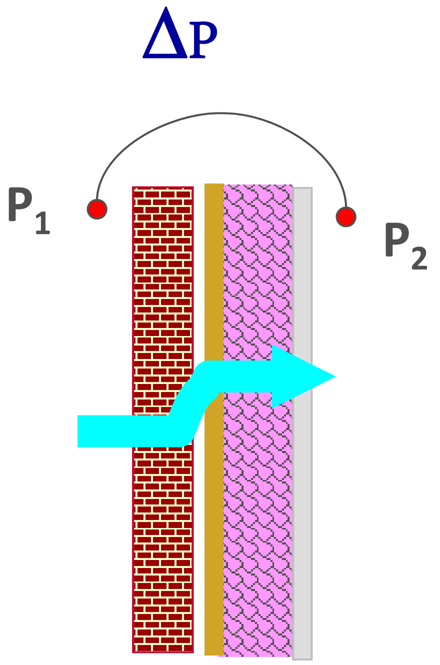
***Un**planned* / ***Un**predictable* / ***Un**intentional Airflow*

(1) Driving Force: *Air Pressure difference* (ΔP)

(2) Pathway: *Porous materials & unintended openings*



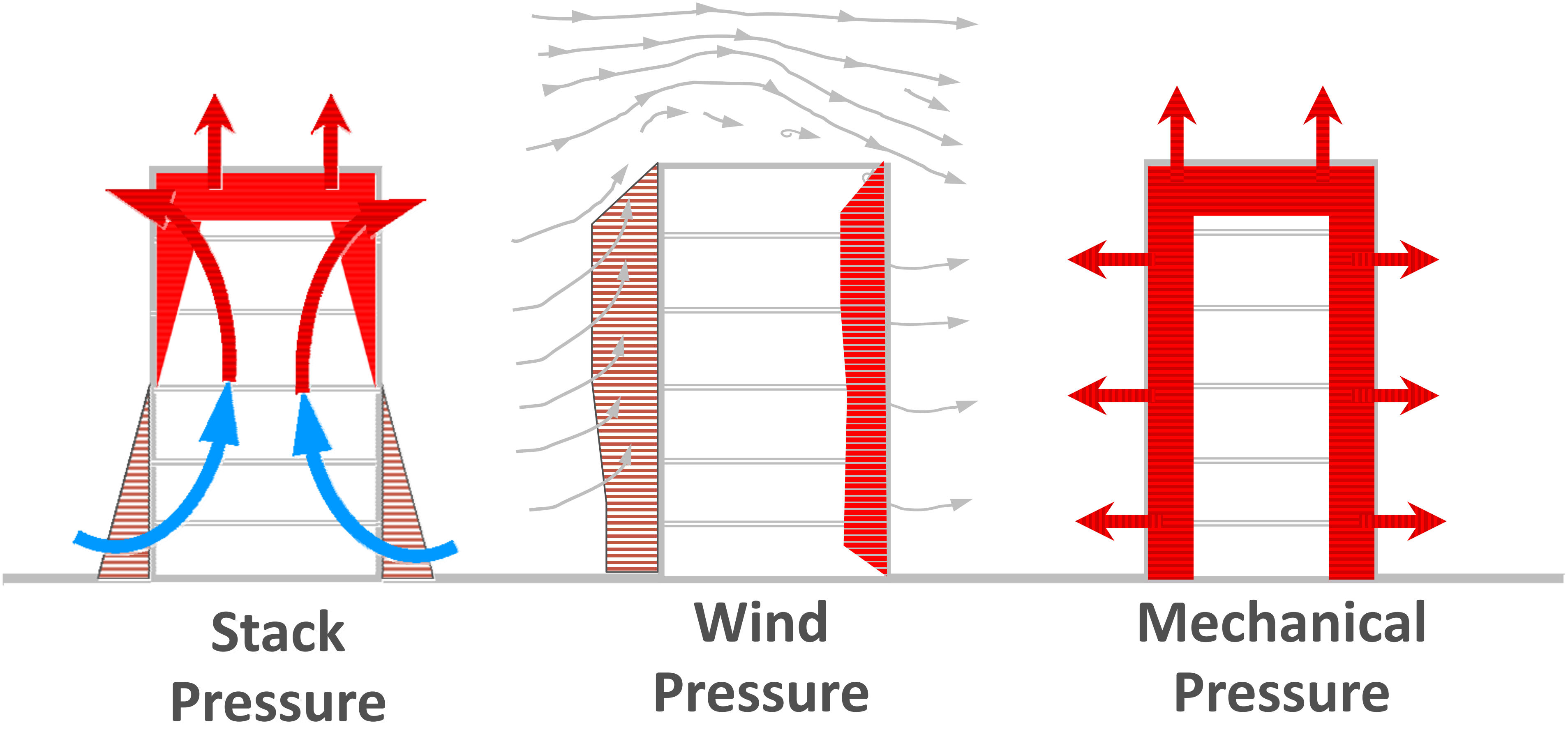
Porous materials



Unintended Openings

Sources of Air Pressure Difference (ΔP)

There are 3 main sources of ΔP:



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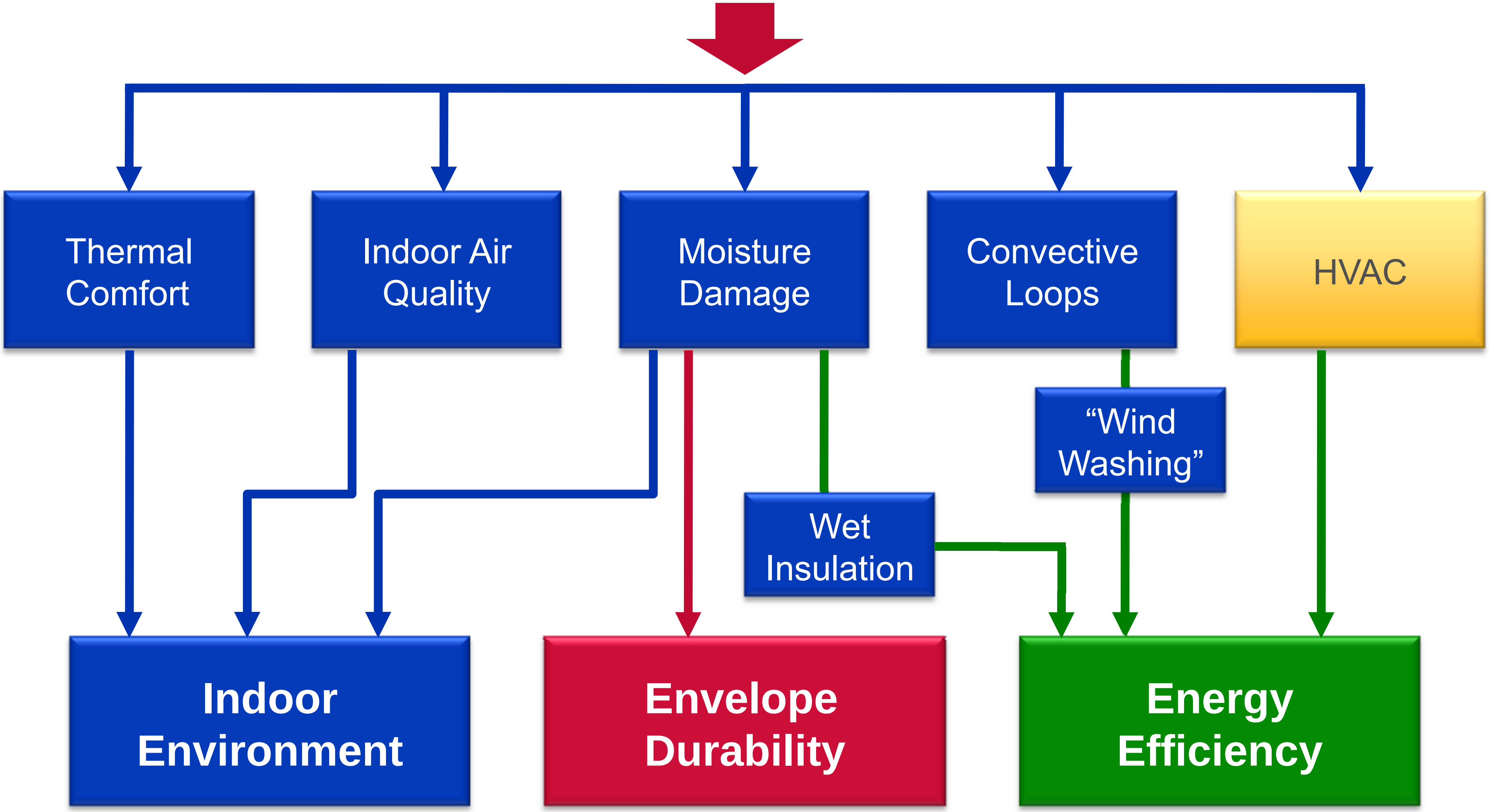
Air Leakage Consequences


Thermal Comfort

Indoor Air Quality

Moisture Damage

Convective Loops

HVAC

"Wind Washing"

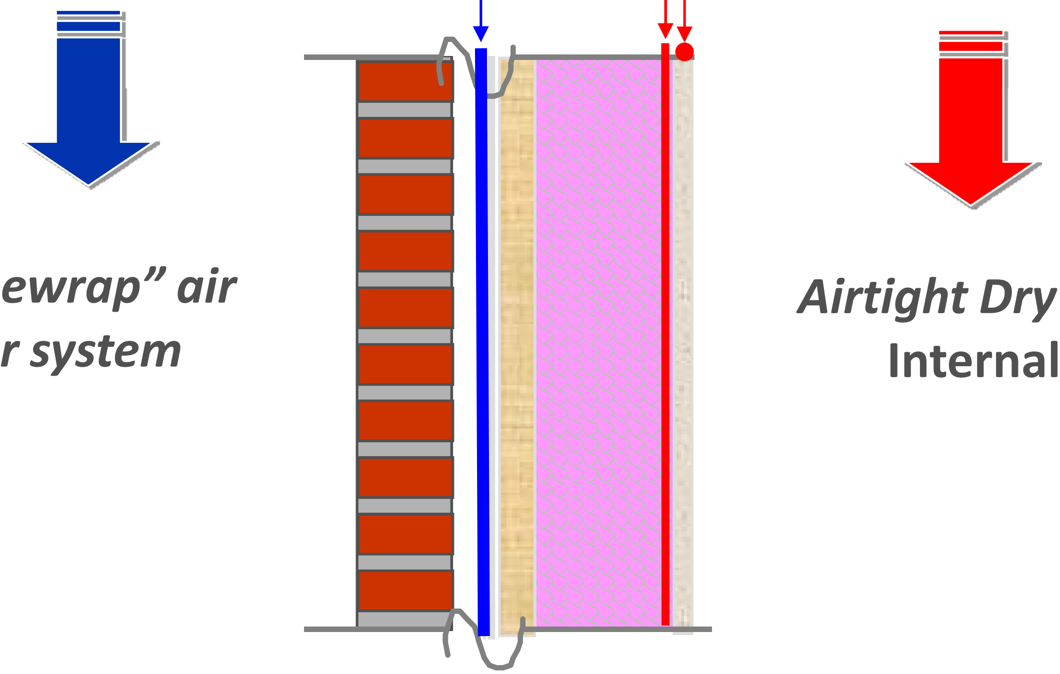
Wet Insulation

Indoor Environment

Envelope Durability

Energy Efficiency

Air Control Layers (ABS)



Air Barrier System

Vapor Barrier

Sealed Drywall

"Housewrap" air barrier system

Airtight Drywall Approach:
Internal Air Barrier

In framed systems, ***two air barrier systems, one inside and one outside of the framing***, are often desirable….. Such redundancy is needed because of the ***susceptibility of these systems to wind washing, convective loops,*** ABS failure, and other airflow control problems.

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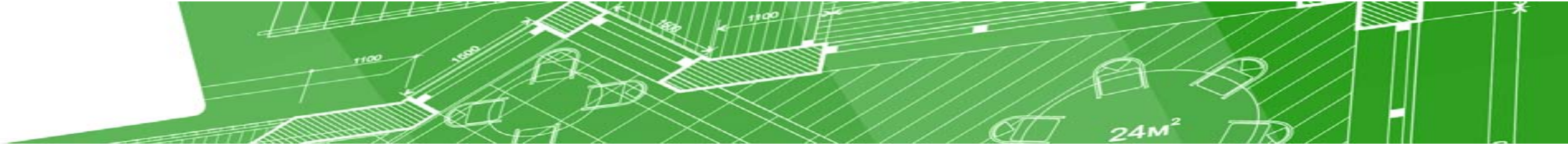
Source: Air Flow Control in Buildings, John Straube -- Building Science Digest 014: last updated 2009/10/14

Air Barrier Requirements[1]

1. Air Infiltration Resistance
2. Continuity
3. Strength (Structural Integrity)
4. Durability



1). Air Infiltration Resistance Requirements: NBC 2005

5.4.1.2.Air Barrier System Properties

…… materials intended to provide the principal resistance to air leakage shall have an air leakage characteristic not greater than

0.02 L/(s•m^2)

2) Air Barrier Continuity Requirements – NBC 2005

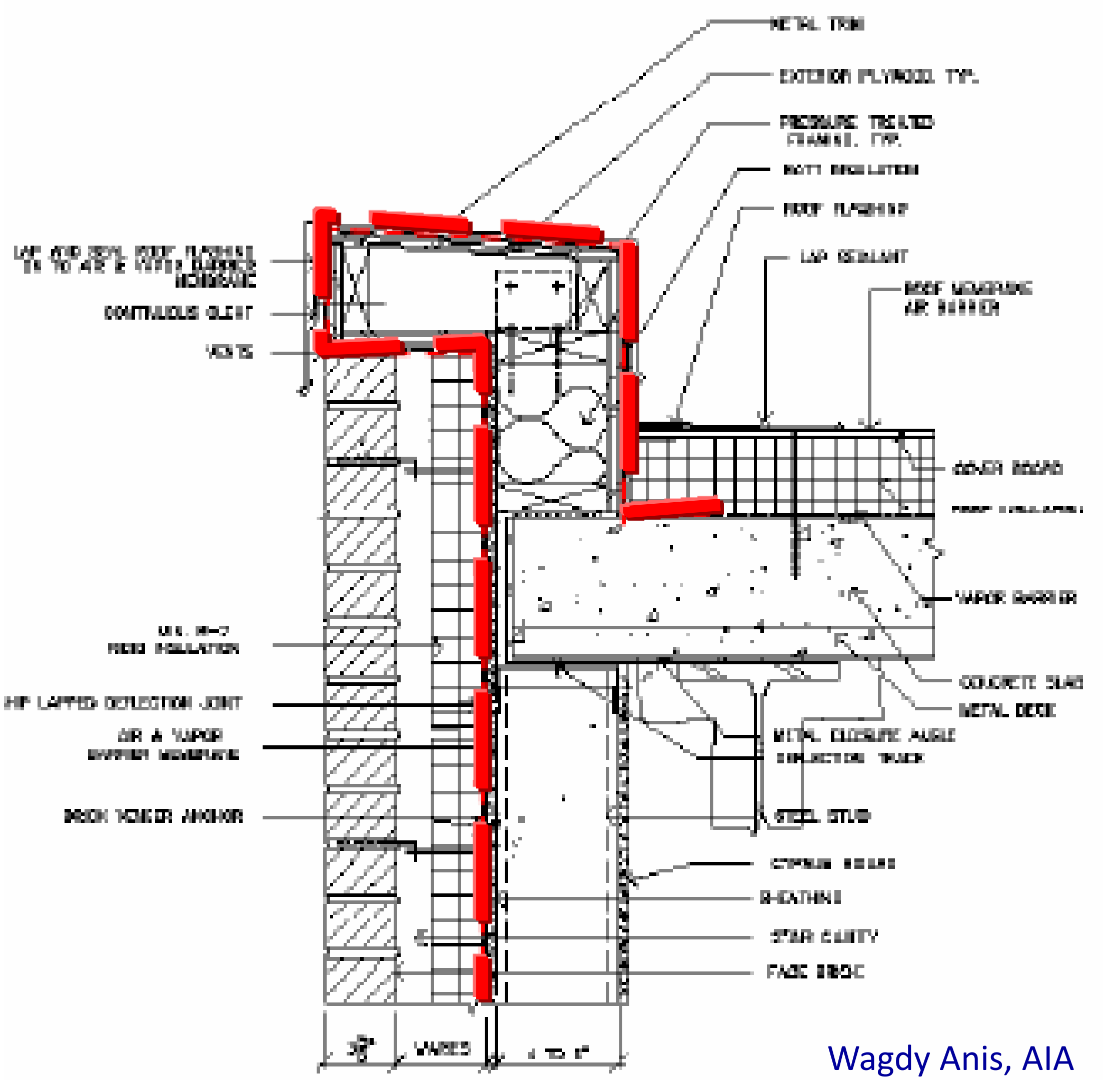
9.25.3.3. Continuity of the Air Barrier System

1) Where the air barrier system consists of an air-impermeable panel-type material, **all joints shall be sealed** to prevent air leakage.

2) Where the air barrier system consists of flexible sheet material, **all joints shall sealed, or lapped , etc……….**

Air Barrier Continuity, *e.g. Wall-Roof Interface*

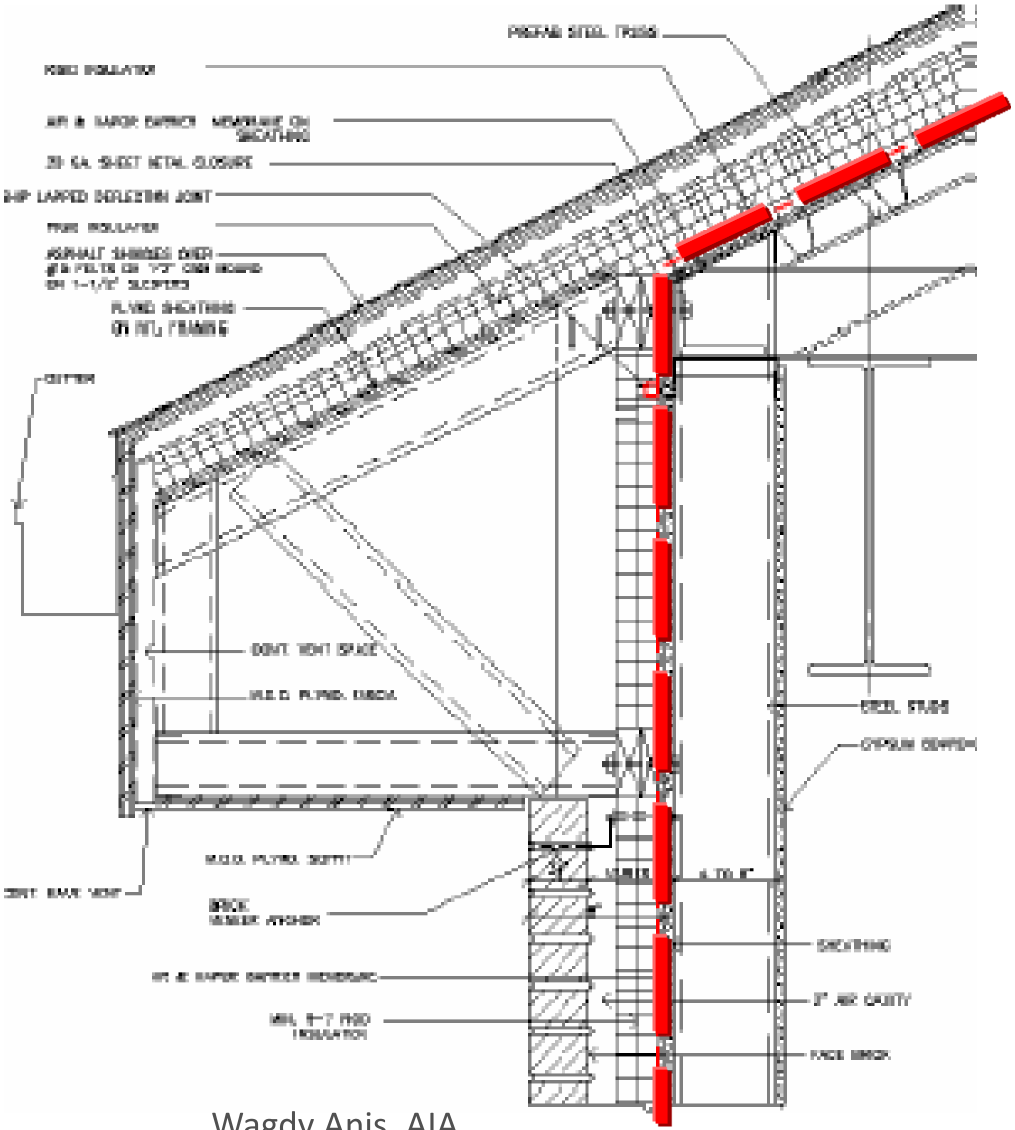
Air Barrier plane must be clearly indicated on drawings, must be continuous, and properly detailed



Wagdy Anis, AIA

Air Barrier Continuity, *e.g. Wall-Roof Interface*

Air Barrier plane must be clearly indicated on drawings, must be continuous, and properly detailed



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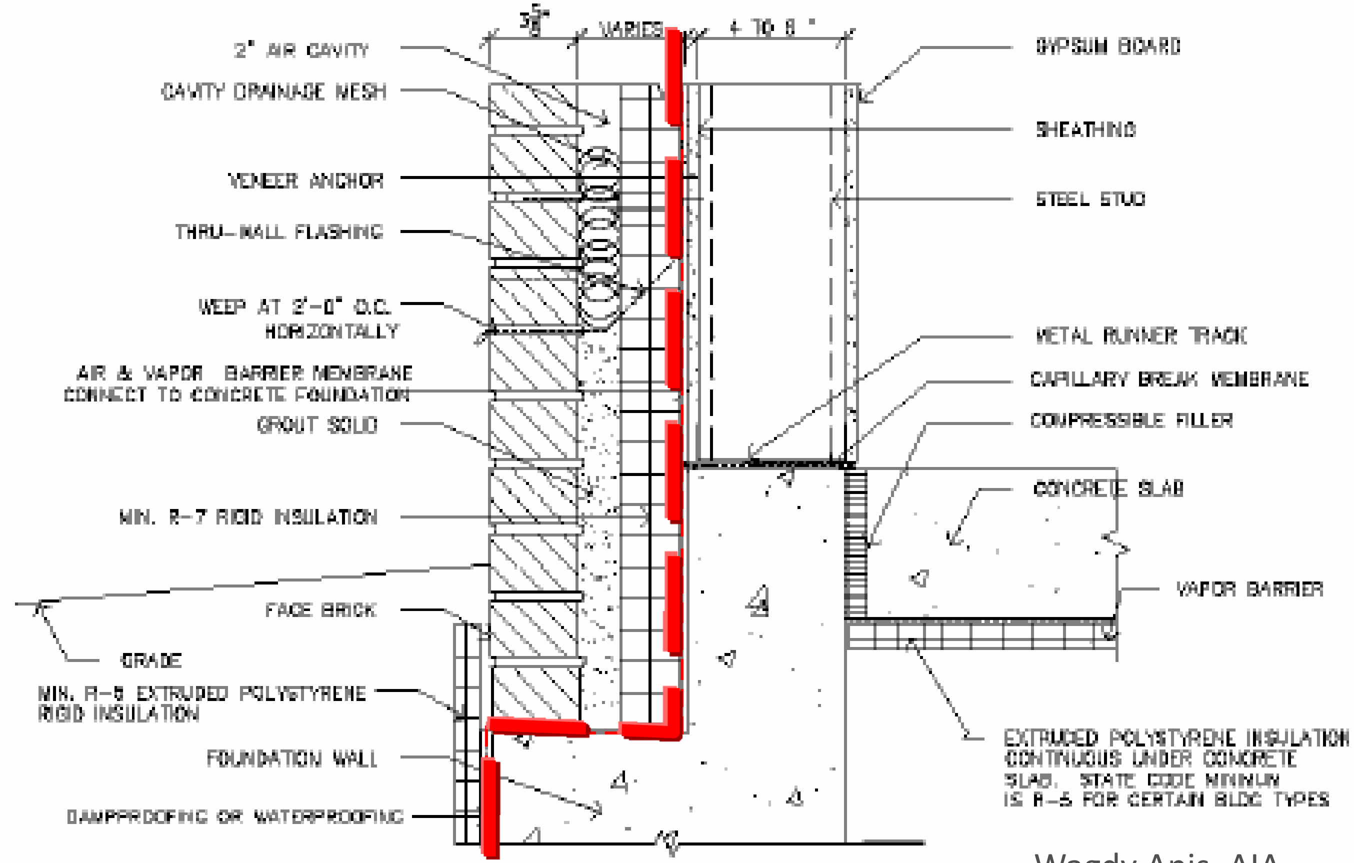
Air Barrier Continuity, *e.g. Wall-Foundation Interface*



Wagdy Anis, AIA

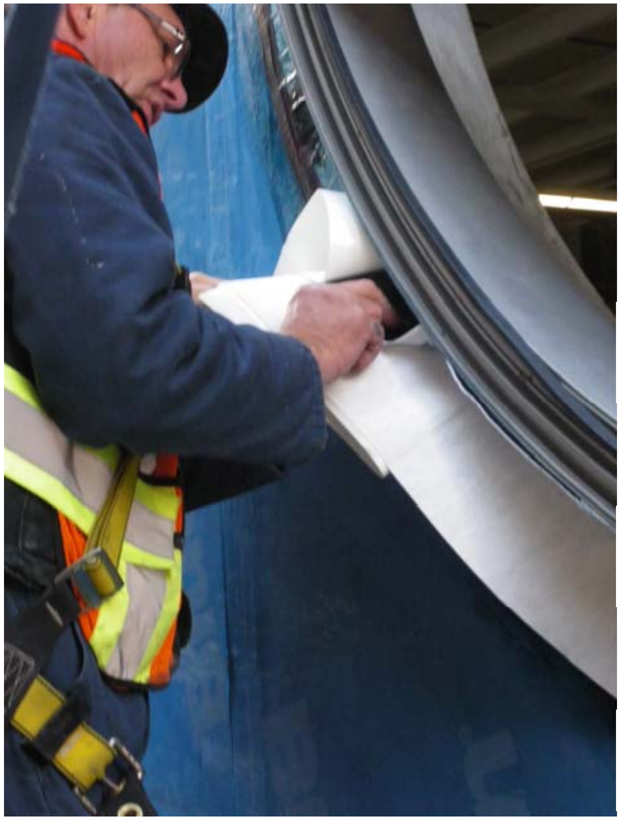
Air Barrier plane must be clearly indicated on drawings, must be continuous, and properly detailed

Air Barrier Continuity

E.g. Flashing of windows and penetrations

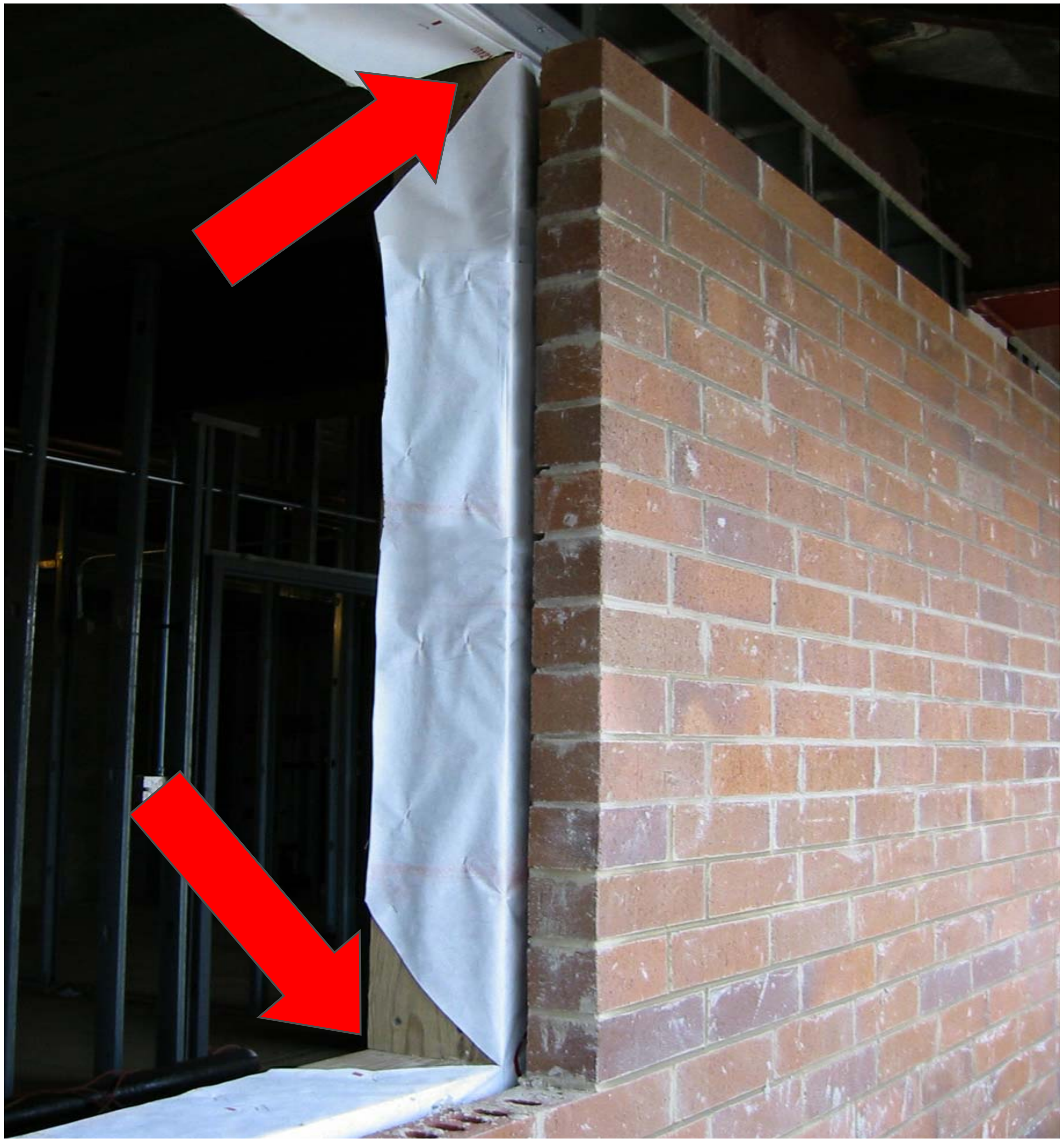
Courtesy: Darren Casale, AIA

Windows Integration



Seamless Flashing, minimum intersections
Time savings: >60% less time

What is wrong with this picture?



Discontinuity at window-wall interface

3) Structural Integrity

2005 NBC – Air Barriers Structural Design Requirements

5.4.1.2.Air Barrier System Properties

The structural design of air barrier systems installed in assemblies subject to air pressure loads shall have sufficient capacity and integrity to resist or accommodate all environmental loads

3) Structural Integrity – US Standards

Air Barriers must withstand pressure loads *or* be able to transfer the load to the substrate

- **Air Barrier assembly testing: *ASTM E1677 or ASTM E2357***
- **ASTM E2357 test procedure: apply positive and negative pressure loads to wall assemblies, and test for air & water infiltration, deflection, or damage to the air barrier**

Opaque wall

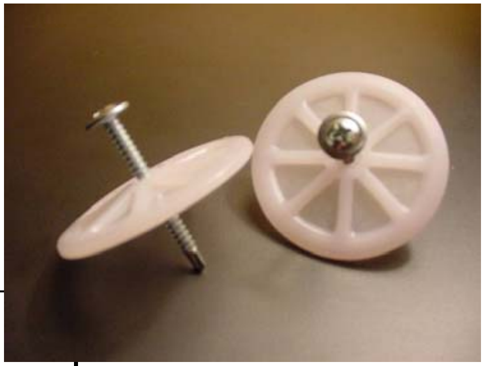
Wall with Penetrations

Wall assemblies (8' x 8') tested for structural integrity

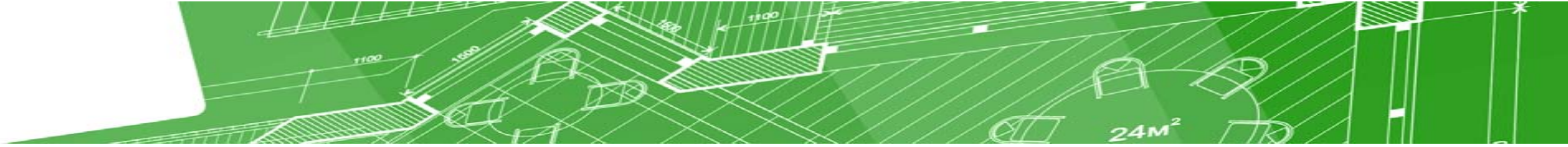
ASTM E1677 and ASTM E2357 Comparison – Structural Requirements

	ASTM E1677-00	ASTM 2357 -05
Number of Test Specimen and configuration	One Specimen: Opaque Wall (8ft x 8 ft walls)	Test two of the three Specimens (8ft x 8 ft walls): 1 - Opaque Wall 2 – Wall with penetrations 3 – Wall-Foundation Interface
Conditions for Air Leakage Testing	Single Test Pressure: 75Pa (1.56 psf, 25 mph) *(Positive pressure, only)*	Seven Test Pressures: +/- 25Pa (0.56 psf, 15 mph) +/- 50Pa (1.04 psf, 20 mph) +/- 75Pa (1.56 psf, 25 mph) +/- 100Pa (2.09 psf, 30 mph) +/- 150Pa (3.24 psf, 35 mph) +/- 250Pa (5.23 psf, 45 mph) +/- 300Pa (6.24 psf, 50 mph) *(Positive & negative pressures)*
Pressure Loading Schedule	Sustained loads up to +500 Pa (10.4 psf, 65 mph) *(Positive pressure, only)*	1 - Sustained, +/- 600Pa (12.5 psf, 71 mph) 2 - Cyclic, +/- 800 Pa (16.7 psf, 82 mph) 3 - Gust, +/- 1200 (25 psf, 100 mph) *(Positive & negative pressures)*

Screw Fasteners and 16" O.C. Steel Stud Spacing



Washer Size	Fastener Spacing	Allowable Pressure	
		Pounds per sq. inch [psf]	Miles per Hour [mph]
2" Metal	12"	90 psf	188 mph
	18"	60 psf	153 mph
2" Plastic	12"	70 psf	165 mph
	18"	45 psf	133 mph
1.25" Metal	12"	60 psf	153 mph
	18"	40 psf	125 mph



4) Durability

Air Barriers must withstands environmental exposures:

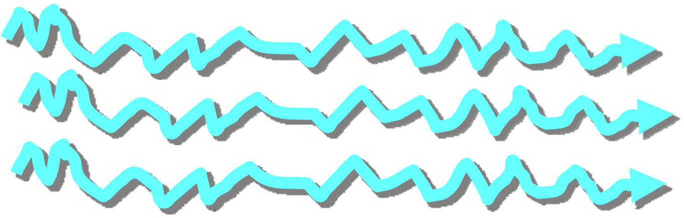
- **UV*** *(must follow manufacturer’s recommendation for exposure limit)*
- **Thermal exposure & thermal cycling**
- **Repeated exposure to water**
- **Abrasion**
- **Mechanical stresses**

** Most air barrier membranes are not designed for continuous UV exposure*

Air and Moisture Transport

H-A-M

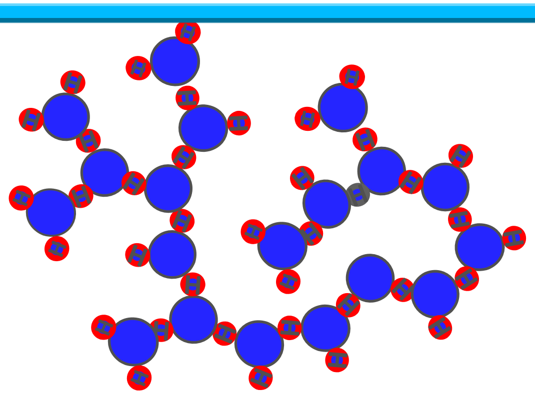
➡ *Air Transport*



ΔP

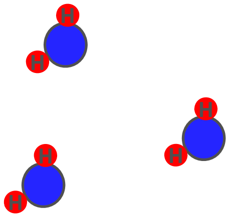
➡ *Moisture Transport*

- **Liquid Water**
  - **Main source: Rain**



Water Vapors

- **Air transported**
- **Diffusion**



Rain Water Management: Water Control Layer (WRBs)

5.6.1.1.Required Protection from Precipitation

…………..

a) minimize ingress of precipitation into the component or assembly, and
b) prevent ingress of precipitation into interior space.

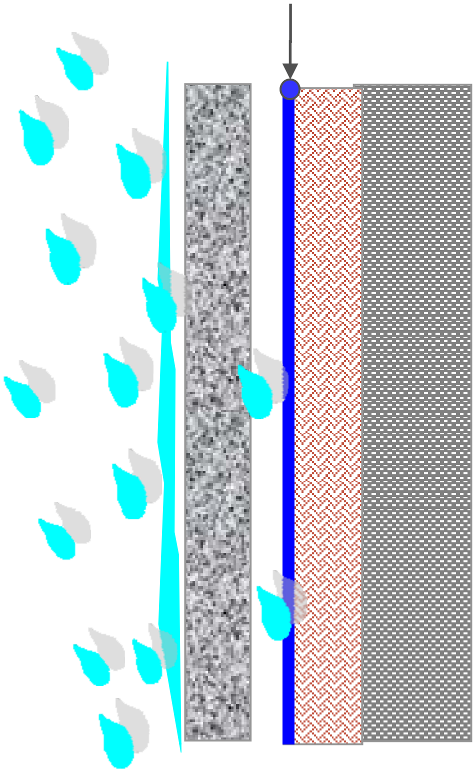
5.6.2.1.Sealing and Drainage

materials, components, assemblies, joints in materials, junctions between components and junctions between assemblies exposed to precipitation shall be

a) sealed to prevent ingress of precipitation, or
b) drained to direct precipitation to the exterior.

Water Control Layer (“WRB”)

“Precipitation Control”



» ***Gravity***
» ***Capillary***
» ***Rain driven***
» ***Pressure Differential***

Best Rain Management: The 4 Ds

1. **Deflection**
2. **Drainable**
3. **Dryable**
4. **Durable**

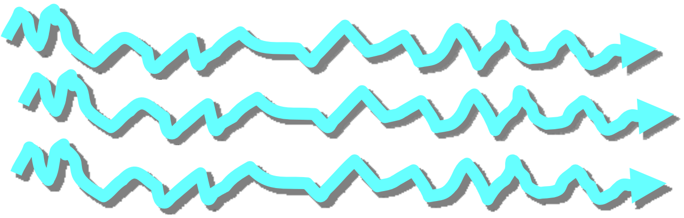
Primary water management: Rain Screen & Drainage Plane

Source: CMHC

Air and Moisture Transport

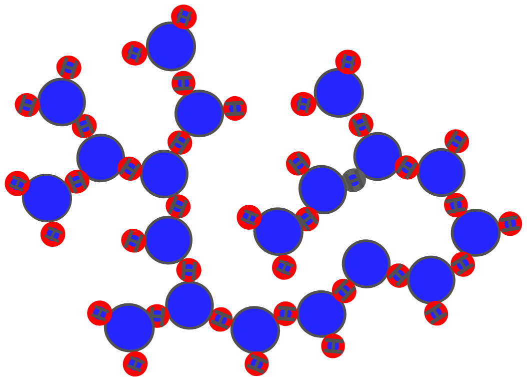
H-A-M

- **_Air Transport_**



ΔP

- **_Moisture Transport_**

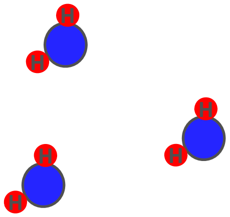


Liquid Water

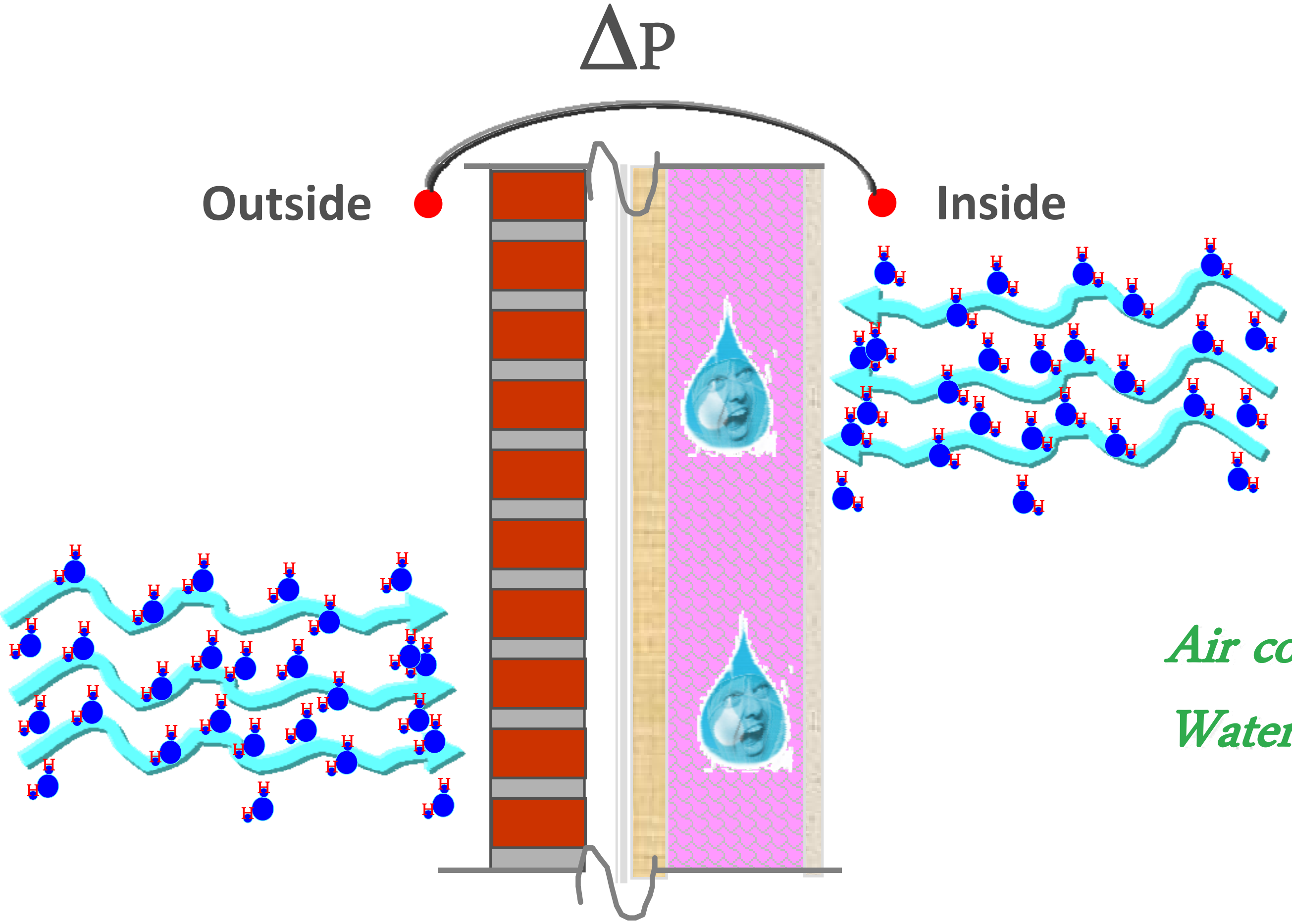
- Main source: Rain

Water Vapors

- Air transported
- Diffusion



Water Vapor transported by Air Currents

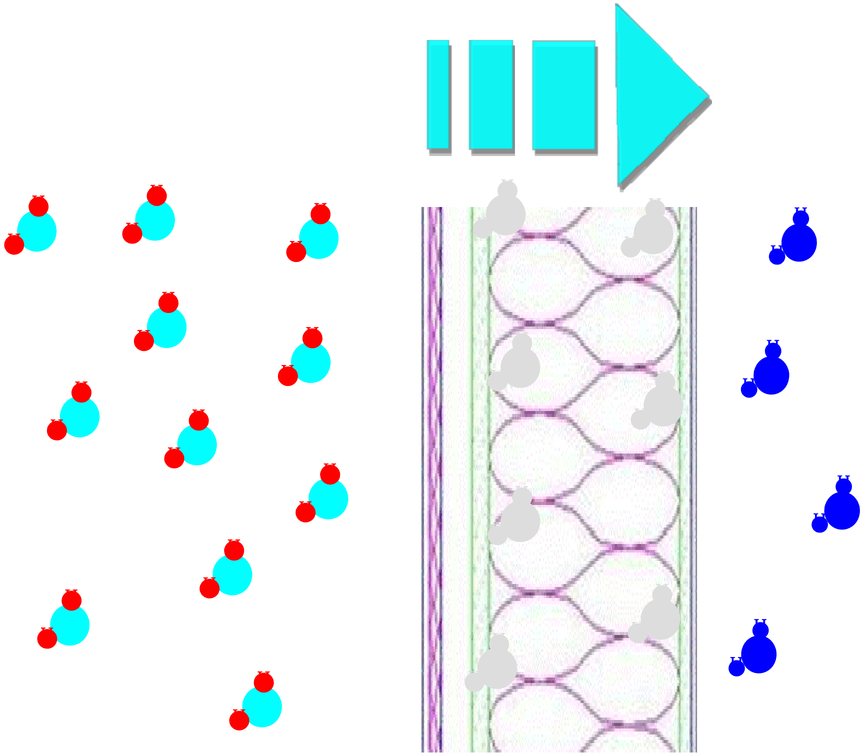


Air contains

Water vapors

Moisture deposited on cooler surfaces → Interstitial Condensation

Vapor Diffusion



1. **Driving Force:**

   Concentration difference (Vapor Pressure Difference)

2. **Pathway:**

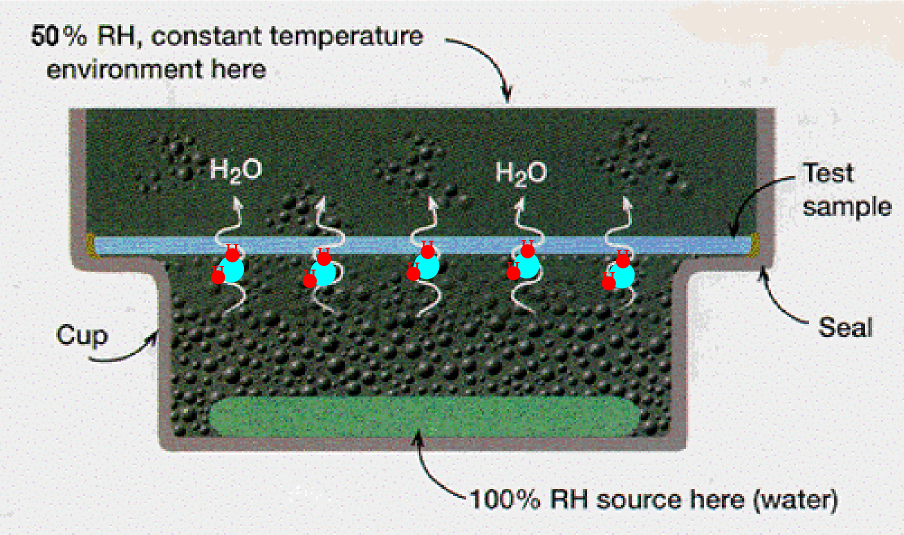
   Vapor Permeable Materials

From Higher to Lower Concentration

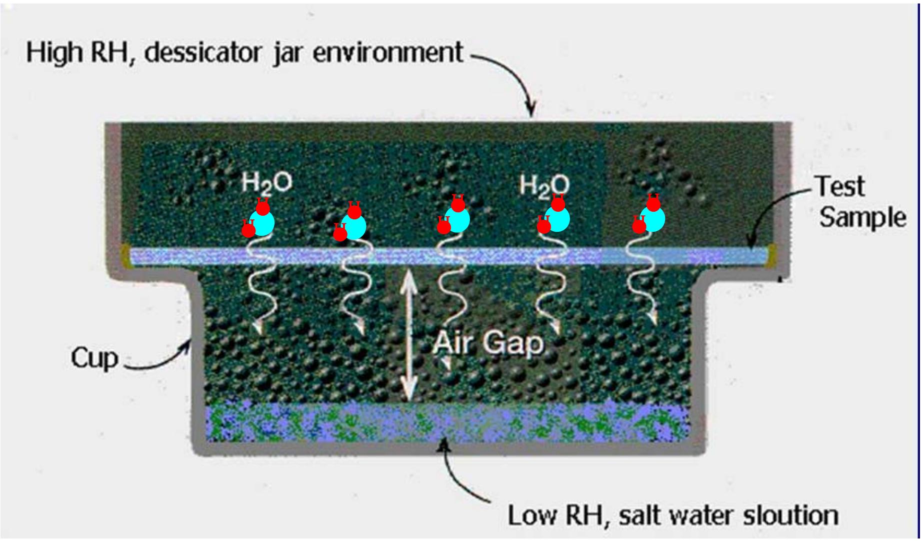
Moisture Vapor Permeability (MVTR)

a measure of the amount of water vapor that passes through the material or assembly by vapor diffusion

ASTM E-96 Wet Cup Test (Method B)



ASTM E-96 Wet Cup Test (Method A)



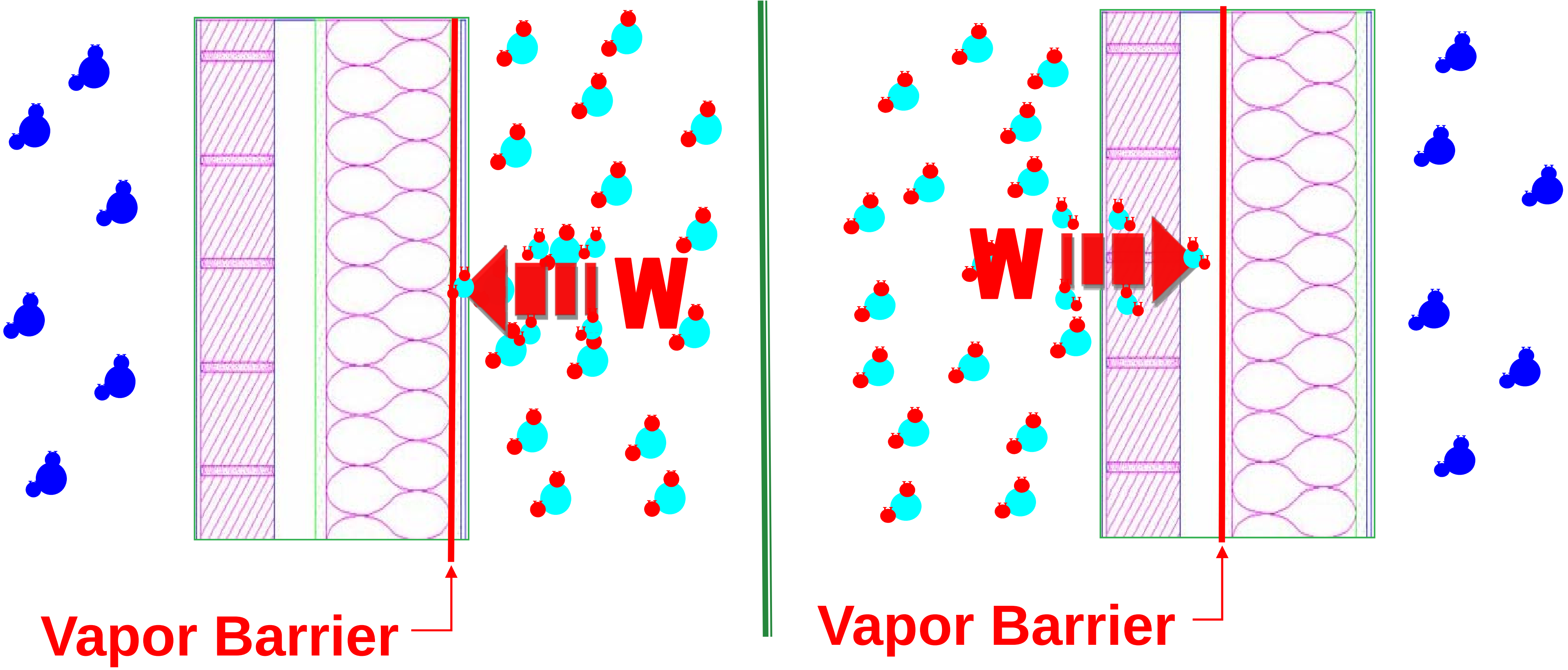
Measured in:

"Perms" (grains/ft^2.hr.inHg) **or *"M Perms"*** (Ng/Pa.s.m^2)

Vapor Control Layer

…. the component (or components) that is (or are) designed and installed in an assembly to control the movement of water by vapor diffusion

Predominantly Heating Climates | **Predominantly Cooling Climates**



Vapor Barrier

Vapor Barrier

Vapor Barrier on the side w/ higher water vapor concentration

2005 NBC – Vapor Barrier Requirements

9.25.4.2.Vapour Barrier Materials

..vapour barriers shall have a permeance **not greater than 60 ng/Pa•s•m^2 (1 Perm)** measured in accordance with ASTM E 96/E 96M, “Water Vapor Transmission of Materials,” using the desiccant method (dry cup).

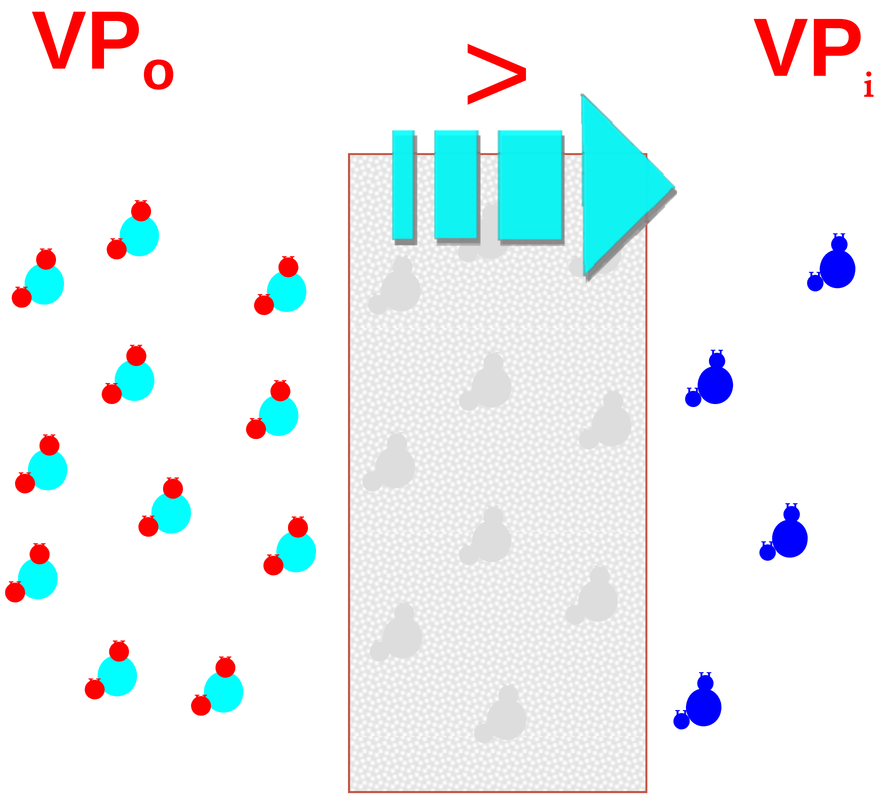
9.25.4.3.Installation of Vapour Barriers

1) Vapour barriers shall be installed to protect the entire surfaces of thermally insulated wall, ceiling and floor assemblies.
2) Vapour barriers shall be installed sufficiently close **to the warm side of insulation** to prevent condensation at design conditions.

1 Perm ~ 57. 22 ng/Pa•s•m2

Water Vapor Diffusion *versus* Air Transported Moisture

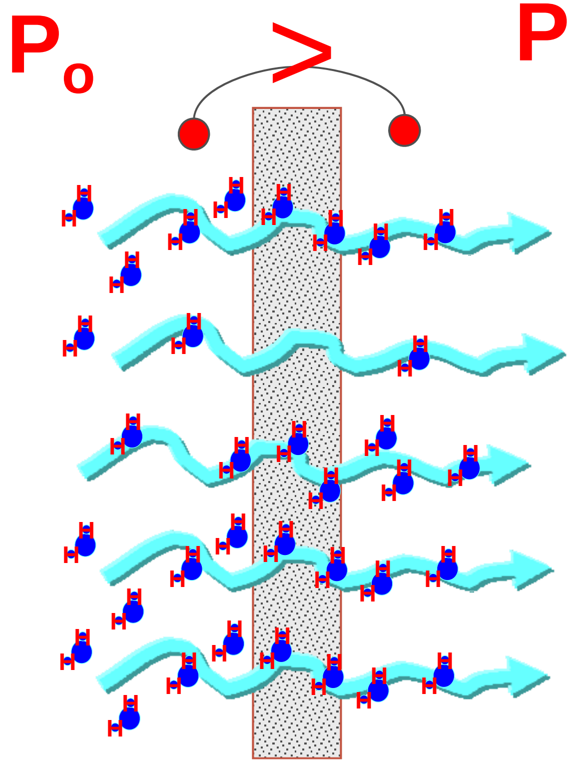
Water Vapor Diffusion



$VP_o > VP_i$

~ 2% of all water vapor migration

Air Transported Moisture



$P_o > P_i$

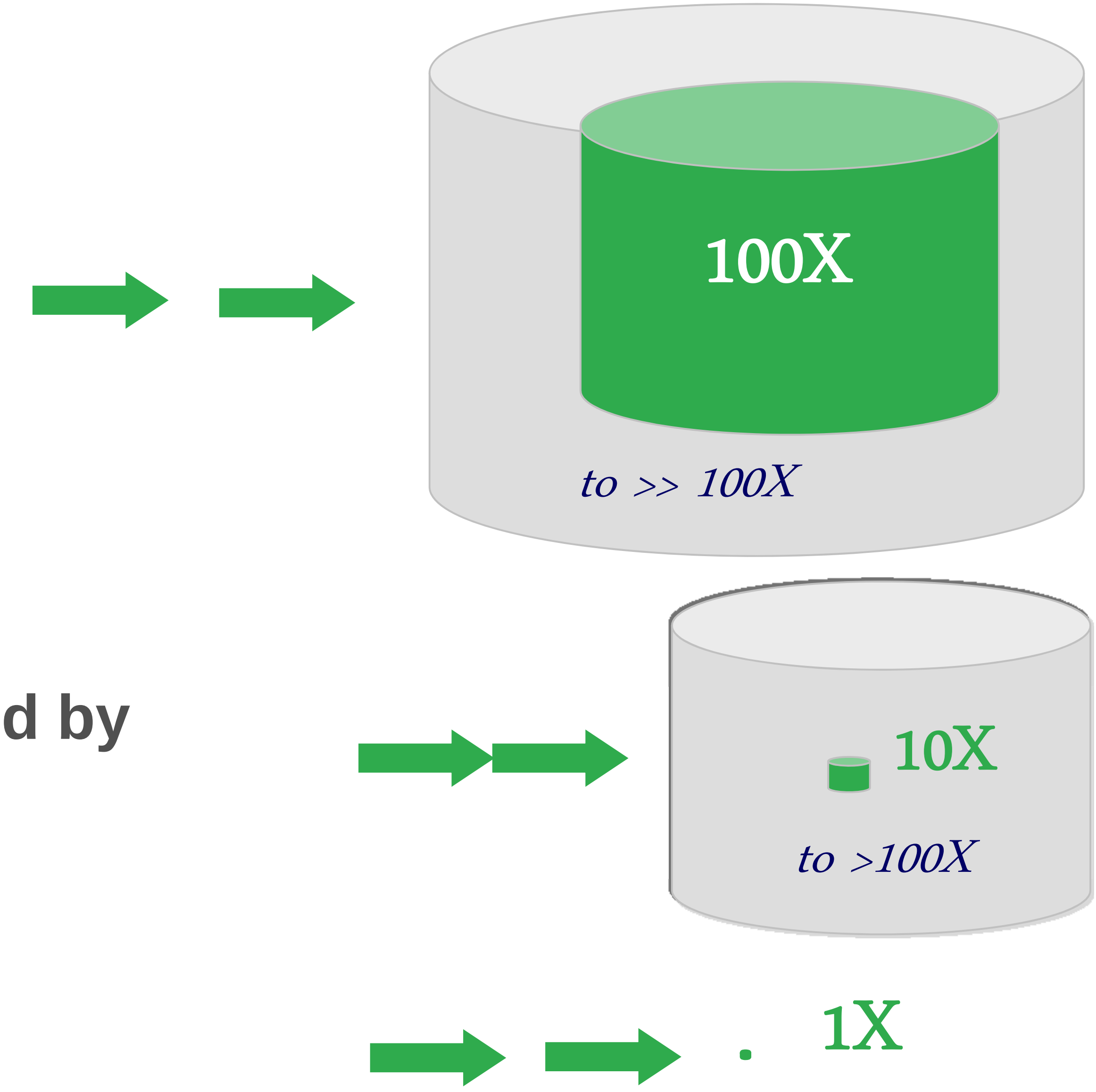
98% of all water vapor migration

Summary: Moisture Transport in Buildings

1 **Liquid** water

2 **Vapor** transported by air currents

3 **Vapor** diffusion



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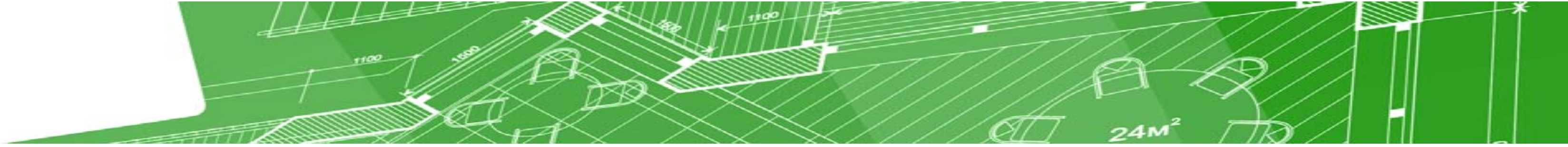


Quiz #3

What is the major moisture source for above grade envelope:

- Vapor Diffusion
- [✓ Rain/Bulk water]
- Air Transported Moisture

Quiz #4

Which of the following control layers should be located on the warm side of insulation?

___ Water Barriers

___ Air Barriers

✓___ Vapor Barriers

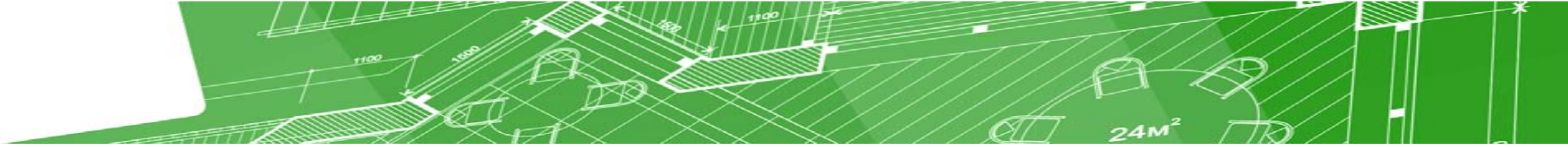
Quiz #5

What is the major source of water vapor in the building enclosure?

2% ___ Vapor Diffusion

98% ✓___ Air Transported Moisture

___ Equal contribution of the 2



Quiz # 6

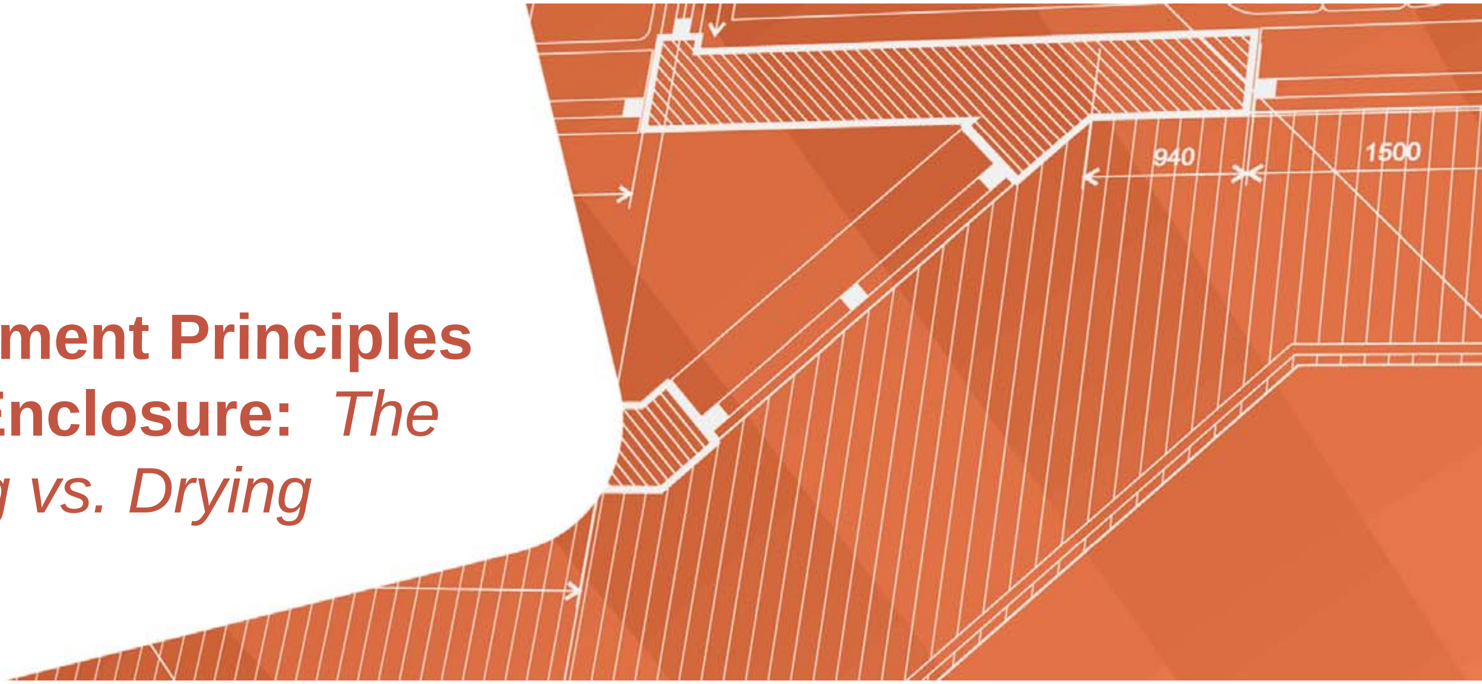
Vapor permeable materials allow:

___ **Liquid water**

✓___ **Water Vapor**

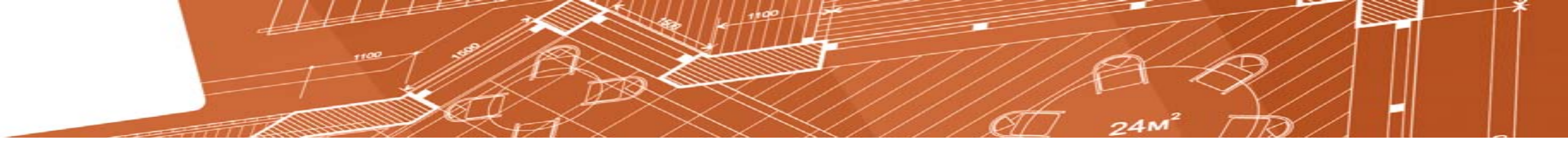
___ **Airflow**

…..to pass through

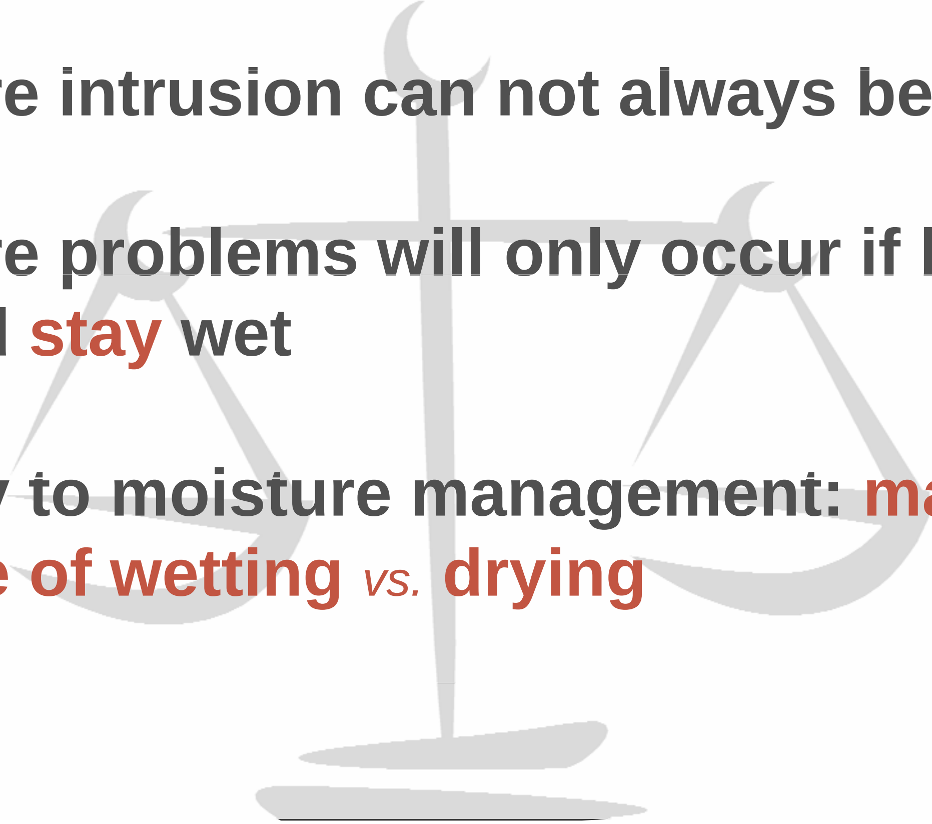


Section 2

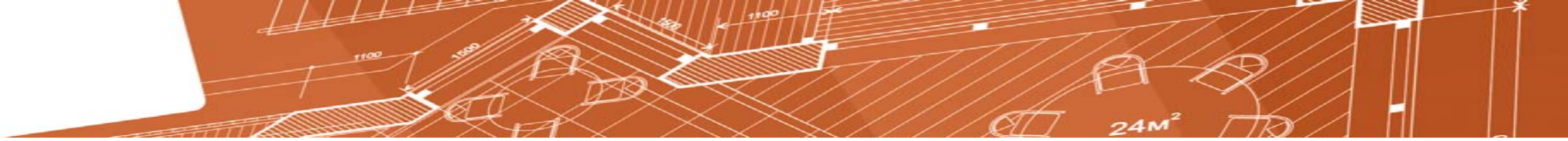
Moisture Management Principles for the Building Enclosure: *The Balance of Wetting vs. Drying*



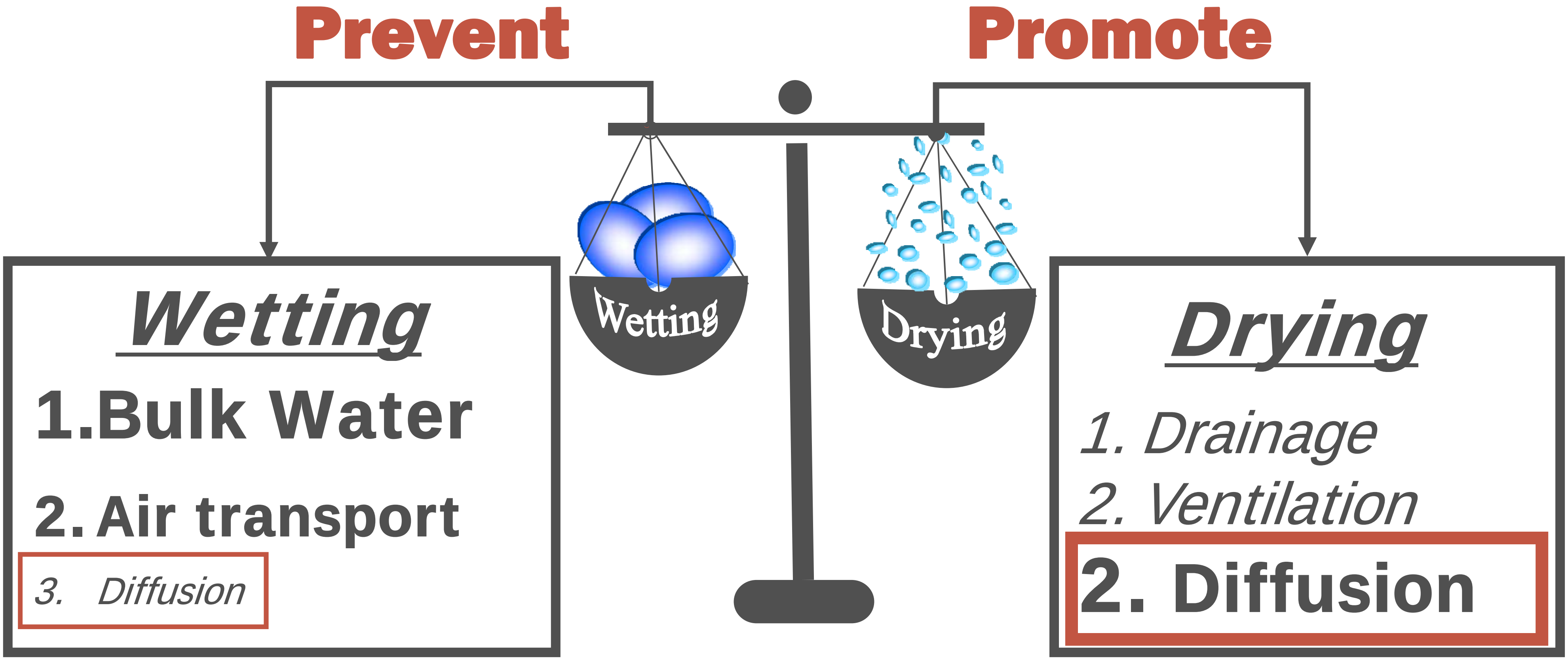
Moisture Management Principles:
Balance of Wetting vs. Drying



- **Moisture intrusion can not always be avoided**
- **Moisture problems will only occur if buildings get wet and stay wet**
- **The key to moisture management: manage the balance of wetting *vs.* drying**



The Balance of Wetting & Drying



Prevent

Promote

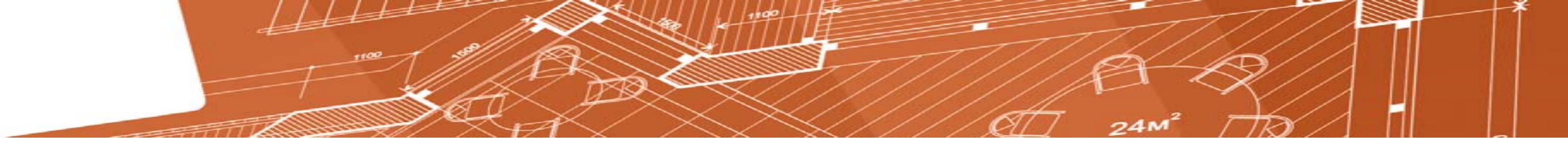
Wetting

1. **Bulk Water**
2. **Air transport**
3. *Diffusion*

Drying

1. *Drainage*
2. *Ventilation*
2. **Diffusion**

Dual Role of Diffusion: Wetting & Drying



Dual Role of Diffusion

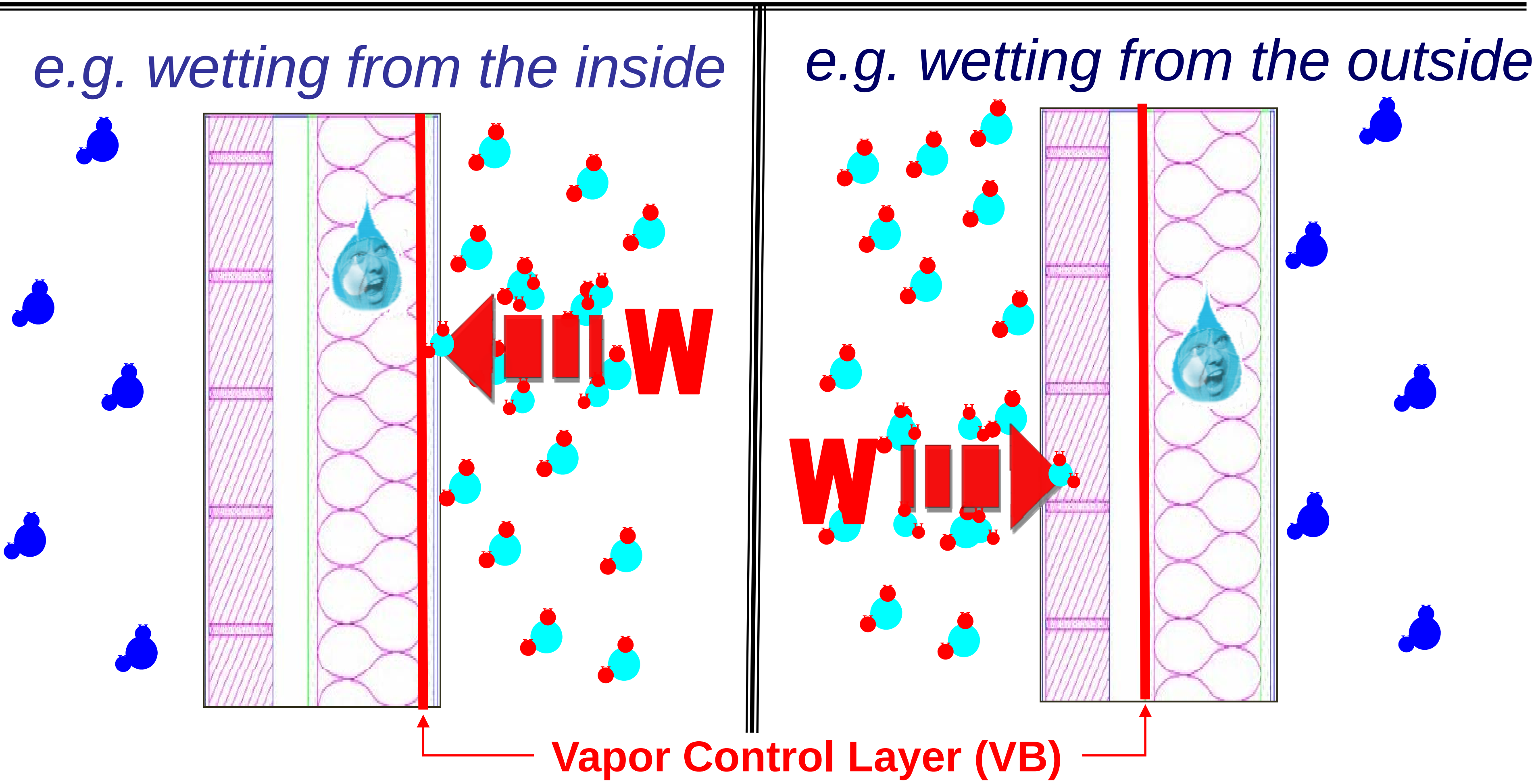
….. increased airtightness must be matched by an *appropriate ventilation system* to dilute pollutants, provide fresh air, and control cold weather humidity levels. Good airflow control through and within the building enclosure will bring many benefits: reduce moisture damage, energy savings, and increased health and comfort. However, *while airflow usually causes wetting in enclosures, it also can be a powerful drying mechanism*. Therefore, ***enclosures with increased air flow control demand greater attention to other sources of drying (diffusion is the only practical mechanism available)*** and the reduction or elimination of other sources of wetting (built-in, rain and diffusion).

Source: Air Flow Control in Buildings, John Straube -- Building Science Digest 014: last updated 2009/10/14

When is Diffusion "Bad"?

When it contributes to **Wetting:**

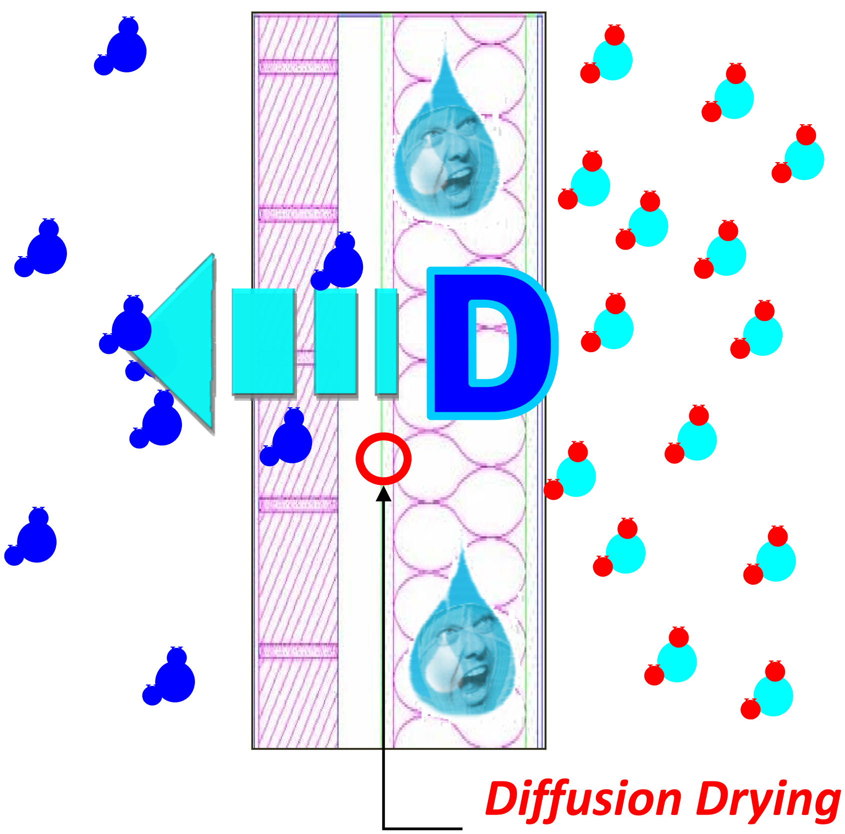
e.g. **Diffusion into the wall cavity**



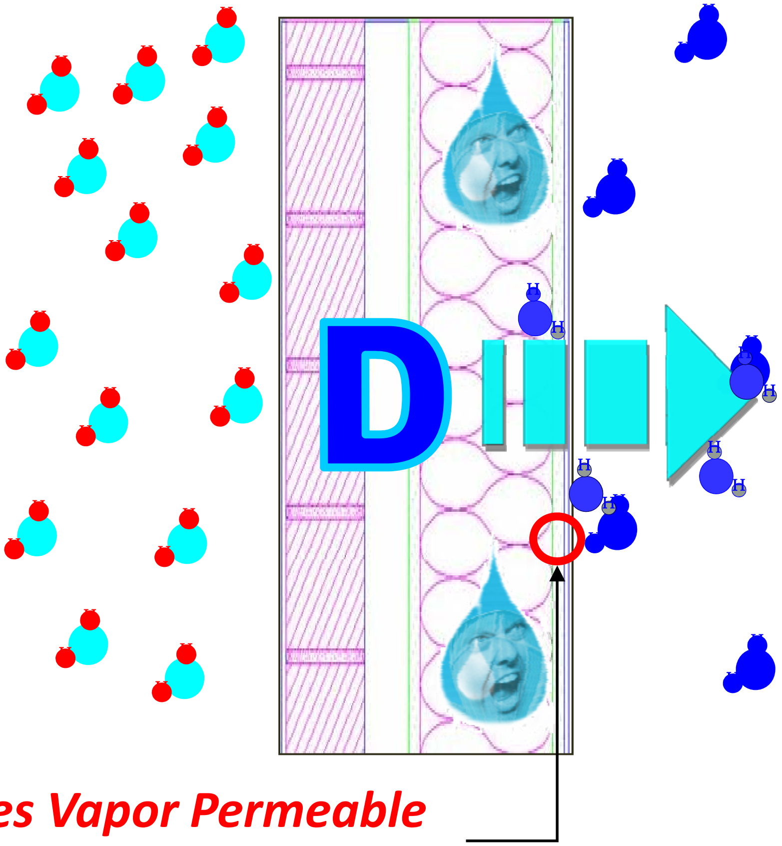
When is Diffusion "Good"?

When it contributes to **Drying** : Diffusion out of the wall cavity

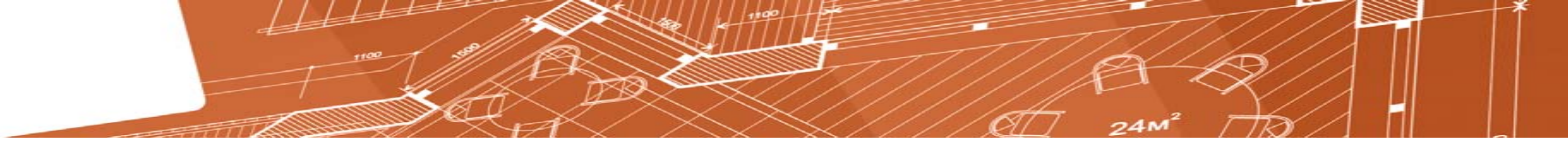
e.g. drying to outside



e.g. drying to inside



Diffusion Drying Requires Vapor Permeable Materials in the preferred drying direction



Quiz # 7

Which of the following materials would allow more vapor diffusion?

____ 5 Perms (286 Ng/Pa.s.m^2)

____ 10 Perms (572 Ng/Pa.s.m^2)

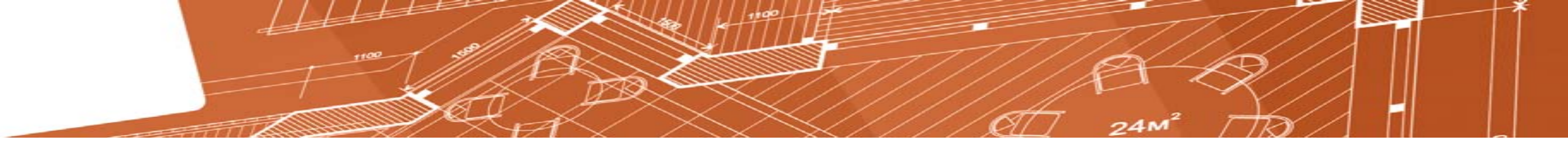
✓ 30 Perms (1717 Ng/Pa.s.m^2)

The higher the Perms, the higher the vapor permeability → more diffusion

Quiz # 8

When is Diffusion *Bad?*

- In cold climates
- In hot climates
- ✓ When it contributes to wetting



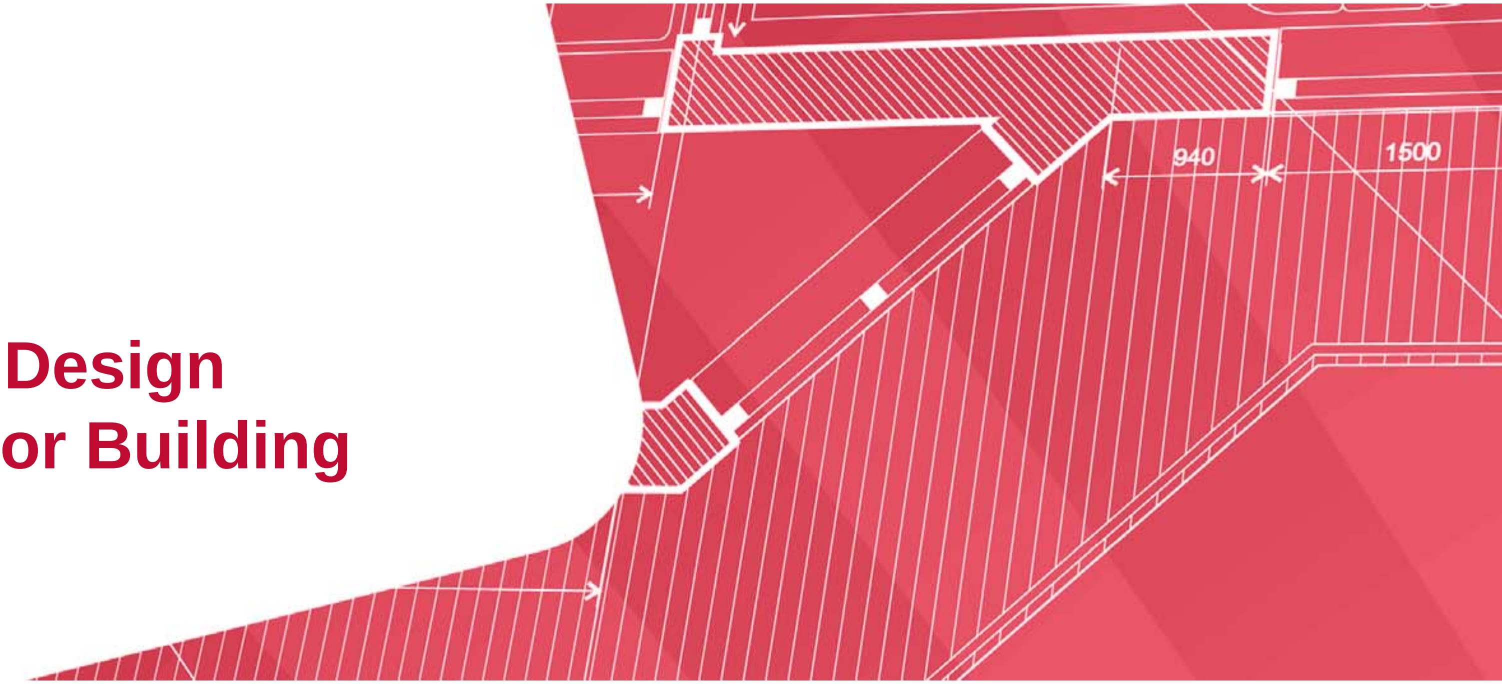
Quiz # 9

When is Diffusion *Good?*

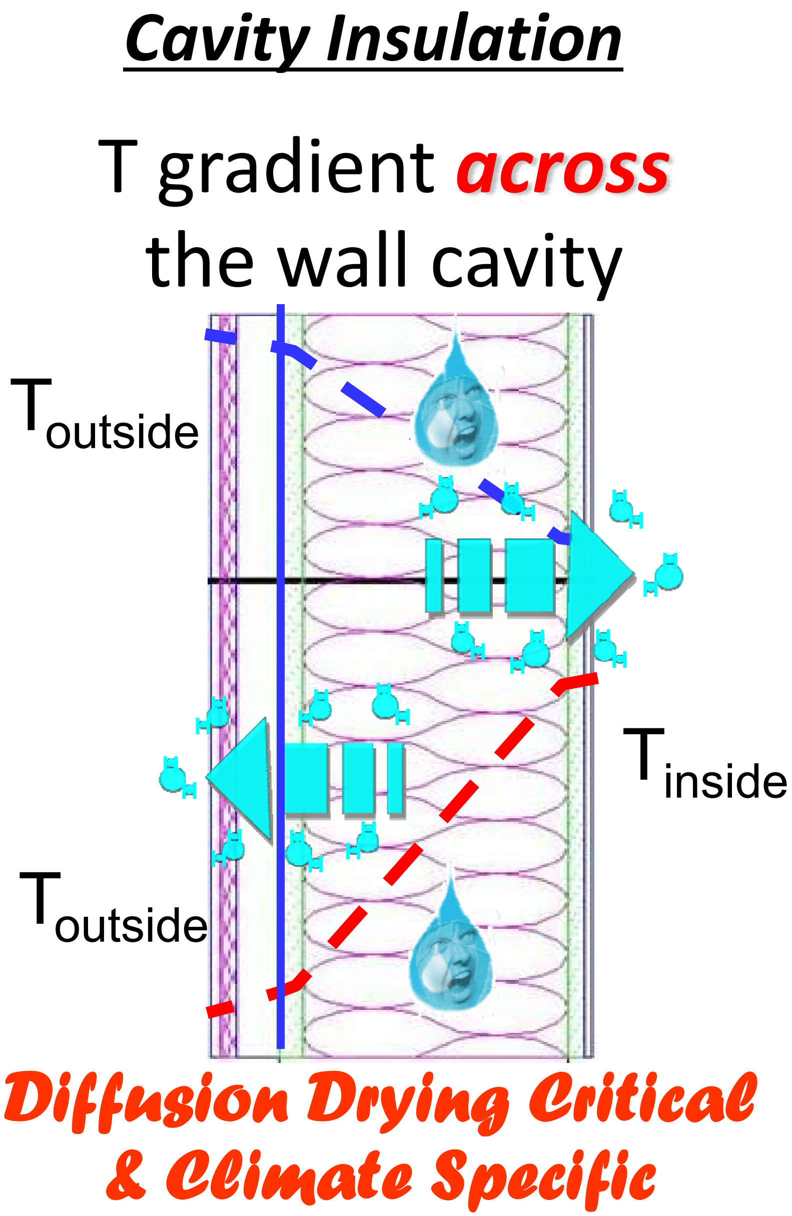
- ✓ When it contributes to drying
- When it occurs from the ***inside to the outside***
- When it occurs from the ***outside to the inside***

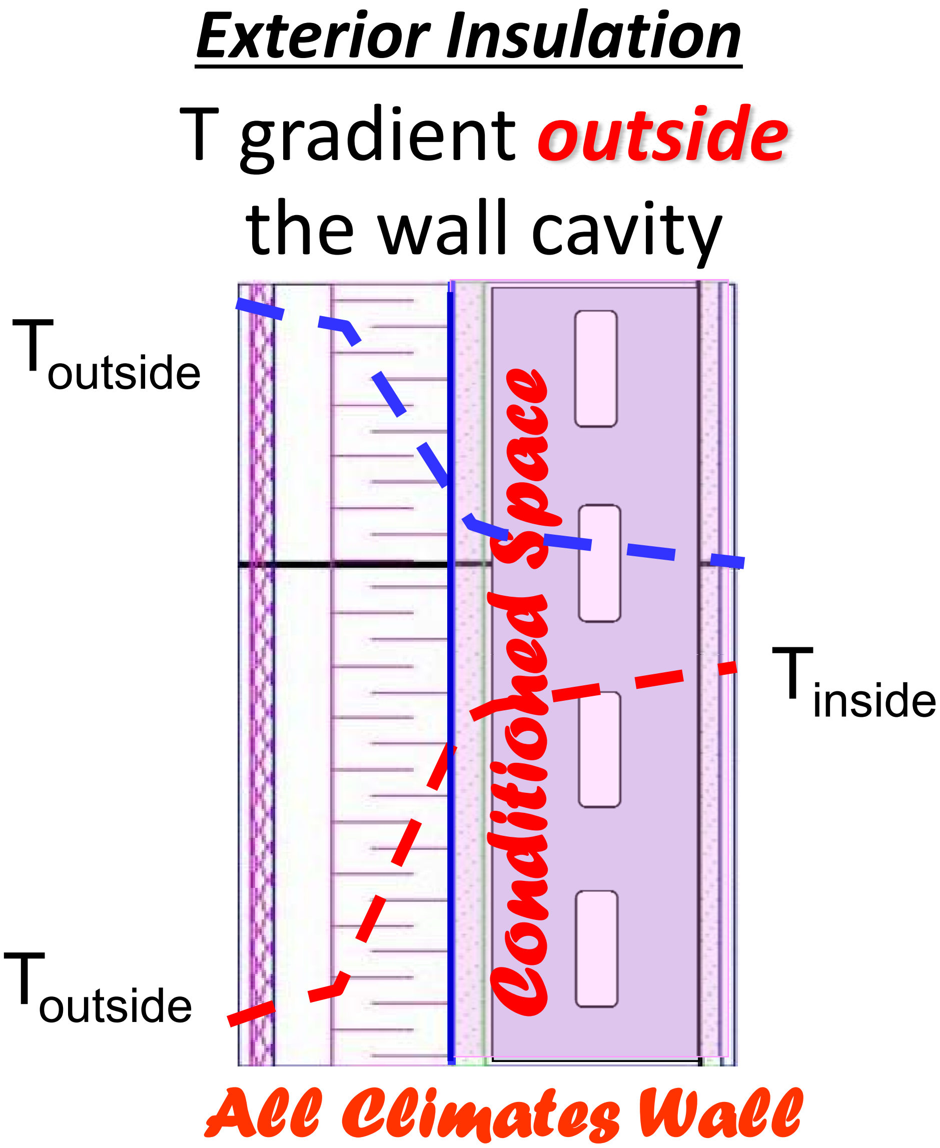
Section 3

Climate-specific Design Considerations for Building Enclosure

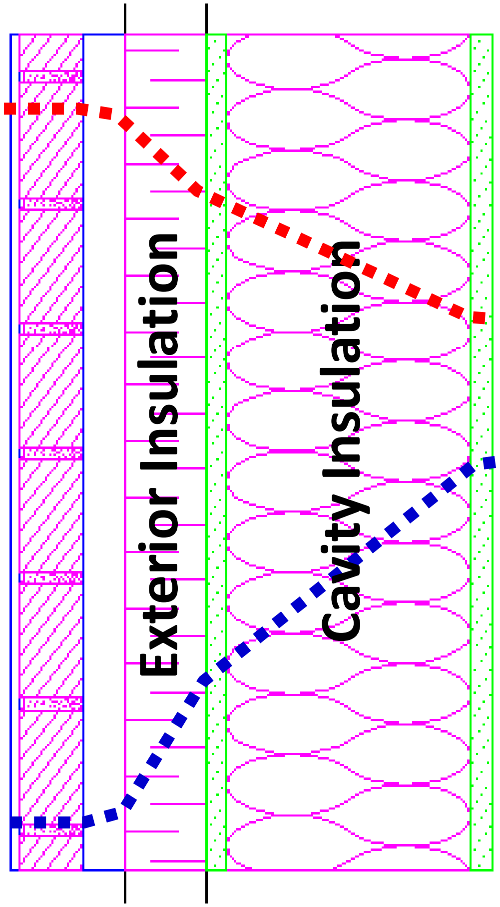


Wall Design and Climate Needs



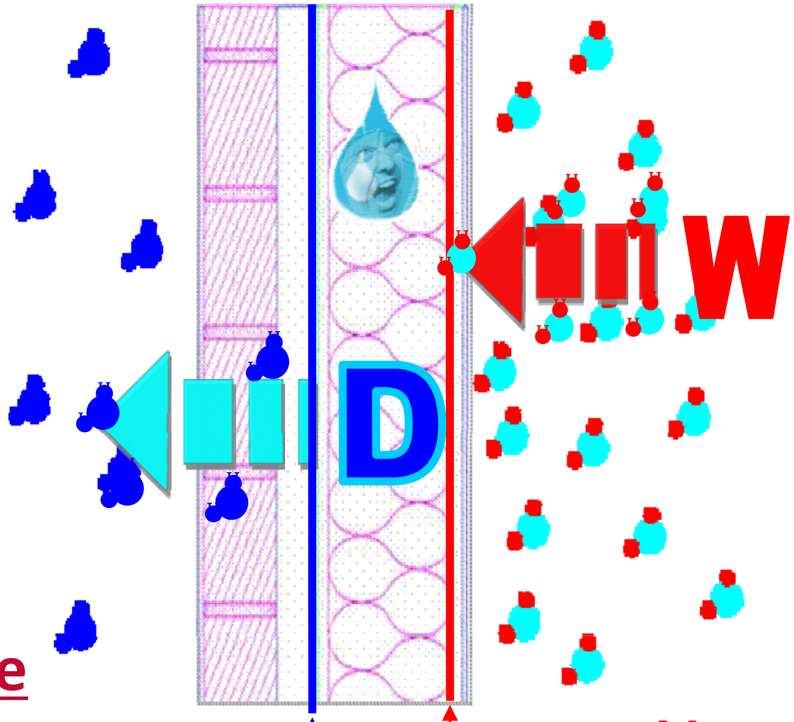


"Hybrid" **Wall Design: Exterior & Cavity Insulation**



- General moisture management principles – similar to cavity insulation walls
- Additional attention must be paid to potential for double vapor barrier:
  - Choice of exterior insulation and other exterior envelope components

Moisture Managed Envelope Design: Cold Climates



Lower *Vapor Pressure side*

Higher *Vapor Pressure side*

Drying to Outside

Wetting from inside

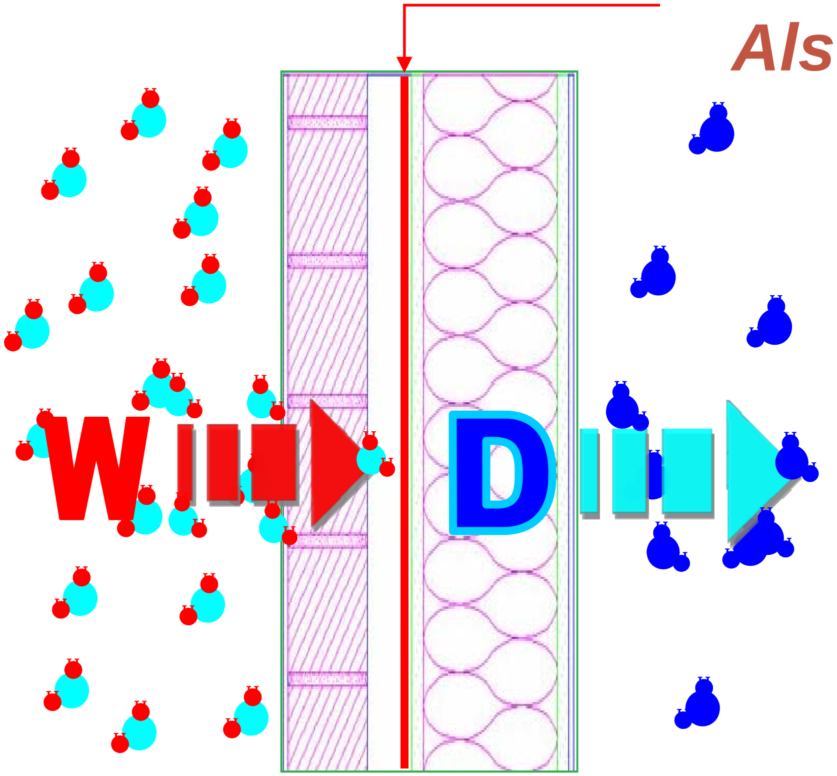
Vapor Permeable

Air & Water Barrier

Vapor Barrier: Prevent Wetting

- ☑ **Vapor Barriers Inside:** *Prevent Wetting*
- ☑ **Vapor Permeable Materials Outside:** *Allow Drying*

Moisture Managed Envelope Design: *Hot & Humid Climates*



Air and Water Barrier
Also Vapor Barrier

***Higher** Vapor*
Pressure side

***Lower** Vapor*
Pressure side

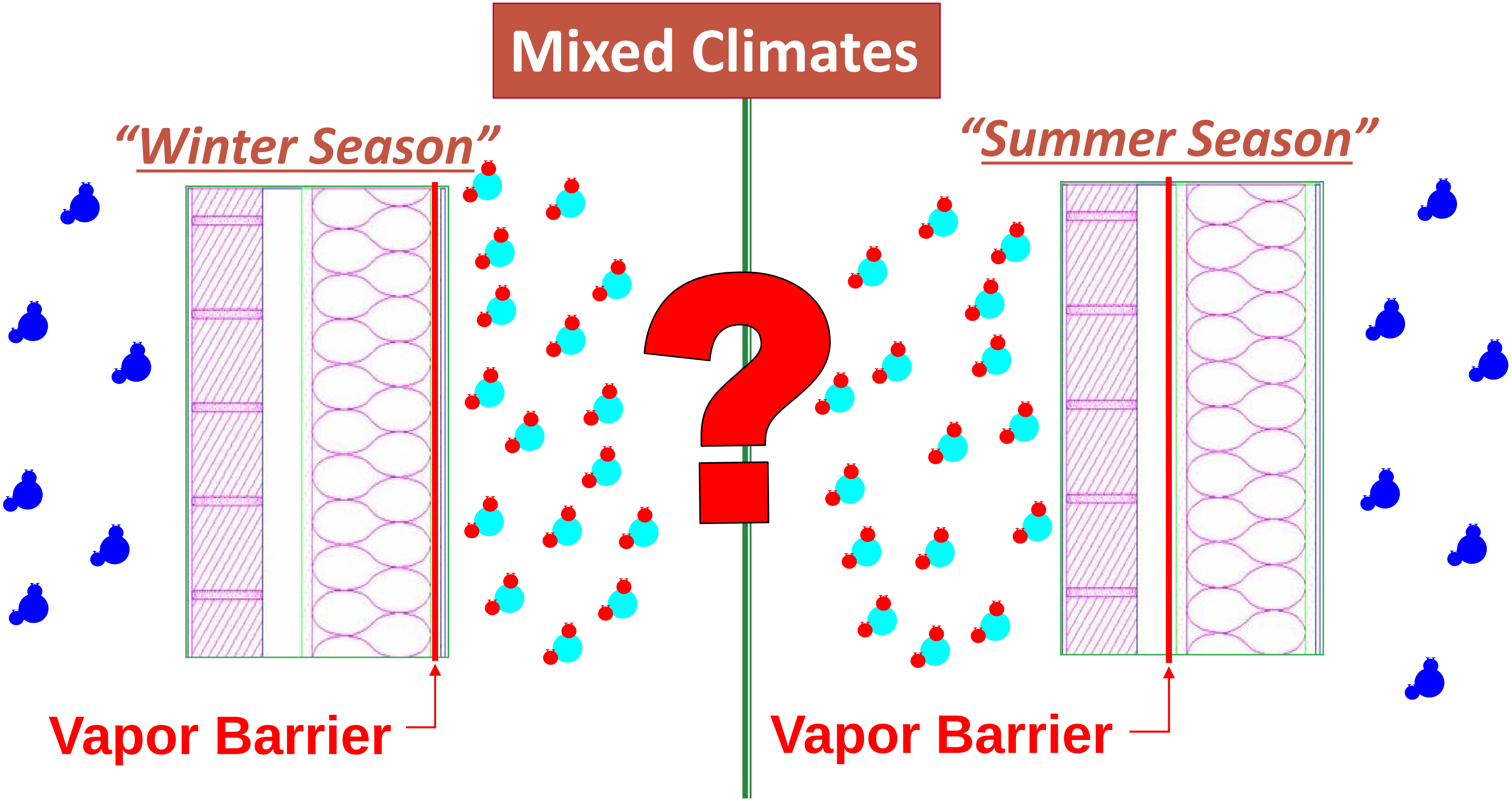
Wetting from outside

Drying to Inside

(e.g. ZONE 1)

- ☑ **Vapor Barrier Outside:** *Prevent Wetting*
- ☑ **Vapor Permeable Materials Inside:** *Allow Drying*

Moisture Managed Envelope Design: *Mixed Humid Climates*



Mixed Climates

"Winter Season"

"Summer Season"

Vapor Barrier

Vapor Barrier

Vapor Barriers should be avoided in mixed climates

International Climate Zone Definitions – ASHRAE 90.1

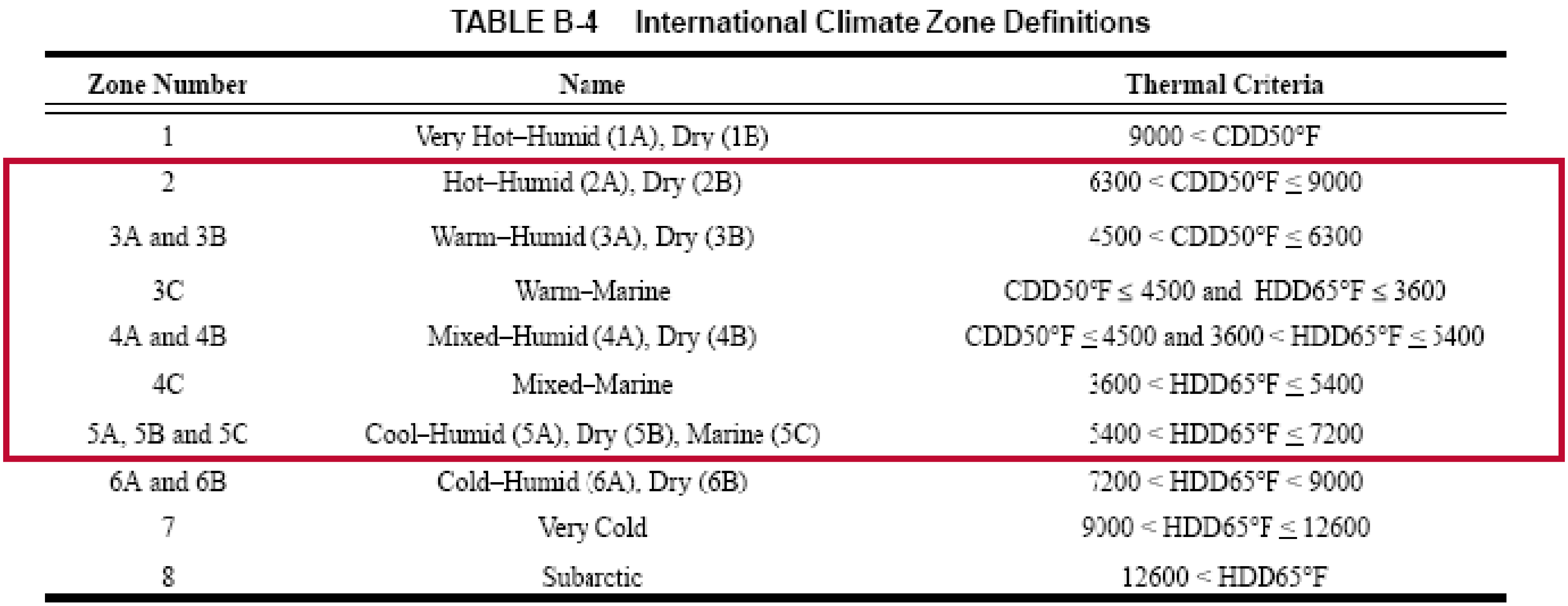
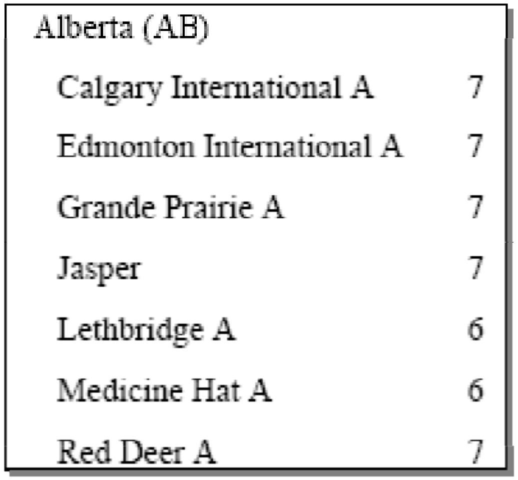


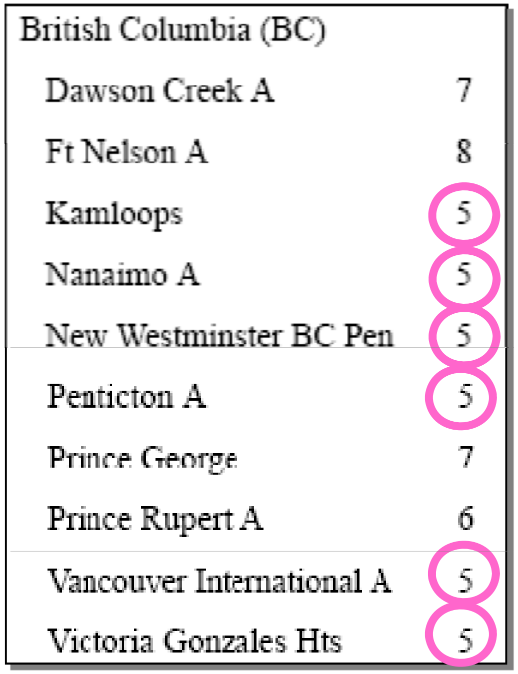
TABLE B-4 International Climate Zone Definitions

Zone Number	Name	Thermal Criteria
1	Very Hot–Humid (1A), Dry (1B)	9000 < CDD50°F
2	Hot–Humid (2A), Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm–Humid (3A), Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm–Marine	CDD50°F ≤ 4500 and HDD65°F ≤ 3600
4A and 4B	Mixed–Humid (4A), Dry (4B)	CDD50°F ≤ 4500 and 3600 < HDD65°F ≤ 5400
4C	Mixed–Marine	3600 < HDD65°F ≤ 5400
5A, 5B and 5C	Cool–Humid (5A), Dry (5B), Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold–Humid (6A), Dry (6B)	7200 < HDD65°F < 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

Canadian Climate Zones: 5, 6, 7 8 (ASHRAE 90.1)



Alberta (AB)	
Calgary International A	7
Edmonton International A	7
Grande Prairie A	7
Jasper	7
Lethbridge A	6
Medicine Hat A	6
Red Deer A	7



British Columbia (BC)	
Dawson Creek A	7
Ft Nelson A	8
Kamloops	5
Nanaimo A	5
New Westminster BC Pen	5
Penticton A	5
Prince George	7
Prince Rupert A	6
Vancouver International A	5
Victoria Gonzales Hts	5

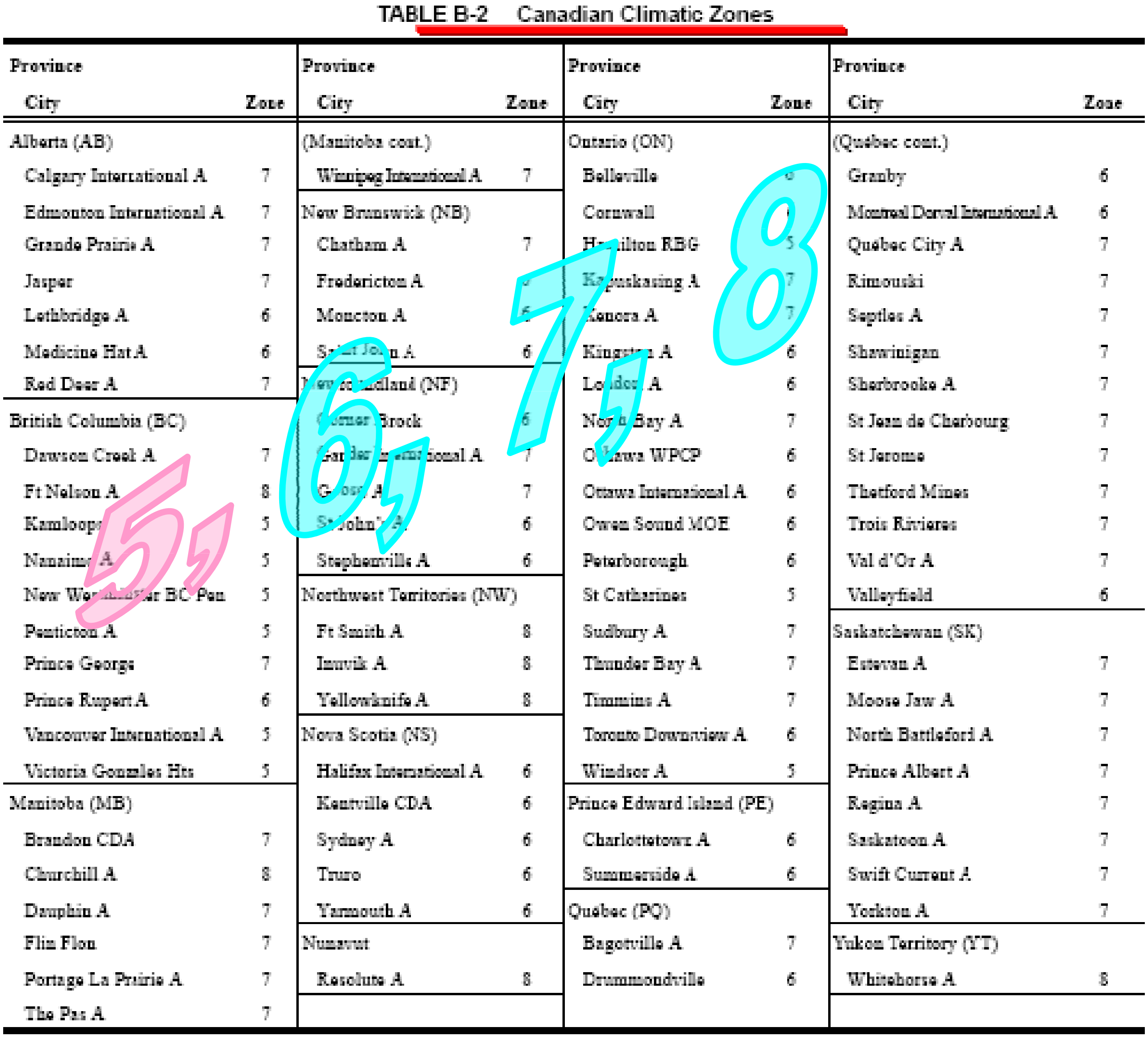
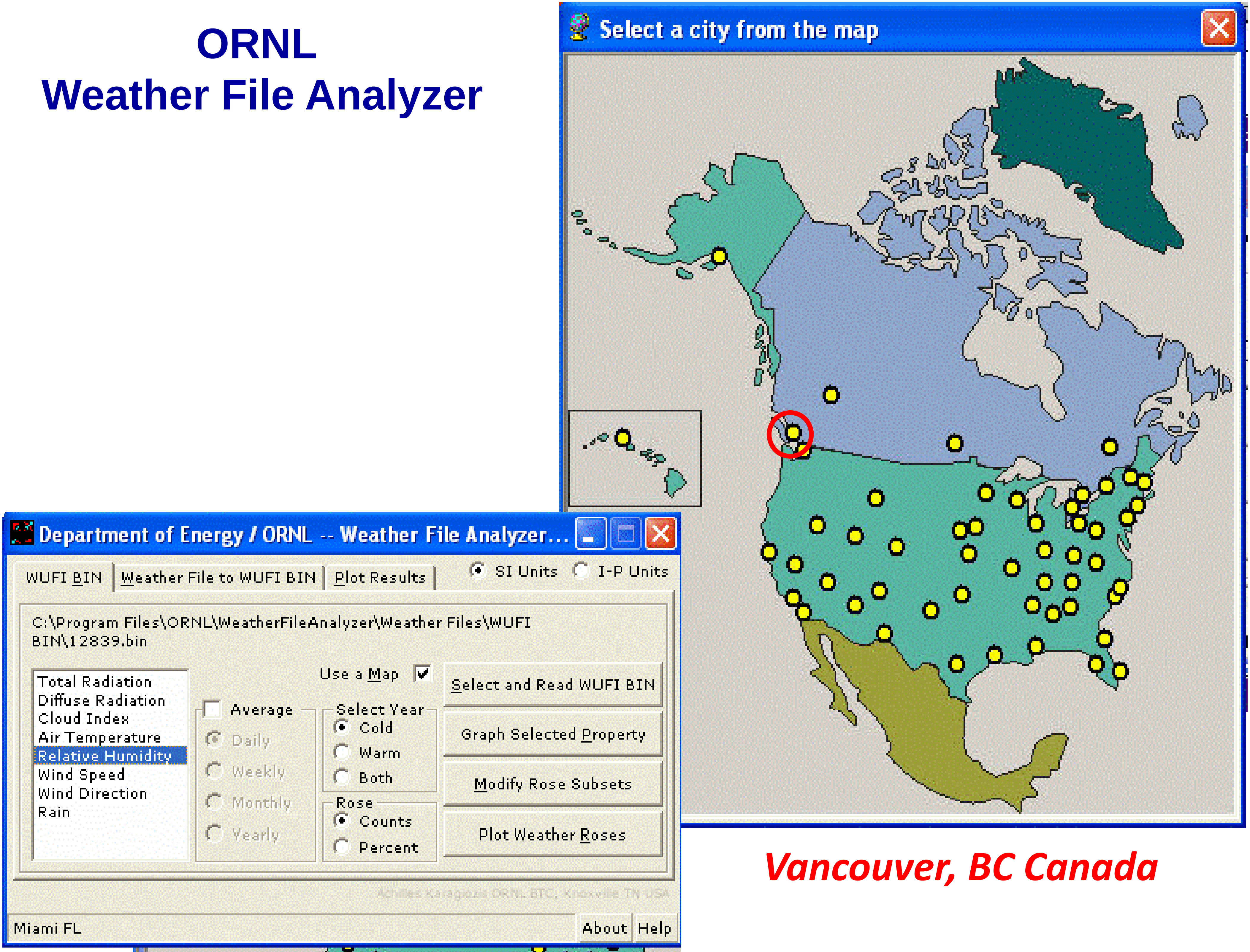


TABLE B-2 Canadian Climatic Zones

Province City	Zone
Alberta (AB)	
Calgary International A	7
Edmonton International A	7
Grande Prairie A	7
Jasper	7
Lethbridge A	6
Medicine Hat A	6
Red Deer A	7
British Columbia (BC)	
Dawson Creek A	7
Ft Nelson A	8
Kamloops	5
Nanaimo A	5
New Westminster BC Pen	5
Penticton A	5
Prince George	7
Prince Rupert A	6
Vancouver International A	5
Victoria Gonzales Hts	5
Manitoba (MB)	
Brandon CDA	7
Churchill A	8
Dauphin A	7
Flin Flon	7
Portage La Prairie A	7
The Pas A	7
(Manitoba cont.)	
Winnipeg International A	7
New Brunswick (NB)	
Chatham A	7
Fredericton A	7
Moncton A	6
Saint John A	6
Newfoundland (NF)	
Corner Brook	6
Gander International A	7
Goose A	7
St John's A	6
Stephenville A	6
Northwest Territories (NW)	
Ft Smith A	8
Inuvik A	8
Yellowknife A	8
Nova Scotia (NS)	
Halifax International A	6
Kentville CDA	6
Sydney A	6
Truro	6
Yarmouth A	6
Nunavut	
Resolute A	8
Ontario (ON)	
Belleville	6
Cornwall	6
Hamilton RBG	5
Kapuskasing A	7
Kenora A	7
Kingston A	6
London A	6
North Bay A	7
Oshawa WPCP	6
Ottawa International A	6
Owen Sound MOE	6
Peterborough	6
St Catharines	5
Sudbury A	7
Thunder Bay A	7
Timmins A	7
Toronto Downview A	6
Windsor A	5
Prince Edward Island (PE)	
Charlottetown A	6
Summerside A	6
Québec (PQ)	
Bagotville A	7
Drummondville	6
(Québec cont.)	
Granby	6
Montreal Dorval International A	6
Québec City A	7
Rimouski	7
Septles A	7
Shawinigan	7
Sherbrooke A	7
St Jean de Cherbourg	7
St Jerome	7
Thetford Mines	7
Trois Rivieres	7
Val d'Or A	7
Valleyfield	6
Saskatchewan (SK)	
Estevan A	7
Moose Jaw A	7
North Battleford A	7
Prince Albert A	7
Regina A	7
Saskatoon A	7
Swift Current A	7
Yorkton A	7
Yukon Territory (YT)	
Whitehorse A	8

ORNL
Weather File Analyzer



Select a city from the map

Department of Energy / ORNL -- Weather File Analyzer...

WUFI BIN | Weather File to WUFI BIN | Plot Results

● SI Units ○ I-P Units

C:\Program Files\ORNL\WeatherFileAnalyzer\Weather Files\WUFI BIN\12839.bin

- Total Radiation
- Diffuse Radiation
- Cloud Index
- Air Temperature
- Relative Humidity
- Wind Speed
- Wind Direction
- Rain

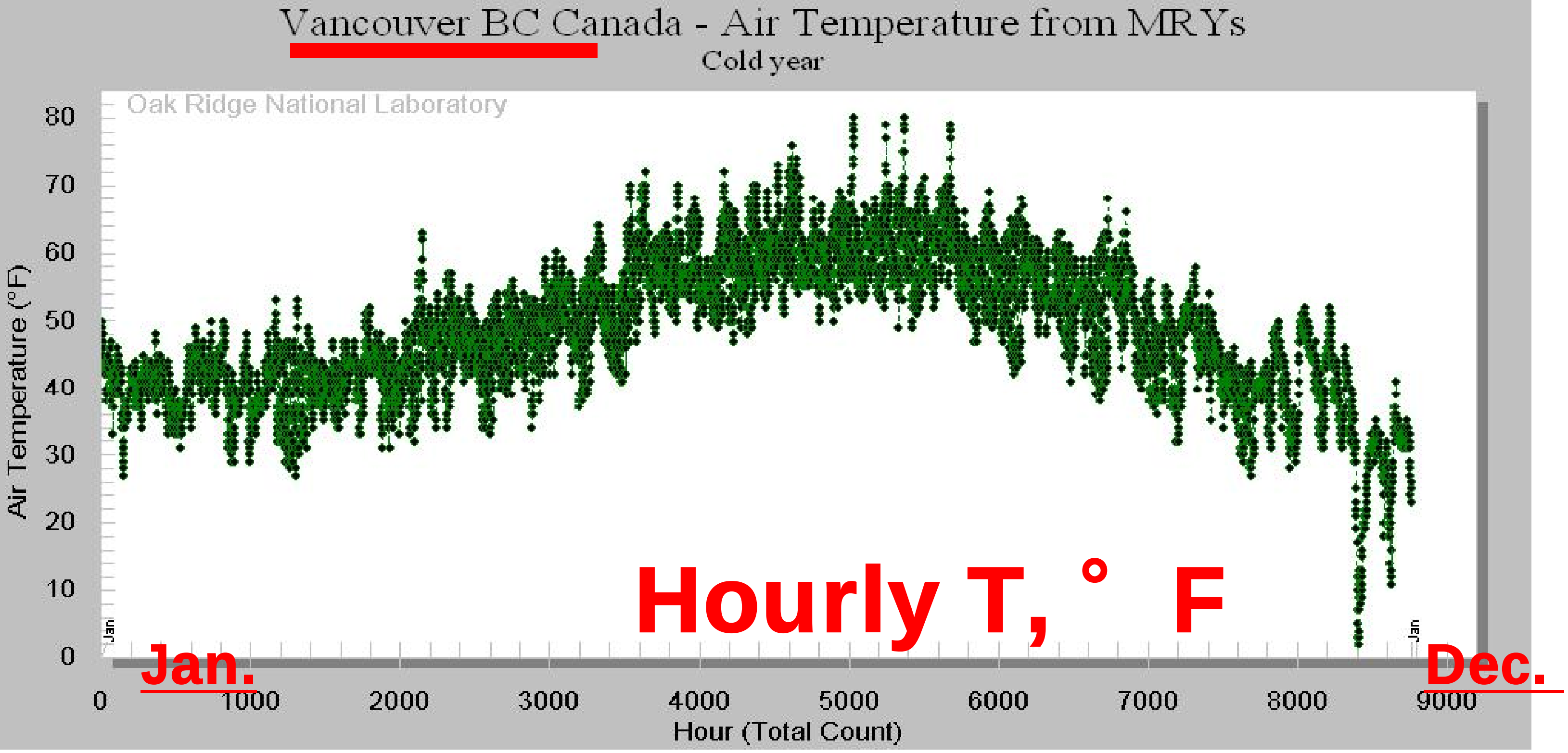
Use a Map ☑

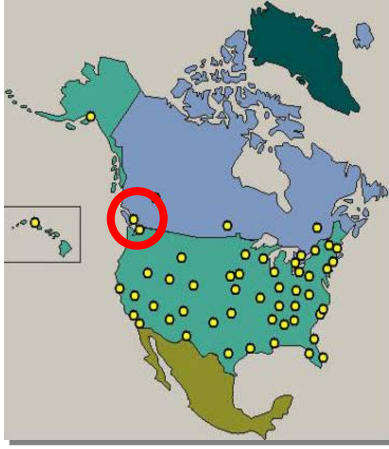
☐ Average
- ● Daily
- ○ Weekly
- ○ Monthly
- ○ Yearly

Select Year
- ● Cold
- ○ Warm
- ○ Both

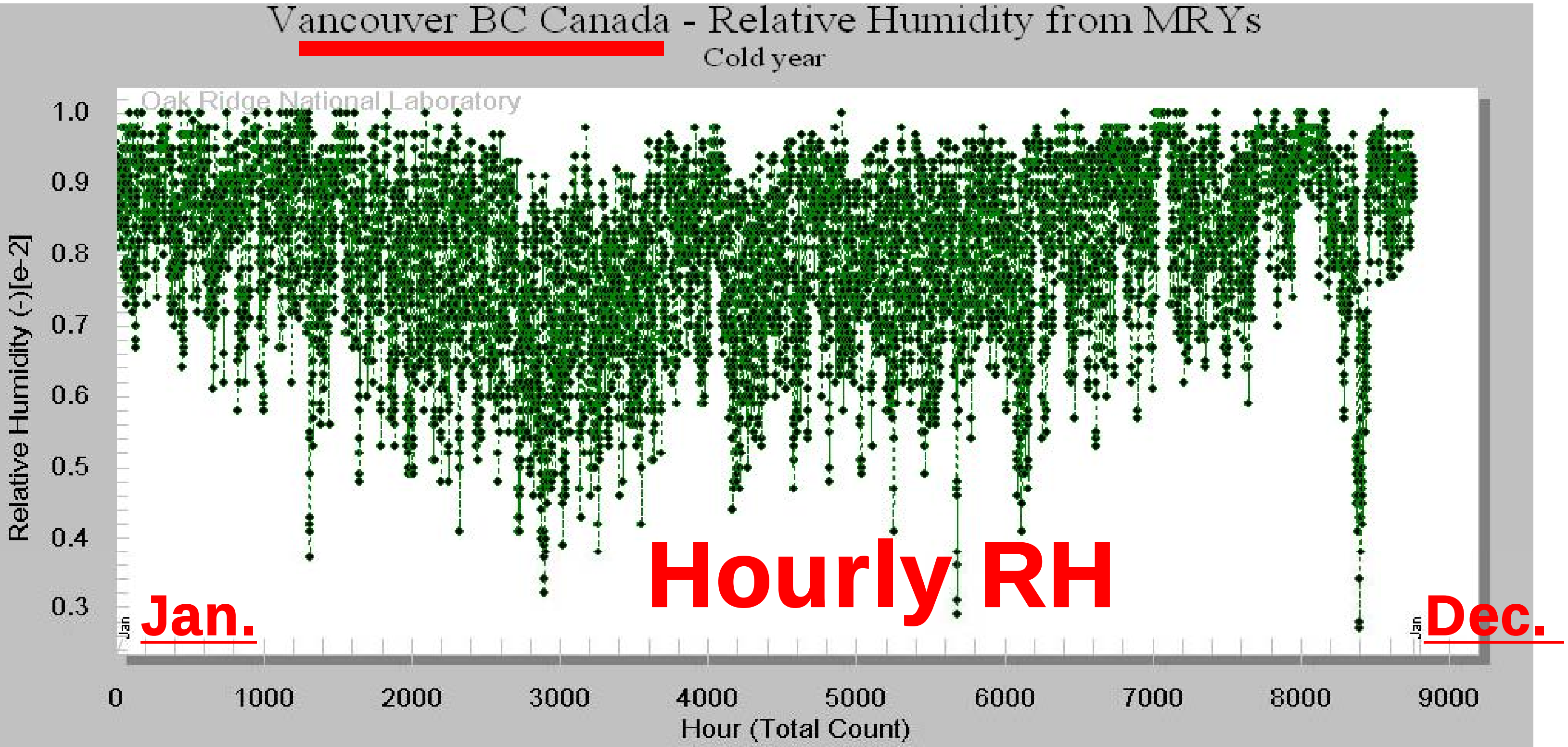
Rose
- ● Counts
- ○ Percent

Vancouver, BC Canada

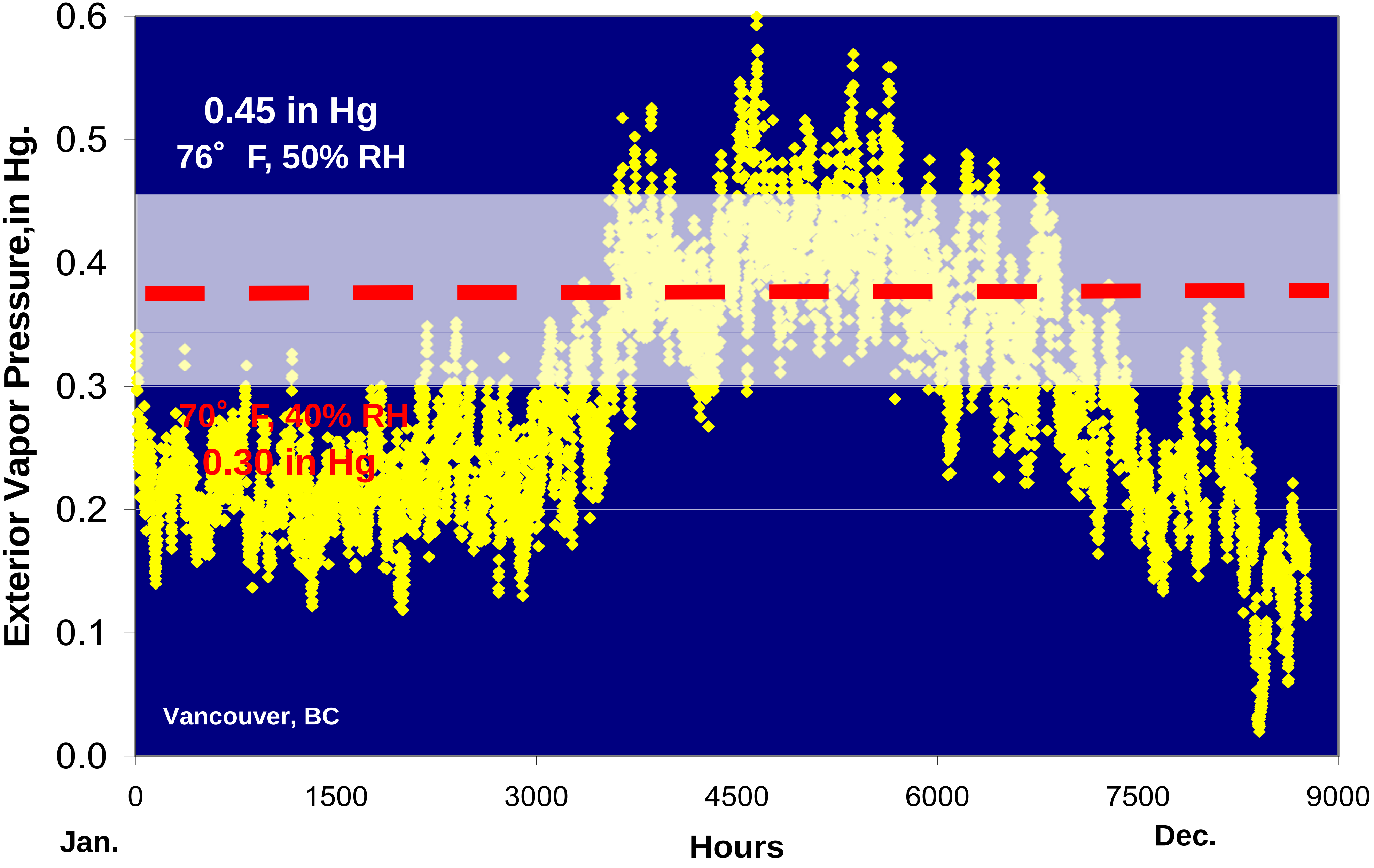




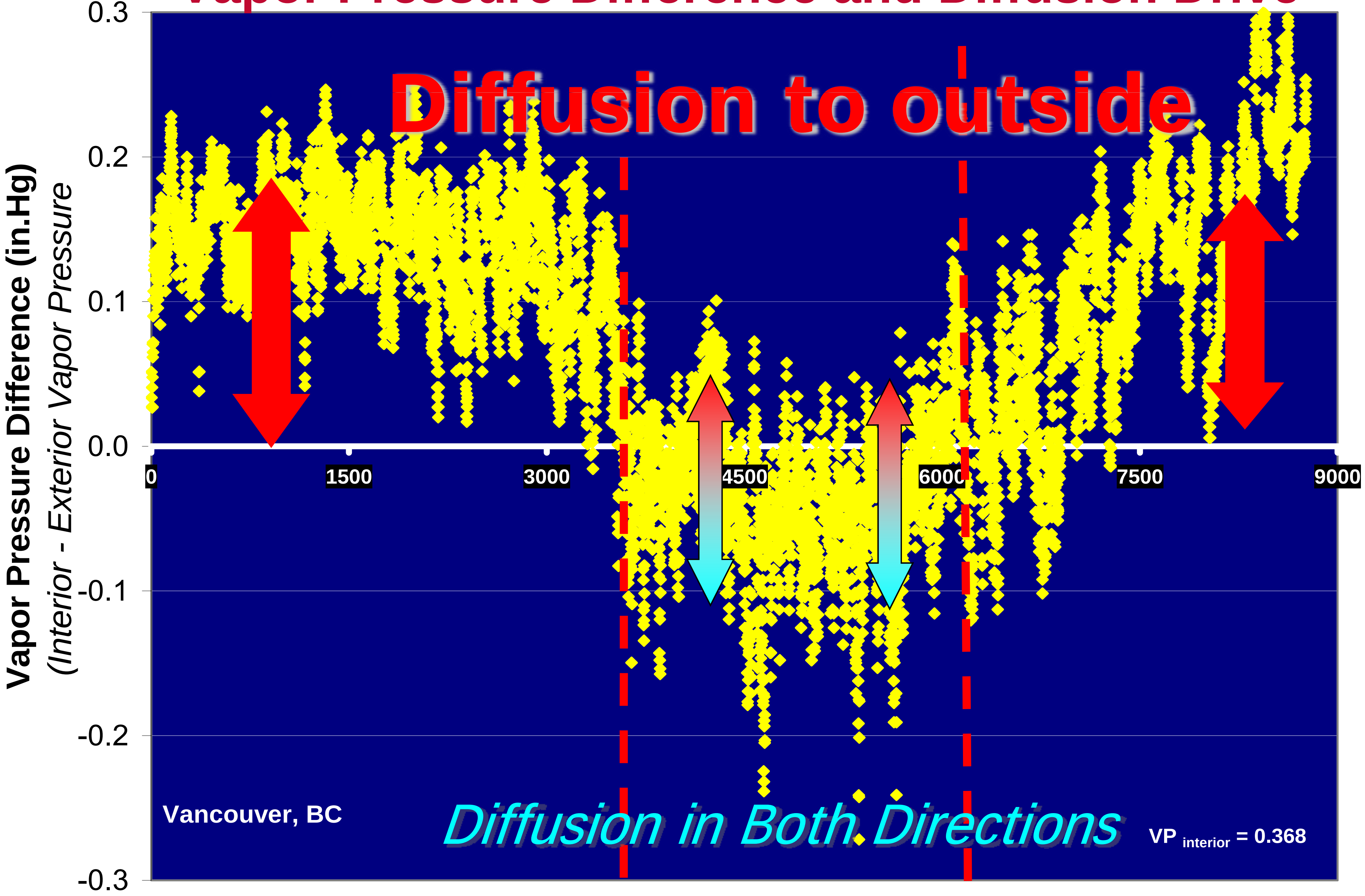
Vapor Pressure



Exterior Vapor Pressure



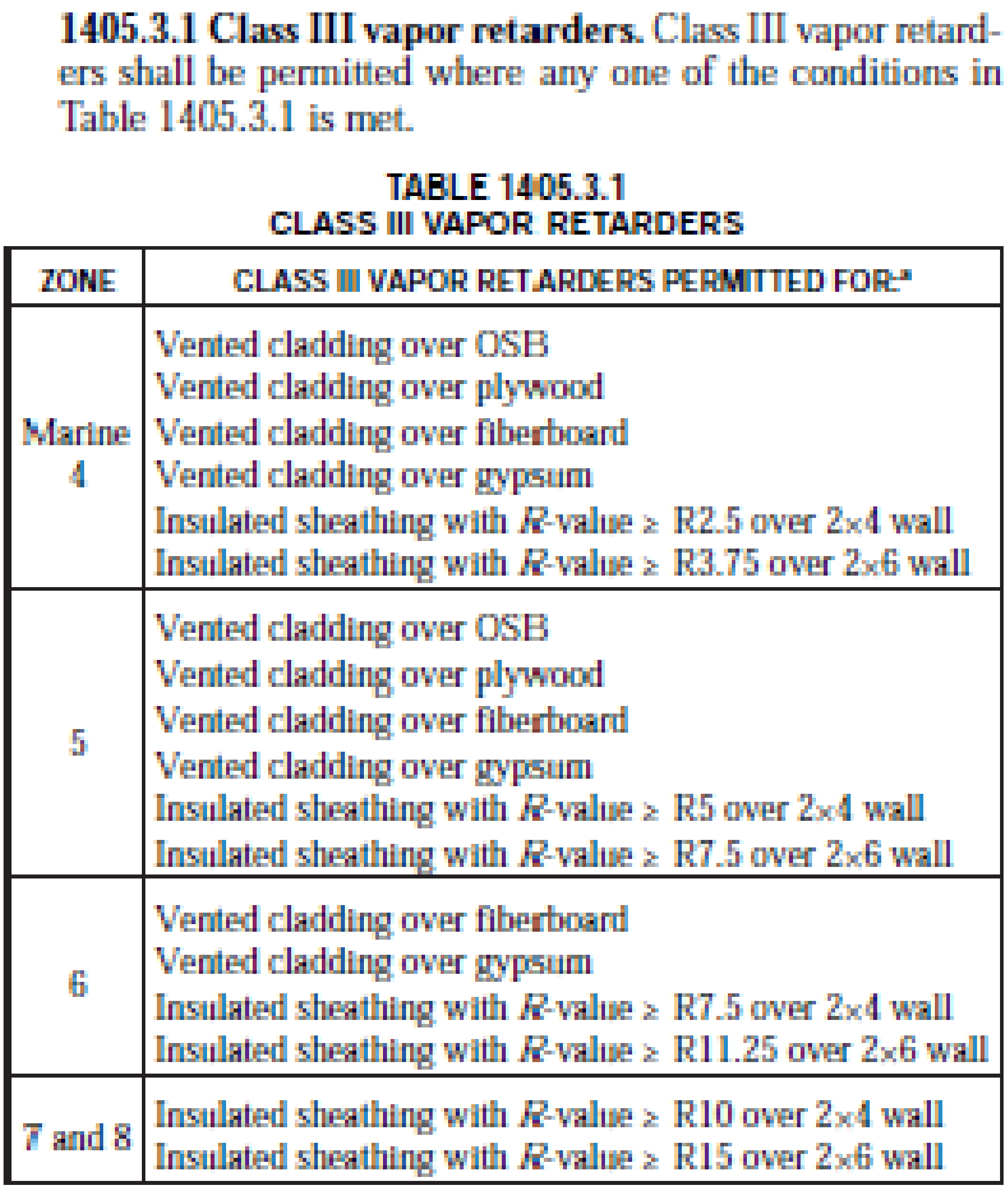
Vapor Pressure Difference and Diffusion Drive



2009 IBC

Section 1405.3: Vapor Retarders

- **Class I:** 0.1 perm or less
- **Class II:** 0.1 < perm ≤ 1.0 perm
- **Class III:** 1.0 < perm ≤ 10 perm



1405.3.1 Class III vapor retarders. Class III vapor retarders shall be permitted where any one of the conditions in Table 1405.3.1 is met.

TABLE 1405.3.1
CLASS III VAPOR RETARDERS

ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a]
Marine 4	Vented cladding over OSB Vented cladding over plywood Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ R2.5 over 2×4 wall Insulated sheathing with *R*-value ≥ R3.75 over 2×6 wall
5	Vented cladding over OSB Vented cladding over plywood Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ R5 over 2×4 wall Insulated sheathing with *R*-value ≥ R7.5 over 2×6 wall
6	Vented cladding over fiberboard Vented cladding over gypsum Insulated sheathing with *R*-value ≥ R7.5 over 2×4 wall Insulated sheathing with *R*-value ≥ R11.25 over 2×6 wall
7 and 8	Insulated sheathing with *R*-value ≥ R10 over 2×4 wall Insulated sheathing with *R*-value ≥ R15 over 2×6 wall

1. Physics of Heat, Air and Moisture Transport *through* the Building Enclosure*: The 4 Control Layers*
2. Moisture Management Principles for the Building Enclosure: *The Balance of Wetting vs. Drying*
3. Climate-specific Design Considerations for Building Enclosure
4. **Condensation Analysis Tools**

Section 4

Condensation Analysis Tools

Condensation Analysis Tools

- **Steady-state calculations:** e.g. Dew Point Analysis
- **Transient Modeling Tools: e.g. WUFI** (Wärme Und Feuchte Instationär *or* Transient Heat and Moisture)

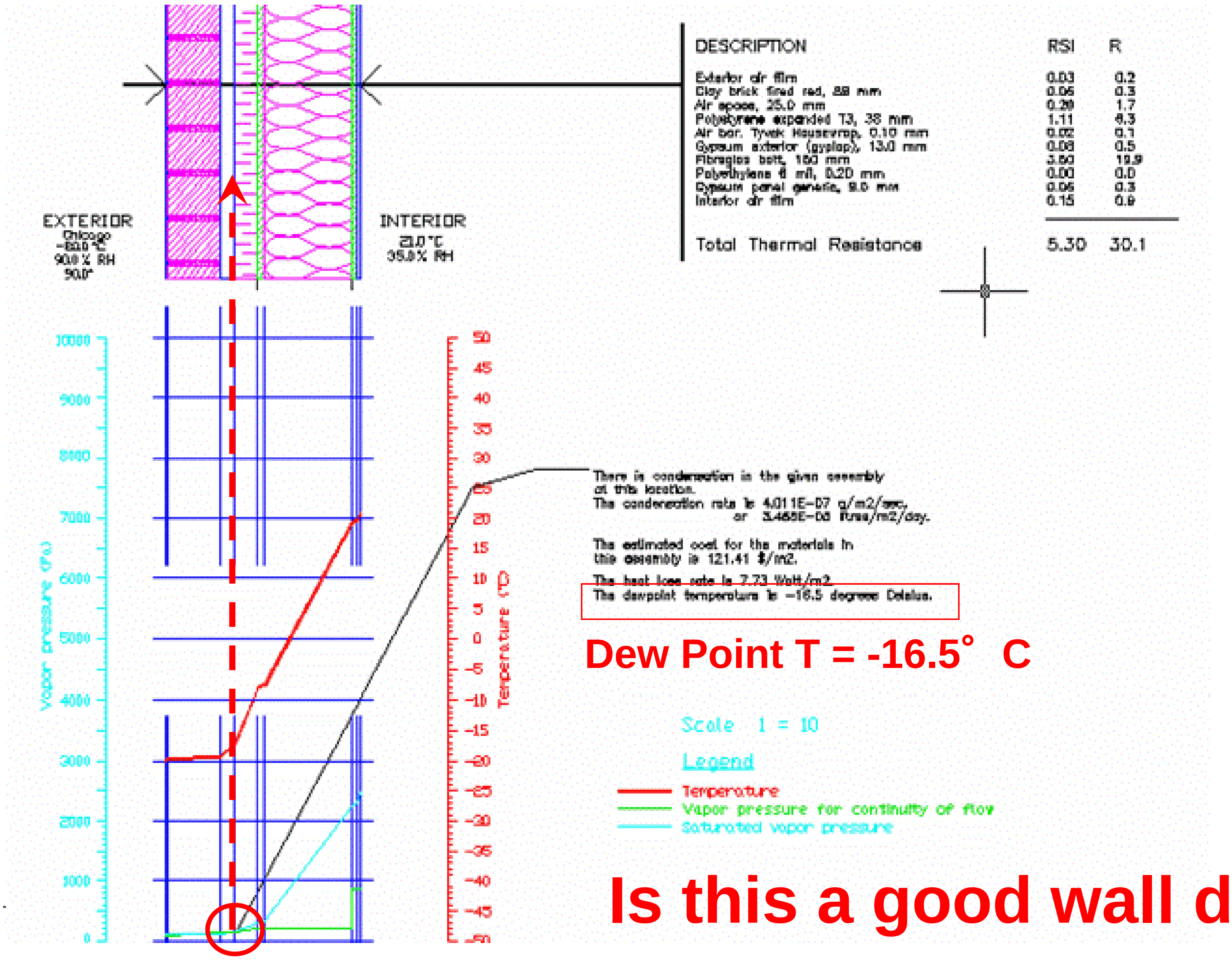
Dew Point Analysis: Inherent Limitations

1. **Based on vapor diffusion only**
2. **Steady-state conditions only** (does not consider diffusion kinetics)

CONDENSE: GES Technologies, 6705 Jean-Talon Est, bureau 201, Montreal, Quebec, H1S 1N2 Canada; Phone: 514-257-5899; www.ges-int.com

The HEAT, AIR & MOISTURE TOOLBOX, developed by Quirouette Building Specialists Ltd., 532 Montreal Road, Suite 107, Ottawa, Ontario, Canada, K1K 4R4; rick.quirouette@sympatico.ca

Example 1: Dew Point outside the Exterior Sheathing



DESCRIPTION	RSI	R
Exterior air film	0.03	0.2
Clay brick fired red, 88 mm	0.06	0.3
Air space, 25.0 mm	0.29	1.7
Polystyrene expanded T3, 38 mm	1.11	6.3
Air bar. Tyvek Housewrap, 0.10 mm	0.02	0.1
Gypsum exterior (gyslap), 13.0 mm	0.08	0.5
Fibreglas batt, 150 mm	3.50	19.9
Polyethylene 6 mil, 0.20 mm	0.00	0.0
Gypsum panel generic, 9.0 mm	0.06	0.3
Interior air film	0.15	0.9
Total Thermal Resistance	5.30	30.1

There is condensation in the given assembly
at this location.
The condensation rate is 4.011E-07 g/m2/sec.
or 3.465E-03 litres/m2/day.

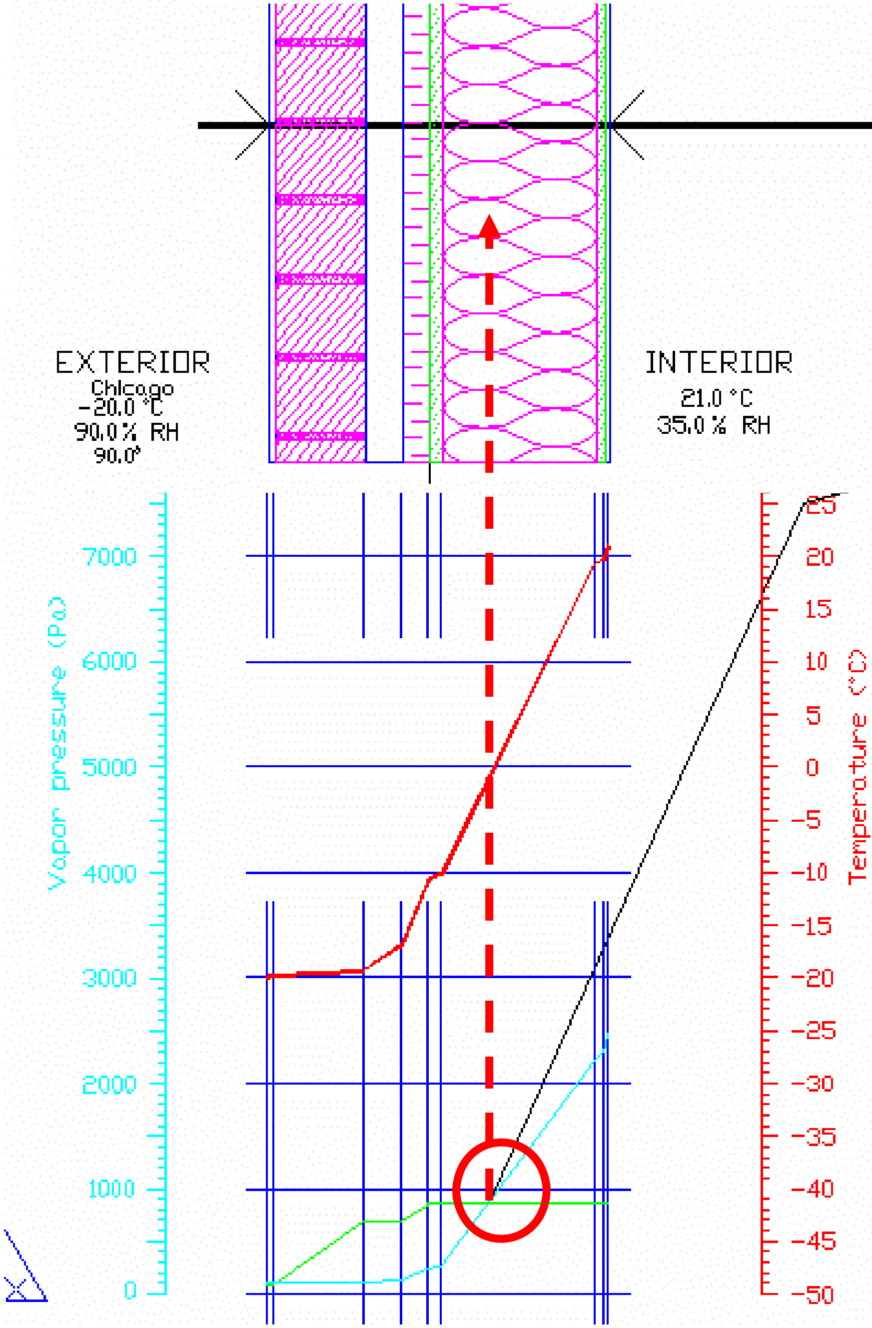
The estimated cost for the materials in
this assembly is 121.41 $/m2.

The heat loss rate is 7.73 Watt/m2.
The dewpoint temperature is -16.5 degrees Celsius.

Dew Point T = -16.5° C

Is this a good wall design?

Example 2: Dew Point in the wall cavity



DESCRIPTION	RSI	R
Exterior air film	0.03	0.2
Clay brick fired red, 89 mm	0.06	0.3
Air space, 38 mm	0.29	1.7
Polystyrene expanded T2, 25.0 mm	0.70	4.0
Air bar. Tyvek Housewrap, 0.10 mm	0.02	0.1
Gypsum exterior (gyplap), 13.0 mm	0.08	0.5
Fibreglas batt, 150 mm	3.50	19.9
Gypsum panel generic, 9.0 mm	0.06	0.3
Interior air film	0.15	0.9
Total Thermal Resistance	4.89	27.8

```
at this location.
The condensation rate is 1.574E-03 g/m2/sec.
                      or  1.360E-01 litres/m2/day.

The estimated cost for the materials in
this assembly is 118.80 $/m2.

The heat loss rate is 8.39 Watt/m2.
The dewpoint temperature is -1.1 degrees Celsius.
```

Dew Point T = -1.1° C

Scale 1 = 10

Legend

- 🟥 Temperature
- 🟩 Vapor pressure for continuity of flow
- Saturated vapor pressure

Is this a good wall design?

What is WUFI

Coupled heat & moisture transport simulation models developed by the Fraunhofer Institute for Building Physics (IBP) and Oak Ridge National Laboratory (ORNL)

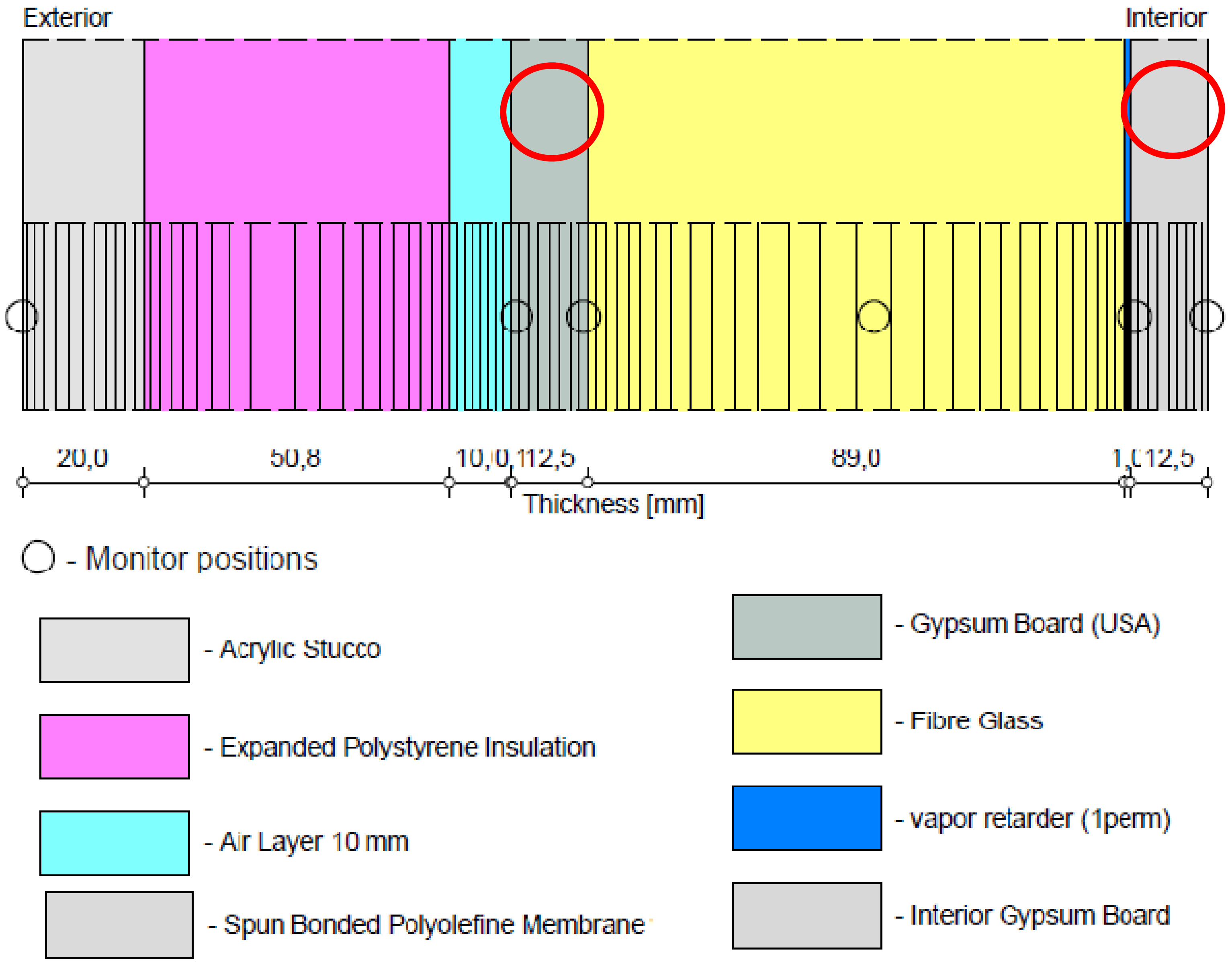
Still based on vapor diffusion only - Does not account for air transported moisture

http://www.ornl.gov/sci/btc/apps/moisture/ibpe_sof161.htm

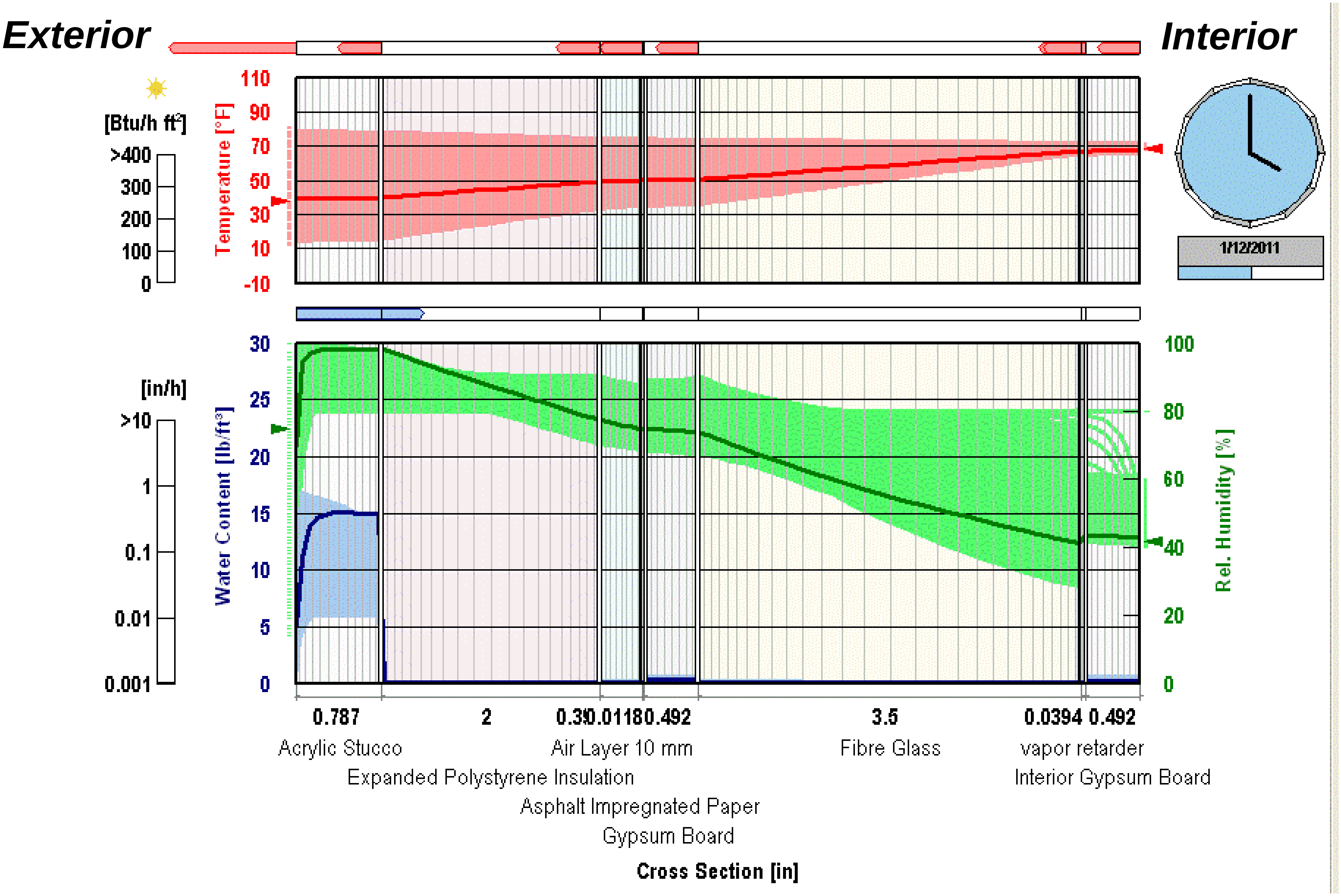
How is WUFI Different?

- **Real climate data/ transient parameters**
  - Not a single point calculation like dew point
- **Models moisture accumulation and diffusion drying in multi-layer building assemblies**

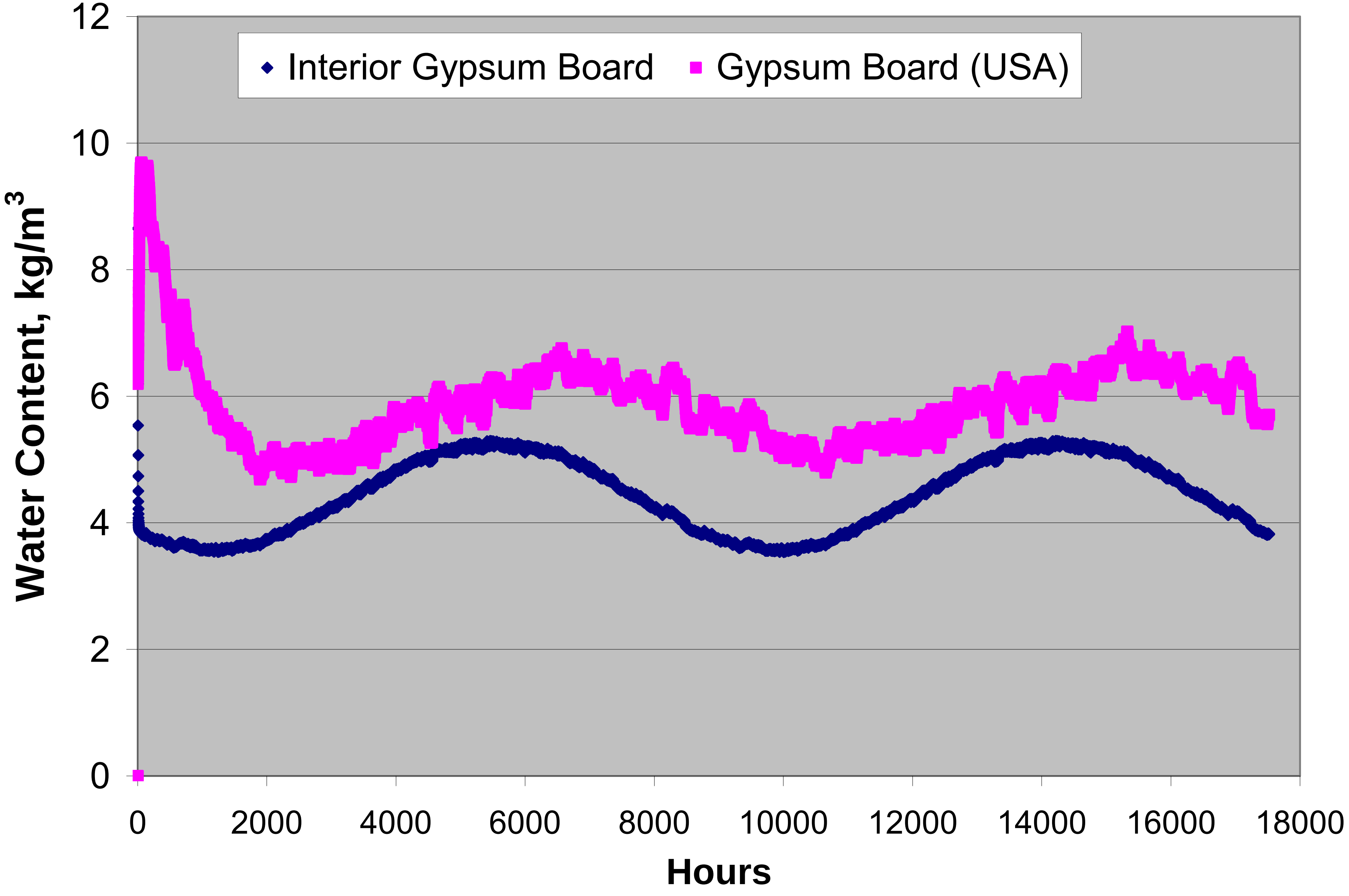
Example
Stucco, Vancouver



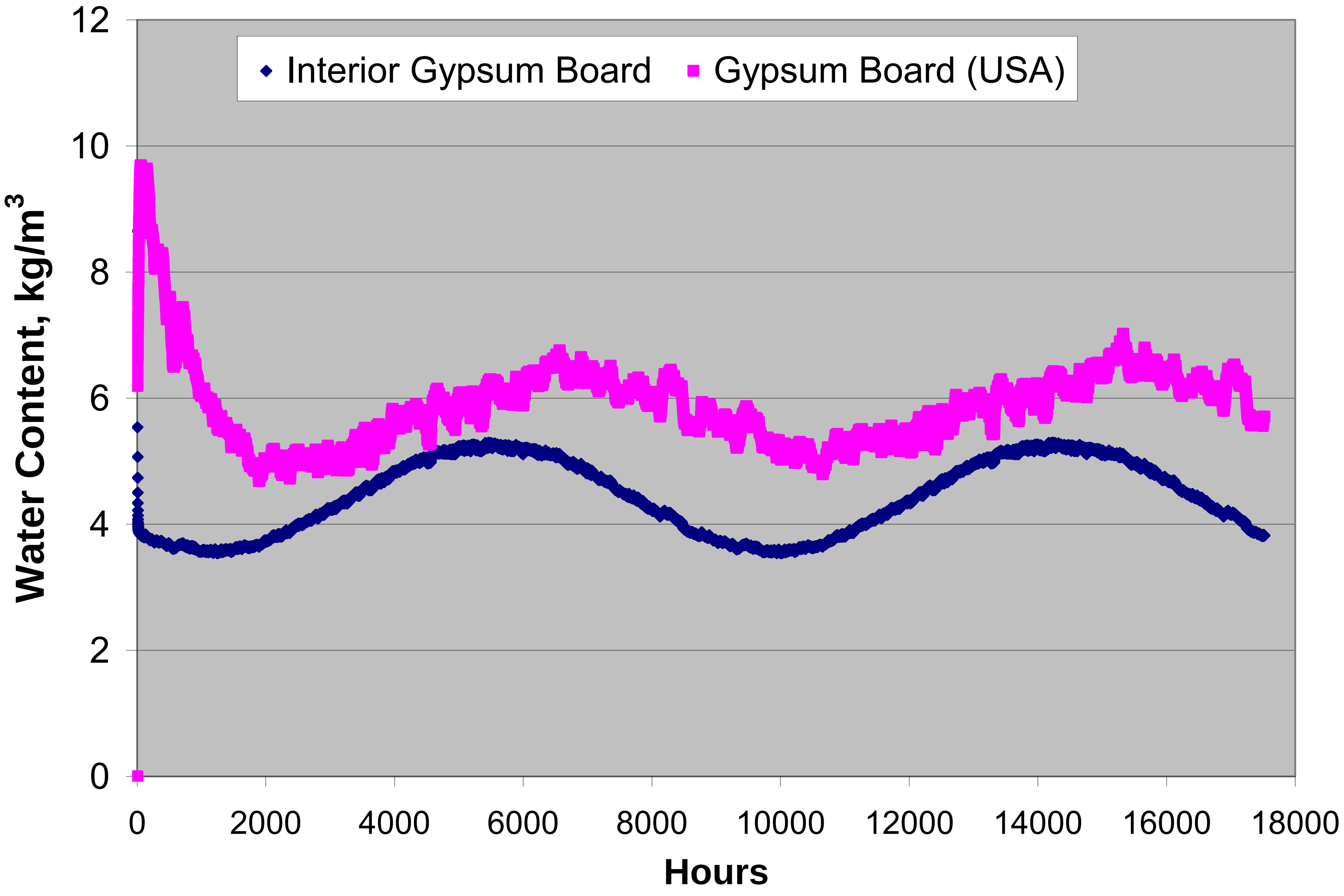
Example WUFI Run

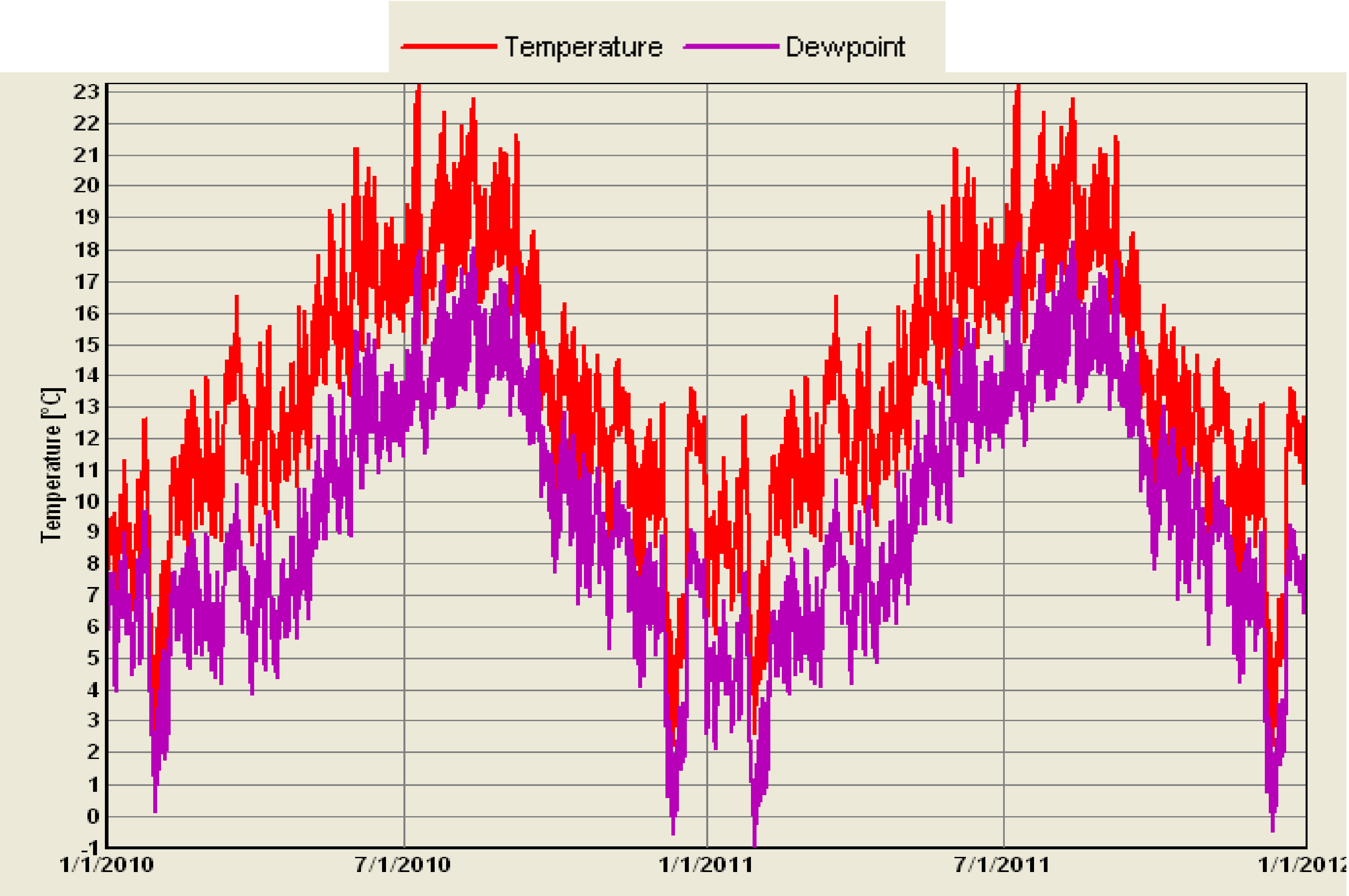


Water Content in the Exterior Sheathing (GB)

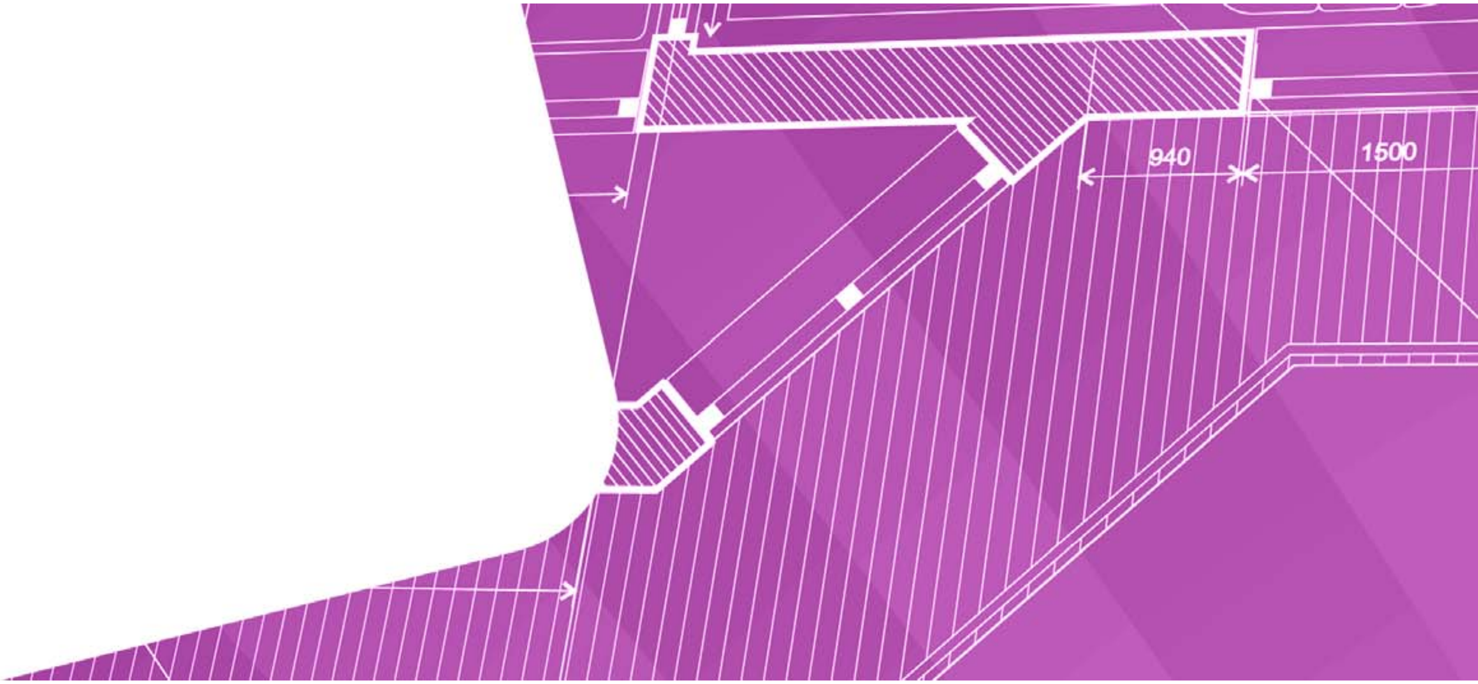


Water Content in the Exterior Sheathing (GB)



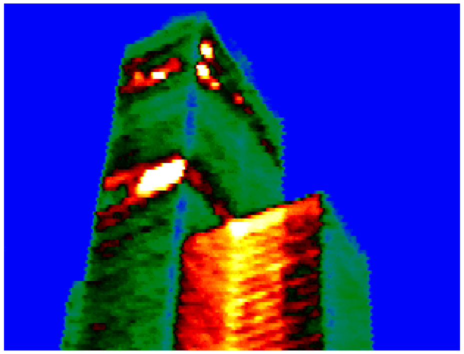

Temperature
Dewpoint
Temperature [°C]
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
1/1/2010
7/1/2010
1/1/2011
7/1/2011
1/1/2012

SUMMARY



Summary

1. *Physics of Heat, Air and Moisture Transport through the Building Enclosure: The 4 Control Layers*
2. *Moisture Management Principles for the Building Enclosure: The Balance of Wetting vs. Drying*
3. *Climate-specific Design Considerations for Building Enclosure*
4. *Condensation Analysis Tools*

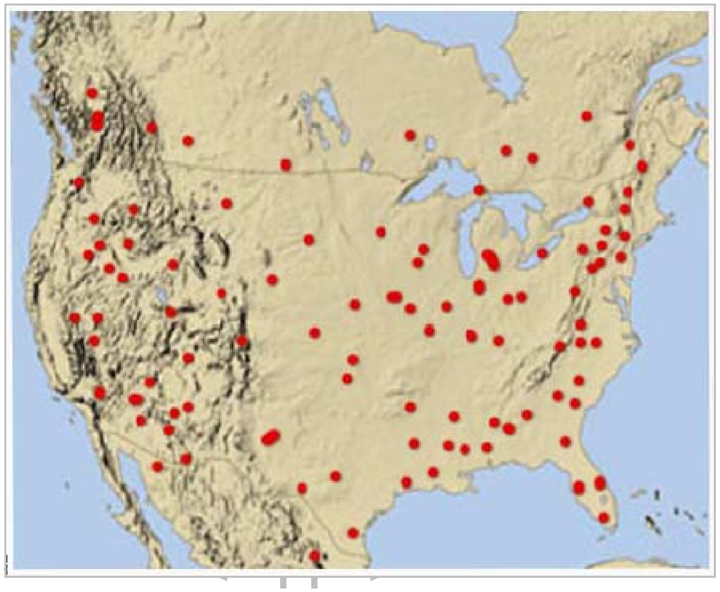


Conclusion

- Building Physics are universal
- The key to moisture management is the balance of wetting vs. drying
- Design for moisture management is climate specific

This concludes The American Institute of Architects Continuing Education Systems Program

DuPont™ Tyvek® Specialist Network and Building Science



- An elite team of highly-trained field representatives; 40 focused specifically on commercial building applications
  - ☐ Participate in a five-year certification process
  - ☐ University-level curriculum and rigorous testing in product knowledge and building science
  - ☐ Help ensure proper installation of DuPont™ Tyvek® Weatherization Systems
  - ☐ Provide information on new code requirements and green building design