fenestration canada

Understanding Thermal Performance for Fenestration Products

PRESENTED FOR FENESTRATION MANITOBA

PRESENTED BY
JEFF BAKER, M.A.SC., P.ENG.
FENESTRATION CANADA TECHNICAL CONSULTANT

FEBRUARY 9, 2016

Fenestration Canada Disclaimer:

Nothing in this handout or presentation constitutes legal advice. Material is presented as general guidance and technical information from Fenestration Canada - a not-for-profit organization. Consult with a lawyer, accountant, and insurance professional before making any decisions.

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

1. Regulatory:

A. Building Energy Codes

B. Energy Acts

C. Non-Regulatory Programs

fenestration canada

1. Regulatory:

A. Building Energy Codes

a. Energy Code regulate products going into buildings where a building permit is required

i. Written at the National level

ii. Adopted at the Provincial level

iii. Enforced at the local level

iv. Final says is in the hands of the local building official

b. Energy Codes also regulates products used in the replacement fenestration market, but enforcement is non-existent

1. Regulatory:

A. Building Energy Codes

a. Manitoba Energy Code requirements

i. Commercial Buildings – December 2014

Table 3.2.2.3.
Overall Thermal Transmittance of Fenestration
Forming Part of Sentences 3.2.2.3.(2) and (3)

Component	Heating Degree-Days of *Building* Location,(1) in Celsius Degree-Days					
	Zone 4:(2) < 3000	Zone 5:(2) 3000 to 3999	Zone 6:(2) 4000 to 4999	Zone 7A:(2) 5000 to 5999	Zone 7B:(2) 6000 to 6999	Zone 8:(2) ≥ 7000
	Maximum *Overall Thermal Transmittance*, in W/(m²·K)					
All *fenestration*	2.4	2.2	2.2	2.0	2.0	1.6

ii. Residential Buildings (Part 9) – April 1, 2016

Table 9.36.2.7.A.
Required Thermal Characteristics of Fenestration and Doors
Forming Part of Sentence 9.36.2.7.(1)

Components	Thermal Characteristics(1)	Heating Degree-Days of *Building* Location,(2) in Celsius Degree-Days					
		Zone 4 < 3000	Zone 5 3000 to 3999	Zone 6 4000 to 4999	Zone 7A 5000 to 5999	Zone 7B 6000 to 6999	Zone 8 ≥ 7000
Fenestration(3) and doors	Max. U-value, W/(m²·K)	1.80	1.80	1.60	1.60	1.40	1.40
	Min. Energy Rating	21	21	25	25	29	29

fenestration canada

1. Regulatory:

B. Energy Acts

a. National Energy Act – regulates product sold in Canada that cross a border

i. Manufactured in Manitoba and sold in Ontario the National Energy Act would apply

ii. Manufactured in Manitoba and sold in Manitoba the National Energy Act would not apply

iii. Manufactured outside Canada and shipped anywhere in Canada the National Energy Act would apply

iv. To date fenestration products have not been regulated under the National Energy Act

1. Regulatory:

B. Energy Acts

a. Provincial Energy Act – regulates all products sold in a province

i. All products regardless of where they were manufactured are required to comply with the provincial energy act

ii. British Columbia Energy Act (under review)

i. Requires certification of energy performance

ii. Window, sliding glass doors, curtain wall, window wall and store front windows U-factor ≤ 2.0 W/m^{2}C

iii. Skylights U-factor ≤ 3.1 W/m^{2}C

iv. Foam filled doors must have an insulation with an RSI ≥ 0.875 m2K/W

v. Wood doors exempt

iii. Ontario Green Energy Act

i. Windows only at this time

ii. Requires certification of energy performance

iii. U ≤ 2.0 W/m^{2}C OR ER ≥ 17

fenestration canada

1. Regulatory:

C. Non-Regulatory Programs

a. ENERGY STAR for Fenestration

i. Marketing program not mandatory, but not participating could be a problem in the marketplace

b. ENERGY STAR for Homes

c. Net Zero Houses

d. Energuide for New Houses

e. R2000

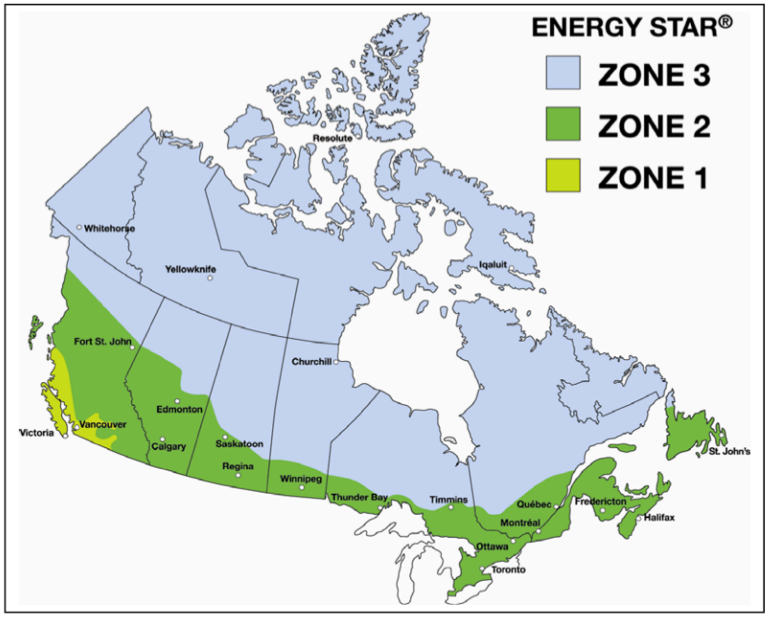
f. International Programs

fenestration canada

1. Regulatory:

a. ENERGY STAR for Fenestration
February 1, 2015 Windows

Zone 3: ≥ 6000 HDDs
Zone 2: 3500 to <6000 HDDs
Zone 1: <3500 HDDs



fenestration canada

1. Regulatory:

a. ENERGY STAR for Fenestration February 1, 2015 Windows

A. Windows

Table A1: Energy Rating Qualifying Criteria for Windows

Zone	Minimum Energy Rating Unitless	Maximum Air Leakage L/s/m2
1	25	1.5
2	29	1.5
3	34	1.5

Table A2: Alternate U-factor Qualifying Criteria for Windows

Zone	Maximum U-factor W/m2·K (Btu/h·ft.2·°F)	Minimum Energy Rating Unitless	Maximum Air Leakage L/s/m2
1	1.60 (0.28)	16	1.5
2	1.40 (0.25)	20	1.5
3	1.20 (0.21)	24	1.5

fenestration canada

1. Regulatory:

a. ENERGY STAR for Fenestration
February 1, 2015 Swinging Doors and Sliding Glass Doors

B. Doors

Table B1: Energy Rating Qualifying Criteria for Swinging Doors, Sidelites and Door Transoms

Zone	Minimum Energy Rating Unitless	Maximum Air Leakage L/s/m2
1	25	1.5
2	29	1.5
3	34	1.5

Table B2: Alternate U-factor Qualifying Criteria for Swinging Doors, Sidelites and Door Transoms

Zone	Maximum U-factor W/m2·K (Btu/h·ft.2·°F)	Maximum Air Leakage L/s/m2
1	1.60 (0.28)	1.5
2	1.40 (0.25)	1.5
3	1.20 (0.21)	1.5

Table B3: Energy Rating Qualifying Criteria for Sliding Glass Doors

Zone	Minimum Energy Rating Unitless	Maximum Air Leakage L/s/m2
1	25	1.5
2	29	1.5
3	34	1.5

Table B4: Alternate U-factor Qualifying Criteria for Sliding Glass Doors

Zone	Maximum U-factor W/m2·K (Btu/h·ft.2·°F)	Minimum Energy Rating Unitless	Maximum Air Leakage L/s/m2
1	1.60 (0.28)	16	1.5
2	1.40 (0.25)	20	1.5
3	1.20 (0.21)	24	1.5

fenestration canada

1. Regulatory:

a. ENERGY STAR for Fenestration
February 1, 2015 Skylights

C. Skylights

Table C1: Qualifying Criteria for Flat-glazed and Domed Skylights

Zone	Maximum U-factor W/m2·K (Btu/h·ft.2·°F)	Maximum Air Leakage L/s/m2
1	2.60 (0.46)	1.5
2	2.40 (0.42)	1.5
3	2.10 (0.37)	1.5

Table C2: Qualifying Criteria for Tubular Skylights

Zone	Maximum U-factor W/m2·K (Btu/h·ft.2·°F)	Maximum Air Leakage L/s/m2
All	2.60 (0.46)	1.5

fenestration canada

1. Regulatory:

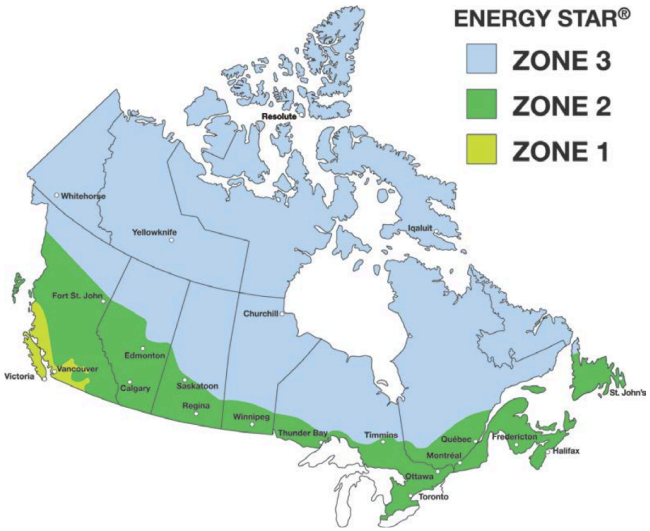
b. ENERGY STAR Homes

i. Natural Resources Canada program

ii. Requires Energy Star rated fenestratio

iii. ENERGY STAR fenestration requirements for three zones

Zone 3: ≥ 6000 HDDs
Zone 2: 3500 to <6000 HDDs
Zone 1: <3500 HDDs



fenestration canada

1. Regulatory:

c. Net Zero Houses

i. A Net Zero Energy house is one that is designed, modeled and constructed to produce as much energy as it consumes on an annual basis.

ii. Canadian Home Builder Association

  i. Net Zero Energy Houses

  ii. Net Zero Energy Ready Houses

iii. How Net Zero Energy Houses will be measured is yet to be determined

iv. As energy performance requirements for houses increase, fenestration energy performance become much more important

v. High performance windows will help builders meet Net Zero

fenestration canada

1. Regulatory:

d. Energuide for New Houses
   i. Natural Resources Canada program
   ii. No prescriptive requirements for fenestration
   iii. Requires computer modeling of the whole house
   iv. National Building Code 9.36 typical Rating 80

Typical Energy Efficiency Ratings

Type of House	Rating
New House build to building code standards	65-72
New house with some energy-efficiency improvements	73-79
Energy-efficient new house	80-90
House requiring little or no purchased energy	91-100

fenestration canada

1. Regulatory:

e. R2000

i. R2000 program run by the Canadian Home Builders Association – voluntary

ii. Based on the R2000 standard developed by Natural Resources Canada (NRCan)

iii. July 2012 Energy Rating requirements for windows was removed

iv. Prescriptive window requirement added

2012

- Removal of energy rating requirements for windows since the specifications were out of date. Minimum requirement is now only double glazed, low-e coating, etc. The more stringent R-2000 energy target should ensure that higher performing windows are installed.

4.3 Window Performance Requirements

Windows shall have the following minimum requirements: double-glazed window with a low-emissivity coating, inert gas fill, and an insulated spacer with a wood, vinyl or fiberglass frame.

Commentary

Decorative windows (side lights, windows in doors, half-circle windows, lead windows, transoms and other specialty glazing products) are allowed provided that the total glazing area of such decorative glazing does not exceed 15% of the total glazing surface area of the house. Canadian ENERGY STAR qualified windows meet or exceed these requirements. A list of these products can be found at: http://oee.nrcan.gc.ca/residential/business/manufacturers/search/windows-search.cfm.

fenestration canada

1. Regulatory:

f. International Programs

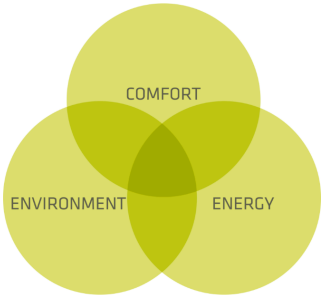
i. Active House
   i. Comfort, Environment, Energy

ii. Passive House
   i. Energy Efficient, Comfortable, and Affordable

ACTIVE HOUSE - A VISION

Buildings that give more than they take

Active House is a vision of buildings that create healthier and more comfortable lives for their occupants without impacting negatively on the climate – moving us towards a cleaner, healthier and safer world.



The Active House vision defines highly ambitious long-term goals for the future building stock. The purpose of the vision is to unite interested parties based on a balanced and holistic approach to building design and performance, and to facilitate cooperation on such activities as building projects, product development, research initiatives and performance targets that can move us further towards the vision.

About Passive House - What is a Passive House?

Passive House is a building standard that is truly **energy efficient**, **comfortable** and **affordable** at the same time.

1. Regulatory:

fenestration canada

Canadian Building Code, Energy Code, Energy Act and Energy Star Update

Updated: November 2, 2015

fenestration canada

Questions?

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

2. Compliance:

A. Performance Standards

B. U-factor (U)

C. Solar Heat Gain Coefficient (SHGC)

D. Visible Transmission (VT)

E. Energy Rating (ER)

F. Condensation Resistance (TI, CRF, CR)

fenestration canada

2. Compliance:

A. Performance Standards
   a. Canadian Standards Association (CSA)
      i. shop.csa.ca
      ii. CSA A440.2-14 – Fenestration Energy Performance
         i. Simulation and only test products that can not be simulated
   b. National Fenestration Rating Council (NFRC)
      i. www.nfrc.org
      ii. NFRC 100-14 Procedure for Determining Fenestration Product U-factors
         i. Combination of computer simulation and testing
      iii. NFRC 200-14 Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
         i. Simulation and only test products that can not be simulated
      iv. NFRC 500-14 Procedure for Determining Fenestration Product Condensation Resistance Values
         i. Combination of computer simulation and testing

2. Compliance:

B. U-factor (U)

a. NFRC U-factor Definition

U-factor, Thermal Transmittance (U): The heat transfer per time per area and per degree of temperature difference. The U-factor multiplied by the interior-exterior temperature difference and by the projected fenestration product area yields the total heat transfer through the fenestration product due to conduction, convection, and long-wave infra-red radiation.

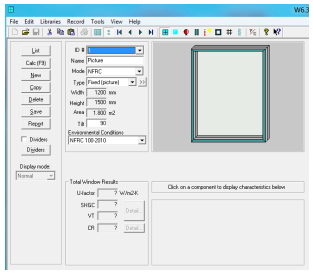
b. Testing for U-factor

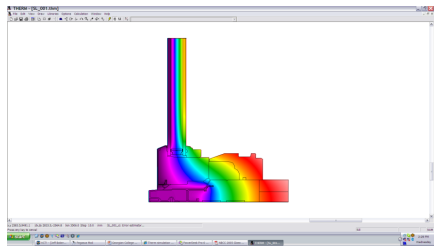
i. Guarded Hot-Box

c. Computer Simulation of U-factor

i. Window Program

ii. Therm Program





fenestration canada

2. Compliance:

B. U-factor (U)

a. CSA and NFRC

b. Metric – W/m^2C

c. Inch-pound – $BTU/hr*ft^2*F$

d. Conversion

a. U (metric) = U(inch-pound) * 5.678263

b. U(inch-pound) = U (metric) / 5.678263

2. Compliance:

C. Solar Heat Gain Coefficient (SHGC)

a. CSA and NFRC

b. NFRC SHGC definition

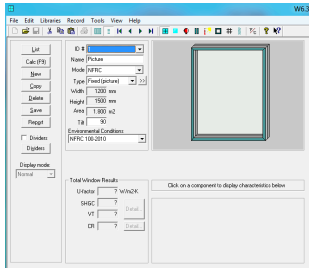
Solar Heat Gain Coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and that portion of the absorbed solar radiation which is then reradiated, conducted, or convected into the space.

c. Testing of SHGC

i. Solar Calorimeter

d. Computer Simulation of SHGC

i. Window Program



e. SHGHC (dimensionless)

2. Compliance:

D. Visible Transmission (VT)

a. CSA and NFRC

b. NFRC VT definition

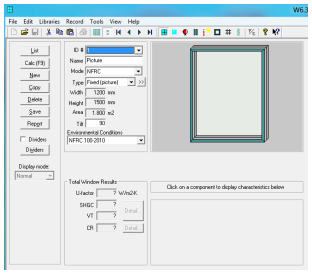
Visible Transmittance (VT): the ratio of visible radiation entering the space through the fenestration product to the incident visible radiation, determined as the spectral transmittance of the total fenestration system, weighted by the photopic response of the eye and integrated into a single dimensionless value. Weighted by a standard solar spectrum

c. Testing

i. NFRC does have a test procedure for VT, to cover products that can not be simulated

d. Computer Simulation of VT

i. Window Program



e. VT(dimensionless)

2. Compliance:

E. Energy Rating (ER)

a. CSA A440.2-14 ER equation (CSA only)

i. ER = 57.76*SHGC - 21.9*U – 1.97*L_{75} + 40

ii. ER is the result of an energy balance on the window or door, ER does not apply to skylights

iii. ER combines the solar heat gain, U-factor loss, Air Infiltration/ Exfiltration loss (L_{75}) and add 40 to make the ER a positive value

iv. The Manitoba Energy Code allows the use of U-factor **OR** ER as a means of proving compliance with the energy code

2. Compliance:

E. Energy Rating (ER)

a. CSA A440.2-14 ER equation

i. $ER = 57.76*SHGC - 21.9*U – 1.97*L_{75} + 40$
   i. SHGC (dimensionless, 2 decimal places)
   ii. U (W/m^2C, 2 decimal places)
   iii. L_{75} ($L/s/m^2$, 1 decimal place)
   iv. ER (dimensionless, zero decimal places)

ii. $ER = 57.76*SHGC - 21.9*U – 1.97*L_{75} + 40$
   i. SHGC (dimensionless, 2 decimal places)
   ii. U (metric) = U(inch-pound, $BTU/hr*ft^2F$, 2 decimal places)*5.678263, rounded to 2 decimal places
   iii. L_{75}(Metric) = L_{75}(inch-pound, CFM/ft^2, 1 decimal place) * 5.08, rounded to 1 decimal place
   iv. ER (dimensionless, zero decimal places)

fenestration canada

2. Compliance:

F. Condensation Resistance (TI, CRF, CR)

a. TI is the CSA A440.2 Temperature Index

i. TI is measured in a hot-box test to find the coldest measured temperature

ii. The larger the TI value the better the resistance to the formation of condensation

b. CRF is the AAMA Condensation Resistance Factor

i. CRF is measured in a hot-box test and the interior measured temperatures are weight to calculate the CRF

ii. The larger the CRF value the better the resistance to the formation of condensation

c. CR is the NFRC Condensation Resistance Rating Number

i. CR is a calculated value base on computer simulation

ii. The larger the CR value the better the resistance to the formation of condensation

d. TI, CRF and CR can not be equated to each other

fenestration canada

Questions?

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

3. Certification:

A. What is it?

B. Who provides certification services in Canada?

C. Is it required?

fenestration canada

3. Certification:

A. What is it?

a. Manufacturers Declaration of Conformity (self-declaration)

i. Is one way for a product manufacturer to show that a product conforms to a standard or technical regulation, in which a manufacturer provides written assurance of conformity to the specified requirements.

ii. The building code allow self-declaration for NAFS compliance. Manufacturers are required to test their products and provide a label that states the product conforms to NAFS.

b. Third Party Certification

i. Means that an independent organization has reviewed the manufacturing process of a product and has independently determined that the final product complies with specific standard or technical regulation.

ii. A certification organization will review the energy simulations and testing data provided by the simulation and test labs. Then they will perform in plant inspections to verify that the products being built are the same as the products simulated and tested.

fenestration canada

3. Certification:

B. Who provides certification services in Canada?

a. CSA A440.2 and NFRC 100 and 200 are both recognized in Canada

b. Standards Council of Canada recognizes the following organizations to certify to the CSA A440.2 standard:

i. CSA Certification (CSA)
ii. Intertek Testing Services (ITS)
iii. Quality Auditing Institute (QAI)

c. NFRC recognizes the following organizations as inspection agents under their certification program:

i. American Architectural Manufacturers Association (AAMA)
ii. Keystone Certification
iii. National Accreditation Management Institute (NAMI)
iv. Window and Door Manufacturers Association (WDMA)

fenestration canada

3. Certification:

C. Is it required?

a. Energy Code Compliance – No

b. Energy Act Compliance

i. BC – Yes (any of the seven programs)

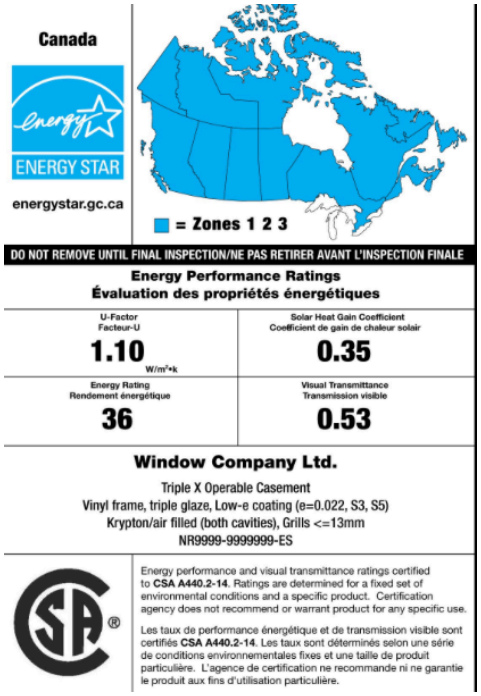
ii. Ontario – Yes (any of the seven programs)

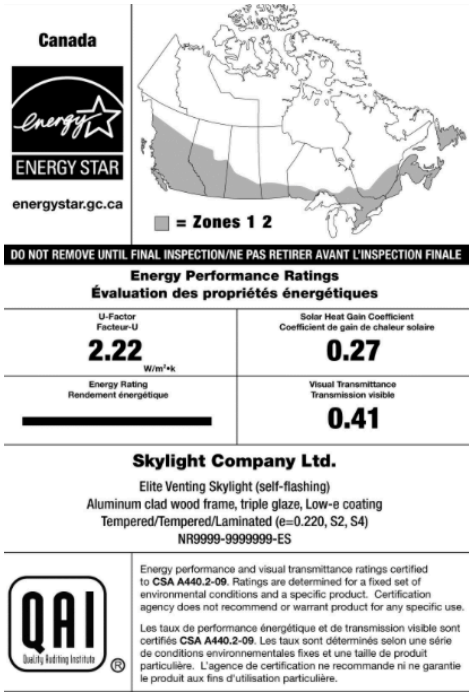
c. ENERGY STAR for Fenestration

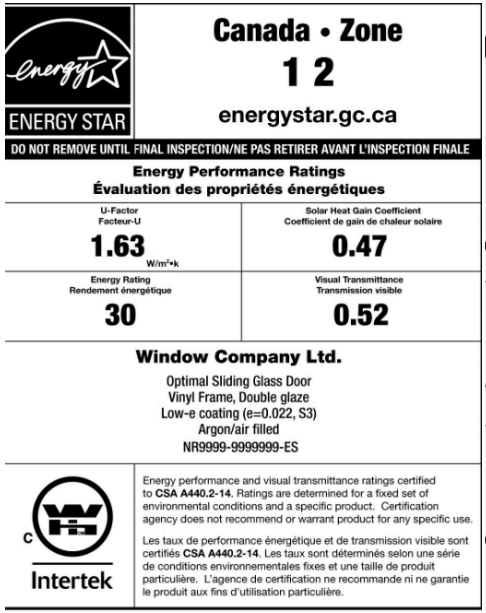
i. Yes (any of the seven programs)

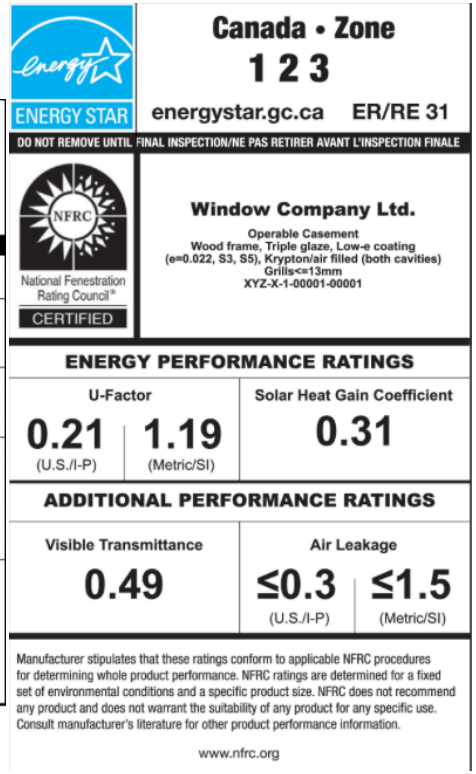
fenestration canada

3. Certification:









fenestration canada

Questions?

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

4. Fenestration Basics:

A. Radiation
   a. Short Wave
   b. Long Wave
B. Convection
   a. Natural
   b. Forced
C. Conduction

4. Fenestration Basics:

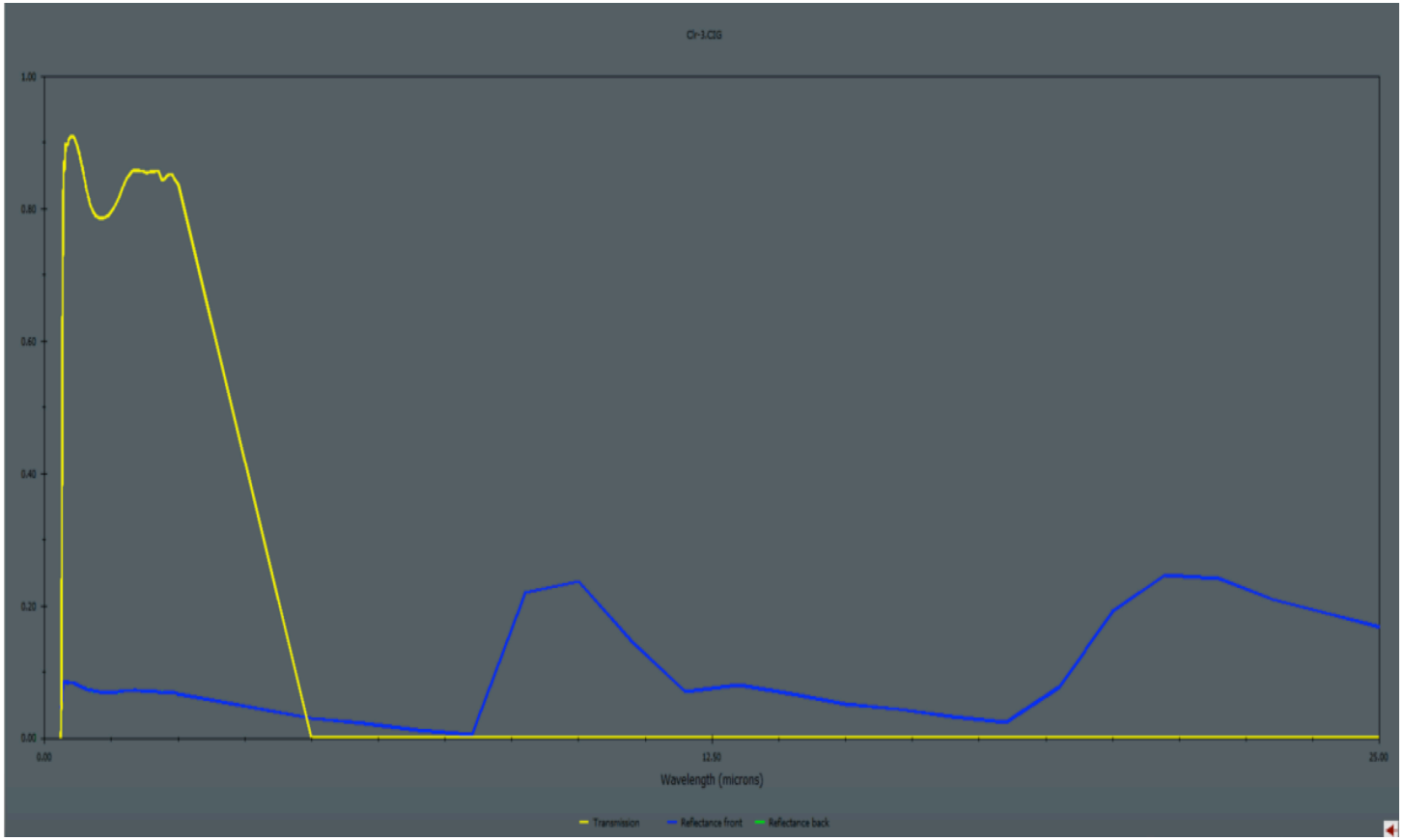
- Radiation - Short Wave
  - Very high temperature source
  - Solar Radiation
  - Transmission + Reflectance + Absorptance = 1
  - Glass allows short wave radiation to be transmitted
  - Low-e coating impact transmission, reflection and absorption

4. Fenestration Basics:

- Radiation - Short Wave
  - Low-e coating impact transmission and absorption
    - Single silver low-e glass high solar transmission, low reflectance, low absorptance (t=0.69, r=0.18, a=0.13)
    - Double silver low-e glass medium solar transmission, medium reflectance, medium absorptance (t=0.43, r=0.33, a=0.24)
    - Triple silver low-e glass low solar transmission, higher reflectance, higher absorptance (t=0.27, r=0.43, a=0.30)

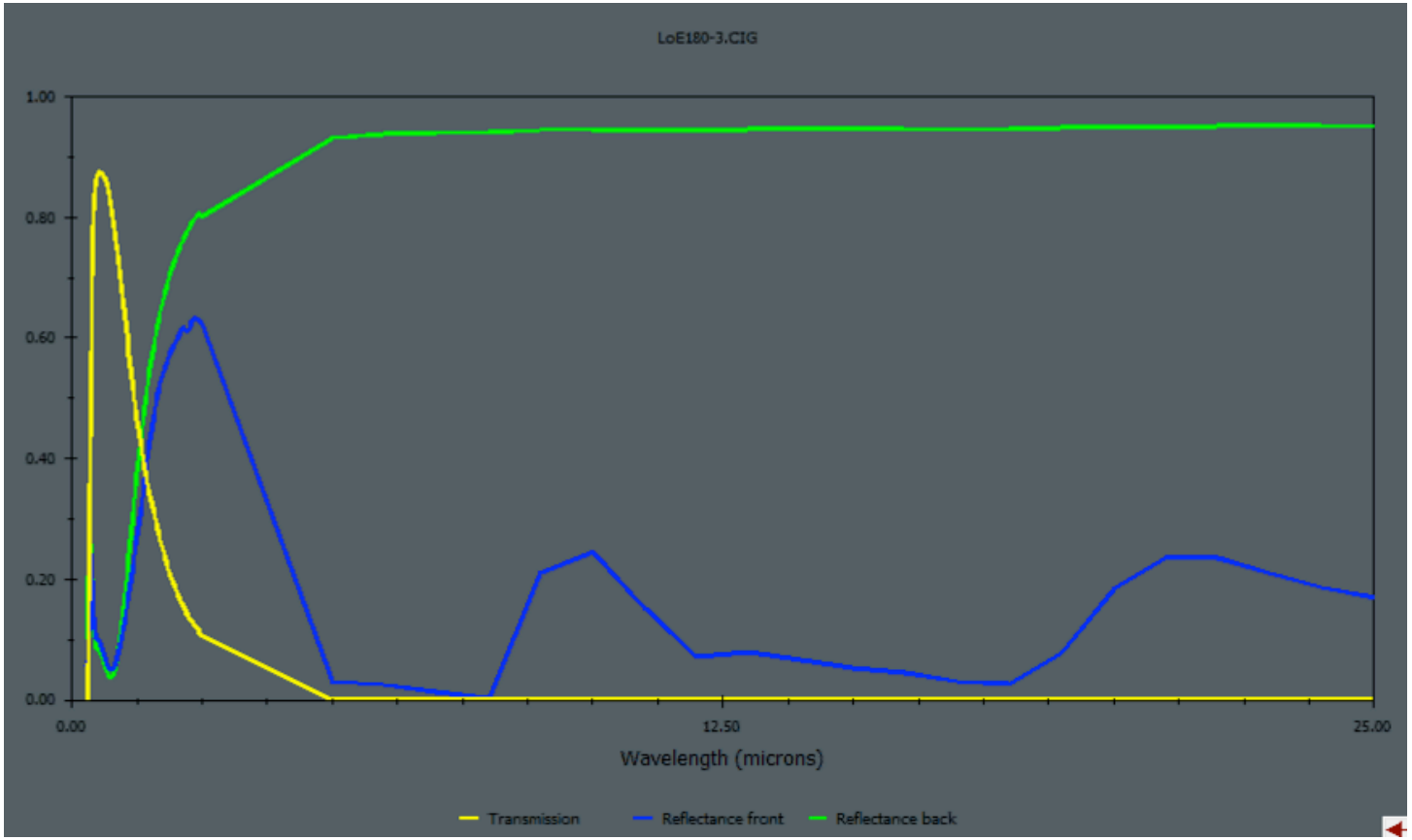
4. Fenestration Basics:

- Clear Glass Solar properties



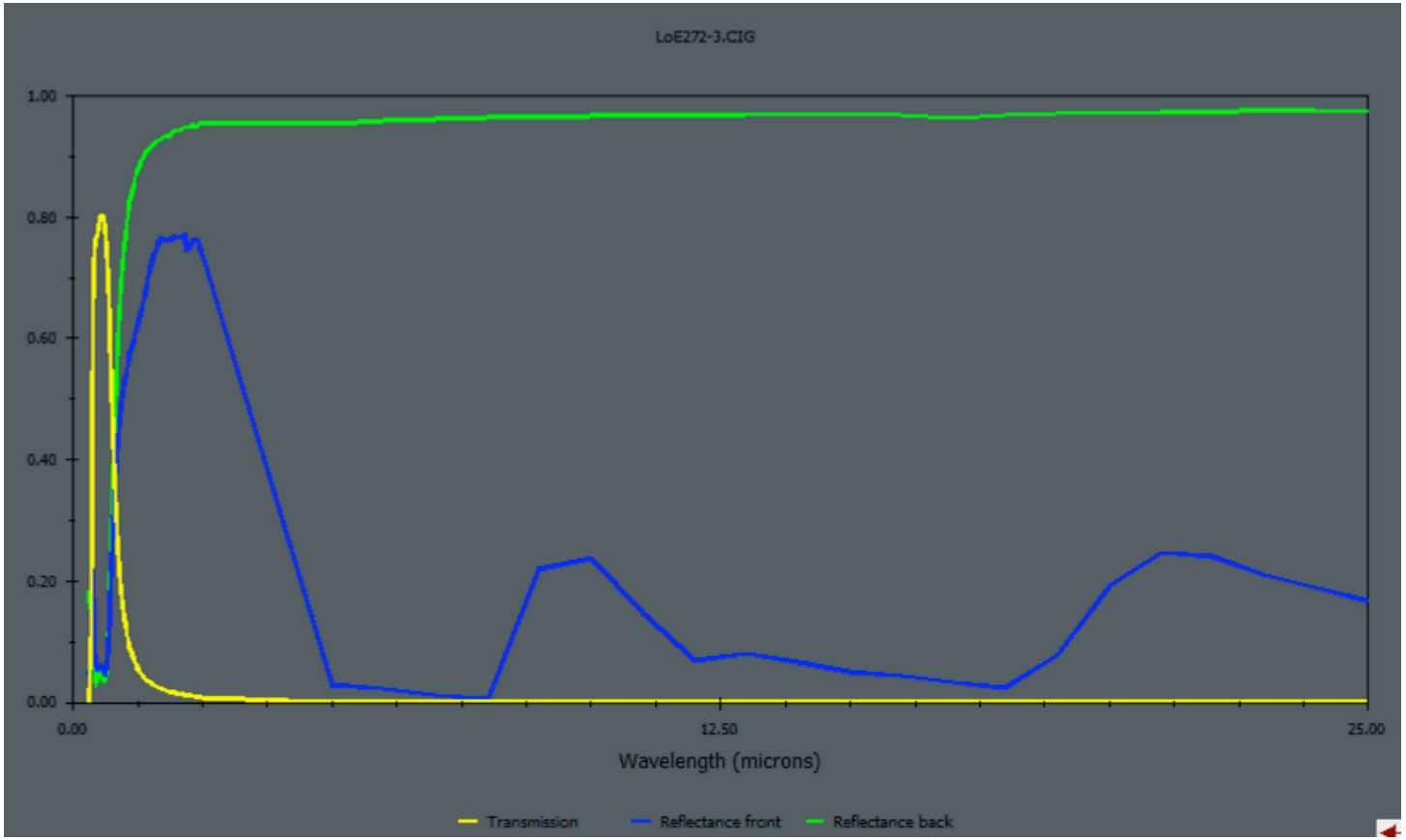
4. Fenestration Basics:

- Single Silver Low-e Coating Solar properties



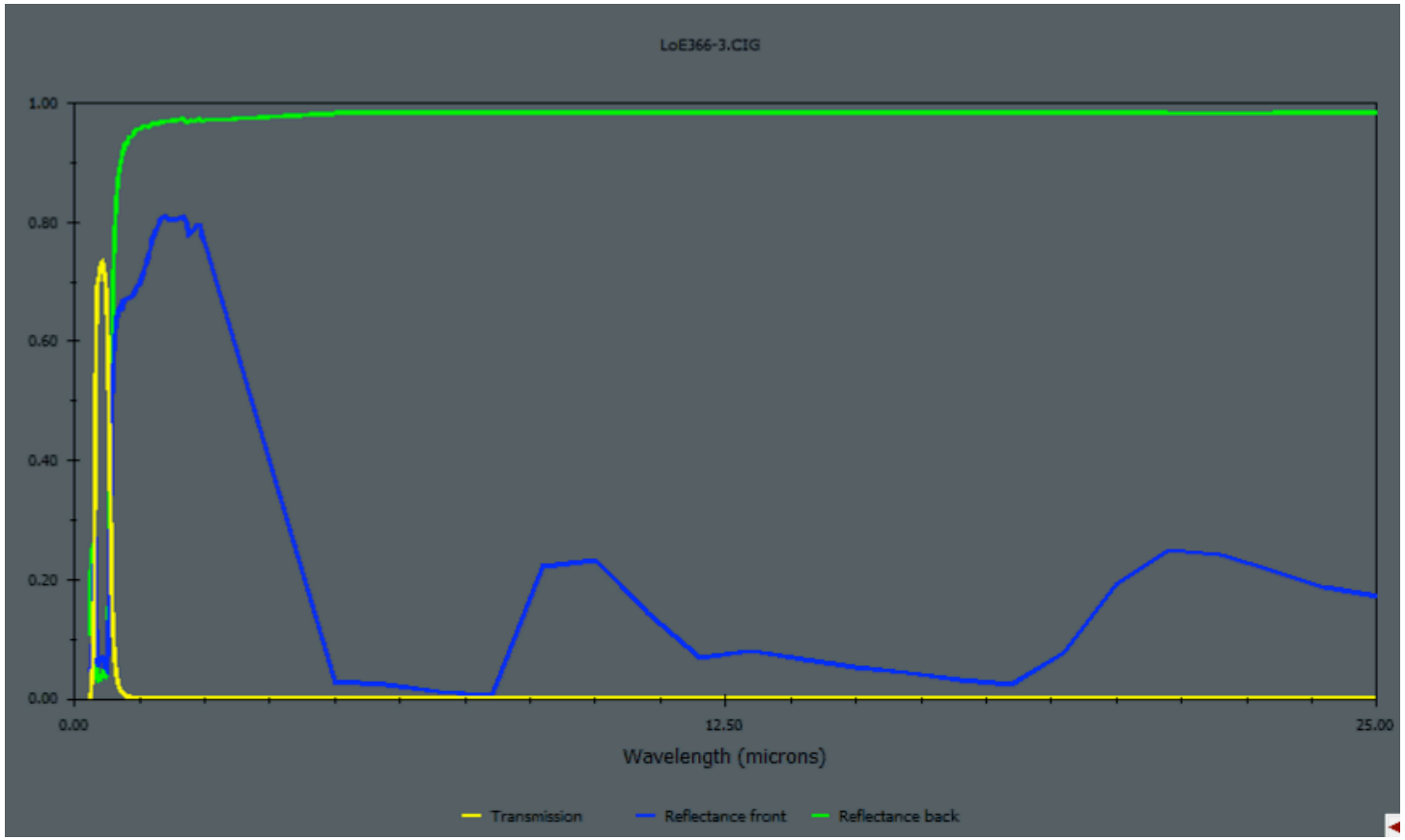
4. Fenestration Basics:

- Double Silver Low-e Coating Solar properties



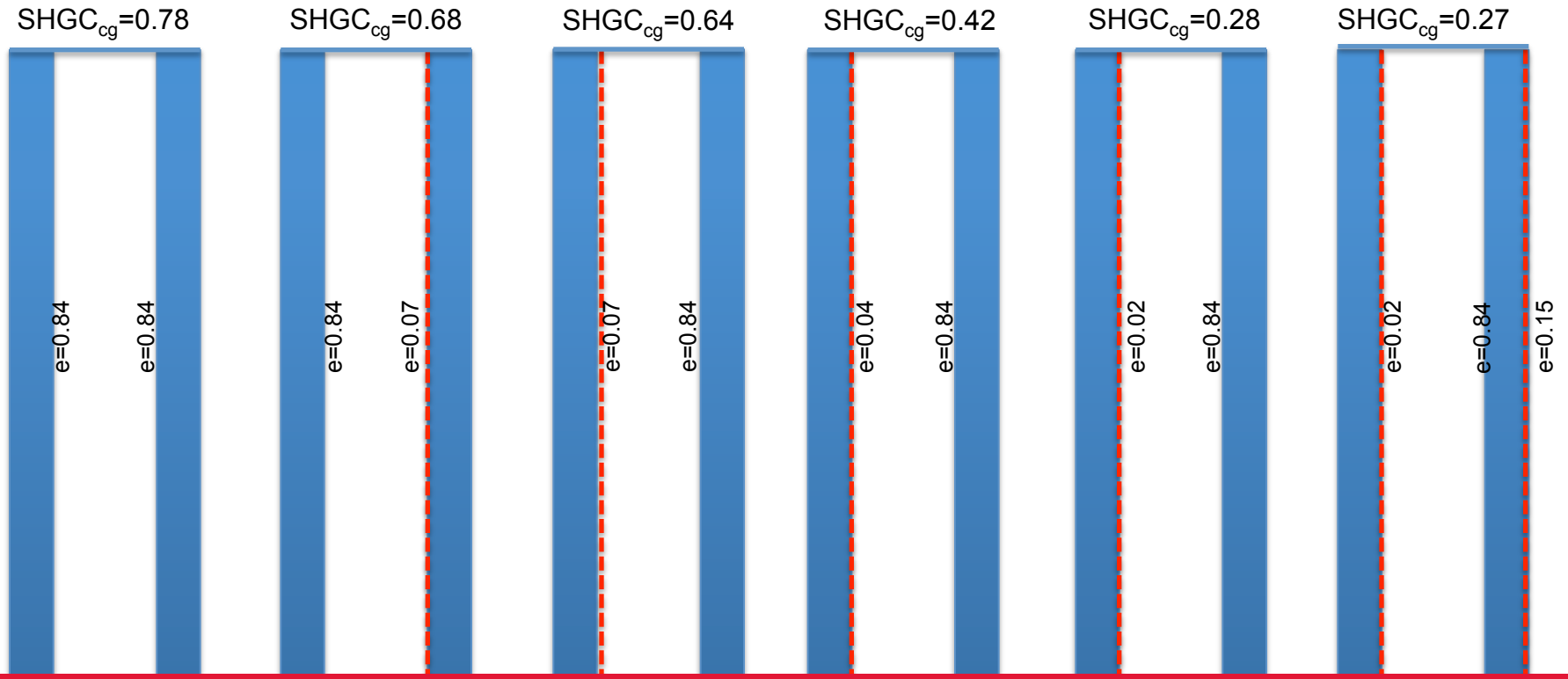
4. Fenestration Basics:

- Triple Silver Low-e Coating Solar properties



4. Fenestration Basics:

- Radiation – Short Wave
  - Double glazed, air filled, ½" cavity, 3mm glass

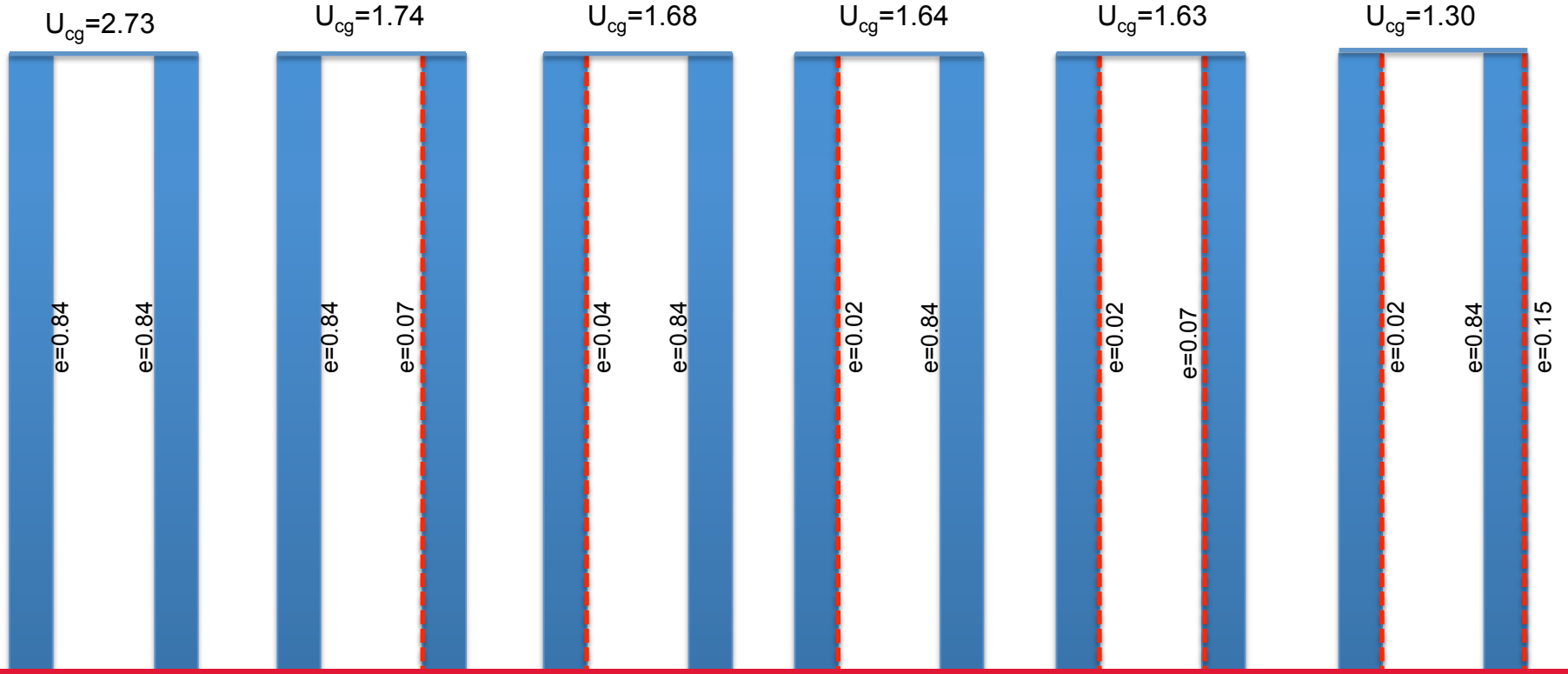


4. Fenestration Basics:

- Radiation – Long Wave
  - Thermal Radiation
  - Lower temperature source
    - Heat from a fire, heat from your body
  - Glass is opaque to long wave radiation
  - Reflectivity + Absorptance = 1
  - Low-e coatings impact reflection and absorption
  - Emissivity + Reflectivity = 1

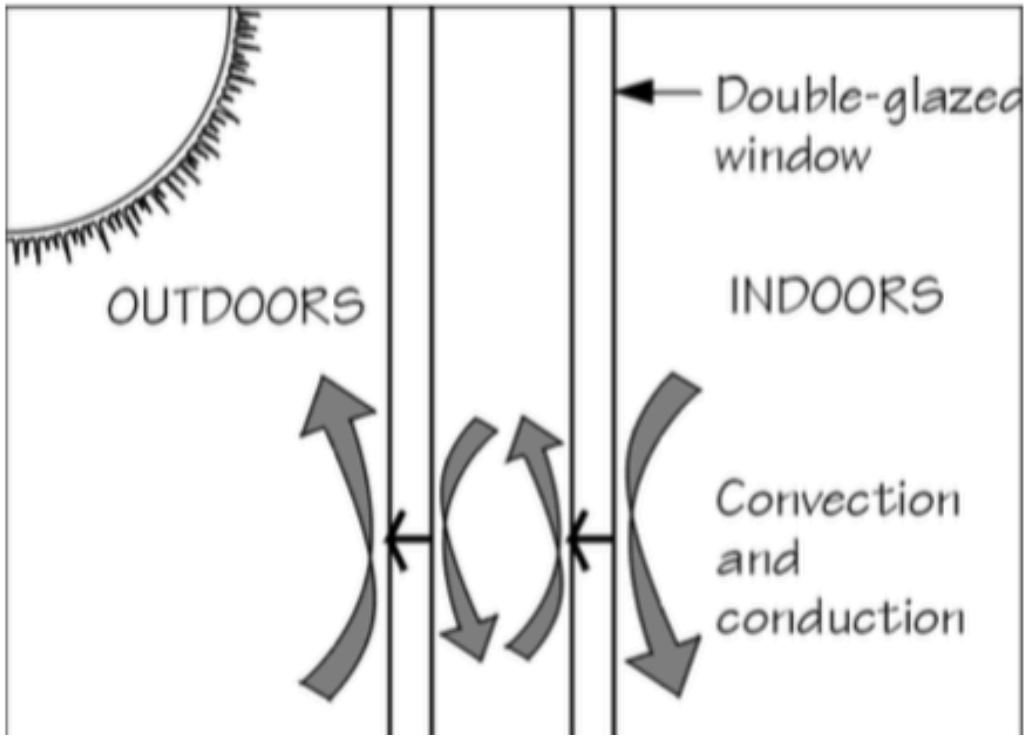
4. Fenestration Basics:

- Radiation – Long Wave
  - Double glazed, air filled, ½” cavity, 3mm glass



4. Fenestration Basics:

- Convection – Forced
  - Forced Convection in Fenestration
    - Wind speed on exterior surfaced
    - NFRC – 15mph
    - Design – any speed

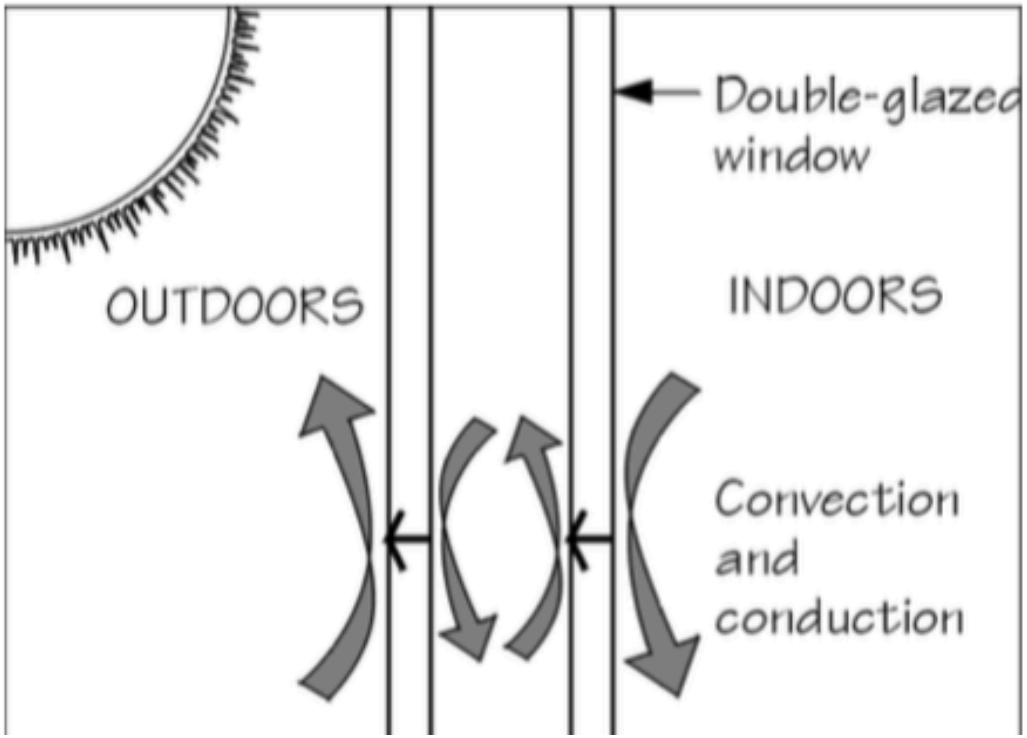


4. Fenestration Basics:

- Convection – Natural
  - Driven by the buoyancy of gas or liquid
  - Cooler gas or liquid becomes heavier and falls
  - Warmer gas or liquid becomes lighter and rises
  - Natural Convection in Fenestration
    - Interior surface of product
    - Between the glass layers
    - Frame Cavities

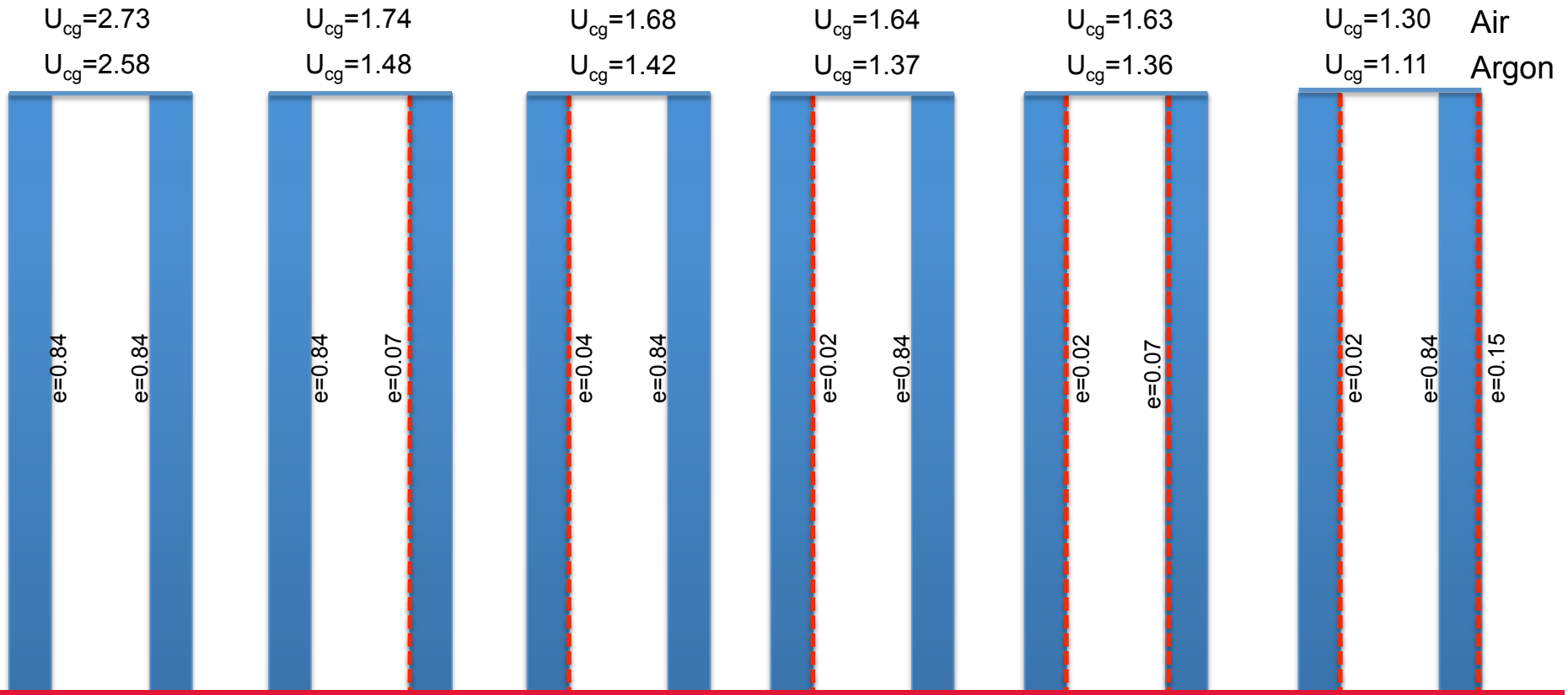
4. Fenestration Basics:

- Convection – Natural
  - Natural Convection in Fenestration
    - Interior Surface
      - Temperature Dependent
    - Between Glass Layers
      - Dependent on: Surface Temperatures, Gas Fill, and Cavity width



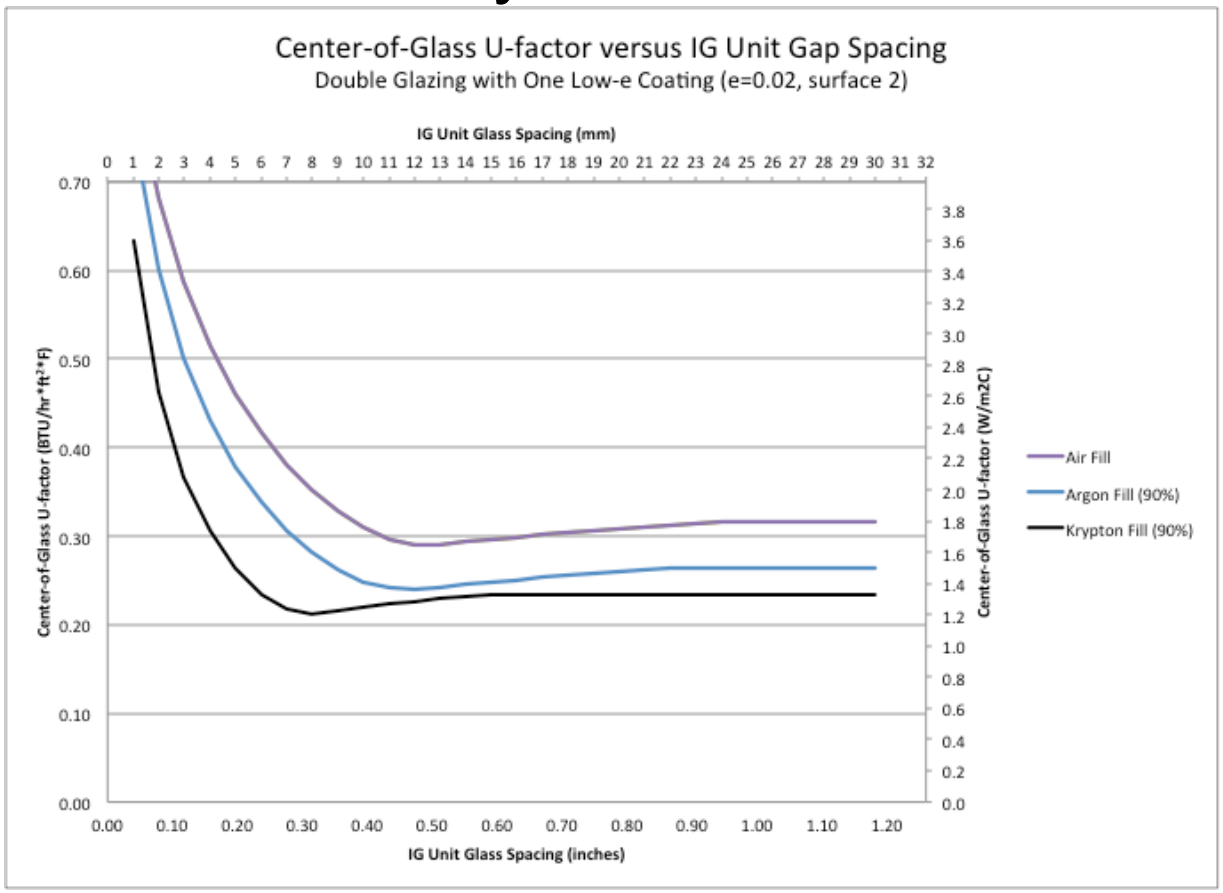
4. Fenestration Basics:

- Convection – Gas filled
  - Double glazed, ½” air filled and argon filled, 3mm glass



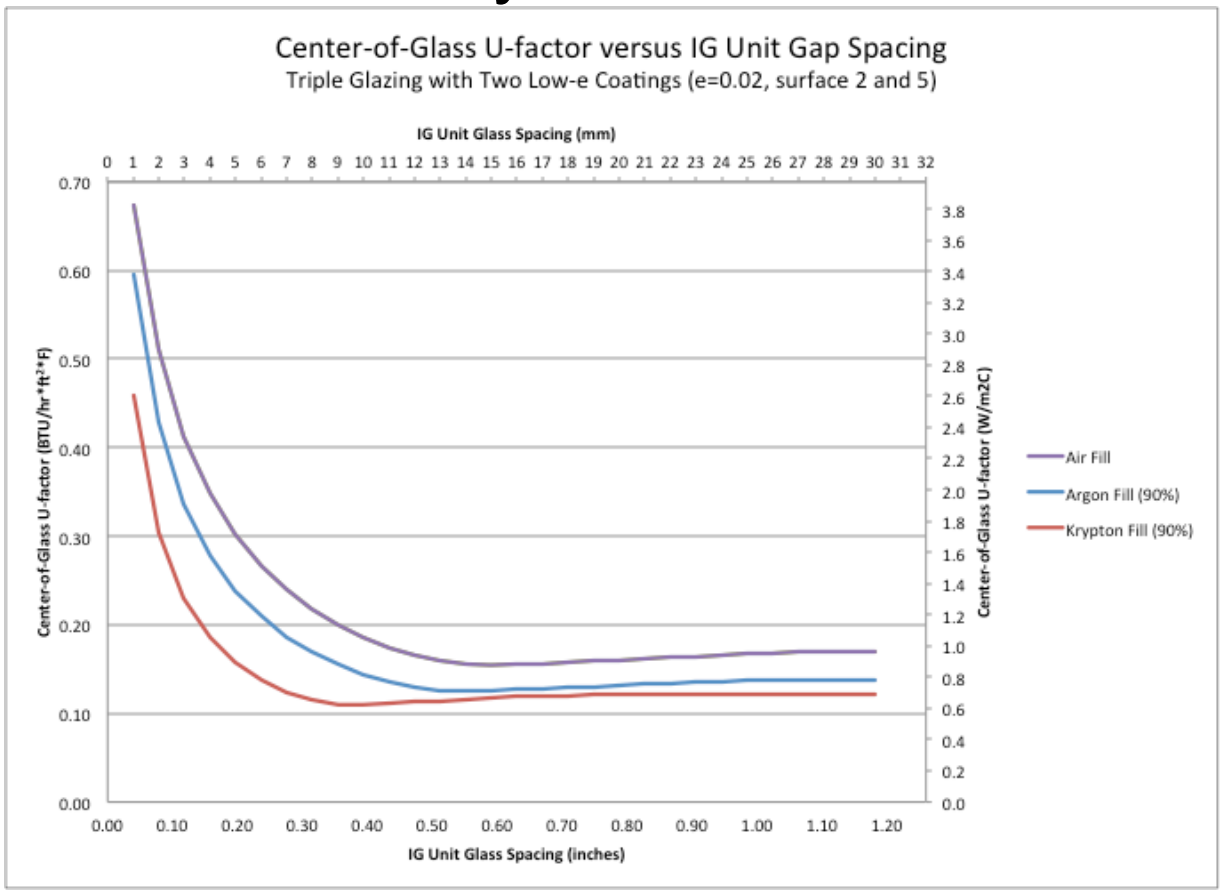
4. Fenestration Basics:

- Convection – Cavity Width



4. Fenestration Basics:

- Convection – Cavity Width

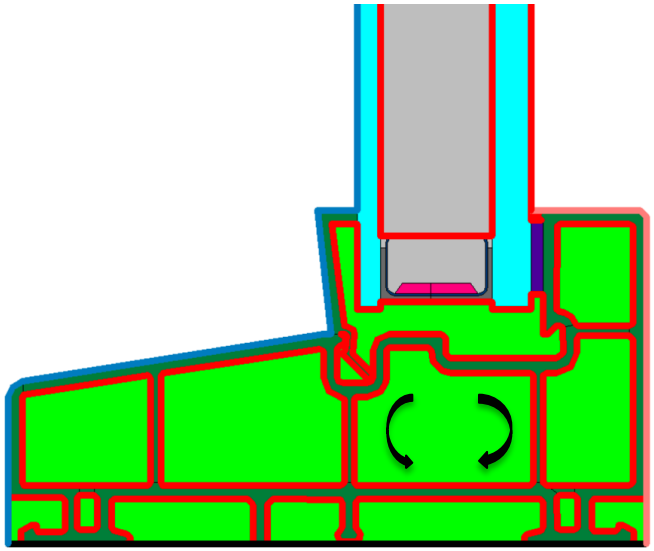


4. Fenestration Basics:

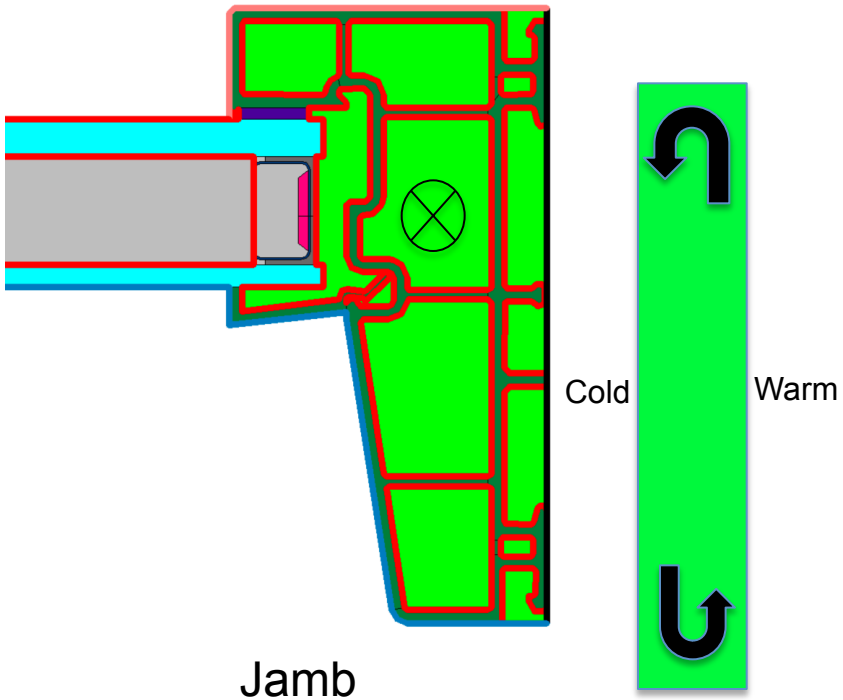
- Convection – Natural
  - Natural Convection in Fenestration
    - Frame Cavities
      - Size and Shape
      - Orientation – Jambs vs. Heads and Sills

4. Fenestration Basics:

- Convection – Frame Cavities



Sill
Section



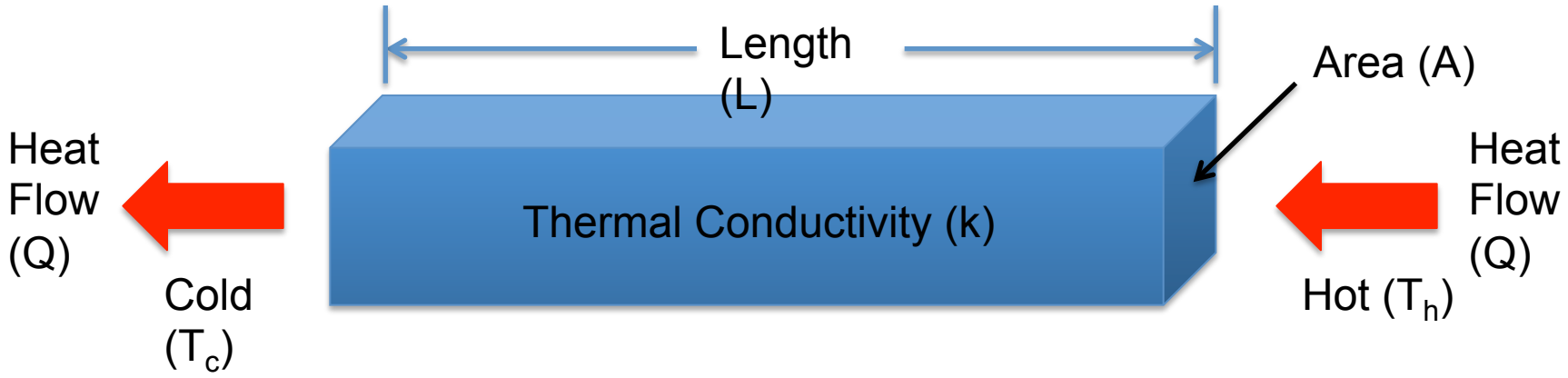
Jamb
Section

4. Fenestration Basics:

- Conduction
  - Diffusion of heat from hot to cold through a material (gas, liquid, or solid)
  - Conduction in a gas or liquid is usually small compared to the convection
  - Thermal conductivity is the material property that defines how much heat can be conducted through the material

4. Fenestration Basics:

- Conduction
  - $$Q = \frac{k * A * (T_h - T_c)}{L}$$



4. Fenestration Basics:

- Thermal Conductivity

National Fenestration Rating Council Incorporated

NFRC 101-2014[E0A14]

Procedure for Determining Thermophysical Properties of Materials For Use in NFRC-Approved Software

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity *k*			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Metals					
Aluminum alloys (mill finish)	160.000	92.446	1109.357	1,4,8, 16, 17	0.05
Aluminum alloys (anodized)	160.000	92.446	1109.357	1,4,8, 16, 17	0.8
Aluminum alloys (painted)	160.000	92.446	1109.357	1,4,8, 16, 17	0.9
Steel (plated)	50.000	28.890	346.674	1, 13	0.05
Steel (rolled, ground)	50.000	28.890	346.674	1, 13	0.1
Steel (rolled, ground, plated)	50.000	28.890	346.674	1	0.2
Steel Stainless (oxidized)	17.000	9.822	117.869	1	0.8
Steel Stainless (buffed)	17.000	9.822	117.869	1	0.2
Steel-galvanized sheet (0.14%C)	62.0	35.823	429.876	8	0.2

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity *k*			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Glazing Materials					
Glass (Plate or Float)	1.000	0.578	6.933	1,4,8	0.84
Glass mosaic	1.200	0.693	8.320	1	0.84
Glass-Flint (lead), Pyrex	1.400	0.809	9.707	3	0.84
Glass-Quartz	1.400	0.809	9.707	1	0.90
Plexiglass (PMMA) / Lucite	0.200	0.116	1.387	8	0.90

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity *k*			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Timbers					
Coniferous woods (Softwoods)	0.140	0.081	0.971	4,8	0.9
Deciduous woods (Hardwoods)	0.160	0.092	1.109	4,,8	0.9
Note: Values are for 12% moisture content. This value may be applied to products of any moisture content for the purposes of this document.					
Wood based panels					
Fiberboard	0.110	0.064	0.763	8	0.9
Particleboard, Plywood	0.240	0.139	1.664	1	0.9

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity *k*			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Polymers					
PVB	0.221	0.128	1.536	15	0.9
Polycarbonate	0.200	0.116	1.387	1	0.9
Polypropylene	0.22	0.127	1.525	1	0.9
Polystyrene	0.160	0.092	1.109	1	0.9
Polytetrafluoroethylene(PTFE)	0.250	0.144	1.733	1	0.9
Polyurethane	0.250	0.144	1.733	1	0.9
Polyvinylchloride (PVC) flexible	0.140	0.081	0.971	1	0.9
PVC/Vinyl (rigid)	0.170	0.098	1.179	4,8	0.9
Silicone	0.350	0.202	2.427	1	0.9
Silicone foam	0.170	0.098	1.179	4,8	0.9
Urethane-thermal break	0.121	0.070	0.839	10	0.9
Urethane/polyurethane	0.210	0.121	1.456	1	0.9
Fiberglass	0.300	0.173	2.080	4,8	0.9

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity, k			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Insulating Materials					
Cellulosic fiber, Cotton fiber	0.042	0.023	0.277	8	0.9
Expanded perlite, organic bonded	0.052	0.030	0.361	2	0.9
Polystyrene-expanded	0.038	0.022	0.263	8,1	0.9
Polystyrene extruded (XPS)	0.034	0.020	0.236	1	0.9
Felt	0.050	0.029	0.347	3	0.9
Glass fiber (rigid)	0.047	0.027	0.326	8	0.9
Insulation Fiberboard	0.050	0.029	0.347	8	0.9
Mineral fiber-loose fill	0.050	0.029	0.347	8	0.9
Perlite	0.053	0.031	0.367	8	0.9
Polyester fibre	0.040	0.023	0.279	1	0.9
Polyurethane Foam Insulation	0.024	0.014	0.166	8	0.9
Urea formaldehyde foam	0.040	0.023	0.277	2	0.9
Vermiculite	0.077	0.044	0.534	7	0.9

4. Fenestration Basics:

- Thermal Conductivity

Name	Conductivity *k*			Source[2]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Aluminum alloys (painted)	160.000	92.446	1109.357	1,4,8, 16, 17	0.9
Steel-galvanized sheet (0.14%C)	62.0	35.823	429.876	8	0.2
Steel Stainless (buffed)	17.000	9.822	117.869	1	0.2
Glass (Plate or Float)	1.000	0.578	6.933	1,4,8	0.84
Fiberglass	0.300	0.173	2.080	4,8	0.9
Coniferous woods (Softwoods)	0.140	0.081	0.971	4,8	0.9
PVC/Vinyl (rigid)	0.170	0.098	1.179	4,8	0.9
Polyurethane Foam Insulation	0.024	0.014	0.166	8	0.9

4. Fenestration Basics:

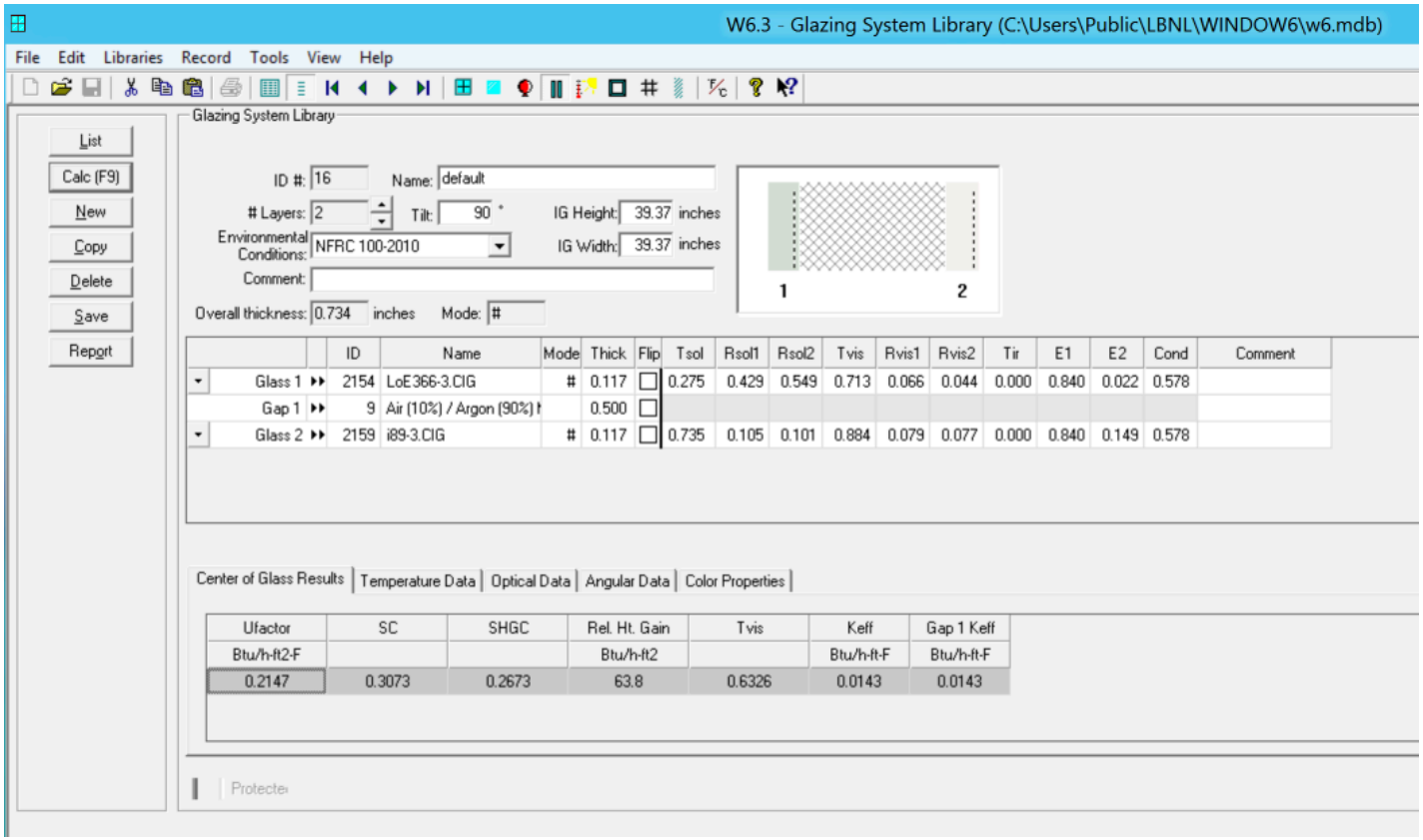
- Tools
  - Window 6.3 (Window 7 coming soon)
  - Therm 6.3 (Therm 7 coming soon)

4. Fenestration Basics:

- Window 6.3
  - Glass calculations
  - Low-e coatings
  - Gas fill
  - Gap spacing

4. Fenestration Basics:

- WIDNOW 6.3

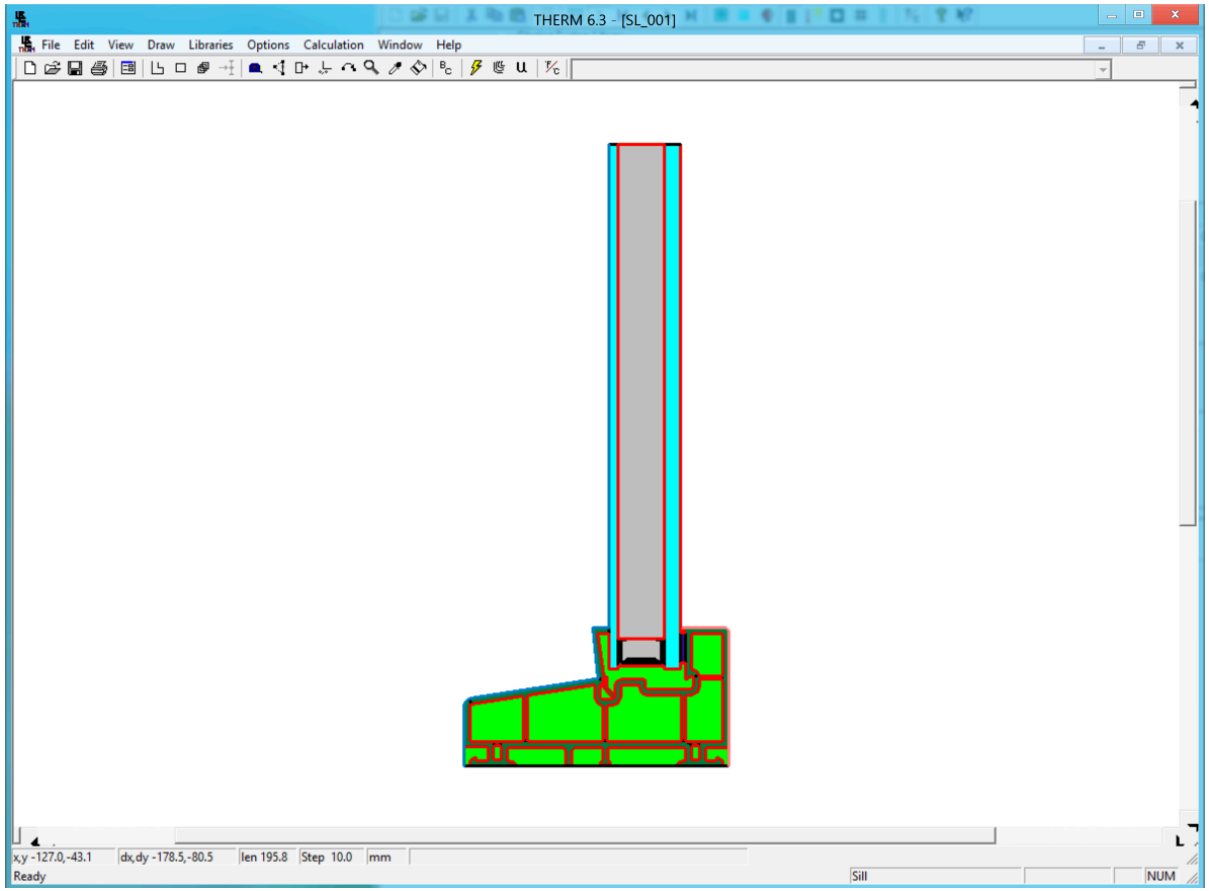


4. Fenestration Basics:

- Therm 6.3
  - Edge-of-glass and Frame simulation
  - Conduction analysis only
    - convection and radiation algorithms
  - Captures glass, spacer and framing materials used in a product

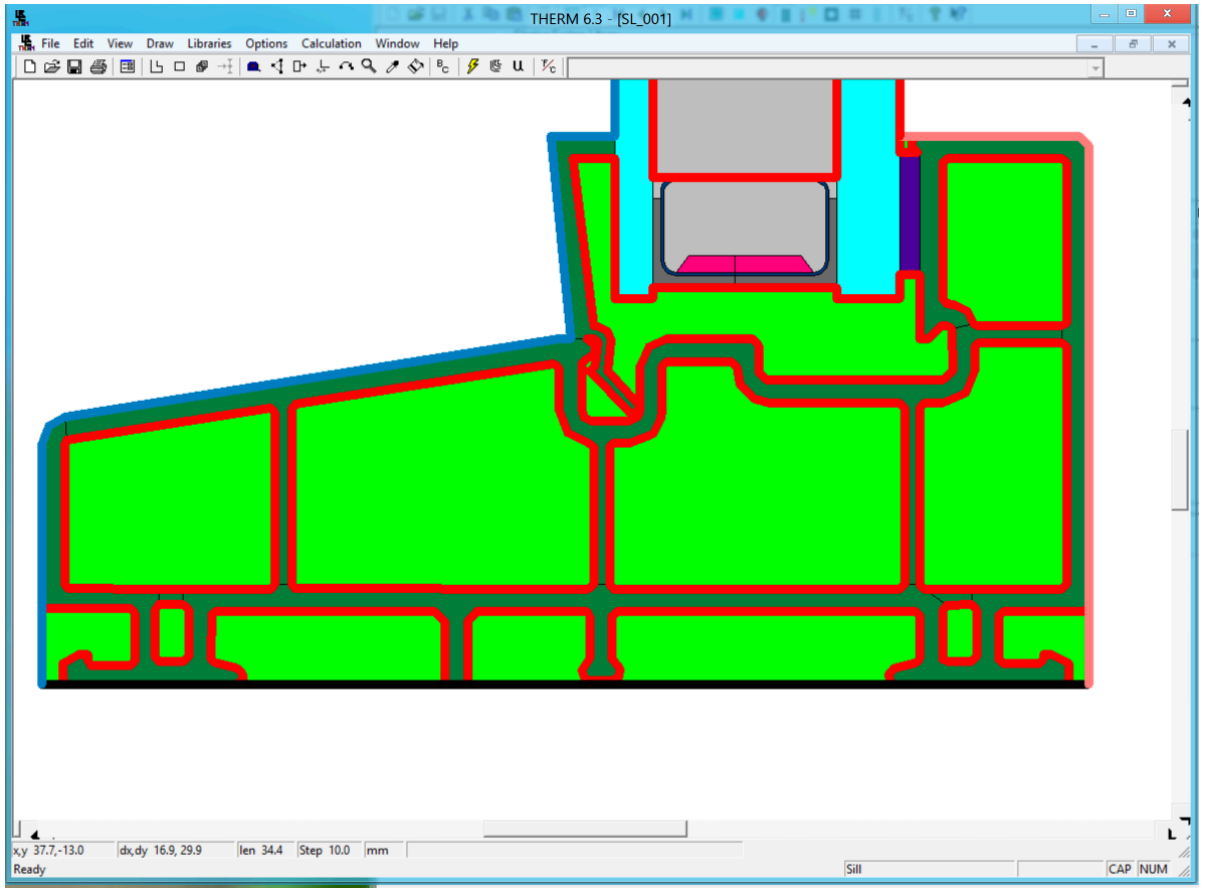
4. Fenestration Basics:

- Therm 6.3



4. Fenestration Basics:

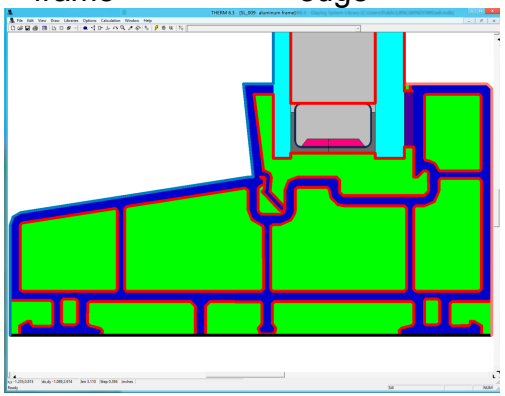
- Therm 6.3



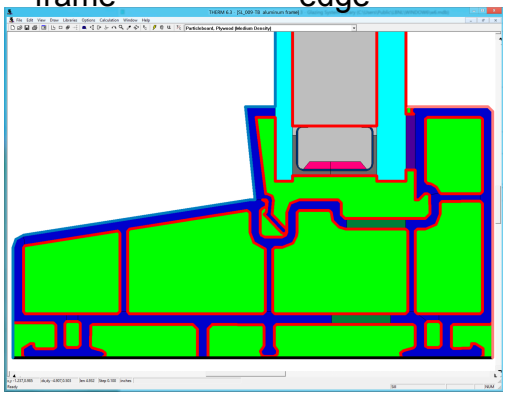
4. Fenestration Basics:

- Frame Materials

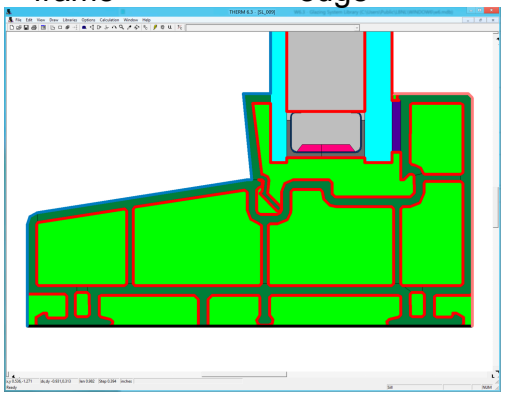
U_{frame}= 7.86 U_{edge}= 2.26



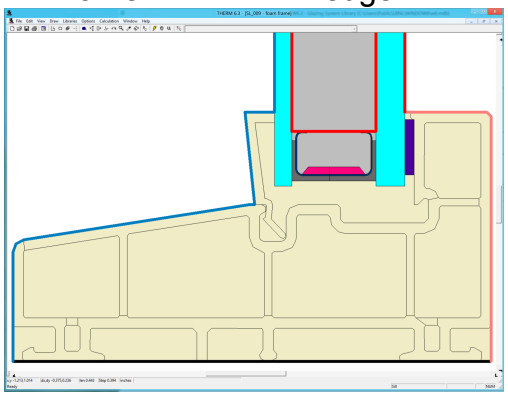
U_{frame}= 4.57 U_{edge}= 2.11



U_{frame}= 1.80 U_{edge}= 2.15



U_{frame}= 0.76 U_{edge}= 2.03

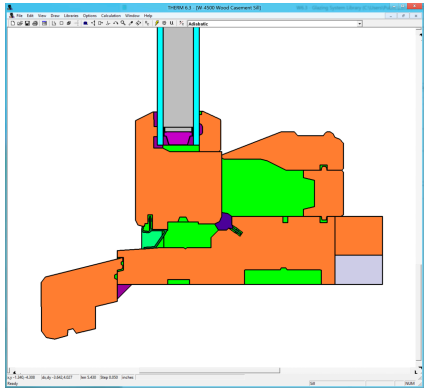


4. Fenestration Basics:

- Frame Materials

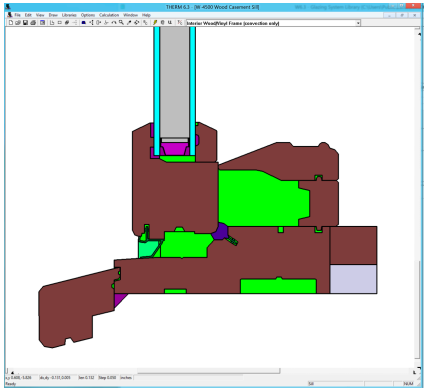
U_{frame}= 1.66U_{edge}= 1.85

Ponderosa Pine



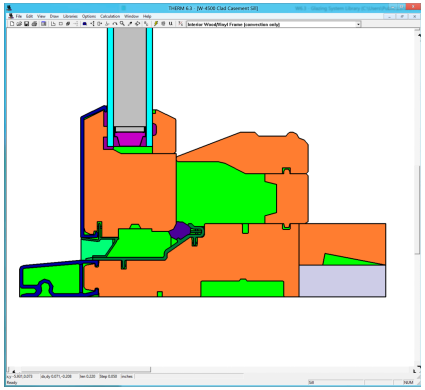
U_{frame}= 1.91 U_{edge}= 1.85

Hardwood



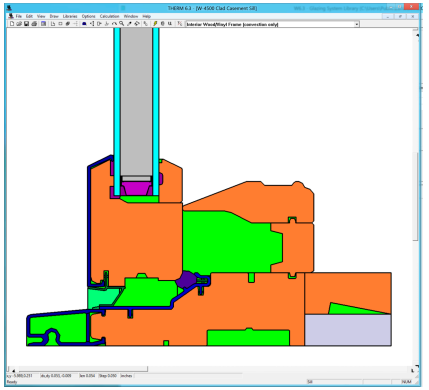
U_{frame}= 1.73 U_{edge}= 1.85

PVC Under Sash



U_{frame}= 2.52 U_{edge}= 1.87

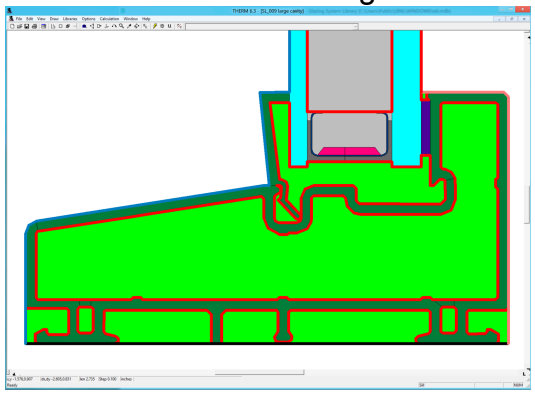
Aluminum Under Sash



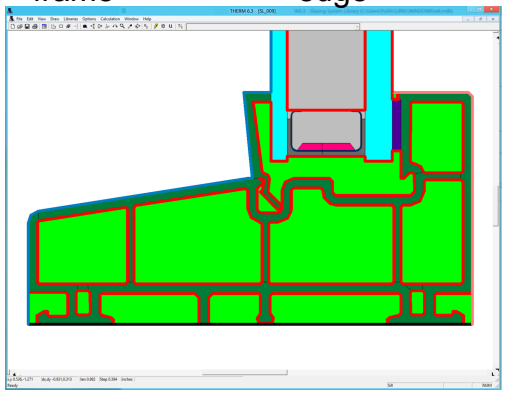
4. Fenestration Basics:

- Frame Cavities

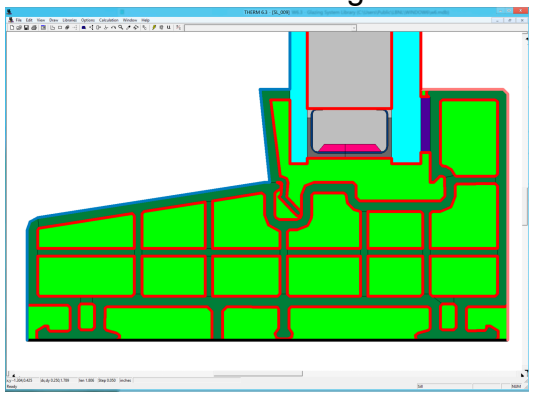
U_{frame}= 2.57 U_{edge}= 1.99



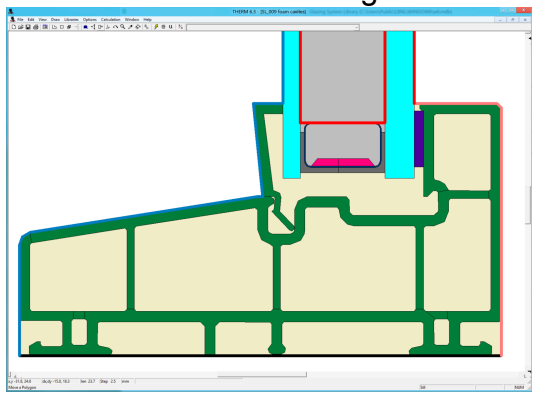
U_{frame}= 1.80 U_{edge}= 2.15



U_{frame}= 1.74 U_{edge}= 2.01



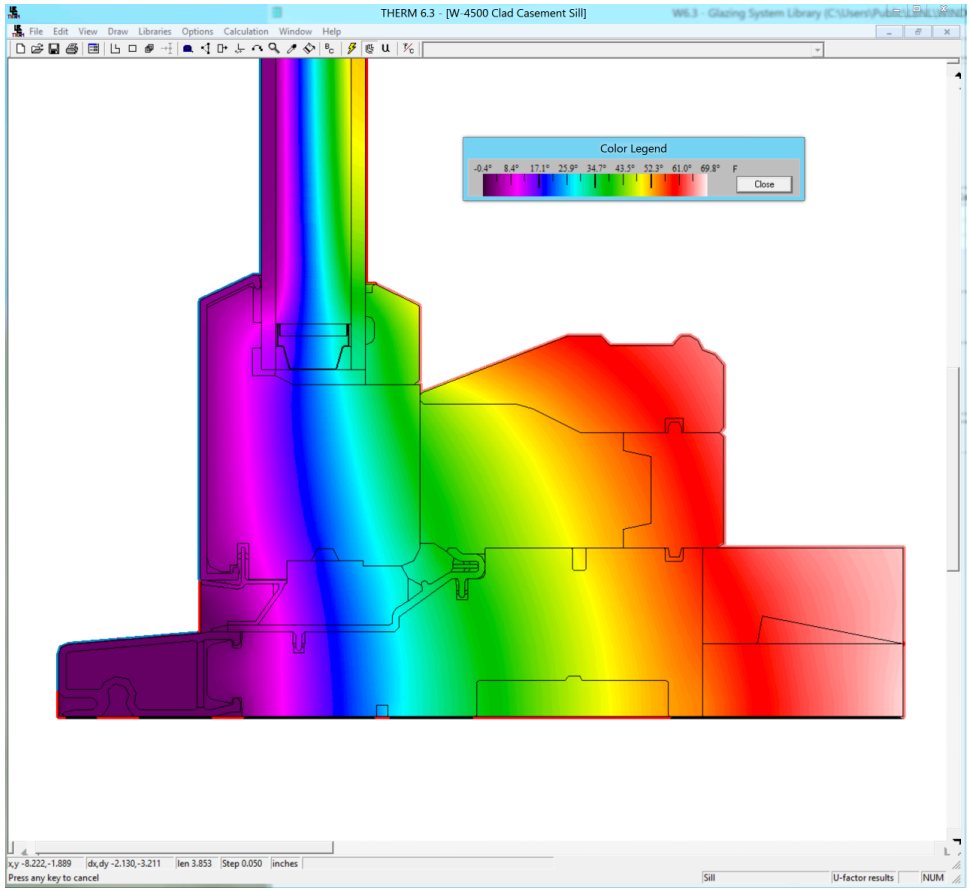
U_{frame}= 1.22 U_{edge}= 2.01



fenestration canada

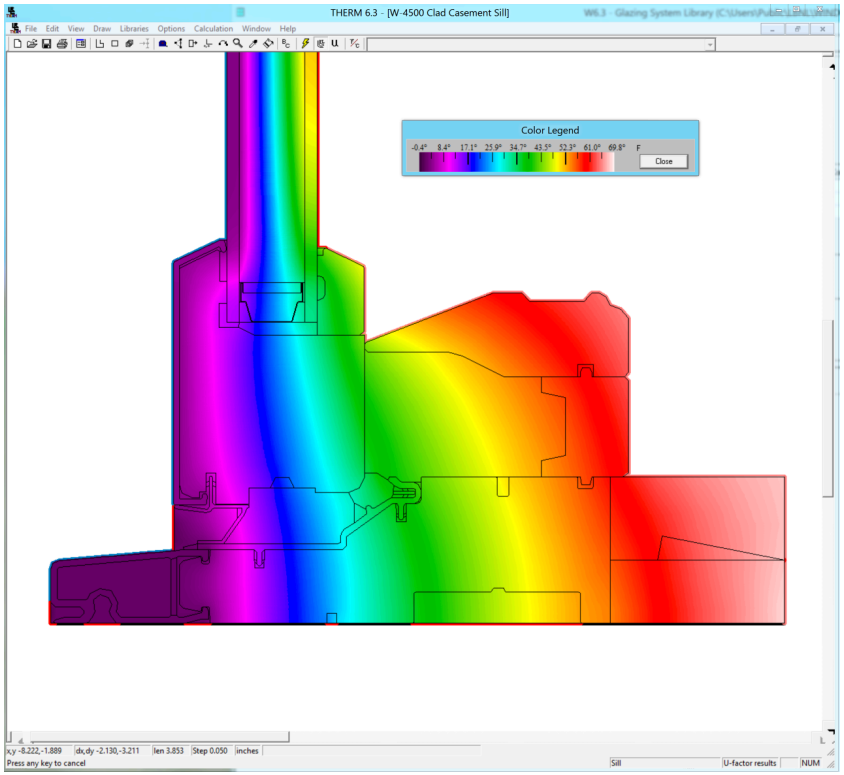
4. Fenestration Basics:

- Therm – Temperature Plot

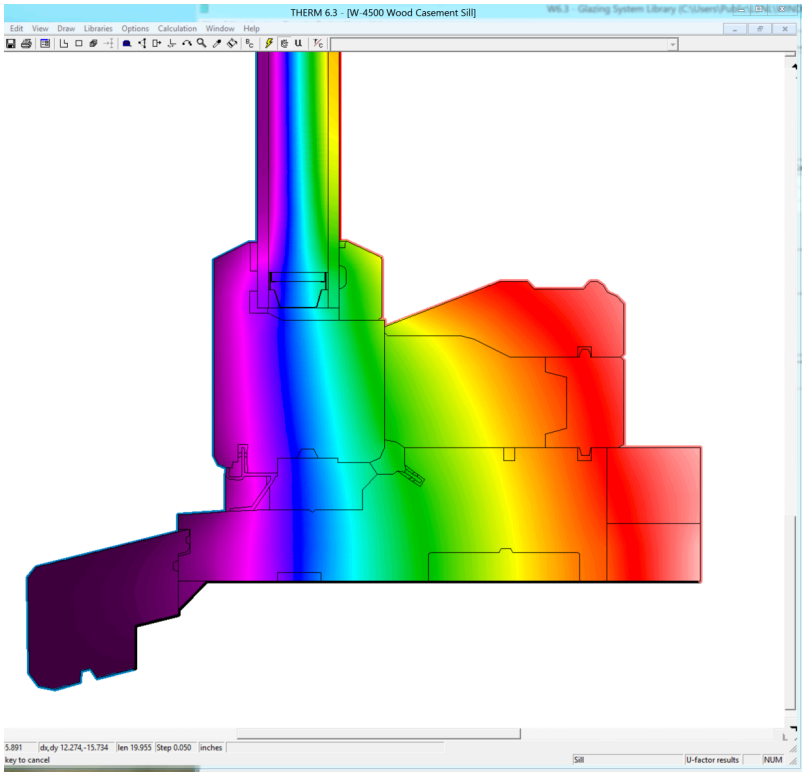


4. Fenestration Basics:

- Therm – Temperature Plot (frame materials)



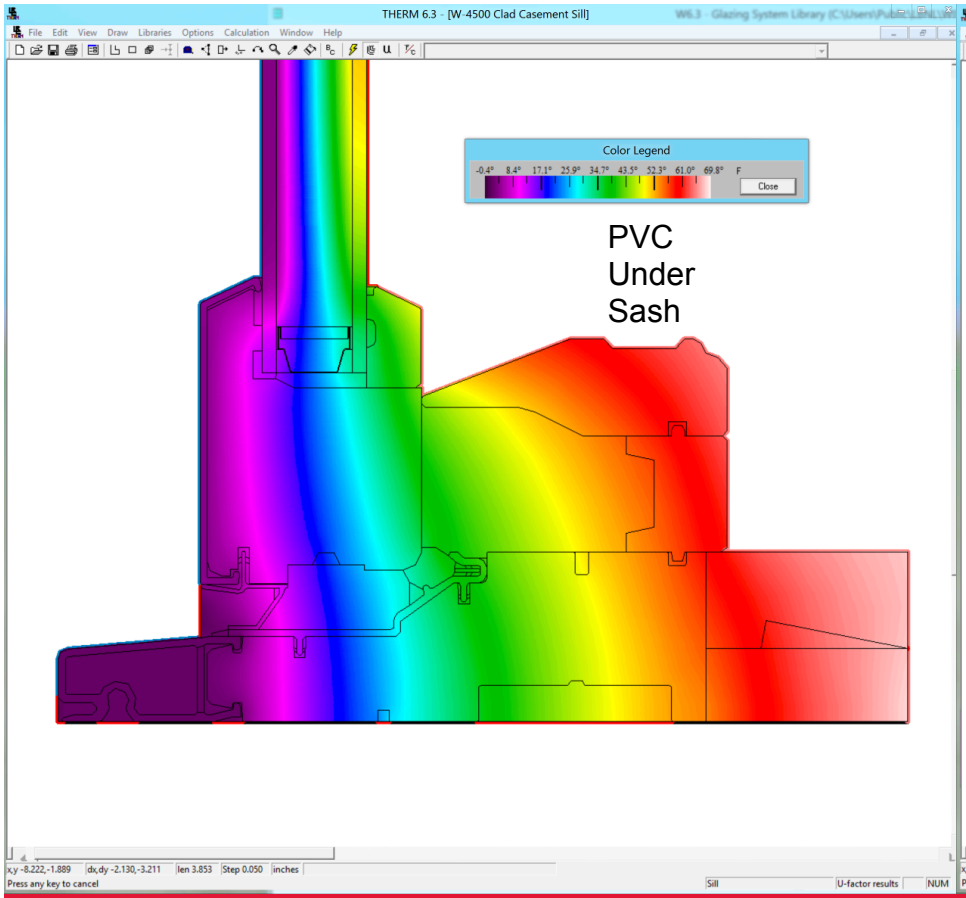
Aluminum Clad Wood Frame

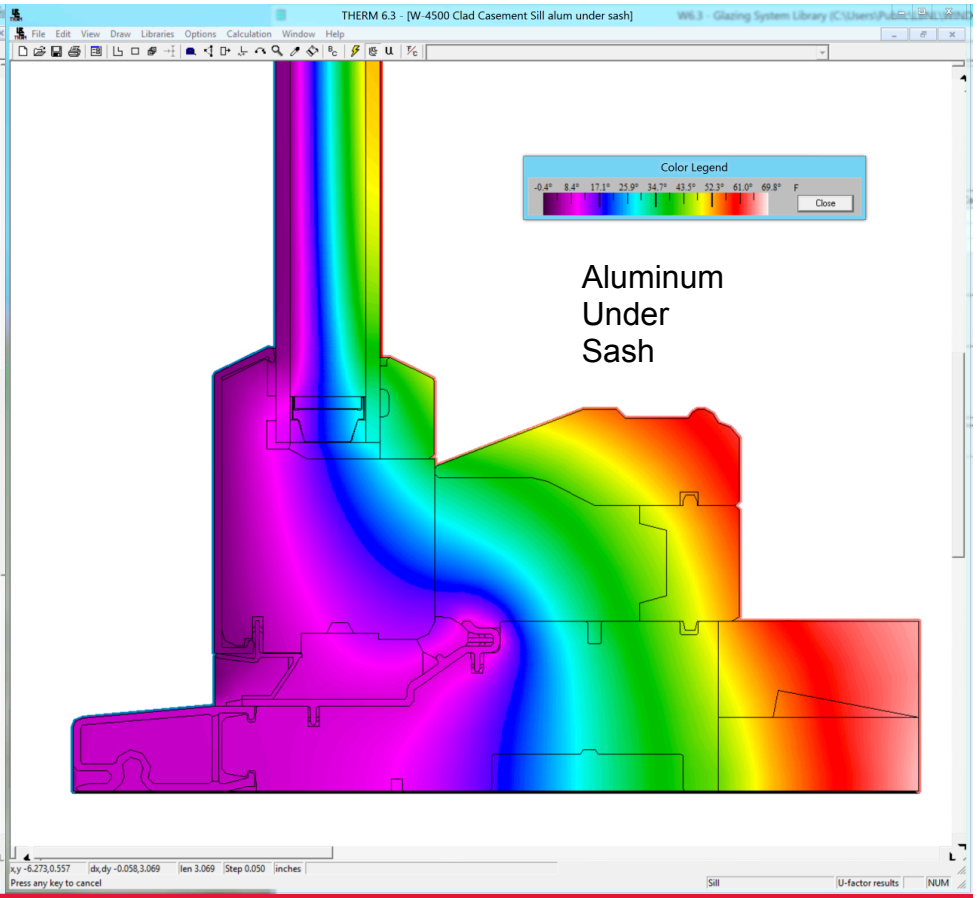


Wood Clad Wood Frame

4. Fenestration Basics:

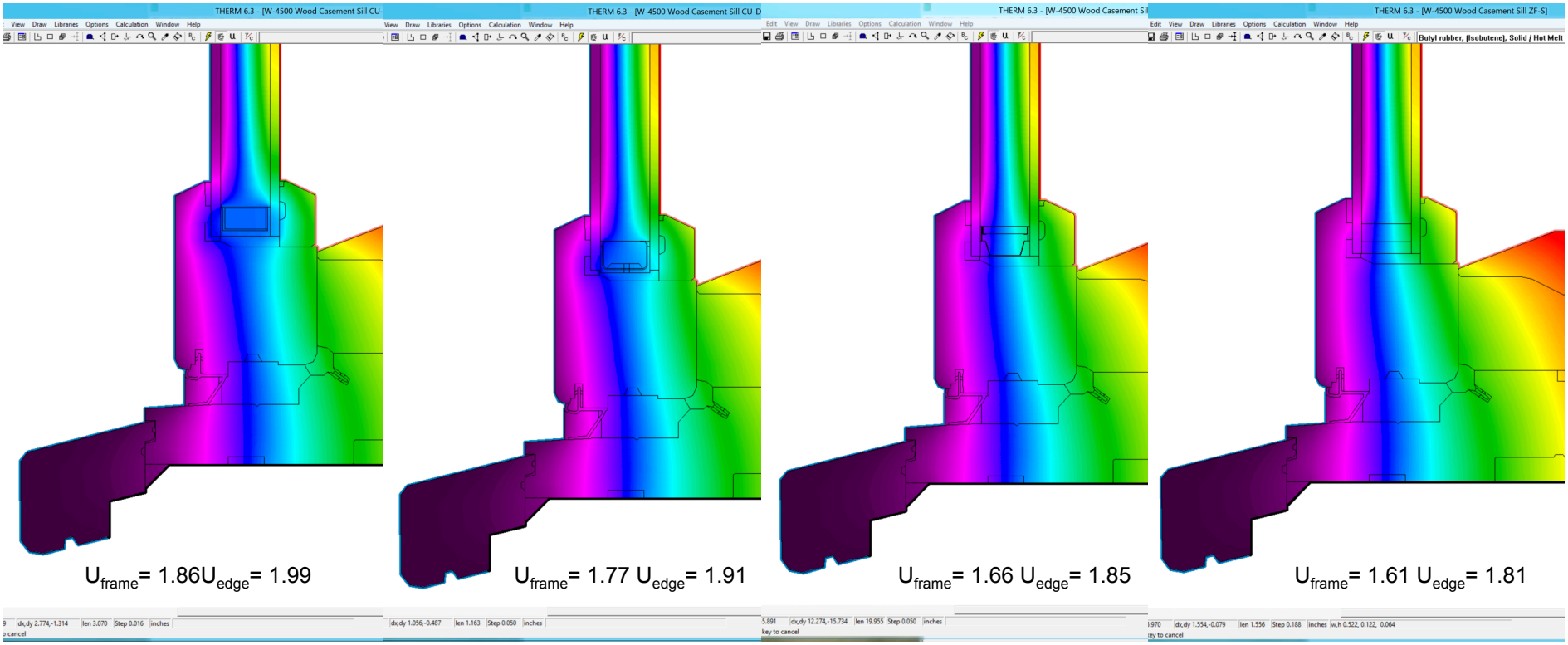
- Therm – Temperature Plot (frame materials)





4. Fenestration Basics:

- Therm – Temperature Plot (spacers)



U_{frame}= 1.86U_{edge}= 1.99 | U_{frame}= 1.77 U_{edge}= 1.91 | U_{frame}= 1.66 U_{edge}= 1.85 | U_{frame}= 1.61 U_{edge}= 1.81

Aluminum spacer | Steel U-channel Spacer | Stainless Steel Spacer | Silicone Foam Spacer

fenestration canada

Questions?

fenestration canada

Overview

1. Regulatory: What is required and who is requiring it?
2. Compliance: How to determine thermal performance and what's involved?
3. Certification: What is it? Who provides it? Is it required?
4. Fenestration Basics: What fenestration technology influences thermal performance and how?
5. The Future: Requirements keep going up, triple glazing is becoming almost common place, what are the emerging technologies that we may one day see?

fenestration canada

5. The Future:

A. Vacuum Insulating Glazing Units

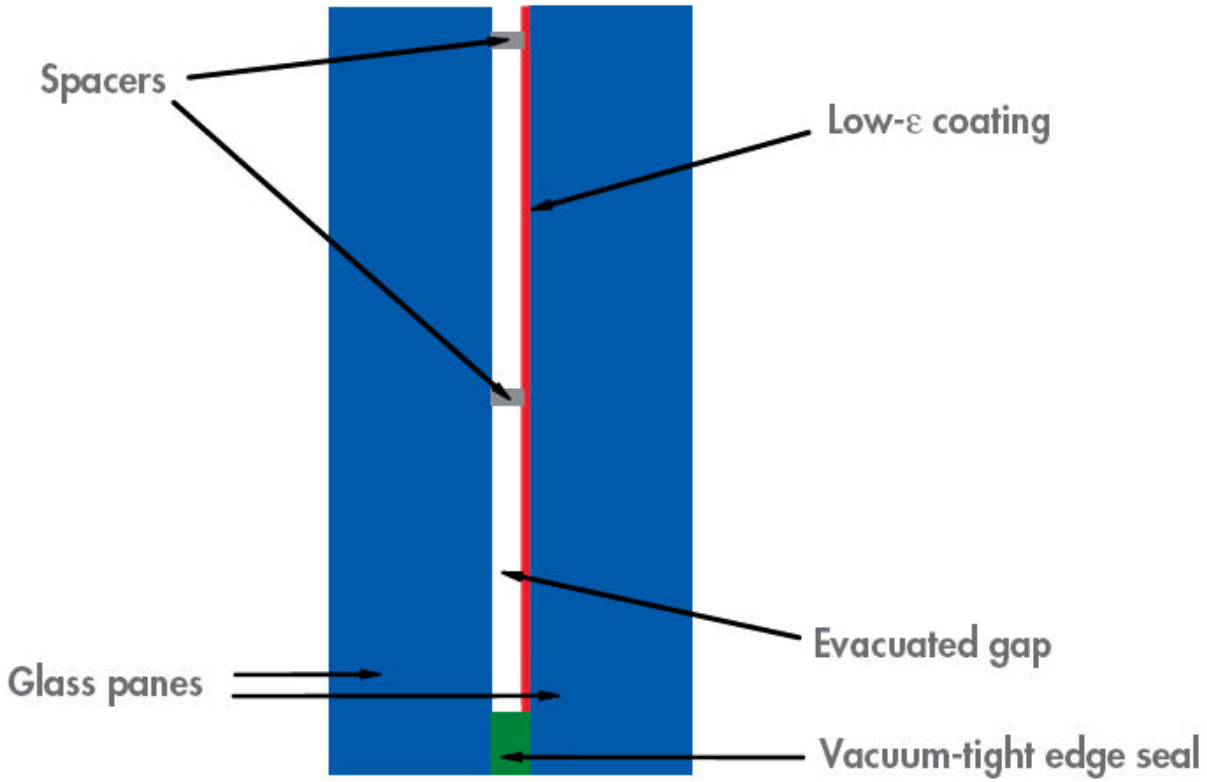
B. Dynamic Glazing

C. Integrated Shade Systems

D. Home Integration of Fenestration Systems

5. The Future:

A. Vacuum Insulating Glass Units (VIG)



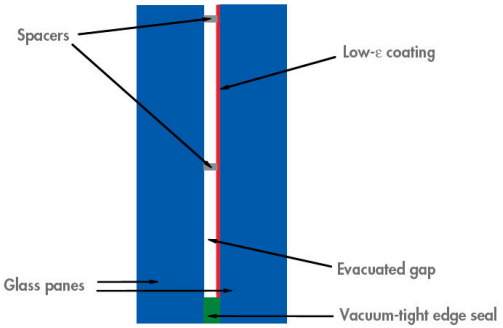
5. The Future:

A. Vacuum Insulating Glass Units (VIG)

a. R&D at University of Sydney in the early 1990s

b. Commercially available for many years

c. Early commercial versions had size limitation, current versions much larger



d. Vacuum pressure is critical

e. Spacers/pillars create a conduction path, but required to separate glass layers

f. Edge seal creates a strong conduction path to be address in the placement of VIG in a window

5. The Future:

B. Dynamic Glazing

a. Electrochromic Glazing

b. Thermochromic Glazing

c. Photochromic Glazing

d. Liquid Crystal Glazing

e. Gasochromic Glazing

Source www.commercialwindows.org

5. The Future:

B. Dynamic Glazing

a. Electrochromic Glazing

ON OFF

i. A very thin electrochromic film stack is deposited on the glass

ii. When a low voltage is applied the film can be changed from clear to a blue/gray tint

iii. The tint has an almost unlimited number of visible transmission levels depending on the voltage

iv. The clarity of the view in not affected

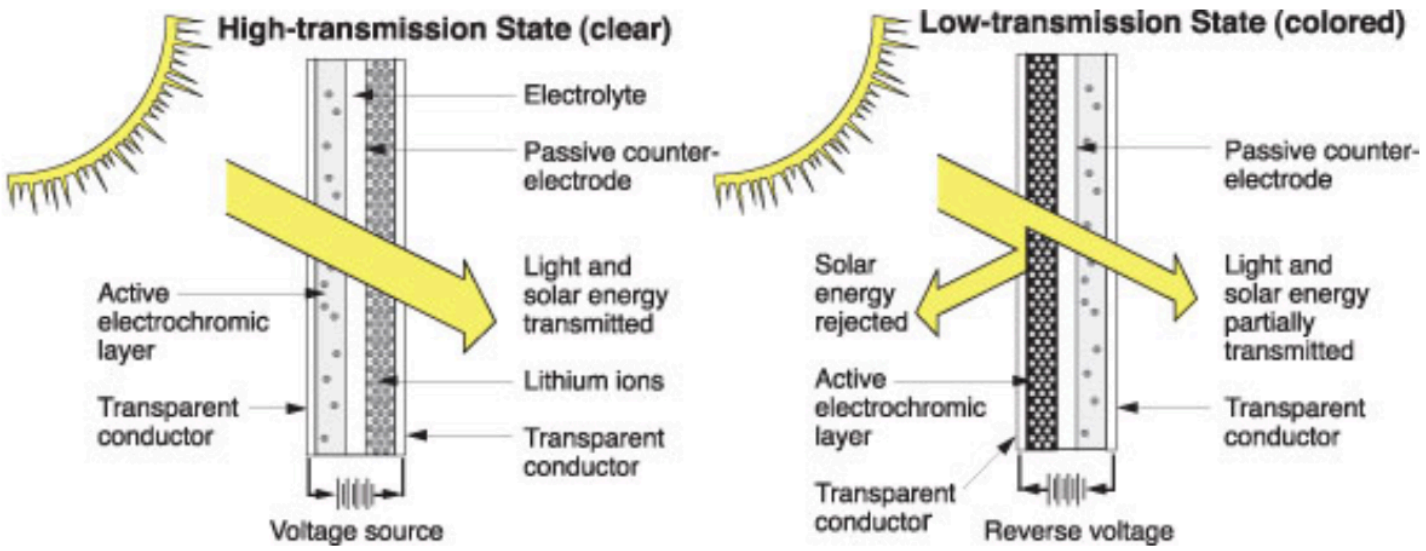
v. Visible light transmission range 0.50-0.70 (on), 0.02-0.25 (off)

vi. SHGC range 0.10-0.50

5. The Future:

B. Dynamic Glazing

a. Electrochromic Glazing



5. The Future:

B. Dynamic Glazing

b. Thermochromic Glazing

i. Adapt to changing sunlight
ii. React to temperature change
iii. Reduce solar heat gain
iv. Properly design they are not sensitive to outdoor air temperature changes but react to direct sunlight on the window
v. Ideally they maintain a high level of visible light transmission
vi. Visible light transmission range 0.10-0.50
vii. SHGC down to 0.13

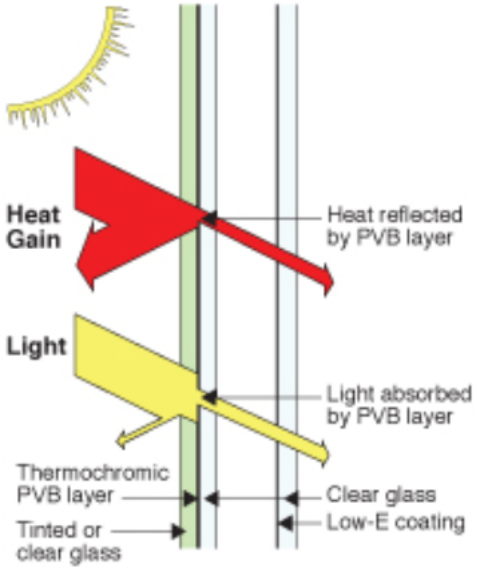


Diagram of heat reflectance and light absorption through the thermochromic film.

5. The Future:

B. Dynamic Glazing

c. Photochromic Glazing

i. Transparency in response to light intensity.

ii. Eye glass are a application of photochromic glass

iii. Large samples for use in windows have yet to be produced in a cost effective way

5. The Future:

B. Dynamic Glazing

d. Liquid Crystal Glazing

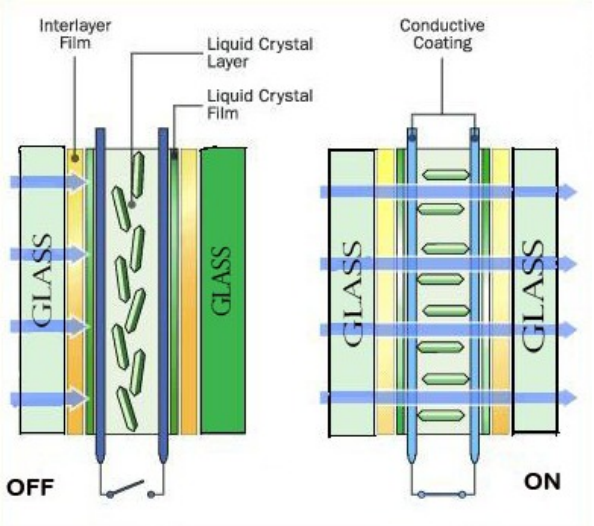
i. Liquid crystal display technology

ii. Sensitive to UV radiation, typically interior privacy glazing

iii. Visible light transmission range 0.50-0.80

iv. SHGC range 0.55-0.69

v. UV stable versions being worked on, but costly



5. The Future:

B. Dynamic Glazing

e. Gasochromic Glazing

i. Diluted hydrogen gas is introduced into the cavity in an insulation glass unit

ii. Hydrogen reacts with a tungsten oxide film to darken the glass

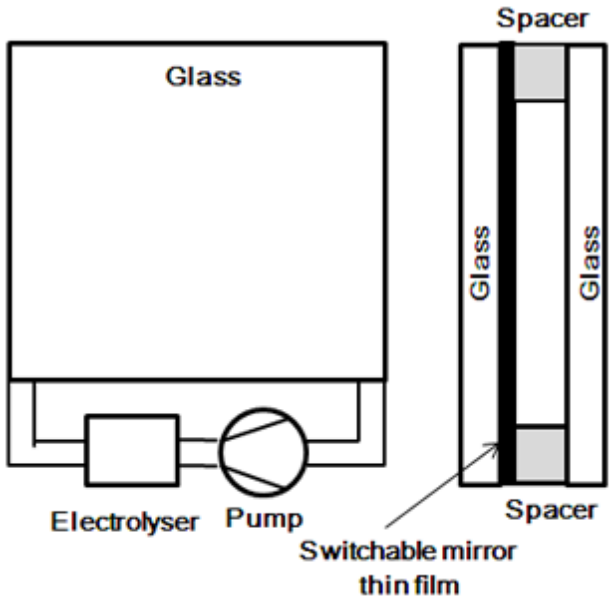
iii. Adding oxygen returns the glass to clear

iv. Visible light transmission range 0.10-0

v. SHGC range 0.12-0.46

vi. Durability testing is underway

vii. Available in the near future



5. The Future:

C. Integrated Shade Systems

a. Interior and exterior systems
b. Completely integrated into the window design
c. Manual operation control by user, including a remote control option
d. System integration with automatic control

5. The Future:

D. Home Integration of Fenestration Systems

a. Many of the dynamic glazing products on the market are being integrated into whole house/building integration systems
b. Controls for energy, glare, privacy and others
c. Some window, door and skylight systems can be integrated to open for ventilation, close for rain

fenestration canada

Questions?

Fenestration Canada

1. www.fenestrationcanada.ca
2. Fenestration Canada Annual Meeting

   June 8-10, 2016 Mont Tremblant, Quebec