# A Building Scientist's Perspective on the Building Enclosure

CLEVELAND BUILDING ENCLOSURE COUNCIL

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C. J. SCHUMACHER

RDH BUILDING SCIENCE LABORATORIES

Building Enclosure Council
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# A Building Scientist's Perspective on the Building Enclosure

**Chris Schumacher** *Principal and Senior Building Science Specialist* at RDH Building Science Inc.

**Tuesday**
**October 25, 2016**
**Corporate College East**
**Warrensville Heights**
**Registration: 4:30 pm**
**Program: 5:30-7:00 pm**

For more information and to register, visit:
www.bec-cleveland.org

1.5 AIA credits

Project teams use their understanding of the enclosure to deliver good buildings to their clients. Decisions need to be based on solid facts about the functioning of the enclosure and mechanical systems in relation to the climate and codes and about physical laws relating to heat, air and moisture flows across the enclosure. With the expanding use of building automation and grid connected sensors monitored in real time, building performance outcomes are increasingly measured and known. Given that our mainstream understanding of building science is based on layers of simplifying assumptions, what widely held beliefs should we be challenging in this new era?

- Should we trust reported R-values?
- How can increasing ventilation rates decrease indoor air quality?
- What common practices ruin the thermal performance of continuous insulation?
- Is the thermostat the right tool to control indoor comfort?
- Do pressure equalized assemblies make walls leak worse?
- Can high solar heat gain window make sense in hot climates?
- Do air conditioners control humidity?

## A Building Scientist's Perspective on the Building Enclosure

1. Should we trust reported R-values?
   → No, question everything
2. How can increasing ventilation rates decrease indoor air quality?
   → Humidity; Pressure Field
3. What common practices ruin the thermal performance of continuous insulation?
   → Thermal Bridges; Air Flanking; Windows
4. Is the thermostat the right tool to control indoor comfort?
   → Almost never
5. Do pressure equalized assemblies make walls leak worse?
   → Yes, they can
6. Can high solar heat gain window make sense in hot climates?
   → No, and rarely make sense in moderate & cold climates
7. Do air conditioners control humidity
   → No, AC affects humidity but can't control it

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# Should we trust reported R-values?

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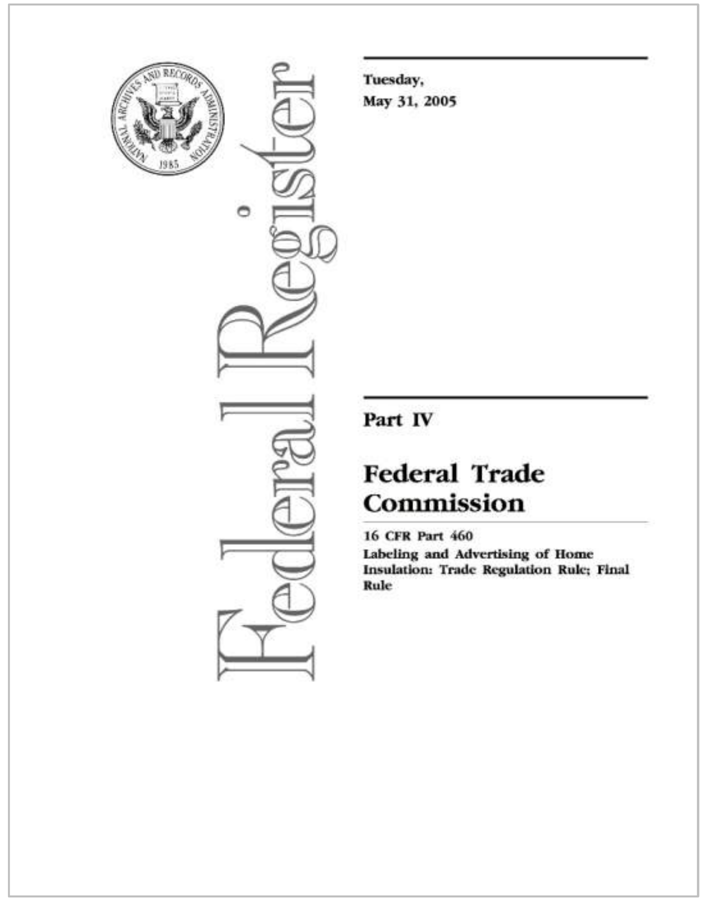
# Label R-Values

→ FTC 16 CFR Part 460

→ Federal Trade Commission

→ Title 16 – Commercial Practices
Commercial Federal Regulation

→ Part 460 – Labeling and Advertising
of Home Insulation Trade Regulations


Federal Register

Tuesday,
May 31, 2005

Part IV

Federal Trade Commission

16 CFR Part 460
Labeling and Advertising of Home Insulation: Trade Regulation Rule; Final Rule

http://www.ecfr.gov/cgi-bin/text-idx?SID=79485feed2653b4002a771a5b34c6cd8&node=pt16.1.460&rgn=div5

## Label R-Values

→ FTC 16 CFR Part 460

"R-value is the numerical measure of the ability of an insulation product to restrict the flow of heat and, therefore, to reduce energy costs — the higher the R-value, the better the product's insulating ability."

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## Label R-Values

→ Promoted by Everett Schuman, Penn State's Housing Research Institute (1940s)

→ Property of a layer of material or assembly

→ Measurement of resistance to heat flow

→ R-value is the reciprocal of thermal conductance

→ ASTM C518,  ASTM C177

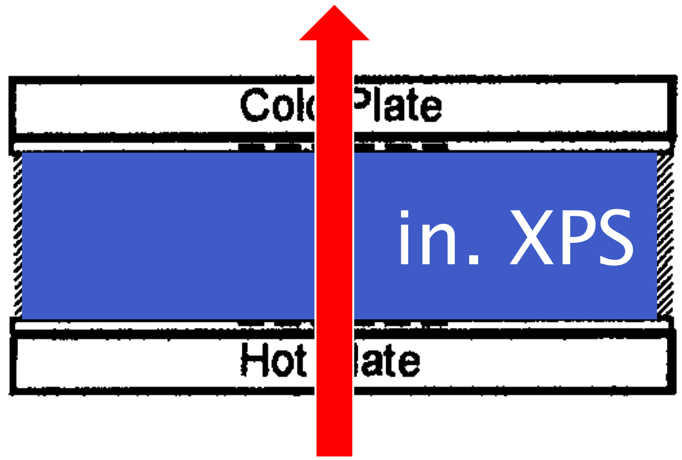
## Measuring Label R-Values (ASTM C518)

1.141 Btu/hr

$T_{cold}$ = 50.0˚F

$T_{mean}$ = 75.2˚F

$T_{hot}$ = 100.5˚F




dT = 50.5˚F

Heat Flux Transducer Area = 16 $in^2$ = 0.111 $ft^2$

Apparent R-value of aged 1 in. XPS

R 4.92

(within 2% of label R-value)

# When should we question R-value?

greenbuildingadvisor.com/blogs/dept/musings/beware-r-value-crooks

## Beware of R-Value Crooks

**Insulation scams for products like P2000 rob unwary consumers by exaggerating R-values**

POSTED ON MAR 3 2009 BY MARTIN HOLLADAY, GBA ADVISOR

Scammers continue to use exaggerated R-value claims to peddle inferior insulation products, in spite of the existence of strong consumer protection laws. Year after year, naïve builders fall prey to Web-based marketing pitches for "miracle" products like "insulating" paint and 1-inch-thick R-10 foam.

In the late 1970s, exaggerated claims by insulation marketers were so common that the U.S. Congress passed a consumer-protection law specifically addressing R-value scams. Although false marketing claims were already illegal, Congress concluded that R-value scams were so rampant and damaging to consumers that the industry needed targeted regulation.

**P2000 Insulation System R-Value Comparison**

| PRODUCT | THICKNESS | R-VALUE |
|---|---|---|
| Thermasheath by R-max | 1" | 5.9 |
| Thermax by Dow | 1" | 6.5 |
| P2000 Insulation Systems | 1" | 10.3 |

# Temperature Dependent R-values

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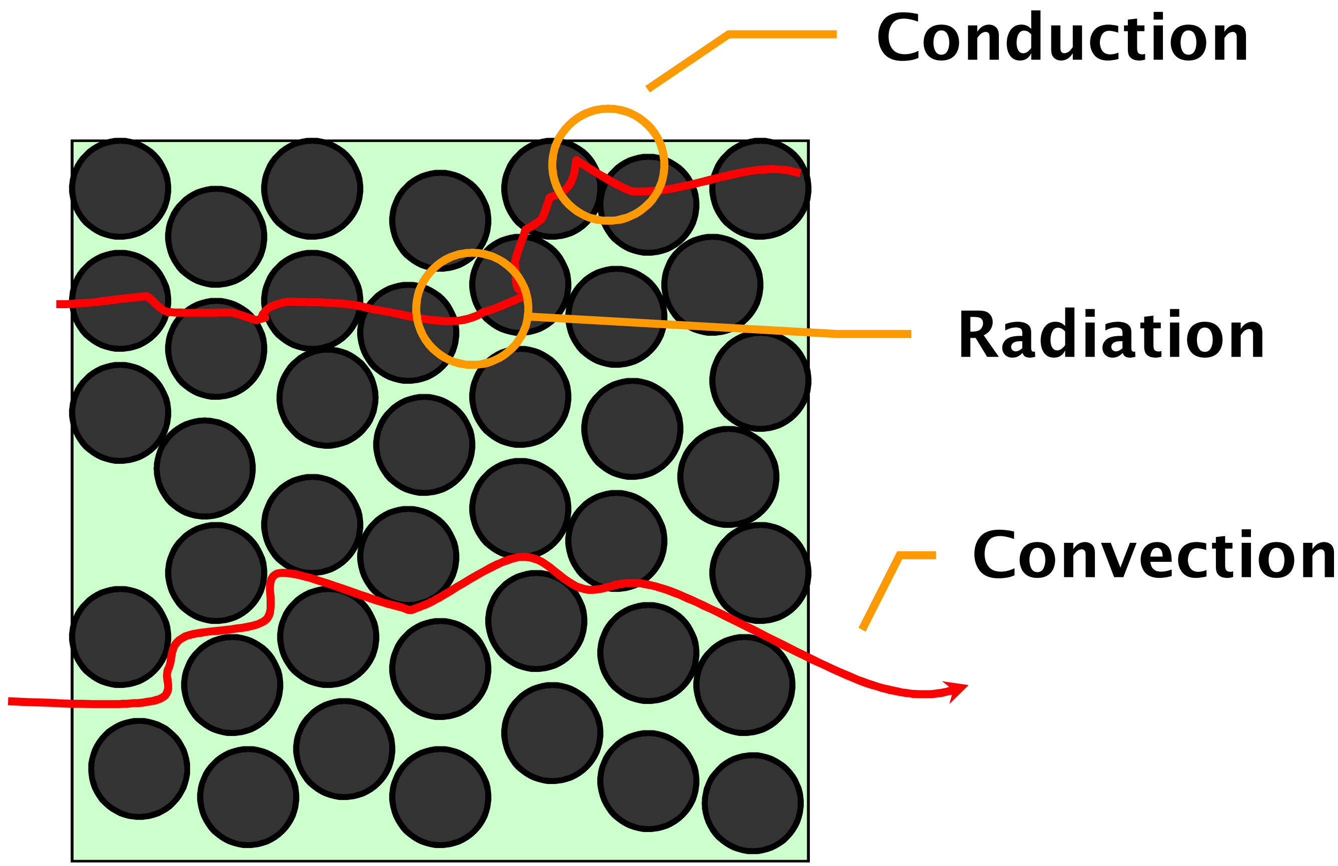
## Heat Transfer ***Inside*** Insulating Materials




**Hypothetical porous material**

# Fiber Glass Insulation

→ Little material

→ Lots of interconnected voids

→ Little surface area

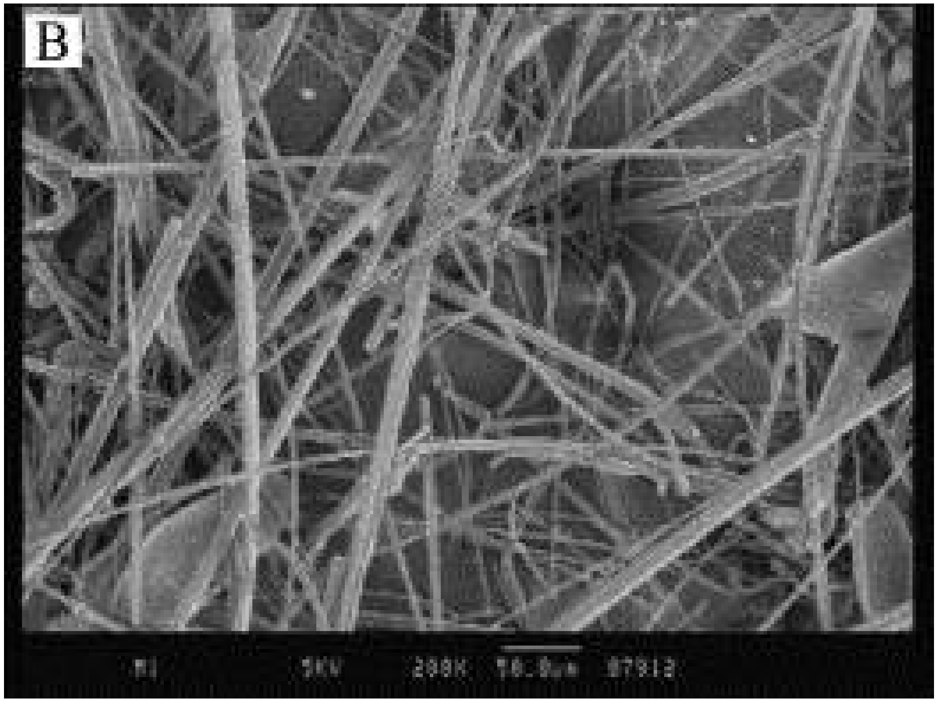




Photo: www.thermapan.com

# Heat Transfer in Fiber Glass

→ Combination of conduction through air and glass plus radiation

From Bankvall, "Heat Transfer in Fibrous Materials," *Journal of Testing and Evaluation*, Vol. 1, No. 3, May 1973

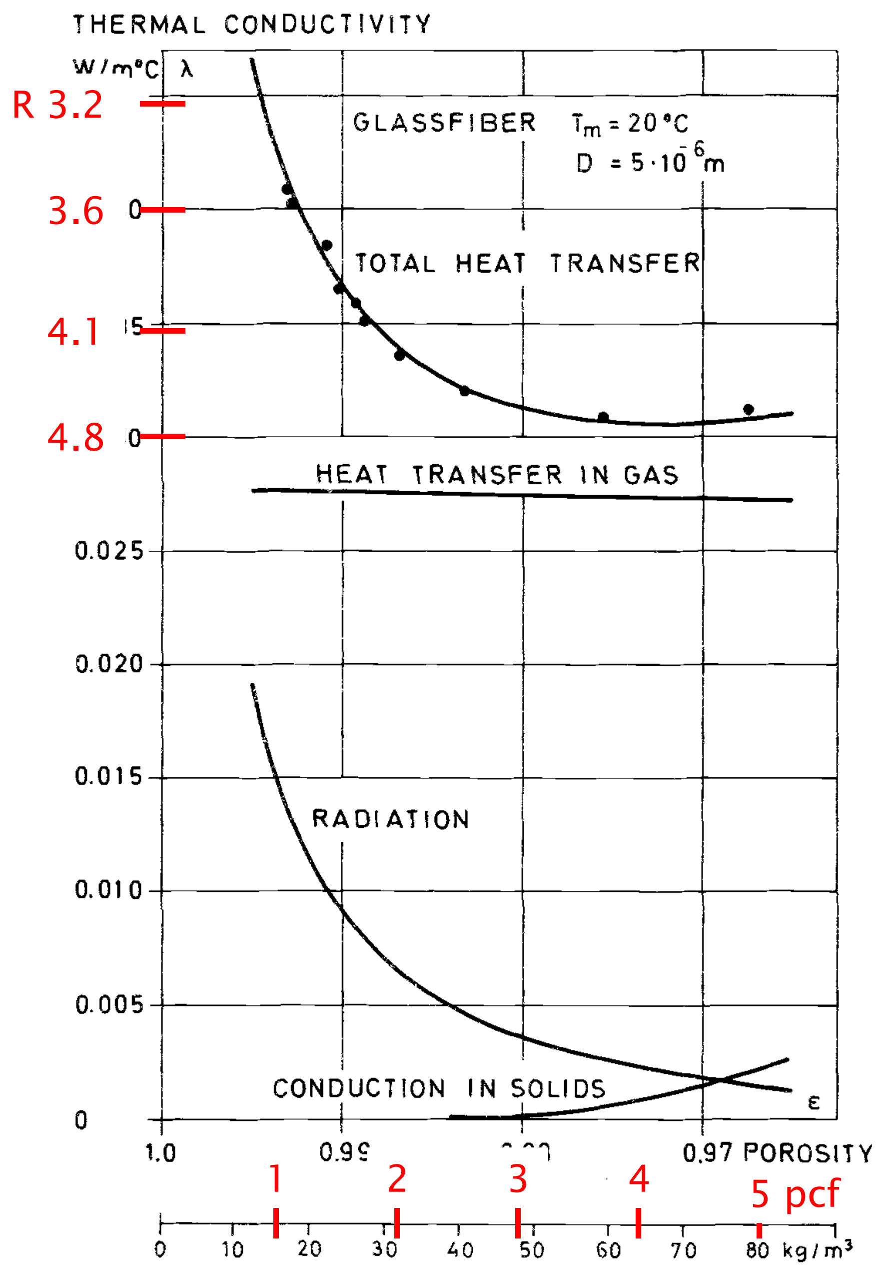



FIG. 16—*The mechanisms of heat transfer in a fibrous material.* — = *calculated and* ● = *measured values.*

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## Expanded Polystyrene

→ (EPS)

→ Little material

→ Some interconnected voids

→ Lots of surface area

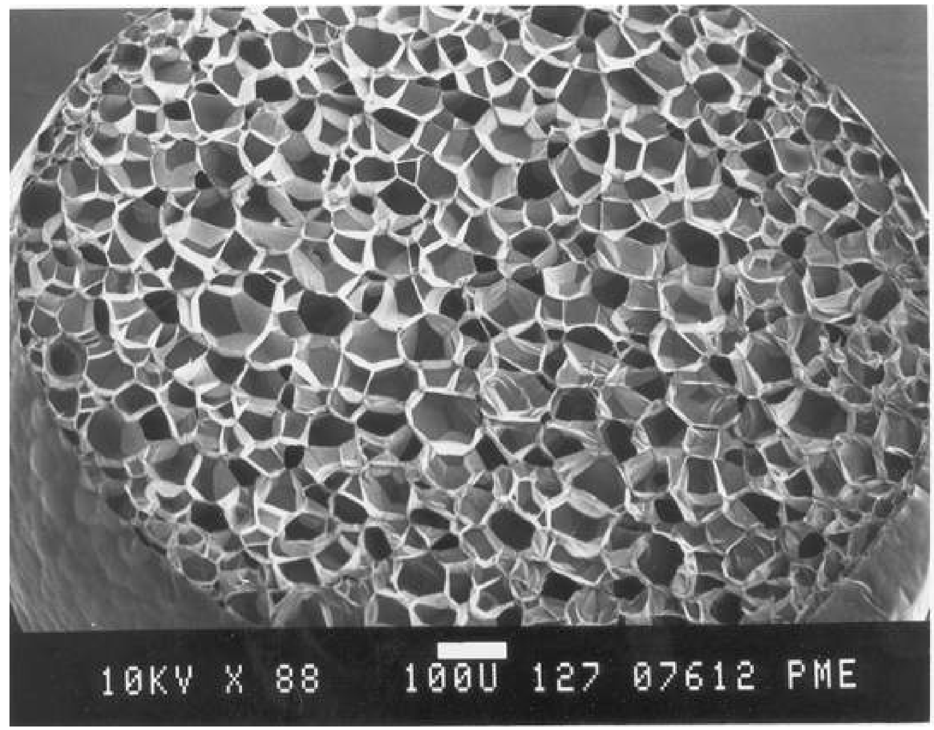


Photo: www.styreneproducts.com

# Open-Cell Polyurethane Foam

→ (0.5lb ocSPF)

→ A little more material

→ Many interconnected voids

→ Lots of surface area

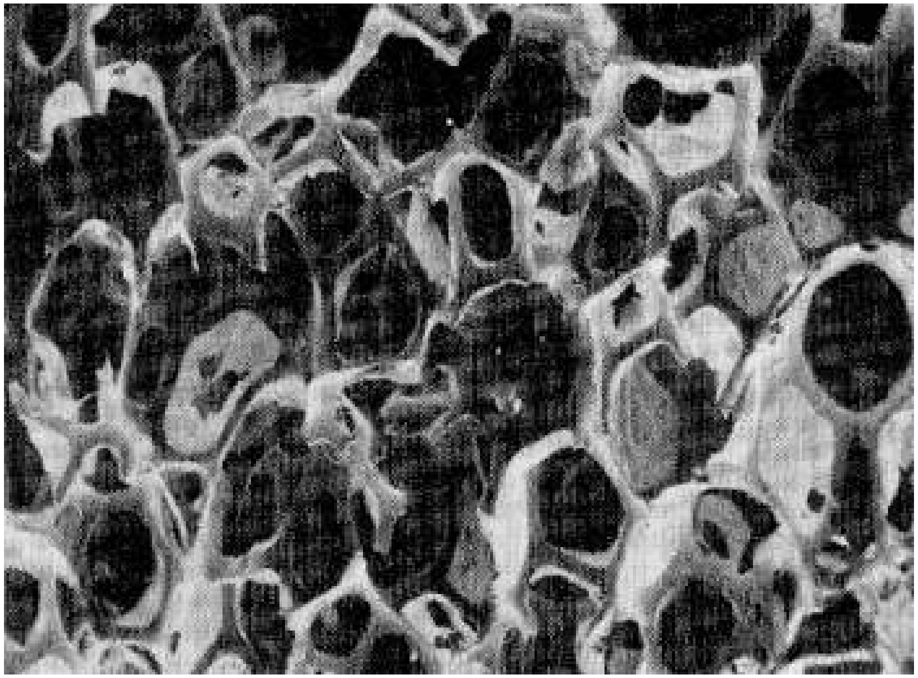

Photo: NRC-IRC

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## Closed-Cell Polyurethane Foam

→ (2lb ccSPF)

→ More material

→ Few interconnected voids

→ Lots of surface area

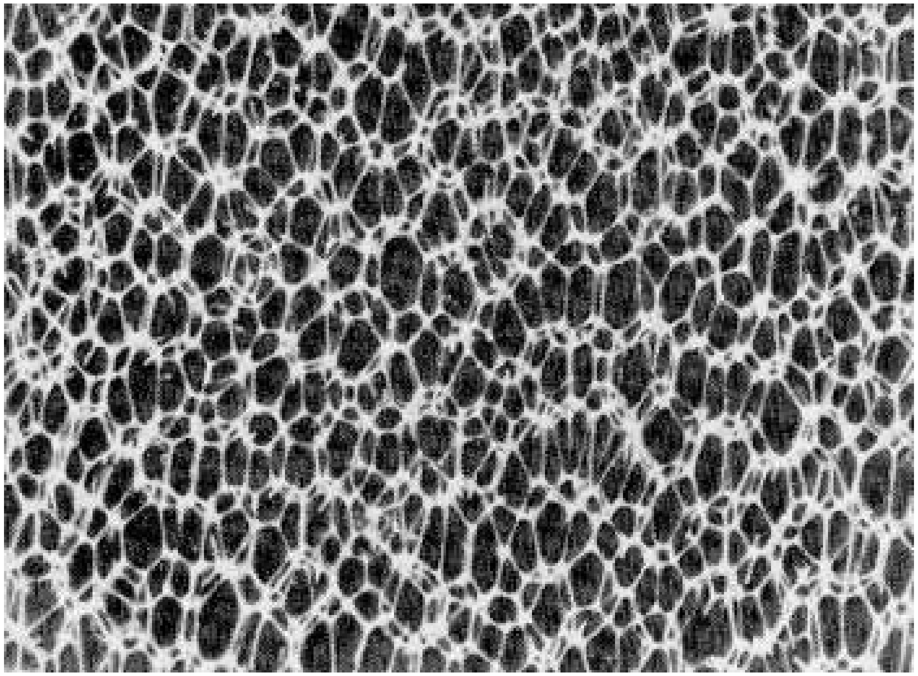

Photo: NRC-IRC

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## Heat Transfer ***Inside*** Insulation Materials

→ **Conduction**

- → Through Solid Material
  - › Conductivity, Cross section, Length of flow path
- → Through Pore Gas
  - › Conductivity, Cross section

→ **Convection**

- → Through Connected Pores
  - › Heat capacity, Flow rate, Temperature difference

→ **Radiation**

- → Across pores
  - › Emissivity & Transparency of solid, Cross section, Path Length

But each of these mechanisms change with temperature

So heat flow varies with temperature

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## Temperature Dependency

Theory and measurements show:

→ Conduction varies with temperature difference

→ Convection varies with temperature difference (and a bit with mean temperature due to the changing density of air)

→ Radiation varies with the mean absolute temperature (i.e. °K or °R)

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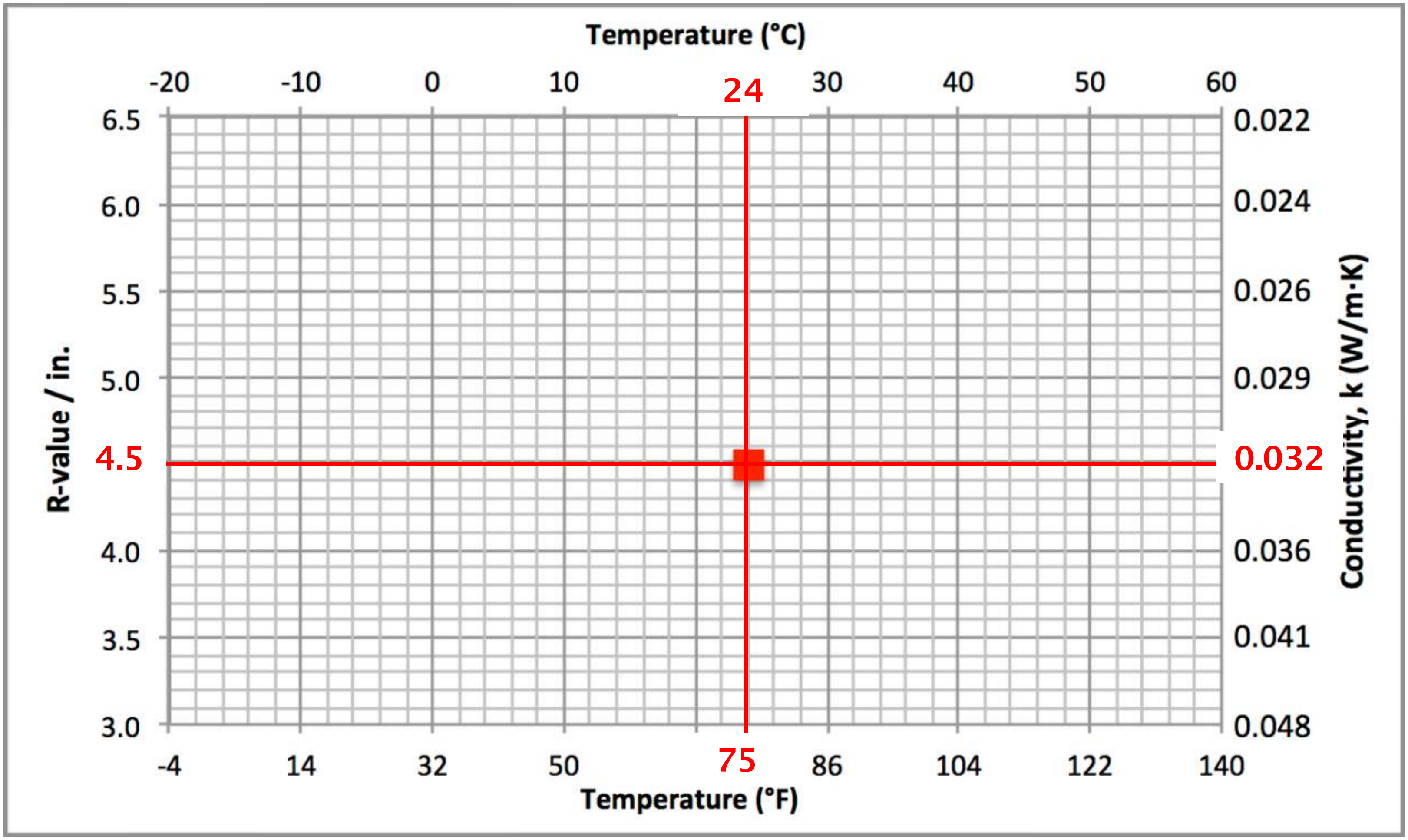
# Temperature Dependency – Semi-Rigid Fiber Glass

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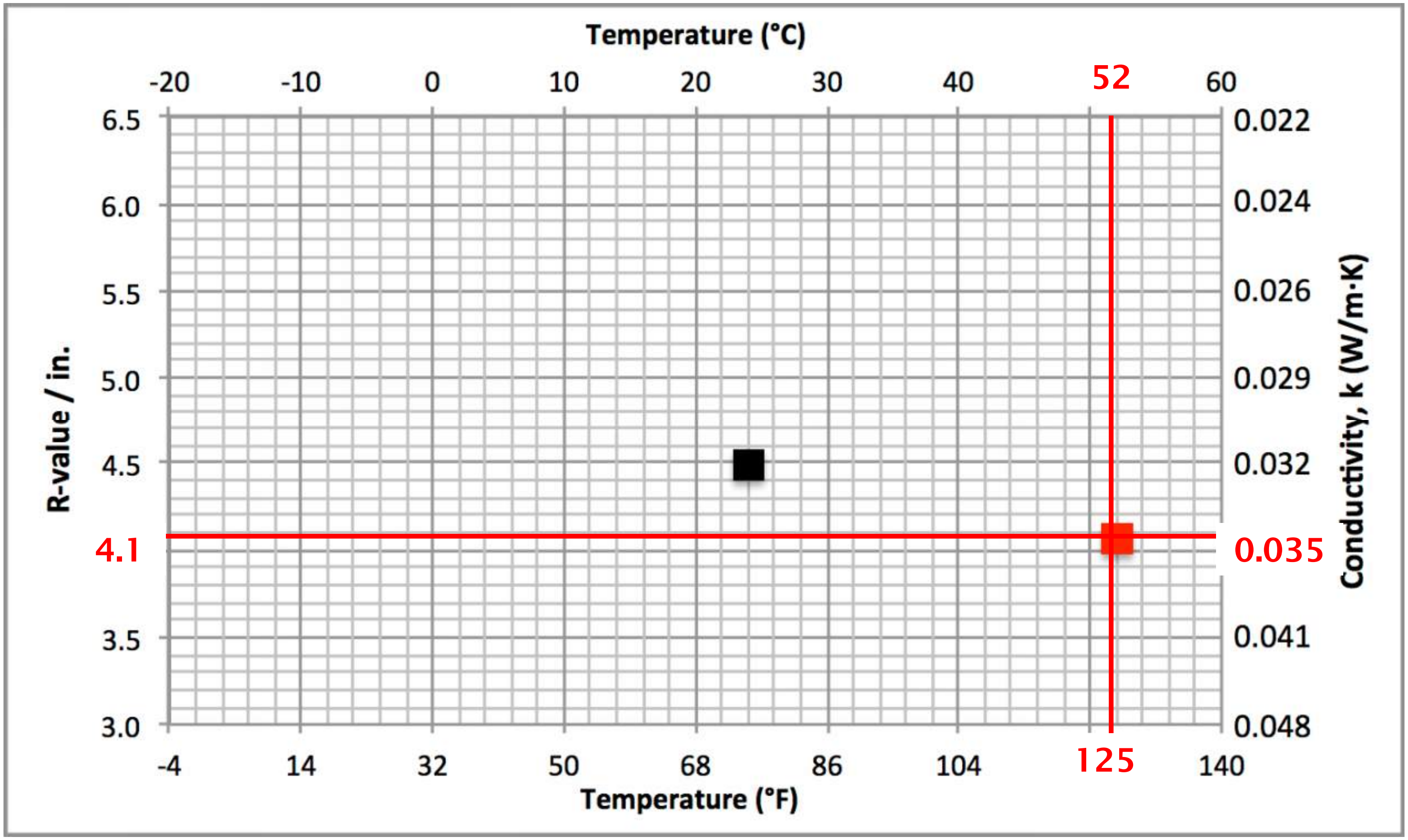


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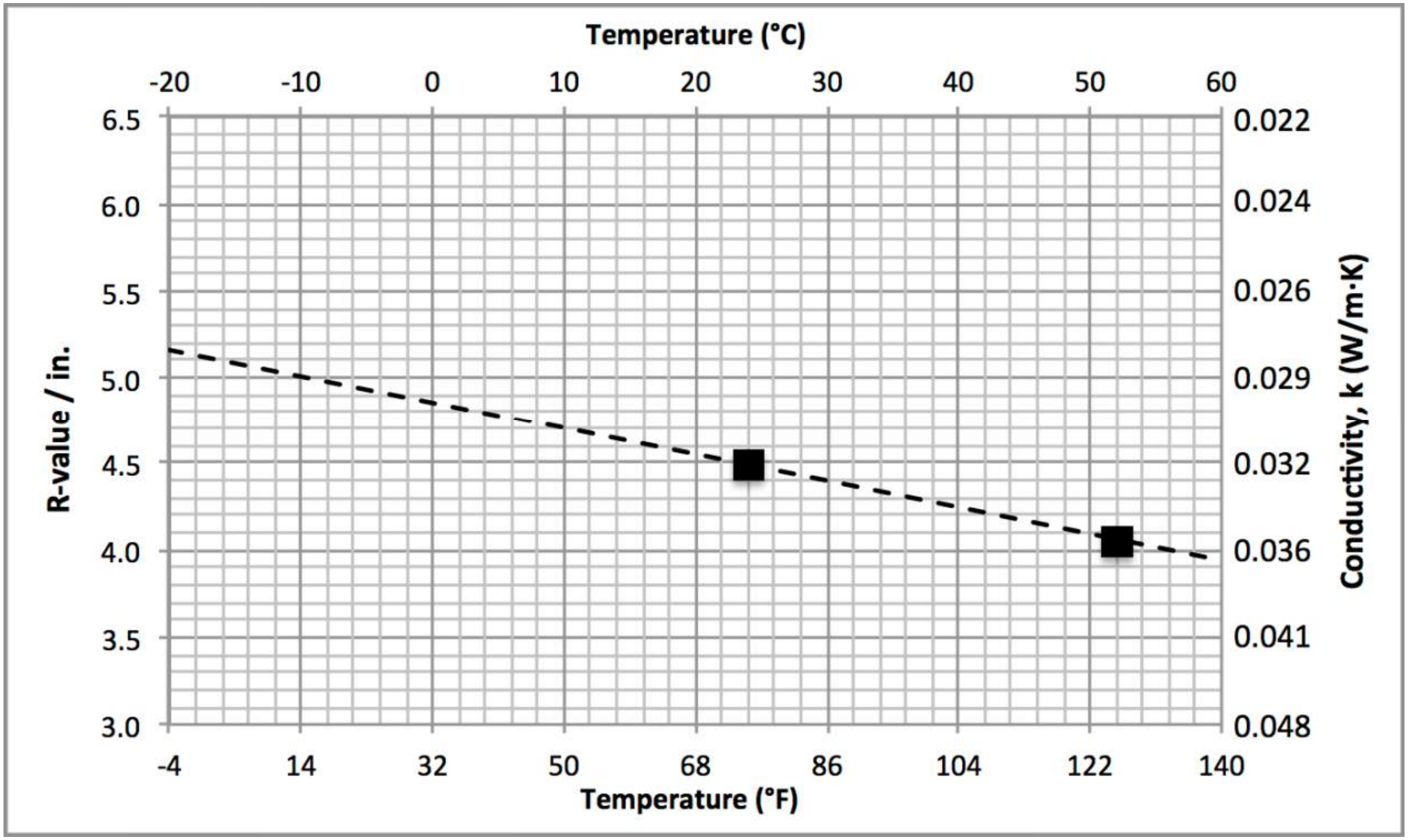


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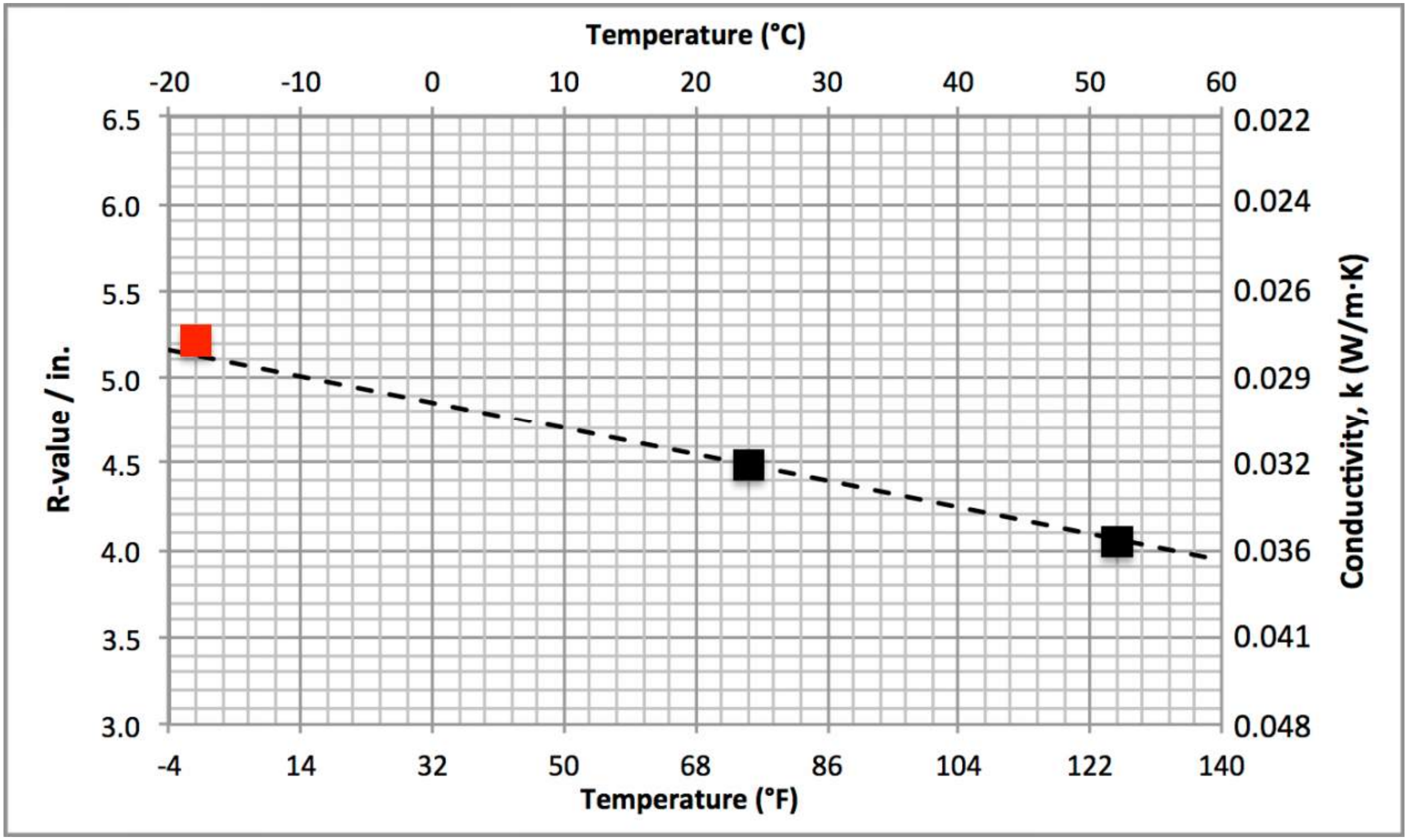
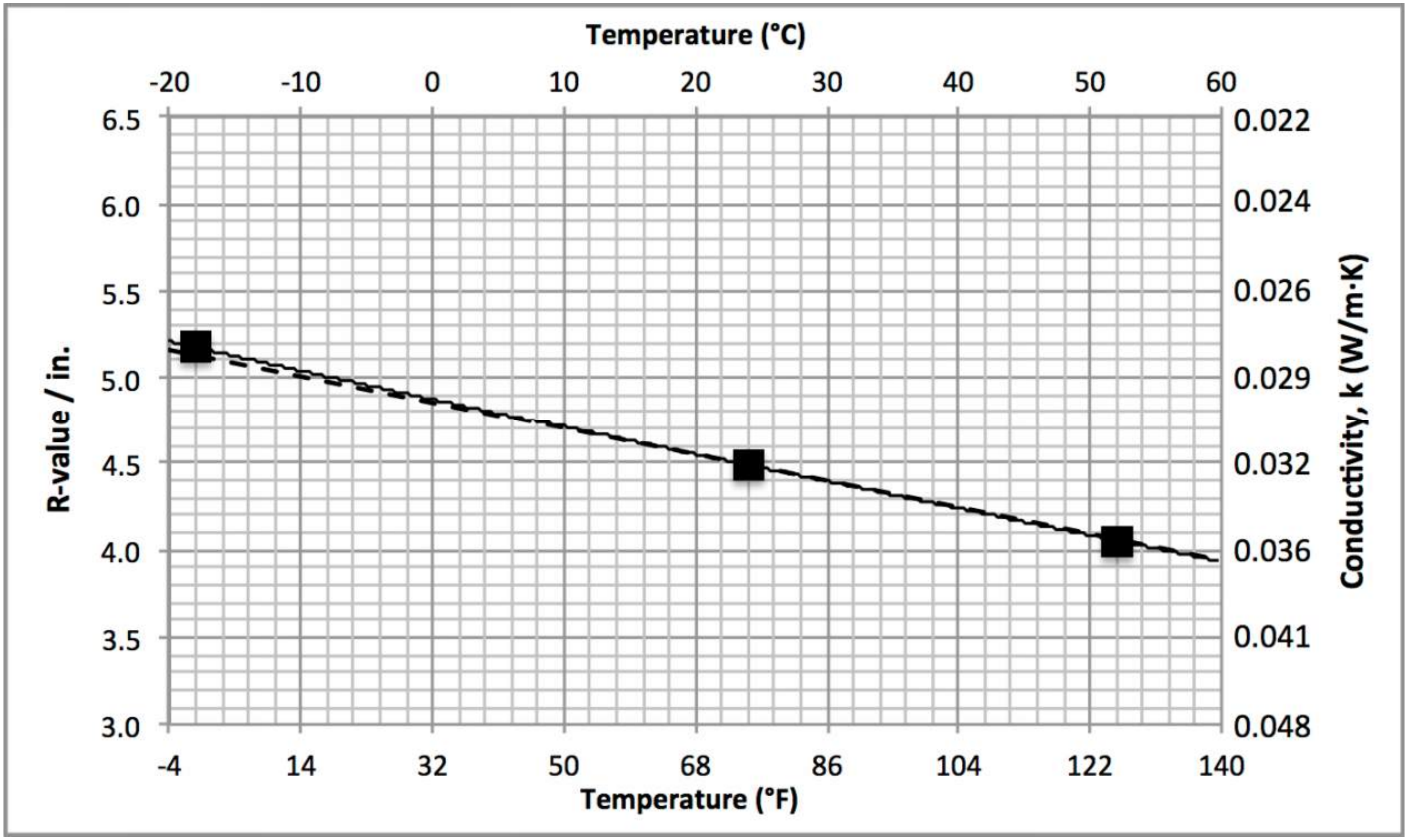
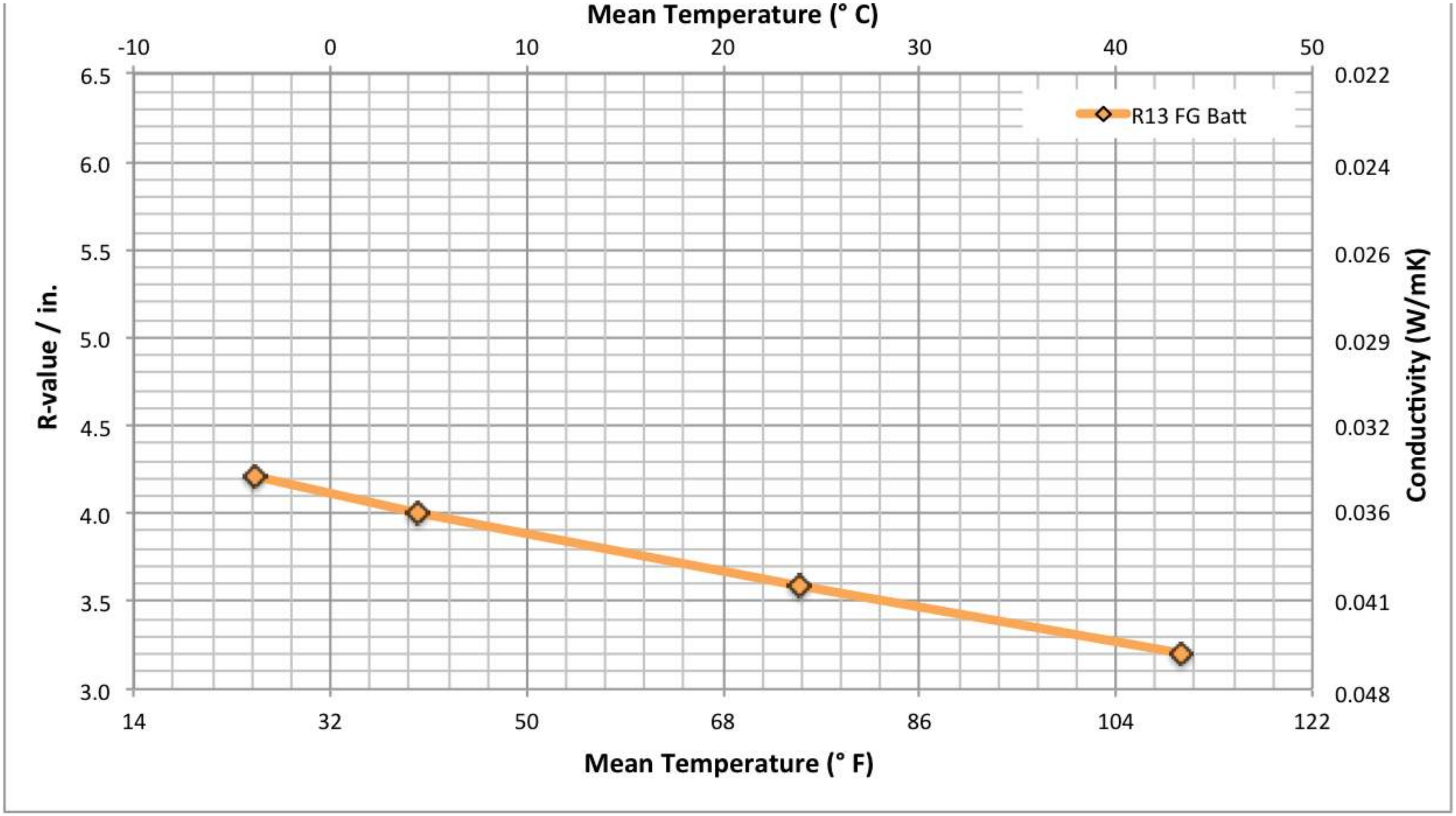


# Temperature Dependency – Semi-Rigid Fiber Glass



# Selected RDH-BSL measurements of Temperature Dependent R-Values

# R13 Fiber Glass Batt

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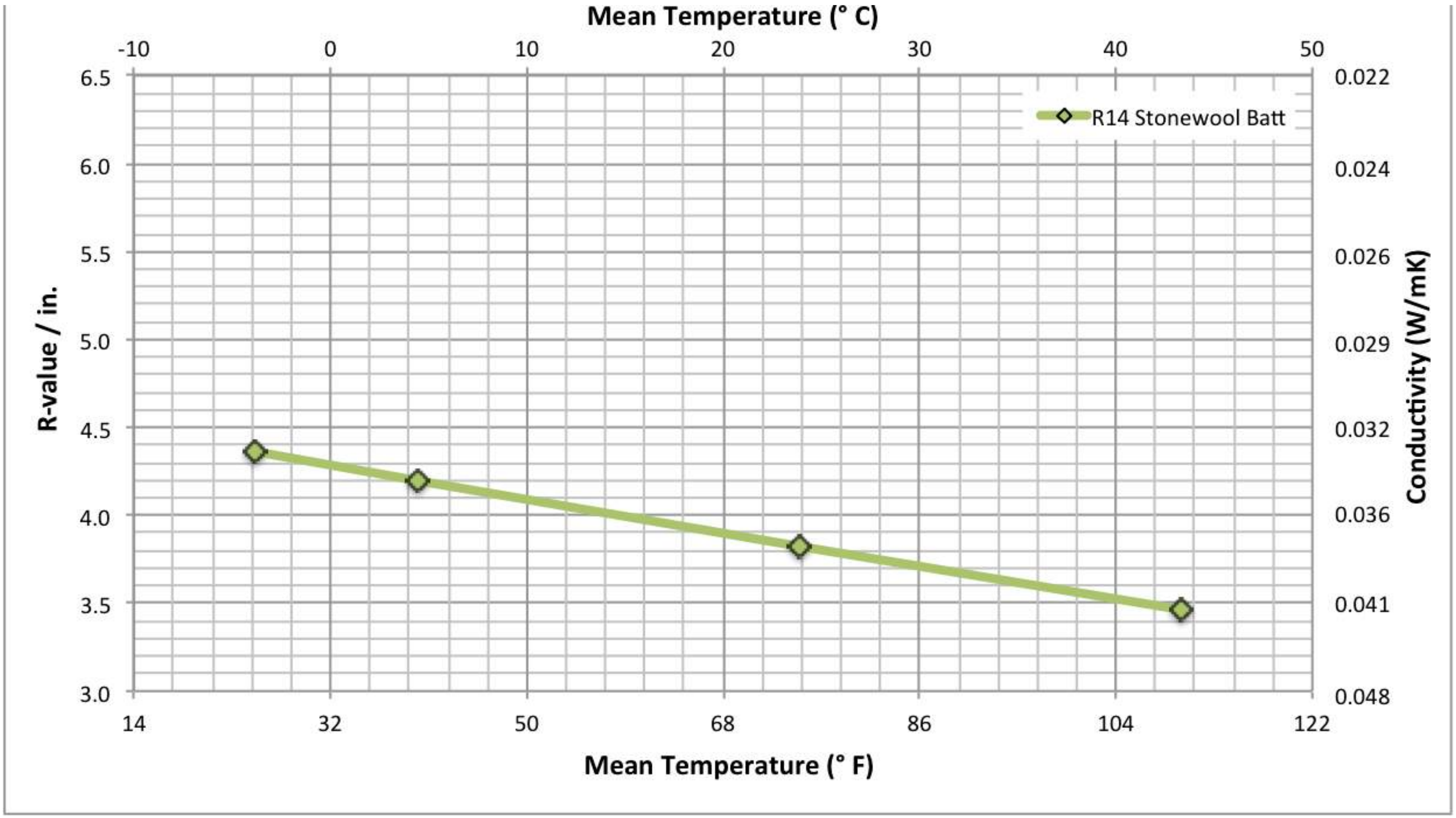
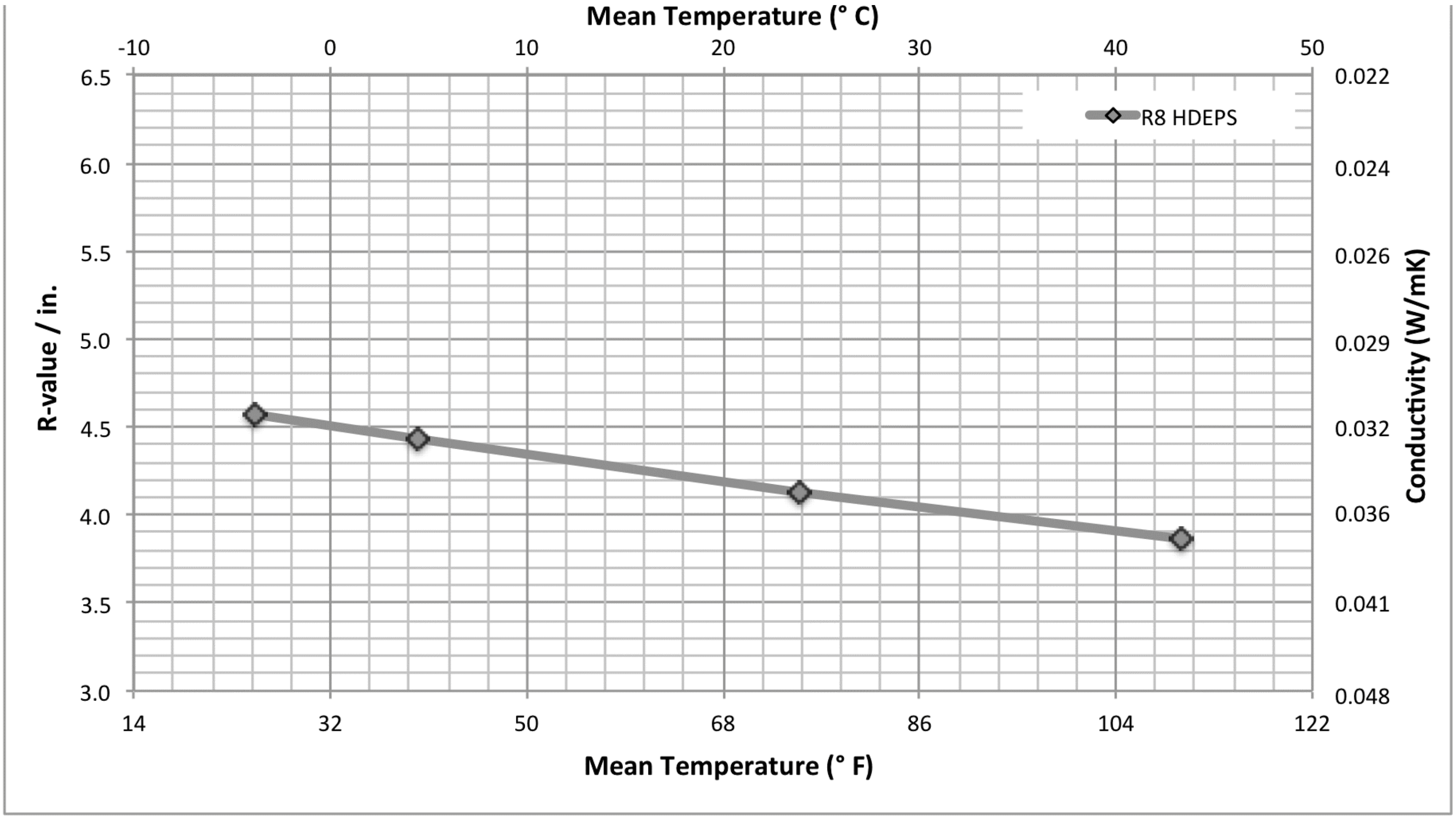
# R14 Stonewool Batt



# R8 HDEPS (1.3 pcf)

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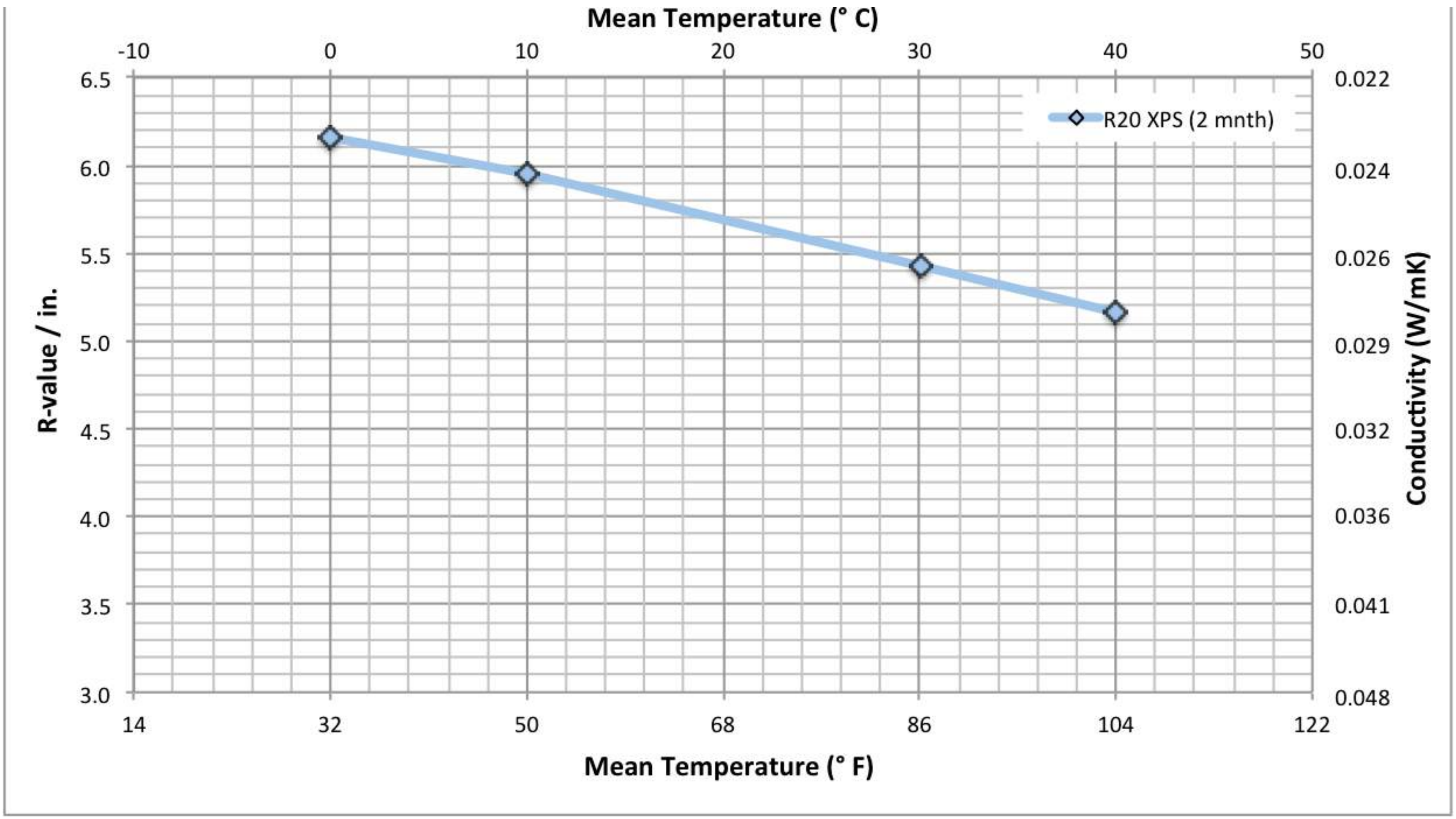
# R20 XPS (2 mnth)

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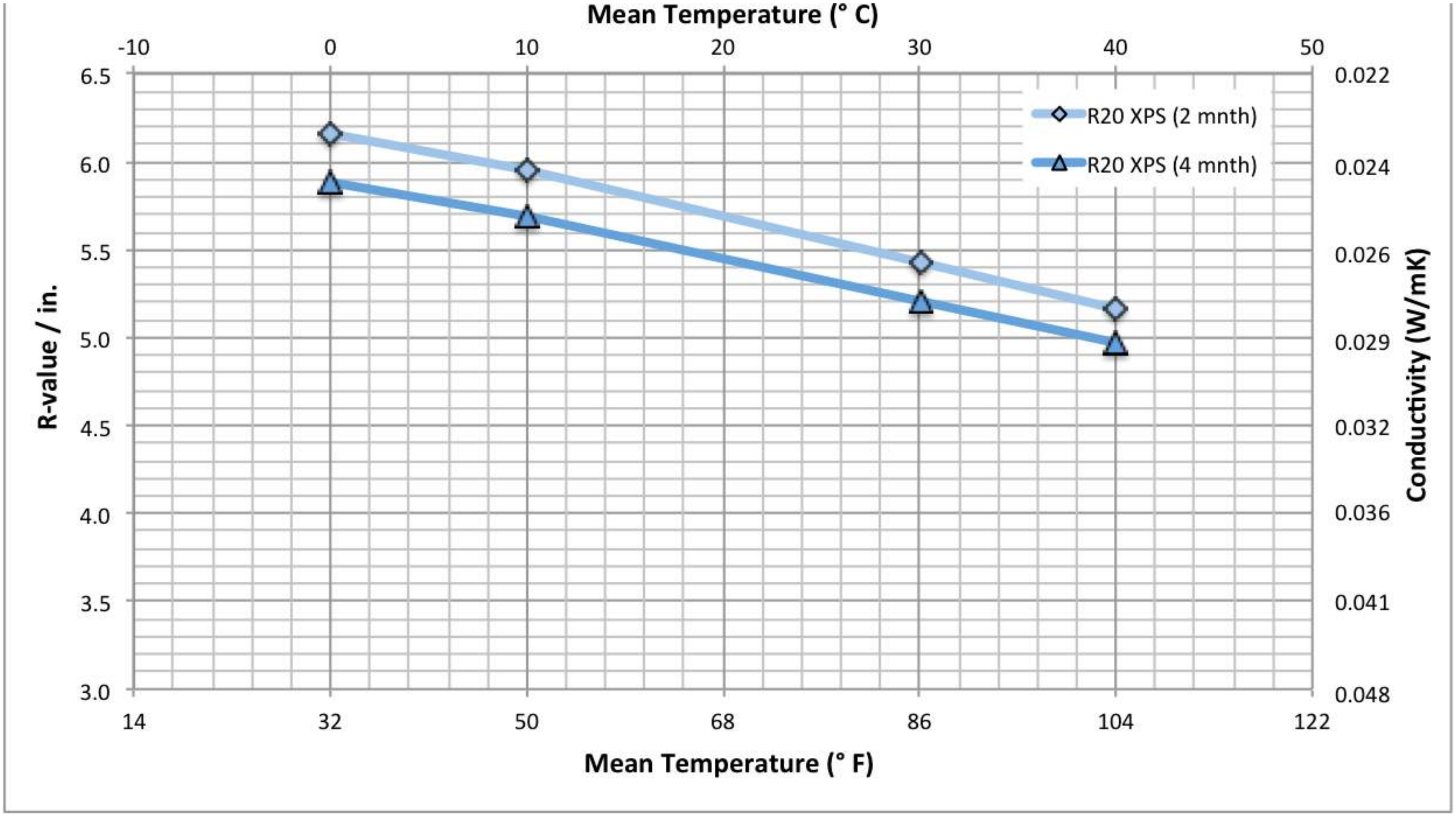
# R20 XPS (2 & 4 mnths)

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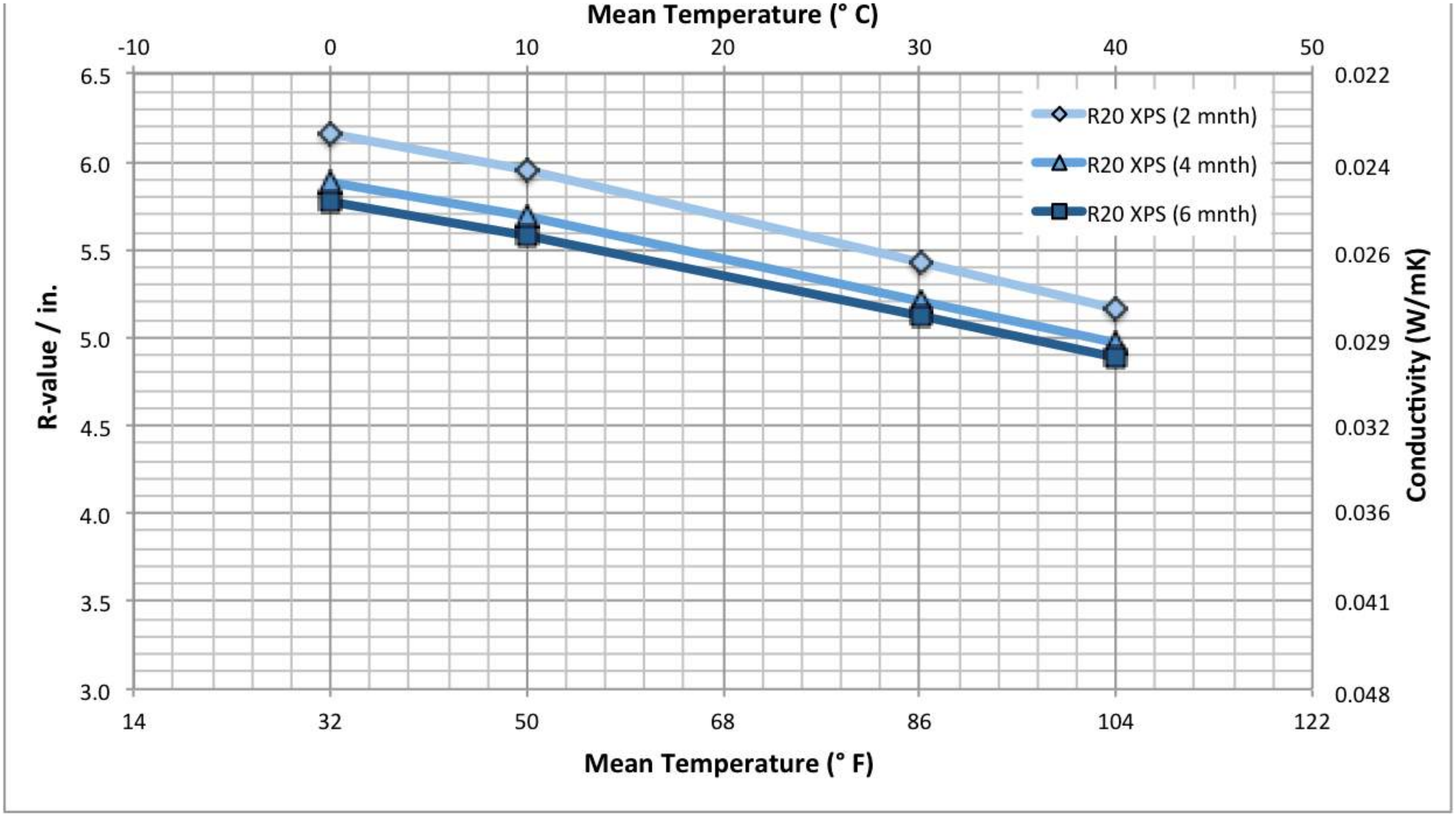
# R20 XPS (2, 4 & 6 mnths)

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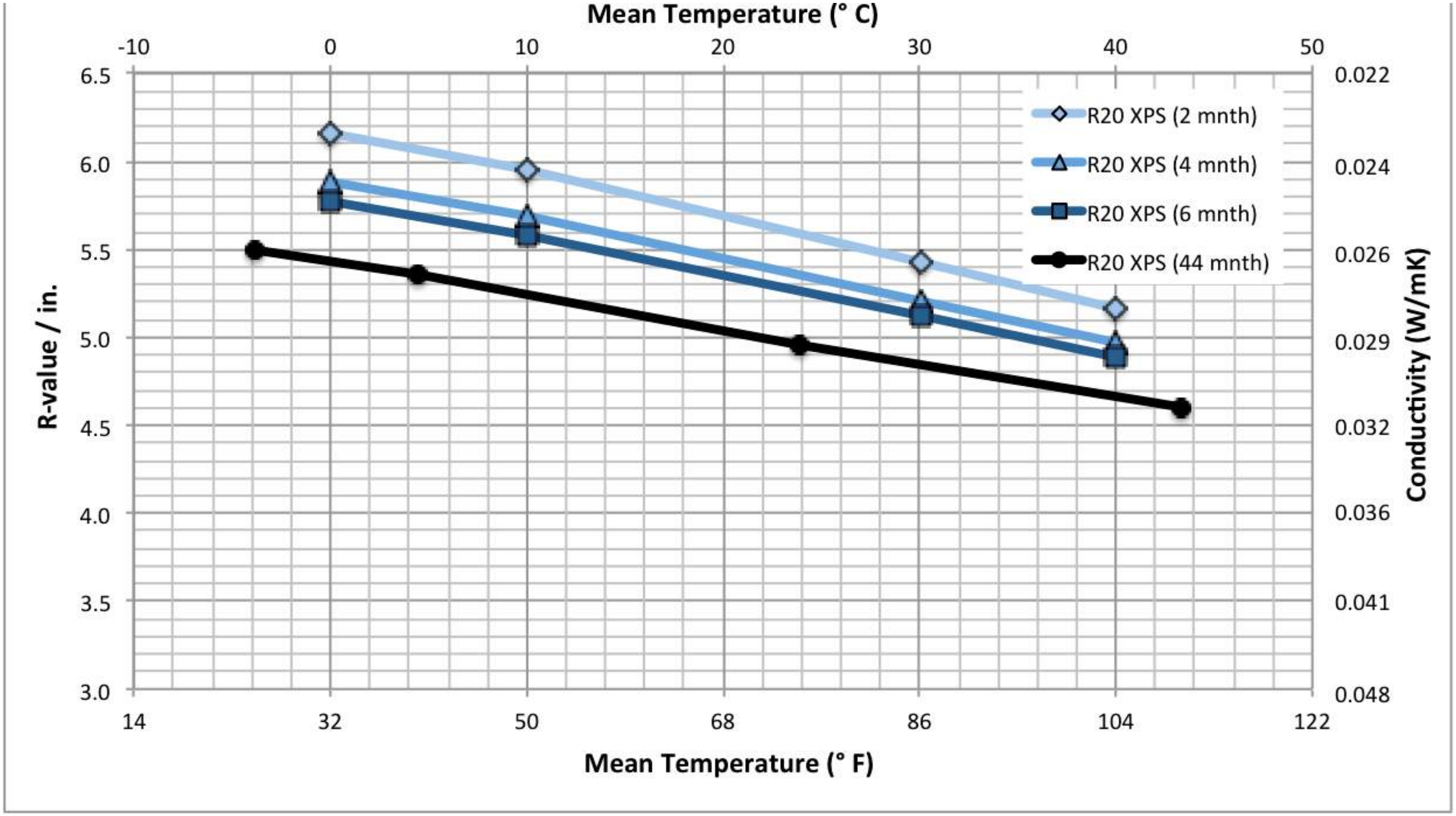
# R20 XPS (2, 4, 6 & 44 mnths)

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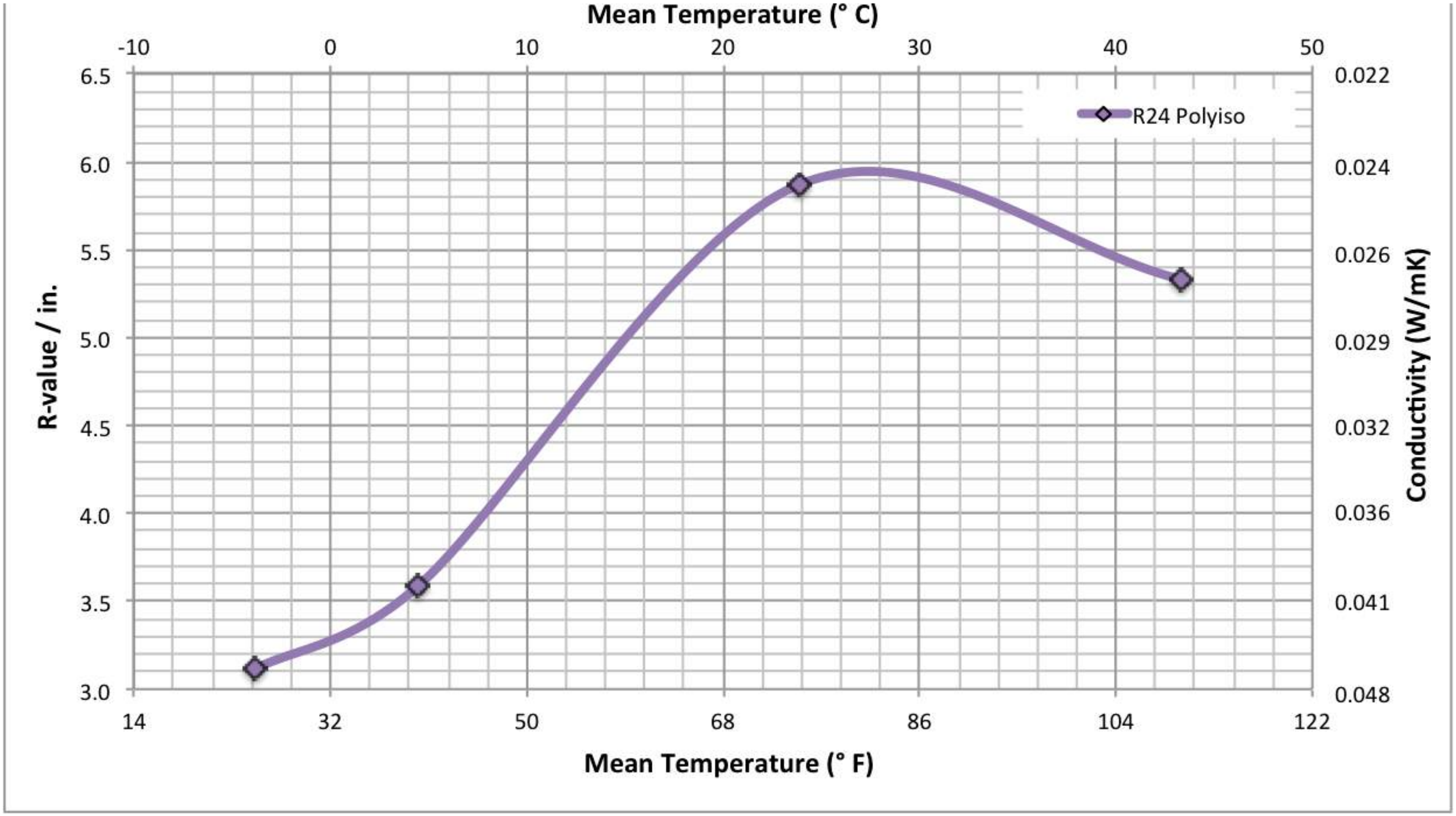
# R24 Glass-faced Polyiso (12 mnths)

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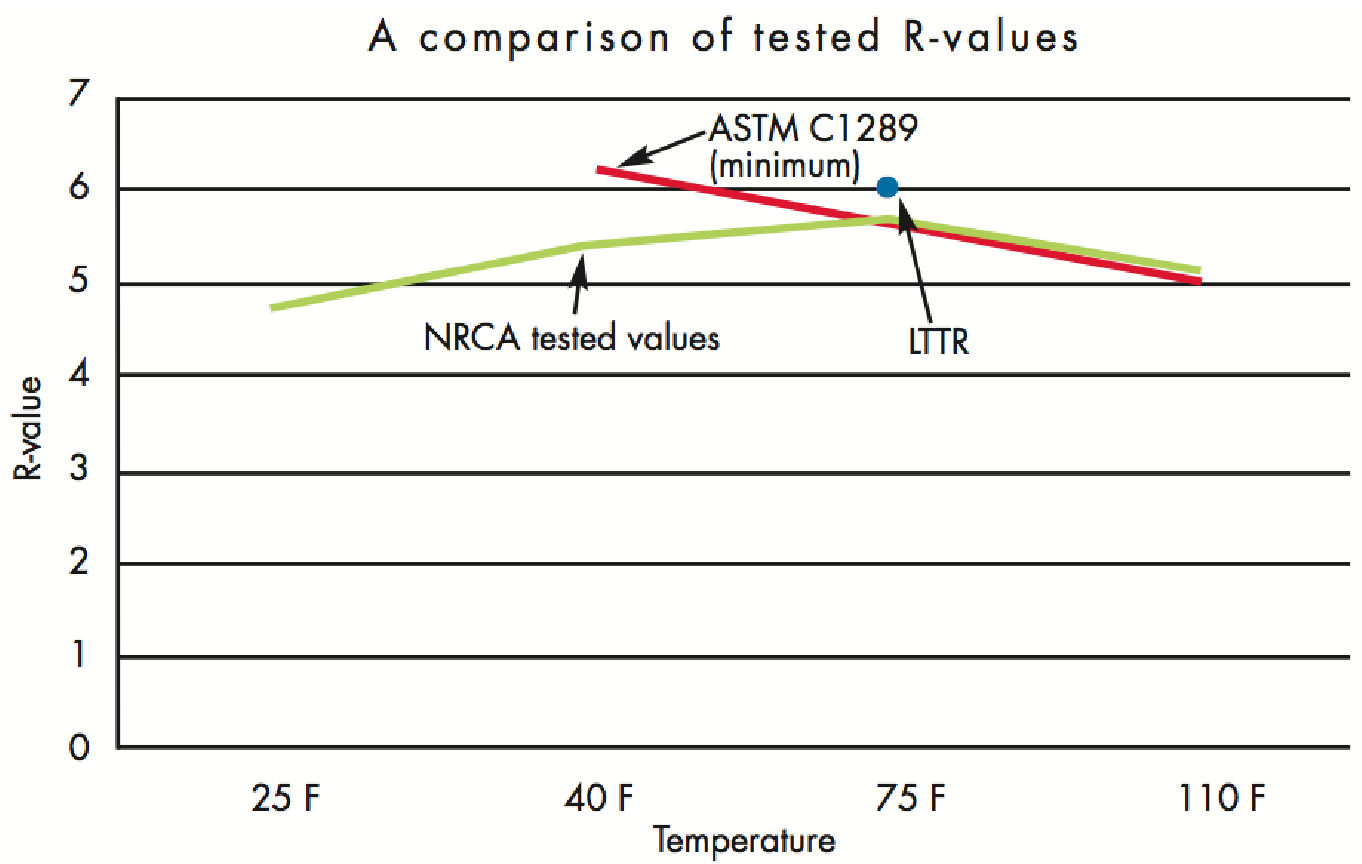
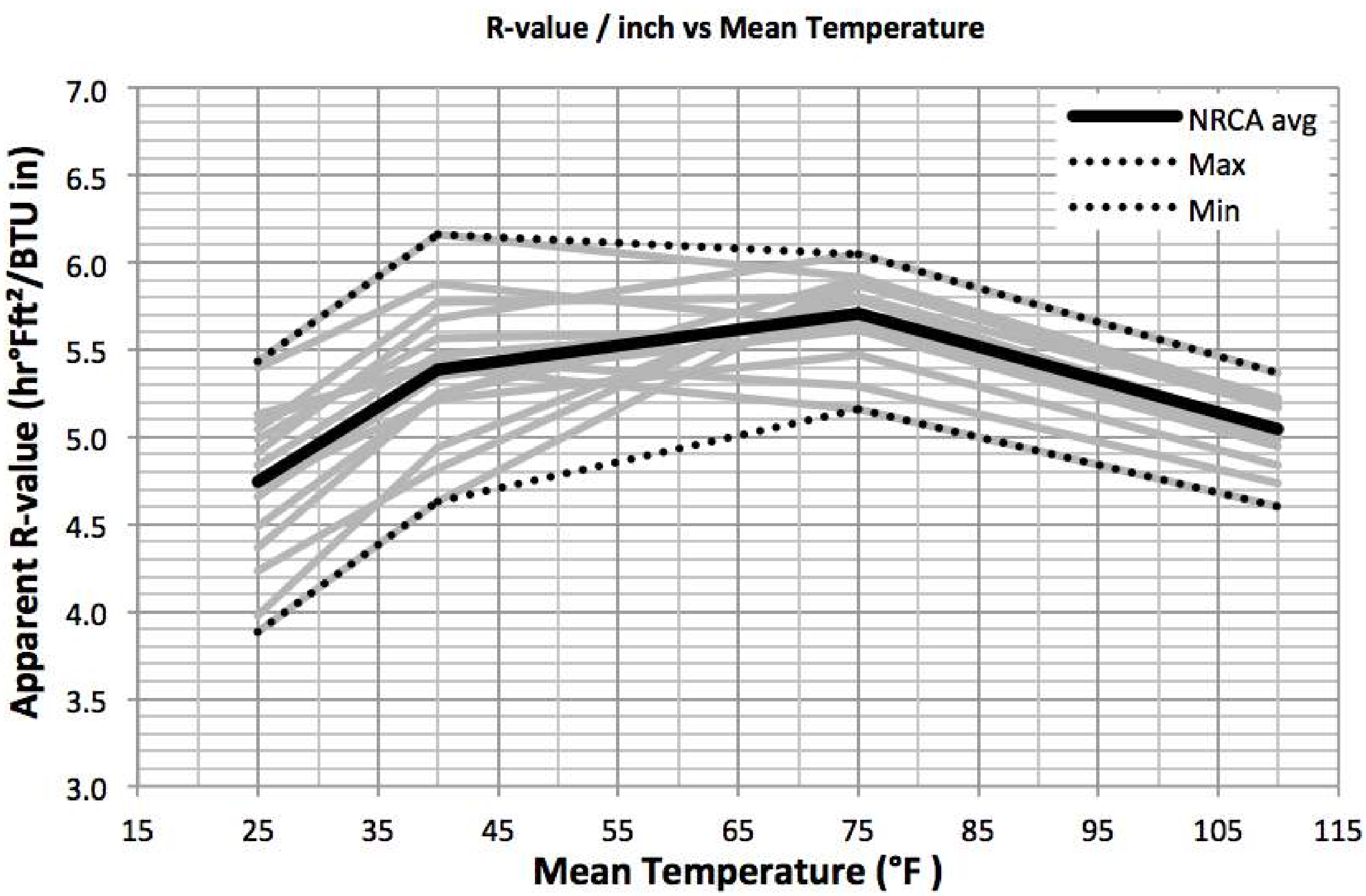
# NRCA Reported Similar Findings




NRCA's tested data, LTTR and ASTM C1289's minimum required R-values

→ Mark Graham, May 2010, Professional Roofing

# NRCA Reported Similar Findings

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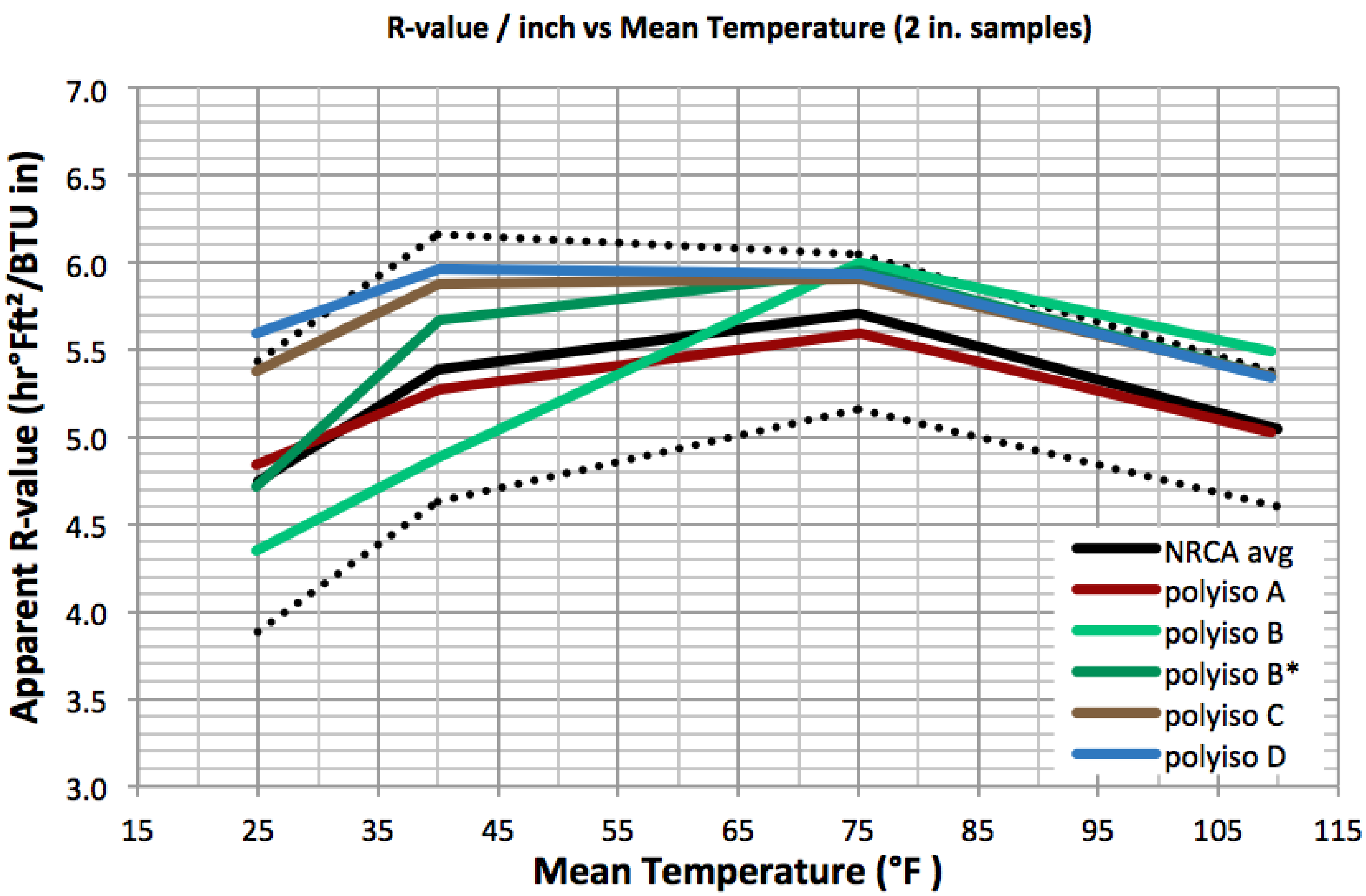
# NRCA vs RDH-BSL 2 in.

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## How Can the Industry Use This?

→ Field measurements indicate that Label R-values may not meet industry needs to predict energy and hygrothermal performance

→ Temperature dependence can be accounted for but need to look at

- → insulation materials rather than insulation layers
- → R-value / in rather than R-value of layer
- → Conductivity rather than Conductance

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## Insulation Layers vs Insulation Materials

→ Most insulating materials have nearly ***linear*** temperature dependence

→ Measure a layer of the insulation (R-value or conductance)

→ Easily predict material properties (R-value / in. or conductivity)

- → Works with "Standard" temperatures
- → Works with "Service Temperatures"
- → Works with (almost) any temperature difference

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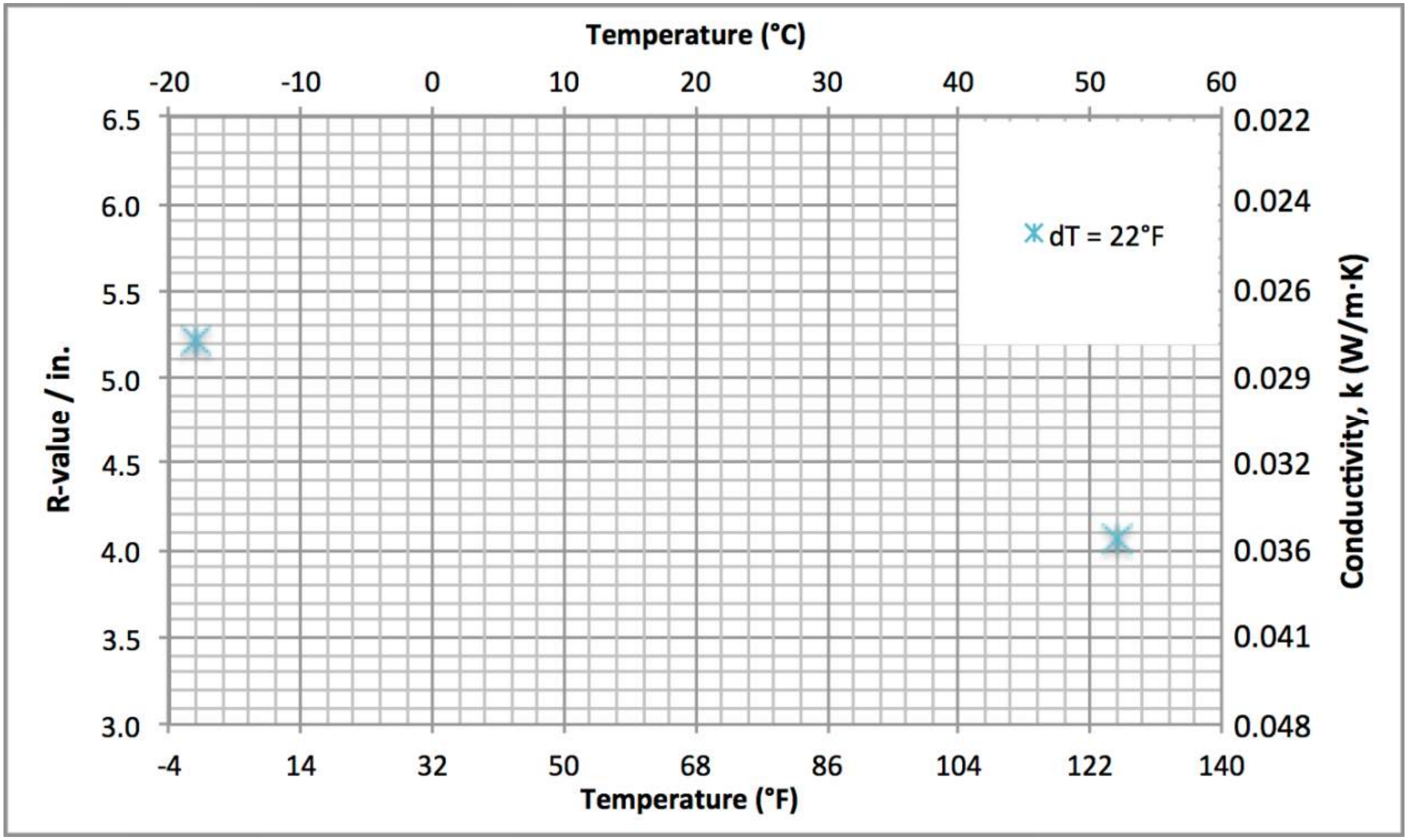
# Temperature Dependent R-value
# Semi-Rigid Fiber Glass

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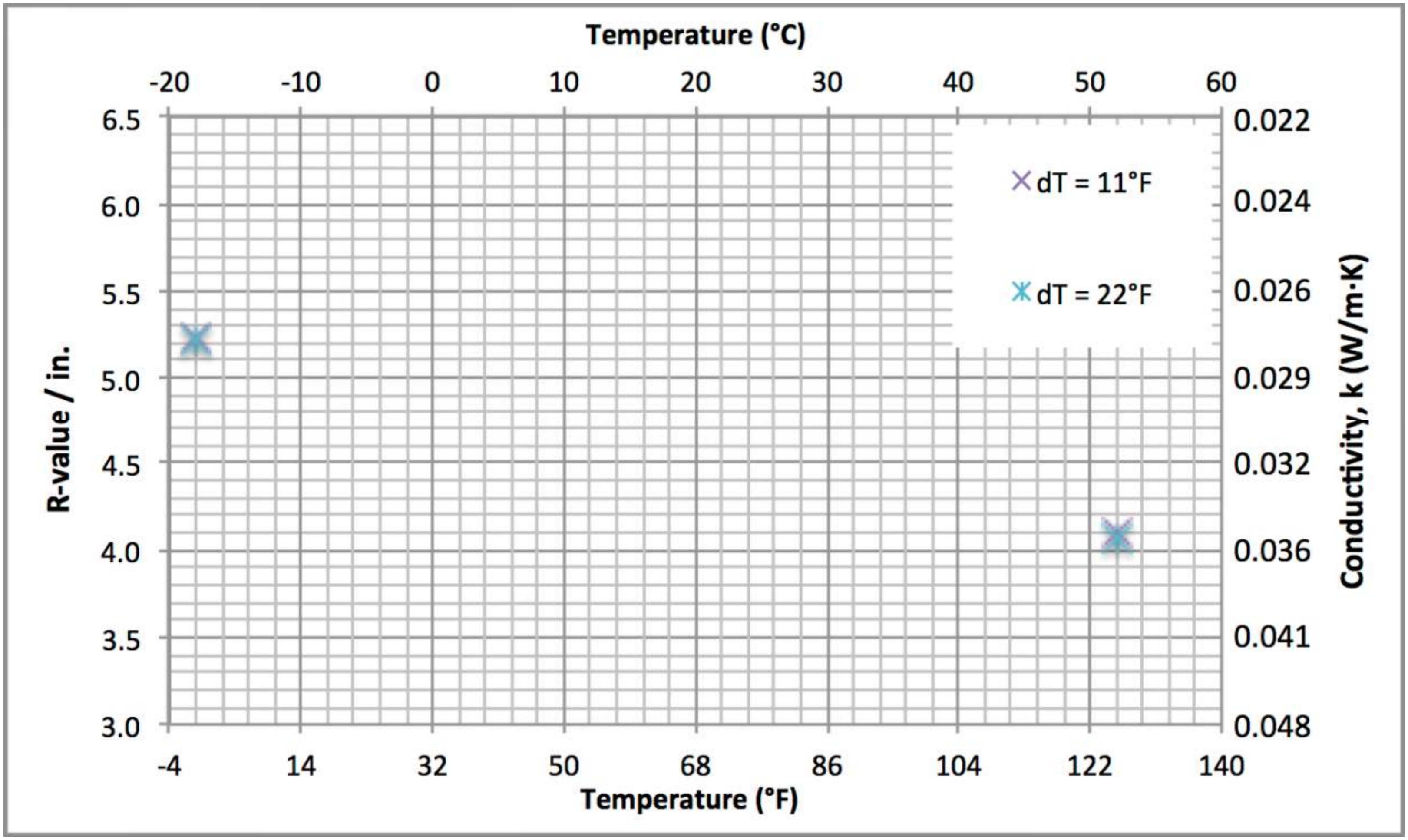
# Semi-Rigid Fiber Glass

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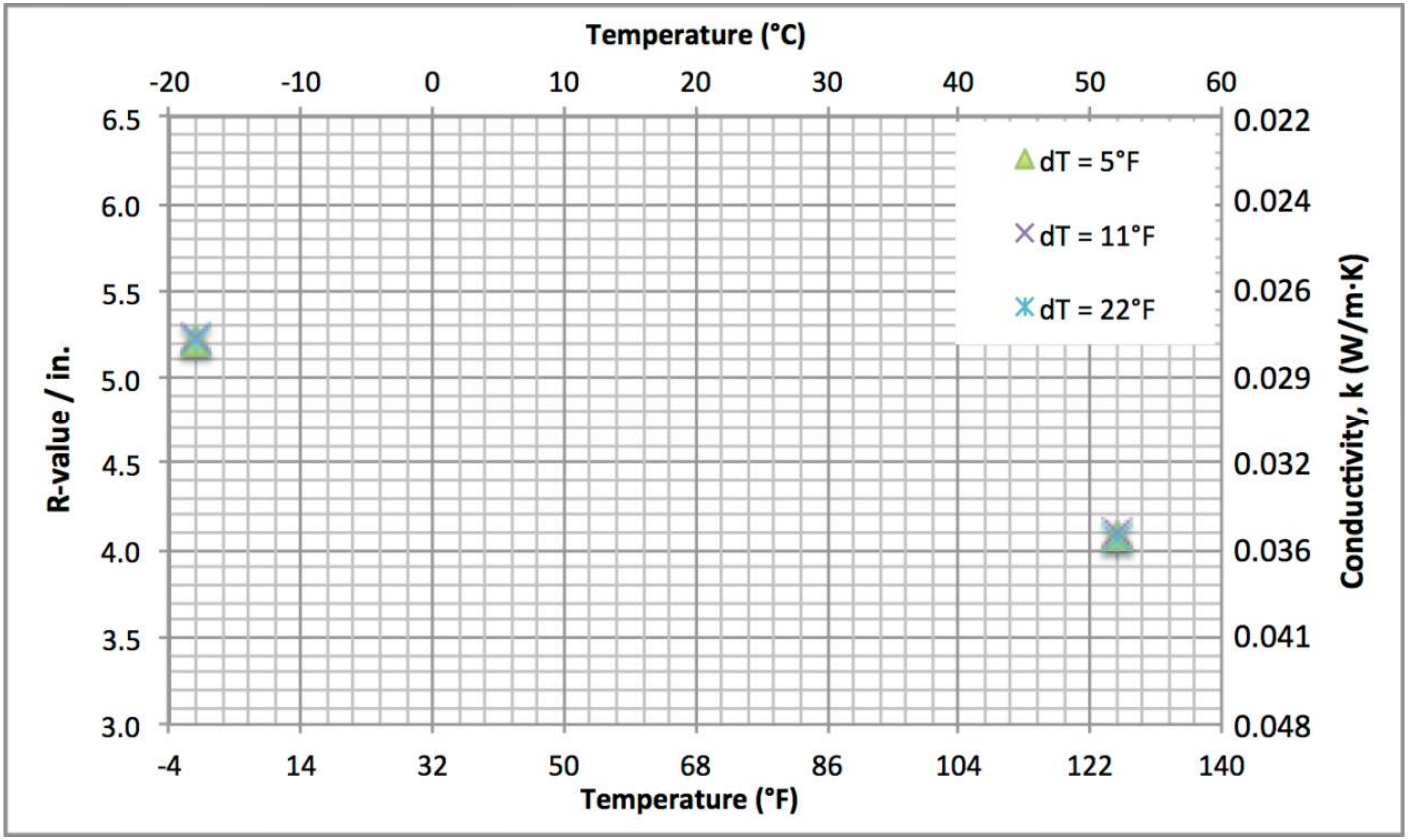


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# Temperature Dependent R-value
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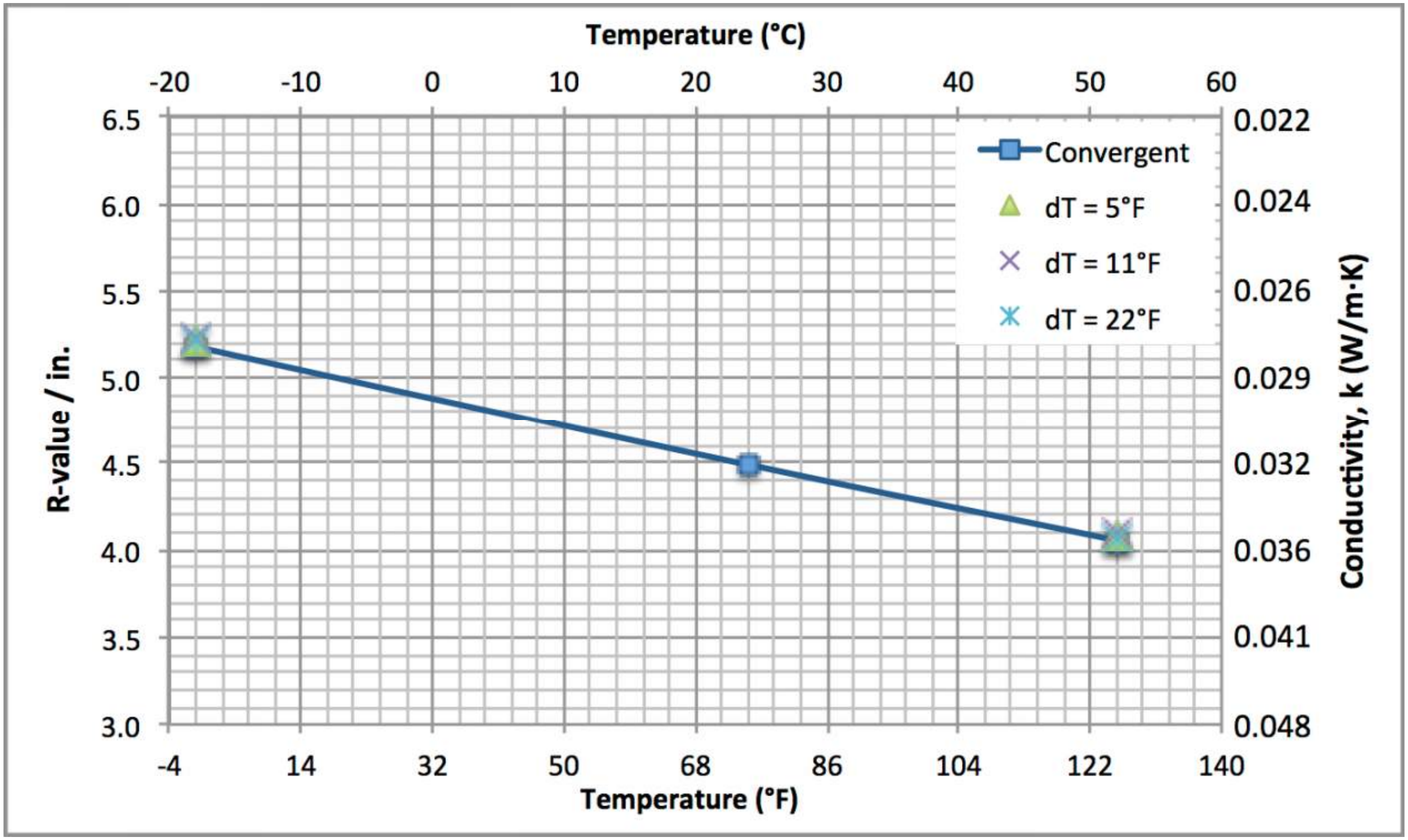


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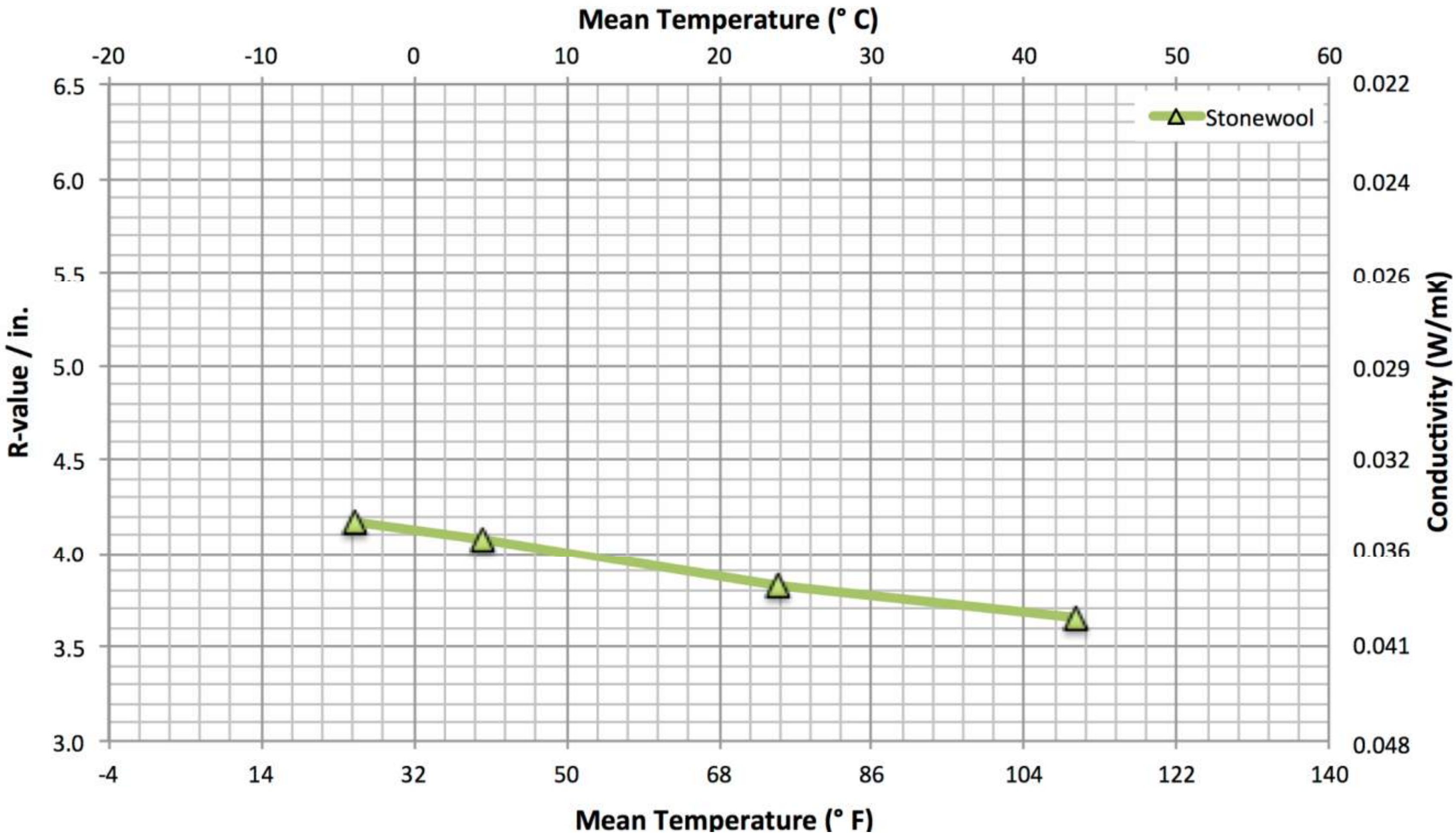
# Temperature Dependent R-value
# Semi-Rigid Stonewool

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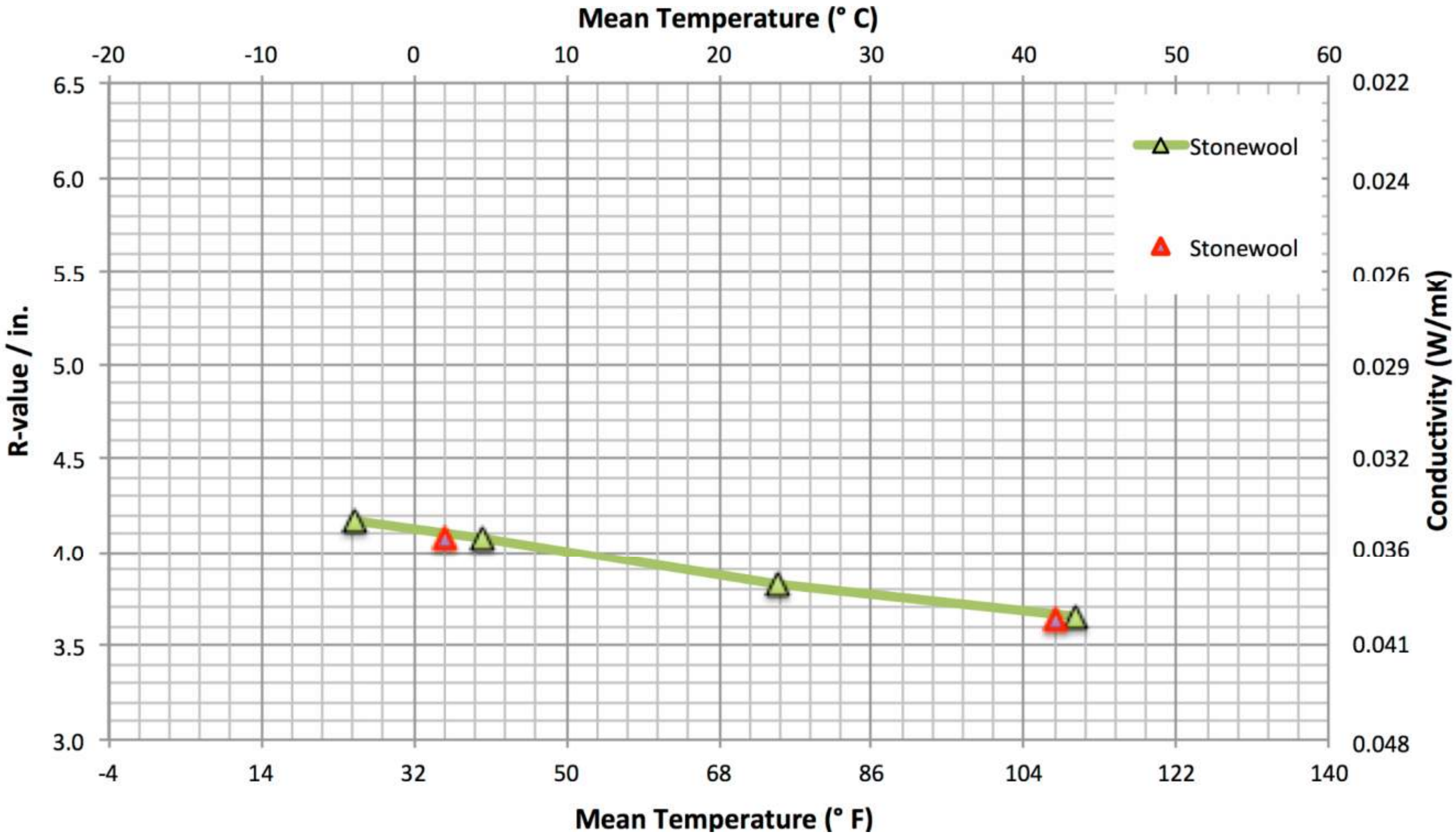
# Temperature Dependent R-value
# Semi-Rigid Stonewool

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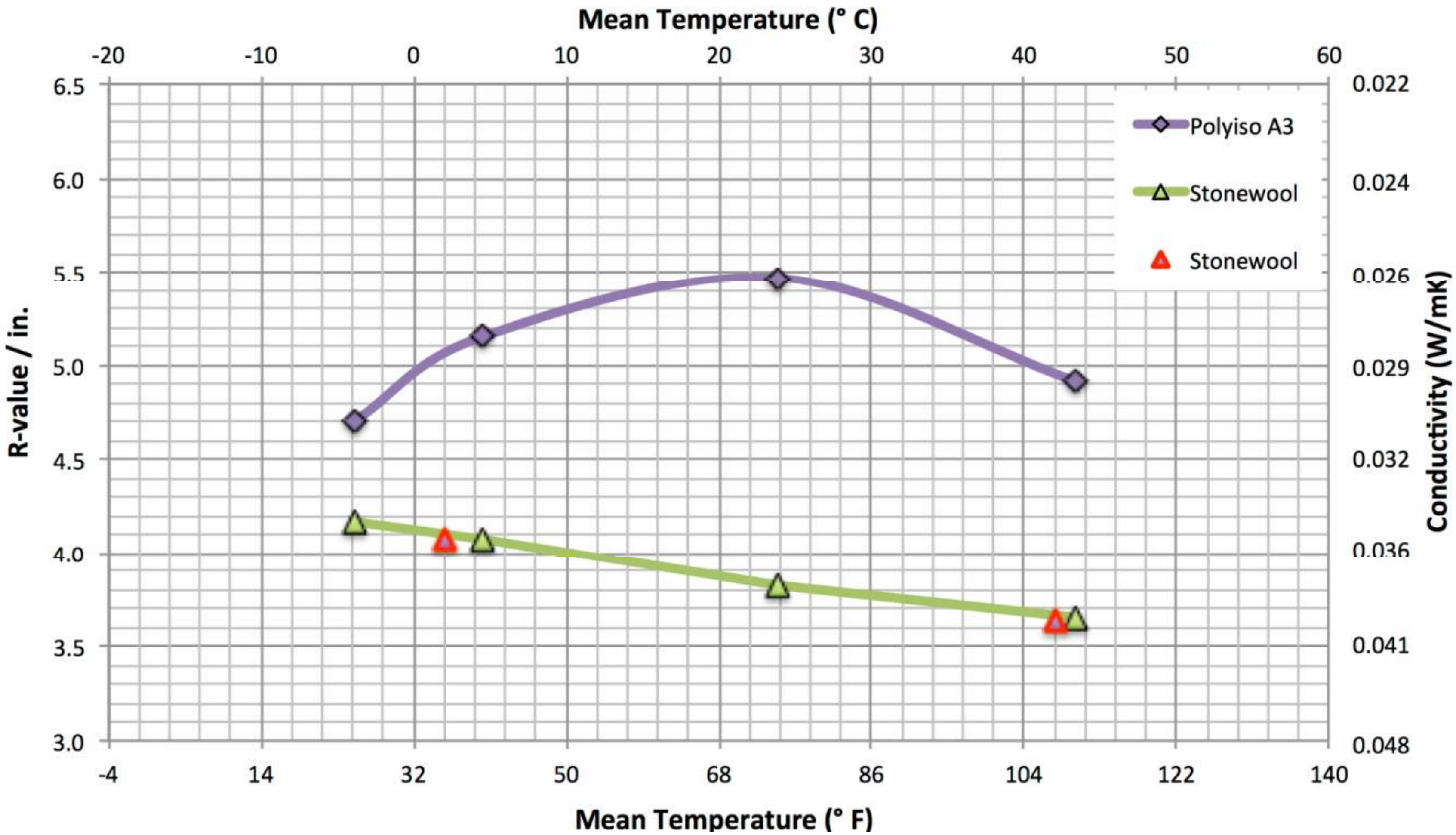
# Temperature Dependent R-value
# Polyisocyanurate Roof Insulation

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## Temperature Dependent R-value
## Insulation Layers vs Materials

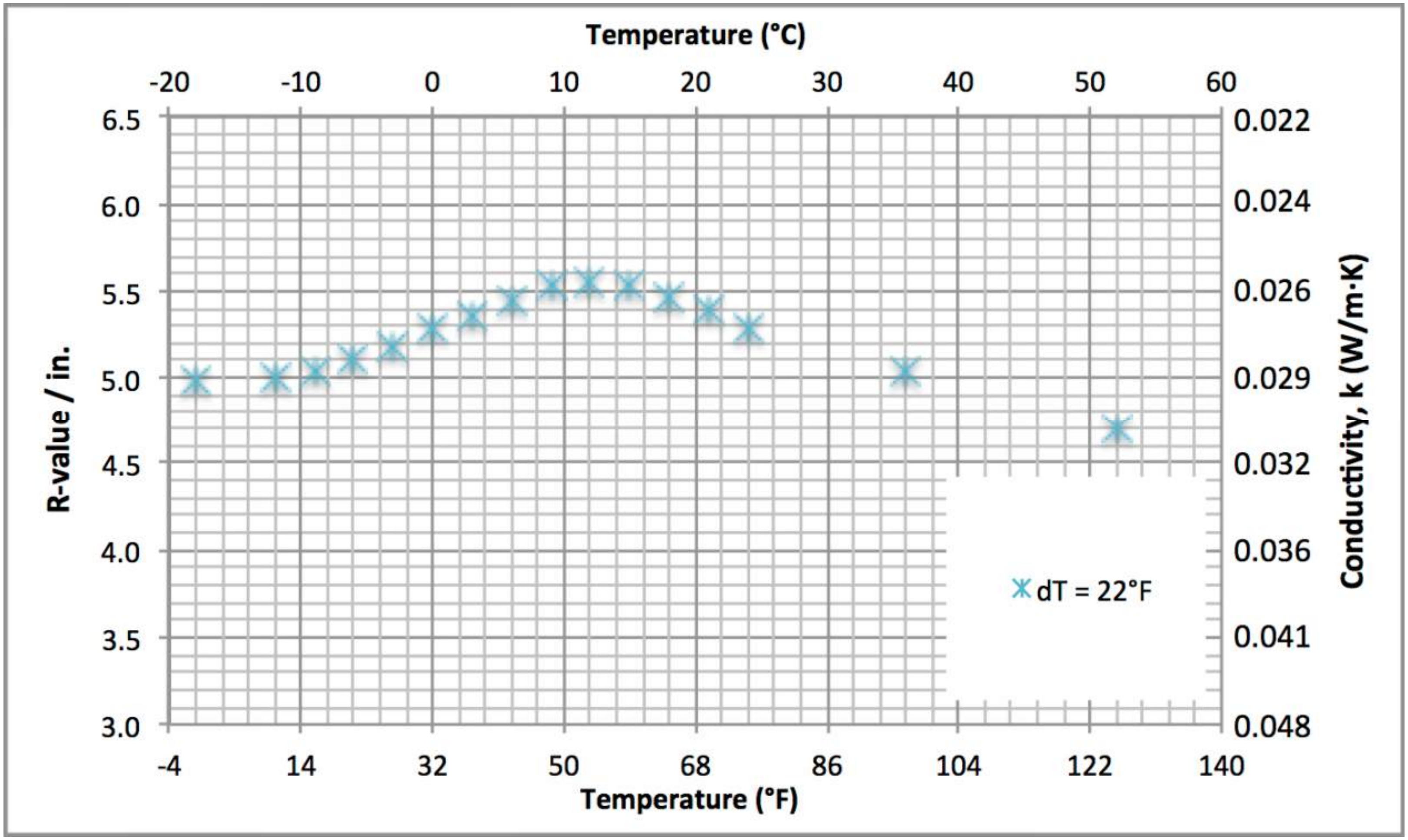
→ Some refrigerant-blown insulation materials have an “unusual” temperature dependence

→ **Cannot** measure a layer of the insulation and easily predict material properties

→ To predict material properties

- → Measure thin layer
- → Measure increasingly smaller temperature differences
- → Many measurements.

# Measuring Decreasing DeltaTs
# (smaller and smaller temperature differences)

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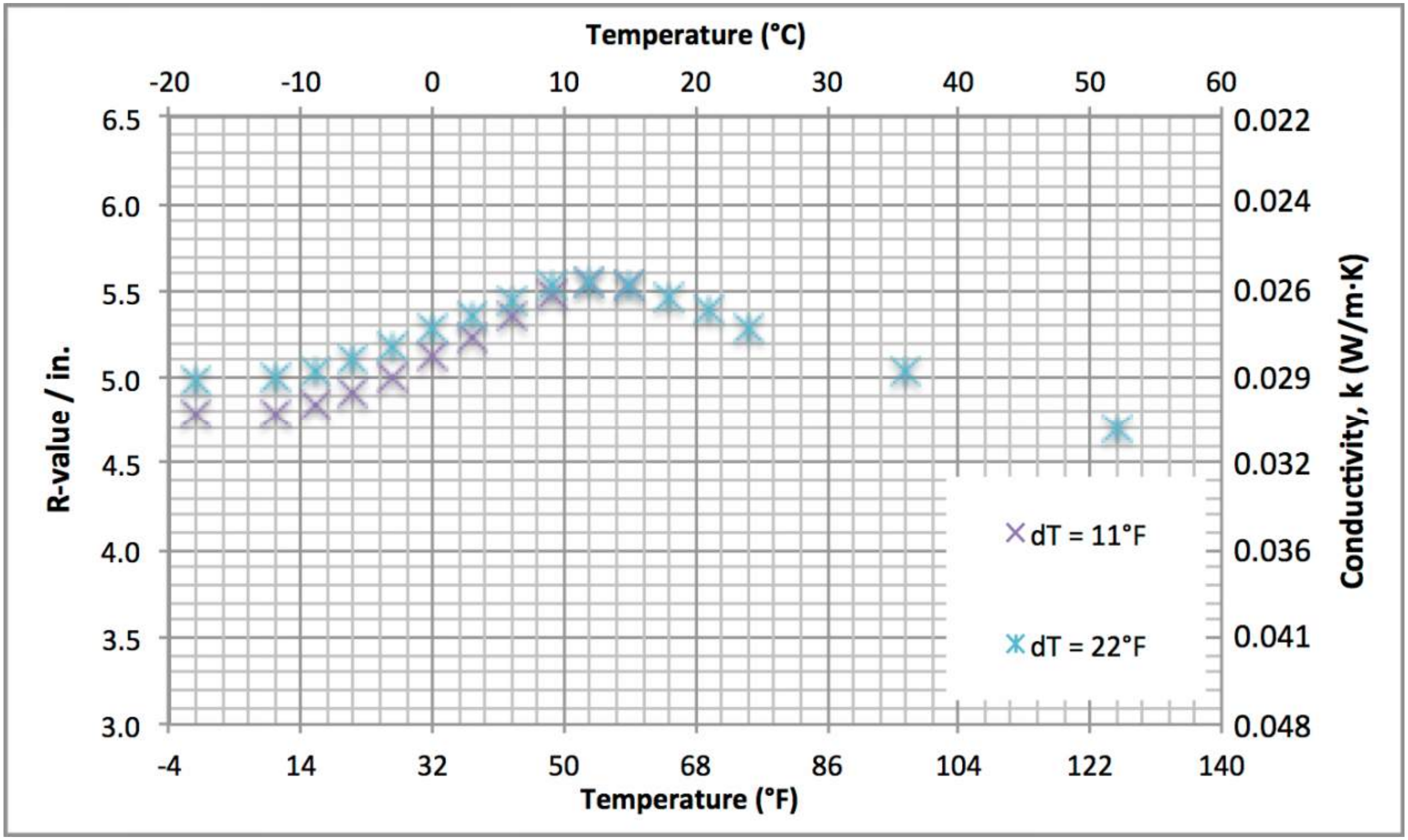
# Measuring Decreasing DeltaTs
# (smaller and smaller temperature differences)

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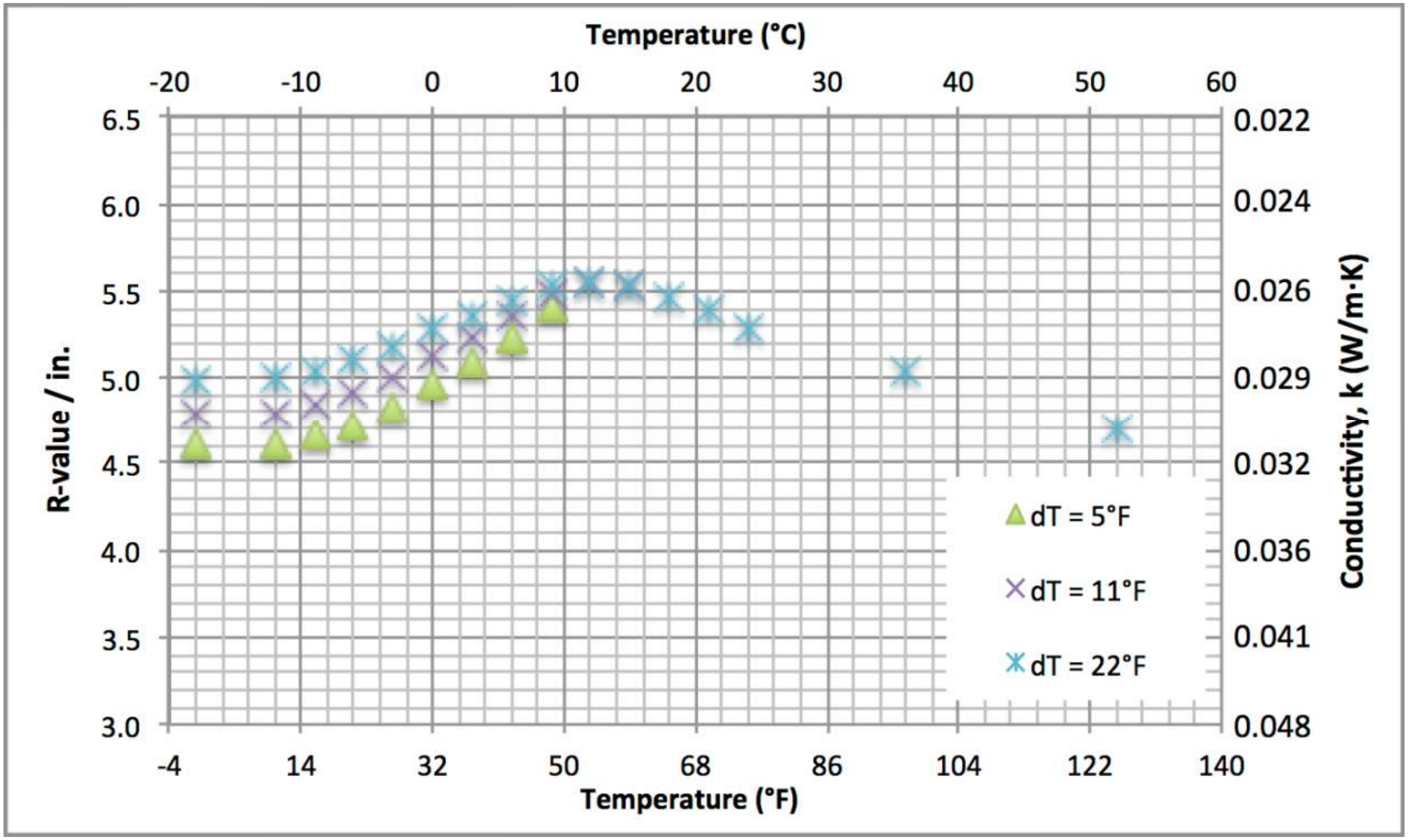


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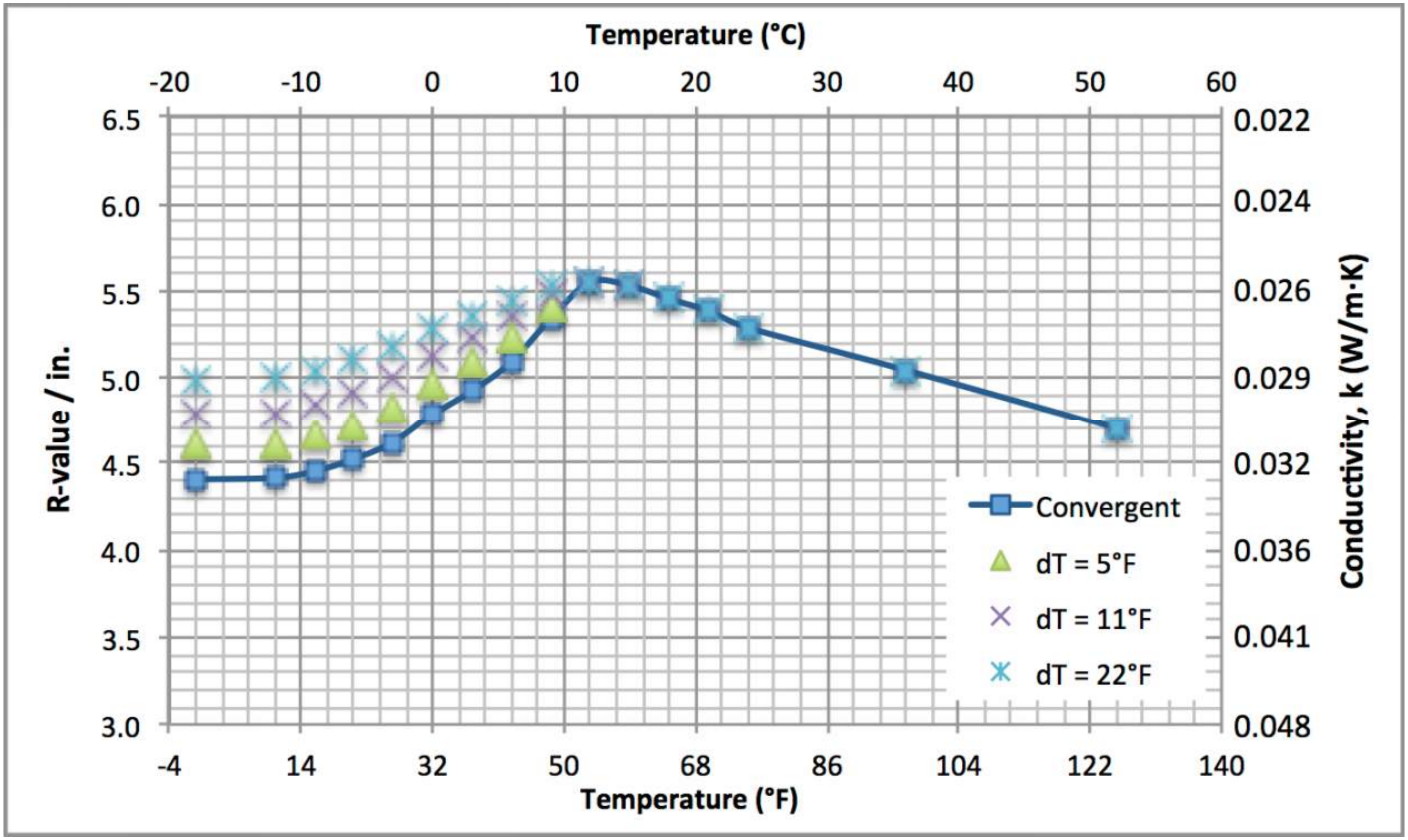
# Measuring Decreasing DeltaTs
# (smaller and smaller temperature differences)

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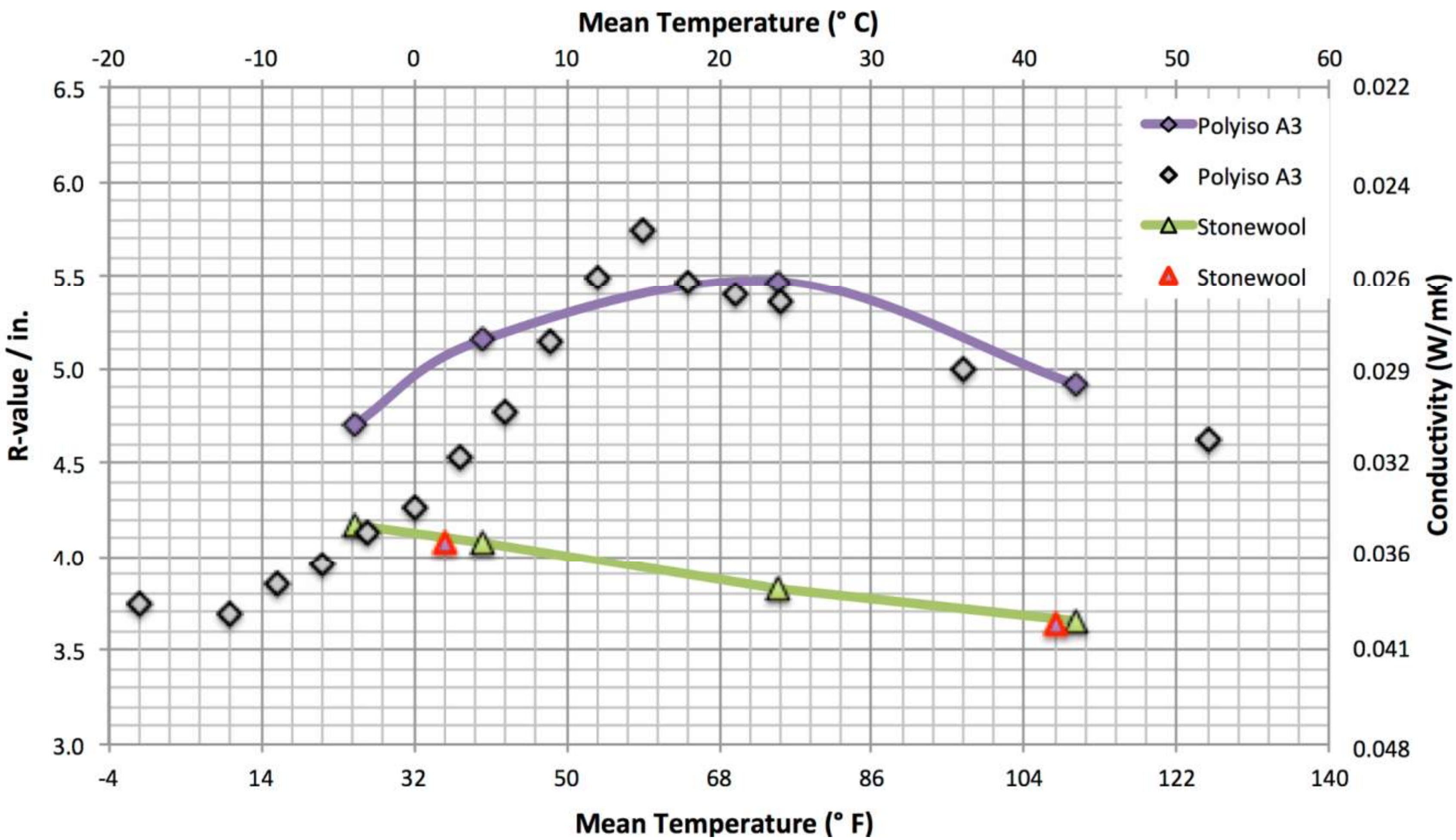
## Measuring Decreasing DeltaTs (smaller and smaller temperature differences)

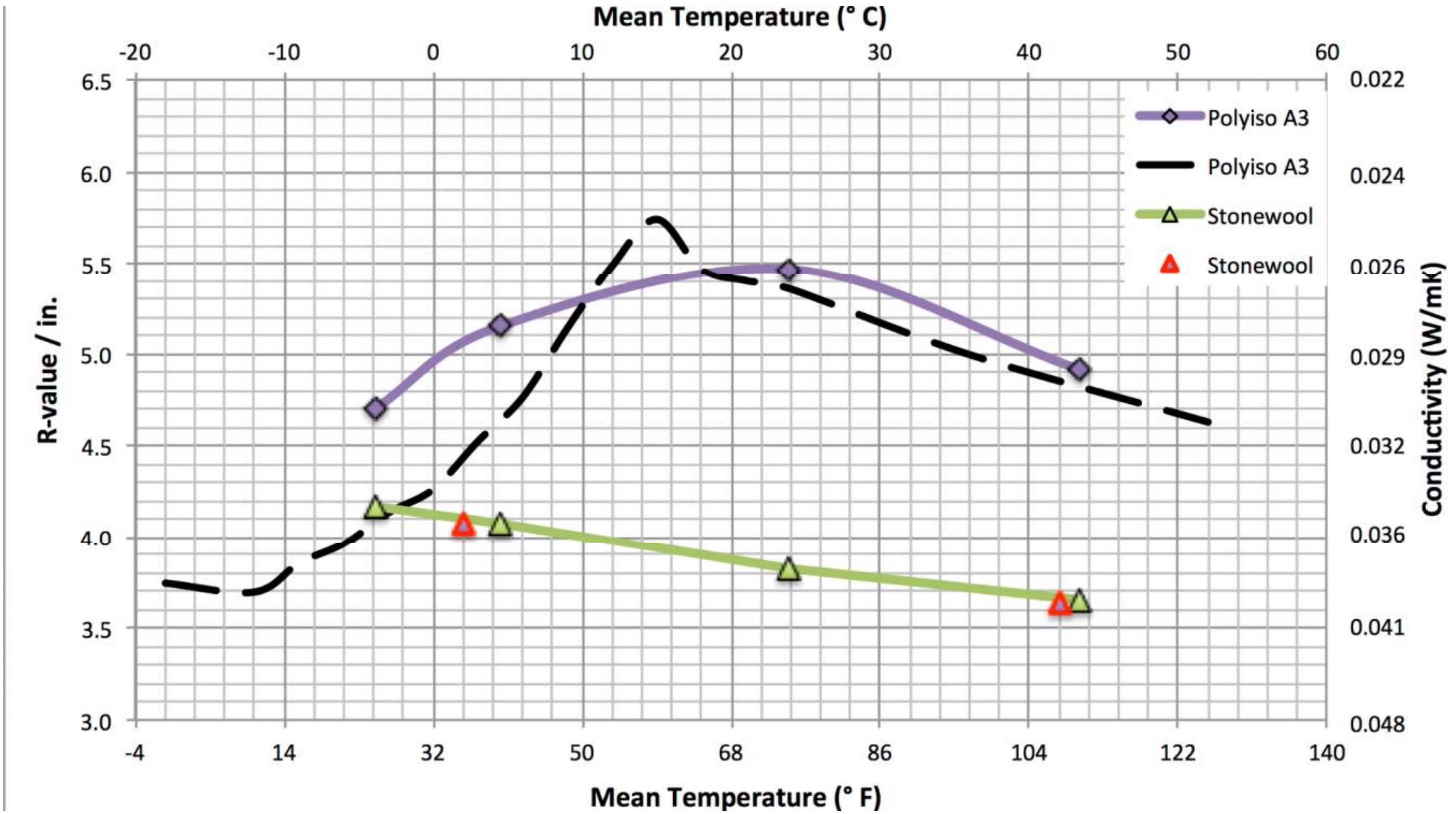
→ For materials that have an ‘odd’ temperature dependency:

Estimate the temperature dependent
R-value / in. or conductivity
using decreasing deltaT approach

# Polyisocyanurate Roof Insulation



# Polyisocyanurate Roof Insulation

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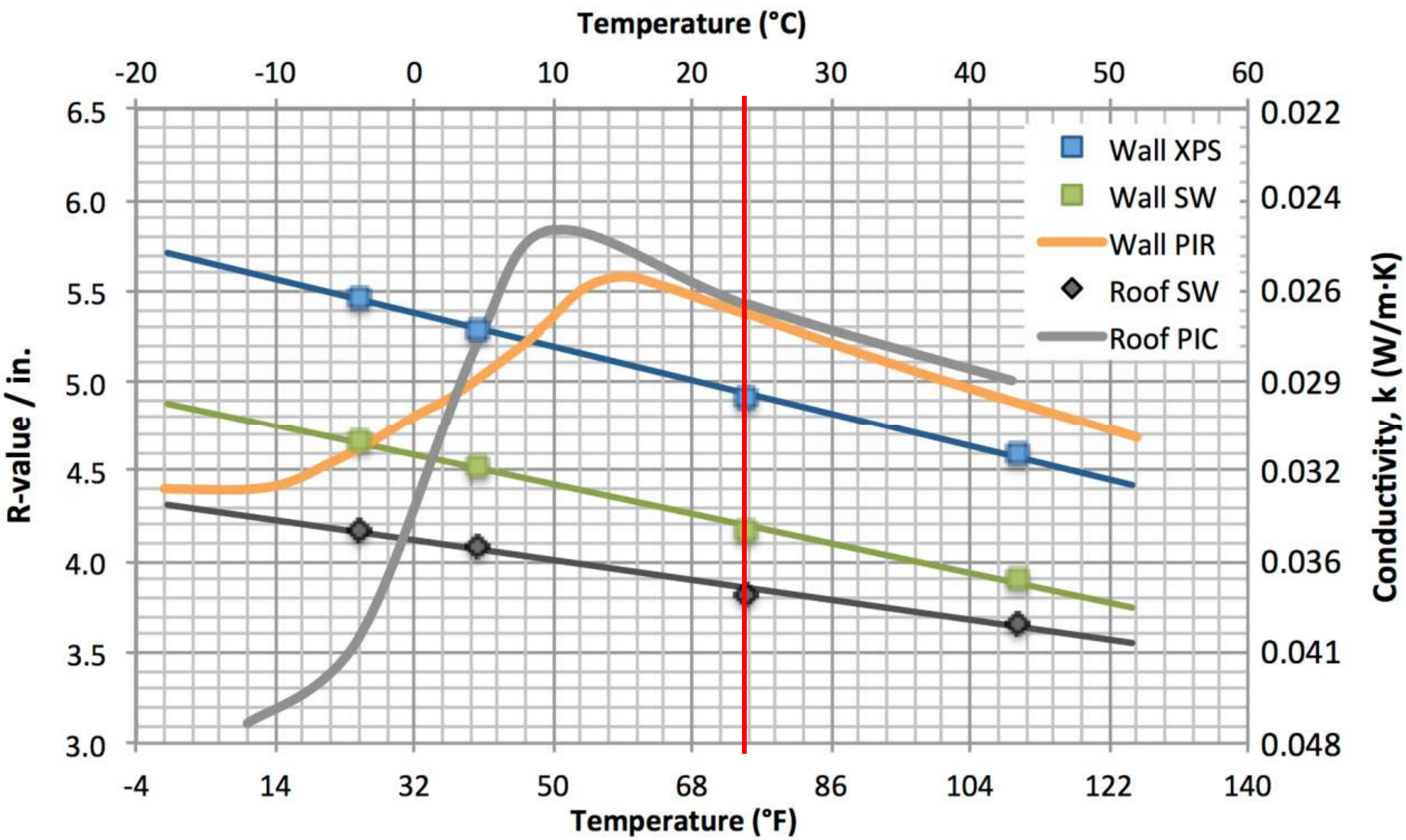
# Temperature Dependent R-values for Select Materials

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# Using Temperature Dependent R-values

## Using Temperature-Dependent R-value / in or Conductivity

→ Most heat, moisture and energy simulation software ***does not*** account for temperature dependent conductivity!

→ WUFI Pro does account for k vs t in 1-D hygrothermal sims

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## What does WUFI say?

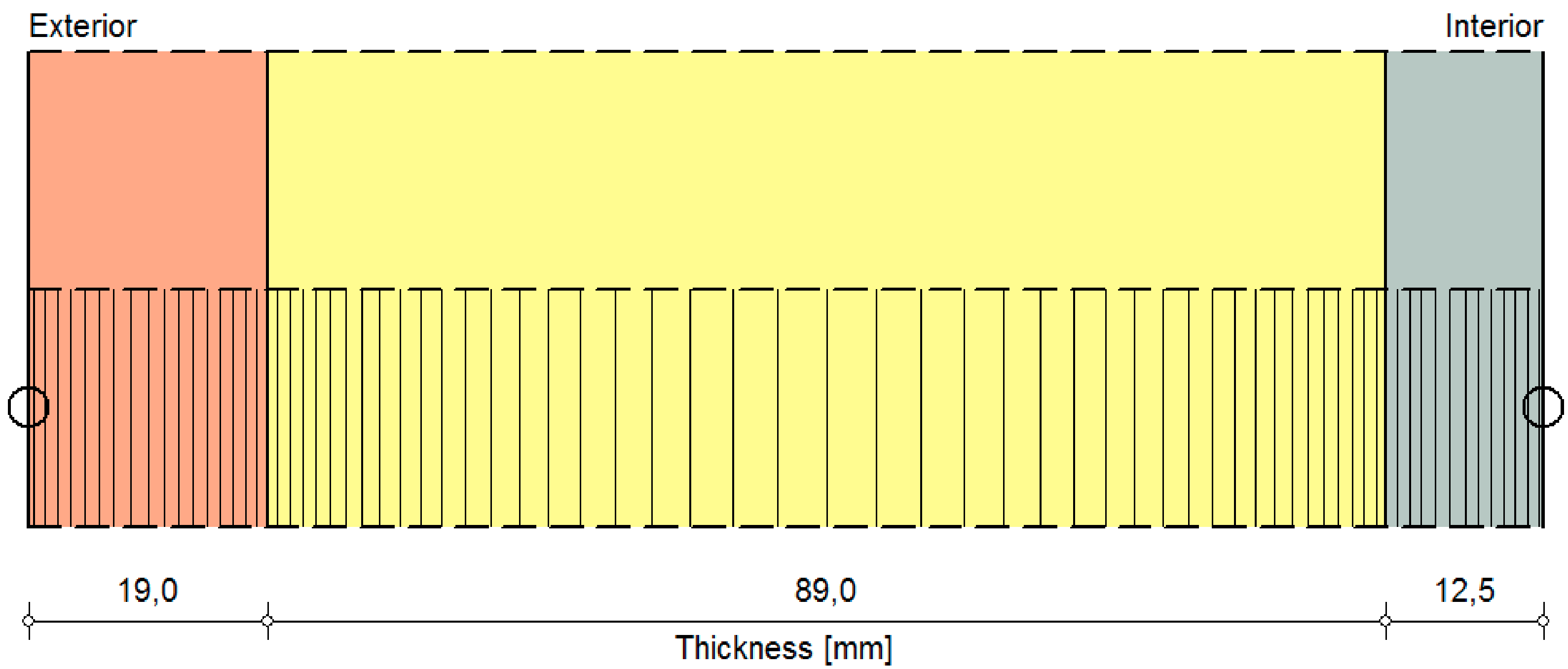
- → Simulate a typical exterior insulated residential wall system:
  - → 3/4 in. continuous polyiso insulation
  - → 3-1/2 in. mineral wool batt insulation
  - → 1/2 in. drywall

  - → (ignore stud frame for now -> 1D)

## Simplified Assembly in WUFI

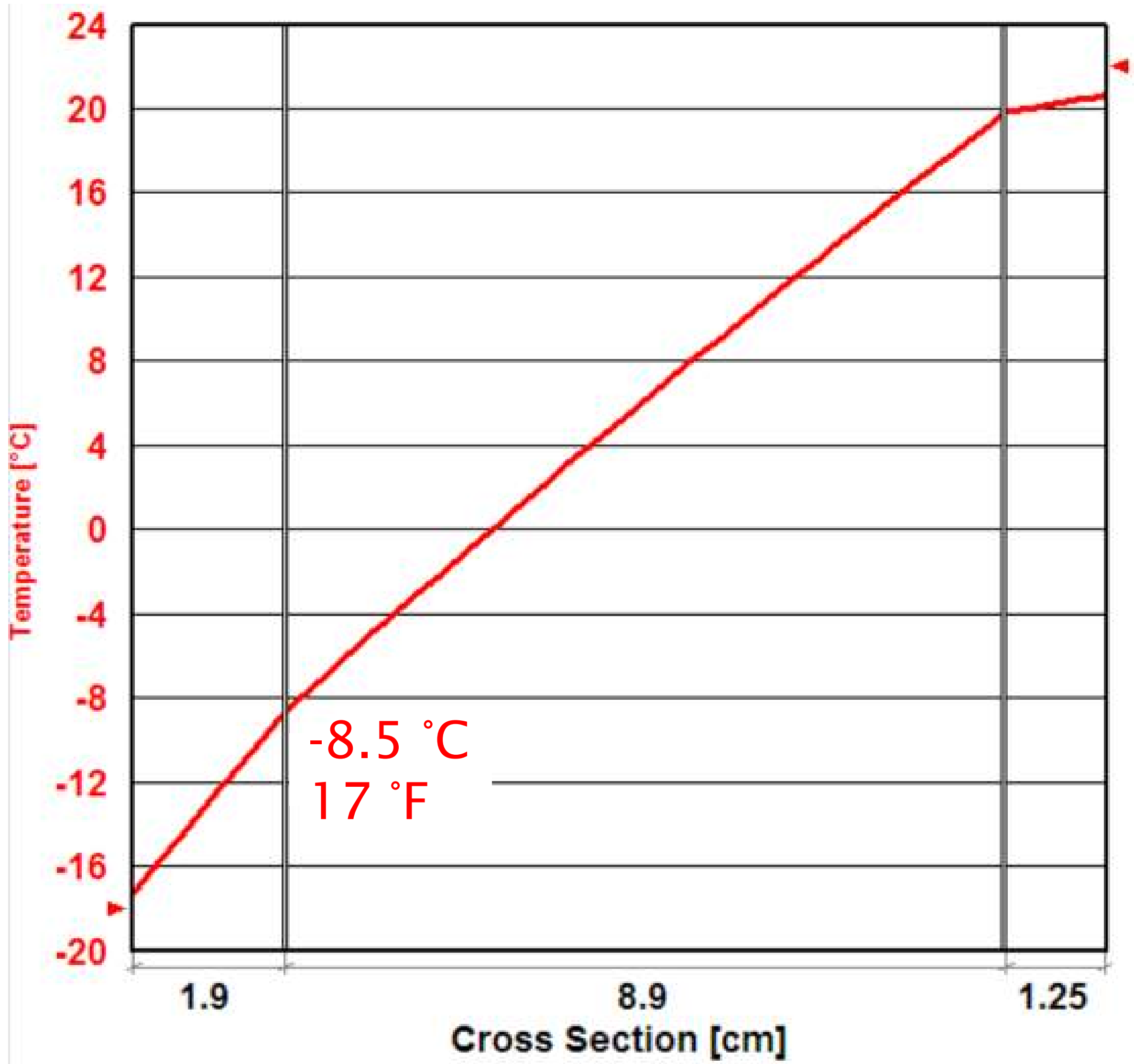
→ Ignore cladding, airspaces, surface films and solar affects (i.e. Temperatures occur ON the surface)

→ Steady state with exterior at -18C & interior at 22C



## WUFI Results using R-6 / in (No Temperature Dependence)

- → R6 / in.
- → Temperature drops faster across ***polyiso*** (higher R/in) (lower k)
- → Condensing surface temp approx -8.5˚C
- → $U_{wall}$ = 0.274
- → $R_{wall}$ = 20.7

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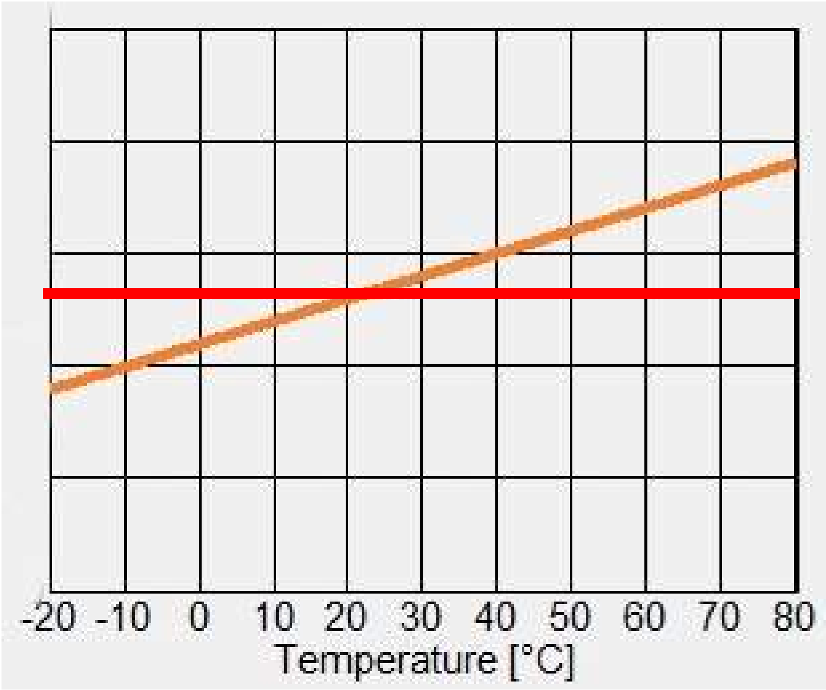
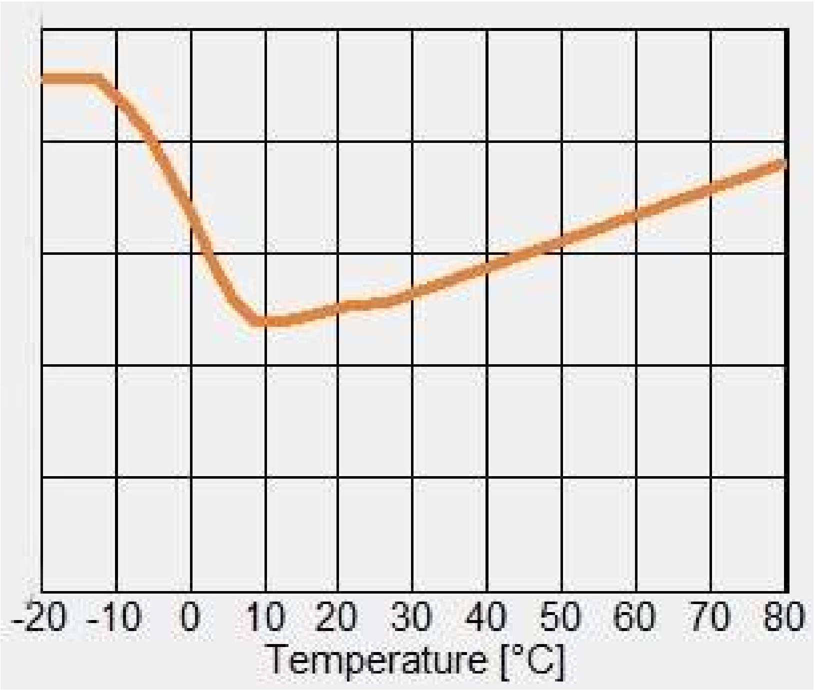
# What if we add temperature dependence?

WUFI's Default Polyiso k vs t curve




Adjusted Polyiso k vs t curve

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# WUFI Results using Default Temperature Dependence

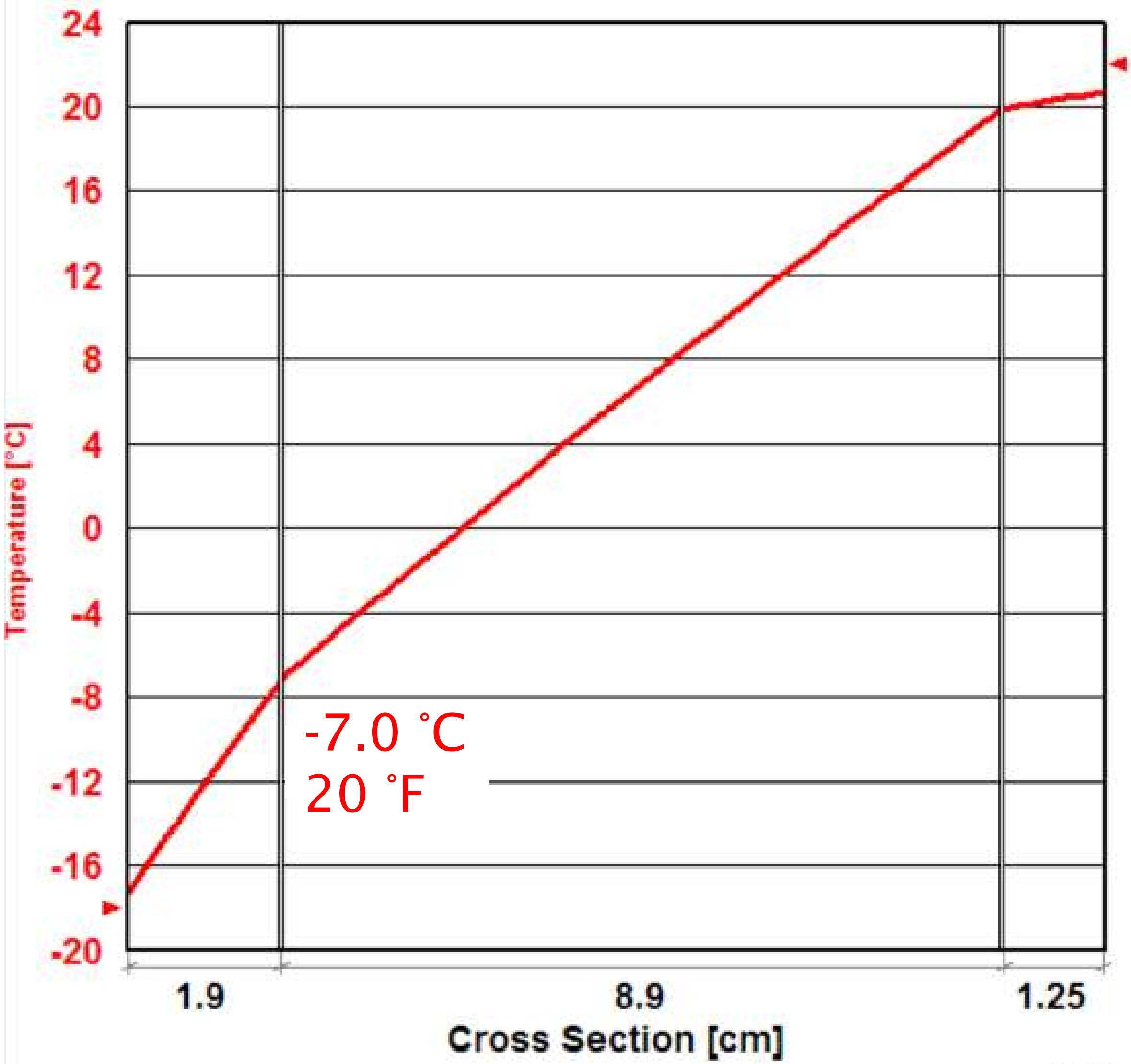
→ WUFI's default

→ Better than assumed constant R6 / in.

→ Condensing surface temp approx -7.0˚C

→ $U_{wall}$ = 0.262

→ $R_{wall}$ = 21.7

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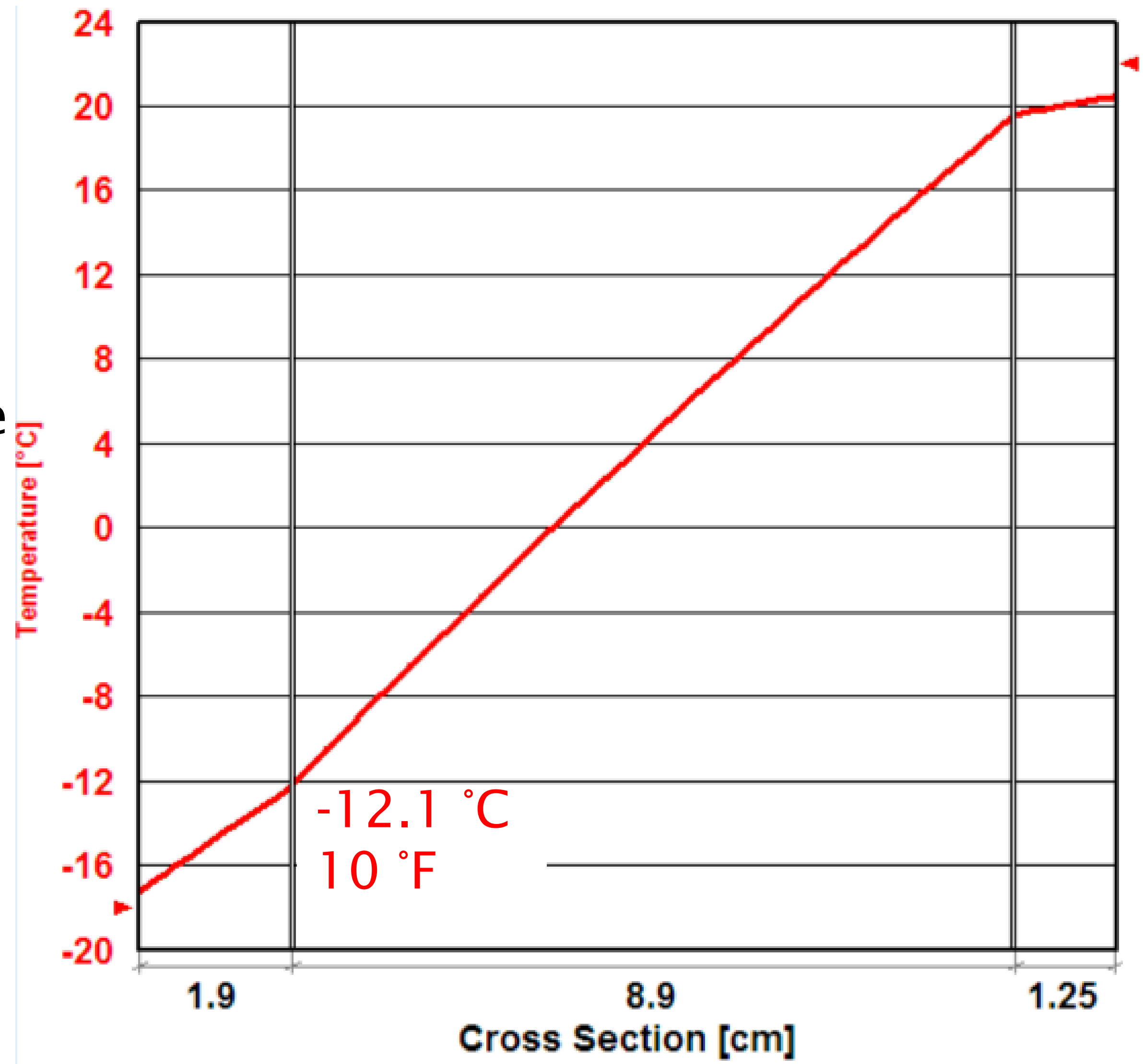
## WUFI Results using Measured Temperature Dependence

- → Measured k vs T
- → Temperature drops faster through ***batt***
- → Condensing surface temp approx -12.1˚C
- → $U_{wall}$ = 0.302
- → $R_{wall}$ = 18.8

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## What can we do to address this?

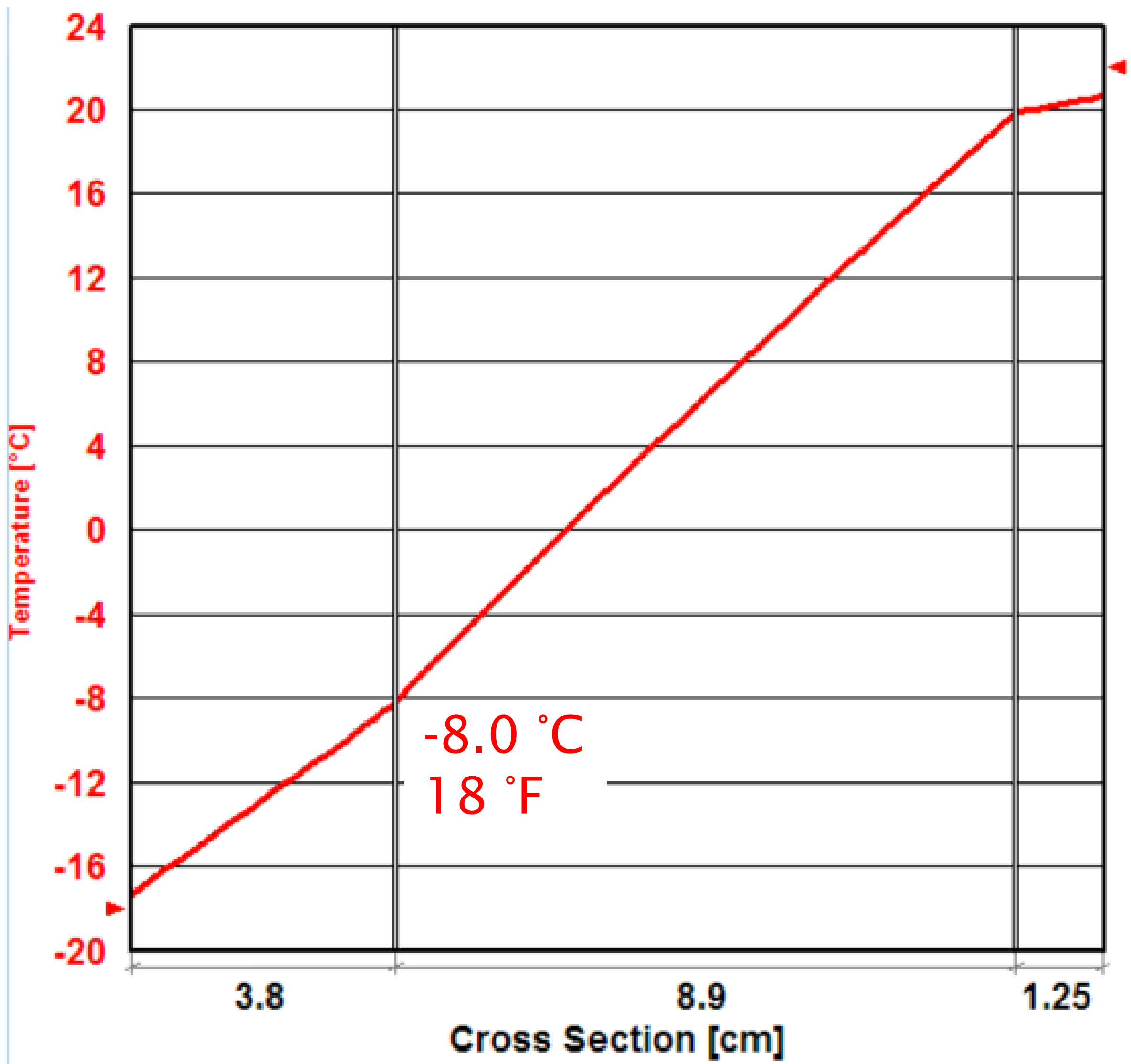
→ Measured k vs T but ***thicker PIC***

→ Temperature drops faster through ***batt***

→ Condensing surface temp approx -8.0˚C

→ $U_{wall}$ = 0.270

→ $R_{wall}$ = 21.0

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## Other R-values to question

→ Radiant "Insulations" tested in unrealistic geometries or at unrealistic temperatures and / or temperature differences

→ Vacuum panel insulations only reporting center-of-panel

→ Any cladding, structural or complete enclosure system (check that thermal bridges are accounted for)

→ Systems claiming air tightness and mass benefits

→ R-value for layer when it is reported *close to but not actually at 1 in. thickness*

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Neopor® GPS (Graphite Polystyrene) rigid foam is today's energy-efficient and cost-effective insulation solution for architects, builders and contractors. The table shows actual test data of Neopor® GPS F5300 Plus and ASTM C578 physical requirements for EPS and XPS.

| Property | Unit | Neopor® GPS Plus vs EPS/XPS[4] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Polystyrene type[1]** | | **EPS** | **GPS +** | **EPS** | **GPS +** | **XPS** | **GPS +** | **XPS** | **GPS +** | **XPS** |
| ASTM C578 Classification[2] | | Type I | Type I | Type VIII | Type VIII | Type X | Type II+ | Type IV | Type IX | Type VI |
| Compressive Resistance | at yield of 10% deformation in psi (min) | 10.0 | 10.0 | 13.0 | 14.0 | 15.0 | 20.0 | 25.0 | 25.0 | 40.0 |
| Thermal Resistance (R-value)[3] | °F·ft2·h/BTU (°C·m2/W) 75 ±2°F (23.9 ±1°C) | 3.6 | 5.0 | 3.8 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Water Vapor Permeance | Max perm (ng/Pa·s·m2) | 5.0 | 4.0 | 3.5 | 3.1 | 1.5 | 3.1 | 1.5 | 2.5 | 1.1 |
| Water Absorption by Total Immersion | Max volume % absorbed | 4.0 | 1.1 | 3.0 | 1.1 | 0.3 | 1.1 | 0.3 | 1.1 | 0.3 |
| Flexural Strength | psi | 25.0 | 25.0 | 30.0 | 32.0 | 40.0 | 40.0 | 50.0 | 50.0 | 60.0 |
| Density | lbs/ ft3 | 0.90 | 0.90 | 1.15 | 1.15 | 1.30 | 1.45 | 1.45 | 1.80 | 1.80 |

1) GPS is Graphite Polystyrene. XPS is extruded Polystyrene
2) Neopor® GPS meets and exceeds ASTM C578-13, "Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation"; published by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959
3) R means resistance to heat flow. The higher the R-value, the greater the insulating power. Ask your seller for the fact sheet on R-values.
4) The technical and physical metrics provided in this table are reference values for insulation products made of Neopor GPS. The values and properties may vary depending on how they are processed and produced. The R-value properties for Neopor GPS Plus are based on 1-1/16 in thickness.

# What common practices ruin the thermal performance of continuous insulation?

# Thermal Bridging

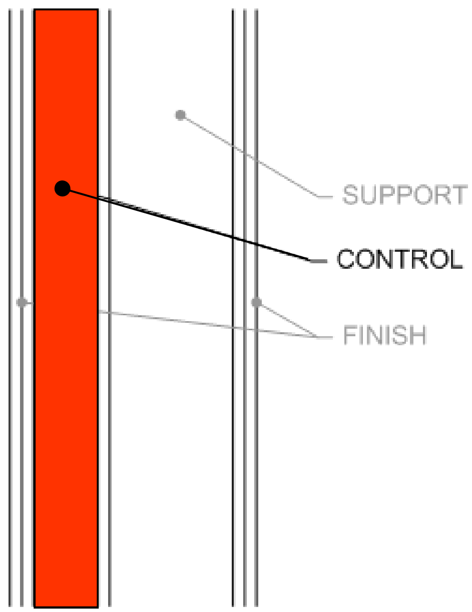
## Basic Enclosure Functions

→ Support
  → Resist & transfer physical forces from inside and out

→ **Control**
  → **Control mass and energy flows**
  - **Rain** (and soil moisture)
    - WRB, gap capillary break, etc.
  - **Air**
    - Continuous air barrier system
  - **Heat**
    - Continuous layer of insulation
  - **Vapor**
    - Balance of wetting/drying

→ Finish
  → Interior and exterior surfaces for people

Functional Layers

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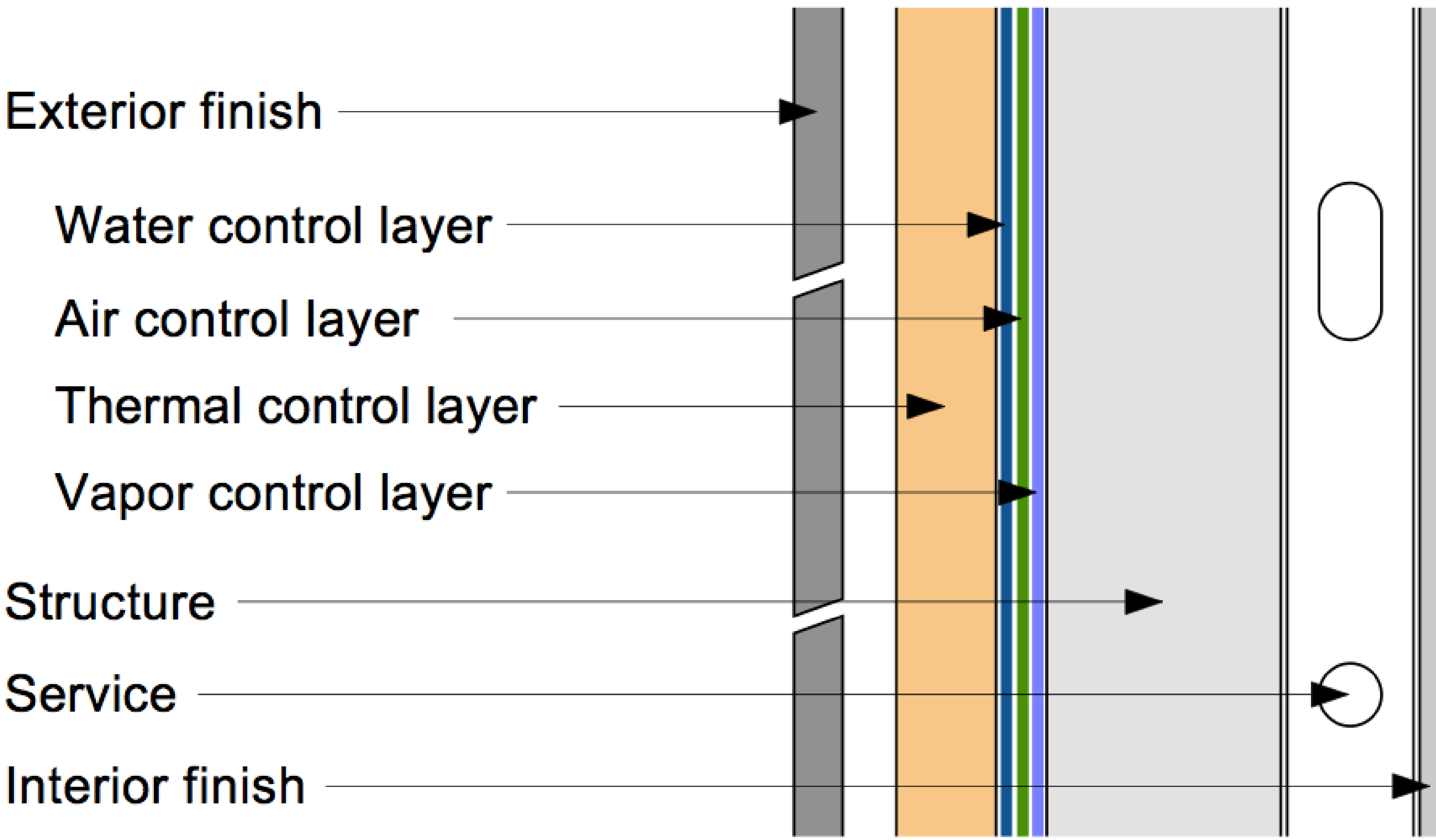
# The classic “Perfect” Wall



## High Performance

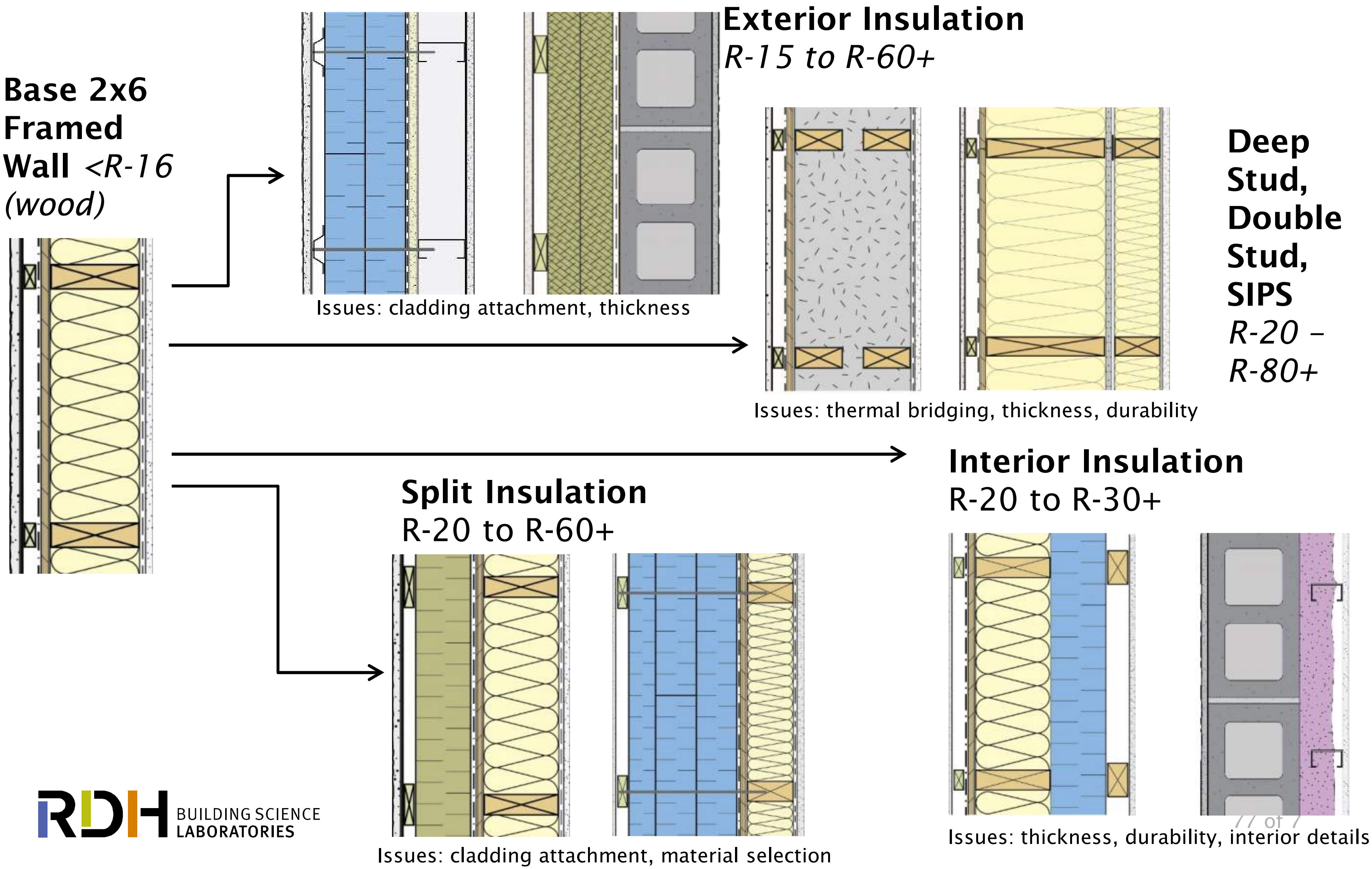
→ Continuity (no holes)

1. Water control layer
2. Air Control layer
3. Thermal Control

→ Good control (how do we measure)

- → Drainage gap and WRB?
- → Airtight
- → High R-value

# Getting to Higher Insulation Levels in Walls

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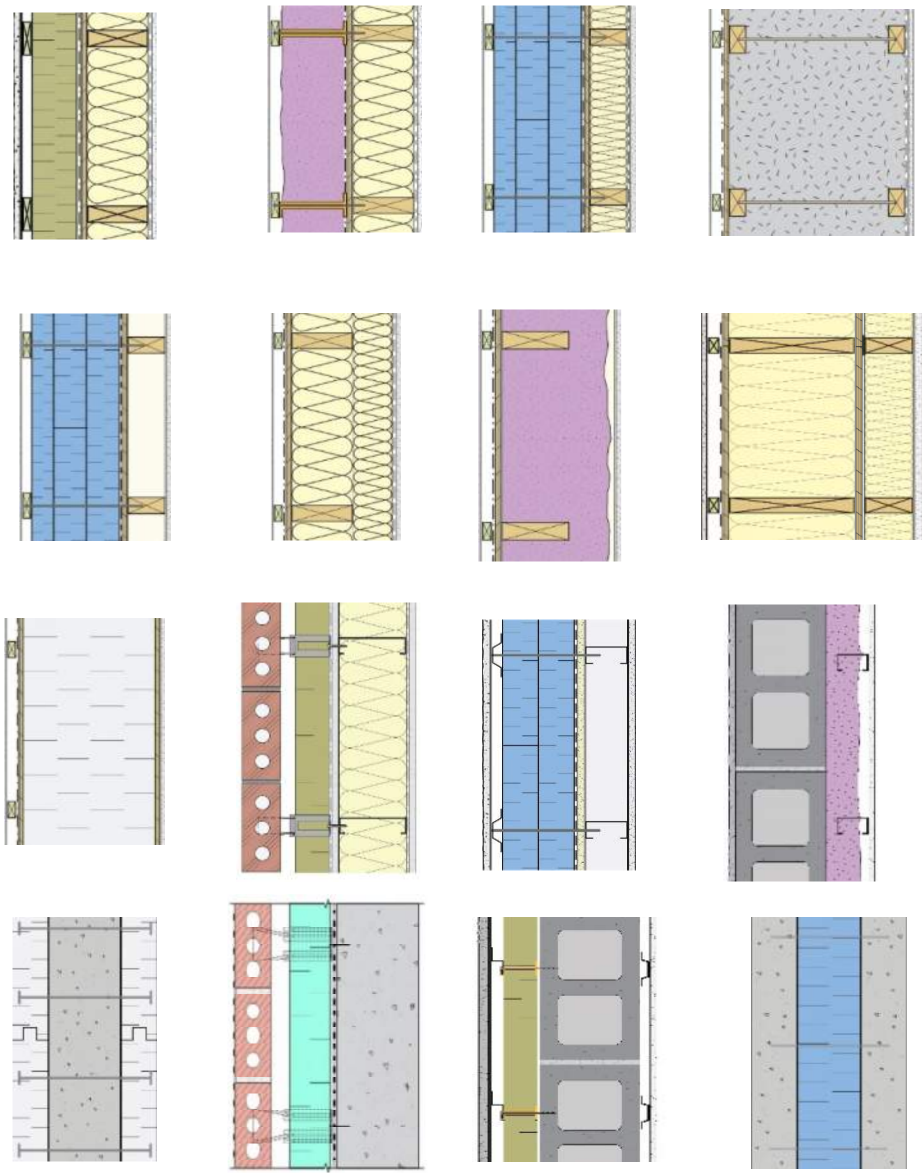
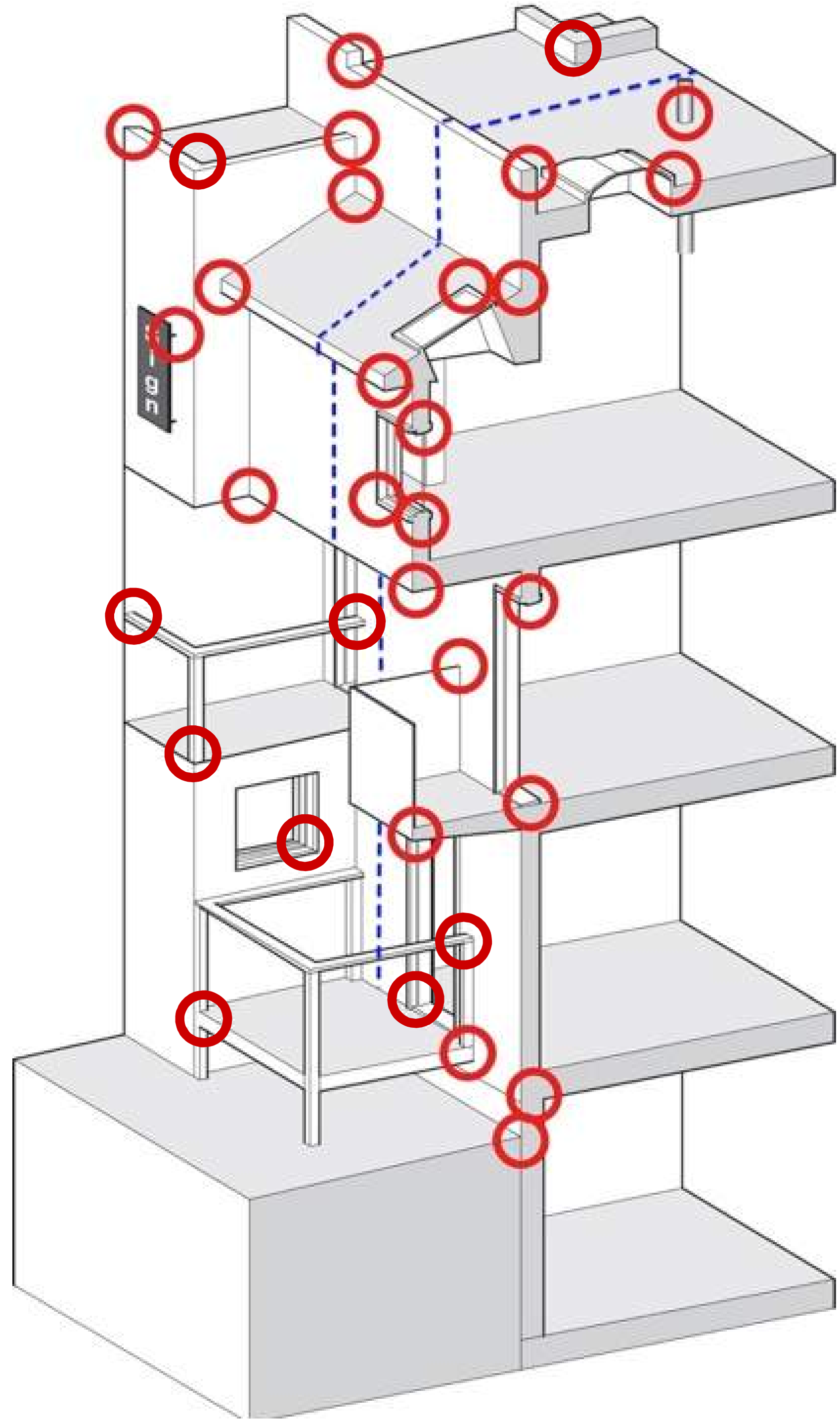
# Design Considerations for Highly Insulated Walls



- → Wood vs Steel vs Concrete Backup
- → Combustibility
- → Material & Labour Cost
- → Durability
- → Ease of Construction
- → Cladding Attachment
- → Rain Water penetration control
- → Air Barrier System & Detailing
- → Vapor diffusion control
- → Pre-fabrication vs Site-Built
- → Thickness & Floor Area
- → Insulation type(s)
- → Environmental aspects/materials
- → and Others…

# Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at ◯
  - change in plane
  - change in material
  - change in trade



→ Its easy to get continuity in a 2D detail

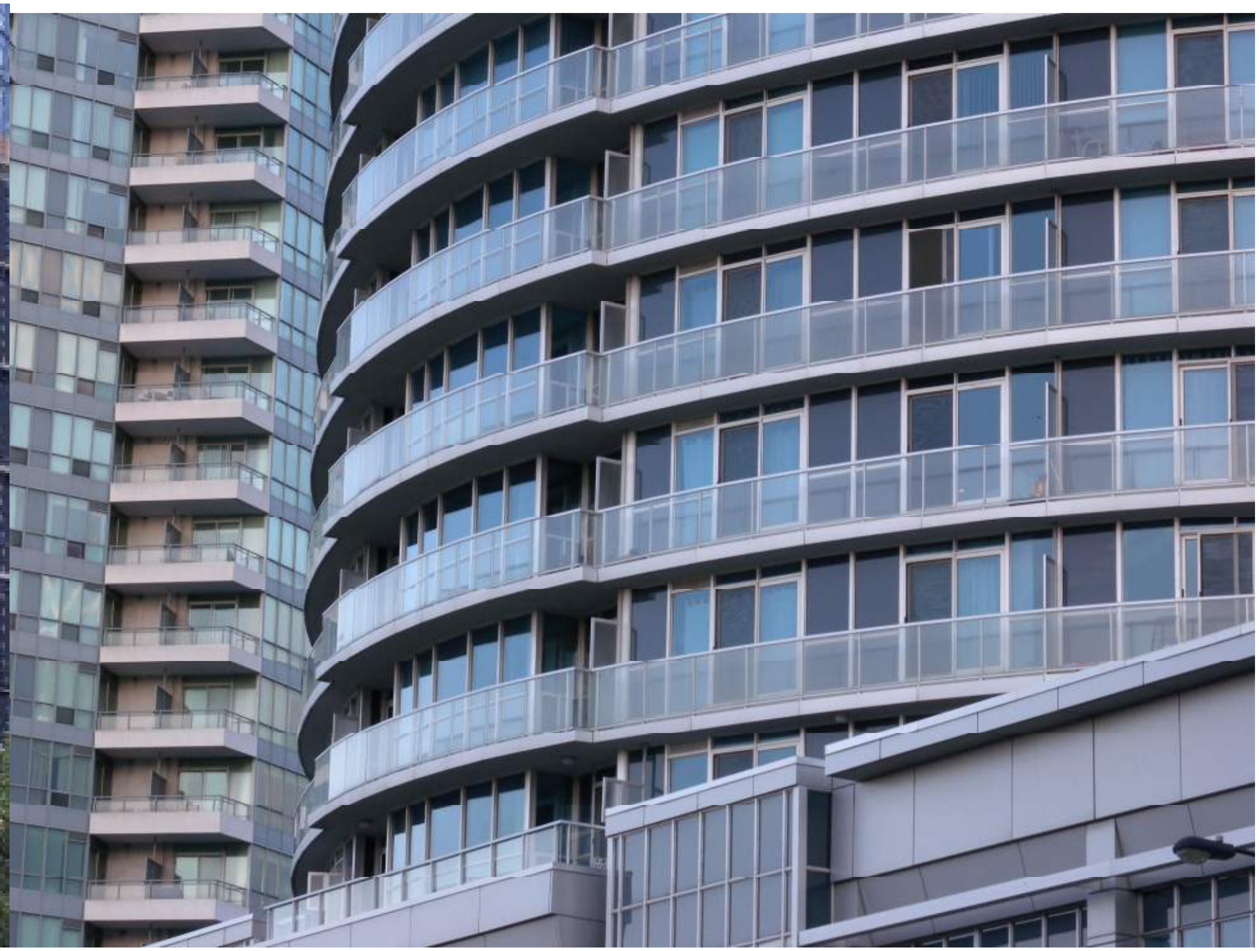
→ Selection of enclosure assembly should consider the number, type, and complexity of details

**Thermal bridging nightmares in plan *and* section**

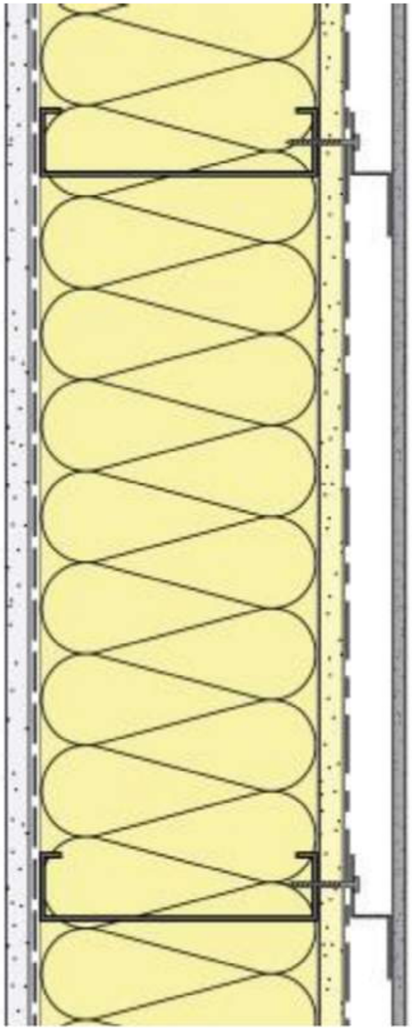
## Thermal Bridges

→ Balconies, etc

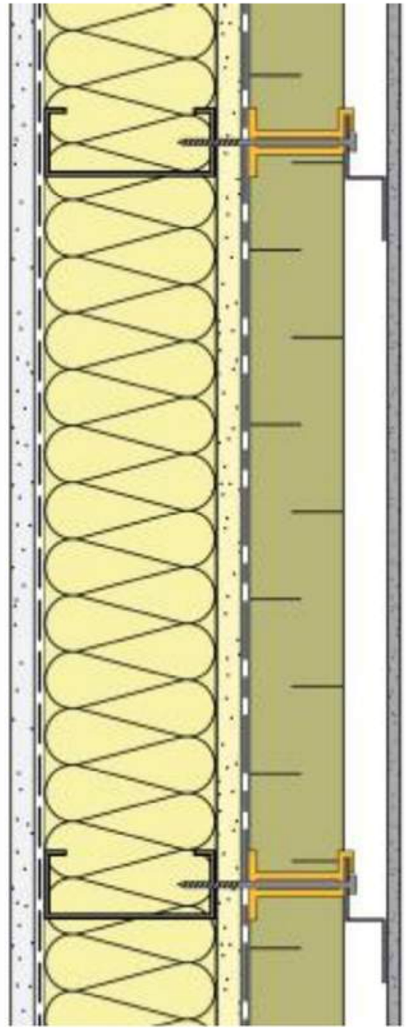
→ Exposed slab edges



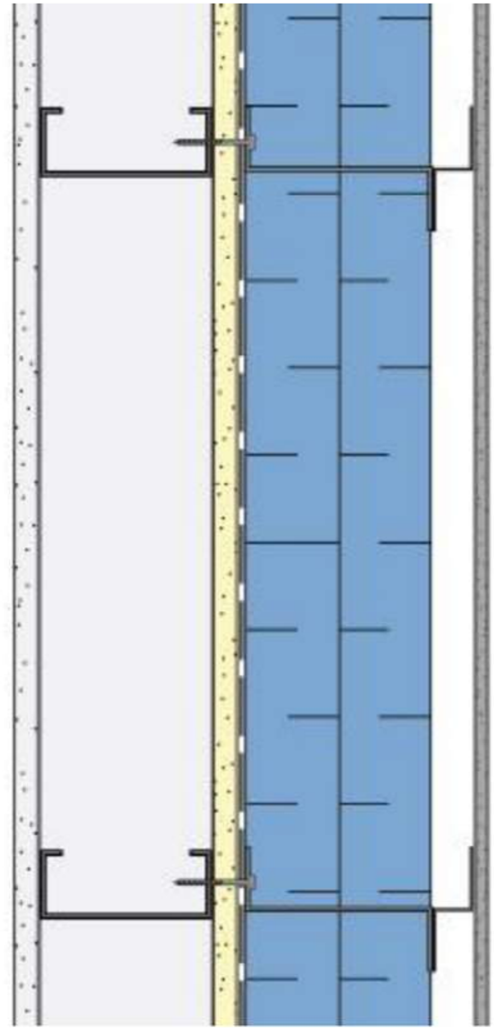
**Projecting slab edges in Austin TX**



**The problem**



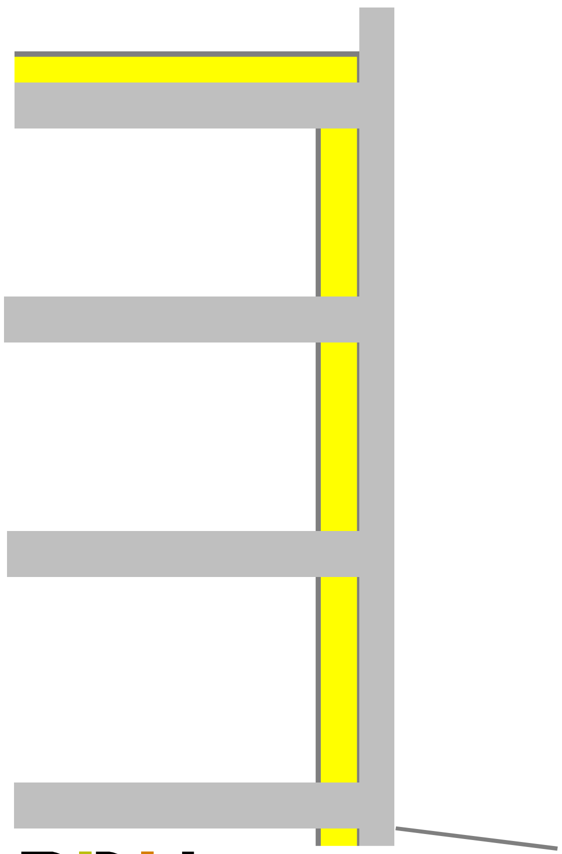
**A Solution**

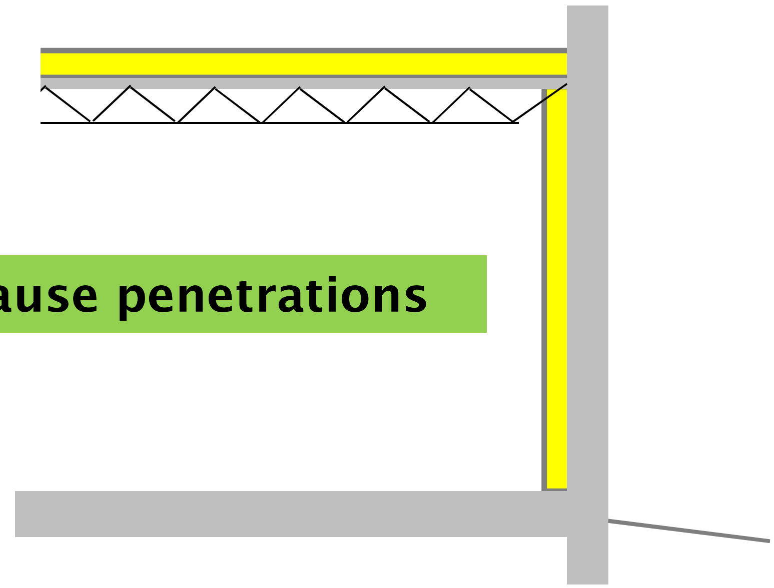


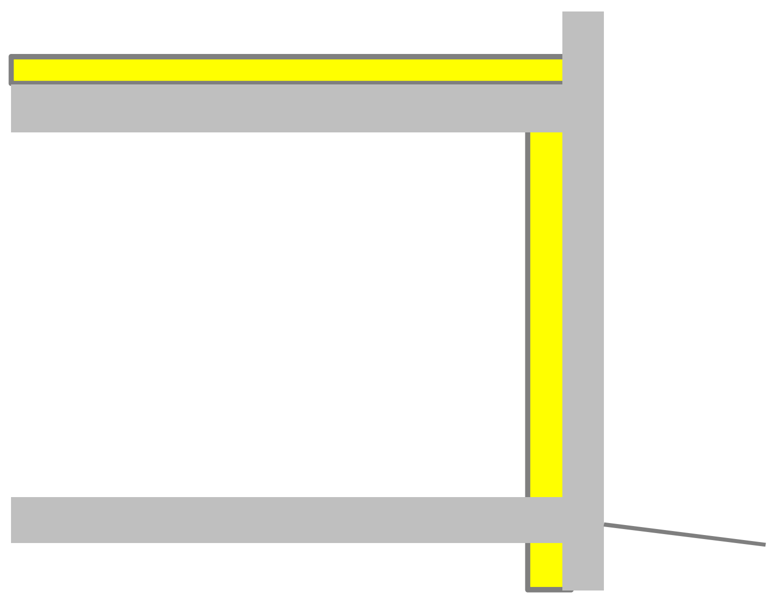
**The Ideal**

# Interior Insulation?

**Floors, roofs, slabs cause penetrations**







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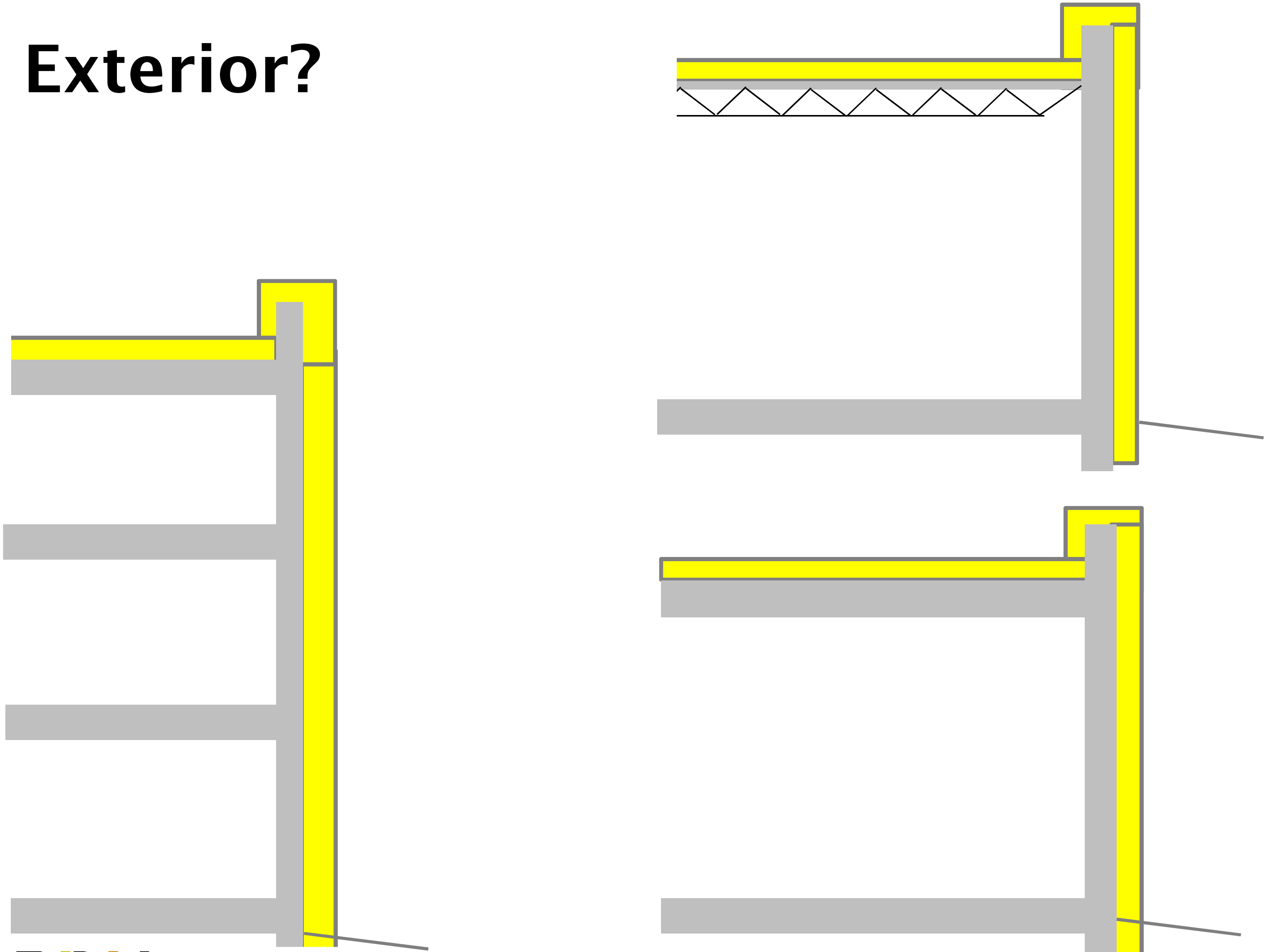
# Exterior?



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# Complexity: Often exterior control layers are only practical solution

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## c.i. Continuous Insulation

→ Code language used to communicate better prescriptive thermal performance

→ Often need to meet U-value requirement

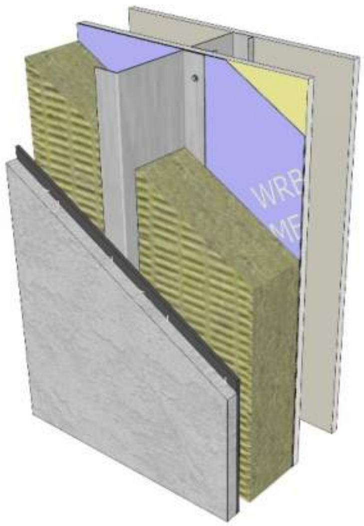
  → Trade-off analysis

  → Computer modelling

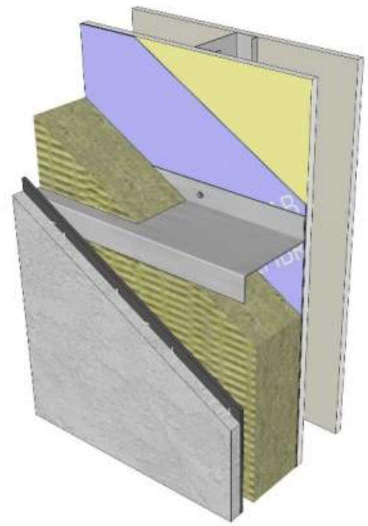
## Challenges for c.i.

- → Limits insulation choice
  - → Cant use natural fibers as insulation
    - › Moisture tolerance!
  - → Needs to be self-supporting/semi-rigid
  - → Fire performance needs to be designed
    - › Can use foam plastic but requires care
- → Cladding attachment
- → Window / door alignment

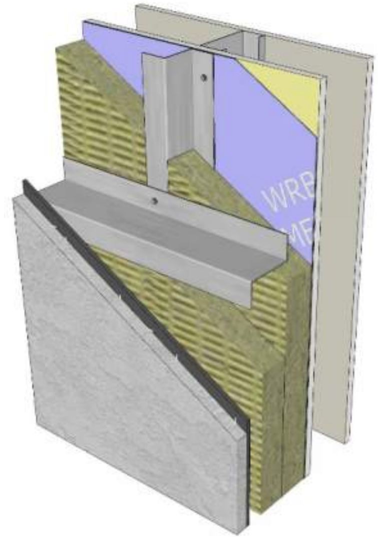
# Many Cladding Attachment Options



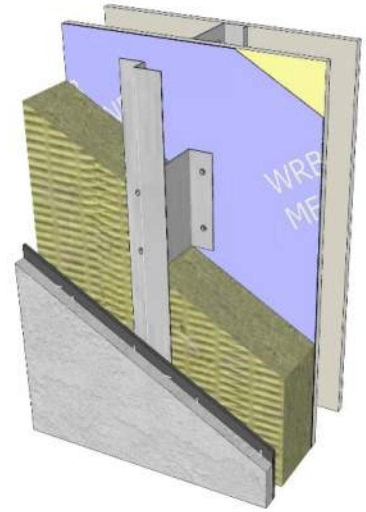
*Vertical Z-girts*



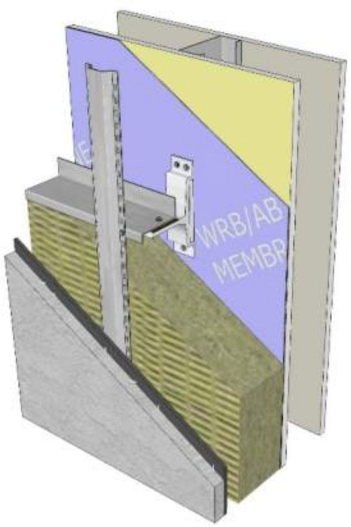
*Horizontal Z-girts*



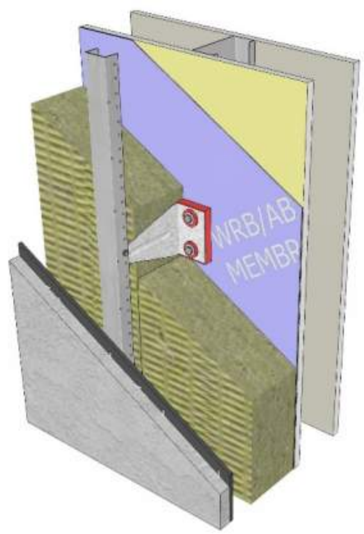
*Crossing Z-girts*



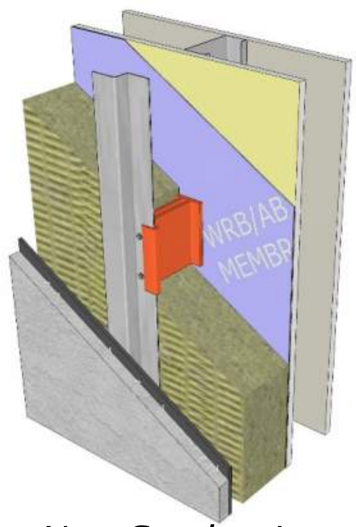
*Galvanized/Stainless Clip & Rail*



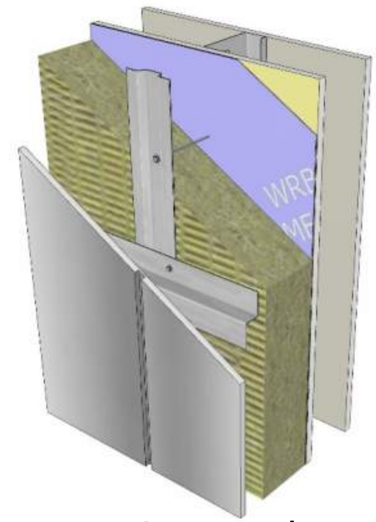
*Aluminum Clip & Rail*



*Thermally Improved Clip & Rail*

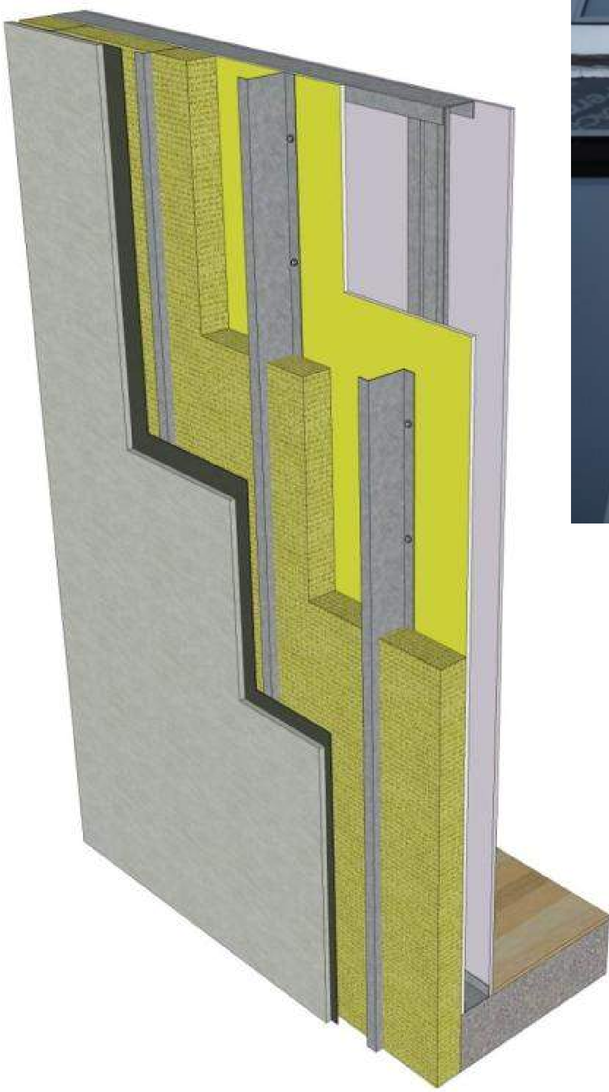


*Non-Conductive Clip & Rail*



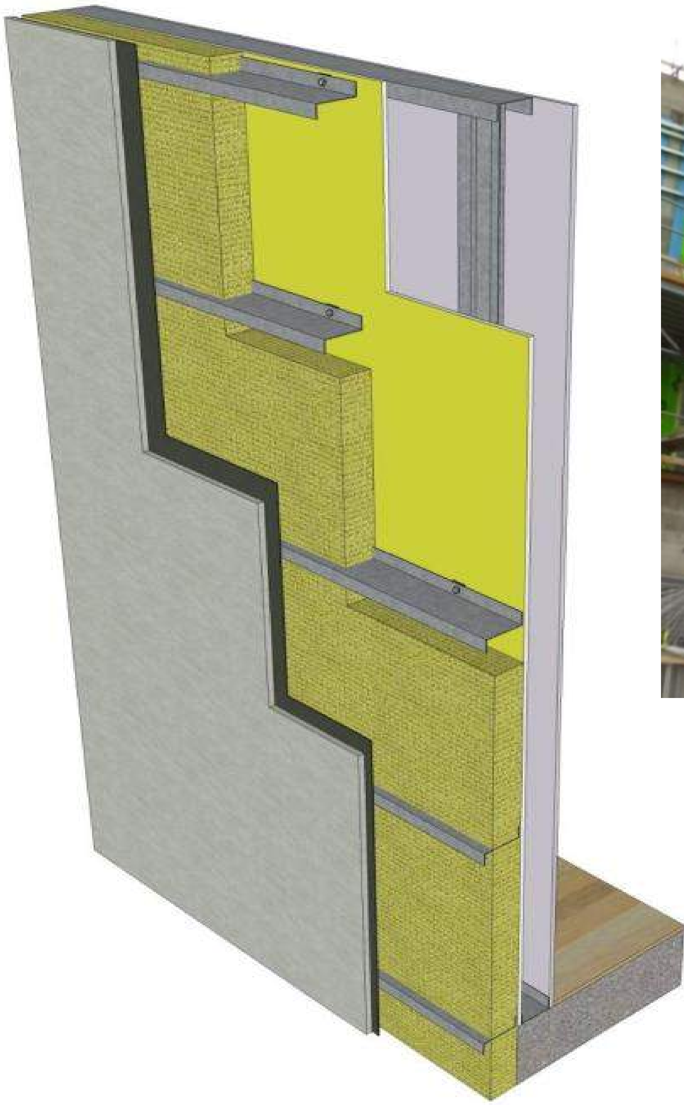
*Long Screws through Insulation*

# Cladding Attachment: Vertical Z-Girts

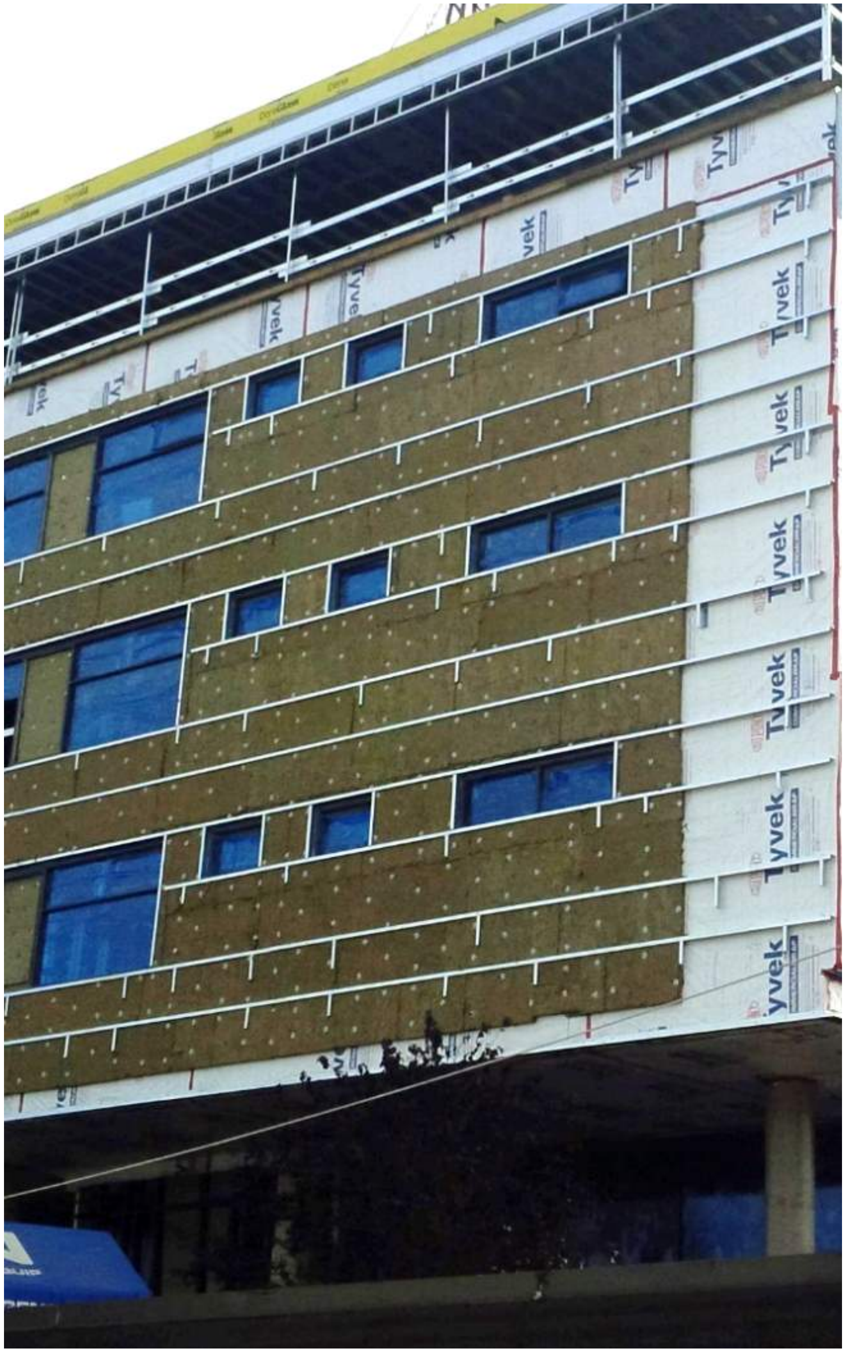



*~60-80%+ loss in R-value*

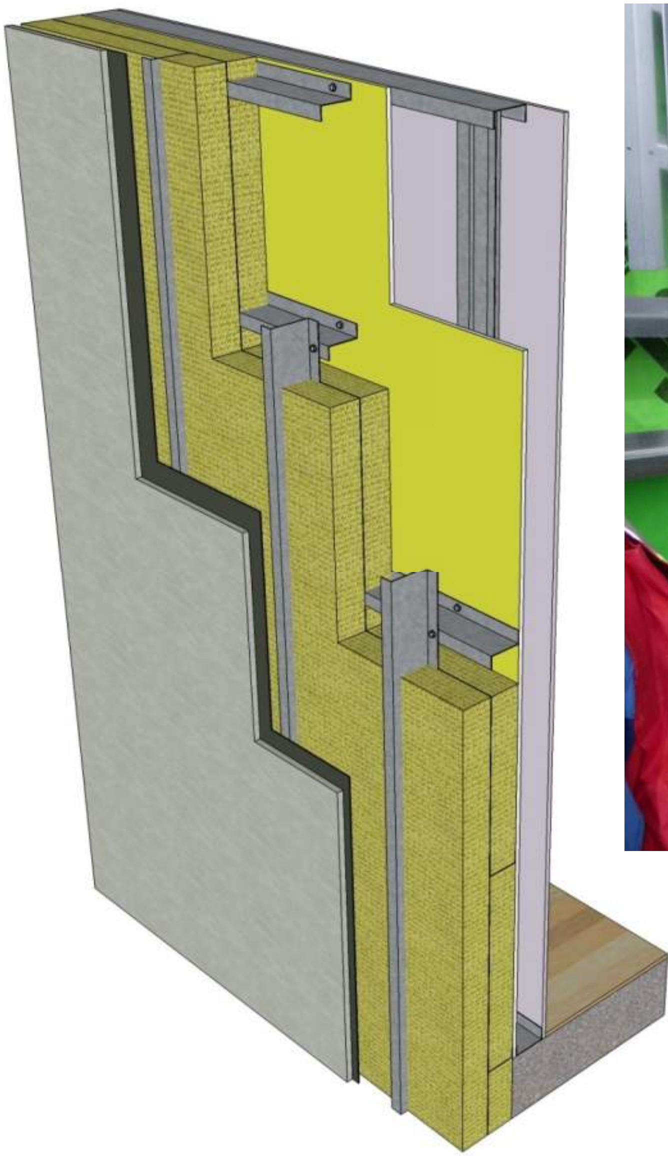
# Cladding Attachment: Horizontal Z-Girts



*~50-70%+ loss in R-value*


Tyvek

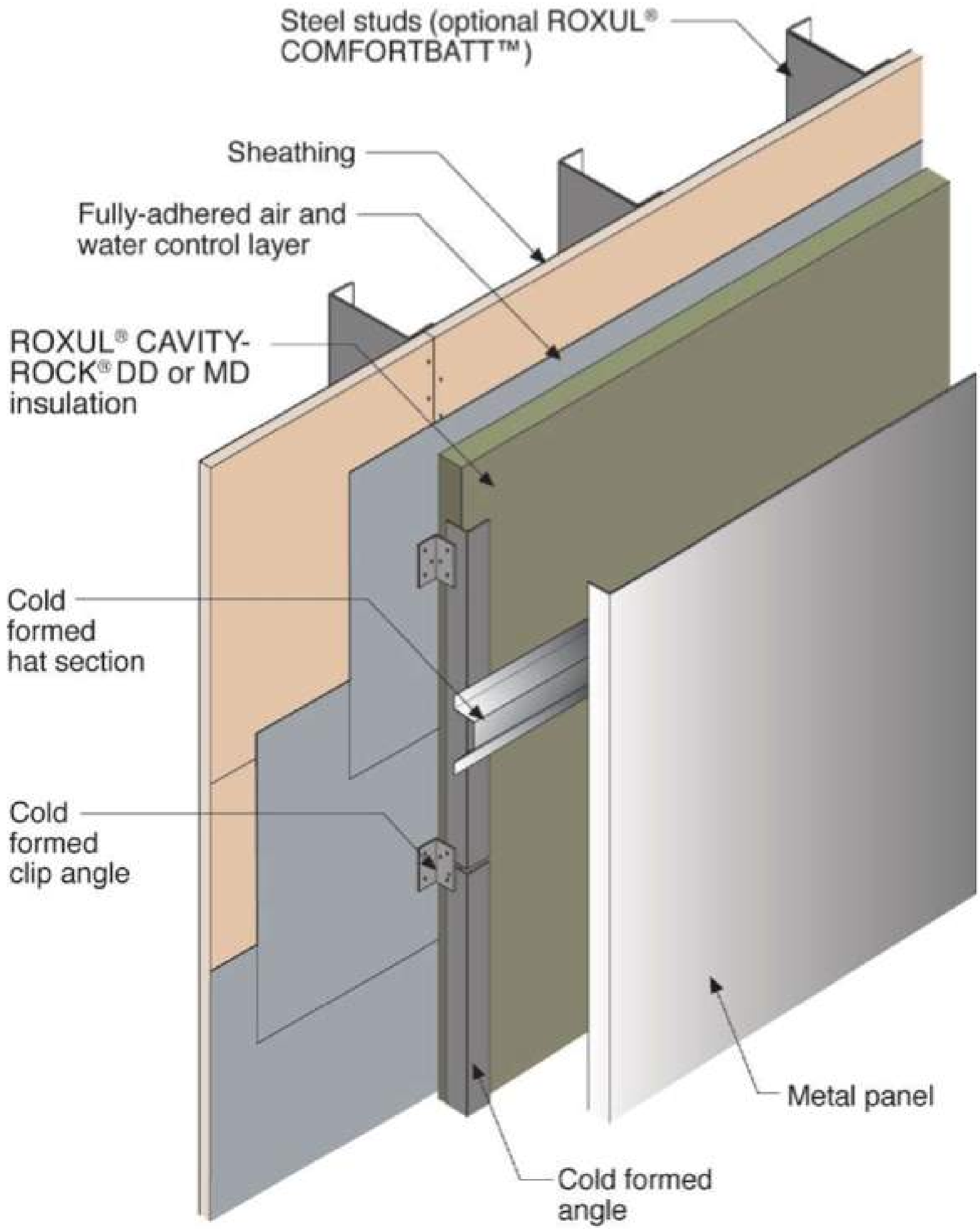
# Cladding Attachment: Crossing Z-Girts



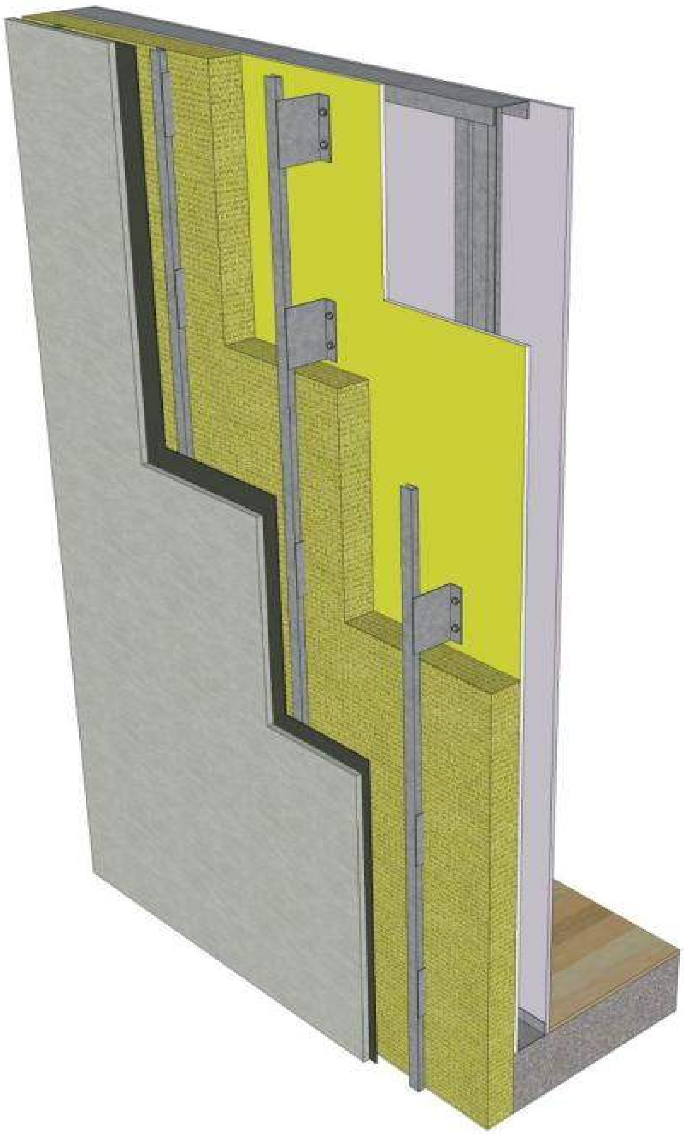
*~40-60%+ loss in R-value*

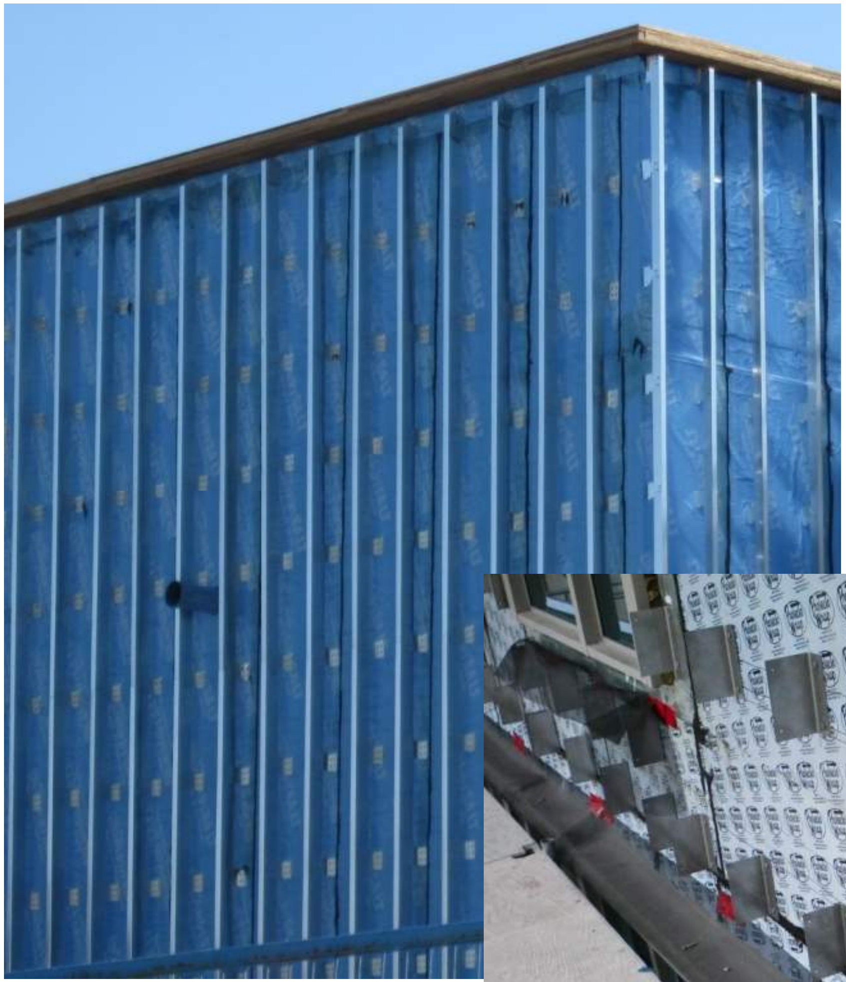
# Cladding Attachment: Crossing Z-Girts

**Stainless steel is much less conductive than steel or aluminum**



# Cladding Attachment: Clip & Rail, Steel



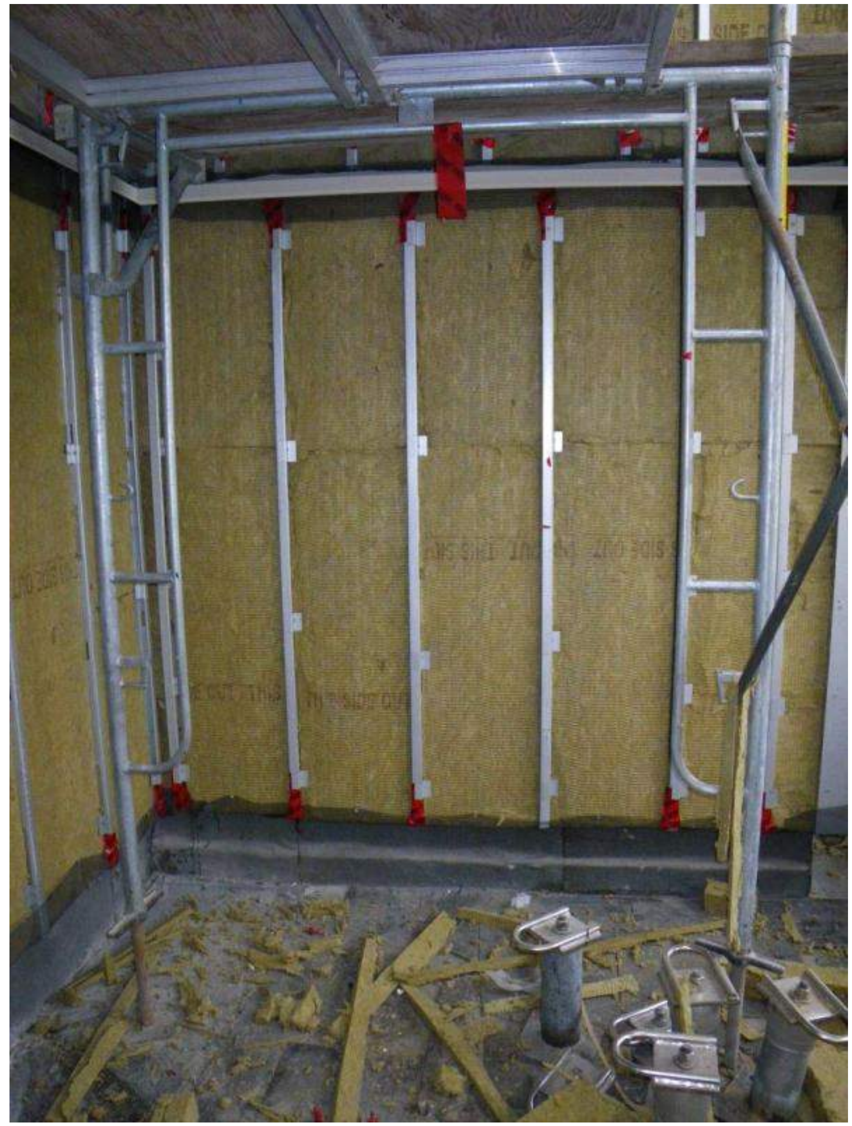


*~25-50% loss in R-value for galvanized, **15-35% for stainless steel (4x less conductivity)***

# Cladding Attachment: Clip & Rail, Steel

# Cladding Attachment: Clip & Rail, Stainless Steel

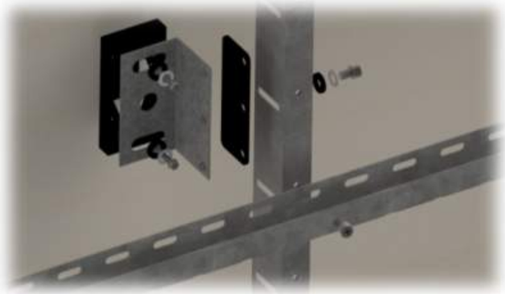
Note: clips *way* over designed



# Stainless Z + rail


# Cladding Attachment: Clips w/ Diagonal L-Girts

# Proprietary Clips for Cladding Systems



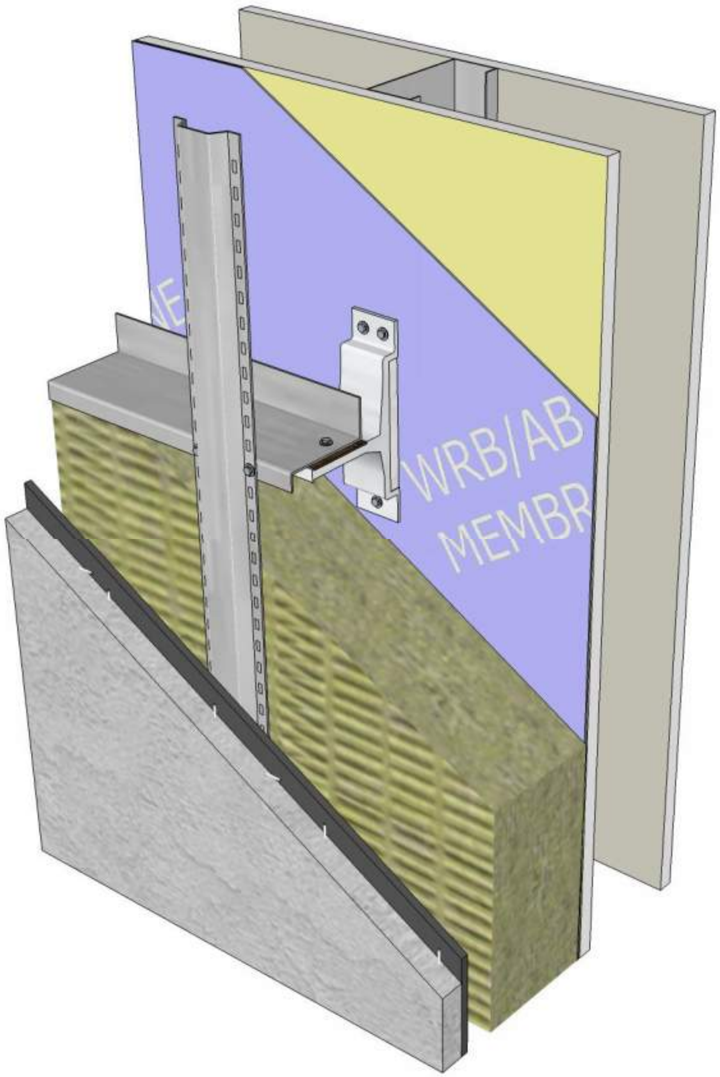
Polymer pad connections used as thermal breaks (generic solution)

Polymer pad connections used as thermal breaks (generic solution)

Thermally broken connections (image courtesy of Cascadia)

# Other Steel & Aluminum Cladding
# Clip & Rail Technologies

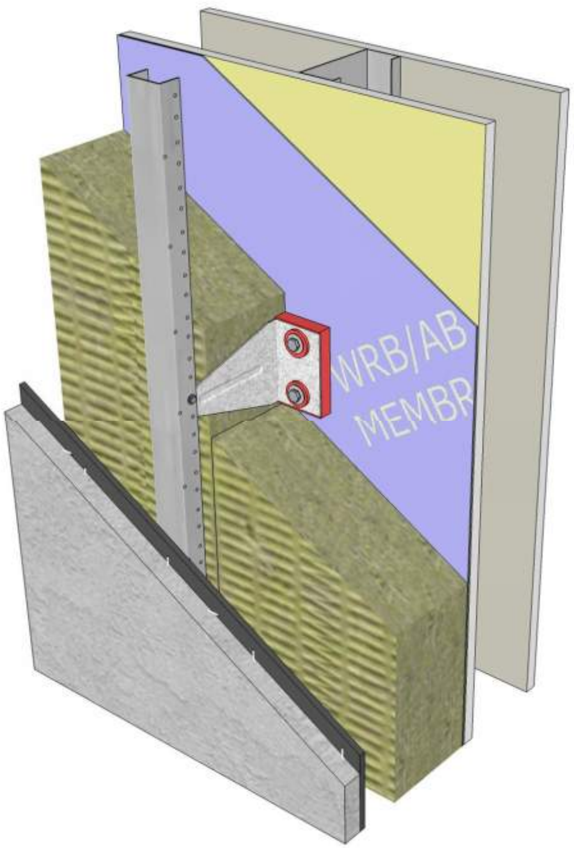
# Cladding Attachment: Aluminum Clip & Dual Girt

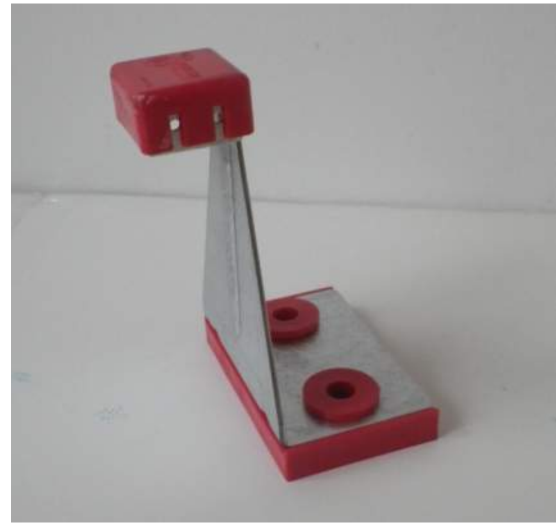



*~30-50% loss in R-value (spacing dependant)*

# Cladding Attachment: Clip & Rail, Isolated Galvanized

→ Isolate the metal, improve the performance



*~10-40% loss in R-value (spacing dependant)*

# Cladding Attachment: Metal Panel Clips (Aluminum)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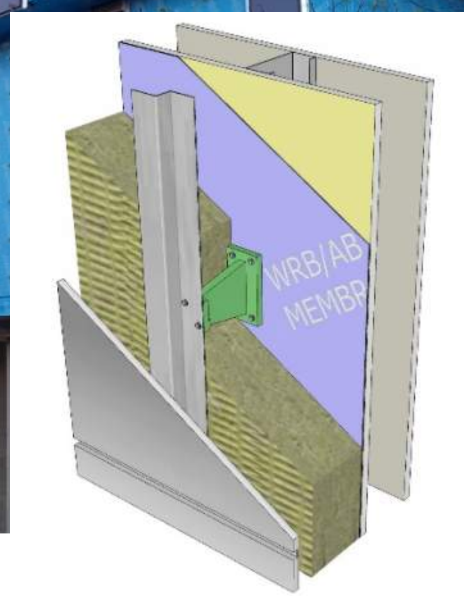
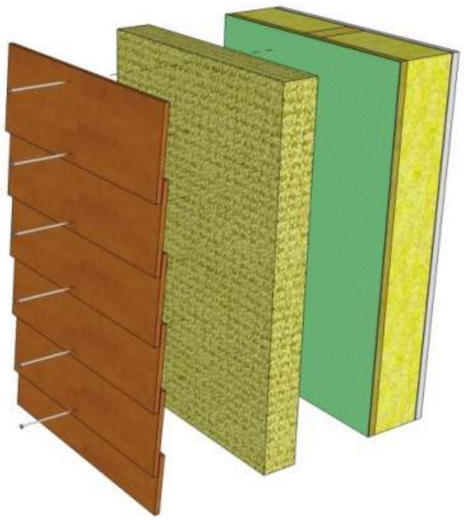
# Cladding Attachment: Clip & Rail Fiberglass (No Screws)



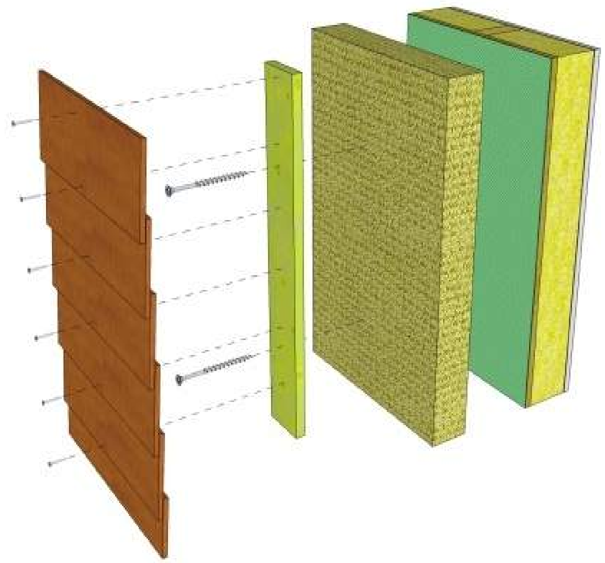

<10% loss in R-value

# Cladding Attachment: Screws through Insulation

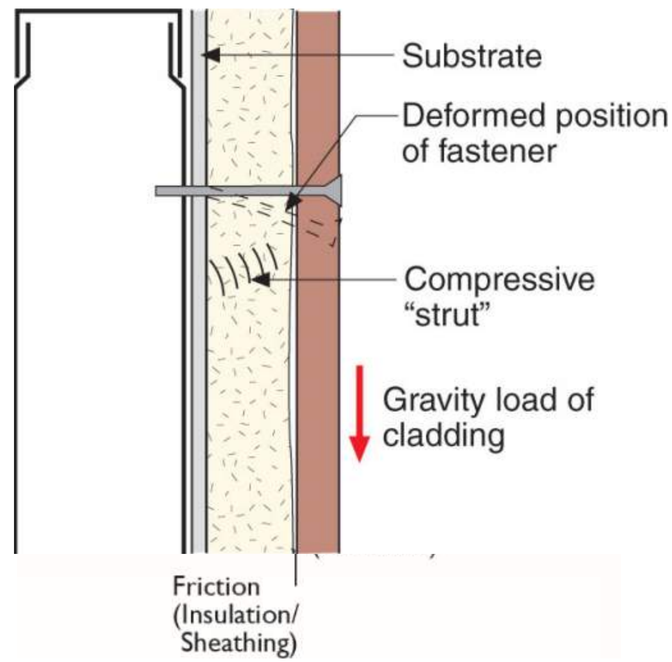
**Screws are NOT supporting cladding as a cantilever!**



Longer cladding Fasteners directly through rigid insulation (up to 2" for light claddings)



Long screws through vertical strapping and rigid insulation creates truss – short cladding fasteners into vertical strapping

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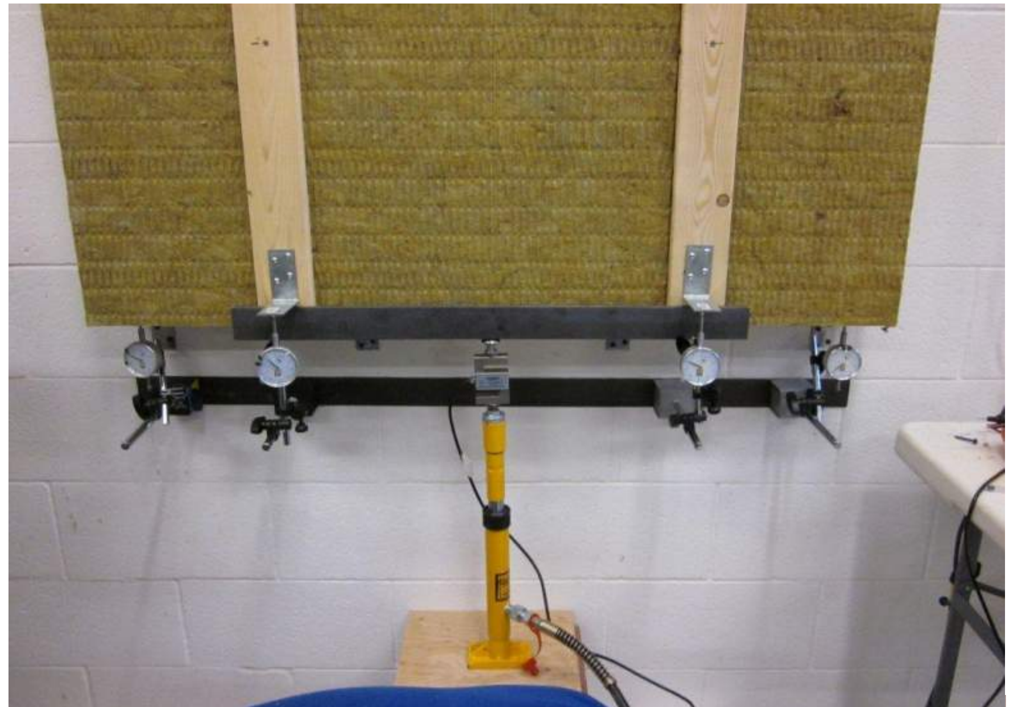
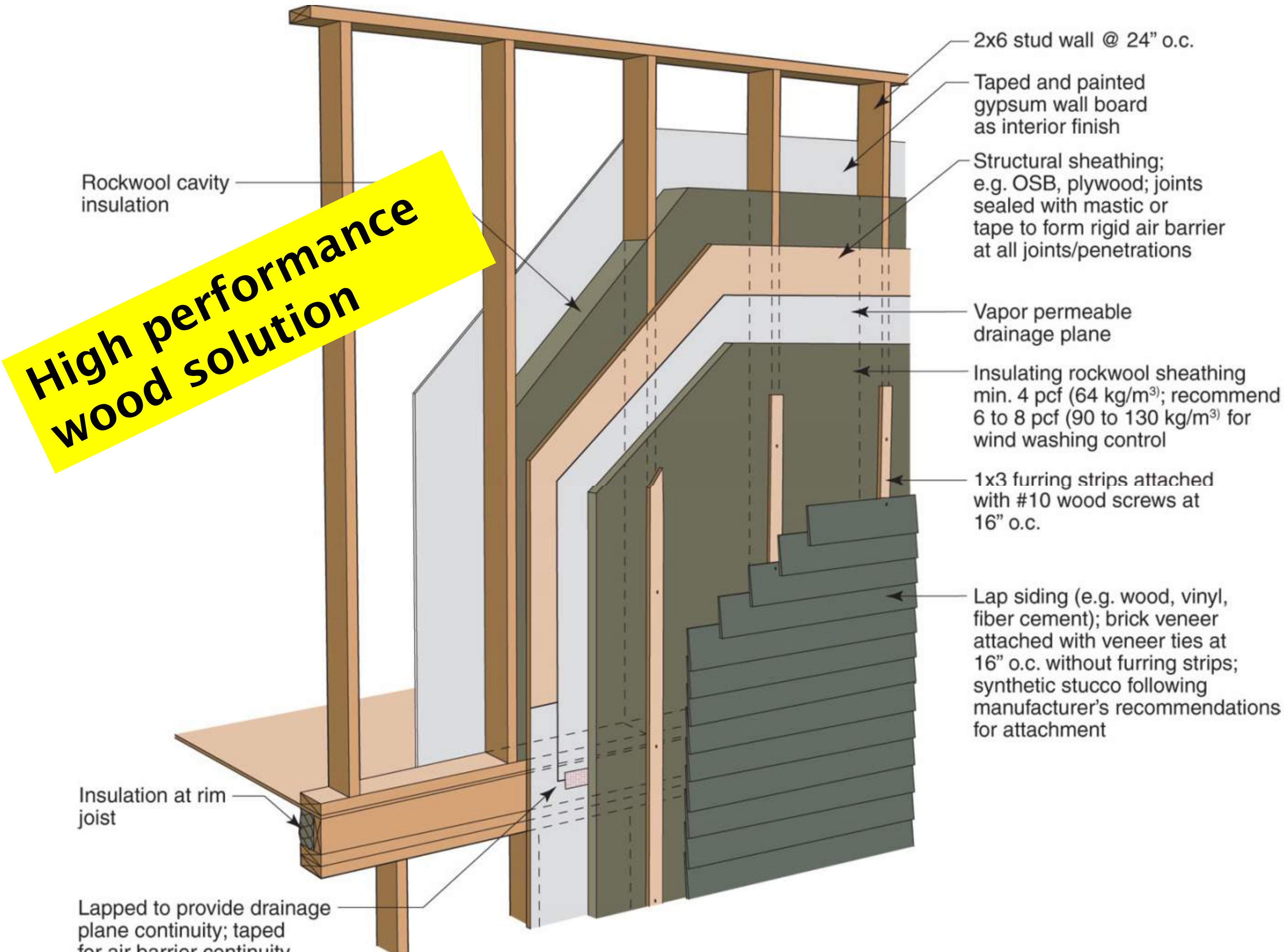
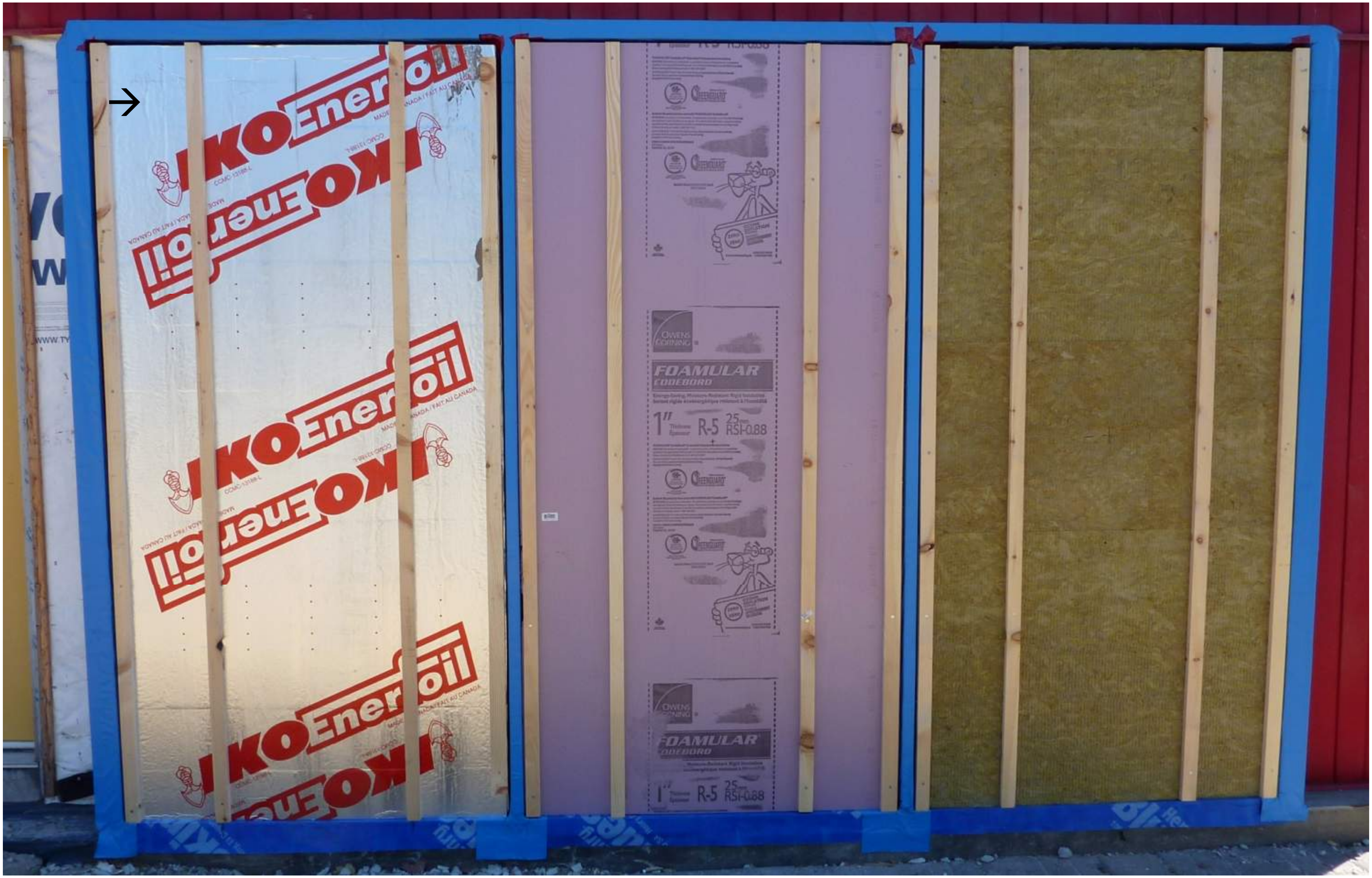



**Extensive testing has demonstrated performance**

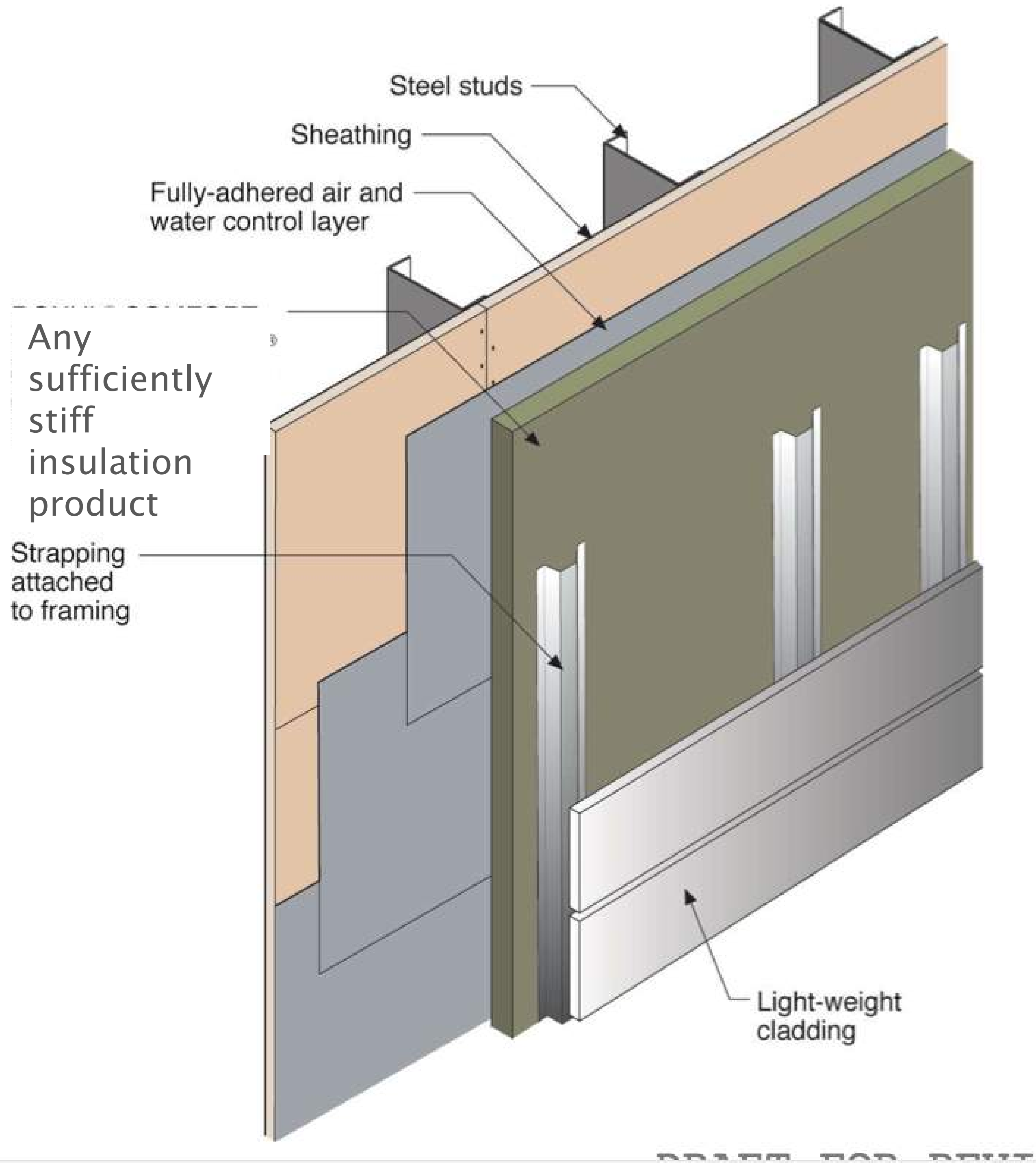

High performance wood solution
Rockwool cavity insulation
2x6 stud wall @ 24" o.c.
Taped and painted gypsum wall board as interior finish
Structural sheathing; e.g. OSB, plywood; joints sealed with mastic or tape to form rigid air barrier at all joints/penetrations
Vapor permeable drainage plane
Insulating rockwool sheathing min. 4 pcf (64 kg/m³); recommend 6 to 8 pcf (90 to 130 kg/m³) for wind washing control
1x3 furring strips attached with #10 wood screws at 16" o.c.
Lap siding (e.g. wood, vinyl, fiber cement); brick veneer attached with veneer ties at 16" o.c. without furring strips; synthetic stucco following manufacturer's recommendations for attachment
Insulation at rim joist
Lapped to provide drainage plane continuity; taped for air barrier continuity

# Wood furring




Joe’s Barn ca. 1995

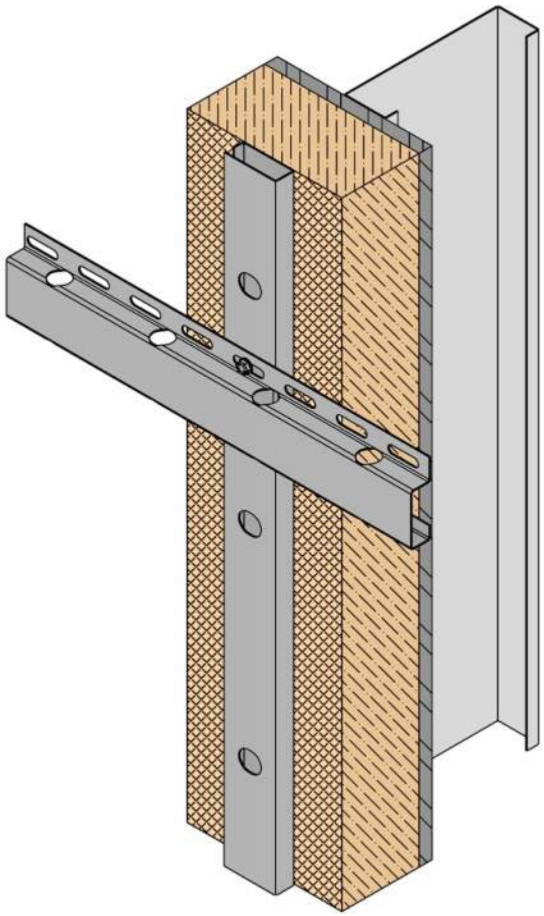

John’s Barn ca. 2015



Steel studs
Sheathing
Fully-adhered air and water control layer
Any sufficiently stiff insulation product
Strapping attached to framing
Light-weight cladding

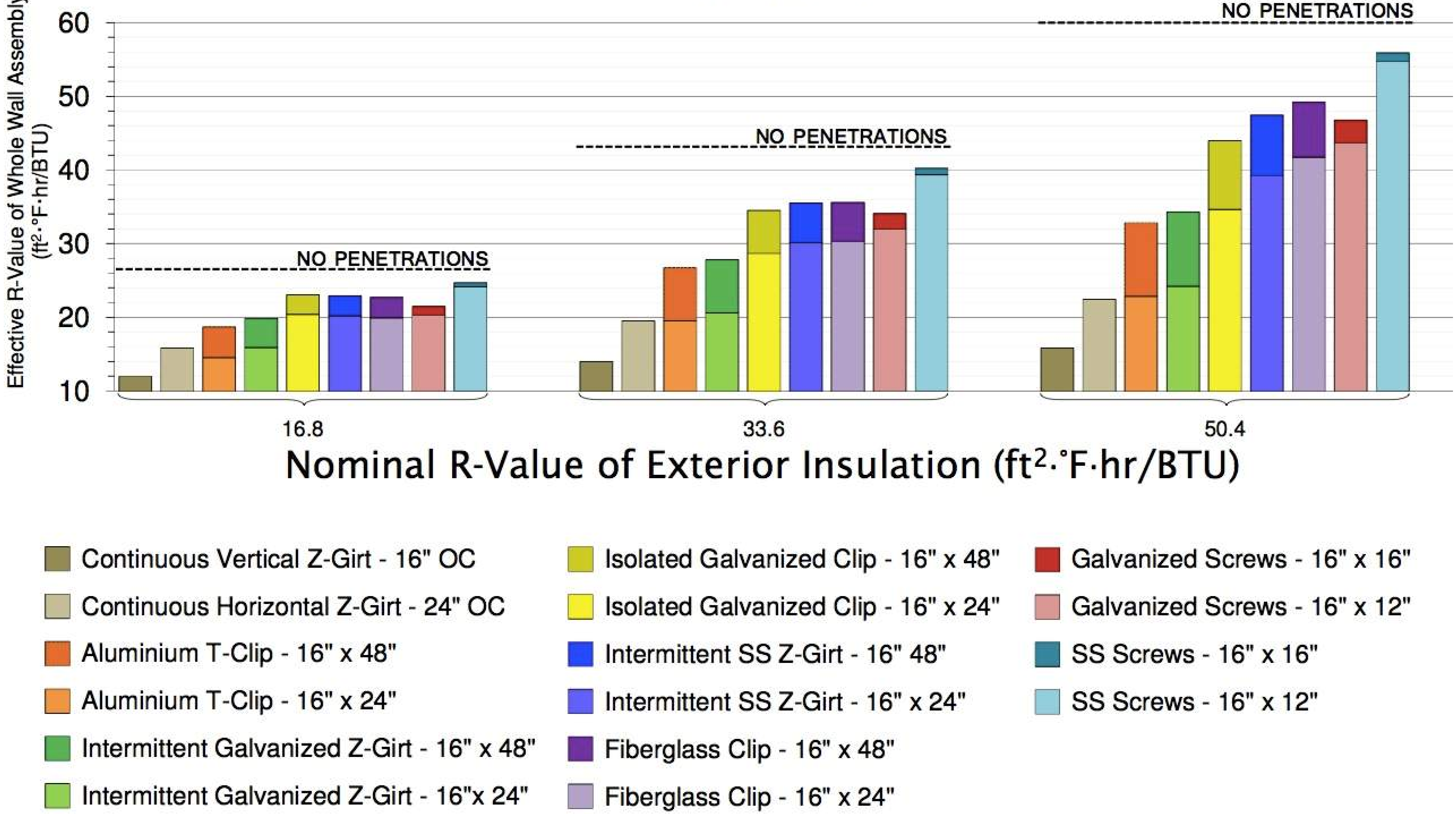
# Cladding Solutions- furring

→ Penetrate with only screws
  → E.g. 16”x12”
→ Requires dense insulation
→ E.g.
  → stonewool over 4 pcf
  → XPS, PIC, EPS, ccSPF
→ *May* not work for heavy or brittle claddings




**Commercially available solutions**

# For 3 5/8” steel stud w/R12 batt + exterior insulation

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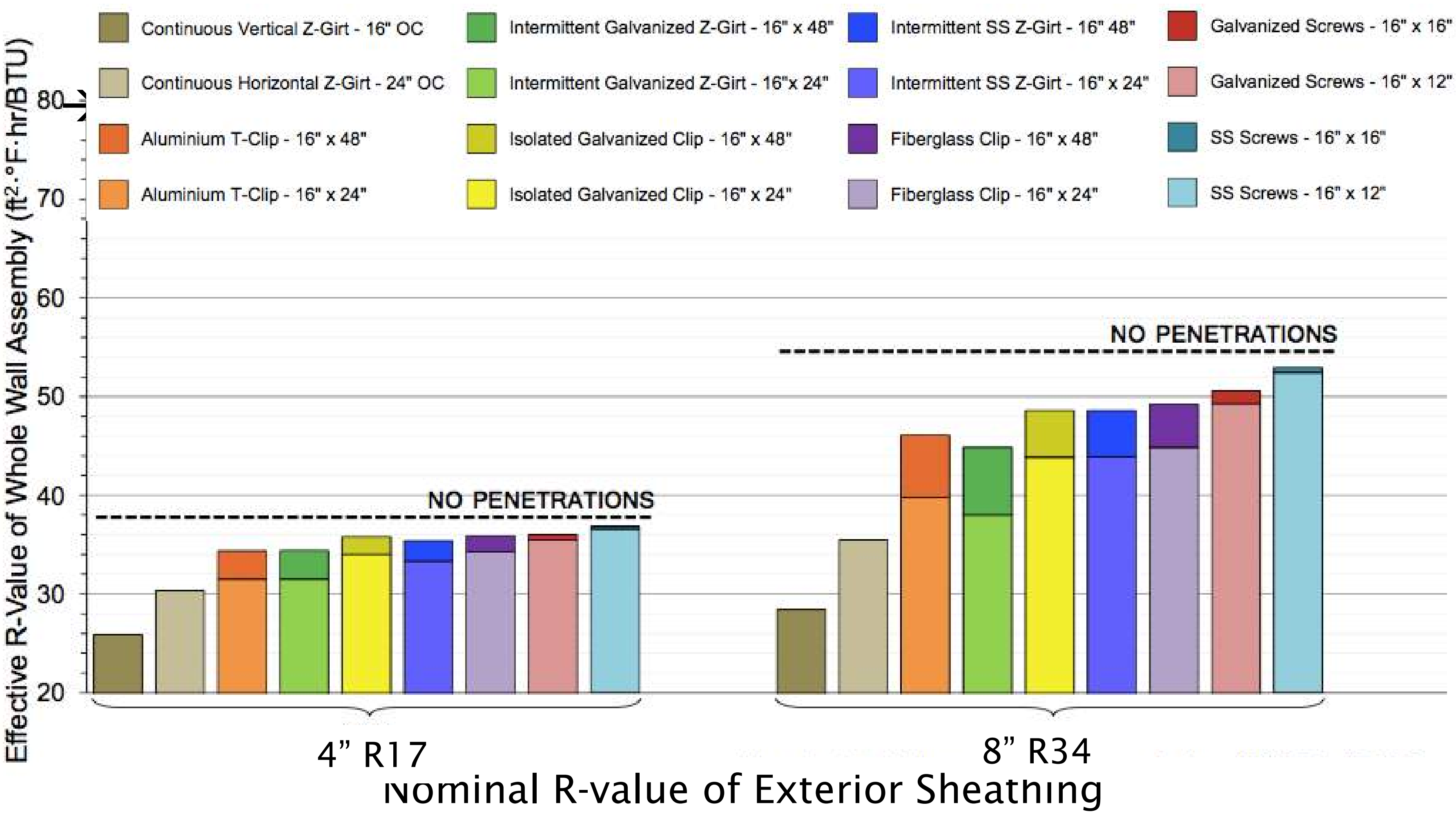
*From: Higgins, Shane & Finch, RDH*

# Effective R-value for 2x6 Wood studs w/R22 batts

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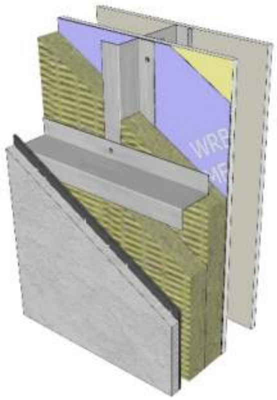
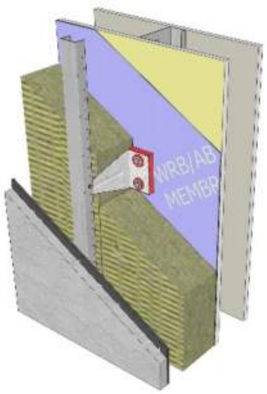
**From: RDH Building Science**

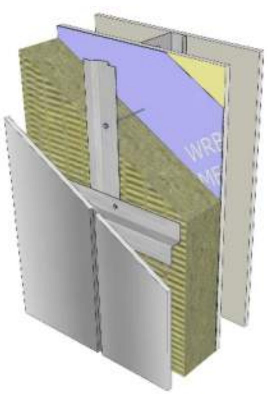
# Cladding Attachment & Insulation Choice



→**Continuous Girts** – Rigid or Semi-rigid boards or spray-foam (i.e. almost anything works)



→**Intermittent Clip & Rail Systems** – Semi-rigid boards or spray foam (i.e. flexibility & ease of installation is key)

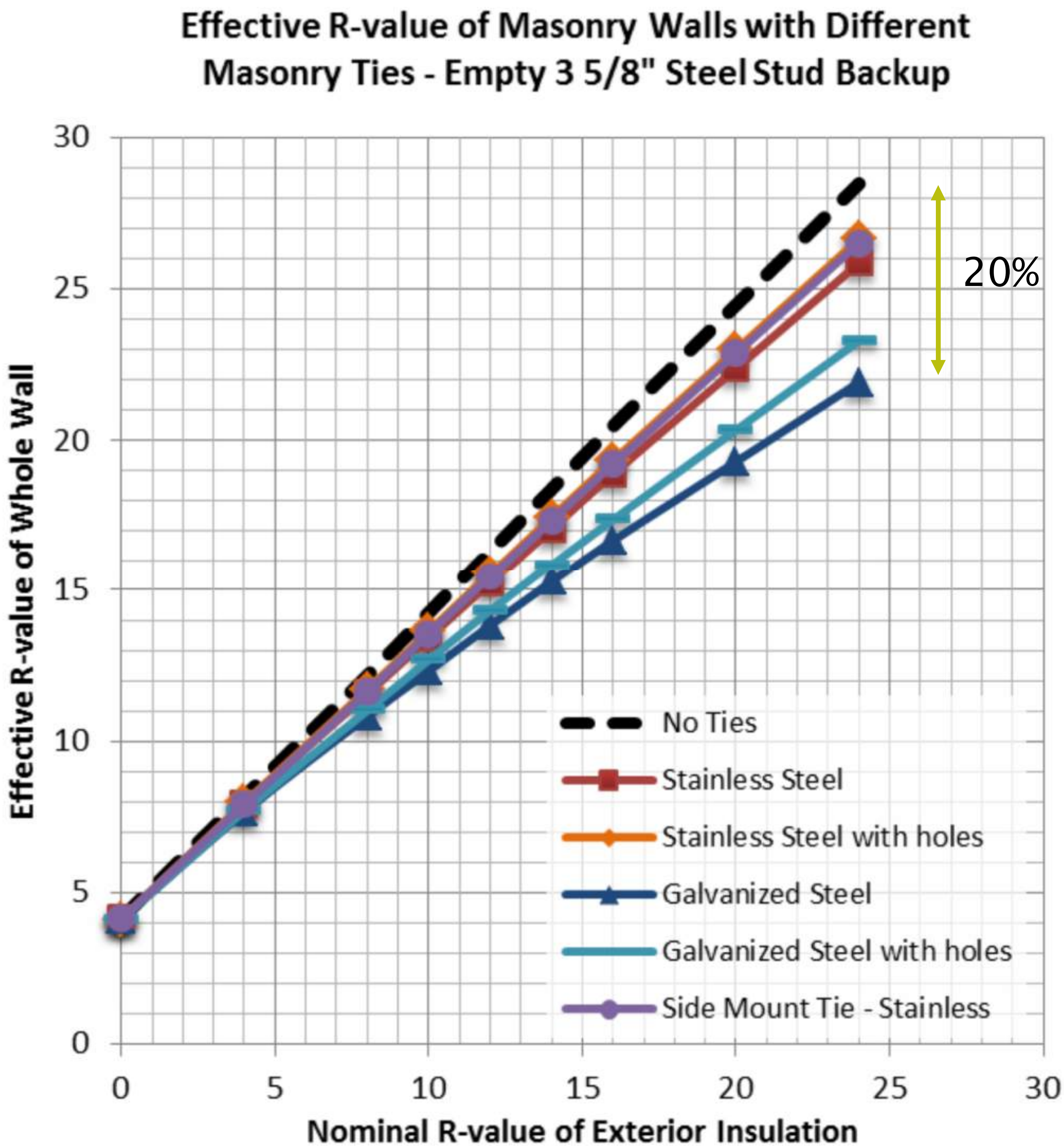


→**Screws through Insulation** – rigid or semi-rigid insulation boards (i.e. stiff enough to support compression load)

## Masonry / Heavy Cladding

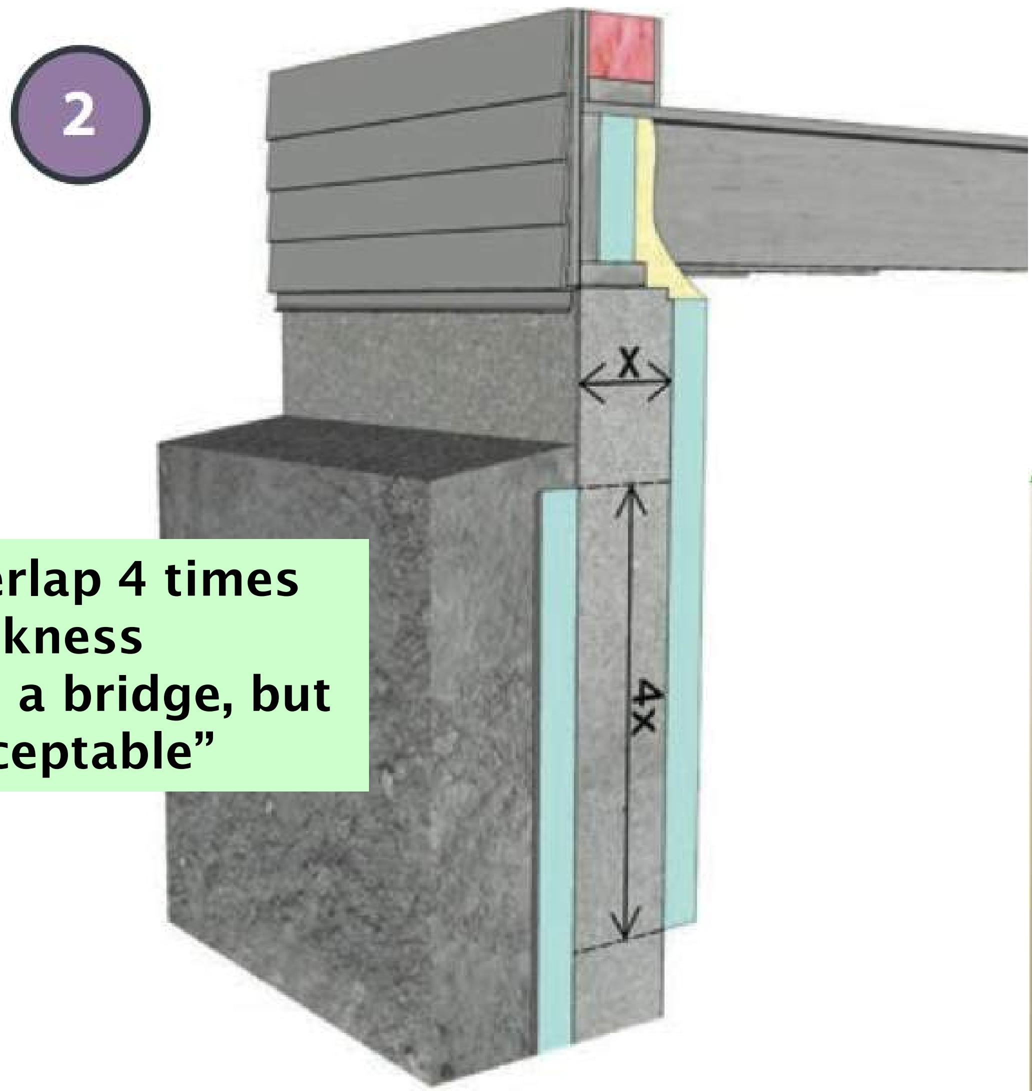
- → Heavy cladding requires different solutions
  - → E.g. 25 to 50+ psf
- → Two types of attachment
  - → Lateral loads: brick ties
  - → Vertical Loads: shelf angle, foundations
- → Many good brick ties available

→

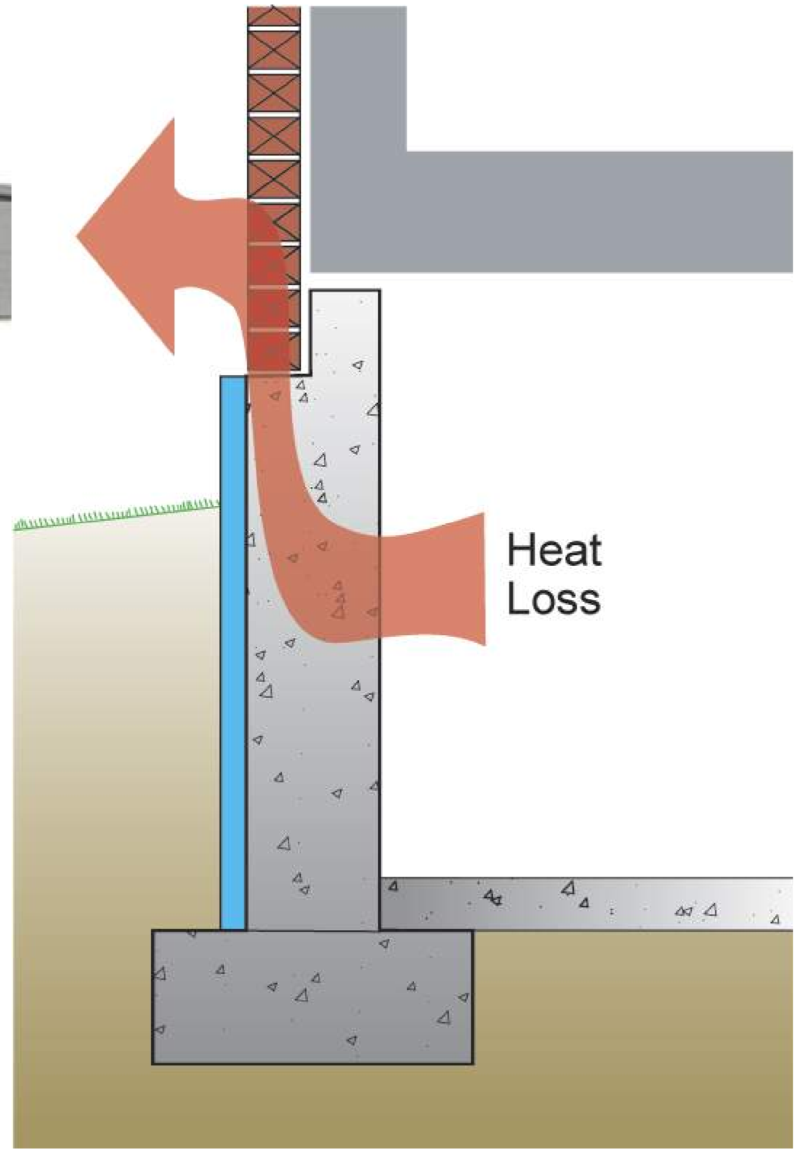


Effective R-value of Masonry Walls with Different Masonry Ties - Empty 3 5/8" Steel Stud Backup
Effective R-value of Whole Wall
Nominal R-value of Exterior Insulation
0
5
10
15
20
25
30
20%
No Ties
Stainless Steel
Stainless Steel with holes
Galvanized Steel
Galvanized Steel with holes
Side Mount Tie - Stainless

## Other challenges

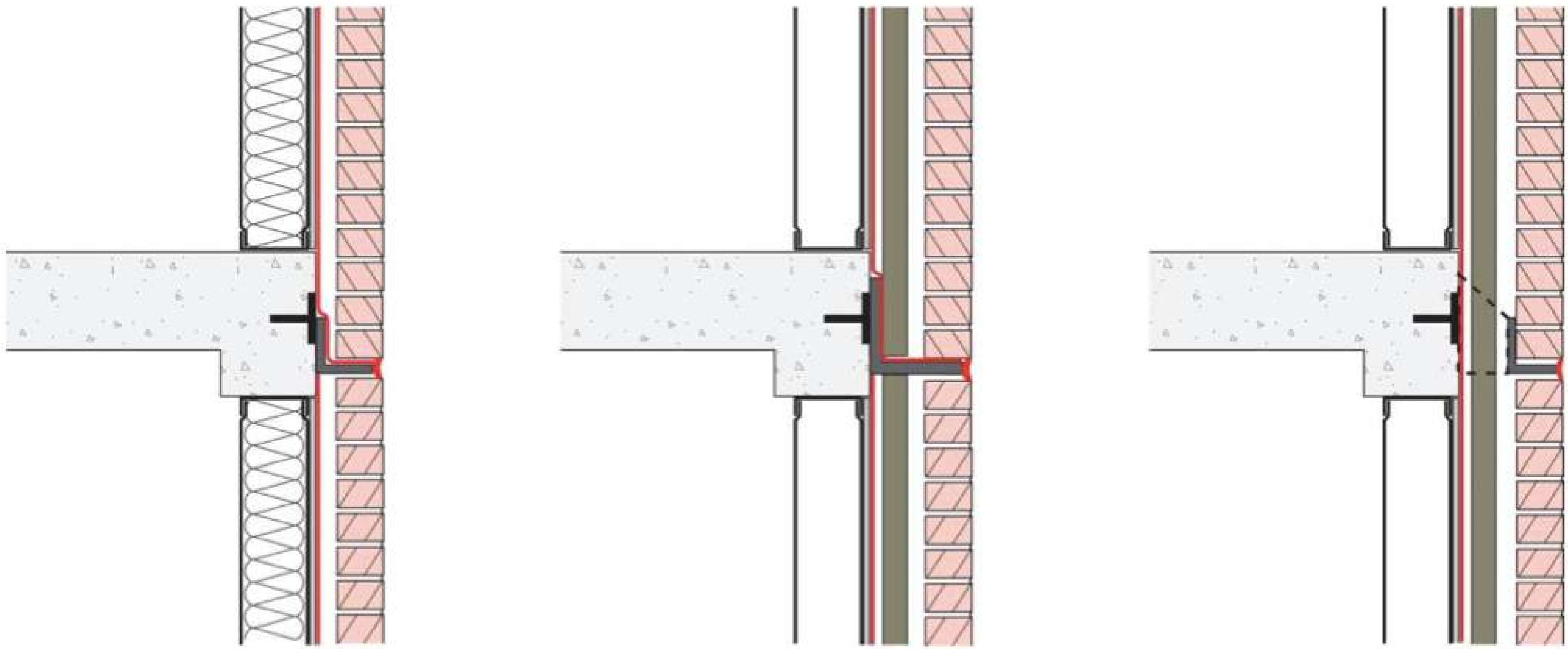



**Overlap 4 times thickness**
**Still a bridge, but "acceptable"**



# Shelf Angles

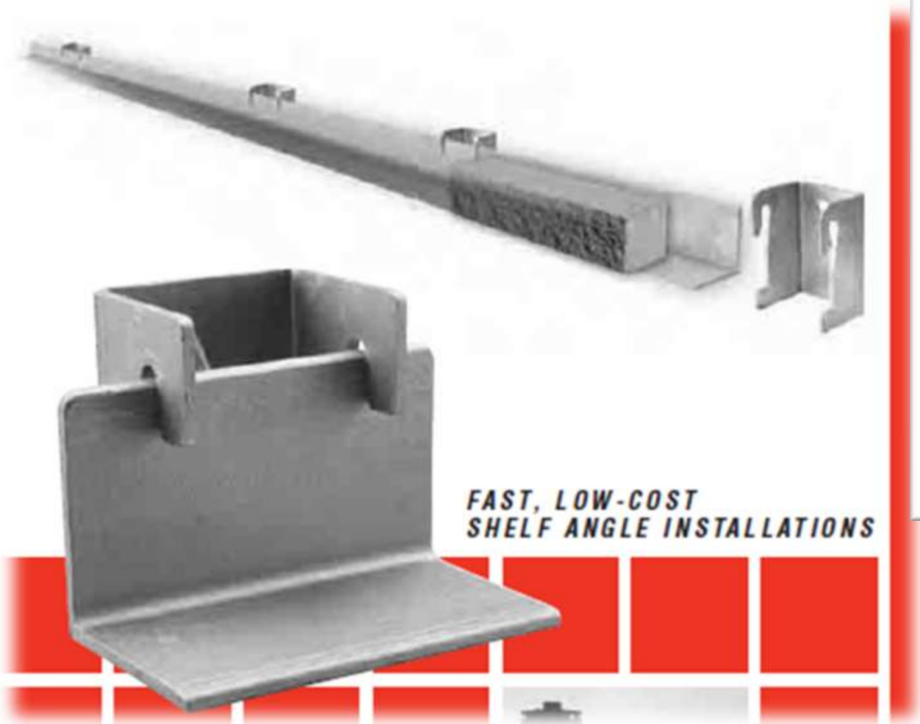
## Heavy Cladding Attachment through Exterior Insulation



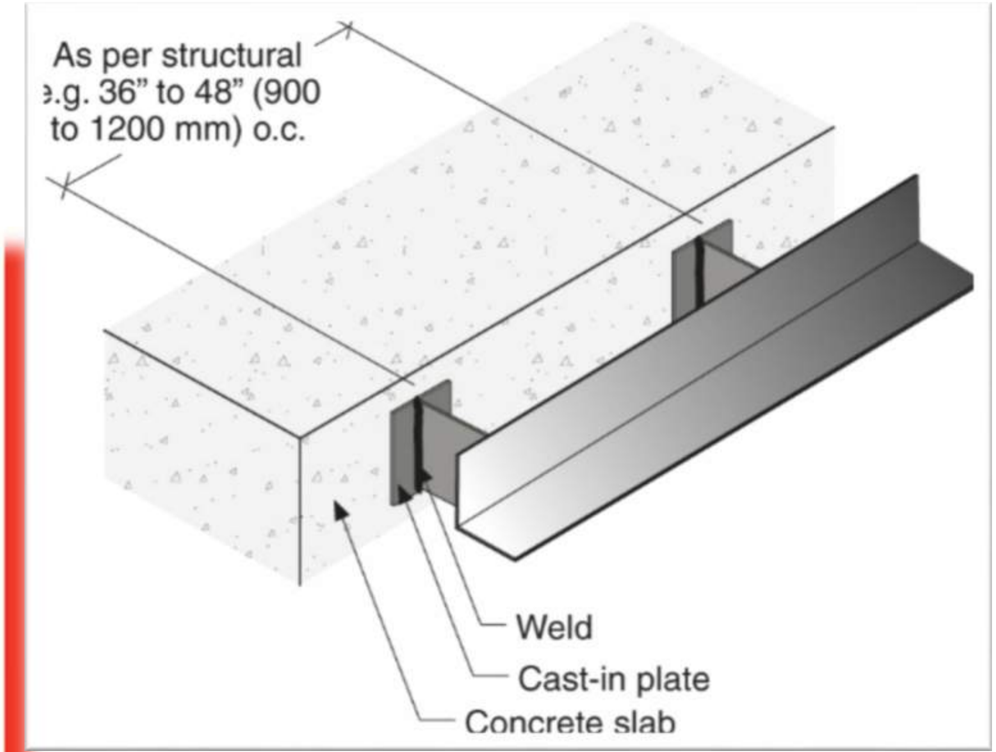
“The Ugly” “The Bad” “The Good”

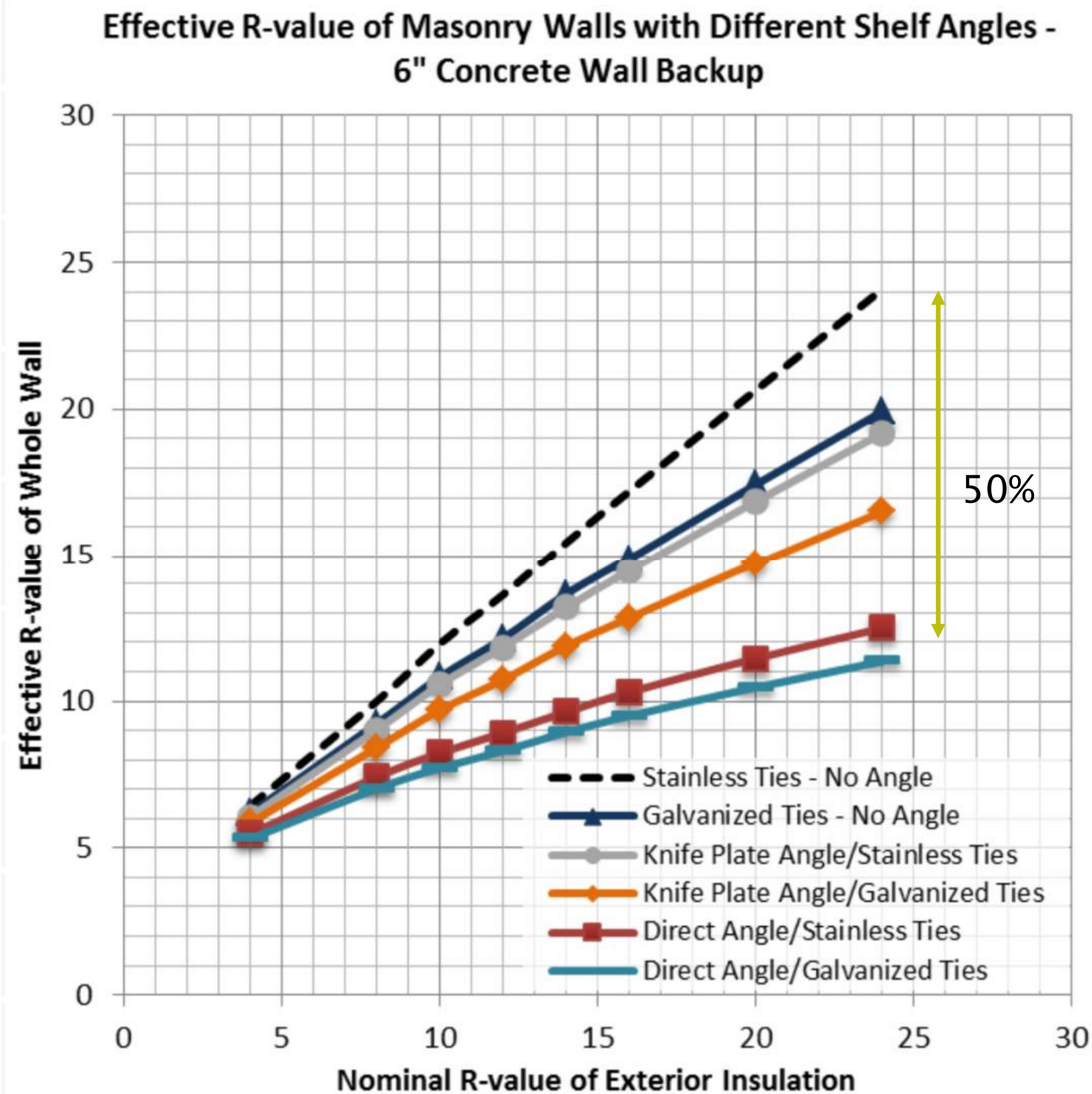
Stupidly large shelf angle
Structural engineers need to be part of the conversation

# Stand-off Shelf Angle




(courtesy of Fero Corp)





Effective R-value of Masonry Walls with Different Shelf Angles - 6" Concrete Wall Backup
Effective R-value of Whole Wall
Nominal R-value of Exterior Insulation
0
5
10
15
20
25
30
50%
Stainless Ties - No Angle
Galvanized Ties - No Angle
Knife Plate Angle/Stainless Ties
Knife Plate Angle/Galvanized Ties
Direct Angle/Stainless Ties
Direct Angle/Galvanized Ties

## Balconies & Exposed Slabs

→ These thermal bridges often reduce overall R-value by 30-50%

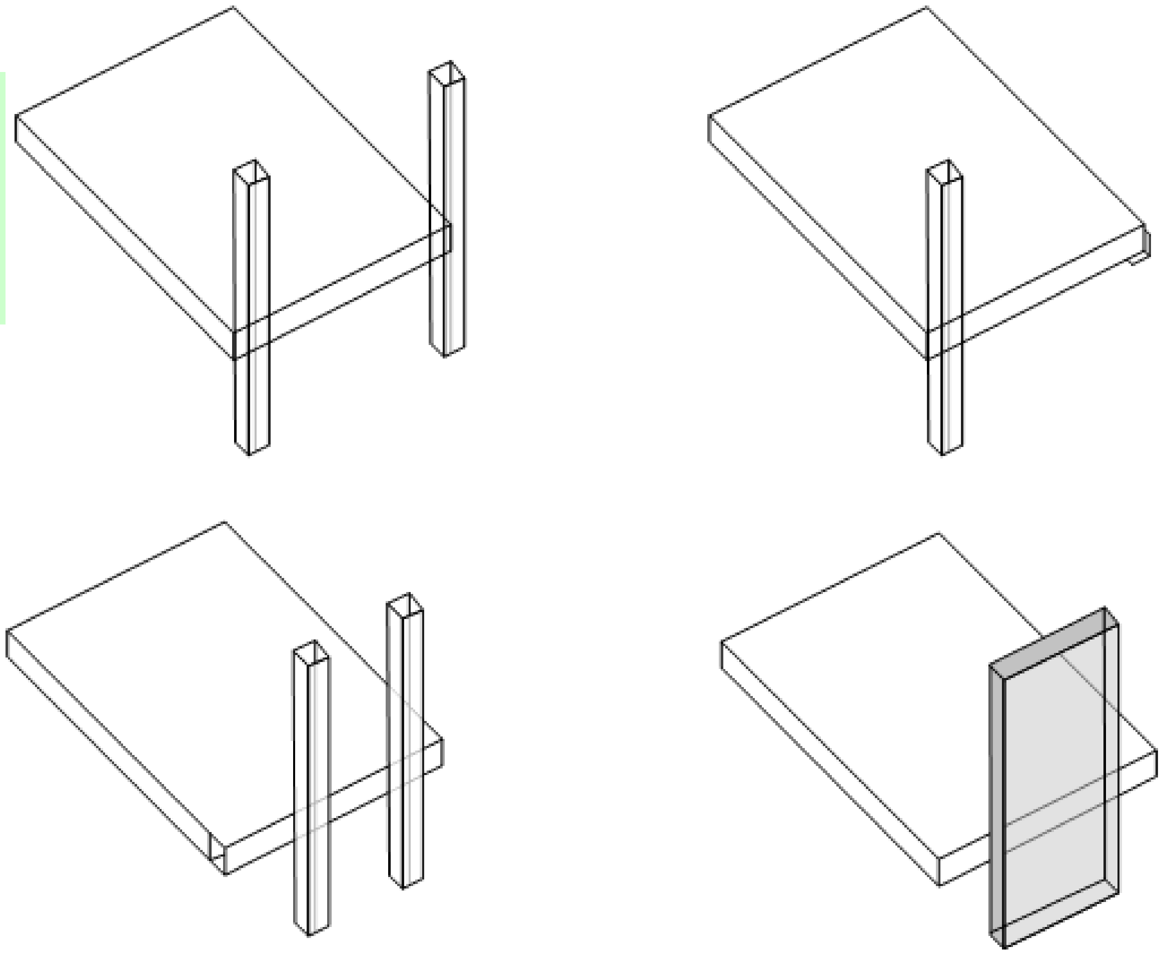
→ Projection of concrete beyond insulation has little impact: 4" or 4 yards

→ Accent lines, sun shades, etc act the same

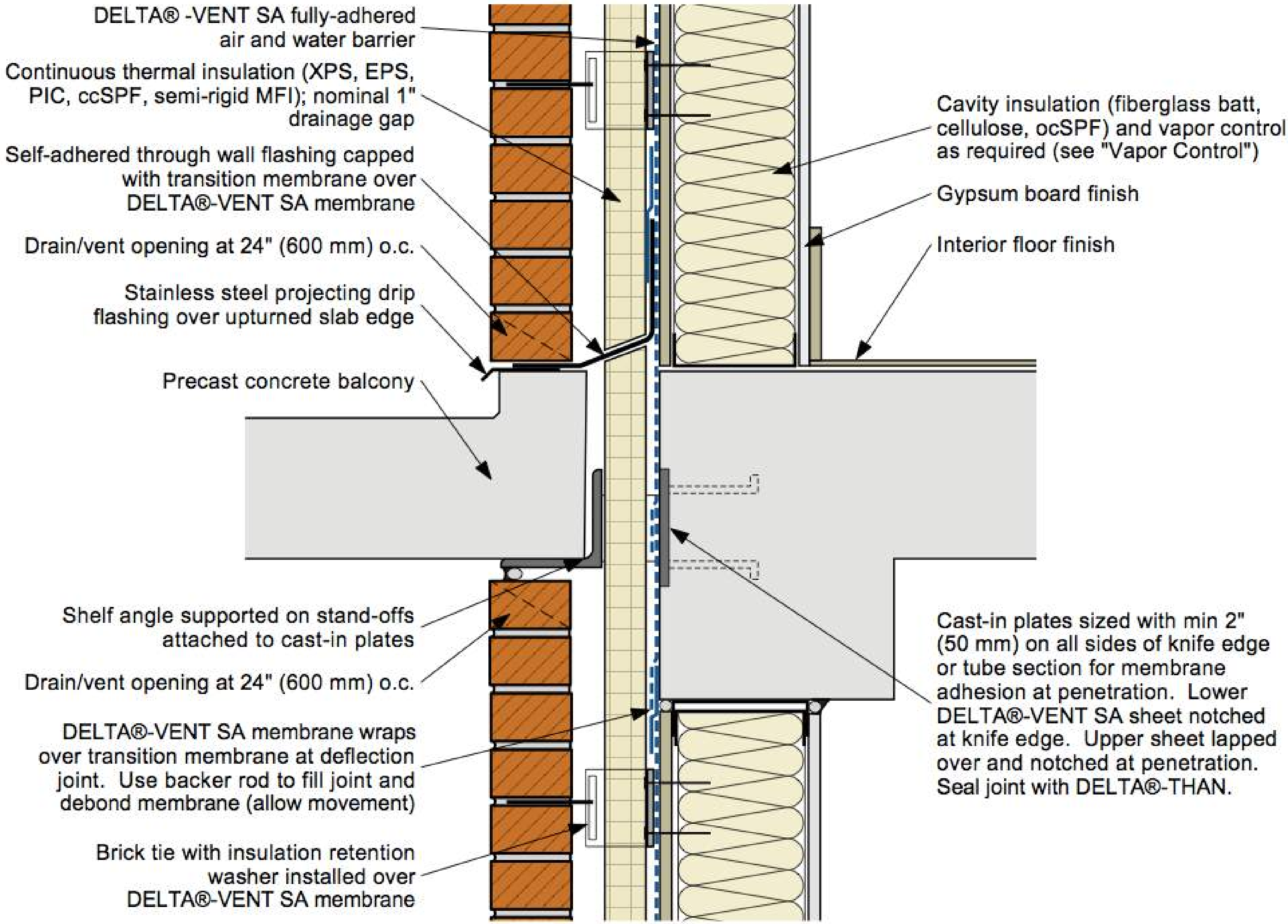
# Structural Thermal break

# Balcony Design Solutions

**Limit attachment to the building**

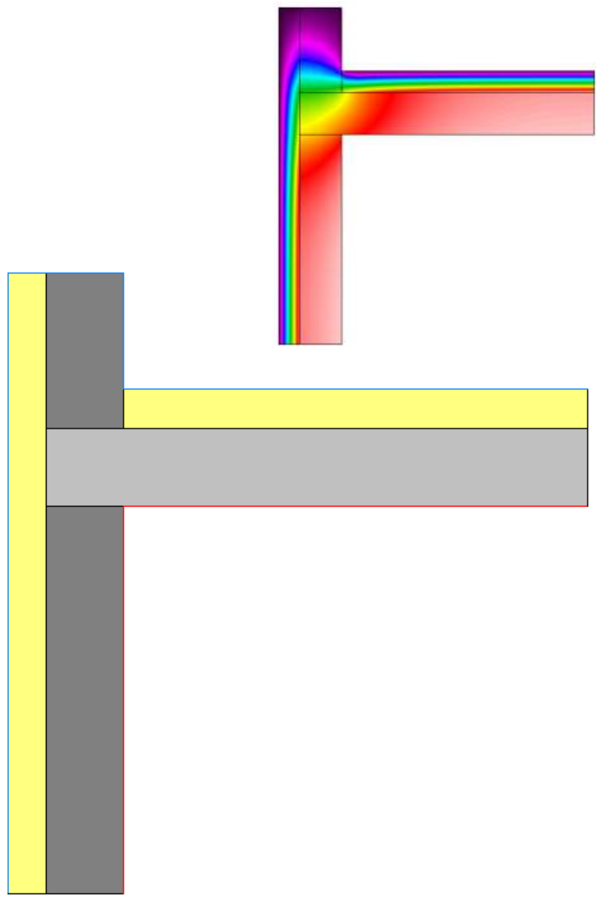



Philly's Best
HOT OVEN

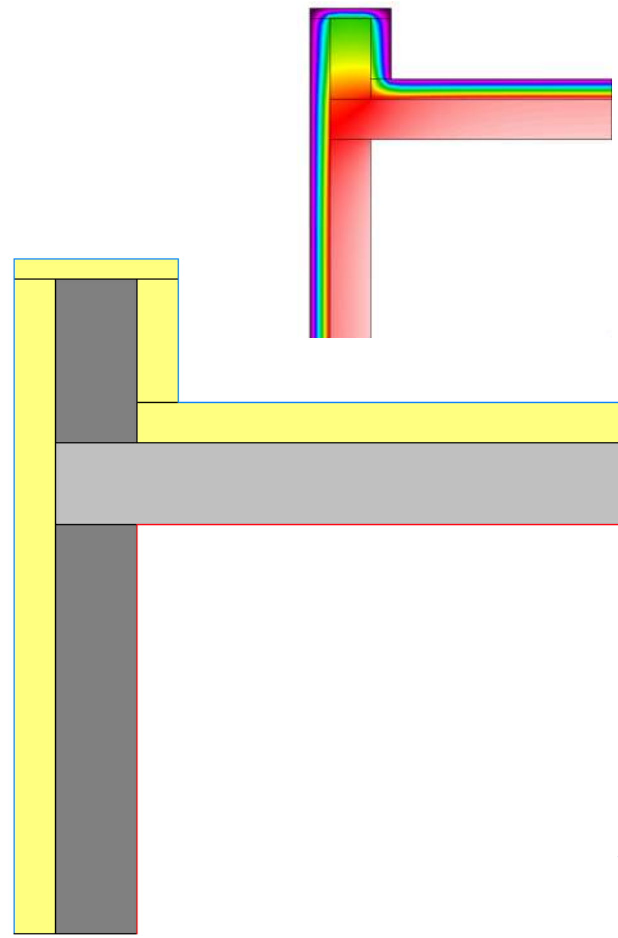

DELTA® -VENT SA fully-adhered air and water barrier
Continuous thermal insulation (XPS, EPS, PIC, ccSPF, semi-rigid MFI); nominal 1" drainage gap
Self-adhered through wall flashing capped with transition membrane over DELTA®-VENT SA membrane
Drain/vent opening at 24" (600 mm) o.c.
Stainless steel projecting drip flashing over upturned slab edge
Precast concrete balcony
Shelf angle supported on stand-offs attached to cast-in plates
Drain/vent opening at 24" (600 mm) o.c.
DELTA®-VENT SA membrane wraps over transition membrane at deflection joint. Use backer rod to fill joint and debond membrane (allow movement)
Brick tie with insulation retention washer installed over DELTA®-VENT SA membrane
Cavity insulation (fiberglass batt, cellulose, ocSPF) and vapor control as required (see "Vapor Control")
Gypsum board finish
Interior floor finish
Cast-in plates sized with min 2" (50 mm) on all sides of knife edge or tube section for membrane adhesion at penetration. Lower DELTA®-VENT SA sheet notched at knife edge. Upper sheet lapped over and notched at penetration. Seal joint with DELTA®-THAN.

**Precast balcony supported on knife edge supports to limit thermal losses**

# Parapets



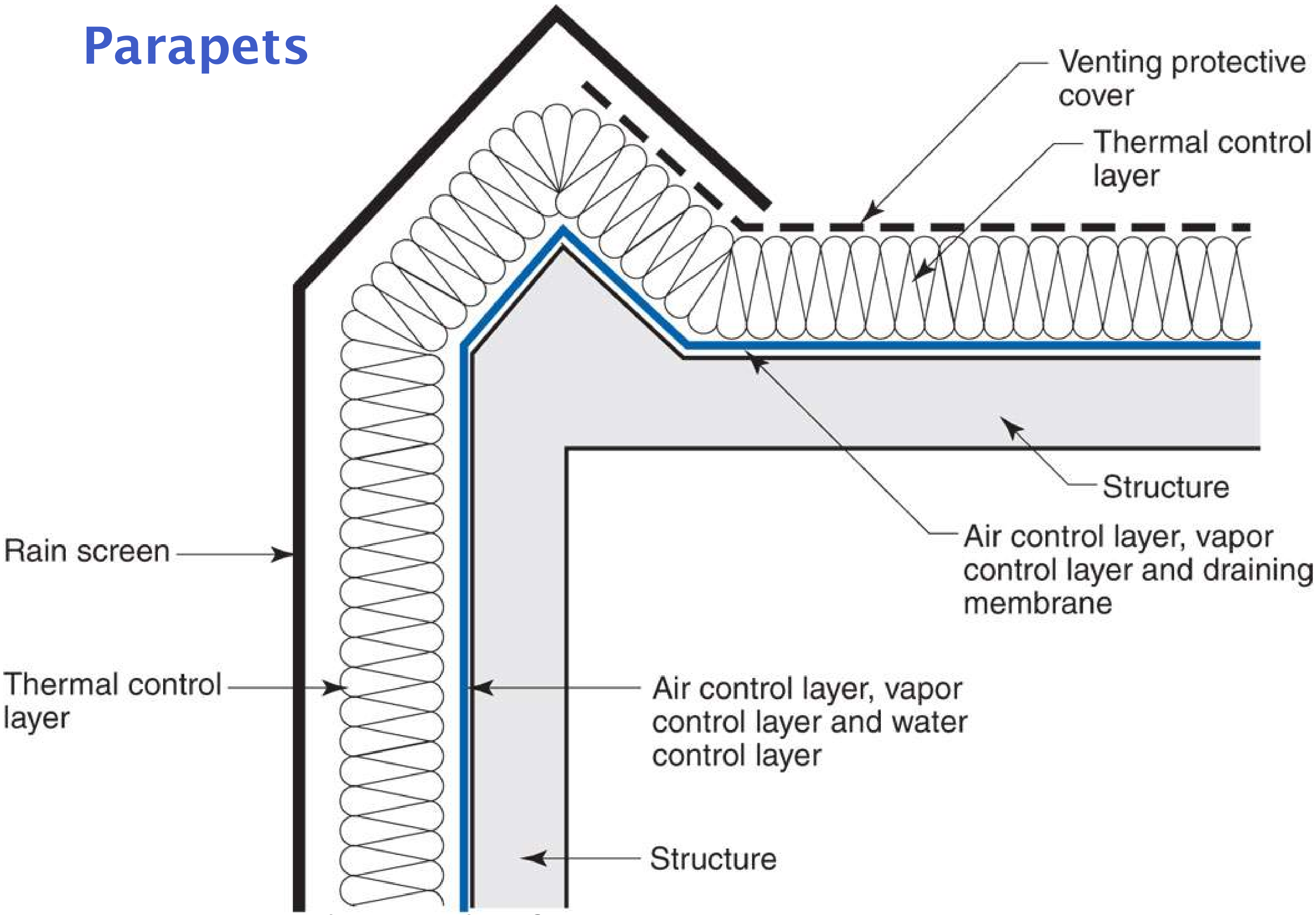
0.428 BTU/hr.ft.F



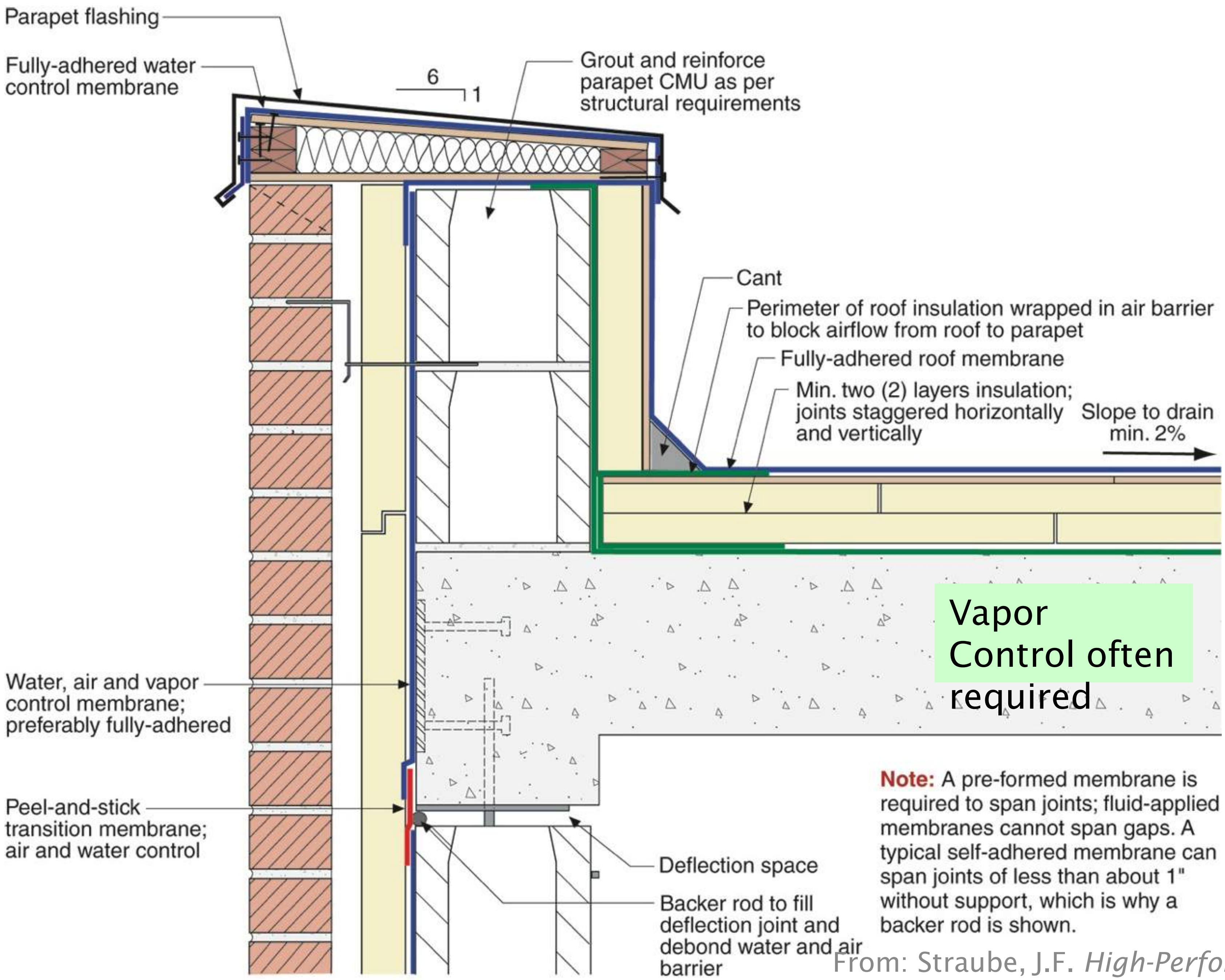
0.039 BTU/hr.ft.F

90%

# Parapets




From: Straube, J.F. *High-Performance Enclosures*, Building Science Press. 2012.




Vapor Control often required

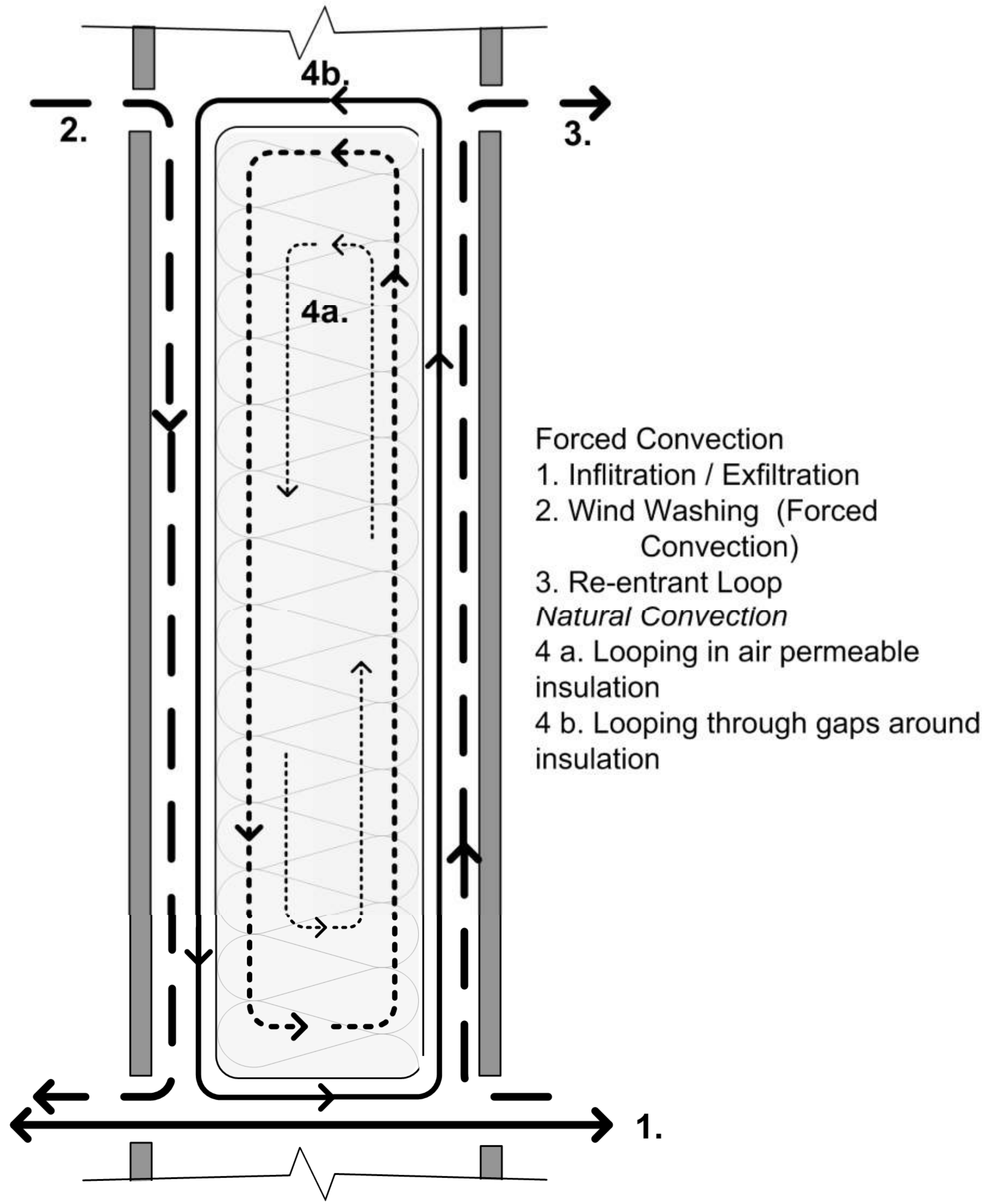
**Note:** A pre-formed membrane is required to span joints; fluid-applied membranes cannot span gaps. A typical self-adhered membrane can span joints of less than about 1" without support, which is why a backer rod is shown.

From: Straube, J.F. *High-Performance Enclosures*, Building Science Press 2012.

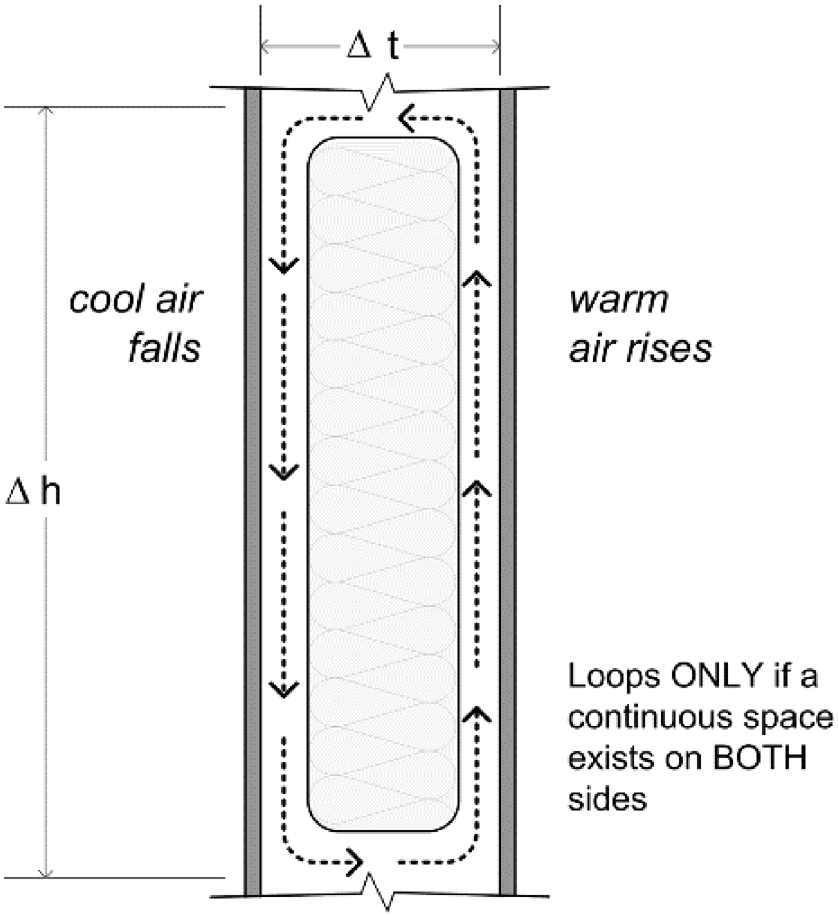
# Airflow Flanking Insulation

## Airflow

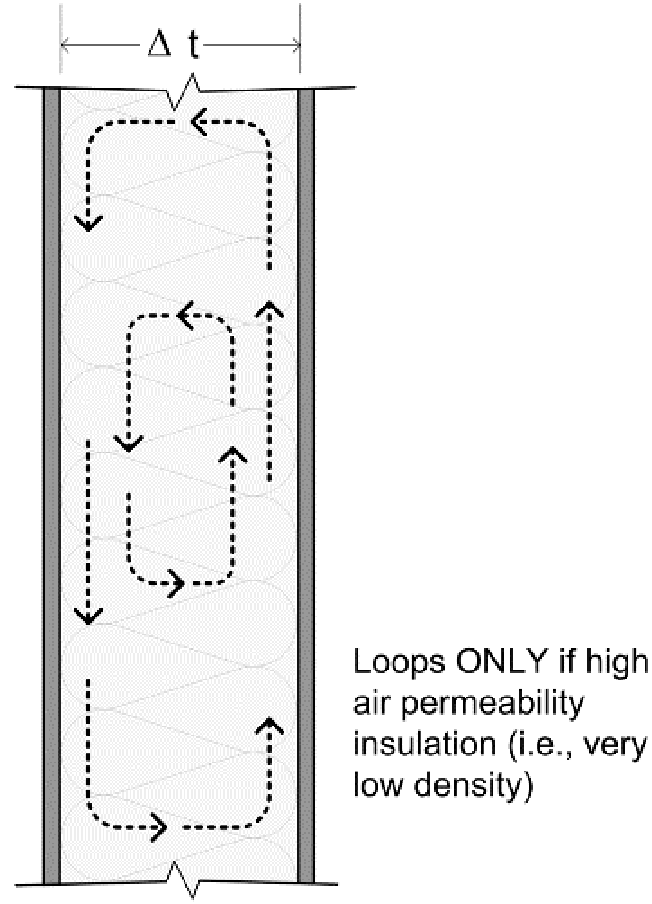
→ Air Leakage is only part of the picture



# Convective Loops



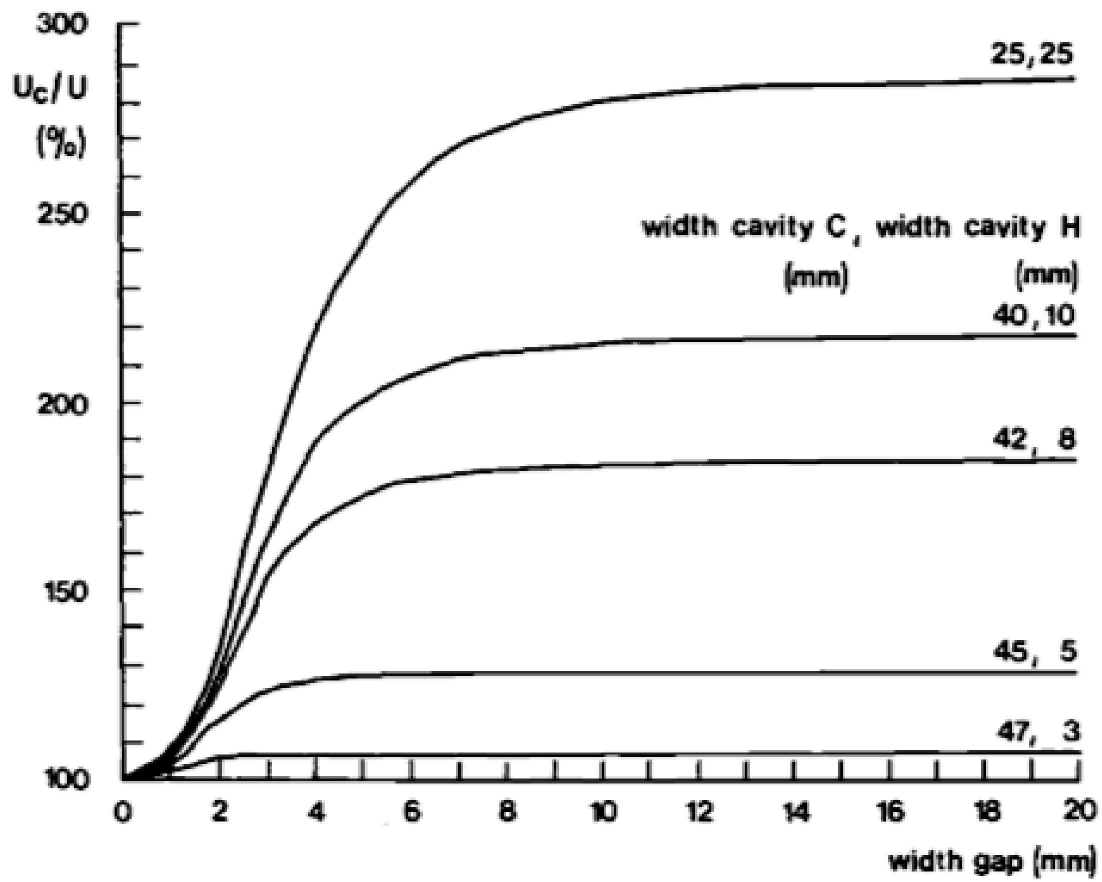

A: Air Loops Around Insulation




B: Air Loops Through Insulation

## Convective Loops

→ 25% reduction in R-Value measured for 3/16” (5mm) gap between insulation & sheathing / backup (Lacompte 1991)

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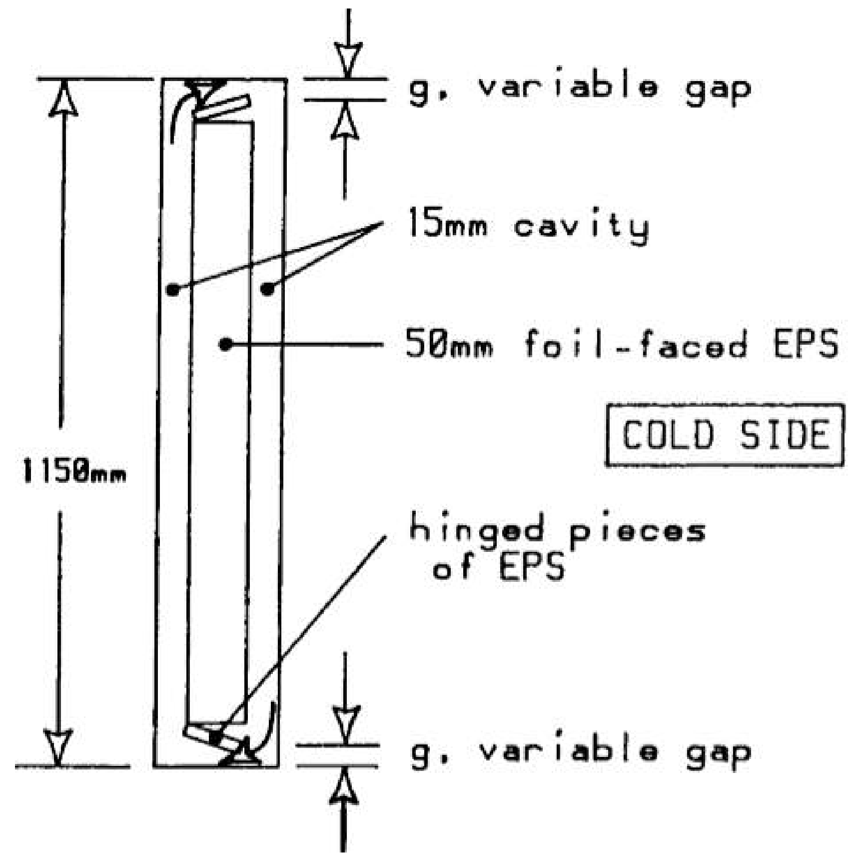
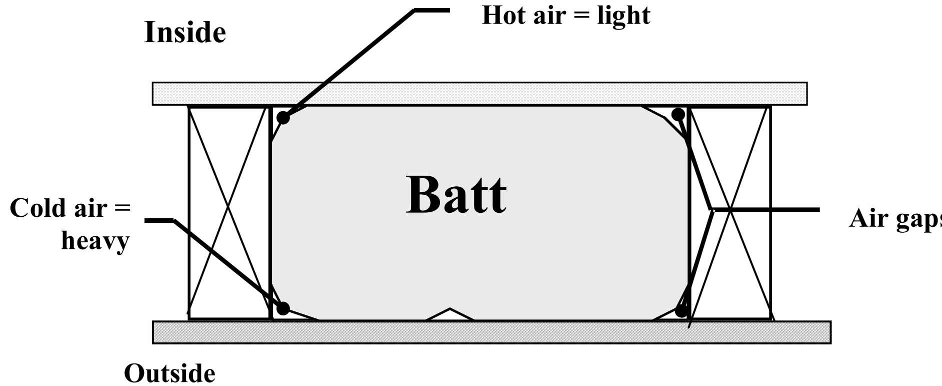
## Convective Loops

→ 50% reduction in thermal performance for 5/8" (15mm) gap front & back and 1/8" (3mm) gap top & bottom
(Trethewen 1991)

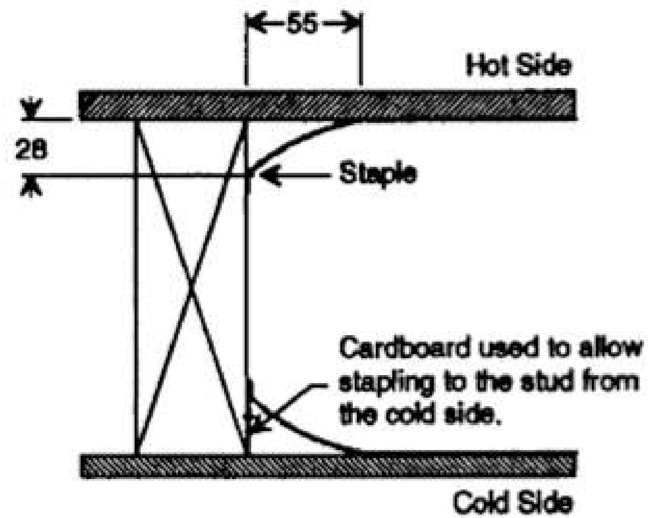


## Convective Loops

→ Gaps in the corners can allow convective loops to bypass heat around the insulation




→ Measurements suggest a possible 25-33% reduction in R-Value
(Bomberg & Brown 2003)

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# Conclusions

→ As target R-values increase . . . .

→ Thermal bridges become more significant

- → Cladding attachment
- → Relieving angles
- → Parapets
- → Balconies / floor edges

→ Airflow becomes a bigger concern

- → Gaps behind continuous insulation
- → Gaps between insulation boards

→ More attention in design to get better thermal continuity

# Discussion + Questions

FOR FURTHER INFORMATION PLEASE VISIT

→ www.rdh.com

→ www.buildingsciencelabs.com

OR CONTACT US AT

→ cschumacher@rdh.com

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