Building America U.S. Department of Energy
Research Toward Zero Energy Homes

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NESEA

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

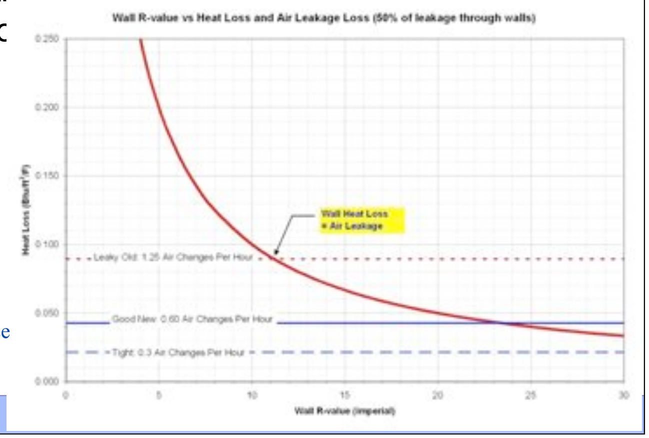
If you can't enclose air, you can't condition it

Energy in Airflow

- 1 CFM is about 1 Btu/hr/F
  - Indoor 70 F, outdoor 10 F
  - 100 cfm
  - Heat = 1 * (70-10) * 100 = 6000 Btu/hr
- Simple approximation
  - Flow in service = Flow @50 Pa / (10-20
  - Eg 2000 CFM@50 = 100

Air Barriers and Energy

- Air leakage is very significant to energy
  cc



For walls of 2200 sf house in heating climate

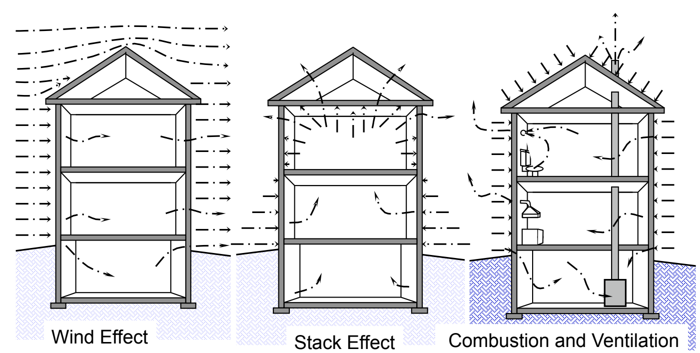
Airflow Control: What?

- 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

Driving Forces

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

Driving Forces

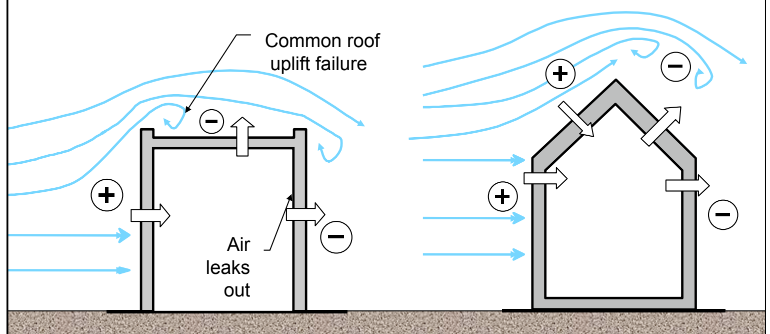


1. Wind

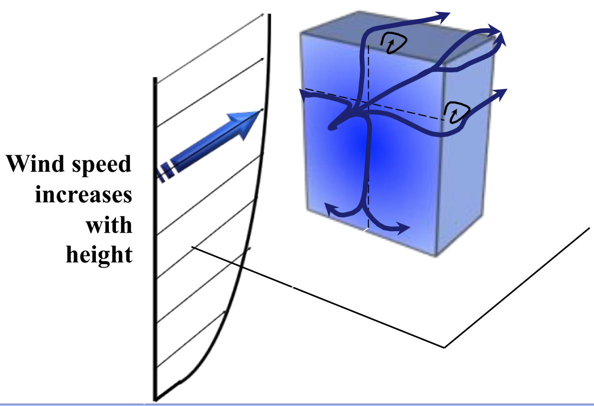
- Peak loads are high (>1000 Pa/20 psf)
- Average pressures much lower (<50 Pa)
- Wind Pressure Increases with Height
  - – low-rise average pressure about 5 Pa
  - – twenty story building about 40 Pa on normal day

Wind Pressures / Flow Patterns

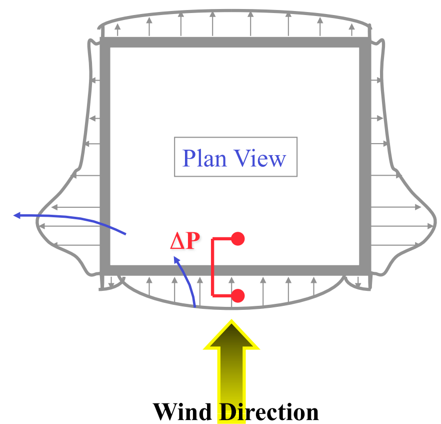
- **Pressure on windward side**
- **Suction on lee and sidewalls**



Wind Flow Patterns

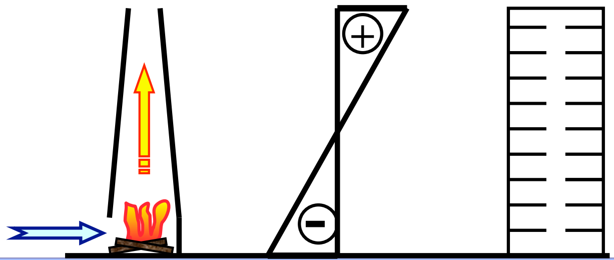


Wind Pressure Distribution



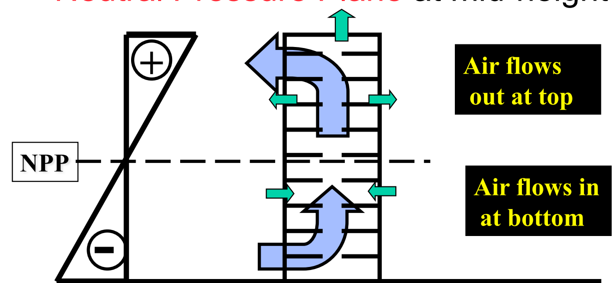
2. Stack Effect: Cold Weather

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



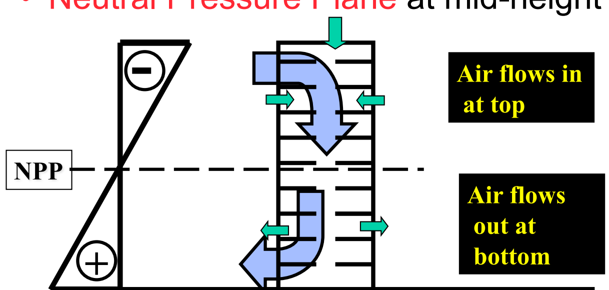
Stack Effect: Cold Weather

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



Stack Effect: Warm Weather

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

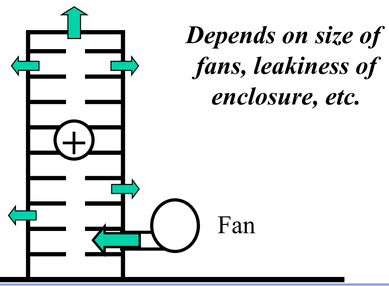


Stack Effect – tall buildings

- 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
  - Major energy penalty
  - Revolving doors
  - We suck air from below in cold weather

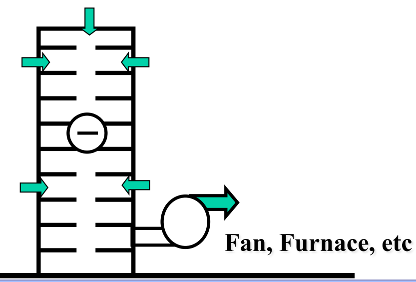
3. HVAC Pressurization

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



De-Pressurization

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



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

Airflow Within Enclosures

More than just air barriers!

1. Convective Loops
2. Wind washing
3. Pumping

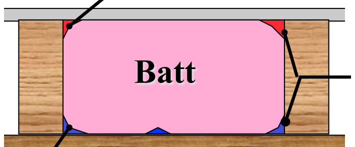
These can cause comfort, condensation, and energy problems

Convective Loops

• Gaps in batt insulation on both sides

Outside

Hot air = light



Air gaps

Cold air = heavy

Inside

A common performance problem

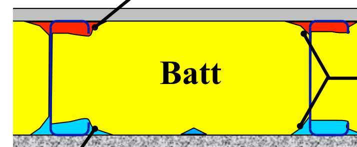
Steel studs are even "better"

• Gaps in batt insulation on both sides

•hard to fill steel studs

Hot

Hot air = light



Air gaps

Cold air = heavy

Cold

Internal Stack Effect

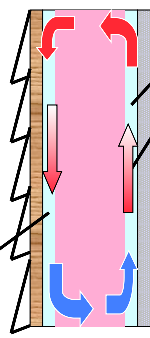
• Gaps in batt insulation on both sides

• closed circuit

• energy cost

• cold surfaces

Cold Weather



Hot air = light

Result: Air Flow

Cold air = heavy

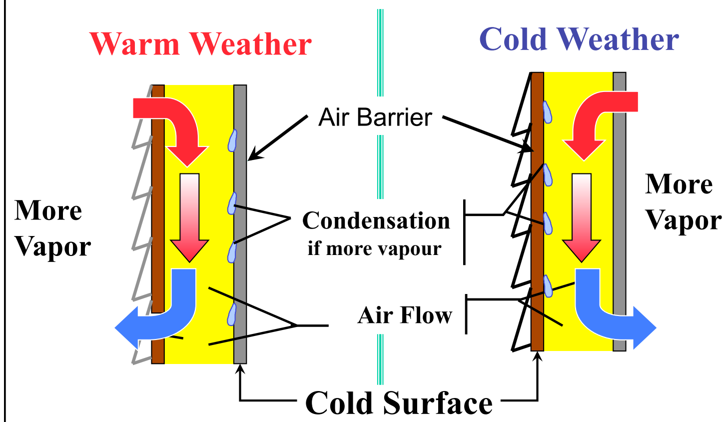
Convective Loops

- 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
- Low air permeance insulations
  - All foams stop air (BUT press boards tight to wall!)
  - higher-density fibrous insulation (2+ pcf) helps, high-density cellulose (4 pcf) helps

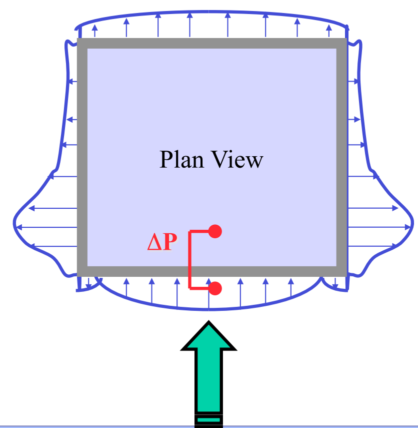
Air movement (Stack Effect)



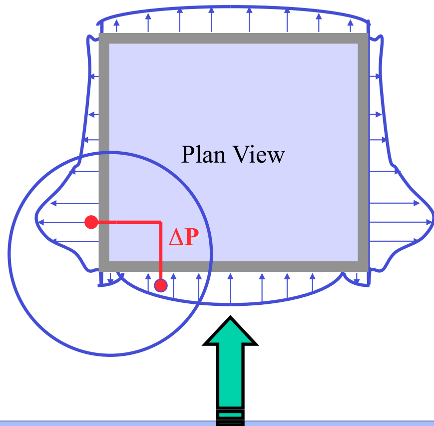
Windwashing

- 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

Pressure Distribution

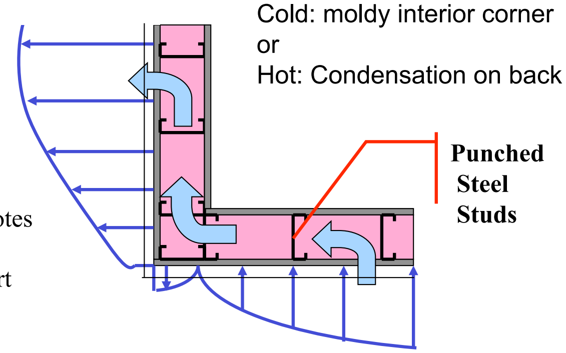


Pressure Distribution



Lateral Airflows

Cold: moldy interior corner
or
Hot: Condensation on back

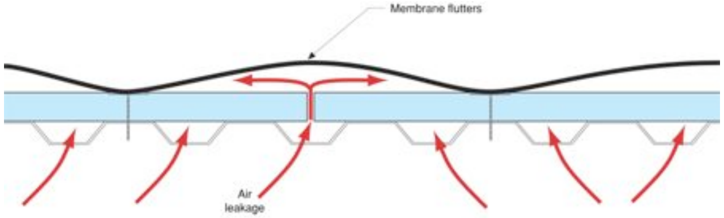


This costs energy, promotes condensation, causes comfort problems

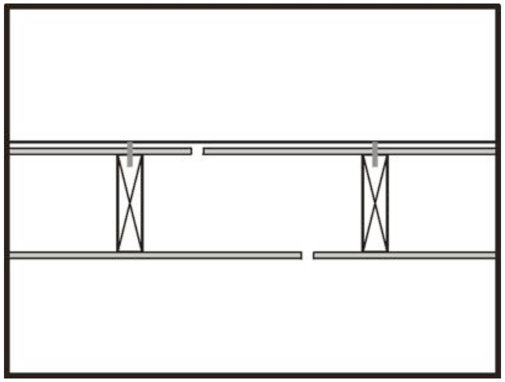
Windwashing Drainage plane: not an air barrier as installed

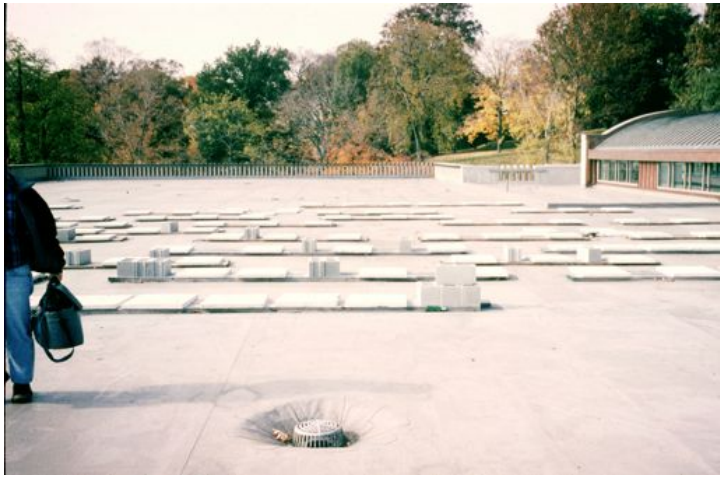
Pumping Airflow and Adhered Membranes

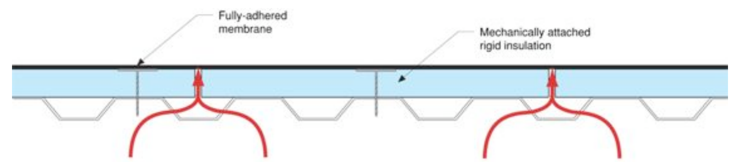
- Membrane is continuous and airtight but …
  - It may not control airflow if not fully adhered or supported
  - E.g. roofing, housewraps, poly



Pumping



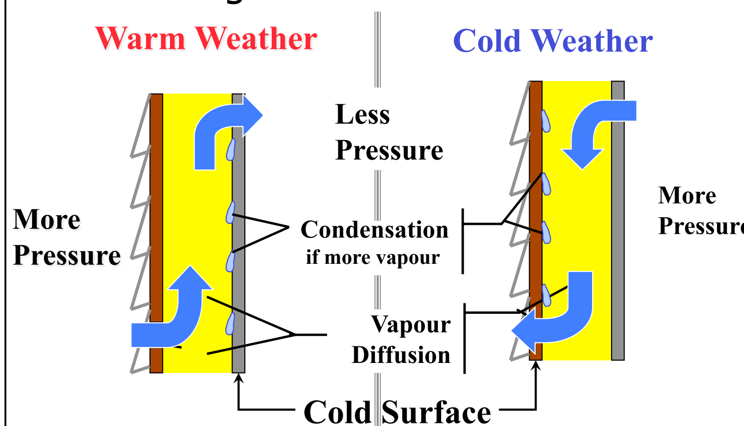




Air Leakage Condensation

- 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

Conditions for Air Leakage Condensation



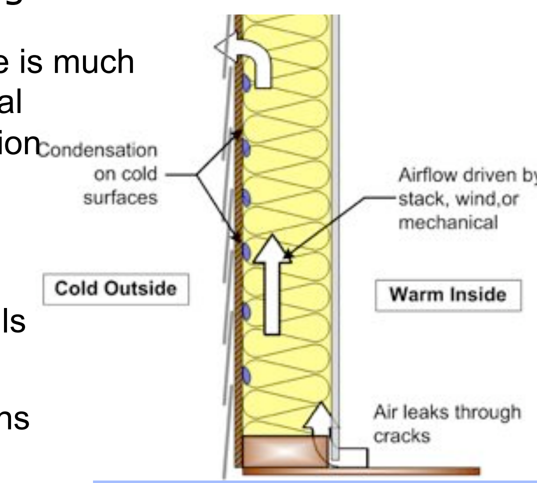
Summer condensation

Air leakage vs Diffusion

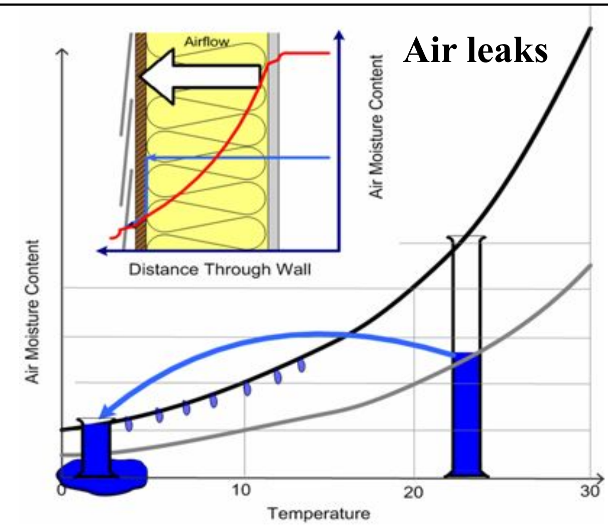
- Air leakage is much more critical than diffusion

Beware

- Parapets
- Hollow walls
- Canopies
- Penetrations

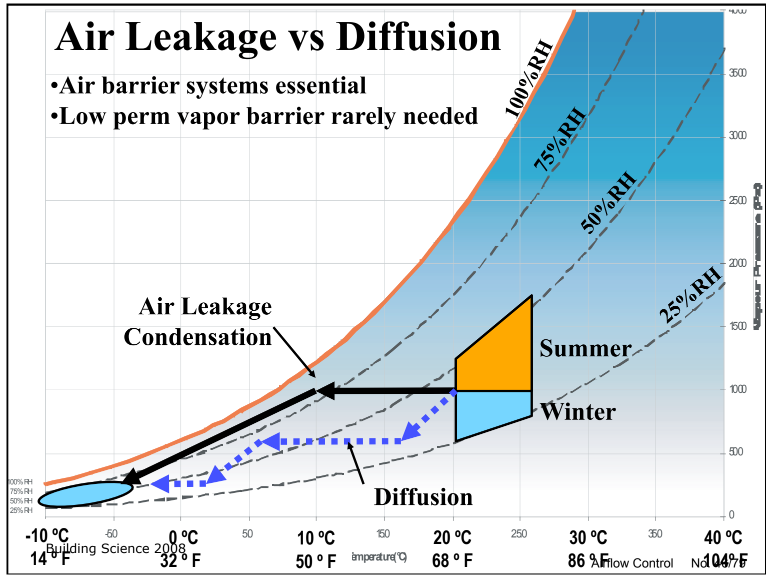


Air leaks



Air Leakage vs Diffusion

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



Why use an ABS or VB?

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

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

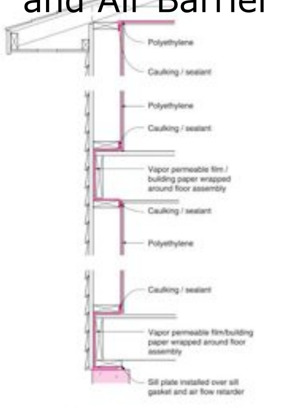
Air Barrier Systems: Requirements

- 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)

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

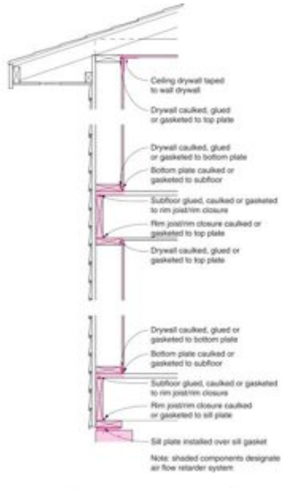
Poly Combined Vapor and Air Barrier



Interior Air Flow Retarder Using Polyethylene

- Combined vapor diffusion and air leakage control
- Thin membrane needs support
- Hard to glue to poly

The Airtight Drywall Approach

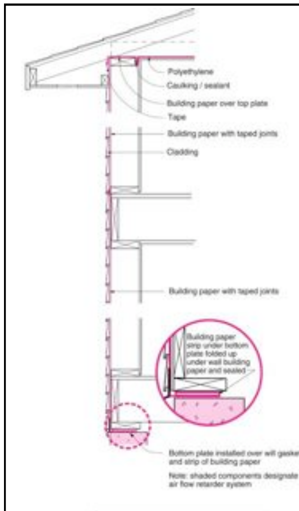


Interior Air Flow Retarder Using Drywall and Framing

Use drywall & framing members, sealed with sealant, gaskets, etc.

- **Is stiff, strong**
- **Often easier to get train**
- **Usually can achieve good airtightness**

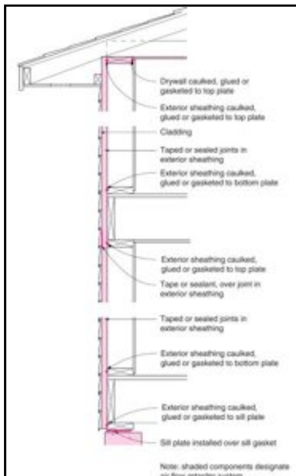
Housewrap Air Barriers



Exterior Air Flow Retarder Using Building Paper or Housewrap

- Exterior is easy to build
- Thin membranes require support
- Special details required for housewrap, eg CCMC air barrier requirements
- Paper products usually not strong enough
- Paper and housewrap help with windwashing

Sheathing



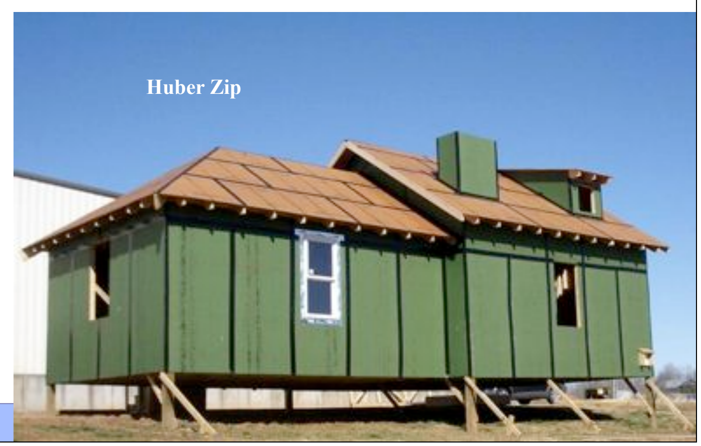
Exterior Air Flow Retarder Using Exterior Sheathing

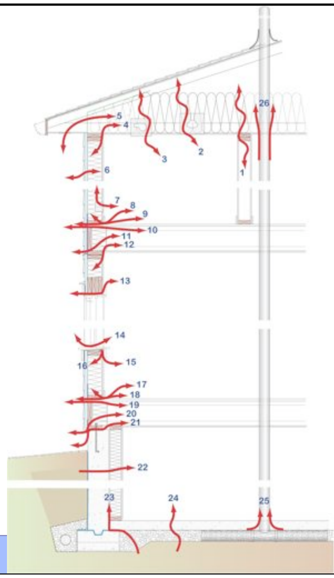
Exterior easy to build

Stiff materials improve performance

Fastening and sealing joints are difficult

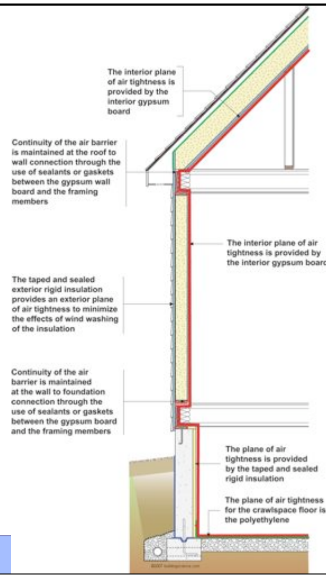
Combined rigid air barrier- drainage plane

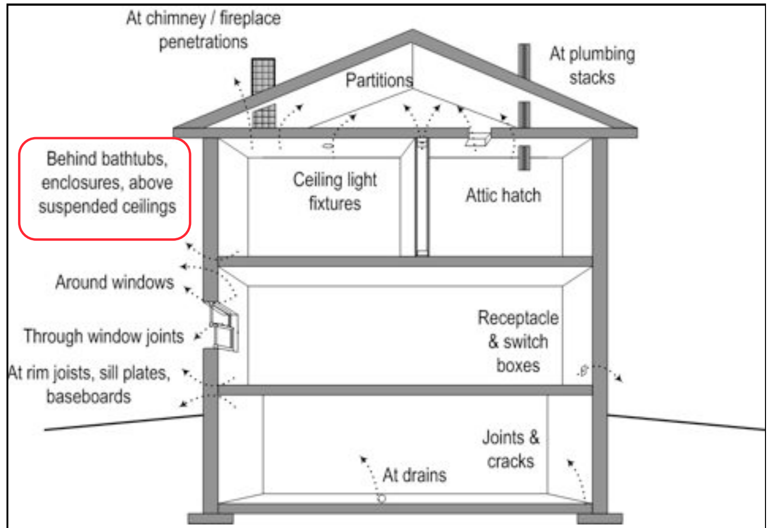




1. Stop the Air Leaks

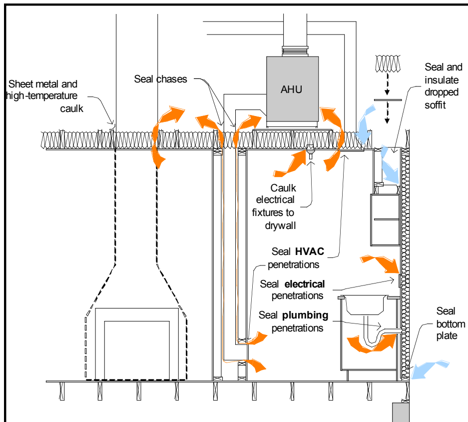
- "Find the holes and plug them"
- Continuity, continuity, continuity
- This requires finicky attention to 3-D details.



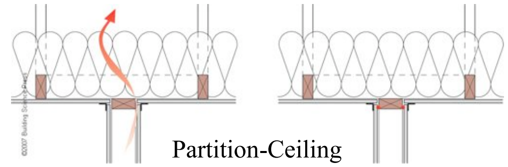


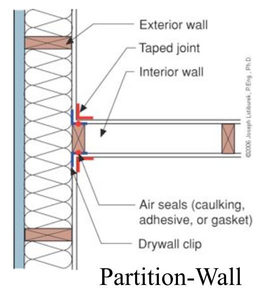
Typical Air Leakage Points

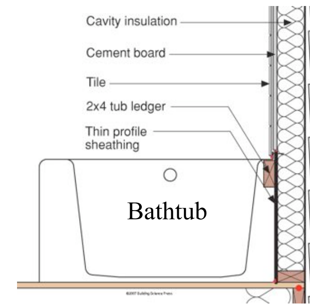
Big Air Leakage Points

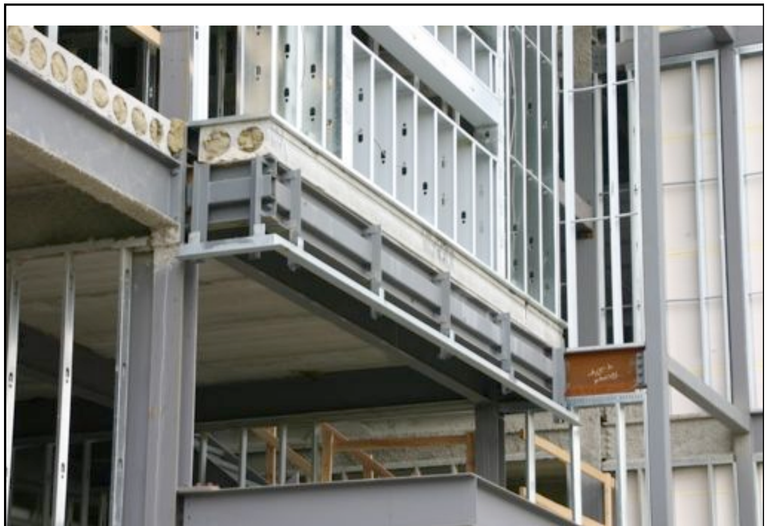


- Ductwork
- Partitions
- Dropped soffits
- Cabinetry
- Ceiling lights
- Rimjoists
- Plumbing stacks
- Attic hatch

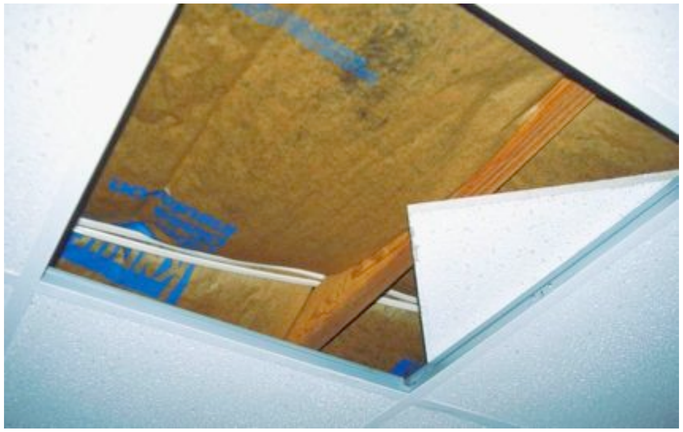




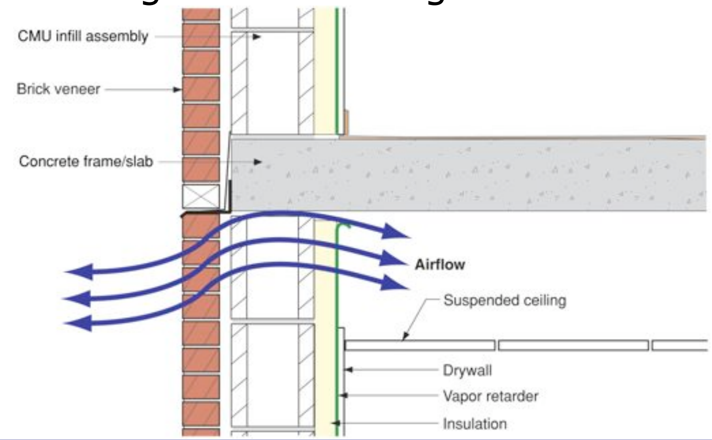




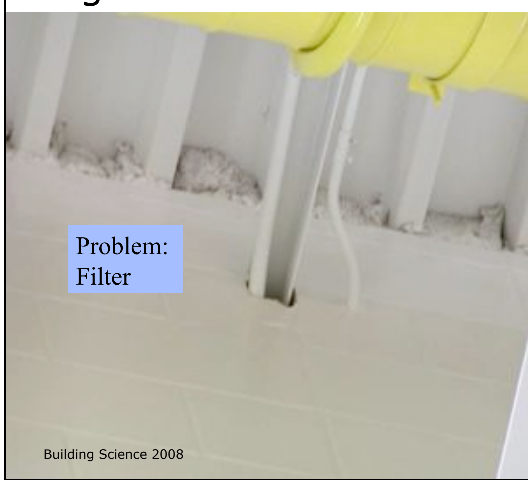
Bigholes



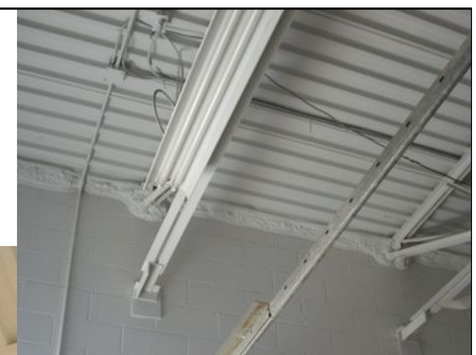
Leakage above ceilings

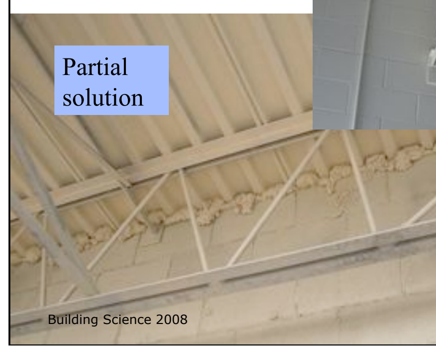


Bigholes

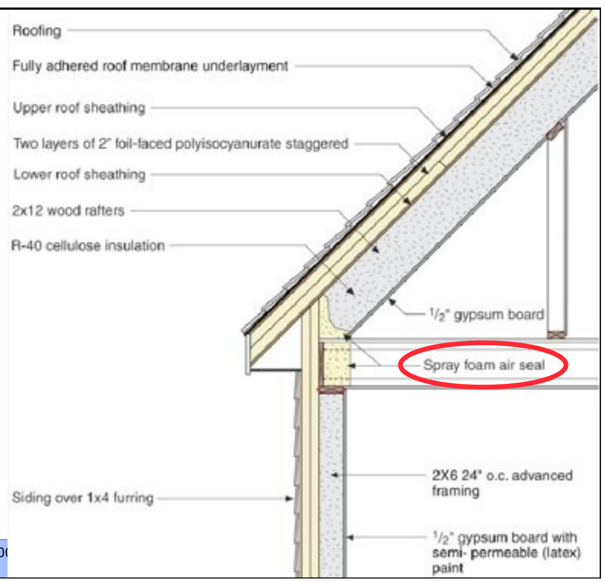


Seal





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



Commercial Air-Water Barriers

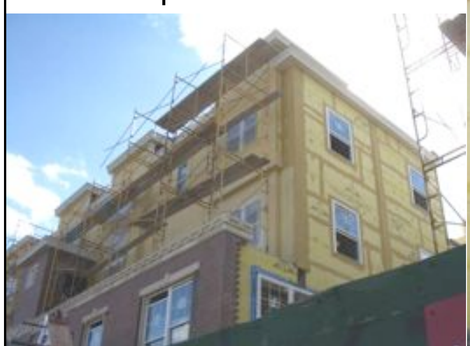
- Drainage plane/air barrier
- Format
  - Sprayed on
  - trowel applied
  - Sheet applied
- Desirable Attributes
  - Self sealing
  - Fully adhered

Details

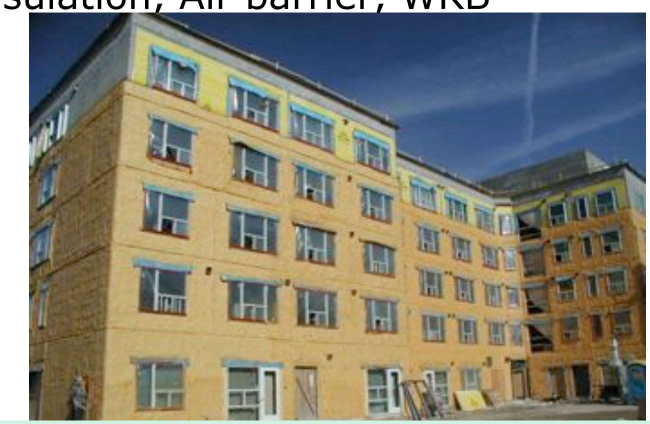
- Air & water & vapor transition membranes

Spray/Trowel Applied Air/water

- Semi-permeable



Insulation, Air barrier, WRB



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

Conclusions

- Design, draw, spec and build a continuous air barrier!
- Some airtightness on both sides of air permeable insulation!
- BuildingScienceSeminars/presentations