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

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

Common roof uplift failure

Wind Flow Patterns
Wind speed increases with height

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

Air flows in at bottom
Air flows out at top

Stack Effect: Warm Weather

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

Air flows in at top
Air flows out at bottom

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

3. HVAC Pressurization

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

Depends on size of fans, leakiness of enclosure, etc.
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

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

Warm Weather
- Less Pressure
- Condensation if more vapour
- Vapour Diffusion
- Cold Surface

Cold Weather
- More Pressure
Cold Weather Air leakage “issues”

Summer condensation

Air leakage vs Diffusion

- Air leakage is much more critical than diffusion

**Beware**
- Parapets
- Hollow walls
- Canopies
- Penetrations
**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

**IRC 2007**
- Sort of an air barrier

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**Air Leakage vs Diffusion**
- Air barrier systems essential
- Low perm vapor barrier rarely needed
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.
Big Air Leakage Points

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

Seal:
- AHU
- Sheet metal and high-temperature caulk
- Electrical fixtures to drywall
- HVAC penetrations
- Plumbing penetrations
- Bottom plate
- Electrical penetrations
- Plumbing penetrations
- Seal and insulate dropped softs
- Seal sheet metal

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**Problem:**
Filter

**Solution:**
Seal

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**Leakage above ceilings**
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 Requirements

- Air impermeability
  - Material: 0.02 lps/m² @ 75 Pa  0.004 cfm / ft² at 0.3" wg
  - Component: 0.2 lps/m² @ 75 Pa  0.04 cfm / ft² at 0.3" wg
  - Building: 2.0 lps/m² @ 75 Pa  0.4 cfm / ft² at 0.3" wg

- Building requirement most important for energy, interior RH, IAQ
- Component requirement may matter for air leakage condensation control
Poly can be (?) an air and vapour barrier
But
BEWARE when Air Conditioning
Definitely not in South

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

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?

2. Control Driving Forces

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

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)
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

Warm = no condensation

Roofs

Air leakage

Cold = Condensation

Vapour Diffusion

Air leakage

Vapour Diffusion

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Air Flow Control

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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
- 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 air = light
- Hot
- Cold air = heavy
- Cold

Internal Stack Effect

- Gaps in batt insulation on both sides
- Closed circuit
- Energy cost
- Cold surfaces
- Cold air = heavy
- Result: Air Flow
- Cold Weather

Outside

- Hot air = light
- Batt
- Air gaps
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

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

Plan View

ΔP

Airflow Control

No. 69/79

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Pressure Distribution

Plan View

ΔP

Airflow Control

No. 70/79

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Lateral Airflows

Cold: moldy interior corner
Hot: Condensation on back

This costs energy, promotes condensation, causes comfort problems

Punched
Steel
Studs

Airflow Control

No. 71/79

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Using Exterior Sheathing to Control Wind washing

Airflow Control

No. 72/79

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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
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 vapor permeable)
**Conclusions**

- Design, draw and spec a continuous air barrier!
- Some airtightness on both 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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**Controlling Stack Effect**

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**Loops within components**