Exterior Wall Assemblies

Meeting Today’s Codes (Thermal and Fire Requirements)

Drew Clausen
Architectural Services Director, Owens Corning
Spring 2014
• Energy Code Updates and Compliance Paths
  – Prescriptive R-value and U-values
  – Project examples

• Continuous Insulation in Cold Climates
  – Thermal conductivity (and R-value) are temperature dependent
  – WUFI (hygrothermal) analysis for wall in Minnesota climate

• NFPA 285 Fire Compliance
  – Foam plastic solutions (Masonry)
  – Mineral wool solutions (Combustible Claddings/WRB’s)
Energy Codes

Compliance paths for Minnesota

ASHRAE 90.1

IECC 2012 (Coming in 2015)
ASHRAE 90.1 Overview

- **ASHRAE 90.1**
- U.S. Energy Standard for all Buildings Except Low-Rise Residential Buildings. *(90.2 for residential)*
- Code provides minimum requirements for energy efficient designs for buildings.
- Originally published in 1975 during a period of dramatic energy cost increases in the U.S..
- Since 1999, the code has been updated every 3 years (due to newer and more efficient technologies).
- Most states apply the standard or equivalent standards for all commercial buildings.
ASHRAE Std. 90.1 Compliance Options

Steps to Ensure Compliance
1. Determine Appropriate Std. 90.1 Edition by State
2. Identify Correct Climate Zone
3. Select Building Type
4. Select Compliance Path

**ASHRAE Std. 90.1 Compliance Options**

**Determine Appropriate Std. 90.1 Edition by State**

<table>
<thead>
<tr>
<th>State</th>
<th>Commercial Building Code Adoption (April 1, 2014)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.1-2010</td>
<td>8</td>
</tr>
<tr>
<td>90.1-2007</td>
<td>78</td>
</tr>
<tr>
<td>90.1-2004</td>
<td>5</td>
</tr>
<tr>
<td>None or &lt;90.1-2004</td>
<td>9</td>
</tr>
</tbody>
</table>

Floor Area - %

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90

Identify Correct Climate Zone
Identify the Building Type

(Categorization: Depends hours of operation and thermostat set point temperatures.)

• **Nonresidential** (Commercial)
  – Fixed Operating Hours, Regulated Set Point Temperatures

• **Residential** (4 stories or more above grade)
  – Operating Hours 24/7, Occupant Defines Set Point Temperatures

• **Semi-heated** (Warehouses)
  – Operating Hours Vary, Heating Only, e.g. 50°F
Select one of 3 Compliance Paths

- **Prescriptive**
  - R-values (cavity and continuous)

- **Performance**
  - U-factors, Thermal Transmittance (above grade)
  - C-factors, Thermal Conductance (below grade)
  - F-factors, Slab Edge Factors

- **Energy Cost Budget Method (ECB)**
  - Annual Operating Cost, Dollars ($)
Prescriptive Path: Minimum R-values and CI

*Applies to multiple assembly types such as:*

- Walls with Framing – *Wood, Steel*
  - Cavity R-values & ci
- Masonry Walls Above Grade without Framing
  - Continuous Insulation
- Roof Insulation Entirely Above Deck
  - R-value of Insulation & ci

This is often the easiest compliance path and it is achieved if the construction contains the insulation materials listed in the standard.
What is continuous insulation (ci)?

- Insulation installed over structural framing without any penetrations (except fasteners and services openings)

CI minimizes thermal bridging (caused by framing)

- Infrared photography depicts how ci minimizes thermal bridging

Same home with and without continuous insulation on exterior.
### Identify “R” Requirements using ASHRAE Table(s) (or equivalent IECC tables)

#### Table 5.5-5 Building Envelope Requirements for Climate Zone 5 (A,B,C)*

<table>
<thead>
<tr>
<th>Opaque Elements</th>
<th>Nonresidential</th>
<th>Residential</th>
<th>Semiheated</th>
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<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>Insulation Min. R-Value</td>
<td>Assembly</td>
</tr>
<tr>
<td><strong>Roofs</strong></td>
<td>Maximum</td>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>Insulation Entirely</td>
<td>U-0.032</td>
<td>R-30 c.i.</td>
<td>U-0.032</td>
</tr>
<tr>
<td>above Deck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal Building</td>
<td>U-0.037</td>
<td>R-19 + R-11 Ls or R-25 + R-8 Ls</td>
<td>U-0.037</td>
</tr>
<tr>
<td>Attic and Other</td>
<td>U-0.021</td>
<td>R-49</td>
<td>U-0.021</td>
</tr>
</tbody>
</table>

| **Walls, above Grade**|               |                         |           |                         |           |                         |
| Mass                  | U-0.090        | R-11.4 c.i.             | U-0.080  | R-13.3 c.i.             | U-0.151b | R-5.7 c.i.b              |
| Metal Building        | U-0.050        | R-0 + R-19 c.i.         | U-0.050  | R-0 + R-19 c.i.         | U-0.094  | R-0 + R-9.8 c.i.         |
| Steel Framed          | U-0.055        | R-13 + R-10 c.i.        | U-0.055  | R-13 + R-10 c.i.        | U-0.084  | R-13 + R-3.8 c.i.        |
| Wood Framed and Other | U-0.051        | R-13 + R-7.5 c.i. or R-19 + R-5 c.i. | U-0.051  | R-13 + R-7.5 c.i. or R-19 + R-5 c.i. | U-0.089  | R-13                     |
ASHRAE Std. 90.1 Compliance Options

R13 Fiber Glas

1.5” XPS
Codes are becoming more stringent. *MN moving from 2004 to 2010.*

<table>
<thead>
<tr>
<th>Zone</th>
<th>2004</th>
<th>2007 &amp; 2010</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>13+3.8</td>
<td>13+3.8</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>13+7.5</td>
<td>13+7.5</td>
</tr>
<tr>
<td>5</td>
<td>13+3.8</td>
<td>13+7.5</td>
<td>13+7.5</td>
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<td>6</td>
<td>13+3.8</td>
<td>13+7.5</td>
<td>13+7.5</td>
</tr>
<tr>
<td>7</td>
<td>13+7.5</td>
<td>13+7.5</td>
<td>13+7.5</td>
</tr>
<tr>
<td>8</td>
<td>13+7.5</td>
<td>13+10</td>
<td>13+7.5</td>
</tr>
</tbody>
</table>
ASHRAE 90.1, 2004 through 2013 editions
Prescriptive R for Mass Walls
(Red text denotes a change from previous edition)

<table>
<thead>
<tr>
<th>Zone</th>
<th>2004</th>
<th>2007 &amp; 2010</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NR</td>
<td>5.7</td>
<td>NR</td>
</tr>
<tr>
<td>2</td>
<td>NR</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>3</td>
<td>5.7</td>
<td>7.6</td>
<td>7.6</td>
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<td>4</td>
<td>5.7</td>
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<td>9.5</td>
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<tr>
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</tr>
<tr>
<td>6</td>
<td>9.5</td>
<td>11.4</td>
<td>13.3</td>
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<tr>
<td>7</td>
<td>11.4</td>
<td>13.3</td>
<td>15.2</td>
</tr>
<tr>
<td>8</td>
<td>13.3</td>
<td>15.2</td>
<td>19</td>
</tr>
</tbody>
</table>

* The R-25 published in 90.1-2007 & 2010 should have been R-19.
Performance Path:

Calculation Procedures

1 - Series Method
2 - Parallel Path Method
3 - Constructions Containing Metal
4 - Isothermal Plane Method
5 - Metal Buildings

Benefits of Performance Path: Requires calculations or testing to demonstrate compliance but offers greater flexibility in system options.
ASHRAE Std. 90.1 Compliance Options

Performance Path: 3 – Metal Framing – U-factors

U-factor Calculations

<table>
<thead>
<tr>
<th>Item</th>
<th>Component</th>
<th>Series</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Inside Air Film</td>
<td>0.68</td>
</tr>
<tr>
<td>2</td>
<td>1/2&quot; Drywall</td>
<td>0.45</td>
</tr>
<tr>
<td>3</td>
<td>Steel and Insulation</td>
<td>5.50</td>
</tr>
<tr>
<td>4</td>
<td>1&quot; Foam Sheathing</td>
<td>5.00</td>
</tr>
<tr>
<td>5</td>
<td>Siding</td>
<td>0.62</td>
</tr>
<tr>
<td>6</td>
<td>Outside Air Film</td>
<td>0.61</td>
</tr>
<tr>
<td>7</td>
<td>Sum = Ro</td>
<td>12.86</td>
</tr>
</tbody>
</table>

\[
U_{wp} = \frac{1}{R_s + \left( R_{vis} \times F_e \right)}
\]

T1
R1 = Inside Air Film

T2
R2 = 1/2" Drywall

T3
R3 = Steel and Insulation in Parallel

T4
R4 = 1" Foam Seathing

T5
R5 = Siding

T6
R6 = Outside Air Film

To
Performance Factors: 3 – Metal Framing – U-factors

Example of how to identify correction factor for Steel Stud Walls

Insulation and Steel Framing in Parallel

\[ R = \text{R-cavity insulation} \times \text{Correction Factor (F_c)} \]

Example:

R-11 cavity insulation in 2x4, 16” o.c.

\[ R = 11 \times 0.5 = 5.5 \]
U-Value Alternative Example:
Walter Payton High School in IL
*Brick veneer 8” steel framing back up*

**Prescriptive R Path (ASHRAE 2010):** Above grade, steel framed wall assemblies in Climate Zone 5 require **R13+R7.5ci**

However, if they were to fill the 8” stud cavity with insulation, that would equal R25 (versus R13). Accordingly, they might be able to get by with **less** than R7.5ci.

In fact, they only need 1” of Foamular ci (vs. 1.5”) to comply via the Performance U-Value alternative compliance path (**Req. U = 0.064**)
While codes are requiring more continuous insulation, it’s important to note:

Not all continuous insulation is created equally.
Building science consultants who perform forensic investigation, building commissioning and research and development.

The thermal conductivity research they performed was sponsored by the groups listed below:

**Sponsors included:**
- Dow Building solutions
- Honeywell
- Huntsman Polyurethanes
- Icynene
- NAIMA
- Greenfiber

The BSC research illustrates that the thermal conductivity of insulation can vary based on the temperature (it is temperature dependent).

*Owens Corning learned about this study during a building science conference in the summer of 2013.*
Mineral Wool
The R-value improves as the mean temperature drops because the thermal conductivity of the material decreases.

Polyisocyanurate*
The R-value diminishes as the mean temperature drops because the thermal conductivity of the material increases.
Sample Wall Assemblies (MN)

ccSPF and Polyisocyanurate ci:
- Closed cell spray foam in the stud cavity (2 inches)
- 2” polyisocyanurate rigid insulation (Direct to framing)

Glass Fiber and Mineral Wool ci:
- R13 FSK-Faced EcoTouch™ in stud cavity
- 5/8” glass mat gypsum sheathing
- Air and water barrier (5 perms)
- Thermafiber® RainBarrier® ci (Mineral Wool)

Both feature: 5/8” Type X int. drywall over 2” x 6” metal framing (16” OC), air space and 4 mil aluminum panel (ACM with polyethylene core)
Sample Wall Assemblies (MN)

• 4 assemblies w/o z-girts
  – ISO: 2” polyiso
  – OC1: 2” MW
  – OC2: 2.5” MW
  – OC3: 3” MW

• 2 assemblies with z-girts
  – 2” polyiso
  – 2” MW

• Hourly Weather data for Minneapolis, MN (WUFI, cold year)

• Indoor moisture load 4.5 g/m³ (600 Pa)

• New 3rd party research regarding thermal conductivity of insulating materials
Walls with less thermal conductivity outperform the ISO-based assembly
Cold months matter the most (there is less heat flow in summer)

Minneapolis, North Facing Wall

<table>
<thead>
<tr>
<th>Month</th>
<th>ISO</th>
<th>OC1</th>
<th>OC2</th>
<th>OC3</th>
</tr>
</thead>
<tbody>
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<td>-2126</td>
<td>-1903</td>
<td>-1722</td>
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<td>-1737</td>
<td>-1555</td>
<td>-1408</td>
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<td>-884</td>
<td>-792</td>
<td>-718</td>
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<td>-665</td>
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<td>11</td>
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<td>-1031</td>
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<td>12</td>
<td>-1798</td>
<td>-1532</td>
<td>-1372</td>
<td>-1243</td>
</tr>
</tbody>
</table>
Heat Flow Through Wall

• Reference case: 3” MW

Minneapolis, North Facing Wall

<table>
<thead>
<tr>
<th></th>
<th>ISO</th>
<th>OC1</th>
<th>OC2</th>
<th>OC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>167%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>165%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>154%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>123%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
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<td>123%</td>
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<td>100%</td>
</tr>
<tr>
<td>8</td>
<td>105%</td>
<td>118%</td>
<td>110%</td>
<td>100%</td>
</tr>
<tr>
<td>9</td>
<td>111%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
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<tr>
<td>10</td>
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<tr>
<td>12</td>
<td>145%</td>
<td>123%</td>
<td>110%</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Heat Flow on Annual Basis

<table>
<thead>
<tr>
<th>ISO</th>
<th>OC1</th>
<th>OC2</th>
<th>OC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual, Btu/ft²</td>
<td>-12764</td>
<td>-10611</td>
<td>-9503</td>
</tr>
<tr>
<td>%nn/OC3</td>
<td>148%</td>
<td>123%</td>
<td>110%</td>
</tr>
</tbody>
</table>

**ISO assembly enables:**
- 20% more heat flow than OC1
- 34% more heat flow than OC2
- 48% more heat flow than OC3

---

What about applications that call for z-girts or support brackets, which penetrate the cl?
Effect of Z-girts (ASHRAE RP1365)

- Z-girts can also act as a thermal bridge.
  - Horizontal is better than vertical
  - Intermittent is better than continuous.
Effect of Z-girts (ASHRAE RP1365)

Figure 6.1: Comparison of Effective and Nominal R-values for Details 1-4
Heat Flow With Z-girts (2”)

Minneapolis, North Facing Wall

ISO w/z-girt = 2” polyiso w/z-girt
OC w/z-girt = 2” MW w/z-girt
ISO ci = 2” polyiso w/o z-girt
OC ci = 2” MW w/o z-girt

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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</thead>
<tbody>
<tr>
<td>ISO w/z-girt</td>
<td>124%</td>
<td>123%</td>
<td>118%</td>
<td>101%</td>
<td>95%</td>
<td>95%</td>
<td>94%</td>
<td>99%</td>
<td>96%</td>
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<td>100%</td>
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<td>100%</td>
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<td>100%</td>
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<tr>
<td>ISO ci</td>
<td>119%</td>
<td>118%</td>
<td>111%</td>
<td>89%</td>
<td>81%</td>
<td>83%</td>
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<td>95%</td>
<td>94%</td>
<td>101%</td>
<td>90%</td>
<td>90%</td>
<td>89%</td>
<td>89%</td>
</tr>
</tbody>
</table>
**Polyiso without z-girts enables:**
7% more heat loss annually than mineral wool with z-girts.

... and
13% more heat loss than mineral wool with intermittent/thermally broken brackets.
*(Based on data from Cladding Corp.)*
Energy Code Compliance

- ASHRAE 90.1 (2010) and IECC 2012
- Above grade metal frame walls in Climate Zone 6
  - R-value path calls for R13 + R7.5ci
  - U-value alternative path calls for 0.064 or less
- In the event the mineral wool ci is secured with z-furring or brackets, the U-value alternative path should be used.
  - Prescriptive R path cannot be used since the z-furring and brackets would cause a thermal bridge.
  - With 2” of RainBarrier (R8.4), the effective R-value would be R16 (See Red star) 1/16 = 0.062, which meets minimum U-value requirement.
Moisture Performance

Wind driven rain leak 1%  
(Per ASHRAE 160)

Monitor points
1. WRB  
2. Gypsum Shtg  
3. FSK Batt
Conditions on WRB (1)

86 Degrees F
Conditions on Ext. Gypsum (2)

![Graph showing temperature and relative humidity over time](image-url)
No mold growth: Germination starts at level 1
Visible growth at 3
Insulation Drying Time

• Chart illustrates 2" Thermafiber RainBarrier moisture content (MN project).
• The simulations were done for the entire year, showing wetting and drying in wall.
• The insulation is very permeable and it dries out very fast (water does not linger in the insulation).

![Graph showing water content with specific dates: 4-27-15, 5-4-15, 5-11-15. The water content is less than 1% by volume.]
WUFI Summary

Thermal
• Polyiso R-value diminishes at low temperatures (questionable in cold climates)
• Annual heat loss with mineral wool (w or w/o z-girts) is less than with polyiso
• OC solutions can comply with energy codes via multiple compliance paths

Moisture
• The wall with mineral wool has acceptable moisture performance with no condensation or mold growth
• Thermafiber RainBarrier dries very rapidly in simulated walls shown
Complying with NFPA 285 fire test is an important IBC code requirement.

Owens Corning offers several NFPA 285 compliant assemblies.
NFPA 285 measures what happens during fire when a non-combustible building is wrapped in combustible materials.

It is used when...

- the IBC requires non-combustible wall construction, and
- the energy code requires the building to be wrapped in air/water resistive barriers, often combustible, and/or
- continuous insulation, often combustible, and/or
- combustible exterior cladding is used.
The Goal of NFPA 285
Limit Spread of Fire Across Surface

Wooshin Golden Suites
Busan, South Korea
- Oct 2010, 38 stories, 202 apartments plus retail
- Started in service room on 4th floor
- Combustible paint on aluminum wall panels fueled fire
- Interior sprinkler system was not effective on exterior

TVCC/Mandarin Oriental Hotel
Beijing, China
- Feb 2009, 40 stories, TV center and hotel
- Started by fireworks landing on roof
- Sprinklers not working
- Fire spread on sides top to bottom in less than 13 minutes

Monte Carlo Resort & Casino
Las Vegas, Nevada
- Jan 2008, 32 stories, hotel, 3,000 guest rooms
- Started by welders working on the roof
- EIFS cladding was not the primary fire driver
- Decorative bands made of EPS covered with a non-EIFS coating drove the fire
Conducting an NFPA 285 Test

Test Apparatus and Premise

- Two-story simulation of a fire
  - Room burner is turned on
  - 5 Minutes – Window burner #2 turns on
  - 30 Minutes - Fire is terminated
  - Monitor Distance fire spreads - visually
  - Monitor Internal wall temperatures

3-sided test rig

Dozens of Thermocouples

Two-story simulation of a fire

Room Burner
Foamular® Extruded Polystyrene (CI)

- Good choice for non-combustible claddings (High R-value / inch)
- Brick with steel stud or CMU, Pre-Cast Concrete, PM EIFS
- New design guide available
Thermafiber® RainBarrier® CI (Mineral Wool)

Ideal for assemblies with combustible claddings and WRB’s

- Engineering judgment letter from Hughes Associates
- Combustible WRB (Covered with min. 2” Thermafiber RainBarrier MW)
- Combustible cladding (previously passing NFPA 285)
Dr. Karagiozis is Director, Building Science at Owens Corning. He is responsible for leading, shaping, driving, educating and training others in energy efficiency and green building science at Owens Corning. His activities involve feeding Owens Corning's innovation pipeline with customer-inspired and building science-informed solutions.

Previously, Dr. Karagiozis was a distinguished research and development engineer at the Oak Ridge National Laboratory (ORNL). He was in charge of research performed at ORNL in heat, air and moisture performance of buildings.

Dr. Karagiozis is still involved in the WUFI-ORNL development team, working closely with ORNL and Fraunhofer Institute. He is the U.S. representative for IEA Annex 55 on Retrofit Analysis in Buildings, and is actively involved in a number of ASTM E06 technical committees and ASHRAE TC 4.4, and SPC 160. He has also developed three or four of the world's most advanced hygrothermal models worldwide (WUIF, MOISTUREEXPERT, LATENITE family). As an expert in the area of Moisture Engineering, he has solved many hygrothermal designs and retrofit challenges, and has developed multiple design guidelines for various envelope systems. Dr. Karagiozis is the author of more than 120 technical papers and reports related to moisture.

**WUFI** is a menu-driven PC program which allows calculation of heat and moisture transport in multi-layer building components exposed to natural weather.
Summary

• Energy Codes Becoming More Stringent
  – Look for new IECC 2012 code in MN as early as January 2015
  – Architects have options. Multiple paths to compliance (R and U)
  – More ci being prescribed ... but not all ci is created equally. Thermal conductivity (R-value) is temperature dependent

• NFPA 285 Fire Test Compliance Required by IBC
  – Cladding choice drives insulation choice

• Managing Moisture and Thermal Performance
  – WUFI analysis can help identify optimum wall design

Owens Corning can assist.
Comments / Questions

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• Thicker walls have limitations
  – Structure ... increased foundation size
  – Thermally broken clips added cost $5/s.f.
  – Flashings
  – Other
Polyiso **without** z-girts (DOW ci) has higher annual heat loss than mineral wool **with** z-girts.
Whole wall performance, including cavity and exterior insulation and other layers.

* Calculated thermal impact of brackets (spaced 24” o.c.) using data from Cladding Corp.