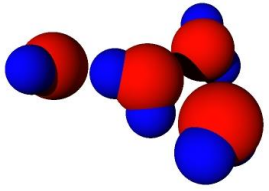
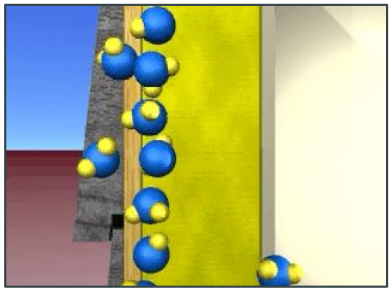
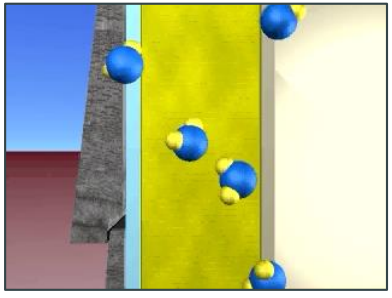






Building Solutions

FINALLY, THE TRUTH ABOUT CONDENSATION

NARI CEU APPROVED

CONTINUING EDUCATION AIA

GBCI CMP

CEU Credits: 1.5

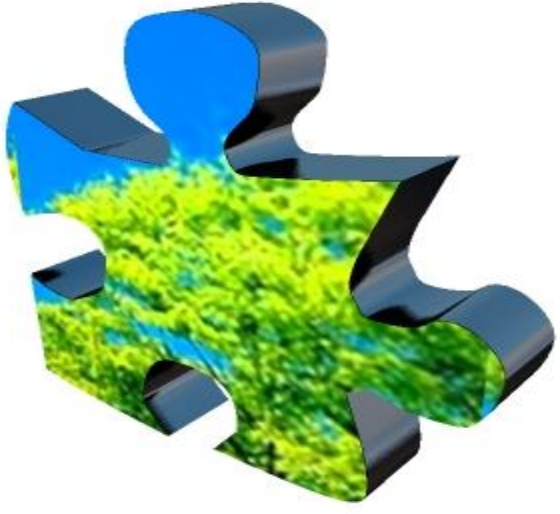
Presenter: Dan Tempas

- Bachelor of Chemical Engineering from the University of Illinois
- 30+ years experience in building and construction industry
  - STYROFOAM™ technical service, product development
  - LEED Associate
  - Building Solutions Technical Support Team
  - Co-inventor of THERMAX™ Wall System
  - Developed presentations on NFPA 285, THERMAX™ Wall System, Ultra Wall System
  - Previously presented various topics at RESNET, CSI, and IMI

Condensation: Scope

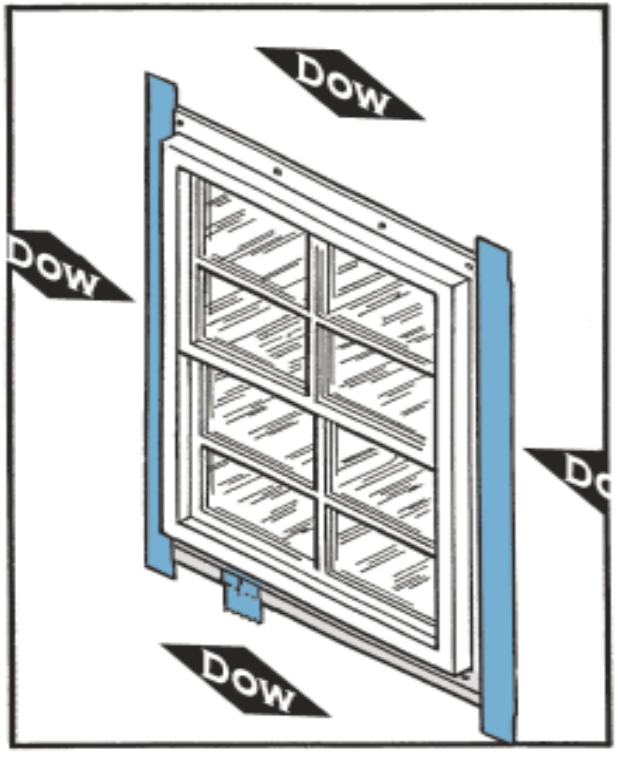
Why This Talk?

- Misconceptions
- Errors
- Incompleteness



Condensation: Scope

Not About
Bulk Water



Condensation: Scope

Bulk Water is Important!

Condensation: The Real Story

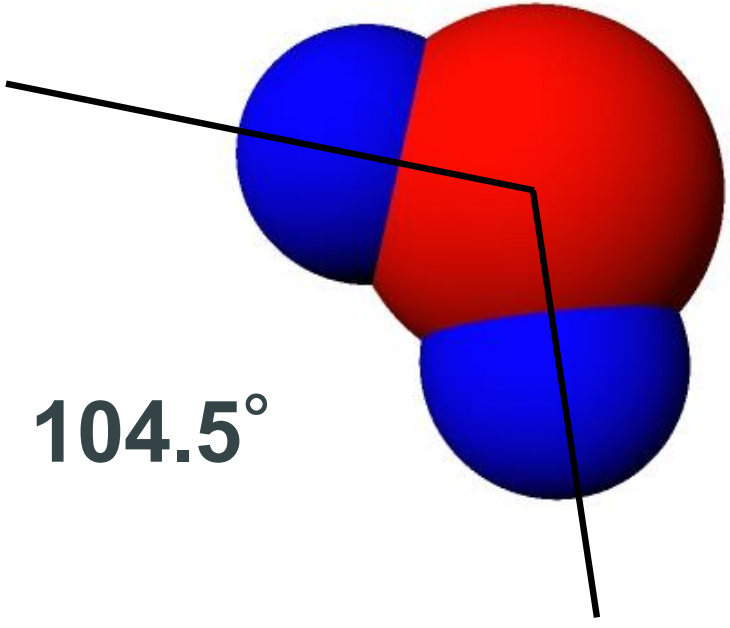
- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies
- Wall Design

Condensation: The Real Story

- **Properties of Water**
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies
- Wall Design

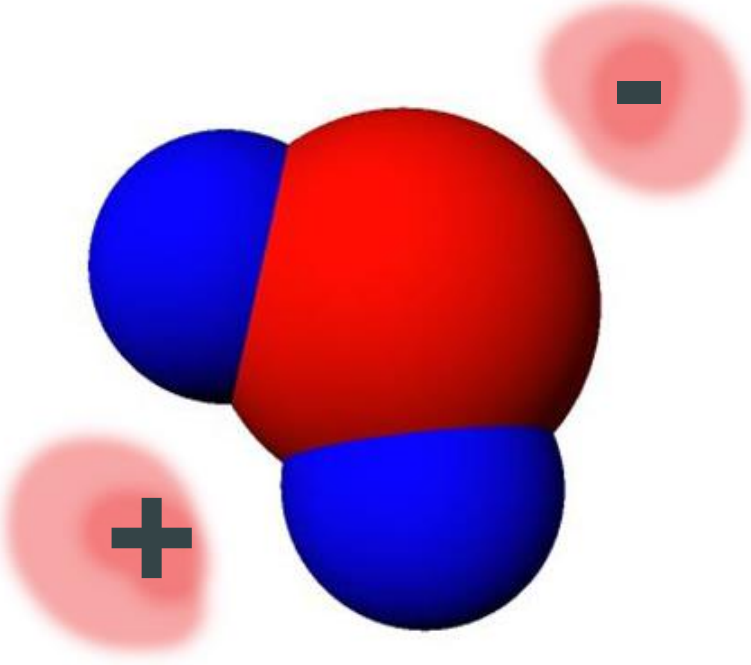
Condensation: Water Properties

Structure



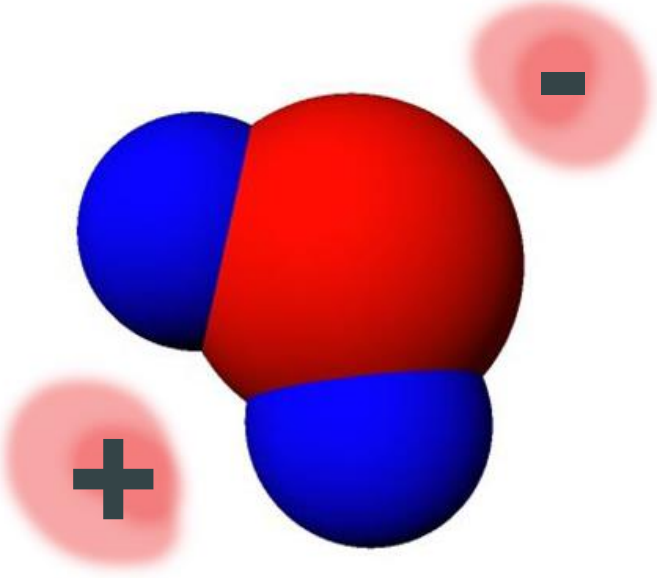
Condensation: Water Properties

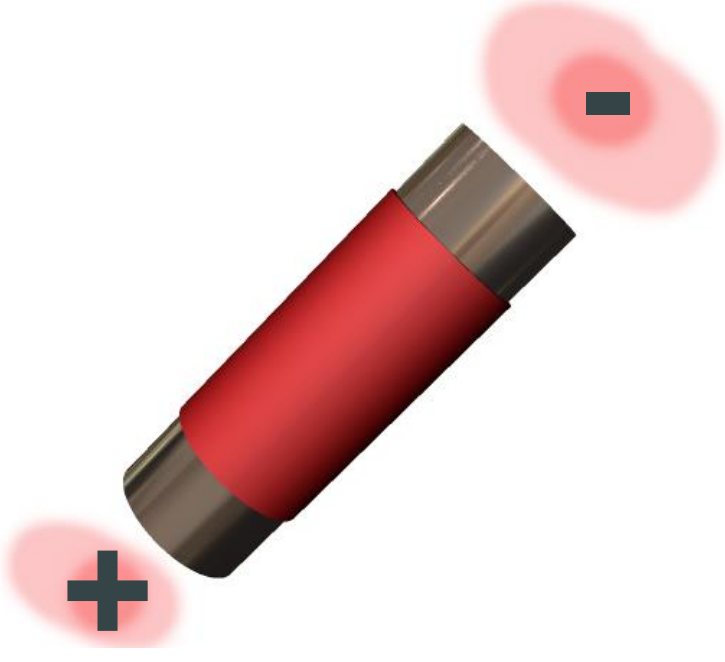
Structure



Condensation: Water Properties

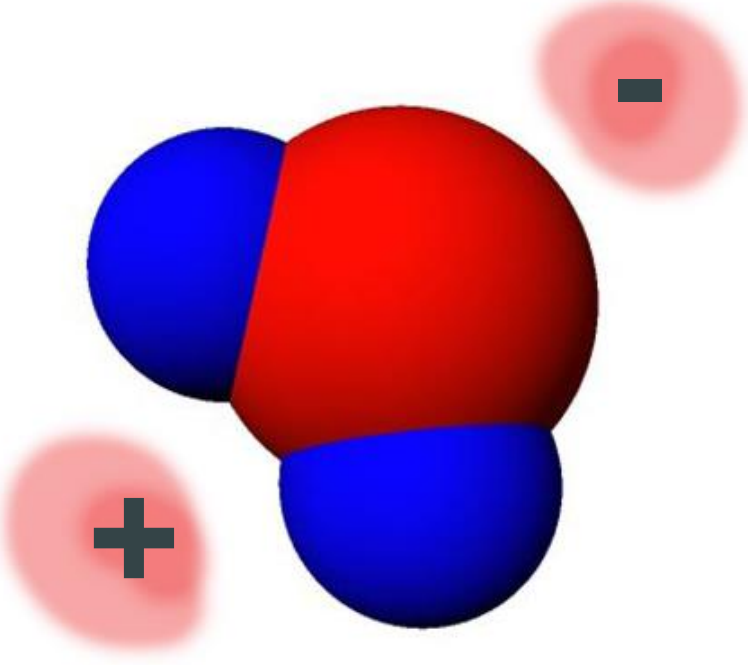
Structure





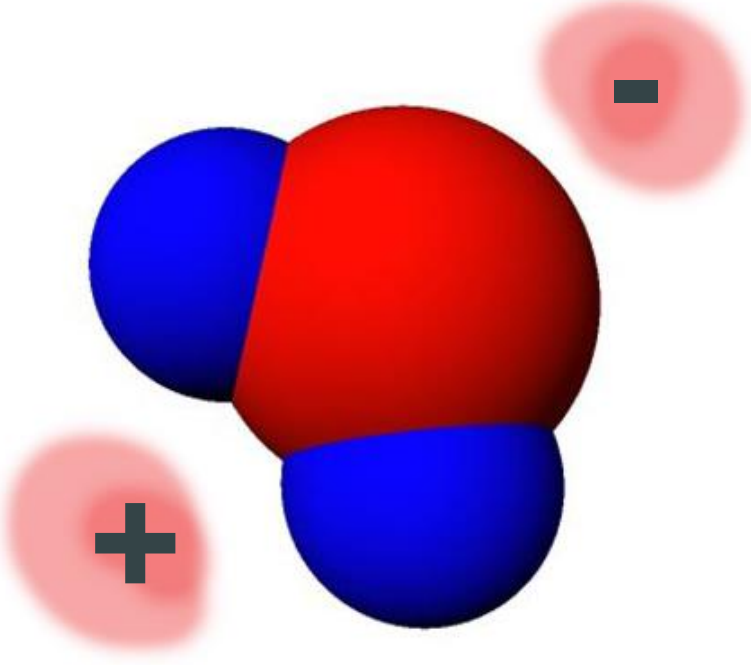
Condensation: Water Properties

Structure



Condensation: Water Properties

Structure



Condensation: Water Properties

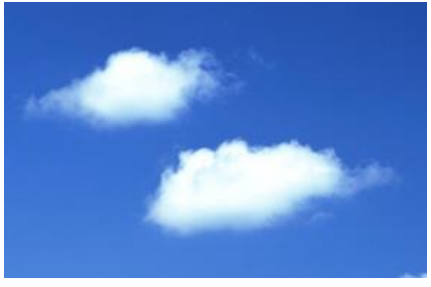
Structure

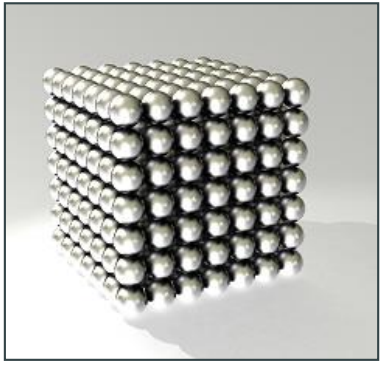
Condensation: Water Properties

Structure

Condensation: Water Properties

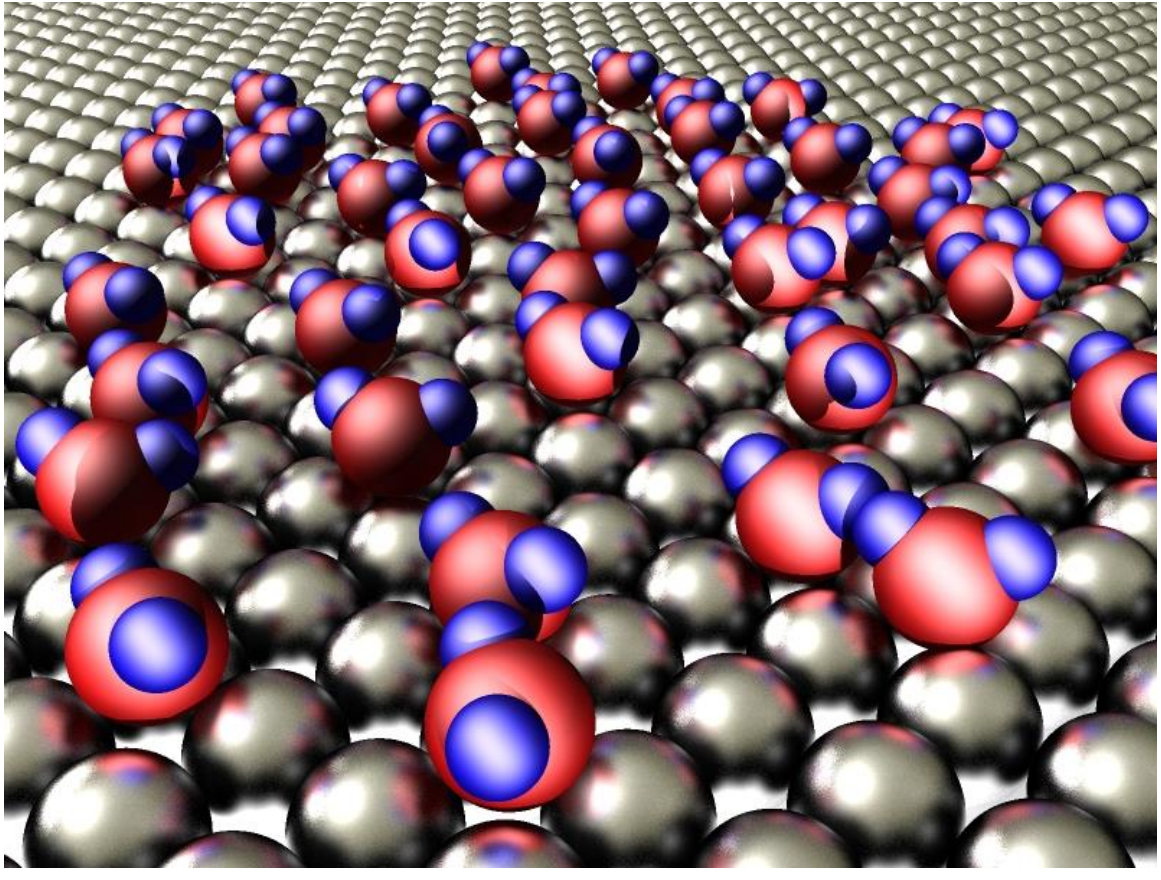
Phases of Water:





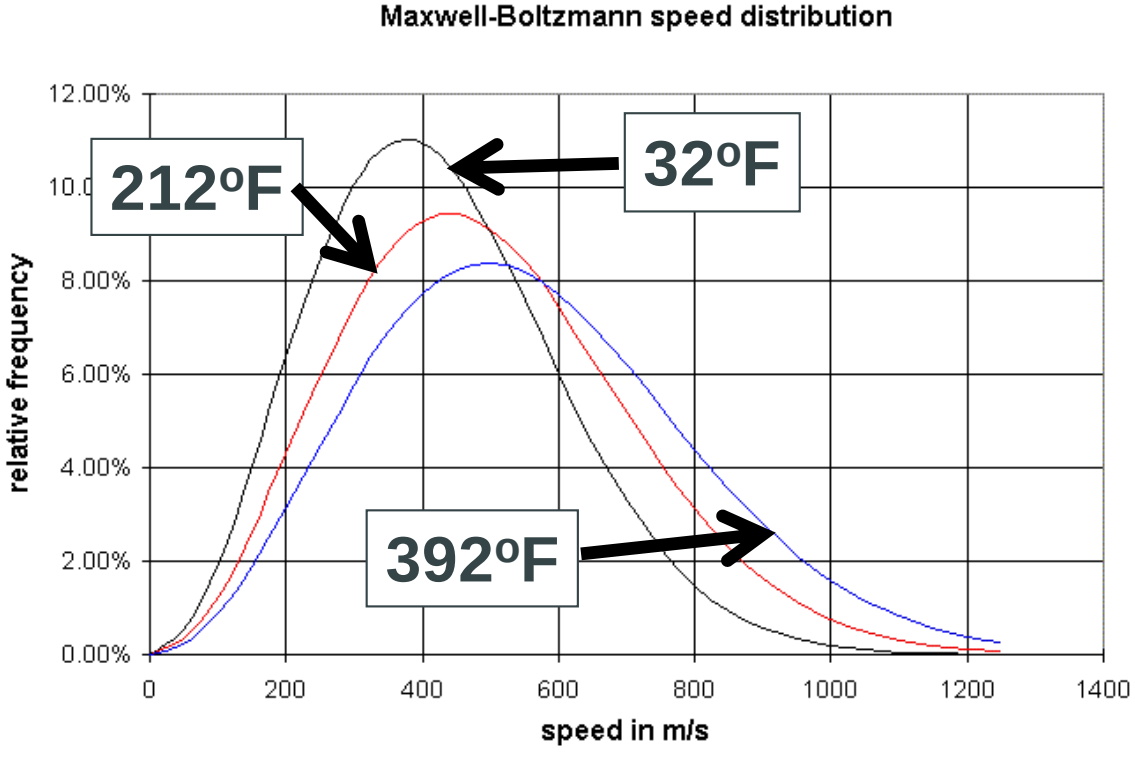
Condensation: Water Properties

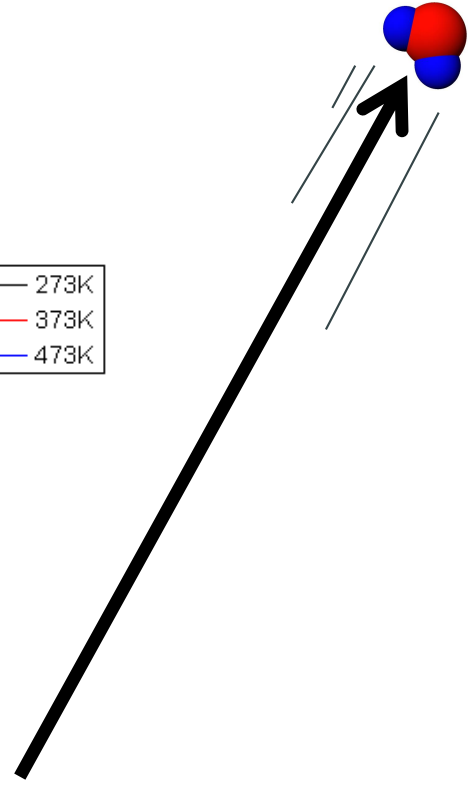
Phases of Water: Adsorbed



Condensation: Water Properties

Effect of Temperature

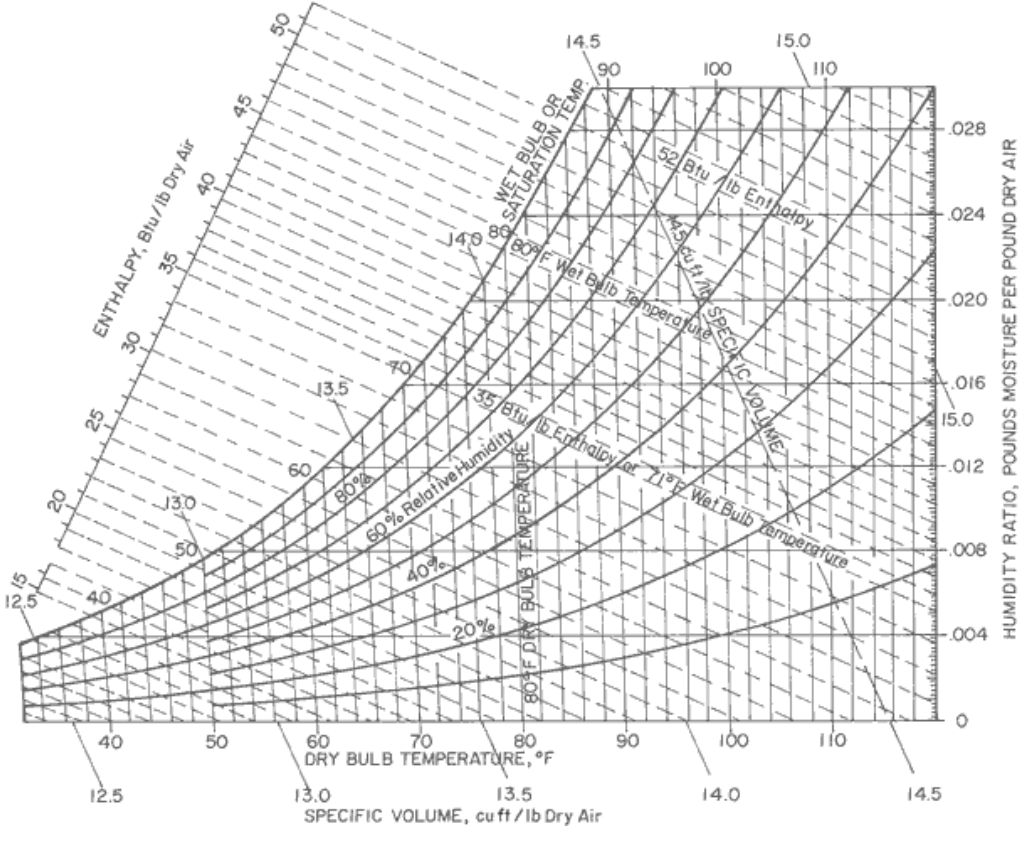




Velocity in m/s

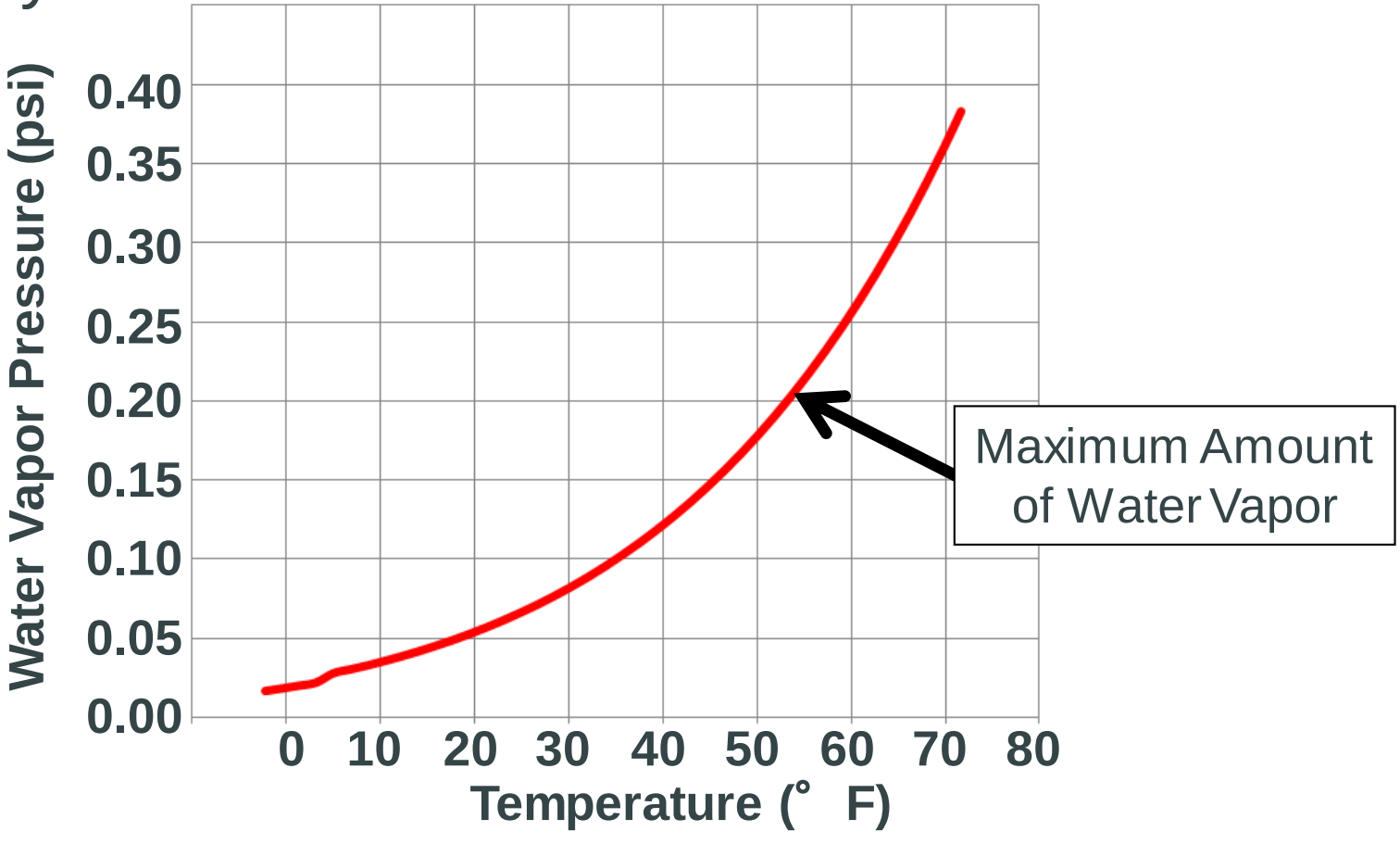
Condensation: Water Properties

Psychrometric Chart



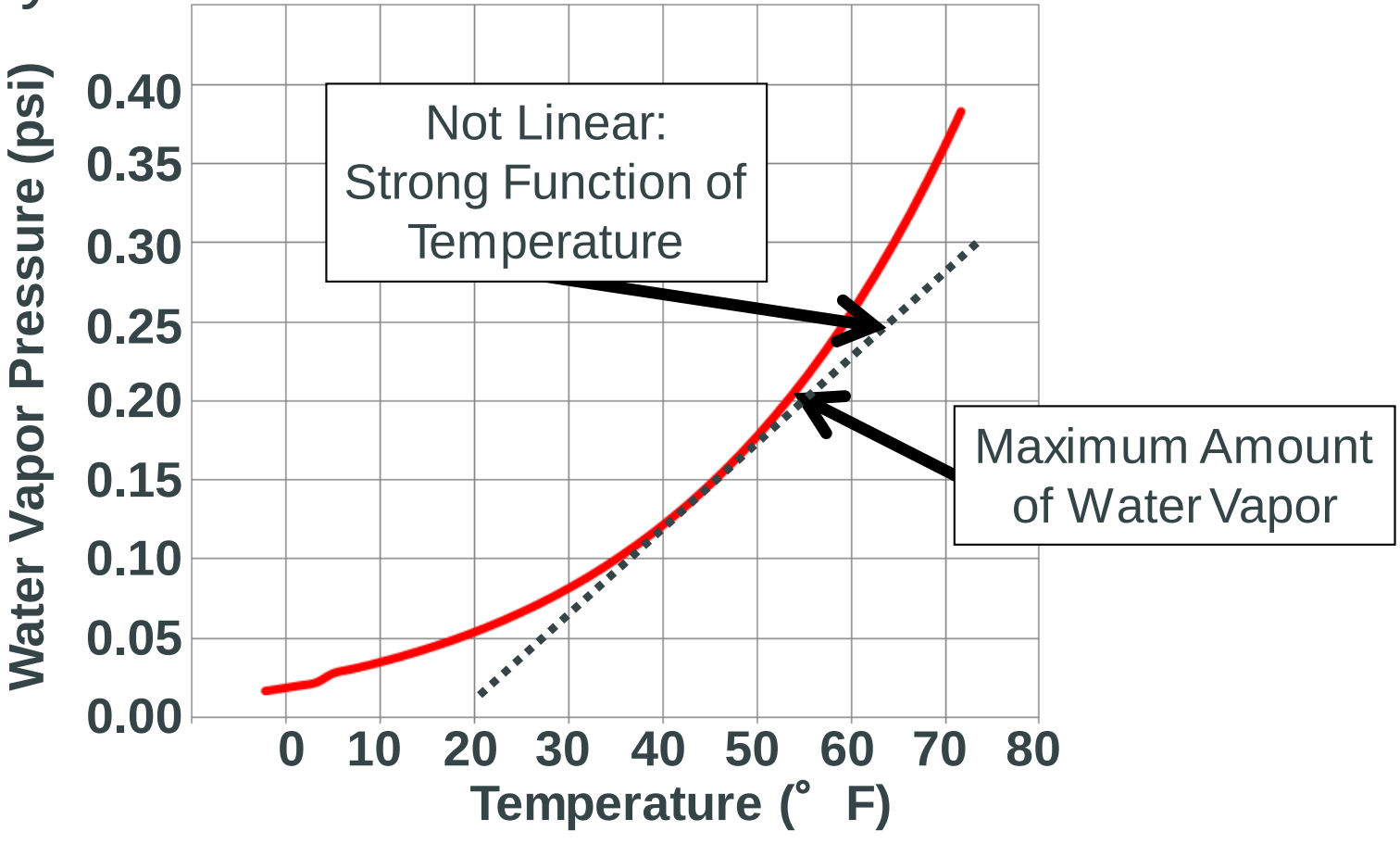
Condensation: Water Properties

Psychrometric Chart



Condensation: Water Properties

Psychrometric Chart



Condensation: The Real Story

- Properties of Water
- **Terms Relating to Condensation**
- Wetting and Drying
- Analyzing Assemblies
- Wall Design

Condensation: Terms

Absolute Humidity

Measured in:

- **Lbs water/lb air**
- **Grains WV/cubic foot**
- **Water Vapor Pressure (Psi)**
- **Dewpoint Temperature**

Condensation: Terms

Relative Humidity

Need 2 pieces of information:

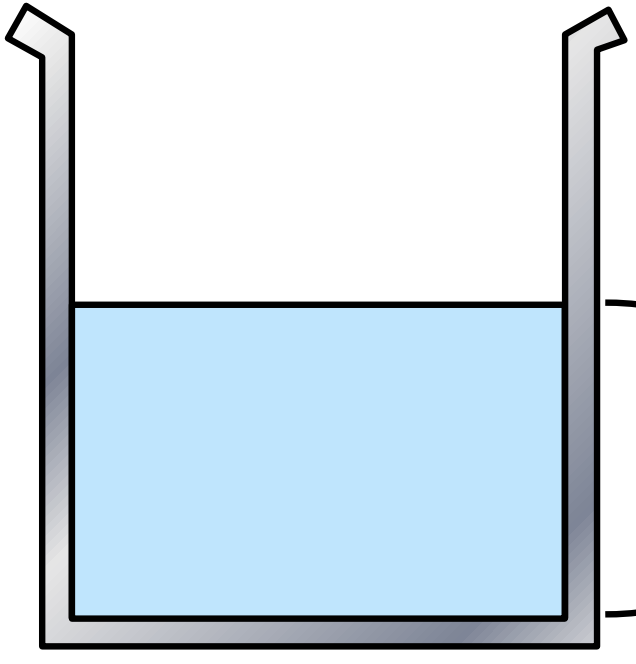
- Temperature (ºF)
- Percent (%)

Condensation: Terms

Relative Humidity

Condensation: Terms

Relative Humidity

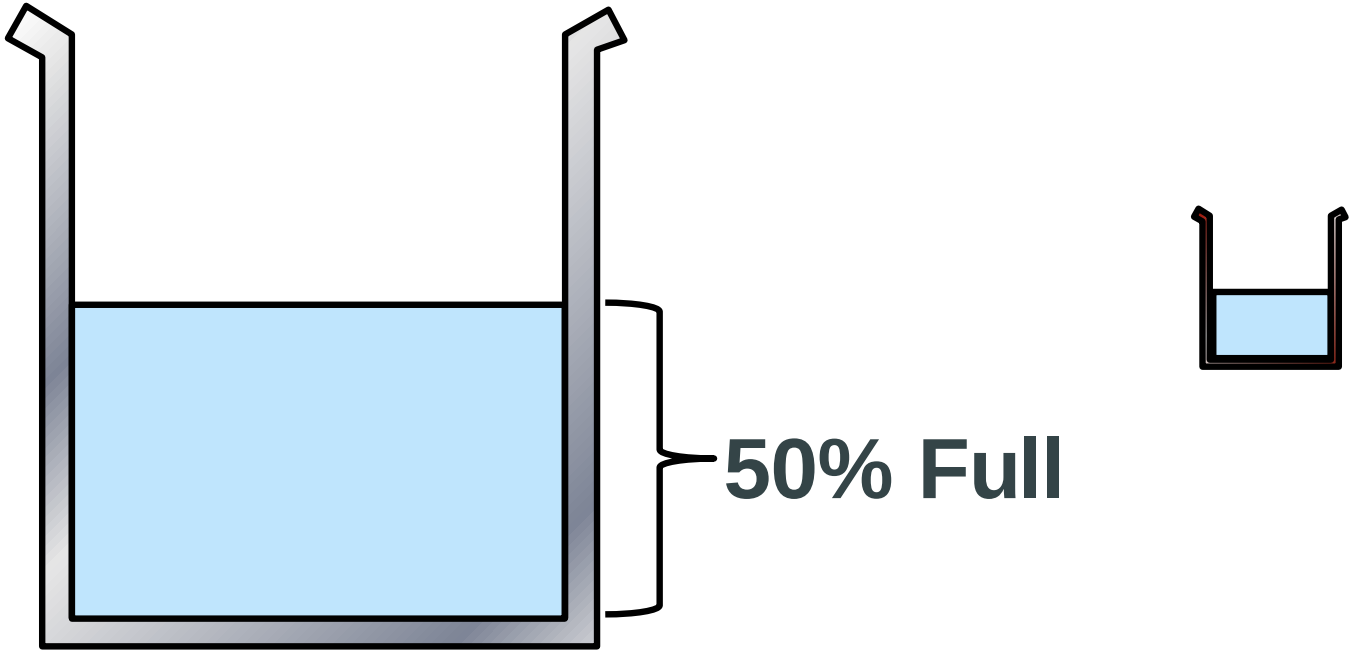


How Much Water??

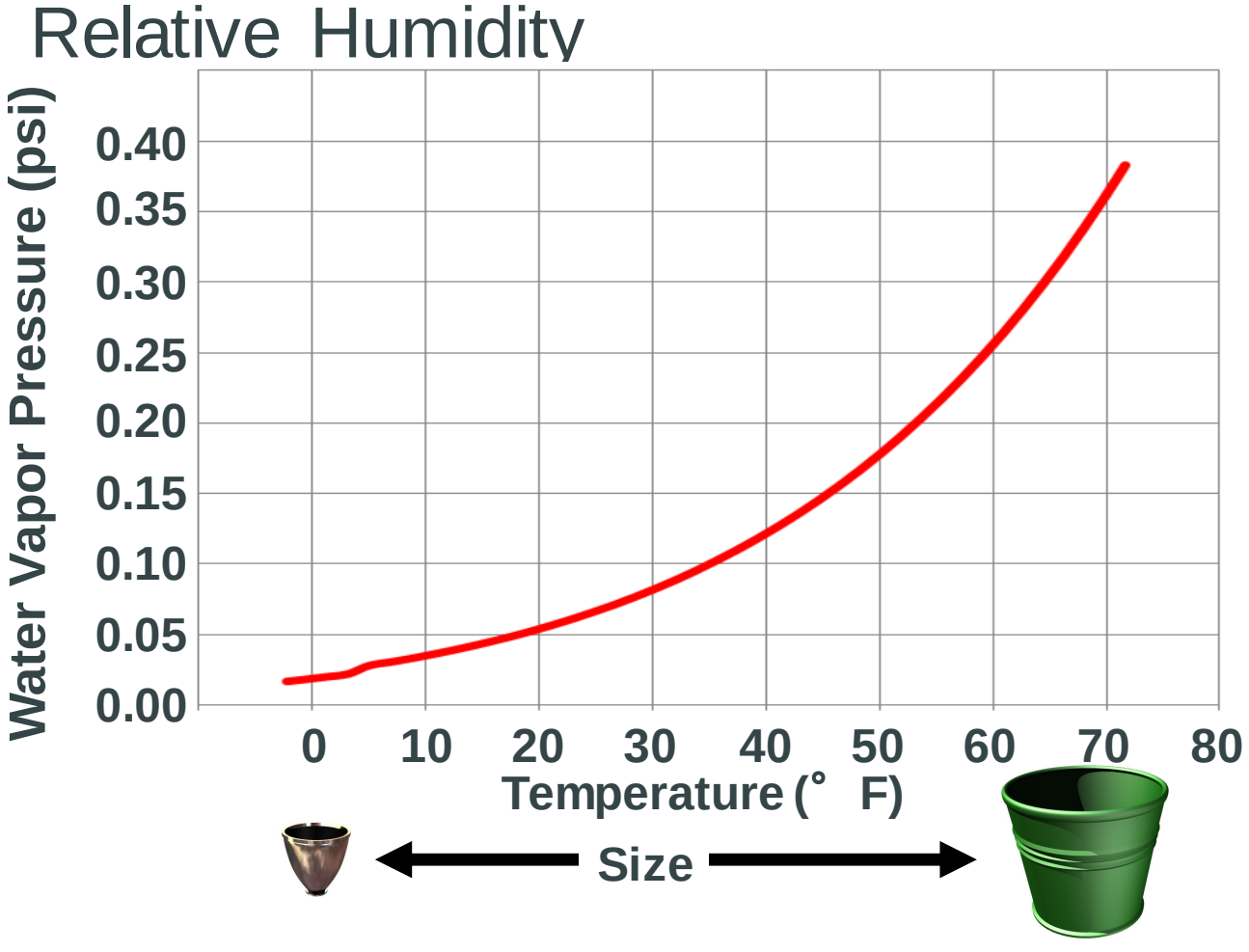
50% Full

Condensation: Terms

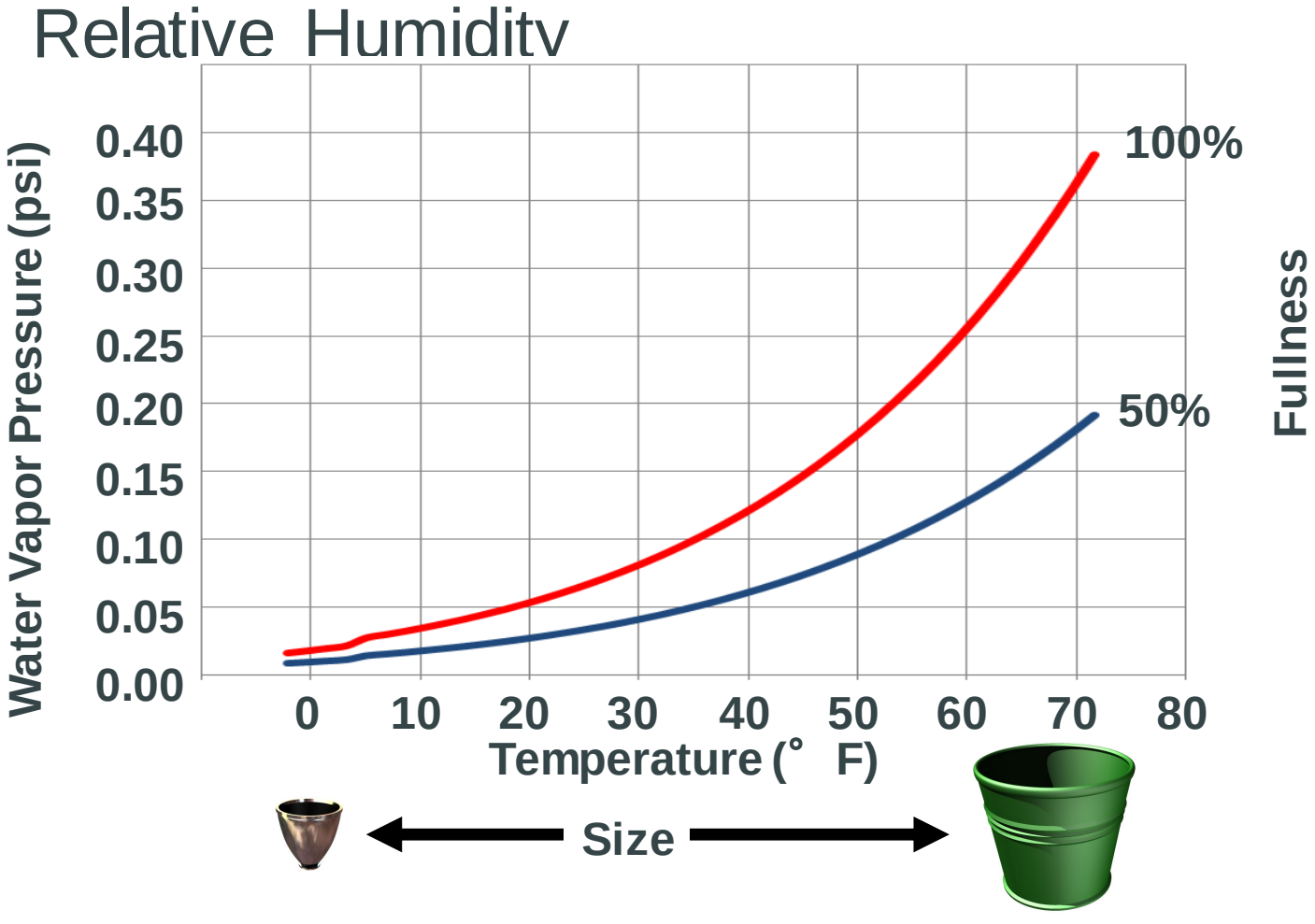
Relative Humidity



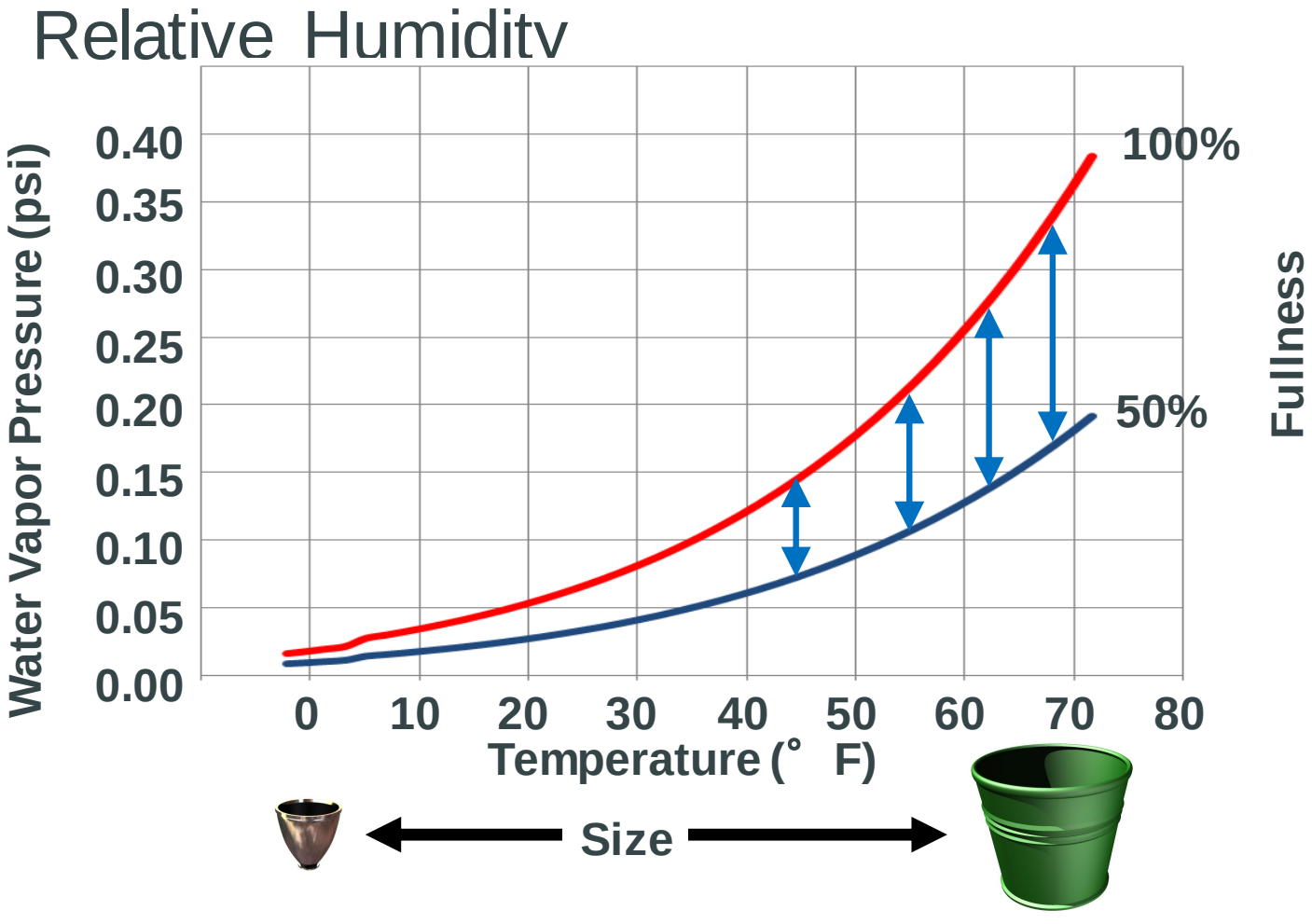
Condensation: Terms



Condensation: Terms

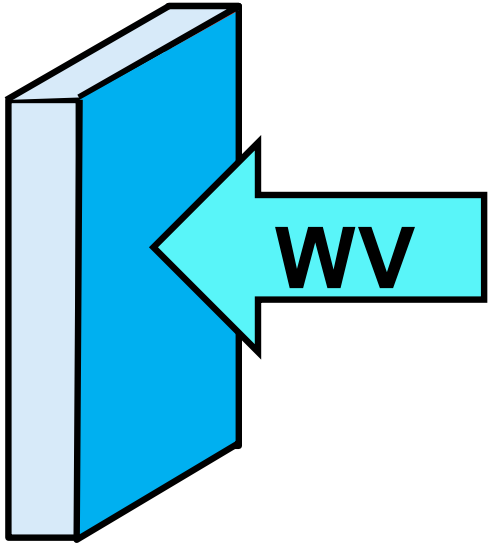


Condensation: Terms



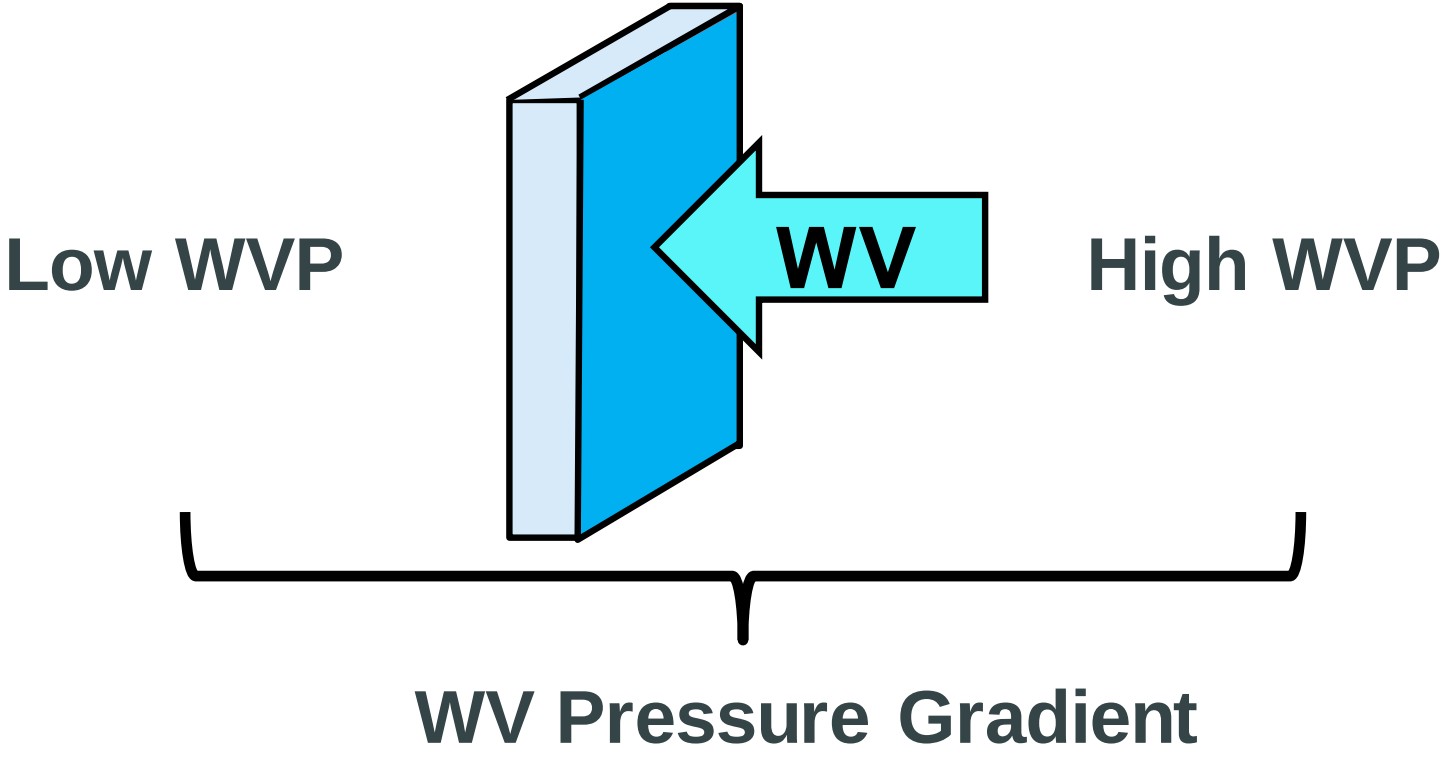
Condensation: Terms

Permeability: Diffusion



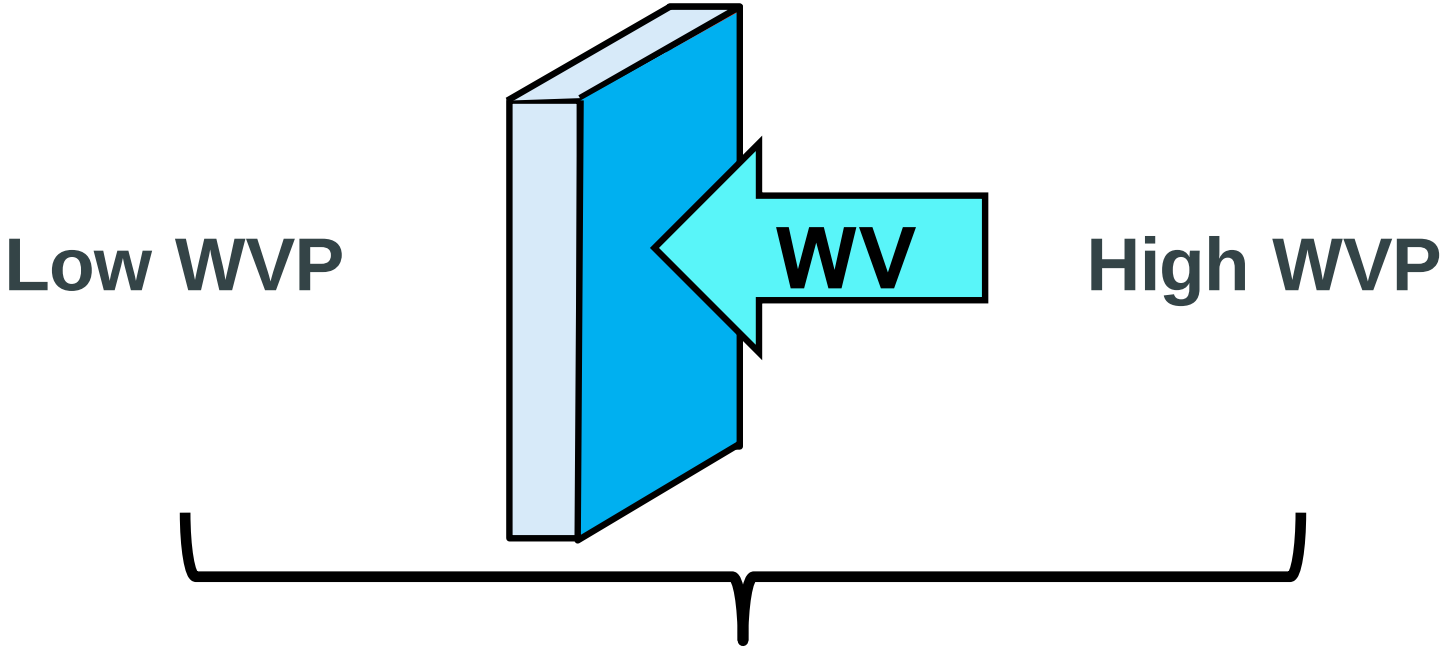
Condensation: Terms

Permeability: Diffusion



Condensation: Terms

Permeability: Diffusion



Not Temperature

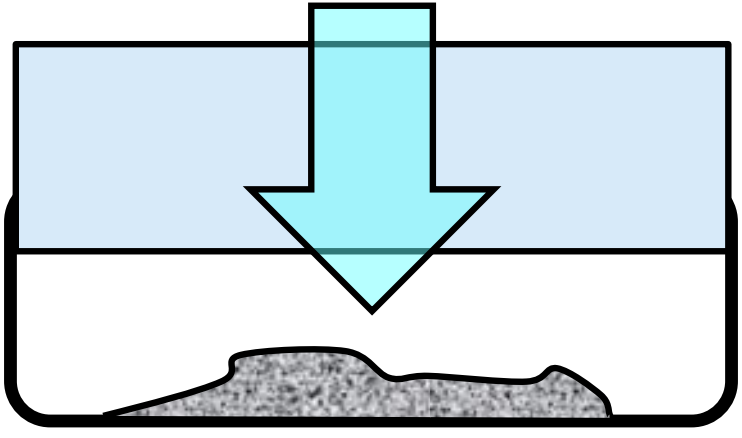
Condensation: Terms

Permeability: Diffusion

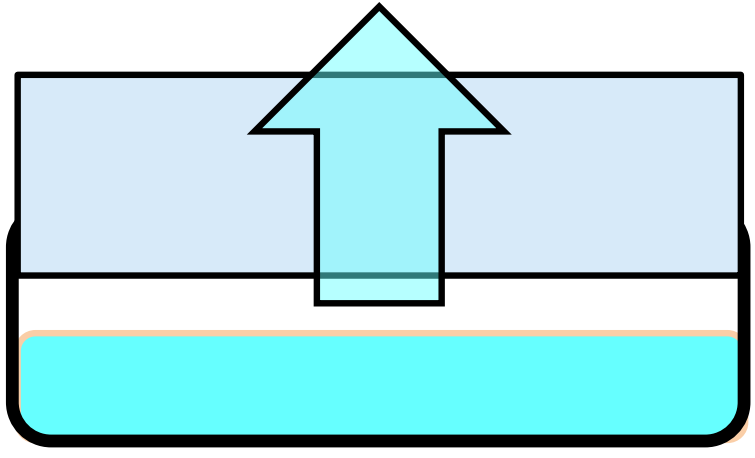
50% RH

ASTM E96

Condensation: Terms



Dry Cup



Wet Cup

Temperature Effects?

Condensation: Terms

Permeability: Diffusion

“Breathability”

Condensation: Terms

Permeability: Diffusion

Confusion:

“Breathability” = Permeability?

or

“Breathability” = Air infiltration?

Condensation: Terms

Permeability: Diffusion

Confusion:

More is Better

“Breathability” = Permeability?

or

“Breathability” = Air infiltration?

Less is Better

Condensation: Terms

Permeability: Diffusion

Confusion:

“Breathability” = Permeability?

or

“Breathability” = Air infiltration?

Condensation: Terms

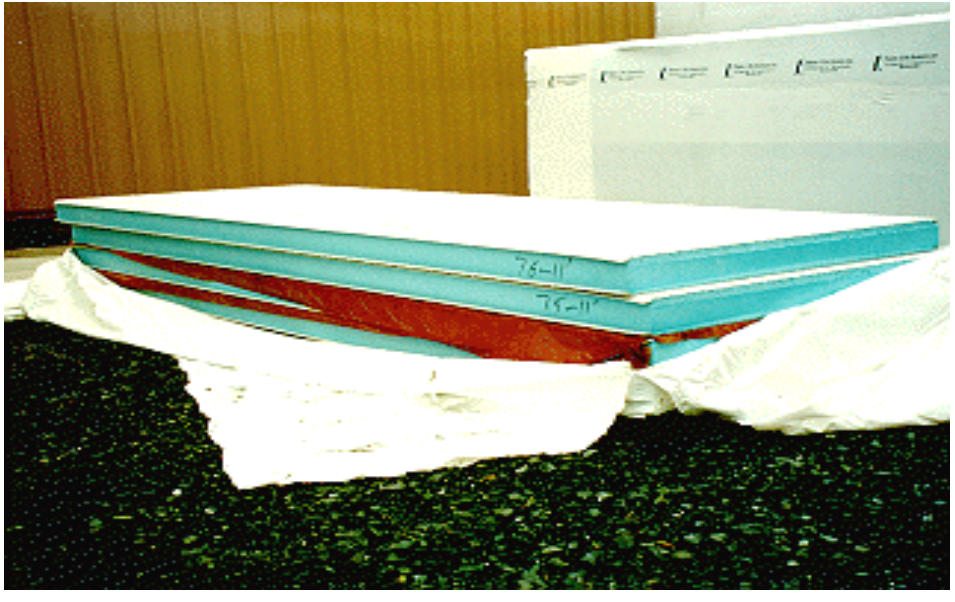
Permeability: Diffusion

Confusion:

“Breathability” = Necessary?

Condensation: Wetting and Drying

Myth of Breathability



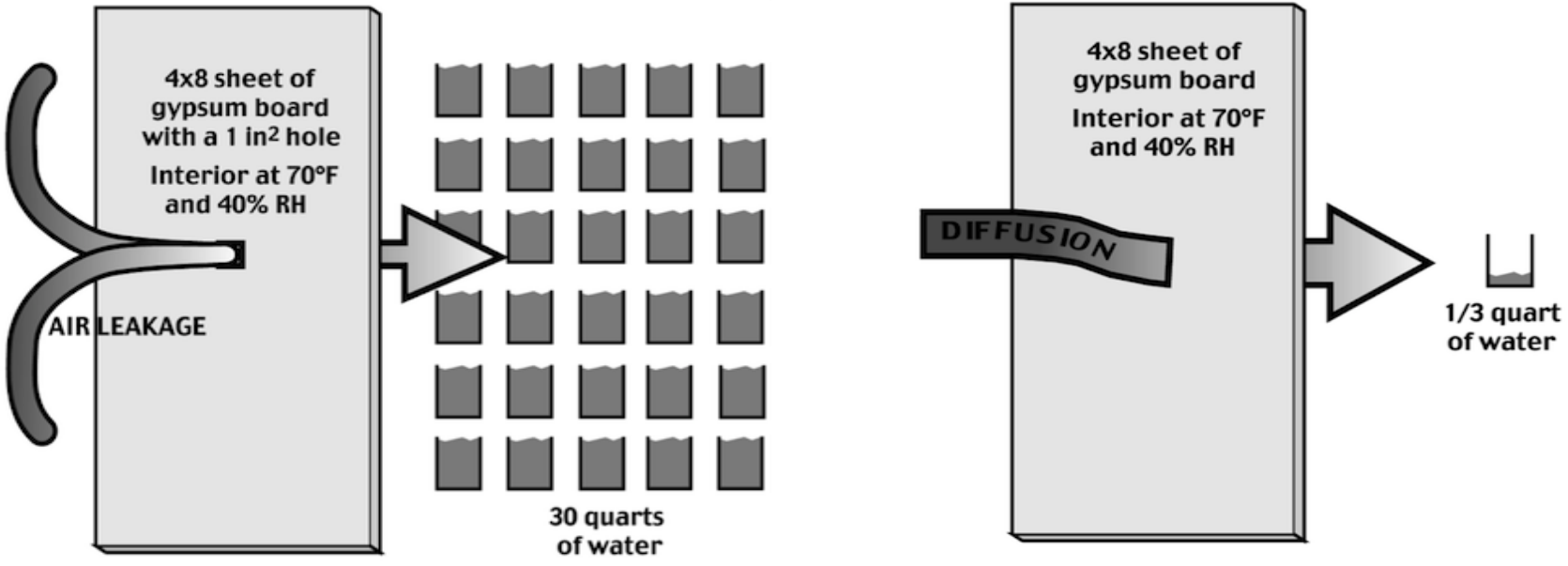
Condensation: Terms

Permeability: Diffusion

Permeability ≠ Necessary

Condensation: Terms

Diffusion vs. Infiltration



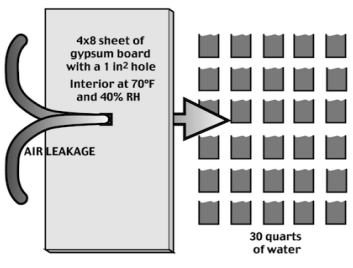
Building Science Corporation

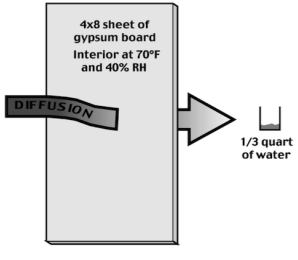
Condensation: Terms

Diffusion vs. Infiltration

C402.4.1.2.2 Assemblies Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft2 (0.2 L/s • m2) under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283 shall comply with this section.

Still more than diffusion





International Energy Conservation Code (IECC) 2012

Condensation: The Real Story

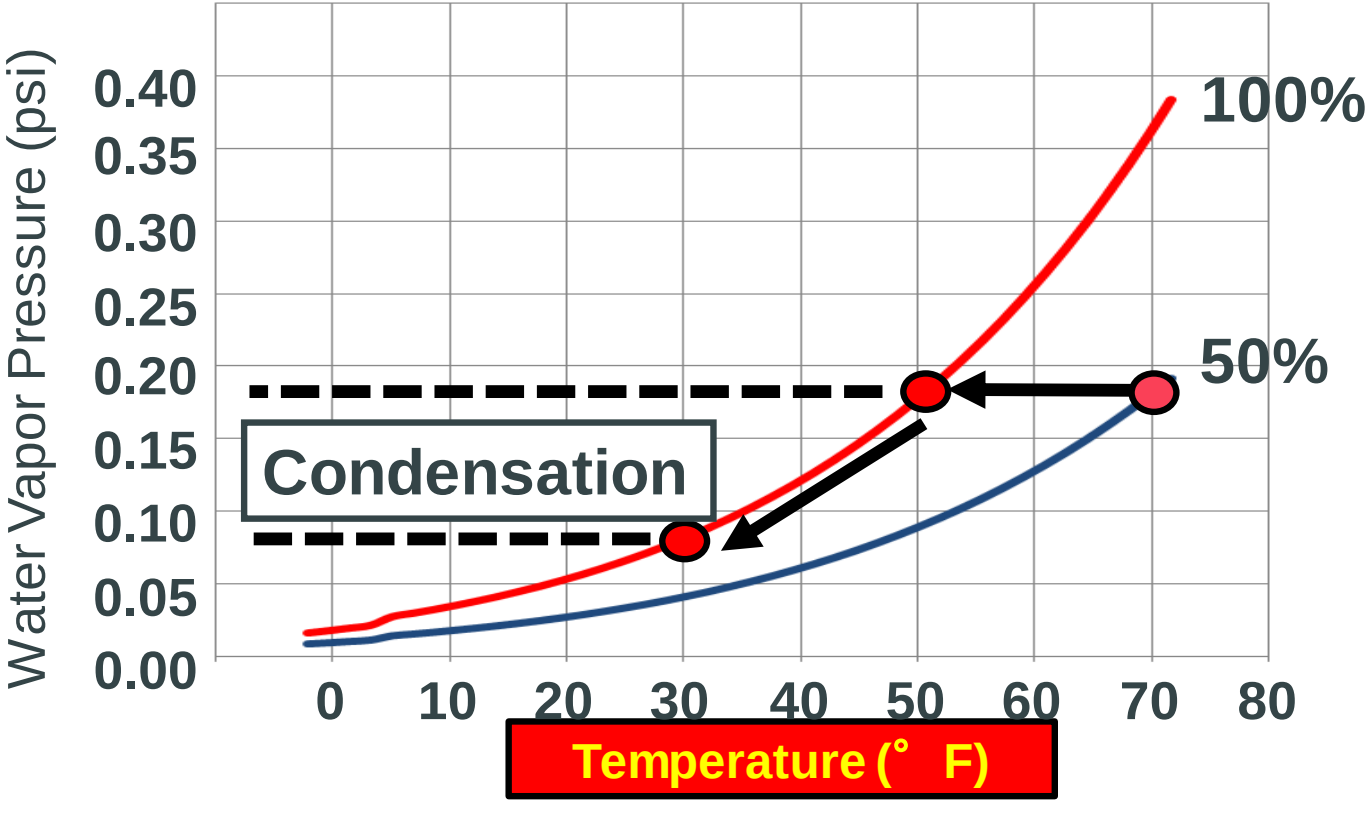
- Properties of Water
- Terms Relating to Condensation
- **Wetting and Drying**
- Analyzing Assemblies
- Wall Design

Condensation: Wetting and Drying

Condensation: Dewpoint

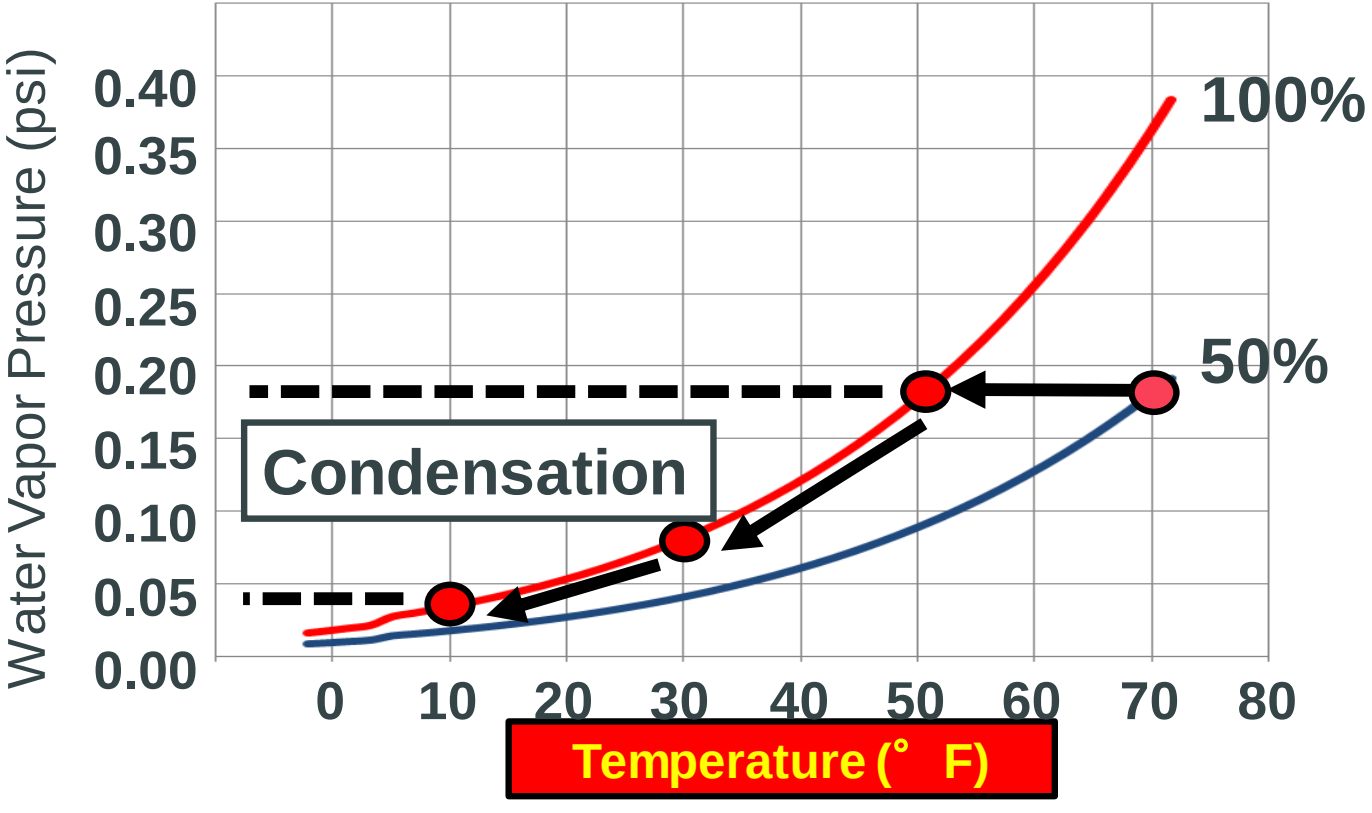
Condensation: Wetting and Drying

Condensation: Dewpoint



Condensation: Wetting and Drying

Condensation: Dewpoint



Condensation: Wetting and Drying

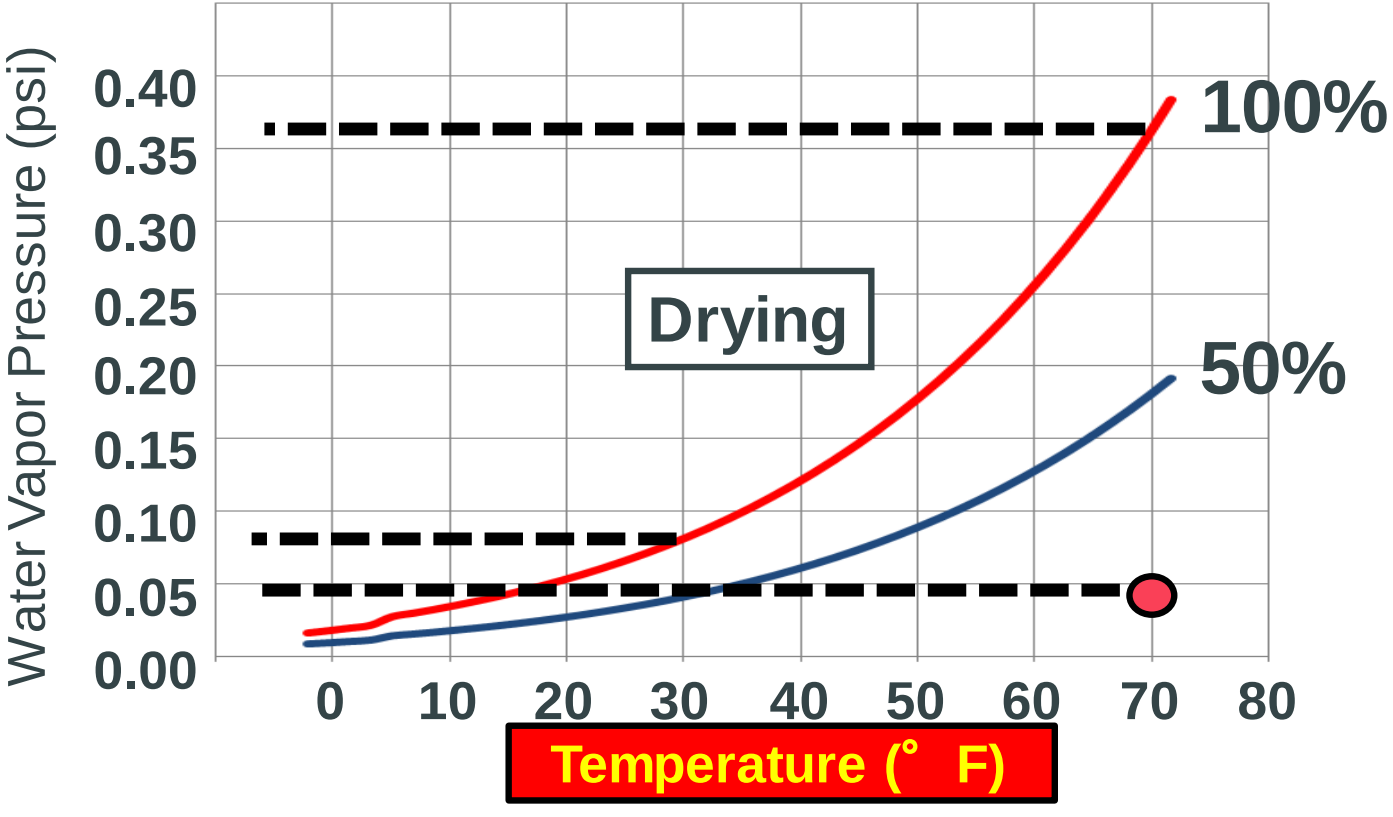
Drying: Evaporation

Condensation: Wetting and Drying

Two Sides of the Same Coin: Temperature

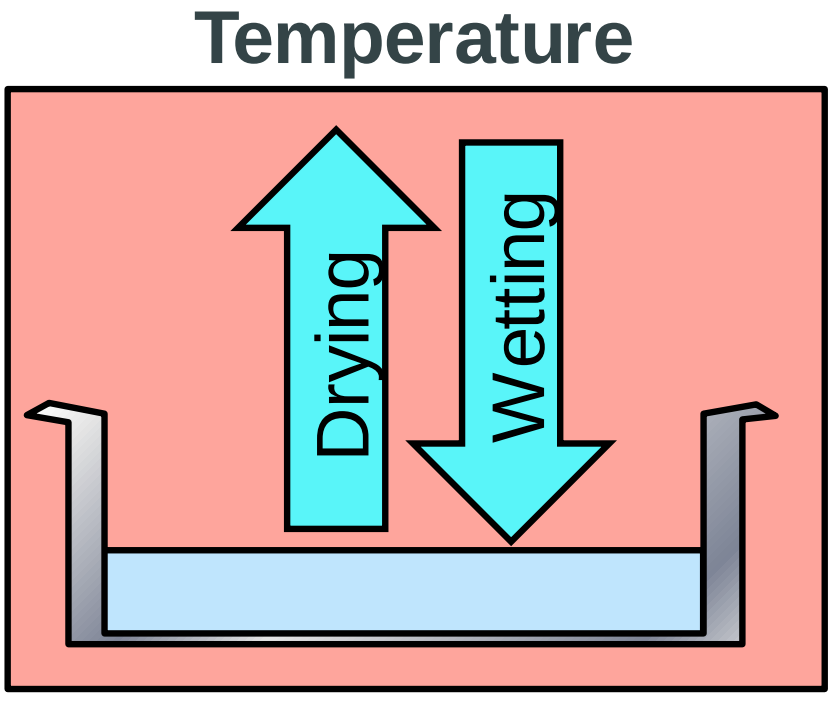
Condensation: Wetting and Drying

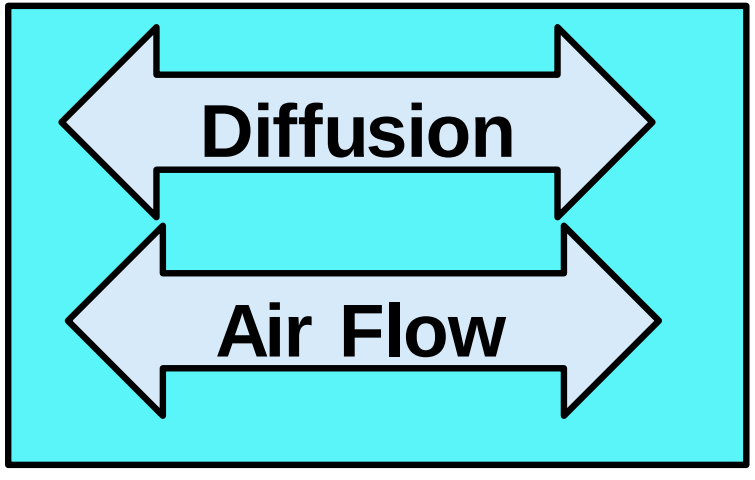
Drying: Evaporation



Condensation: Wetting and Drying

Two Phenomena coupled together





- Permeability
- Infiltration

Condensation: Wetting and Drying

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- Joseph Lstiburek, 2006, Understanding Vapor Barriers, BSC
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- Smegal, Lstiburek, Straube, Grin, 2012, Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis, BSC
- Straube, 2002, The Influence of Low Permeance Vapor Barriers on Roof and Wall Performance, Buildings VIII
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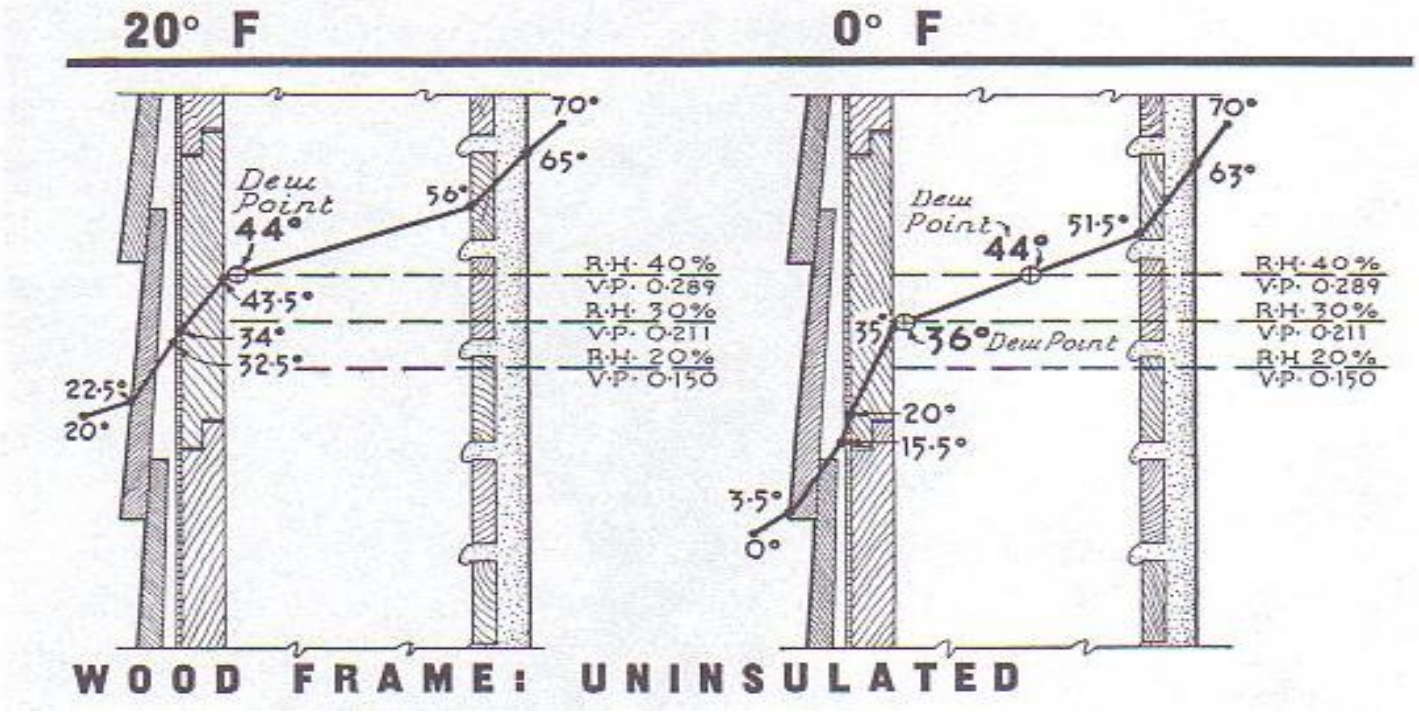
Condensation: The Real Story

- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- **Analyzing Assemblies**
- Wall Design

Condensation: Analyzing Assemblies

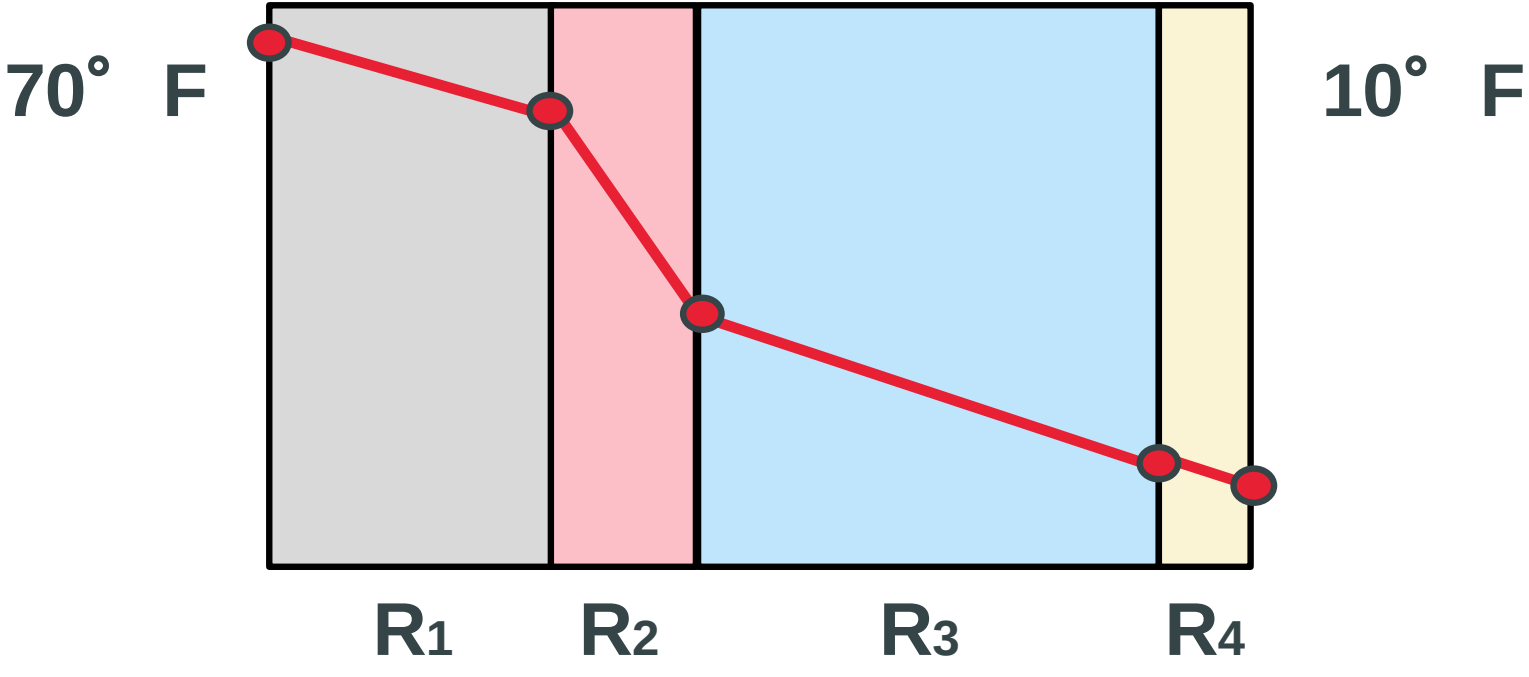
Profile Method



Teesdale, 1938 (Water in Buildings, Rose)

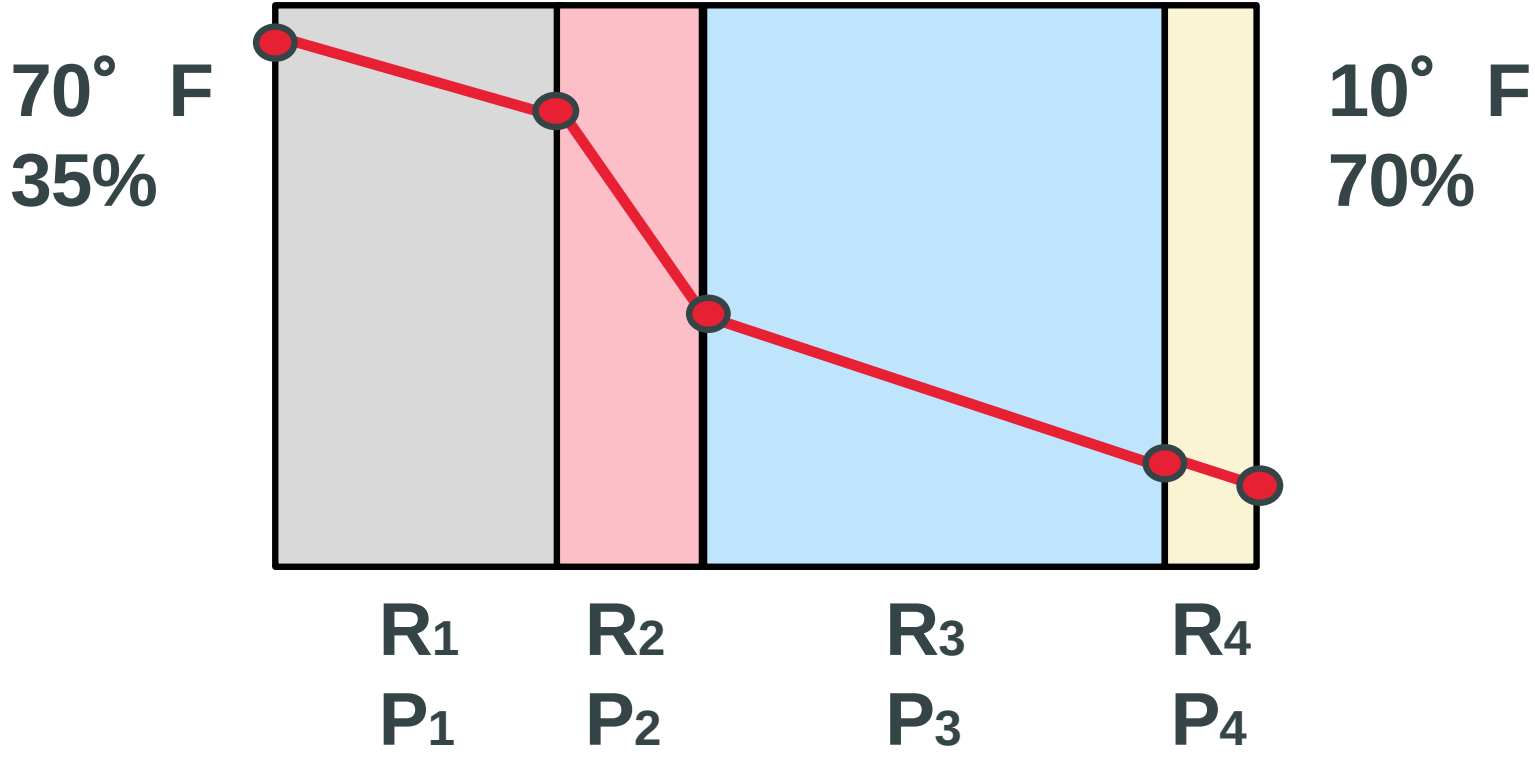
Condensation: Analyzing Assemblies

Profile Method: Temperature



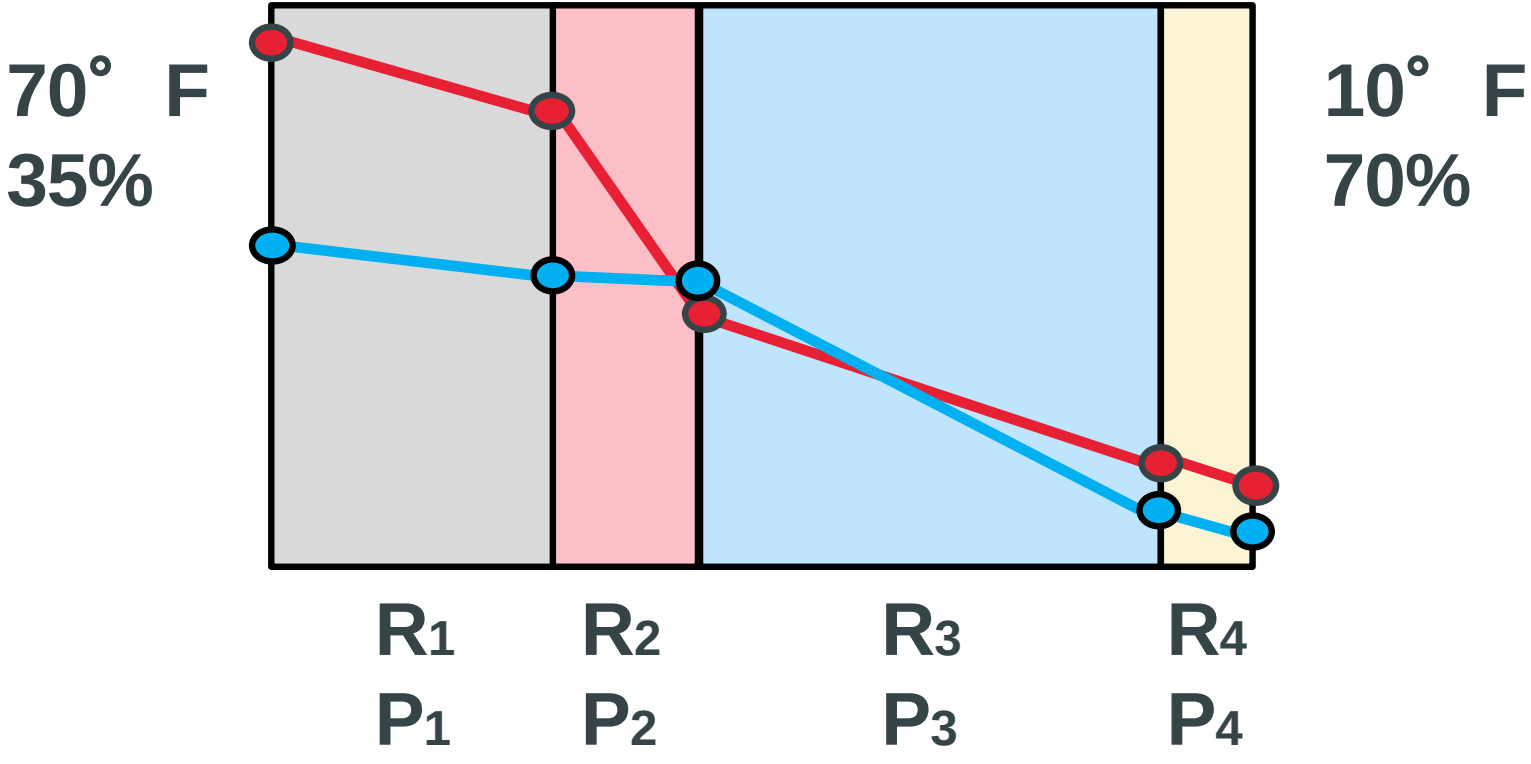
Condensation: Analyzing Assemblies

Profile Method: Temperature



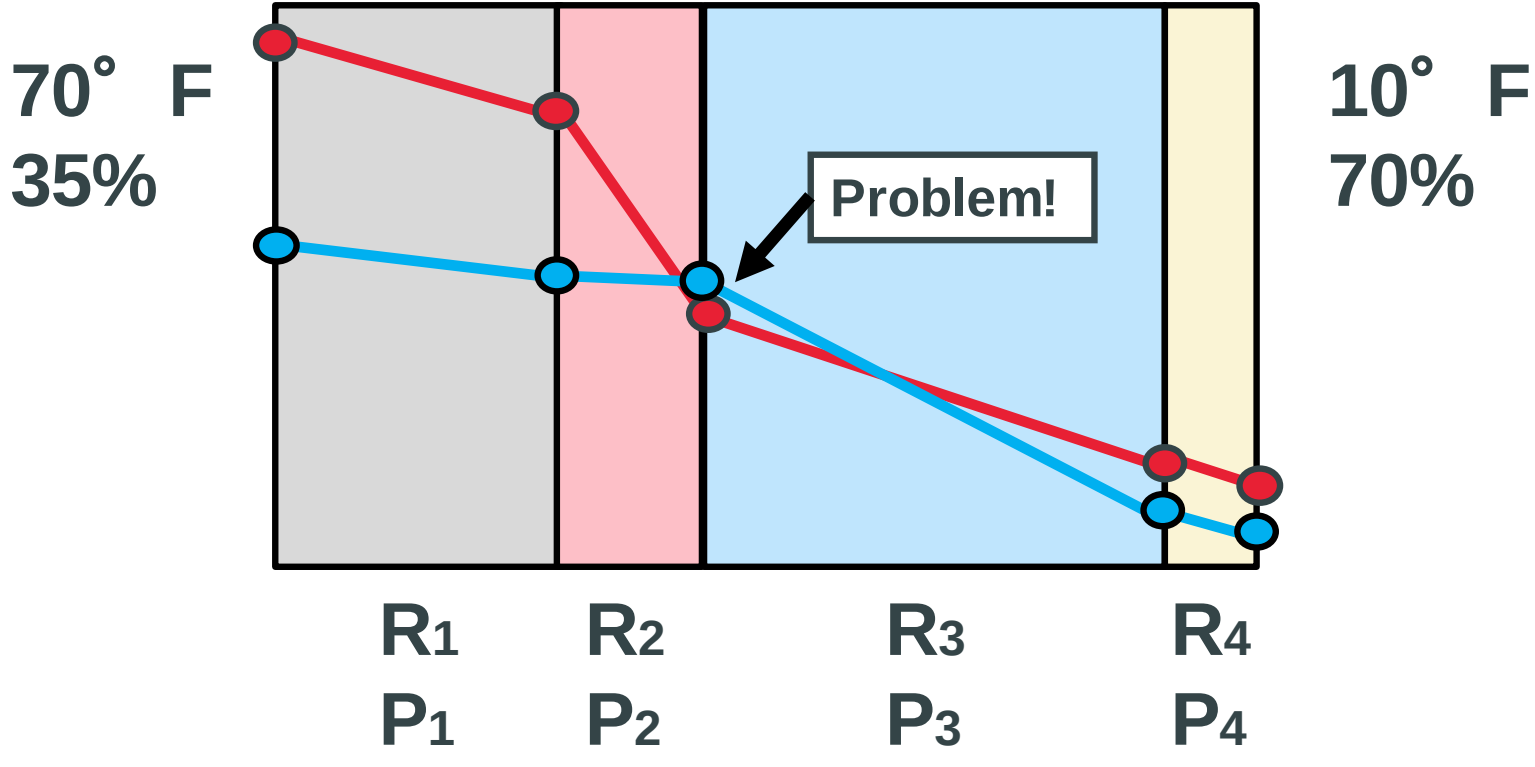
Condensation: Analyzing Assemblies

Profile Method: Temperature



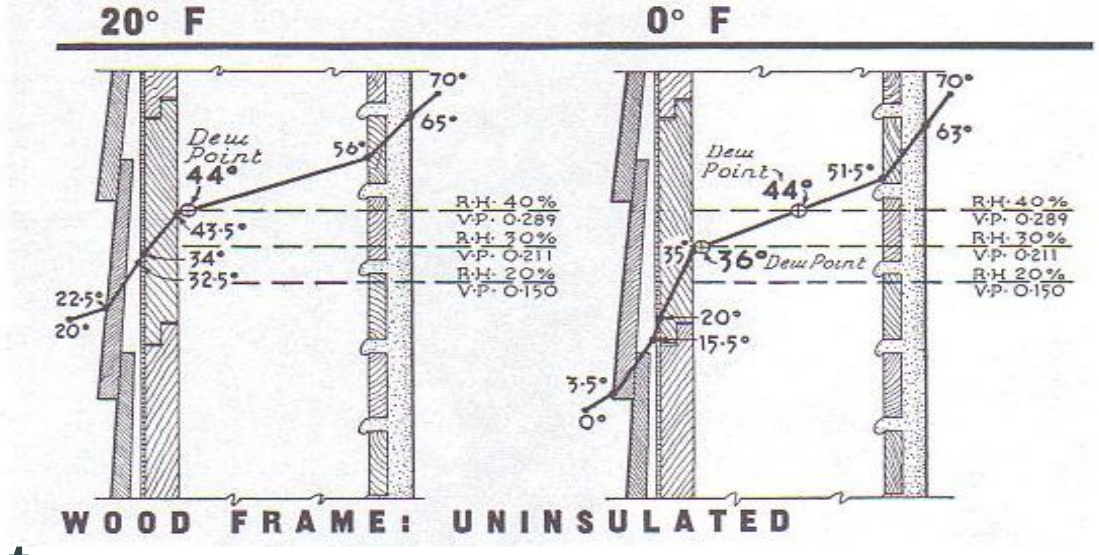
Condensation: Analyzing Assemblies

Profile Method: Temperature



Condensation: Analyzing Assemblies

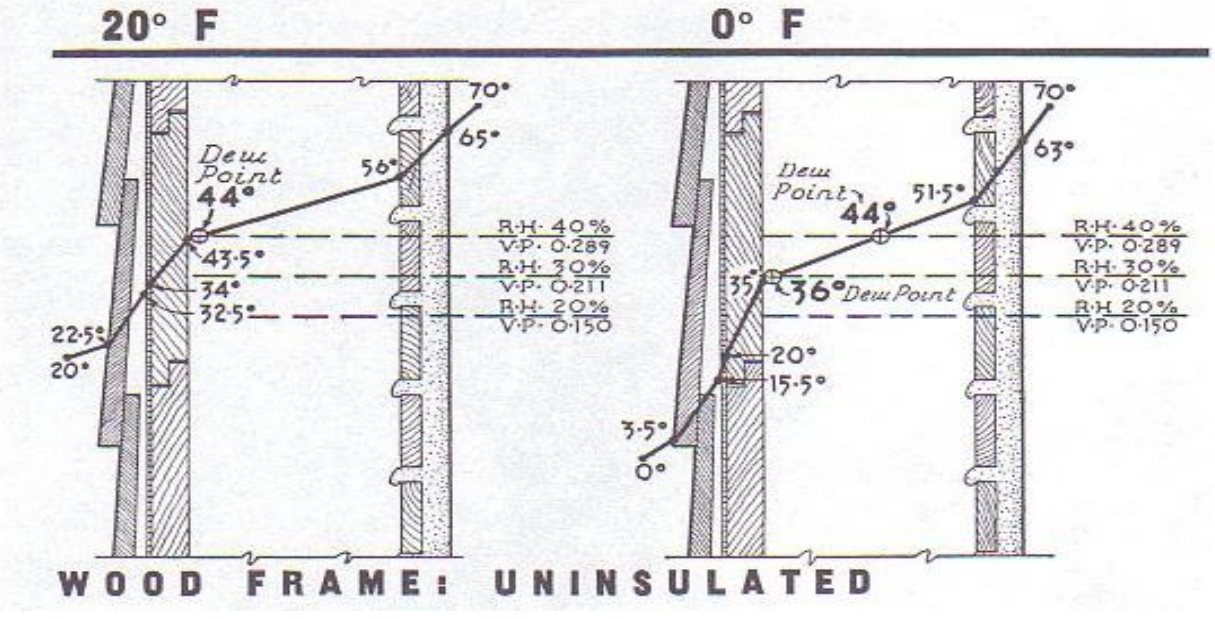
Profile Method: **Limitations**



- **No infiltration**
- **Not dynamic**
- **No Water movement**
- **RH or Temperature Dependencies**
- **Adsorption**

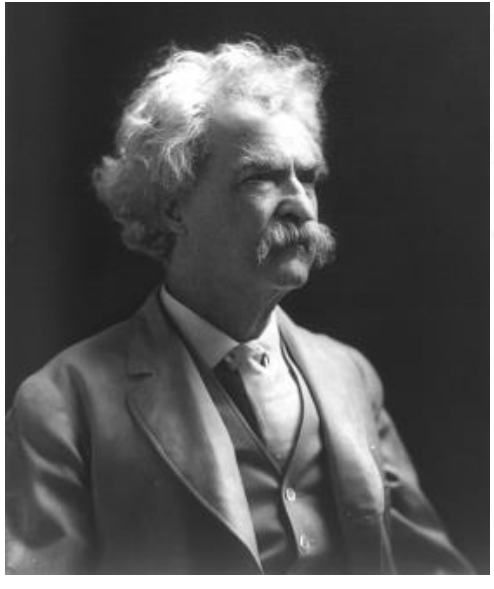
Condensation: Analyzing Assemblies

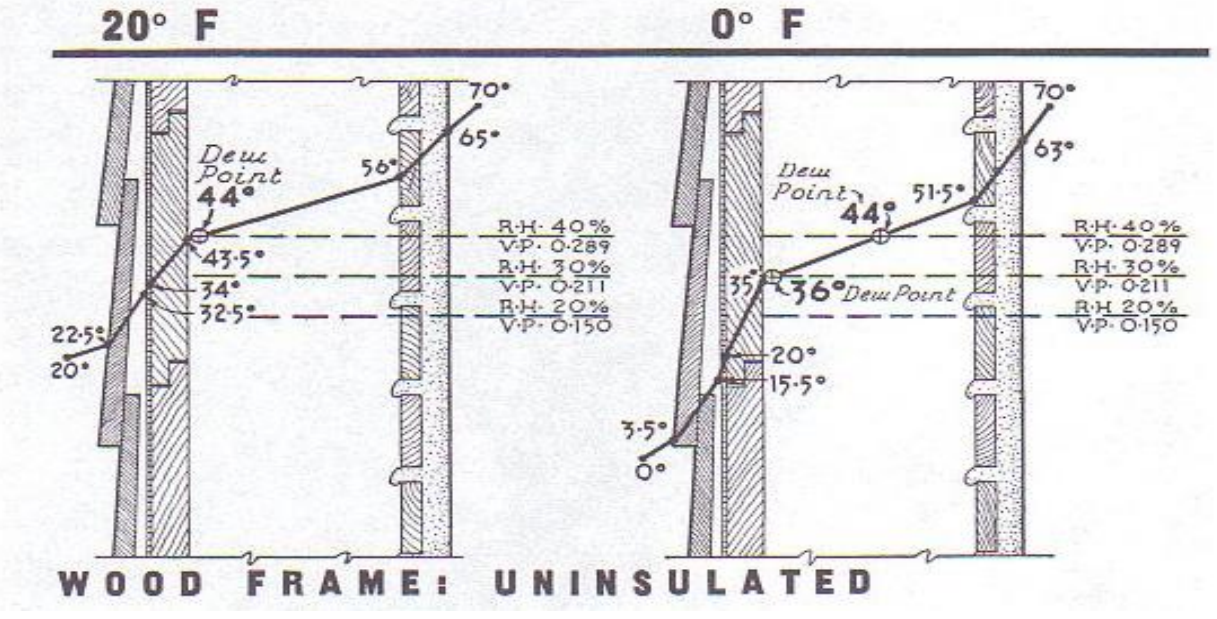
Profile Method



Condensation: Analyzing Assemblies

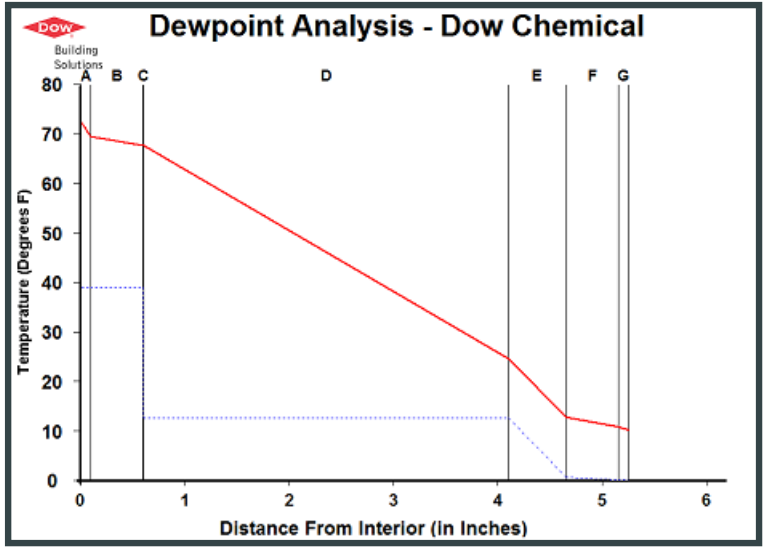
Profile Method

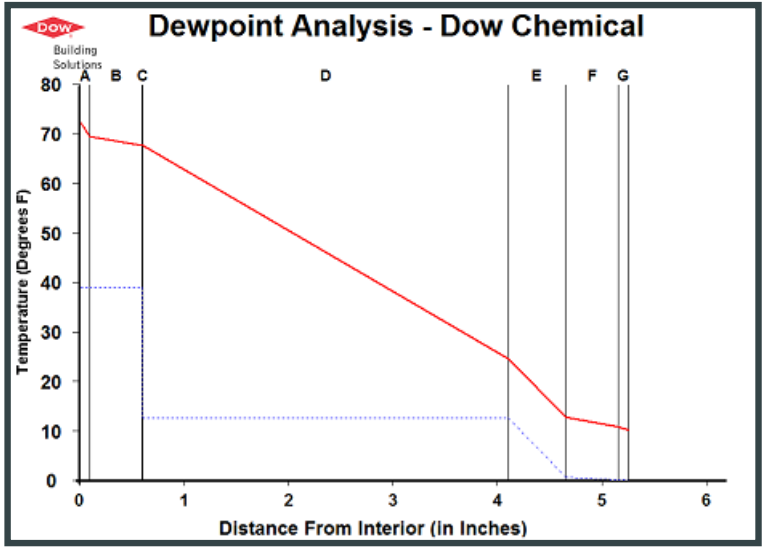




Condensation: Analyzing Assemblies

Profile Method

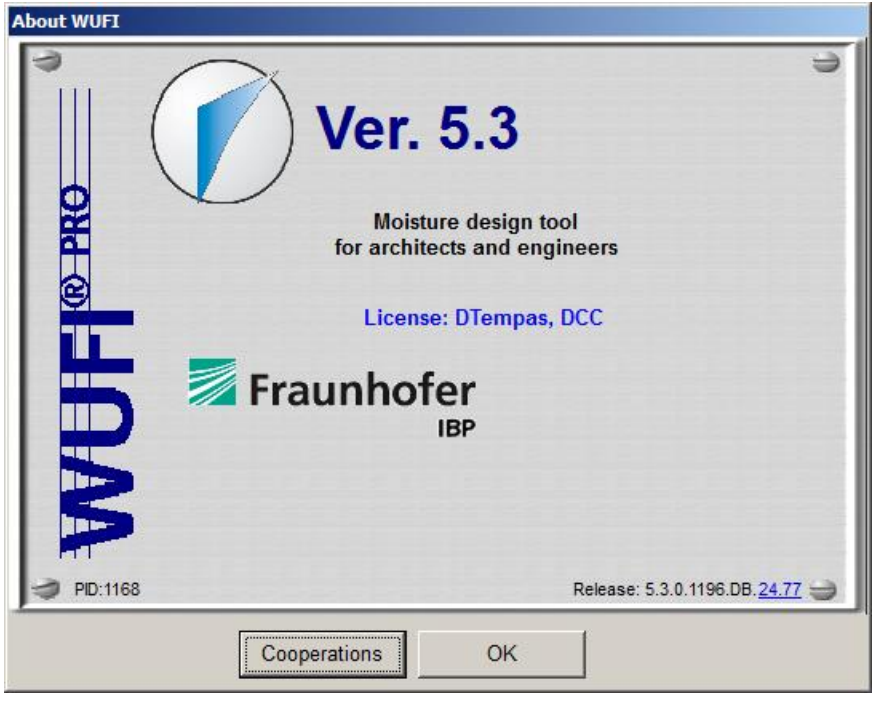




Compare Assemblies

Condensation: Analyzing Assemblies

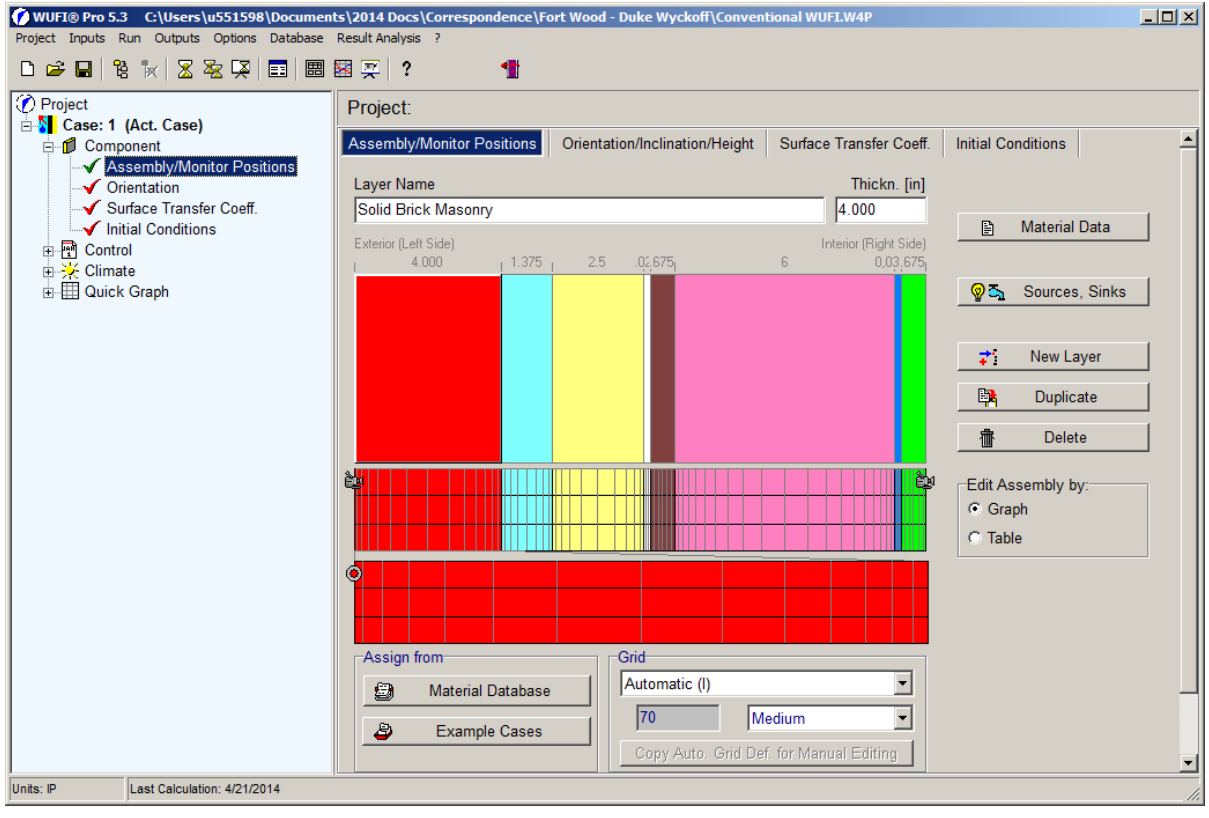
WUFI Method



Oak Ridge National Laboratory (ORNL)/Fraunhofer IBP

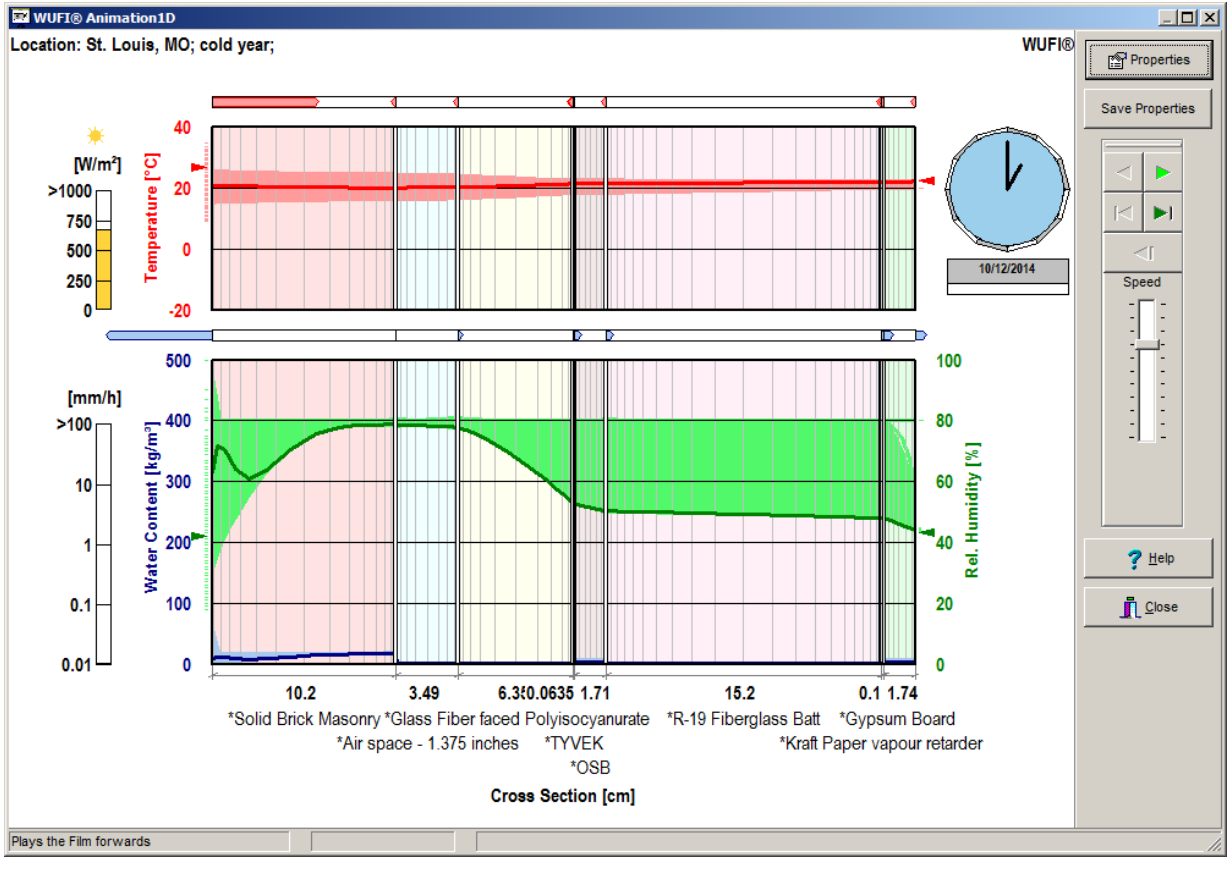
Condensation: Analyzing Assemblies

WUFI Method



Condensation: Analyzing Assemblies

WUFI Method



Condensation: Analyzing Assemblies

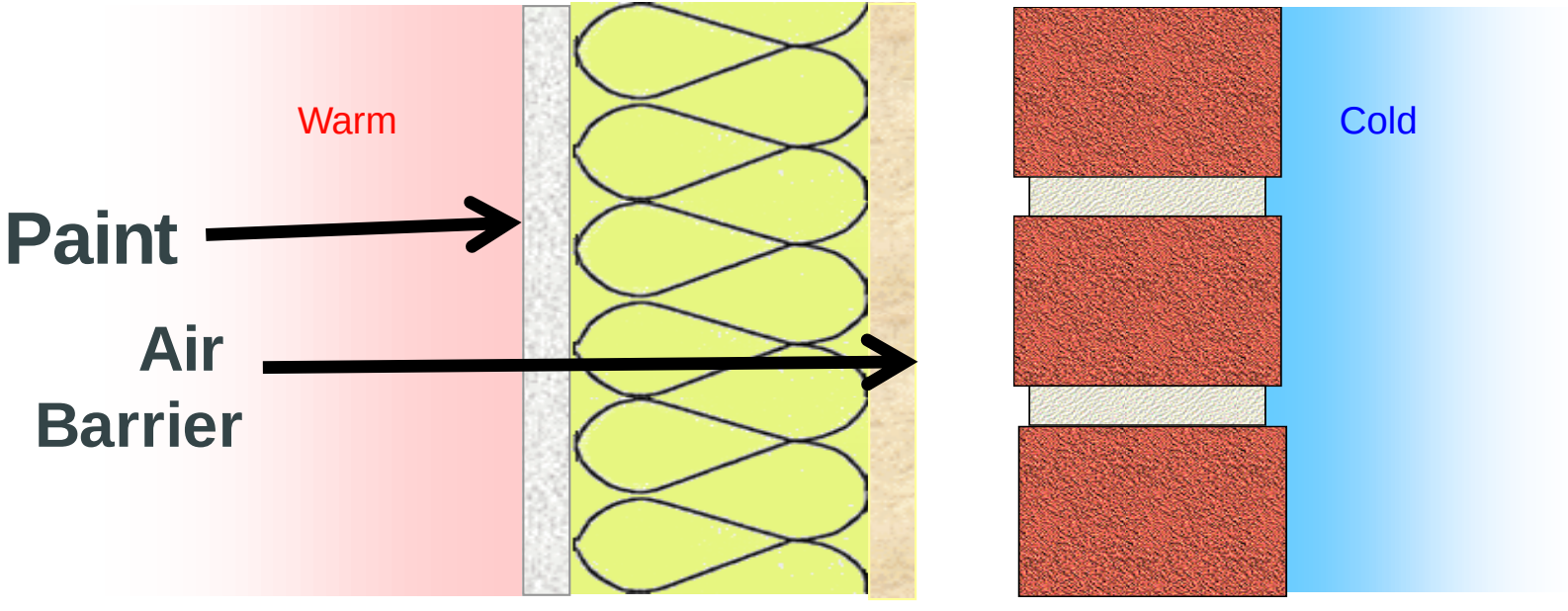
WUFI: Limitations

- No infiltration
- Subtle data may not exist
- Temperature Dependencies
- Hard to learn
- Time consuming

Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

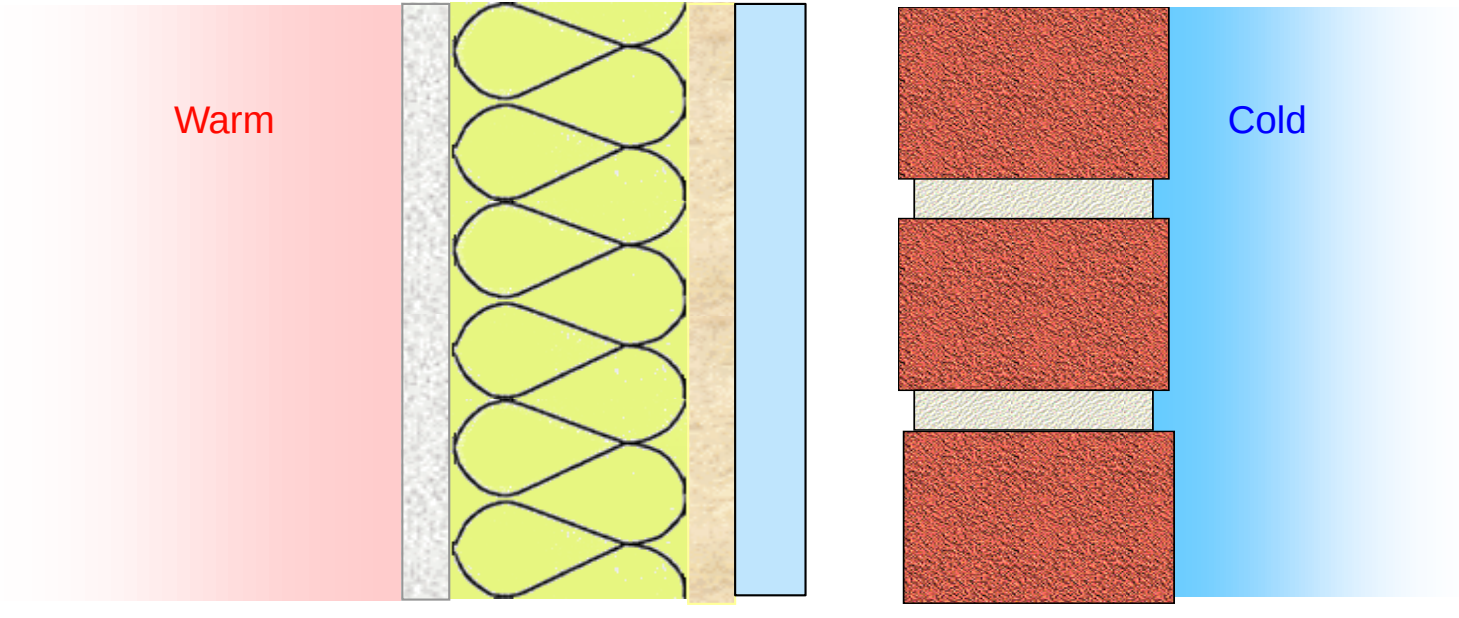
Old Wall



Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

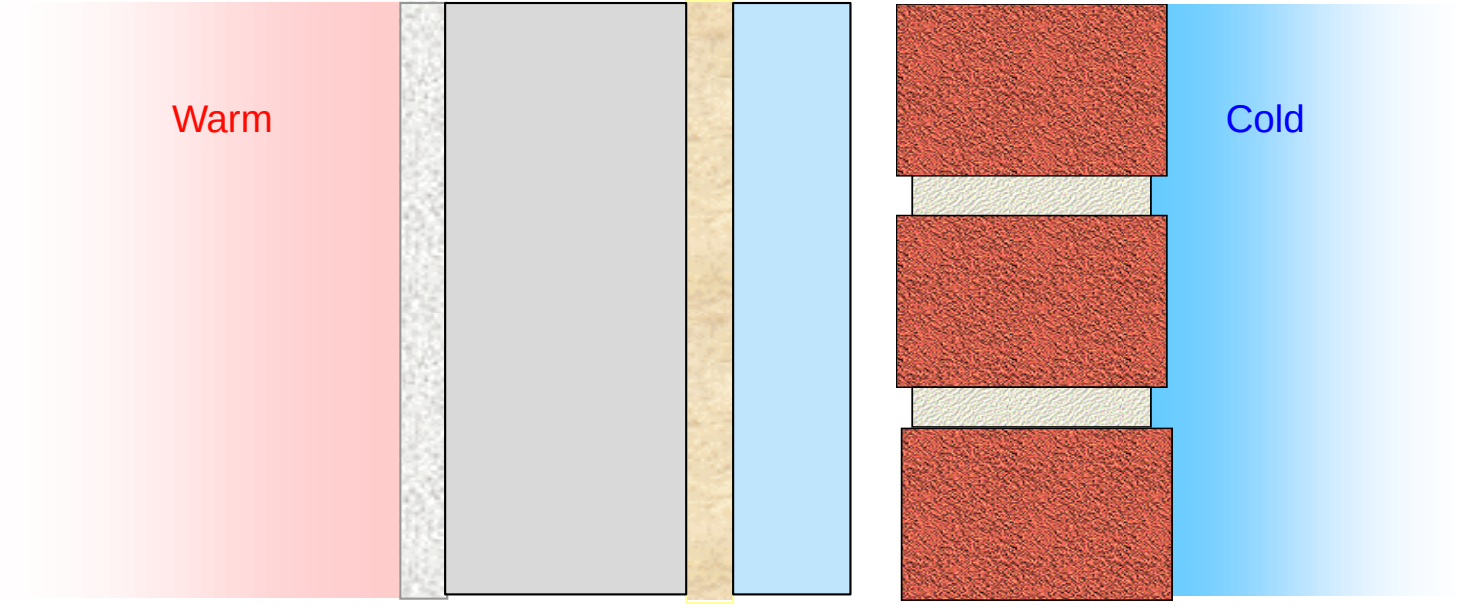
Medium Wall



Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

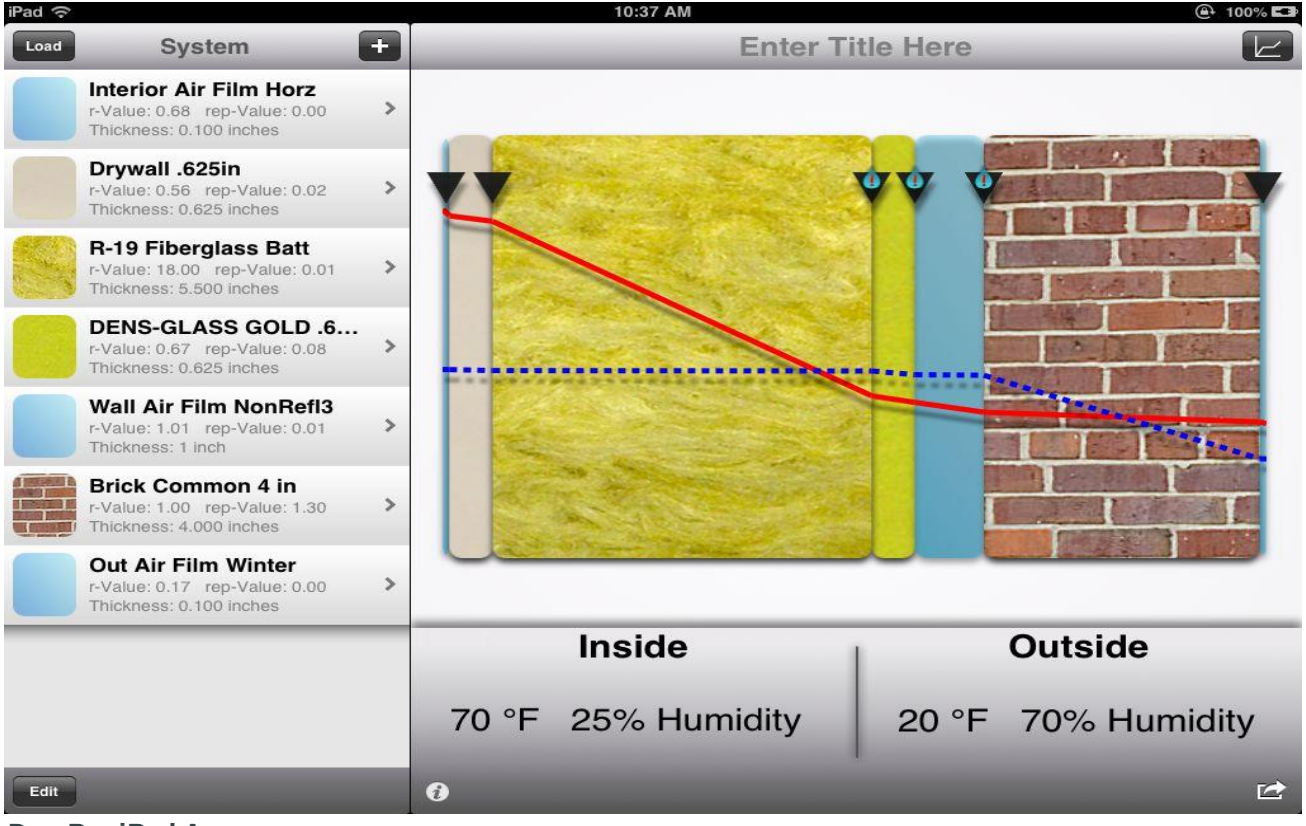
Perfect Wall



Building Science Corporation

Condensation: Analyzing Assemblies

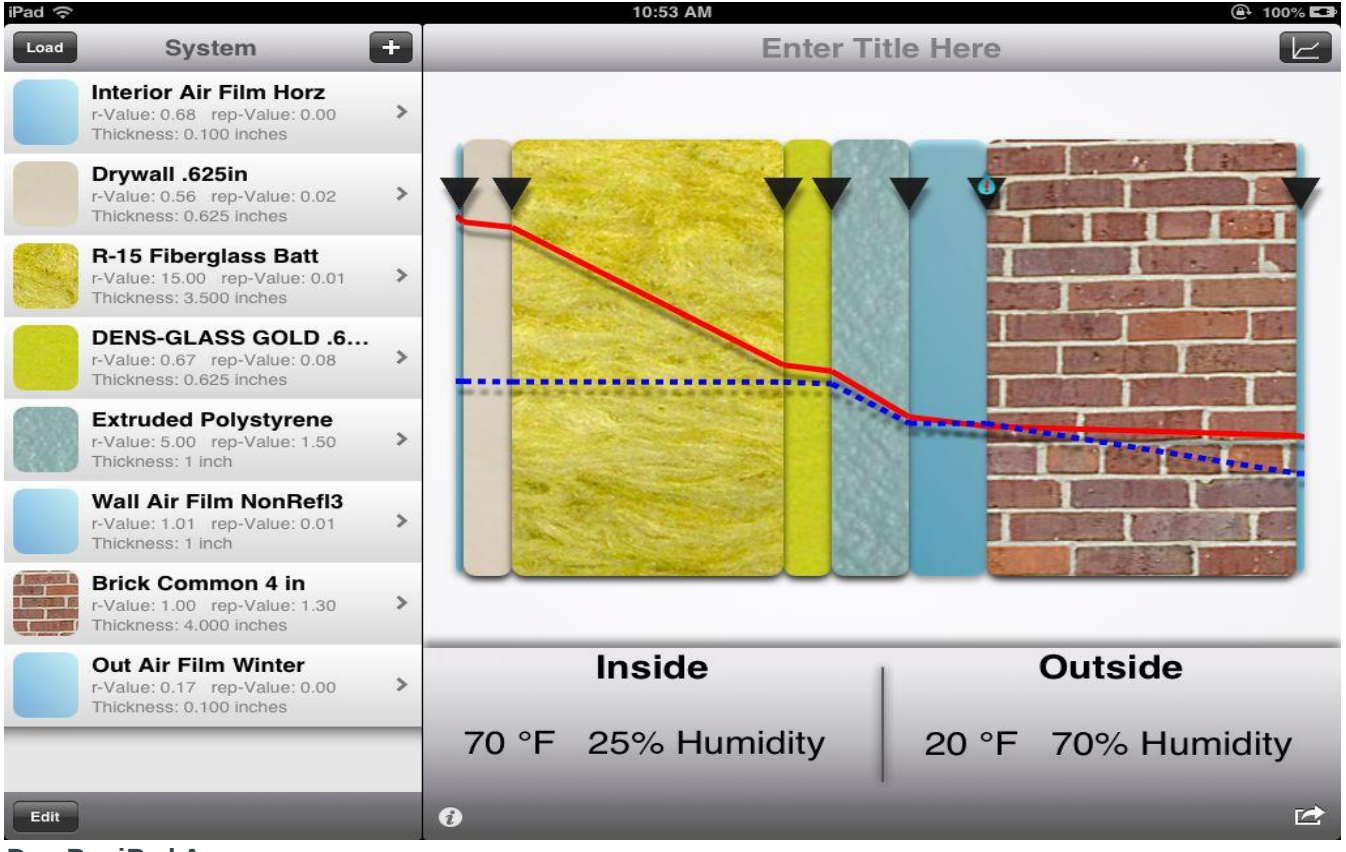
Profile vs. WUFI: Predictions



DewPro iPad App

Condensation: Analyzing Assemblies

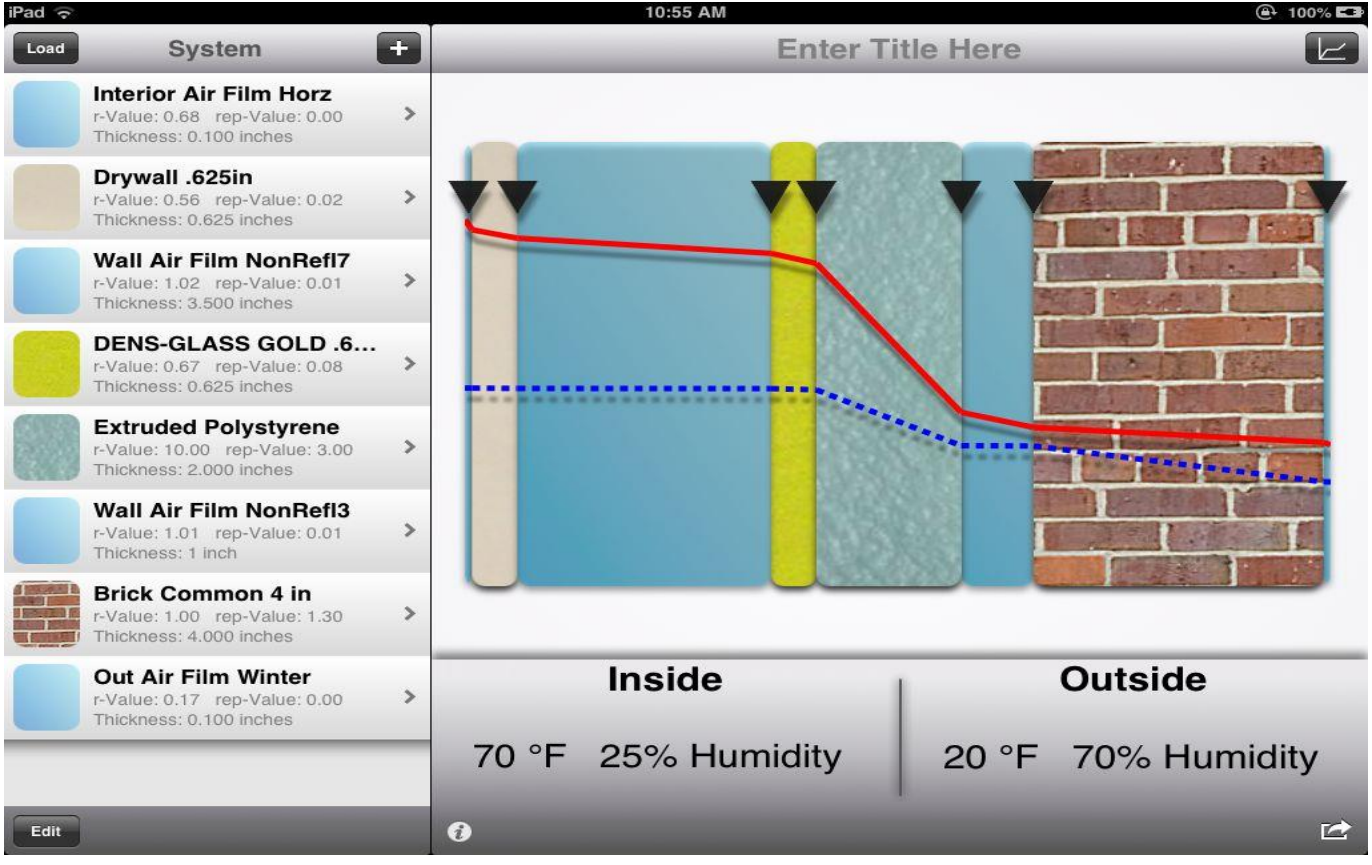
Profile vs. WUFI: Predictions



DewPro iPad App

Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

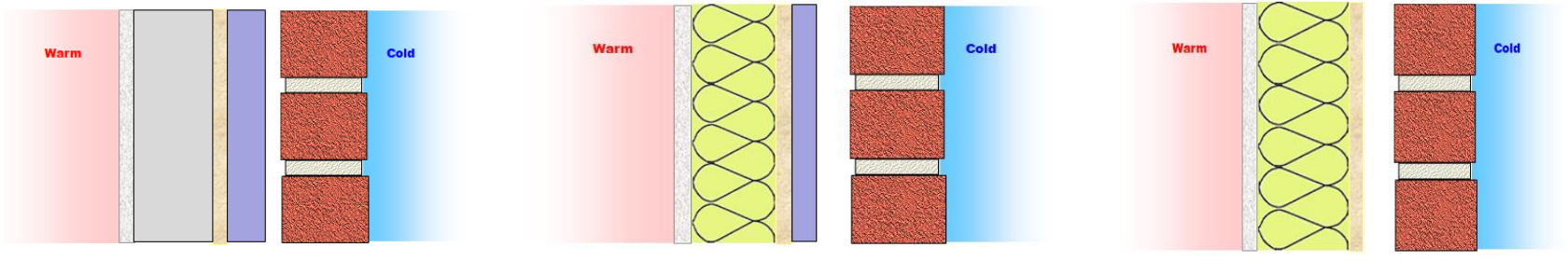


DewPro iPad App

Condensation: Analyzing Assemblies

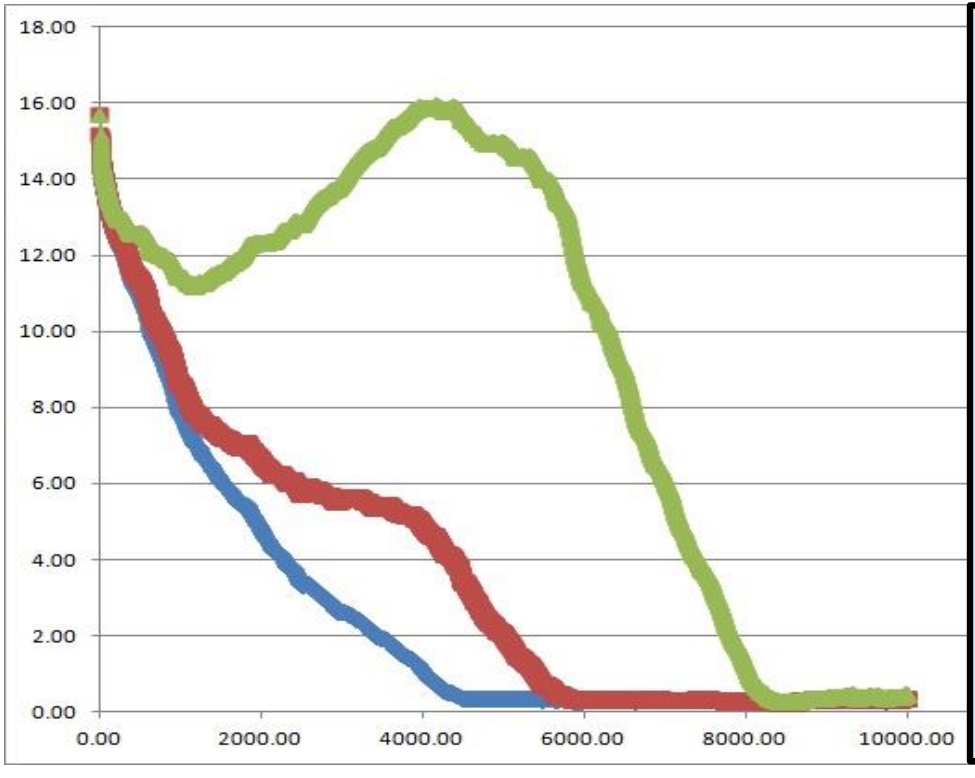
Profile vs. WUFI: Predictions

Perfect Wall > Medium Wall > Old Wall

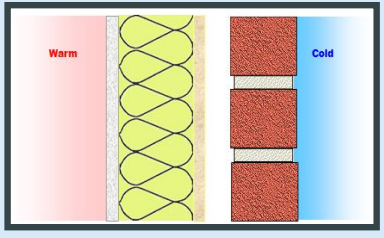


Condensation: Analyzing Assemblies

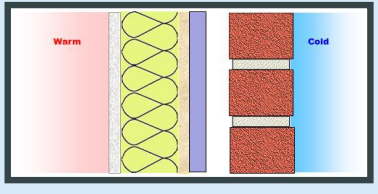
Profile vs. WUFI: Predictions



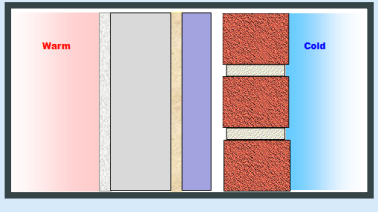
Old



Medium



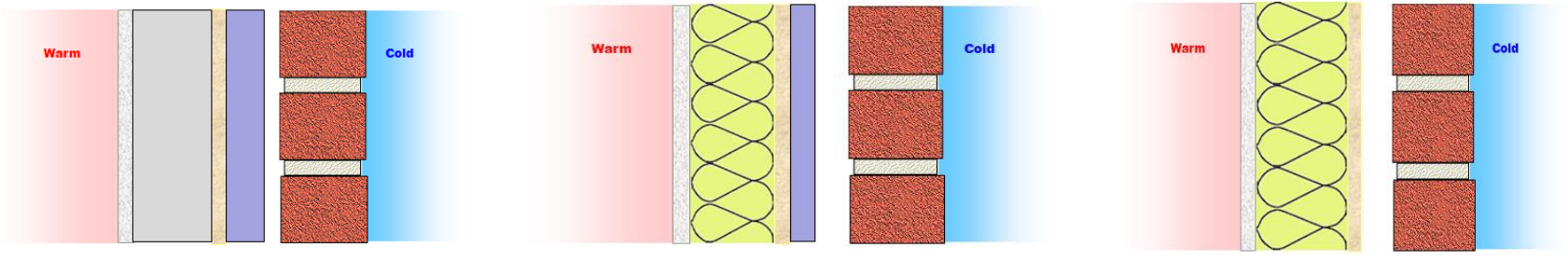
Perfect



Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

Perfect Wall > Medium Wall > Old Wall



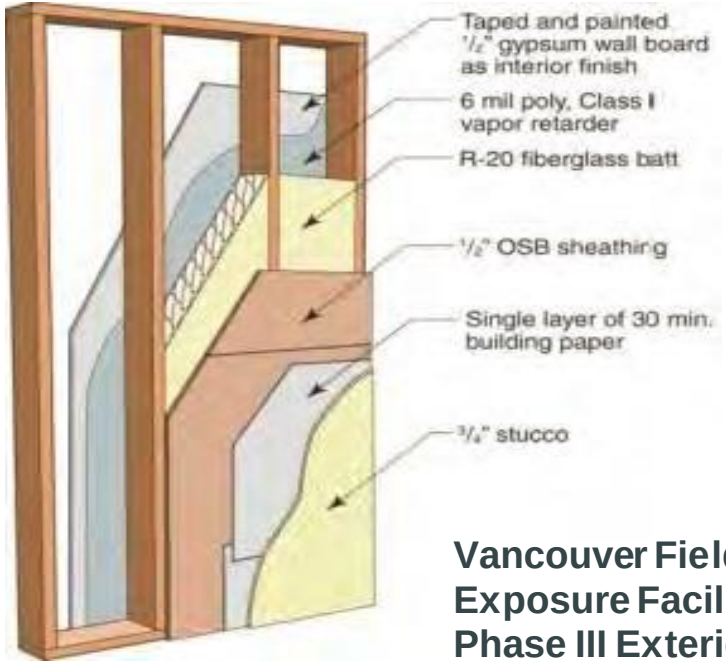
Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis
Research Report – 1207, 17 February 2012, Coquitlam, BC
Jonathan Smegal, Joseph Lstiburek, John Straube, Aaron Grin

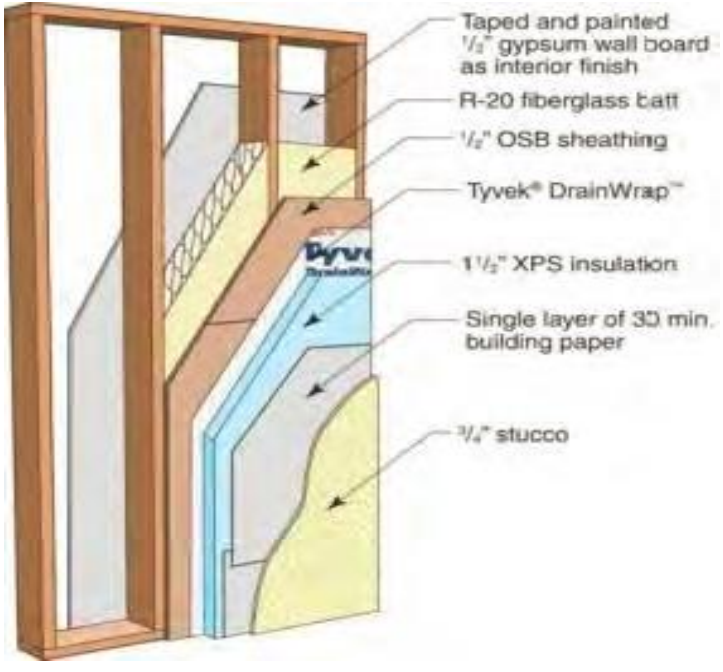
Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality



Wall 2

Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis



Wall 7

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

Medium Wall > Old Wall

	Wall 2 (direct applied stucco)	Wall 7 (XPS ext. ins.)
North	>106 days	68 days
East	>106 days	53 days
South	68 days	29 days
West	95 days	47 days

Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

Medium Wall > Old Wall

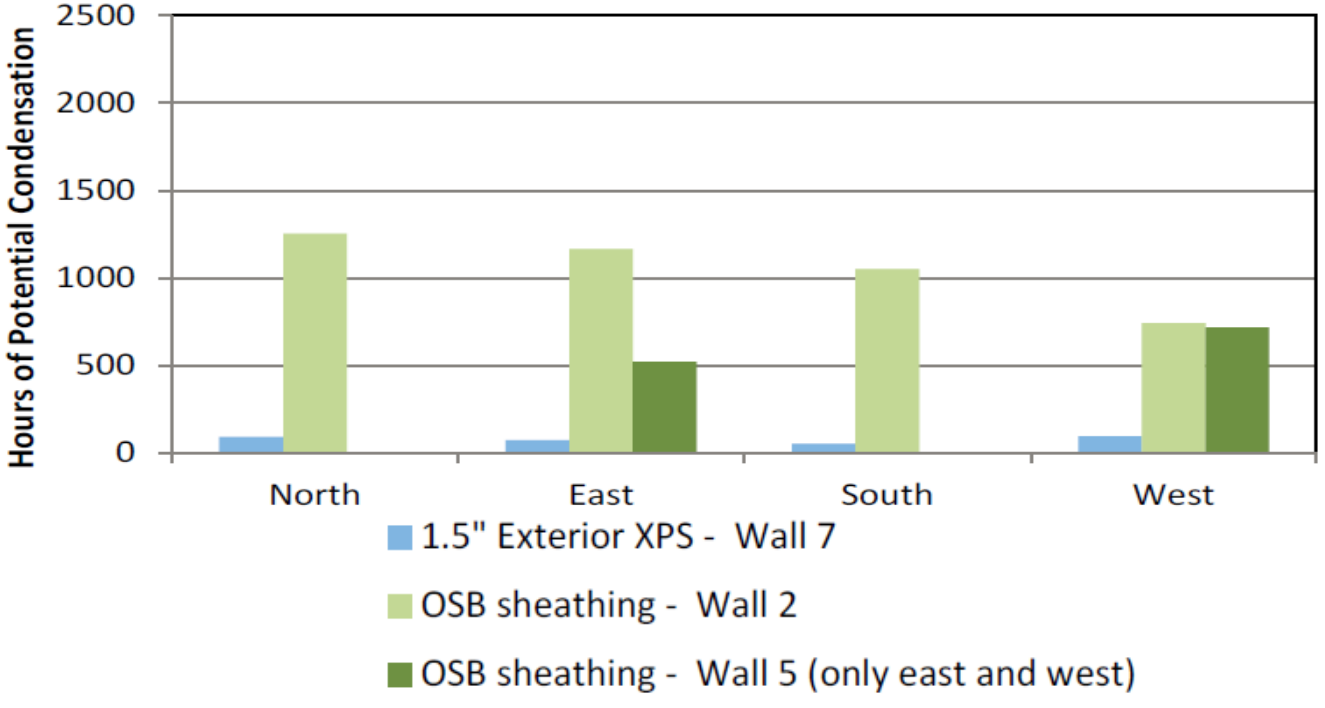
In 1964, Neil Hutcheon demonstrated how the temperature gradients across a masonry wall changed when the insulation was moved from the interior of the structure to the exterior of the structure. He showed that condensation issues at 35% interior relative humidity were solved by moving the insulation to the exterior.

Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

Medium Wall > Old Wall



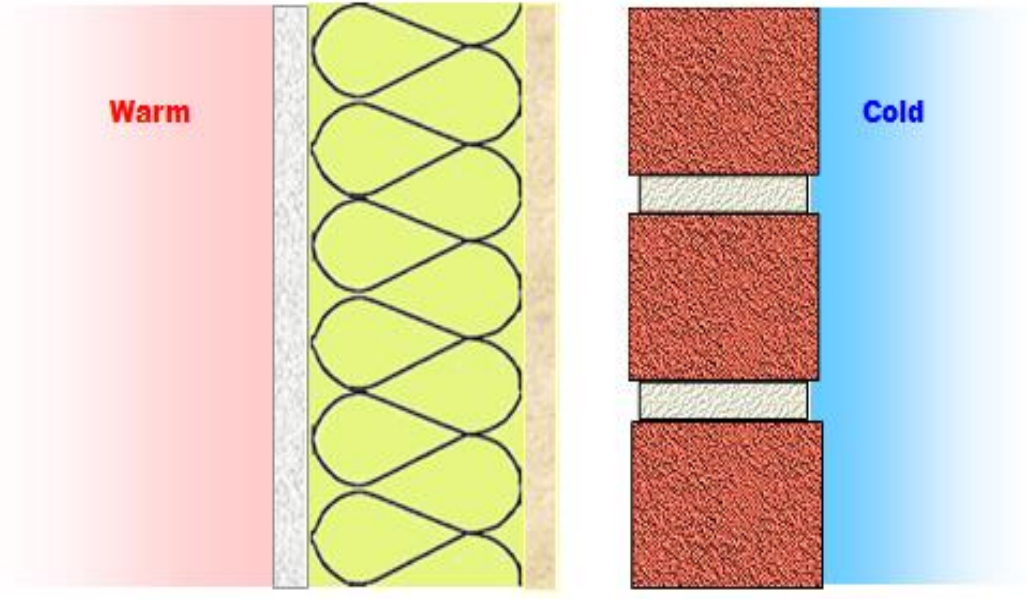
Comparison of the hours of potential condensation between Wall 2 and Wall 7

Condensation: The Real Story

- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies
- **Wall Design**

Condensation: Wall Design

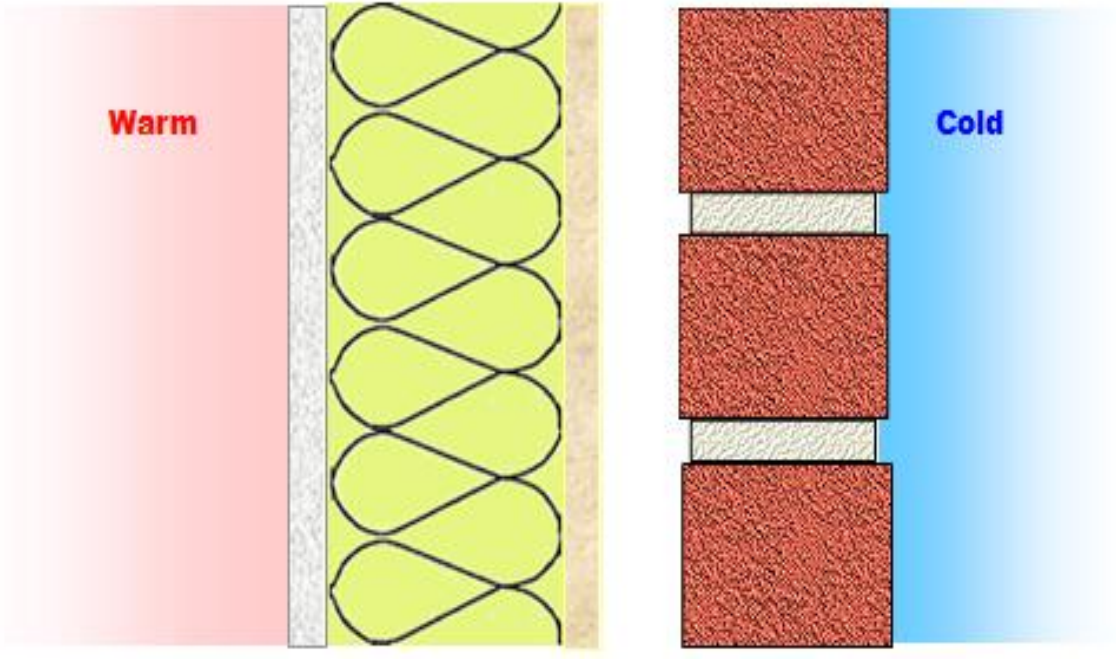
Cold Climates: Permeability



What happens when we try to design a wall by altering the permeability of the materials?

Condensation: Wall Design

Cold Climates: Permeability



Cavity insulation forces interior vapor retarders.

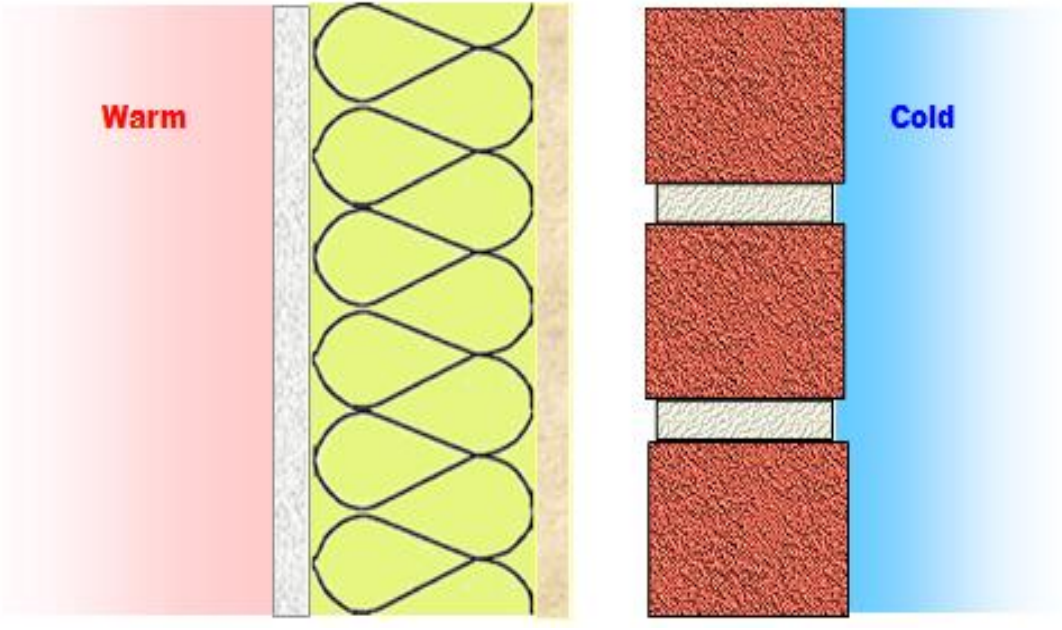
Condensation: Wall Design

Cold Climates: Permeability

Very hard to deal with the various kinds of penetrations

Condensation: Wall Design

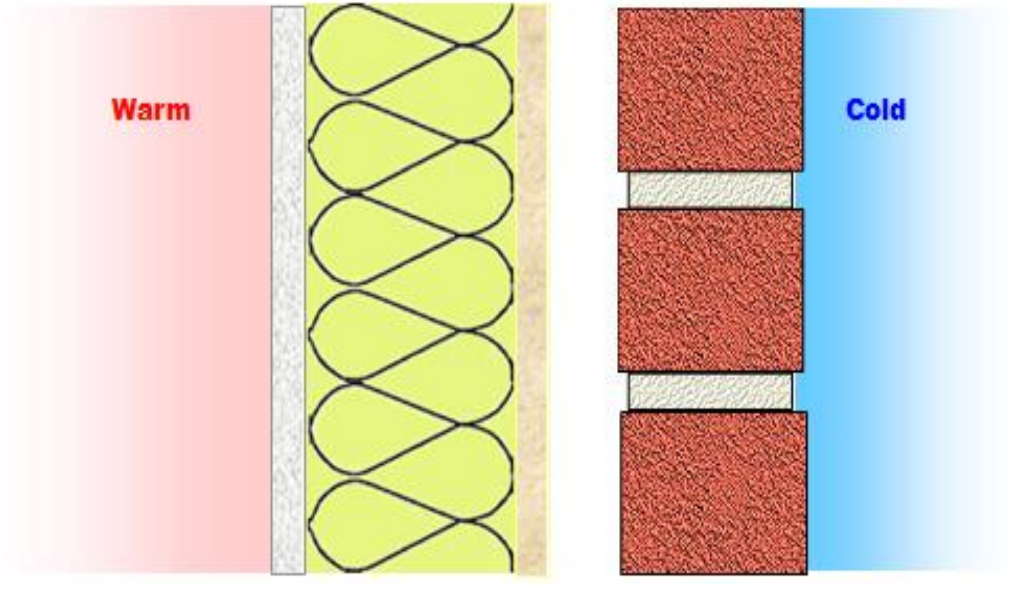
Cold Climates: Permeability



Poor effective drying because it is too often cold.

Condensation: Wall Design

Cold Climates: Permeability

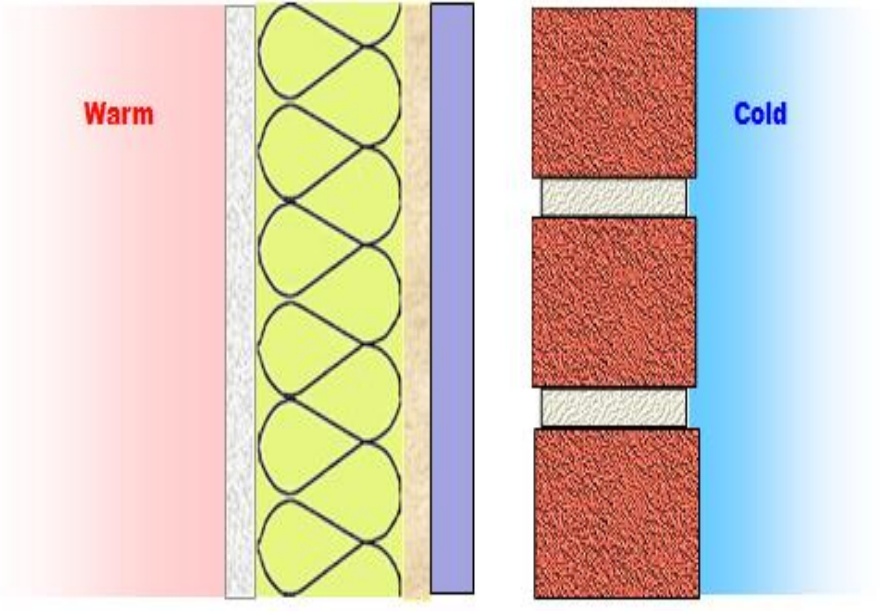


Delicate system.
What about changes by the owner? Maintenance?

Condensation: Wall Design

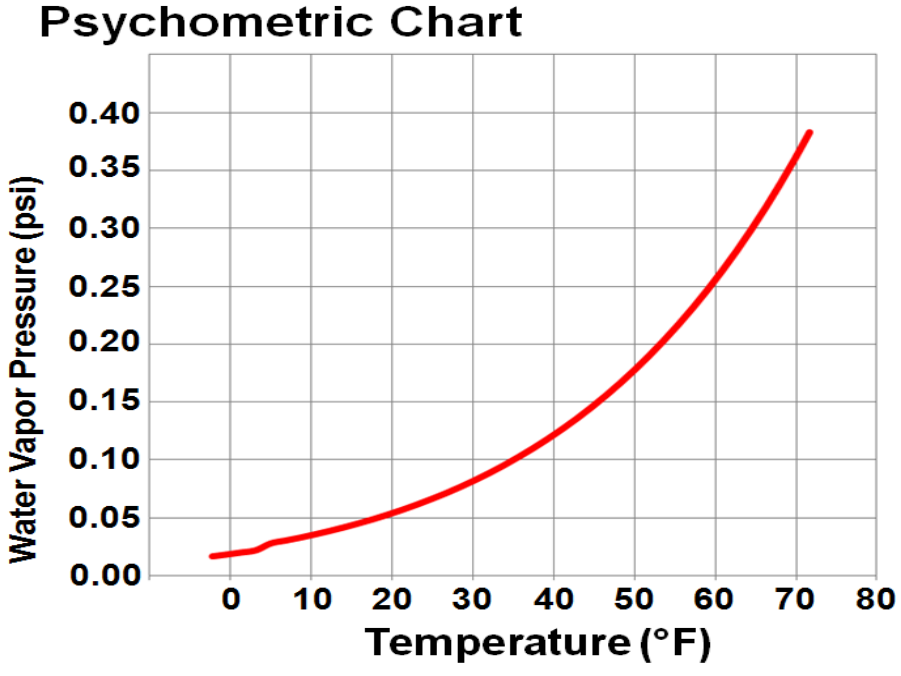
Cold Climates: Temperature

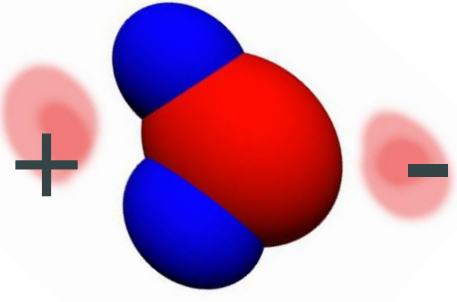
Easier to make right.
Reduced cavity insulation.
Sheathing insulation.
Broader applicability.
Effective drying.
ROBUST!



Condensation: Summary

- Properties of Water

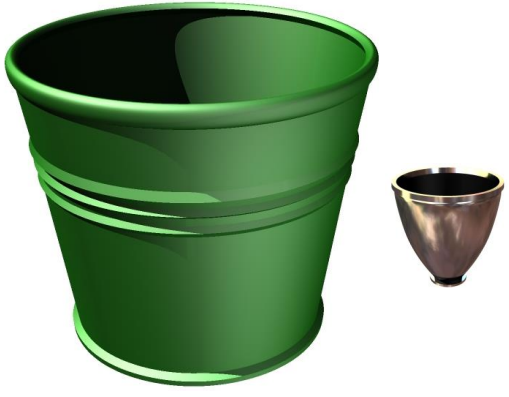




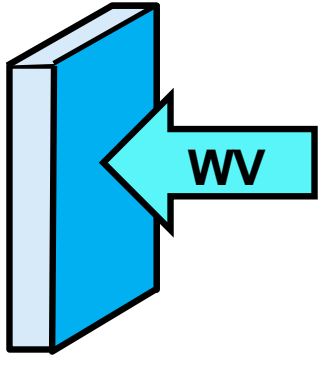
Condensation: Summary

- Properties of Water
- Terms Relating to Condensation

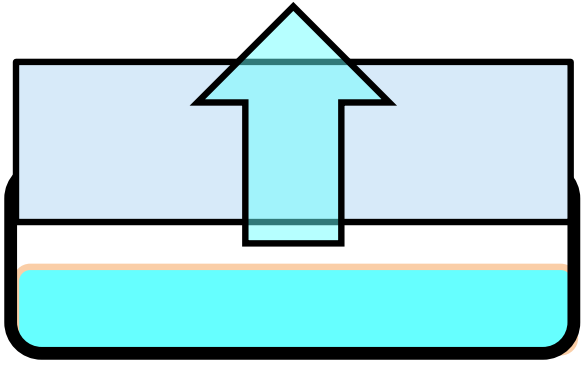
Relative Humidity



- **Permeance**
- **Perms**



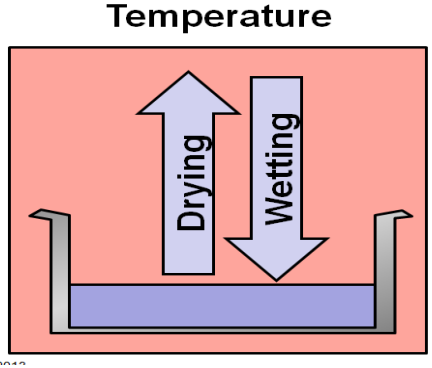
gr/hr ft² in Hg

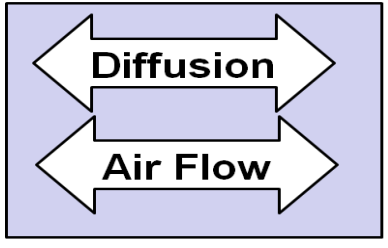


Wet Cup

Condensation: Summary

- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying

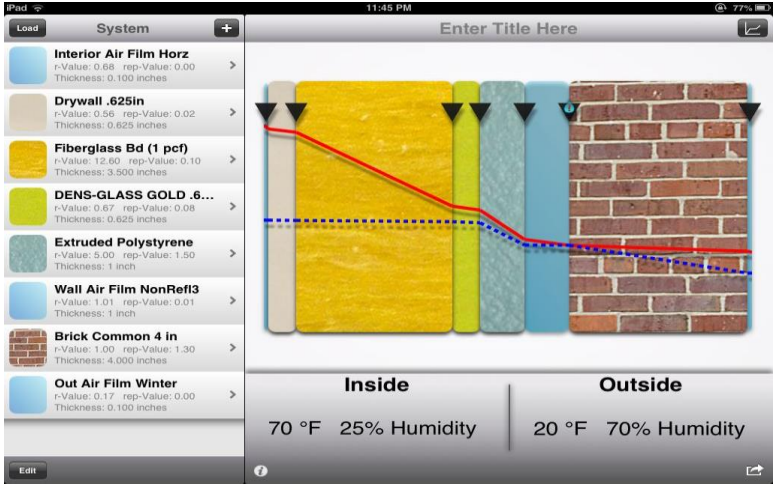




Permeability
Infiltration

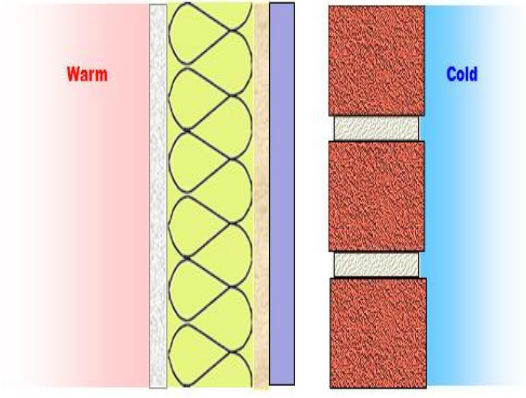
Condensation: Summary

- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies



Condensation: Summary

- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies
- Wall Design



Easier to make right.
Reduced cavity insulation
Sheathing Insulation
Broader applicability
Effective Drying
ROBUST!

Webinar References

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Thank You