Effects of Moisture on Thermal Insulation

Steve Badger, Ph.D.

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98% of Insulation System Failures are Moisture Related*

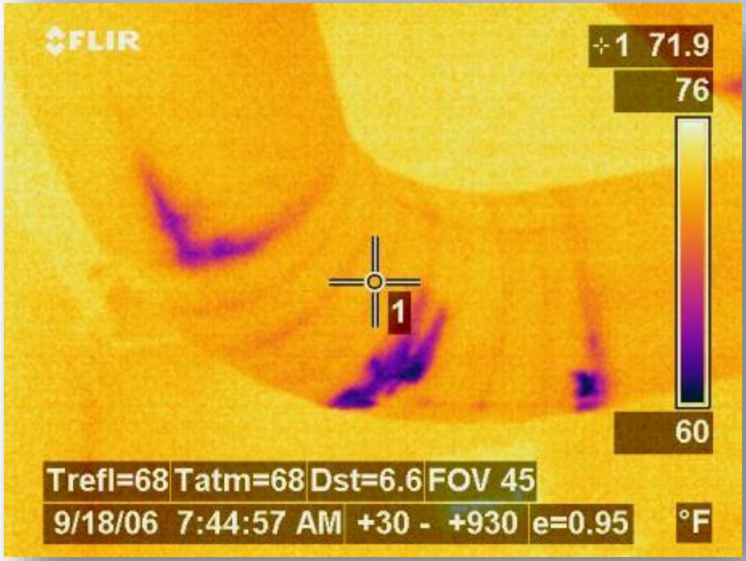
- Insulation is a key to saving energy
- In order for insulation to be effective it needs to remain as close to its manufactured state as possible.
  - Dry, uncompressed, fully intact
- It is very easy for systems to be compromised and for water to be introduced
- Care must be taken when selecting a system to achieve affective results.

Both cold and hot systems are subject to moisture intrusion.

*Thermal Conductivity of Wet Insulation
Ludwig Adams - ASHRAE Journal

Moisture Absorption in Thermal Insulation is Detrimental Because:

- It affects heat gain that leads to increased energy consumption.
- Wet insulation can lead to pipe support damage from excess weight.
- Moisture deteriorates insulation and will ultimately lead to mold growth/other issues.
- Corrosion under insulation (CUI) can lead to significant damage to a system's pipe and equipment.



Sources of Wet Insulation

External Water Sources

- Rainfall
- Humidity
- Ground water
- Condensation falling from cold service equipment
- Spray from fire sprinklers, deluge systems, wash-downs, etc.

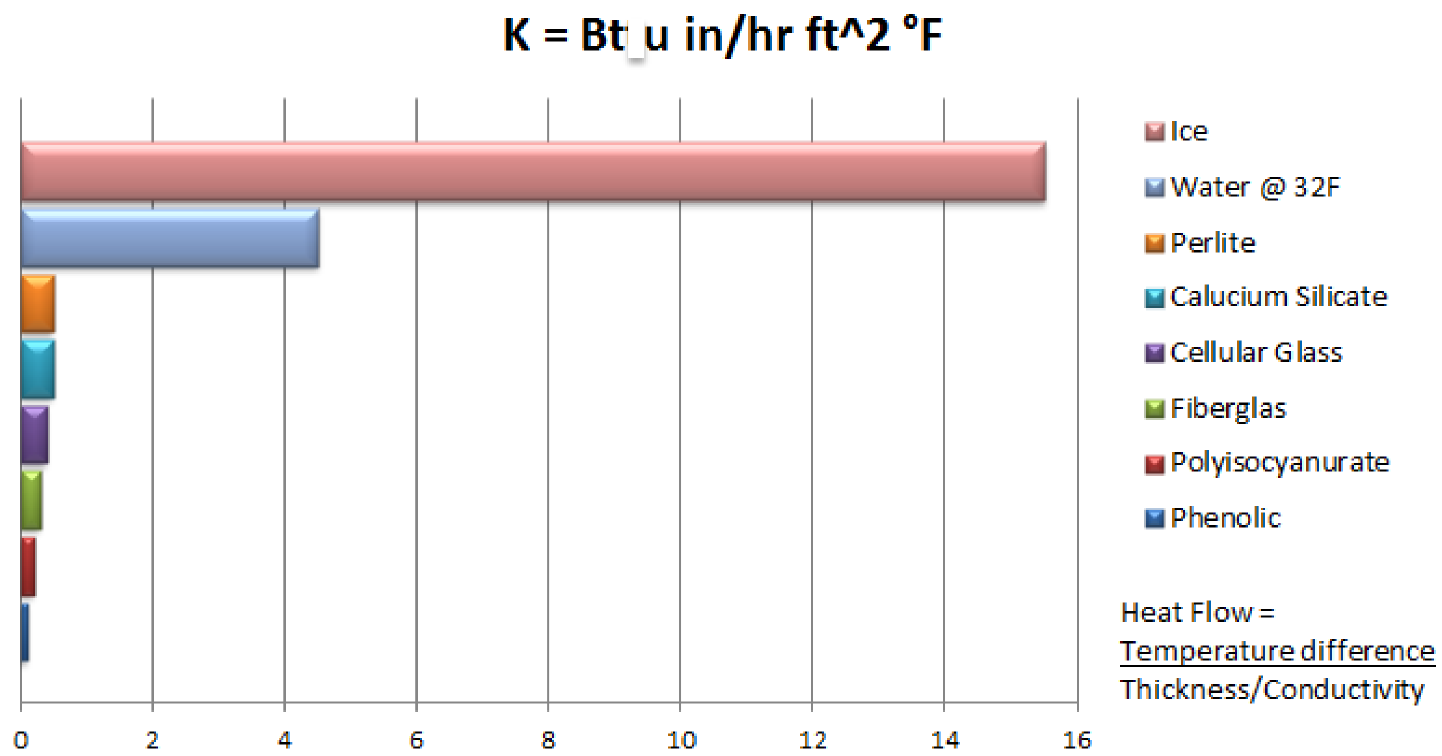
Internal Water Sources

- Condensation from vapor drive (damaged vapor barrier)
- Leaking pipe, flange, or valve
- Insulation applied on wet pipe

Thermal Conductivity Comparison

Definition of Thermal Conductivity:

The amount of heat transferred through a unit area of a material in a unit time, through a unit thickness, with a unit of temperature difference between the surface of the two opposite sides.

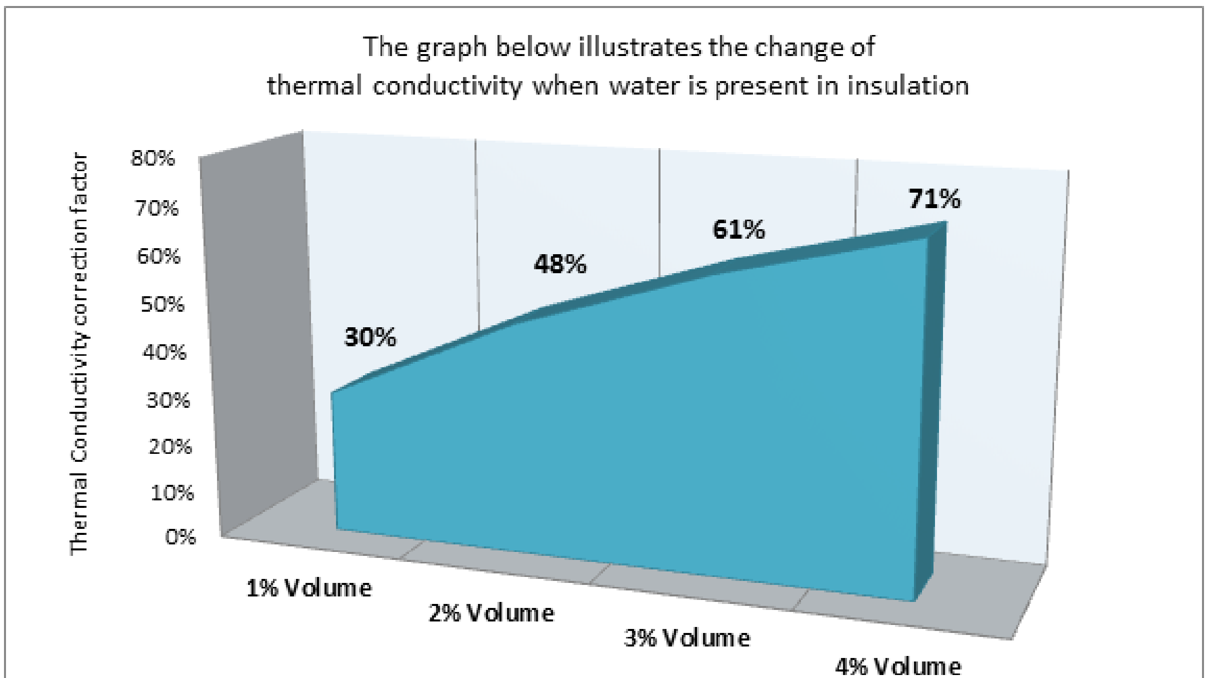


Heat Flow =
Temperature difference
Thickness/Conductivity

Thermal Conductivity & Moisture

Water has a **Thermal Conductivity** of 4 BTU-in/hr•ft^2•°F. This is almost twenty times higher than the conductivity of the average thermal insulation.

The graph below illustrates the change in thermal Conductivity when water is present in the insulation.



	1% Volume	2% Volume	3% Volume	4% Volume
Factor	30%	48%	61%	71%

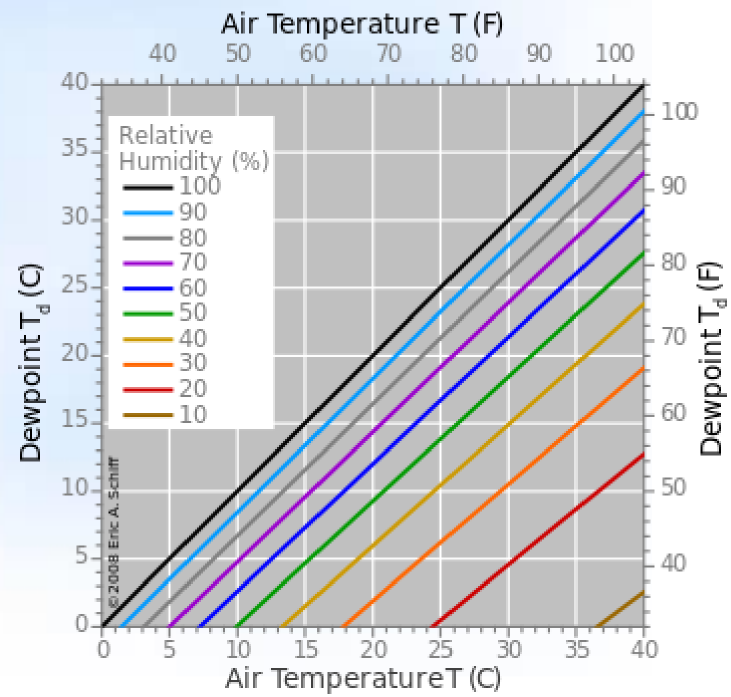
"The thermal performance of an insulation material is based in part upon the existence of small air pockets within the structure. When these air pockets are replaced with water, the thermal conductivity of the material increases since water transfers heat more readily then air."

"Thermal Conductivity of Wet Insulation"
Ludwig Adams **ASHRAE Journal**

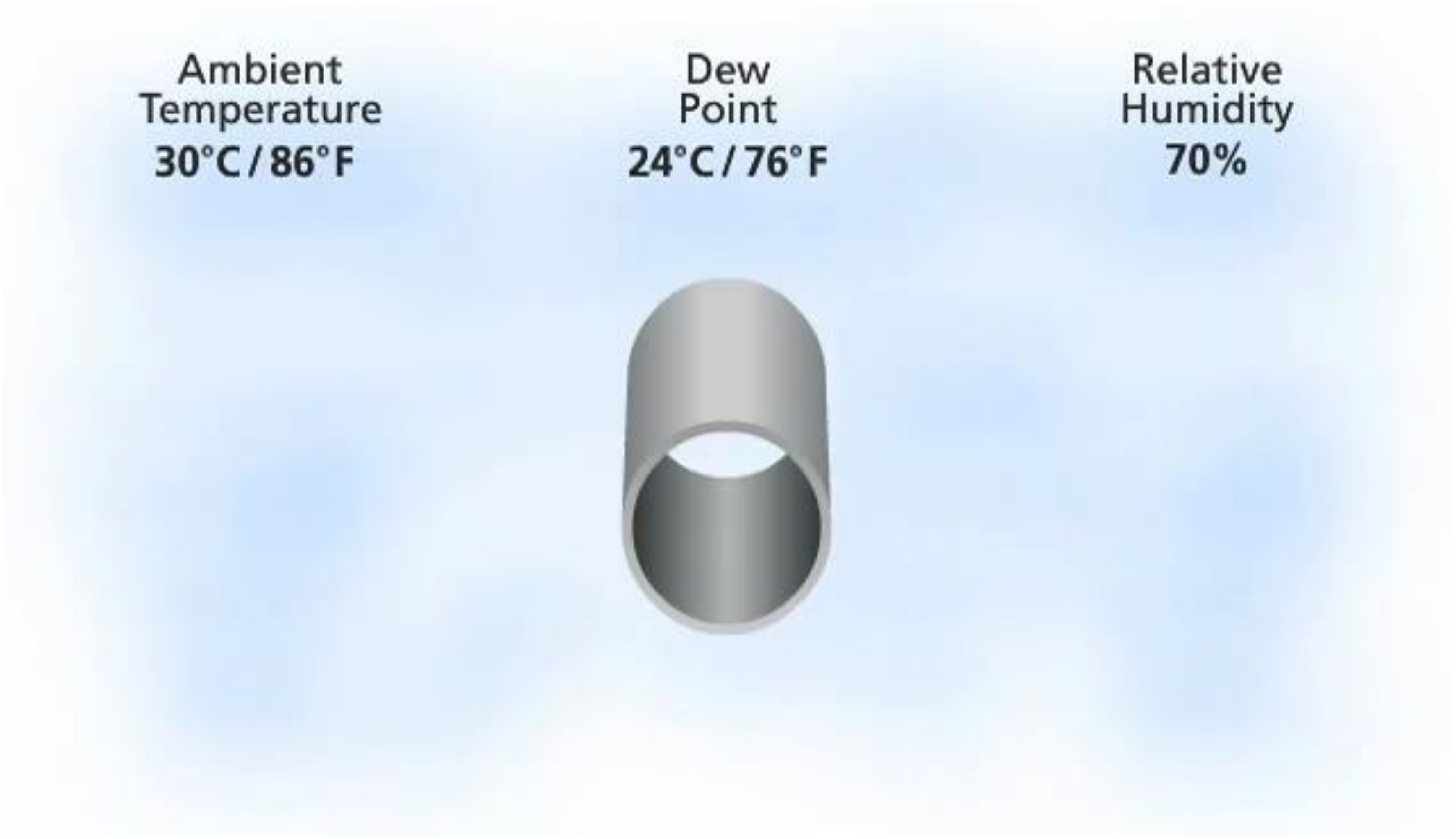
Effects of Moisture in Insulation

Ambient Temperature	Dew Point	Relative Humidity
30°C / 86°F	24°C / 76°F	70%

Vapor Drive



Insulate to prevent condensation



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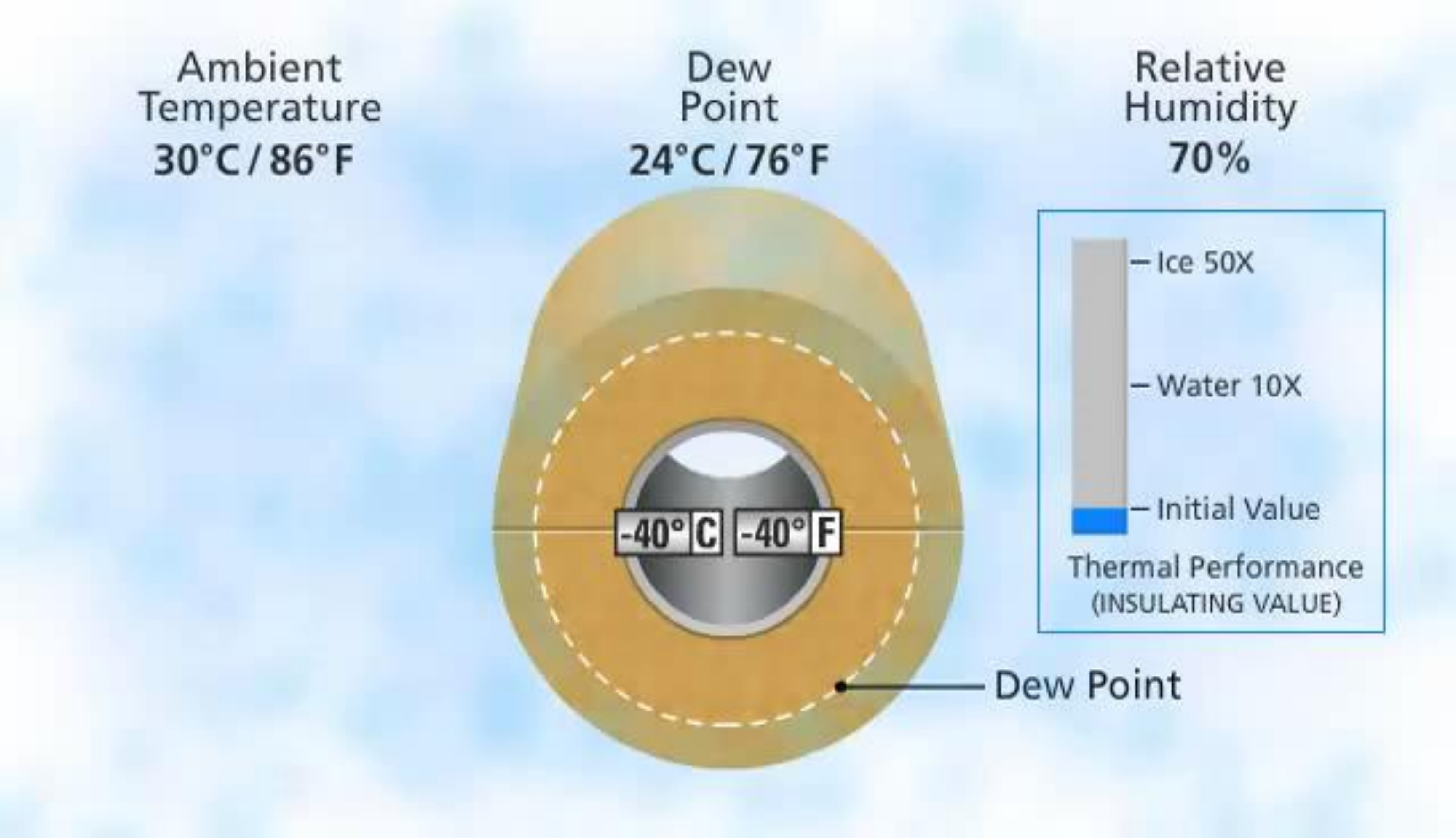

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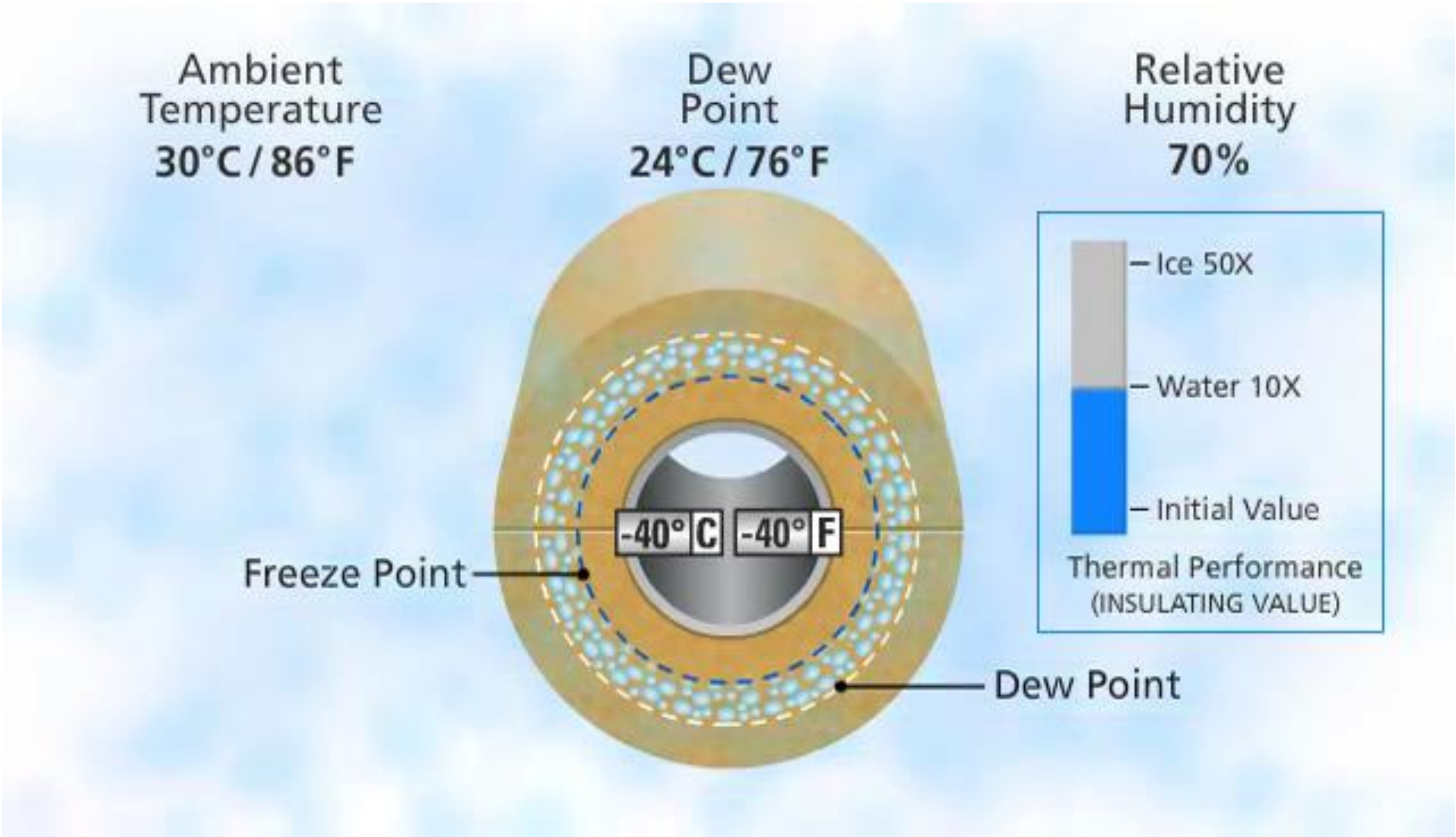

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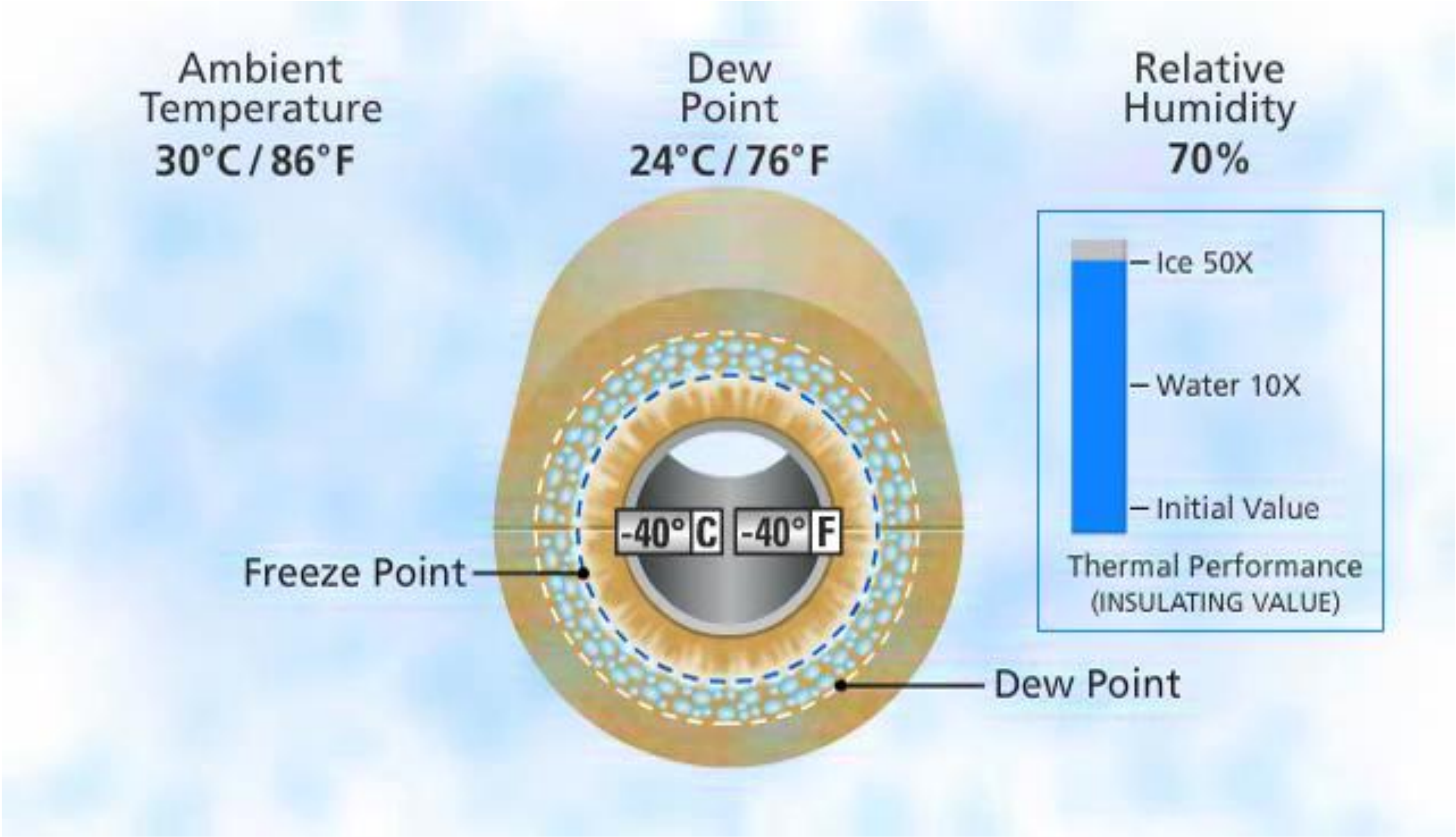
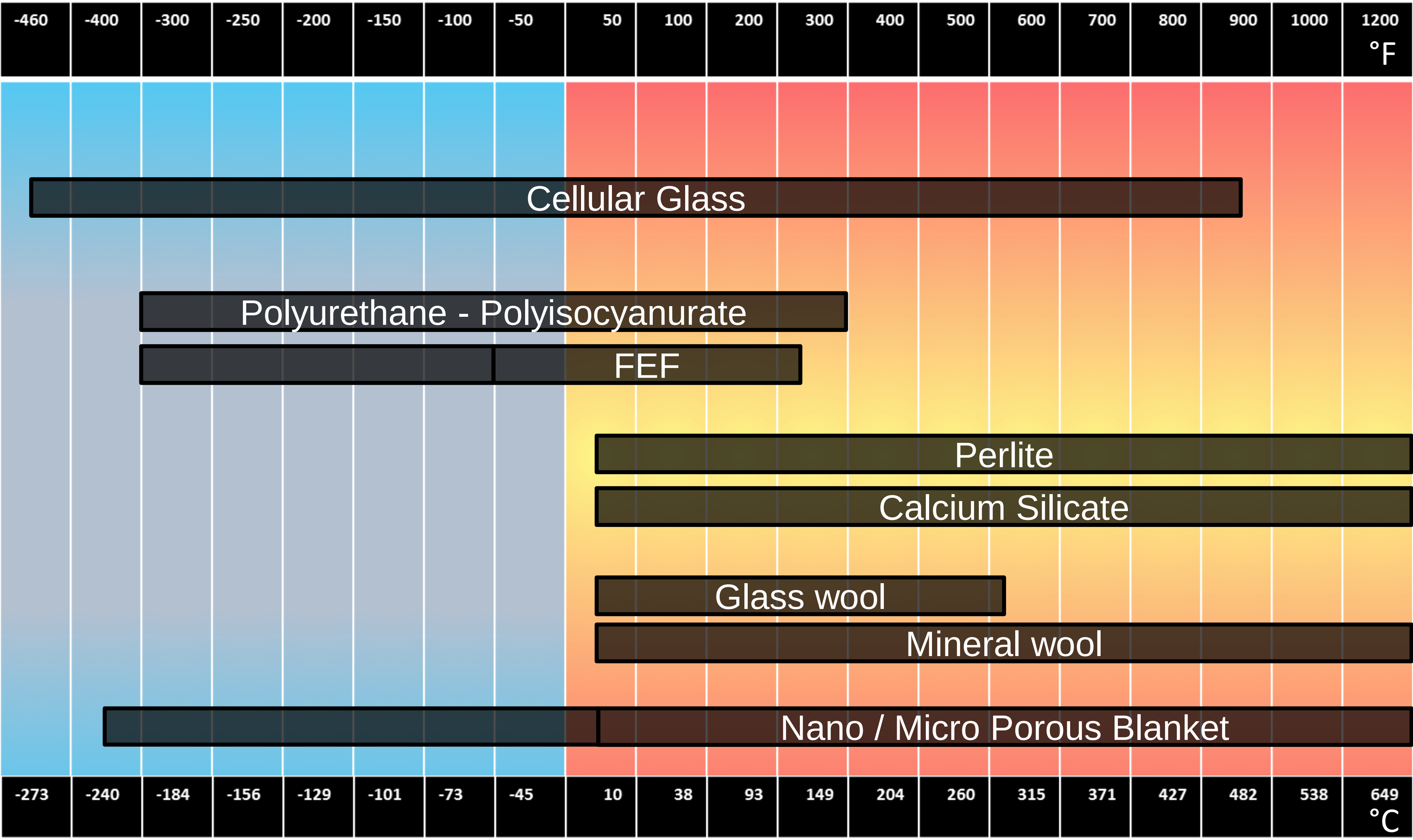
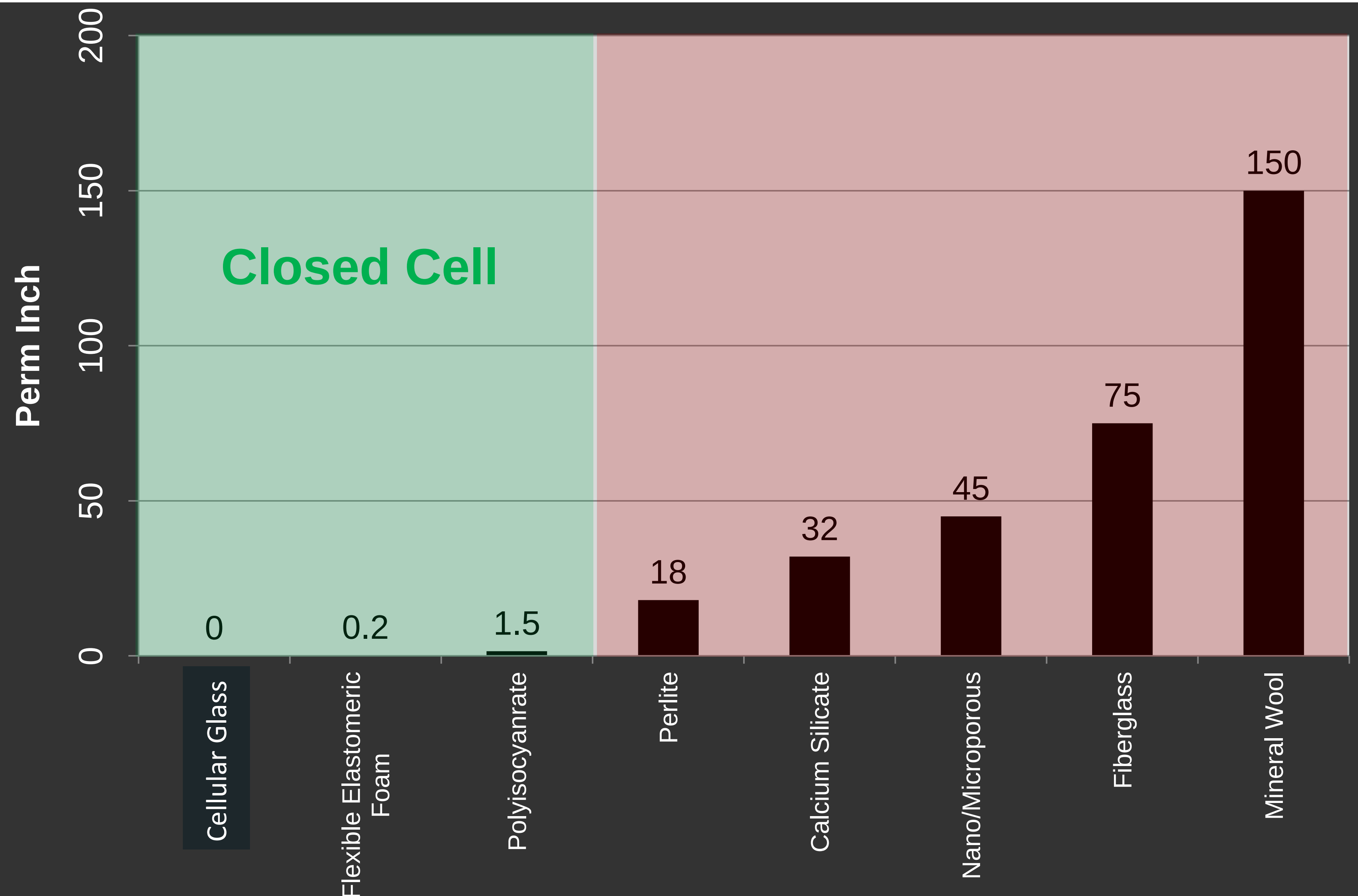


Service Temperature Range



Water Vapor Permeability

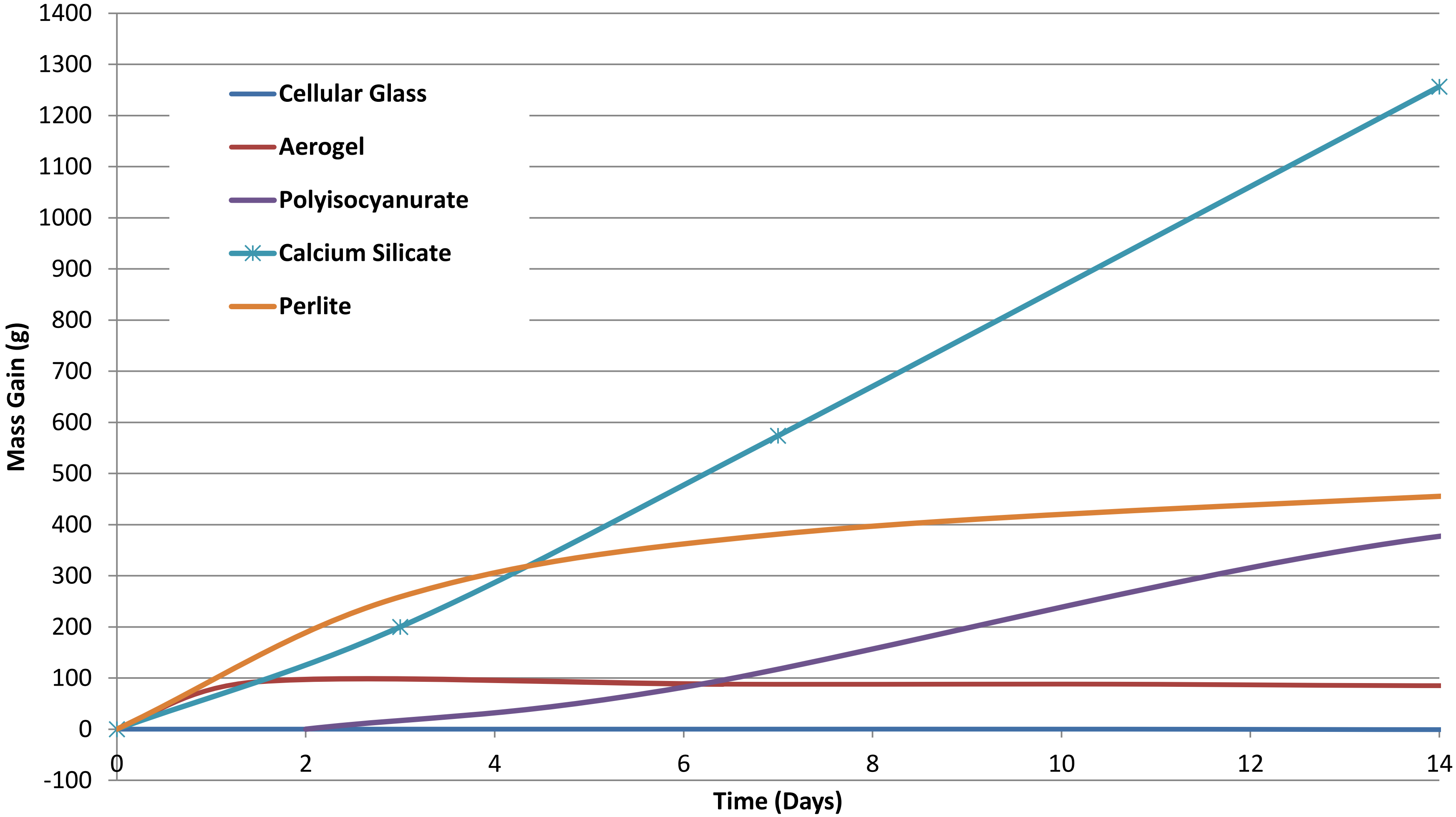


Bars may represent multiple products / manufacturers. Always consult manufacturer's literature for declared temperature range for specified product grade.

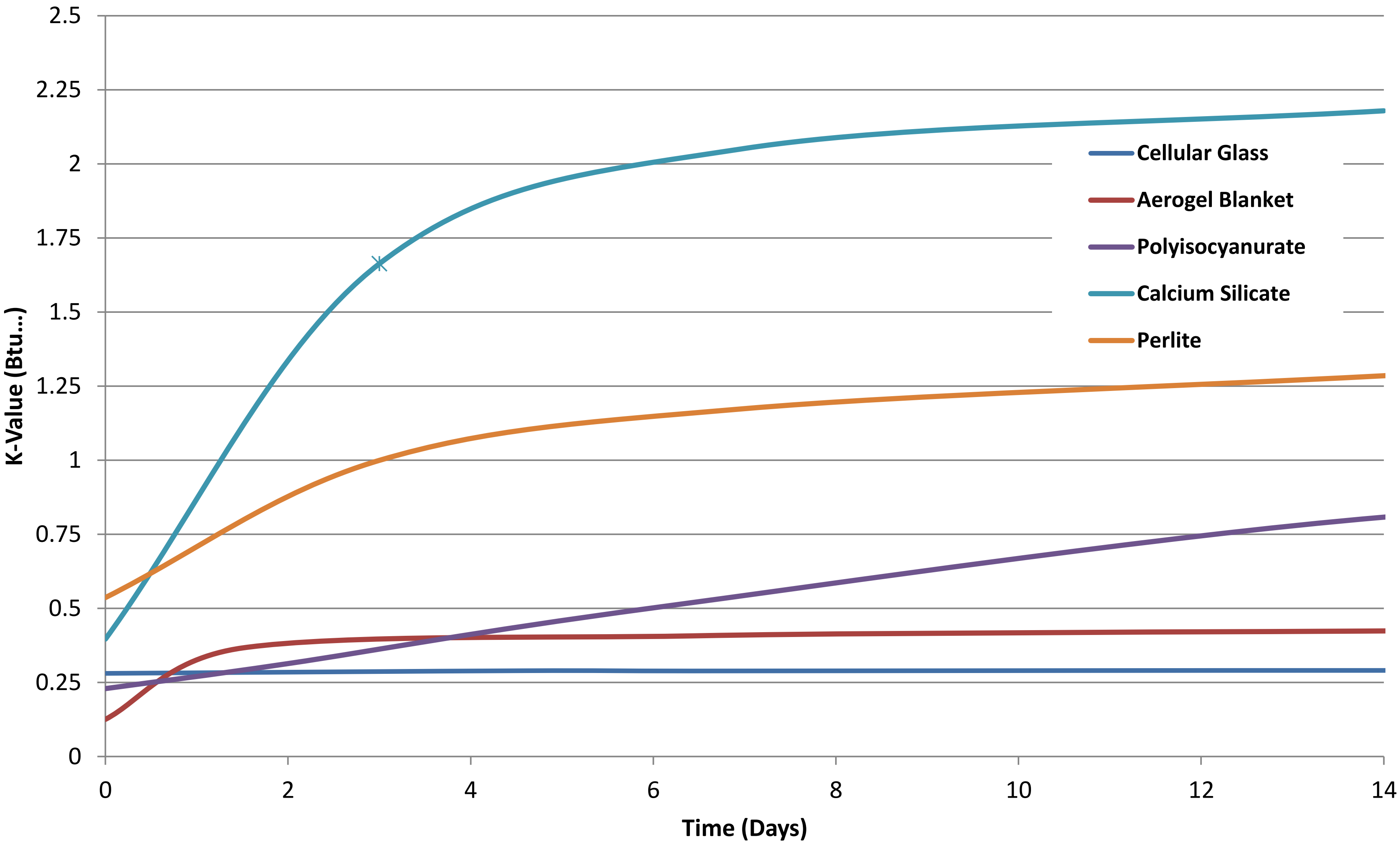
Long Term Water Diffusion Testing of Insulation Products

Modified EN 12088 Method (28 day test)

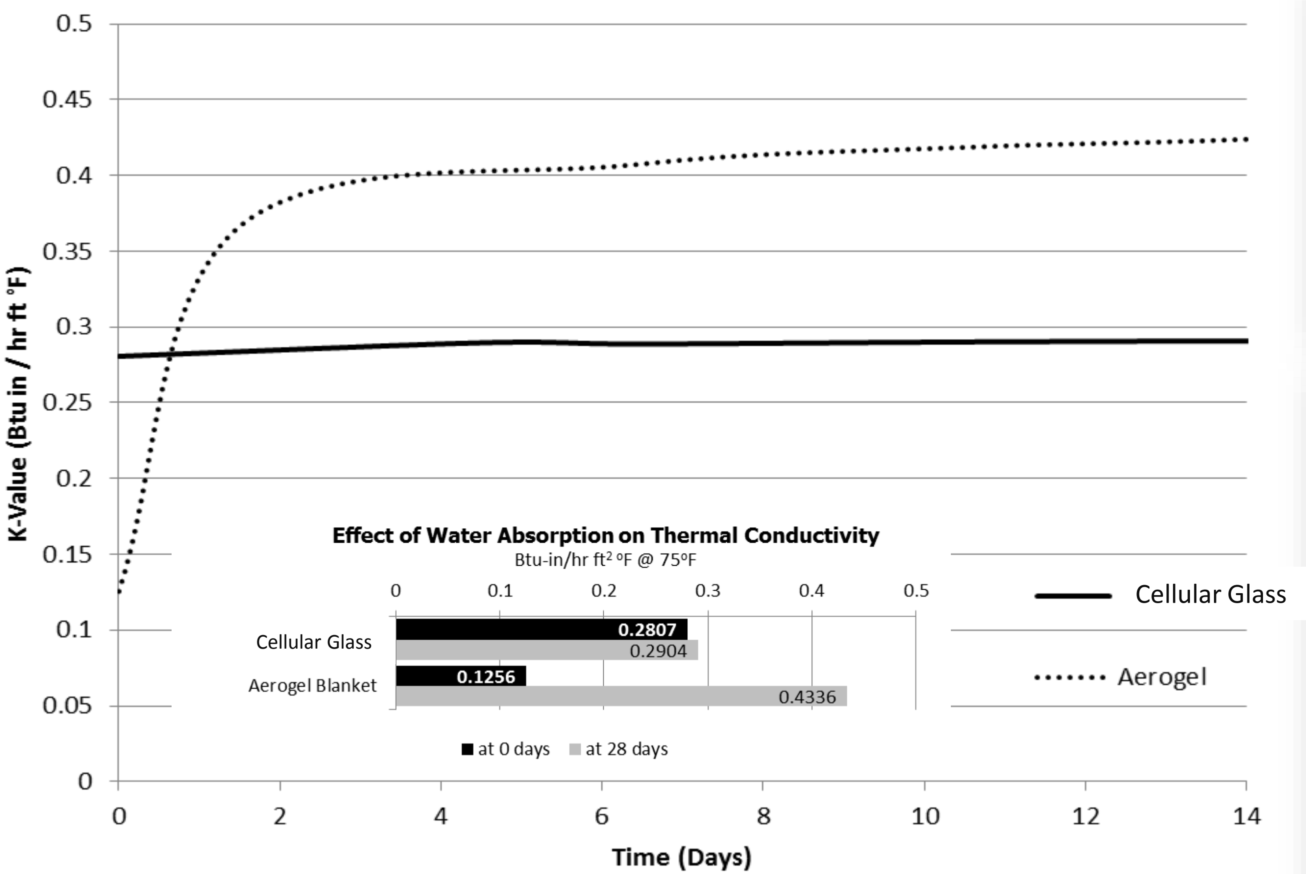
Water Diffusion - Mass increase after 2 weeks

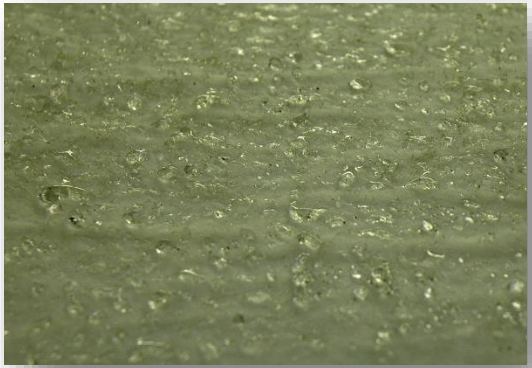


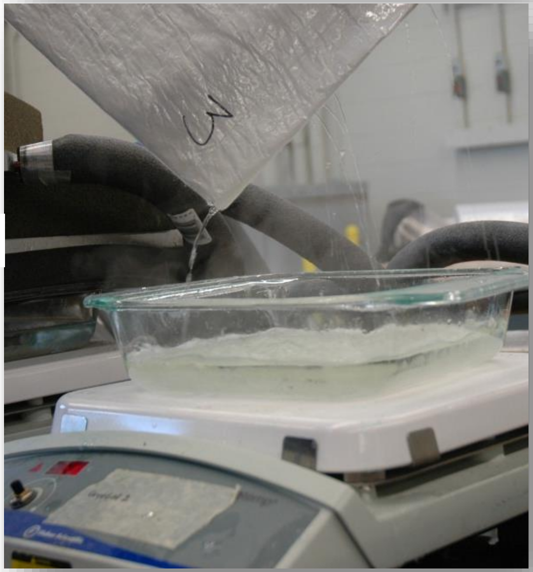
Thermal Conductivity Increase after 2 weeks of Moisture Exposure



Effect of Moisture on Thermal Conductivity

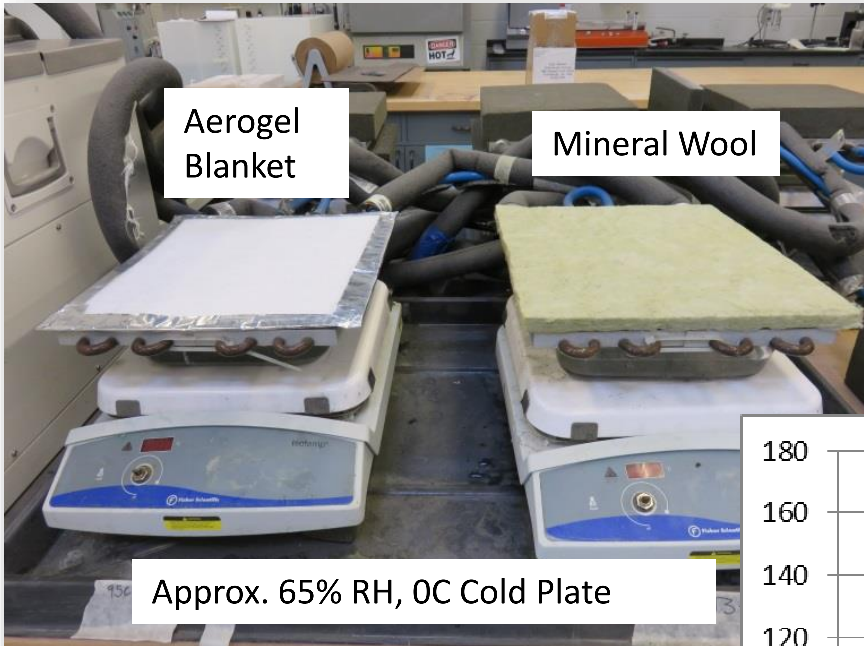


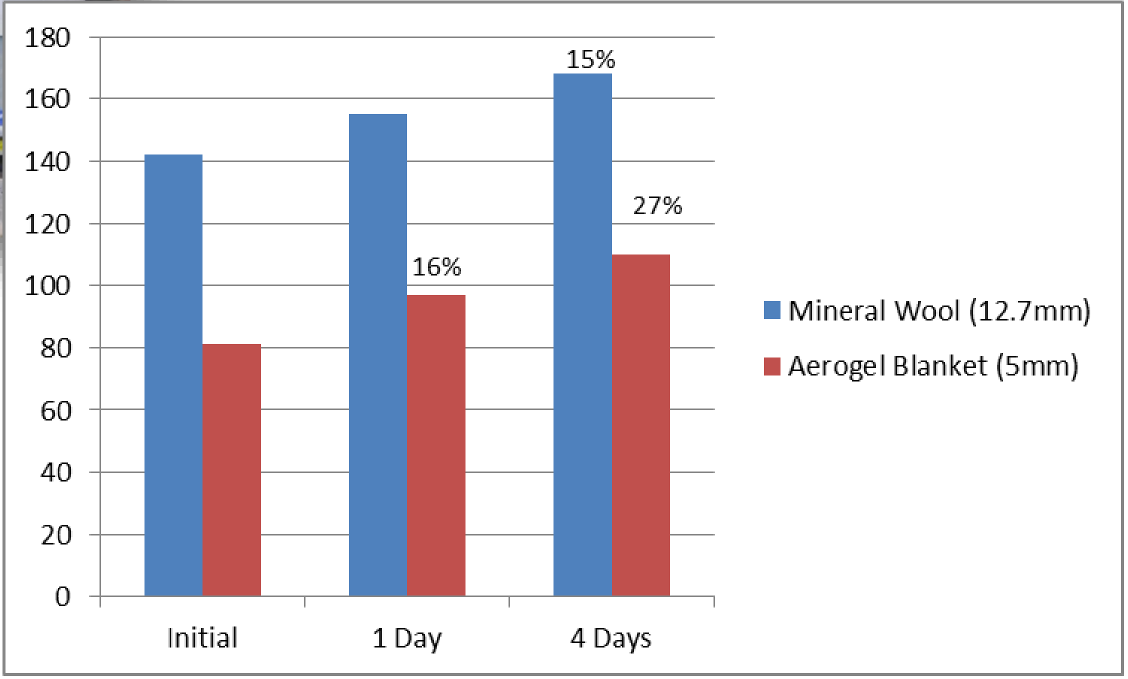




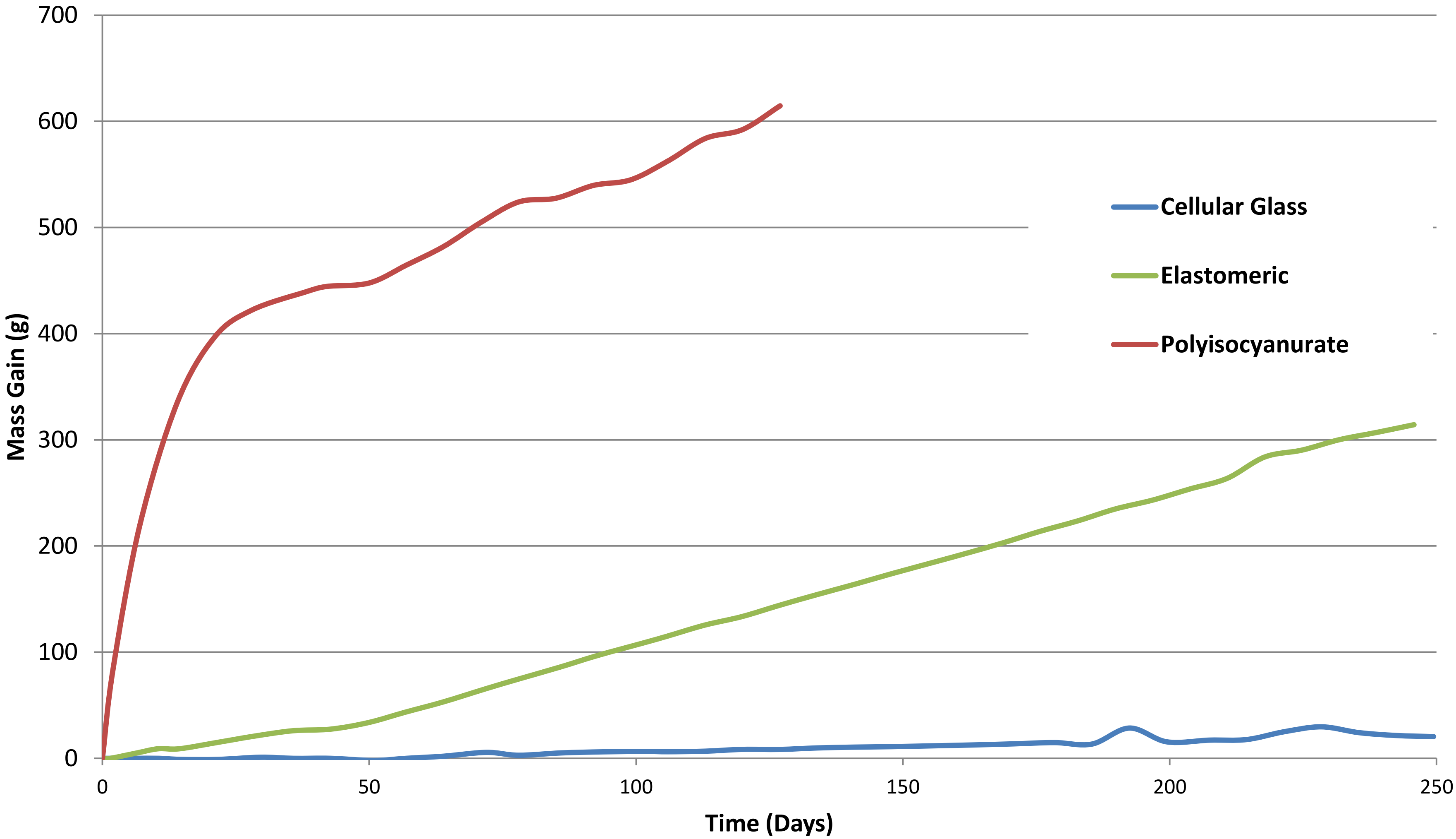
Square insulation samples were subjected to a vapor drive established by exposing an 8”x8” area to 50 C water and a 1 C plate on opposite faces, no sealant was used. Thermal conductivity (k-value) of the samples was by the method described in ASTM C518. Samples were not turned during testing.

Effect of Moisture on Thermal Conductivity

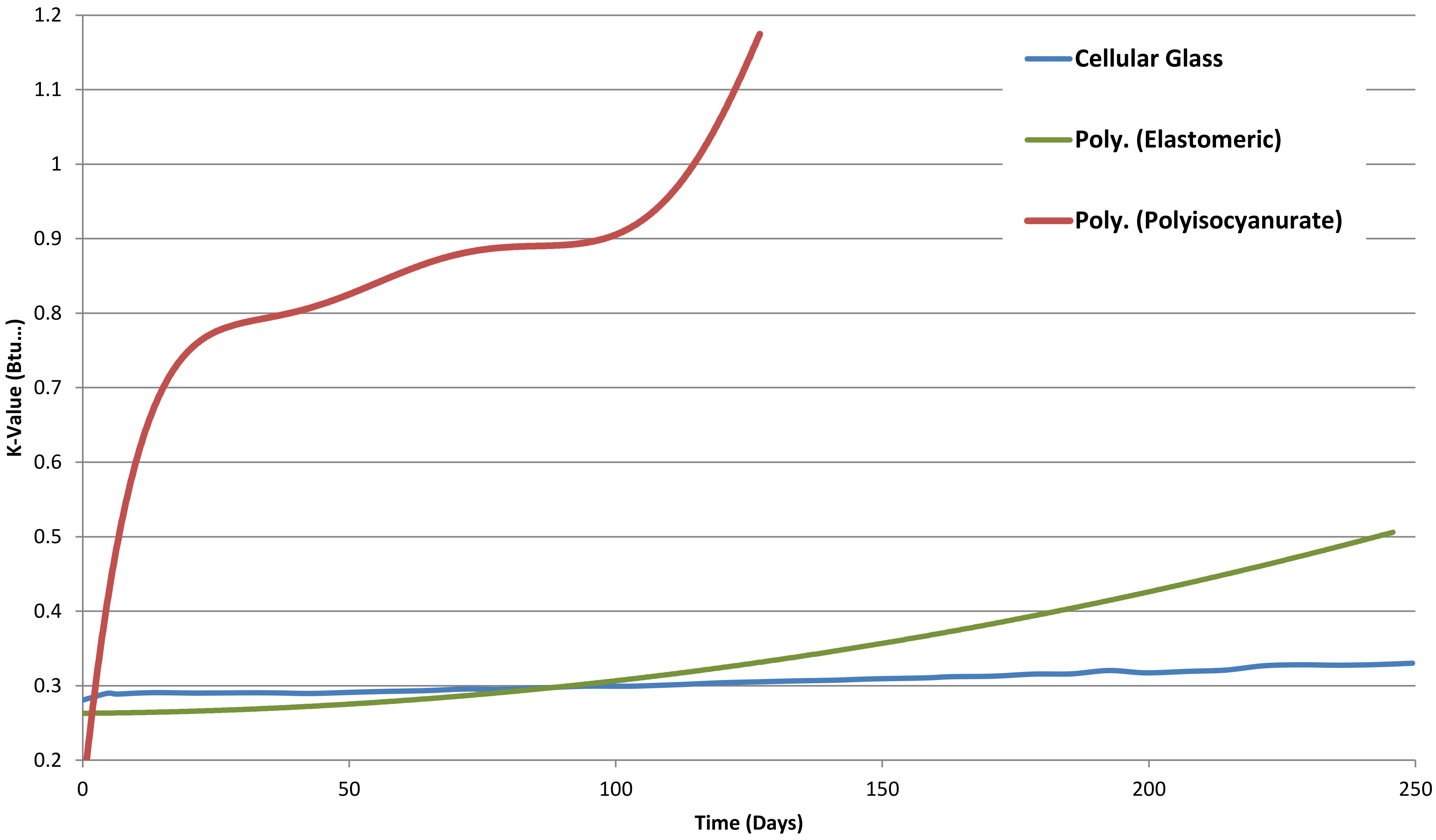




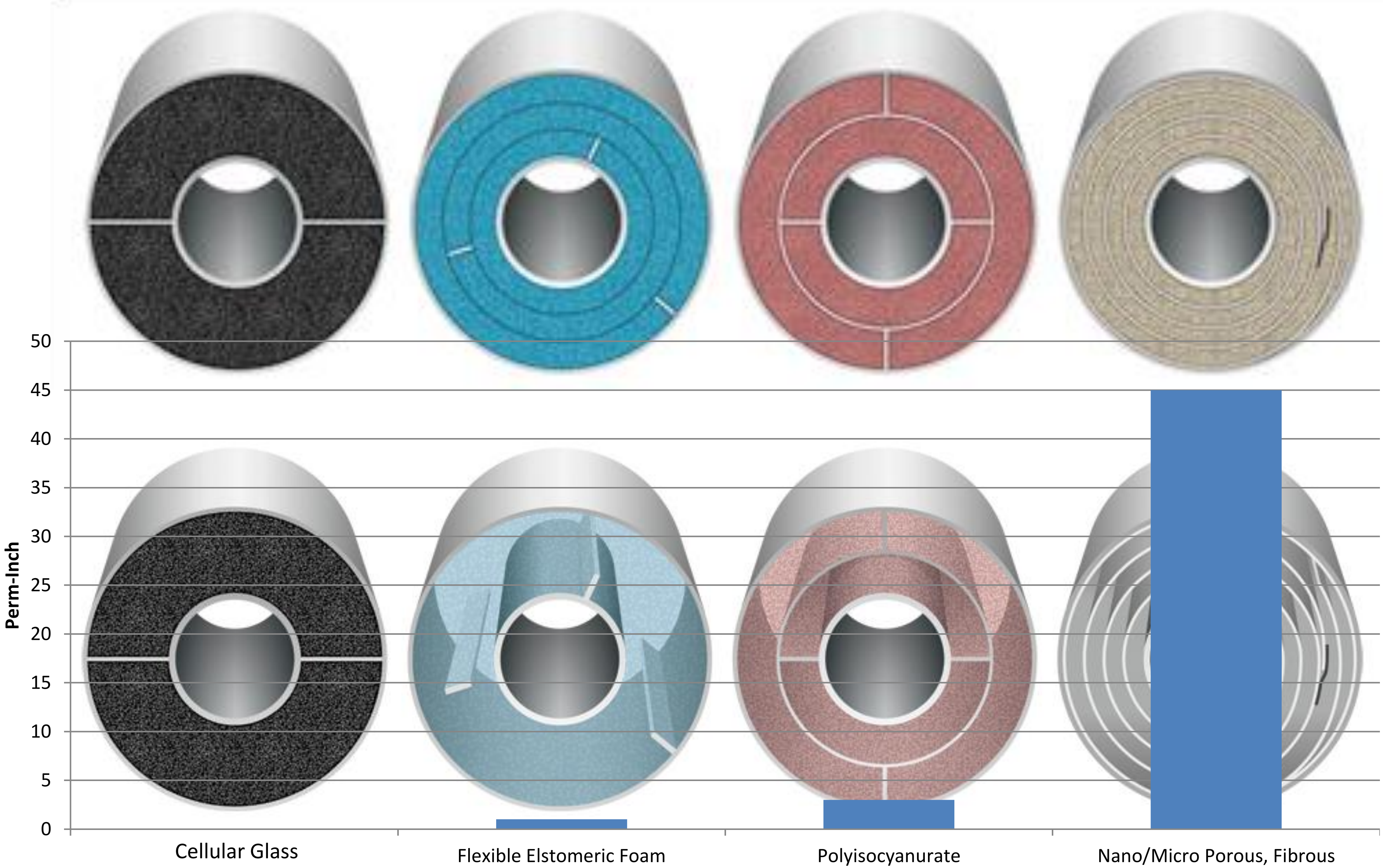
Long Term Testing - Mass Increase After 250 days



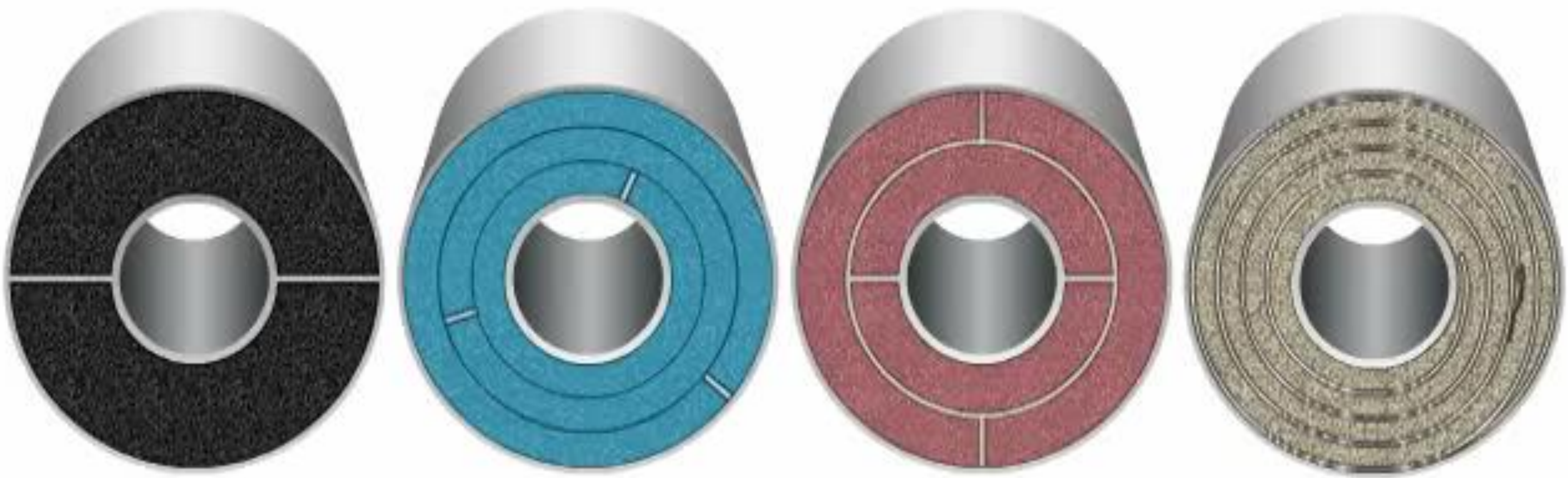
Thermal Conductivity Increase After 250 days



Effect of Vapor Barrier / Sealing failure



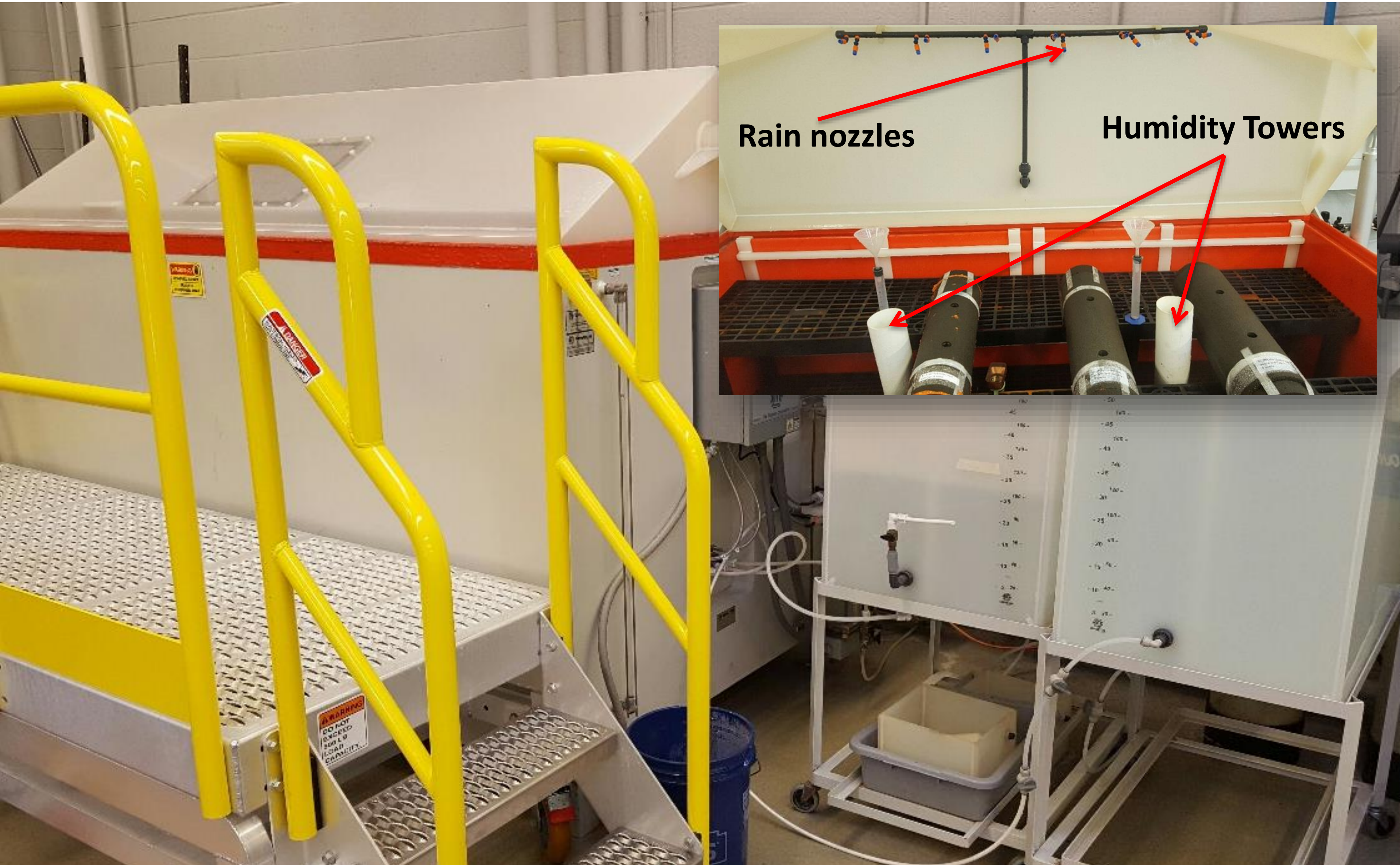
Vapor Permeability of System Components



Moisture & Corrosion Under Insulation (CUI)

- Carbon steel operating in the temperature range of approximate ambient temperatures of 32 to 300ºF is at the risk for CUI.
- Within 32ºF to 212ºF the rate of corrosion increases with rising temperatures.
- The rate of corrosion doubles as the temperature increases 30 to 40 degrees.
- For carbon steel the maximum corrosion rate is ambient to 250ºF.
- Stainless steel, operating in the temperature range of 120ºF to 400ºF, is at risk for stress corrosion cracking.
- Lines below 25ºF can also be subjected to CUI because of extended plant shutdowns.

Moisture & Corrosion Under Insulation (CUI)



Moisture & Corrosion Under Insulation (CUI)

ASTM B227 Guidelines

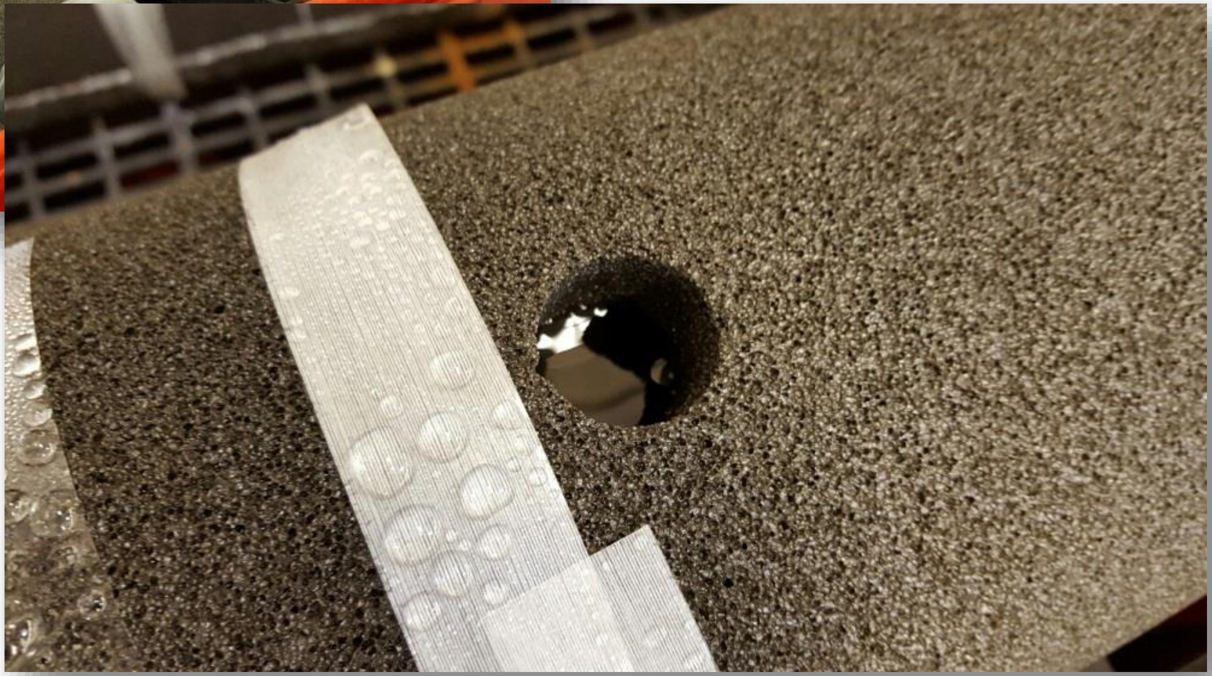
Conditions:

- **Moderate Conditions**
  - 75F Chamber Temperature
  - Only Rain (1/20) time
  - Both Hot and Ambient Test Specimens
  - Both Defects and Non-Defect Systems
- **Severe Conditions**
  - 95F Chamber Temperature
  - Rain (1/20) time & 100% Humidity
  - Both Hot and Ambient Test Specimens
  - Both Defects and Non-Defect Systems

Controlled Rainfall

Sprayers, Reservoir Tank, Hot Circulator

Moisture & Corrosion Under Insulation (CUI)



Moisture & Corrosion Under Insulation (CUI)

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Open System

Sealed System

Moisture & Corrosion Under Insulation (CUI)

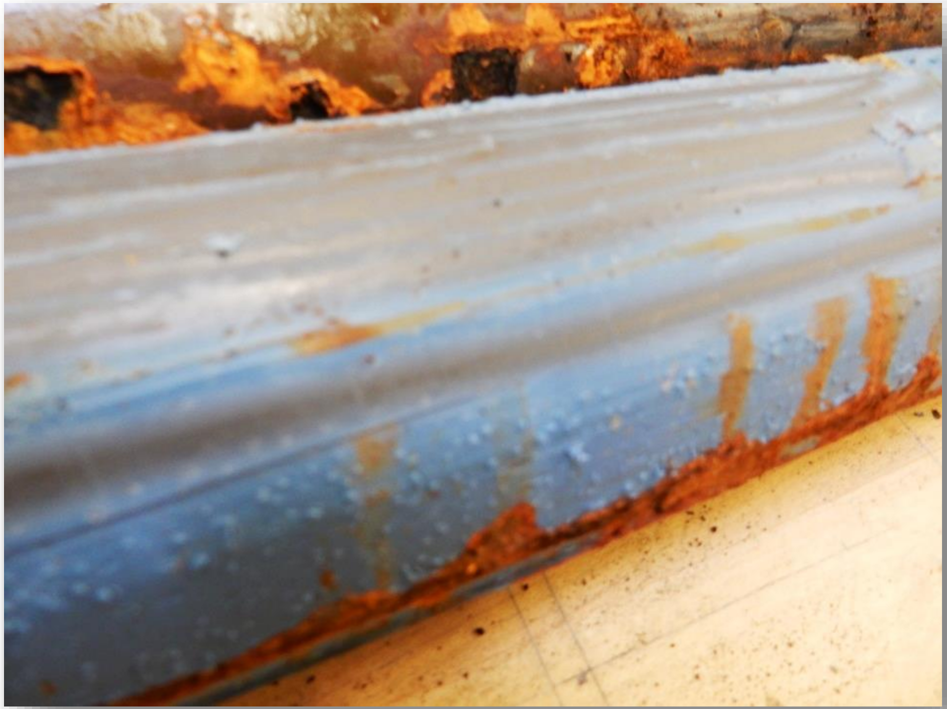
Example results from testing:

- Water must be kept out of direct contact at insulation/metal interface.
- Annular fillers work help to limit corrosion (ex. Tight fitting elastomeric products, corrosion inhibitors, etc.).
- Avoid application methods that open a sealed system (ex. screws in metal over wraps, etc.).
- Closed systems are often difficult to accomplish due to workmanship and available accessory products (sealant & wrap application methods often leak).
- Fibrous insulation products tend to perform poorly if other components are not designed properly.

Moisture & Corrosion Under Insulation (CUI)

- Bare Pipes with Corrosion Inhibitors – Without and With Heat Treating (350ºF)
- Test #33: Curing solvent-borne inhibitor, un-heated
- Test #34: Non-curing gel inhibitor- un-heated
- Test #35:Curing solvent-borne inhibitor- heated
- Test #36:Non-curing gel inhibitor- heated
- Test #37: Competitive corrosion inhibitor- heated
- All worked well at ambient, severe limitations to temperature, coating must be applied carefully for good performance

Moisture & Corrosion Under Insulation (CUI)



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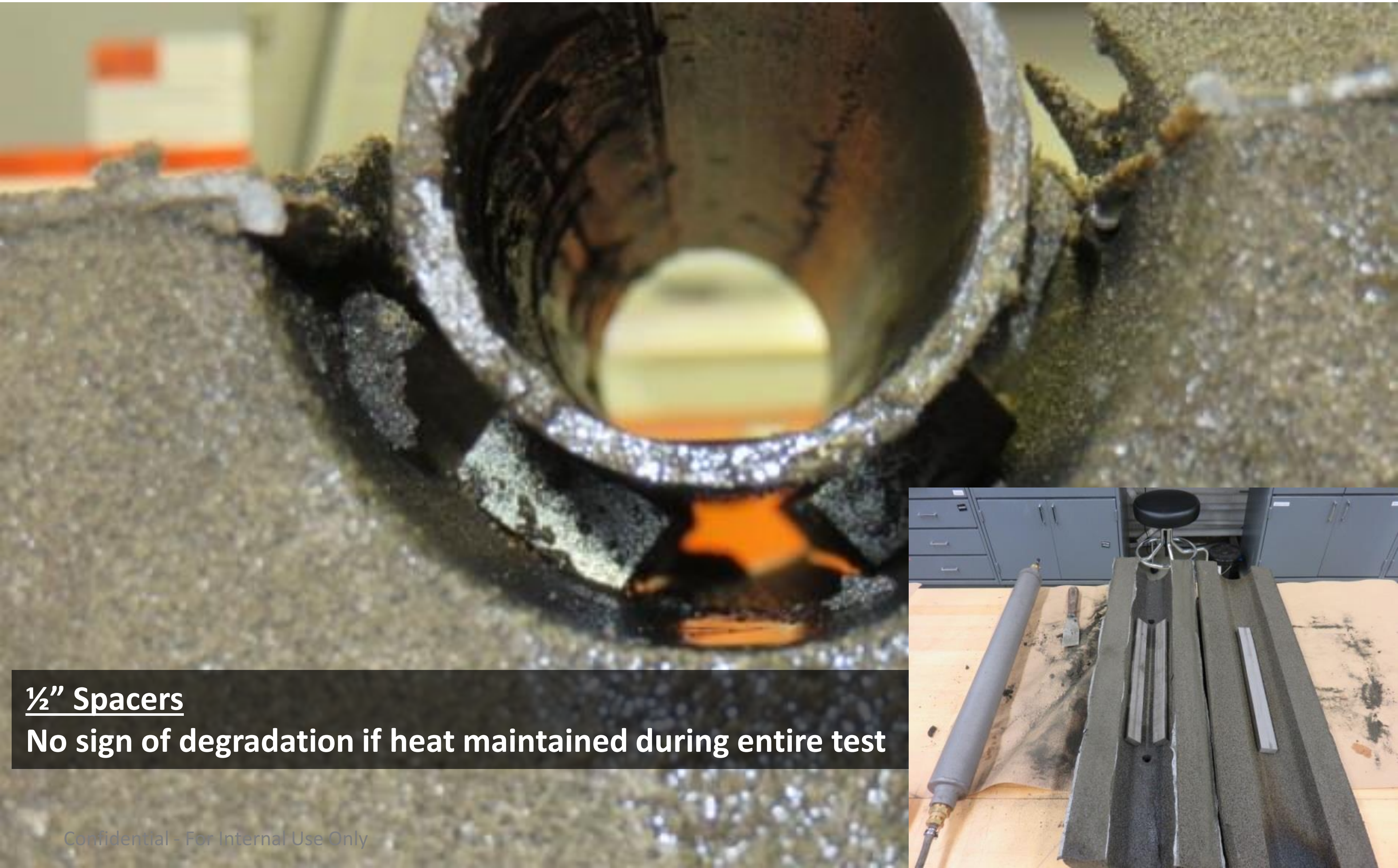
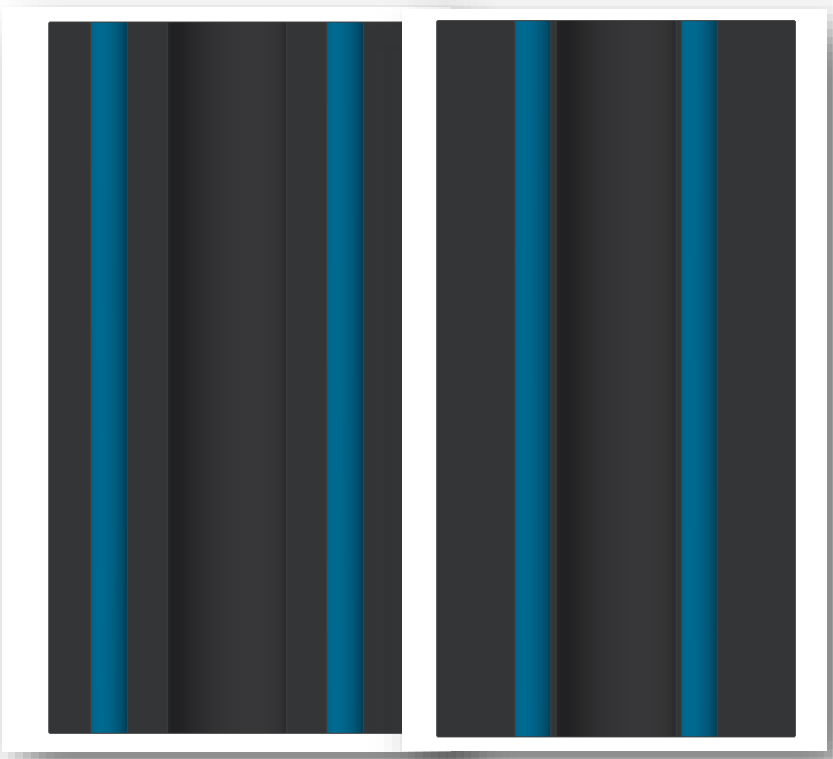
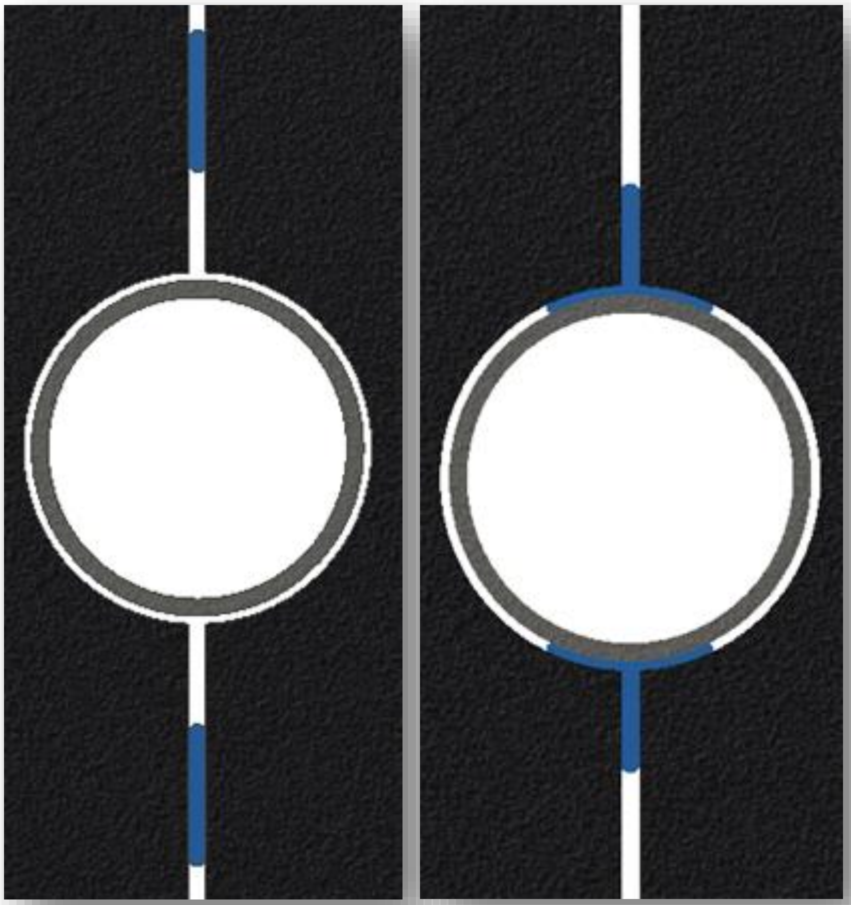


<u>½" Spacers</u>
No sign of degradation if heat maintained during entire test

Moisture & Corrosion Under Insulation (CUI)



* Blue indicates adhesives



4-8 times increase in bead width under compression

Effects of Moisture on Thermal Insulation

- Consider insulation material properties when designing piping and insulation systems.
- Add jacketing/protective layers to open cell systems. Use of corrosion inhibitors may be helpful.
- Use spacers to keep wet insulations away from piping surface on higher perm products.
- Seal closed-cell products properly.
- Seal with a technique to localize water intrusion if it occurs.