Vapour Barriers, Air Barriers

and

The CUFCA Vapour Barrier Study

University of Waterloo

Outline

- In 1.5 hours
  - Background on water vapor in air
  - Air Barriers vs Vapor Barriers
  - Vapor Barrier History
  - CUFCA Experiment

Air Barriers & Vapour Barriers

- ***Air Barriers Control Air Leakage***
  - Heat (for comfort & energy considerations)
  - Smoke & odours
  - Sound
  - Moisture
- ***Vapour Barriers Control Vapour Diffusion***
  - Moisture

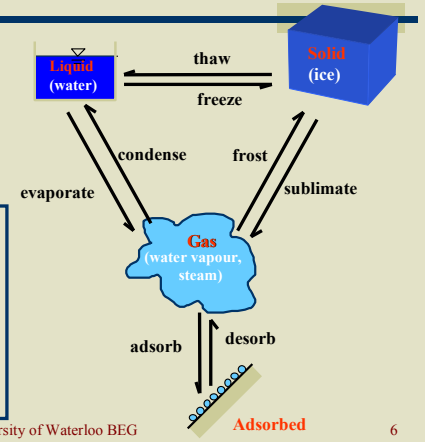
SPUF

- Spray applied (continuous) product that
  - Provides insulation (high R/inch)
  - Provides vapor resistance (varies)
  - Provides an air barrier
  - Stops convection
  - Some provide a drainage surface for rainwater
- All of these features and function inter-relate!

The Backround

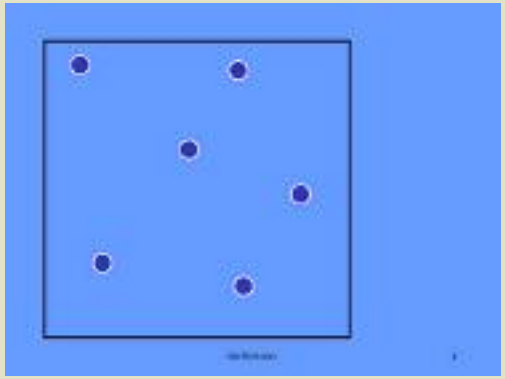
Vapour in Air

The 4 phases of Water



Air Barriers & Vapour Barriers only deal with the ***Vapour Phase***

Water Vapour Pressure

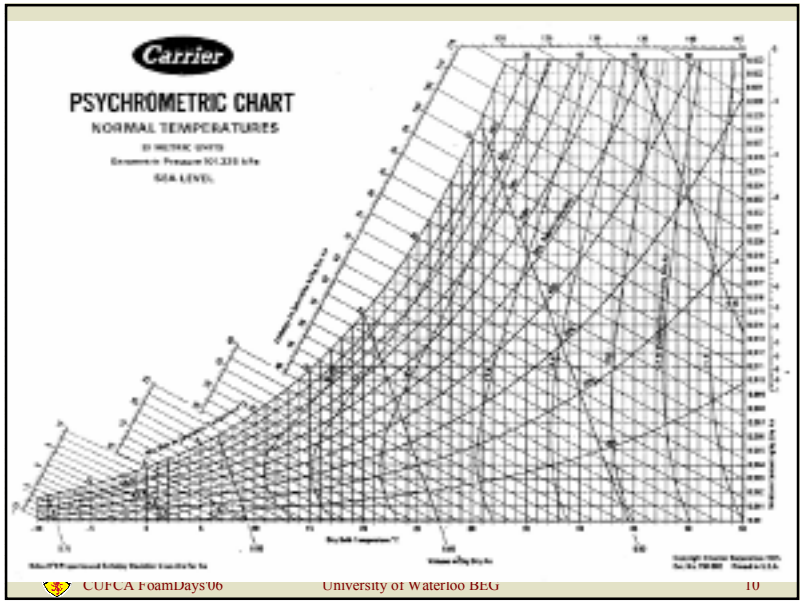


Water Vapour Pressure

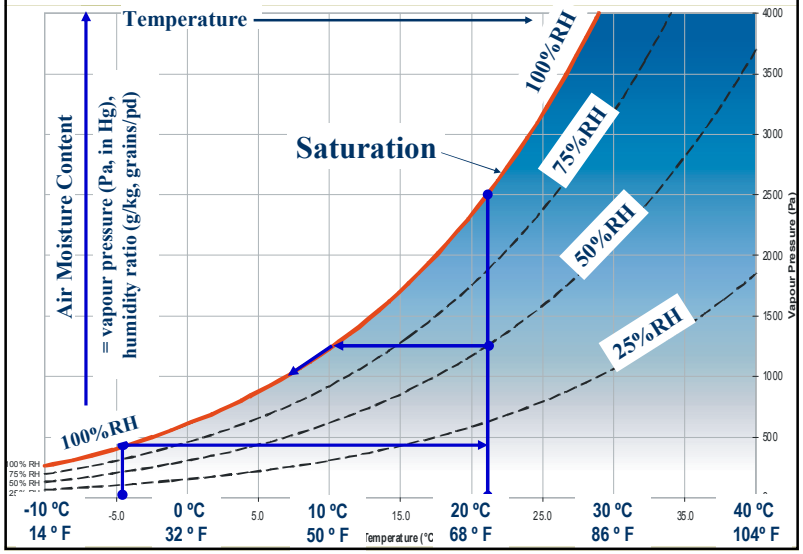
- For water vapour in a container
- Higher temperature =
  - more energy
  - higher velocity
  - harder collisions with wall (higher pressure)
- Greater number of molecules =
  - more collisions with walls (higher pressure)
  - pressure simply another measure for moisture content

Water Vapour in Air

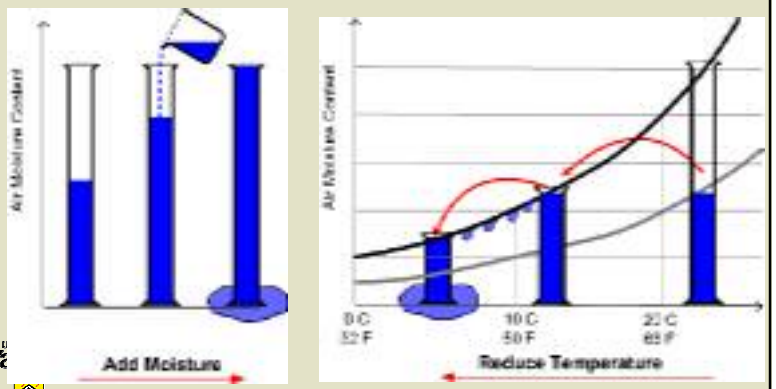
- Water vapour exists in all air
- Air has a maximum vapour holding capacity
  - This capacity changes dramatically with temperature
  - When the maximum holding capacity is exceeded, *condensation* occurs
- These facts are summarized by the ***psychrometric*** chart

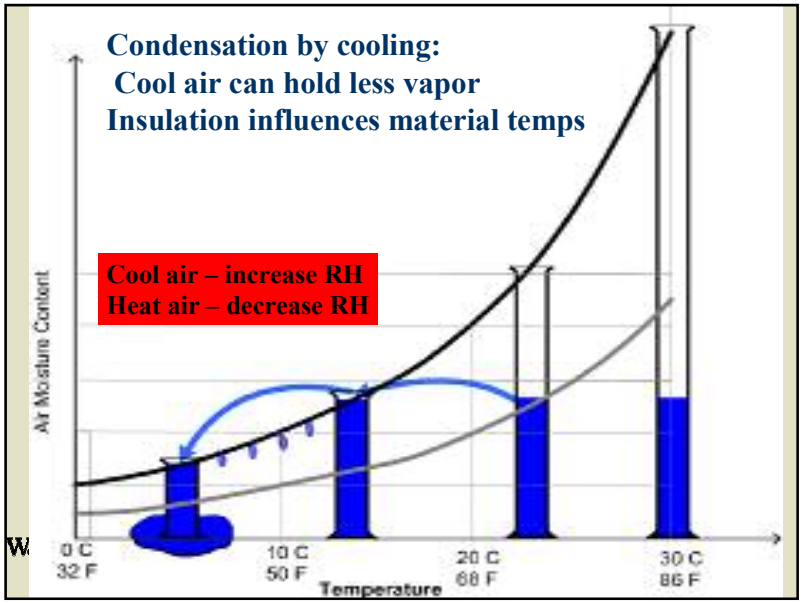


Psych Chart: Air Vapour Content vs Temperature



Methods to get Condensation





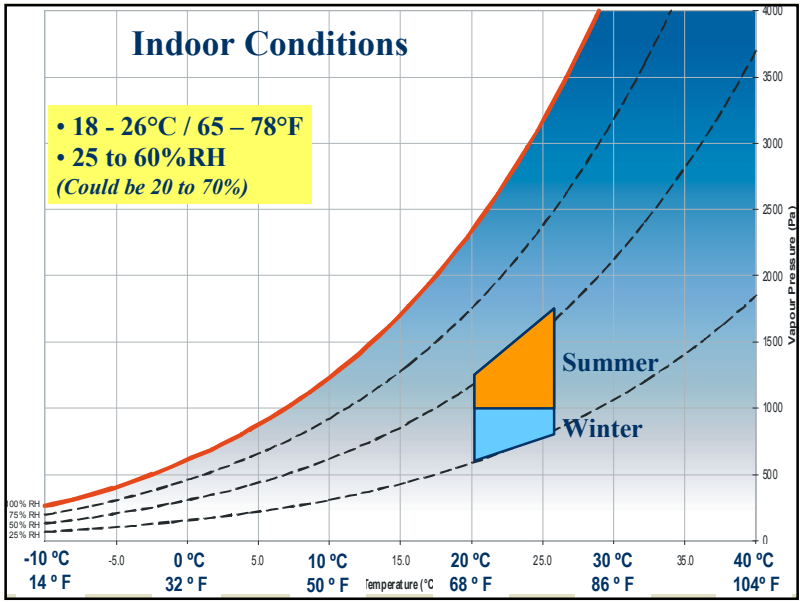
Vapor Movement

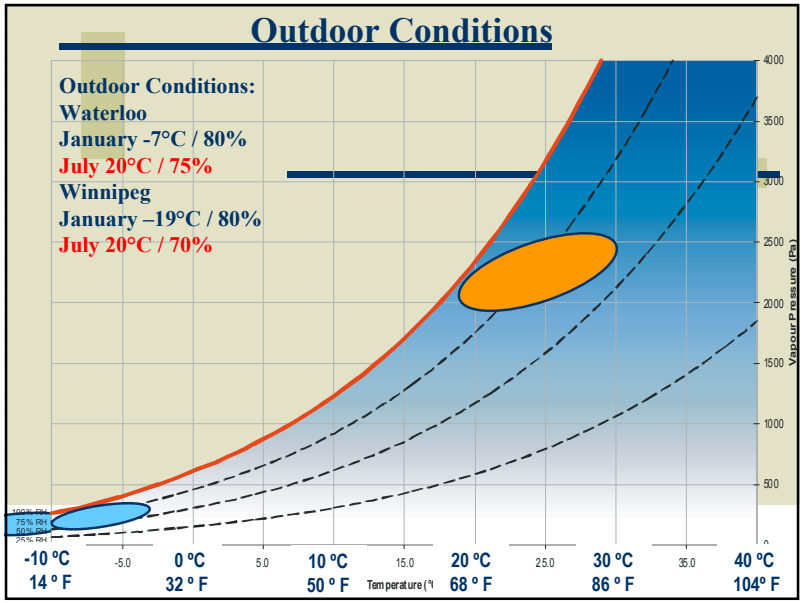
Water Vapour Transport

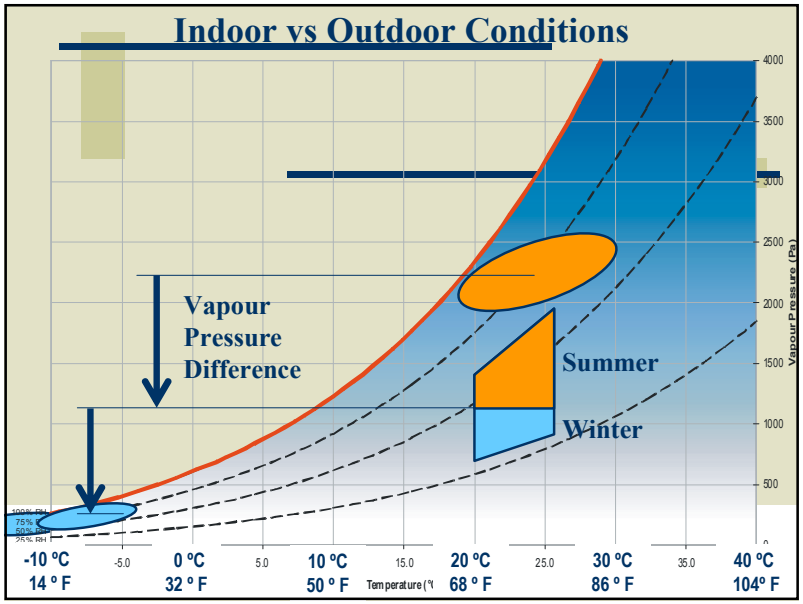
- Vapour Diffusion (like heat conduction)
  - more to less vapour
- Air Convection (like heat convection)
  - more to less air pressure
  - vapour is along for the ride

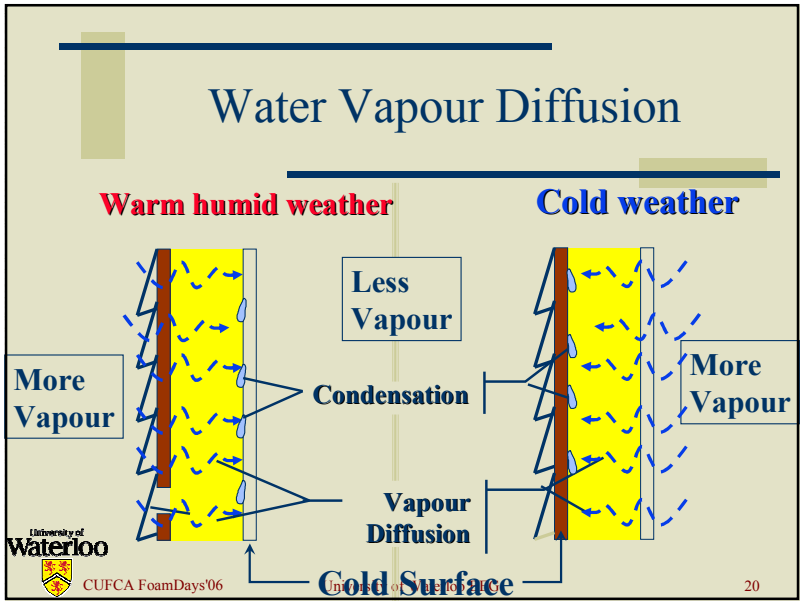
Vapour Diffusion

- Movement from ***more*** vapour to ***less***
- Slow process
- Many materials slow this process
  - concrete, brick, stone
- Some stop, or practically stop it
  - many plastics (poly), steel, glass
- May provide supply of vapour need to support condensation (but not often)


Indoor Conditions
• 18 - 26°C / 65 – 78°F
• 25 to 60%RH
(Could be 20 to 70%)
Summer
Winter
Vapour Pressure (Pa)
-10 °C 14 ° F
0 °C 32 ° F
10 °C 50 ° F
20 °C 68 ° F
30 °C 86 ° F
40 °C 104° F


Outdoor Conditions
Outdoor Conditions:
Waterloo
January -7°C / 80%
July 20°C / 75%
Winnipeg
January –19°C / 80%
July 20°C / 70%
Vapour Pressure (Pa)
-10 °C 14 ° F
0 °C 32 ° F
10 °C 50 ° F
20 °C 68 ° F
30 °C 86 ° F
40 °C 104° F


Indoor vs Outdoor Conditions
Vapour Pressure Difference
Summer
Winter
Vapour Pressure (Pa)
-10 °C 14 ° F
0 °C 32 ° F
10 °C 50 ° F
20 °C 68 ° F
30 °C 86 ° F
40 °C 104° F


Water Vapour Diffusion
Warm humid weather
Cold weather
More Vapour
Less Vapour
More Vapour
Condensation
Vapour Diffusion
Cold Surface
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CUFCA FoamDays'06
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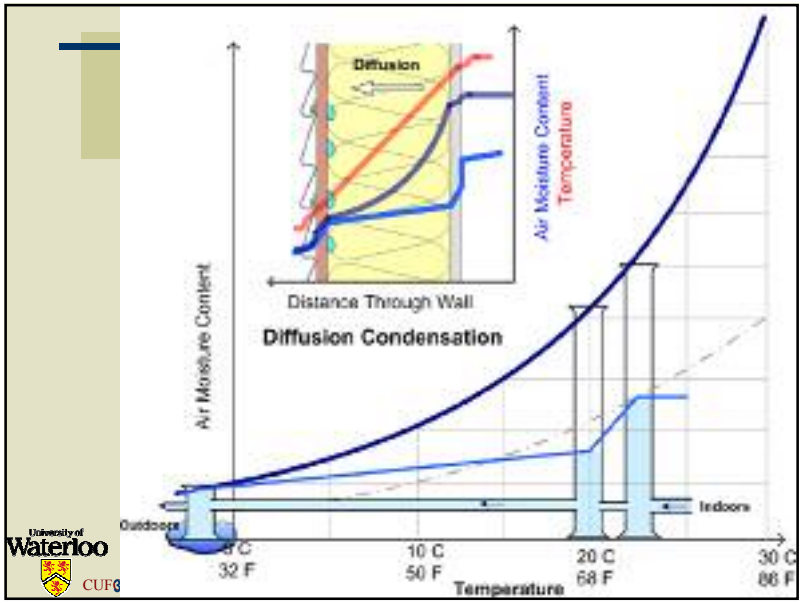
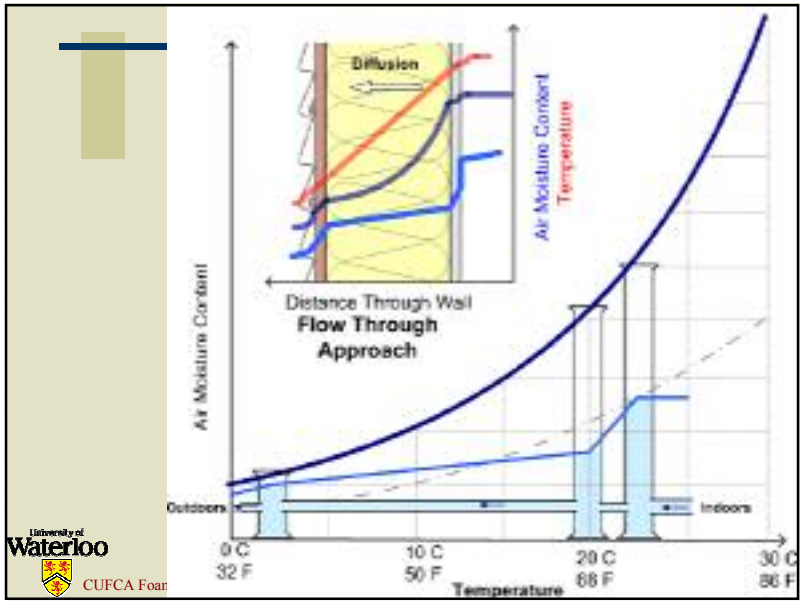

Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Diffusion Condensation
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
University of Waterloo
CUFC


Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Flow Through Approach
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
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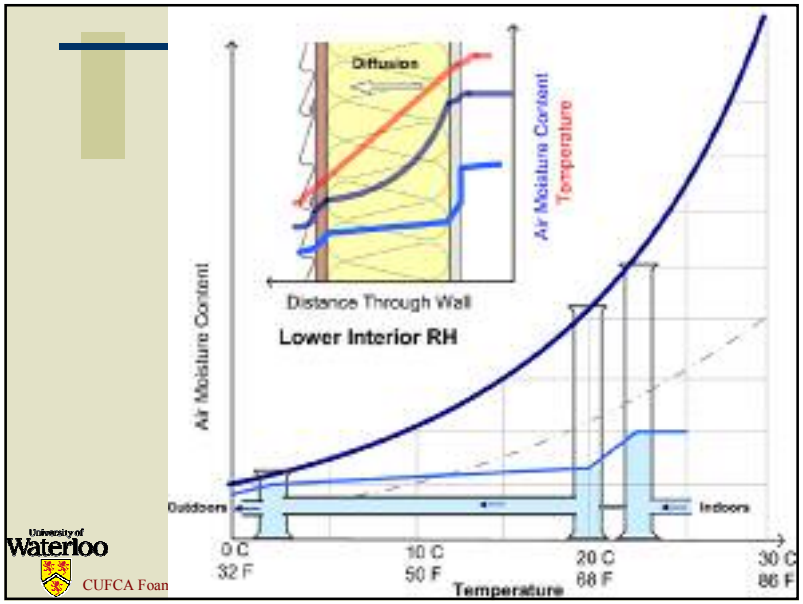
Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Lower Interior RH
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
University of Waterloo
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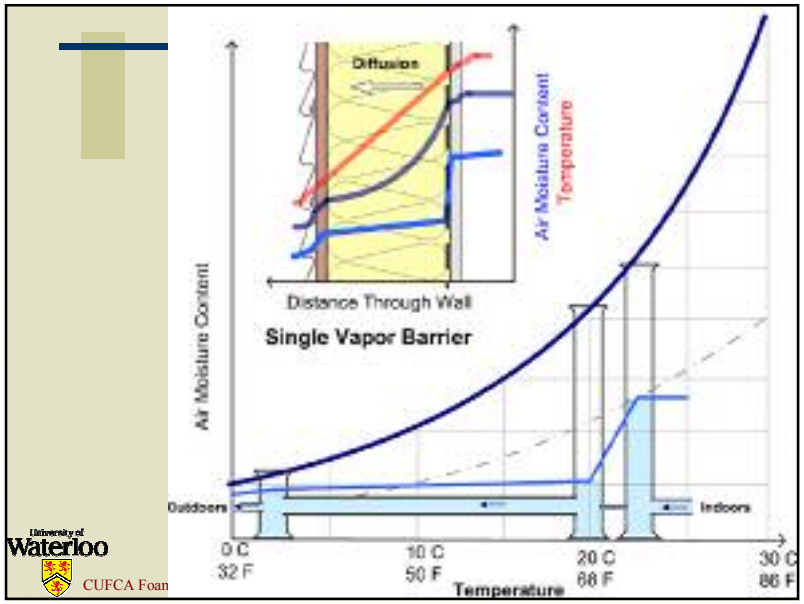
Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Single Vapor Barrier
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
University of Waterloo
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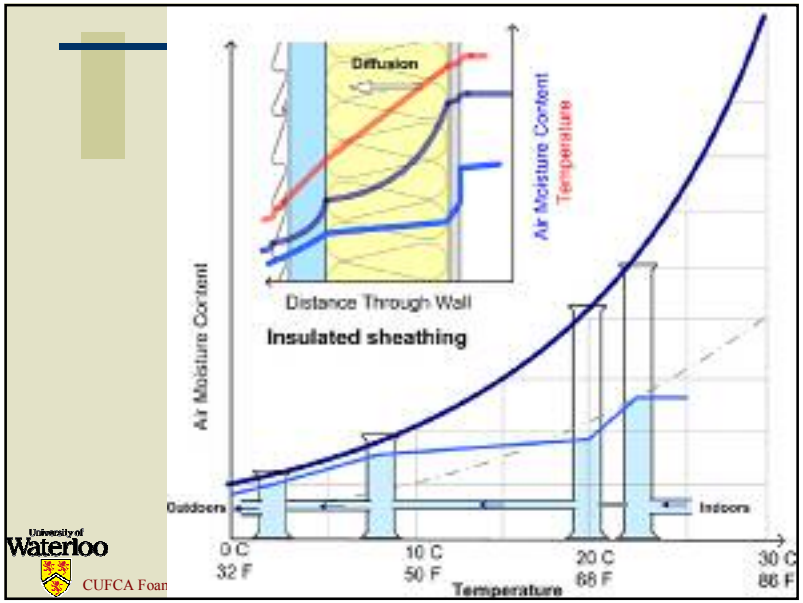
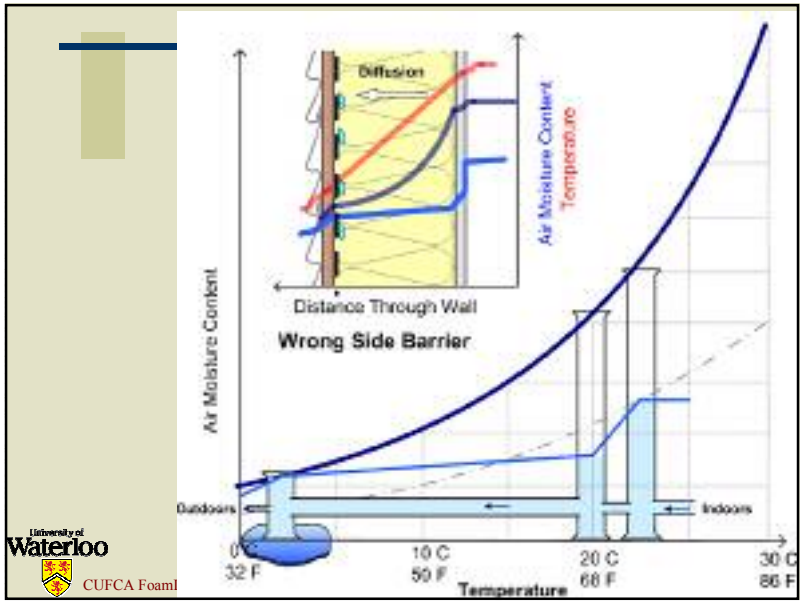
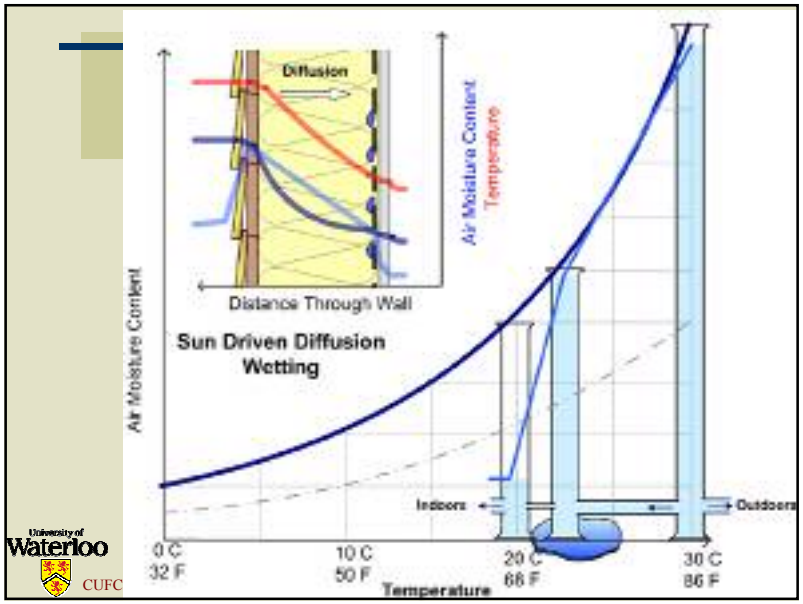






Vapour Retarders

- Vapour retarders are needed to ***control vapour diffusion***
- ***Don't*** need be continuous – small tears and openings OK
- Usually placed near the warm side of the wall or roof -- near the inside in our climates
- Semi-permeable barriers allow more design flexibility (and more drying)

Vapour Barriers

- Vapour barriers in Code: <1 US perm
  - based on Rowley 1937
  - no good science
- Vapour retarder approx 2-5 US perm
- Measurement Units
  - ***Metric*** perms ng /(s·m²·Pa)
  - ***US*** perm grain/(hr·in Hg· ft²)
  - WVT grams/(sq ft/24 hours)

Vapour Retarders

- Inner permeance usually should be less than outer in cold climates with few hot humid hours
  - E.g. unvented metal cladding, use low perm inside
- Walls with insulated sheathing do not need as much inner resistance
  - e.g., low perm paint works well in this case
- Too low inner permeance resists drying, promotes summer condensation
  - e.g., polyethylene is often too much

Low-perm Materials (<1/60)

- 6 mil Poly 0.1 US perm (5.7 metric)
- Vinyl wall paper 0.3 perm (17.1)
- 8" Conc. Fdn. wall 1/2 perm (28.5)
- Drywall with a VB paint 0.1 to 1 perm (5.7- 57)
- Brick veneer 1/2 - 2 perms (28.5-57)
- Extruded foam 1/2 - 1 for 1.5" (28.5-85.5)
- Plywood 0.5 to 20 (dry to wet) (28.5-1140)
- Kraft paper 0.3 to 2 (dry and wet) (17.1-114)

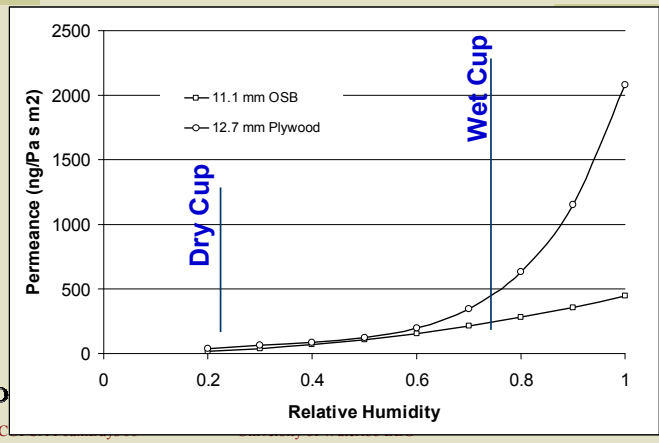
Mid-perm Materials (1-10)

- Plywood 0.5 to 20 (dry to wet) (28 -1100)
- Expanded polystyrene foam 2.5 - 5 perms for 1 inch (150-300)
- Spray PUR about 1-2 perms/inch (60-120)
- Drywall with latex paint (2-8 perms) (120-500)

High-perm Materials (>10/600)

- Fibreboard over 20 (>1100)
- Plywood 0.5 to 20 (dry to wet) (30-1100)
- Icynene open cell spray foam 10-13 (500-750)
- Tyvek other housewraps
  20 to 50 perms (1100-2800)
- Building paper over 5 to 20 (250-1200)

Vapour Permeance: Sheathing

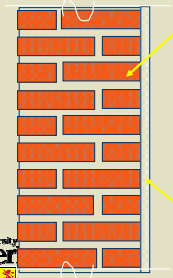


In the beginning

- **Find the vapour barrier**

Old Assemblies

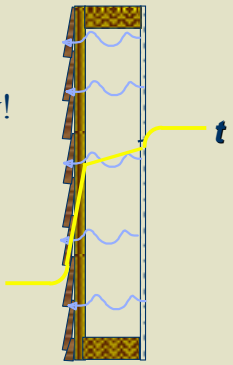
- Integral vapour resistance
- Massive moisture storage



Old Framed Assemblies

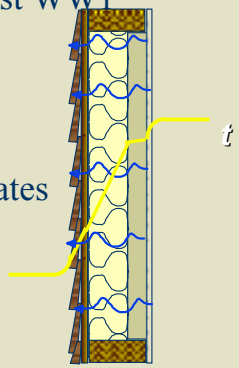
- Little to some vapour resistance
- Little moisture storage
- Little insulation / air leaky = dry!

No vapour barrier of course



Changes . . .

- Increase in wood frame, esp. post WW1
- Began to add insulation
  - comfort
  - wood scarcity, coal
- Moisture problems in cold climates noted in 1930's
- Paint peeling of siding

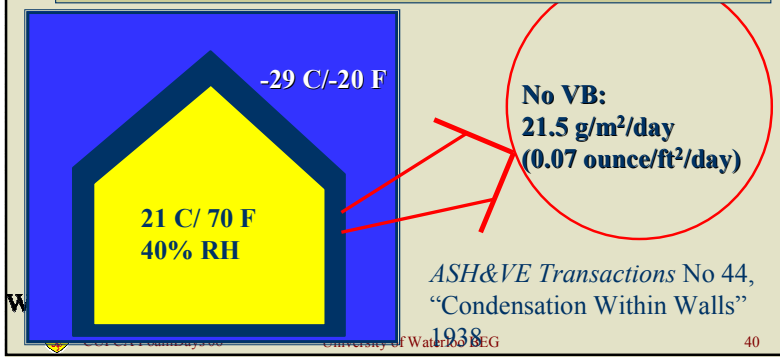


Dr Frank Rowley

- Professor of Mechanical Engineering at University of Minnesota
- ASH&VE 1932 president
- Proponent of using heat flow analogy for vapor flow in calculations
- Conducted full scale house in climate chamber studies –paid for by insulation companies

The One US Perm

This research resulted in 1 perm / 60 ng/Pa s m² or less vapor barriers



ASH&VE Transactions No 44, "Condensation Within Walls" 1938

Air barriers discovered

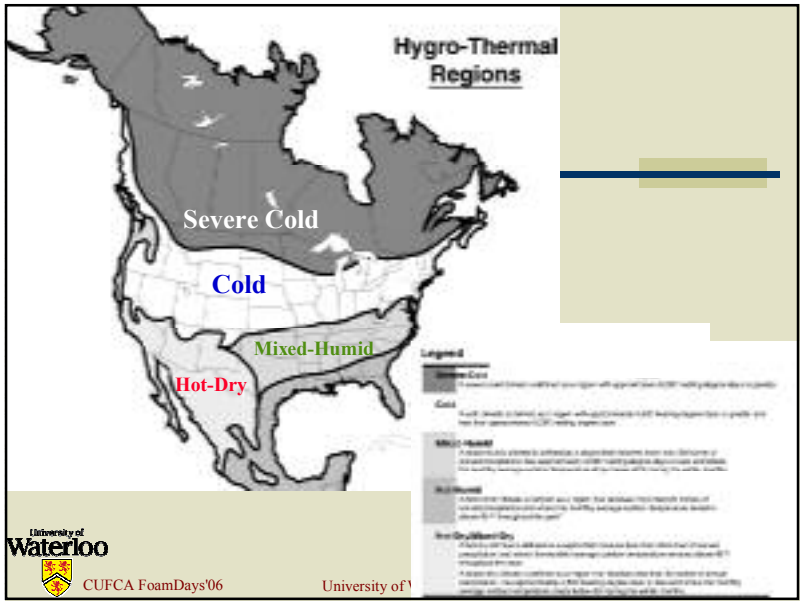
- Air leakage identified by : *"The rate of condensation is about ten times that at which vapour might be expected to diffuse through ...It seems necessary to assume some other mechanism ... the leakage of warm moist air outward .."* Neal Hutcheon, 1950
- Solution suggested by many:
  - Why not use the vapour barrier
- Add "sealed" or "continuous" to codes language
- Air barriers spelled out in 1985 NBCC

When and where

- Choice of vapour permeance and location of vapor barrier depends on
  - Exterior Climate
  - Interior Climate
  - Wall Assembly
- *Any "rule" that does not consider these factors cannot provide correct guidance*

When and Where

- Place on warm side of enclosure
  - summer and winter balance
- If you use a VB on cold side of wall - ventilate!
- If extreme temps/RH, use VB
- If moderate, use VR (retarder, like paint)
- Insulated sheathing changes everything
- If in doubt - figure it out
- Climate is one guide



Climate and VB

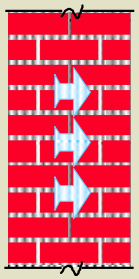
- Florida is hot and humid
  - moisture is outdoors
  - place VB near outside
  - allow vapour to flow INWARD
- Winnipeg/Bismark is cold/dry
  - bitterly cold winters
  - summers are hot and dry
  - place VB near inside
  - allow vapour to flow outward

Climate and VB

- Vancouver
  - moisture is both indoors outdoors
  - allow vapour to flow inward and outward
  - use VR near inside (paint)
- Toronto
  - summers are hot and humid, winters cold
  - if rain-wetted cladding, inward is important!
  - allow vapour to flow inward and outward
  - use VR near inside (paint) or exterior insulation

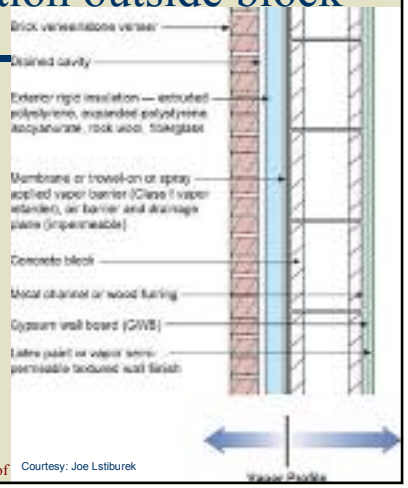
VB and Wall design

- **Likely need vapour barriers:**
  - low integral vapour resistance
    - framed walls with batt
- **Rarely need VB:**
  - Integral vapour resistance
    - SIPS
    - spray foam
  - Built in VB
    - concrete
  - Kept warm
    - insulating sheathing

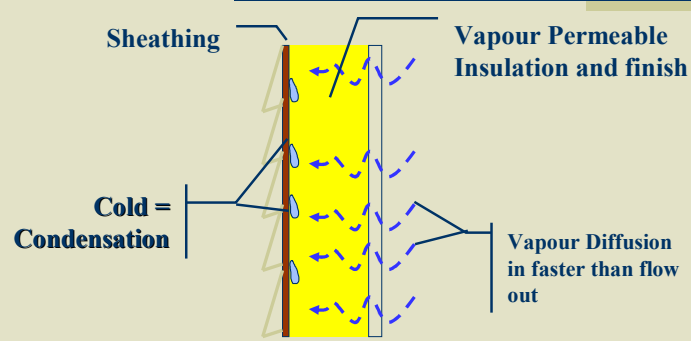


Foam Insulation outside block

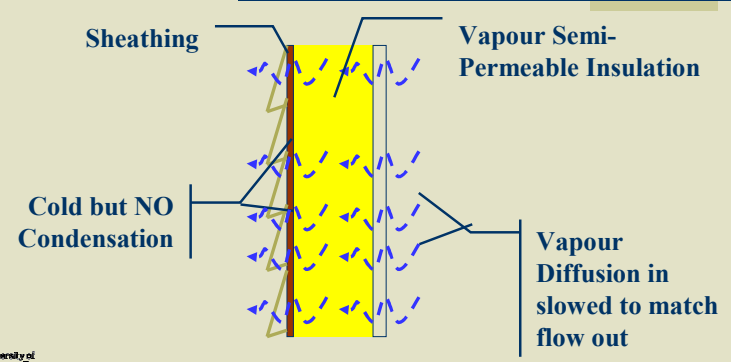
- Works everywhere without calculation



Wall permeable insulation, no VR



Semi-permeable insulation, no VR



Drying

- Vapour barriers stop wetting ***and*** drying
- Overkill (e.g. poly) can cause problems!
- Inward drying is useful in many climates

Summary for Vapour Barriers

- Vapour flows from ***more*** to ***less***
  - It goes ***both*** ways (In-Out & Out-In)
- Vapour Barriers do not need to be continuous
- Don't always need a separate vapour barrier many walls have integral resistance
- Be careful to allow drying
  - ***Vapour Barrier = Drying Retarder***

Back to Air Barriers

A strong, continuous, durable, stiff air impermeable layer must be provided to stop uncontrolled airflow in all building enclosures.

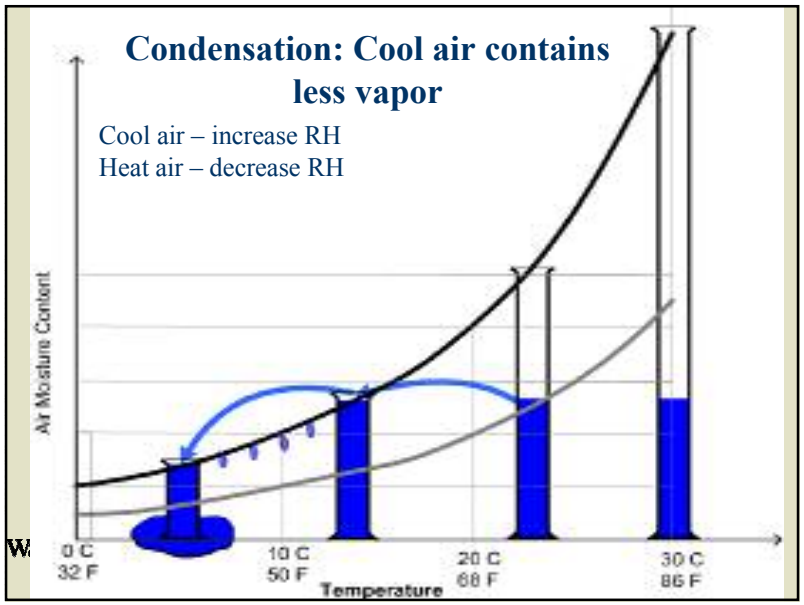
Remember

- ***Vapour Barriers Control Vapour Diffusion***
  - Why? 1. Wetting and drying
- ***Air Barriers Control Air Leakage***
  - Why control air leakage? ***Six*** reasons.
  - Heat (for 1. comfort & 2. energy considerations)
  - 3. Fire & Smoke & 4. odours
  - 5. Moisture
  - 6. Sound

Why Air Barriers for Moisture?

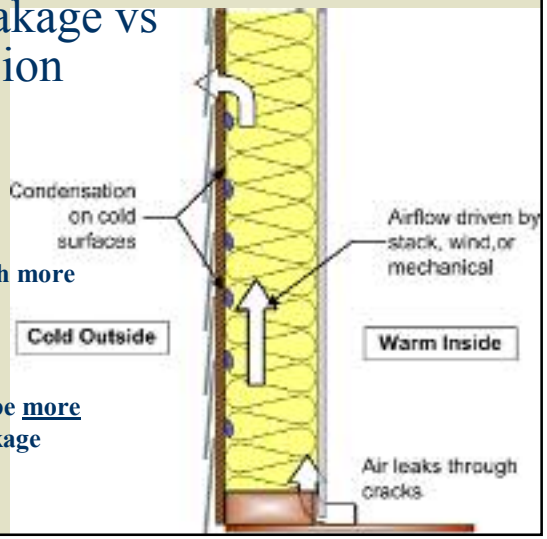
- **Air leakage** moves **moist** air (**vapour**) through the assembly to locations where it can condense
- Two air leakage concerns for moisture:
  1. Through Wall
  2. Wind Washing

} Air Barrier



Air leakage vs Diffusion

- **Air leakage is much more critical**
- **Walls sensitive to diffusion-related condensation will be more sensitive to air leakage**



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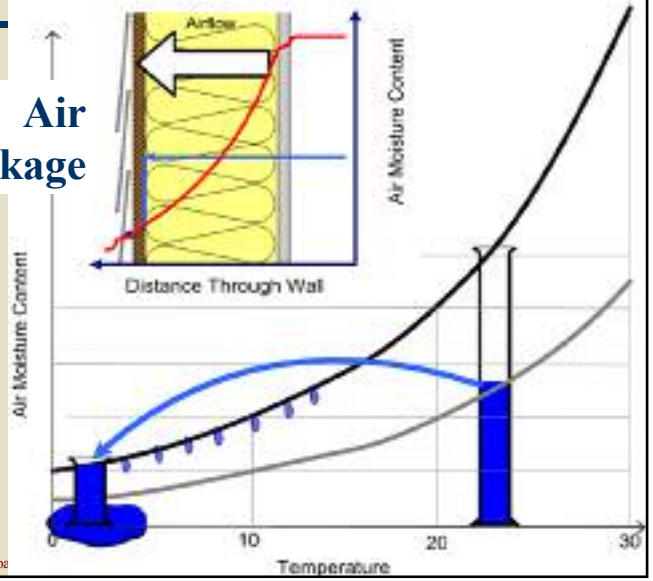
Air leakage



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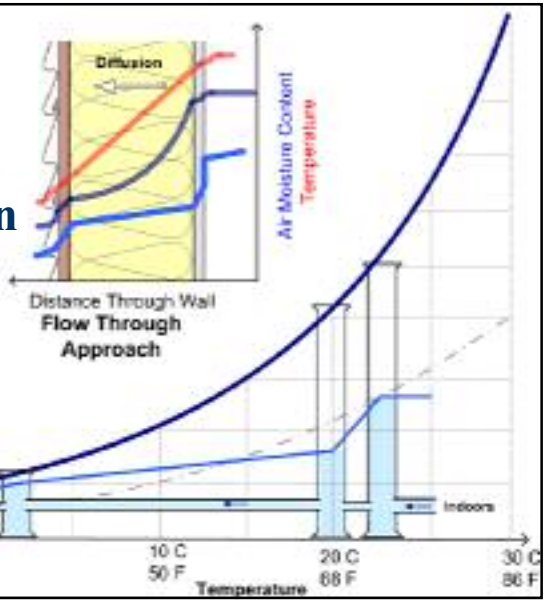
Diffusion



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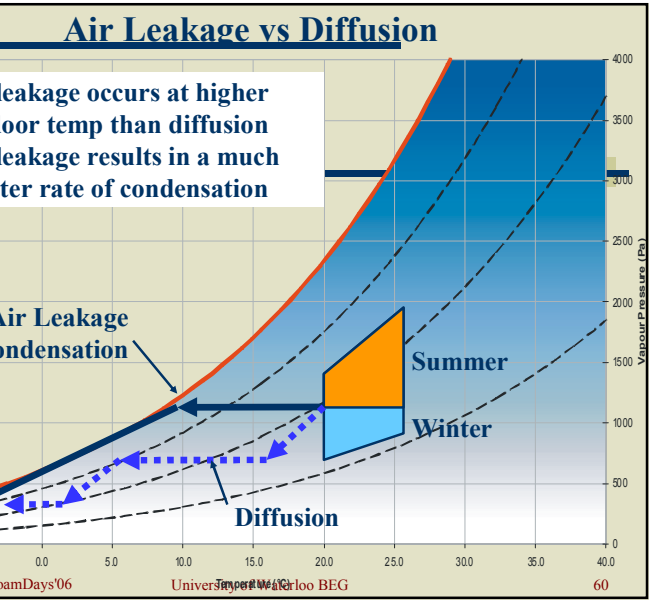
Air Leakage vs Diffusion

1. **Air leakage occurs at higher outdoor temp than diffusion**
2. **Air leakage results in a much greater rate of condensation**



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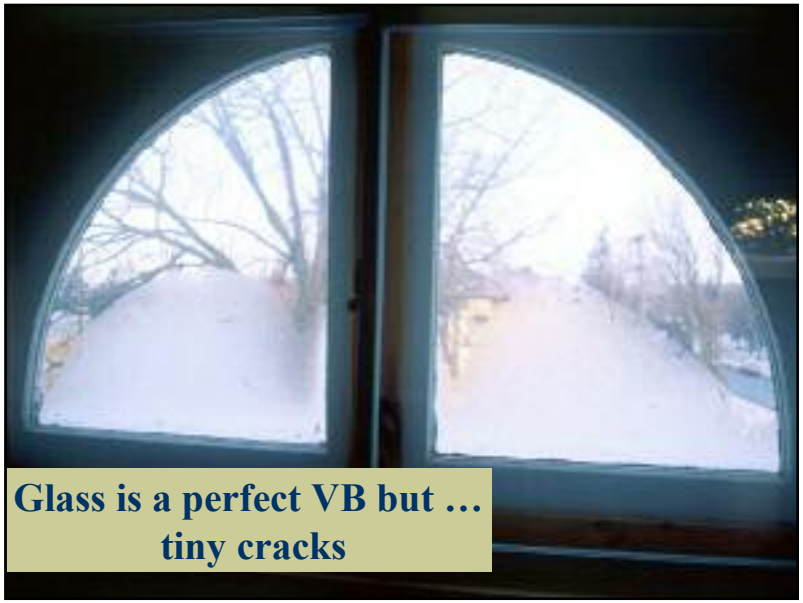

Air Leakage & Condensation

- **Damaging** airflow direction is:
  - cold weather ***inside to outside***
  - warm weather ***outside to inside***
- Condensation can **ONLY** occur if *both*:
  - air contacts a cold surface (no ABS), **and**
  - air flow is in the direction of more to less vapour (driving forces)

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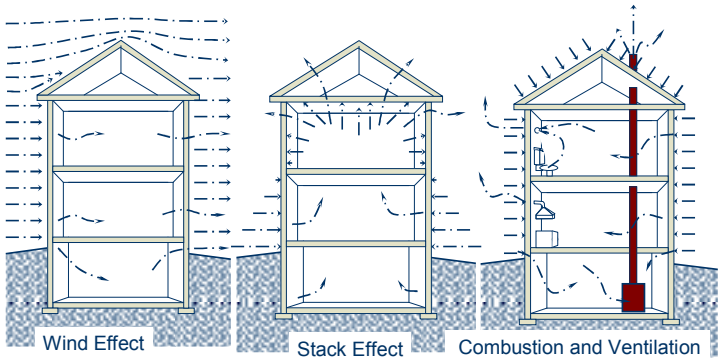
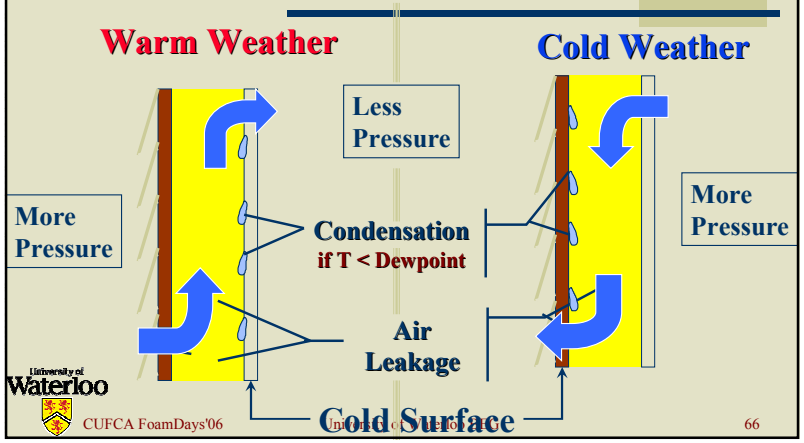
Driving Forces



Controlling Air Leakage Condensation

1. Stop all airflow
2. Control driving forces (HVAC/ air pressures)
3. Control Temperature of condensing surface
4. Reduce interior moisture load

Air leakage (Convection)



Airflow Control: Where

- Stop airflow = stop many problems
  = ***Air Barrier***
  = ***SPUF***
- Can locate anywhere in enclosure
- Important in all climates, and all interior conditions
- The more extreme, the more important

Air Barriers are Systems (not materials)

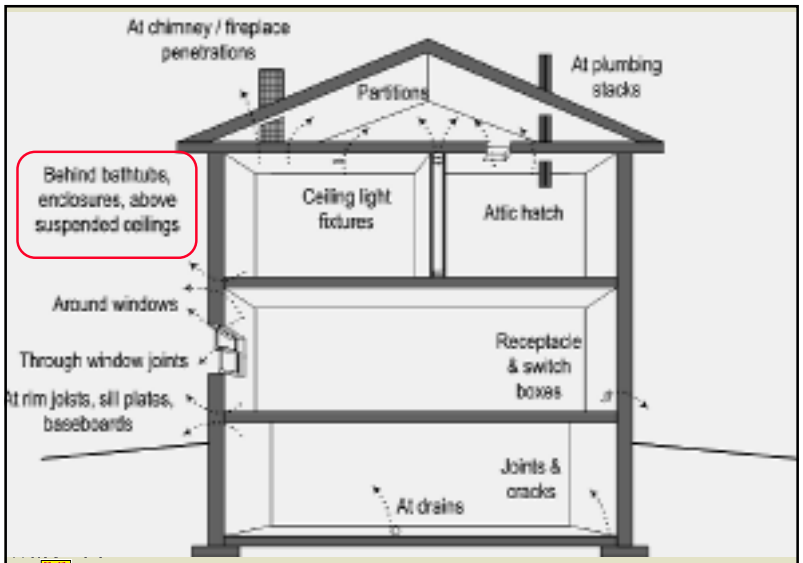
- **Air barrier systems are required to *stop airflow through enclosure***
- **ABS can be placed anywhere in the enclosure**
- **Must be strong enough to take wind gusts**
- **Air barrier systems must be *continuous***
  They leak at *joints, interfaces, penetrations*
- **multiple air barrier planes are useful for redundancy**

Air Barrier Systems Summary

- Buildings leak at ***joints, interfaces, penetrations***
- Hence
  - "The air permeance of materials used is less important than continuity of the system"
- Air permeance of wall/roof etc should be low
  - Suggest less than about 0.2 lps/m^2@75 Pa, usually better
  - Any material that allows this is OK, even if >0.02 lps required by CCMC

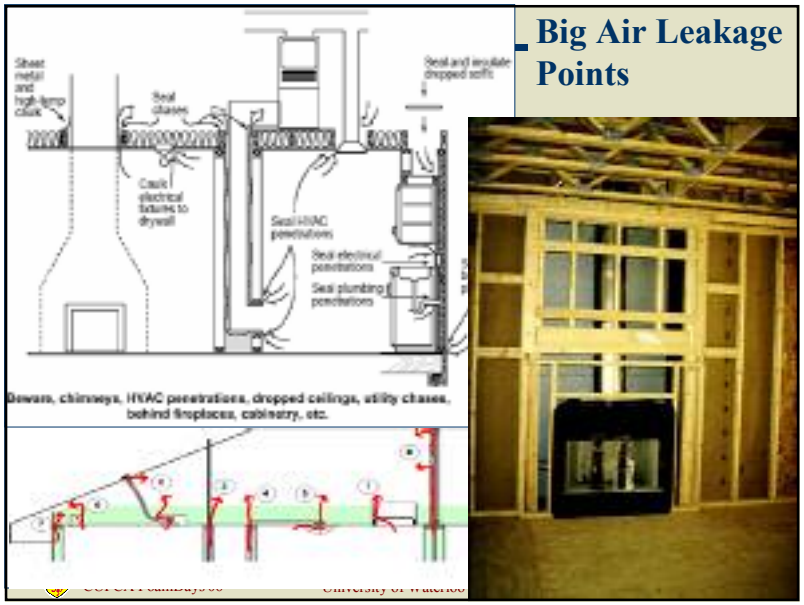
Air Barrier System Requirements

- **Continuous**
  - **primary need**
- **Strong**
  - **designed for full wind load**
- **Durable**
  - **critical component - repair, replacement**
- **Stiff**
  - **control billowing, pumping**
- **Air Impermeable**
  - **(may be vapour permeable)**



Typical Air Leakage Points

Big Air Leakage Points




Big Air Leakage Points
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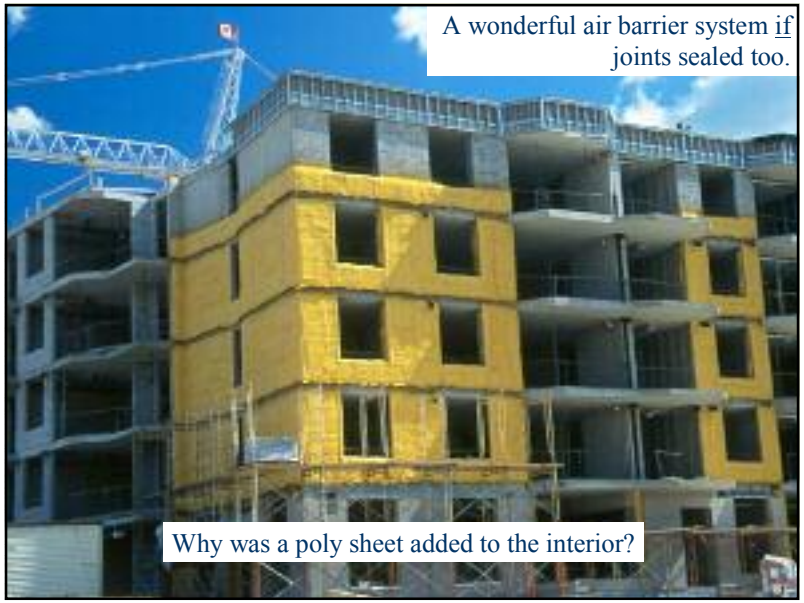
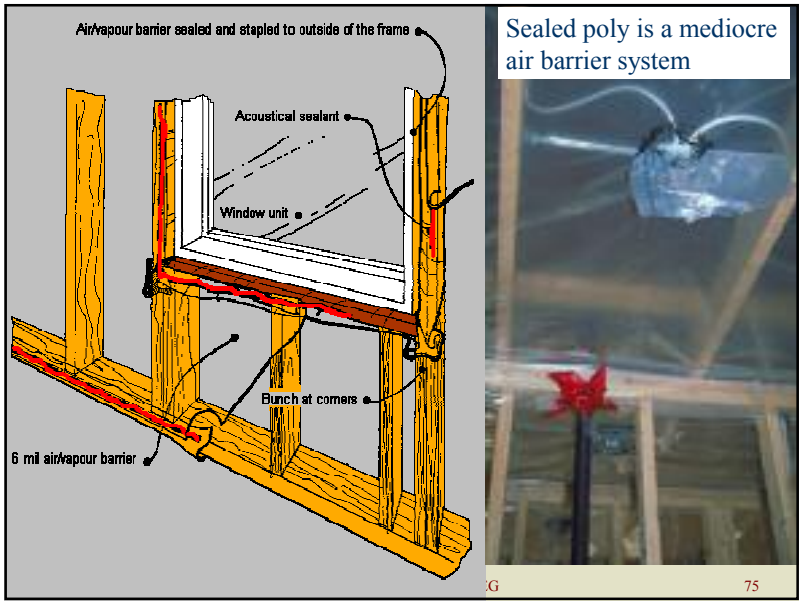

A wonderful air barrier system if joints sealed too.
Why was a poly sheet added to the interior?


Air/vapour barrier sealed and stapled to outside of the frame
Acoustical sealant
Window unit
Bunch at corners
6 mil air/vapour barrier
Sealed poly is a mediocre air barrier system
75


Air sealing around windows and other openings
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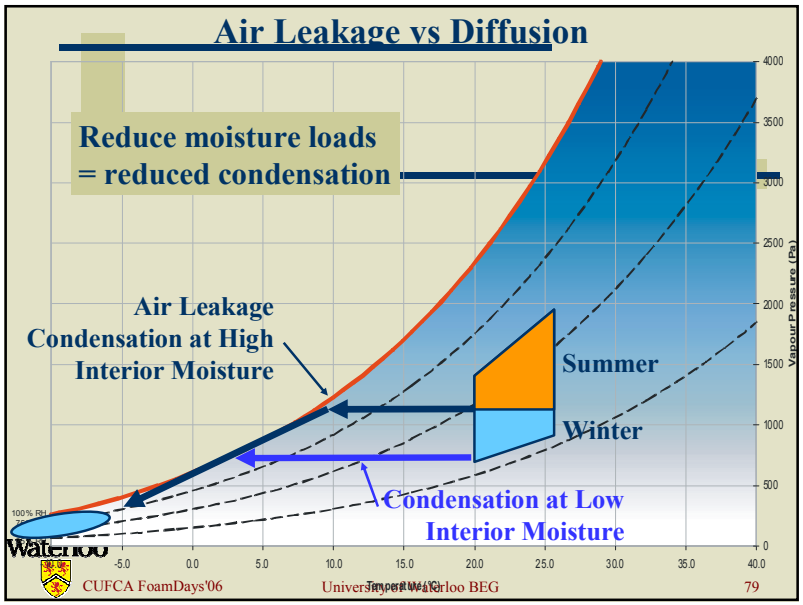
Internal Moisture Loads

- Important for cold climate use of 0.5 pcf SPUF!

Primary load for vapour diffusion and air leakage condensation

- More unknown (!) than exterior
- Temperature
  - 8 to 76 F (21 to 26)
- Relative Humidity
  - 20 to 75% ?



Control Interior RH!

Canadian Climate

- Exhaust ventilation
  - $150 + operating
- Air-to-Air Heat exchanger
  - $1000 + operating

Air Barrier Systems Summary

- Air barrier systems are required to **stop uncontrolled airflow**
- ABS can be placed anywhere in the enclosure
- Must be **strong** enough to take wind gusts
- Must be **continuous**
- Must be **durable**
- Should be **stiff** enough not flap around

The CUFCA Study

Objectives

- Answer "When and where do I need a vapor barrier?"
- Provide Scientific, third-party, open information

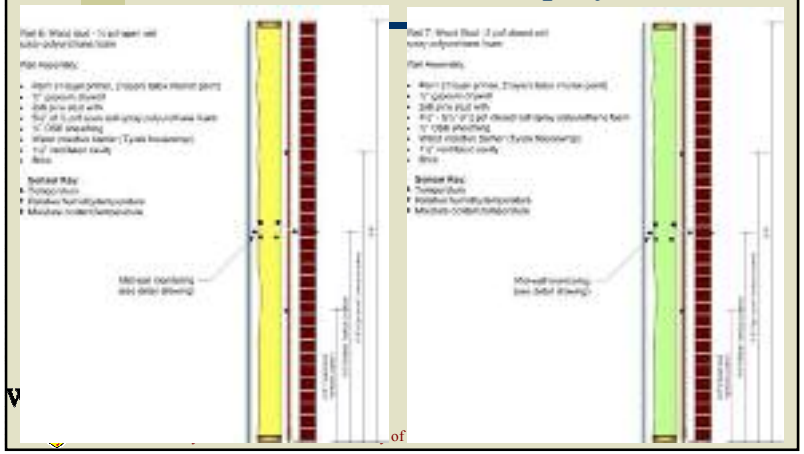
Approach

- Full-scale field measurements of real walls
- Laboratory Climate Chambers of different types of foams
- Computer modeling of different climates

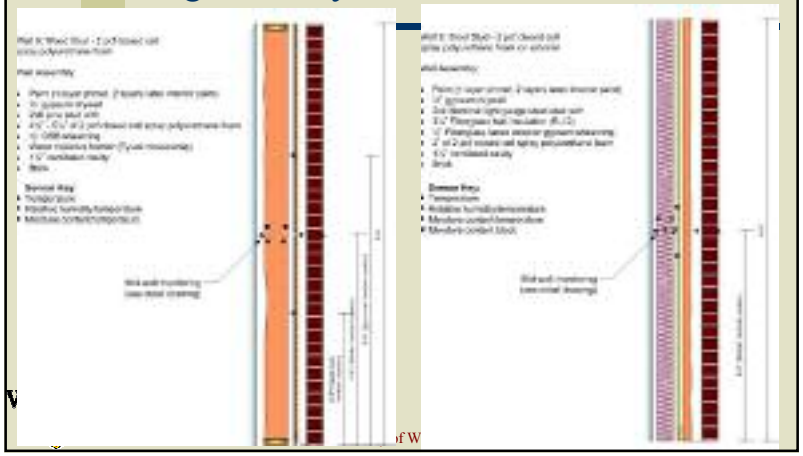
Walls

- Four different types
  - ½ pcf wood frame
  - 2 pcf wood frame (types)
  - 2 pcf exterior spray, steel studs
- Pair of each installed: north and south facing

Walls #6/7: two densities no poly



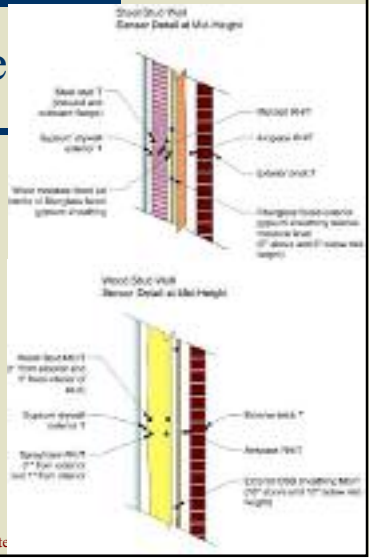
Walls#8/9: high-density, commercial/residential

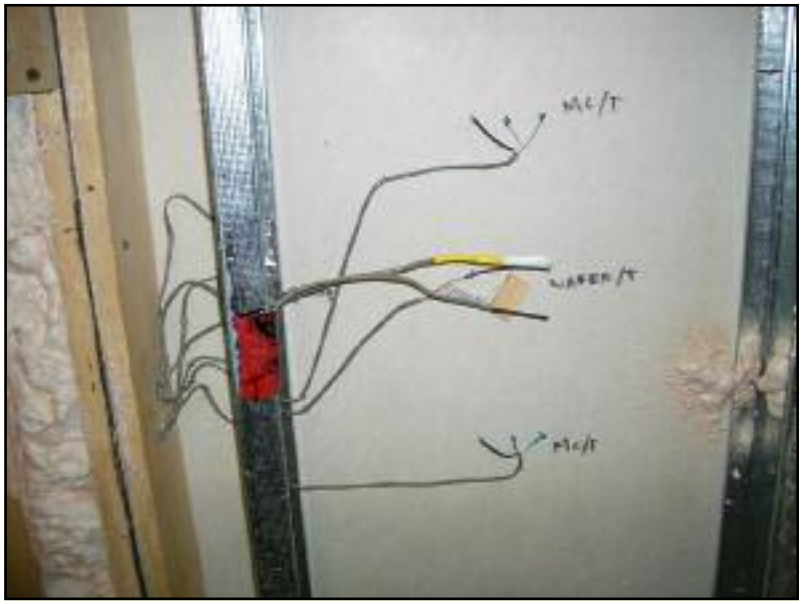


The Beghut

Sensor Package

- Within walls
  - Temp, RH, MC
- Interior and Weather conditions:
  - Temp, RH, sun, rain, wind,
- Every 5 minutes, saved hourly





Environmental Conditions

- Interior
  - Warm (21 C) and very humid (50%)
- Exterior
  - Cool 4650 DD, design temp -21 C
- Computer modeling allows us to *extrapolate* to other conditions – colder, warmer, drier

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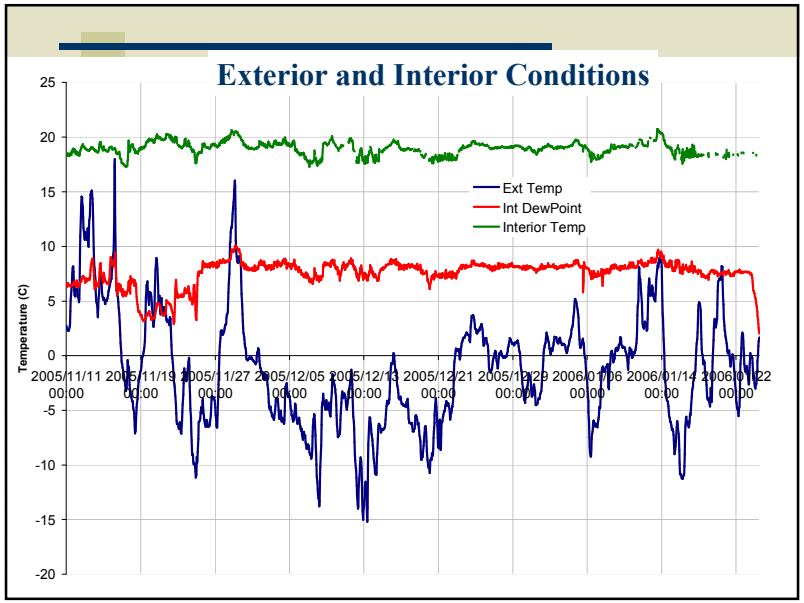
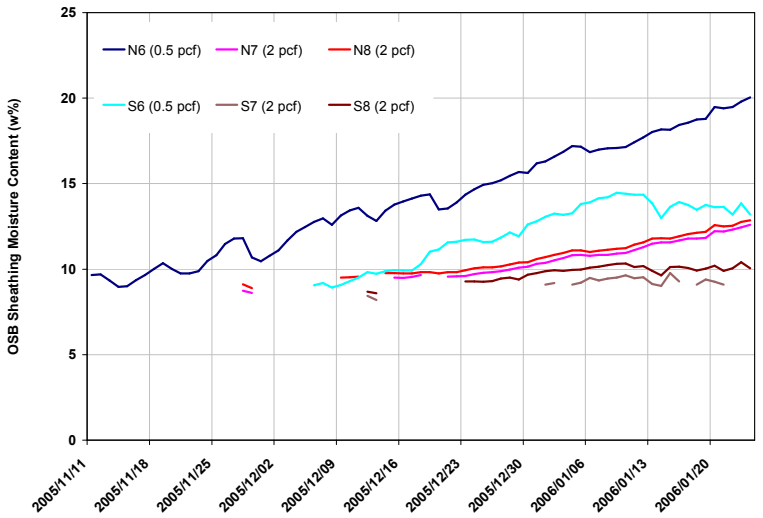


OSB moisture Content to end of January



Preliminary Results

- Performance as expected
  - 2 pcf closed cell foam controls vapor flow even in challenging conditions
  - ½ pcf foam requires consideration – in high humidity conditions may need paint layer

Future

- Climate chamber
  - 14 or more combinations of foam, and poly
  - Run at for a few weeks at large temperature and humidity differences
- Computer model
  - Show that they work
  - Extend results to different climates/conditions

Conclusions

- Existing vapor barrier rules are based on little science and often wrong
- SPUF can provide an excellent air barrier system
  - This is more important to moisture control than vapor barriers
- Closed cell SPUF does not require special VB layer, certainly not poly!
- ½ pcf SPUF may need vapor control in some cases

Website

- University of Waterloo

Building **E**ngineering **G**roup

www.civil.uwaterloo.ca/beg

Building Science Textbook at

www.johnstraube.ca

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