NRC·CNRC

Manitoba Energy Code for Buildings

Part 3 – Building Envelope

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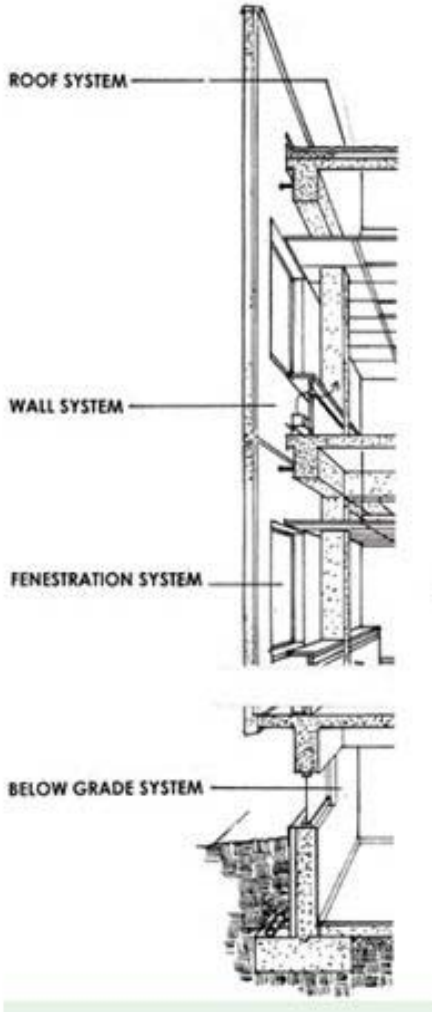
Manitoba Energy Code for Buildings (MECB) Training Day

Part 3 - Scope

Part 3 is concerned with the transfer of heat and air through the **building envelope**

The building envelope is the collection of components that separate conditioned space from unconditioned space, exterior air, or the ground.



Graphic – Whole Building Design Guide http://www.wbdg.org/

Part 3 - Scope

The **building envelope** also includes the separation between separate interior spaces that are intended to be conditioned at temperatures differing by >10^{o}C at design conditions, such as:

- Cold storage warehouses
- Swimming pools to ice rinks
- Offices to warehouses with minimal heat

Part 3 - Application of Manitoba Energy Code / NECB

Applies to:

All new “Part 3” Buildings

Additions to “Part 3” Buildings

“Part 9” Buildings under certain circumstances

Does Not Apply to:

Existing buildings

Renovations

Farm Buildings

Buildings with Heating or Cooling System with output capacity < 10 w/m^2

(limitation in Part 3)

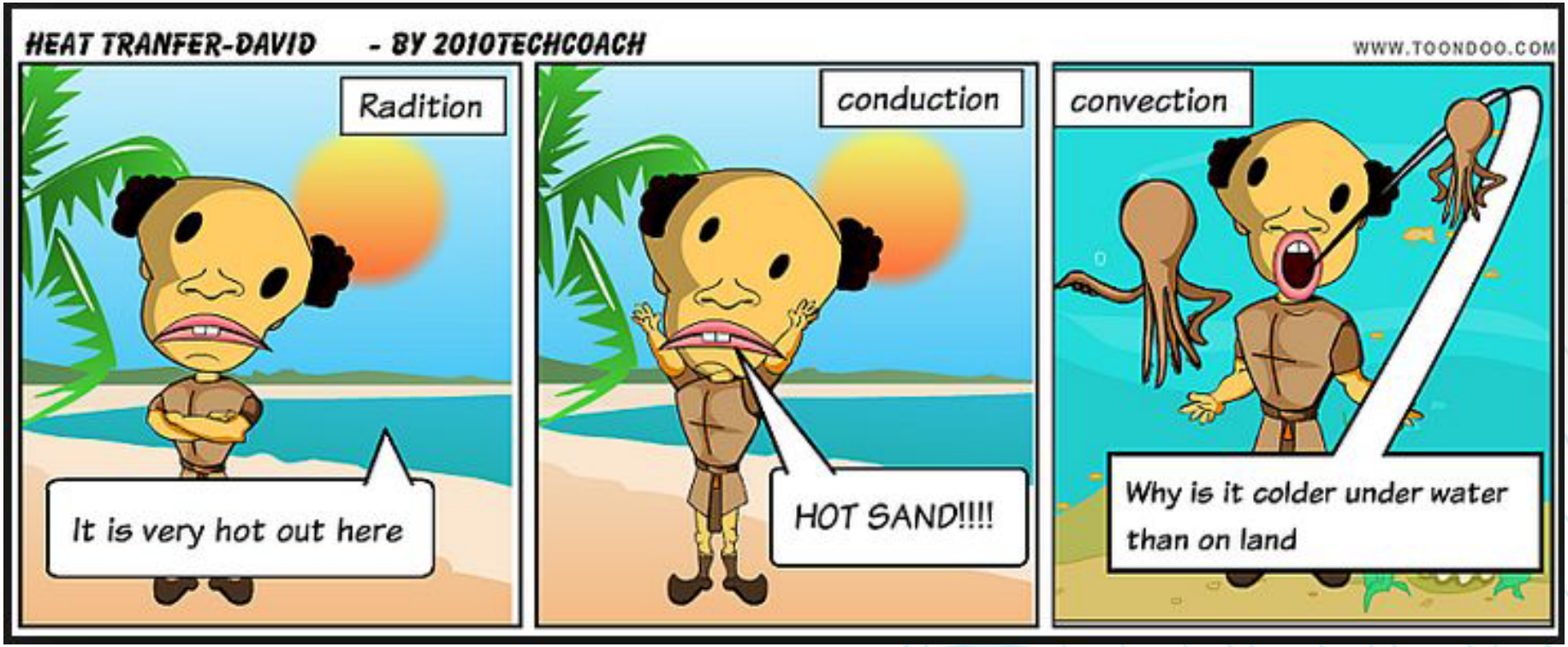
Compliance options

- Prescriptive path
- Trade-off path
  - Simple trade-off
  - Detailed trade-off
- Performance path – whole-building modeling

Thermal Characteristics of Building Materials

- Typically obtained through testing in accordance with relevant material standards.
- Testing in accordance with ASTM C 177 (...”Guarded Hot Plate Apparatus”) or ASTM C 518 (…”Heat Flow Meter Apparatus”).
- Heat Flow though opaque assemblies occurs through a combination of:
  - Conduction.
  - Convection.
  - Radiation.

Elements of Heat Flow



Thermal Characteristics of Building Materials

Overall Thermal Transmittance (U-value) – measure of the rate of transfer through a building assembly. Expressed in units of

$$W/(m^2/^oK)$$

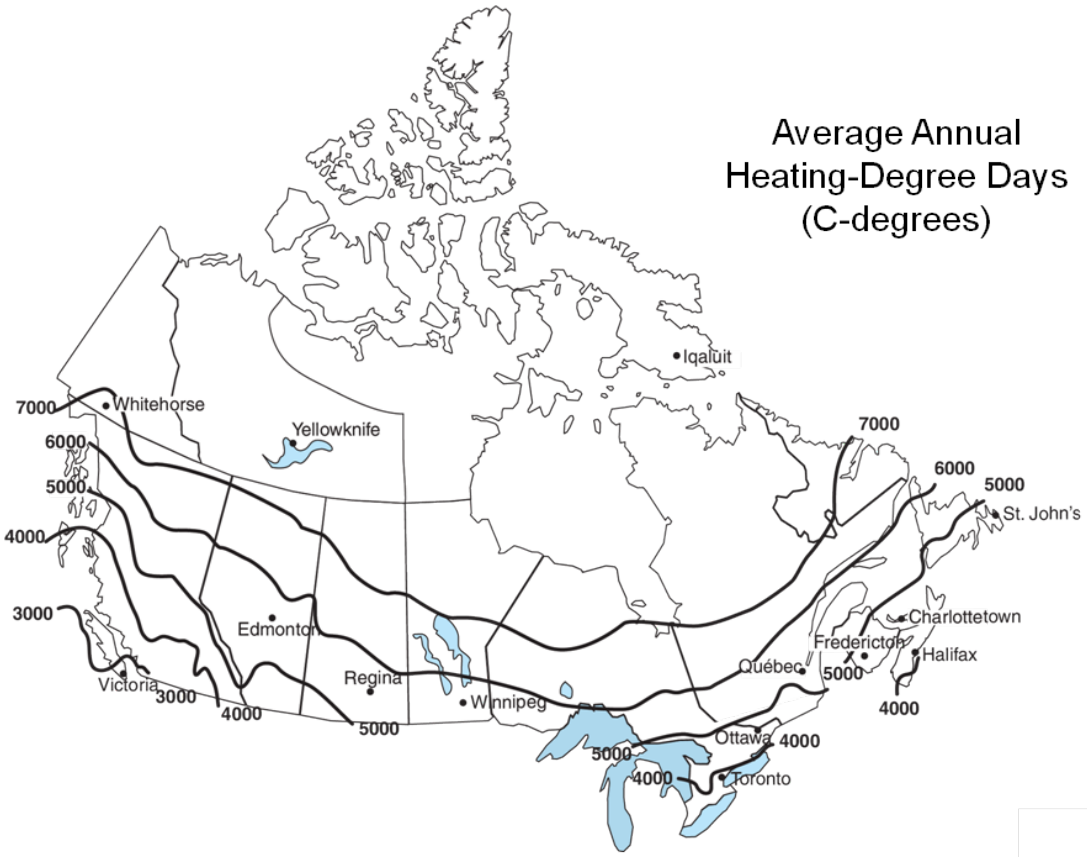
Effective Thermal Resistance (RSI) is the reciprocal of the overall thermal transmittance, expressed in units of $(m^2/^oK)/W$

$$RSI = 1/U$$

$$R_{imp} = RSI \times 5.67$$

Prescriptive – building envelope thermal characteristics

Part 3 requirements for opaque elements, fenestration, and doors are related to the applicable Heating Degree-Day (HDD) category for the building.

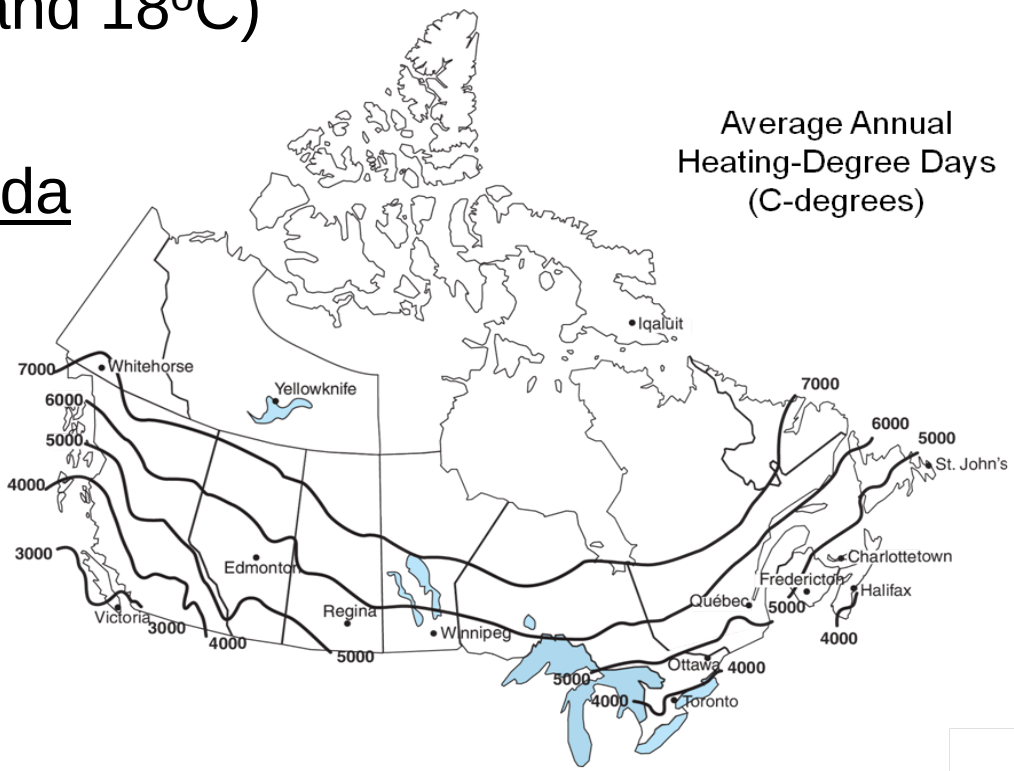


Prescriptive – building envelope thermal characteristics

HDD = annual Σ (Δ between the mean temperature for each day and 18°C)

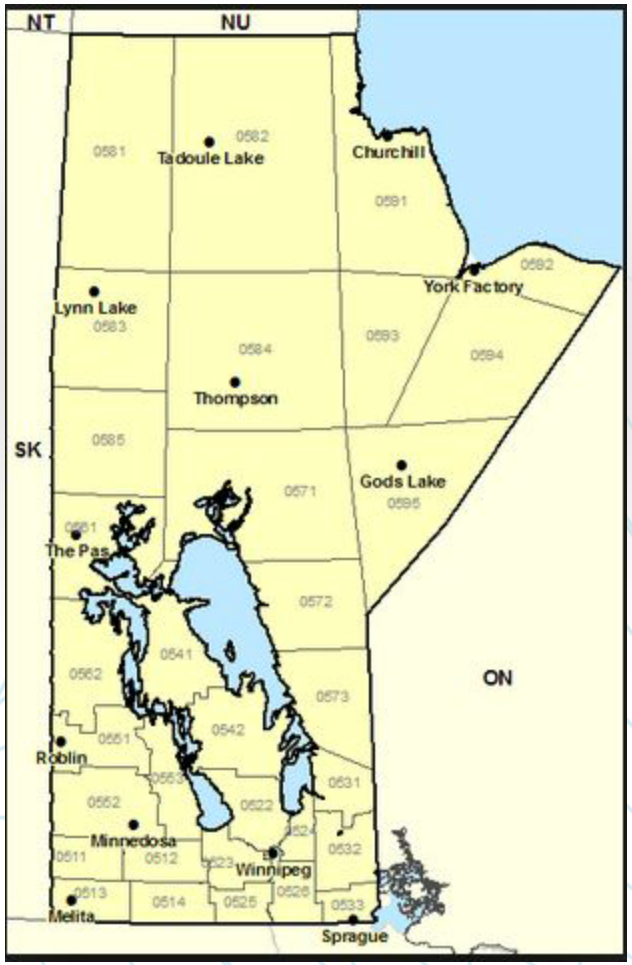
<u>Six Climate Zones in Canada</u>

4	< 3000 HDD
5	3000 – 3999 HDD
6	4000 – 4999 HDD
7A	5000 – 5999 HDD
7B	6000 – 6999 HDD
8	≥ 7000 HDD



Representative Manitoba Climate Zones

	HDD	
Winnipeg	5670	
Brandon	5760	**ZONE 7A**
Portage la Prairie	5600	
Steinbach	5700	
Flin Flon	6440	
Island Lake	6900	**ZONE 7B**
The Pas	6480	
Thompson	7600	
Churchill	8950	**ZONE 8**
Lynn Lake	7770	



Part 3 Prescriptive Path Requirements

General Requirements

Above Ground

- **Components of the Building Envelope**

Building Assemblies in Contact with the Ground

Air Leakage

Part 3 Prescriptive Path Requirements

General Requirements

Above Ground

Components of the Building Envelope

Building Assemblies in Contact with the Ground

Air Leakage

Protection of Insulation Materials

Continuity of Insulation

Spaces Heated to Different Temperatures

Allowable Fenestration and Door Area (FDWR)

Part 3 Prescriptive Path Requirements

General Requirements

Above Ground

- Components of the Building Envelope

Building Assemblies in Contact with the Ground

Air Leakage

Vestibules

Thermal Characteristics of

- Above-Ground Opaque Building Assemblies

Thermal Characteristics of

- Fenestration

Thermal Characteristics of

- Doors and Access Hatches

Part 3 Prescriptive Path Requirements

General Requirements

Above Ground

Components of the Building Envelope

Building Assemblies in Contact with the Ground

Air Leakage

Thermal Characteristics of Walls in Contact with the Ground

Thermal Characteristics of Roofs in Contact with the Ground

Thermal Characteristics of Floors in Contact with the Ground

Part 3 Prescriptive Path Requirements

General Requirements

Above Ground

- Components of the Building Envelope

Building Assemblies in

- Contact with the Ground

Air Leakage

General

Opaque Building

- **Assemblies**

Fenestration

Doors

Fireplace Doors

Part 3 Prescriptive Path Requirements

General Requirements

Protection of insulation materials against degradation of their thermal properties due to:

- air leakage or convection
- wetting, or
- moisture bypassing the plane of thermal resistance.

Continuity of insulation

- At penetrations
- Keep continuous or overlap

Part 3 Prescriptive Path Requirements

General Requirements

Spaces Heated to Different Temperatures

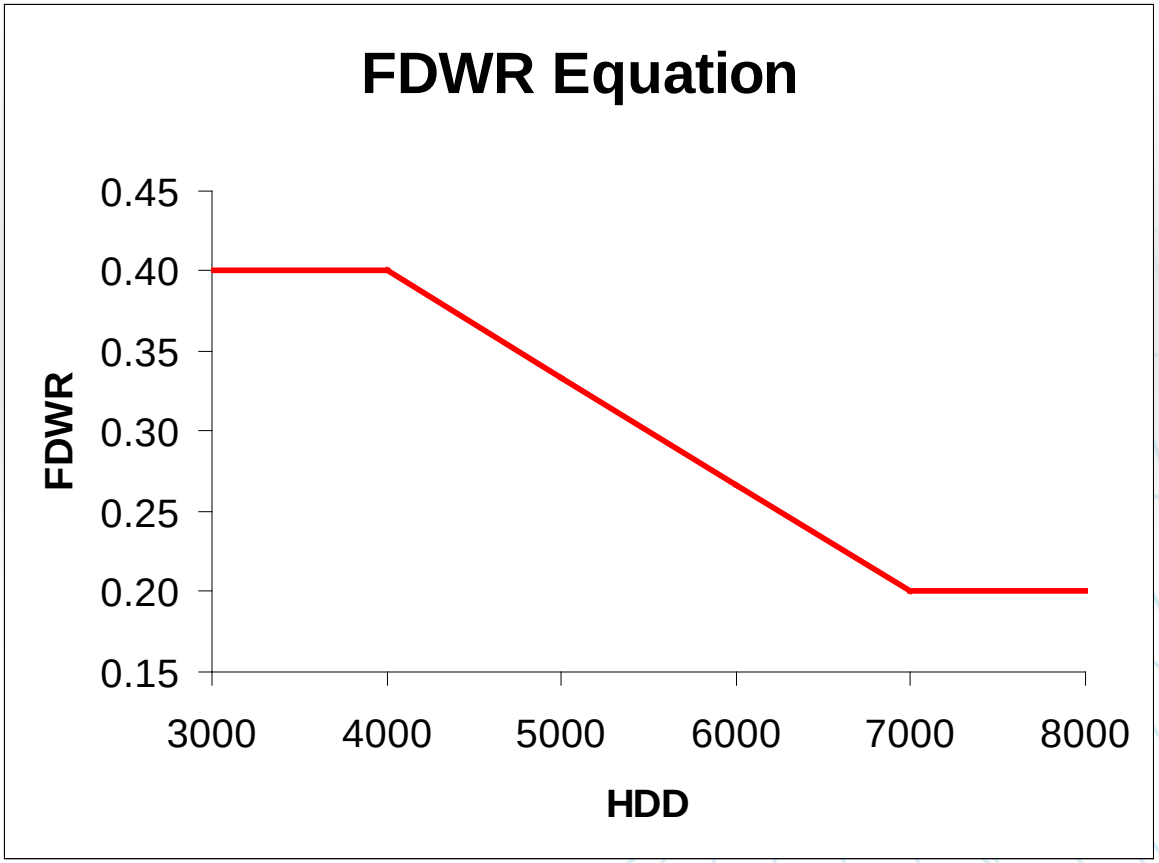
- Formula given to calculate, based on the temperature difference and table values for above grade assemblies, fenestration, and doors

Allowable Fenestration-and-door-to-wall ratio (FDWR) – new concept – varies from 20% to 40%, based on HDD of location

- FDWR = 0.40 for HDD < 4000
- FDWR ≤ (2000-0.2HDD)/3000 for 4000 ≤ HDD ≤ 7000
- FDWR = 0.20 for HDD > 7000

Skylights – maximum 5% of gross roof area

Prescriptive - FDWR



Part 3 Prescriptive Path Requirements

Above Ground Component Requirements

Vestibules – required at all “main” entries (some exceptions)

Maximum overall thermal transmittance expressed in tables, per climate zone, for

- Walls
- Roofs
- Floors (examples – cantilevered floor or at-grade parkade under condo)
- Fenestration
- Doors & Access Hatches

Part 3 Prescriptive Path Requirements

Building Assemblies in Contact with the Ground

Maximum overall thermal transmittance expressed in tables, per climate zone, for

- Below-grade Walls
- Below Grade Roofs (tunnels, projecting basement roofs)
- Floors

Prescriptive – above-ground opaque building assemblies

	Heating Degree-Days of Building Location, Celsius degree-days					
	Zone 4: Less than 3000	Zone 5: 3000 to 3999	Zone 6: 4000 to 4999	Zone 7A: 5000 to 5999	Zone 7B: 6000 to 6999	Zone 8: Greater than or equal to 7000
Maximum Overall Thermal Transmittance (U-value, W/(m²•K))						
Walls	0.315	0.278	0.247	**0.210**	**0.210**	**0.183**
Roofs	0.227	0.183	0.183	**0.162**	**0.162**	**0.142**
Floors	0.227	0.183	0.183	**0.162**	**0.162**	**0.142**

Prescriptive – assemblies in contact with ground

	Heating Degree-Days of Building Location, Celsius degree-days					
	Zone 4: Less than 3000	Zone 5: 3000 to 3999	Zone 6: 4000 to 4999	Zone 7A: 5000 to 5999	Zone 7B: 6000 to 6999	Zone 8: Greater than or equal to 7000
Maximum Overall Thermal Transmittance (U-value, W/(m²•K))						
Walls	0.568	0.379	0.284	**0.284**	**0.284**	**0.210**
Roofs	0.568	0.379	0.284	**0.284**	**0.284**	**0.210**
Floors	0.757 for 1.2m	0.757 for 1.2m	0.757 for 1.2m	**0.757 for 1.2m**	**0.757 for 1.2m**	**0.379 full area**

Prescriptive – assemblies in contact with ground

- Roofs < 1.2 m below ground
- Walls
  - Insulate to lesser of 2.4 m below ground or bottom of wall
  - Footings < 0.6 m below ground → insulate slab perimeter to 1.2 m
  - Embedded radiant heating/cooling → reduce U-value by 20%
- Floors < 0.6 m below grade → insulate
  - 1.2 m around perimeter, except climate zone 8
  - Full area of floor slab in zone 8.
  - Full area of floor slab if ducts or radiant heating/cooling cables or pipes are embedded

Prescriptive – Fenestration

	Heating Degree-Days of Building Location, Celsius degree-days					
	Zone 4: Less than 3000	Zone 5: 3000 to 3999	Zone 6: 4000 to 4999	Zone 7A: 5000 to 5999	Zone 7B: 6000 to 6999	Zone 8: Greater than or equal to 7000
Maximum Overall Thermal Transmittance (U-value, W/(m²•K))						
All Fenestration	2.4	2.2	2.2	2.0	2.0	1.6

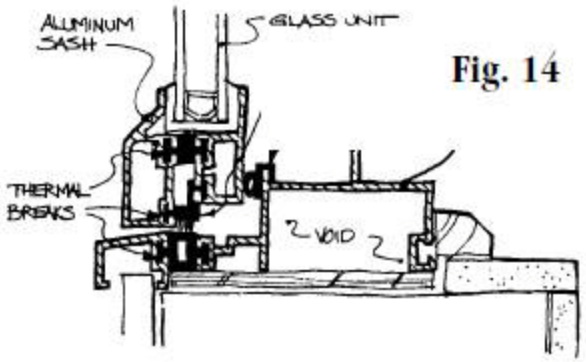


Fig. 14

U = 2.0 MECB revision

Zone 7A and 7B:

Dual- glazed units with:

- **Low-emissivity coating**
- **Good quality non-metallic spacer**
- **Argon fill**

Zone 8

– Triple-glazed units

Prescriptive – doors and access hatches

	Heating Degree-Days of Building Location, Celsius degree-days					
	Zone 4: Less than 3000	Zone 5: 3000 to 3999	Zone 6: 4000 to 4999	Zone 7A: 5000 to 5999	Zone 7B: 6000 to 6999	Zone 8: Greater than or equal to 7000
Maximum Overall Thermal Transmittance (U-value, W/(m²•K))						
Doors	2.4	2.2	2.2	**2.2**	**2.2**	**1.6**

- Relaxation: U ≤ 4.4 W/(m²•K) if assembly area ≤ 2% of gross wall area - Allows for “feature” doors
- Exemption for storm, automatic sliding glass, revolving doors, fire shutters
- Access hatches U ≤ 1.3 W/(m²•K)

Summary – Prescriptive Requirements

Climate Zone 7A and 7B

Roofs & Exposed Floors	U=0.162	(R-35)
Walls	U=0.210	(R-27)
Below-Grade Walls	U=0.284	(R-20)
Floors (No Radiant Heat)	U=0.757 for 1.2m	(R-7.5, 4’0” perimeter)
Floors (Radiant Heat)	U=0.757 (R-7.5)	Full Area

Climate Zone 8

Roofs & Exposed Floors	U=0.142	(R-40)
Walls	U=0.183	(R-31)
Below-Grade Walls	U=0.210	(R-27)
Floors (All)	U=0.379 for full area	(R-15)

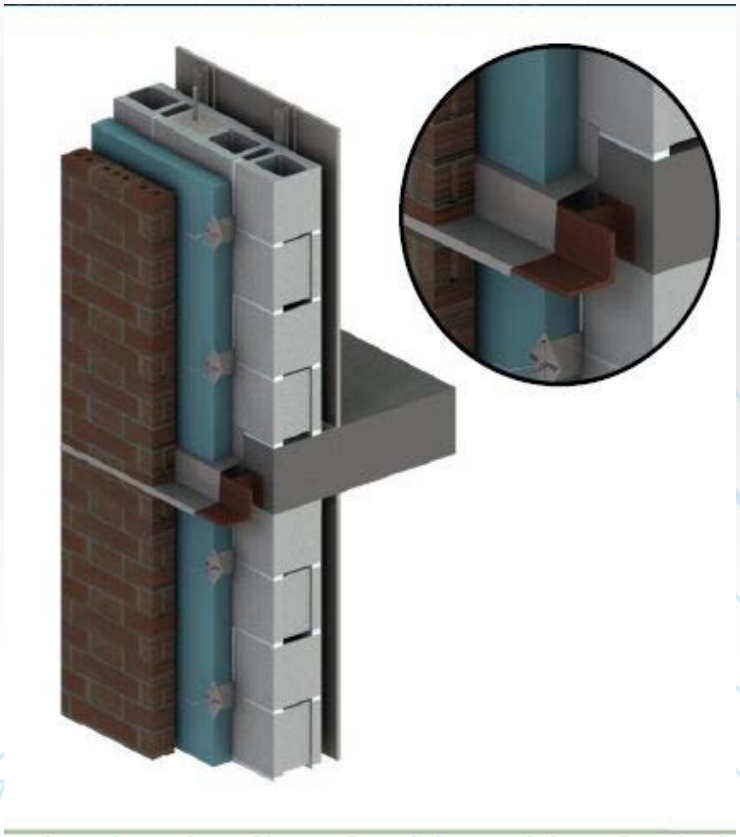
Summary – Prescriptive Fenestration Requirements

City	HDD	Zone	Glass U_{SI}	Max FDWR
Winnipeg	5670	7A	2.00	29%
Brandon	5760	7A	2.00	28%
Flin Flon	6440	7B	2.00	23%
Thompson	7600	8	1.60	20%
Churchill	8950	8	1.60	20%

Validation of Building Envelope Thermal Characteristics

Opaque Assemblies - Effective “U” values – NOT nominal

- All thermal bridges to be accounted for
- Calculation Procedures per ASHRAE Fundamentals
  - Isothermal Planes Method
  - Isothermal Planes and Parallel Path Method
- Software analysis – 2D or 3D
- Lab Testing in accordance with ASTM 1363



Graphic – Morrison Hershfield Energy and Construction Workshop - 2012

Validation of Building Envelope Thermal Characteristics

Calculation of U-Values

Isothermal Planes Calculation – used for assemblies with continuous components and no thermal bridging.

Isothermal Planes and Parallel Path Calculation – applies to wood frame assemblies where flow through thermal bridge is parallel to heat flow through insulation.

Metal Frame Assembly Calculation – method where an effective value for metal framing is used and added to isothermal planes method for continuous layers. (ASHRAE 90.1 Table A3.3)

Example for calculation – steel framed wall

Table 3-3
Effective RSI Values of the Insulation/Framing Layer in Metal-frame Wall Assemblies(1)

Nominal Depth of Cavity, mm	Actual Depth of Cavity, mm	Rated RSI Value of Air Space or Insulation	Effective Framing/Cavity RSI Value at 406 mm o.c.	Effective Framing/Cavity RSI Value at 610 mm o.c.
Empty Cavity, No Insulation				
100	89	0.16	0.14	0.16
Insulated Cavity				
100	89	1.94	0.97	1.16
100	89	2.29	1.06	1.27
100	89	2.64	1.13	1.37
150	152	3.35	1.25	1.51
150	152	3.70	1.30	1.58
200	203	4.40	1.37	1.69

(1) This Table is reproduced from ANSI/ASHRAE/IES 90.1-2010 with permission (©ASHRAE).

Figure 3-3 shows a graphical representation of the U-value calculation for metal-frame construction.

An example of a U-value calculation for metal-frame construction assemblies is presented in Example 3-9.

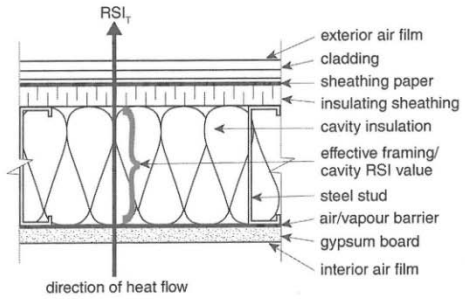


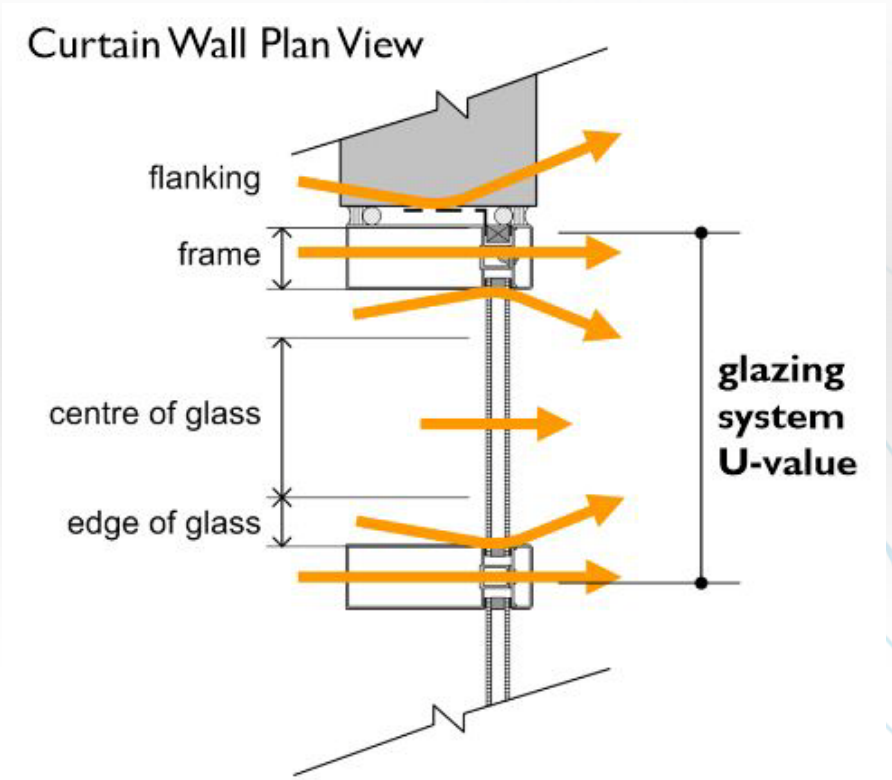
Figure 3-3
Graphical representation of U-value calculation for metal-frame construction

Source – NECB User's Guide 2014
Item 24, Table 3-3

Validation of Building Envelope Thermal Characteristics

Assembly Fenestration “U”-values - NOT centre of glass

- Software analysis (LBNL THERM or WINDOW)
- Lab Testing in accordance with ASTM 1363
- Calculation Procedures per ASHRAE Fundamentals



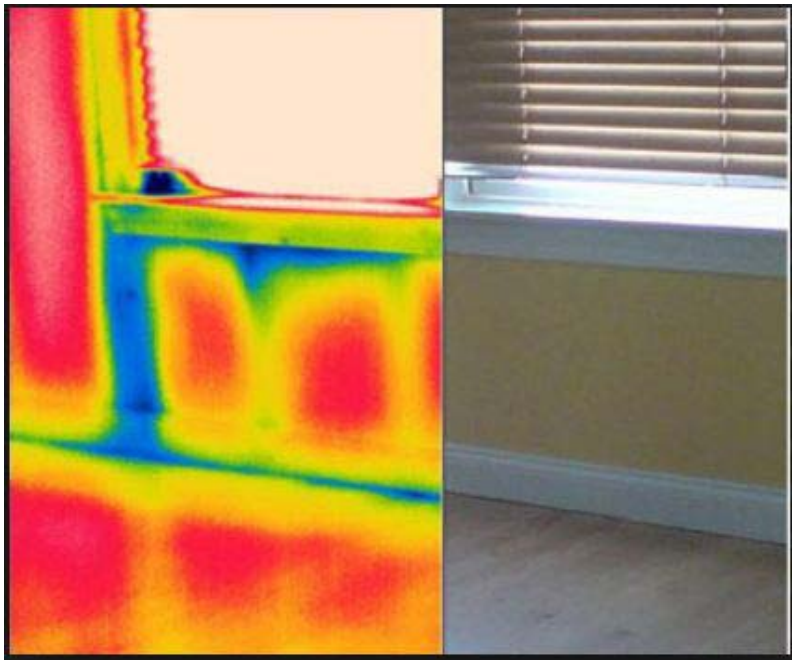
Graphic – Ontario Architects Association

Prescriptive Requirements – Air Leakage

- “The Building envelope shall be designed and constructed with a continuous air barrier system comprised of air barrier assemblies to control air leakage into and out of the conditioned space”.
- Opaque assemblies – air barrier assembly required

Prescriptive – air leakage

- Fenestration → tested to referenced standards
  - Metal and Glass Curtain Walls, per AAMA 501.5, to ASTM E283.
  - Fixed windows, operable windows, and skylights per AAMA/WDMA/CSA 101.1 S.2 A440 (“NAFS”)
  - Higher air leakage rate allowed for operable windows and operable skylights



Prescriptive Requirements – Air Leakage - Doors

- Doors → tested to referenced standard (ASTM E283)
  - Higher air leakage rate allowed for
    - Revolving doors
    - Automatic commercial sliding doors
    - Overhead doors
    - Main entry exterior doors
  - Loading docks that interface with truck boxes must have seals
  - Fireplaces must have doors (dampers) or enclosures

Simple trade-off path

- Very easy to apply
- Allows flexibility while maintaining minimum performance level set by prescriptive requirements
- Based on trading U-values, FDWR
  - Not permitted for additions
  - Not permitted for semi-heated buildings
  - Above-ground only
  - Trade only vertical to vertical, horizontal to horizontal

Simple Trade-Off Path Equation

Proposed **Reference**

$$\sum_{i=1}^{n} U_{ip} A_{ip} \leq \sum_{i=1}^{n} U_{ir} A_{ir}$$

Simple Trade-Off Path Example

Prescriptive

Simple Trade-Off

FDWR increased through using better glazing and increasing the U-Value of the walls

Simple Trade-Off Path Example 1

source – NECB User's Guide 2014

Commentary on Part 3

Example 3-13 – Simple Trade-off Path Calculation for Commercial Building

A one-storey community centre is proposed for Winnipeg, Manitoba. The building has a gross wall area of 560 m².

According to Table C-2 of Appendix C of the NBC, Winnipeg, Manitoba is classified as Zone 7A with 5670 HDD. Using the prescriptive path, the maximum allowable FDWR for a building located in Winnipeg is 0.289 (FDWR = 2000 – 0.2 × HDD ÷ 3000), however, based on the owner's requirements, the proposed design has an FDWR of 0.38.

According to the prescriptive requirements for Zone 7A, above-ground walls are required to have an overall thermal transmittance (U-value) of not more than 0.210 W/(m²·K) and both fenestration and doors are required to have a U-value of not more than 2.2 W/(m²·K). Using the maximum allowable FDWR of 0.289, the UA of the prescriptive building is calculated as follows:

Prescriptive Path (Reference Building)

Building Envelope Assembly	Prescriptive Path U-Value (U_{ir}), W/(m²·K)	Area (A_{ir}), m²	Area Ratio due to Maximum FDWR	UA (U_{ir} x A_{ir}), W/K
Walls	0.21	398.16	0.711	83.61
Fenestration and doors	2.2	161.84	0.289	356.05
	Totals:	560	1	ΣUA = 439.66 (440)

Following the method of the simple trade-off path, the owner's requirement for a higher FDWR can be traded-off against the U-values for the fenestration and doors and/or walls, since these assemblies are vertical above-ground portions of the building envelope, provided that the sum of the UAs (ΣUA) of the proposed building does not exceed the ΣUA of the reference building (440 W/K in this Example).

Simple Trade-Off Path Example 1

source – NECB User's Guide 2014

In order to show compliance using the proposed FDWR of 0.38, the designer applies the simple trade-off calculations using fenestration and doors with lower U-values (i.e. better performing than prescriptive). As shown in Option 1, by using fenestration and doors with U-values of 1.7 W/(m²·K), the ΣUA of the proposed building (435 W/K) remains below that of the reference building (440 W/K) and the design is compliant with the trade-off path.

Option 1 – Simple Trade-off Path (Proposed Building)

Building Envelope Assembly	Required U-Value (U_{ip}), W/(m²·K)	Area (A_{ip}), m²	Area Ratio due to Design Requirements	UA (U_{ir} x A_{ir}), W/K
Walls	0.21	347.2	0.62	72.91
Fenestration and doors	1.7	212.8	0.38	361.76
	Totals:	560	1	ΣUA = 434.67 (435)

The designer could also use a combination of measures to lower the U-value of the proposed building, for example, by modifying the U-values of both the walls and the fenestration and doors. In the calculation in Option 2, the U-value of the fenestration and doors is again decreased, but this permits an increased wall U-value.

Option 2 – Simple Trade-off Path (Proposed Building)

Building Envelope Assembly	Required U-Value (U_{ip}), W/(m²·K)	Area (A_{ip}), m²	Area Ratio due to Design Requirements	UA (U_{ir} x A_{ir}), W/K
Walls	0.27	347.2	0.62	93.74
Fenestration and doors	1.6	212.8	0.38	340.48
	Totals:	560	1	ΣUA = 434.22 (434)

Simple Trade-Off Path Example 2

source – NECB User's Guide 2014

Example 3-14 – Simple Trade-off Path Calculation for Warehouse

A warehouse with a total gross wall area of 2313 m² and a FDWR of 0.082 (8.2%) is proposed for Winnipeg, Manitoba. Since the FDWR is less than the maximum allowable for Winnipeg (0.289), the designer wishes to trade-off that better performing element against the U-value of the fenestration and doors and/or above-ground walls.

The prescriptive building's UA is calculated as follows using the maximum allowable FDWR of 0.289:

Prescriptive Path (Reference Building)

Building Envelope Assembly	Prescriptive Path U-Value (U_{ir}), W/(m²·K)	Area (A_{ir}), m²	Area Ratio due to Maximum FDWR	UA (U_{ir} x A_{ir}), W/K
Walls	0.21	1642.41	0.711	344.91
Fenestration and doors	2.2	667.59	0.289	1468.70
	Totals:	2310	1	ΣUA = 1813.61 (1814)

Following the simple trade-off path method, the proposed FDWR that is less than the maximum allowable can be traded-off against the U-values of the fenestration and doors and/or walls, since these assemblies are vertical above-ground portions of the building envelope, provided that the ΣUA of the proposed building does not exceed the ΣUA of the reference building (1814 W/K in this Example).

The designer applies the simple trade-off calculations using only wall U-values that are increased from the NECB prescriptive (less performing than prescriptive). As shown in Option 1, by using walls with a maximum U-value of 0.658 W/(m²·K), the ΣUA of the proposed building (1812 W/K) remains below that of the reference building (1814 W/K) and the design is compliant with the trade-off path.

Simple Trade-Off Path Example 2

source – NECB User's Guide 2014

Option 1 – Simple Trade-off Path (Proposed Building)

Building Envelope Assembly	Required U-Value (U_{ip}), W/(m²·K)	Area (A_{ip}), m²	Area Ratio due to Design Requirements	UA (U_{ir} x A_{ir}), W/K
Walls	0.658	2120.58	0.918	1395.34
Fenestration and doors	2.2	189.42	0.082	416.72
	Totals:	2310	1	ΣUA = 1812.06 (1812)

The designer could also use a combination of measures to lower the U-value of the proposed building, for example, by modifying the U-values of the walls, fenestration and doors. The calculation in Option 2 shows the trade-off of FDWR for lesser performing walls, fenestration and doors.

Option 2 – Simple Trade-off Path (Proposed Building)

Building Envelope Assembly	Required U-Value (U_{ip}), W/(m²·K)	Area (A_{ip}), m²	Area Ratio due to Design Requirements	UA (U_{ir} x A_{ir}), W/K
Walls	0.56	2120.58	0.918	1187.52
Fenestration and doors	3.3	189.42	0.082	625.09
	Totals:	2310	1	ΣUA = 1812.61 (1813)

Detailed trade-off path

- Scaled-down performance compliance
- Annual energy consumption of proposed building envelope $\leq$ energy target of reference building envelope
- Parameter inputs for calculations: areas of assemblies, U-values, configuration, orientation, thermal mass

Performance Path

If design does not or cannot comply with Part 3, sends you to Part 8.

Subject to Limitations:

- Limits on U-values of above-ground assemblies with embedded radiant heating/cooling (that is; cannot be changed)
- Building envelope air leakage is neutral (that is; cannot be traded)

Questions

Thank you

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