EFFICIENCY WORKS TRAINING
August 20, 2014

RobertClarkeAssociates.com
303-641-6476
Boulder, Colorado
1865 DOUBLE GLAZING PATENT
(“Lincoln” Movie Year)
2014 INSULATING GLASS U-VALUE

- Single Glass
- Double Glass - Single Low-e
- Triple Glass - Double Low-e
- QuadPane - Triple Low-e
- QuintPane

U-values:
- Single Glass: 1.00
- Double Glass - Single Low-e: 0.24
- Triple Glass - Double Low-e: 0.14
- QuadPane - Triple Low-e: 0.08
- QuintPane: 0.06
2014 INSULATING GLASS R-VALUE (R = 1/U)
Optimal Interspace

Air, Argon, Krypton & Xenon

Air: 1/2”
Argon: 1/2”
Krypton: 3/8”
Xenon: 1/4”
ARGON/KRYPTON CONTAINMENT MONITORING

Argon Percentage Instantly Displayed

German Standard: Fill To 90+% - Maintain Gas Loss Below 1% Per Year

FDR Design (Buffalo, MN) 12-Year Argon Containment < ½% Per Year

Contact: Randi Ernst: FdrDesign.com
Performance Increase Due To Gas Filling
(2014 Triple Insulating Glass)

GAS IMPROVEMENT IN R-VALUE
(TriPane IG / Double Low-e) 43%

25% 53%

Argon (90%) Krypton (90%) Xenon (90%)

September 2014 Price Note:
Krypton Down 60% / Xenon Up 10X

R-VALUE BY GAS FILL
(TriPane IG / Double Low-e) 8.4 9.0

5.9 7.4 8.4 9.0

Air Argon (90%) Krypton (90%) Xenon (90%)
## Frame Only U-Values

<table>
<thead>
<tr>
<th>Material</th>
<th>Low</th>
<th>High</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (no break)</td>
<td>1.7</td>
<td>2.4</td>
<td>2.05</td>
</tr>
<tr>
<td>Aluminum (thermal break)</td>
<td>0.8</td>
<td>1.3</td>
<td>1.05</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>0.40</td>
<td>0.57</td>
<td>0.49</td>
</tr>
<tr>
<td>Insulated Vinyl &amp; Fiberglass</td>
<td>0.2</td>
<td>0.4</td>
<td>0.30</td>
</tr>
</tbody>
</table>

### WINDOW FRAME AVERAGE U-VALUE

- **Aluminum (no break)**: 2.05
- **Aluminum (thermal break)**: 1.05
- **Carbon Steel**: 0.49
- **Insulated Vinyl & Fiberglass**: 0.30
Fading
Overheating
Too cold on cloudy winter days
Undercooking
Moveable Insulation Burden
Daily temperature swings
Lack of privacy or security
Glare

Figure 3: Home Buyers’ Most Frequent Complaints about Passive Solar Homes

Builders were asked to describe the kinds of complaints most frequently expressed by the buyers of passive solar homes. (Data received from 71 builders; some gave more than one response.)

- Fading carpets, furniture, drapes
- Overheating
- Too cold on cloudy winter days
- Produces inadequate heat
- Undercooking
- Moveable insulation burden
- Daily temperature swings too great
- Underheating
- Lack of privacy or security
- Glare
- Nandalism
- Other

All directly benefited by Alpenglass™.
Directional Window “Tuning”

“Most designers feel safer specifying low-solar-gain glazing for the west elevation.”

Martin Holladay
GreenBuildingAdvisor.com
End Of Empirical Testing For Commercial Windows (?)

CMAST = Component Modeling Approach Software Tool

ACE = Approved Calculation Entity
University Of Colorado - $63 Visual Arts Center

Super IG + 131” Pultrusion FG Frames

Architects: KMW-Boston & OZ-Colorado

Woodbury Hall – 1890 – Original Steel – to Interim Aluminum – to Serious Fiberglass
Alex Wilson – Building Green

2007 Top-10 Green Building Product
GreenSpec
www.BuildingGreen.com
Passive House Occupant Comfort

Six Human Comfort Factors

1. Air Temp
2. Mean Radiant Temp
3. Air Velocity
4. Relative Humidity
5. Activity Level
6. Clothing Factor

Solar Radiation

Longwave Radiation

Convective Loop

CFD Modeling

GOOGLE – New York City
20-Degree Surface Temp Difference
**Insulating Glass “Passive Performance Coefficient”**

**CONFIGURATION**

<table>
<thead>
<tr>
<th>Label</th>
<th>Outer Light</th>
<th>Triple Versus QuadPane</th>
<th>Interspaces</th>
<th>(SFC) Suspended Coated Film</th>
<th>Inner Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>LI-HM88-LI (Ar)</td>
<td>1/8&quot; Low Iron</td>
<td>Triplet</td>
<td>2 @ 1/2&quot; Argon</td>
<td>HM88</td>
<td>1/8&quot; Low Iron</td>
</tr>
<tr>
<td>LI-2HM88-LI (Kr)</td>
<td>1/8&quot; Low Iron</td>
<td>Quad</td>
<td>3 @ 3/8&quot; Krypton</td>
<td>Double HM88</td>
<td>1/8&quot; Low Iron</td>
</tr>
<tr>
<td>C180-2HM88-LI (Kr)</td>
<td>1/8&quot; Low Iron</td>
<td>Quad</td>
<td>3 @ 3/8&quot; Krypton</td>
<td>Double HM88</td>
<td>1/8&quot; Low Iron</td>
</tr>
<tr>
<td>Dbl C180 + 3HM88 (Xe)</td>
<td>1/8&quot; C180 (#2)</td>
<td>Qua int</td>
<td>4 @ 1/4&quot; Xenon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PERFORMANCE**

<table>
<thead>
<tr>
<th></th>
<th>U-Value (Winter)</th>
<th>R-Value</th>
<th>Solar Heat Gain Coefficient</th>
<th>&quot;PPC&quot; Passive Performance Coefficient</th>
<th>Tvis</th>
<th>UV Blockage (to 380 nm)</th>
<th>ASHRAE-NFRC “Winter” Glass Temp (+)</th>
<th>ASHRAE-NFRC “Summer” Glass Temp (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.20</td>
<td>5.0</td>
<td>0.60</td>
<td>3.0</td>
<td>74%</td>
<td>99.5%</td>
<td>59 Deg F</td>
<td>91 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.11</td>
<td>9.3</td>
<td>0.51</td>
<td>4.7</td>
<td>66%</td>
<td>100.0%</td>
<td>63 Deg F</td>
<td>94 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>12.2</td>
<td>0.44</td>
<td>5.3</td>
<td>63%</td>
<td>100.0%</td>
<td>65 Deg F</td>
<td>90 Deg F</td>
</tr>
<tr>
<td></td>
<td>0.050</td>
<td>20.0</td>
<td>0.38</td>
<td>7.5</td>
<td>53%</td>
<td>100.0%</td>
<td>67 Deg F</td>
<td>96 Deg F</td>
</tr>
</tbody>
</table>

All values are Center Of Glass - as calculated by LBNL Window 6 Software

**"PPC" = PASSIVE PERFORMANCE COEFFICIENT = SHGC/U-VALUE**

- **Li-HM88-LI (Ar)**: 3.0
- **LI-2HM88-LI (Kr)**: 4.7
- **C180-2HM88-LI (Kr)**: 5.3
- **Dbl C180 + 3HM88 (Xe)**: 7.5

Low Iron Glass (no green)
Institutional/Commercial Passive House Presence

Morristown Maple Avenue City Building

NRDC Headquarters - NYC
Empire State Building *Before* And *After* Glass Performance

<table>
<thead>
<tr>
<th>Performance</th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Value</td>
<td>0.48</td>
<td>0.13</td>
<td>-72%</td>
</tr>
<tr>
<td>R-value</td>
<td>2.1</td>
<td>7.6</td>
<td>+261%</td>
</tr>
<tr>
<td>SHGC</td>
<td>0.72</td>
<td>0.49</td>
<td>+32%</td>
</tr>
<tr>
<td>Tvis</td>
<td>80%</td>
<td>64%</td>
<td>-20%</td>
</tr>
<tr>
<td>Winter NFRC (70 in/0 out/15 mph) Glass Temp</td>
<td>44 Deg F</td>
<td>62 Deg F</td>
<td>+ 18 Degrees F</td>
</tr>
<tr>
<td>Summer NFRC (75 in/90 out)</td>
<td>95 Deg F</td>
<td>76 Deg F (LBNL)</td>
<td>- 19 Degrees F</td>
</tr>
<tr>
<td>Overall Thickness</td>
<td>1&quot;</td>
<td>1&quot;</td>
<td>No Change</td>
</tr>
<tr>
<td>UltraViolet Blockage</td>
<td>46.8%</td>
<td>98.6%</td>
<td>-111%</td>
</tr>
</tbody>
</table>
EMPIRE STATE BUILDING SCF
GLAZING RENOVATION

Windows: 6,514
IG Units: 13,028
Glazing: ~160,000 ft2
Start: March, 2010
End: November 2010

ESB Renovation Measure Contributions

<table>
<thead>
<tr>
<th>Measure</th>
<th>Tonnage</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) DDC (Direct Digital Control)</td>
<td>603</td>
<td>36.8%</td>
</tr>
<tr>
<td>2) Demand Controlled Ventilation</td>
<td>5</td>
<td>0.3%</td>
</tr>
<tr>
<td>3) Tenant Lighting &amp; Plug Load Reduction</td>
<td>424</td>
<td>25.9%</td>
</tr>
<tr>
<td>4) Windows</td>
<td>440</td>
<td>26.9%</td>
</tr>
<tr>
<td>5) Tenant Energy Management</td>
<td>166</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

Total Tonnage Reduction 1,638 100.0%

Total Avoided HVAC (Chiller) Expenditure $17,400,000
Windows Share Of Chiller Savings $4,673,993

So, by GSB Valedictorian Mel Hodge Logic, payback is: "Immediate"
$/Ton Savings 10,623 (High?)
Manufacturing Innovation
Reuse Of Existing Glass

Production/Installation Capacity:
35-50 Windows/Night

Traco 9000 Windows Identical To Those Of 111 8th Avenue
EMPIRE STATE: Before

**Performance:**
- U-Value: 0.48
- R-value: 2.1
- SHGC: 0.72
- Tvis: 80%
- Winter NFRC Glass Temp (70 in/0 out/15 mph): 44 °F
- Summer NFRC Glass Temp (75 in/90 out): 95 °F
- Overall Thickness: 1"
- UltraViolet Blockage: 46.8%

Two 3/16” thick clear glass panes
One 5/8” wide cavity
Air-filled
**EMPIRE STATE: After**

- **3/16” thick glass panes**
  - Cleaned and re-used from old IGs
- **New suspended coated film**
  - “Twin-Coated” film (low-e coatings front & back)
- **Two 5/16” wide gas-filled cavities**
  - Blend of 90% krypton / 10% air

### Performance:

<table>
<thead>
<tr>
<th>Performance</th>
<th>After Retrofit</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-Value</td>
<td>0.13</td>
<td>-72%</td>
</tr>
<tr>
<td>R-value</td>
<td>7.6</td>
<td>261%</td>
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<tr>
<td>SHGC</td>
<td>0.49</td>
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<td>Overall Thickness</td>
<td>1”</td>
<td>No Change</td>
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</table>
$63M UNIVERSITY OF COLORADO VISUAL ARTS CENTER

- SCF North-South-East-West “Tuned” Glazing
- Fiberglass Storefront In High Humidity Galleries
  - 99.9% UV Blockage
- 62 Degree “Winter” Glass Temp
- Perimeter Baseboard Heating Removal
- Payback Under One Year
LEED PLATINUM FIBERGLASS
WINDOWS & SCF GLASS

- Pultrusion Fiberglass Casement Frames
- 1 3/8” SCT Glazing Pocket For Thermal & Acoustic Performance
  - R-8 SCF Glass
  - Warm Winter / Cool Summer
- Directionally “Tuned” SCF Glass
  - 99.5% UV Blockage
  - Inside/Outside Color Freedom
  - 1/500th Aluminum Frame Conductivity
  - High Volume Pricing
FIBERGLASS CROSS-SECTION

Pultrusion Lineal Mechanical Corner Sash

Pultrusion “End” (Al Dueck – Duxton)
COMMERCIAL FIBERGLASS FRAMES

Internal Anchor Blocks

Winnipeg Church In Blizzard – Warm To The Touch Window Frames
“European” High End Windows – (Denver Passive House)

Average Frame + Sash Width: 4.9”
Marvin Ultimate Windows
Passive House Certified
(Zone 3 & Marine South)

Glass Options: Tri-Pane & Quad Pane Heat Mirror®
Alpen Windows
Passive House Certified
AlpenHpp.com

Glass Options: Alpenglass Heat Mirror Tri & Quad Pane
GRHAM WRIGHT
R-9 Window Design

- Frame
  - Wood and spray foam
  - Width 90 mm
  - Depth 140 mm (5.5”)

- Glazing
  - 4-pane, 90% Argon, 50 mm
  - Cardinal lo-e 180 and clear

- Spacers
  - Chromatech Ultra F

“…I feel glazing is not the limiting factor for window performance at this time, but rather frame design.”
FIBERGLASS WINDOW
SASH/FRAME CROSS SECTION

TectonProducts.com
InlineFiberglass.com
OmniGlass.com
VACUUM SILICA BASED SASH/FRAME R-40 INSULATION

KevoThermal.com – Albuquerque (9/14/14 Update)
2014 Passive House Window “Core” Insulation
Pricing: $7-$10/SF = $2.13/Lineal 3” x 3/9” Strip
Effective R-Value: 13.5
<table>
<thead>
<tr>
<th>Glazing Type</th>
<th>Sound Transmission Class (STC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Double Pane (1/8”) Glass</td>
<td>29</td>
</tr>
<tr>
<td>Solid ½” Gypsum Wall</td>
<td>36</td>
</tr>
<tr>
<td>SCF: 1” Overall with ¼” Glass</td>
<td>35</td>
</tr>
<tr>
<td>SCF: 1 ½” Overall with ¼” Glass</td>
<td>38</td>
</tr>
<tr>
<td>SCF: One Lite Laminated</td>
<td>40</td>
</tr>
<tr>
<td>SCF: Two Lites Laminated</td>
<td>43</td>
</tr>
<tr>
<td>SCF: Two Dissimilar Laminated Lites</td>
<td>49</td>
</tr>
<tr>
<td>SCF: Two &quot;Acoustic&quot; Laminated Lites</td>
<td>52</td>
</tr>
</tbody>
</table>
TEST WINDOW:

- 87 Wide x 72” High
- Two large upper fixed
- One small fixed and one small awning below
- Insulating Glass
  - Outer: ¼”
  - Airgap: ¾”
  - Inner: 3/16”

National Research Council of Canada Inline Fiberglass Window Acoustic Report (STC = 35)
COMMERCIAL FIBERGLASS CURTAINWALL
100% Fiberglass Framing (22’ Height)

Infra Red (Interior) With
New Aluminum
Insulated Door

Colorado State
University Power Center
DYNAMIC GLAZING
Electrochromic / Photochromic / Thermochromic
BIPV GLAZING
Integral PV Cells / Transparent PV

Onyx Solar - (Spain)

Pythagoras Solar
Amory Lovins: *All of the energy pumped through the Alaska Pipeline each year goes literally “out America’s windows.”*