Joseph Lstiburek, Ph.D., P.Eng
John Straube, Ph.D., P.Eng

# Building Science

## Air-Vapor 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.

Building Science 2008 — Heat Air and Moisture No.2/78

## 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

Building Science — Heat Air and Moisture No.3/78


Heat Air and Moisture No.4/78

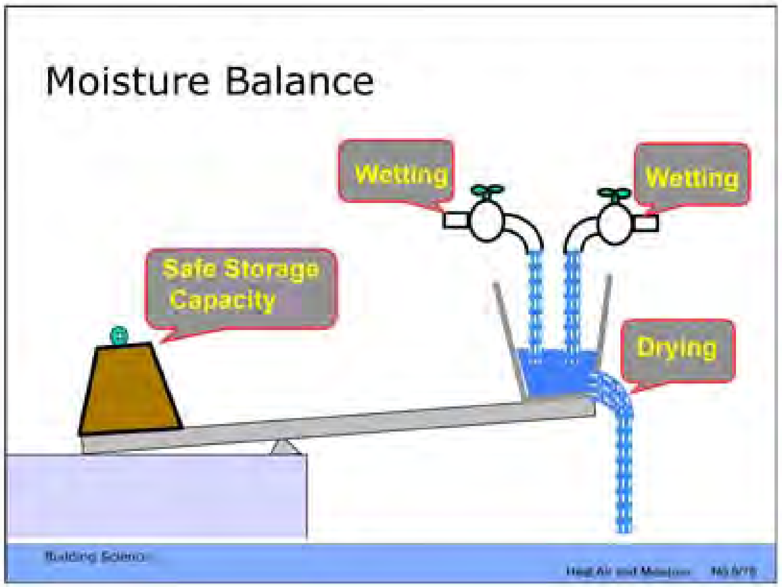


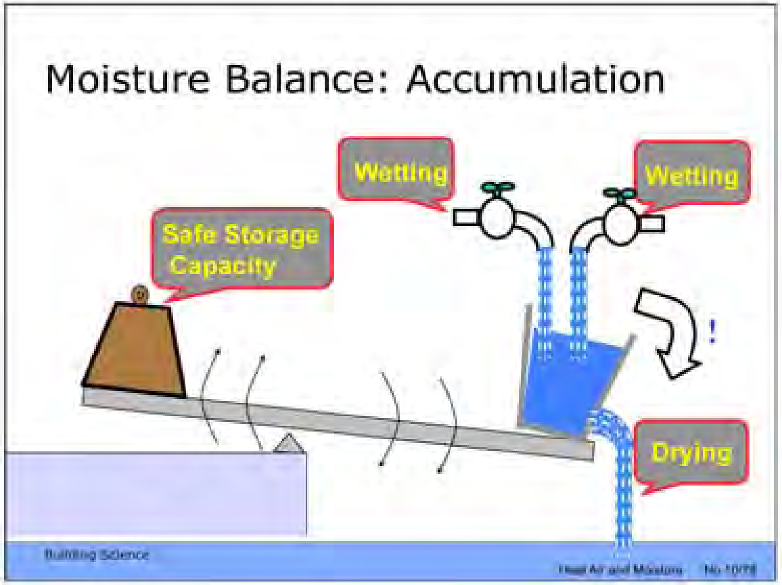

## Moisture Control

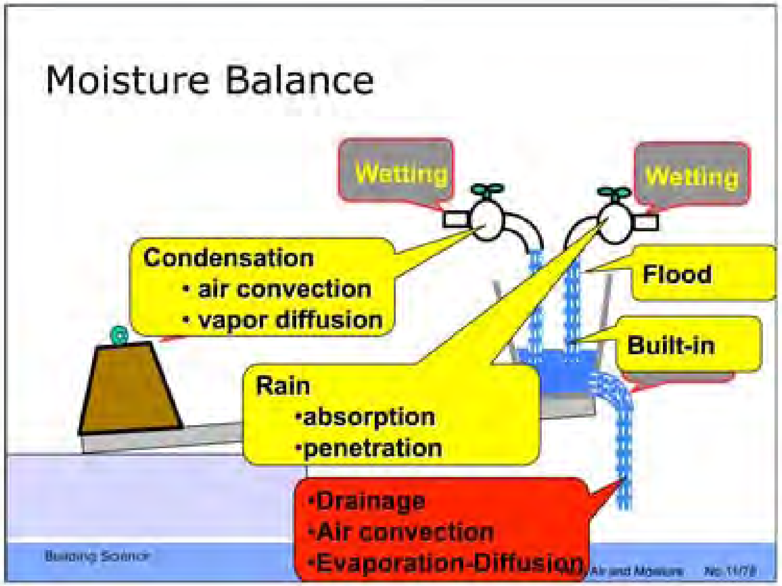
- Moisture-related Problems
  1. **Moisture** must be available
  2. There must be a route or **path**
  3. There must be a **force** to cause movement
  4. The material must be **susceptible** to damage
- Theory:
  – eliminate any one for complete control
- Practice:
  – control as many as possible

Building Science

Heat Air and Moisture No.8/78




## 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

Building Science

Heat Air and Moisture No. 12/78

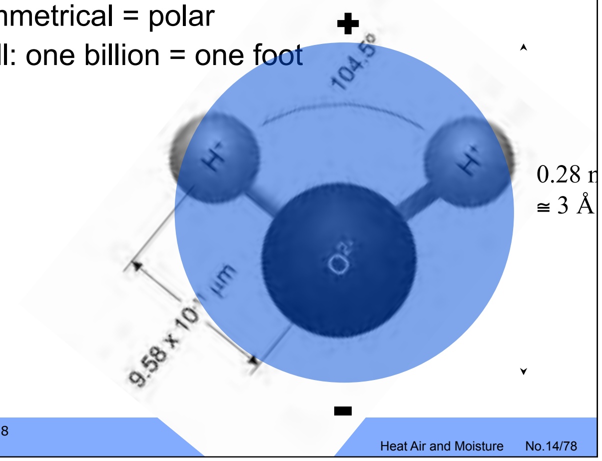
## Design Solutions

- *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

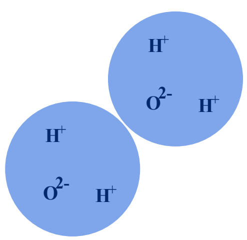
- Asymmetrical = polar
- Small: one billion = one foot

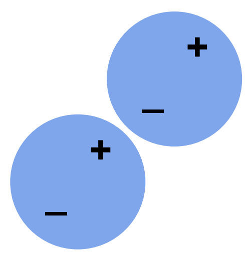





## The Polar Molecule

- Hydrogen end is "more" positive
- Oxygen end is "more" negative



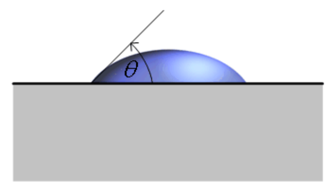






## Surface Tension: Wettable

**Water attracted to surface more than**

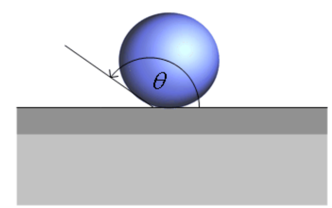
$\theta < 90°$




normal material: "wettable"

**Water attracted to self more than surface**

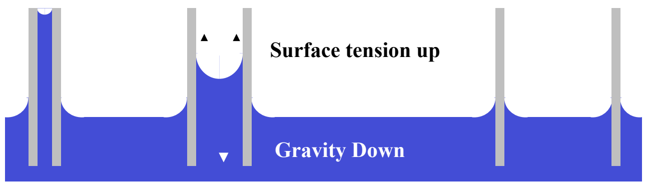
$\theta > 90°$




hydrophobically treated: "non-wettable"

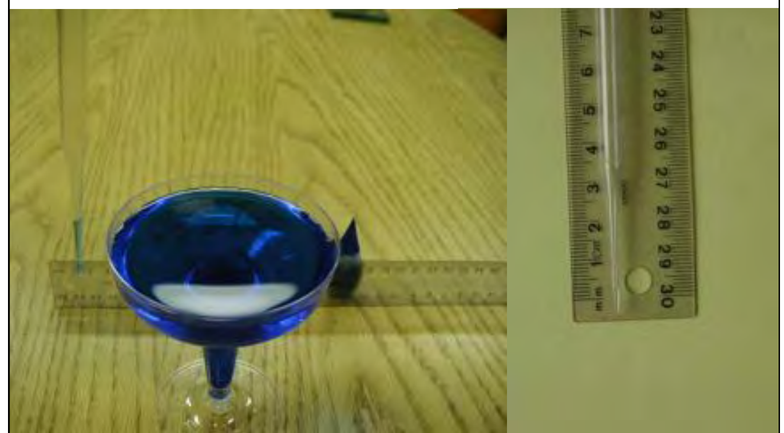
## Capillary Pressures

- Result of surface tension = attraction to surfaces
  - pressure varies with pore size
  - e.g., height rise in a glass tube



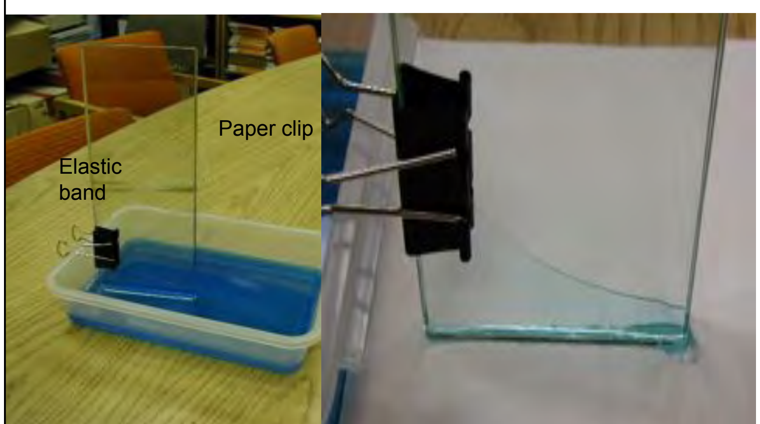



## Surface Tension





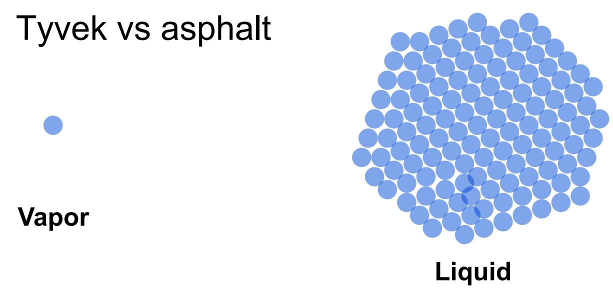
## Capillary rise between glass sheets



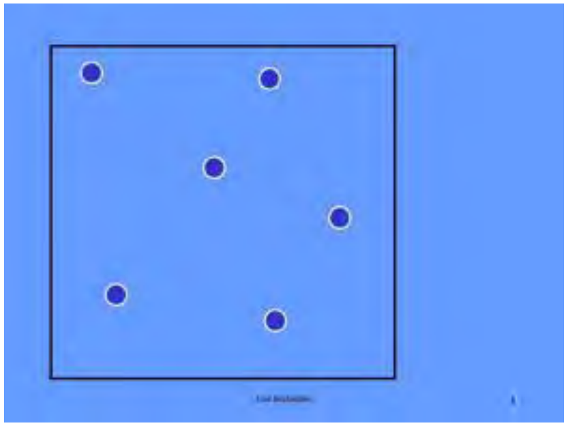



## Water: Liquid vs Vapor

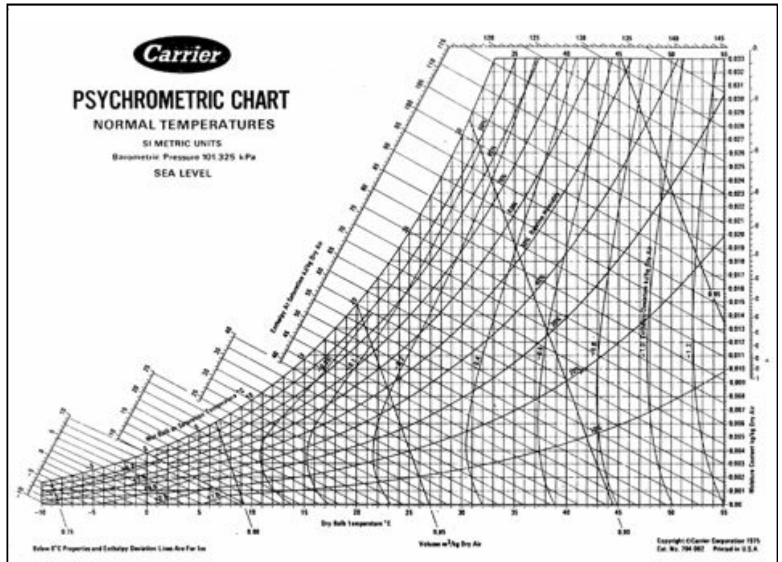
- Vapor is a single molecule
- Liquid is molecular clumps, 60 or more
- Tyvek vs asphalt



## Vapor Pressure: water as a gas

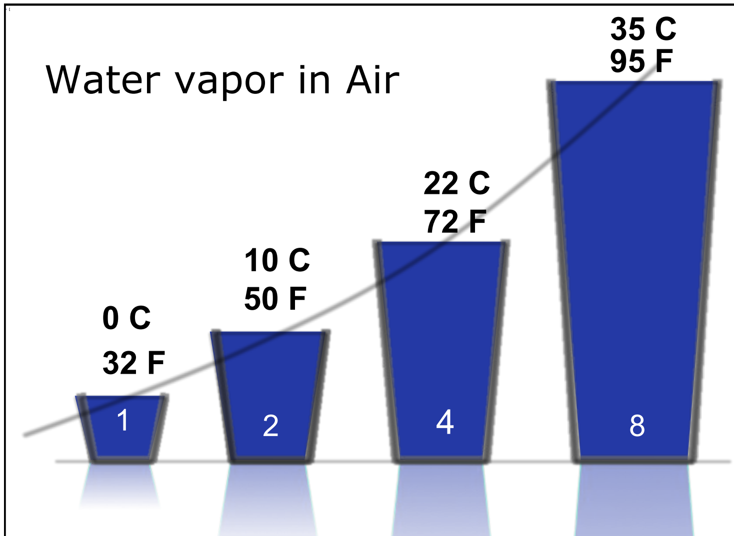






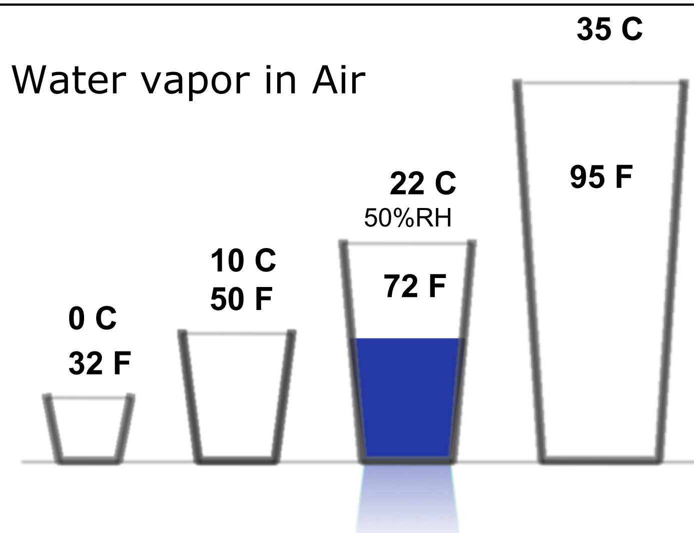


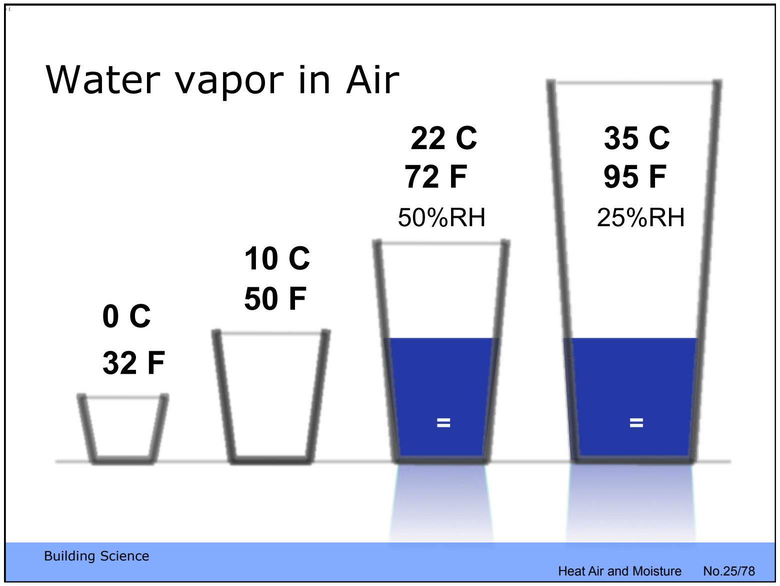

## Water vapor in Air

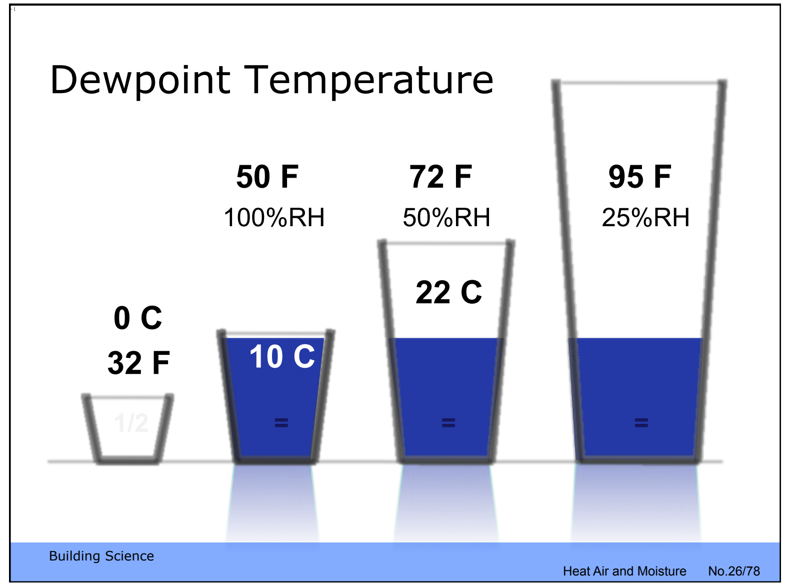


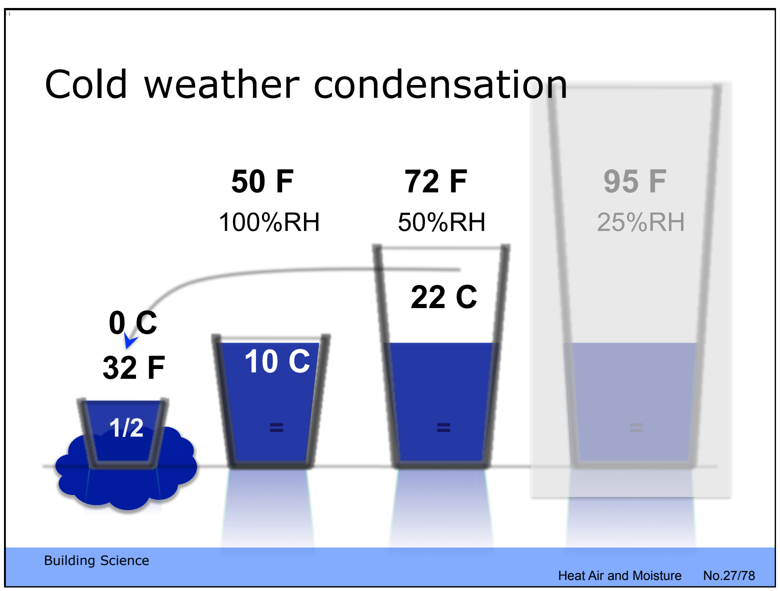


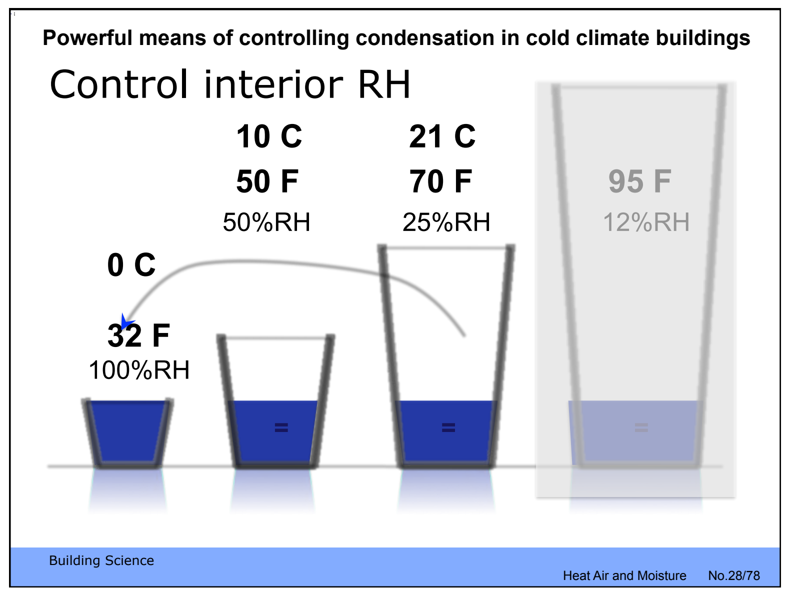

## Water vapor in Air

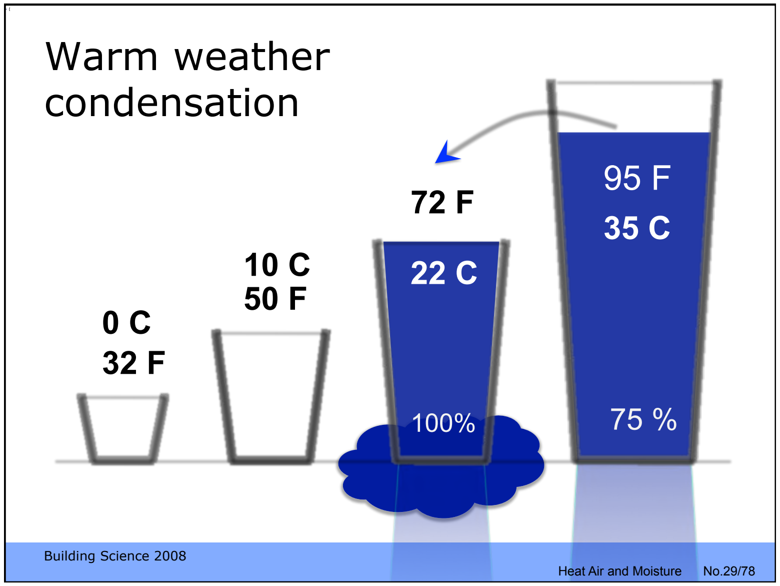


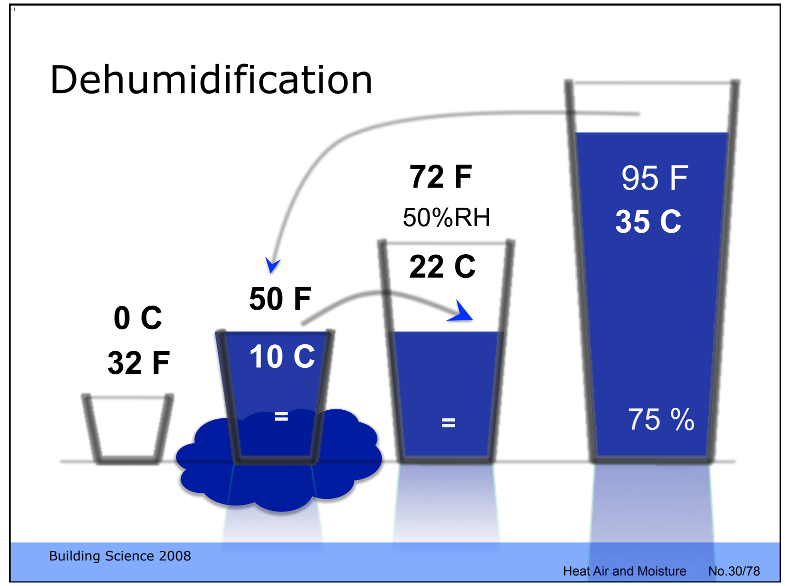

Water vapor in Air
0 C
32 F
10 C
50 F
22 C
72 F
50%RH
35 C
95 F
25%RH
=
=
Building Science
Heat Air and Moisture No.25/78

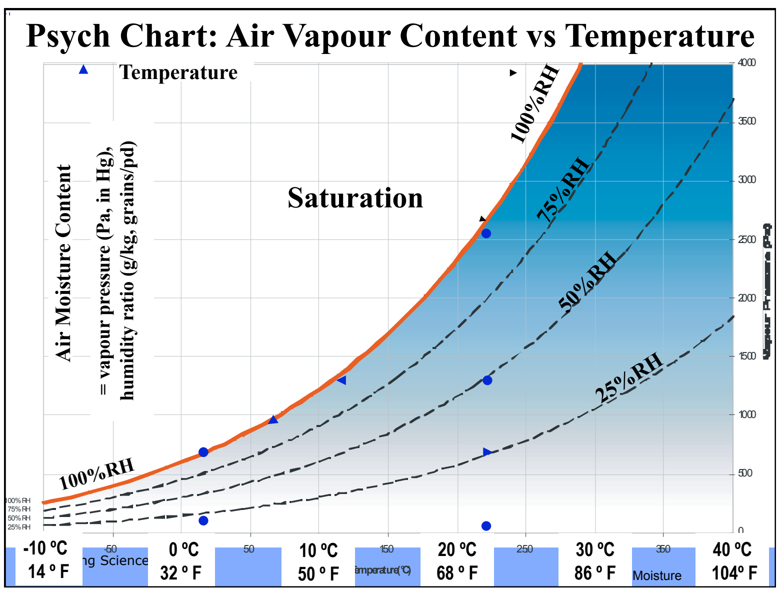

Dewpoint Temperature
0 C
32 F
50 F
100%RH
10 C
72 F
50%RH
22 C
95 F
25%RH
=
=
=
Building Science
Heat Air and Moisture No.26/78

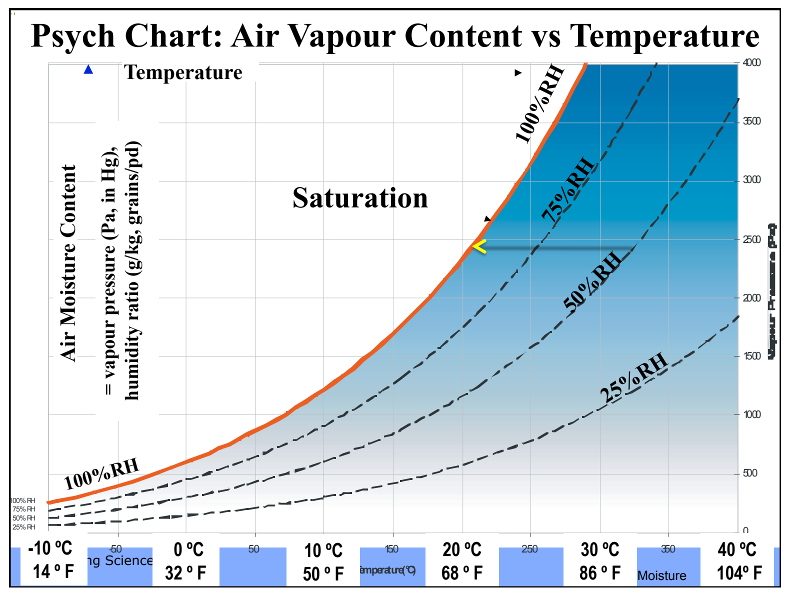

Cold weather condensation
0 C
32 F
1/2
50 F
100%RH
10 C
72 F
50%RH
22 C
95 F
25%RH
=
=
=
Building Science
Heat Air and Moisture No.27/78

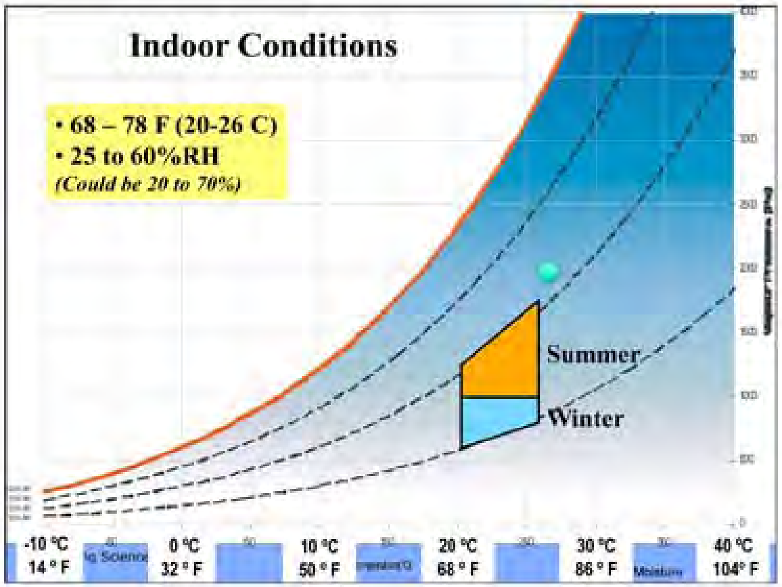

Powerful means of controlling condensation in cold climate buildings
Control interior RH
0 C
32 F
100%RH
10 C
50 F
50%RH
21 C
70 F
25%RH
95 F
12%RH
=
=
=
Building Science
Heat Air and Moisture No.28/78

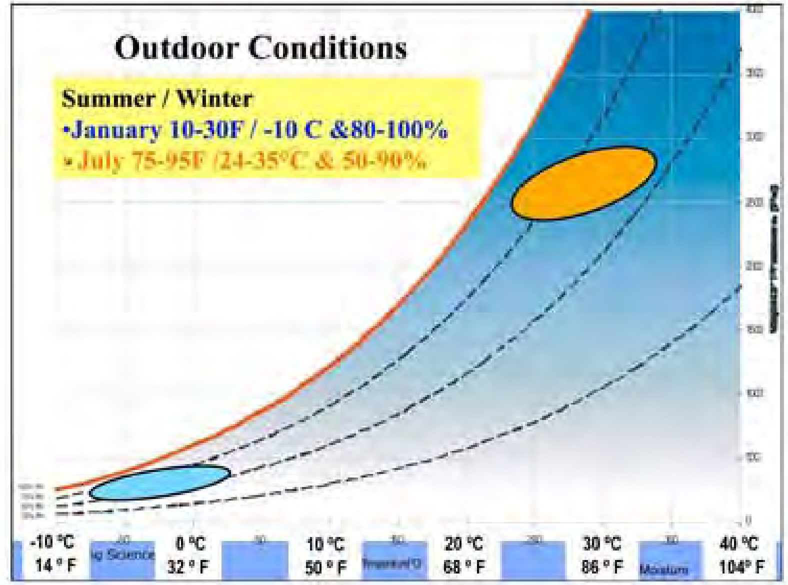

Warm weather condensation
95 F
35 C
72 F
22 C
10 C
50 F
0 C
32 F
100%
75 %
Building Science 2008
Heat Air and Moisture No.29/78

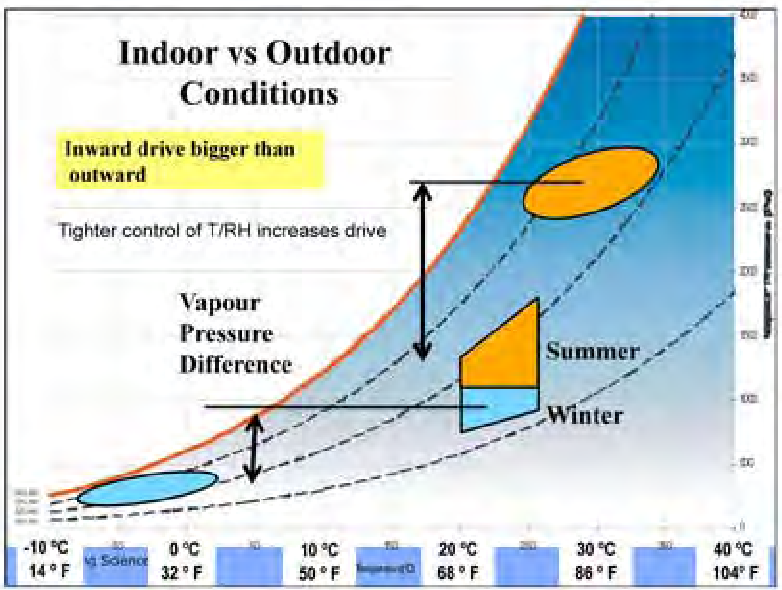

Dehumidification
95 F
35 C
72 F
50%RH
22 C
50 F
10 C
0 C
32 F
=
=
75 %
Building Science 2008
Heat Air and Moisture No.30/78


Psych Chart: Air Vapour Content vs Temperature
Temperature
Saturation
Air Moisture Content
= vapour pressure (Pa, in Hg), humidity ratio (g/kg, grains/pd)
100%RH
75%RH
50%RH
25%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


Psych Chart: Air Vapour Content vs Temperature
Temperature
Saturation
Air Moisture Content
= vapour pressure (Pa, in Hg), humidity ratio (g/kg, grains/pd)
100%RH
75%RH
50%RH
25%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



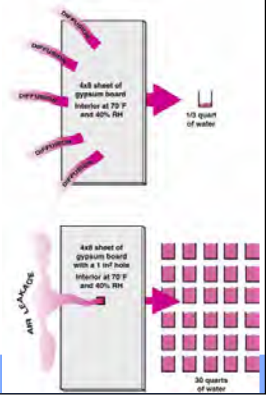

## Water Vapour Transport

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

Building Science .com Heat Air and Moisture No.30/78

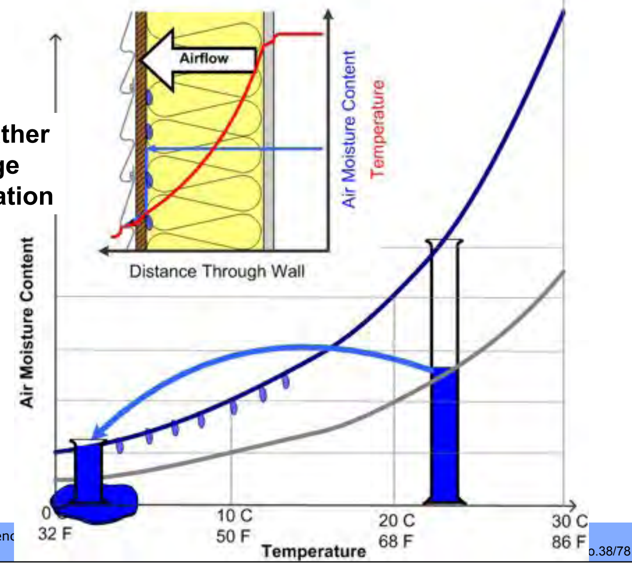
# Air leakage

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

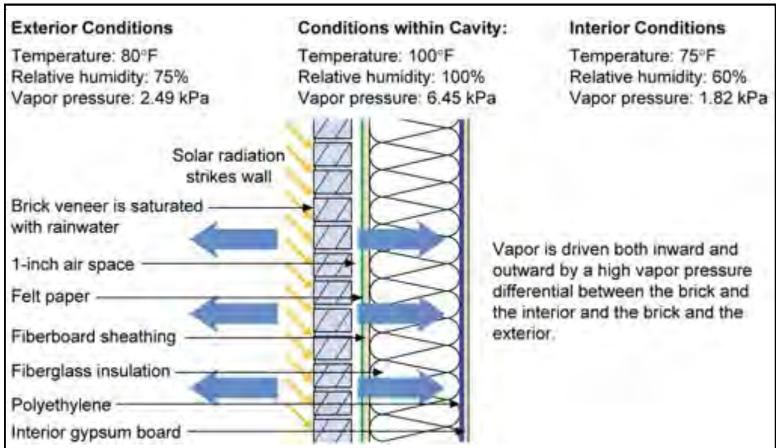


Building Science

**Cold-weather air leakage condensation**

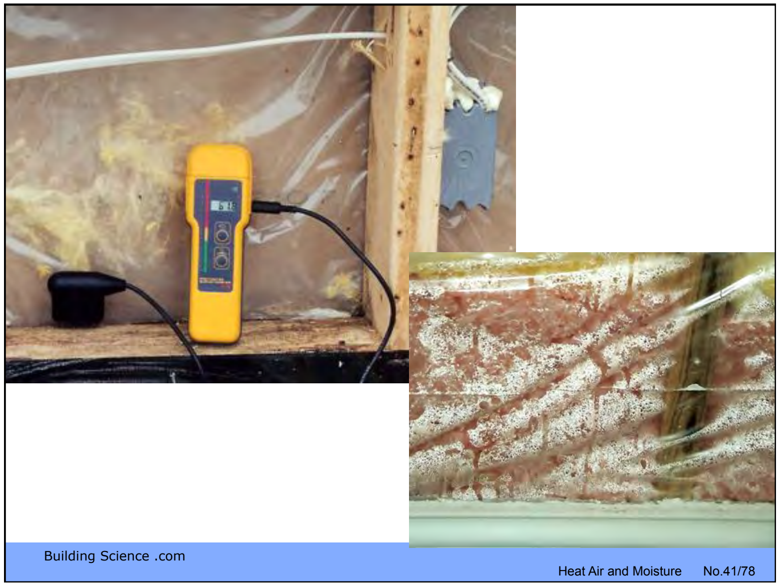


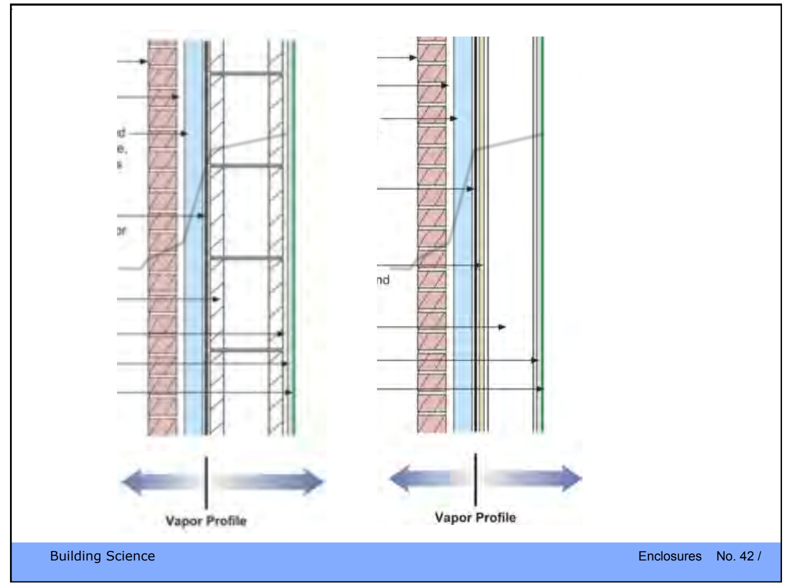

Building Science No.38/78

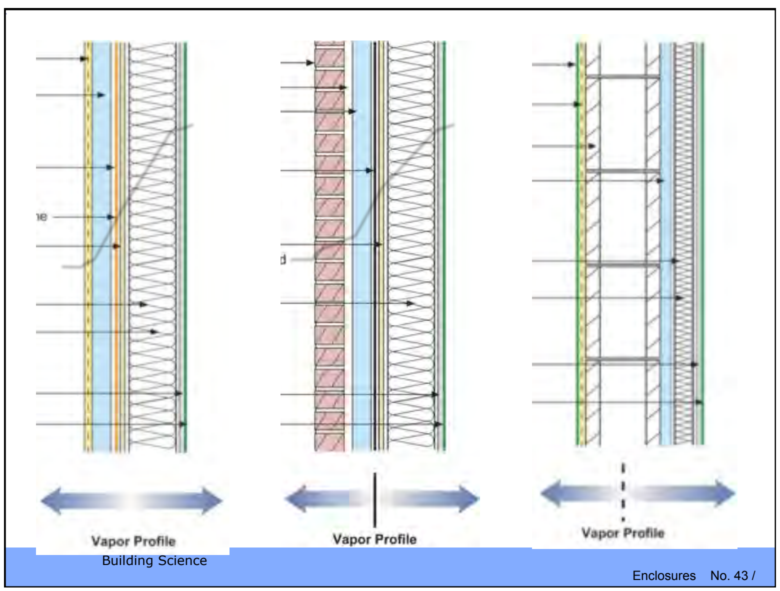


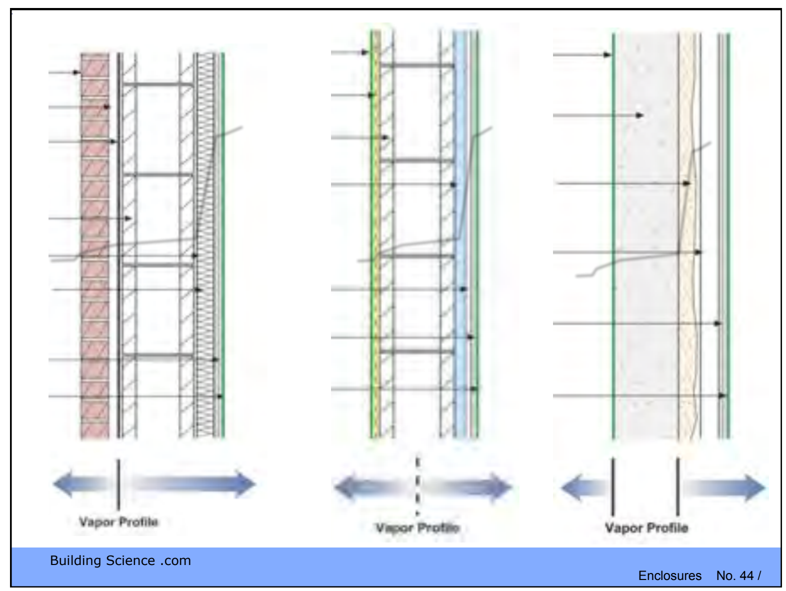

Building Science .com

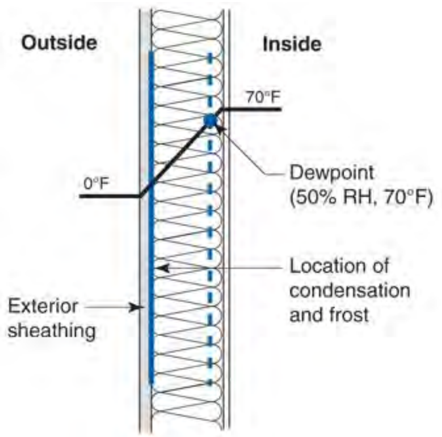
Heat Air and Moisture No.39/78


Building Science .com
Heat Air and Moisture No.41/78


Vapor Profile
Vapor Profile
Building Science
Enclosures No. 42 /


Vapor Profile
Vapor Profile
Vapor Profile
Building Science
Enclosures No. 43 /

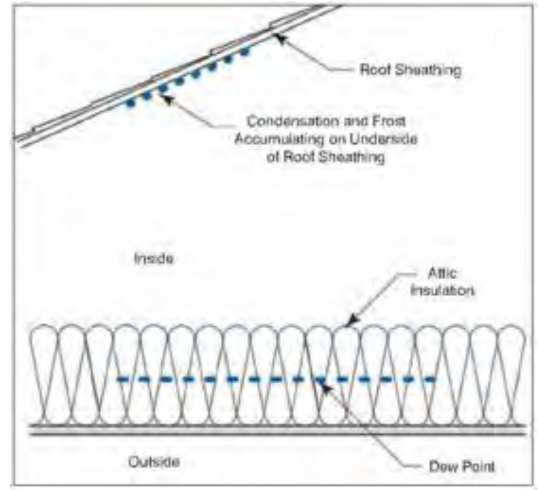

Vapor Profile
Vapor Profile
Vapor Profile
Building Science .com
Enclosures No. 44 /




**Valid for Diffusion of Air Leakage (Convection)**

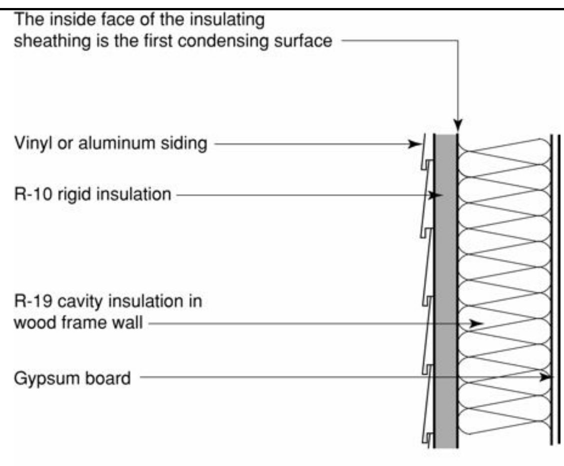
Building Science .com

Heat Air and Moisture No.45/78




Building Science 2008

Heat Air and Moisture No.46/78

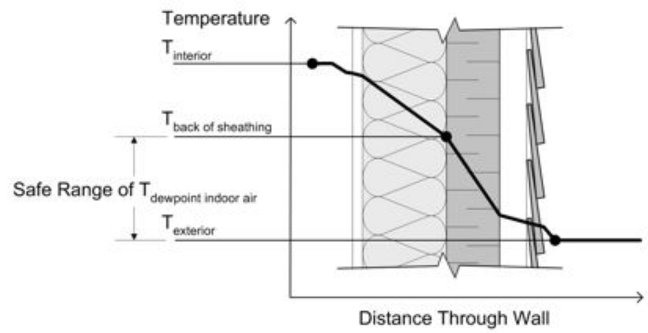



Warm Sheathing Approach

Building Science

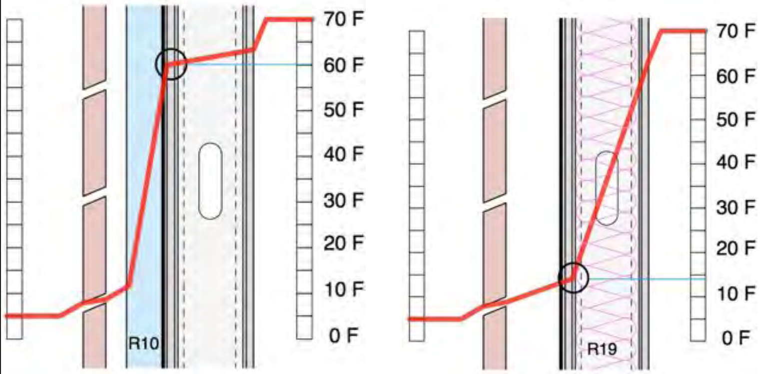
Heat Air and Moisture No.47/78

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




Building Science

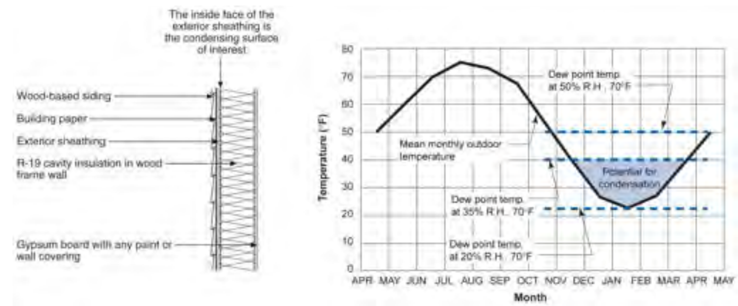
Heat Air and Moisture No.48/78




Building Science 2008

Heat Air and Moisture No.49/78

## No exterior insulation

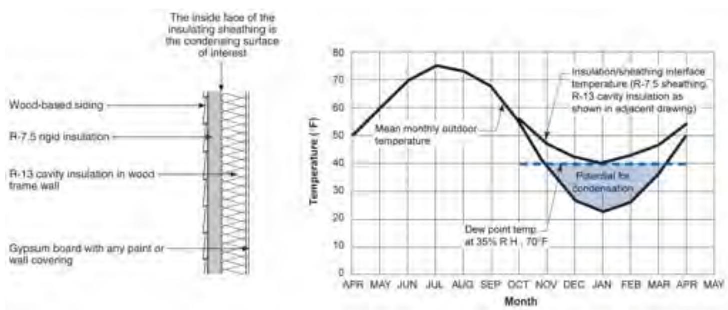



**Keep it real dry . . .**

Building Science .com

Heat Air and Moisture No.50/78

## R7.5 Exterior Insulation




Building Science .com

Heat Air and Moisture No.51/78

## Water Vapour Transport

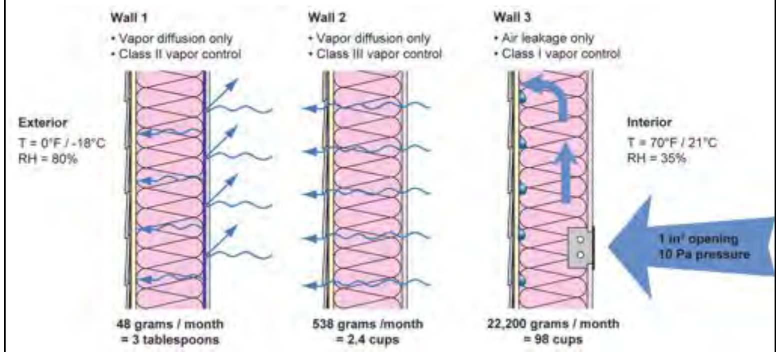
- Vapour Diffusion (like heat conduction)
  - more to less vapor
  - No air flow
  - Flow through tiny pores
- Air Convection (like heat convection)
  - more to less air pressure
  - flow through visible cracks and holes
  - vapour is just along for the ride

Building Science .com

Heat Air and Moisture No.52/78

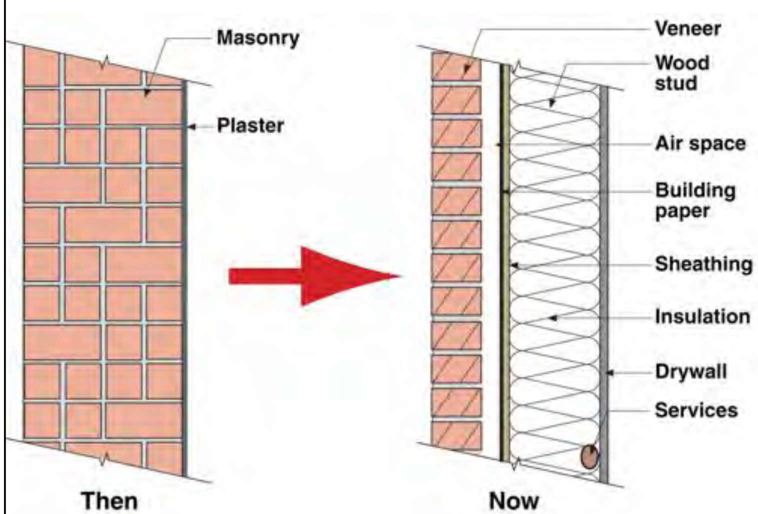

Building Science

Heat Air and Moisture No.53/78



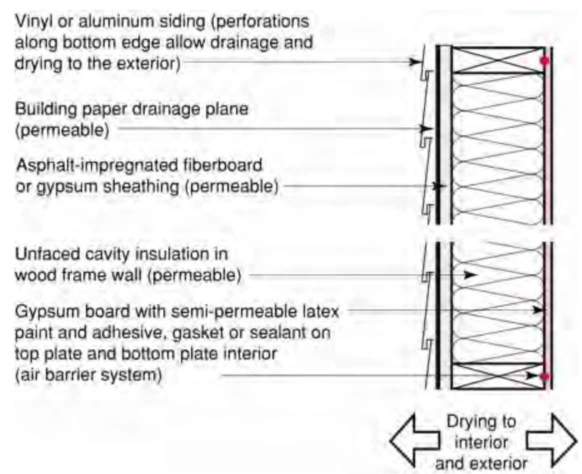

Building Science .com

Heat Air and Moisture No.54/78




Building Science 2008

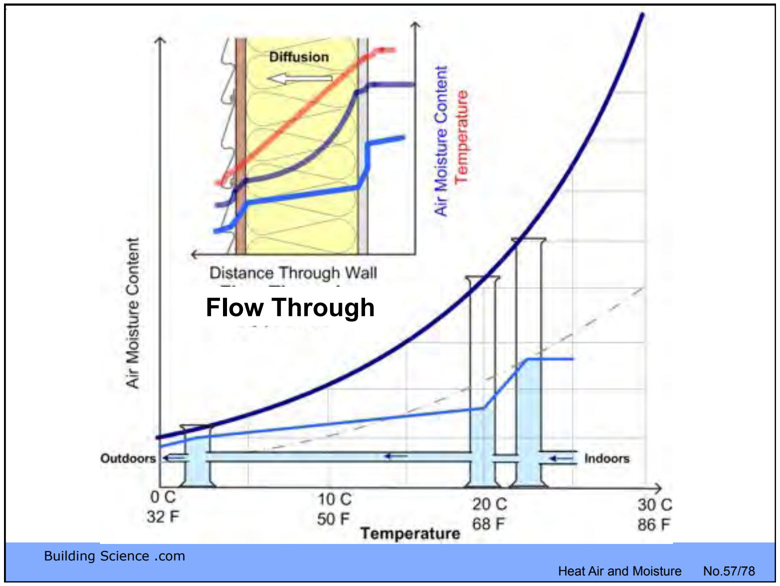
Heat Air and Moisture No.55/78

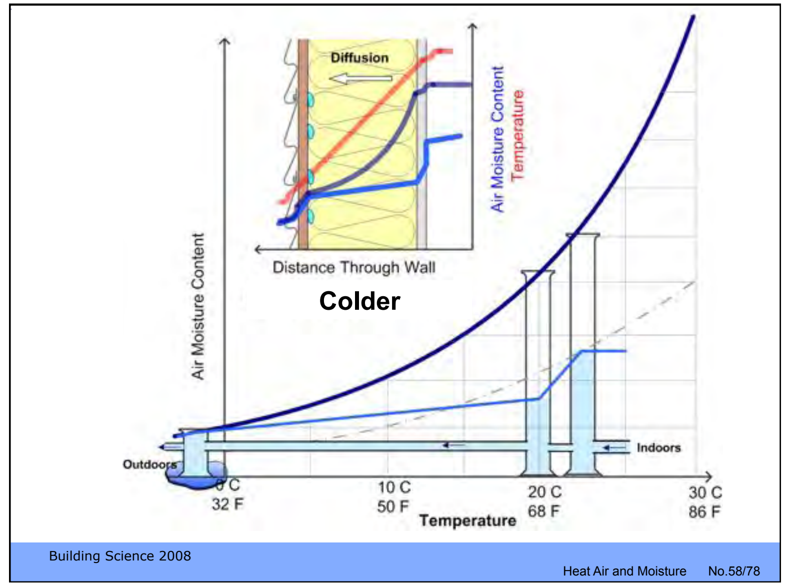


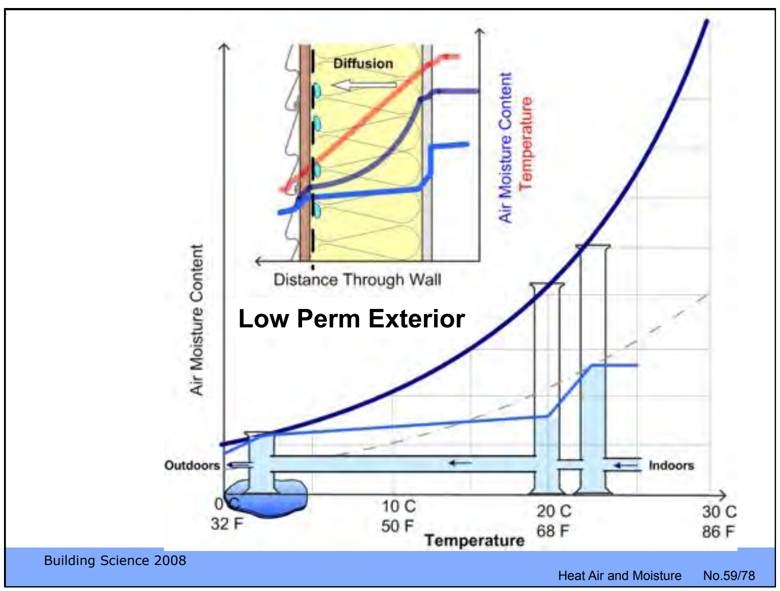

Flow Through Design

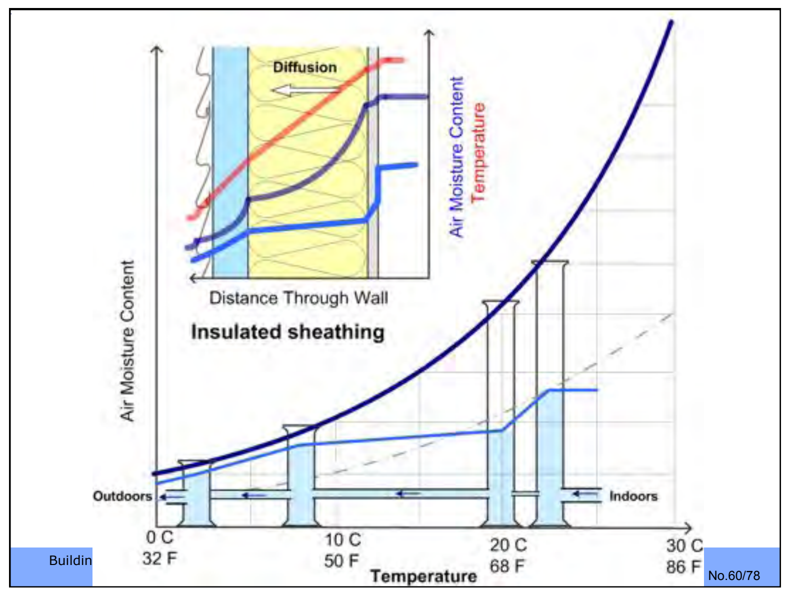
Building Science .com

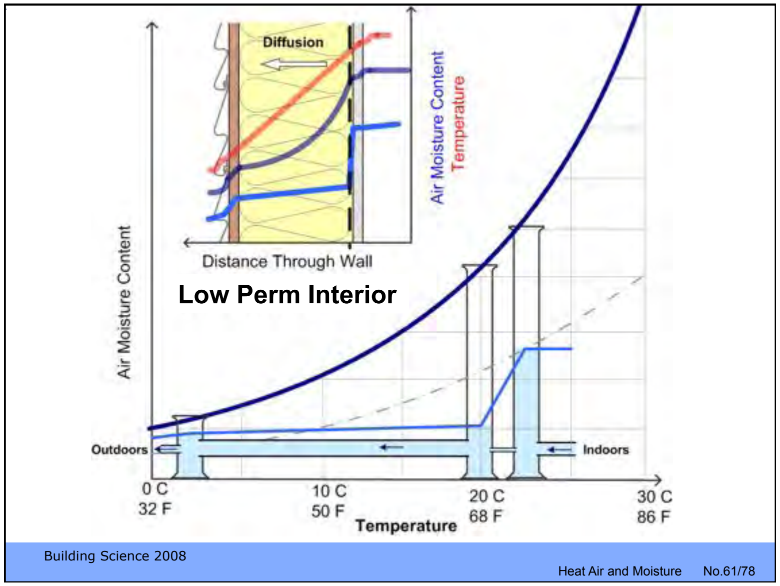
Heat Air and Moisture No.56/78

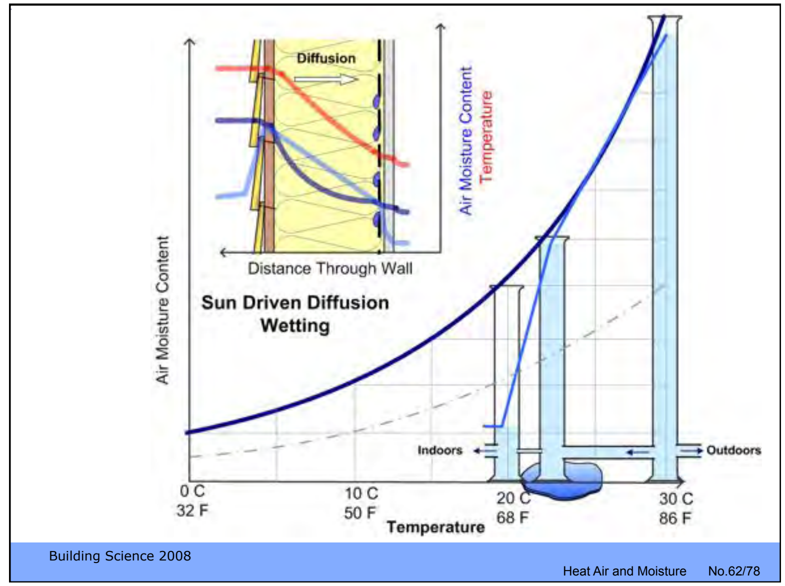

Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Flow Through
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
Building Science .com
Heat Air and Moisture No.57/78


Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Colder
Air Moisture Content
Outdoors
Indoors
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
Building Science 2008
Heat Air and Moisture No.58/78


Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Low Perm Exterior
Air Moisture Content
Outdoors
Indoors
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
Building Science 2008
Heat Air and Moisture No.59/78


Diffusion
Air Moisture Content
Temperature
Distance Through Wall
Insulated sheathing
Air Moisture Content
Outdoors
Indoors
0 C
32 F
10 C
50 F
20 C
68 F
30 C
86 F
Temperature
No.60/78




## 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

Building Science
Heat Air and Moisture No.63/78