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Building Science

Moisture Physics

presented by www.buildingscience.com

Moisture and Buildings

- Moisture is involved in almost all building envelope performance problems
  - In-service .... Durability
- Examples:
  - rot,
  - corrosion,
  - mould (IAQ)
  - termites, (!),
  - staining
  - etc.

Moisture Damage

- Damage caused by
  - Very high humidity for a long time
  - Wet (100%RH) for a shorter time
- Time required depends
  - on material
  - Temperature
- Temperature
  - Accelerates slows or stops process

Moisture Control

- Moisture-related Problems
  1. **Moisture** must be available
  2. There must be a route or **path**
  3. There must be a **force** to cause movement
  4. The material must be **susceptible** to damage
- Theory:
  – eliminate any one for complete control
- Practice:
  – control as many as possible

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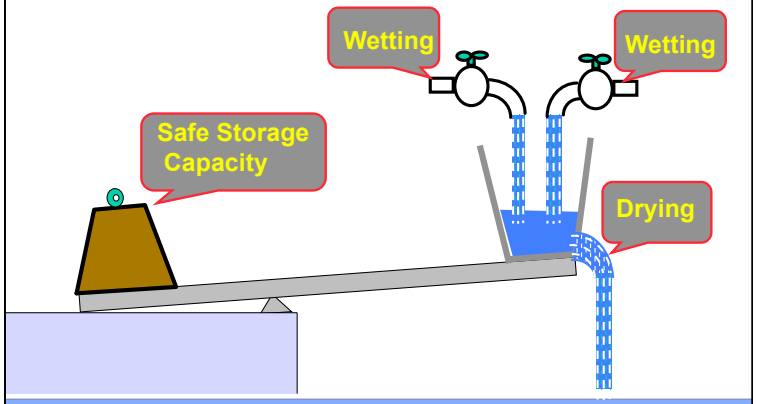
Moisture Balance



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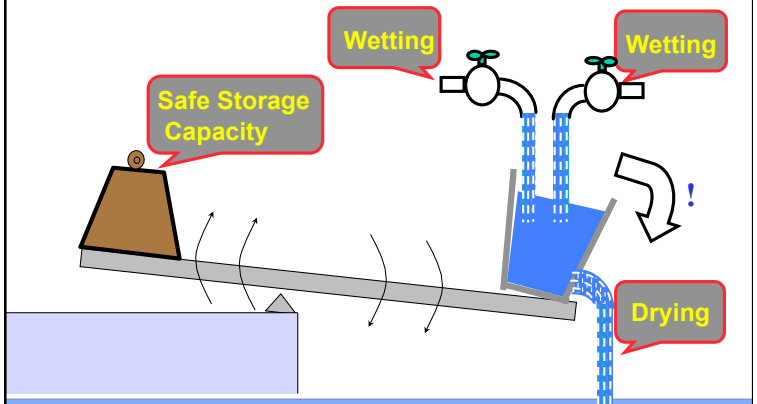
Moisture Balance: Accumulation



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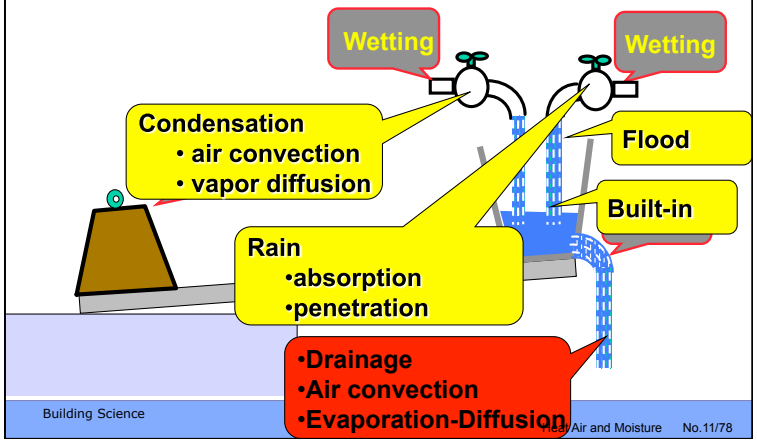
Moisture Balance



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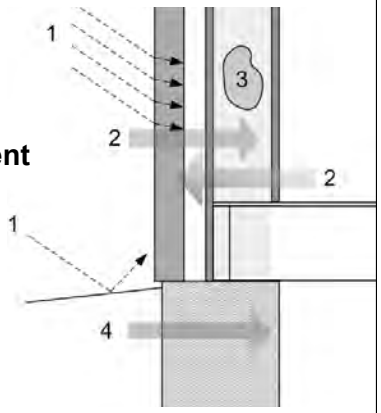
Wall + Roof Wetting

Sources/ Mechanisms

1. **Rain**
   - absorption
   - penetration
   - splash and drips
2. **Water Vapor Movement**
   - Diffusion
   - Convection (air leaks)
3. **Built in**
4. **Ground**
   - Capillary (wicking)
   - Gravity
   - Diffusion



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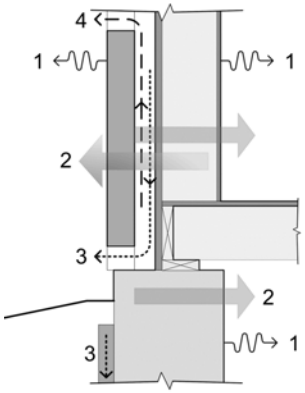
Wall + Roof Drying
Sinks and Mechanisms

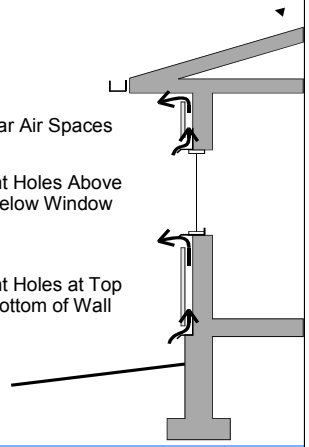
1. **Surface Evaporation**
   - Wicking to surface
2. **Vapor Movement**
   i) Diffusion
   ii) Convection
3. **Drainage**
4. **Intentional Convection** = Ventilation Drying



Note above and below grade

Ventilation Drying

- **Ventilation provides drying to the exterior**
- Can be important for:
  1. **vapor impermeable cladding**
     - metal panels
     - most roofing
  2. **systems which retain rainwater**
     - Improves survivability of small rain leaks and condensation

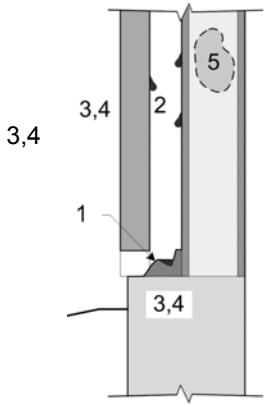


Storage

- Bridges gap in time between wetting and drying
- How much moisture for how long before damage
- *Safe* storage: safe against what?
  - mold, rot, freeze-thaw, corrosion
- Basic mechanisms
  - Absorbed into materials= capillary pores (*bound liquid*)
  - Adsorbed to materials = sorption (*vapor*)
  - pools and puddles (*free liquid*)

Moisture Storage in Assemblies

1. Trapped / undrained
2. Surface tension
   - Liquid or solid
3. Adsorbed
4. Absorbed
5. Vapor
   - small



Design Choices

- Either avoid wetting
- Or, provide enough drying to accommodate wetting
- Depending on the storage provided

The balance has shifted over time

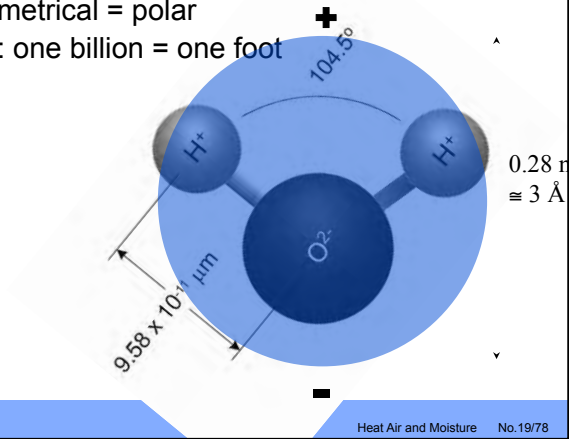
- *Amount* of storage has changed over last 100 yrs
  - e.g. steel stud, vs wood stud vs concrete block
  - 1: 10 : 100+
- Wetting is usually less
- Drying is often much less

Design Solutions

- *Balance* wetting, drying, and storage
- Practical Rules
  - Provide a continuous plane of rain control including each enclosure detail
  - Provide continuous air barriers and insulation to control condensation problems
  - Allow drying of built-in and accidental moisture – beware drying retarders

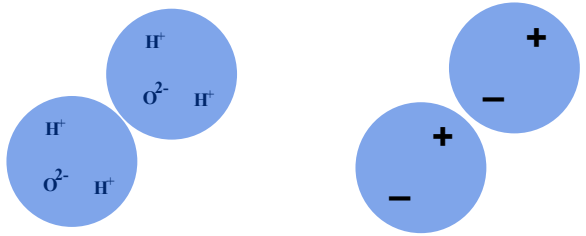
The Water Molecule

- Asymmetrical = polar
- Small: one billion = one foot



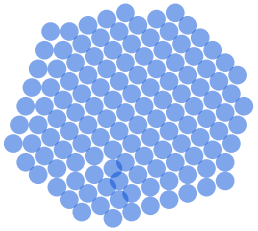
The Polar Molecule

- Hydrogen end is “more” positive
- Oxygen end is “more” negative



Water: Liquid vs Vapor

- Vapor is a single molecule
- Liquid is molecular clumps, 60 or more
- Tyvek vs asphalt



Vapor

Liquid

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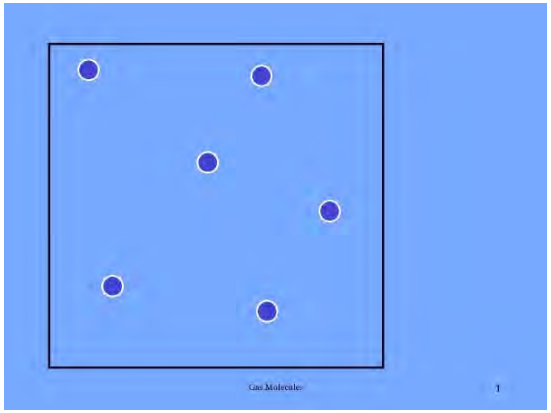
Vapor Pressure: water as a gas



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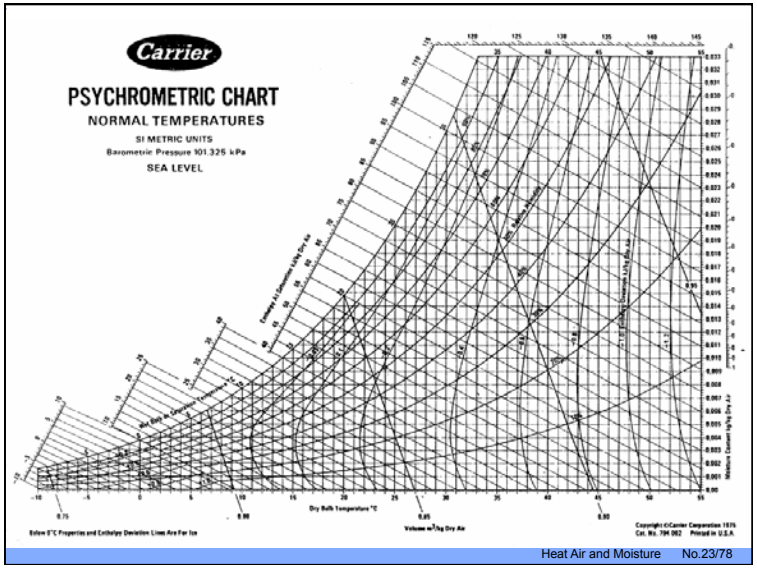
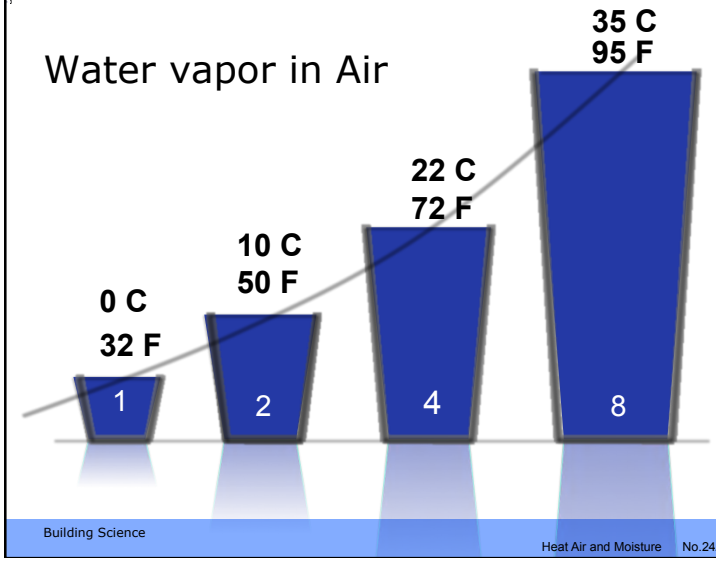
Heat Air and Moisture No.22/78



Heat Air and Moisture No.23/78

Water vapor in Air



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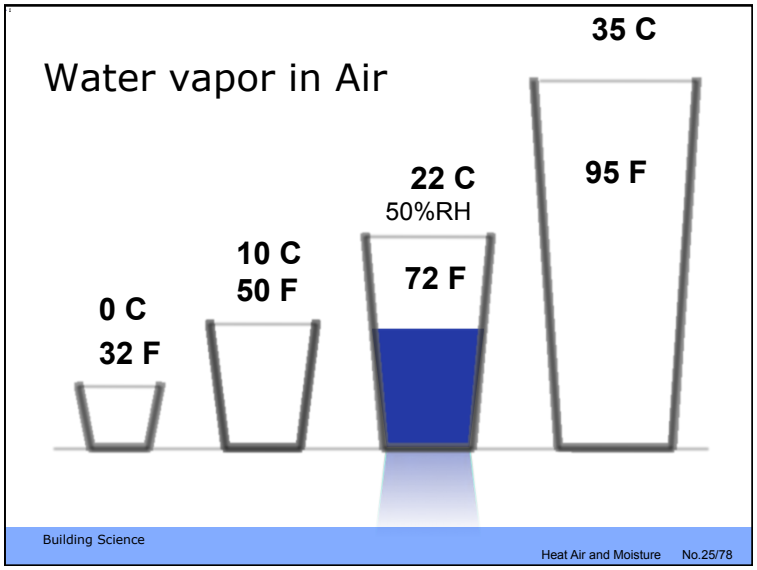
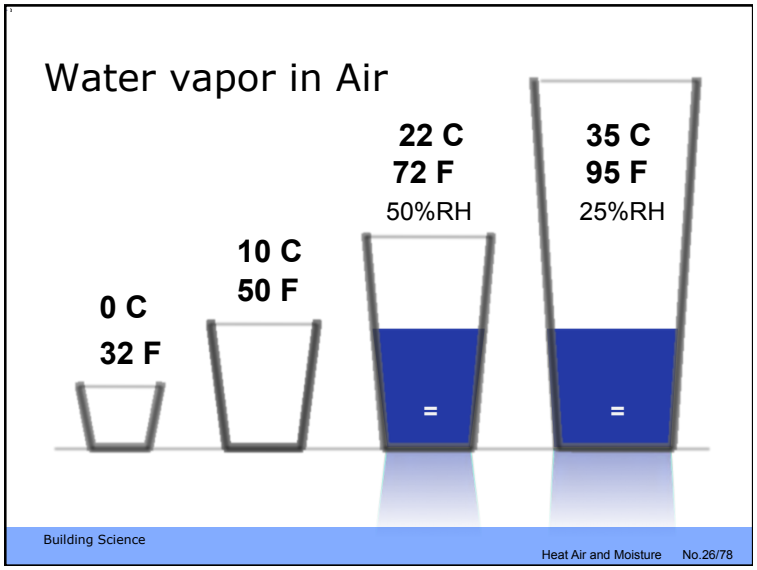
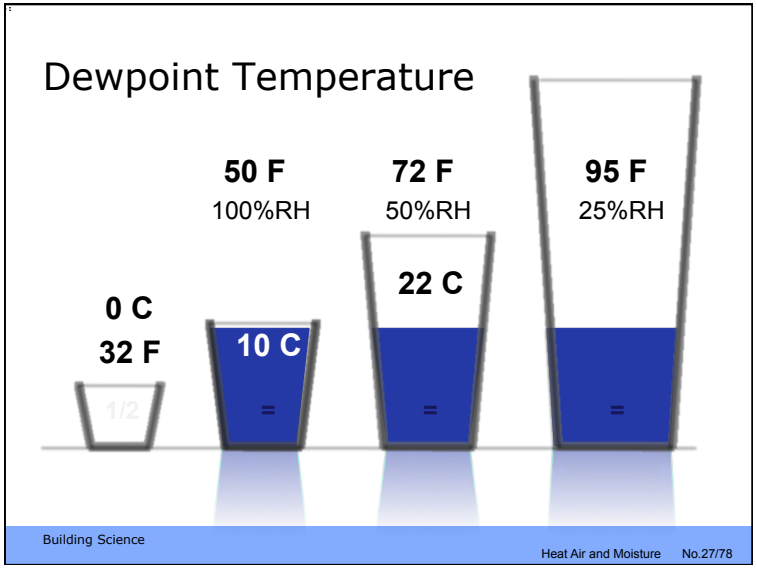
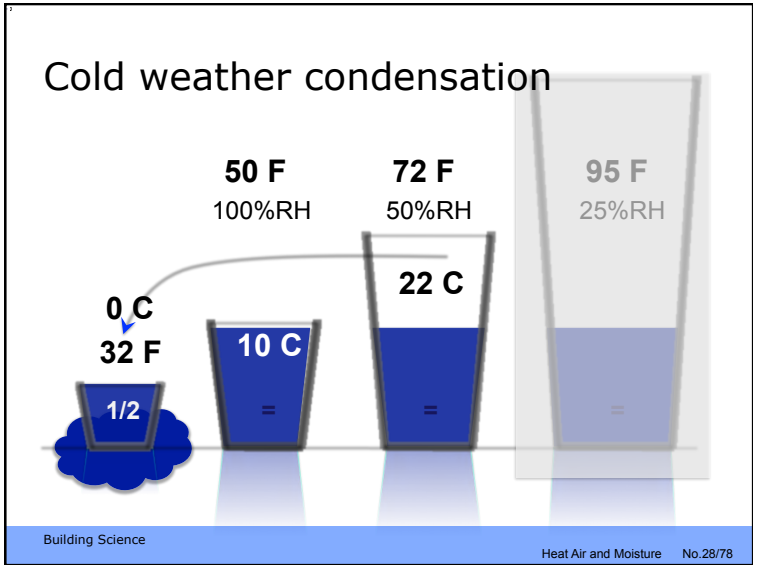
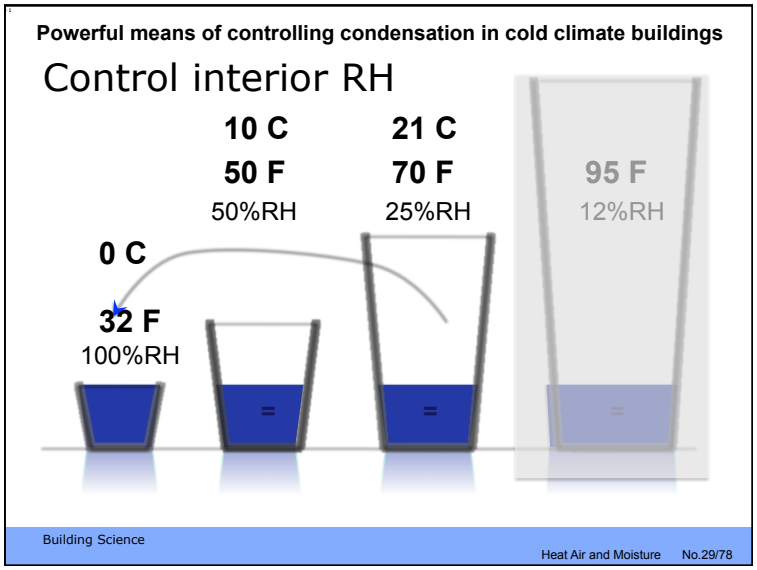
Heat Air and Moisture No.24/78

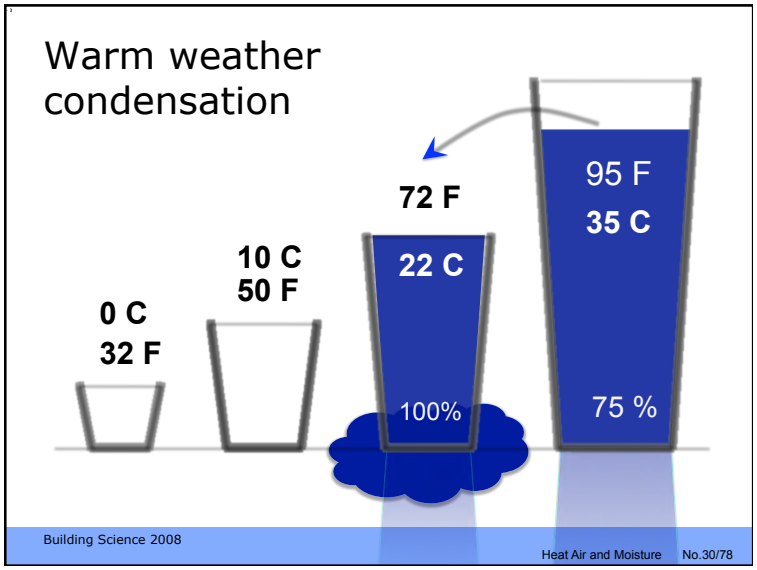


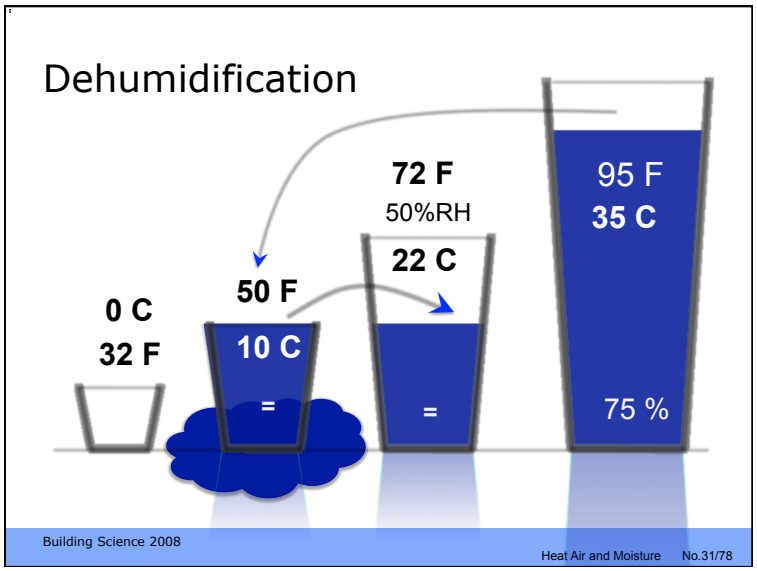


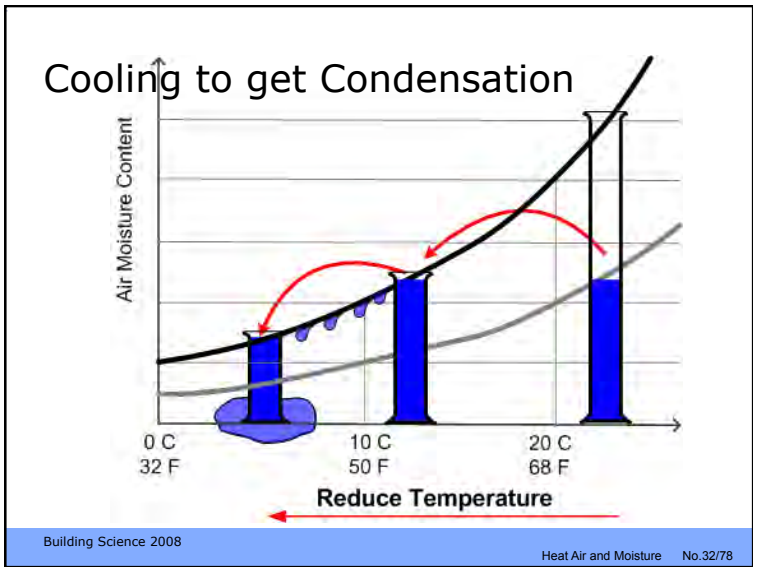


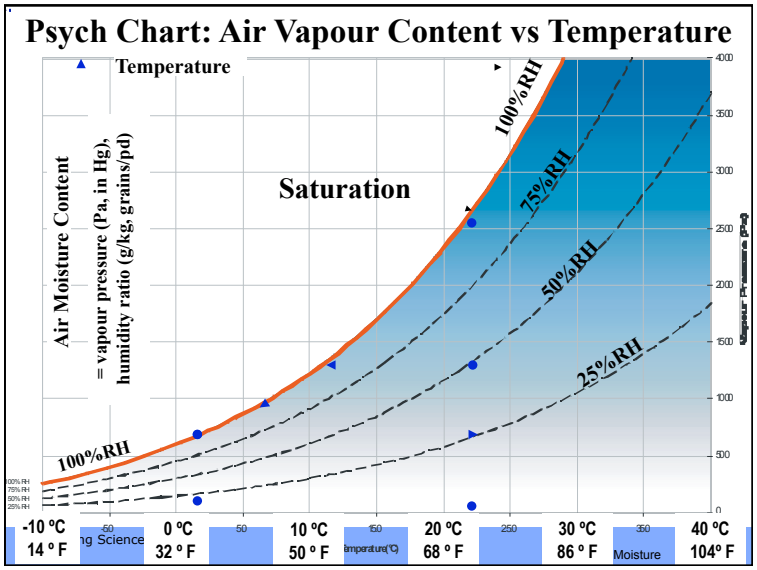


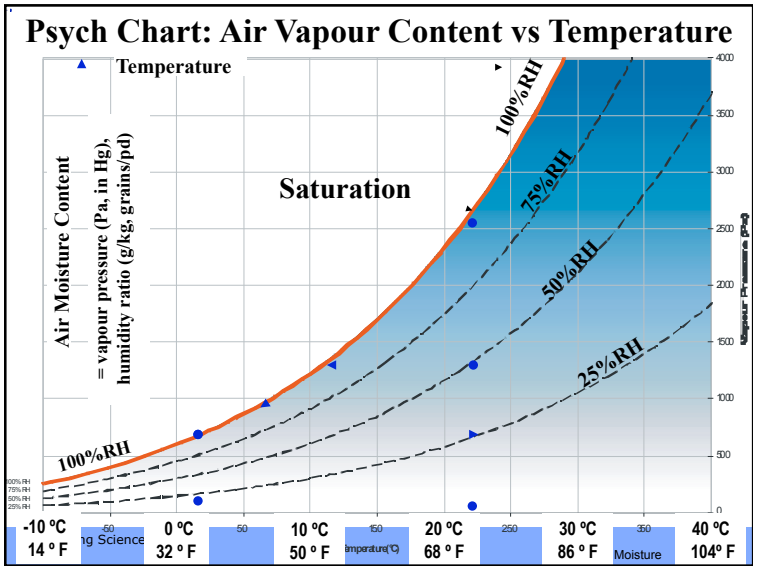

Powerful means of controlling condensation in cold climate buildings
Control interior RH
10 C
50 F
50%RH
21 C
70 F
25%RH
95 F
12%RH
0 C
32 F
100%RH
=
=
=
Building Science
Heat Air and Moisture No.29/78


Warm weather condensation
72 F
22 C
95 F
35 C
10 C
50 F
0 C
32 F
100%
75 %
Building Science 2008
Heat Air and Moisture No.30/78


Dehumidification
72 F
50%RH
22 C
95 F
35 C
50 F
10 C
0 C
32 F
=
=
75 %
Building Science 2008
Heat Air and Moisture No.31/78


Cooling to get Condensation
Air Moisture Content
0 C
32 F
10 C
50 F
20 C
68 F
Reduce Temperature
Building Science 2008
Heat Air and Moisture No.32/78


Psych Chart: Air Vapour Content vs Temperature
Temperature
Air Moisture Content
= vapour pressure (Pa, in Hg),
humidity ratio (g/kg, grains/pd)
Saturation
100%RH
75%RH
50%RH
25%RH
100%RH
-10 °C
14 ° F
0 °C
32 ° F
10 °C
50 ° F
20 °C
68 ° F
30 °C
86 ° F
40 °C
104° F
Moisture


Psych Chart: Air Vapour Content vs Temperature
Temperature
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Saturation
100%RH
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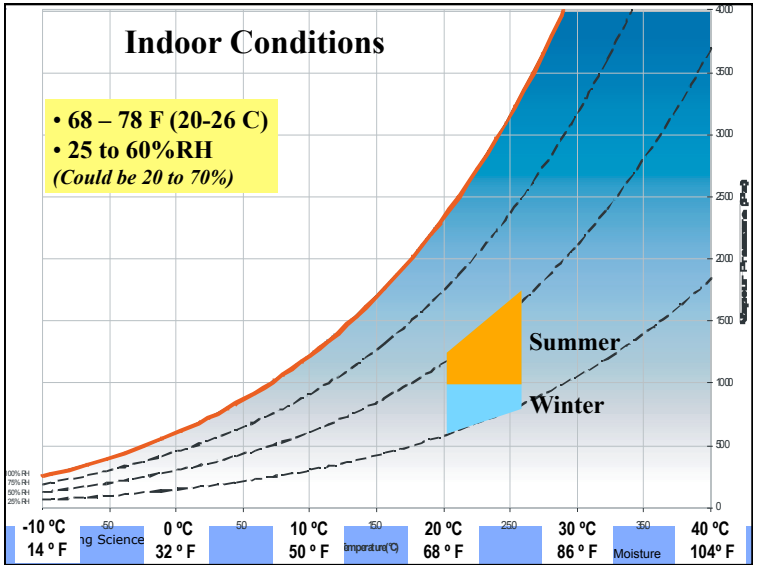
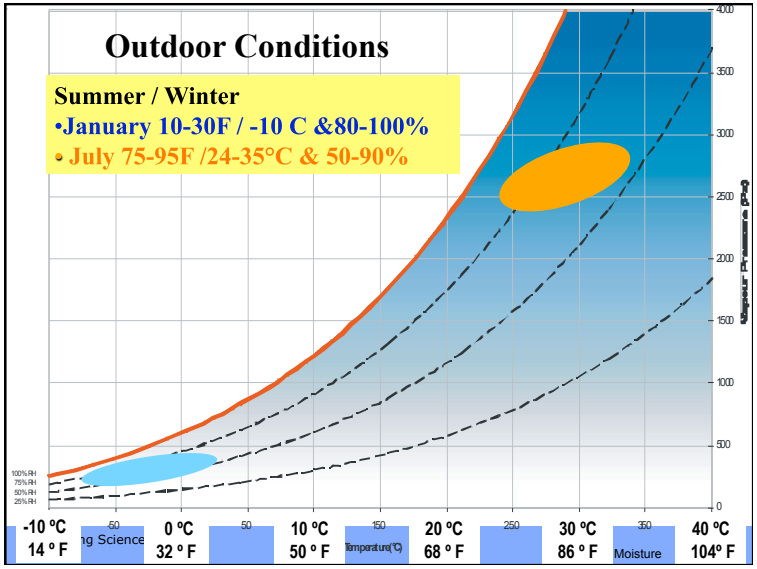
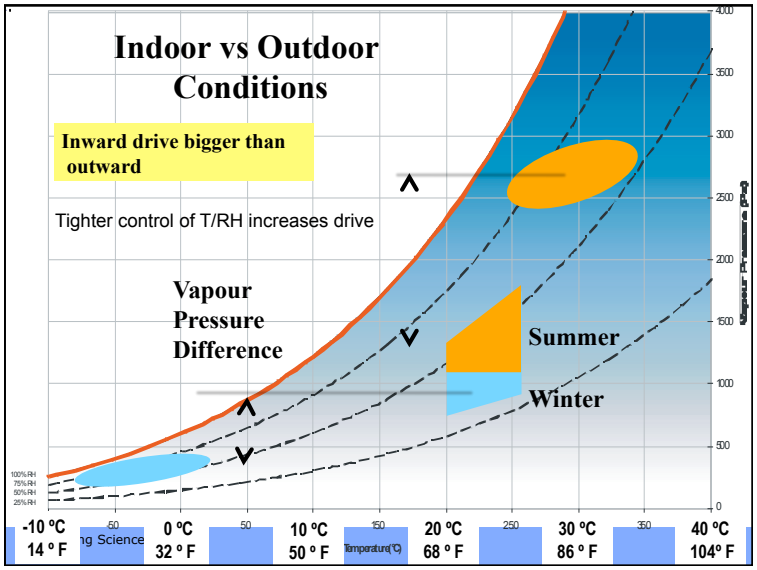
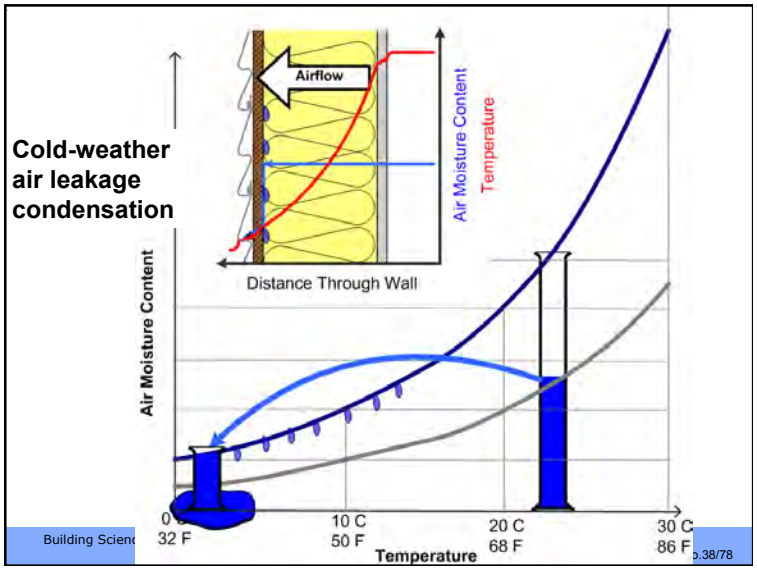
50%RH
25%RH
100%RH
-10 °C
14 ° F
0 °C
32 ° F
10 °C
50 ° F
20 °C
68 ° F
30 °C
86 ° F
40 °C
104° F
Moisture


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

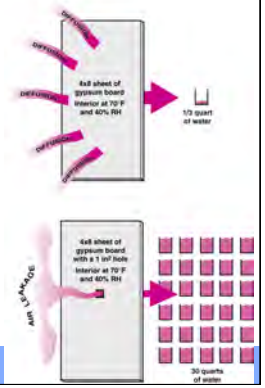

Outdoor Conditions
Summer / Winter
•January 10-30F / -10 C &80-100%
• July 75-95F /24-35°C & 50-90%
-10 °C
14 ° F
0 °C
32 ° F
10 °C
50 ° F
20 °C
68 ° F
30 °C
86 ° F
40 °C
104° F
Moisture





Air leakage

- Much more vapor can be carried on back of air flow than diffusion
- Condensation only happens if air flows towards cold surface



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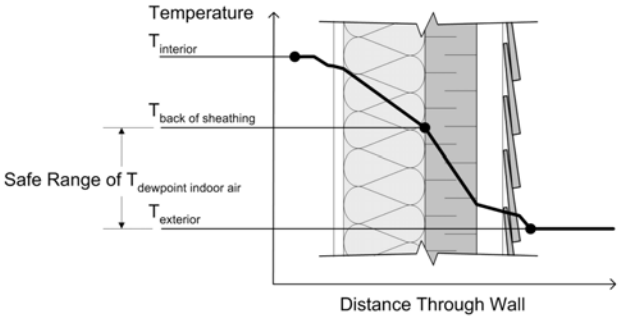
$$T_{back\ of\ sheathing} = T_{interior} - (T_{interior} - T_{exterior})\ R_{batt}/R_{total}$$



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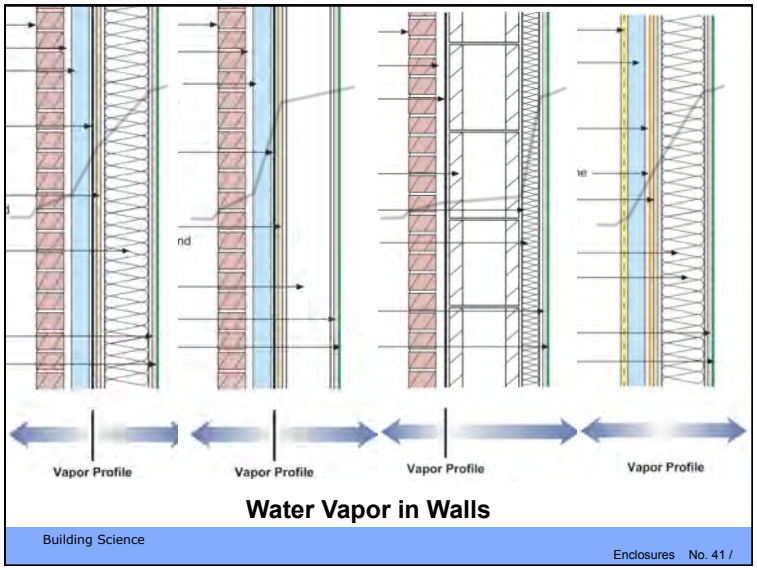
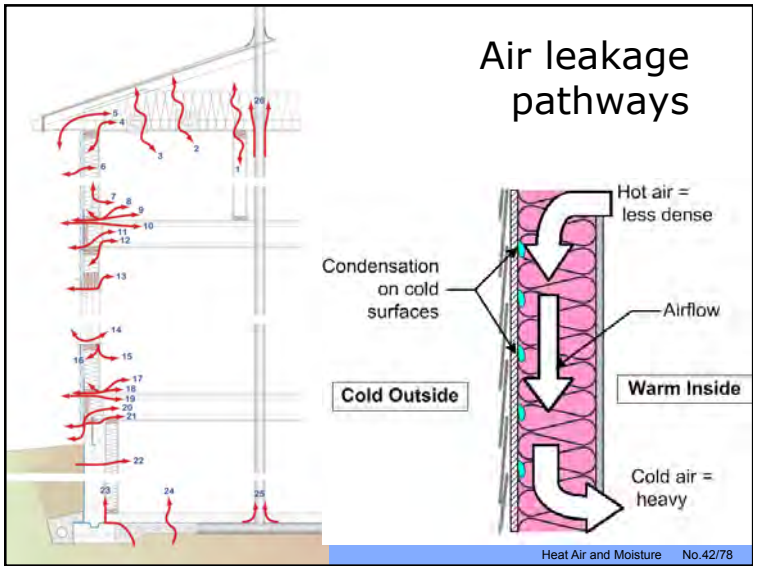
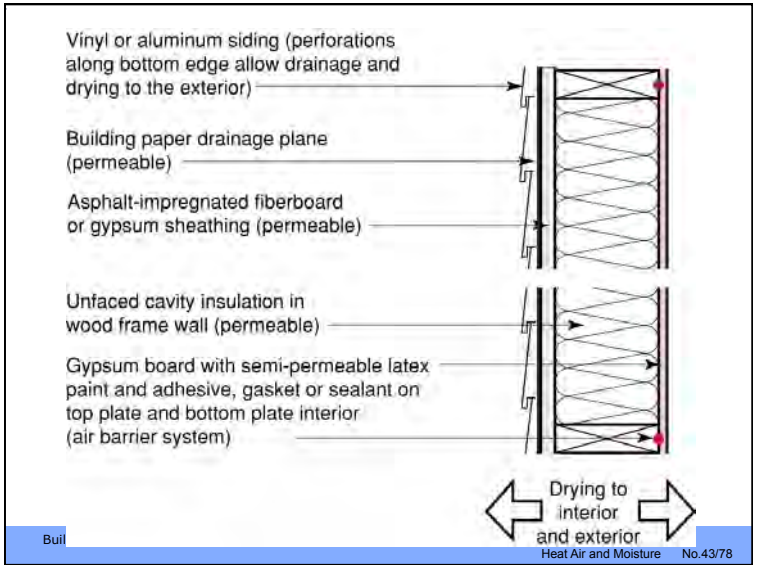
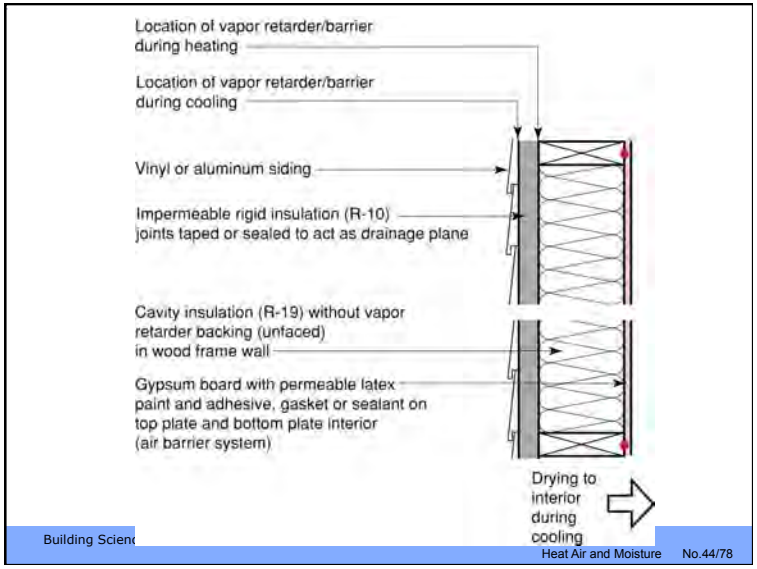
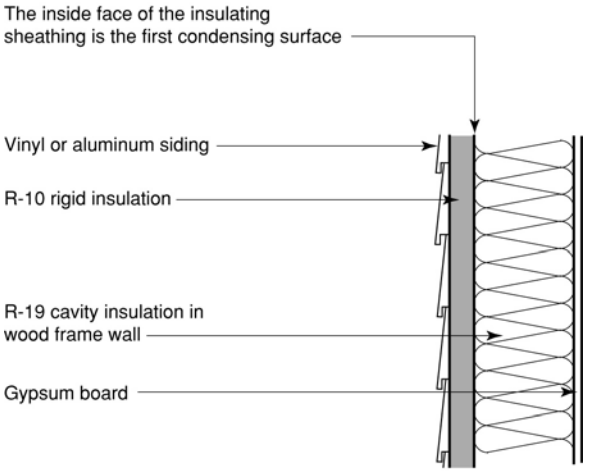
Heat Air and Moisture No.40/78


Vapor Profile
Vapor Profile
Vapor Profile
Vapor Profile
Water Vapor in Walls
Building Science
Enclosures No. 41 /


Air leakage pathways
Hot air = less dense
Condensation on cold surfaces
Airflow
Cold Outside
Warm Inside
Cold air = heavy
Heat Air and Moisture No.42/78


Vinyl or aluminum siding (perforations along bottom edge allow drainage and drying to the exterior)
Building paper drainage plane (permeable)
Asphalt-impregnated fiberboard or gypsum sheathing (permeable)
Unfaced cavity insulation in wood frame wall (permeable)
Gypsum board with semi-permeable latex paint and adhesive, gasket or sealant on top plate and bottom plate interior (air barrier system)
Drying to interior and exterior
Heat Air and Moisture No.43/78


Location of vapor retarder/barrier during heating
Location of vapor retarder/barrier during cooling
Vinyl or aluminum siding
Impermeable rigid insulation (R-10) joints taped or sealed to act as drainage plane
Cavity insulation (R-19) without vapor retarder backing (unfaced) in wood frame wall
Gypsum board with permeable latex paint and adhesive, gasket or sealant on top plate and bottom plate interior (air barrier system)
Drying to interior during cooling
Heat Air and Moisture No.44/78



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Heat Air and Moisture No.45/78

Water Vapour Transport

- Vapour Diffusion (like heat conduction)
  - more to less vapor
  - No air flow
  - Flow through tiny pores
- Air Convection (like heat convection)
  - more to less air pressure
  - flow through visible cracks and holes
  - vapour is just along for the ride

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Heat Air and Moisture No.46/78

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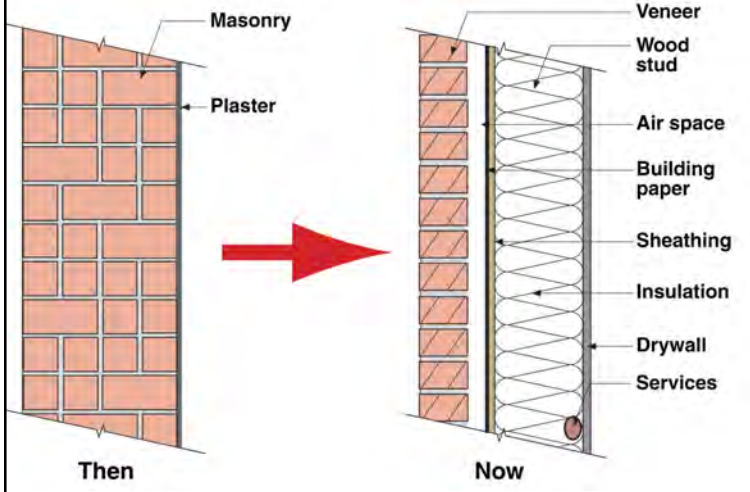
Heat Air and Moisture No.47/78



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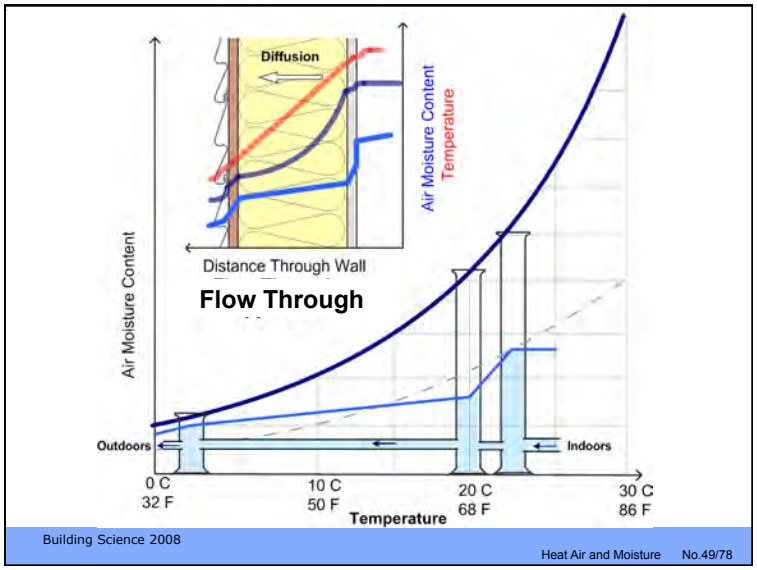
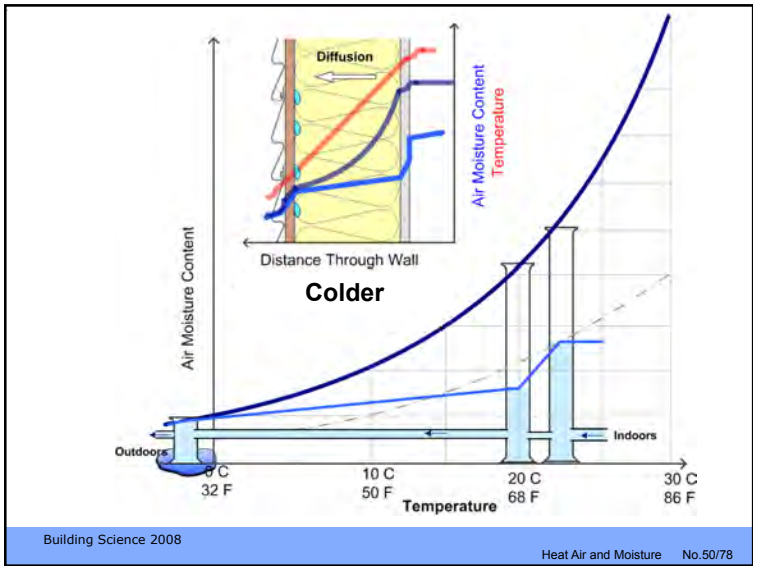
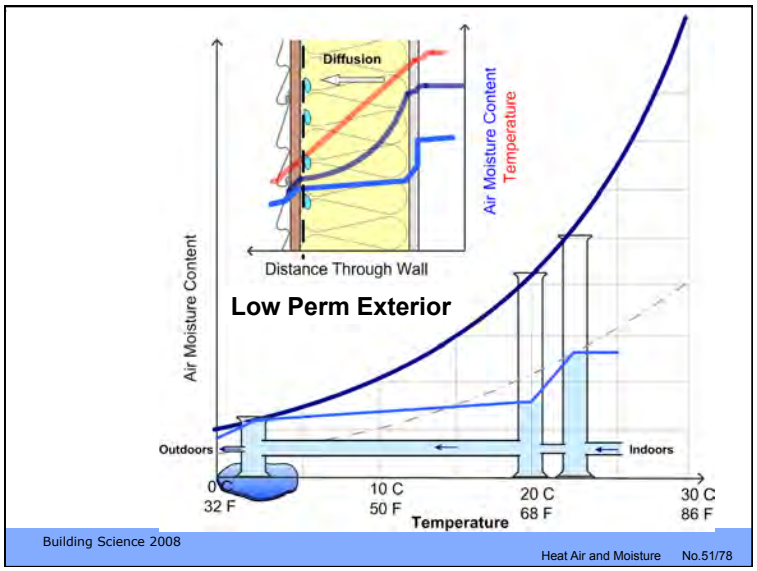
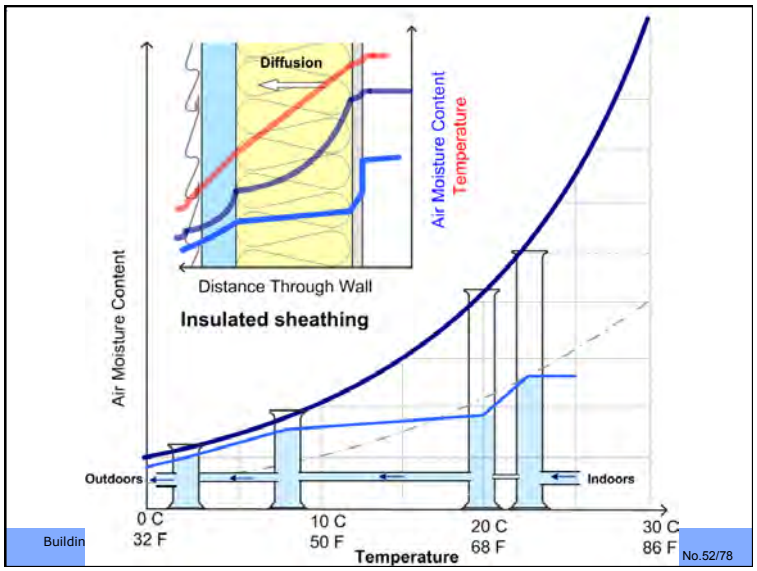
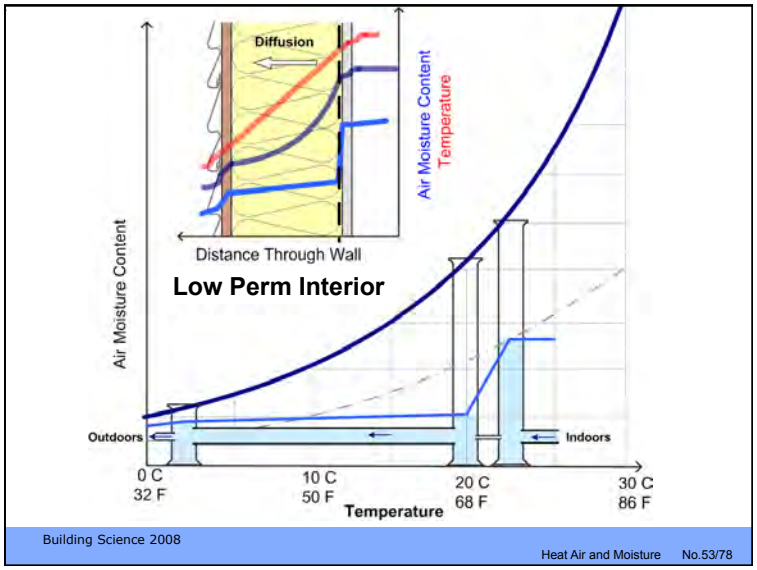
Heat Air and Moisture No.48/78

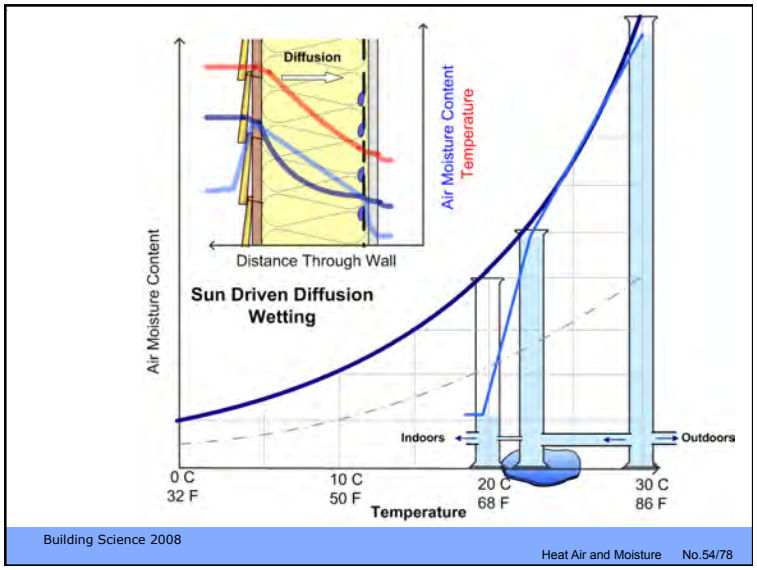












Conclusions

- Air can store much more water vapor as temperature increases
- Water vapor moves in two modes
  - Diffusion (vapor control)
  - Air Leakage (air control)
- Vapor control is less important
- Air control requires all holes sealed

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Heat Air and Moisture No.55/78