MORRISON HERSHFIELD

November 14, 2014

621 – 100 Paget Street
Winnipeg, MB
Canada R3P 1C6

Dear Ted Cullen:

Re: Quik-Therm Building Energy Modelling

Morrison Hershfield was engaged to evaluate the annual energy cost impact of incorporating the Quik-Therm product into pre-engineered metal building envelope assemblies compared to typical assemblies. The intent of this letter is to outline the results of the energy analysis.

A whole-building energy model was created for a typical, representative building based on information provided by Quik-Therm and this model was used to perform various analyses. The typical building that was analyzed is approximately 929 m^2 (10,000ft^2), consisting primarily of a large, open shop area. The information used to create the model included drawings of a typical pre-engineered, metal building, roughly four months of utility data and basic information such as HVAC system types and envelope construction. Detailed model inputs can be found in Appendix A.

The details of wall and roof assemblies for metal buildings can vary; as such, the baseline building uses walls and roofs with generic performance data taken from ASHRAE 90.1-2010, Appendix A. The wall performance was taken from Table A3.2 for a single layer of R-19 insulation, yielding an effective R-value of R12. The roof performance was taken from Table A2.3 for “Thru-Fastened without Thermal Spacer Blocks” and R-19 batt insulation, yielding an effective R-value of R10. Excerpts from the relevant sections of ASHRAE 90.1-2010, Appendix A, have been included in Appendix C of this letter.

The baseline building, with the above wall and roof performance, is compared to an improved case where a 2 inch layer of Quik-Therm is added to the assembly. Installing a continuous (or near continuous) layer of insulation outside of the batt, such as Quik-Therm, reduces the impact of thermal bridging of the insulating layer between studs or girts and yields an improved effective R-value. The R-value improvement is close to that of the rated R-value of the product itself, which is about R5 per inch based on ASTM testing data provided. Therefore, the performance of the walls and roofs with the Quik-Therm product was estimated at R22 and R20, respectively. Note that no 2D or 3D thermal modeling or testing was performed for any of the specific assemblies considered in either the baseline or improved cases. As such, all performance values were estimated using existing data from ASHRAE 90.1-2010.

Increasing the building’s overall equivalent insulating value, as shown in this comparison, reduced envelope-related losses by approximately 46% and overall heating energy by 22%. Peak heating capacity was also reduced by 12%, which in some cases could allow a reduction in the rated heating capacity of mechanical equipment. A summary of the economic impact of these savings is shown below in Table 1, with the utility rates used summarized in Table 2.

Table 1 – Summary of Energy Modelling Results

Scenario	Electricity (GJ)	Natural Gas (GJ)	Annual Energy (GJ)	Energy Savings	Annual Cost	Cost Savings
Baseline	384	870	1,254	-	$14,505	-
Improved with Quik-Therm	383	676	1,059	15.6%	$13,038	10.1%

Table 2 – Utility Rate Summary

Electricity	Electrical Demand	Natural Gas
$0.0752 / kWh	$10.1 / kW (after first 50kW)	$7.4665 / GJ

It should be noted that natural gas prices in Manitoba are currently low and only about 65% of what they were at the peak of 2008. If the gas prices were at 2008 peak values, the cost savings would be $2,288.

The energy and energy cost end use breakdown of the baseline building is shown in Figures 1a and 1b below.

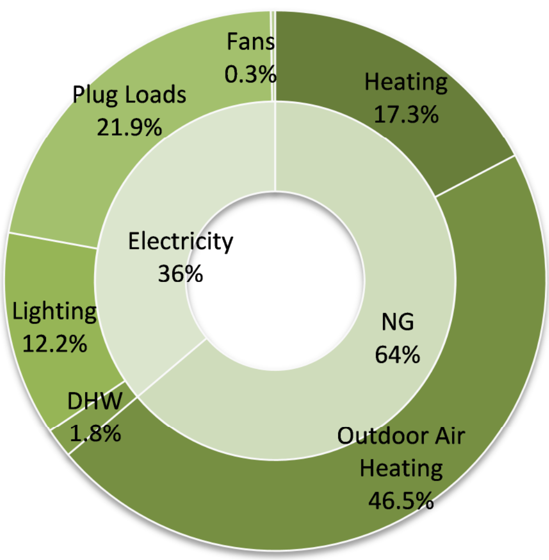

Figure 1a: Energy *Use* by End Use

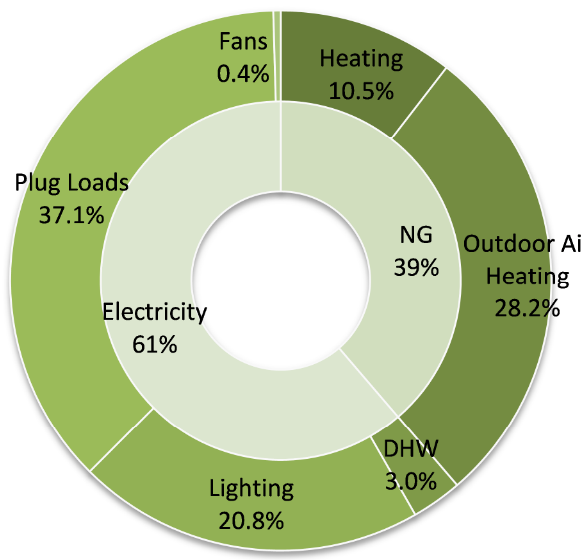

Figure 1b: Energy *Cost* by End Use

The relatively cheaper cost per unit of energy for natural gas means that it is significantly less prominent in the cost breakdown even though it is by far the largest energy use. Also, outdoor-air heating (both related to ventilation and infiltration) is the largest of the natural gas-related end-uses. This relative weighting of end-uses is important to note when an analysis is being done from the point of view of envelope performance comparison. The result is that only 10.5% of the building's total utility cost can be affected by envelope-related upgrades. However, in looking at the envelope related energy only, continuous insulation products like Quik-Therm reduce envelope related heating energy by about 46%.

Energy Code Requirements

Despite the results of the payback analysis, the upcoming introduction of the National Energy Code for Buildings (NECB 2011) in Manitoba will provide a greater incentive for improving building envelope performance. Buildings will need to show compliance with the NECB 2011 by either meeting the prescriptive, trade-off or performance path requirements.

The prescriptive building envelope requirements for Zone 7A are R27 walls and R35 roofs. Figure 2 below shows that the wall requirements can be met by a typical metal building with R30 batt and 2" of Quik-Therm. A roof with R30 batt and 3" of Quik-Therm falls short of the NECB 2011 requirements; however, one could use the trade-off path in NECB to use the over-performing walls to compensate for the underperforming roof. For the dimensions of the typical building considered in this analysis, the building would comply with the NECB 2011 envelope requirements using the trade-off path (assuming all other envelope components are code-compliant or better).

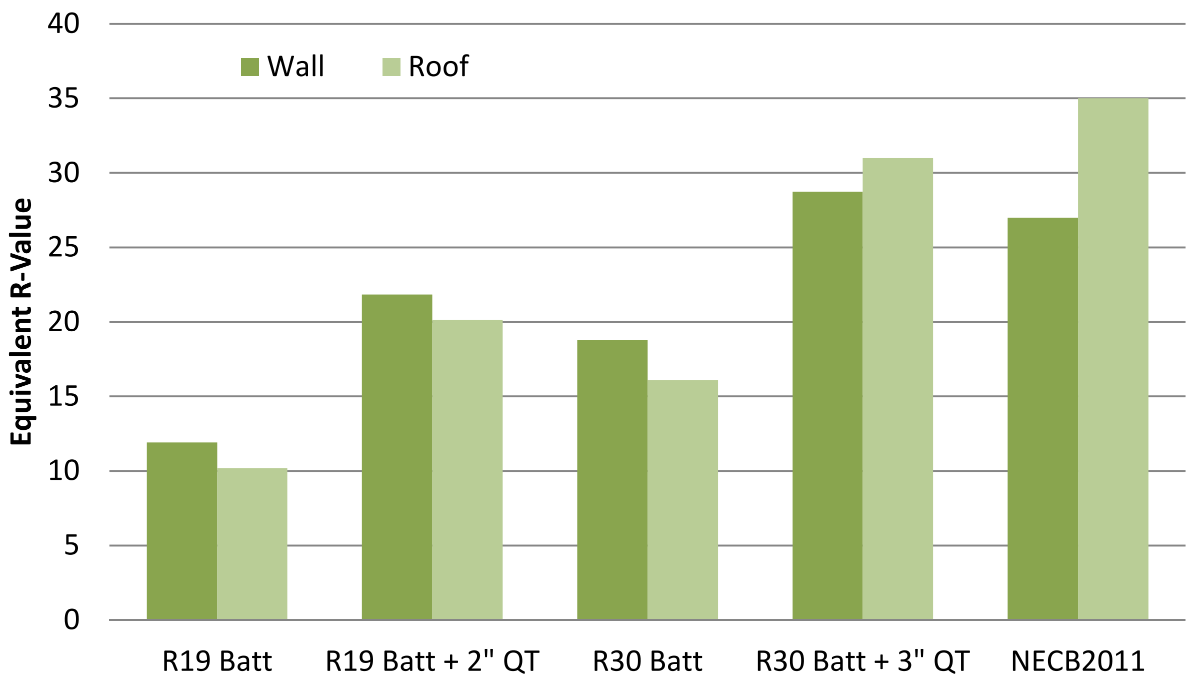

Figure 2: Equivalent Wall and Roof Insulating Values for Various Cases

The above analysis and comparisons were done for specific scenarios with and without the Quik-Therm product installed. However, a more general analysis was also done to be able to approximate potential energy savings of similar buildings (similar in use, construction, and geometry) in various climates. Appendix B contains graphs which show the change in natural gas energy consumption over varying wall and roof R-values. If wall and roof R-values are known, the corresponding energy savings can be looked up on the graphs for comparison.

If you have any questions or comments regarding the above information, please feel free to contact the undersigned.

Yours truly,
Morrison Hershfield Limited

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Nov 14, 2014

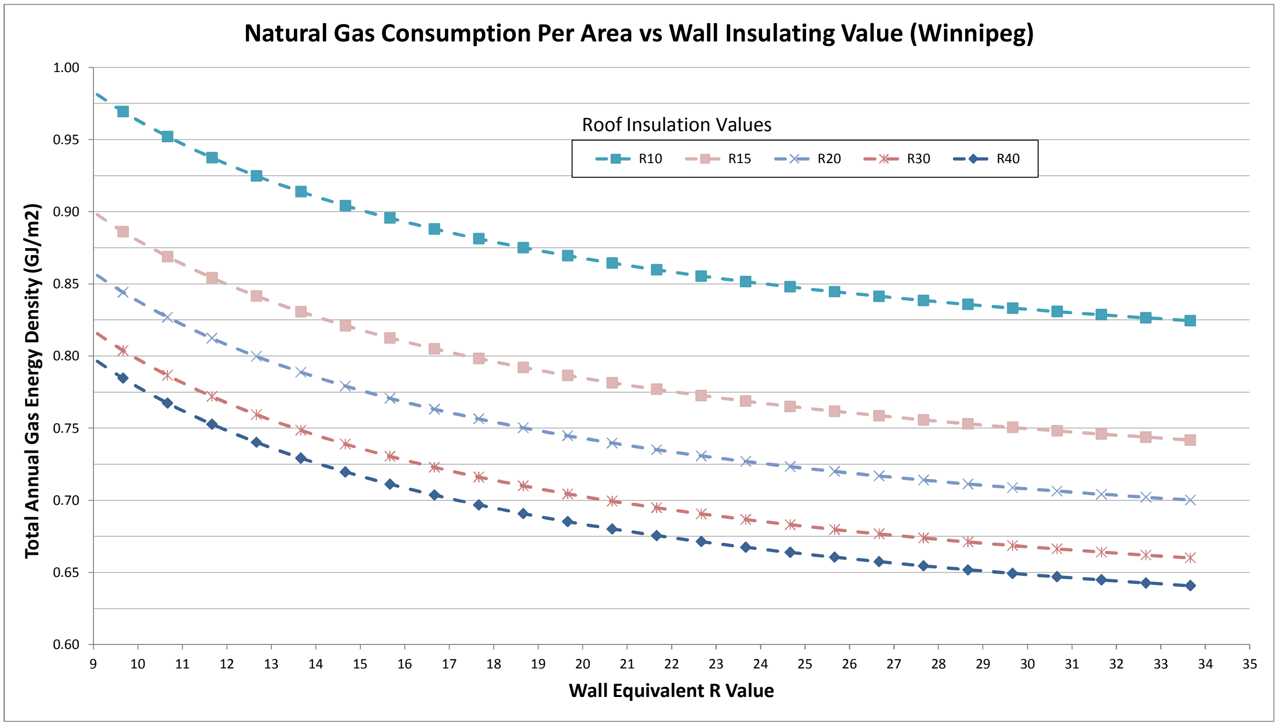
Appendix A – Model Inputs

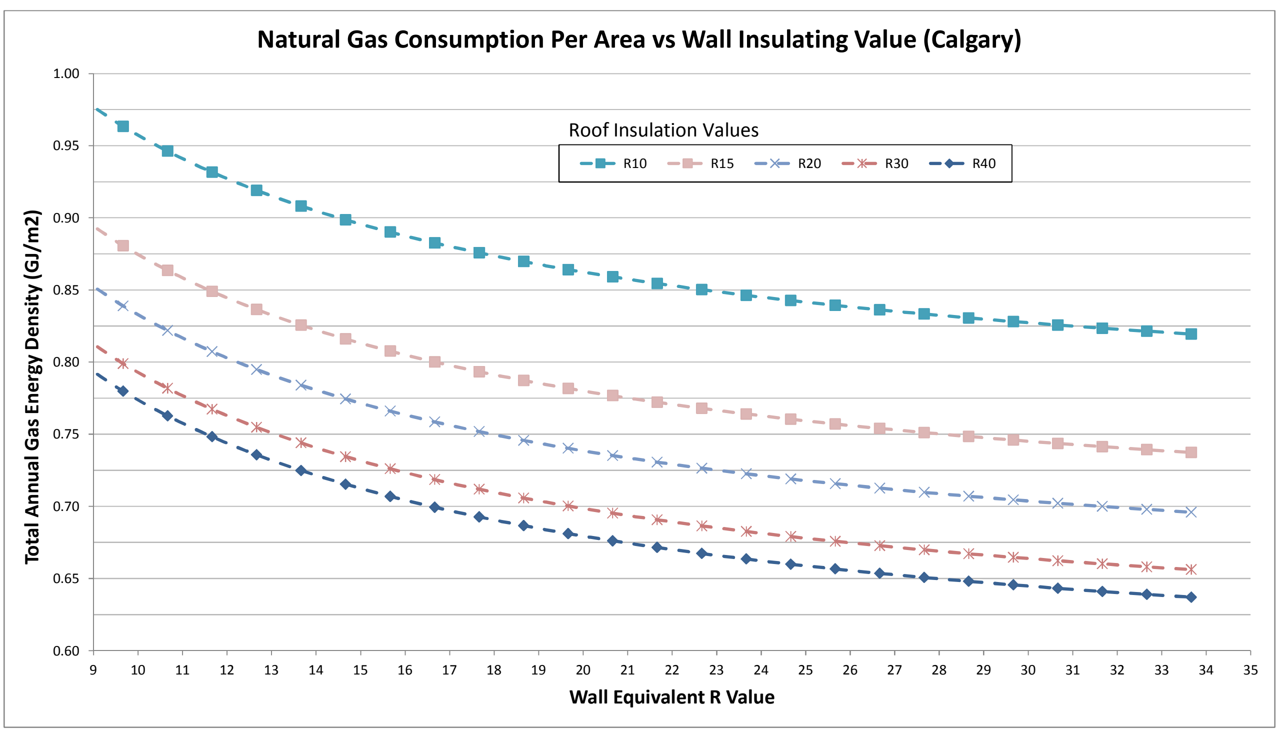
The data used to develop the energy model was based on information provided by Quik-Therm. The inputs are shown below and compared to those used for the typical baseline building model.

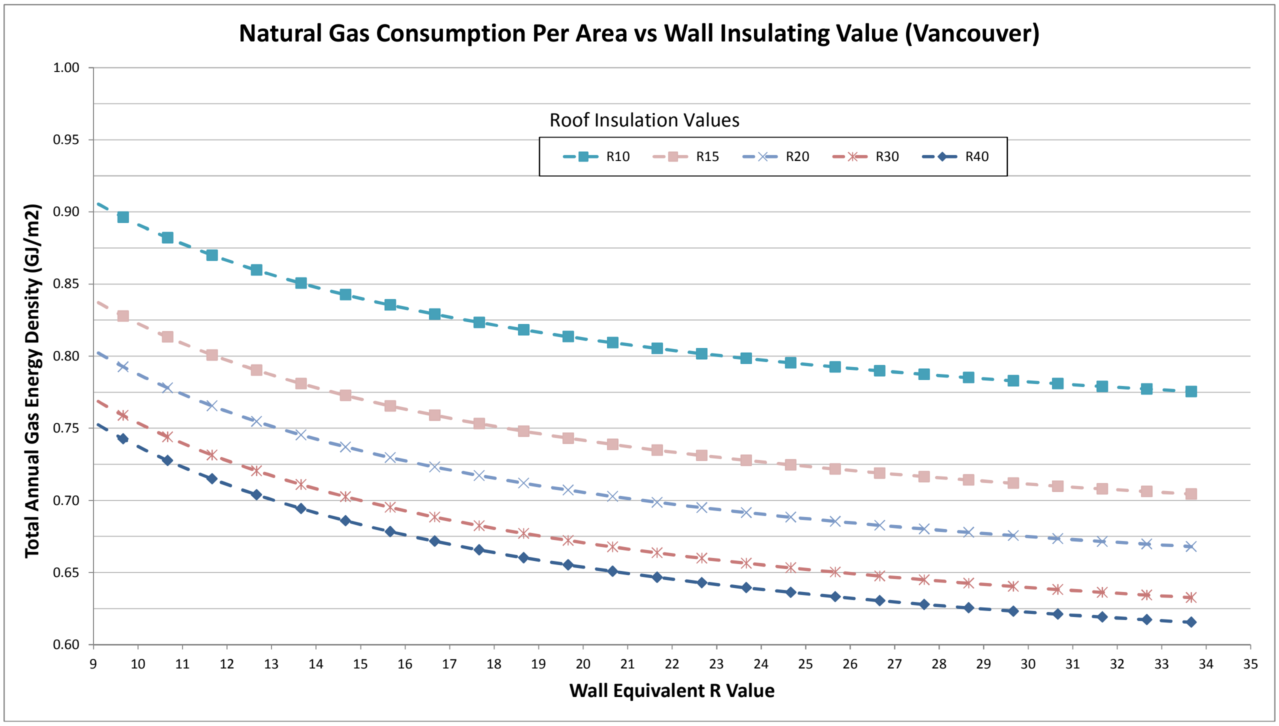
Table 3 – Comparison of Inputs for Typical and Reference Models

Characteristic	Typical	Typical + Quik-Therm
Weather	Winnipeg – Manitoba CWEC, with 5,750 HDD (Base 18.3C)	
Building Area	929 m^2	
Operating Hours	ASRHAE 90.1 building profiles for occupancy, lighting and plug loads	
Occupancy	18.6 m^2 / person	
Plug loads	22.6 W/m^2 equipment	
Outdoor Air	1,085 L/s from side-wall fan, 0.35 L/s/m^2 of wall area for infiltration	
Wall RSI (R-Value)	2.1 (R-12)	3.9 (R-22)
Roof RSI (R-Value)	1.8 (R-10)	3.5 (R-20)
Floor Insulation	Uninsulated Slab	
Window USI (U-Value)	2.72 (0.48) SHGC: 0.65	
Interior Lighting	12.9 W/m^2	
Equipment	23.7 W/m^2	
HVAC Systems	Gas-fired, recirculating heater (80% efficient) Side-wall fan (24”x24”) for ventilation	
Fans	62 Pa for side-wall fan, 187 Pa for heating fan	

Appendix B – Natural Gas Energy Use Graphs






Natural Gas Consumption Per Area vs Wall Insulating Value (Vancouver)
Roof Insulation Values
R10
R15
R20
R30
R40
Total Annual Gas Energy Density (GJ/m2)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Wall Equivalent R Value

Appendix C – ASHRAE 90.1-2010, Appendix A Excerpts for Metal Buildings

TABLE A3.2 Assembly U-Factors for Metal Building Walls

Insulation System	Rated R-Value of Insulation	Total Rated R-Value of Insulation	Overall U-Factor for Entire Base Wall Assembly	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing) — Rated R-Value of Continuous Insulation					
				R-5.6	R-11.2	R-16.8	R-22.4	R-28.0	R-33.6
Single Layer of Mineral Fiber									
	None	0	**1.180**	0.161	0.086	0.059	0.045	0.036	0.030
	R-6	6	**0.184**	0.091	0.060	0.045	0.036	0.030	0.026
	R-10	10	**0.134**	0.077	0.054	0.051	0.033	0.028	0.024
	R-11	11	**0.123**	0.073	0.052	0.040	0.033	0.028	0.024
	R-13	13	**0.113**	0.069	0.050	0.039	0.032	0.027	0.024
	R-16	16	**0.093**	0.061	0.046	0.036	0.030	0.026	0.023
	R-19	19	**0.084**	0.057	0.043	0.035	0.029	0.025	0.022
Double Layer of Mineral Fiber									
(Second layer inside of girts)									
(Multiple layers are listed in order from inside to outside)									
	R-6 + R-13	19	**0.070**	N/A	N/A	N/A	N/A	N/A	N/A
	R-10 + R-13	23	**0.061**	N/A	N/A	N/A	N/A	N/A	N/A
	R-13 + R-13	26	**0.057**	N/A	N/A	N/A	N/A	N/A	N/A
	R-19 + R-13	32	**0.048**	N/A	N/A	N/A	N/A	N/A	N/A

A3.2 Metal Building Walls

A3.2.1 General. For the purpose of Section A1.2, the base assembly is a *wall* where the insulation is compressed between metal wall panels and the metal structure. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing.

A3.2.2 Rated R-Value of Insulation for Metal Building Walls

A3.2.2.1 The first *rated R-Value of insulation* is for insulation compressed between metal wall panels and the steel structure.

A3.2.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed from the inside, covering the girts.

A3.2.2.3 For continuous insulation (e.g., insulation boards) it is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members.

A3.2.2.4 Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

A3.2.3 *U-Factors* for *Metal Building Walls*. U-factors for metal building walls shall be taken from Table A3.2. It is not acceptable to use these *U-factors* if additional insulation is not continuous.

A3.3 Steel-Framed Walls

A3.3.1 General. For the purpose of Section A1.2, the base assembly is a *wall* where the insulation is installed within the cavity of the steel stud framing but where there is not a metal exterior surface spanning member. The steel stud framing is a minimum uncoated thickness of 0.043 in. for 18 gauge or 0.054 in. for 16 gauge. The *U-factors* include R-0.17 for exterior air film, R-0.08 for stucco, R-0.56 for 0.625 in. gypsum board on the exterior, R-0.56 for 0.625 in. gypsum board on the interior, and R-0.68 for interior vertical surfaces air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2B. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing. *U-factors* are provided for the following configurations:

a. *Standard framing*: steel stud framing at 16 in. on center with cavities filled with 16 in. wide insulation for both 3.5 in. deep and 6.0 in. deep wall cavities.

b. *Advanced framing*: steel stud framing at 24 in. on center with cavities filled with 24 in. wide insulation for both 3.5 in. deep and 6.0 in. deep wall cavities.

A3.3.2 *Rated R-Value of Insulation* for Steel-Framed Walls

A3.3.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between steel studs. It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing.

A3.3.2.2 If there are two values, the second *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing, etc., to be installed in addition to the first insulation.

A3.3.2.3 Opaque mullions in spandrel glass shall be covered with insulation complying with the steel-framed wall requirements.

A3.3.3 U-Factors for Steel-Framed Walls

A3.3.3.1 U-factors for steel-framed walls shall be taken from Table A3.3.

A2.3 Metal Building Roofs

A2.3.1 General. For the purpose of Section A1.2, the base assembly is a *roof* with *thermal spacer blocks* where the insulation is draped over the steel structure (purlins), spaced nominally 5 ft on center and compressed when the metal roof panels are attached to the steel structure (purlins).

A2.3.2 Rated R-Value of Insulation

A2.3.2.1 The first *rated R-value of insulation* is for insulation draped over purlins and then compressed when the metal roof panels are attached, or for insulation hung between the purlins. A minimum R-3.5 thermal spacer block between the purlins and the metal roof panels is required when specified in Table A2.3.

A2.3.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed parallel to the purlins.

A2.3.2.3 For continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

A2.3.2.4 ***Liner System* (Ls).** A continuous vapor barrier liner is installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the liner between the purlins. For multilayer installations, the first *rated R-Value of insulation* is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3.5, thermal spacer block between the purlins and the metal roof panels is required when specified in Table A2.3.

A2.3.3 U-factor. *U-factors* for *metal building roofs* shall be taken from Table A2.3 It is not acceptable to use these *U-factors* if additional insulated sheathing is not continuous.

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of Section A1.2, the base *attic roof* assembly is a *roof* with nominal 4 in. deep wood as the lower chord of a roof truss or ceiling joist. The ceiling is attached directly to the lower chord of the truss and the attic space above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood and then later covering both the wood and cavity areas. No credit is given for roofing materials. The *single-rafter roof* is similar to the base *attic roof*, with the key difference being that there is a single, deep rafter to which both the *roof* and the ceiling are attached. The heat flow path through the rafter is calculated to be the same depth as the insulation. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing. The *U-factors* include R-0.46 for semi-exterior air film, R-0.56 for 0.625 in. gypsum board, and R-0.61 for interior air film heat flow up. *U-factors* are provided for the following configurations:

a. *Attic roof, standard framing:* insulation is tapered around the perimeter with a resultant decrease in thermal resistance. Weighting factors are 85% full-depth insulation, 5% half-depth insulation, and 10% joists.
b. *Attic roof, advanced framing:* full and even depth of insulation extending to the outside edge of exterior walls. Weighting factors are 90% full-depth insulation and 10% joists.
c. *Single-rafter roof:* an *attic roof* where the roof sheathing and ceiling are attached to the same rafter. Weighting factors are 90% full-depth insulation and 10% joists.

A2.4.2 Rated R-Value of Insulation

A2.4.2.1 For *attics and other roofs*, the *rated R-value of insulation* is for insulation installed both inside and outside the roof or entirely inside the roof cavity.

A2.4.2.2 Occasional interruption by framing members is allowed but requires that the framing members be covered with insulation when the depth of the insulation exceeds the depth of the framing cavity.

A2.4.2.3 Insulation in such roofs shall be permitted to be tapered at the eaves where the building structure does not allow full depth.

A2.4.2.4 For *single-rafter roofs*, the requirement is the lesser of the values for *attics and other roofs* and those listed in Table A2.4.2.

A2.4.3 U-factors for Attic Roofs with Wood Joists. *U-factors* for *attic roofs* with wood joists shall be taken from Table A2.4. It is not acceptable to use these *U-factors* if the framing is not wood. For *attic roofs* with steel joists, see Section A2.5.

A2.5 Attic Roofs with Steel Joists

A2.5.1 General. For the purpose of Section A1.2, the base assembly is a roof supported by steel joists with insulation between the joists. The assembly represents a *roof* in many ways similar to a *roof with insulation entirely above deck* and a *metal building roof*. It is distinguished from the *metal building roof* category in that there is no metal exposed to the exterior. It is distinguished from the *roof with insulation entirely above deck* in that the insulation is located below the deck and is interrupted by metal trusses that provide thermal bypasses to the insulation. The *U-factors* include R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. The performance of the insulation/framing layer is calculated using the values in Table A9.2A.

A2.5.2 *U-factors* for *attic roofs* with steel joists shall be taken from Table A2.5. It is acceptable to use these *U-factors* for any *attic roof* with steel joists.

A3. ABOVE-GRADE WALLS

A3.1 Mass Wall

A3.1.1 General. For the purpose of Section A1.2, the base assembly is a masonry or concrete *wall*. *Continuous insulation* is installed on the interior or exterior or within the masonry units, or it is installed on the interior or exterior of the concrete. The *U-factors* include R-0.17 for exterior air film and R-0.68 for interior air film, vertical surfaces. For

TABLE A2.3 Assembly U-Factors for Metal Building Roofs

Insulation System	Rated R-Value of Insulation	Total Rated R-Value of Insulation	Overall U-Factor for Entire Base Roof Assembly	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (Uninterrupted by Framing) Rated R-Value of Continuous Insulation					
				R-5.6	R-11.2	R-16.8	R-22.4	R-28.0	R-33.6
Standing Seam Roofs with Thermal Spacer Blocks									
Single Layer	None	0	**U-1.280**	0.157	0.083	0.057	0.043	0.035	0.029
	R-6	6	**U-0.167**	0.086	0.058	0.044	0.035	0.029	0.025
	R-10	10	**U-0.097**	0.063	0.046	0.037	0.031	0.026	0.023
	R-11	11	**U-0.092**	0.061	0.045	0.036	0.030	0.026	0.022
	R-13	13	**U-0.083**	0.057	0.043	0.035	0.029	0.025	0.022
	R-16	16	**U-0.072**	0.051	0.040	0.033	0.028	0.024	0.021
	R-19	19	**U-0.065**	0.048	0.038	0.031	0.026	0.023	0.020
Double Layer	R-10 + R-10	20	**U-0.063**	0.047	0.037	0.031	0.026	0.023	0.020
	R-10 + R-11	21	**U-0.061**	0.045	0.036	0.030	0.026	0.023	0.020
	R-11 + R-11	22	**U-0.060**	0.045	0.036	0.030	0.026	0.022	0.020
	R-10 + R-13	23	**U-0.058**	0.044	0.035	0.029	0.025	0.022	0.020
	R-11 + R-13	24	**U-0.057**	0.043	0.035	0.029	0.025	0.022	0.020
	R-13 + R-13	26	**U-0.055**	0.042	0.034	0.029	0.025	0.022	0.019
	R-10 + R-19	29	**U-0.052**	0.040	0.033	0.028	0.024	0.021	0.019
	R-11 + R-19	30	**U-0.051**	0.040	0.032	0.027	0.024	0.021	0.019
	R-13 + R-19	32	**U-0.049**	0.038	0.032	0.027	0.023	0.021	0.019
	R-16 + R-19	35	**U-0.047**	0.037	0.031	0.026	0.023	0.020	0.018
	R-19 + R-19	38	**U-0.046**	0.037	0.030	0.026	0.023	0.020	0.018
Liner System	R-11+R-19	30	**U-0.035**						
	R-11+R-25	36	**U-0.031**						
	R-11+R-30	41	**U-0.029**						
	R-11+R-11+R-25	47	**U-0.026**						
Standing Seam Roofs without Thermal Spacer Blocks									
Liner System	R-11+R-19	30	**U-0.040**		0.028	0.024	0.021	0.020	0.017
Filled Cavity with Thermal Spacer Blocks									
	R-19+R-10	29	**U-0.041**	0.033	0.028	0.024	0.021	0.019	0.017
Thru-Fastened without Thermal Spacer Blocks									
	R-10	10	**U-0.153**						
	R-11	11	**U-0.139**						
	R-13	13	**U-0.130**						
	R-16	16	**U-0.106**						
	R-19	19	**U-0.098**						
Liner System	R-11+R-19	30	**U-0.044**						

(Multiple R-values are listed in order from inside to outside.)