Heat Flow, in 2 and 3 D

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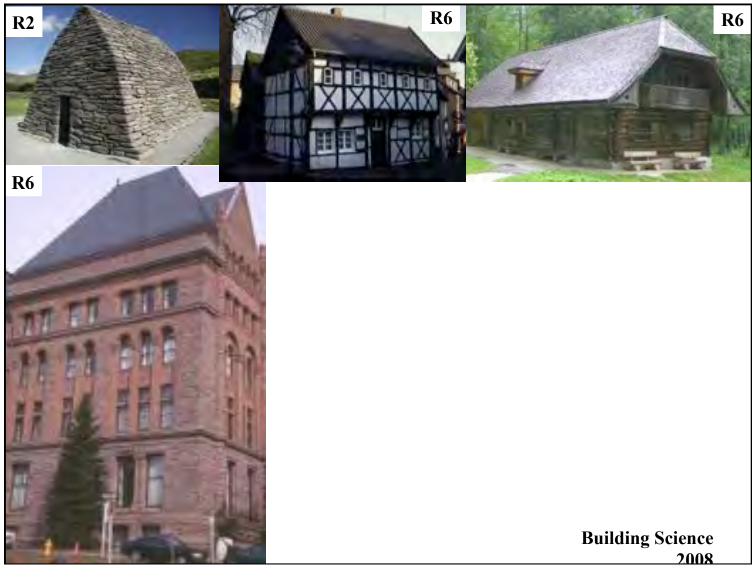
R2
R6
R6
R6
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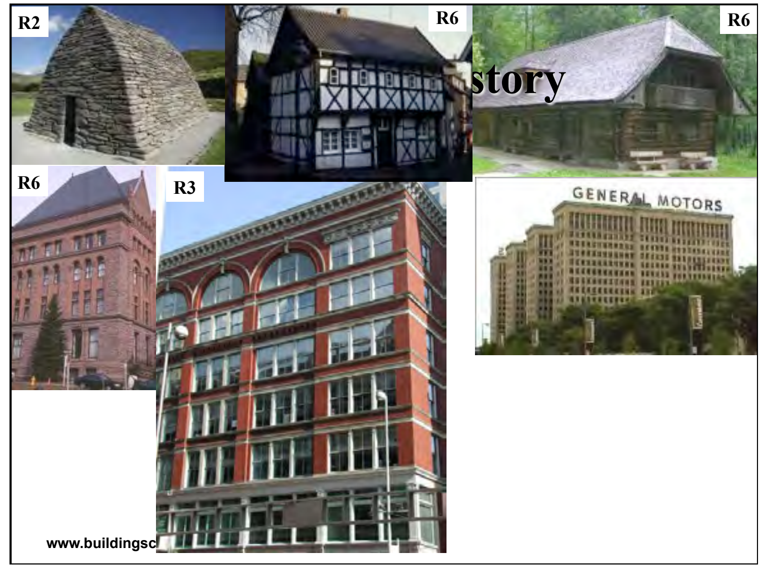
R2
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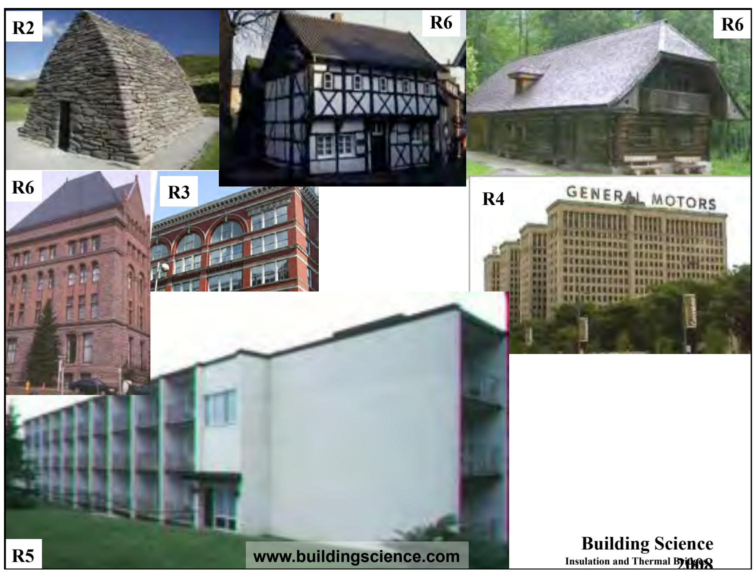
R3
GENERAL MOTORS


R2
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R3
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GENERAL MOTORS
R5
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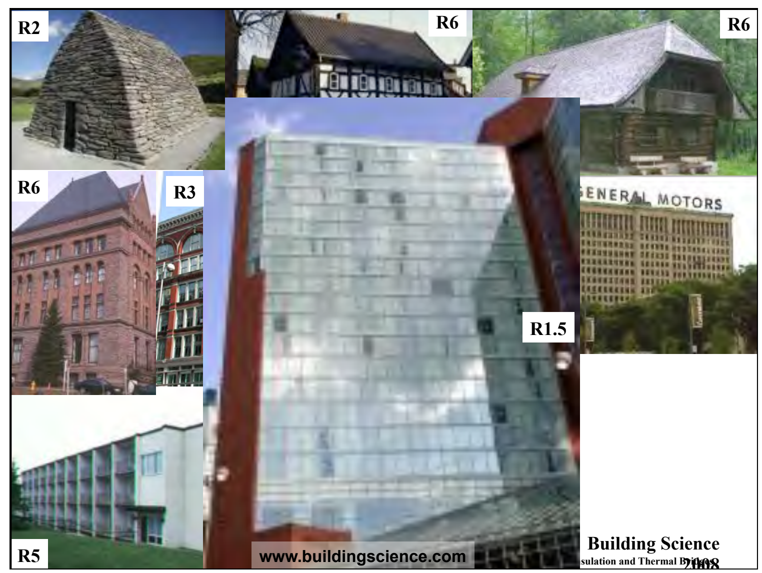
R2
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R3
R1.5
R5
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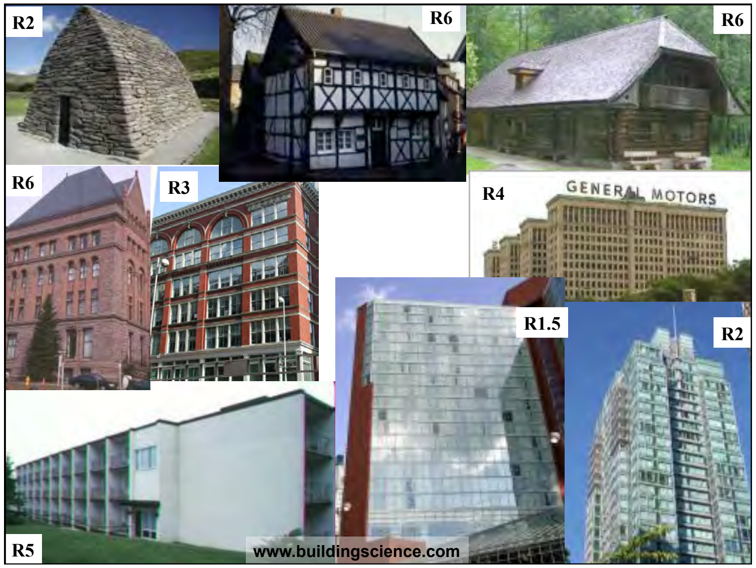

Presentation

- Heat Flow
  - Basics: One D
  - Two D
  - Three D
- Walls + Windows
- Practical Detailing Applications
- Window Solar Gain Control

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Heat Flow Basics

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Why control heat flow?

- Occupant Comfort
- Energy Savings
- Control surface and interstitial condensation
- Save duct and heating plant costs (Capital)
- Meet Codes and specs

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Heat & Temperature

- Heat
  - A form of energy (like Light & Sound)
- Temperature
  - A measure of the amount of thermal energy
- Heat Flow
  - From more to less energy

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Heat Flow

- Always moves from more to less
- Rate of flow depends on
  - Temperature Difference
  - Material Properties
  - Type & Mode of Heat Flow

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Categories of Heat Flow

- Mode of Heat Flow
  - Conduction
  - Convection
  - Radiation
- Type of Heat flow
  - steady-state or dynamic
  - one-, two- or three-dimensional
  - We usually use 1-D static!

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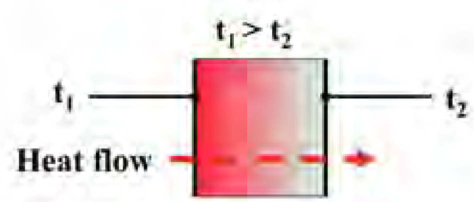
Conduction

- Heat Flow by direct contact
- Vibrating molecules
- Most important for solids



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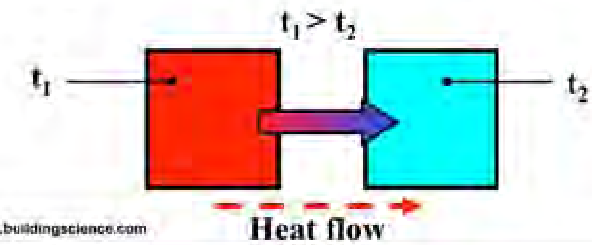
Convection

- Heat Flow by bulk movement of molecules
- Most important for liquids and gases
- E.g. air flow (forced air furnace)



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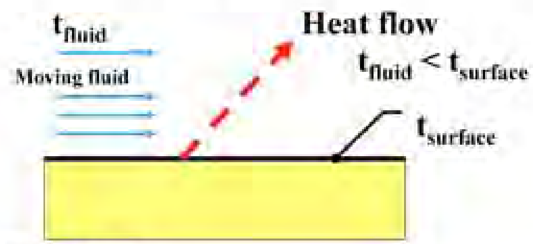
Convection

- Also heat flow from solid to liquid or gas
- Critical for surface heat transfer (e.g convectors, hot + cold surfaces)



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Radiation

- Heat flow by electromagnetic waves
- Heat radiates from *all* materials, e.g. campfire
- Passes through gases and vacuum (NOT Solid)

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Radiation

- Important for surfaces, air spaces, voids
- Foil faced insulation, radiant barriers only work when facing an air space
- Radiation within *pores* important for high void insulation (e.g., glass batt)
- e.g. Thermos bottle
- Critical for low-E windows

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Calculating Heat Flow

- Conduction
  - $q = k/l\ A(T_1-T_2) = C\ A\ \Delta T = A\ \Delta T\ /R$
  - k = conductivity f(T, MC, density, time?)
  - C = k/l conductance
  - R = resistance = 1/C
- Convection
  - E.g. $q = 1.42\ (\Delta T/L)^{0.25}A(\Delta T)$
  - Typical C_{equiv}=2 to 20 W m²K
- Radiation
  - E.g. $q = F_E A_1 \sigma(T_1^4-T_2^4)$

Calculating Heat Flow

$Q = CA(\Delta T)$

$C= k/l \quad R = 1 / C$

- Where
  - Q = heat flow rate (Btu/hr, W = J/s)
  - A = area heat is flowing through (ft², m²)
  - ΔT = temperature difference (°F, °C)
  - C = conductance of the layer (W/m²K)
  - U = conductance of an assembly (Btu/hr/ft²/°F)
  - k = thermal conductivity (Btu/ft/F, W/mk)
  - l = length of flow path (ft, m)

Example

0.144 Btu·in / (hr·ft²·°F) = W / m·K
6.944 W/mk = Btu·in / (hr·ft²·°F)

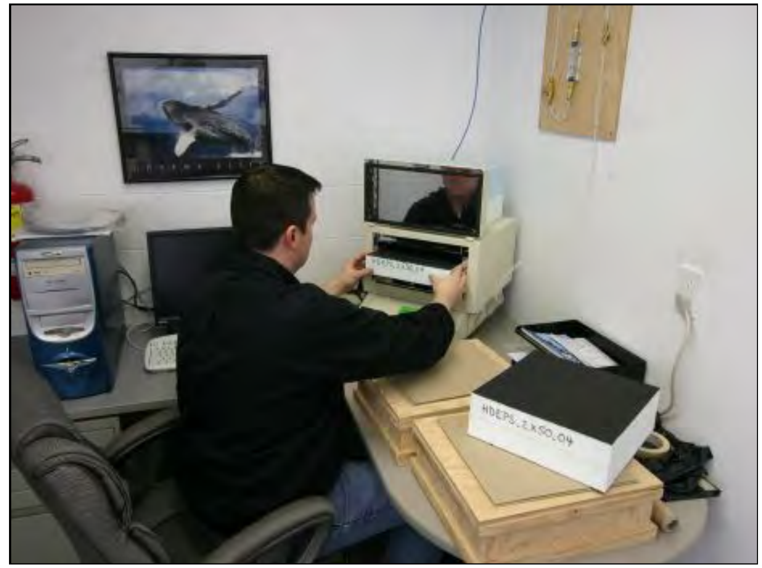
- Insulation
  - k= 0.20 Btu·in / (hr·ft²·°F) (= 0.029 W/mK)
  - R5 /inch (= 1 / 0.20)
- 3 inch thick layer
- T_{in}= 70 °F
- T_{out}= 20 °F
- $Q= k/L\ (T_{in}-T_{out}) = 0.20/3\ (70 - 20)= 0.0667 * 50$ $= 3.33$ Btu/hr/sf

$Q= \Delta T/R = 50 / 15 = 3.33$

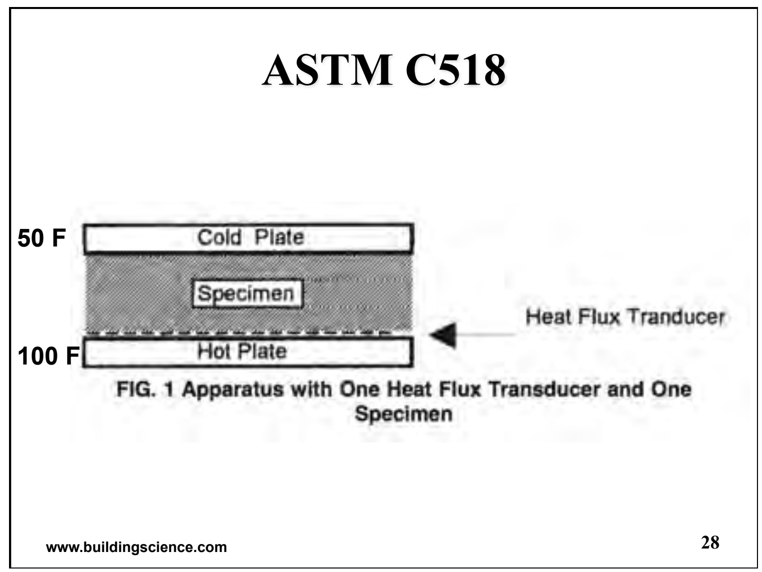
Measuring Thermal Conductivity

- A material property
- Measure heat flow through a unit thickness and unit area of material under a unit temperature difference
- Heat flow Btu/h, J/s
- Area sq ft, sq m
- Thickness ft, m

ASTM C518
ASTM C166




HDEPS_50_01


ASTM C518
50 F
Cold Plate
Specimen
Heat Flux Tranducer
100 F
Hot Plate
FIG. 1 Apparatus with One Heat Flux Transducer and One Specimen
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Thermal Performance Metrics

- Conduction Only:
  - Thermal Conductivity k
  - Conductance C = k / thickness
  - Resistance = thickness / conductivity
- "Effective" conductivity includes other modes
  - ASTM "R-value" includes all three modes
  - ASTM picks "standard" conditions

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Effective Conductance

- A layer property
- Expresses how easily heat can flow through a layer of the material

C = k/*l* = 1/R

Conductance = Conductivity / Thickness = 1 / Resistance

- R-Value is an expression of how well a *layer* of the material resists heat flow
  - = 1 / C

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Apparent Conductance

- Measurements are actually a result of conductivity, radiation, convection
- Typical batt is
  - 35-45% radiation
  - 40-60% conduction
  - 0-20% convection
- Depending on orientation, temperature, etc

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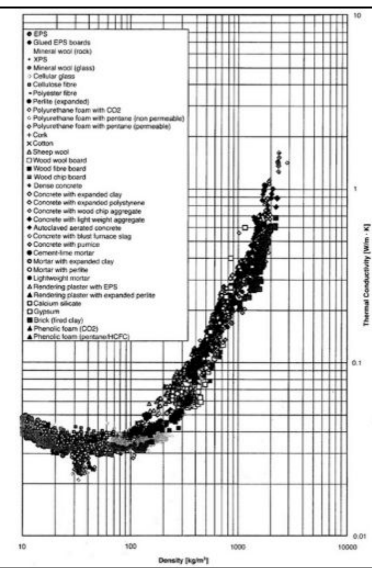
At a single mean temperature we can compare materials

Density matters



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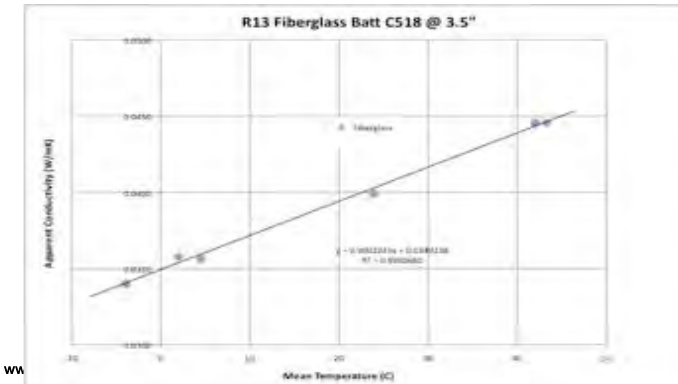
Thermal Insulation

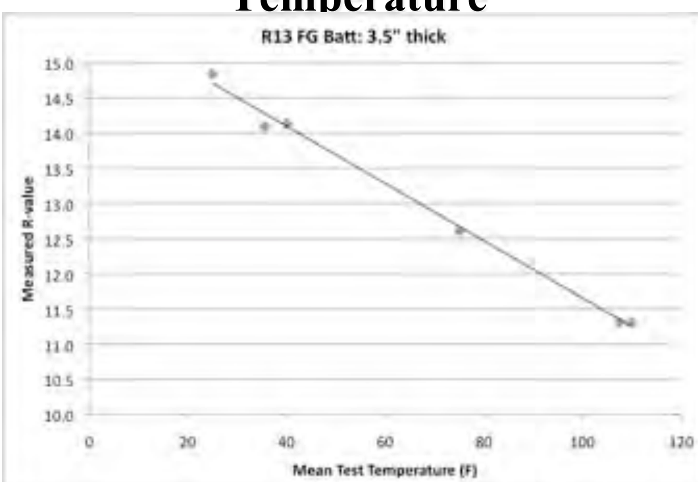
Insulation	R-value/inch	k (W/mK)
Empty airspace 0.75"-1.5" (20-40 mm)	R2.0 - 2.75	0.36 –0.50 W/m²K
Empty airspace 3.5"-5.5" (90-140 mm)	R2.75	0.50 W/m²K
Batt (mineral fiber)	3.5-3.8	0.034 - 0.042
Extruded polystyrene (XPS)	5.0	0.029
Polyisocyanurate (PIC)	6.0-6.5	0.022 - 0.024
Expanded polystyrene (EPS)	3.6-4.2	0.034 - 0.040
Semi-rigid mineral fiber (MFI)	3.6-4.2	0.034 - 0.040
Spray fiberglass	3.7-4.0	0.034 - 0.038
Closed-cell spray foam (2 pcf) ccSPF	5.8-6.6	0.022 - 0.025
Open-cell spray foam (0.5 pcf) ocSPF	3.6	0.040
Aerogel	8-12	0.012-0.018
Vacuum Insulated Panels (VIP)	20-35	0.004-0.008

Design vs Actual

- "Safe" k or "Actual" k



Temperature



EPS Thermal measurements

30 mm (1.25 in.) HD EPS insulation, aged 2 mnths					
Setpoints (°C)		Setpoints (°F)		Conductivity	
Upper	Lower	Upper	Lower	(w/mK)	(R/inch)
20	60	68	140	0.03964	3.6
20	40	68	104	0.03825	3.8
0	20	32	68	0.03537	4.1
-20	20	-4	68	0.03399	4.2

50 mm (2 in.) HD EPS insulation, aged 2 mnths					
Setpoints (°C)		Setpoints (°F)		Conductivity	
Upper	Lower	Upper	Lower	(w/mK)	(R/inch)
20	60	68	140	0.0369	3.9
20	40	68	104	0.03568	4.0
0	20	32	68	0.0332	4.3
-20	20	-4	68	0.03209	4.5

100 mm (4 in.) XPS insulation, aged 2 mnths					
Setpoints (°C)		Setpoints (°F)		Conductivity	
Upper	Lower	Upper	Lower	(w/mK)	(R/inch)
20	60	68	140	0.02793	5.2
20	40	68	104	0.0266	5.4
0	20	32	68	0.02425	5.9
-20	20	-4	68	0.02342	6.2

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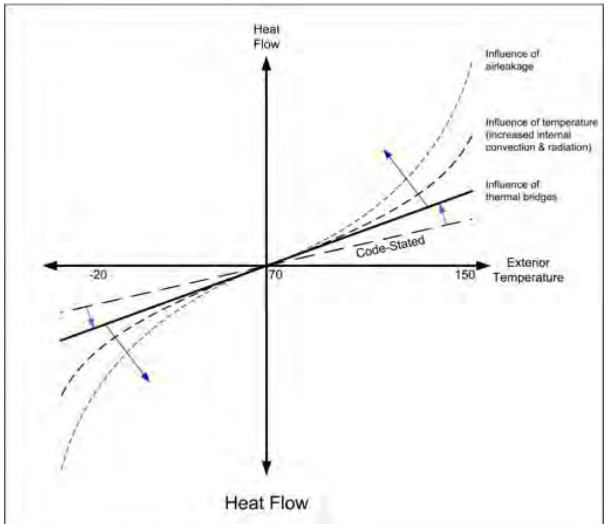

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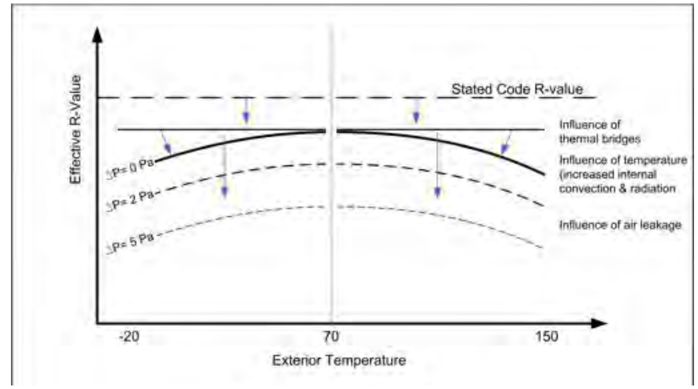
Deviations from lab tests



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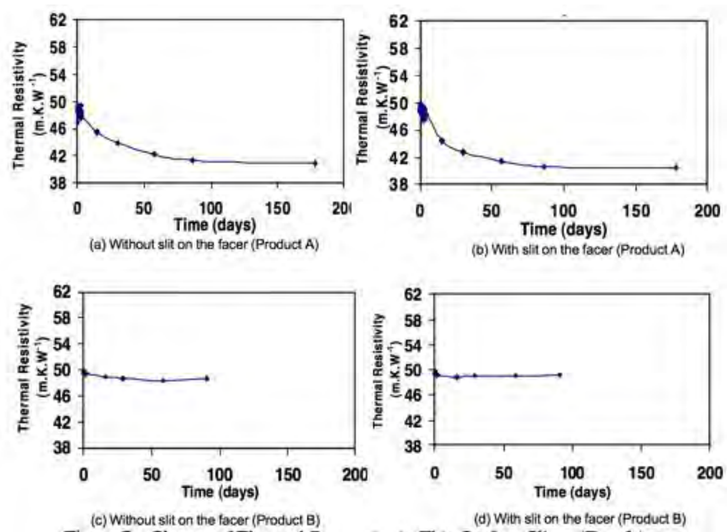

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Multi-layer Assemblies

- Building enclosures are typically assemblies of several layers of different materials
- R-value of each layer

$$R_1 = l_1/k_1 = 1/C_1$$

- The overall resistance must be calculated

$$R_{tot} = R_1 + R_2 + R_3 \ldots$$

- The conductance of the assembly is then

$$U = 1/R_{tot}$$

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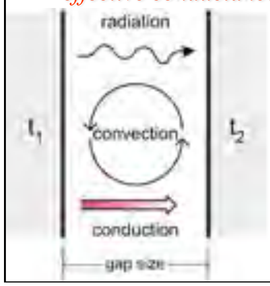
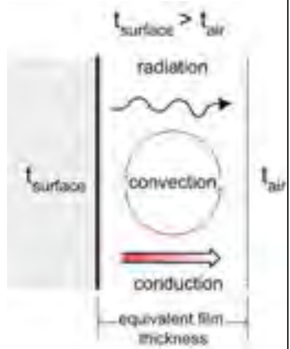
Air Spaces & Surface Films

- All 3 modes of heat transfer play a large role
- The effects are lumped into a coefficient, h_o which can be used in the conduction equation as an *effective conductance*





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Air Spaces

- Airspaces are important in windows and old buildings
- Heat flow depends on heat flow *direction* and surface *emissivity*

Situation (poorly vented or sealed)	R/ RSI Value	Conductance
Heat Flow Down (20-100 mm)	1.0 / 0.18	5.5
Heat Flow Across (20-100 mm)	0.96 / 0.17	5.9
Heat Flow Up (20-100 mm)	0.85 / 0.15	6.5
Reflective Airspace (Fe=0.05)	3.46 / 0.61	1.6

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Surface Films

- "Surface film" is a fictitious layer with a thermal property that represents resistance to heat flow from the air to the surface
- Surface films are important to define surface temperature at poorly insulated components
  - E.g. thermal bridges, windows, old building walls
- Convection PLUS radiation
  - Both convection and radiation coefficient vary

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Surface Films

Surface Position	Flow Direction	Resistance	Conductance
Still Air (e.g. indoors)		**R / RSI**	**[W/m²K]**
Horizontal (i.e. ceilings & floors)	Upward	0.61 / 0.11	9.3
	Downward	0.93 / 0.16	6.1
Vertical (i.e. walls)	Horizontal	0.68 / 0.12	8.3
Moving Air (e.g. outdoors)			
Stormy 6.7m/s (winter)	Any	0.17 / 0.03	34
Breeze 3.4m/s (summer)	Any	0.25 / 0.04	23
Average Conditions	Any	0.33 / 0.06	17

Look to *ASHRAE Handbook* or *Bldg Sci for Bldg Enclosures* for more detailed data.

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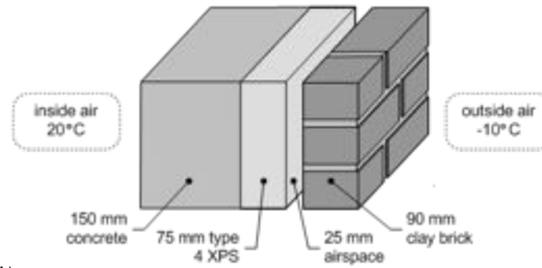
But there are Complications

- Add up the R-values of the layers to get the total R-value of the assembly
- BUT the actual thermal resistance of an assembly is affected by
  - Thermal Bridges
  - Thermal Mass
  - Air Leakage

Calculating Heat Flow through an Assembly

- To calculate assembly, add layers: materials, air gaps and surface films



How much Insulation

- Heat Flow = $\dfrac{\text{Area} * (T_{inside} - T_{outside})}{\text{R-value}}$
- Double R-value, halve heat flow. Always.
- Optimum depends on
  - Cost of energy over life of building
  - Cost of adding more insulation
  - Savings in mechanical equipment, controls

Thermal Bridges

What is a thermal bridge?

- A local area with significantly higher heat transmission (lower heat flow resistance) than
  - intended for the assembly, or
  - than the majority of the area

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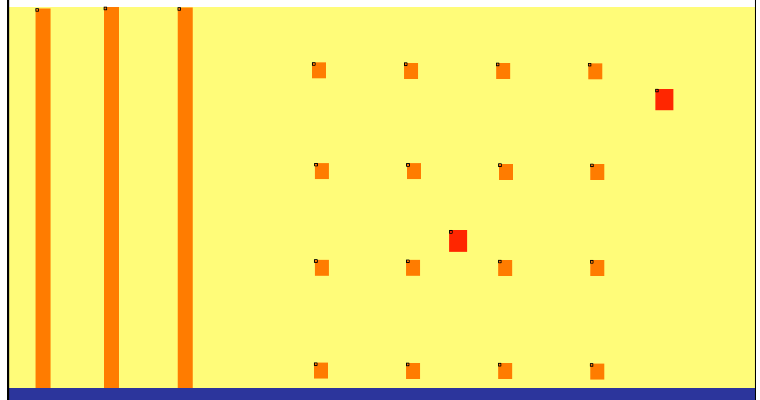
Types of Thermal Bridge



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Types of Thermal Bridges

- Occurrence
  - A) Repeating
    - Non-interacting, but numerous
  - B) Unique/Special Case
    - non-interacting, but few
- Geometry
  - 1) Linear
  - 2) Point
  - 3) complex
- Can be A1 or B2 or B3, etc

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Calculating Impact

- Simple area-weighted average for materials without very dissimilar properties
- Often computer calculations needed
  - 2D (linear)
  - 3D (point, complex)
- Results presented as either
  - Additional heat flow/unit
  - Total heat flow of specific area around TB

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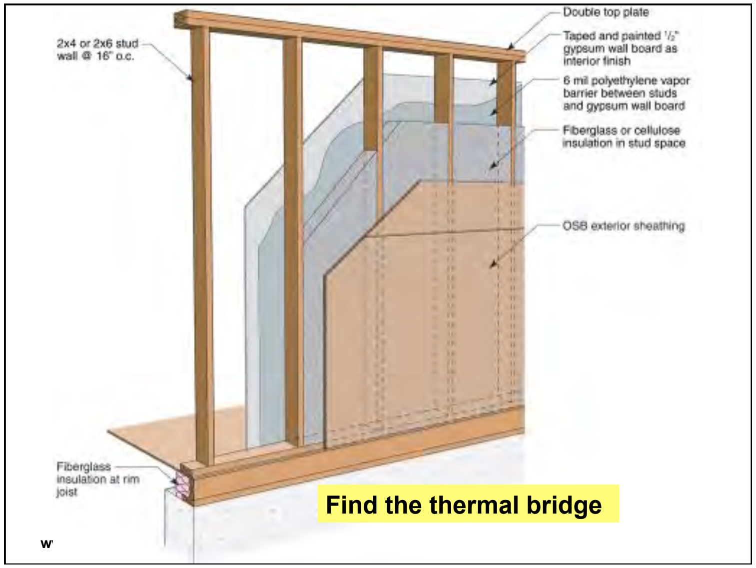
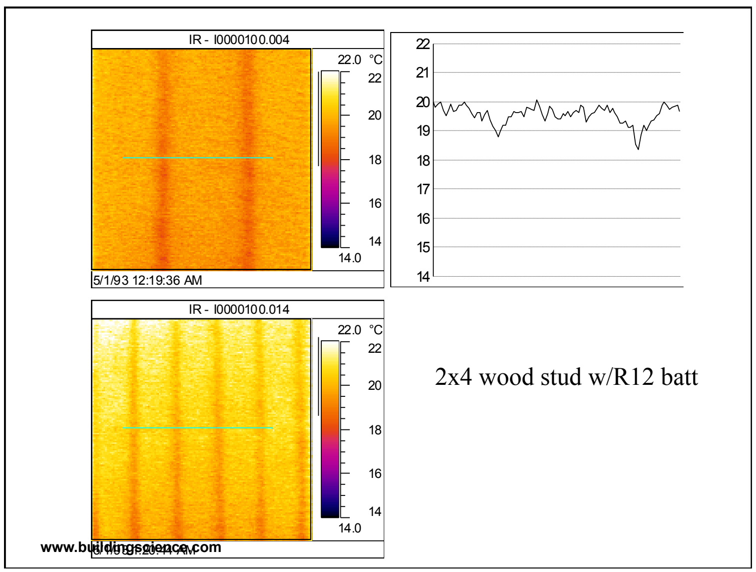

2x4 or 2x6 stud wall @ 16" o.c.
Double top plate
Taped and painted ½" gypsum wall board as interior finish
6 mil polyethylene vapor barrier between studs and gypsum wall board
Fiberglass or cellulose insulation in stud space
OSB exterior sheathing
Fiberglass insulation at rim joist
Find the thermal bridge


Find the thermal bridge


IR - I0000100.004
22.0 °C
14.0
5/1/93 12:19:36 AM
IR - I0000100.014
2x4 wood stud w/R12 batt
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UNITED AIRLINES

Two-dimensional heat flow

- Works for wood studs

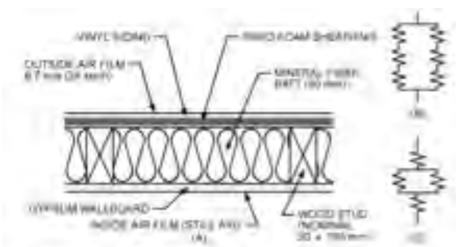

Fig. 3 (A) Wall Assembly for Example 3, with Equivalent Electrical Circuits: (B) Parallel Path and (C) Isothermal Planes

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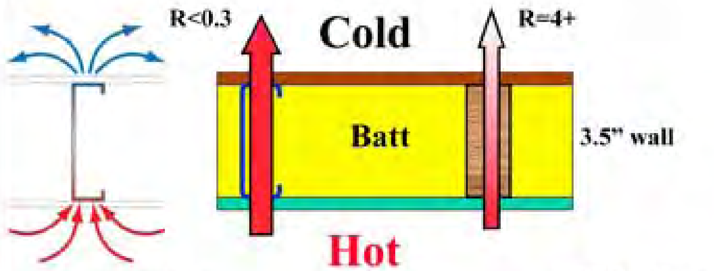
Thermal Bridging

- Steel is 400 times more conductive than wood
- Steel studs are about 40 times thinner



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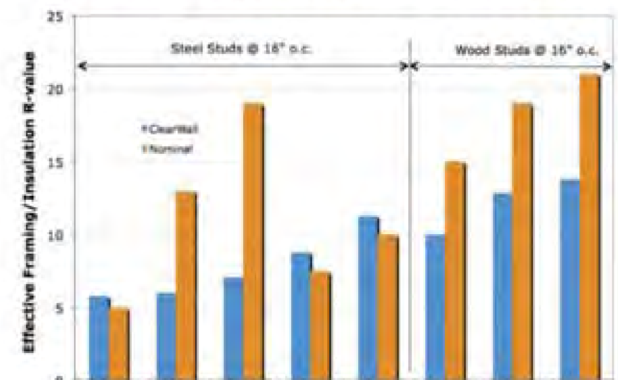
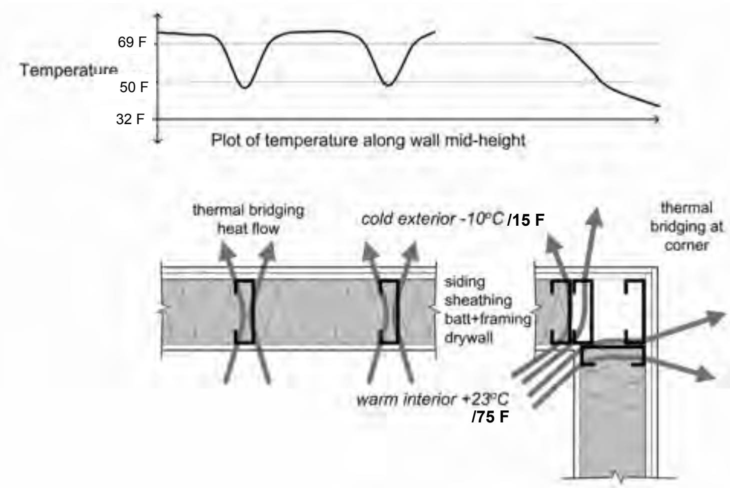
Assumes no floor slabs, no double studs etc.

Best-case R-values for stud walls



	R5ci 3.5in	R-13 3.5in	R-19 6in	R7.5ci 6in	R10ci 6in	R-15 3.5in	R-19 6in	R-21 6in
ClearWall	5.8	6.0	7.1	8.8	11.3	10.0	12.9	13.8
Nominal	5	13	19	7.5	10	15	19	21

Cold surfaces where R<5



Solutions?

- A continuous layer of insulation not interupted by structure
- E.g. insulated sheathing on the exterior

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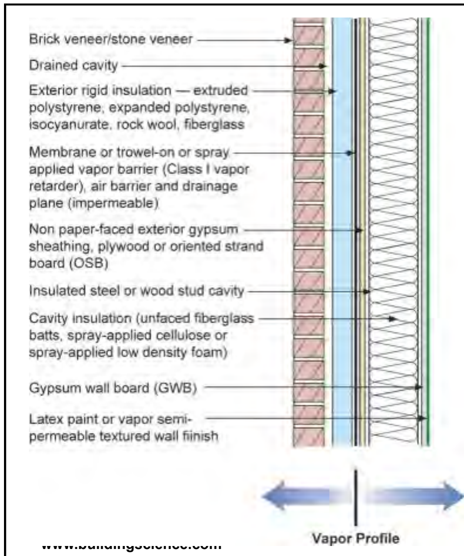

Any R-value, e.g.
6" wood stud+
2" PIC= R30
3"XPS= R32
4"SPF= R40

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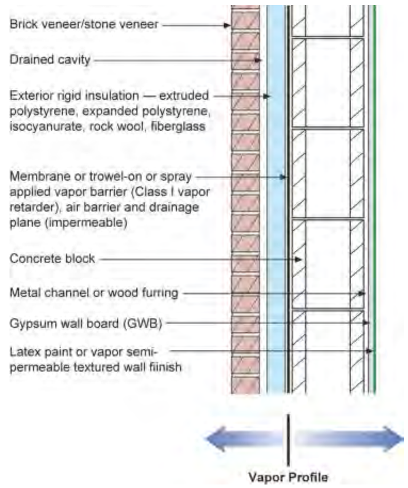
Any R-value, e.g. 4" PIC=R25
5"XPS =R25
6"MFI=R25



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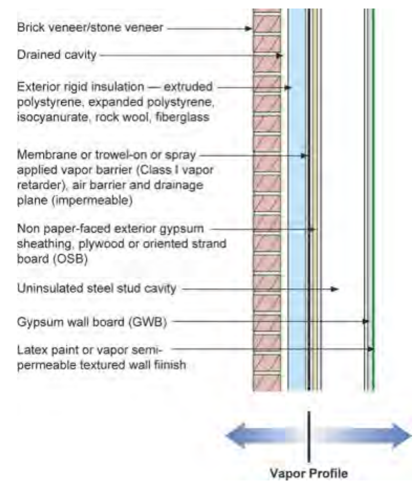
Any R-value, e.g. 4" PIC=R25
5"XPS =R25
6"MFI=R25



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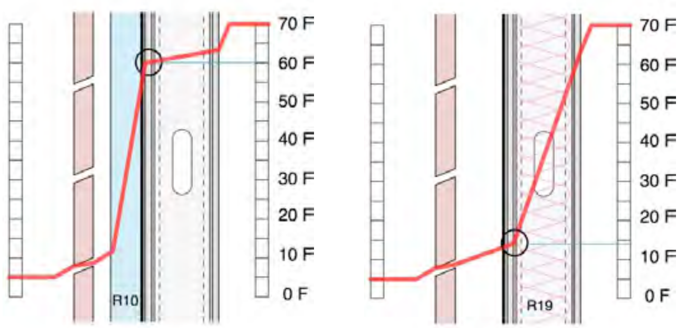
Condensation & Drying



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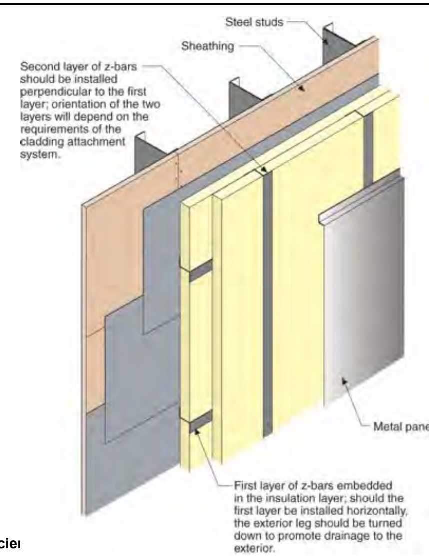

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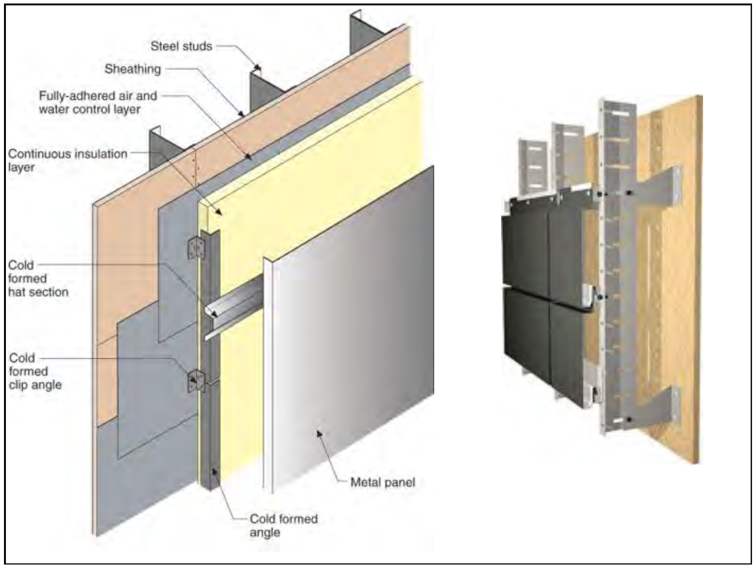
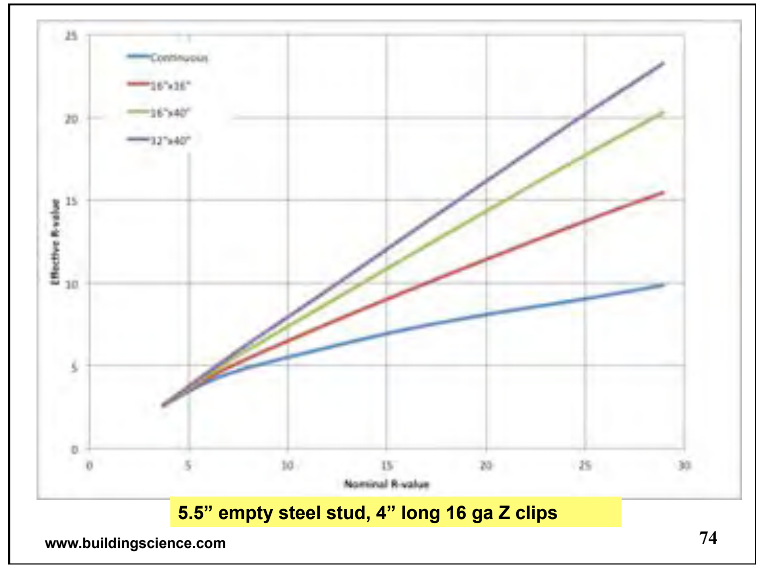

Steel studs
Sheathing
Fully-adhered air and water control layer
Continuous insulation layer
Cold formed hat section
Cold formed clip angle
Metal panel
Cold formed angle


Continuous
16"x16"
16"x40"
32"x40"
Effective R-value
Nominal R-value
5.5” empty steel stud, 4” long 16 ga Z clips
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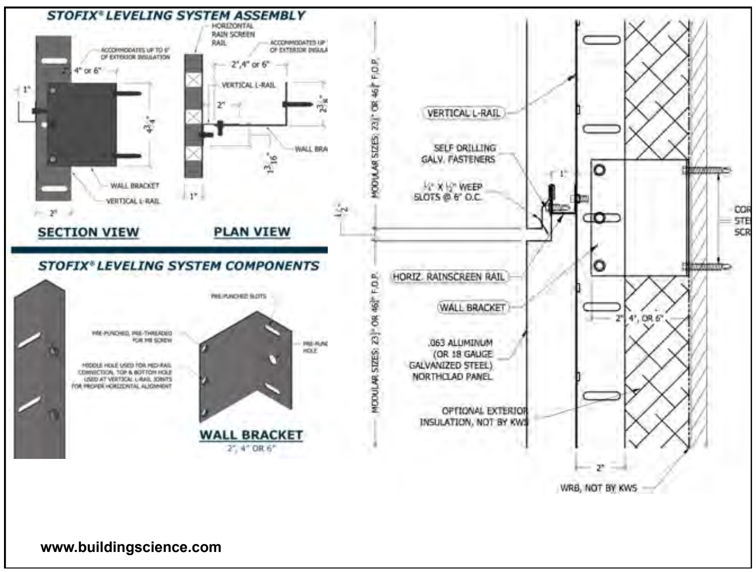
74


STOFIX® LEVELING SYSTEM ASSEMBLY
SECTION VIEW
PLAN VIEW
STOFIX® LEVELING SYSTEM COMPONENTS
WALL BRACKET
VERTICAL L-RAIL
SELF DRILLING GALV. FASTENERS
HORIZ. RAINSCREEN RAIL
WALL BRACKET
.063 ALUMINUM (OR 18 GAUGE GALVANIZED STEEL) NORTHCLAD PANEL
OPTIONAL EXTERIOR INSULATION, NOT BY KWS
WRB, NOT BY KWS
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Special Cases

- Relieving angles
- Balconies
- Canopies

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Can we air-cool our buildings?

07/12/2011

Schöck Isokorb®: Thermally protective and load-bearing

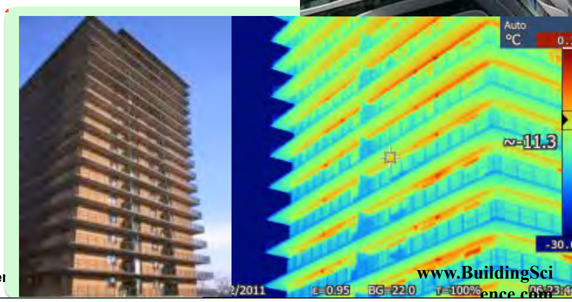
Free cantilever balconies are, and have always been, an important asset to any construction project, helping obtaining a higher quality of living. When a balcony slab without a thermal break at the perimeter is cast, it creates a thermal bridge.

The **Schöck Isokorb®** can eliminate this "Weak Link" in the building envelope. Effective thermal insulation of the Schöck Isokorb® reduces the risk of condensation, mold formation and associated damage caused by this effect.

Thermal leakage and energy loss is minimized with Isokorb®. The optimum thermal insulation of Isokorb® is found in the highly effective HCFC-free insulation layer made from Polystyrol foam, used together with stainless steel load transfering members.

From: www.schoeck-canada.com

Award-winning Aqua Tower



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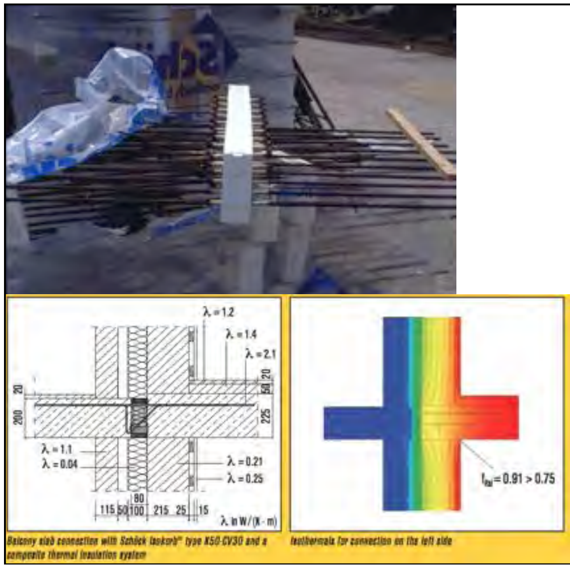
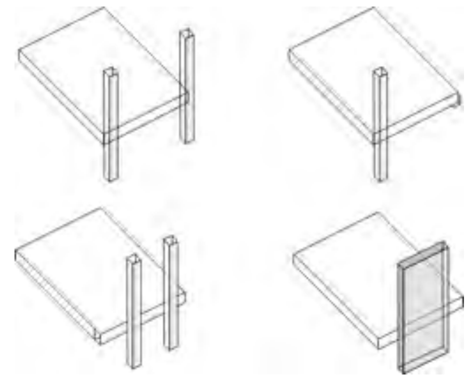


Insulation and Thermal

Balconies



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Insulation and

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Insulation and Thermal

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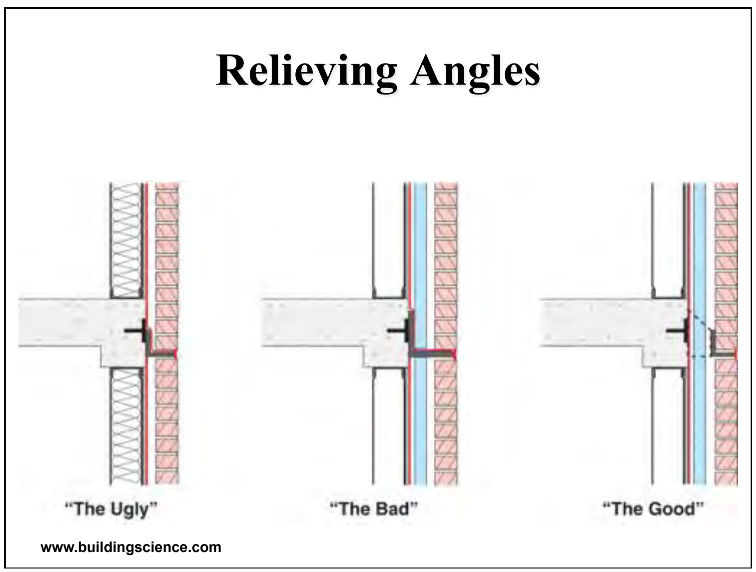
Precast balcony supported on knife edge supports to limit thermal losses


Relieving Angles
"The Ugly"
"The Bad"
"The Good"
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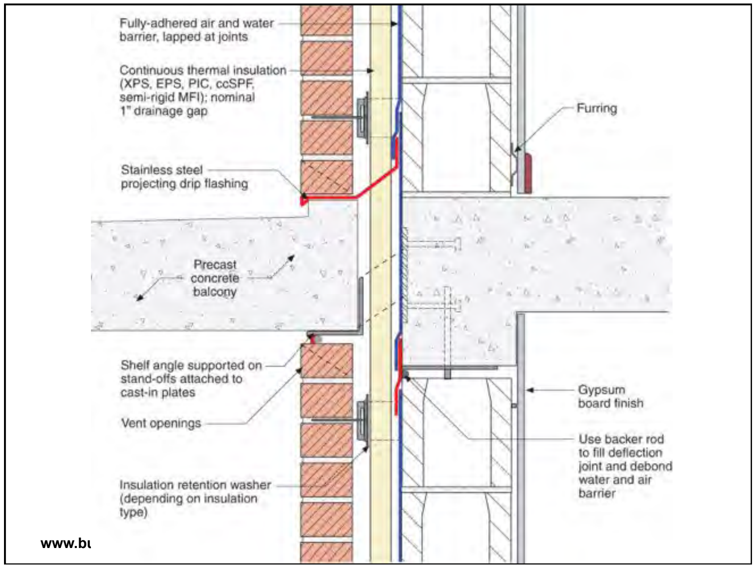
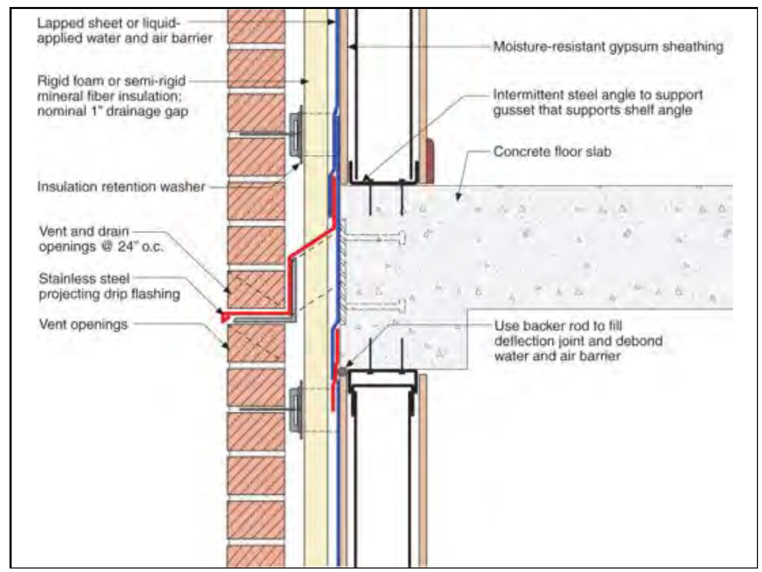
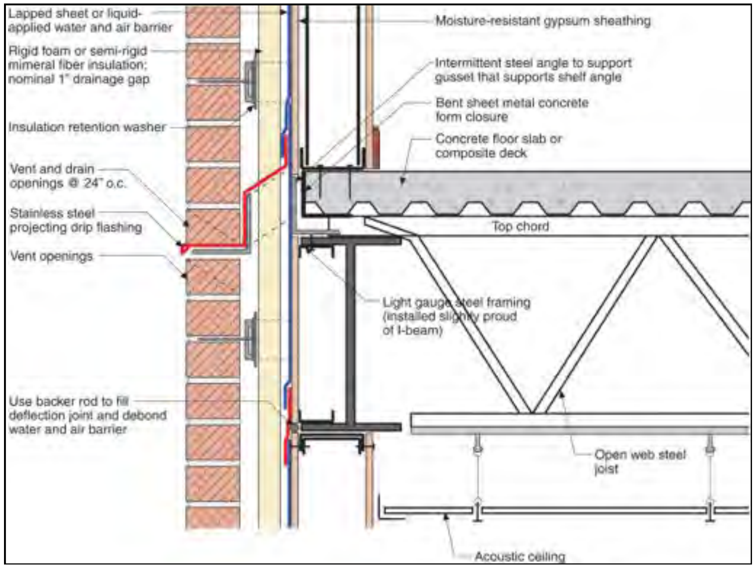


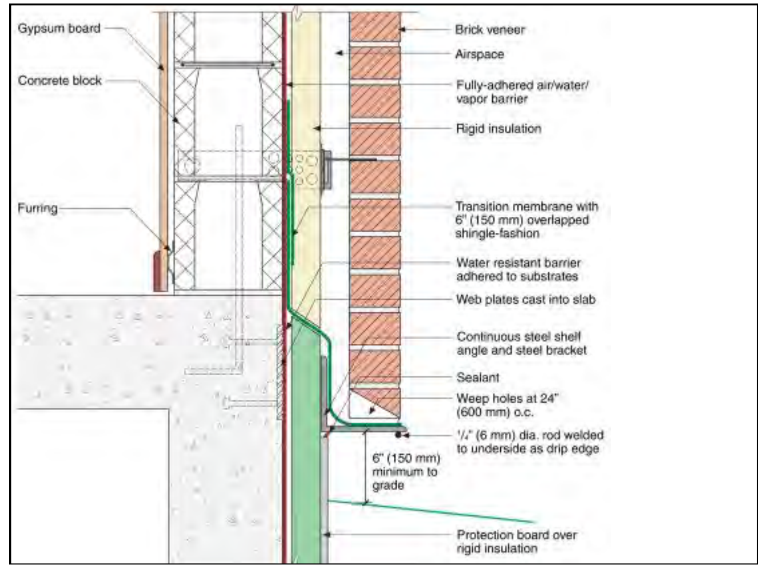
Fully-adhered air and water barrier, lapped at joints
Continuous thermal insulation (XPS, EPS, PIC, ccSPF, semi-rigid MFI); nominal 1" drainage gap
Stainless steel projecting drip flashing
Precast concrete balcony
Shelf angle supported on stand-offs attached to cast-in plates
Vent openings
Insulation retention washer (depending on insulation type)
Furring
Gypsum board finish
Use backer rod to fill deflection joint and debond water and air barrier

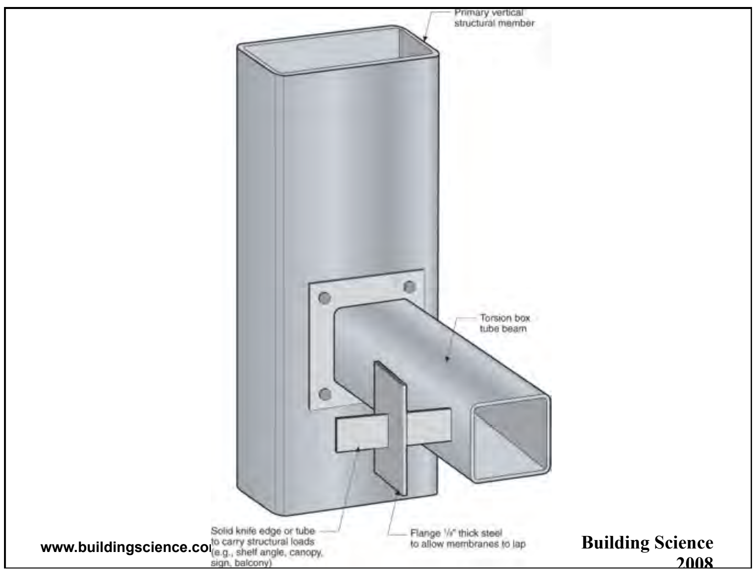
Small metal clips dramatically reduce thermal bridging



Lapped sheet or liquid-applied water and air barrier
Rigid foam or semi-rigid mineral fiber insulation; nominal 1" drainage gap
Insulation retention washer
Vent and drain openings @ 24" o.c.
Stainless steel projecting drip flashing
Vent openings
Moisture-resistant gypsum sheathing
Intermittent steel angle to support gusset that supports shelf angle
Concrete floor slab
Use backer rod to fill deflection joint and debond water and air barrier


Lapped sheet or liquid-applied water and air barrier
Rigid foam or semi-rigid mineral fiber insulation; nominal 1" drainage gap
Insulation retention washer
Vent and drain openings @ 24" o.c.
Stainless steel projecting drip flashing
Vent openings
Use backer rod to fill deflection joint and debond water and air barrier
Moisture-resistant gypsum sheathing
Intermittent steel angle to support gusset that supports shelf angle
Bent sheet metal concrete form closure
Concrete floor slab or composite deck
Top chord
Light gauge steel framing (installed slightly proud of I-beam)
Open web steel joist
Acoustic ceiling


Gypsum board
Concrete block
Furring
Brick veneer
Airspace
Fully-adhered air/water/vapor barrier
Rigid insulation
Transition membrane with 6" (150 mm) overlapped shingle-fashion
Water resistant barrier adhered to substrates
Web plates cast into slab
Continuous steel shelf angle and steel bracket
Sealant
Weep holes at 24" (600 mm) o.c.
1/4" (6 mm) dia. rod welded to underside as drip edge
6" (150 mm) minimum to grade
Protection board over rigid insulation


Primary vertical structural member
Torsion box tube beam
Solid knife edge or tube to carry structural loads (e.g., shelf angle, canopy, sign, balcony)
Flange 1/8" thick steel to allow membranes to lap
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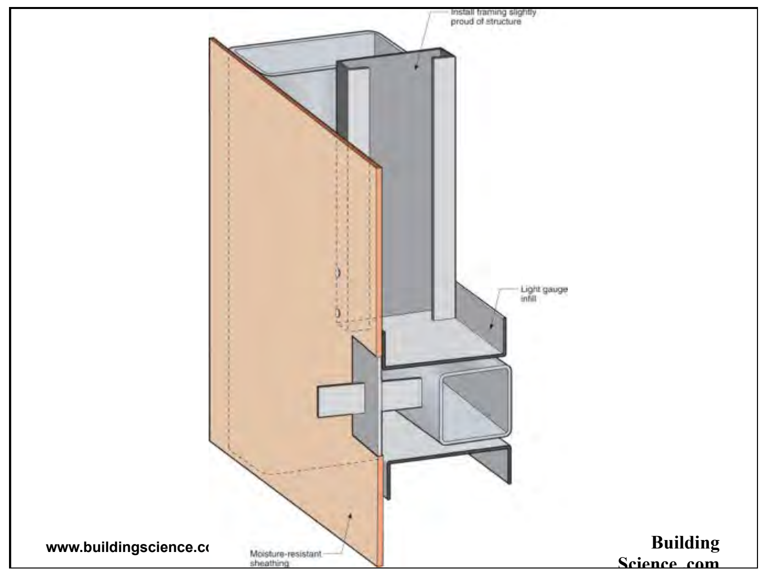
Install framing slightly proud of structure
Light gauge infill
Moisture-resistant sheathing
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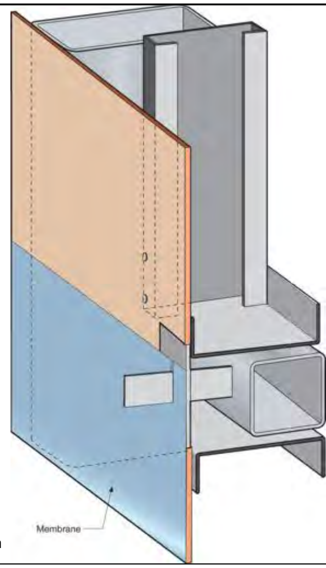

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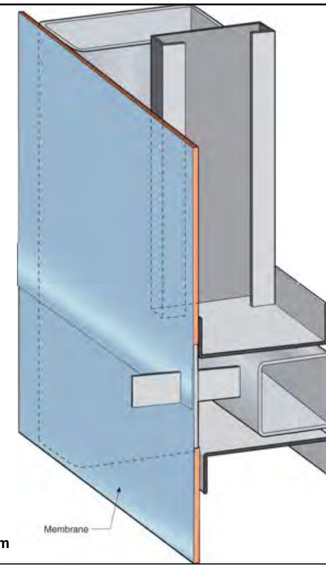

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Hard to avoid

- Some we choose to live with, especially if they are not large or the climate is moderate

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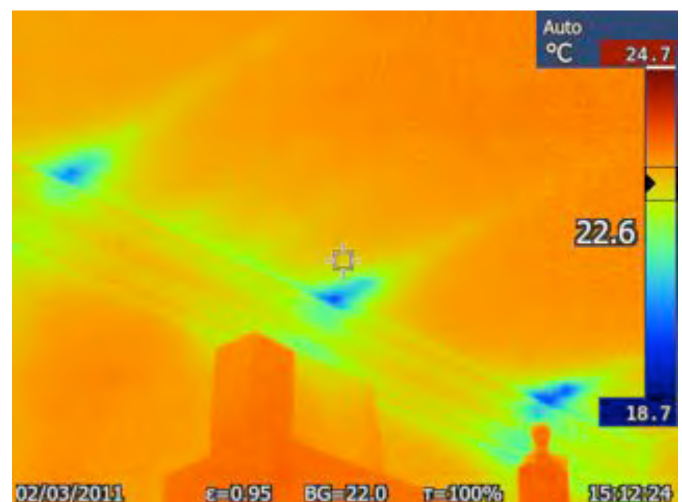

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Windows

… such a pane.

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Windows

- Our most expensive thermal bridges
- Aluminum is 4-5 times as conductive as steel
- Or 1600 times more than wood
- Difficult to buy commercial aluminum windows / curtainwall over R3.
- Allow solar heat in
  - Useful in cold weather
  - Requires cooling in summer

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Frames

- A large amount of heat can also be conducted through the frame
  - Conductivity of the material (lower = better)
  - Geometry of the frame

Frame Material	Conductivity W/mk	Conductivity R/inch
Wood	0.10 to 0.18	0.8 to 1.4
PVC	0.17	0.8
Fiberglass	0.30	0.5
Bronze	93	0.002
Aluminum	221	0.001

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Gas Fills

- Gas fills reduce the amount of heat transferred by conduction and convection through the space in the glazing unit
- Gas fills leak about +/-1% per year

Fill	Conductivity W/mK	Conductivity R/inch	Reduction in Conduction
Air	0.0241	6.0	-
Argon	0.0162	8.9	33%
Krypton	0.0086	16.8	64%
Xenon	0.0051	28.3	79%

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Window U-values

- Window U-value = 1 /R-value
- Window values usually include airfilms
  - Inside and outside R-1.0
- Hence, single-glazed, R1
- A still air space adds R1
- Change to argon, another R1
- Add low-e, another R1

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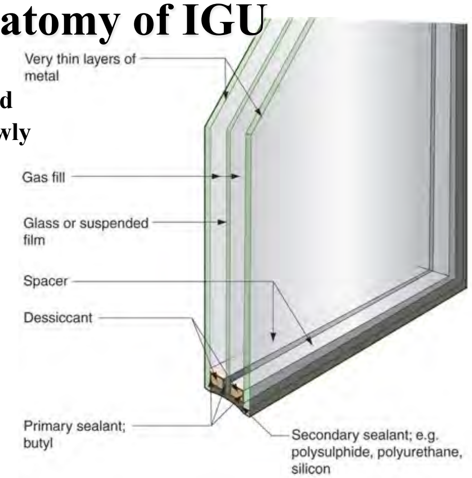
Anatomy of IGU

- Hermetically sealed
- Gas leaks very slowly



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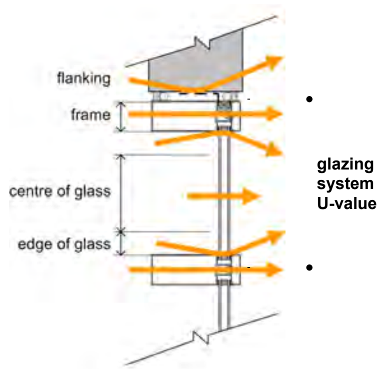
Windows and

Total Heat Flow

Curtain Wall Plan View



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Windows and Curtainwalls

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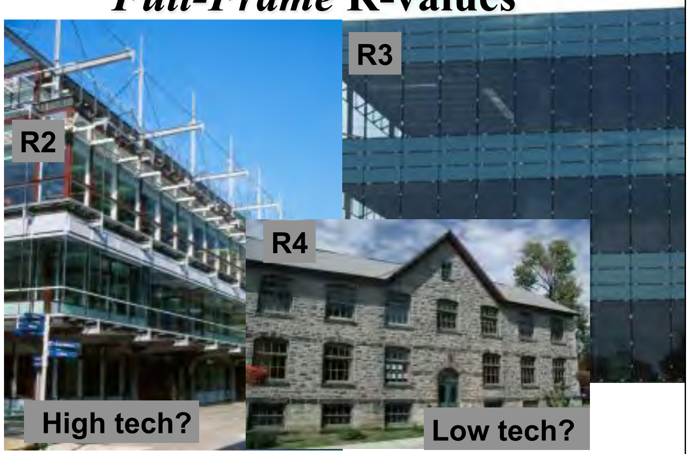
Full-Frame R-values



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Windows and Curtainwalls

Thermal Break

- Critical for alu windows
- ½" should be min thermal break

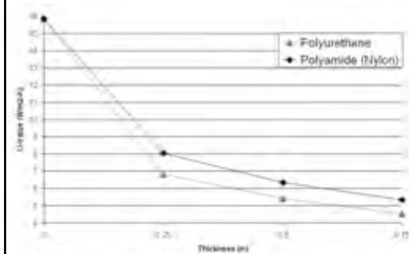
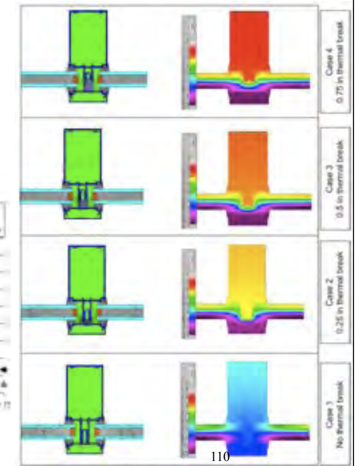


Figure 4: Frame U-Value vs. thermal break thickness.



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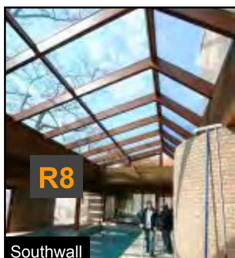
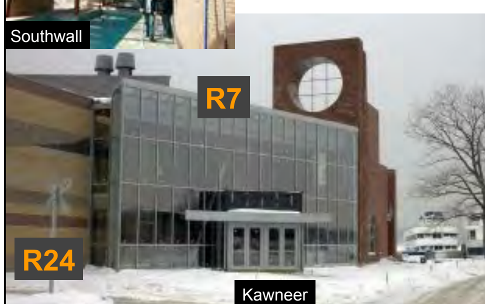
High Performance

Getting better . .





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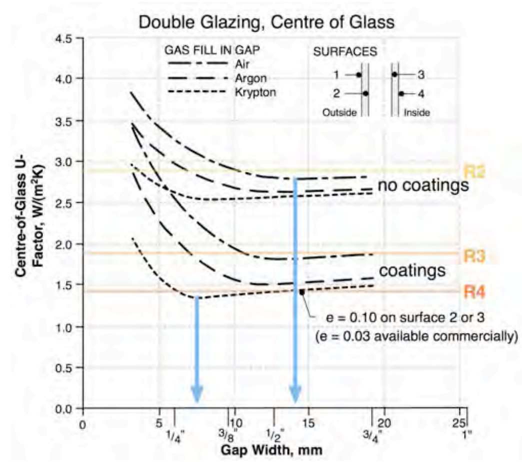

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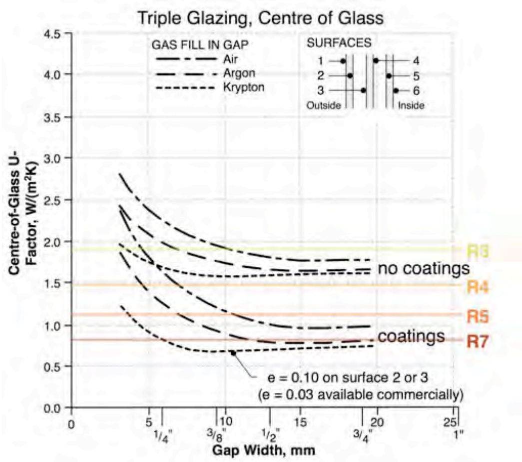

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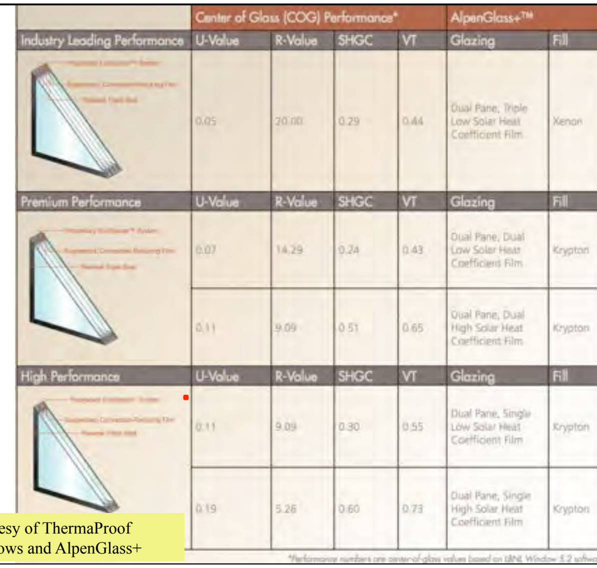

	Center of Glass (COG) Performance*				AlpenGlass+™	
Industry Leading Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.05	20.00	0.29	0.44	Dual Pane, Triple Low Solar Heat Coefficient Film	Xenon
Premium Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.07	14.29	0.24	0.43	Dual Pane, Dual Low Solar Heat Coefficient Film	Krypton
	0.11	9.09	0.51	0.65	Dual Pane, Dual High Solar Heat Coefficient Film	Krypton
High Performance	U-Value	R-Value	SHGC	VT	Glazing	Fill
	0.11	9.09	0.30	0.55	Dual Pane, Single Low Solar Heat Coefficient Film	Krypton
	0.19	5.26	0.60	0.73	Dual Pane, Single High Solar Heat Coefficient Film	Krypton

*Performance numbers are center-of-glass values based on LBNL Window 5.2 software

Courtesy of ThermaProof Windows and AlpenGlass+

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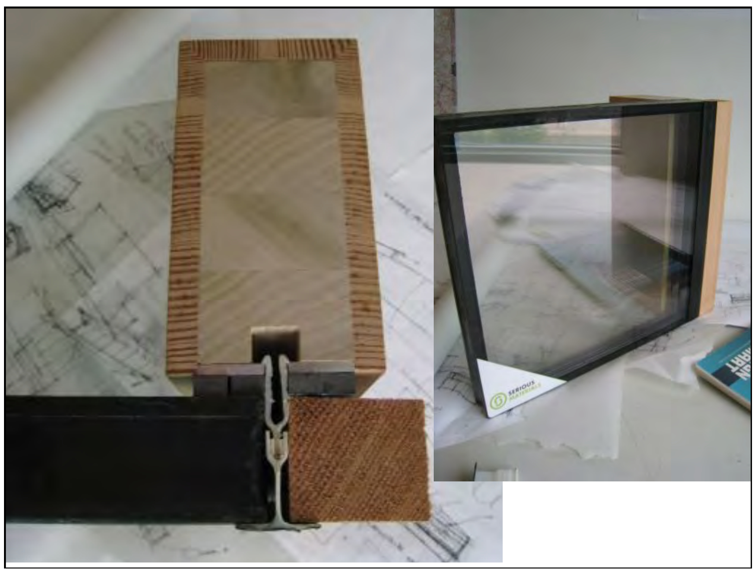

Flanking

- Defined as heat flow around a window
- Includes the rough opening and any special flashing, fasteners, etc.
- Wood bucks often have R-value of 1/inch
- Plywood bucks usually 0.75/inch
- Air gaps >1/4" have low R-value
- Gaps filled with spray foam, R4-6/inch

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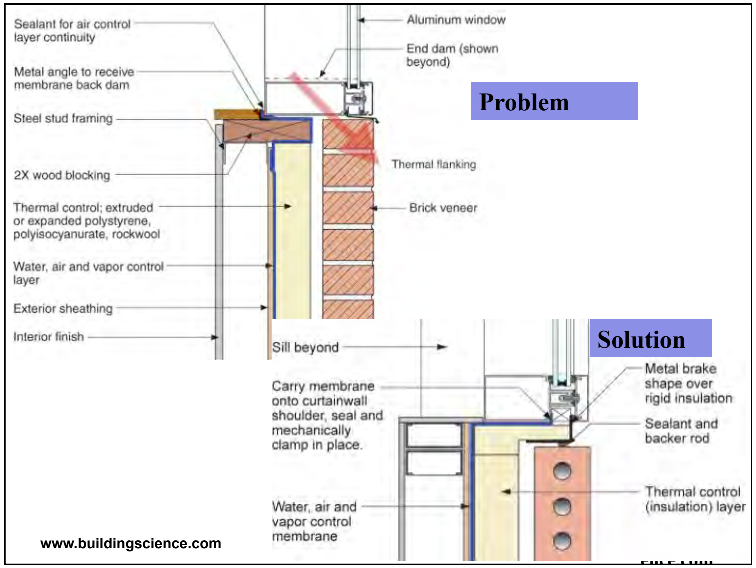
Sealant for air control layer continuity
Metal angle to receive membrane back dam
Steel stud framing
2X wood blocking
Thermal control; extruded or expanded polystyrene, polyisocyanurate, rockwool
Water, air and vapor control layer
Exterior sheathing
Interior finish
Aluminum window
End dam (shown beyond)
Problem
Thermal flanking
Brick veneer
Solution
Sill beyond
Carry membrane onto curtainwall shoulder, seal and mechanically clamp in place.
Metal brake shape over rigid insulation
Sealant and backer rod
Thermal control (insulation) layer
Water, air and vapor control membrane
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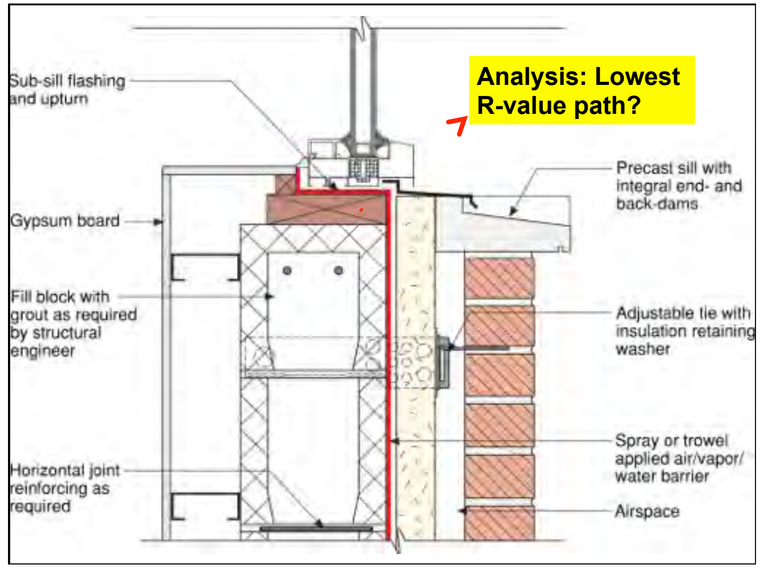
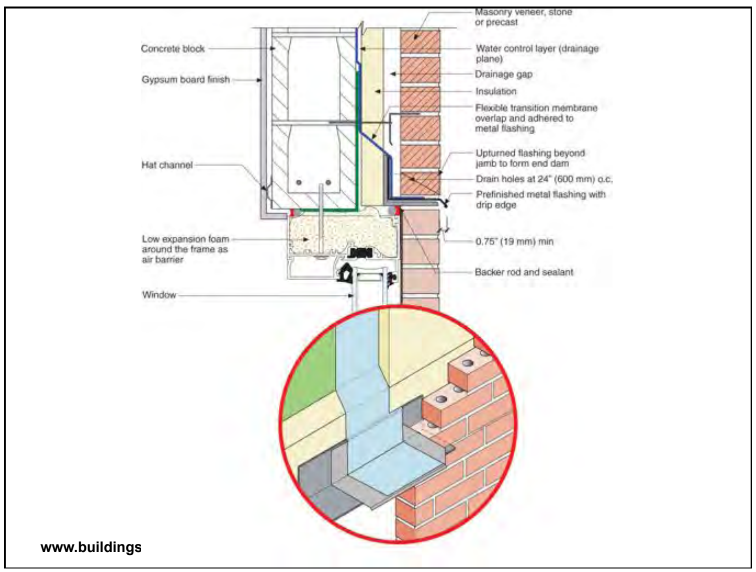

Analysis: Lowest R-value path?
Sub-sill flashing and upturn
Gypsum board
Fill block with grout as required by structural engineer
Horizontal joint reinforcing as required
Precast sill with integral end- and back-dams
Adjustable tie with insulation retaining washer
Spray or trowel applied air/vapor/ water barrier
Airspace


Concrete block
Gypsum board finish
Hat channel
Low expansion foam around the frame as air barrier
Window
Masonry veneer, stone or precast
Water control layer (drainage plane)
Drainage gap
Insulation
Flexible transition membrane overlap and adhered to metal flashing
Upturned flashing beyond jamb to form end dam
Drain holes at 24" (600 mm) o.c.
Prefinished metal flashing with drip edge
0.75" (19 mm) min
Backer rod and sealant
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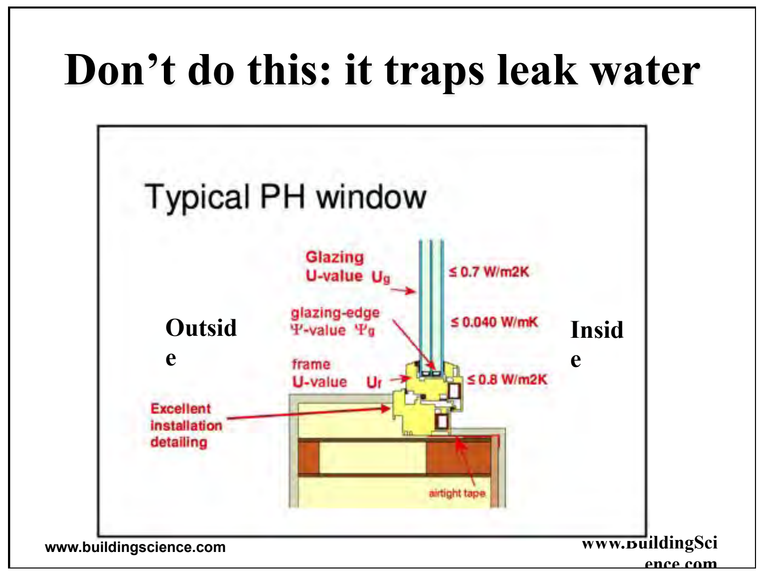
Don't do this: it traps leak water
Typical PH window
Outside
Inside
Glazing U-value Ug
≤ 0.7 W/m2K
glazing-edge Ψ-value Ψg
≤ 0.040 W/mK
frame U-value Uf
≤ 0.8 W/m2K
Excellent installation detailing
airtight tape
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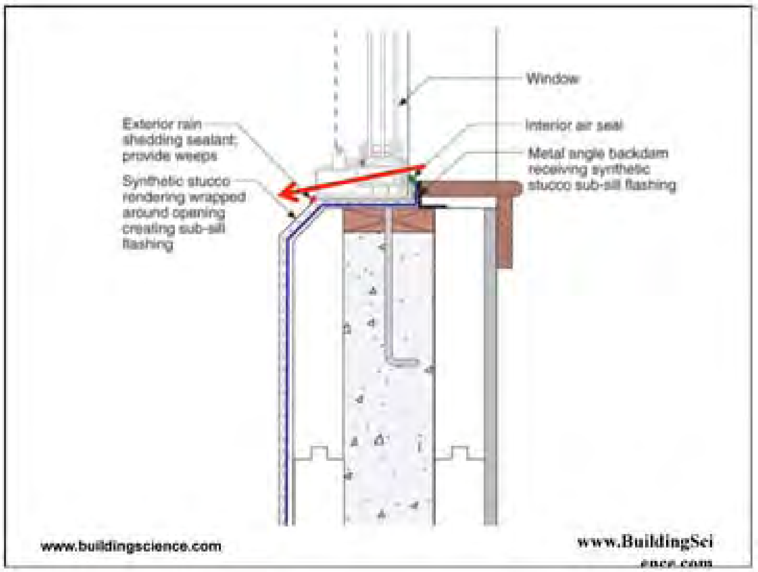
Window
Exterior rain shedding sealant; provide weeps
Interior air seal
Metal angle backdam receiving synthetic stucco sub-sill flashing
Synthetic stucco rendering wrapped around opening creating sub-sill flashing
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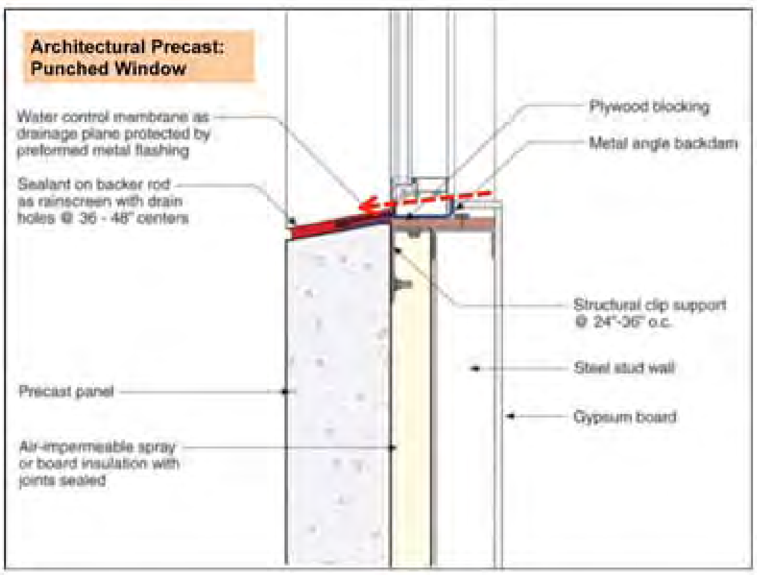
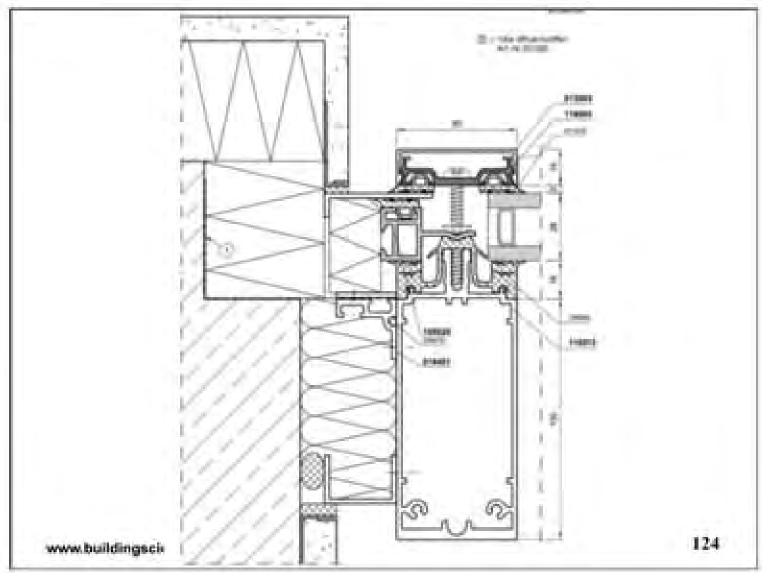
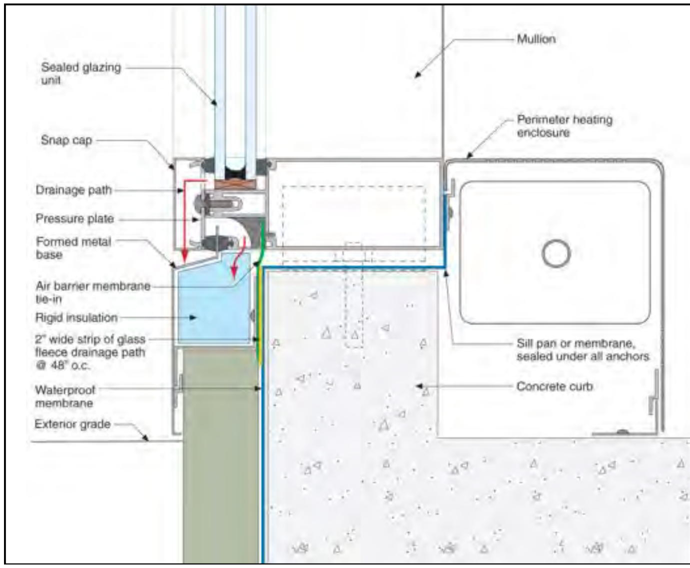

Architectural Precast: Punched Window
Plywood blocking
Water control membrane as drainage plane protected by preformed metal flashing
Metal angle backdam
Sealant on backer rod as rainscreen with drain holes @ 36 - 48" centers
Structural clip support @ 24"-36" o.c.
Steel stud wall
Precast panel
Gypsum board
Air-impermeable spray or board insulation with joints sealed


124



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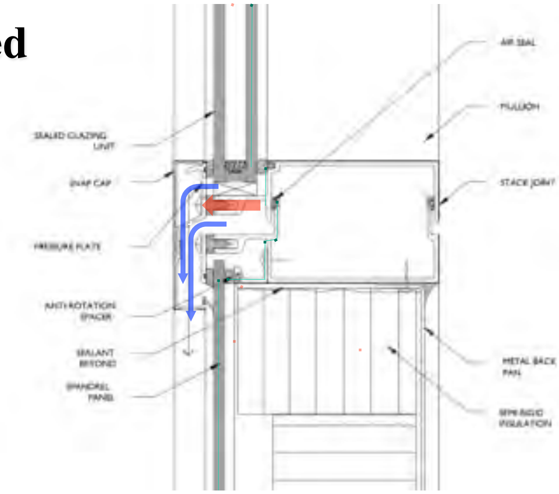
Unitized



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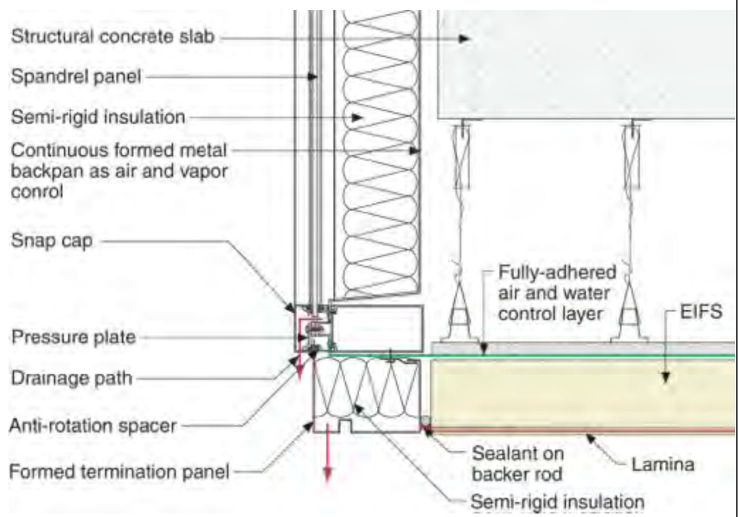

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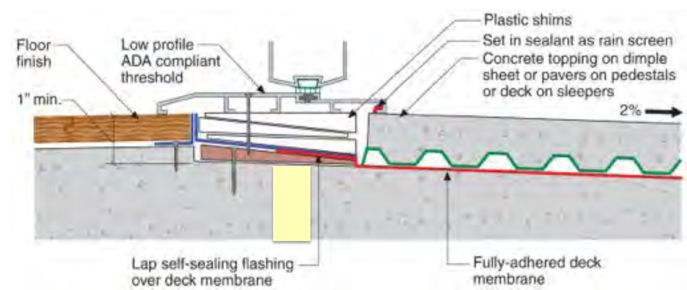

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Total Window

- Remember for total window installed, need to consider
  - IGU
  - Spacer
  - Window frame
  - Rough opening

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Window Overall U-value

$$U_w = (U_c A_c + U_e A_e + U_f A_f)/A_w$$

where

- U_w = U-value of complete window product
- U_c = calculated centre of glass U-value
- U_e = calculated edge of glass U-value
- U_f = calculated frame U-value
- A_c = centre of glass area
- A_e = edge of glass area
- A_f = frame area
- A_w = total window area

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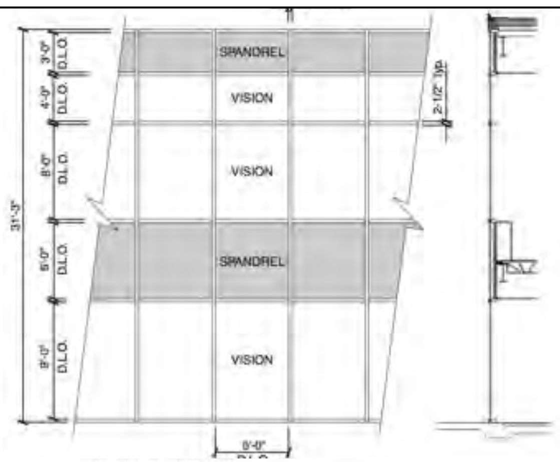

Vision Area = 5(9 + 8 + 4) = 105.0 ft²

Total Area (Vision) = 5' 2-1/2"(9' 3-3/4"+ 8' 2-1/2" + 4' 2-1/2") = 113.2 ft²

Percent of Vision Glass = (Vision Area ÷ Total Area)100 = (105.0 ÷ 113.2)100 = 93%

Courtesy Kawneer

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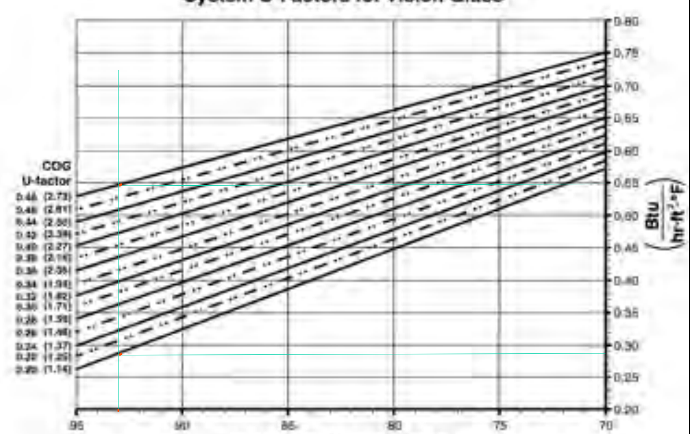
Example Kawneer 1600

System U-Factors for Vision Glass



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Glazing size matter

Example: curtainwall
- 4’ x4’ lite size (4’ x 4’) = 16
- Total Area: (4’2.5” x 4’2.5”) =17.71
- Percent Vision: 90%

Example: punched window
- 2’6” x6’ clear glass size = 15
- Total Area: (2’6”+5”) =18.71
- Percent Vision: 80%

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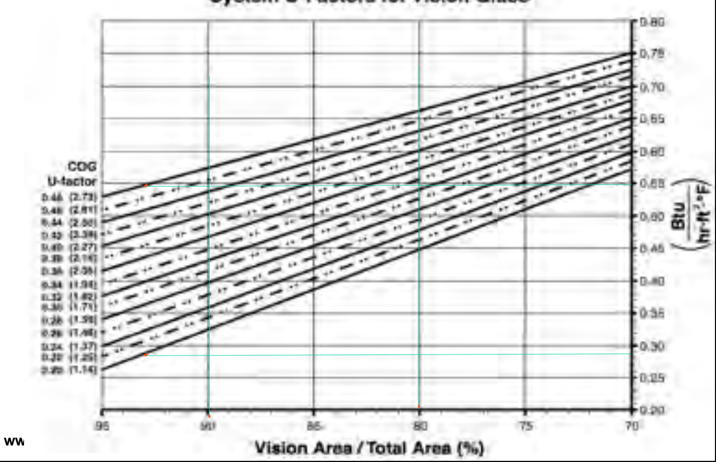
Example Kawneer 1600



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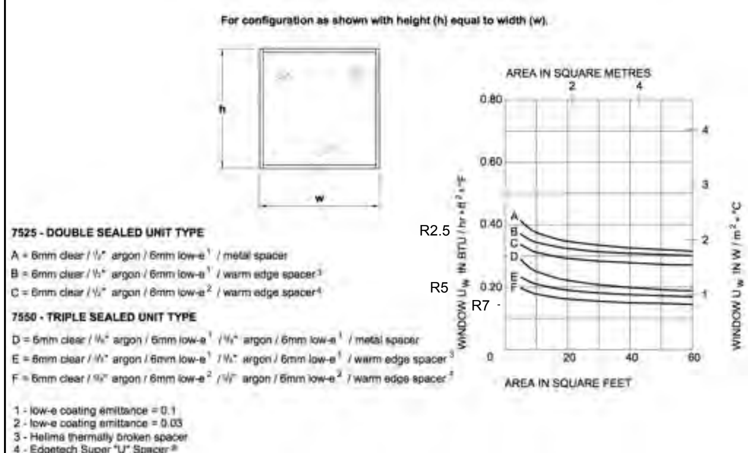
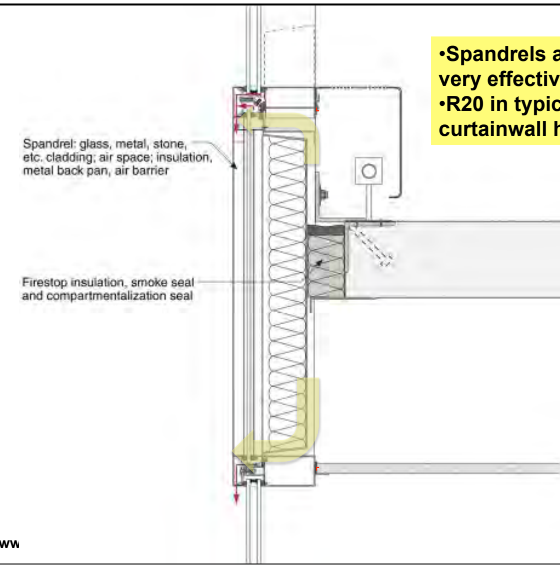
Example Kawneer 7550





- Spandrels are not very effective
- R20 in typical curtainwall has R5

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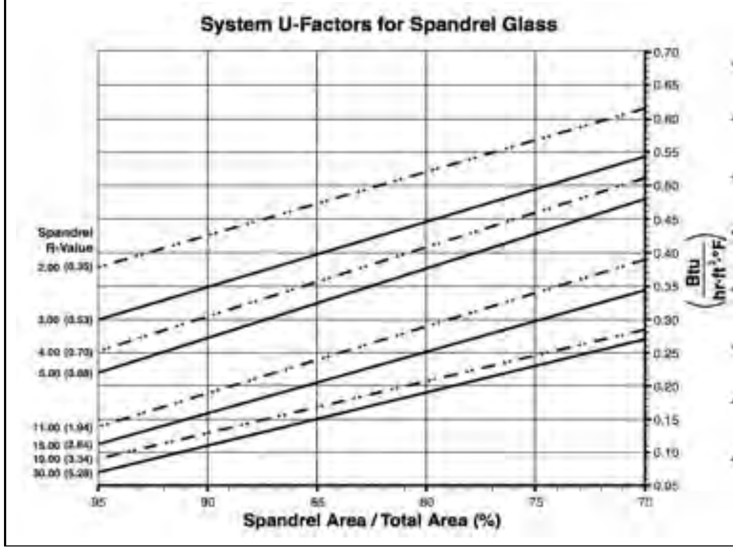

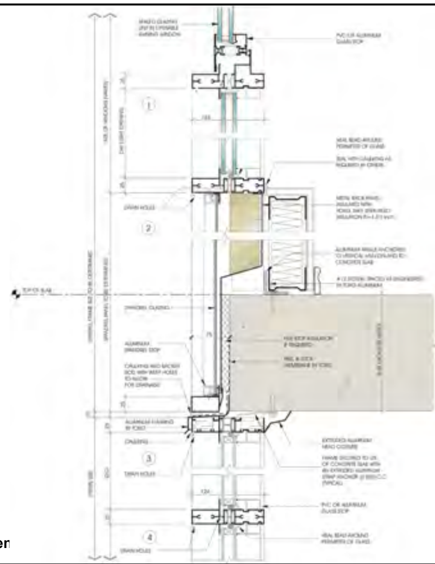

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Total System Impacts

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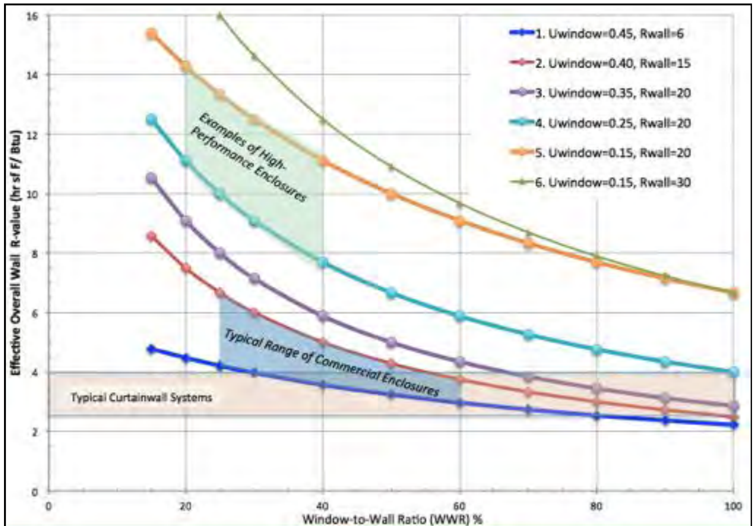

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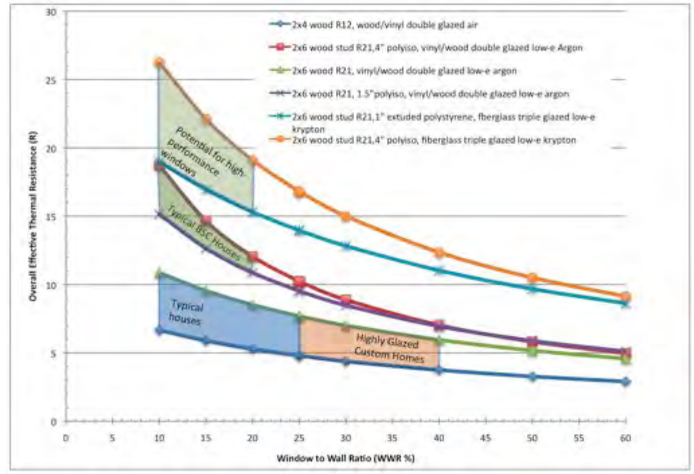

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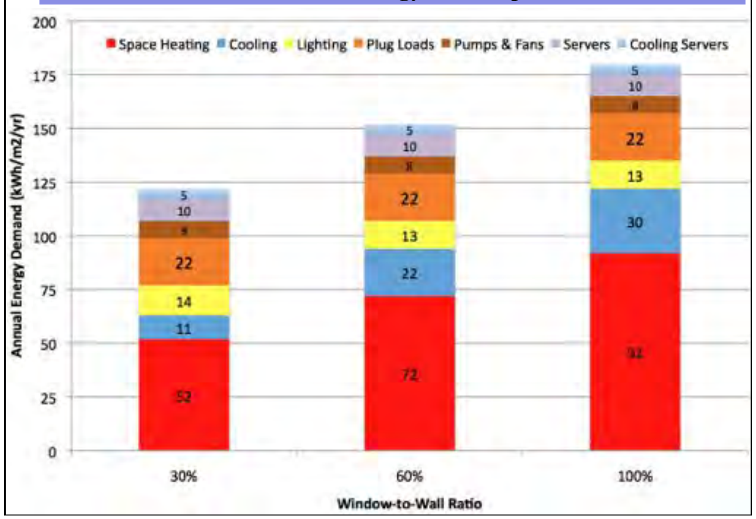
Windows and

More Windows means more energy consumption in a cold climate



Solar Heat Gain Control

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Solar Control and Shading

- Solar Control Glass
- Fixed exterior
- Operable Exterior
- Operable interior

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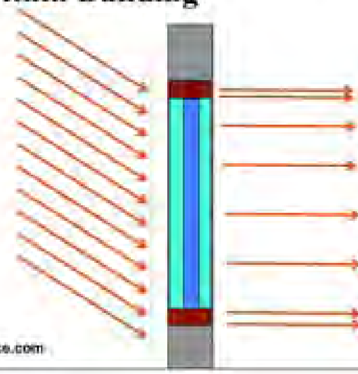
Solar Heat Gain

- SHGC = Ratio of Solar Incident to Heat Gain within Building



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Solar Gain

- Solar gain useful during cold sunny weather
- But … least heating is needed during daytime for commercial buildings
- Overheating discomfort is a real risk
- Must size glass Area x SHGC carefully
  - High values = air conditioning and discomfort

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Impact of Angle

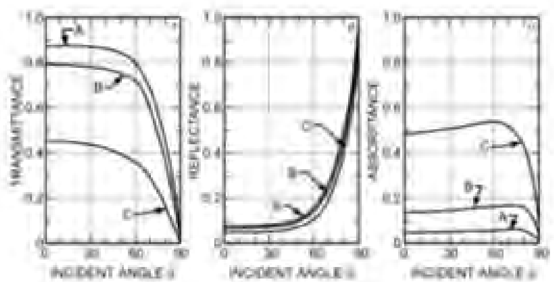

Fig. 8 Variations with Incident Angle of Solar-Optical Properties for (A) Double-Strength Sheet Glass, (B) Clear Plate Glass, and (C) Heat-Absorbing Plate Glass

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Solar Properties

Table 10 Visible Transmittance (T_v), Solar Heat Gain Coefficient (SHGC), Solar Transmittance (T), Front Reflectance (R^f), Back Reflectance (R^b), and Layer Absorptance ($\mathcal{A}^f_n$) for Glazing and Window Systems (*Continued*)

	Glazing System				Center-of-Glazing Properties							Total Window SHGC at Normal Incidence				Total Window T_v at Normal Incidence			
					Incidence Angles							Aluminum		Other Frames		Aluminum		Other Frames	
ID	Glass Thick., mm		Center Glazing T_v		Normal 0.00	40.00	50.00	60.00	70.00	80.00	Hemis., Diffuse	Operable	Fixed	Operable	Fixed	Operable	Fixed	Operable	Fixed
Low-e Double Glazing, e = 0.2 on surface 2																			
17a	3	LE CLR	0.76	SHGC	0.65	0.64	0.61	0.56	0.43	0.23	0.57	0.59	0.60	0.53	0.58	0.68	0.68	0.61	0.67
				T	0.59	0.56	0.54	0.48	0.36	0.18	0.50								
				R^f	0.15	0.16	0.18	0.24	0.37	0.61	0.22								
				R^b	0.17	0.18	0.20	0.26	0.38	0.61	0.24								
				$\mathcal{A}^f_1$	0.20	0.21	0.21	0.21	0.20	0.16	0.20								
				$\mathcal{A}^f_2$	0.07	0.07	0.08	0.08	0.07	0.05	0.07								

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Spectrally Selective

- Allows low SHGC and high VT
- Coolness Factor (LSG)
  - VT / SHGC
  - Look of 1.7-2.0
  - E.g. VT=0.60, SHGC=0.30, LSG=2

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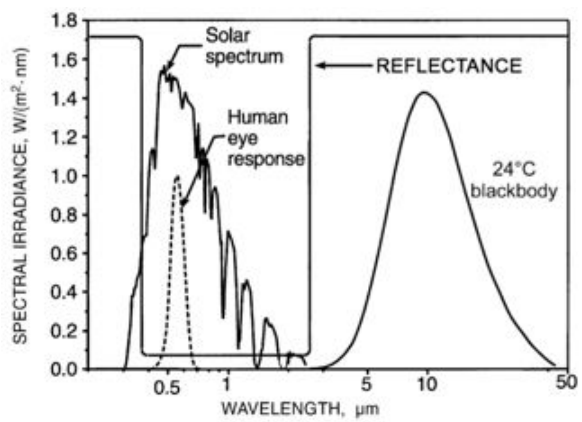
Solar Control Glazing



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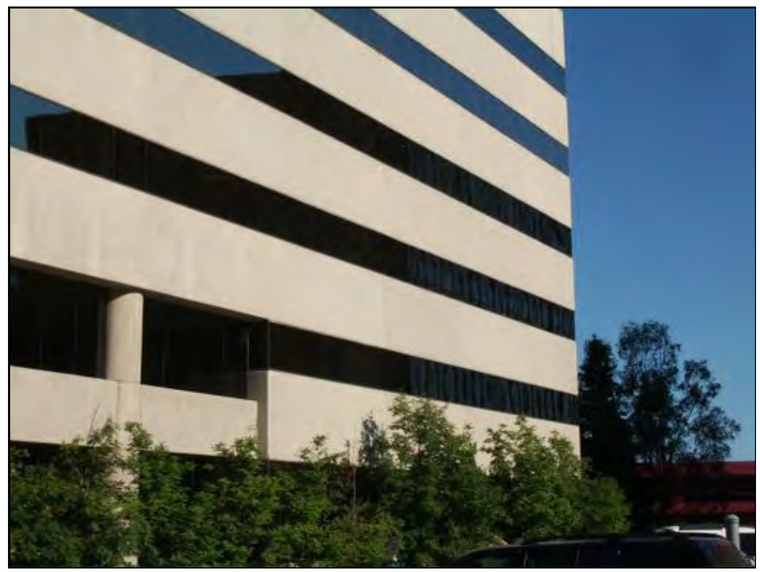

Fixed Shade

- **Only work some of the time**
- **Allow all diffuse light in**
  - **This is good for daylight and view!**
- **Limits solar reduction to about 50-60%**
- **Often can get shoulder season over heating**

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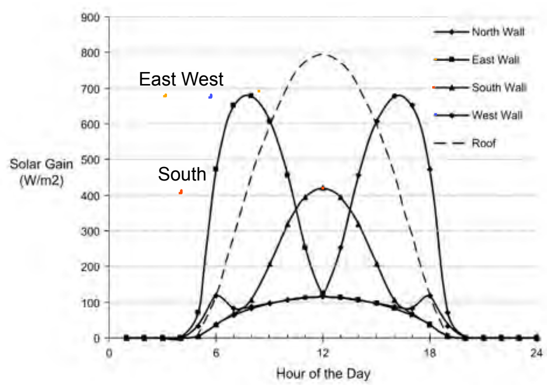
Solar Gains - July 21 @45 N



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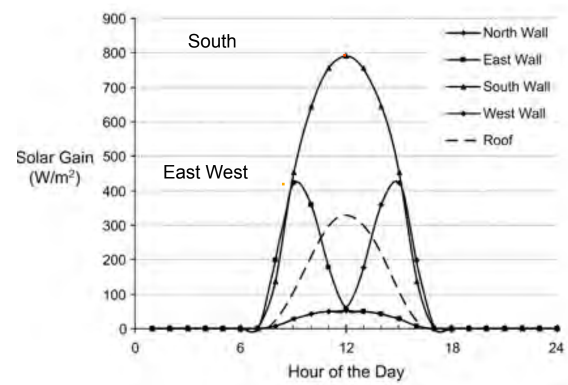
Mother Nature is try to tell you something



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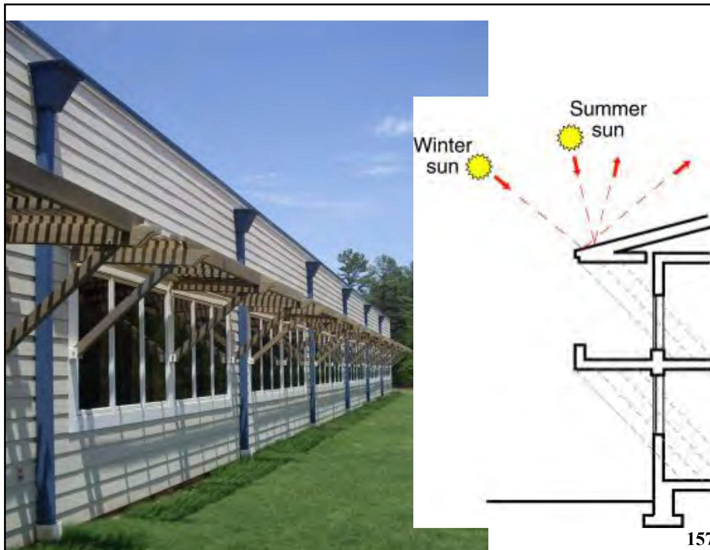

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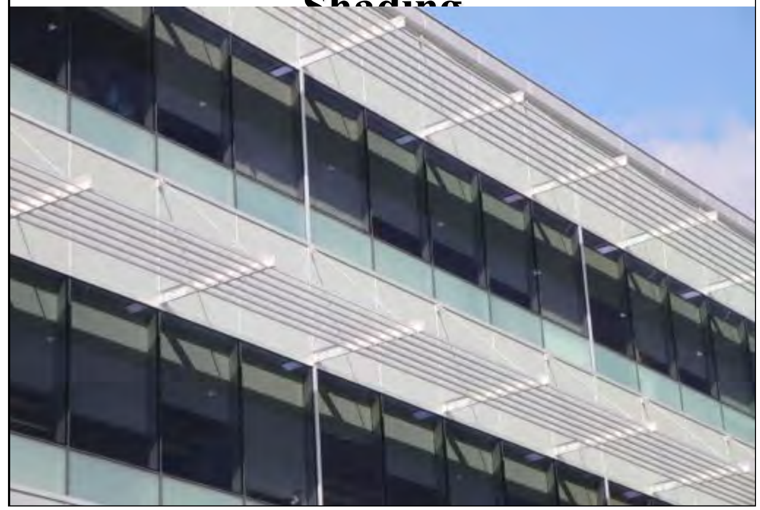
Shading



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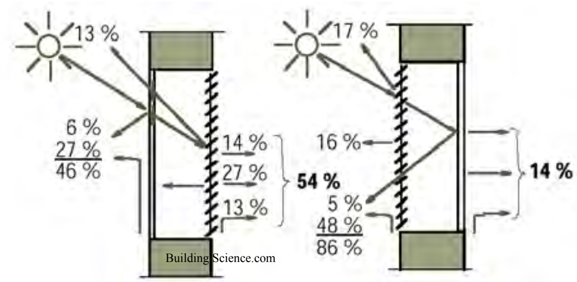
Interior or Exterior Shade

- Operable Solar Control of windows may be necessary for ultra-low energy buildings
- Exterior Shades always beat low SHGC glazing
  - But increased cost capital and maintenance
- Interior shades don't work well with good windows



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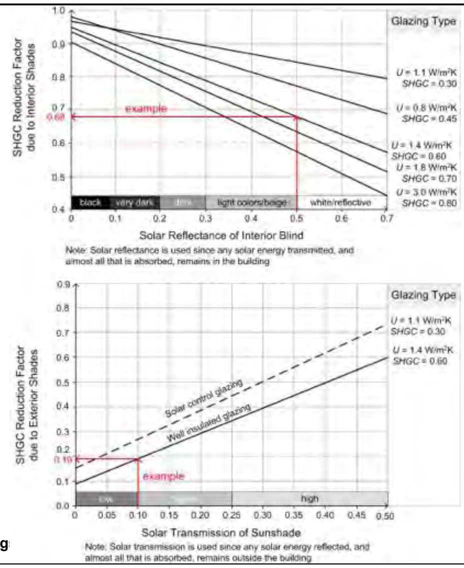

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Solar Control + shades

Double Glazing Results **Gas fill is 90% Ar**
SB70XL Strph-6 (5439) & Clear_6.PPG (5012), Low-e 2

	Case	Measure	0	rb	vb30	vb60	vb85
Summer	Interior	U-Value	4.3	4.9	4.9	4.9	4.9
	Shade	SHGC	0.27	0.2	0.24	0.2	0.16
	Exterior	U-Value	4.3	5.0	4.9	5.1	5.3
	Shade	SHGC	0.27	0.13	0.2	0.07	0.02
	Shade	U-Value	4.3	6.0	6.9	7.6	8.2
	Between	SHGC	0.27	0.16	0.23	0.16	0.11
Winter	Interior	U-Value	4.2	5.1	5.0	5.2	5.4
	Shade	SHGC	0.27	0.19	0.23	0.19	0.16
	Exterior	U-Value	4.2	5.5	5.5	5.6	5.6
	Shade	SHGC	0.27	0.13	0.2	0.07	0.02
	Shade	U-Value	4.2	4.3	4.4	4.3	4.3
	Between	SHGC	0.27	0.15	0.22	0.15	0.09

Triple Glazing Results **Gas fill is 90% Ar**
SB70XL Strph-6 (5439), LoE272-6.CIG (2014), Clear_6.PPG (5012), Low-e 2 & 4

	Case	Measure	0	rb	vb30	vb60	vb85
Summer	Interior	U-Value	7.2	7.7	7.7	7.7	7.7
	Shade	SHGC	0.18	0.15	0.16	0.15	0.13
	Exterior	U-Value	7.2	8.0	7.8	8.2	8.5
	Shade	SHGC	0.18	0.09	0.13	0.05	0.01
	Shade	U-Value	7.2	7.5	7.0	6.9	7.2
	Between	SHGC	0.18	0.11	0.15	0.1	0.06
Winter	Interior	U-Value	8.1	9.0	8.9	9.0	9.3
	Shade	SHGC	0.18	0.15	0.16	0.15	0.13
	Exterior	U-Value	8.1	9.5	9.3	9.5	9.5
	Shade	SHGC	0.18	0.09	0.14	0.05	0.01
	Shade	U-Value	8.1	8.4	8.4	8.4	8.4
	Between	SHGC	0.18	0.11	0.14	0.1	0.06

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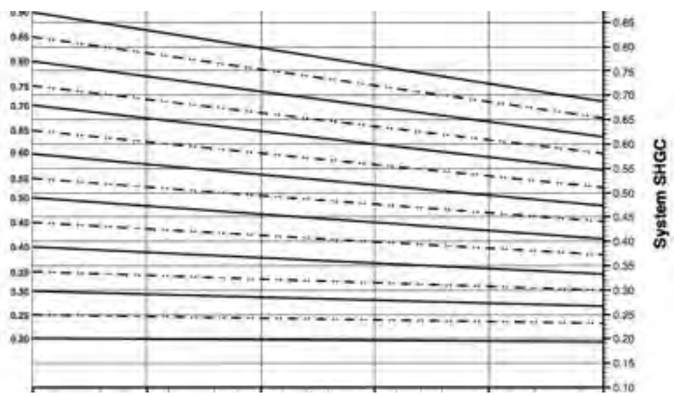
Kawneer 1600 SHGC



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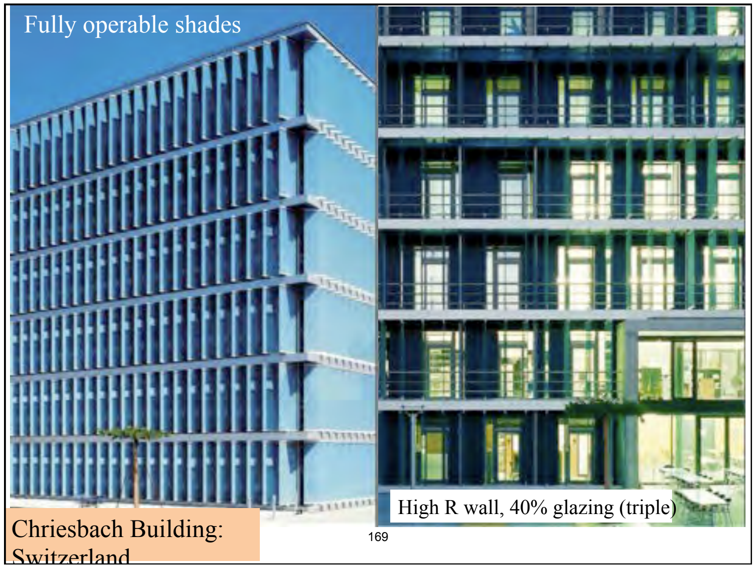
Fully operable shades
High R wall, 40% glazing (triple)
Chriesbach Building:
Switzerland
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65 kWh/m^2/yr
=20 kBtu/ft^2/yr
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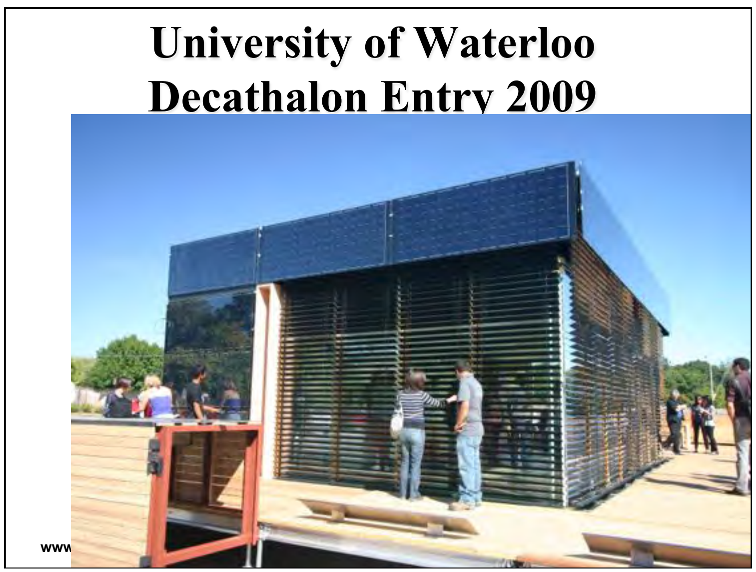
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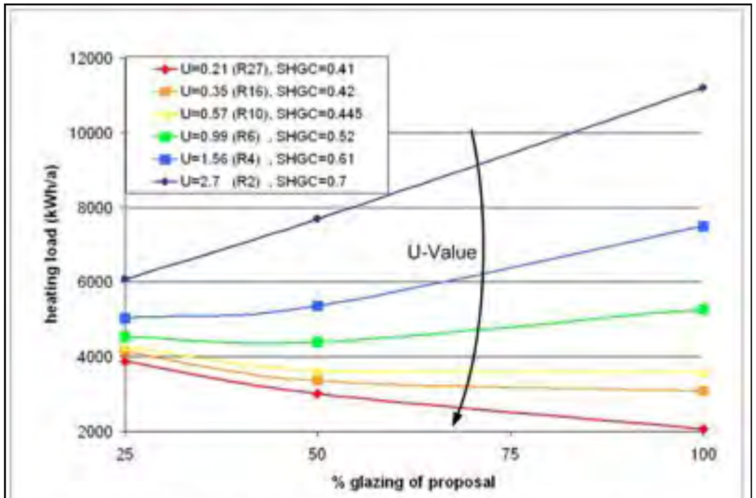

Figure 3.3.1 b): Heating load vs. % glazing of proposal for various windows.

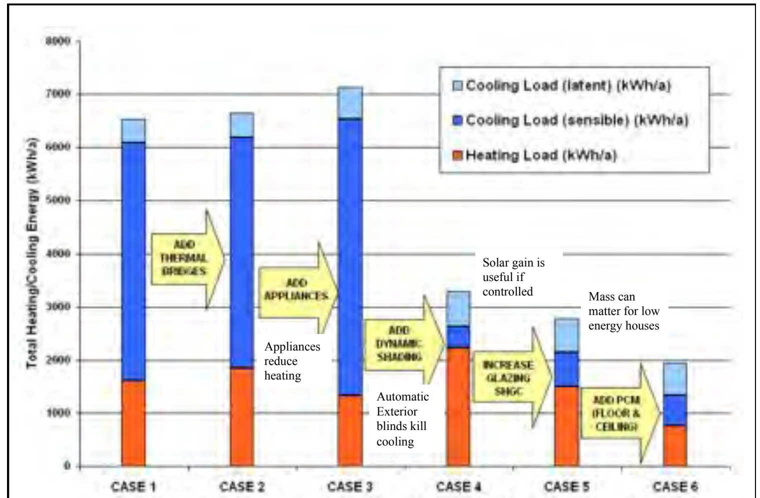

Figure 3.6.1 b: ESP-r simulation results for the refined house model.

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