John Straube, Ph.D., P.Eng

Spray Foam

Air Flow Control

presented by www.buildingscience.com

Overview of Presentation

- Why control airflow? Vapor flow?
- Review of Driving Forces
- Air Barrier Systems
  - Functions + Requirements
- Airflow Within Enclosures
  - convective loops, windwashing, pumping
- Air Leakage Condensation
  - Control Strategies
- Tall Buildings

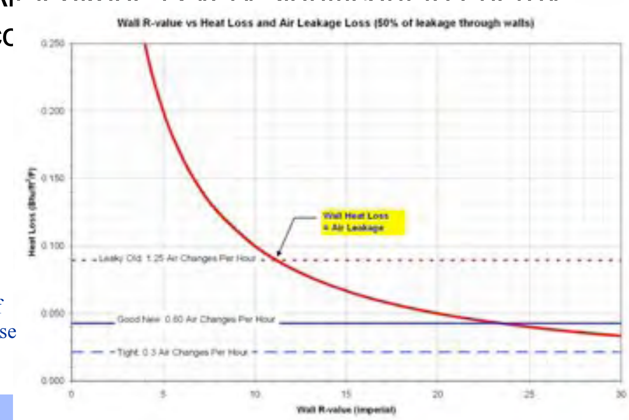
Airflow Control: Why

- Comfort and Health
  - Drafts
  - Odors, particles, gases
- Moisture control
  - air leakage condensation
- Energy
  - Heat transferred with air
- Sound
- Required by some codes

If you can't enclose air, you can't condition it

Air Barriers and Energy

- Air leakage is very significant to energy
  cc



For walls of 2200 sf house in heating climate

Airflow Control: What?

- 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

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Driving Forces

- 1. Wind Pressures
- 2. Buoyancy (or stack effect)
- 3. HVAC

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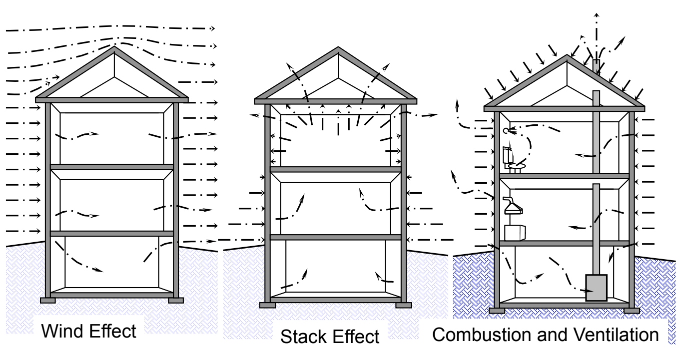
Driving Forces



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1. Wind

- Peak loads are high (>1000 Pa/20 psf)
- Average pressures much lower (<50 Pa)
- Wind Pressure Increases with Height
  – low-rise average pressure about 5 Pa
  – twenty story building about 40 Pa on normal day

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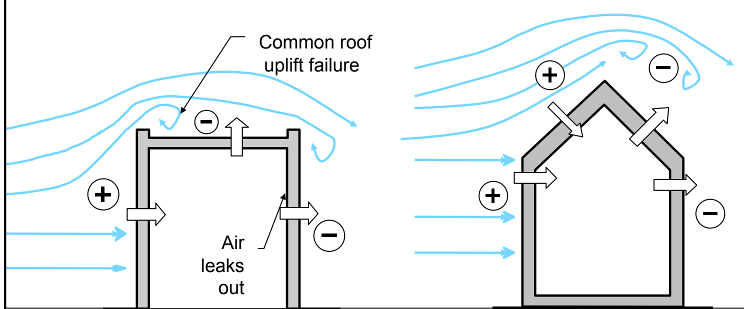
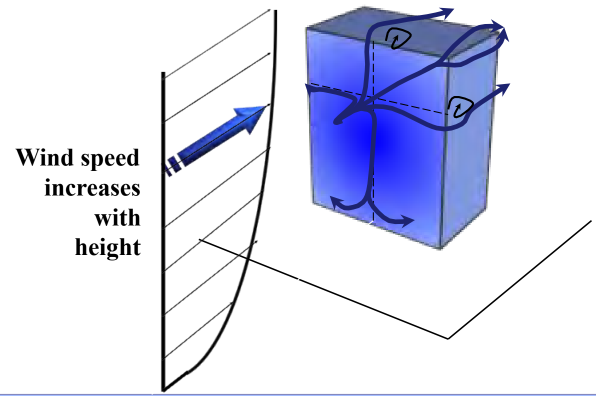
Wind Pressures / Flow Patterns

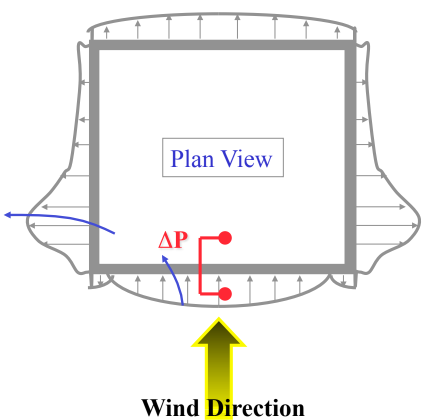
- **Pressure on windward side**
- **Suction on lee and sidewalls**



Wind Flow Patterns

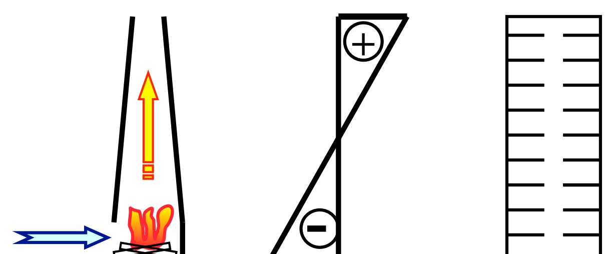


Wind Pressure Distribution



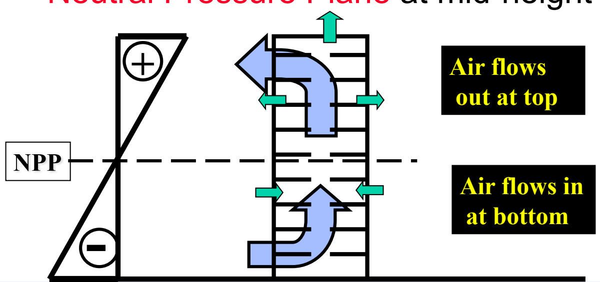
2. Stack Effect: Cold Weather

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



Stack Effect: Cold Weather

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



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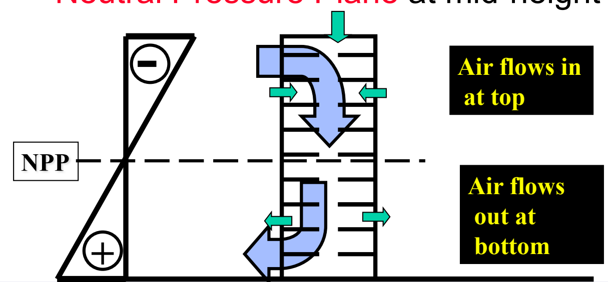
Stack Effect: Warm Weather

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



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Stack Effect

- When cold (20 F) outside
  - About 4 Pa per storey (10') of height
- When hot (95 F) outside
  - About 1.5 Pa per storey (10') of height
- Result
  - Revolving doors
  - We suck air from below in cold weather

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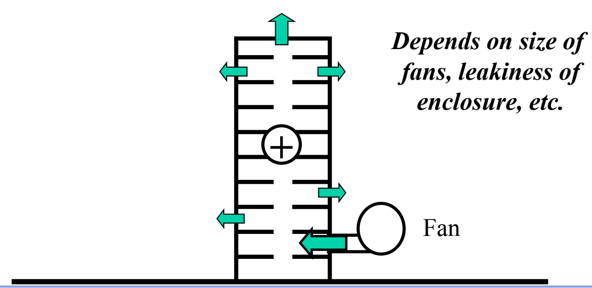
3. HVAC Pressurization

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



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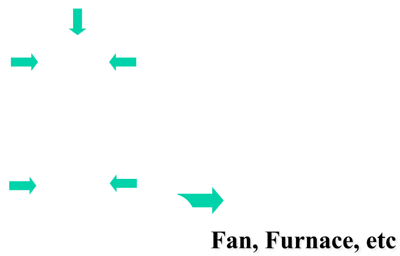
De-Pressurization

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



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Driving Forces

- Wind
  - Taller buildings see high pressures!
  - 2-10 Pa low bldgs, 30-200+ Pa tall buildings
- Stack Effect
  - Pressure increases directly with temperature difference and height
- HVAC
  - Depends on design and operation

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Air Leakage Condensation

- Controlling interstitial condensation is a major reason to control airflow
- If moist air contacts cool surface: Condensation occurs
- When
  - winter: cold outside surfaces
  - summer: cold inside surfaces
- Damaging airflow direction:
  - cold weather inside to outside
  - warm weather outside to inside

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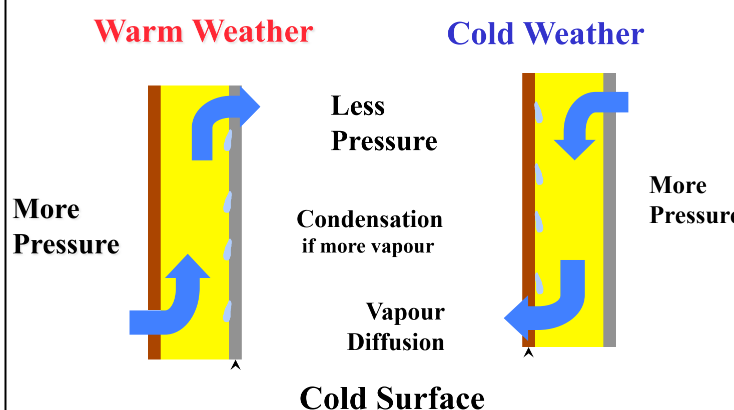
Conditions for Air Leakage Condensation



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Summer condensation

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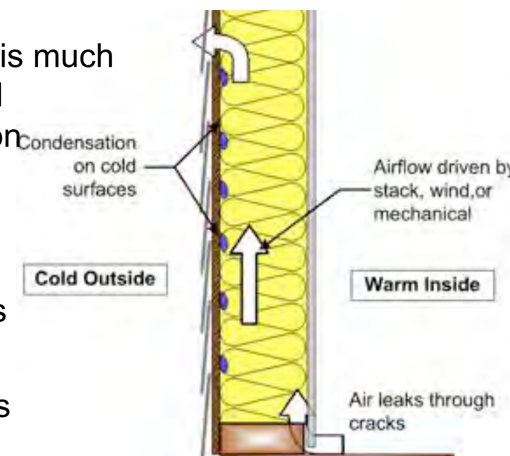
Air leakage vs Diffusion

- Air leakage is much more critical than diffusion

Beware

- Parapets
- Hollow walls
- Canopies
- Penetrations



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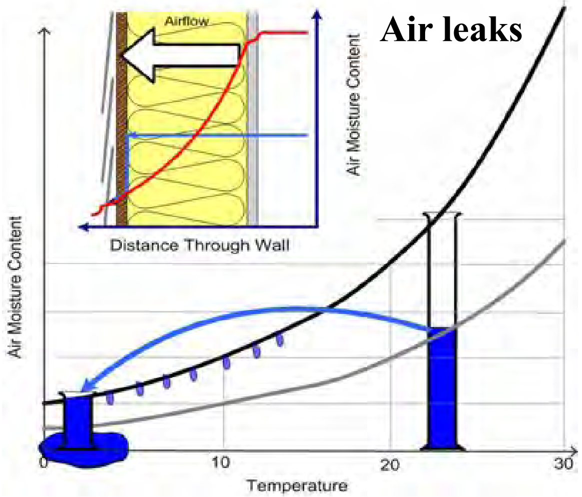
Air leaks



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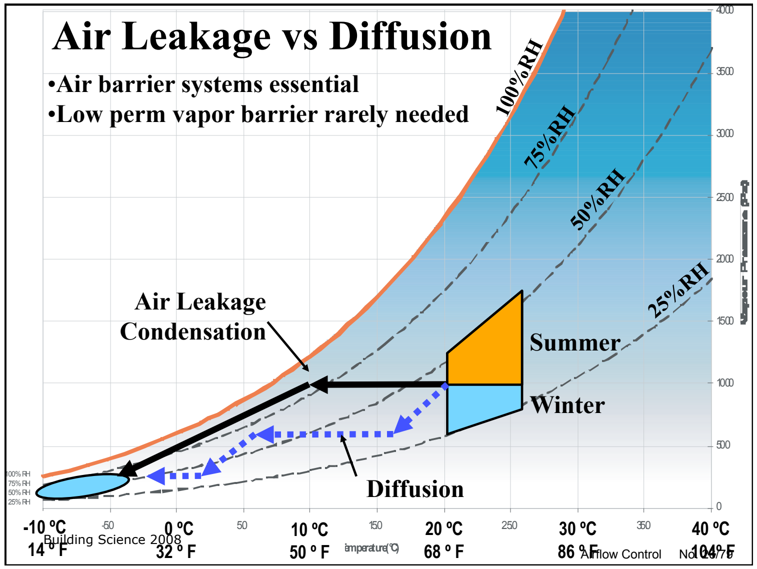
Air Leakage vs Diffusion

- Air barrier systems essential
- Low perm vapor barrier rarely needed



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Why use an ABS or VB?

- Building Code (ABS)
  - Eg Canada, Massachusetts commercial
- VB only *helps* control interstitial condensation
- ABS about interstitial condensation *and*
  - comfort
  - energy
  - health
  - sound
  - odour/smoke

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IRC 2007

- Sort of an air barrier

N1102.4.1 Building thermal envelope. The building thermal envelope shall be durably sealed to limit infiltration. The sealing methods between dissimilar materials shall allow for differential expansion and contraction. The following shall be caulked, gasketed, weatherstripped or otherwise sealed with an air barrier material, suitable film or solid material.

1. All joints, seams and penetrations.
2. Site-built windows, doors and skylights.
3. Openings between window and door assemblies and their respective jambs and framing.
4. Utility penetrations.
5. Dropped ceilings or chases adjacent to the thermal envelope.
6. Knee walls.
7. Walls and ceilings separating the garage from conditioned spaces.
8. Behind tubs and showers on exterior walls.
9. Common walls between dwelling units.
10. Attic access openings.
11. Other sources of infiltration.

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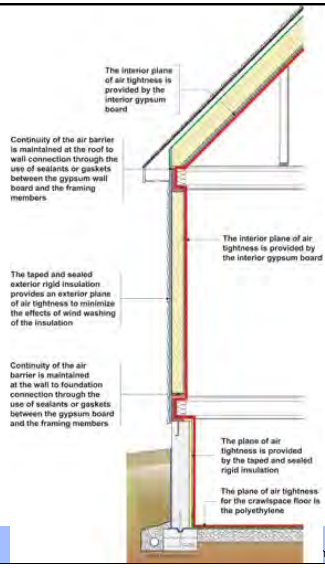
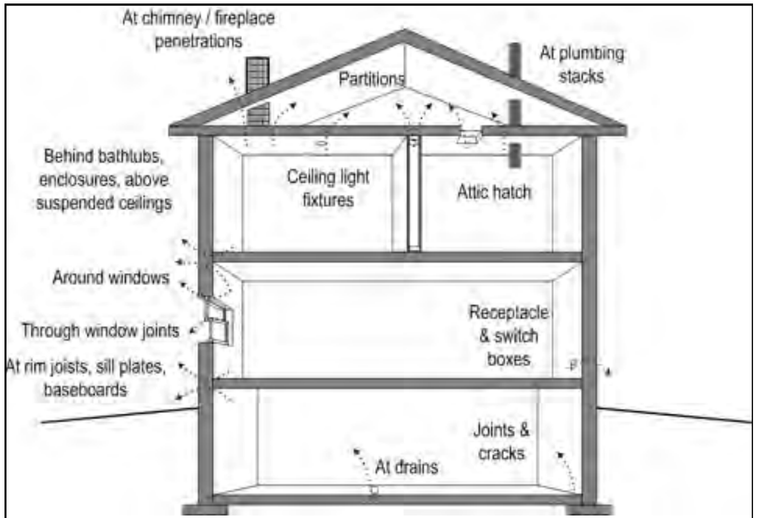
Air Leakage Condensation: Control Strategies

- 1. "Plug all holes" - an air barrier system
- 2. Control driving forces
  - HVAC pressure differences, stack effect, wind
  - Reduce interior moisture (control interior RH to control interior T)
- 3. Control Temperature of condensing surface
  - insulated sheathing, special heating, etc.

1. Stop the Air Leaks

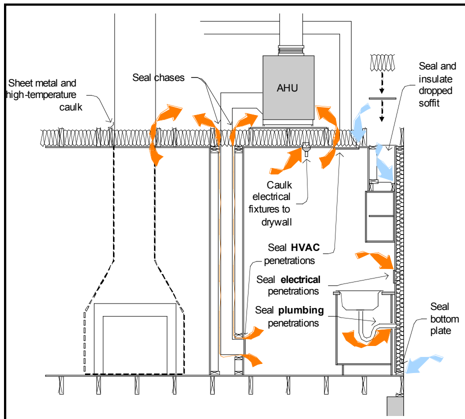
- "Find the holes and plug them"
- This requires finicky attention to 3-D details.





Typical Air Leakage Points

Big Air Leakage Points



- •Ductwork
- •Partitions
- •Dropped soffits
- •Cabinetry
- •Ceiling lights
- •Rimjoists
- •Plumbing stacks
- •Attic hatch

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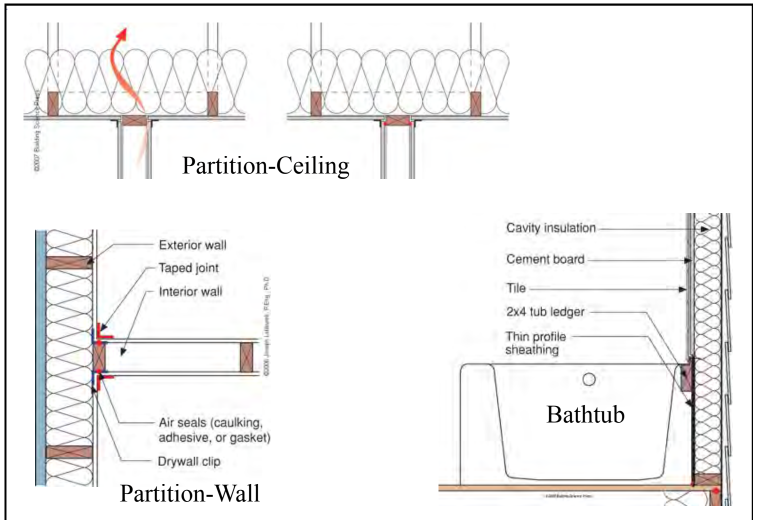

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Airflow Control No. 35/79

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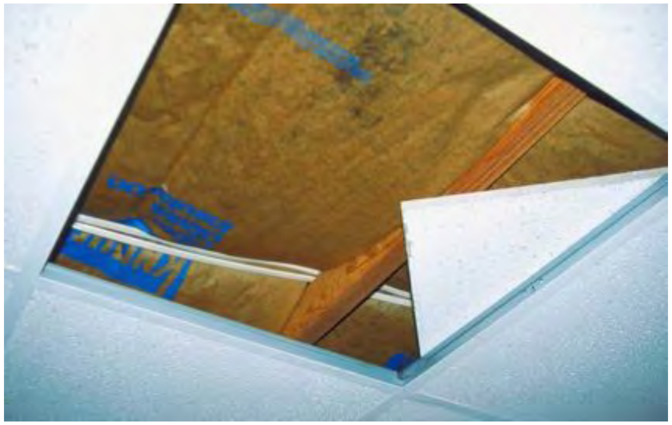
Airflow Control No. 36/79

Bigholes



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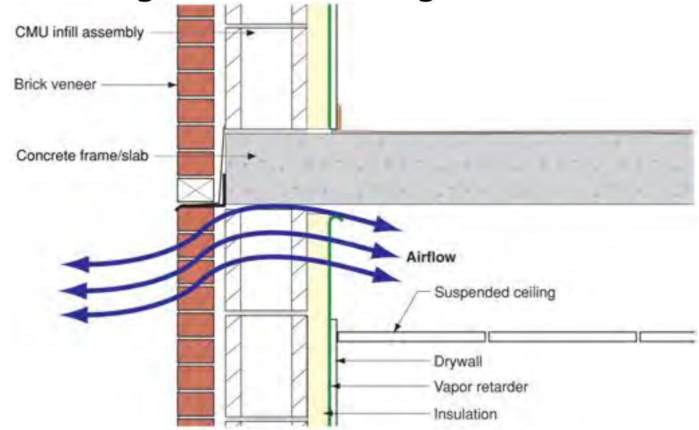
Leakage above ceilings



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Bigholes

Problem:
Filter

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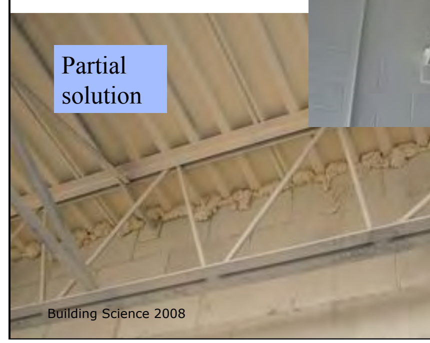
Seal



Partial
solution

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Air Barrier Systems

- Function: to stop airflow through enclosure
- ABS can be placed anywhere in the enclosure
- Must be strong enough to take wind gusts (code requirement)
- Many materials are air impermeable, but most systems are not airtight

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Air Barrier Systems: Requirements

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

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Airflow Control No. 43/79

Air Barrier Requirements

- Air impermeability
  - Material: 0.02 lps/m^2 @ 75 Pa 0.004 cfm / ft^2 at 0.3” wg
  - Component: 0.2 lps/m^2 @ 75 Pa 0.04 cfm / ft^2 at 0.3” wg
  - Building: 2.0 lps/m^2 @ 75 Pa 0.4 cfm / ft^2 at 0.3” wg
- *Building* requirement most important for energy, interior RH, IAQ
- *Component* requirement *may* matter for air leakage condensation control

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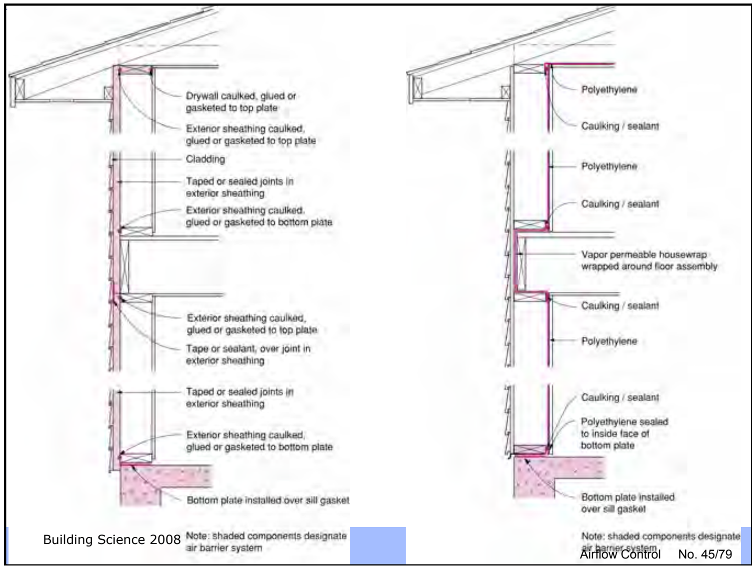
Airflow Control No. 44/79



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Poly can be (?) an air *and* vapour barrier

But

BEWARE when Air Conditioning

Definitely not in South

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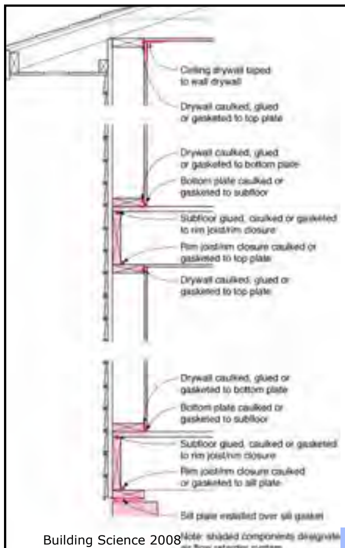

The Airtight Drywall Approach

Use drywall, framing members

- Seal with sealant, gaskets, etc.
- Is stiff, strong
- Often easier to ensure quality
- Widely applicable to all forms of commercial, residential
- Allows choice of vapor permeance

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Air sealing around components: e.g., windows and walls other Openings and penetrations

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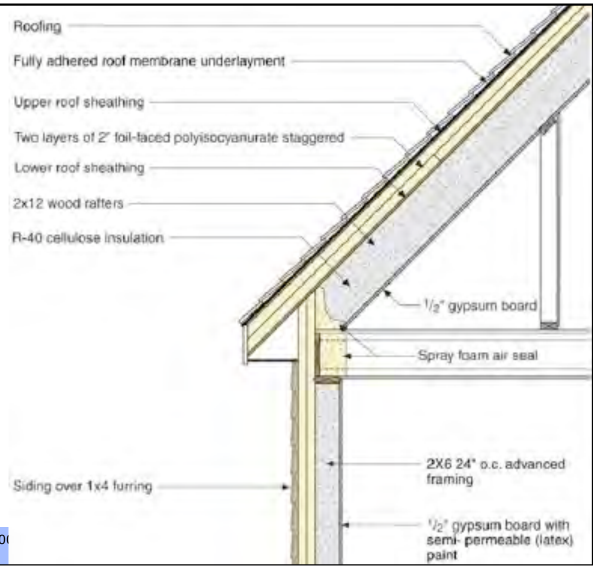

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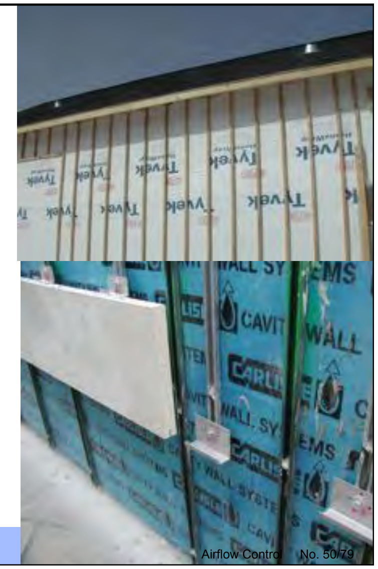
Commercial Air-Water Barriers

- Drainage plane/air barrier
- Format
  - Sprayed on
  - trowel applied
  - Sheet applied
- Desirable Attributes
  - Self sealing
  - Fully adhered



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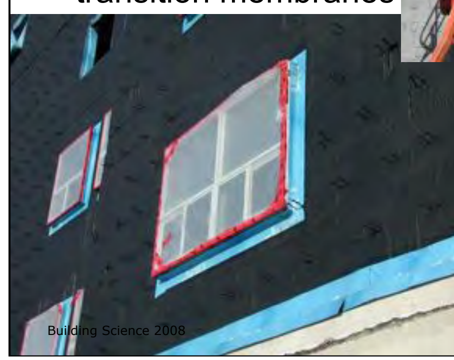
Building Science 2008 Airflow Control No. 51/79

Details

- Air & water & vapor transition membranes



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Spray/Trowel Applied Air/water

- Semi-permeable

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Airflow Control No. 53/79

Insulation, Air barrier, WRB

- Fully adhered air barrier drainage plane and insulation
- Joints, movement, cost?

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2. Control Driving Forces

- Control Air Pressure:
  - Properly use pressurization / depressurization
  - Control excessive pressure differences
  - Compartmentalize tall buildings

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Airflow Control No. 55/79

Control HVAC Effects

- Solution: Understand and Control
- In many buildings, exhaust-only fans or unbalanced flows depressurize
  - air leaks inward all the time
  - Moisture problems in south!
- Some buildings often pressurize to reduce drafts
  - Control pressures to less than 5 Pa
  - don't do this in humidified buildings and cold weather (museums, mills, fab plants)

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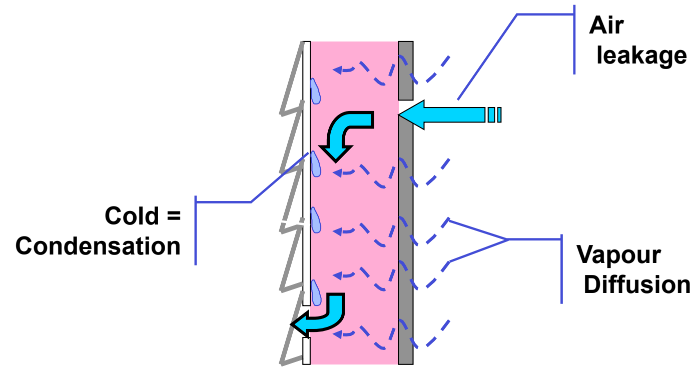
Airflow Control No. 56/79

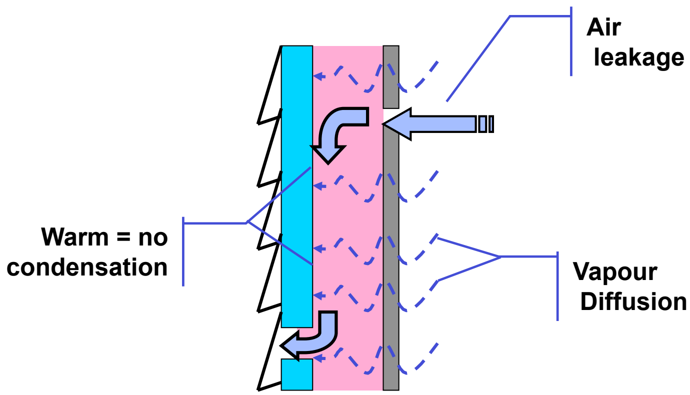
3. Control Temperature

- Control temperature of condensing surface
- Warm condensing surface above dewpoint of leaking air
  - Moist air can be outdoors or indoors

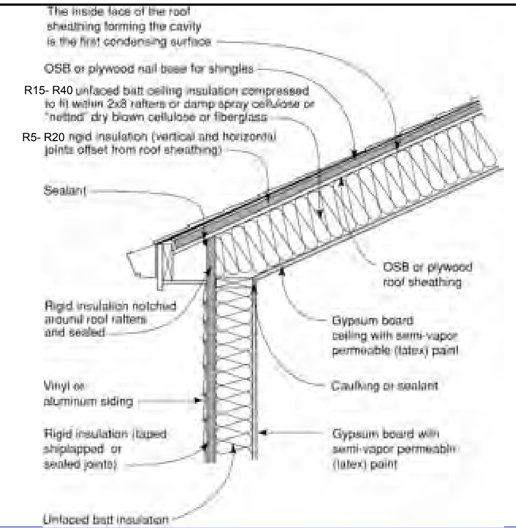
Wall w/o Insulated Sheathing



Wall with Insulated Sheathing



Roofs



Airflow Within Enclosures

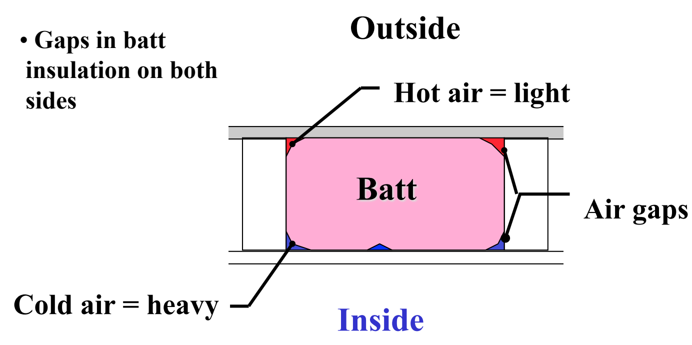
More than just air barriers!

1. Convective Loops
2. Wind washing
3. Pumping

These can cause comfort, condensation, and energy problems

Convective Loops

• Gaps in batt insulation on both sides

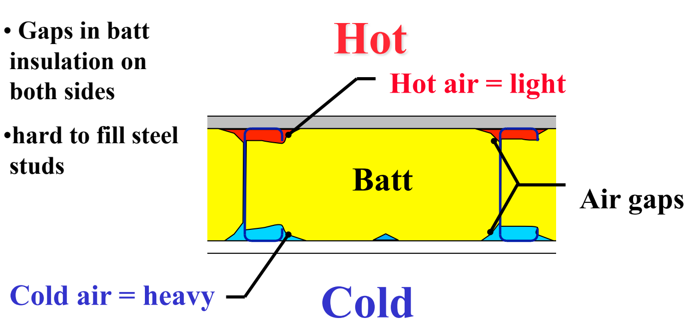


A common performance problem

Steel studs are even “better”

• Gaps in batt insulation on both sides

•hard to fill steel studs



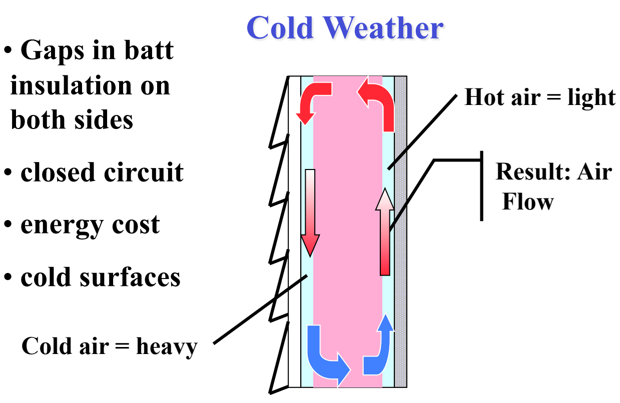
Internal Stack Effect

• Gaps in batt insulation on both sides

• closed circuit

• energy cost

• cold surfaces



Convective Loops

- Convection varies with temperature difference
- Air flows through gaps/insulation

Solutions

- Minimize temperature difference by using layers of insulation
- Fill space completely
  - Workmanship & Inspection
  - Spray-applied fibrous or foam
- Use low air permeance insulations
  - All foams stop it (press boards tight to wall!)
  - high-density fibrous insulation (2+ pcf) helps, high-density cellulose (4 pcf) helps

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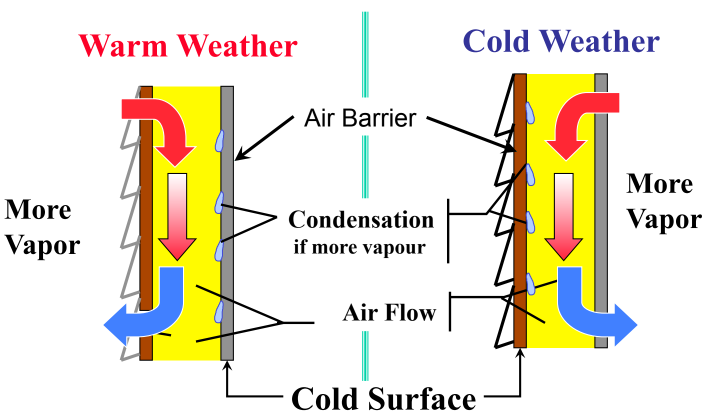
Air movement (Stack Effect)



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Windwashing

- Need some airtightness outside air 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

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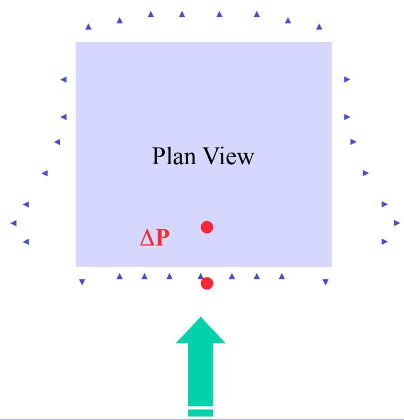
Pressure Distribution



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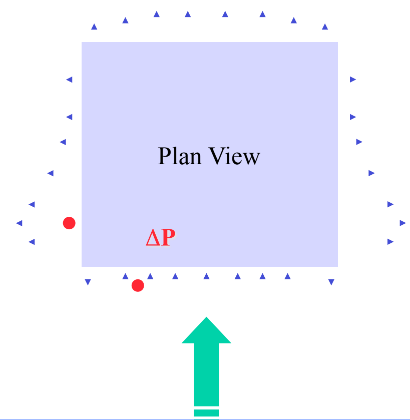
Pressure Distribution



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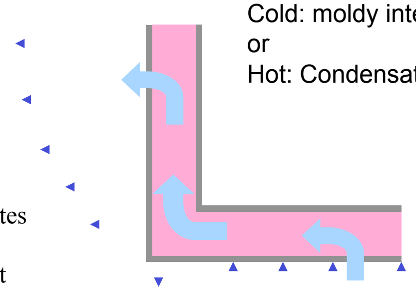
Lateral Airflows



Cold: moldy interior corner
or
Hot: Condensation on back

Punched Steel Studs

This costs energy, promotes condensation, causes comfort problems

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Airflow Control No. 72/79

Windwashing Drainage plane not an air barrier as installed

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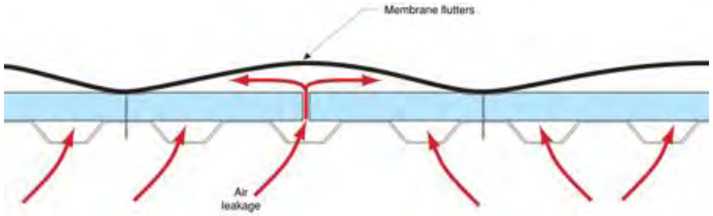
Pumping Airflow and Adhered Membranes

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



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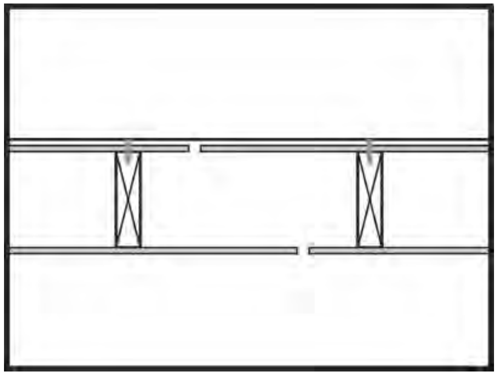
Pumping



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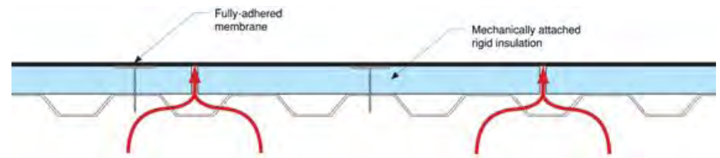
Joseph Lstiburek 76



Solutions:Airflow within enclosures

- Interior & exterior air tightness (batt)
  - Batt needs six sides covered
- 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?)

Review Air Barrier : Requirements

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

Conclusions

- Design, draw and spec a continuous air barrier!
- Some airtightness on <u>both</u> sides of air permeable insulation!
- Control driving forces
  - pressurization
  - temperature (insulated sheathing)
- Beware flow within enclosures/buildings
  - compartments, stiff air barriers

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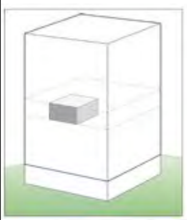
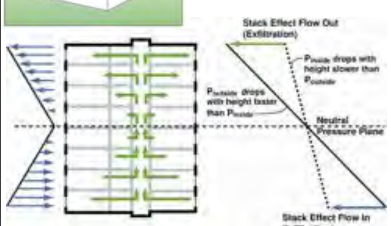
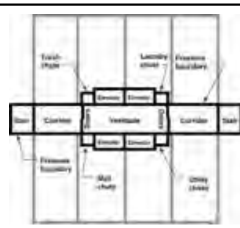
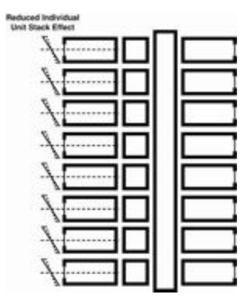
Airflow Control No. 81/79

Controlling Stack Effect









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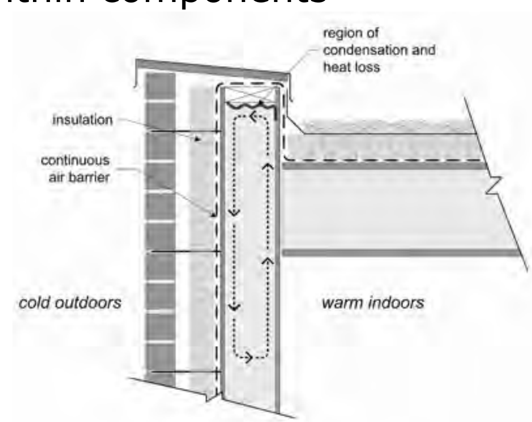
Loops within components



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