Affordable Comfort

Moisture Physics and
Air & Vapour Barriers

Airflow Control: Why

- Comfort and Health
  - Drafts
  - odours, particles, gases
- Energy
- Moisture control
  - air leakage condensation
- Sound
- Required by codes?

Air Barriers

There must be a continuous, durable, strong and stiff assembly of materials that is defined as the* plane of air tightness *in all buildings with conditioned space

Air Barriers & Vapour Barriers

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

Remember

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

Airflow Control

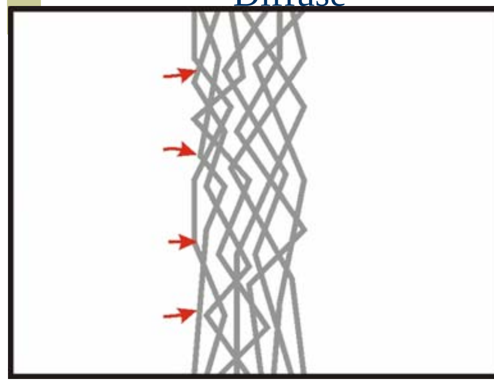
- Air flow *through* enclosure
  - Code requirement?
- Air flow *within* enclosure
  - Air loops inside enclosure
  - Air loop from interior and back
  - Air loop from exterior and back
- Therefore, CONTROL
  = Limit or eliminate air flow *through* and *within*

Airflow Behaviour

- Diffuse
  - through open materials, many cracks
- Orifice
  - large openings
- Channel or pipe
  - direct small openings
- Tortuous
  - combination of others
  - many building situtations

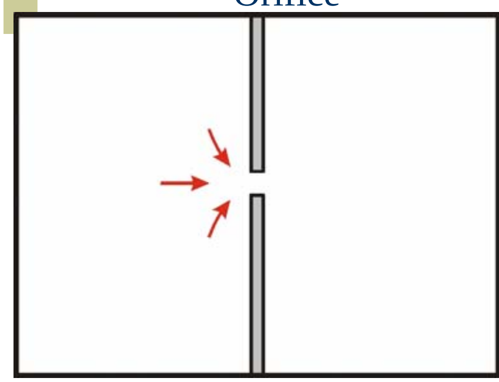
Diffuse

$Q = K \times A \times \Delta P$



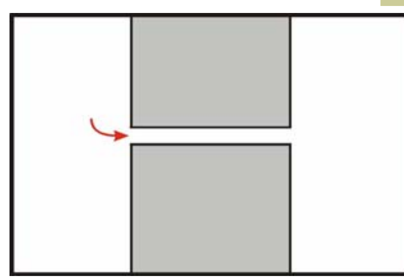
Orifice

$Q = C_d \times A \times \sqrt{(\Delta P)}$



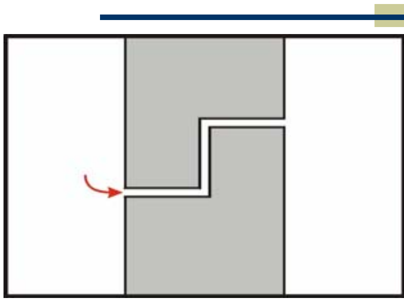
Channel or Pipe Flow

$Q = C \times A \times (\Delta P)^n$



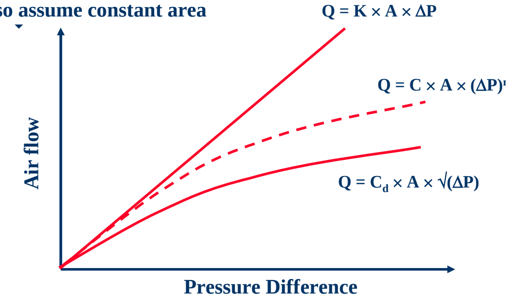
Tortuous Flow

$Q = C \times A \times (\Delta P)^n$



Test Results

ELA and blower door assumes n=0.65
Also assume constant area



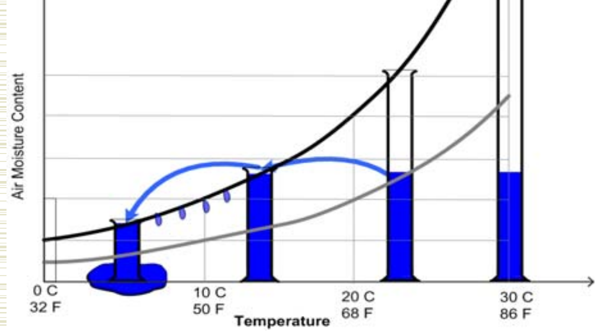
Why Air Barriers for Moisture?

- **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

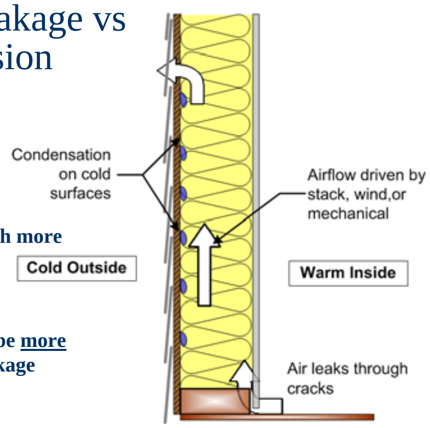
  } Air Barrier

Condensation: Cool air contains less vapor

Cool air – increase RH
Heat air – decrease RH

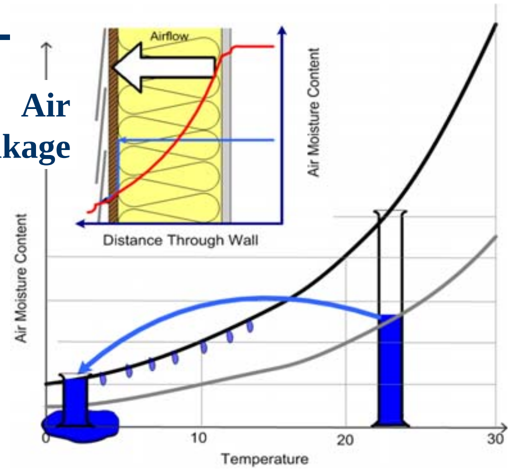


Air leakage vs Diffusion

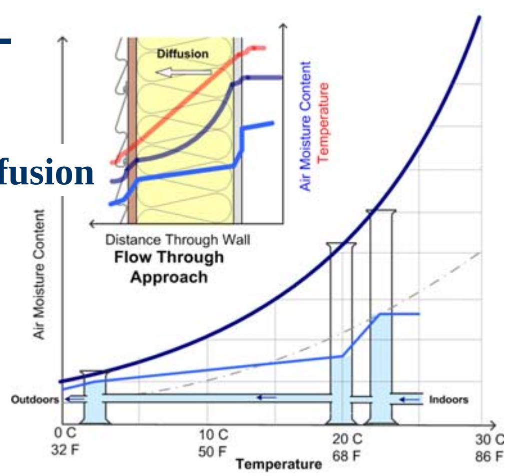


- **Air leakage is much more critical**
- **Walls sensitive to diffusion-related condensation will be <u>more</u> sensitive to air leakage**

Air leakage

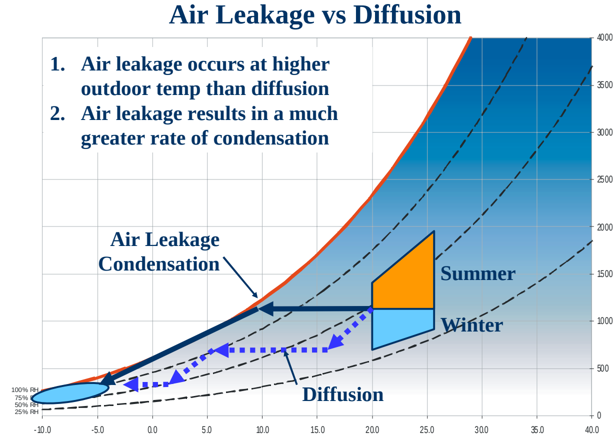


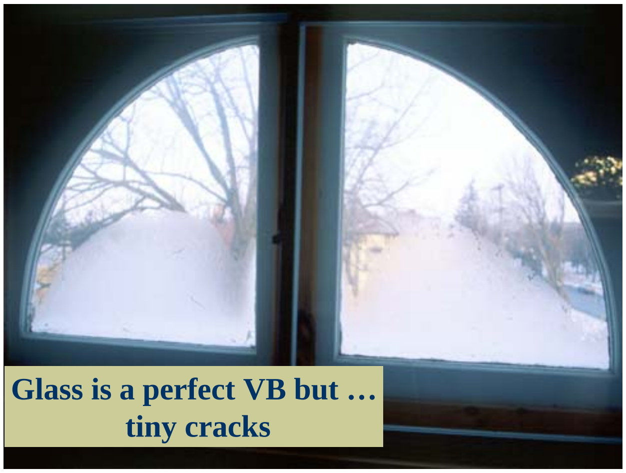
Diffusion

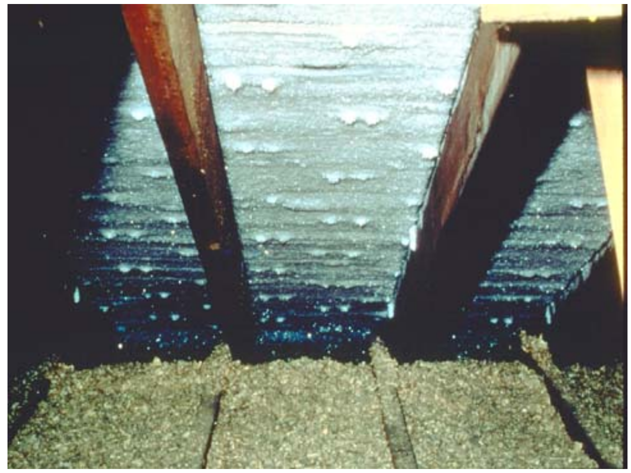


Air Leakage vs Diffusion

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







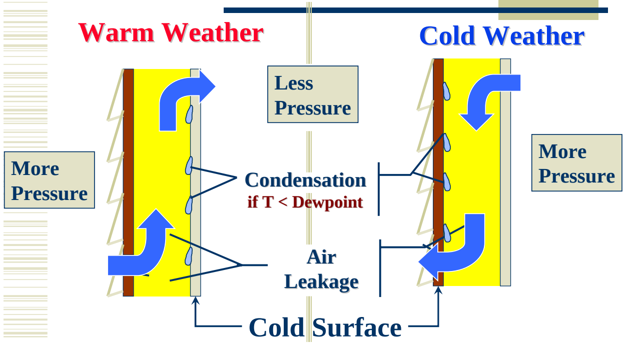
Air Leakage & Condensation

- Difficult to predict direction of air pressures and unintentional flow paths
- 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, **and**
  - air flow is in the direction of more to less vapour

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

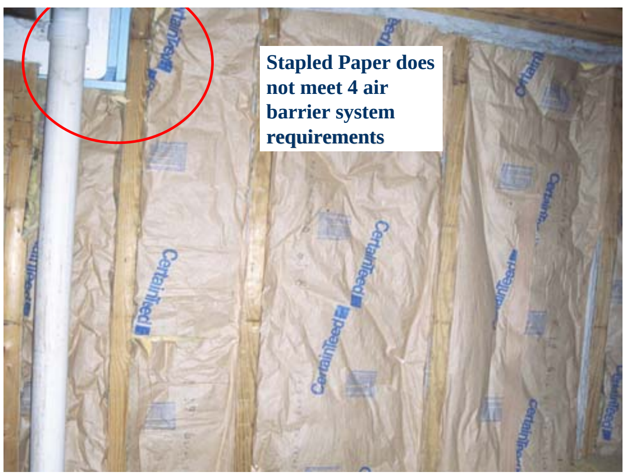
- Stop airflow = stop many problems = ***Air Barrier***
- Can locate anywhere in enclosure
- Should be protected if possible
- Multiple layers are good
- Important in all climates

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

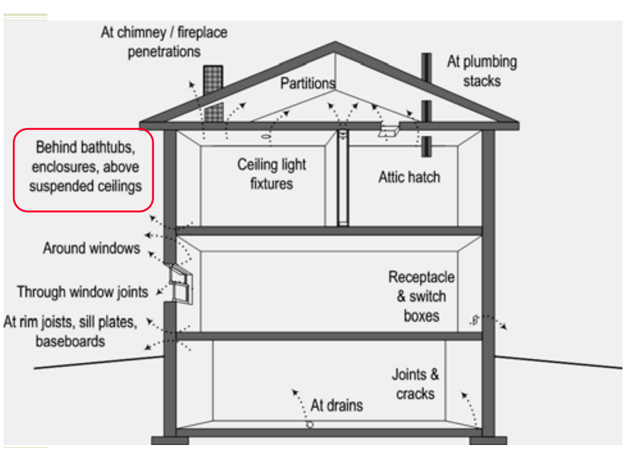
Air Barrier System Requirements

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



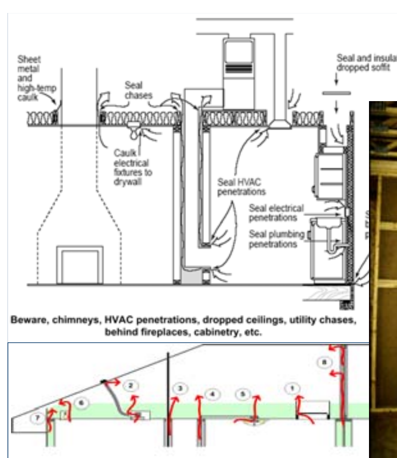
1. Stopping Leaks

"Find the holes and plug them"
This requires finicky attention to 3-D details.

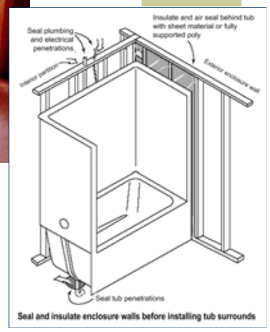


Typical Air Leakage Points

Big Air Leakage Points

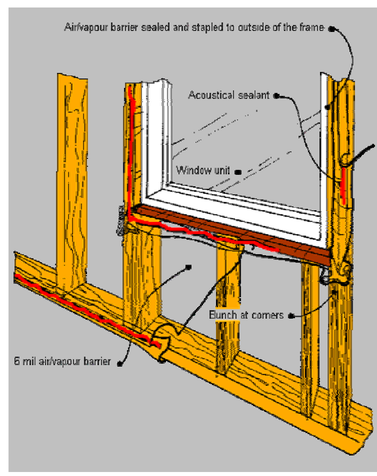


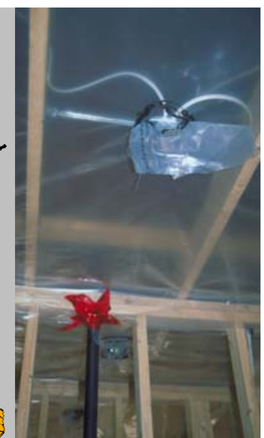
Big Air Leakage Points

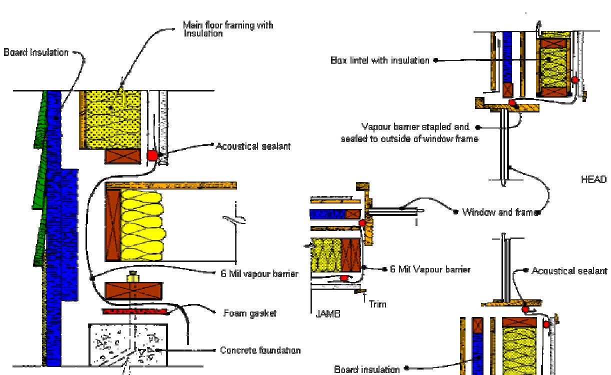


Air sealing around windows and other openings

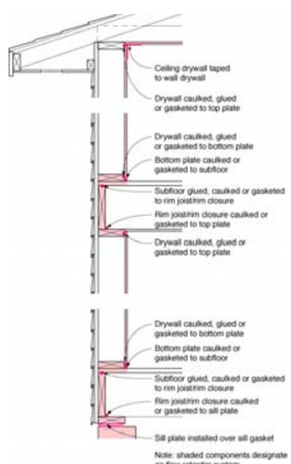
Poly can be (?) an air and vapour barrier







Beware: poly is a VB -- keep on warm side

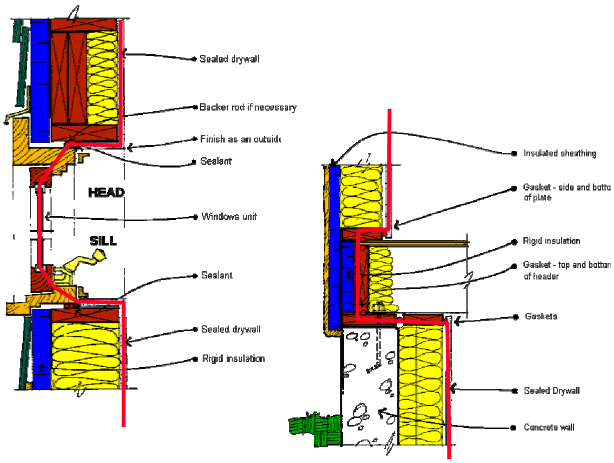


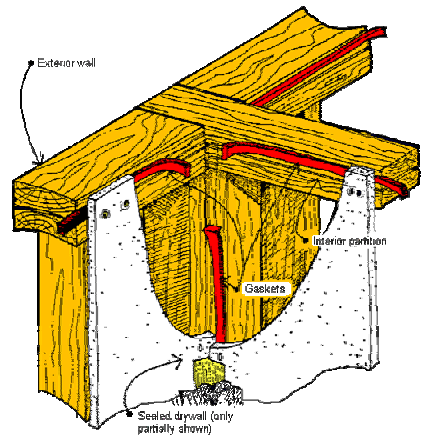
The Airtight Drywall Approach

Use drywall, framing members

- Seal with sealant, gaskets, etc.
- Is stiff, strong
- Often easier to get better

Drawing From:
Dr. Joe Lstiburek
Builders Guide





2. Controlling Temperatures

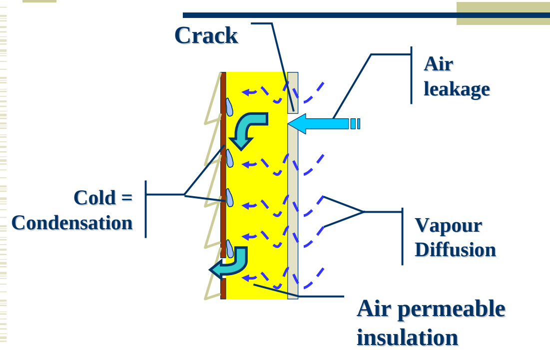
A potent *cold-weather* strategy for framed enclosure systems

Insulated Sheathing

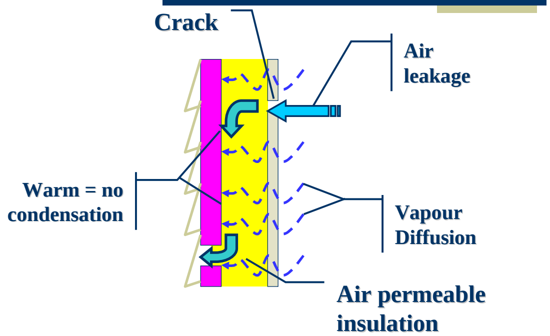
- Increases temperature of first condensation surface in winter
  - adding R5 to R7 on exterior of R12 batt practically eliminates possibility of condensation
- Many foam sheathings reduce summer vapour drives, e.g., they have permeances of M<200
- Some sheathings are vapour impermeable -- they reduce drying outward!
- Remember

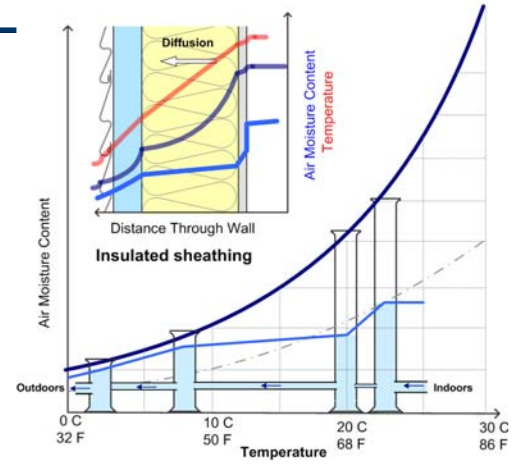
Insulated Sheathing = Moisture Control Strategy

Wall w/o Insulated Sheathing



Wall with Insulated Sheathing





Insulated Sheathing

- Fibreboard
  - A high density cellulose R2.5/inch
  - not air or water tight
- EPS, XPS, PIC
  - may be airtight if closed cell (not EPS)
  - control wind washing
  - water tolerant
  - vapour barriers to vapour retarders
- Semi-rigid MFI
  - not airtight but a drainage layer
  - R values of 4 to 4.4/inch
  - vapour permeable

May Exterior Sheathing as air Barrier

How long will the tape last?

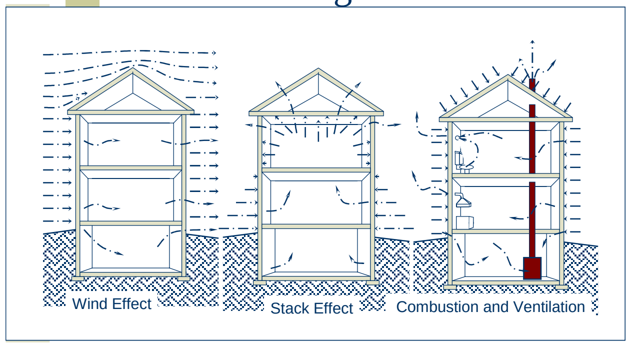
3. Controlling Driving Pressures

Wind+stack: understand them.

Control HVAC pressures!
Cold weather suck

Hot-humid climates blow

Driving Forces



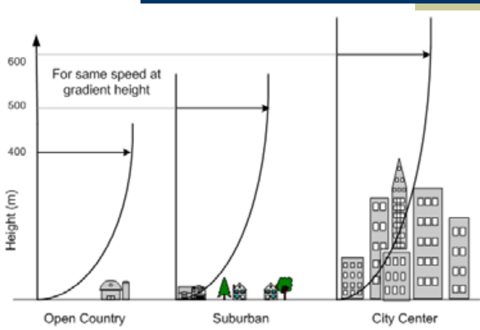
a. Wind

- Major driving force
- Codes - Extensive data for Structural Design Loads
- Average pressures much lower
- Wind Pressure Increases with Height
- Exposure Conditions Matter!
- Beware Corner and Suction pressures

a. Wind Values

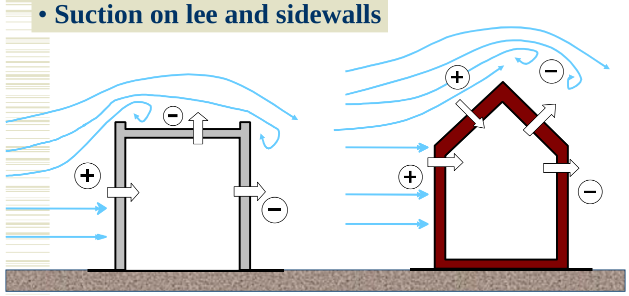
- Peak loads are high (over 1000 Pa)
- Average pressures much lower (<50 Pa)
- Wind Pressure Increases with Height
  - low-rise average pressure about 5 Pa
  - twenty story building about 40 Pa

a. Windspeed/Exposure



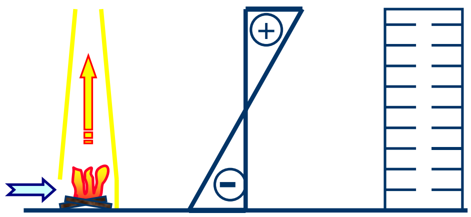
a. Wind Pressures / Flow Patterns

- **Pressure on windward side**
- **Suction on lee and sidewalls**



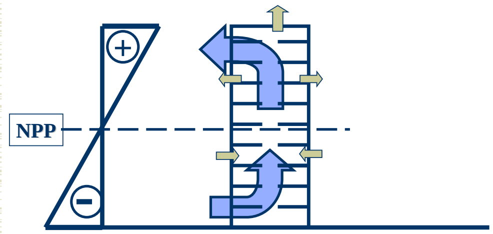
b. Stack Effect

- Hot air rises
- Tall Building in Winter = Heavy Balloon



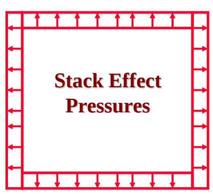
b. Stack Effect

- "Perfect" Building equally leaky everywhere
- **Neutral Pressure Plane** at mid-height



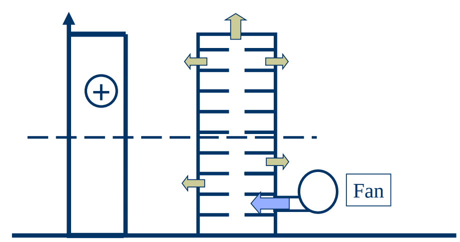
b. Stack Pressure Distribution

Pressures are height dependent (i.e. different at each specific height)



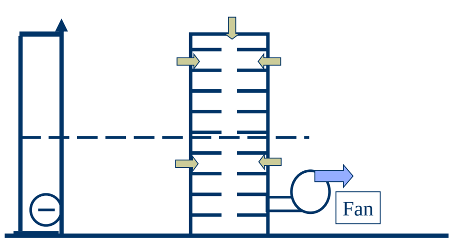
c. HVAC Pressurization

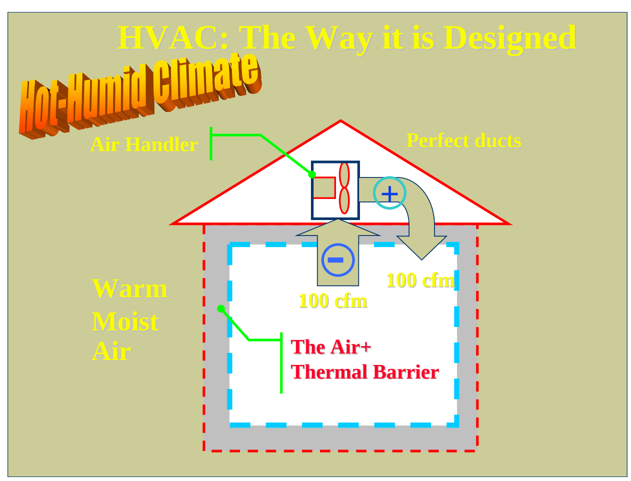
- More airflow forced into building than sucked out of building = **Pressurization**

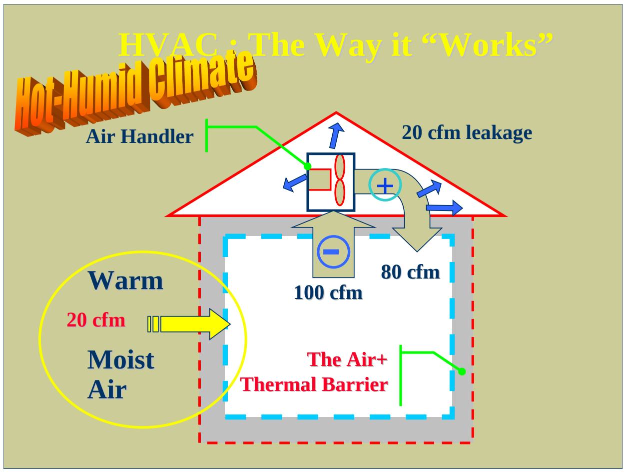


c. HVAC De-Pressurization

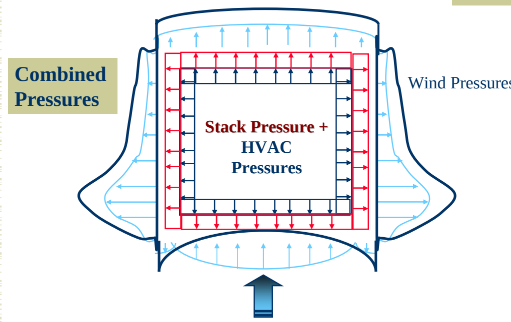
- More airflow forced out of building than forced into building = De-**Pressurization**







Pressure Distribution



Control Driving Forces (Pressures)

- HVAC can be reduced by controlling fan operation
- In many houses, exhaust-only fans depressurize
  - less air leaks outward
  - *good* for cold weather
- Commercial buildings often pressurize to reduce drafts
  - don't do this in cold weather -- plug holes!
- Control Stack effect by horizontal compartmentalisation

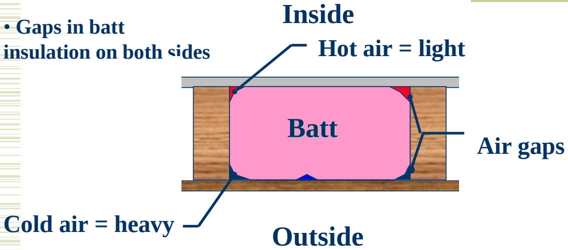
Airflow Within Enclosures

More than just air barriers!

1. Convective Loops
2. Wind washing
3. Pumping

Convective Loops

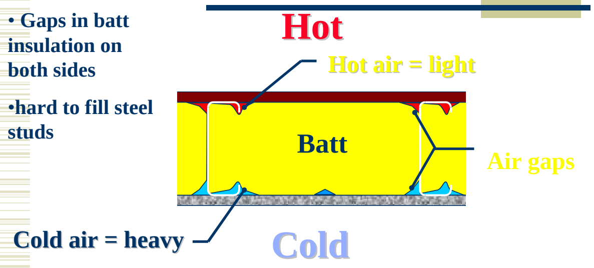
• Gaps in batt insulation on both sides



Common performance problem

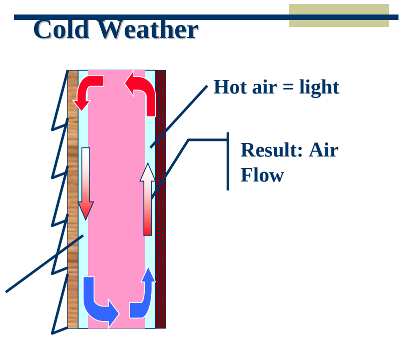
Steel studs are even “better”

- Gaps in batt insulation on both sides
- hard to fill steel studs

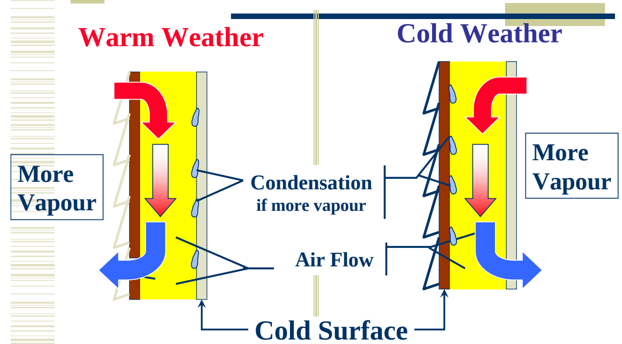


Internal Stack Effect

- Gaps in batt insulation on both sides
- closed circuit
- energy cost
- cold surfaces



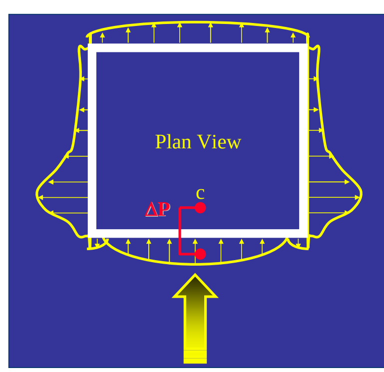
Air movement (Stack Effect)



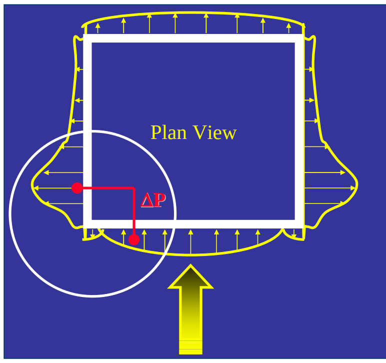
Windwashing

- Need some airtightness outside permeable insulation
- Sealed housewrap, attached building paper
- Sheathing sealed with tape
  - both OSB and insulated sheathing
  - high density MFI?
- High density cavity insulation
  - some foams, maybe dense cellulose

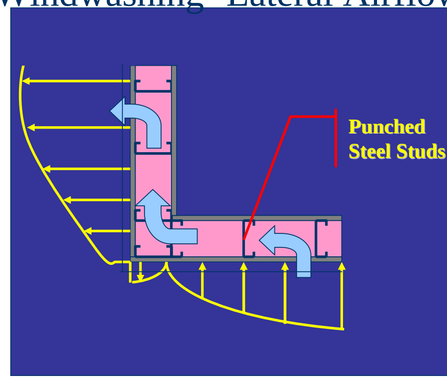
Pressure Distribution



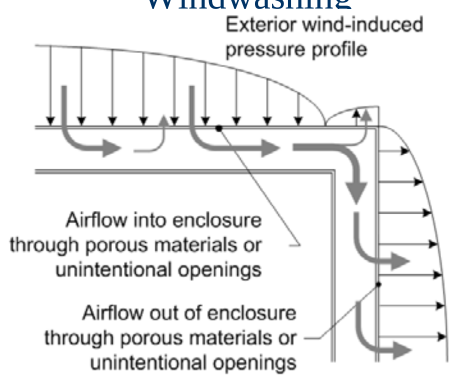
Pressure Distribution



Windwashing- Lateral Airflows



Windwashing



Using Exterior Sheathing to Control Wind washing

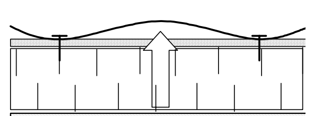
Using Exterior Sheathing to:
•Control Wind washing
•Provide a redundant air barrier layer

•Tape? Mastic?

Pumping Airflow and Adhered Membranes

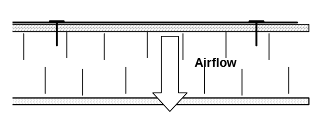
- Membrane is continuous and airtight but …
  - It may not control airflow if not fully adhered or supported
  - E.g. roofing, housewraps, poly

1. Outside= negative pressure gust



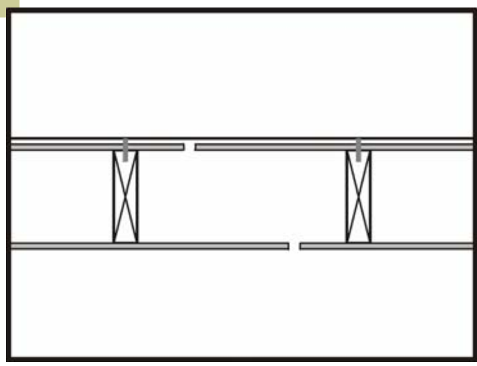
- Membrane balloons outward
- Airflows into roof

2. Outside= positive pressure gust



- Membrane pressed tight to sheathing
- Airflows out of roof

Pumping



Airflow within enclosures

Solutions

- Interior & exterior air tightness (batt)
- Provide lateral (3D) airflow resistance
  - batt insulation allows easy lateral flow
  - high-density fibrous insulation, dense-packed cellulose slows lateral flow
  - closed cell foam solid materials stop lateral flow
- Compartment Separators
  - Various solid airflow resistors (studs?)

Airflow within Enclosures

- Air barrier system
  - Inside or outside, well sealed!
- Control loop from outside
  - Windwashing, wind barrier
- Control loop from inside
  - Interior drywall or finish

Controlling Interior Moisture Loads

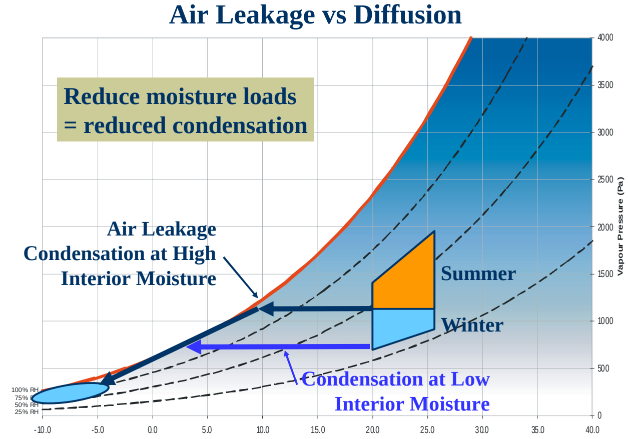
Most difficult to predict

Ventilate to remove excess moisture

Internal Moisture Loads

- Critically important for cold climate!! *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% ?

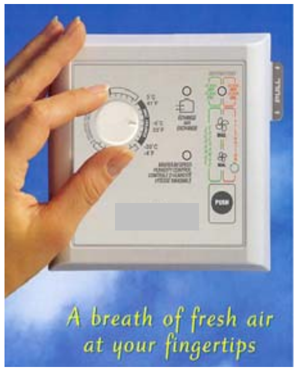
Air Leakage vs Diffusion



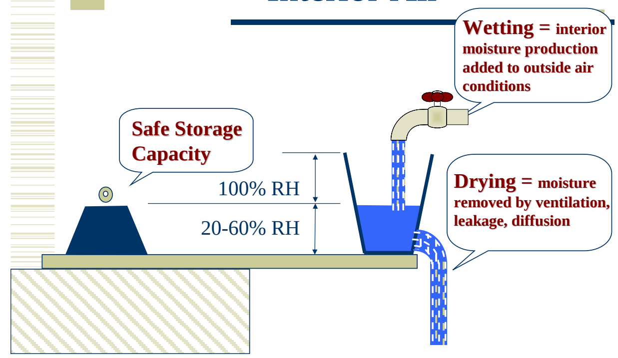
Control Interior RH!

Cold Climate

- Air-to-Air Heat exchanger
- Exhaust ventilation



The Moisture Balance for Interior Air

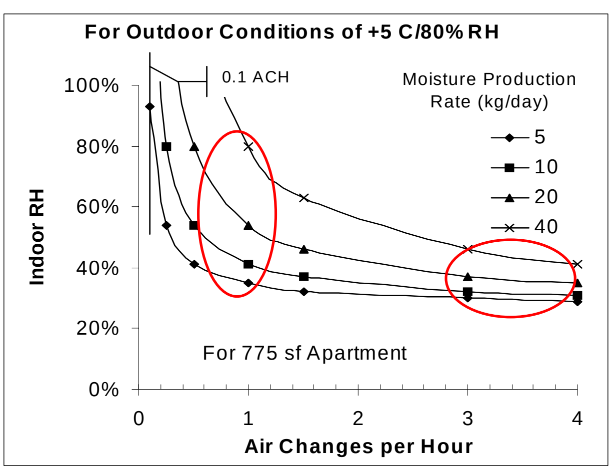


Sources of Moisture Within Buildings

Source	Strength kg per day
People - evaporation per person	0.9 to 1.25 *
Humidifier	2-20+
Hot tub, Whirlpool	2-20+
Firewood, per cord	1-3
Washing floors, counters, etc.	0.2
Dishwashing	0.5*
Cooking for four	0.9 to 2 (3 with gas range)*
Defrosting (frost free) Fridge	0.5*
Typical bathing/washing per person	0.2 to 0.4*
Shower (ea)	0.5
Bath (ea)	0.1+
Uncovered Crawlspace	0.5 / m^2
Unvented Gas Appliance (ea)	1
Seasonal Desorption	3-8 depends on the type of construction
Plants/Pets	0.2 - 0.5 (five small plants or one dog)
Total (Typical Family of 4)	**About 10 , but potential ranges 3 to 40**

Internal Moisture

- Total for Family of 4: 10 to 14 kg/day
- CMHC Study Of Detached Homes
  - 90%> 3 kg/day and <21 kg/day
- Also drying out of construction moisture



Cold + Mixed Climate Only

Mechanical Ventilation

- Old houses had 3 or more ACH
  - hence, moisture production rate had little effect on interior humidity
- New houses have 0.25 to 1 ACH
  - hence, moisture production dominates interior humidity
- Mechanical ventilation ensures
  - proper fresh air supply
  - reduces energy consumption
  - controls interior humidty

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

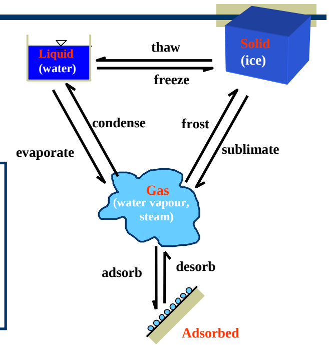
Air Barrier Systems Summary

- Air barrier systems must be **continuous**
- They leak at ***joints, interfaces, penetrations***
- Hence
  - "The air permeance of the materials is less important than continuity of the system"
- Air permeance should be low
  - say less than about 0.1 lps/m^2@75 Pa, usually better

Windows

The 4 phases of Water

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



Water Vapour Pressure

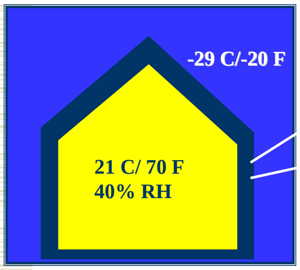
- For water vapour in a container
- Higher temperature =
  - more energy
  - higher velocity
  - harder collisions with wall (higher pressure)
- Greater number of molecules =
  - more collisions with walls (higher pressure)
  - pressure simply another measure for moisture content

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 m^2 or less vapor barriers



No VB:
21.5 g/m^2/day
(0.07 ounce/ft^2/day)

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

Air barriers discovered

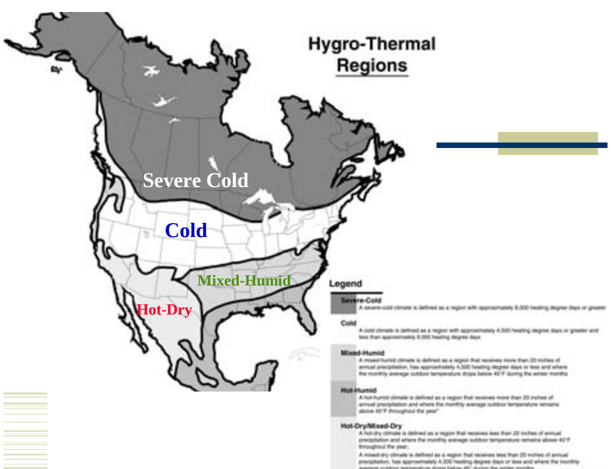
- Air leakage identified by : *"The rate of condensation is about ten times that at which vapour might be expected to diffuse through …It seems necessary to assume some other mechanism … the leakage of warm moist air outward .."* Neal Hutcheon, 1950
- Solution suggested by many:
  - Why not use the vapour 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

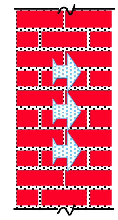
- Florida is hot and humid
  - moisture is outdoors
  - place VB near outside
  - allow vapour to flow INWARD
- Winnipeg/Bismark is cold/dry
  - bitterly cold winters
  - summers are hot and dry
  - place VB near inside
  - allow vapour to flow outward

Climate and VB

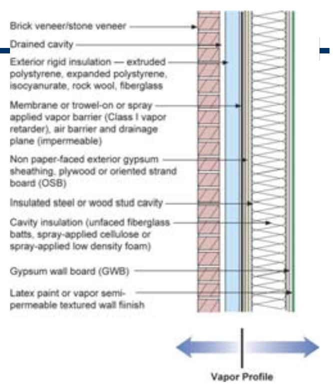
- Vancouver/Seattle
  - moisture is both indoors outdoors
  - allow vapour to flow inward and outward
  - use VR near inside (paint)
- Toronto/Detroit
  - summers are hot and humid, winters cold
  - if rain-wetted cladding, inward is important!
  - allow vapour to flow inward and outward
  - use VR near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

VB and Wall design

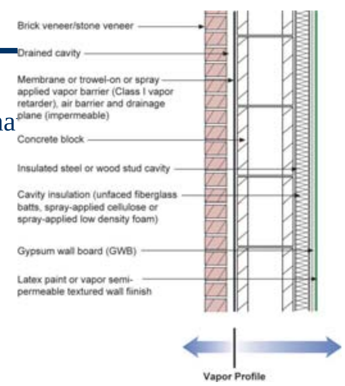
- **Likely need vapour barriers:**
  - low integral vapour resistance
    - framed walls with batt
- **Rarely need VB:**
  - Integral vapour resistance
    - SIPS
    - spray foam
  - Built in VB
    - concrete
  - Kept warm
    - insulating sheathing



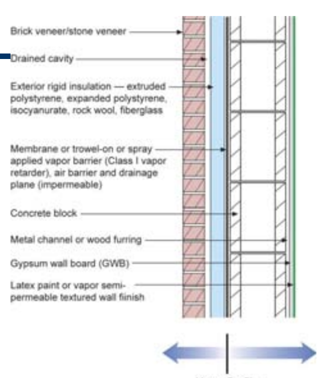
- OK for cool climates if the ratio of exterior R value to interior is high. Calculate.



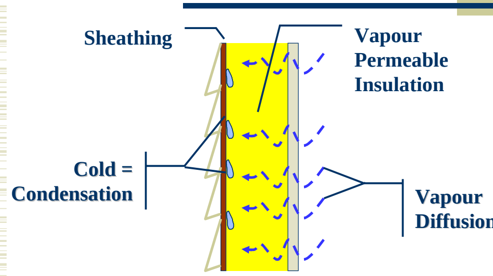
- Good for hot-humid climates tha
- NEVER for cold climates



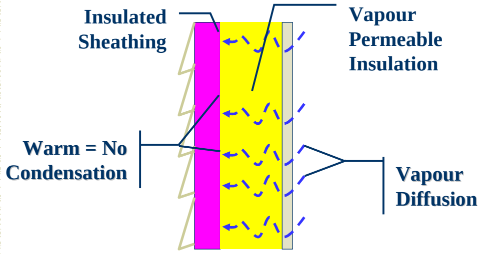
- Works everywhere without calculation



Wall w/o Insulated Sheathing



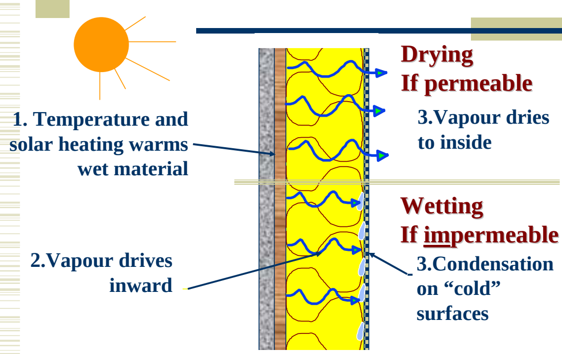
Wall with Insulated Sheathing

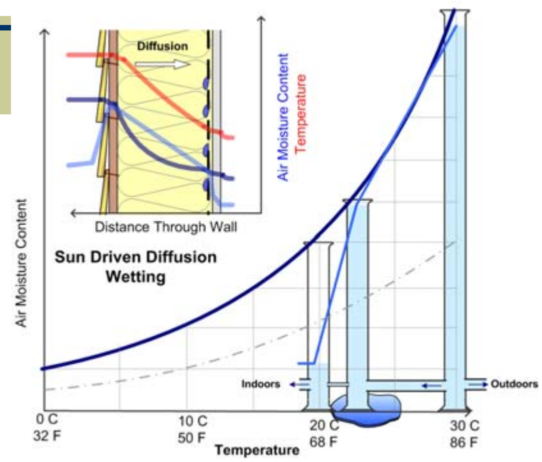


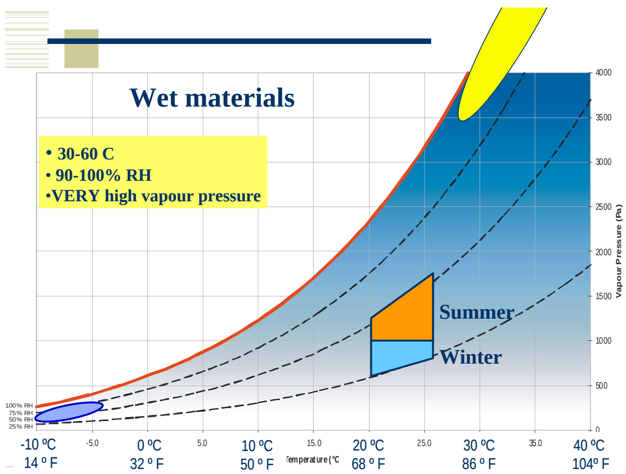
Drying

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

Inward Diffusion







Warm climates


Cool climates


Summary

- **Air leakage** and **Diffusion** can cause
  - Wetting AND
  - Drying
  - Depends on Weather Conditions!
- Vapour barriers and air barriers reduce or slow flow in BOTH directions
- **all** vapour barriers slow inward drying
- **all** vapour resistant claddings and sheathings slow outward drying

Conclusions

- Air barriers and vapour barriers are ***different***
  - can be combined in same materials
- Vapour barriers control diffusion
  - use only when needed
  - place near WARM side only
- Air barriers control air flow
  - can be placed any where
- **Air barriers** usually ***more important***
  - continuity is key!

Website

- University of Waterloo

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