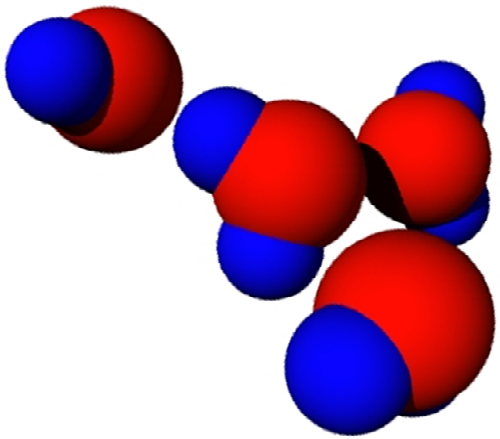
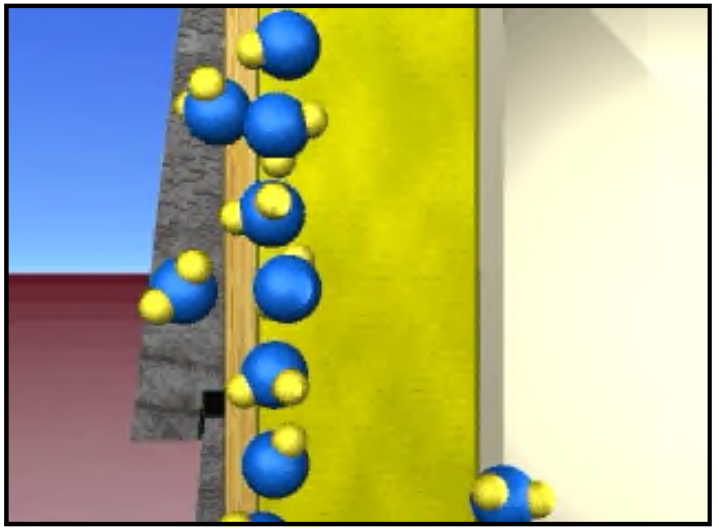
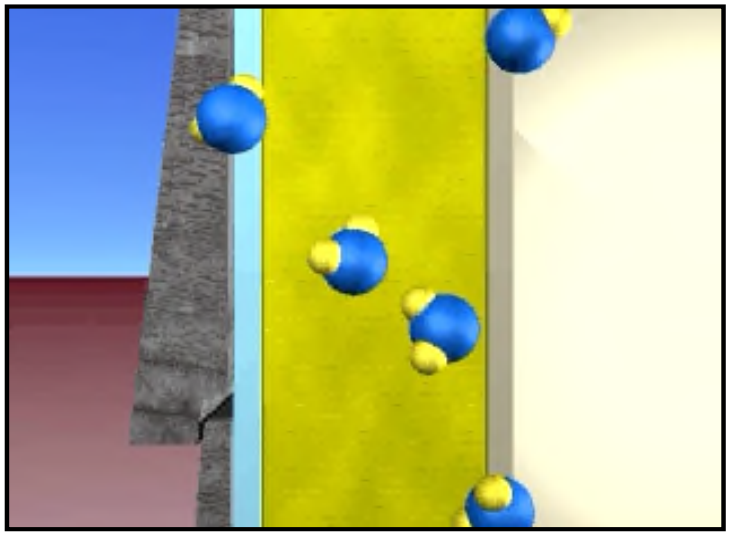
FINALLY, THE TRUTH ABOUT CONDENSATION







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Learning Objectives

At the end of the this course, participants will be able to:

1. Recognize the properties of water and how they lend themselves to condensation.

2. Define the terms relating to condensation and understand how water vapor moves through walls.

3. Analyze wall assemblies using models.

4. Understand how proper wall design can reduce condensation within wall cavities.

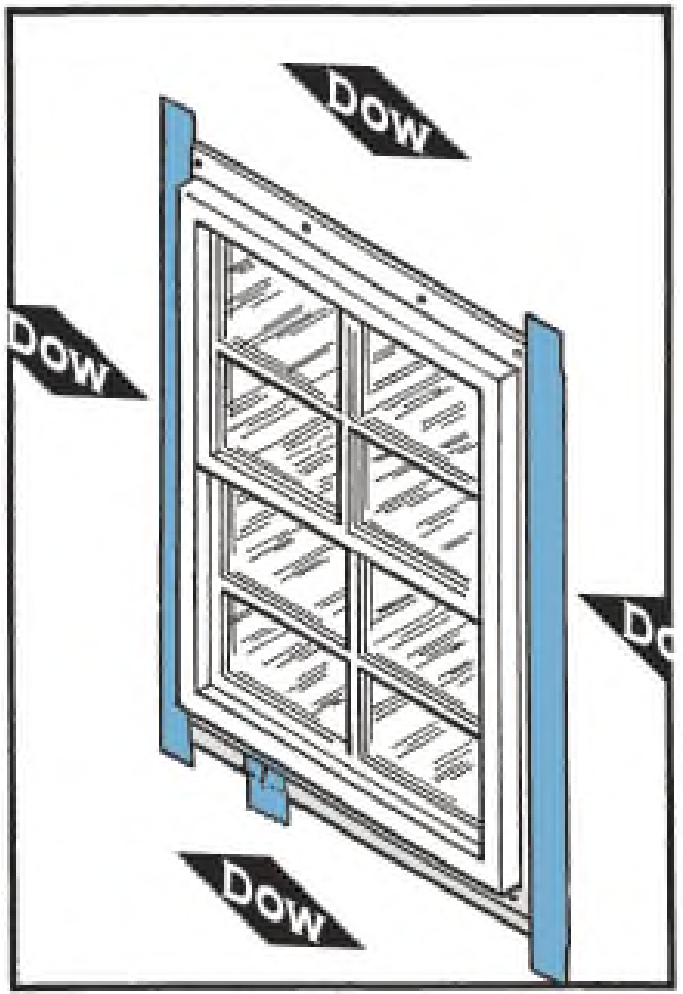
Condensation: Scope

Why This Talk?

- Misconceptions
- Errors
- Incompleteness

Condensation: Scope

Not About Bulk Water



Condensation: Scope

Bulk
Water is
Important!

Condensation: The Real Story

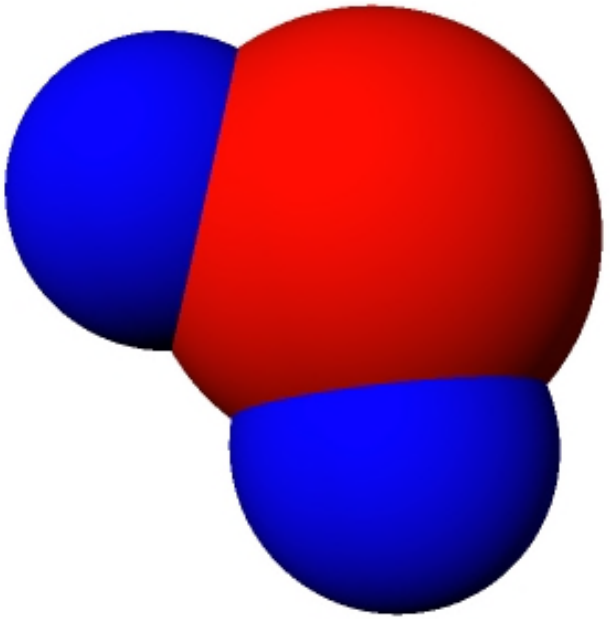
- Properties of Water
- Terms Relating to Condensation
- Wetting and Drying
- Analyzing Assemblies
- Wall Design

Condensation: The Real Story

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

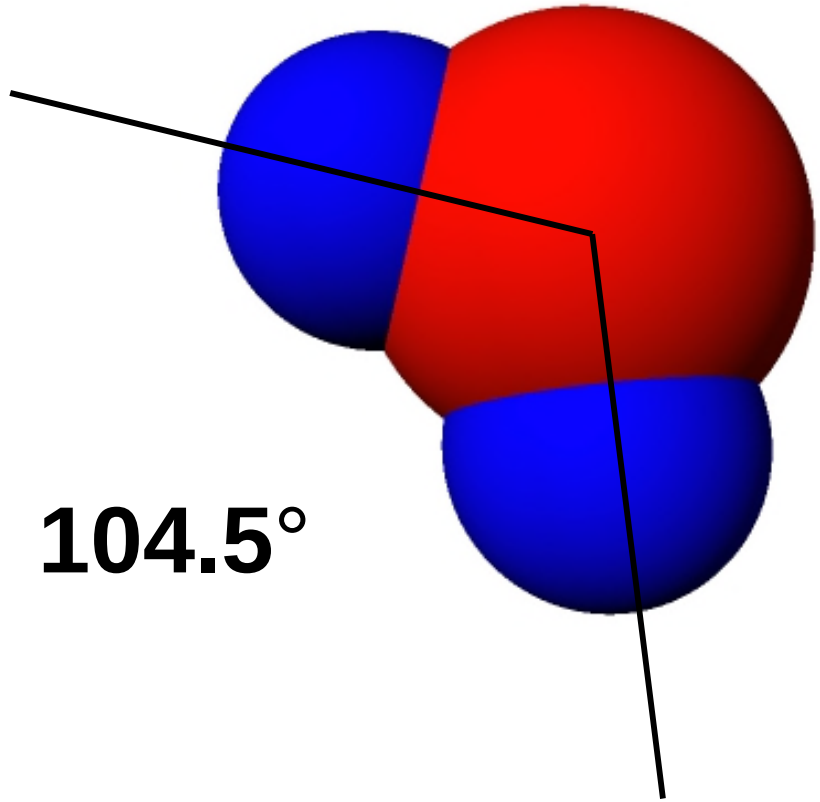
Condensation: Water Properties

Structure



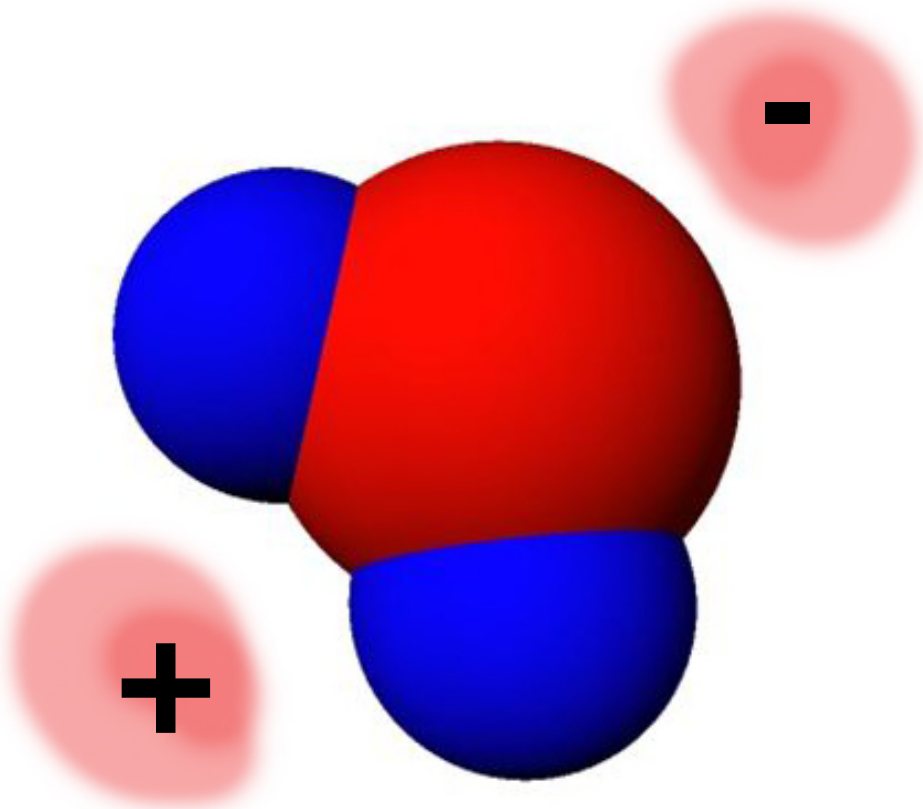
Condensation: Water Properties

Structure



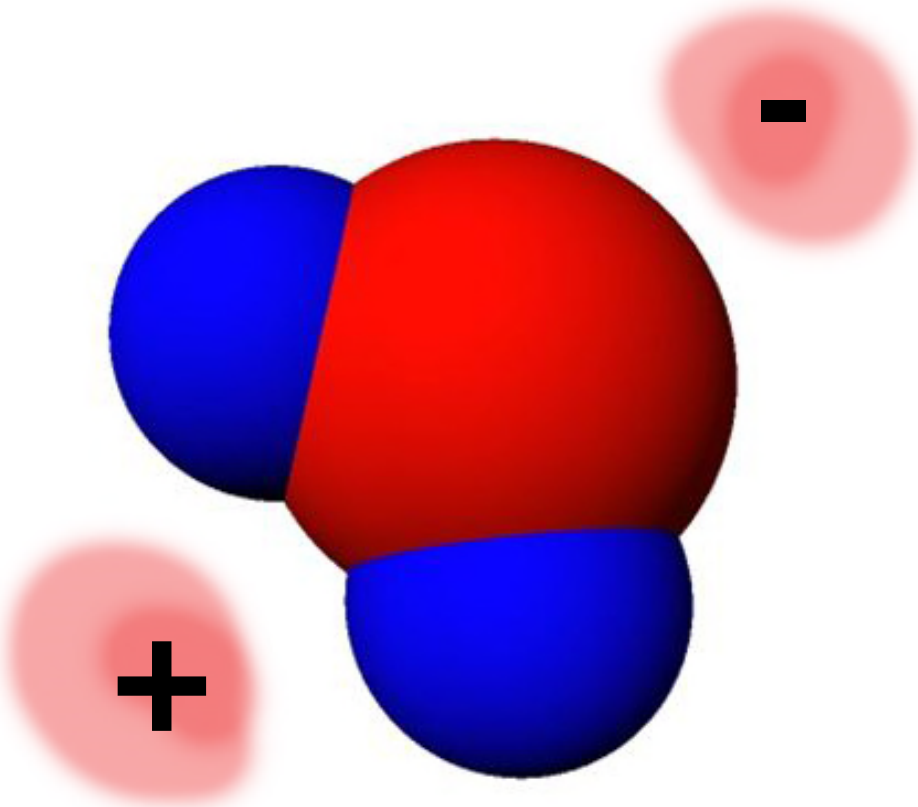
Condensation: Water Properties

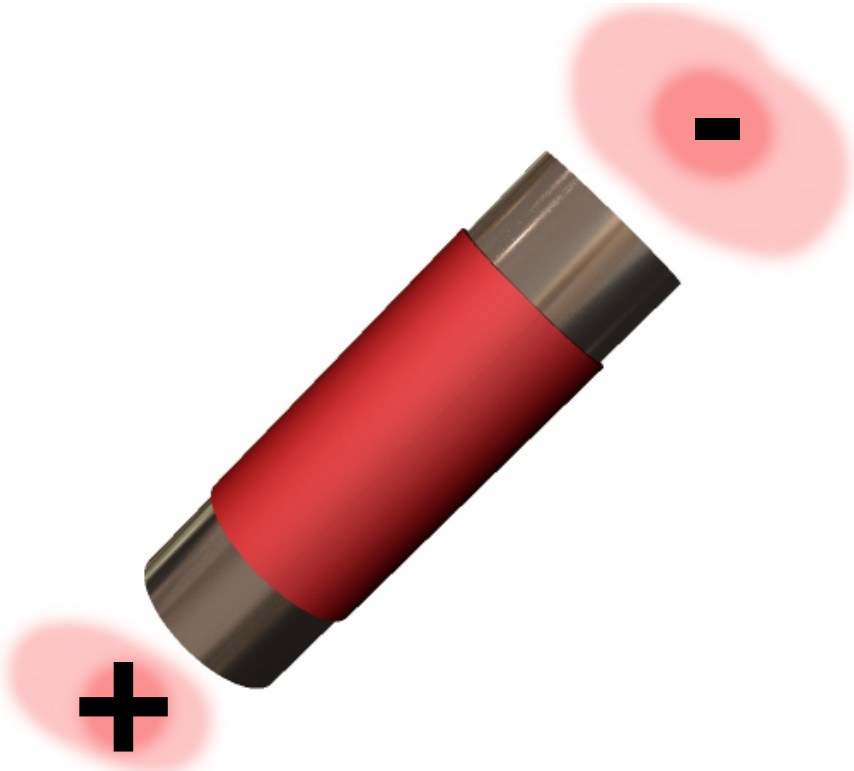
Structure



Condensation: Water Properties

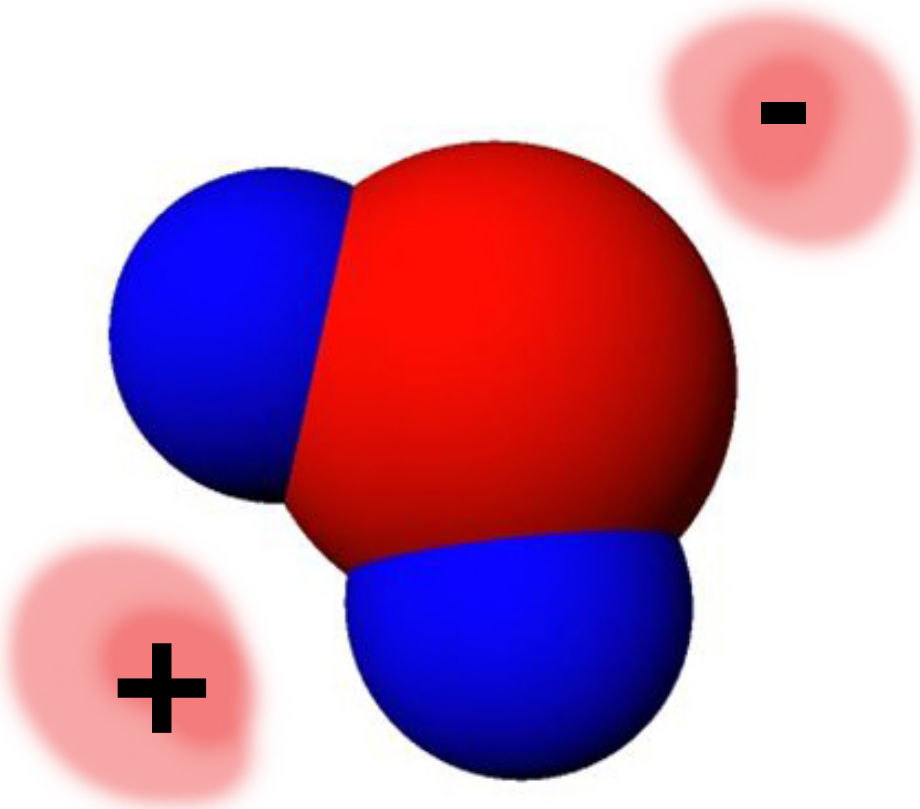
Structure

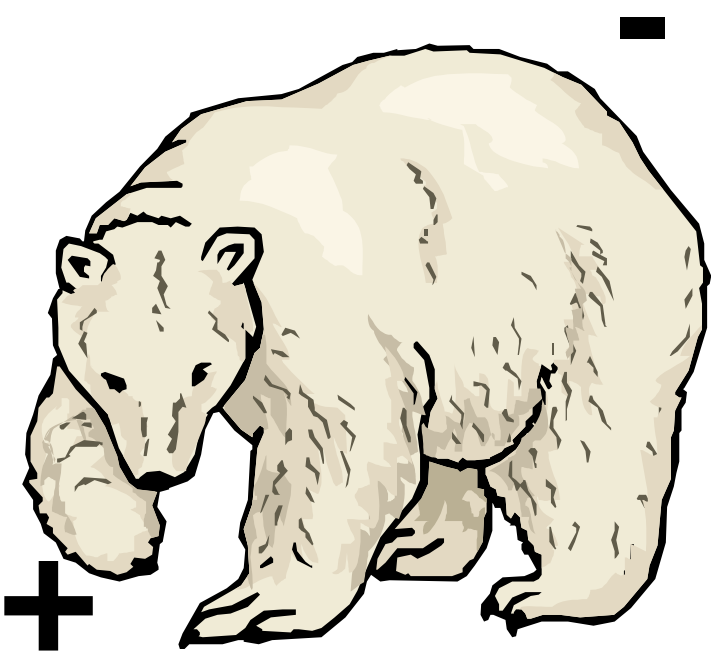




Condensation: Water Properties

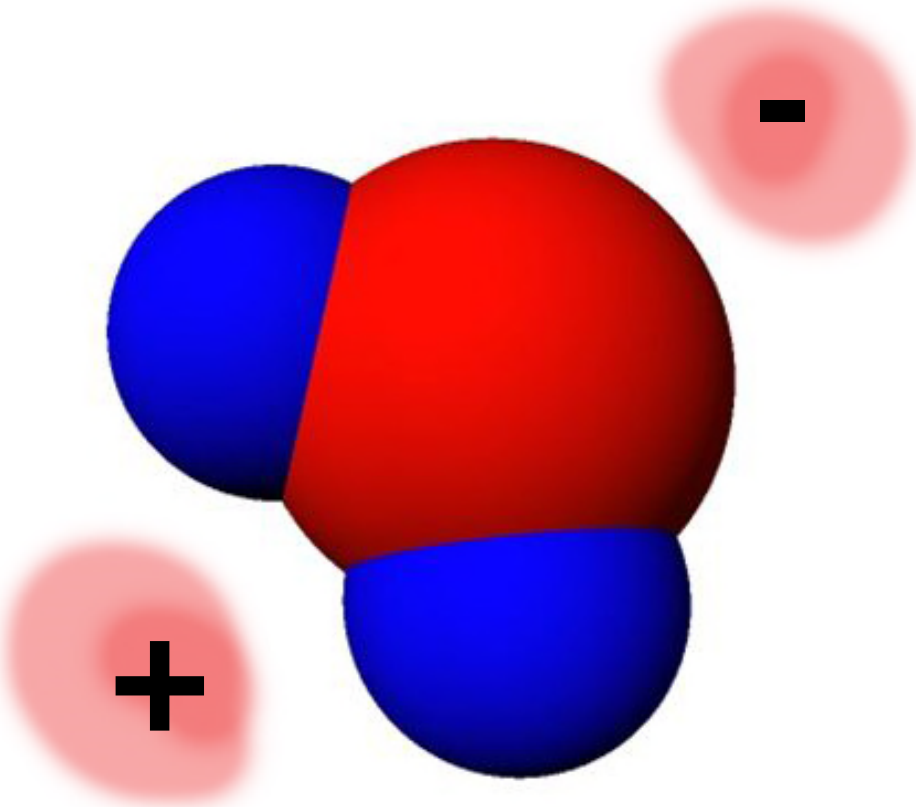
Structure





Condensation: Water Properties

Structure



Condensation: Water Properties

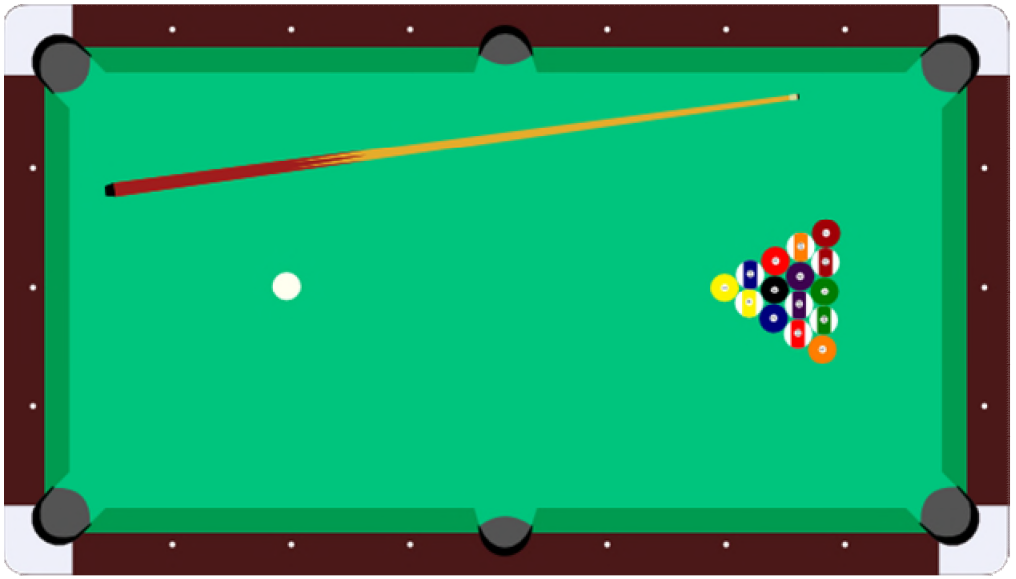
Structure

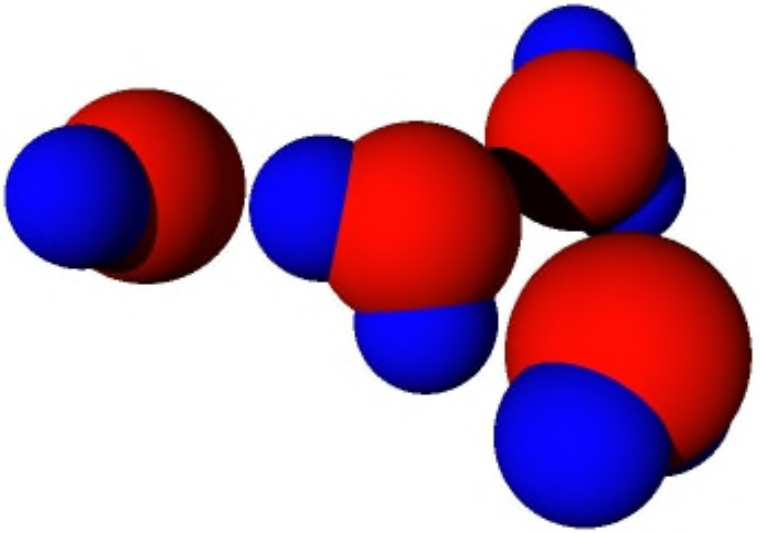
Condensation: Water Properties

Structure

Condensation: Water Properties

Structure





Condensation: Water Properties

Phases of Water: Gas

Condensation: Water Properties

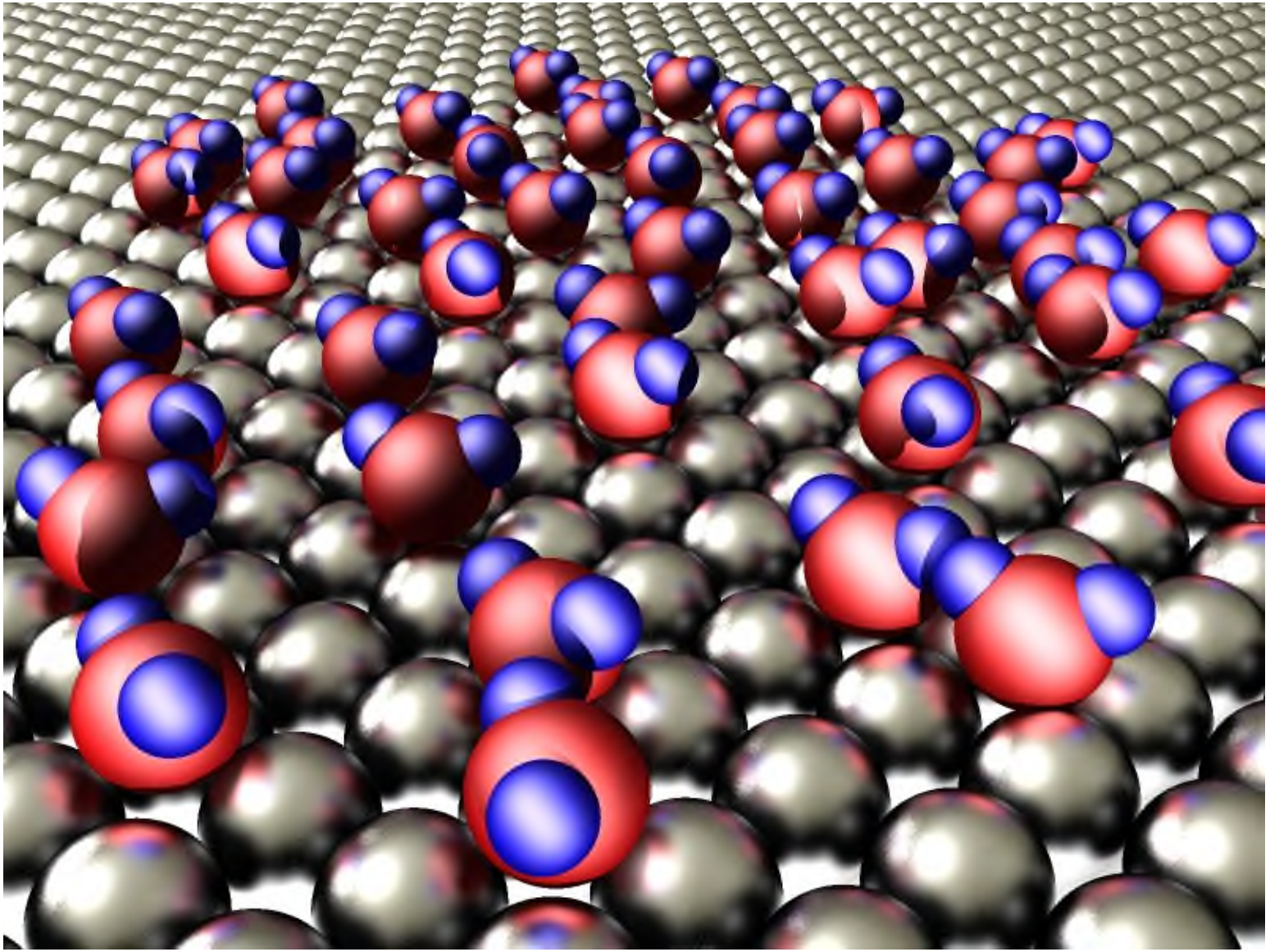
Phases of Water: Liquid

Condensation: Water Properties

Phases of Water: Solid

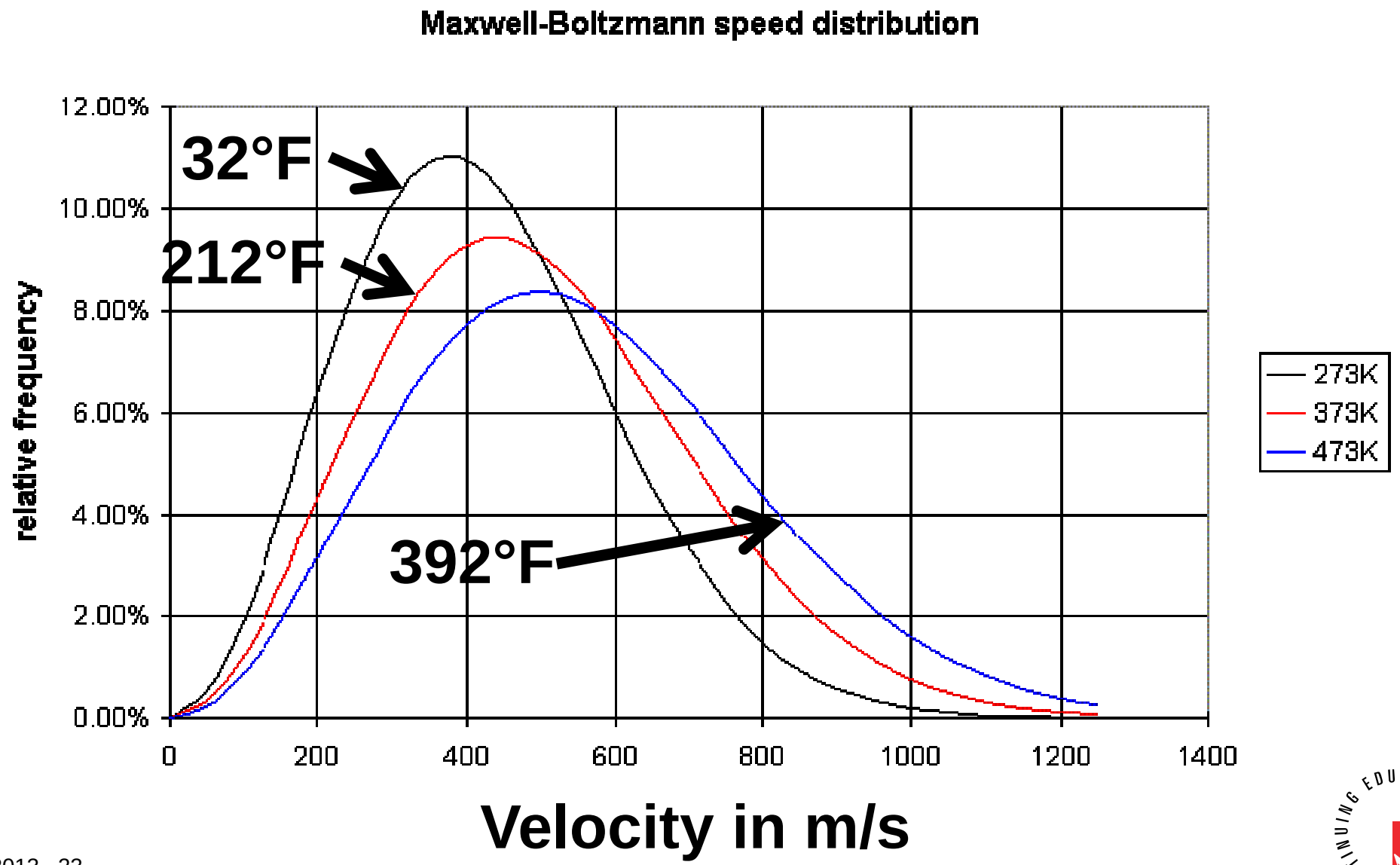
Condensation: Water Properties

Phases of Water: Adsorbed



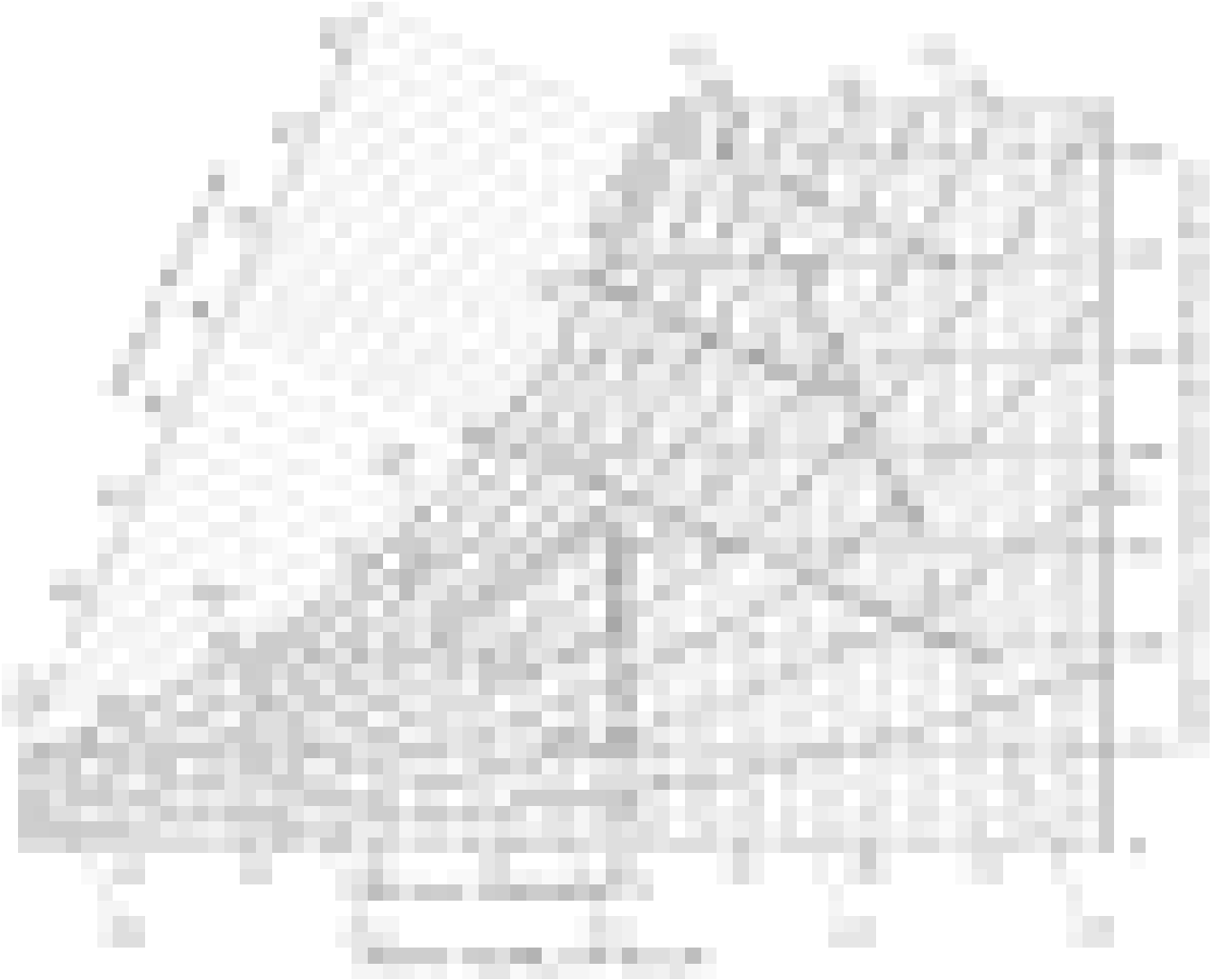
Condensation: Water Properties

Effect of Temperature



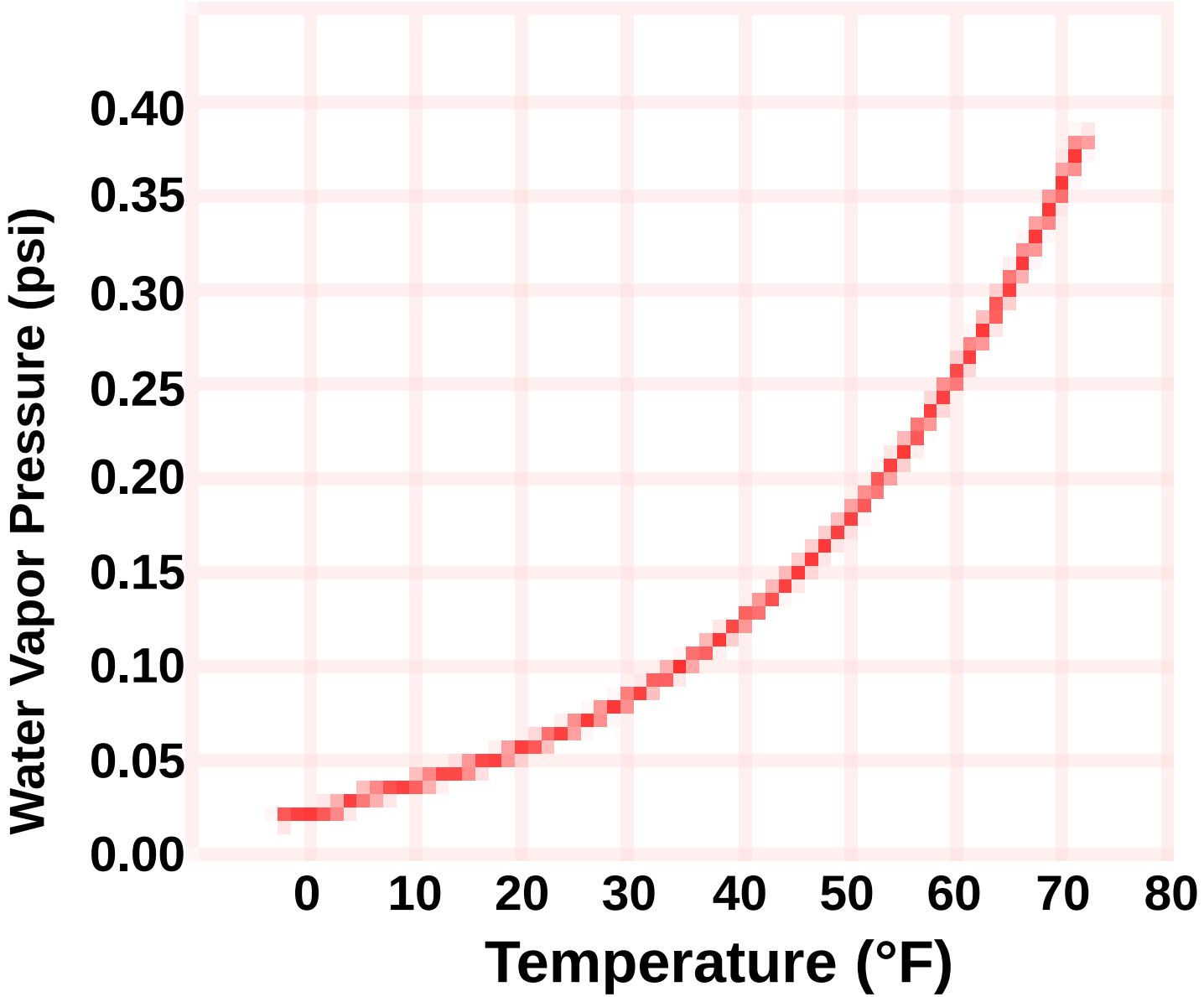
Condensation: Water Properties

Psychometric Chart



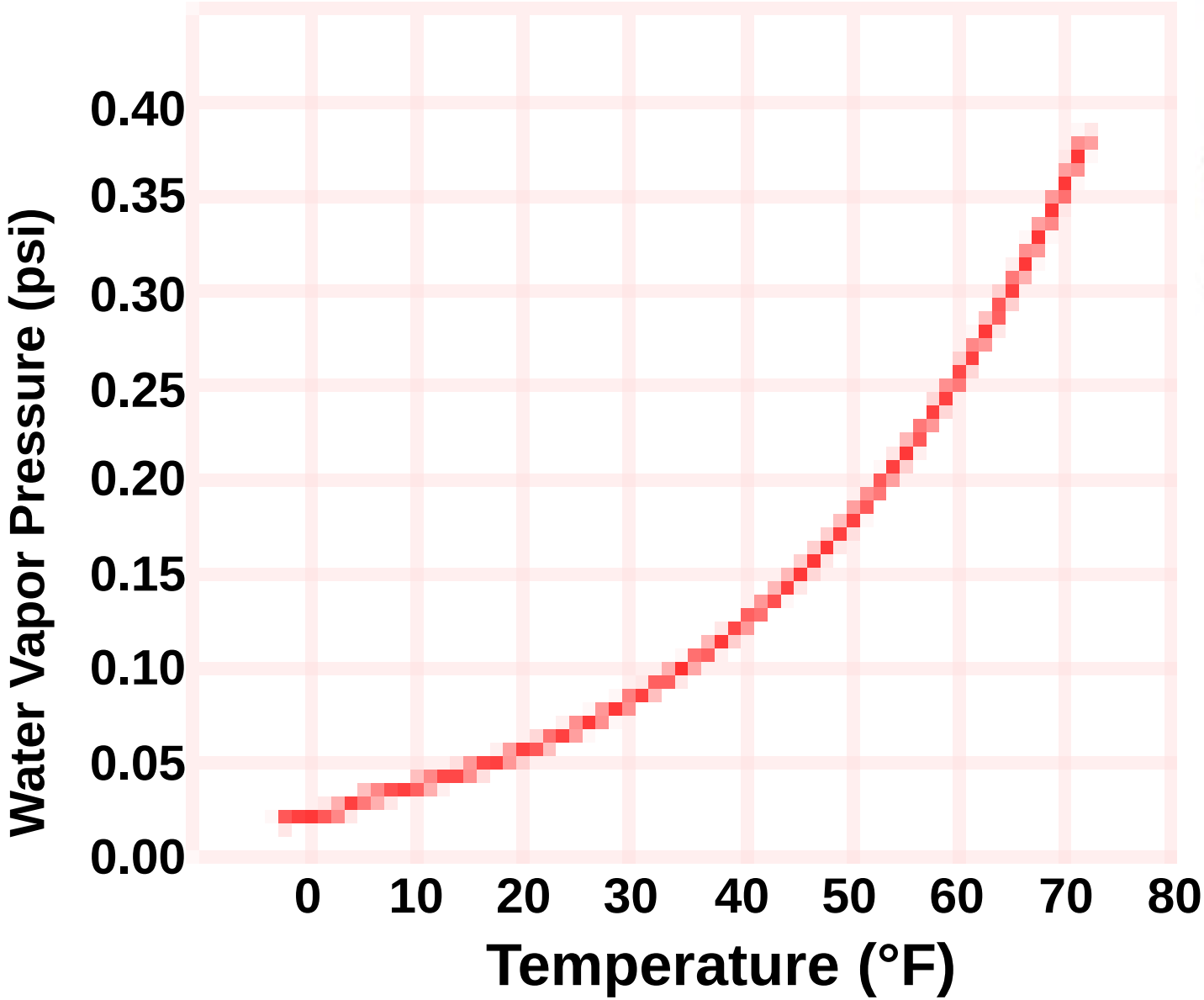
Condensation: Water Properties

Psychometric Chart



Condensation: Water Properties

Psychometric 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/cubic foot**
- **Psi**
- **Dewpoint Temperature**

Condensation: Terms

Relative Humidity

Need 2 pieces of information:

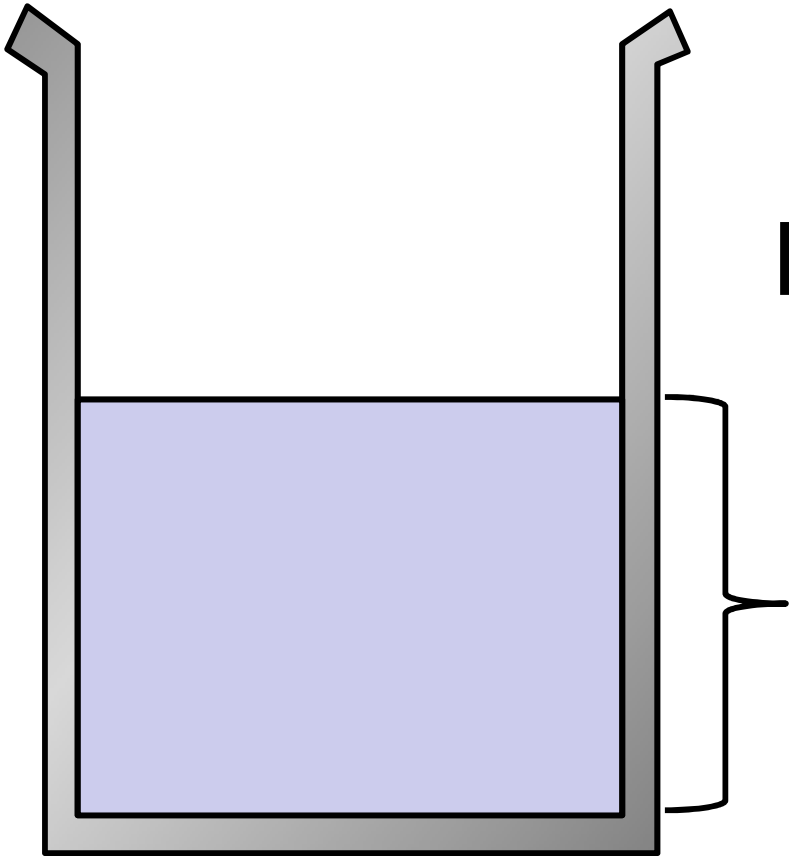
- **Temperature (°F)**
- **Percent (%)**

Condensation: Terms

Relative Humidity

Condensation: Terms

Relative Humidity

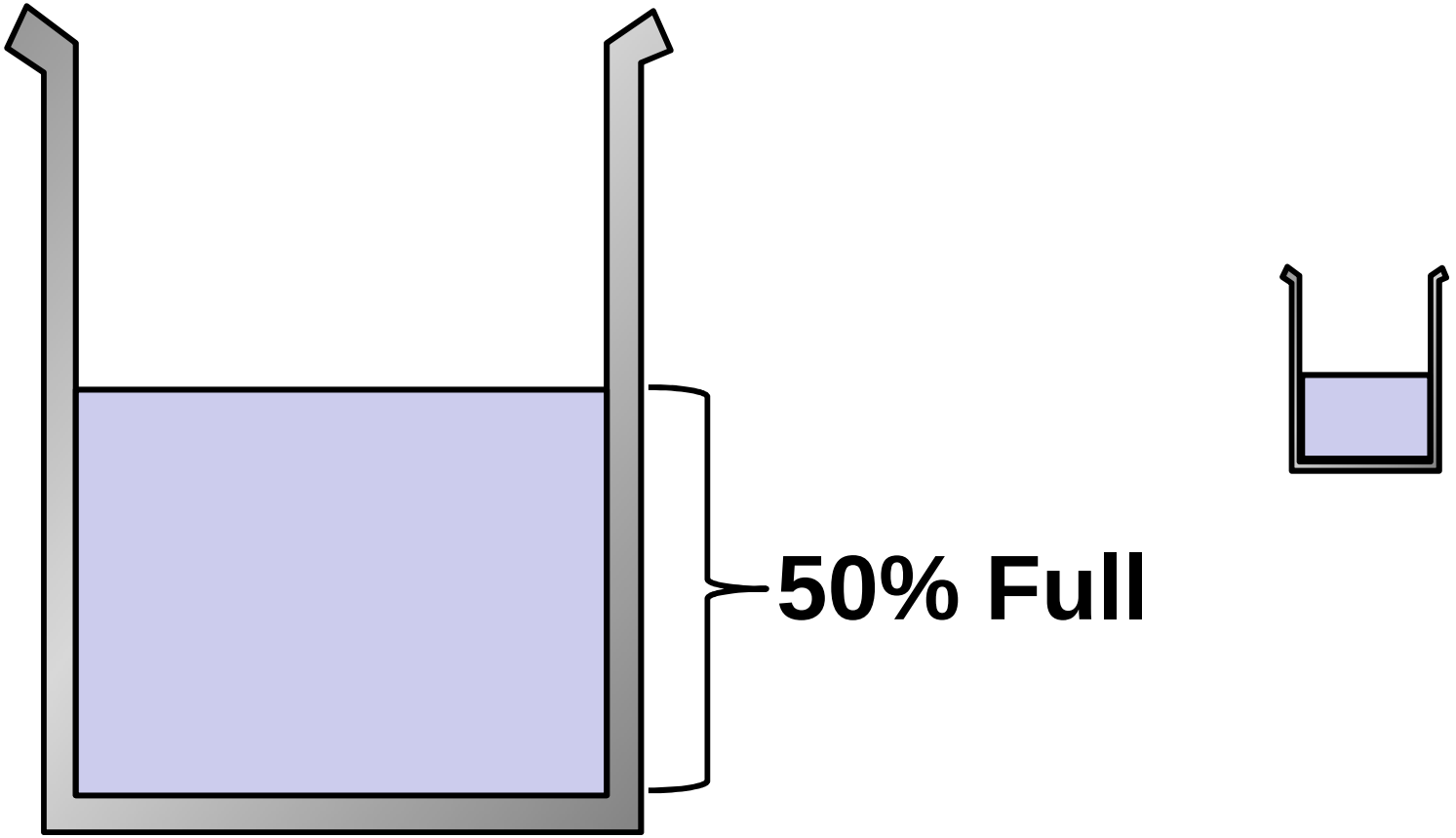


How Much Water??

50% Full

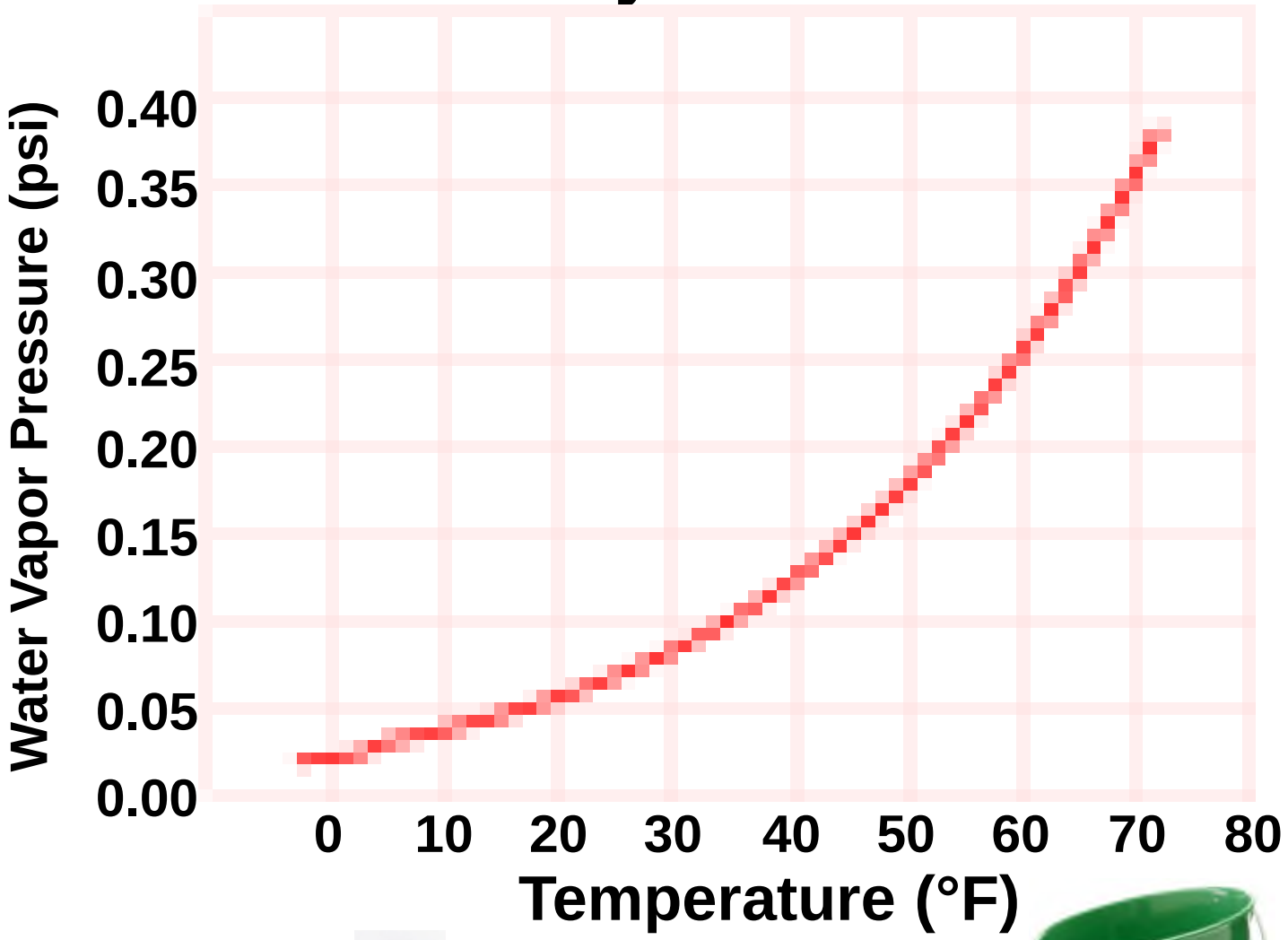
Condensation: Terms

Relative Humidity



Condensation: Terms

Relative Humidity



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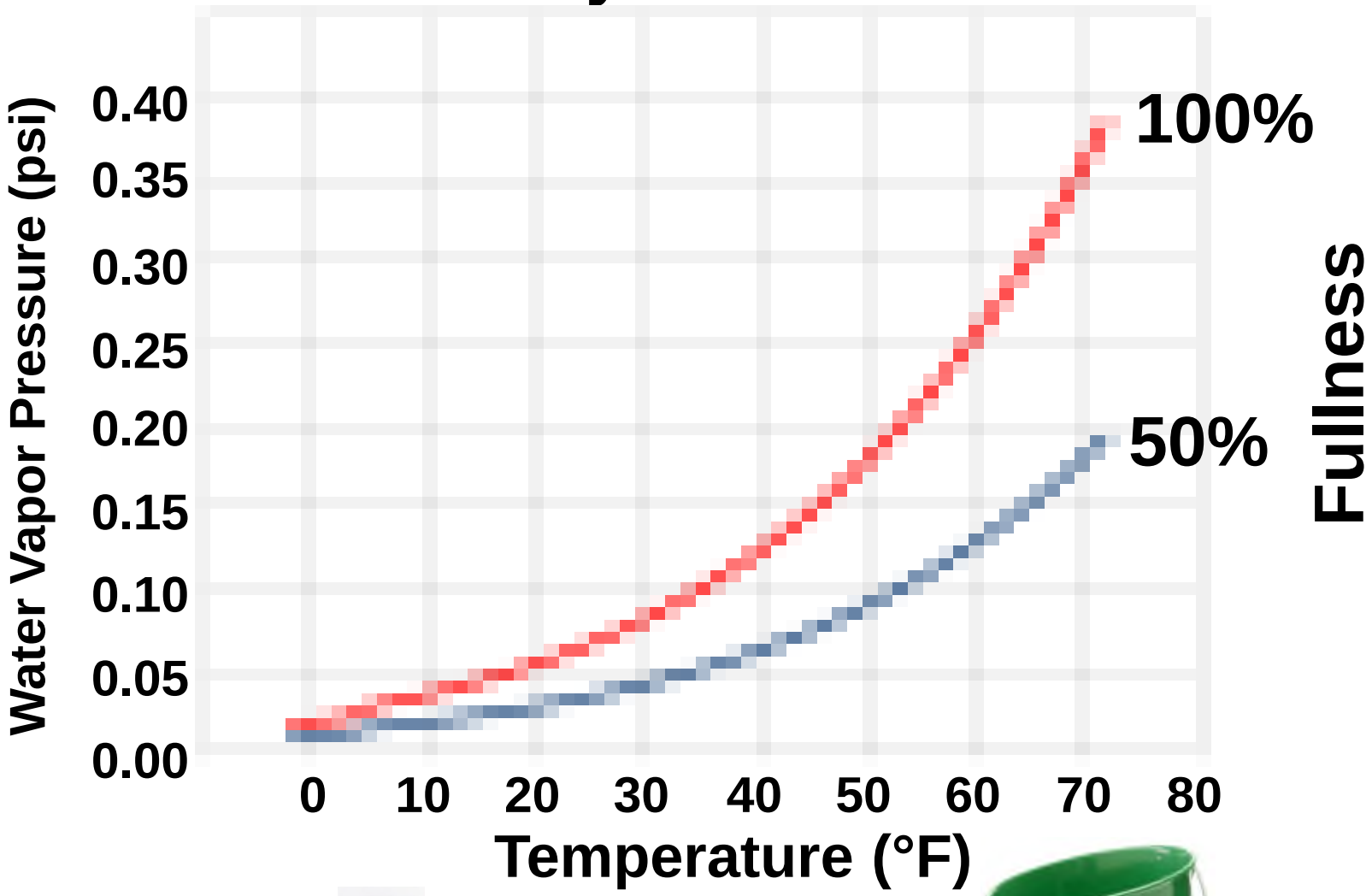
Condensation: Terms

Relative Humidity



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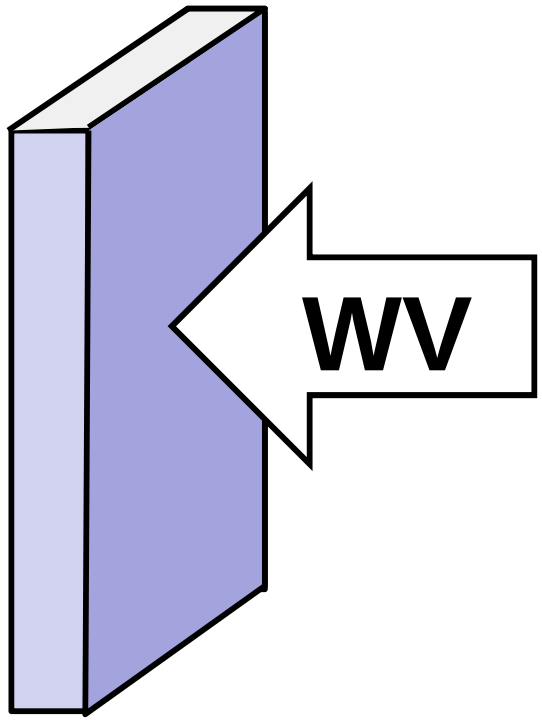
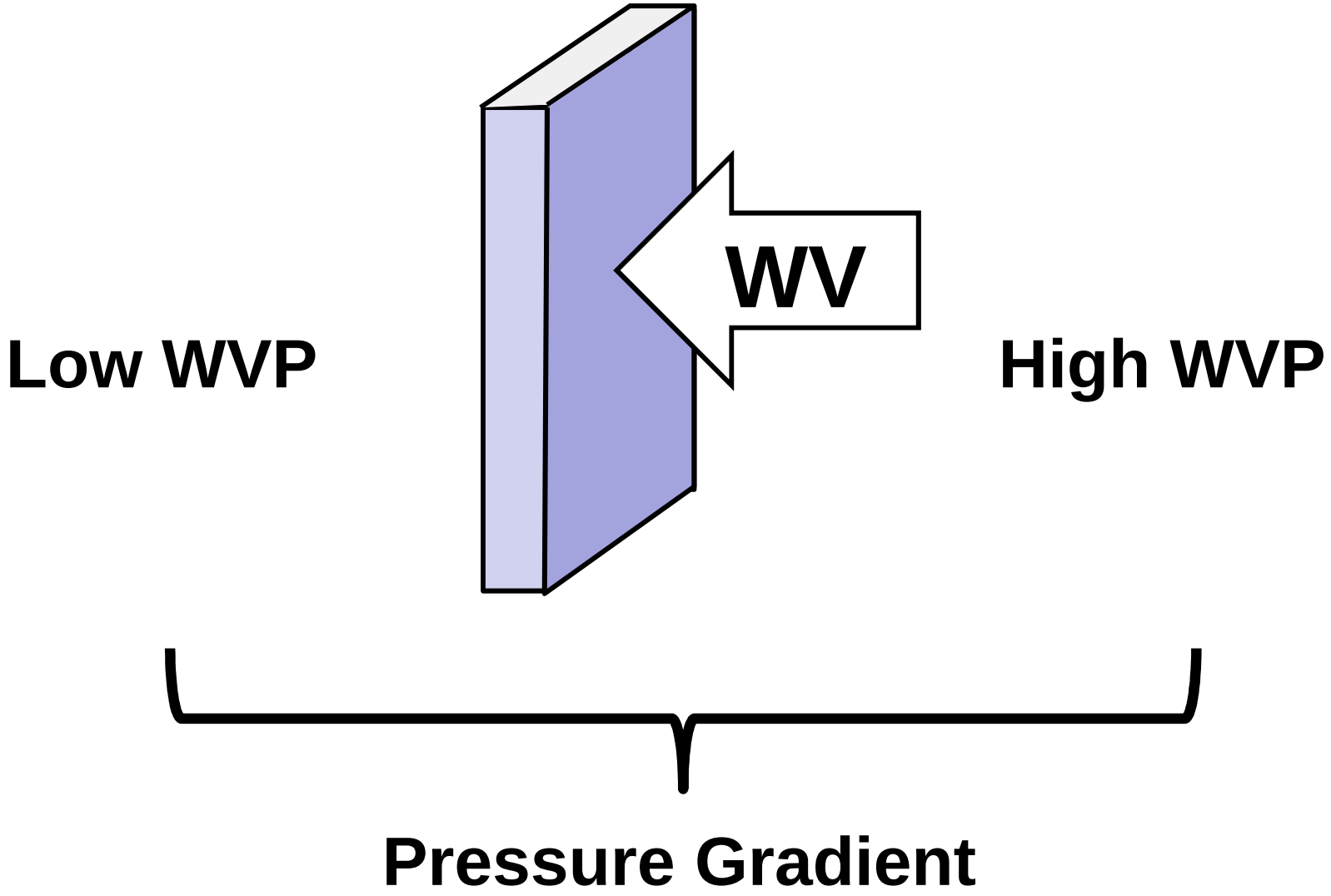
Condensation: Terms

Permeability: Diffusion



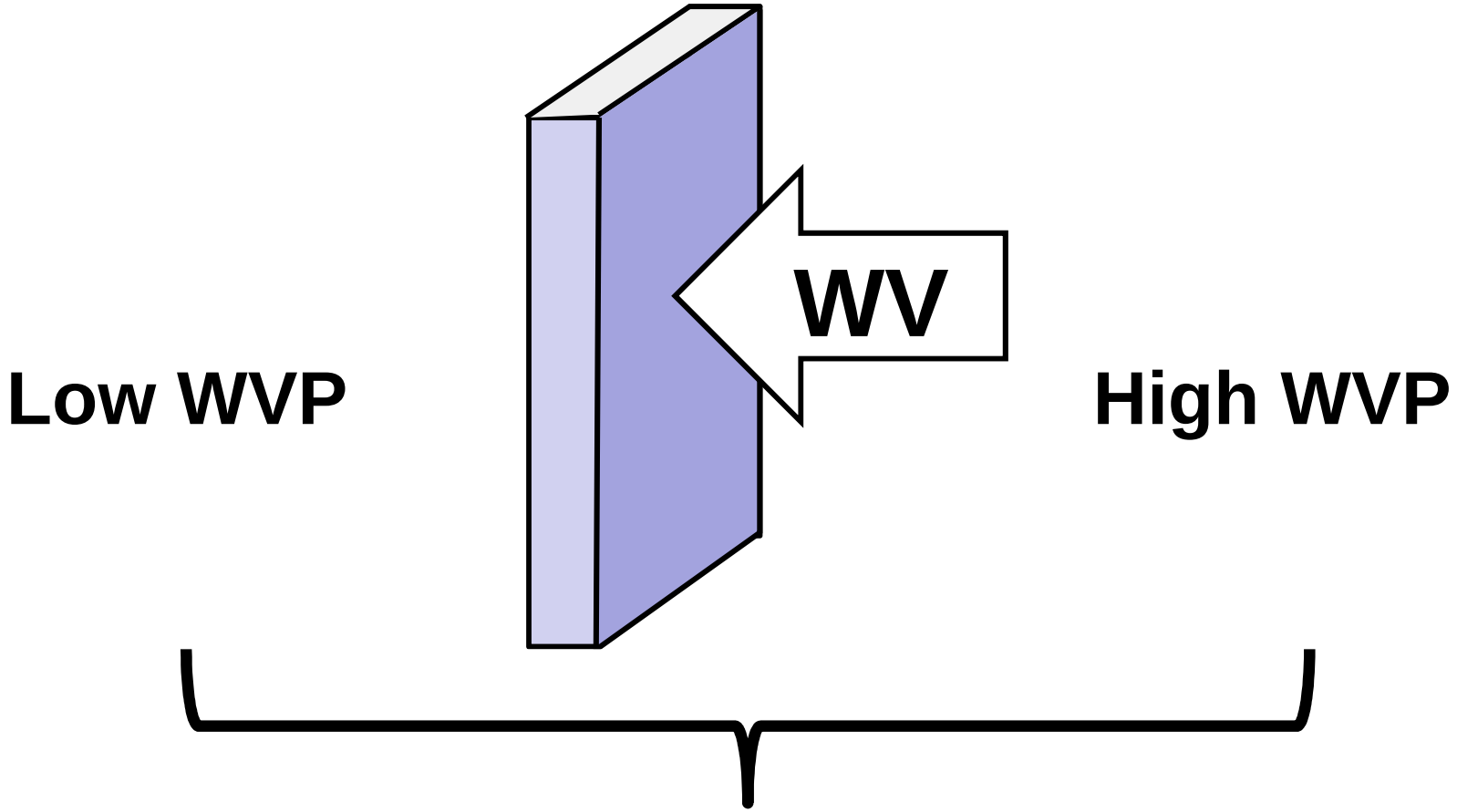
Condensation: Terms

Permeability: Diffusion



Condensation: Terms

Permeability: Diffusion



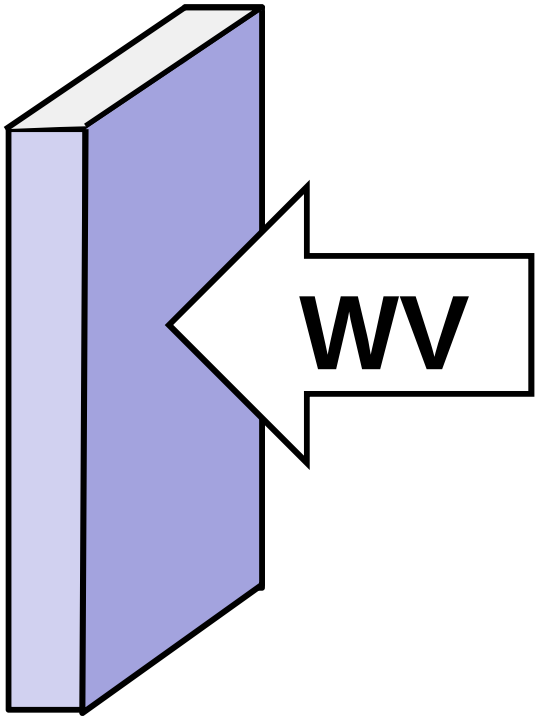
Not Temperature

Condensation: Terms

Permeability: Diffusion

- Permeance
- Perms

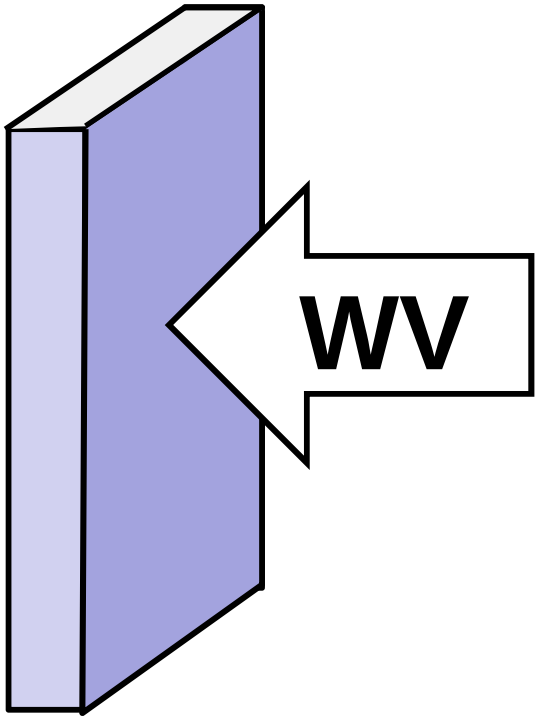
$$\frac{\text{Mass water}}{\text{Time x Area x dP}}$$



Condensation: Terms

Permeability: Diffusion

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



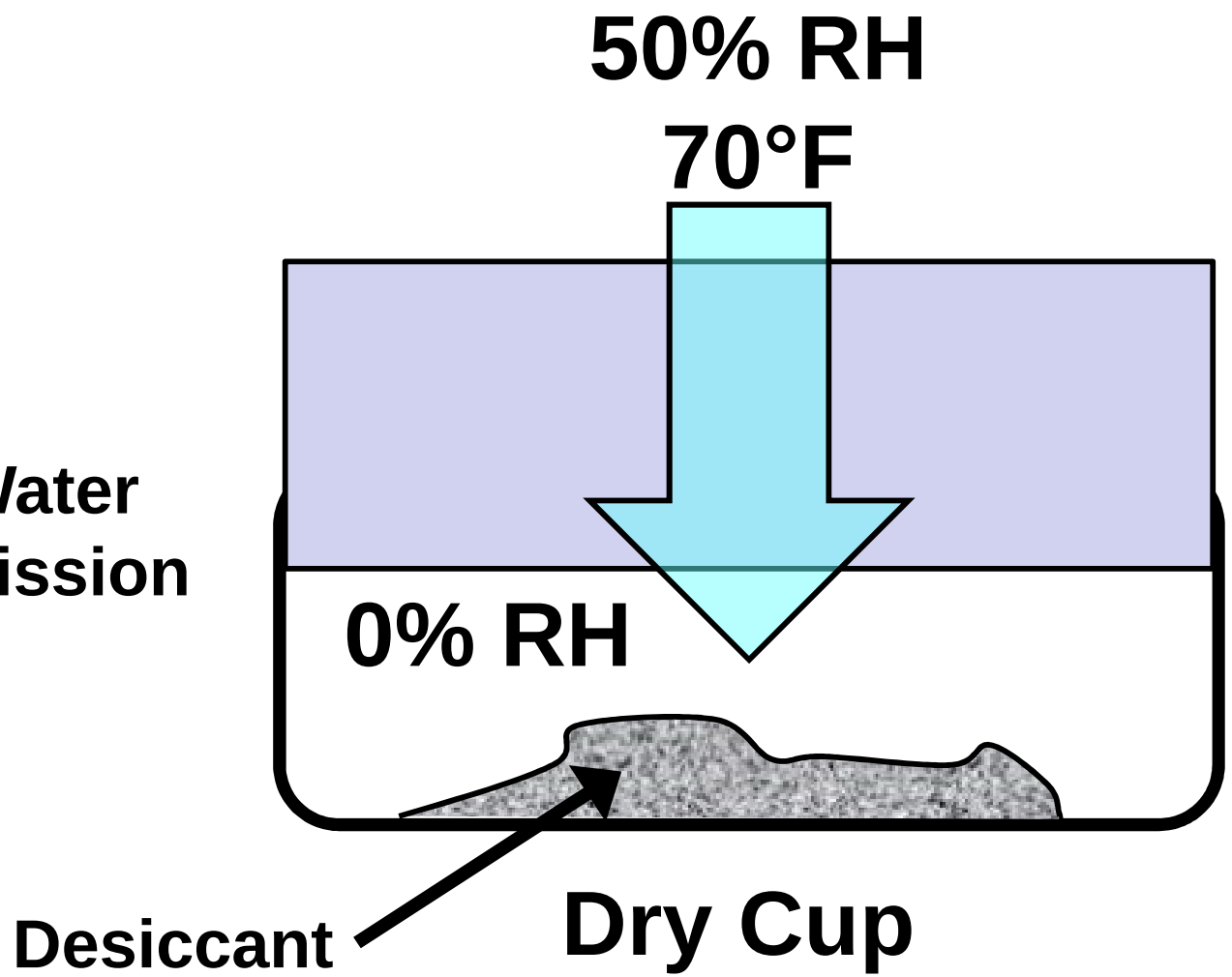
gr/hr ft^2 in Hg

Condensation: Terms

Permeability: Diffusion

ASTM E96

Standard Test Methods for Water Vapor Transmission of Materials

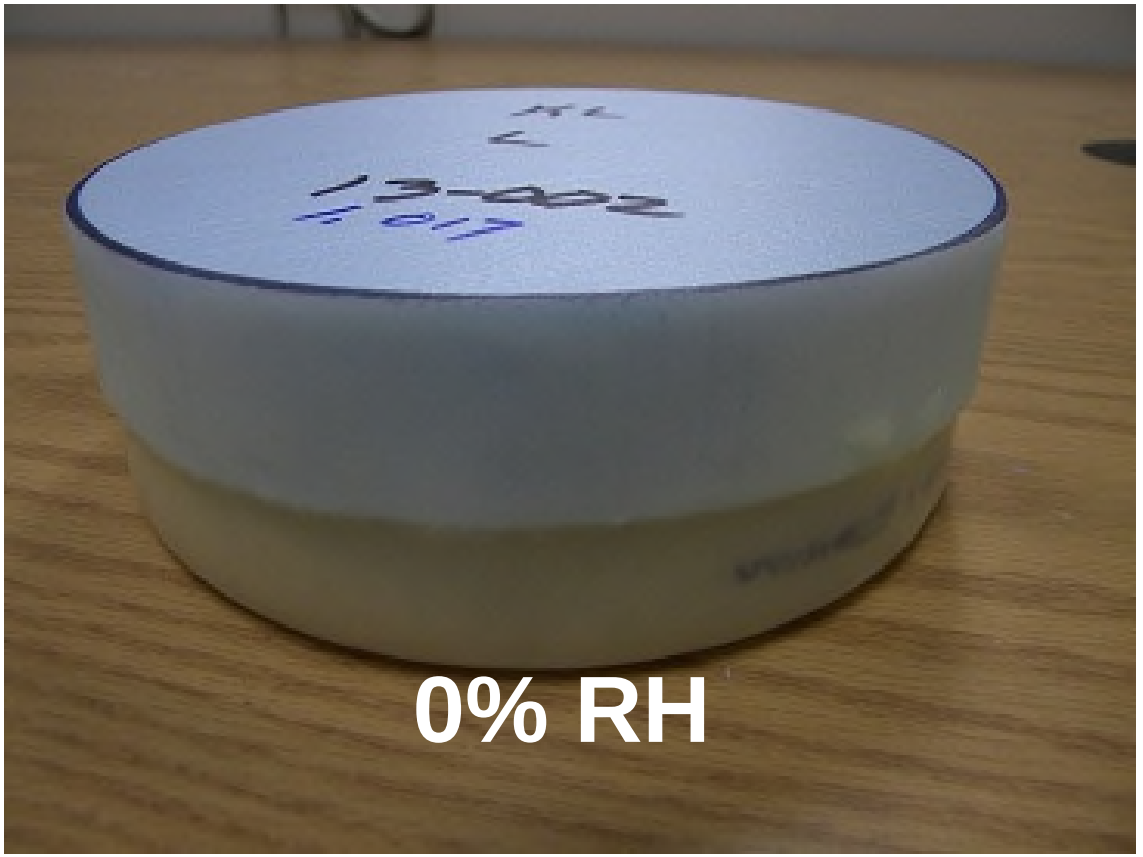


Condensation: Terms

Permeability: Diffusion

50% RH

ASTM E96

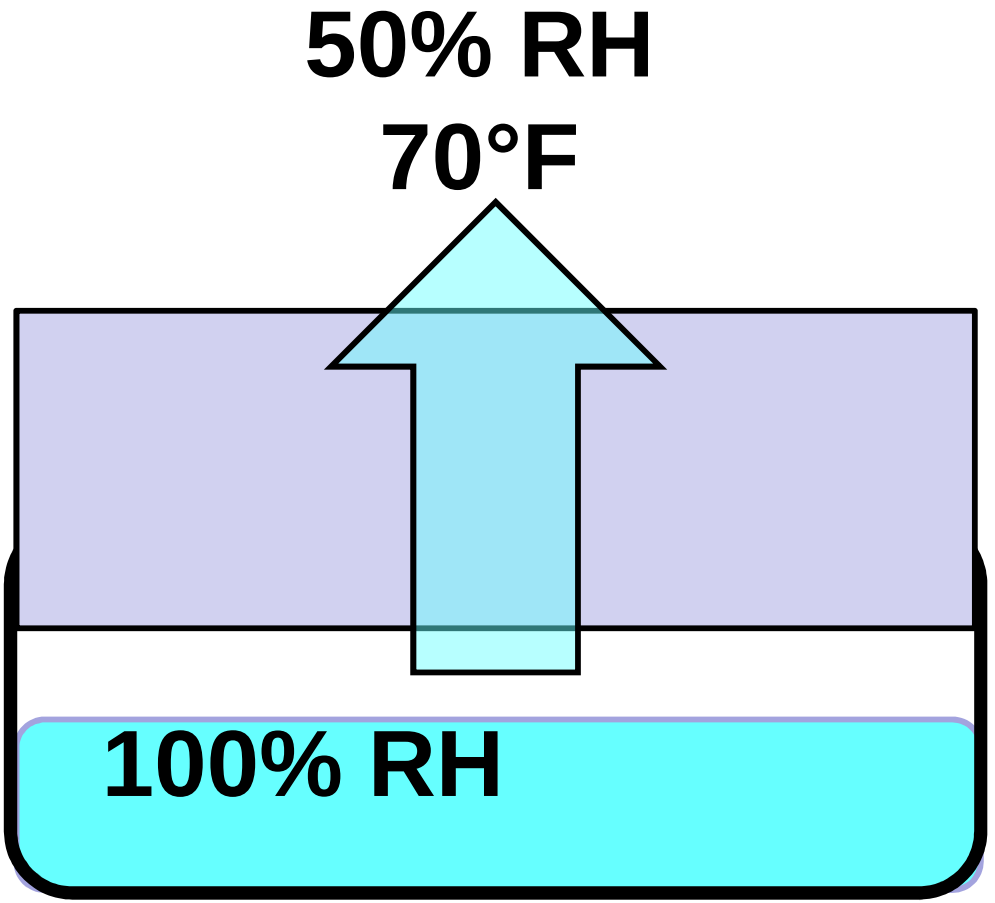


0% RH

Condensation: Terms

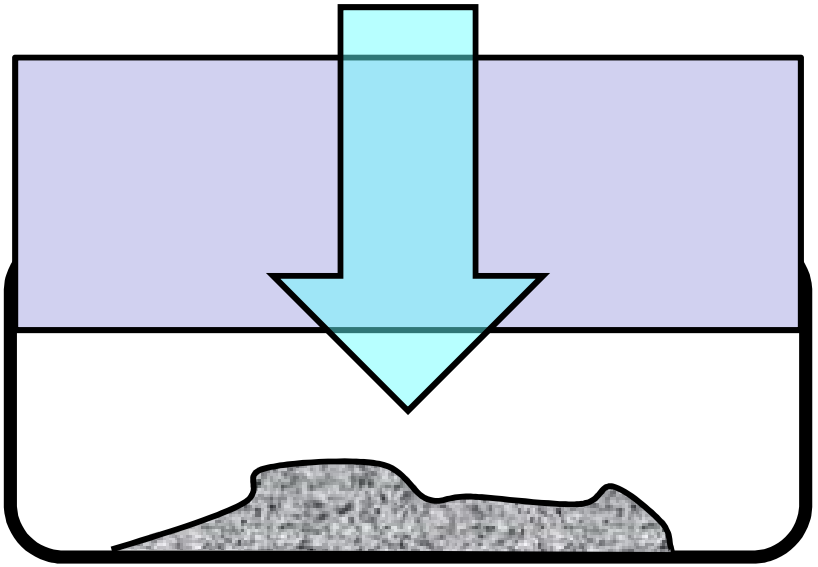
Permeability: Diffusion

ASTM E96

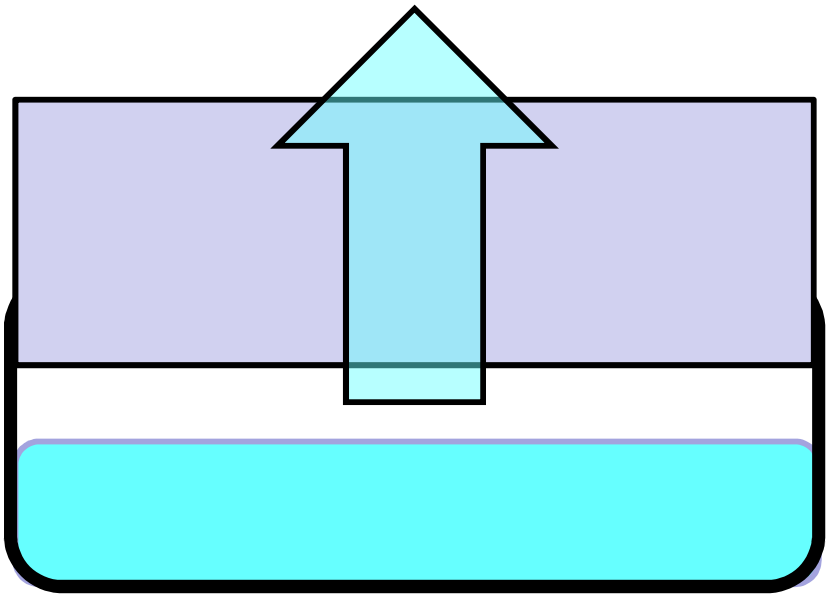


Wet Cup

Condensation: Terms



Dry Cup

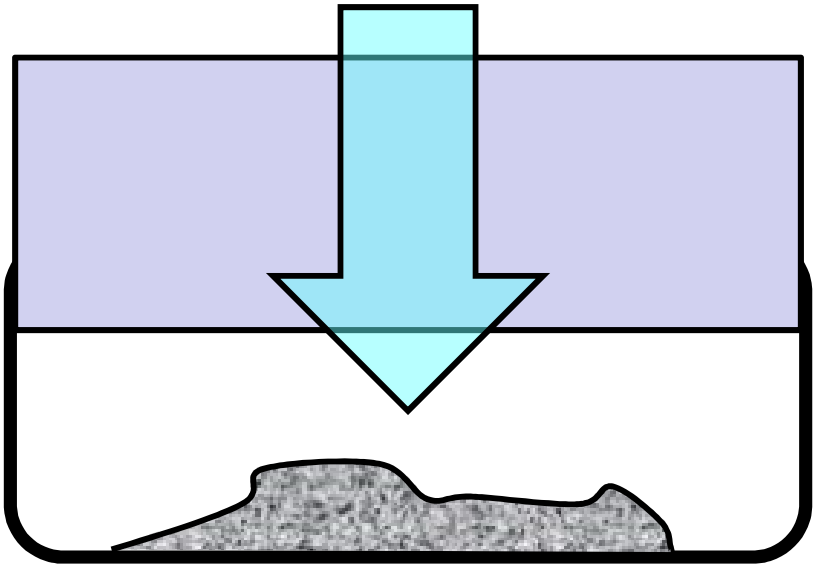


Wet Cup

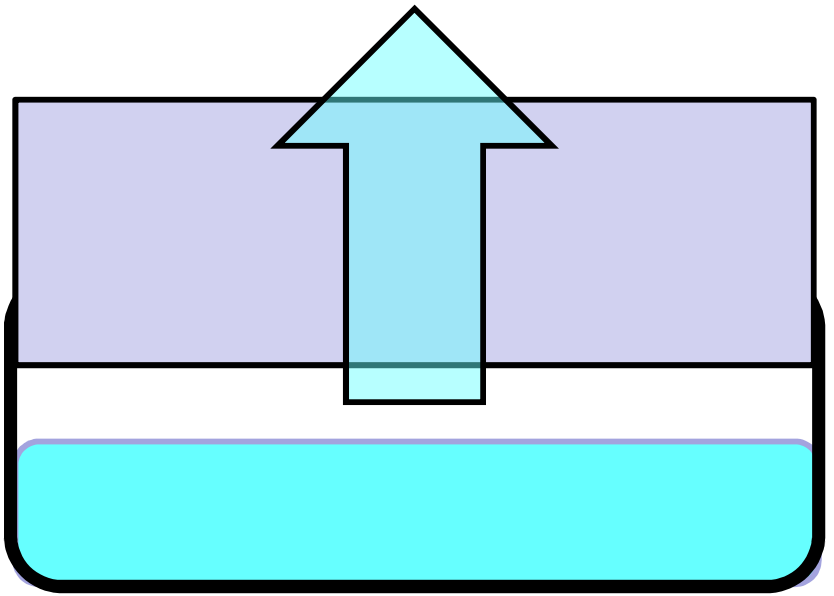
Different Results

Condensation: Terms

Permeability: Diffusion



Dry Cup



Wet Cup

Temperature Effects?

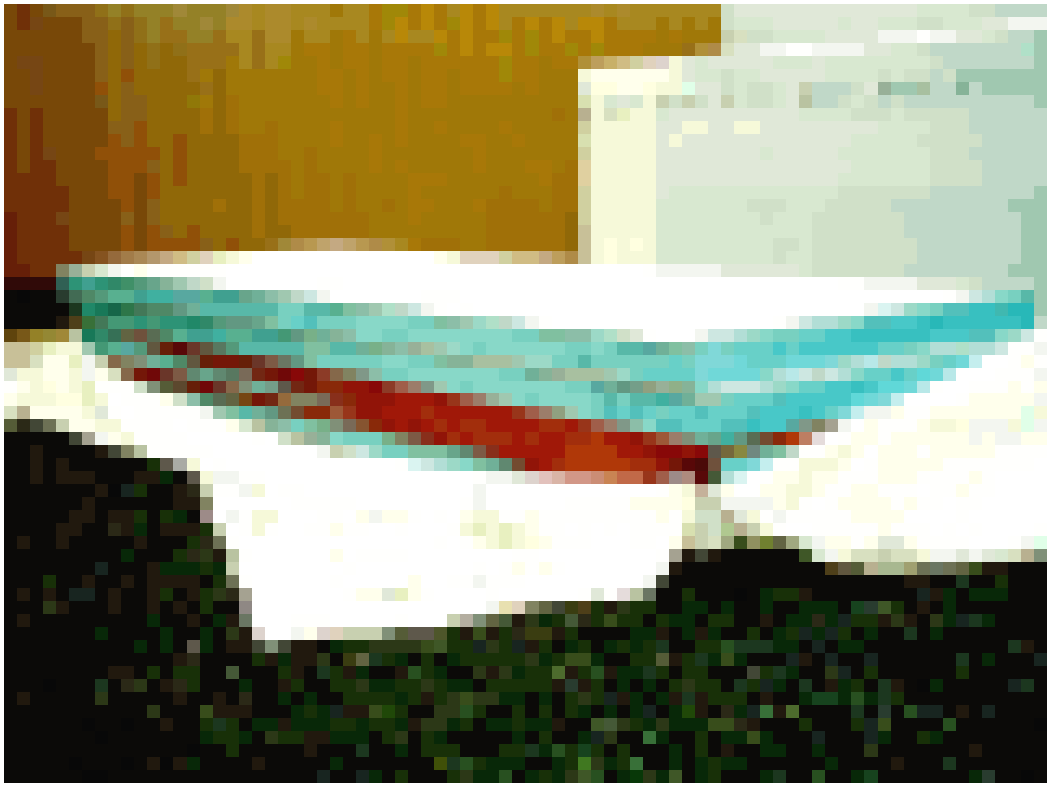
Condensation: Terms

Permeability: Diffusion

Permeability = “Breathability”?

Condensation: Wetting and Drying

Myth of Breathability



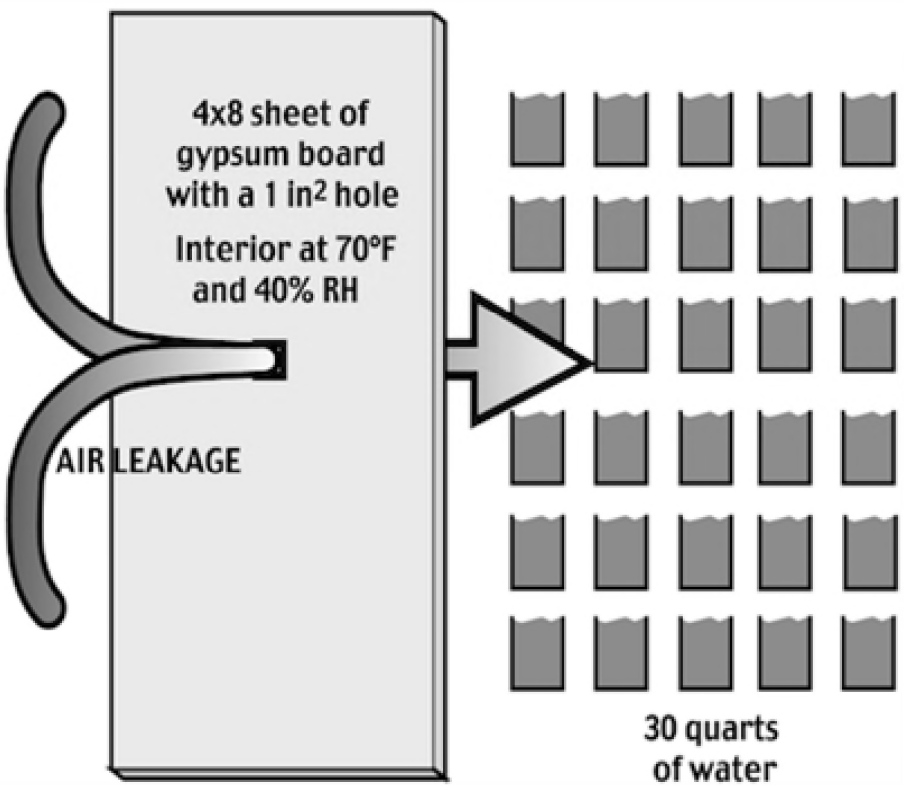
Condensation: Terms

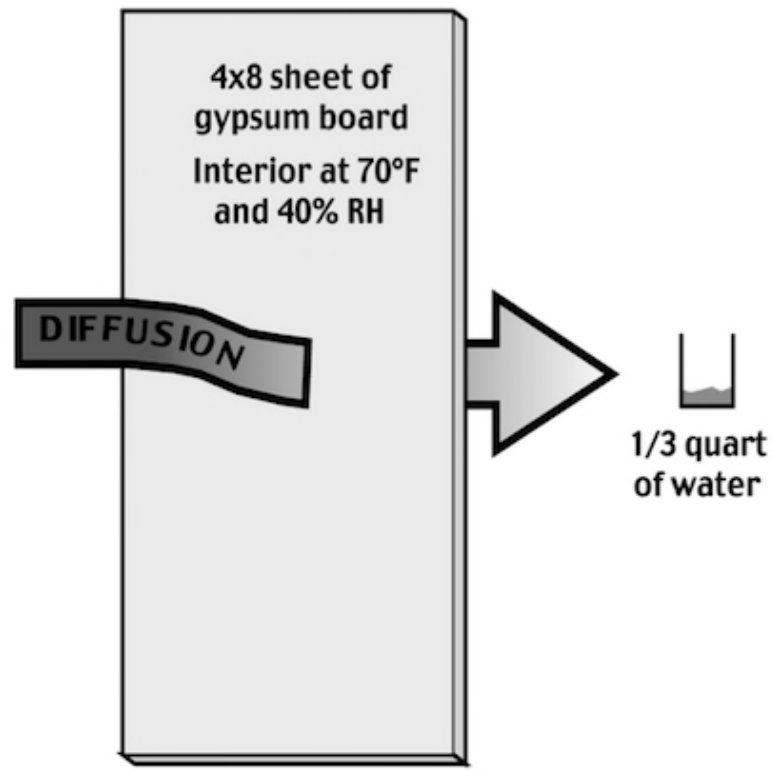
Permeability: Diffusion

Permeability = “Breathability”?

Condensation: Terms

Diffusion vs. Infiltration





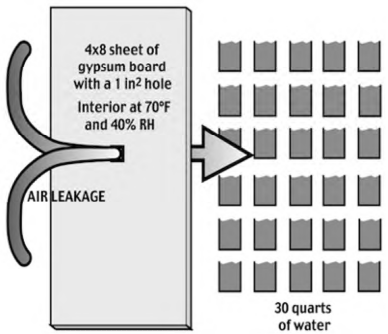
***Building Science Corporation**

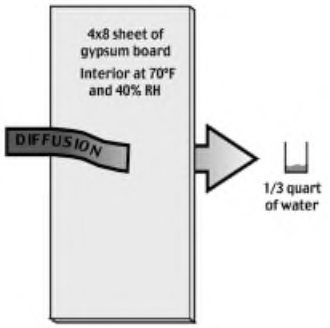
Condensation: Terms

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





Condensation: The Real Story

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

Condensation: Wetting and Drying

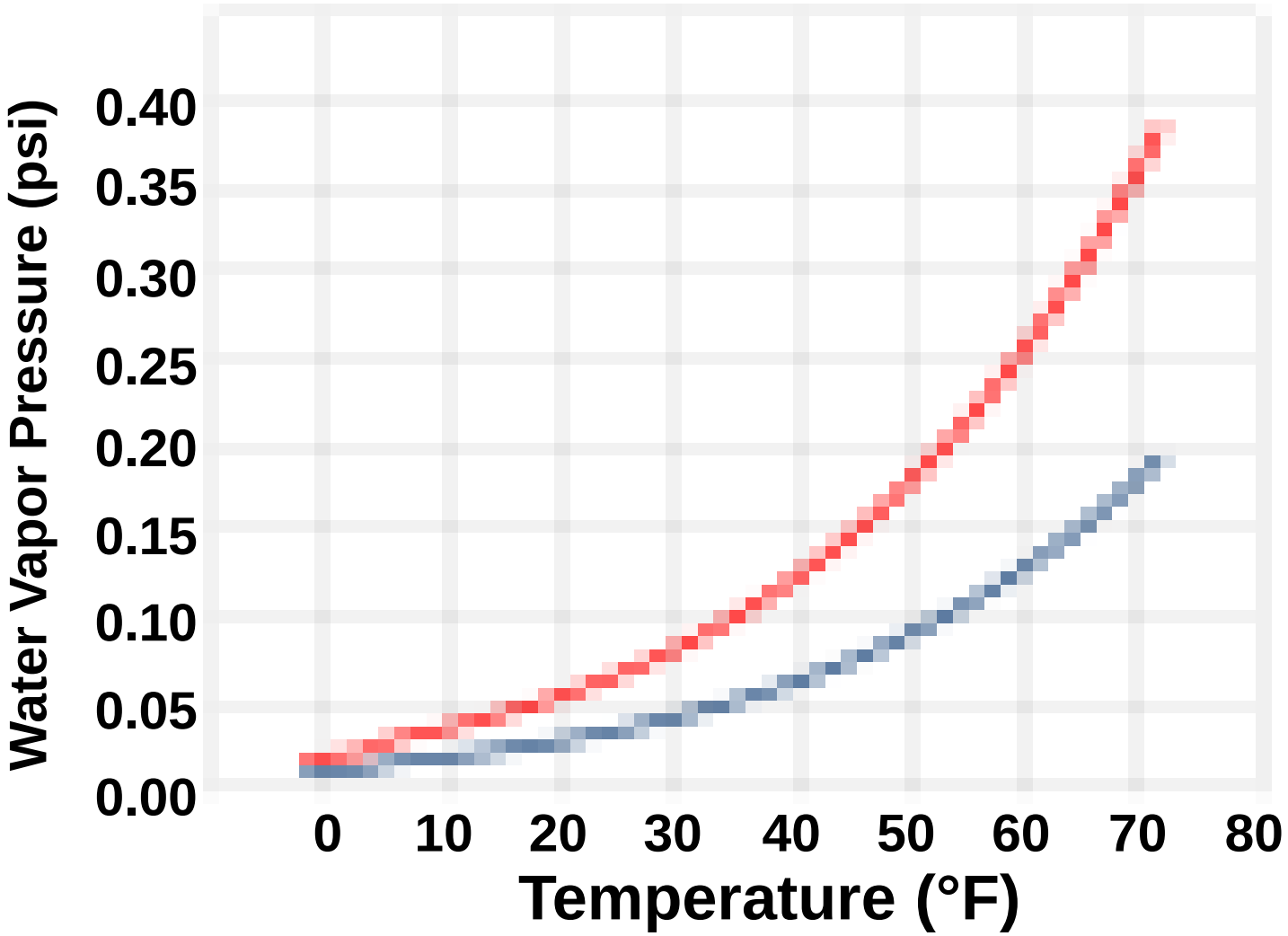
Two Sides of the Same Coin

Condensation: Wetting and Drying

Condensation: Dewpoint

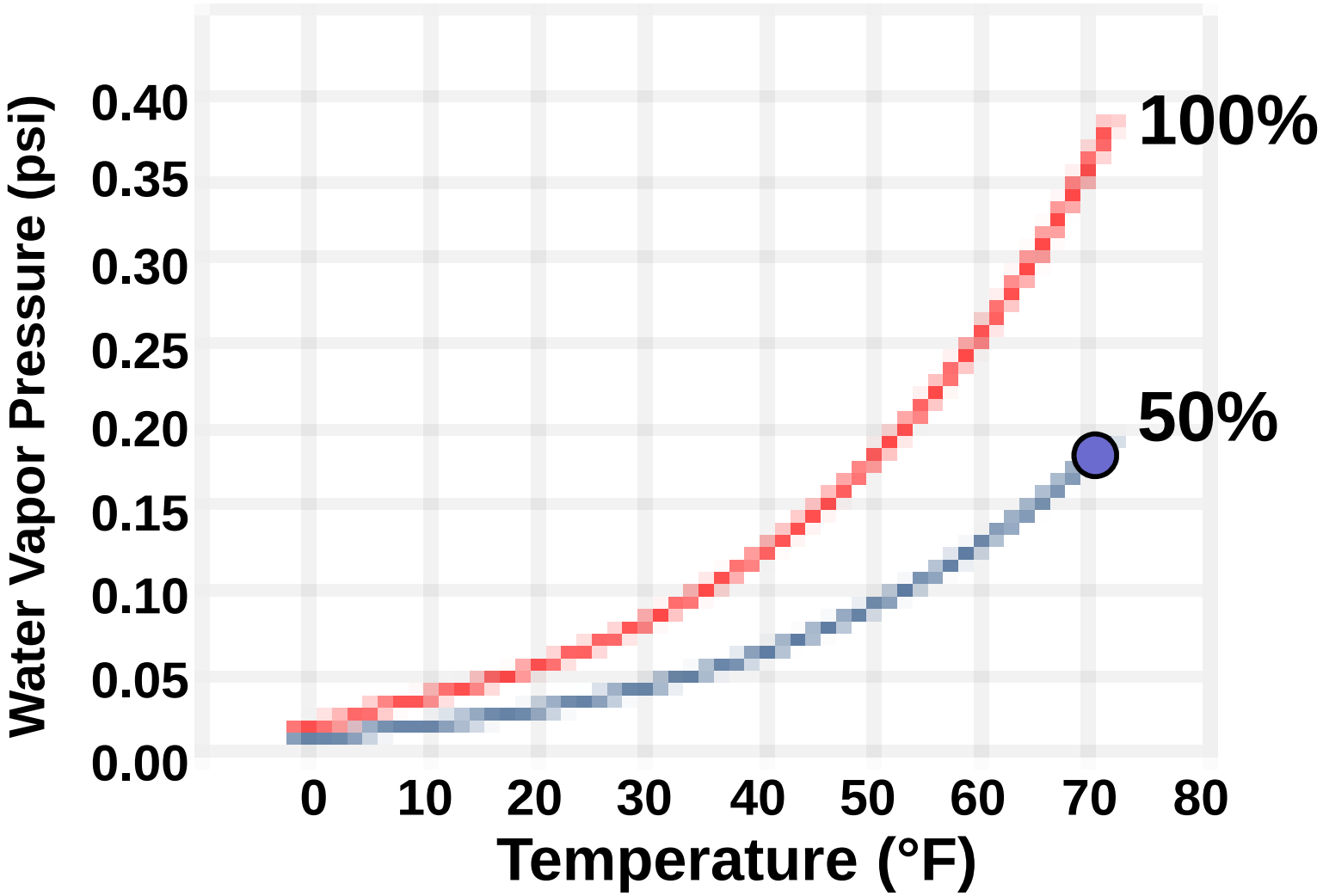
Condensation: Wetting and Drying

Condensation: Dewpoint



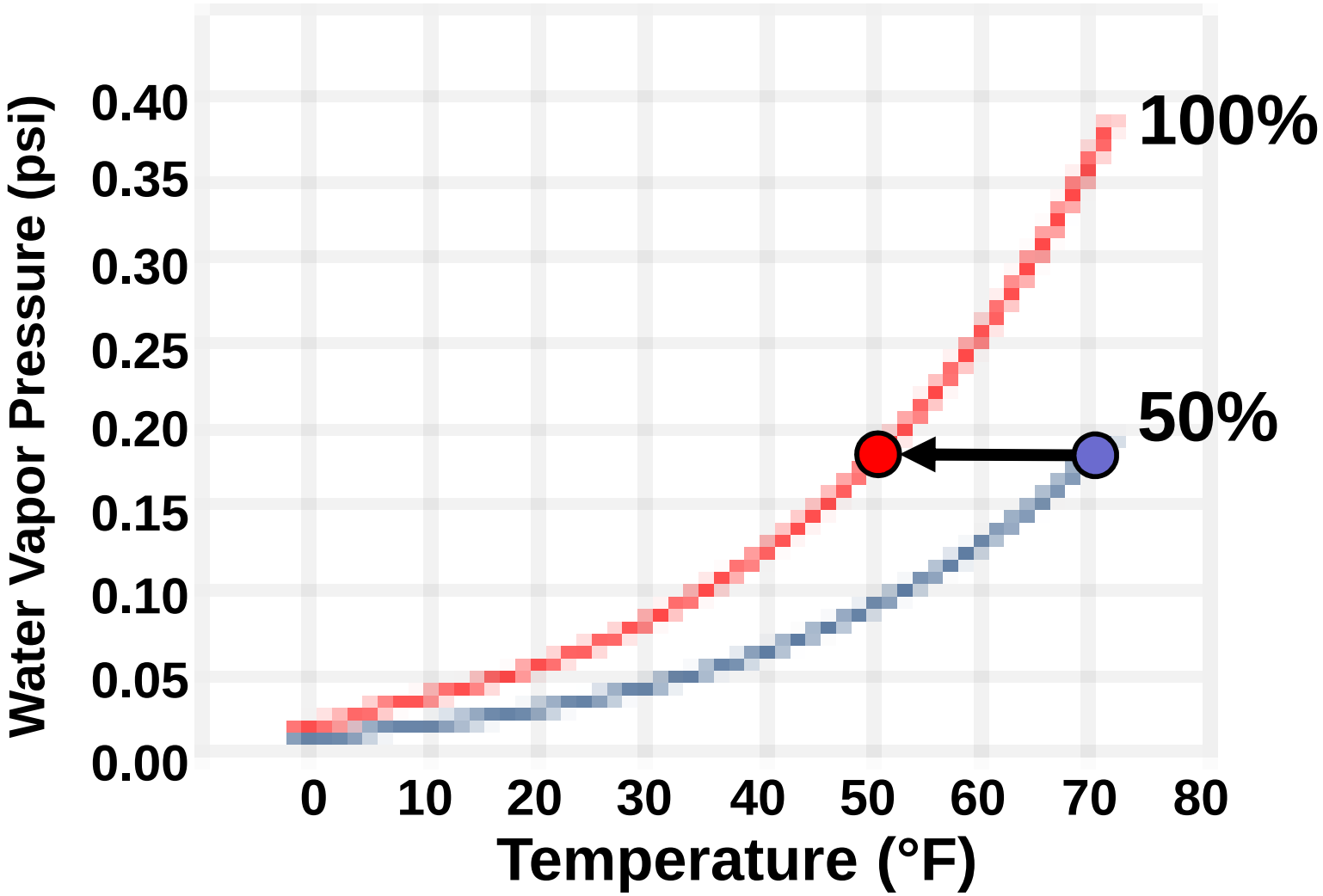
Condensation: Wetting and Drying

Condensation: Dewpoint



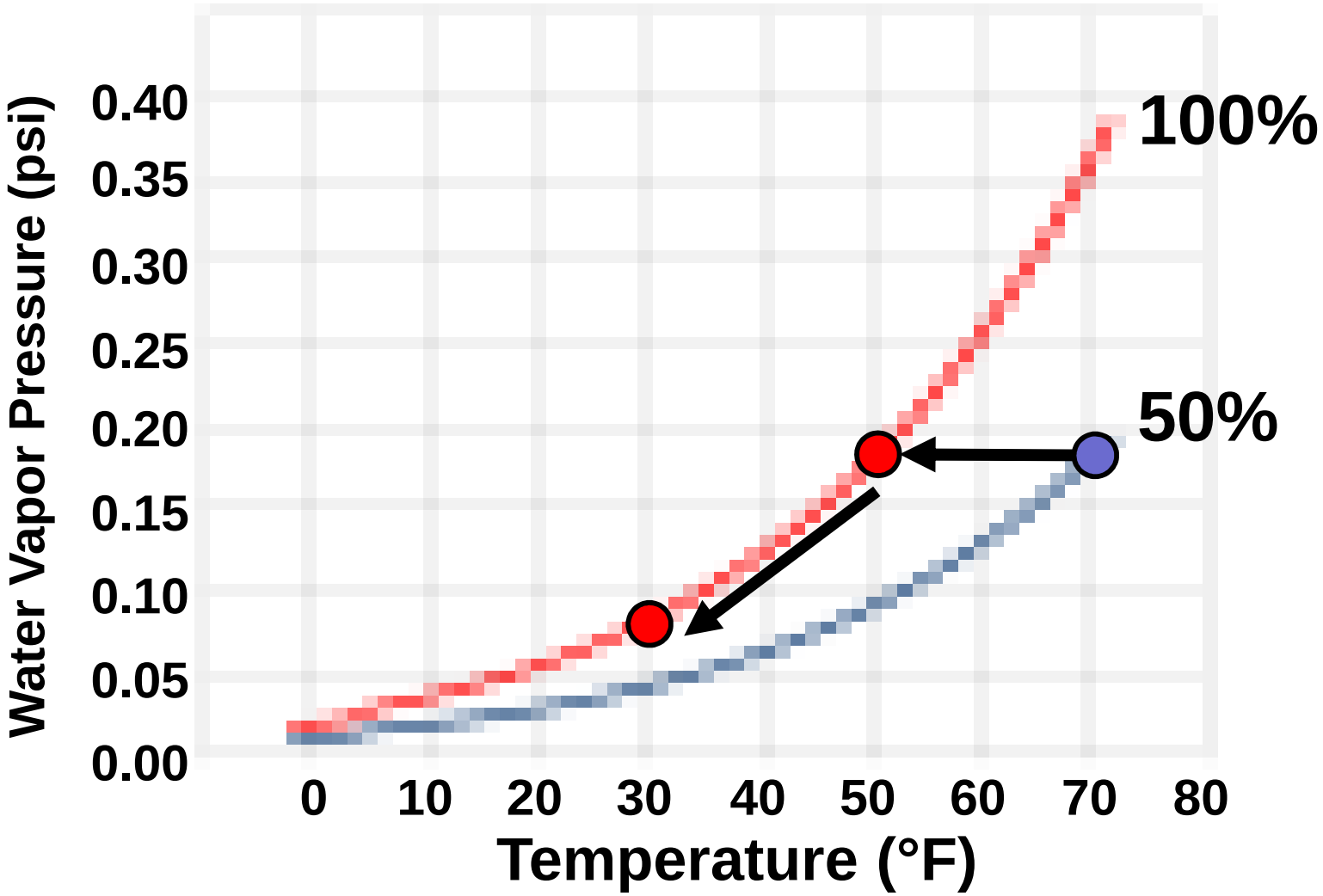
Condensation: Wetting and Drying

Condensation: Dewpoint



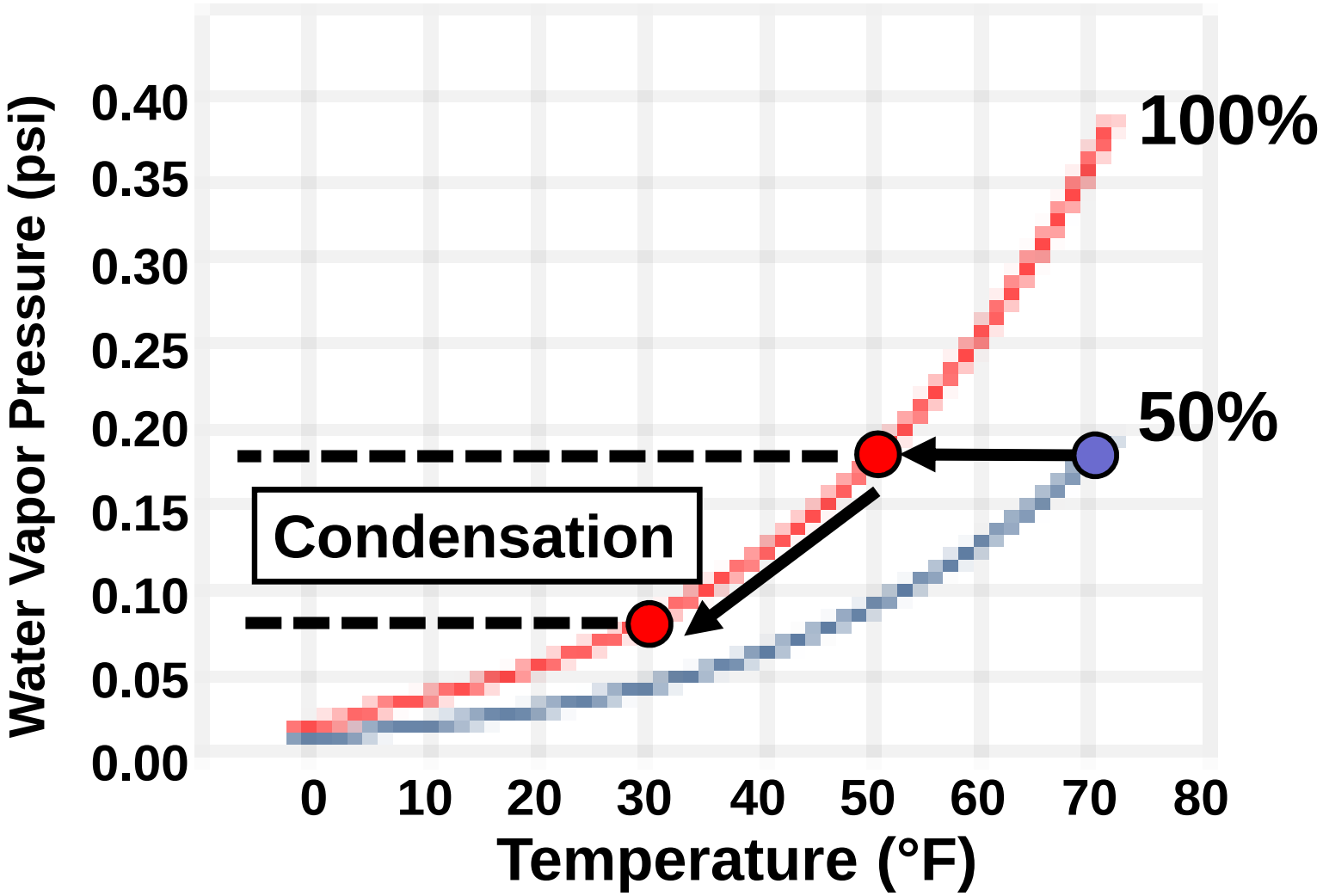
Condensation: Wetting and Drying

Condensation: Dewpoint



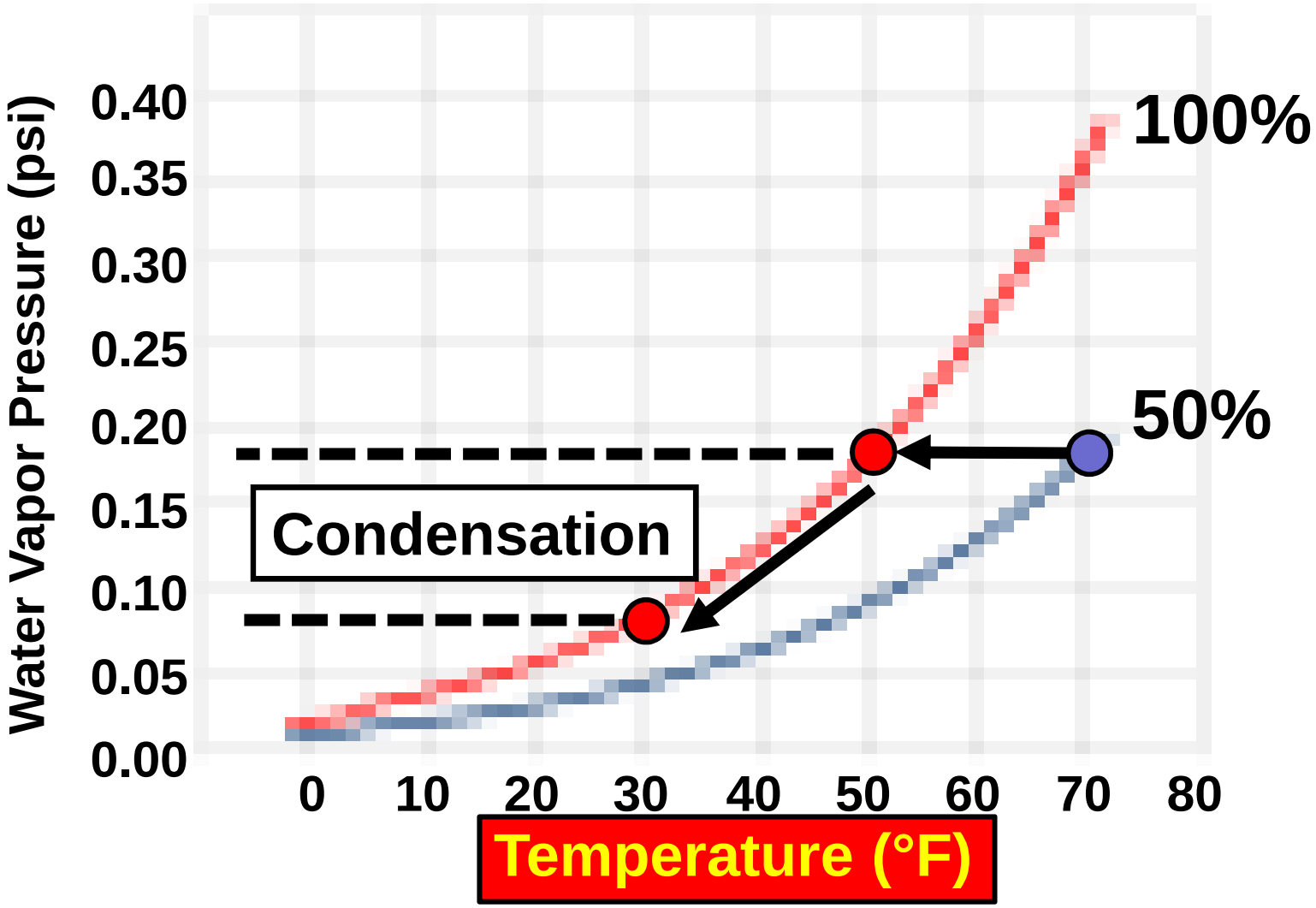
Condensation: Wetting and Drying

Condensation: Dewpoint



Condensation: Wetting and Drying

Condensation: Dewpoint



Condensation: Wetting and Drying

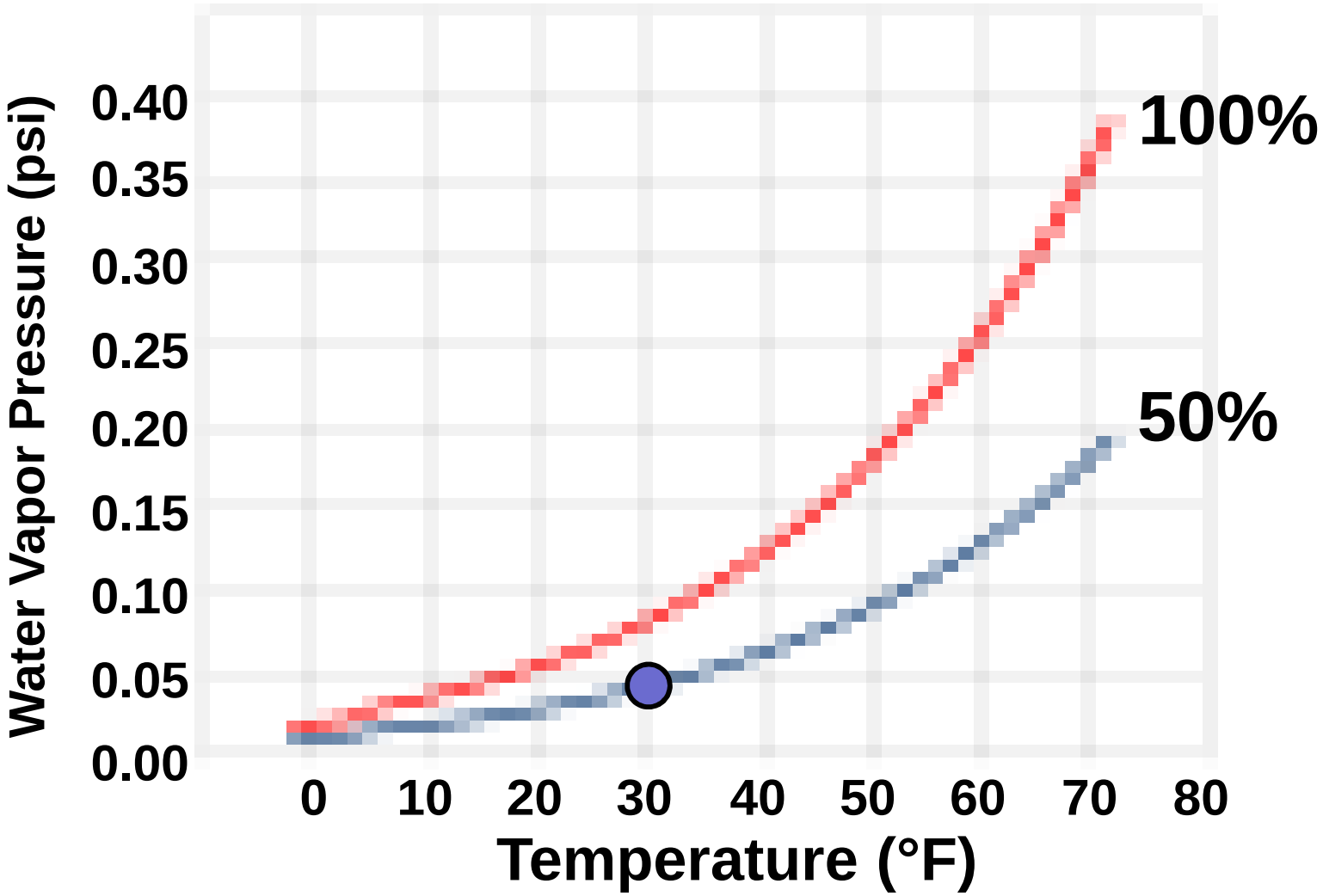
Drying: Evaporation

Condensation: Wetting and Drying

Two Sides of the Same Coin: Temperature

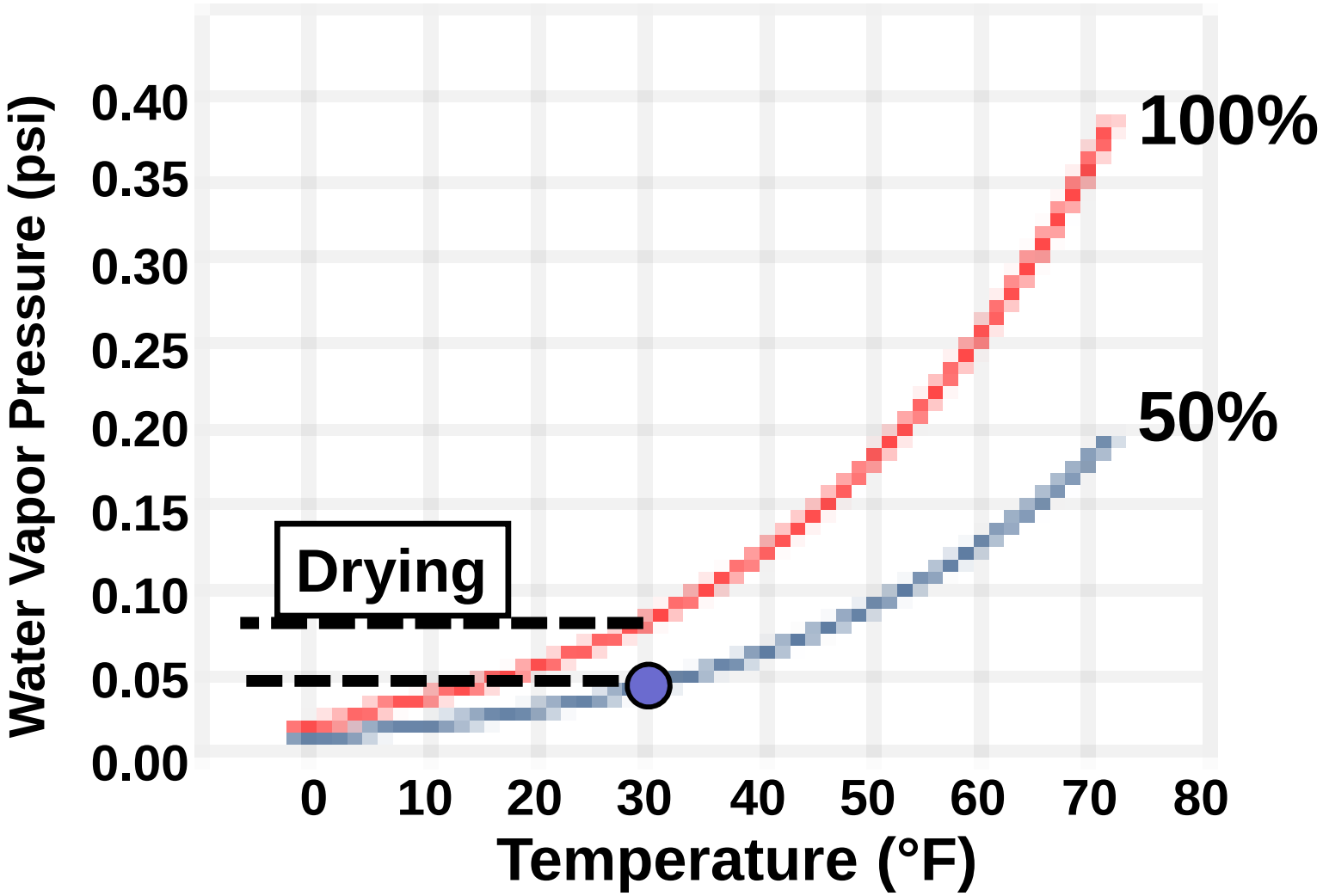
Condensation: Wetting and Drying

Drying: Evaporation



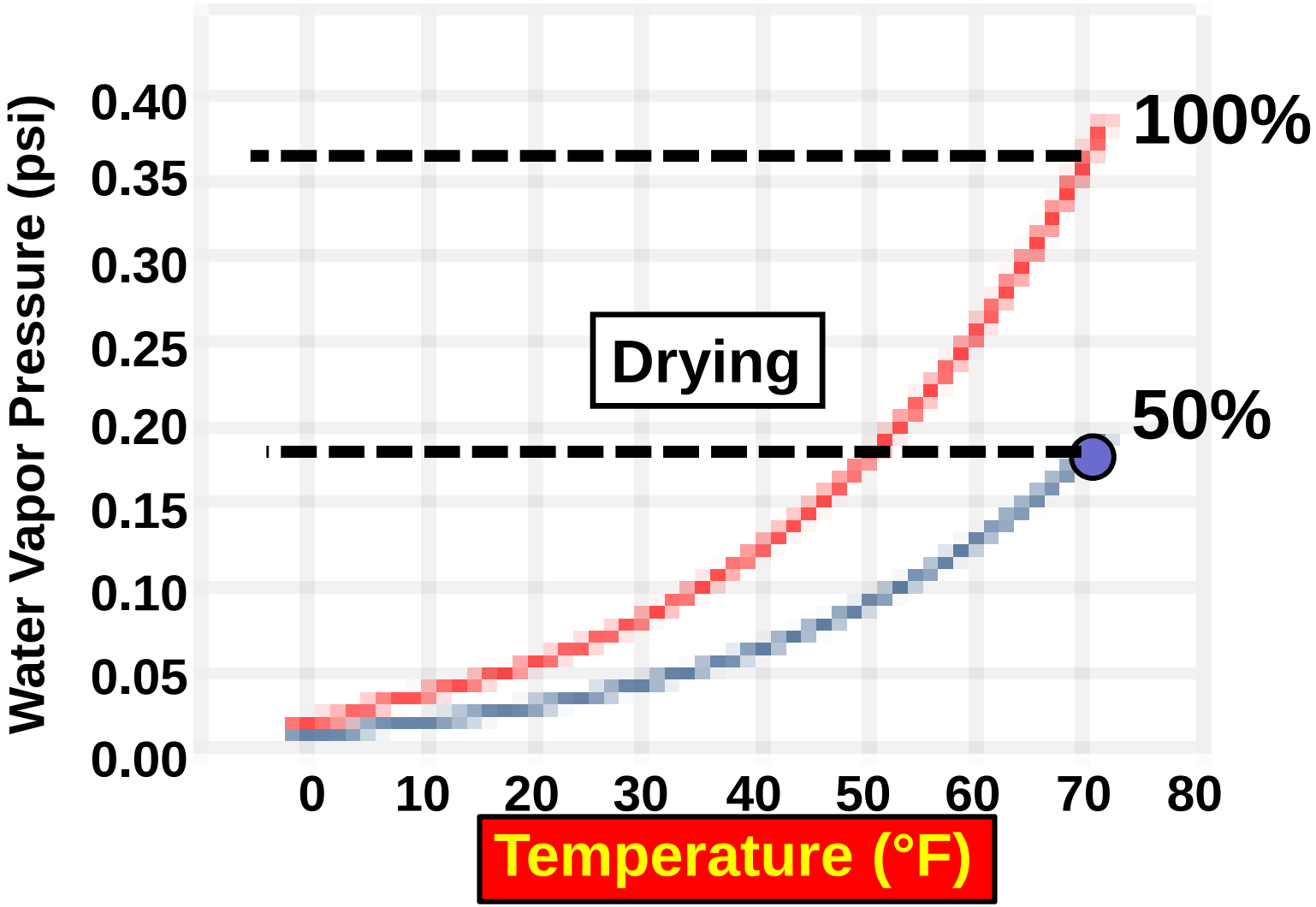
Condensation: Wetting and Drying

Drying: Evaporation



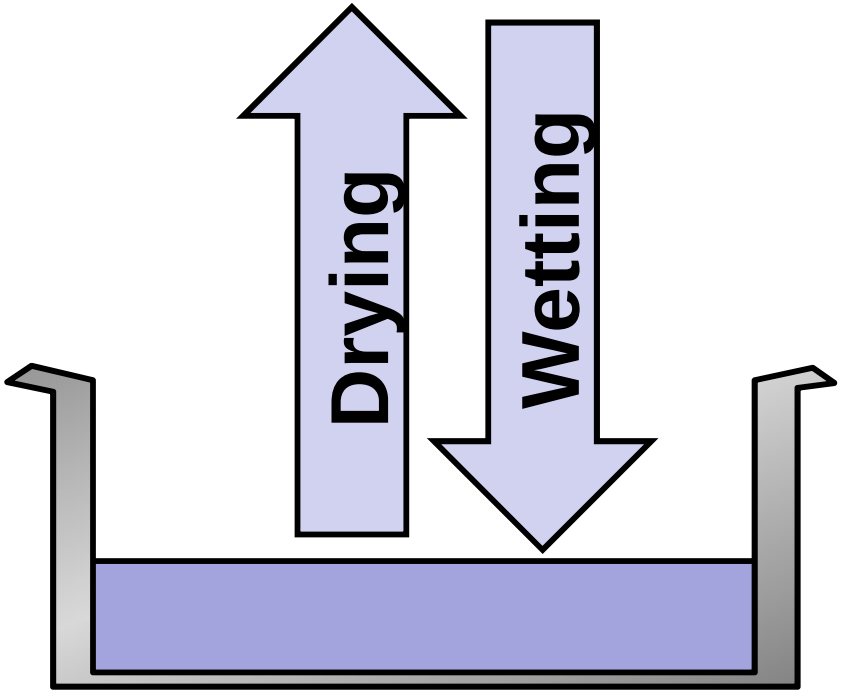
Condensation: Wetting and Drying

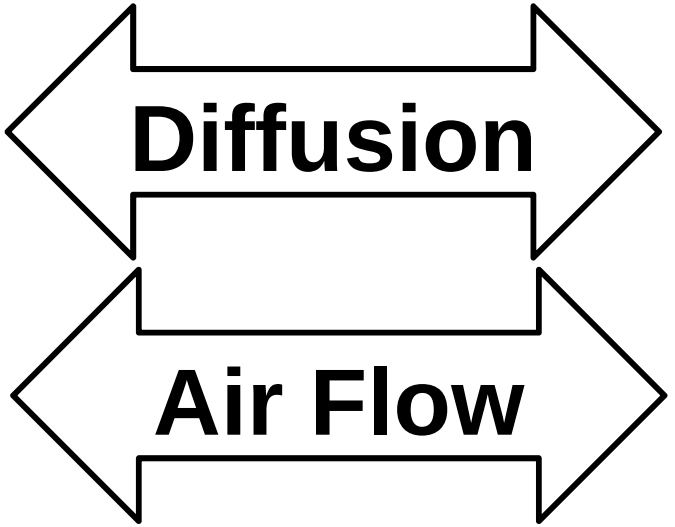
Drying: Evaporation



Condensation: Wetting and Drying

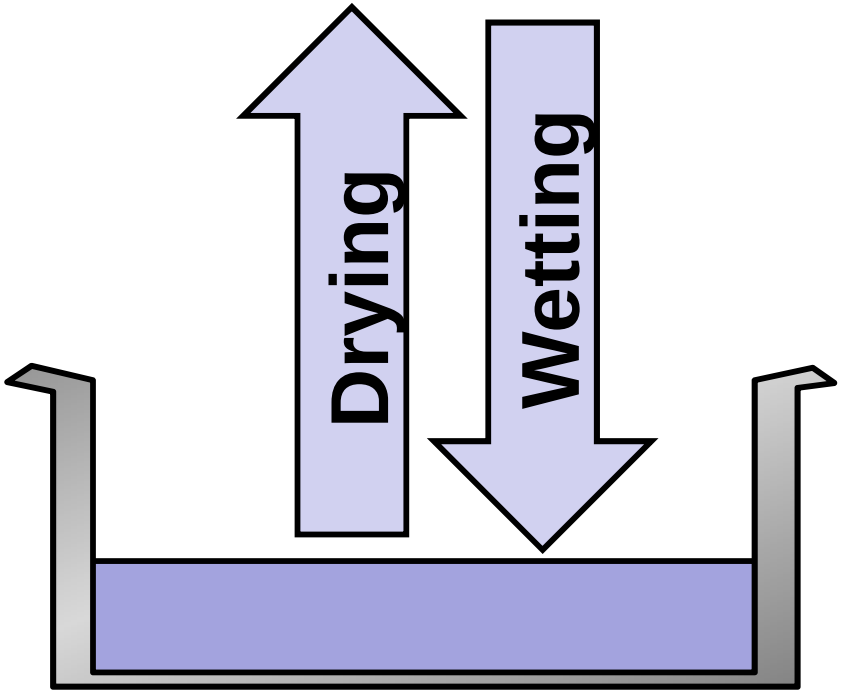
Two Phenomena coupled together

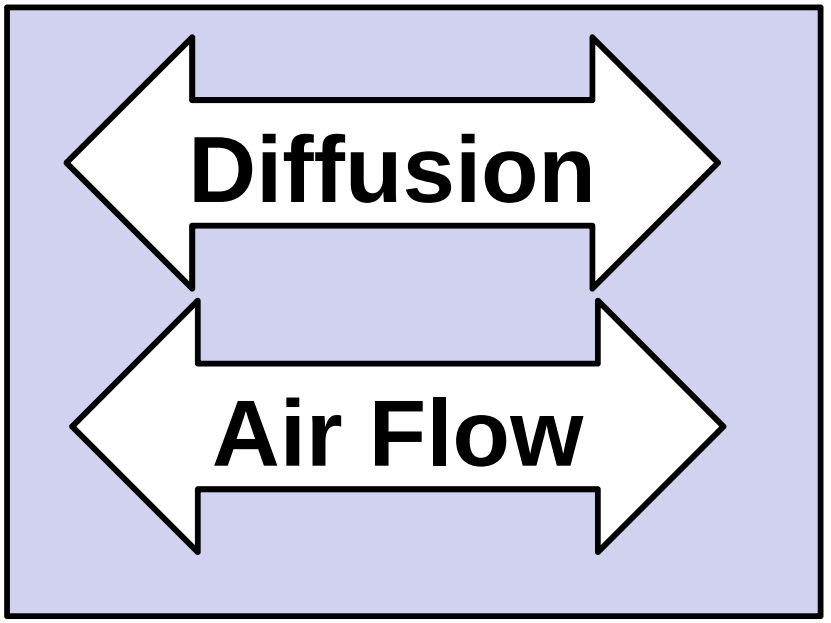




Condensation: Wetting and Drying

Two Phenomena coupled together



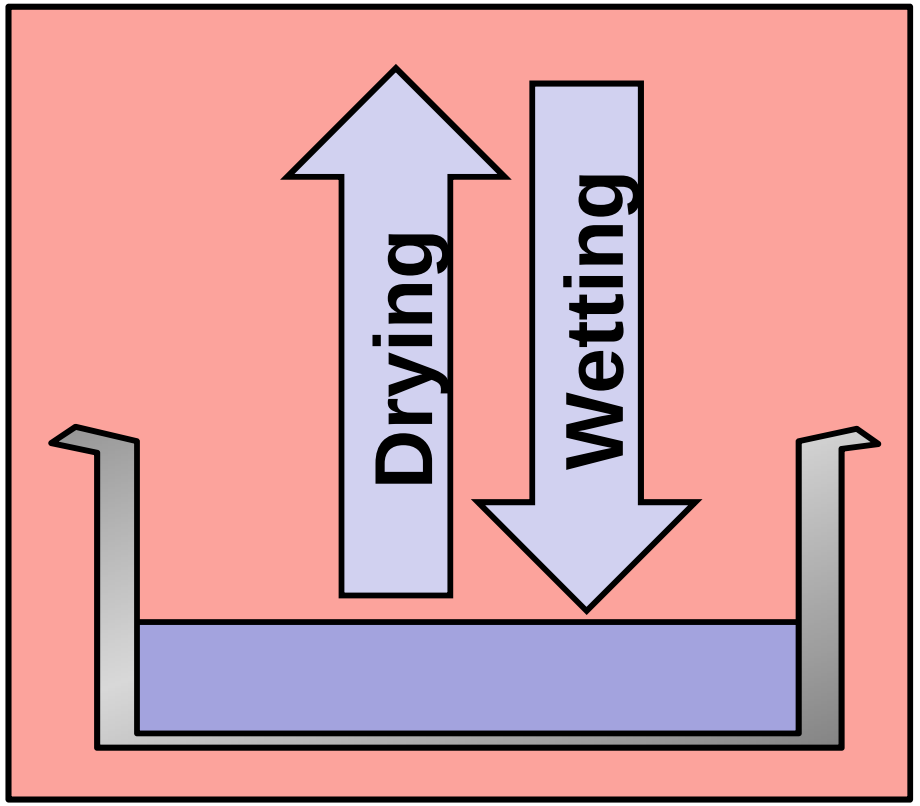


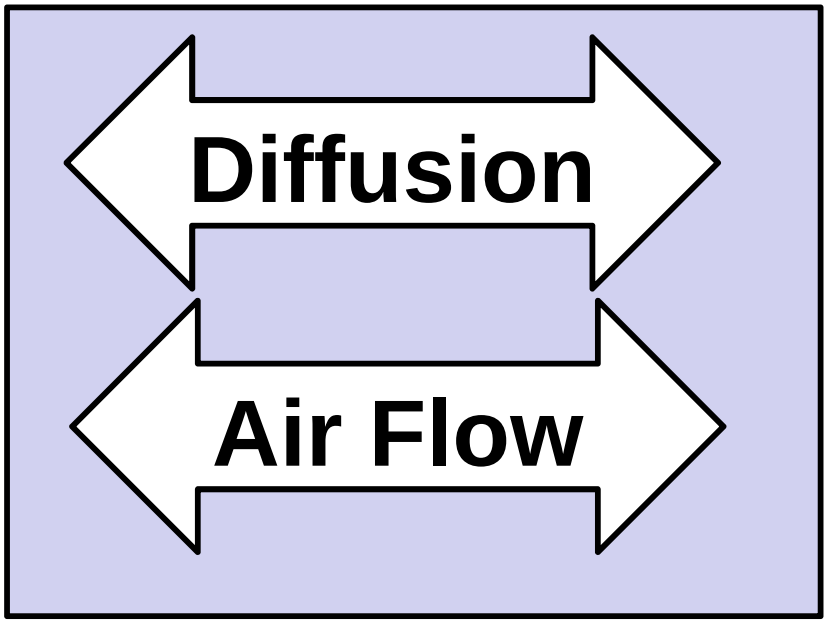
Permeability
Infiltration

Condensation: Wetting and Drying

Two Phenomena coupled together

Temperature





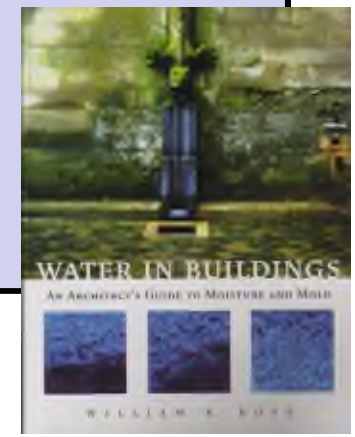
Permeability
Infiltration

Condensation: Wetting and Drying

Myth of Breathability

"The vapor retarder also seems to have served yeoman's duty in keeping the thoughts of the public and the construction industry off the subject of thermal wetting."

William Rose, Water in Buildings



Condensation: Wetting and Drying

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- Straube, 2002, The Influence of Low Permeance Vapor Barriers on Roof and Wall Performance, Buildings VIII
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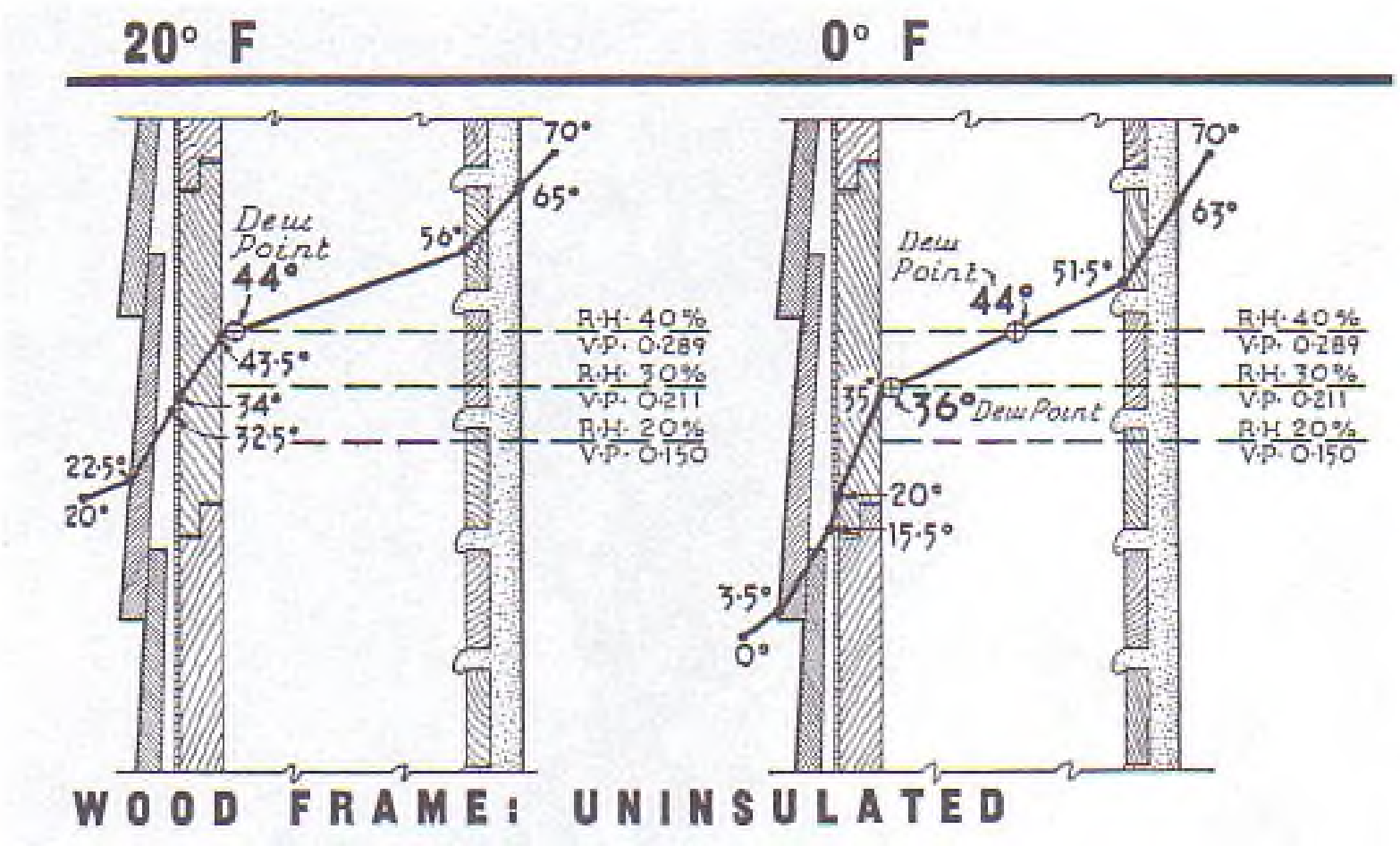
Condensation: The Real Story

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

Condensation: Analyzing Assemblies

Profile Method

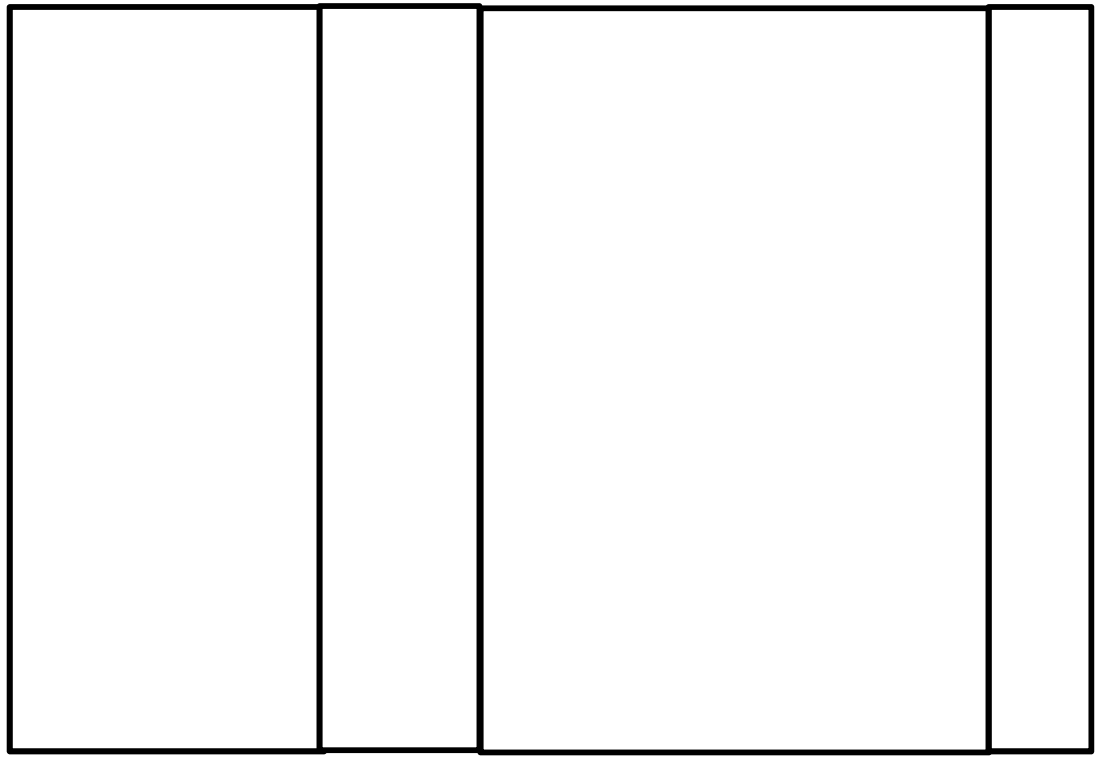


Teesdale, 1938 (Water in Buildings, Rose)

Condensation: Analyzing Assemblies

Profile Method: Temperature

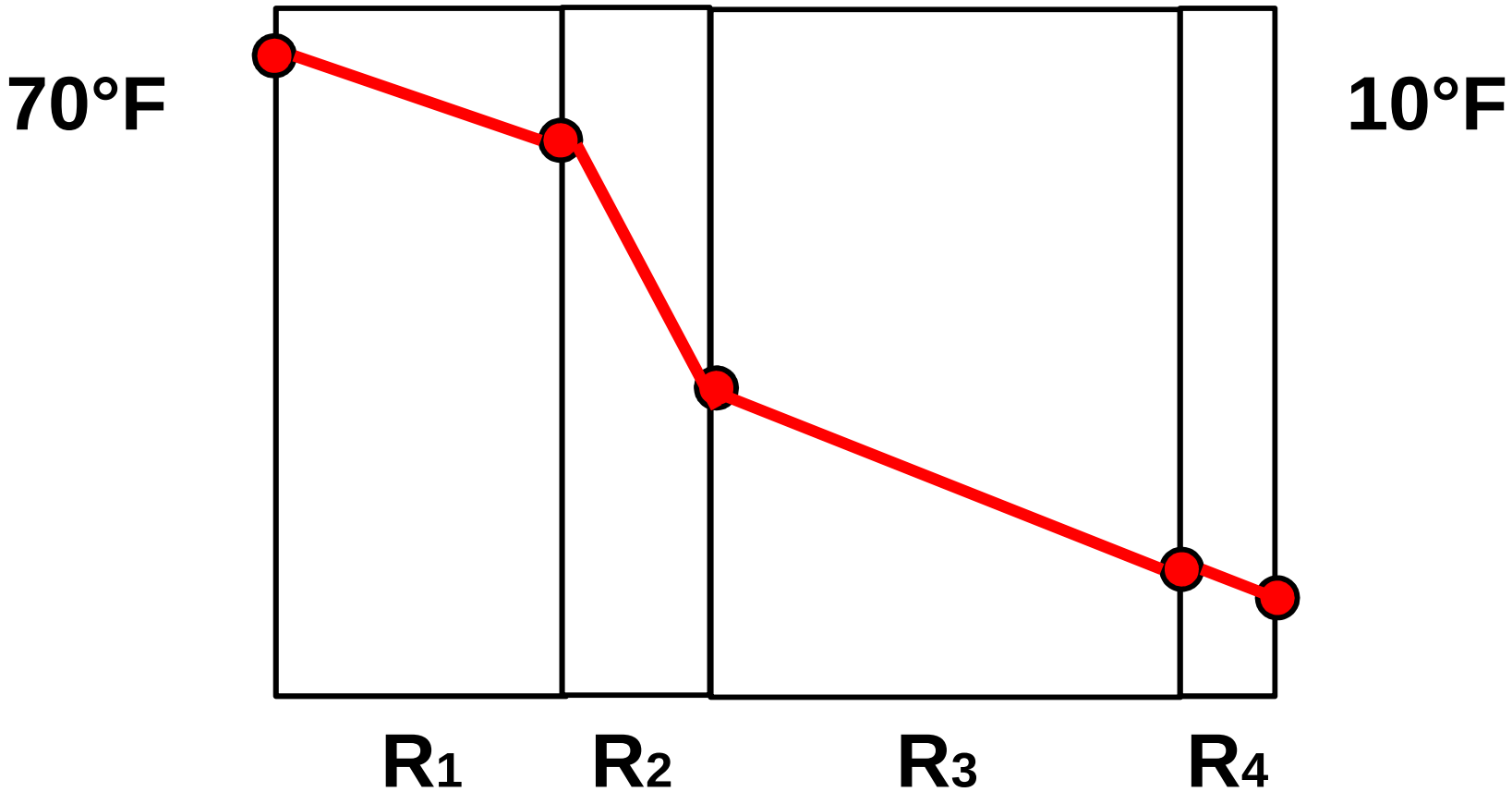
70°F



10°F

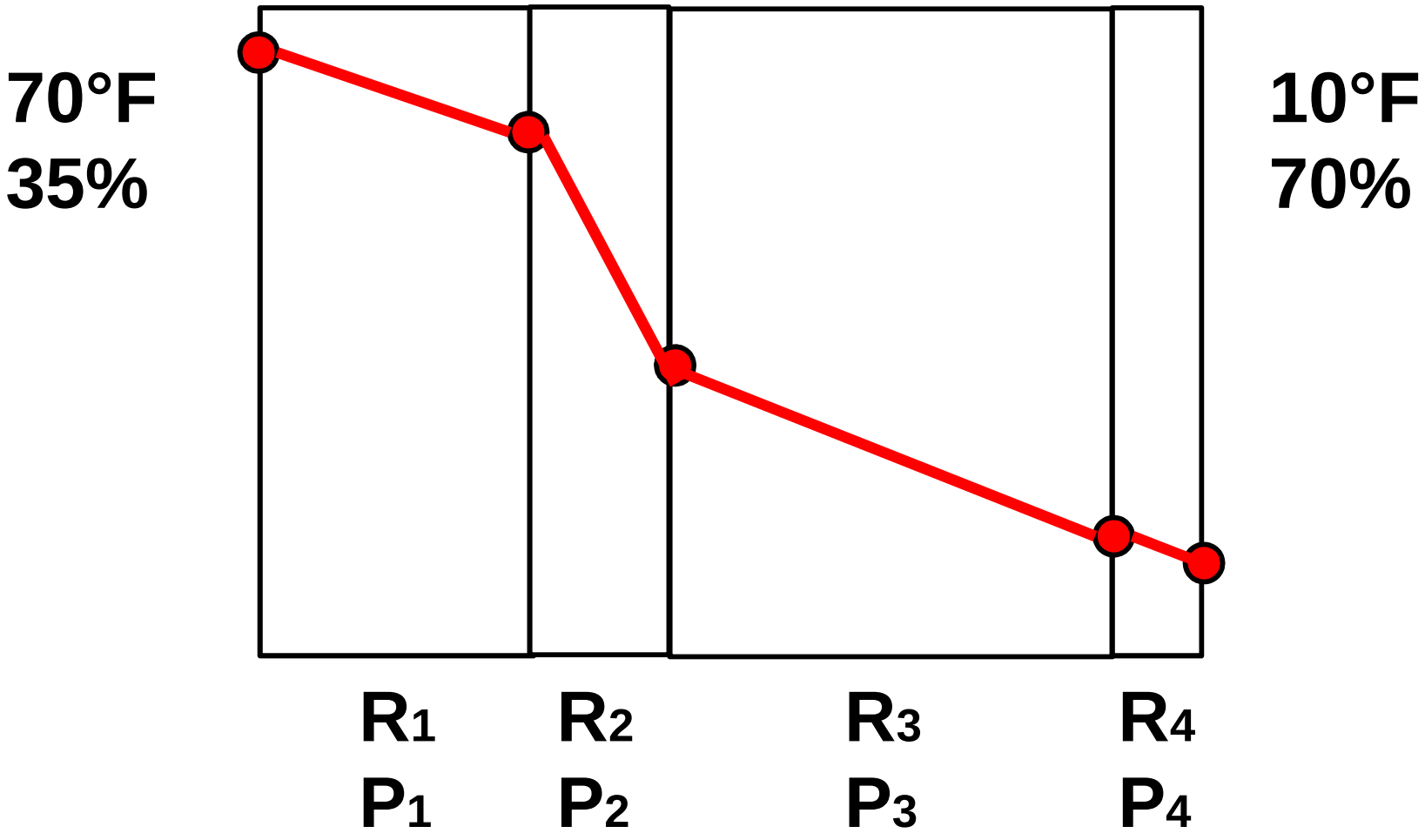
Condensation: Analyzing Assemblies

Profile Method: Temperature



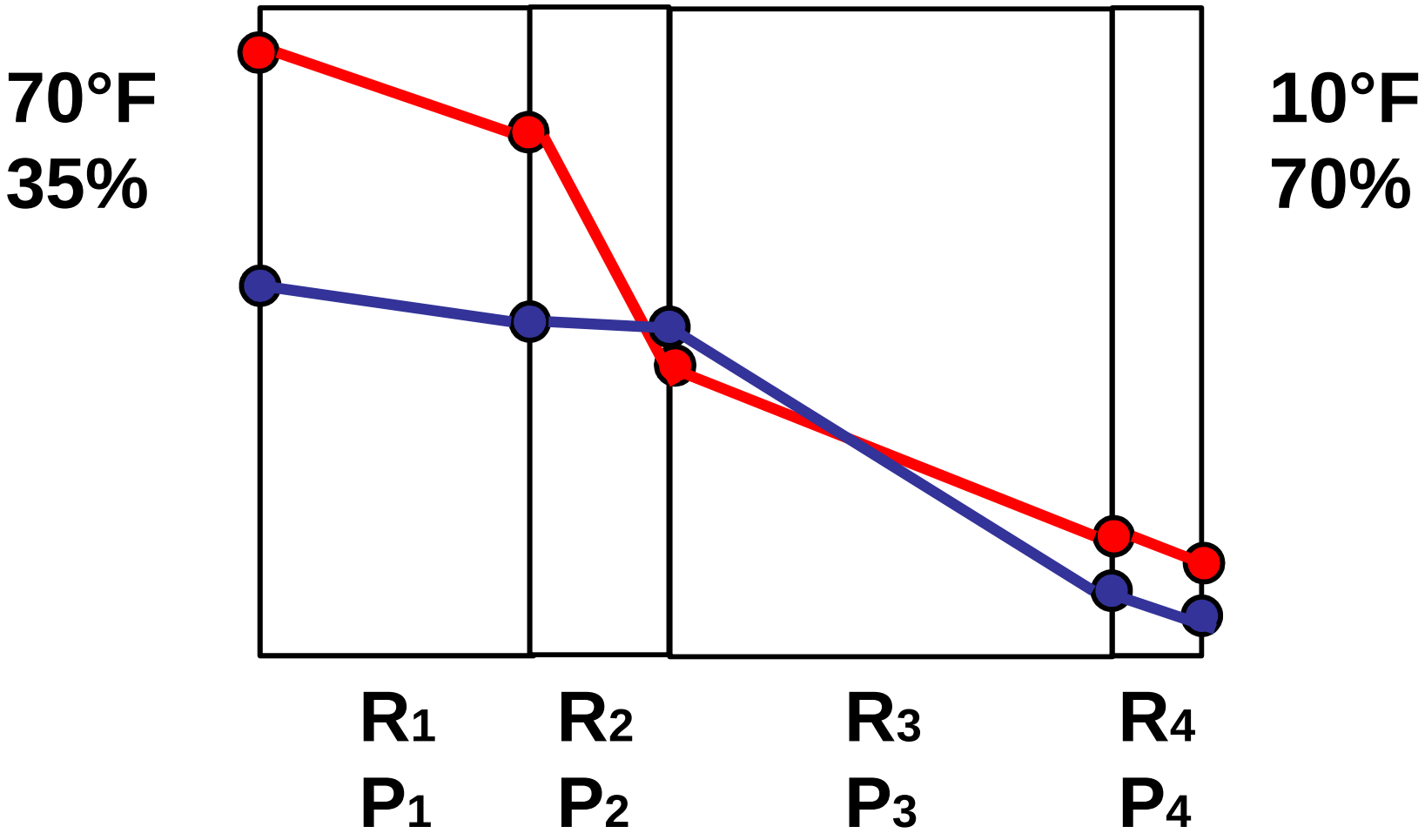
Condensation: Analyzing Assemblies

Profile Method: Temperature



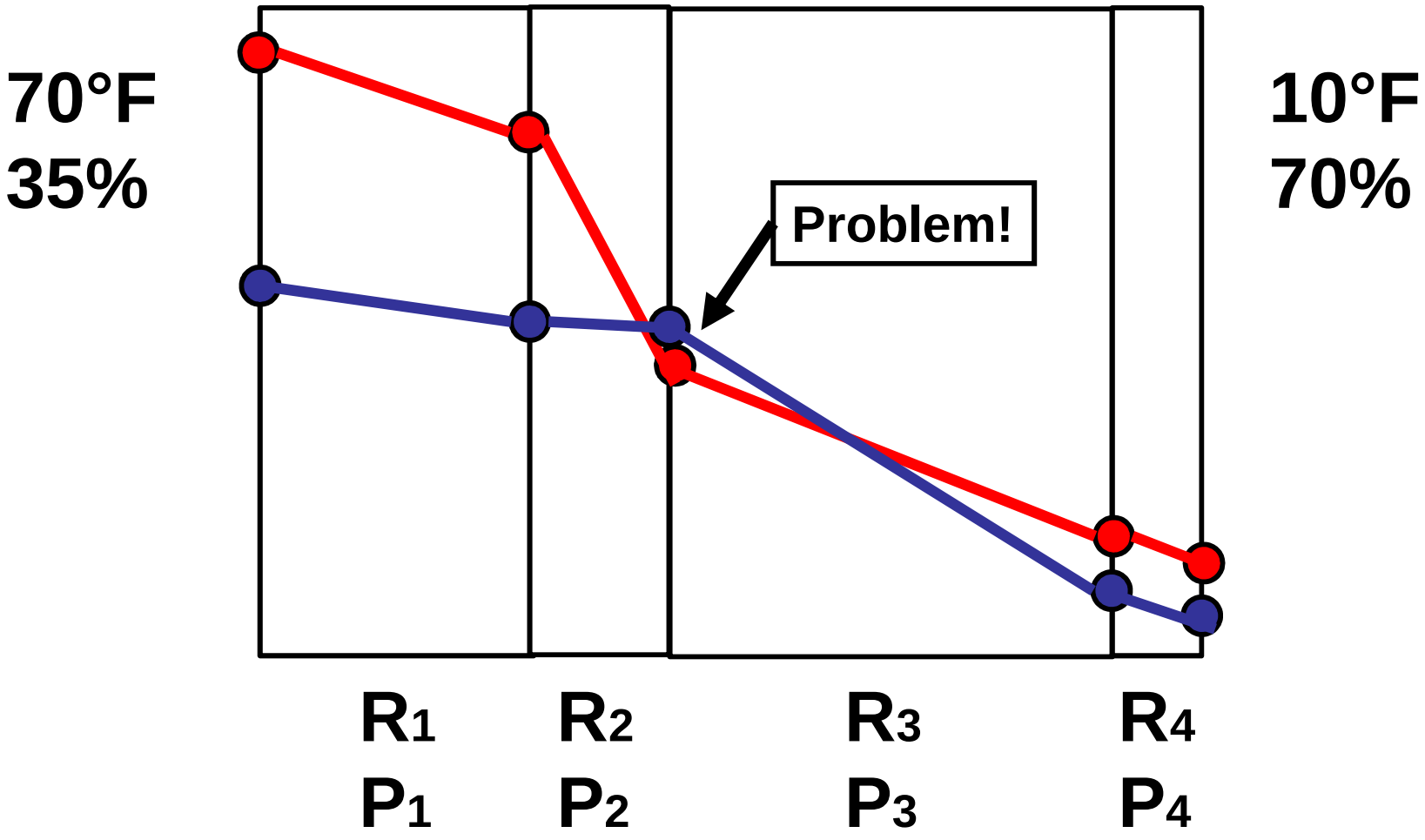
Condensation: Analyzing Assemblies

Profile Method: Temperature



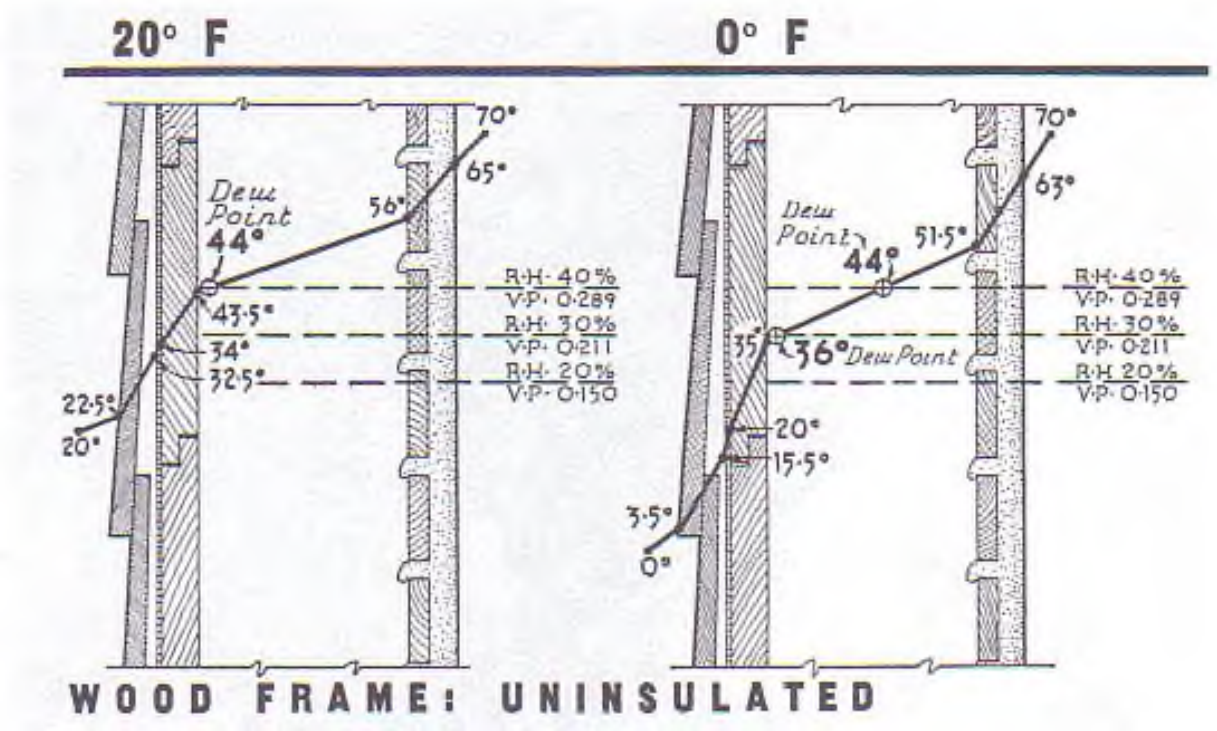
Condensation: Analyzing Assemblies

Profile Method: Temperature



Condensation: Analyzing Assemblies

Profile Method: Limitations



No infiltration

Not dynamic

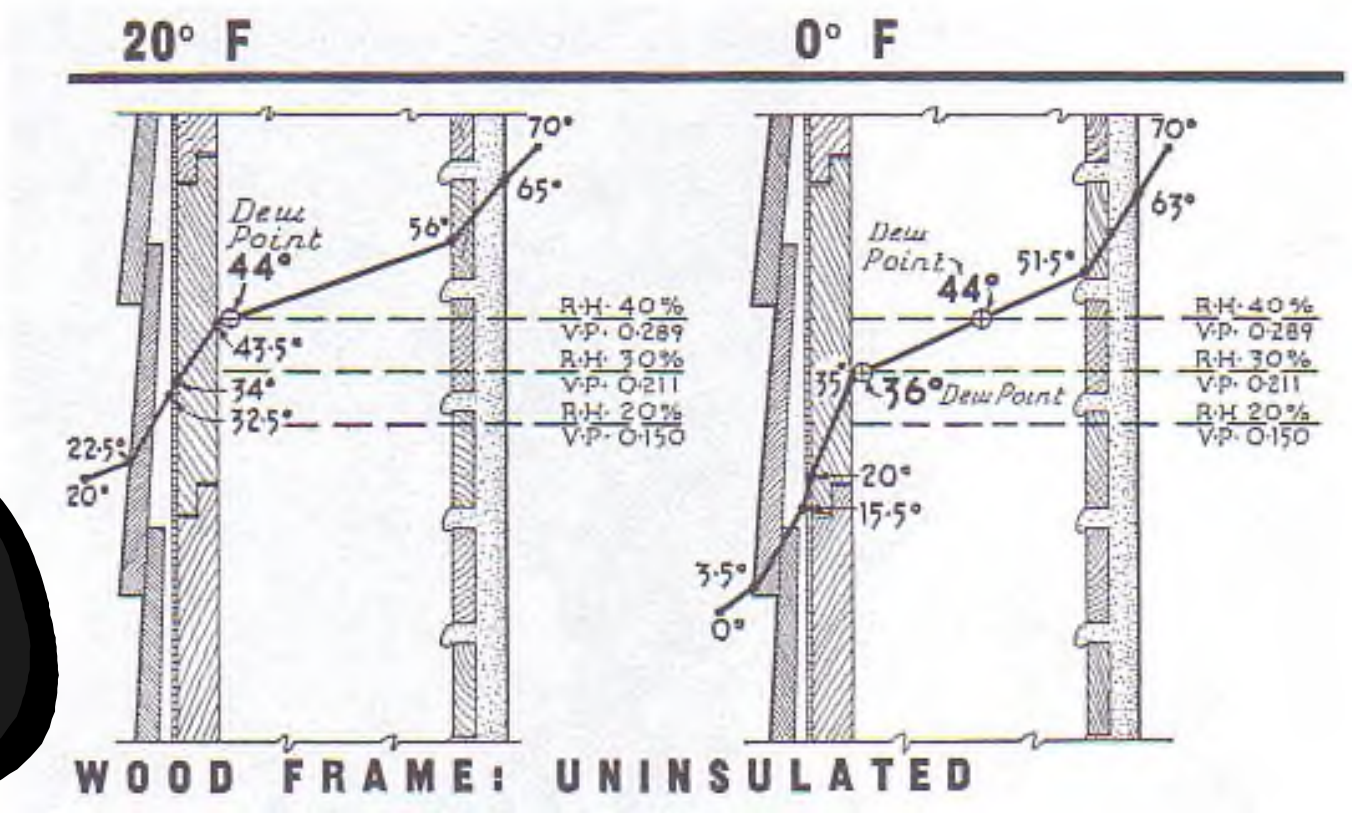
No Water movement

RH or Temperature Dependencies

Adsorption

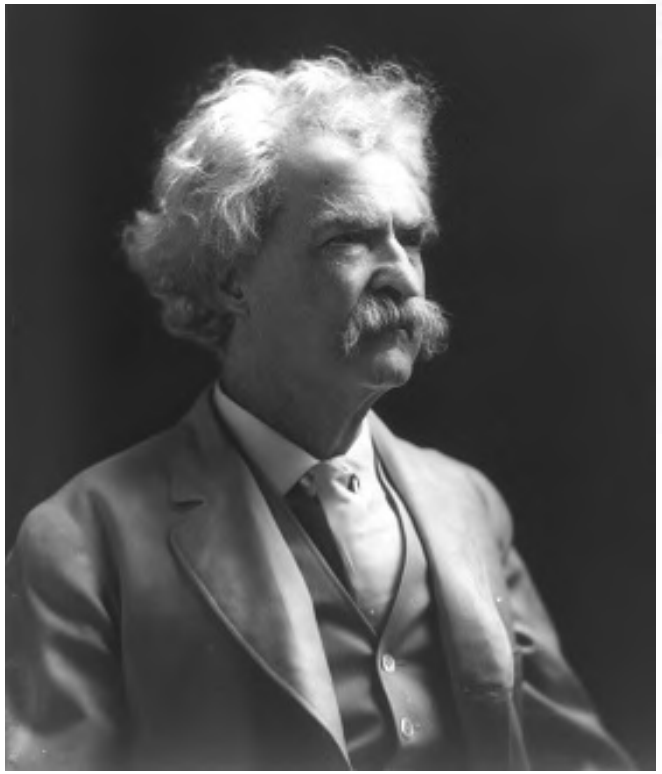
Condensation: Analyzing Assemblies

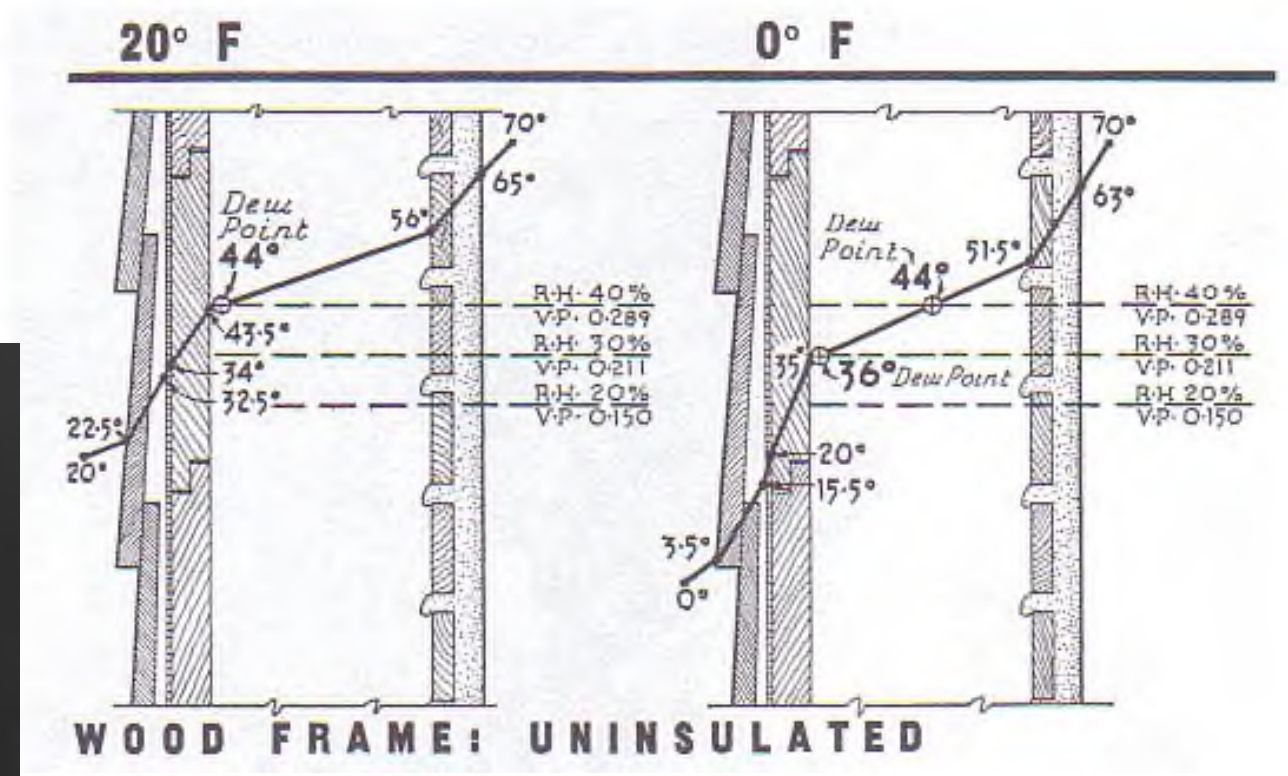
Profile Method



Condensation: Analyzing Assemblies

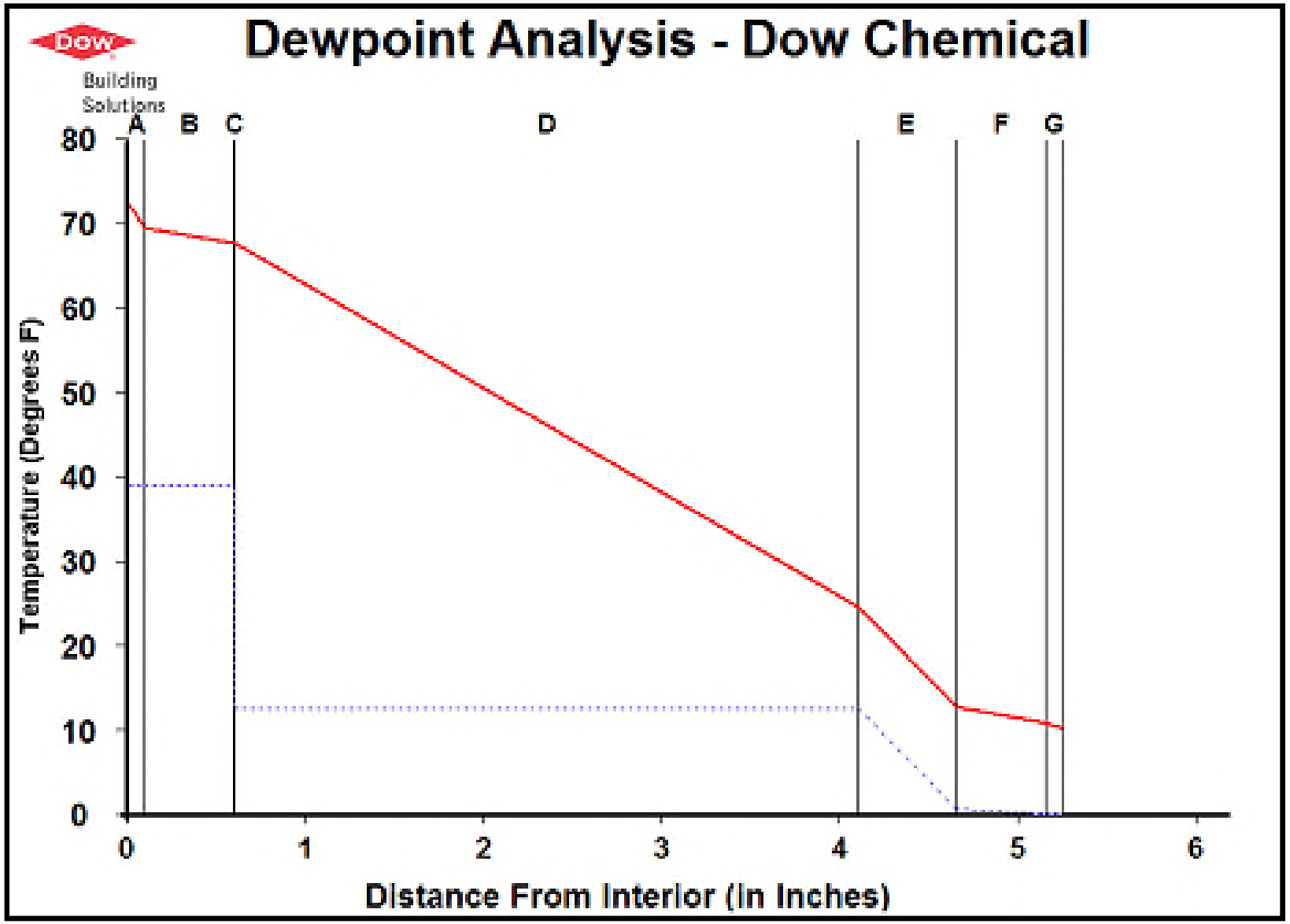
Profile Method





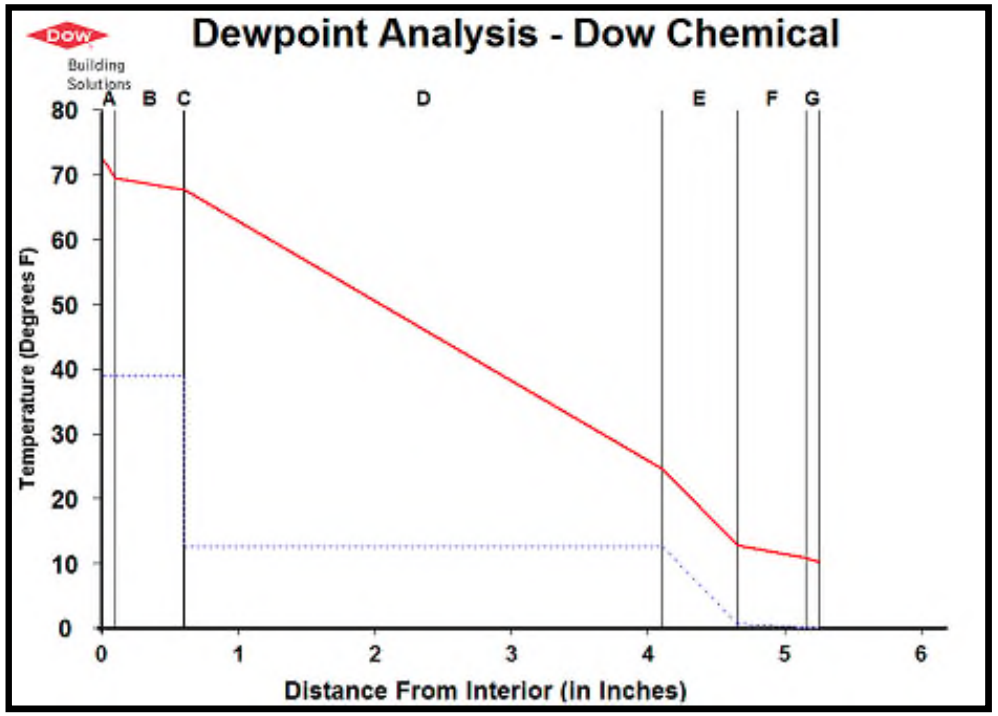
Condensation: Analyzing Assemblies

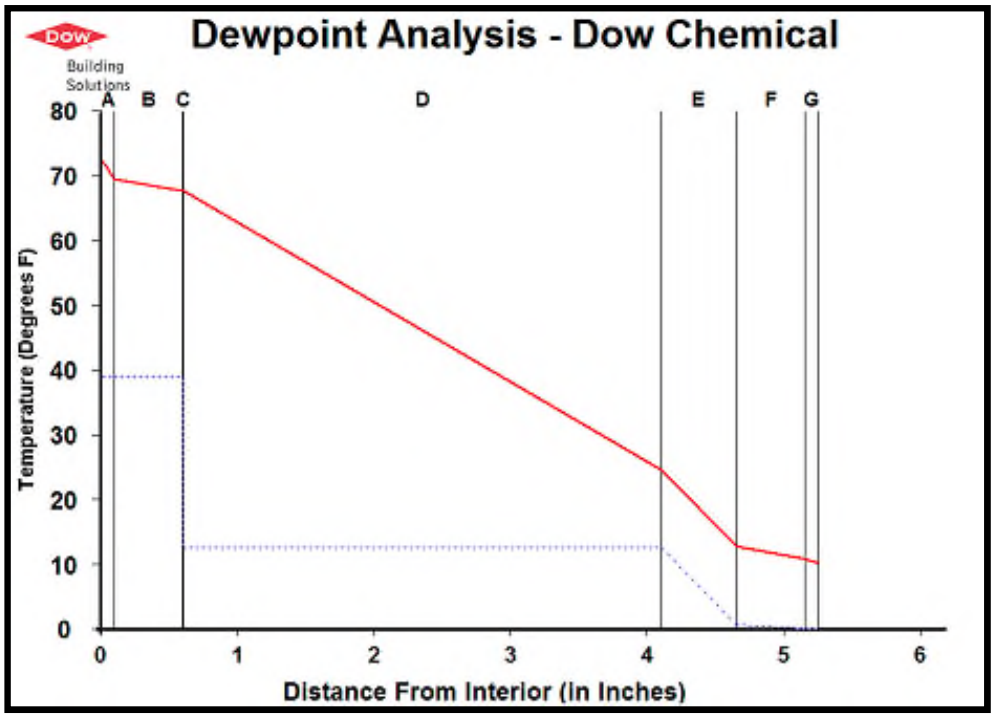
Profile Method



Condensation: Analyzing Assemblies

Profile Method

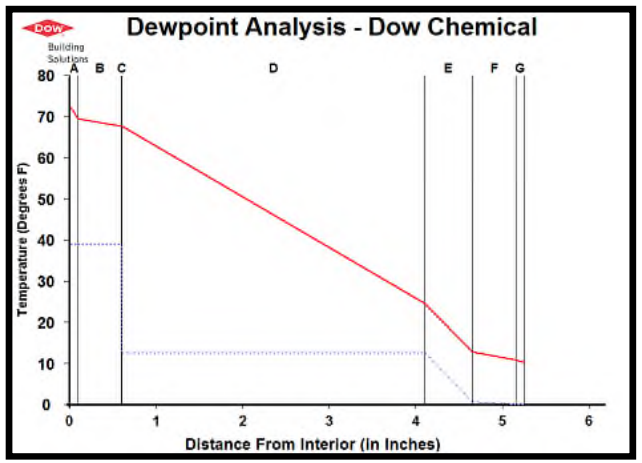


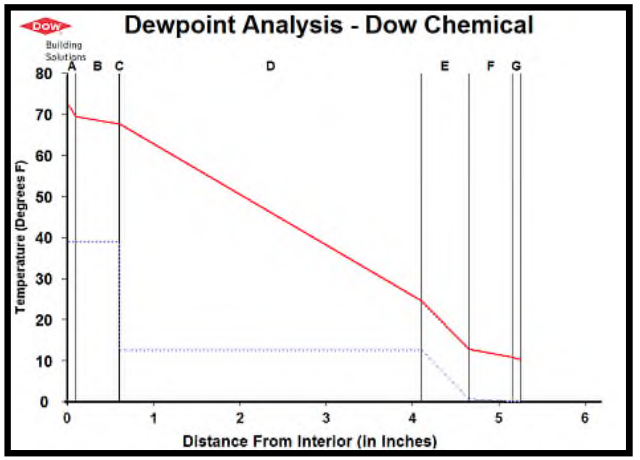


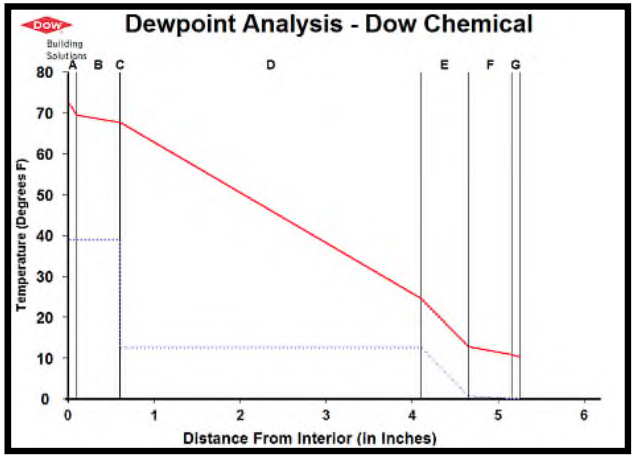
Compare Assemblies

Condensation: Analyzing Assemblies

Profile Method







"The results from transient modeling do a much better job of replicating physical processes. They have entirely supplanted the profile method as a design tool. This comes at the expense, however, of tinkering."

William Rose, Water in Buildings

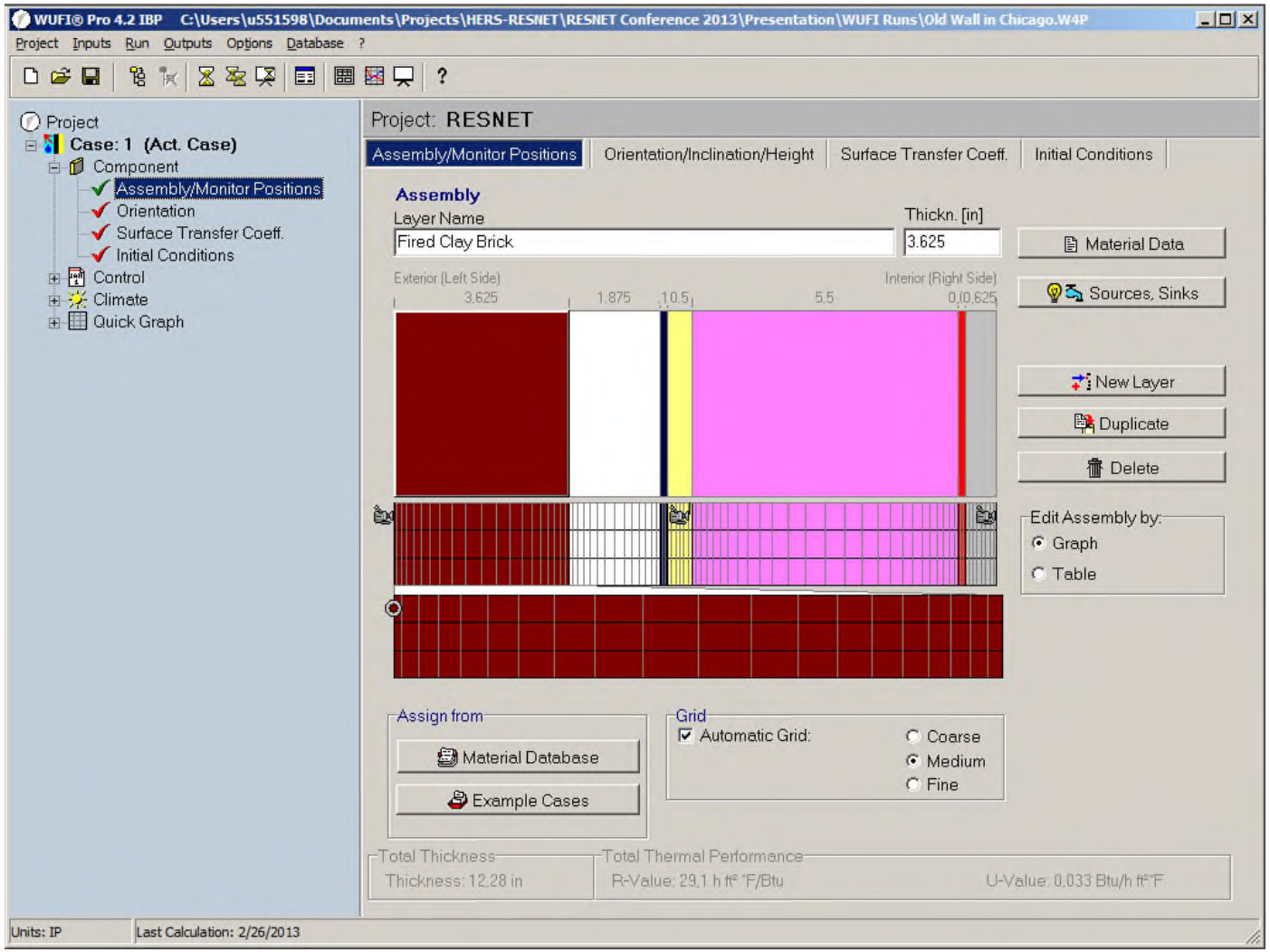
Condensation: Analyzing Assemblies

WUFI Method

Oak Ridge National Laboratory (ORNL)/Fraunhofer IBP

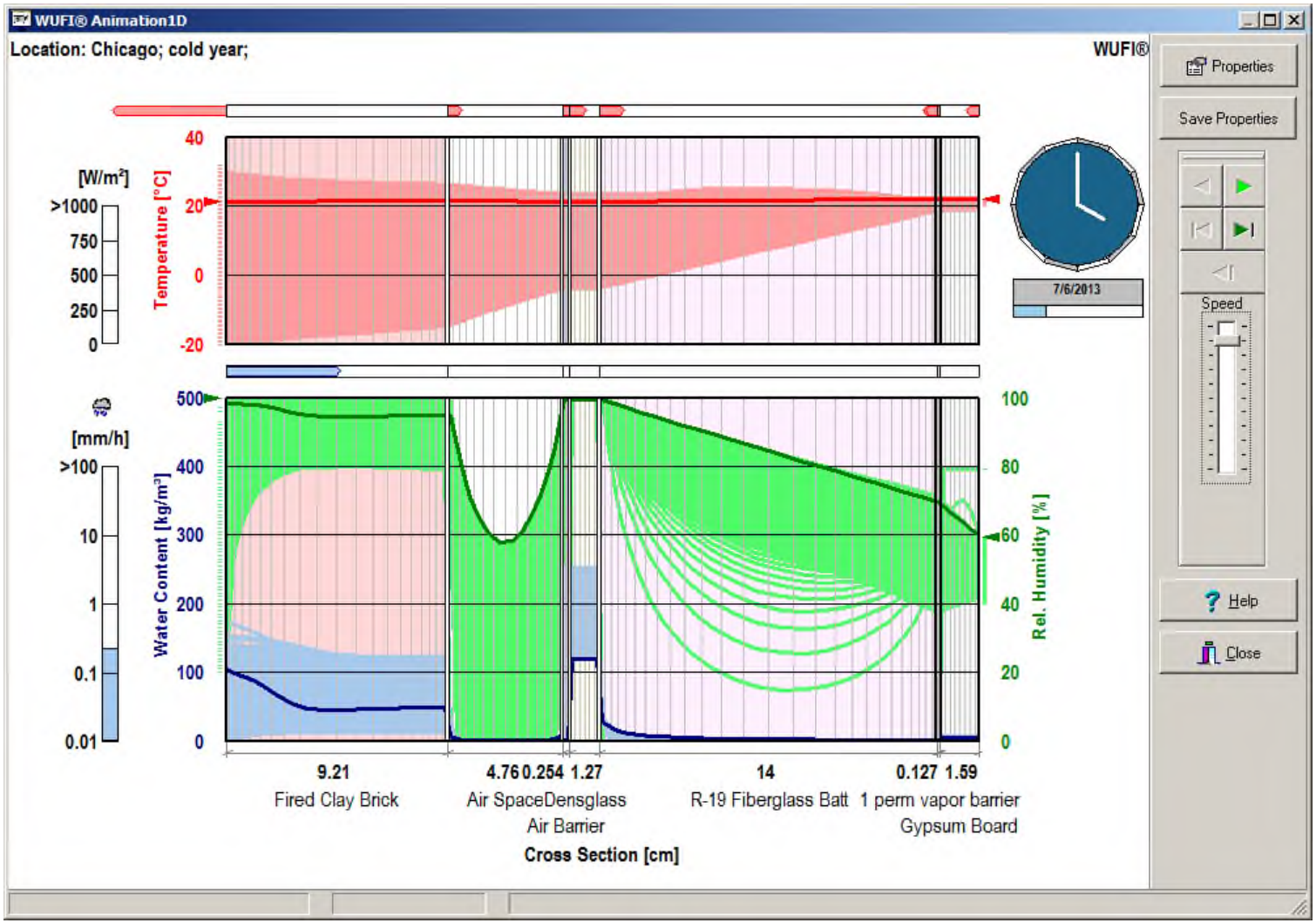
Condensation: Analyzing Assemblies

WUFI Method



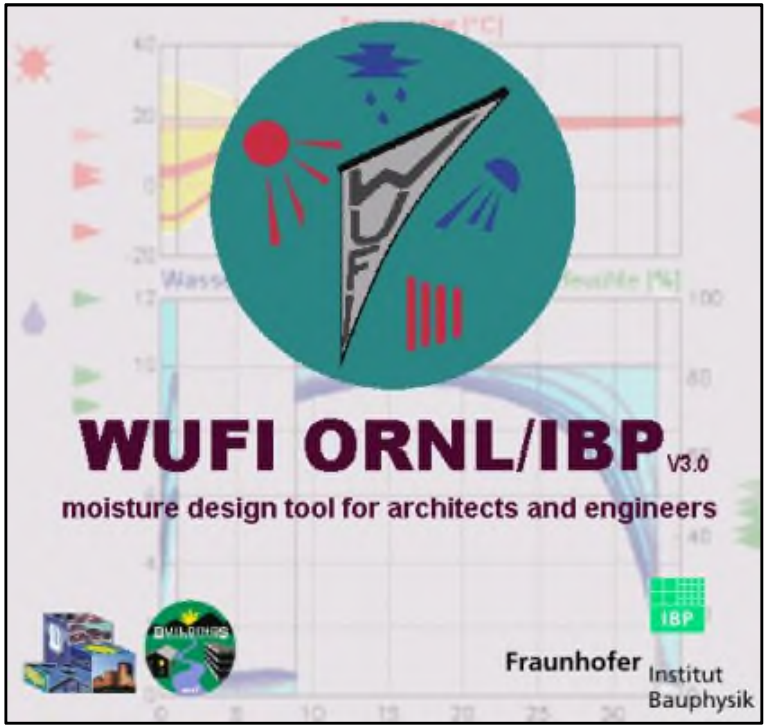
Condensation: Analyzing Assemblies

WUFI Method



Condensation: Analyzing Assemblies

WUFI: Limitations



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

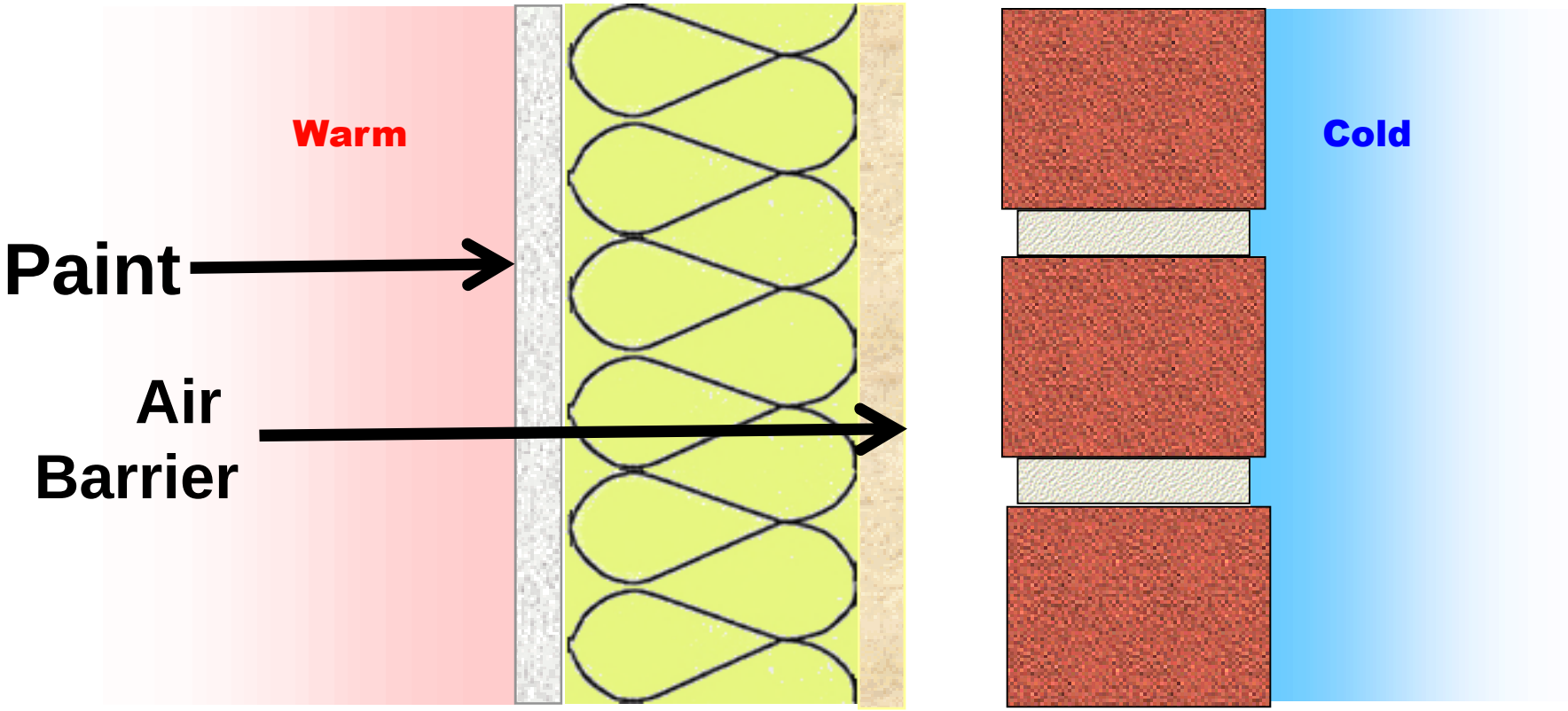
Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

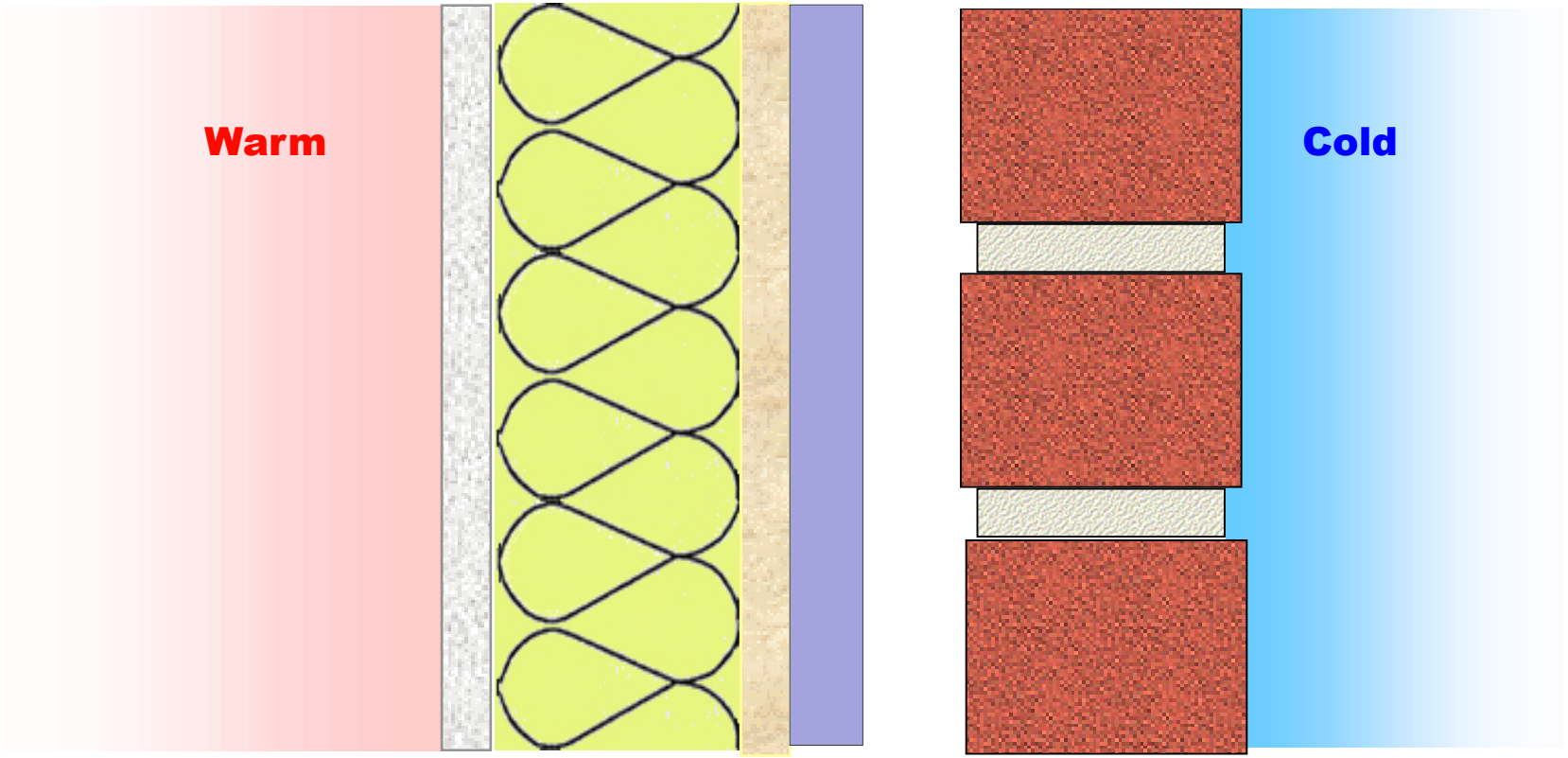
Old Wall



Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions

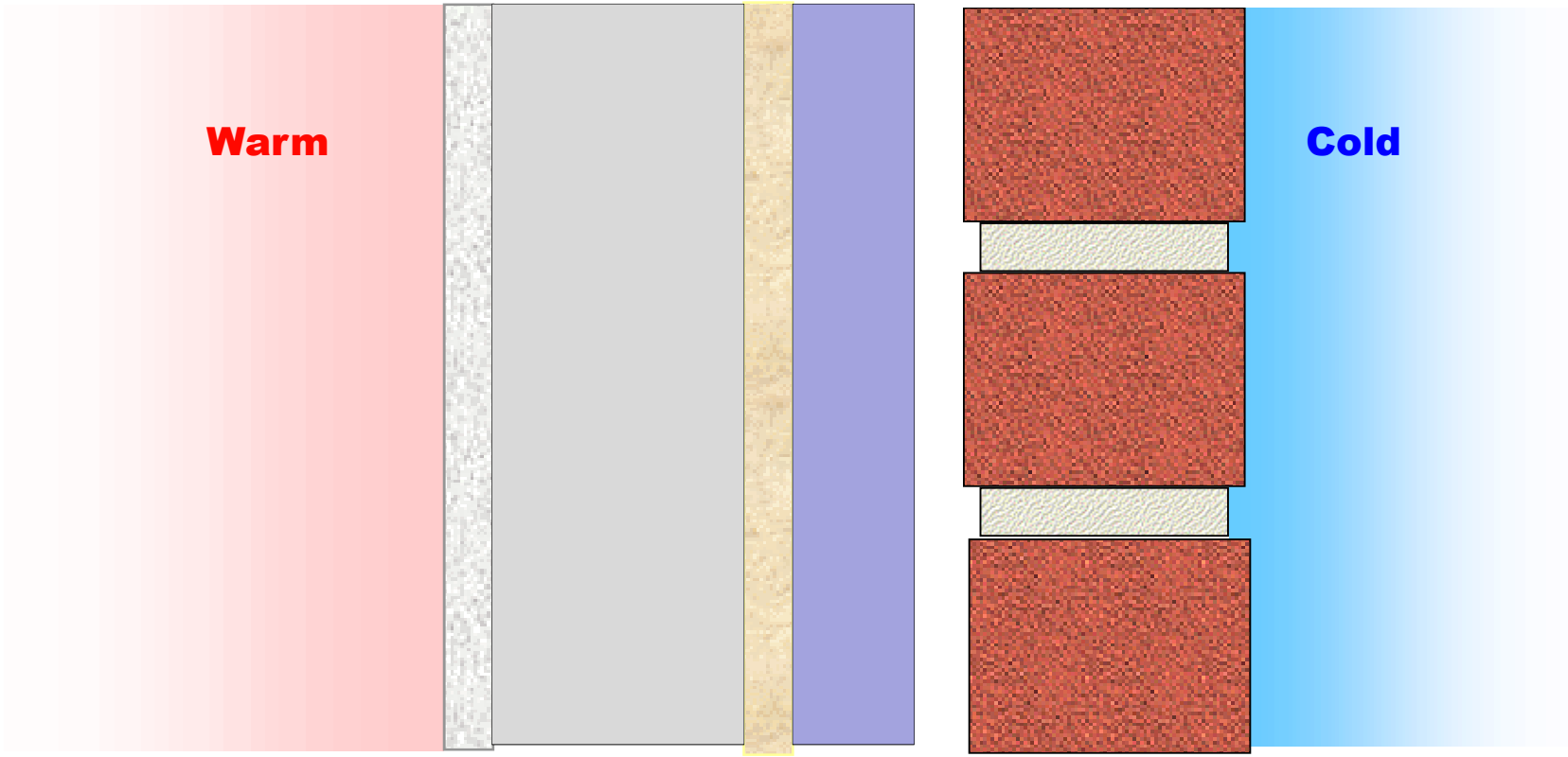
Medium Wall



Condensation: Analyzing Assemblies

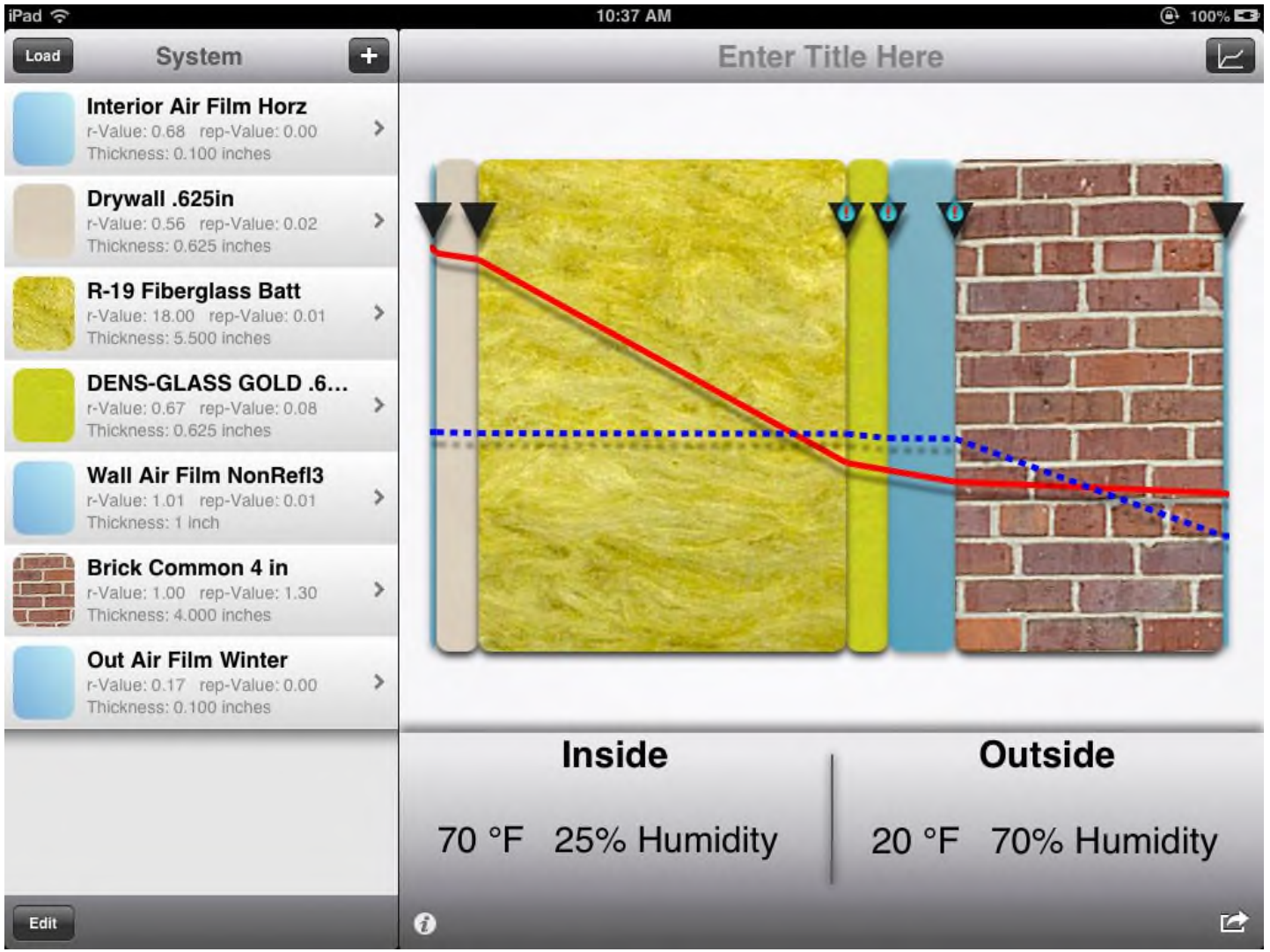
Profile vs. WUFI: Predictions

Perfect Wall



Condensation: Analyzing Assemblies

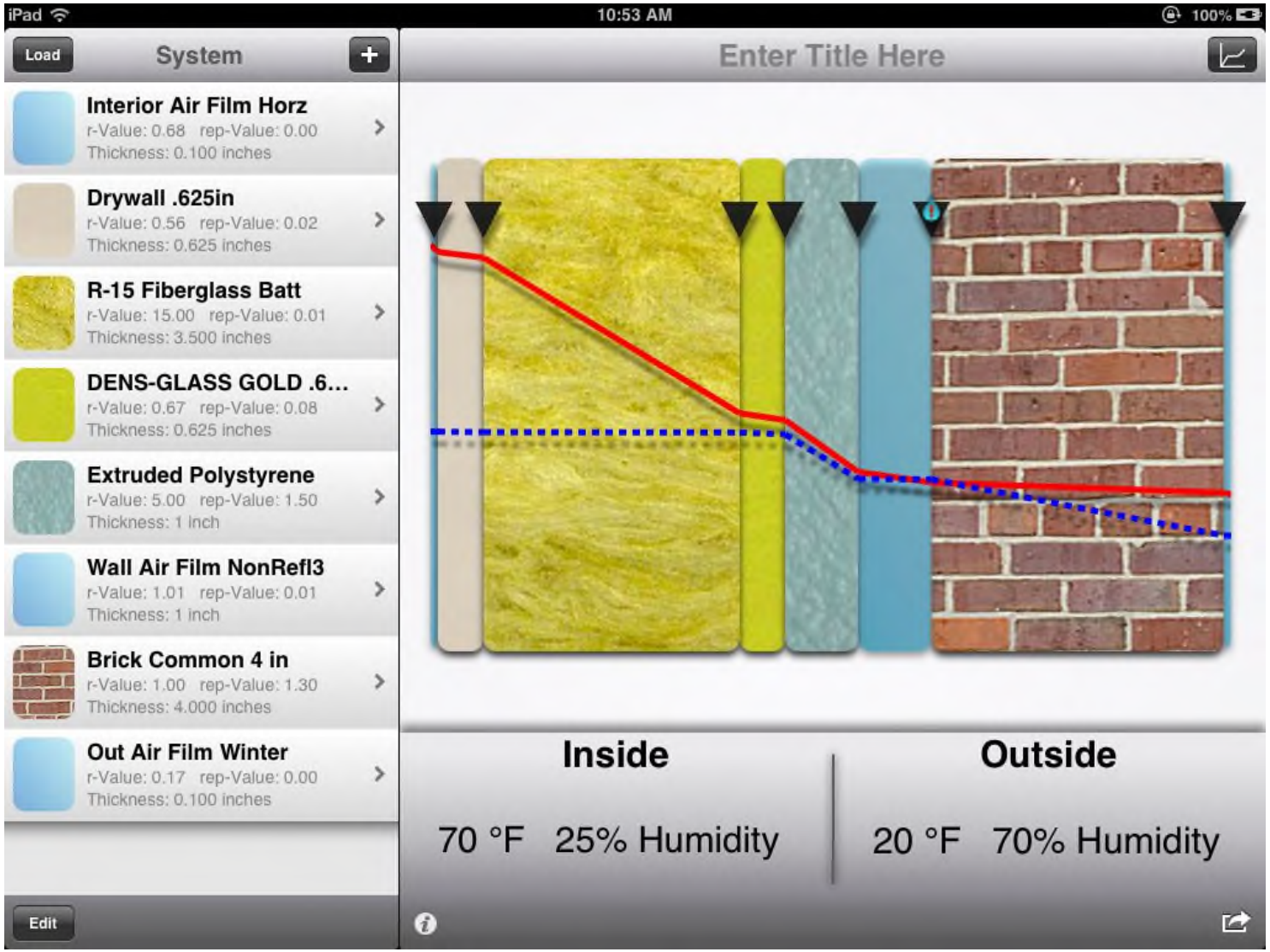
Profile vs. WUFI: Predictions



DewPro iPad App

Condensation: Analyzing Assemblies

Profile vs. WUFI: Predictions



DewPro iPad App

Condensation: Analyzing Assemblies

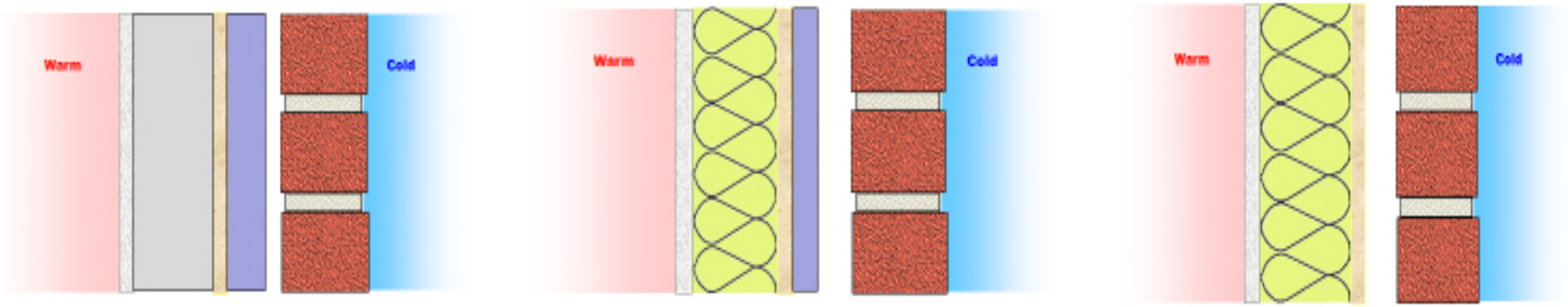
Profile vs. WUFI: Predictions

DewPro iPad App

Condensation: Analyzing Assemblies

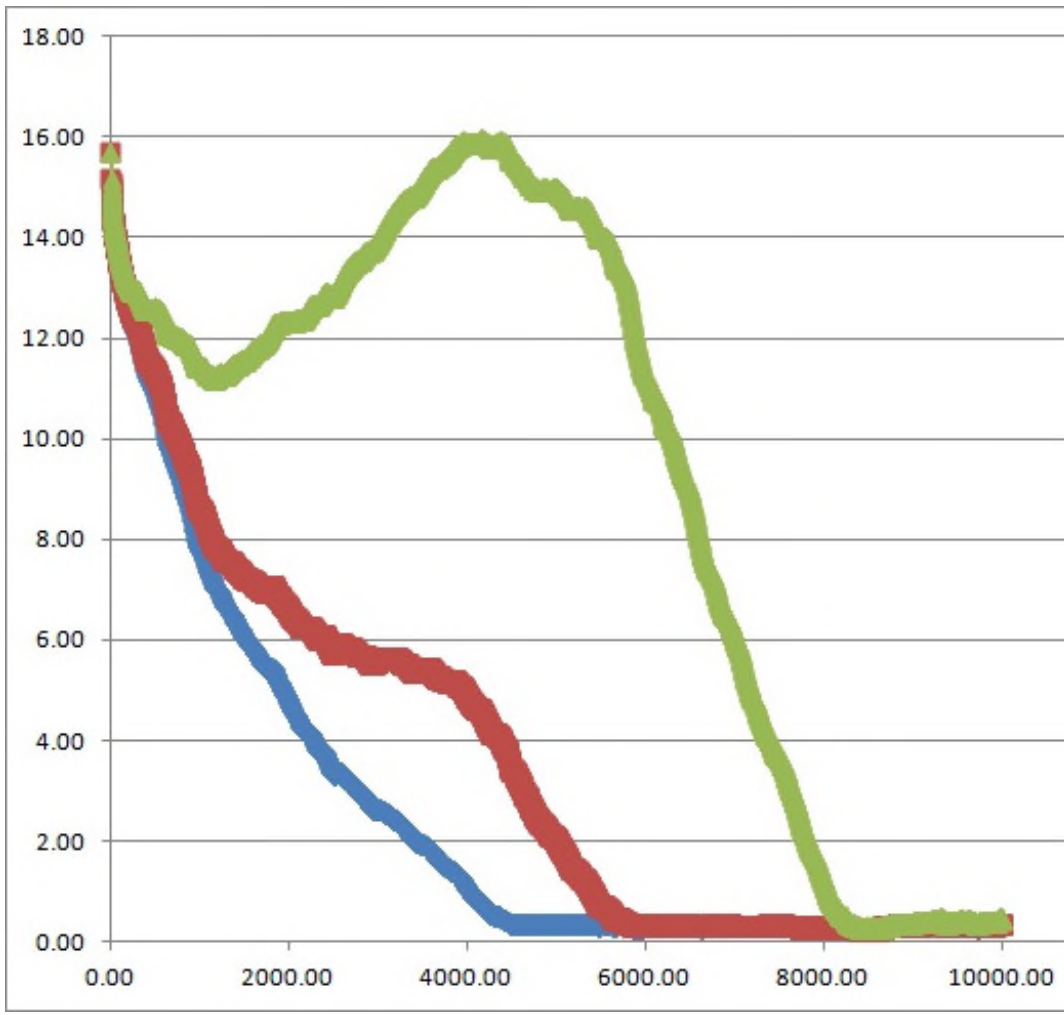
Profile vs. WUFI: Predictions

Perfect Wall > Medium Wall > Old Wall

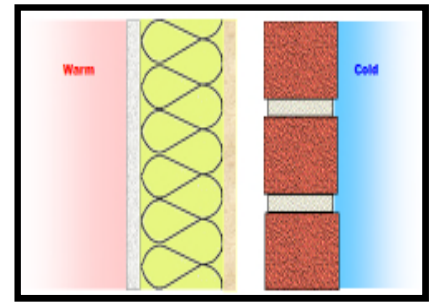


Condensation: Analyzing Assemblies

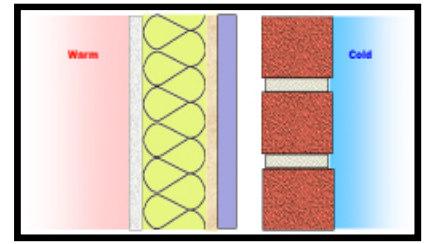
Profile vs. WUFI: Predictions



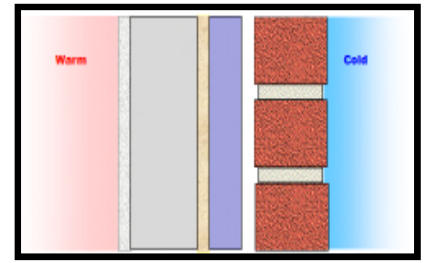
Old



Medium



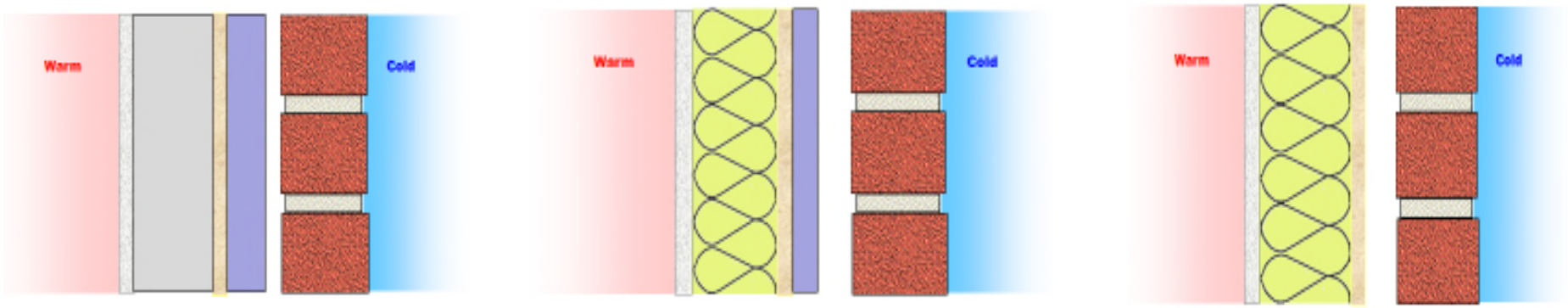
Perfect



Condensation: Analyzing Assemblies

Profile vs. WUF: Predictions

Perfect Wall > Medium Wall > Old Wall



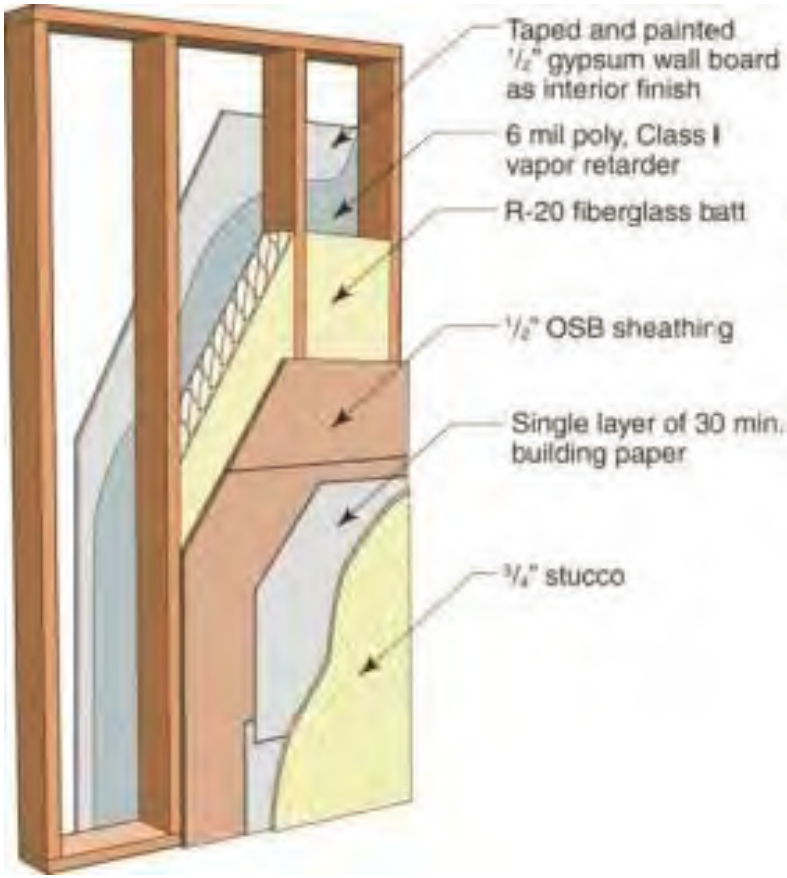
Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

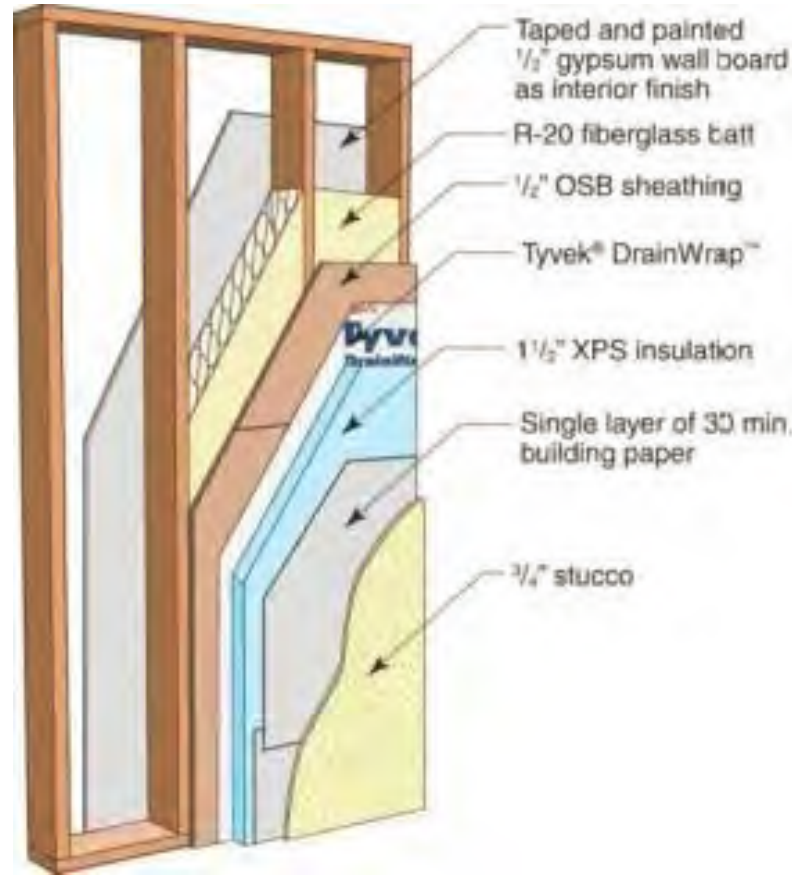
Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis
Research Report - 1207
17 February 2012
Jonathan Smegal, Joseph Lstiburek, John Straube, Aaron Grin

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality



Wall 2



Wall 7

Vancouver Field Exposure Facility: Phase III Exterior Insulation Analysis

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

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

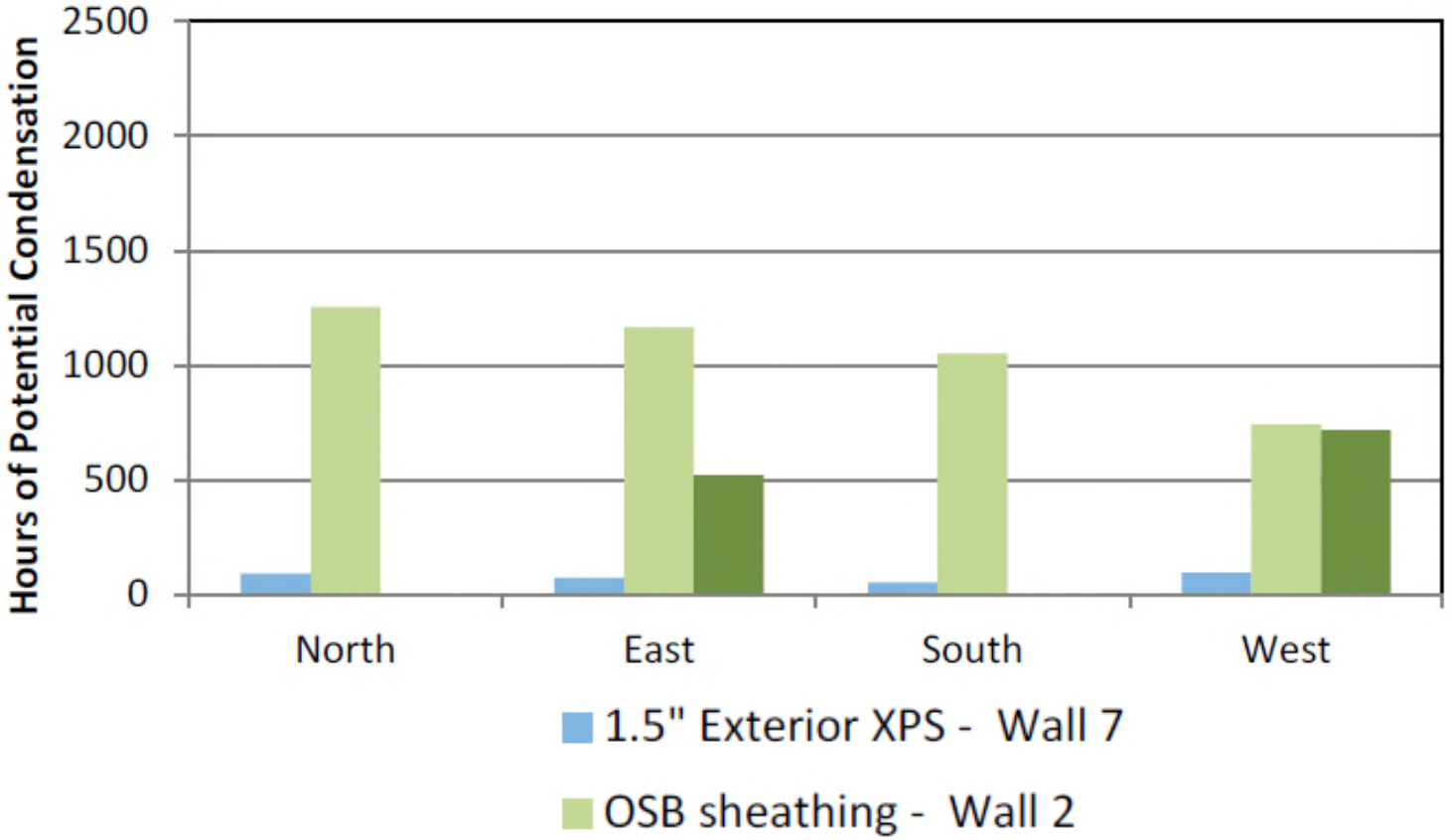
Medium Wall > Old Wall

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.

Condensation: Analyzing Assemblies

Profile vs. WUFI: Reality

Medium Wall > Old Wall



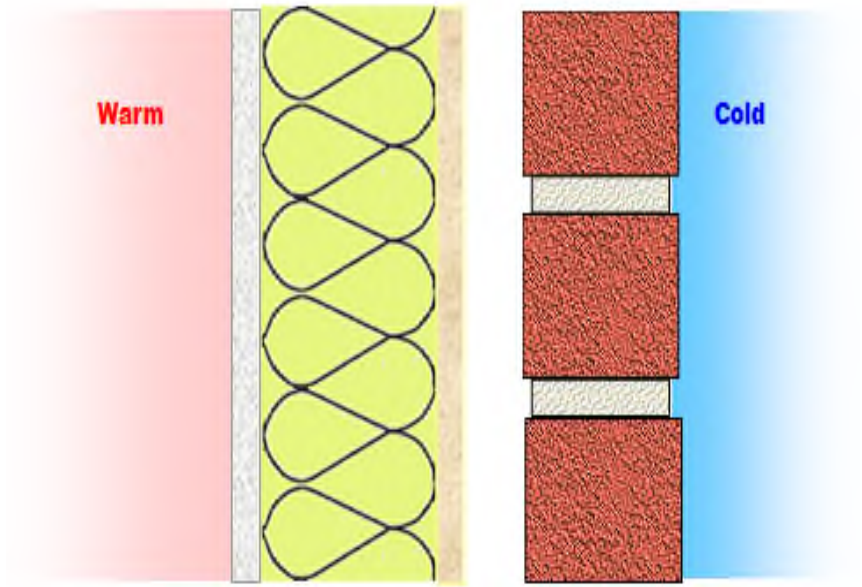
Comparison of the hours of potential condensation between Wall 2 and Wall 7

Condensation: The Real Story

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

Condensation: Wall Design

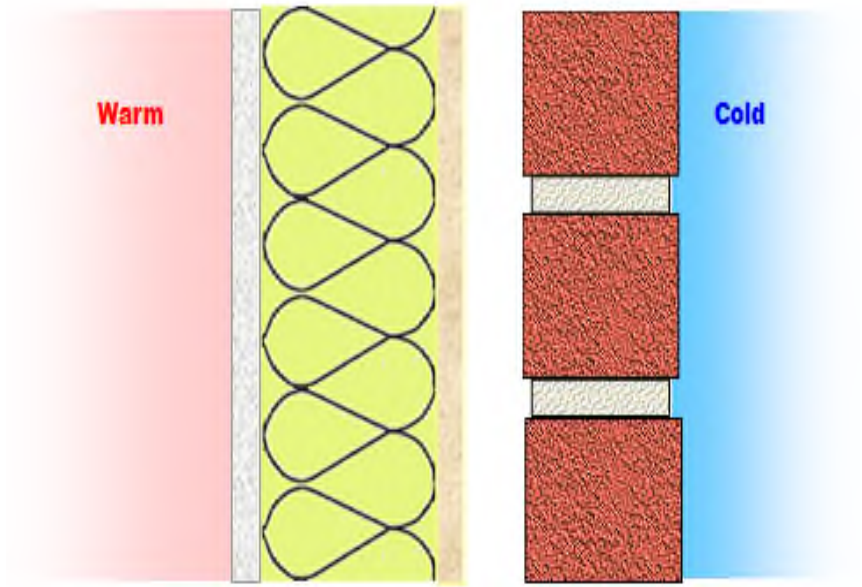
Cold Climates: Permeability



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.

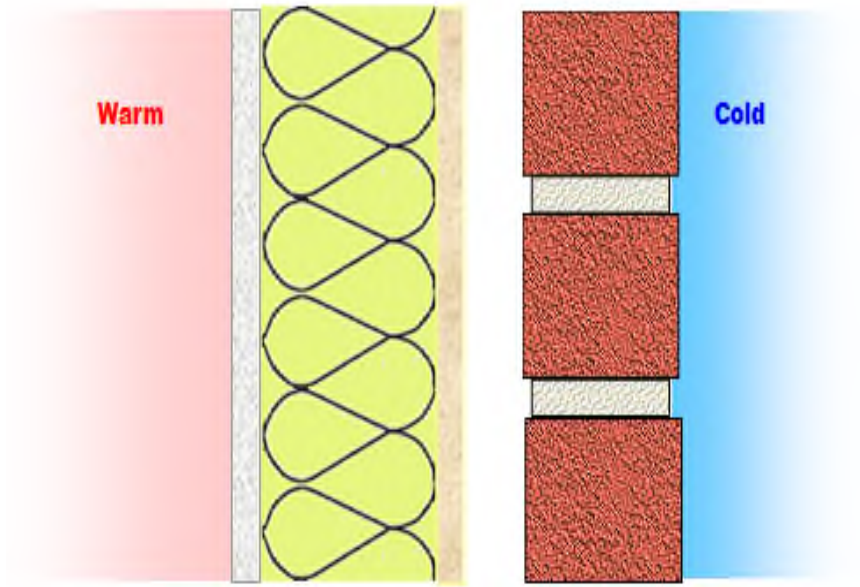
Condensation: Wall Design

Cold Climates: Permeability

Very hard to deal with the various kinds of penetrations

Condensation: Wall Design

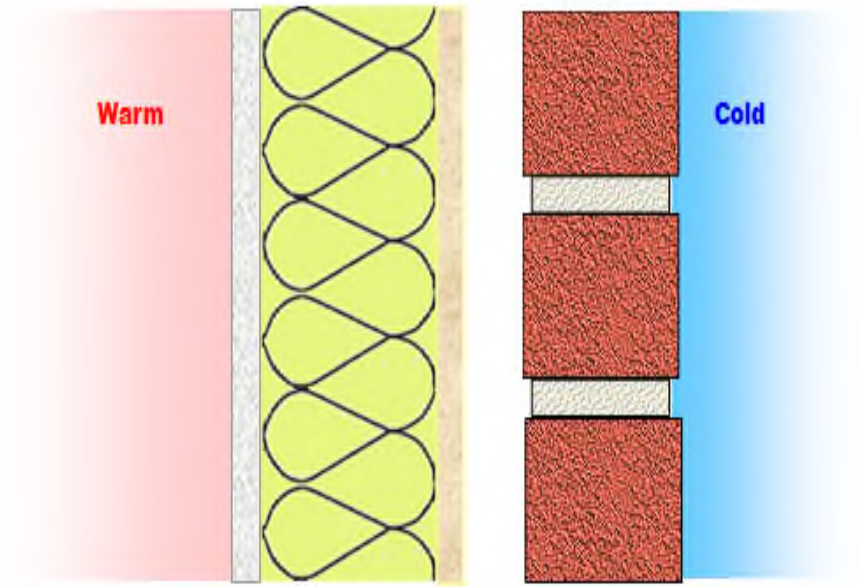
Cold Climates: Permeability



Poor effective drying because it is too often cold.

Condensation: Wall Design

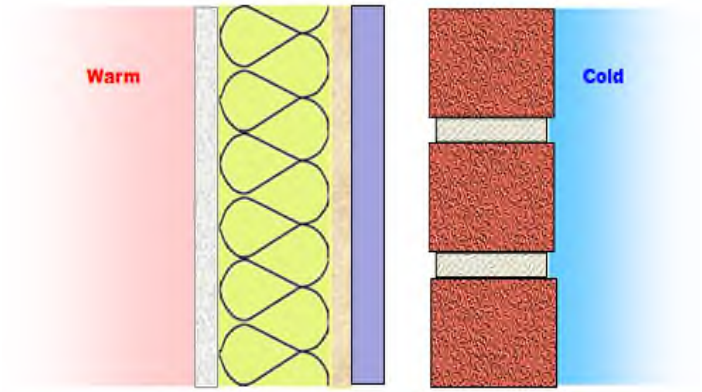
Cold Climates: Permeability



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

Condensation: Wall Design

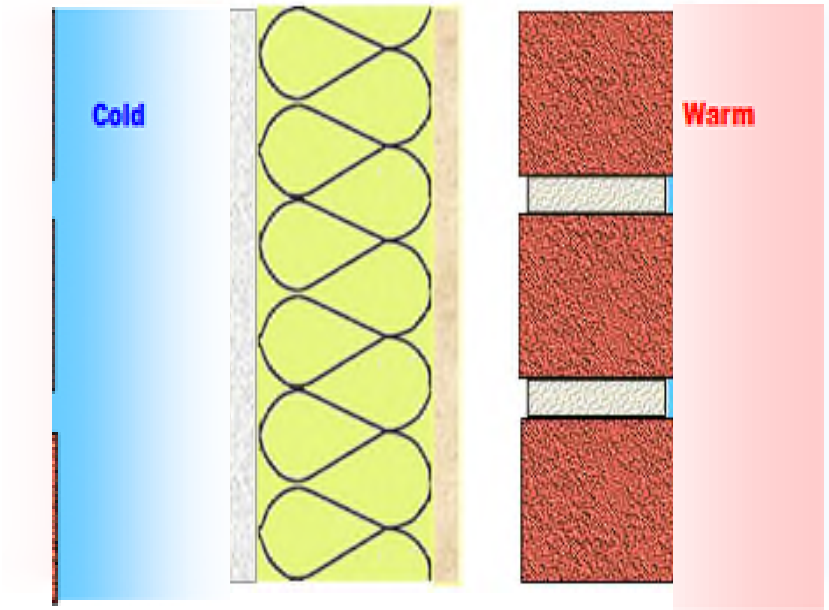
Cold Climates: Temperature



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

Condensation: Wall Design

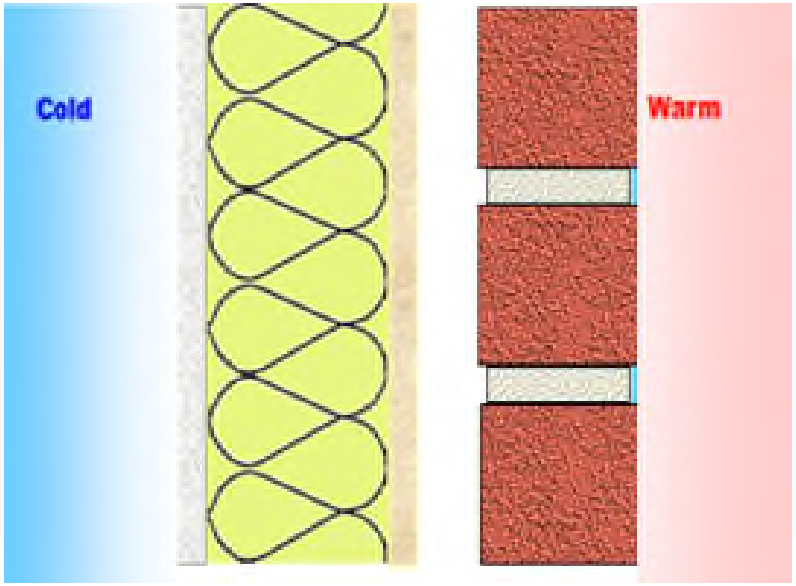
Warm Climates: Permeability



Easier VB design
Easier installation
Effective Drying

Condensation: Wall Design

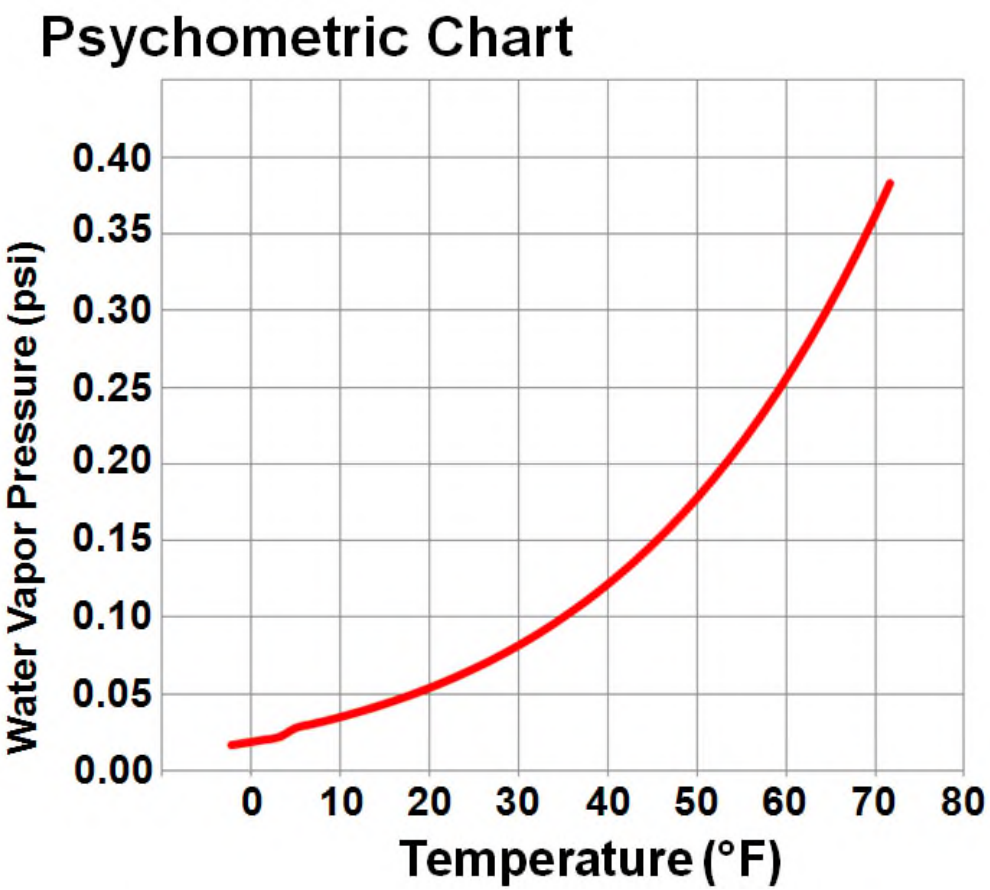
Warm Climates: Temperature

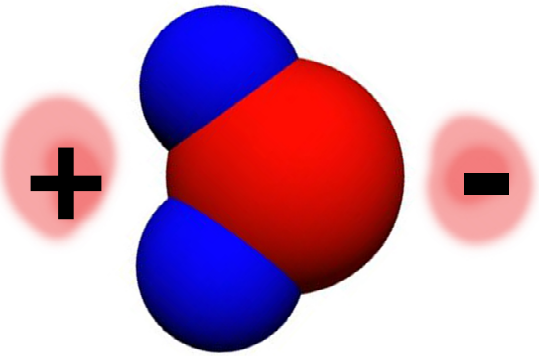


No VB
Easier installation
Effective Drying

Condensation: Summary

- Properties of Water



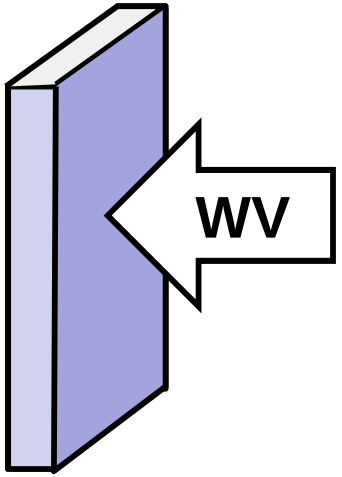


Condensation: Summary

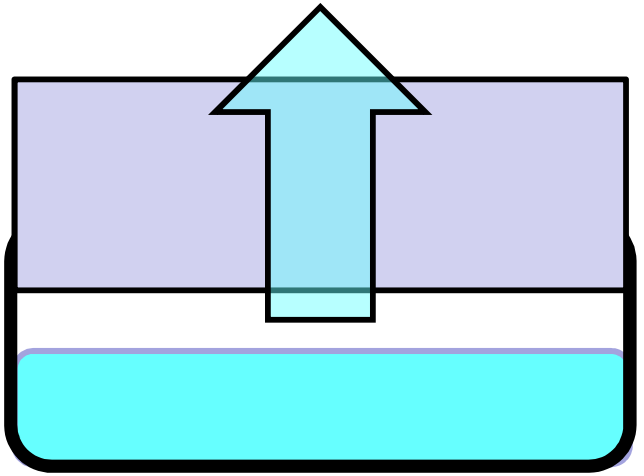
- Properties of Water
- Terms Relating to Condensation

Relative Humidity

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



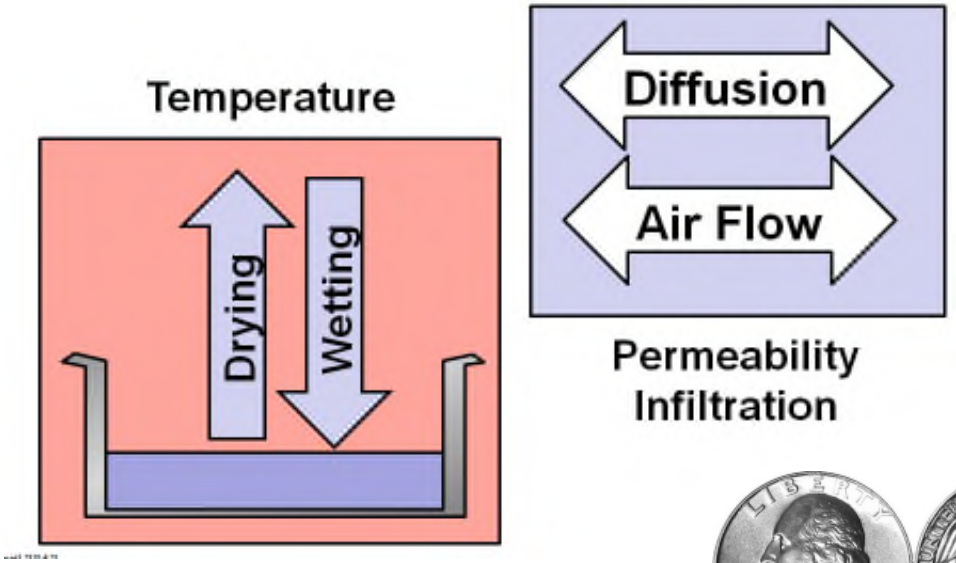
gr/hr ft^2 in Hg



Wet Cup

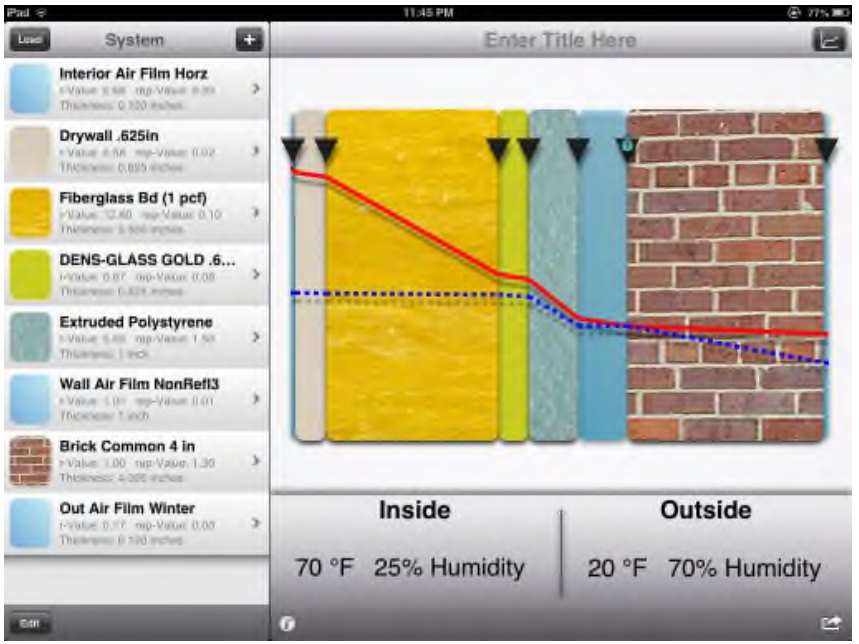
Condensation: Summary

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



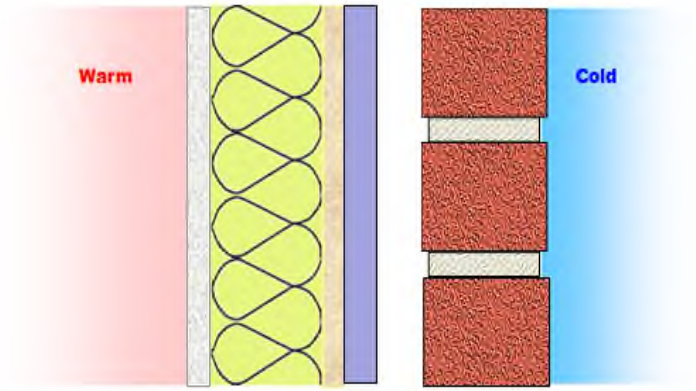
Condensation: Summary

- 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!

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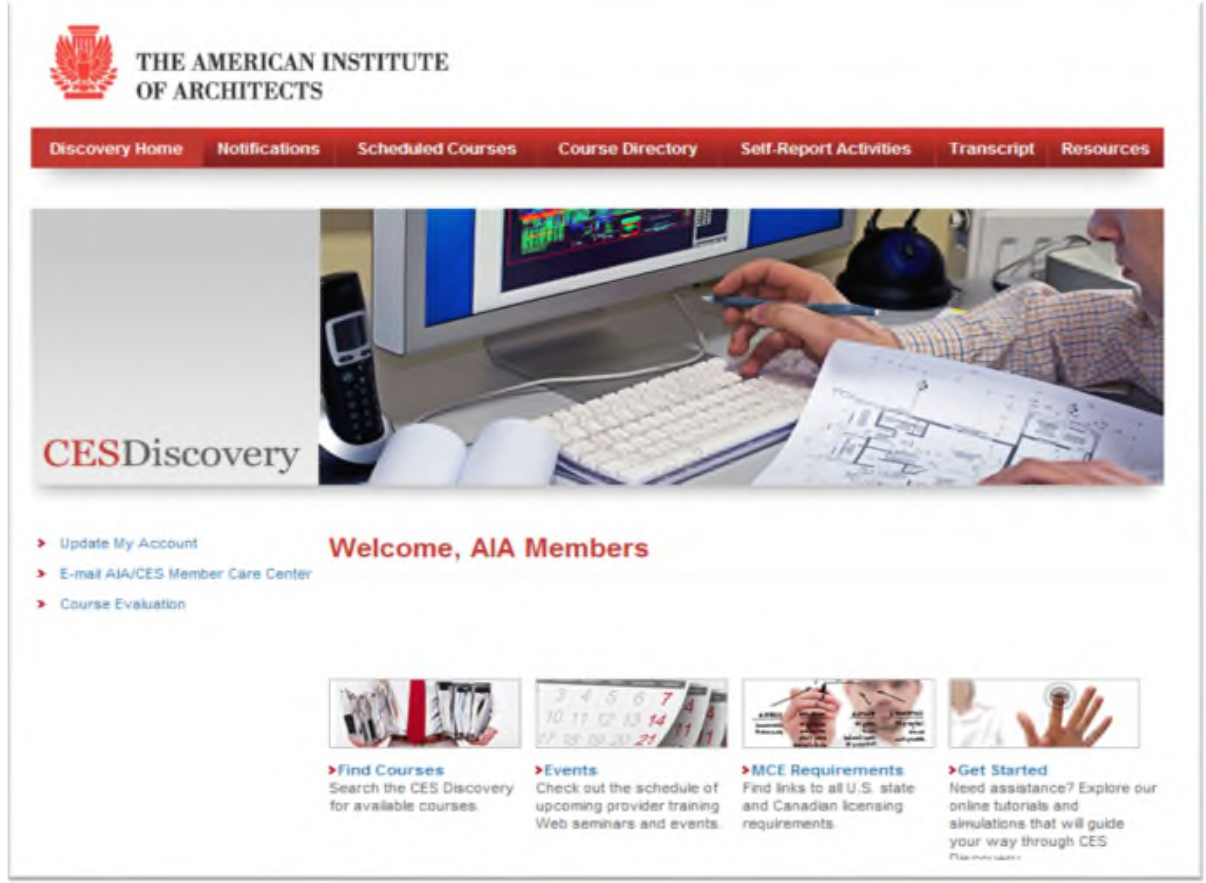

Web References

Wall Solutions

- www.ThermaxWallSystem.com
- www.AirSealWithDow.com
- www.DowBuildingSolutions.com
- www.DowKnightSolutions.com
- www.DowMetalBuilding.com
- www.UltraWallSystem.com

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