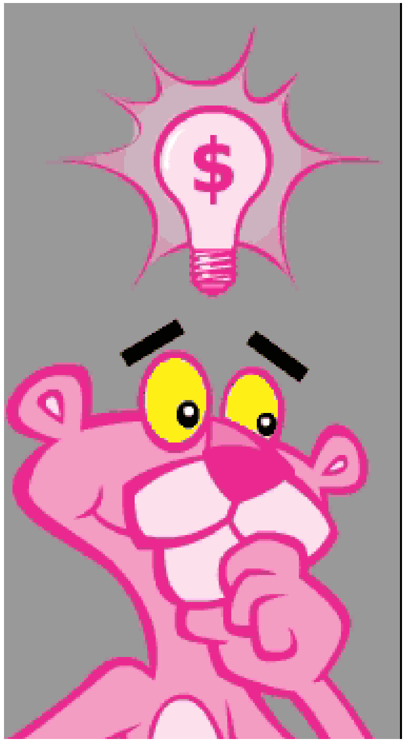
R-value and Heat Loss



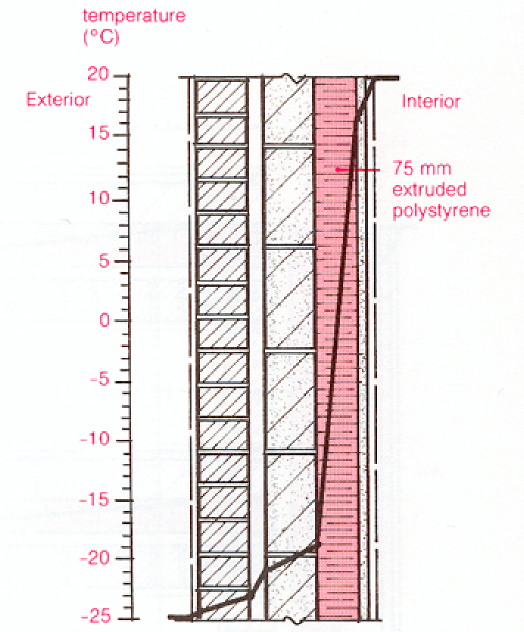


Figure 2.6 Insulation Placed on Interior

What is the R-value?

- R-value is an assessment of resistance to heat flow through a wall; *ie. it is a measure of the wall or material's ability to RESIST heat movement*
- speaks about insulation merit of the wall/material
- The higher the r-value, the better the material
- expressed as $m^2 * {}^oC/W$
- heat flow is driven by temperature difference from the interior to the exterior (higher the difference, more tendency for heat to move)
- also a function of the area (m^2) of the building envelope - more envelope, more area for heat to escape through
- opaque building elements are usually expressed in terms of their R-value

What is the U-value?

- U-value is the rate of heat flow through a wall - conductance
- it is a measure of the wall or material's ability to PROMOTE heat flow.
- The lower the U-value, the better the material
- expressed as W/ m^2 * ^oC
- heat flow is driven by temperature difference from the interior to the exterior (higher the difference, more tendency for heat to move)
- also a function of the area (m^2) of the building envelope - more envelope, more area for heat to escape through
- glazing materials usually speak in terms of U-values

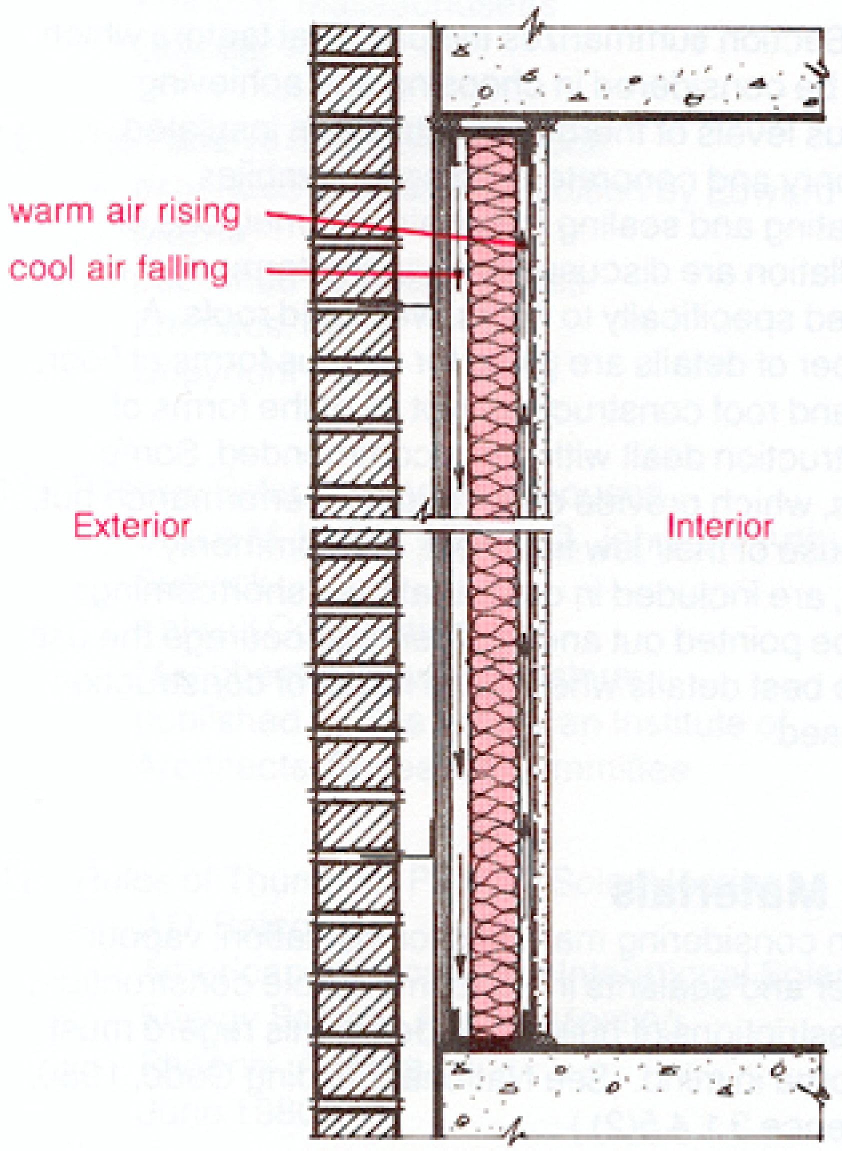


Figure 4.1 Loose Fitting Insulation Resulting in Convection Currents

Insulation materials need to be tightly packed in the wall to prevent airflow within the cavity. This kind of convection/air movement can decrease the insulation merit of the wall, in spite of the actual r-value that might "appear" to be accurate.

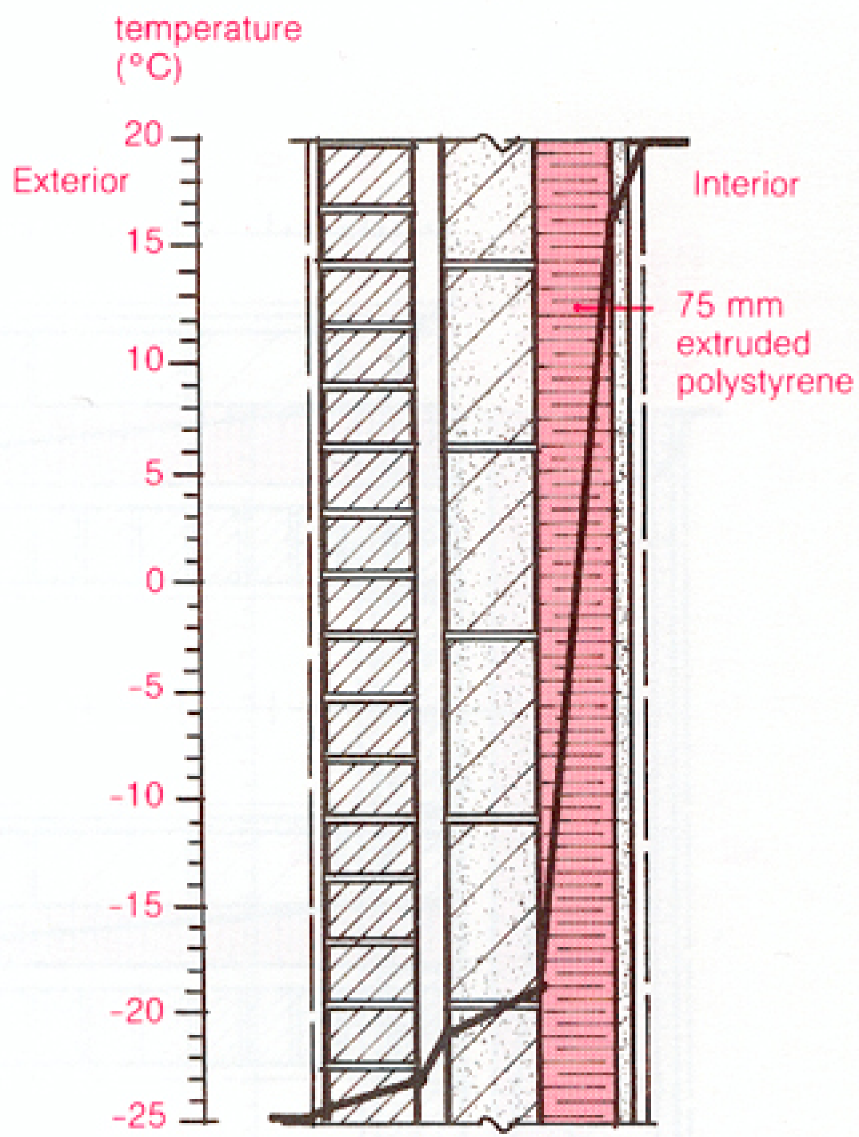


Figure 2.6 Insulation Placed on Interior

This image shows the temperature profile of a wall. The amount of insulating capability of each material will affect the temperature. Highly insulative materials make the greatest contribution to the resistance to heat flow.

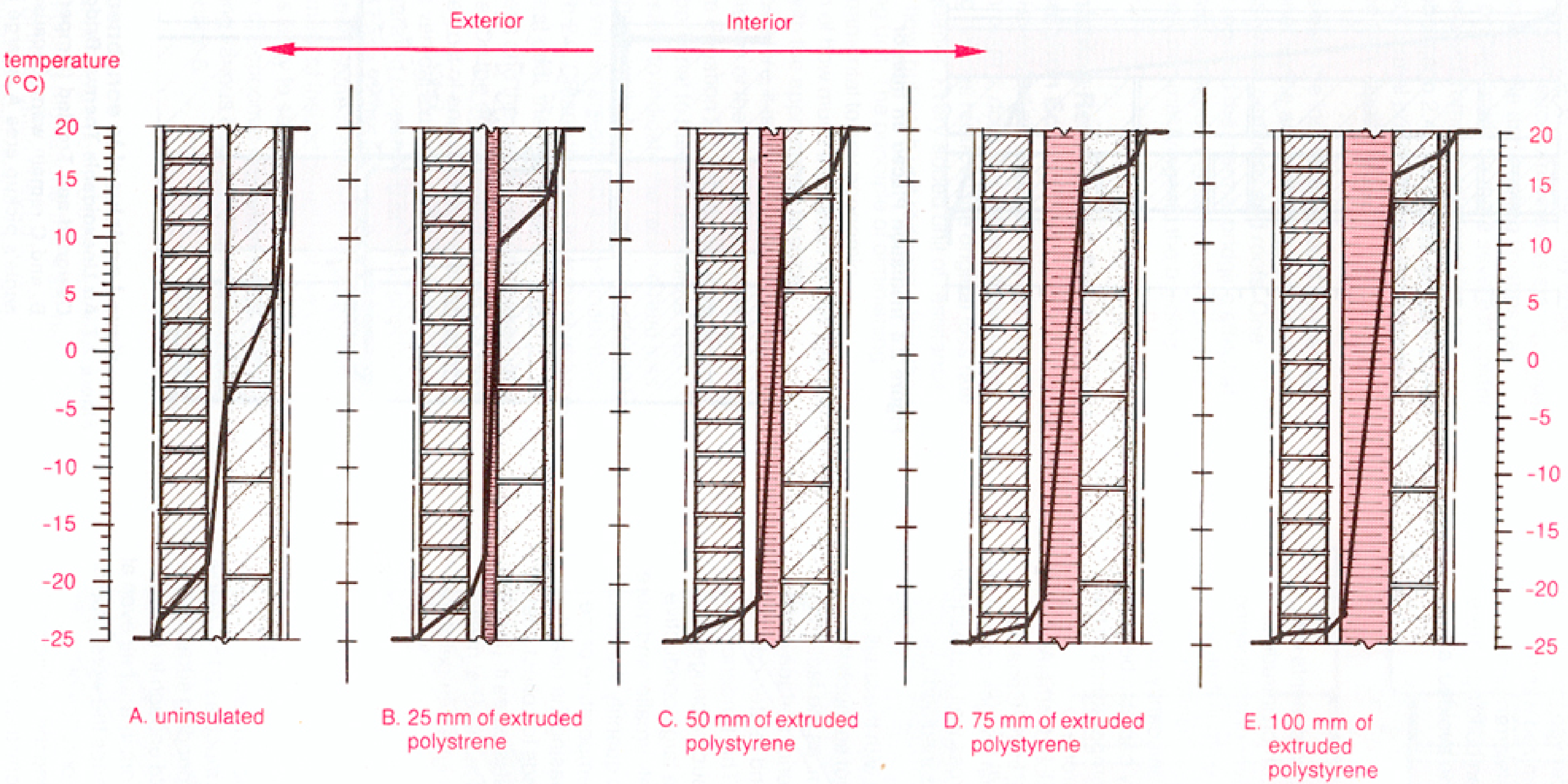
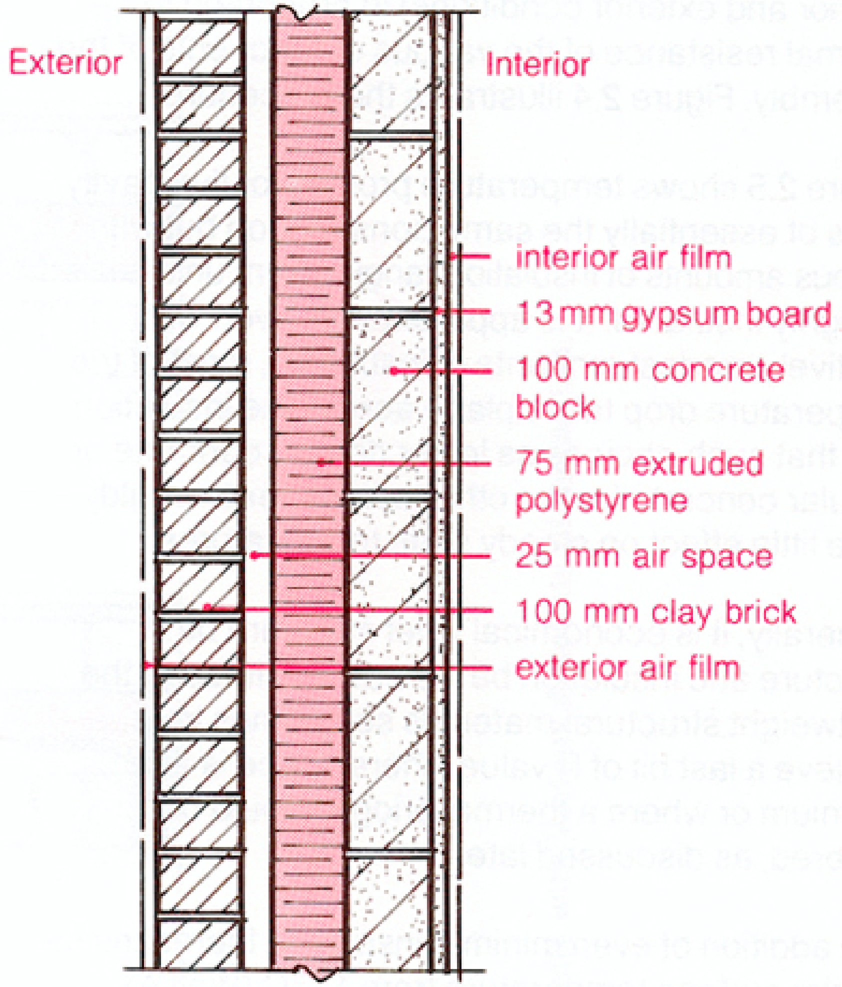


Figure 2.5 Temperature Profiles on a Typical Cold Winter Day for Five Cavity Walls with Various Amounts of Insulation.

The R-value for a wall is the sum of all of the R-values for all of the individual components PLUS values for inside/outside air films and air spaces.



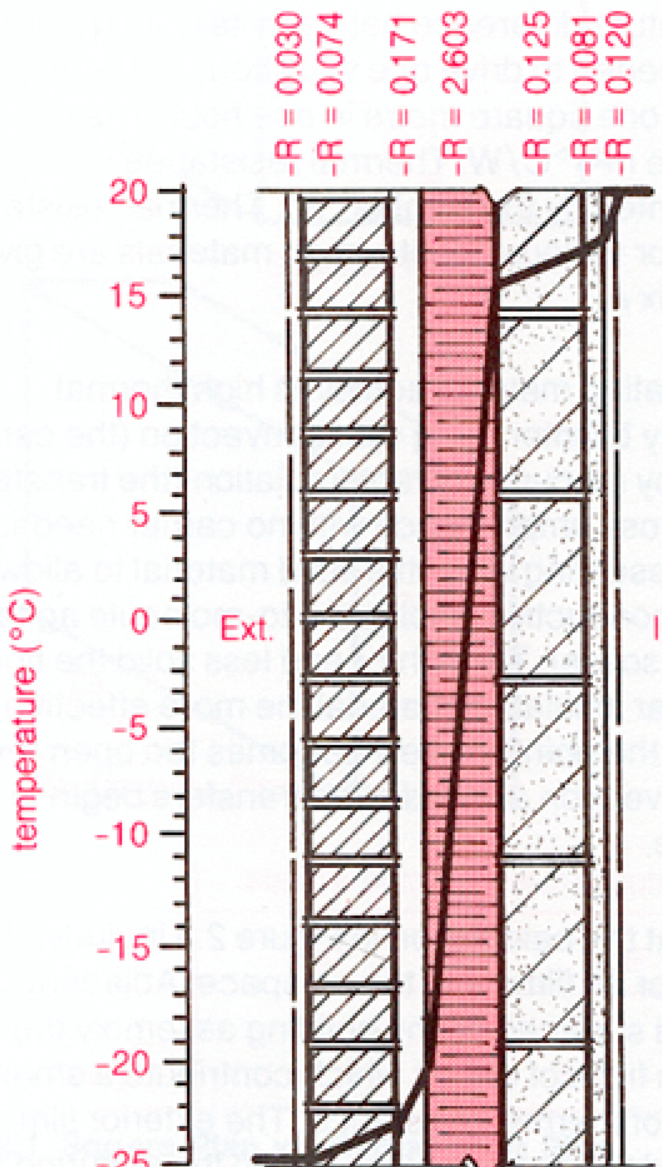
component		R value ($m^2 \cdot °C/W$)
interior air film	—	0.120
gypsum board	—	0.081
concrete block	—	0.125
ext. polystyrene	—	2.603
air space	—	0.171
clay brick	—	0.074
exterior air film	—	0.030

$\sum R = 3.20\ m^2 \cdot °C/W$

Figure 2.3 Calculation of the Thermal Resistance of a Building Assembly.

This diagram shows the calculation of the temperature profile across the assembly. Changes are calculated as a proportion of the overall temperature difference from interior to exterior.

So what you need to calculate here is the amount of temperature drop across the envelope that each material is responsible for!



R_n ($m^2 \cdot °C/W$)	0.120	0.201	0.326	2.929	3.100	3.174
$\frac{R_n}{R_t}$	0.037	0.063	0.102	0.913	0.968	0.991
$T_n = T_i - (\frac{R_n}{R_t})\Delta T$ (°C)	18.3	17.2	15.4	-21.1	-23.5	-24.6

$\Delta T = T_i - T_o = 45°C$

$R_t = 3.20\ m^2 \cdot °C/W$

where R_n — total thermal resistance to outer edge of n'th component

R_t — total thermal resistance of wall

T_n — temperature of outer edge of n'th component

T_i — inside temperature

T_o — outside temperature

Figure 2.4 Calculation of Temperature Profile in a Building Assembly

APPENDIX E
DEGREE-DAY VALUES FOR VARIOUS LOCATIONS

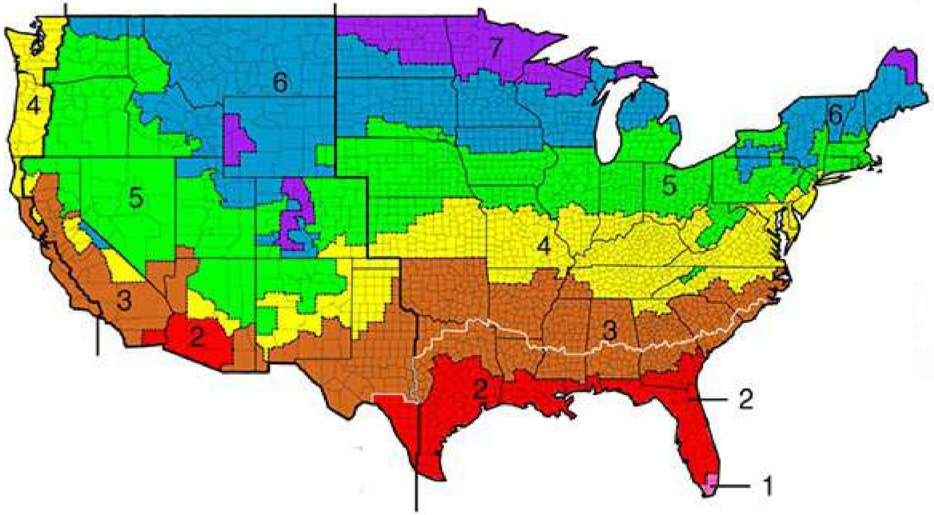
WEATHER DATA AND JANUARY DESIGN TEMPERATURES FOR 100 CANADIAN COMMUNITIES

Province and Station [1]	Degree days below 18°C	Design temperatures 2 1/2% °C	Design temperatures 1% °C
Newfoundland			
Corner Brook	4 900	−19	−22
Gander	5 039	−18	−21
Goose Bay	6 522	−31	−33
St. John's	4 804	−14	−16
Stephenville	4 783	−17	−20
Northwest Territories			
Fort Smith	7 852	−43	−45
Frobisher Bay	9 845	−40	−42
Inuvik	10 174	−46	−48
Resolute	12 549	−44	−45
Yellowknife	8 593	−43	−45
Nova Scotia			
Amherst	4 580	−21	−24
Halifax	4 123	−16	−18
Kentville	4 240	−18	−20
New Glasgow	4 580	−21	−23
Sydney	4 459	−16	−18
Truro	4 704	−21	−23
Yarmouth	4 024	−13	−15
Ontario			
Belleville	4 190	−22	−24
Chatham	3 530	−16	−18
Cornwall	4 470	−23	−25
Hamilton	3 710	−17	−19
Kapuskasing	6 366	−33	−35
Kenora	5 932	−33	−36
Kingston	4 266	−22	−24
Kitchener	4 110	−19	−21
London	4 068	−18	−20
North Bay	5 318	−28	−30
Oshawa	4 130	−19	−21
Ottawa	4 673	−25	−27
Owen Sound	4 220	−19	−21
Peterborough	4 520	−23	−25
St. Catharines	3 550	−16	−18
Sarnia	3 840	−16	−18
Sault Ste. Marie	5 180	−25	−28
Sudbury	5 447	−28	−30
Timmins	6 189	−34	−36
Toronto	4 082	−18	−20
Windsor	3 590	−16	−18
Prince Edward Island			
Charlottetown	4 623	−20	−22
Summerside	4 600	−20	−22
Québec			
Bagotville	5 776	−31	−33
Chicoutimi	5 510	−30	−32
Drummondville	4 740	−25	−28
Granby	4 580	−25	−27
Hull	4 740	−25	−28
Mégantic	5 280	−27	−29
Montréal	4 471	−23	−26
Québec	5 080	−25	−28
Rimouski	5 400	−25	−27
St. Jean	4 630	−24	−26
St. Jérôme	5 060	−25	−27
Sept Îles	6 135	−30	−32
Shawinigan	5 110	−26	−29
Sherbrooke	5 242	−28	−30
Thetford Mines	5 350	−26	−28
Trois Rivières	5 070	−25	−28
Val d'Or	6 146	−33	−36
Valleyfield	4 520	−23	−25
Saskatchewan			
Estevan	5 542	−32	−34
Moose Jaw	5 400	−32	−34
North Battleford	6 050	−34	−36
Prince Albert	6 562	−37	−41
Regina	5 920	−34	−36
Saskatoon	6 077	−35	−37
Swift Current	5 482	−32	−34
Yorkton	6 239	−34	−37
Yukon Territory			
Dawson	8 274	−50	−51
Whitehorse	6 879	−41	−43

[1] Temperature observations at airports and/or local weather offices were used to develop design data.
For additional data refer to *The Supplement to the National building Code of Canada 1980*.

Wall design and mandatory R-values for assemblies are determined based on the severity of local climates, expressed in degree-days. The more severe the climate, the more insulating value required by the code.

*Canadian Climate Zones	Heating degree-days
Zone 4	< 3000 HDD
Zone 5	3000 – 3999 HDD
Zone 6	4000 – 4999 HDD
Zone 7A	5000 – 5999 HDD
Zone 7B	6000 – 6999 HDD
Zone 8	≥ 7000 HDD



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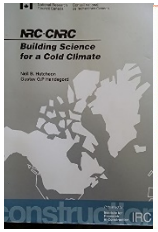
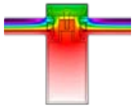
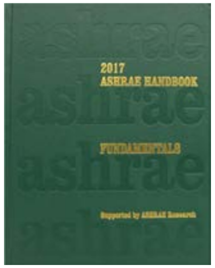
Finding R and U Values



- Textbooks
- Reference document (Building Enclosure Fundamentals)
- ASHRAE Handbooks
- Simulation Software
- National Fenestration Rating il (w ,
- Manufacturer



THERM



Imperial:
R
(ft^2·F·hr/Btu**)**

$$R = RSI \times 5.678$$

Metric:
RSI
(m^2K/W)

Insulation – nominal values look-up

- Above-ground requirements

Opaque Building Assembly	Heating-degree day (HDD) of building location, °C days					
	Zone 4	Zone 5	Zone 6	Zone 7a	Zone 7b	Zone 8
	<3000	3000 to 3999	4000 to 4999	5000 to 5999	6000 to 6999	≥7000
	Effective thermal resistance (RSI) in m² °C/W					
Walls (No HRV)	**2.78**	**3.08**	**3.08**	**3.08**	**3.85**	**3.85**
Walls (HRV)	**2.78**	**2.97**	**2.97**	**2.97**	**3.08**	**3.08**

- Appendix – lookup tables

Description of Framing or Material	Thermal Resistance of Insulated Assembly			Minimum Effective Thermal Resistance Required by Article 9.36.2.6. for Above-ground Wall Assemblies, (m²·K)/W			
	Nominal, (m²·K)/W (ft²·°F·h/Btu)		Effective, (m²·K)/W	2.78	2.97	3.08	3.85
	Insulation in Framing Cavity	Continuous Materials	Entire Assembly	Minimum Nominal Thermal Resistance,[1] in (m²·K)/W, to be Made up by Insulation, Sheathing[2] or Other Materials and Air Film Coefficients			
38 x 140 mm wood at 406 mm o.c.	3.34 (R19)[3]	None	2.36	0.42[4]	0.61	0.72	1.49
		1.32 (R7.5)	3.68	—	—	—	0.17
	3.87 (R22)	None	2.55	0.23	0.42	0.54	1.30
		0.88 (R5)	3.43	—	—	—	0.42
	4.23 (R24)	None	2.66	0.12	0.30	0.42	1.18

Insulation – windows, doors and skylights

- U-value – requirements for windows, doors and skylights

Component	Zone 4	Zone 5	Zone 6	Zone 7a	Zone 7b	Zone 8
	<3000	3000 to 3999	4000 to 4999	5000 to 5999	6000 to 6999	≥7000
	Maximum Overall Thermal Transmittance (USI) in W/m² °C					
Doors and windows	**1.8**	**1.8**	**1.6**	**1.6**	**1.4**	**1.4**
Skylights	**2.9**	**2.9**	**2.7**	**2.7**	**2.4**	**2.4**

- Energy Rating (ER) – requirements for windows and doors

Component	Zone 4	Zone 5	Zone 6	Zone 7a	Zone 7b	Zone 8
	<3000	3000 to 3999	4000 to 4999	5000 to 5999	6000 to 6999	≥7000
	Minimum Energy Rating					
Doors and windows	**21**	**21**	**25**	**25**	**29**	**29**

- Exceptions
  - Storm doors (exempt)
  - One front door and attic/crawl space hatches Umax= 2.6 W/M²k
  - Glass block up to 1.85 m² Umax= 2.9 W/M²k
  - Garage door RSI = 1.1 m²K/W

The psychrometric chart can be used to determine the dewpoint as a function of the indoor dry bulb temperature and the relative humidity of the space.

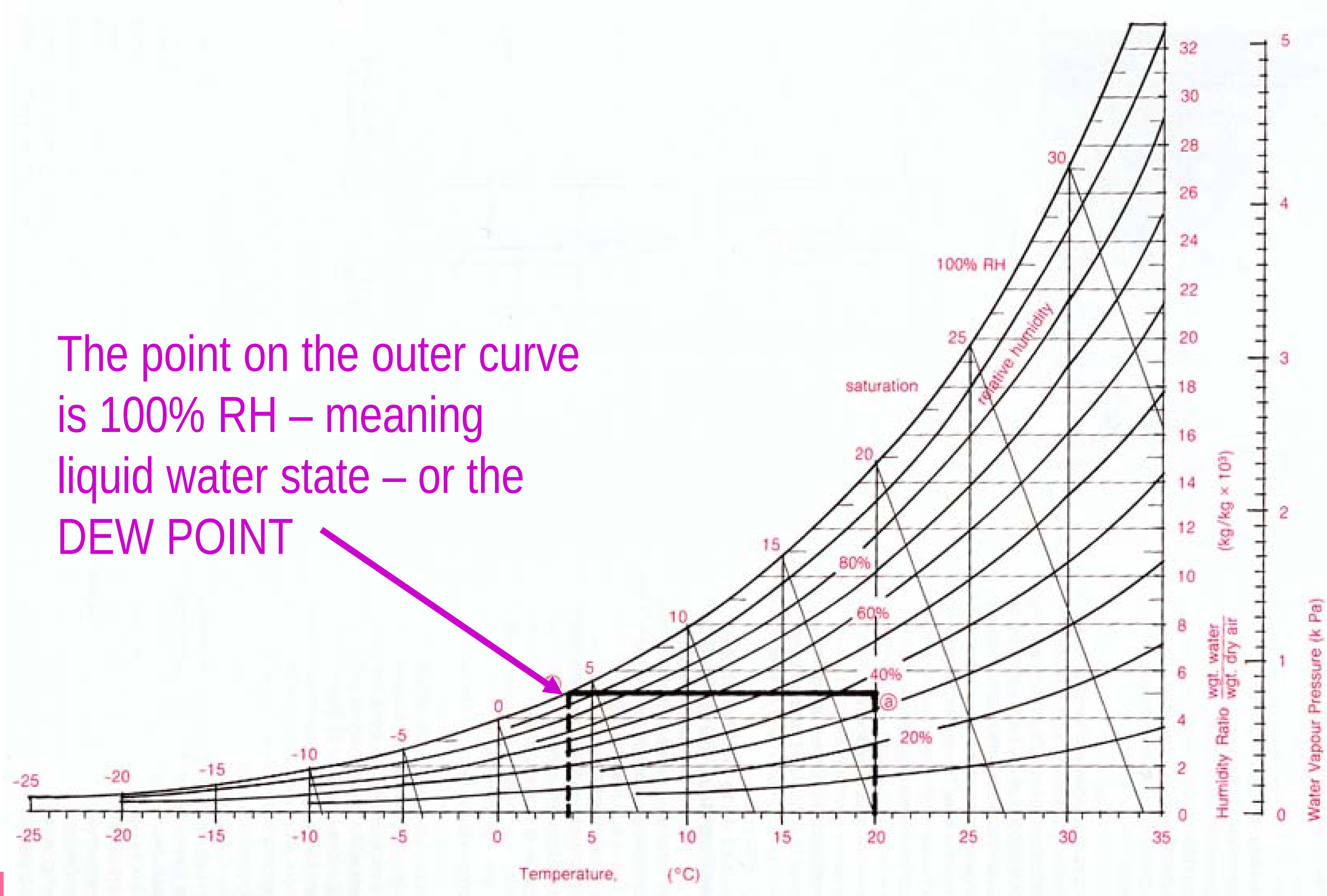


Figure 2.11 Simplified Psychrometric Chart

Q. Where do we find the RSI values for our wall sections??

A. Scroll down to

5.2 Thermal Resistance of Continuous Materials

https://www.nrcan.gc.ca/energy/efficiency/housing/new-homes/energy-starr-new-homes-standard/tables-calculating-effective-thermal-resistance-opaque-assemblies/14176#a5

The NRCan table is your first priority for accurate information. If you cannot find the material there, please use the following charts. If there is a disagreement between the following charts and the NRCan site, use the NRCan values.

R to RSI Converter:
https://isolofoam.com/en/r-rsi-converter/

THERMAL RESISTANCE VALUES OF VARIOUS BUILDING MATERIALS

Description	Thermal Resistance* Per Unit of Thickness** RSI	R	For Thickness Listed RSI	R
Insulation				
Mineral Wool and Glass Fibre	**0.0208**	**(3.00)**		
Cellulose Fibre	0.0253	(3.65)		
Vermiculite	**0.0144**	**(2.08)**		
Wood Fibre	**0.0231**	**(3.33)**		
Wood Shavings	**0.0169**	**(2.44)**		
Sprayed Asbestos	0.0201	(2.90)		
Expanded Polystyrene Complying with CGSB 41-GP-14a (1972)				
— TYPE 1	0.0257	(3.70)		
— TYPE 2	0.0277	(4.00)		
— TYPE 3	0.0298	(4.30)		
— TYPE 4	0.0347	(5.00)		
Rigid Glass Fibre Roof Insulation	**0.0277**	**(4.00)**		
Natural Cork	**0.0257**	**(3.70)**		
Rigid Urethane or Isocyanurate Board	0.0420	(6.00)		
Mineral Aggregate Board	**0.0182**	**(2.63)**		
Compressed Straw Board	**0.0139**	**(2.00)**		
Fibreboard	**0.0194**	**(2.80)**		
Phenolic Thermal Insulation	0.0304	(4.34)		
Structural Materials				
Cedar Logs and Lumber	0.0092	(1.33)		
Other Softwood Logs and Lumber	0.0087	(1.25)		
Concrete:				
— 2400 kg/m³ (150 lb/cu.ft.)	0.00045	(0.065)		
— 1760 kg/m³ (110 lb/cu.ft.)	0.0013	(0.19)		
— 480 kg/m³ (30 lb/cu.ft.)	0.0069	(1.00)		
Concrete Block — 3 Oval Core				
Sand and Gravel Aggregate				
— 100 mm (4")			0.125	(0.71)
— 200 mm (8")			0.195	(1.11)
— 300 mm (12")			0.225	(1.28)
Cinder Aggregate				
— 100 mm (4")			0.125	(0.71)
— 200 mm (8")			0.195	(1.11)
— 300 mm (12")			0.225	(1.28)
Lightweight Aggregate				
— 100 mm (4")			0.264	(1.50)
— 200 mm (8")			0.352	(2.00)
— 300 mm (12")			0.400	(2.27)

* Values are given in m²·°C/W followed by values in ft². hr. °F/B.T.U. in parentheses.

** Metric values are given per mm of thickness. Imperial values are given per inch of thickness.

Multiply the thickness listed by the thickness of your element

THERMAL RESISTANCE VALUES OF VARIOUS BUILDING MATERIALS

Description	Thermal Resistance* Per Unit of Thickness** RSI	R	For Thickness Listed RSI	R
Sheathing Materials				
Softwood Plywood	0.0087	(1.25)		
Mat-Formed Particle Board	0.0087	(1.25)		
Insulating Fibreboard Sheathing	**0.0165**	**(2.38)**		
Gypsum Sheathing	0.0062	(0.90)		
Sheathing Paper			0.011	(0.06)
Asphalt Coated Kraft Paper				
Vapour Barrier			Negligible	
Polyethylene Vapour Barrier			Negligible	
Cladding Materials				
Fibreboard Siding	0.0107	(1.54)		
Softwood Siding				
Drop — 18 × 184 mm (1" × 8")			0.139	(0.79)
Bevel — 12 × 184 mm (1/2" × 8") — Lapped			0.143	(0.81)
Bevel — 19 × 235 mm (3/4" × 10") — Lapped			0.185	(1.05)
Plywood — 9 mm (3/8") — Lapped			0.103	(0.59)
Brick				
Clay or Shale — 100 mm (4")			0.074	(0.42)
Concrete and Sand/Lime — 100 mm (4")			0.053	(0.30)
Stucco	0.0014	(0.20)		
Metal Siding				
Horizontal Clapboard Profile			0.123	(0.70)
Horizontal Clapboard Profile with Backing			0.246	(1.40)
Vertical V-Groove Profile			0.123	(0.70)
Vertical Board and Batten Profile			Negligible	
Roofing Materials				
Asphalt Roll Roofing			0.026	(0.15)
Asphalt Shingles			0.078	(0.44)
Built-Up Roofing			0.058	(0.33)
Wood Shingles			0.165	(0.94)
Crushed Stone — Not Dried	0.0006	(0.08)		

* Values are given in m²·°C/W followed by values in ft². hr. °F/B.T.U. in parentheses.

** Metric values are given per mm of thickness. Imperial values are given per inch of thickness.

THERMAL RESISTANCE VALUES OF VARIOUS BUILDING MATERIALS

Description	Thermal Resistance* Per Unit of Thickness** RSI	R	For Thickness Listed RSI	R
Air Surface Films				
Still Air-Horizontal Surface — Heat Flow Up — e.g. inside of ceilings			0.105	(0.61)
Still Air-Horizontal Surface — Heat Flow Down — e.g. inside of floors			0.162	(0.92)
Still Air-Vertical Surface — Heat Flow Horizontal — e.g. inside of walls			0.120	(0.68)
Moving Air — Any Position — e.g. outside of any surface			0.030	(0.17)
Air Spaces — Faced with Non-reflective Materials — 12 mm (1/2") Minimum Dimension				
Horizontal Space — Heat Flow Up			0.150	(0.85)
Horizontal Space — Heat Flow Down			0.180	(1.02)
Vertical Space — Heat Flow Horizontal			0.171	(0.97)
Air Spaces Less than 12 mm (1/2") in Minimum Dimension			0	
Air Spaces — Faced with Reflective Materials* — 12 mm (1/2") Minimum Dimension**				
Horizontal Space-Faced 1 Side — Heat Flow Up			0.324	(1.84)
Horizontal Space-Faced 2 Side — Heat Flow Up			0.332	(1.89)
Horizontal Space-Faced 1 Side — Heat Flow Down			0.980	(5.56)
Horizontal Space-Faced 2 Side — Heat Flow Down			1.034	(5.87)
Vertical Space-Faced 1 Side — Heat Flow Horizontal			0.465	(2.64)
Vertical Space-Faced 2 Side — Heat Flow Horizontal			0.480	(2.73)
Air Spaces Less than 12 mm (1/2") in Minimum Dimension			0	

* Values are given in m²·°C/W followed by values in ft². hr. °F/B.T.U. in parentheses.

** Metric values are given per mm of thickness. Imperial values are given per inch of thickness.

*** These values may not be used in calculations for areas where the mean annual total degree days exceed 4400 Celsius degree days (8000 Fahrenheit degree days).

The interior and exterior air film (based on the texture of the surface, combined with speed of air flow over) contribute to the overall R-value of the wall. *For a piece of single glazing, the contribution is very high!*

When selecting values for air spaces, be careful to note the direction of heat flow, up or across the envelope.

THERMAL RESISTANCE VALUES OF VARIOUS BUILDING MATERIALS

Description	Thermal Resistance* Per Unit of Thickness** RSI	R	For Thickness Listed RSI	R
Interior Finish Materials				
Gypsum Board, Gypsum Lath	0.0062	(0.90)		
Gypsum Plaster — Sand Aggregate	0.0014	(0.20)		
Gypsum Plaster — Lightweight Aggregate	0.0044	(0.64)		
Plywood	0.0087	(1.25)		
Hard-Pressed Fibreboard	0.0050	(0.72)		
Insulating Fibreboard	0.0165	(2.38)		
Mat-Formed Particleboard	0.0087	(1.25)		
Carpet Fibrous Underlay			0.366	(2.08)
Carpet Rubber Underlay			0.226	(1.28)
Resilient Floor Coverings			0.014	(0.08)
Terrazzo — 25 mm (1")			0.014	(0.08)
Hardwood Flooring — 9.5 mm (3/8")			0.060	(0.34)
— 19 mm (3/4")			0.120	(0.68)
Wood Fibre Tiles — 13 mm (1/2")			0.209	(1.19)

* Values are given in $m^2 \cdot {}^\circ C/W$ followed by values in $ft^2 \cdot hr \cdot {}^\circ F/B.T.U.$ in parentheses.

** Metric values are given per mm of thickness. Imperial values are given per inch of thickness.