

TO **Stephen Wieroniey**
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Alberta Unvented Roofs |
Evaluation Report

DATE September 10, 2025

REGARDING **Engineered Solution for Part 9 Unvented Roof Assemblies in Alberta**

Dear Mr. Wieroniey,

As requested by the Spray Foam Coalition, RDH Building Science Inc. (RDH) is pleased to provide you with this engineered solution for the design and construction of unvented spray foam roof systems within Part 9, Housing and Small Buildings, of the National Building Code – 2023 Alberta Edition (NBC(AE)) which is the governing building code within the province of Alberta, Canada.

It is our understanding that the Province of Alberta is considering allowing unvented spray foam roof assemblies in the construction of Part 9 buildings. This report supports that decision with a review of existing literature, summary of moisture physics, some typical schematic details, as well as limitations and requirements of these assemblies. There are many unvented spray foam roofs already being constructed in Part 9 buildings in the province of Alberta, but within the current building code provisions each project must be approved individually.

This report explains the performance of wood framed roofs with 2 pound per cubic foot (pcf) closed-cell spray polyurethane foam, conforming to CAN/ULC S705.1, the standard for the spray foam specification within the NBC, referred to in this report as medium density spray polyurethane foam (MDSPF). This report also includes discussion of wood framed roofs with 0.5 pcf open-cell spray polyurethane foam, referred to in this report as light density spray polyurethane foam (LDSPF) which conforms to CAN/ULC S712.1, the standard for the spray foam specification within the NBC. This report assumes that all spray foam is installed as per the manufacturer's instructions, and in compliance with the installation guidelines of CAN/ULC S712.2 for LDSPF, and CAN/ULC S705.2 for MDSPF. It is further assumed that all rainwater management details are designed and constructed correctly.

Construction under Part 5 construction already allows unvented spray foam roof assemblies since all Part 5 buildings require design and engineering by registered professionals

This report is limited to the province of Alberta and the climate zones it includes (Figure 1).

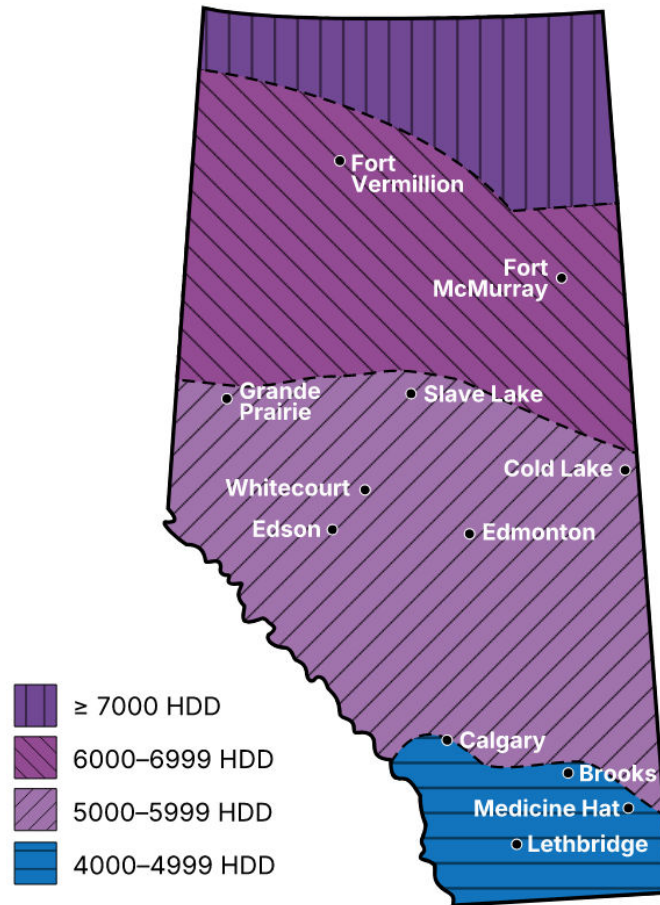


Figure 1 : Canadian climate zones of Alberta (NBC 2023 Alberta Edition)

1 Background

In preparation of this report, a combination of codes, peer reviewed scientific conference papers, and industry documents have been reviewed regarding the use of unvented spray foam roof assemblies. These documents are listed here;

- National Building Code of Canada – Alberta Edition. 2023
- United States International Residential Code (IRC). 2024
- Smegal, J. et al. “State of the Art Review of Unvented Sloped Wood-framed Roofs in Cold Climates”. *Proc of 15th Canadian Conference on Building Science and Technology*. Paper 106. 2017
- Smegal, Jonathan and John Straube. 2014. *Ventilation and Vapor Control for PSF-Insulated Cathedral Ceilings*. Report by Building Science Consulting Inc. in coordination with the University of Waterloo Building Engineering Group BEGHut for the Canadian Urethane Foam Contractors Canadian Spray Foam Guide 2013
- Schumacher (2007). *BSD-149 Unvented Roof Assemblies for All Climates*. www.buildingscience.com. Building Science Consulting. Westford, MA.

- Straube, J., Smegal, J., and Smith, J. 2010. "Moisture-safe unvented wood roof systems". In *Proceedings of Building Enclosure Science & Technology*, Portland, Or, 12-14 April 2010. National Institute of Building Sciences, Washington, DC.

1.1 Building Code Review

In Canada, a vented roof assembly is the only roof assembly currently prescriptively allowed in Part 9 buildings. Engineering reports that can demonstrate that ventilation is unnecessary are considered by the building code official as per Sentence 9.19.1.1 (1) of the NBC.

Except where it can be shown to be unnecessary, where insulation is installed between a ceiling and the underside of the roof sheathing, a space shall be provided between the insulation and the sheathing, and vents shall be installed to permit the transfer of moisture from the space to the exterior.

The justification for this sentence in the code can be found in the NBC Appendix in A-9.19.1.1.(1):

Controlling the flow of moisture by air leakage and vapour diffusion into attic or roof spaces is necessary to limit moisture-induced deterioration. Given that imperfections normally exist in the vapour barriers and air barrier systems, recent research indicates that venting of attic or roof spaces is generally still required. The exception provided in Article 9.19.1.1 recognizes that some specialized ceiling-roof assemblies, such as those used in some factory-built buildings, have, over time, demonstrated that their construction is sufficiently tight to prevent excessive moisture accumulation. In these cases, ventilation would not be required.

This appendix note explains that the reason attic ventilation is required is to manage the moisture related to air leakage and vapour diffusion from the interior moving towards the cold roof sheathing and accumulating, potentially causing damage to the wood substrates. However, if an air impermeable insulation combined with the required vapour control is installed directly to the underside of the roof deck, and there are no parallel air leakage paths, then there is limited risk of air leakage or substantial vapour flow, and ventilation below the roof deck is not necessary to provide moisture control within the roof assembly.

The International Residential Code (IRC 2024) in the United States, has recognized that there are assemblies that can be constructed prescriptively as unvented roof assemblies. Section 806.5 (5.1) explains the prescriptive criteria for an unvented roof assembly. As explained in the summary below, there are three conditions that are allowed by the code:

1. Sufficient rigid board or sheet insulation shall be installed directly above the structural roof sheathing. (Note that this type of construction is widely used for commercial buildings with low-slope roofing where all of the roofing insulation is installed on the exterior of the structure and air control layer and is then covered by the roofing membrane. This is a very safe roof strategy since the structure stays warm, preventing moisture accumulation. Furthermore, the air control layer can be reliably installed in an airtight manner over the structure which reduces the risk of condensation related to air leakage.)

2. Where air-impermeable insulation such as spray polyurethane foam insulation is installed, it shall be applied in direct contact with the underside of the structural roof sheathing.
3. Where a combination of air impermeable (board foam or SPF) and air permeable (mineral fiber batts) are used in the assembly, then the air impermeable insulation must either be on the exterior of the structure, or directly adhered to the underside of the roof sheathing, and the air permeable insulation must be installed directly to the interior so there are no voids or gaps in the assembly. Most importantly, the R-value ratio between the two types of insulation must ensure that condensation will not occur at the interface between the two.

These stipulations in the IRC allow construction of unvented roof assemblies in any climate zone in the United States (climate zone designations are the same in the US as the Canadian climate zones).

Currently, every Part 9 construction project in Alberta that is specified with an unvented roof assembly must provide a sealed engineering judgement letter for each specific case. Acceptance of the prescriptive use of certain unvented assemblies that are known to be very low risk would make design and construction of these assemblies more time and cost efficient, while providing durable, energy efficient roof systems.

2 Unvented Roof Assemblies

This report addresses three options for unvented roof assemblies in Part 9 construction. The images in this report focus on the sloped portion of the roof assembly, but it is important to remember that roof assemblies with vertical portions, such as gable ends, will require the same treatment as portions that are sloped. The three options are:

1. Unvented Cathedral Ceiling – The thermal control (insulation) is located within the roof framing, and the ceiling plane follows the plane of the roof (Figure 2).
2. Unvented Cathedralized Attic – The thermal control (insulation) is within the roof framing or above the roof deck, and the ceiling plane is horizontal leaving an attic space that will require some space conditioning. (Figure 3)
3. Unvented Low-slope (“Flat”) Roofs – The thermal control (insulation) is located within the roof framing, and the ceiling plane follows the plane of the roof; however, unlike the unvented cathedral ceiling, both the roof framing and ceiling plane are essentially horizontal with minimal slope (less than 25% but greater than 2%) provided at the roof membrane so that water will drain from the surface. This slope is usually achieved with sloped insulation on a horizontal structure, but in some cases, the structure itself is sloped for drainage.

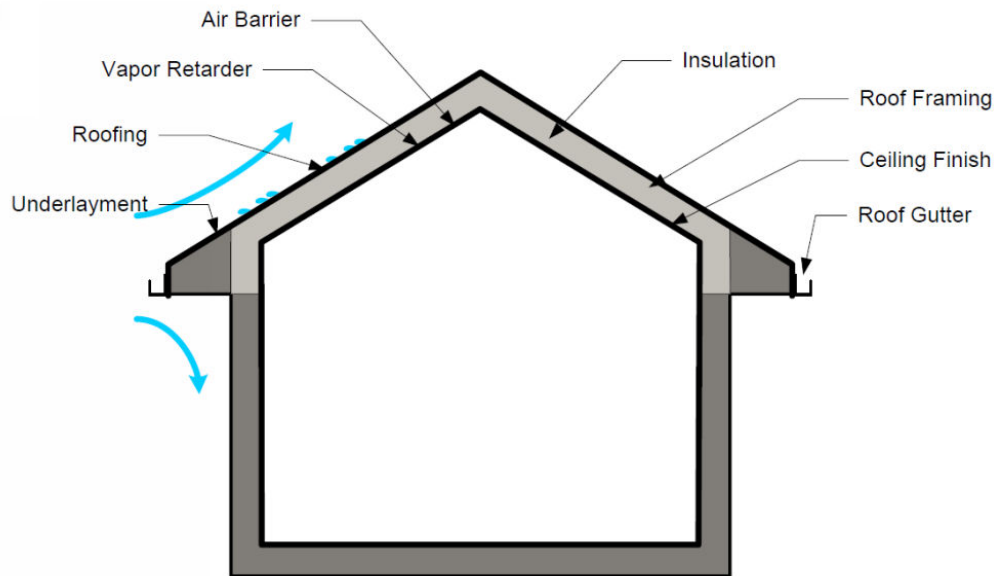


Figure 2 : Unvented Cathedral Ceiling (Schumacher¹)

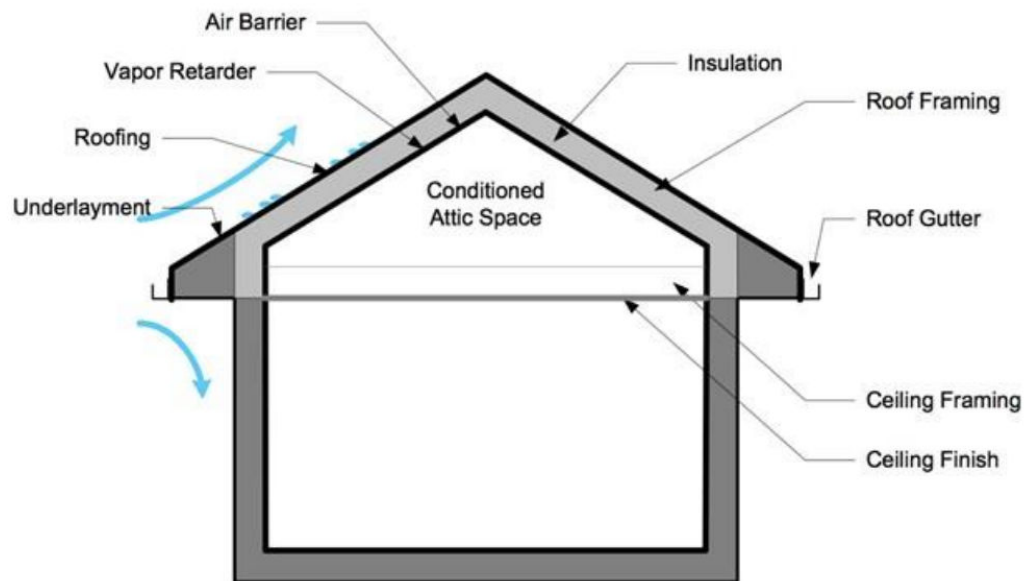


Figure 3 : Unvented cathedralized attic (Schumacher²)

There are several architectural, practical, and durability related advantages to unvented roof assemblies.

- In roof designs where the geometries are complex, it can be very difficult to incorporate adequate and effective ventilation into a ventilated roof assembly, potentially increasing the risk of moisture accumulation.
- Unvented roof assemblies do not allow the ingress of blowing snow, rain, or burning ashes in wildfire areas. In many locations with high forest fire risk,

¹ Schumacher, C. *Hygrothermal Performance of Insulated, Sloped, Wood-Framed Roof Assemblies*, Masters Thesis, University of Waterloo, Waterloo, Canada. 2008

² Schumacher, C. *Hygrothermal Performance of Insulated, Sloped, Wood-Framed Roof Assemblies*, Masters Thesis, University of Waterloo, Waterloo, Canada. 2008

ventilated roof systems are not allowed because of the history of fires due to embers entering the attic.

- Unvented cathedralized attic assemblies allow for easier installation of HVAC into the attic (compared to a vented attic); also, because the HVAC equipment is inside the thermal enclosure, there is less concern for leaky ductwork, and less concern for the impact of extreme temperature conditions on the equipment and any condensate or drain lines.
- Unvented cathedralized attics allow more useable space for the occupants either as conditioned storage space or bonus rooms.
- Unvented cathedral ceilings provide a greater interior volume which is often architecturally desirable to the homeowners.
- There are typically fewer penetrations at the roof deck compared to the ceiling level which often includes lights, speakers, and other wiring that results in air leakage through the air barrier.

Table 1 shows a summary of the effective thermal resistance requirements for unvented roofs of the National Building Code – 2023 Alberta Edition based on Tables 9.36.2.6.-A and B which account for buildings with and without heat-recovery ventilators. The effective R-value accounts for thermal bridging and is described in detail in A-9.36.2.4.(1) *Calculating the Effective Thermal Resistance of Building Envelope Assemblies* of the NBC.

TABLE 1 : REQUIRED EFFECTIVE* THERMAL CONTROL IN UNVENTED ROOF ASSEMBLIES (NBC 2023)		
ZONE (HDD 18)	THERMAL INSULATION R-VALUE [FT ² · °F · H/BTU]	THERMAL INSULATION RSI VALUE [M ² · K/W]
Zone 6 (4000 to 4999)	26.5	4.7
Zone 7A (5000-5999)	28.5	5.0
Zone 7B (6000 to 6999)	28.5	5.0
Zone 8 (≥7000)	28.5	5.0

* Effective thermal resistance calculations will account for closely spaced, repetitive structural members such as studs and joists. (See NBC Note A-9.36.2.4.(1) for calculation equations)

Following the example in NBC A-9.36.2.4.(1), Table 2 below shows the assembly effective R-value calculation for a cathedral ceiling with 2x10 wood rafters 406mm (16 in) o.c., including the following assumptions:

- Based on the NBC Table A-9.36.2.4.(1)-A, this equates to assumed 13% framing, and 87% insulated cavity.
- The RSI value chosen for the MDSPF was 0.04 RSI/mm (R5.6/in) based on the published long term thermal resistance (LTTR) test data of some common MDSPF products. Please note that, when these calculations are completed for the submittal of a specific project, the advertised RSI value of the specific foam being installed must be used in the calculation.

Table 2 shows that a depth of 7" (178mm) of MDSPF between 2x10 rafters will achieve a total effective RSI of 5.0, or R-value of 28.5. This means that, based on the calculation

assumptions outlined above, a minimum of 7" of MDSPF would be required in this assembly to achieve the minimum effective R-value for Zones 7A, 7B, and 8 currently required in Table 1 above.

TABLE 2 : CALCULATION OF EFFECTIVE R-VALUE IN A CATHEDRAL CEILING		
LAYER	T	THERMAL RESISTANCE RSI
Outside air film		0.03
Shingles		0.08
Underlay		-
Framing (2x10 rafters) 16" o.c. (406 mm o.c.)	$RSI_f = 1.56 - 13\% \text{ area}^1$	4.55 ²
Insulation - 7" (178mm) MDSPF	$RSI_c = 7.12^3 - 87\% \text{ area}^1$	
Air space ~50mm		0.16
Gypsum (12.7 mm)		0.08
Interior air film		0.11
Total Assembly Effective RSI		5.0

¹ Framing and Cavity Percentages for Typical Wood-frame Assemblies NBC Table A-9.36.2.4.(1)-A

² RSI parallel using the assumed material R-values and framing factors

³ Use the listed RSI data for actual MDSPF product being installed when submitting this calculation for approval of AHJ.

3 Building Science of Unvented Roofs

The main concern with all aspects of the enclosure, but most importantly roofs in cold climates, is moisture accumulation on the interior surface of the wood-based roof sheathing as a result of outward air leakage or vapour diffusion of interior air. Air leakage moves 1-2 orders of magnitude more moisture in a given timeframe than vapour diffusion, so it is less common that vapour diffusion causes significant condensation and moisture issues.

One key variable related to the moisture durability risk of any enclosure assembly (wall or roof) of a building is the interior relative humidity level of the interior space in the wintertime when the risk of moisture accumulation in the enclosure is the greatest in a cold climate. Interior relative humidity must be maintained at the recommended level, which in cold climates is a maximum of 35% according to the NBC 2023. (A-9.25.5.2)

Roofs have a higher risk of condensation than walls, because the exterior surface of the roof assemblies can cool to temperatures lower than the ambient environment as a result of radiative heat transfer with the sky. This means that even if the temperature outside is slightly above freezing (ie. 2-3°C), frost can develop on the roof assembly in areas that are exposed to the sky on a clear night because the exposed surface temperature of the roof is depressed by radiation to below freezing temperatures. This mechanism creates a situation where the roof sheathing temperature is reduced to and maintained at colder temperatures than the wall sheathing and increases the severity and duration of possible moisture accumulation within the roof sheathing.

Unvented Roof Assembly Options

There are two primary strategies for unvented roof assemblies that minimize the risk of moisture accumulation within the roof assembly. A third strategy is a hybrid of the two primary strategies. These strategies follow the recommendations of the widely accepted United States IRC prescriptive requirements and are summarized as follows:

Option 1: Install only rigid or semi-rigid insulation on the exterior of the roof structure and provide an air barrier to meet the building code requirement. This will ensure that the temperature of the roof sheathing is approximately the same as the interior space and will not result in elevated relative humidity or moisture accumulation. The exterior insulation also minimizes the thermal bridging effects of the roof framing, increasing the effective R-value of the roof assembly. This assembly may have an empty cavity space below, or in some cases may have an exposed structural wood deck such as tongue and groove pine, or mass timber products such as cross-laminated timber (CLT). It's important to install an air barrier and vapour retarder at the interior of the insulation to prevent the migration of water vapour, both by air leakage and vapour diffusion, into the insulation layers.

Figure 4 and Figure 5 show labelled drawings of both an exterior insulated sloped and flat roof assembly, including the key components and their identified roles in the assembly as recommended for construction.

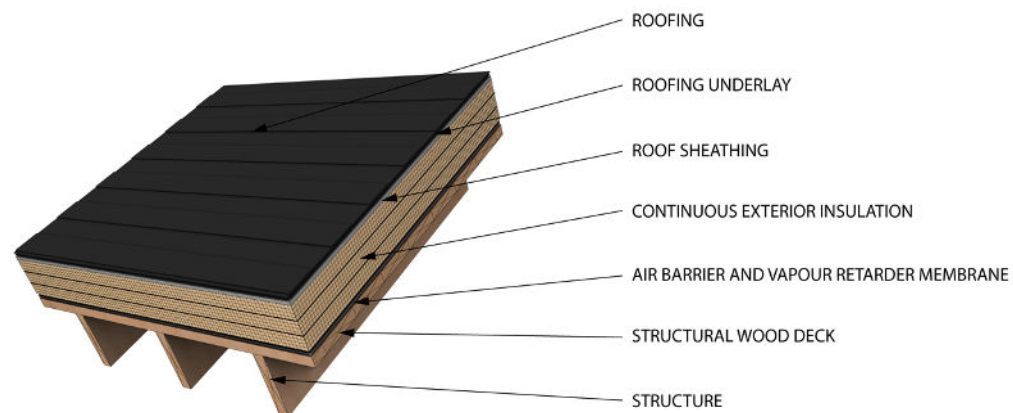


Figure 4 : Exterior insulated sloped roof assembly

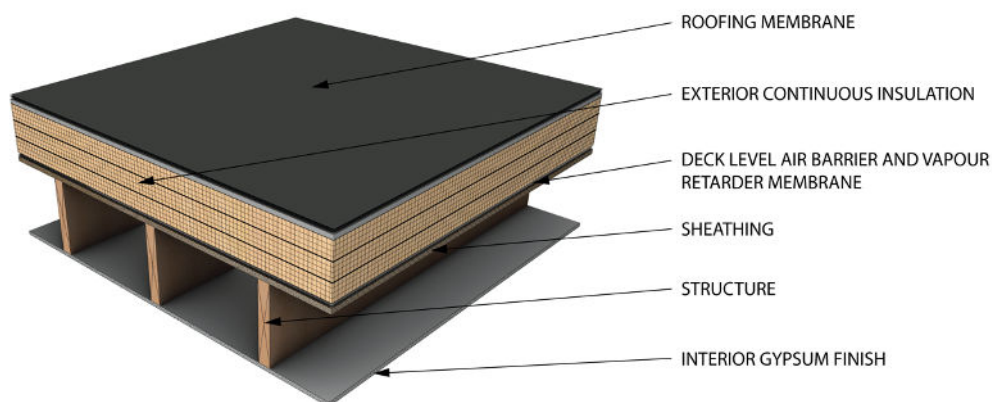


Figure 5 : Exterior insulated low slope (flat roof) assembly

Option 2: Install medium density closed cell spray foam (MDSPF) or light density open cell spray foam (LDSPF) plus vapour control against the underside of the roof deck in sufficient quantity to meet the building code thermal requirements for effective R-value. Both LDSPF and MDSPF meet the air barrier requirement when correctly installed, however only MDSPF is an approved vapour barrier layer at the required installed thicknesses. This means that with MDSPF, interior moisture will not reach the sheathing by either vapour diffusion or air leakage through the field of the spray foam. LDSPF requires additional continuous effective vapour control on the interior of the spray foam in cold climates to meet the building code requirements and to prevent moisture accumulation in the spray foam. Vapour control can be achieved with sheet applied approved vapour barriers (such as 6mil polyethylene), sealed around all penetrations so that it also acts as the primary air barrier. Variable permeance vapour control membranes (i.e., so-called “smart” vapour barriers) that meet the vapour barrier requirements of the code but allow for higher vapour permeance when inward drying is possible could also be used in cases where the interior relative humidity is adequately controlled. Vapour barrier paints specifically tested and approved for use on spray foam could also be installed provided the installation recommendations and specifications are followed.

Figure 6 and Figure 7 show labelled drawings of both a sloped and flat roof assembly insulated with spray foam, including the key components and their identified roles in the assembly as recommended for construction.

Installing insulation between the framing does allow thermal bridging of the insulation through the wood structure since the thermal conductivity of wood is greater than insulation. This thermal bridging will decrease the effective R-value of the assembly and therefore greater insulation thickness is required to achieve the required effective R-value. The effective R-value can be calculated and is required to meet the building code in many jurisdictions. In any assembly with spray foam installed between structural members, care must be taken to ensure the air barrier continuity is maintained between side-by-side or built-up wood components (essentially any wood-to-wood joint) where spray foam cannot be installed.

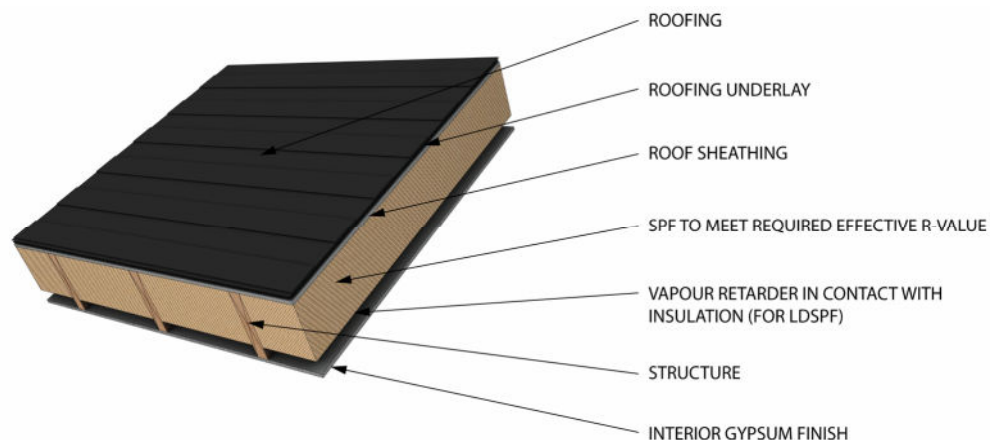


Figure 6 : SPF insulated sloped roof assembly

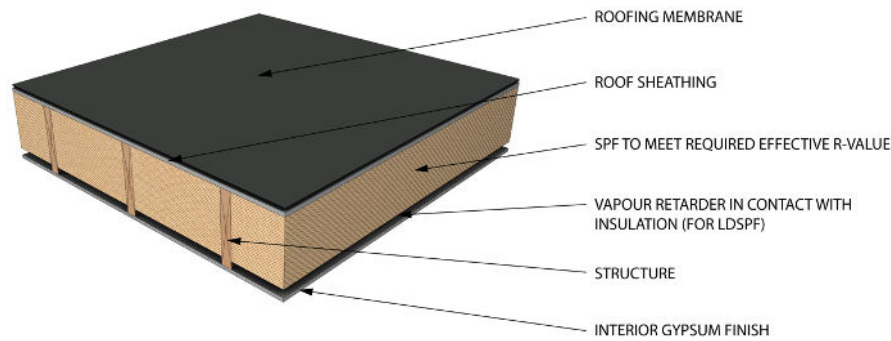


Figure 7 : SPF insulated flat roof

Option 3: A hybrid approach which combines exterior insulation against the exterior of the sheathing (Option 1) and MDSPF installed directly to the interior of the sheathing (Option 2) with a combined effective R-value sufficient to meet the code is also an option (Figure 8). This approach minimizes the thermal bridging of the structure through the assembly compared to MDSPF installed directly to the interior of the sheathing alone (Option 2). Substituting LDSPF for MDSPF may require a vapour barrier installed on the interior side of the assembly (i.e., the “warm side” in winter), depending on the R-value ratio of the exterior board foam to the interior LDSPF. This should be determined on a case-by-case basis.

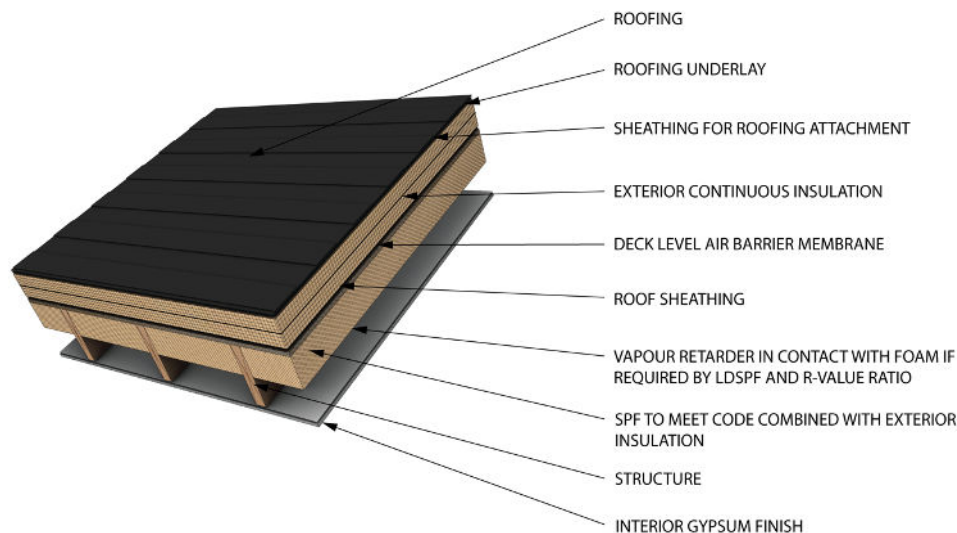


Figure 8 : Roof assembly with exterior insulation and MDSPF

Further variations of this hybrid approach include combining air and vapour impermeable insulation such as MDSPF or continuous exterior board insulation with air permeable insulation such as mineral wool batts or blown in fibrous insulation between the framing (Figure 9 and Figure 10). These approaches can also work, but appropriate balance in the R-value ratio of the air impermeable insulation to the air permeable insulation needs to be determined to ensure that condensation and moisture accumulation does not occur at the interface of the two insulation types. As mentioned previously, these two insulation layers need to be installed without any gaps or voids between the insulation layers.

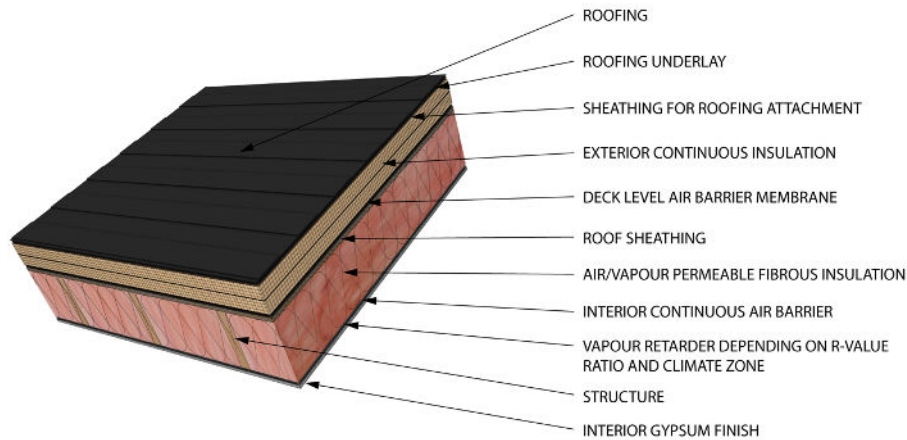


Figure 9 : Hybrid roof assembly combination of air impermeable exterior insulation and air/vapour permeable insulation within the framing.

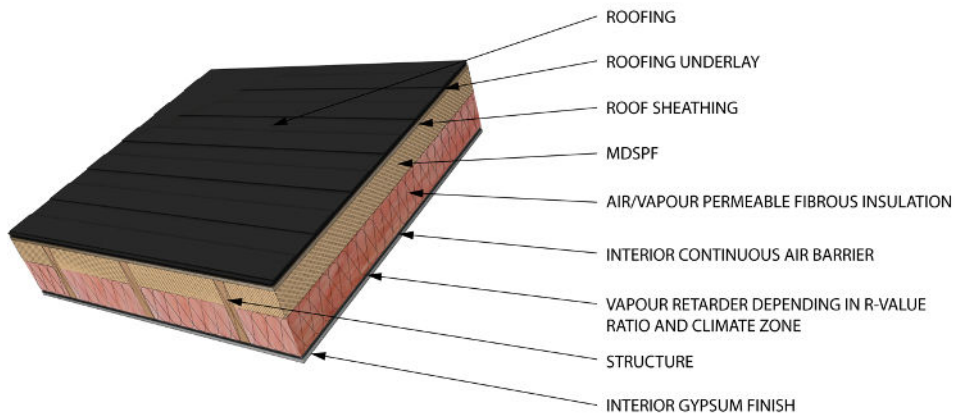


Figure 10 : Hybrid roof assembly combination of air impermeable exterior MDSPF insulation installed against the interior of the roof sheathing and air/vapour permeable fibrous insulation to the interior of the spray foam.

There is general guidance related to the R-value ratios in these hybrid insulation assemblies based on building physics available in the 2024 International Building Code (IBC) in Table 1202.3 "Insulation for Condensation Control". An excerpt of the IBC table is shown below in Table 3. The table demonstrates that for any location in Alberta (i.e., > 4000 HDD), at least half of the R-value must be air and vapour impermeable insulation to minimize moisture accumulation risks.

TABLE 3 : MINIMUM R-VALUE OF AIR-IMPERMEABLE INSULATION. EXPRESSED AS A PERCENTAGE OF TOTAL R-VALUE (EXCERPT FROM TABLE 1202.3 OF 2024 IBC)	
ZONE (HDD 18)	MINIMUM PERCENTAGE REQUIRED OF AIR AND VAPOUR IMPERMEABLE INSULATION FOR CONDENSATION CONTROL
Zone 6 (4000 to 4999)	50%
Zone 7A (5000-5999)	60%
Zone 7B (6000 to 6999)	60%
Zone 8 (≥ 7000)	70%

Additional Considerations: Encapsulation of Framing in Spray Foam

As discussed previously, the spray foam material is an air barrier everywhere it is continuously installed within the roof assembly. Therefore, if the framing can be encapsulated and the spray foam is continuous over the framing as shown in Figure 11, the joints between built up framing will be sealed and air leakage to the roof sheathing stopped. For this reason, it is recommended that framing be encapsulated in foam, that is partially embedded in SPF, whenever possible. However, it may not be possible to fully encapsulate the framing of the roof assembly – for example, where the interior gypsum is to be installed against the interior surface of the framing, such as at the rafters of a cathedral ceiling. In this case, the air barrier system must be continuous over the joint between the framing and the wood-wood joint must be sealed as shown in Figure 12. High quality sealant or tapes could be used that accommodate some movement in the wood framing following installation.

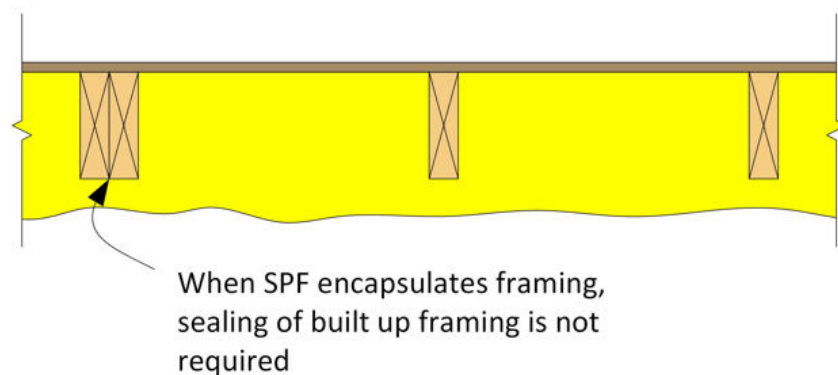


Figure 11 : Framing embedded in SPF should be encapsulated when possible to ensure air barrier continuity around the roof framing. (credit image to SFC³)

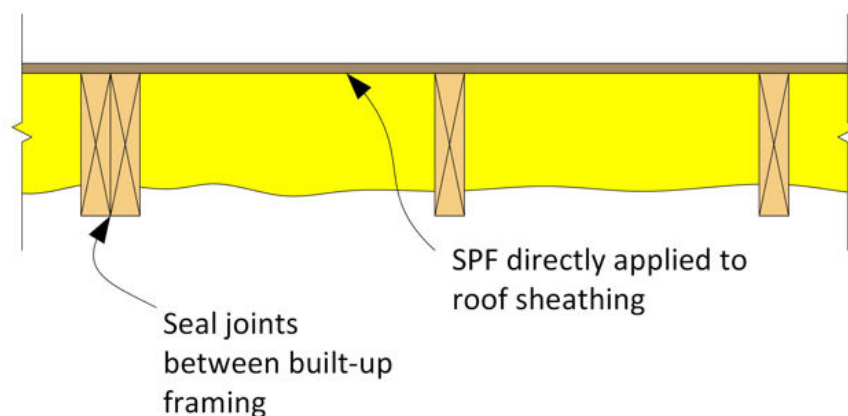


Figure 12 : In many cases, such as cathedral ceiling rafters, it is not possible to encapsulate framing, with SPF, and the joint between built up framing must be sealed by alternative means continuously along the entire length. (credit image to SFC³)

³ Spray Foam Coalition. Installing High Performance Insulation Part 3: A Guide to Installing Unvented Attics in Canada. <https://sprayfoamcoalition.org/wp-content/uploads/RDH-Report-on-Engineered-Solution-for-Part-9-Unvented-Roof-Assemblies-in-Alberta.pdf>.

4 Literature Review

There have been many studies conducted on the measured and predicted performance of unvented roof assemblies. All of the reviewed reports have been provided as a separate appendix in support of this report.

An extensive literature review regarding sloped wood-framed roof assemblies was conducted⁴ and presented at the 15th Canadian Conference on Building Science and Technology in 2017. The conclusion of the peer-reviewed conference paper was that the construction industry has the required information and experience from Canada, the United States, and elsewhere, to design moisture safe unvented roof assemblies for all climate zones in Canada utilizing appropriate design and existing construction technology.

A hygrothermal analysis study in 2010⁵ looked at the predicted performance of different unvented roof assemblies, with various insulation strategies including full-depth MDSPF, and a combination of MDSPF with spray fiberglass to the interior in various climates in the United States. The roof assemblies were primarily north-facing and all had a 3:12 pitch. One of the variables of the study was the colour of the roofing which affects the solar absorption and energy available for drying within the roof assembly. It was found that in Climate Zones 6 and 7, the full-depth MDSPF roof assembly did not show any risk of moisture accumulation in the sheathing with dark asphalt shingles, even with an elevated interior relative humidity. The assembly with 4" MDSPF and spray fiberglass performed the same. If the same insulation strategies were clad with a light metal roof with more solar reflection and less solar absorption, then the predicted sheathing moisture contents were still acceptable at recommended interior relative humidity levels but did have a predicted elevated sheathing moisture content when the interior relative humidity was higher than recommended. Elevated interior relative humidity levels will put all roof (vented or unvented) and wall enclosure systems at a higher risk of cold weather moisture accumulations.

There have been other studies that look at the impact of solar absorption of the roof related to moisture accumulation and durability. For example, one study by Nusser et al.⁶ of unvented low-slope roofs with mineral wool batt insulation conducted in Europe investigated the measured performance differences between full-scale test hut roofs with different amounts of solar absorption, and different interior smart vapour barrier membranes. It was concluded that low temperatures on the roof, whether from shading or a green roof, lead to high and long-lasting relative humidity in the cavity.

On a similar topic to Nusser et al., Kehrer and Pallin⁷ also found in their hygrothermal study that the colour and solar reflectance of the roof surface is very important. The amount of accumulated moisture is almost doubled in cool roof (white) construction compared to a traditional black roof under certain modeled parameters, but the factor of

⁴ Smegal, J. et al. State of the Art Review of Unvented Sloped Wood-framed roofs in cold climates. 15th Canadian Conference on Building Science and Technology. Paper 106. 2017

⁵ Straube, J., Smegal, J., and Smith, J. 2010. Moisture-safe unvented wood roof systems. *In* Proceedings of Building Enclosure Science & Technology, Portland, Or, 12-14 April 2010. National Institute of Building Sciences, Washington, DC.

⁶ Nusser, Bernd et al. 2010. "Low-Pitched Timber Roofs". World Conference on Timber Engineering

⁷ Kehrer, Manfred and Simon Pallin. 2013. "Condensation Risk of Mechanically Attached Roof Systems in Cold Climate Zones."

safety with moisture-related durability is higher in all low-slope roofs with the high solar absorption of dark roof membranes.

A field study was conducted between 2010 and 2012 on unvented and vented roof assemblies in Waterloo, Ontario (CZ6, 4200HDD). Following the field monitoring study, a hygrothermal model was correlated to the monitored data to predict the performance in other Canadian climate zones⁸. The hygrothermal analysis was very conservative in nature using the coldest weather data available, north steep slope orientations with very little solar energy, and elevated interior relative humidity levels. Even under very conservative prediction criteria for climate zones up to 7A (5777 HDD 18), it was found that an unvented full MDSPF application did not result in increased sheathing moisture content with an average winter interior relative humidity of 30% RH. With elevated interior relative humidity, and the coldest weather data available to the model, there were some elevated sheathing moisture contents on the north orientation following repeated years of analysis.

A CMHC document titled Arctic Hot Roof Design⁹ was published in 2001 explaining the benefits of an unvented exterior insulated roof assembly with board foam insulation compared to a typical ventilated attic assembly, minimizing the risk of attic condensation related to air leakage, and minimizing the risk of snow blowing into the attic. Short construction seasons, expensive construction materials, and seasonal temperature limitations in the far north (i.e., CZ8) can all make construction more difficult; selecting a long-lasting durable solution is even more important in this context.

Based on a review of the literature, it can be concluded that continuous exterior insulation, full depth MDSPF, or a combination of both to meet the effective R-value requirements can provide a durable high-performance unvented roof assembly in cold climates.

5 Other Considerations for Unvented Roofs

5.1 Roof Underlay in Sloped Roofs

Because an unvented roof assembly with full depth MDSPF has limited drying to the interior, it is critical that the wood sheathing not get wet and/or remain wet for extended periods. In a typical shingled or metal roof assembly, the manufacturer's recommended best practices for roofing underlayment should be followed, this typically requires a self-adhered membrane (i.e., ice and water shield) in some areas to minimize the risk of water ingress from ice damming, combined with a synthetic underlay over the remainder of the roofing assembly. Some manufacturers even recommend a self-adhered membrane beneath the whole roof system. The traditional building paper or felt paper should not be used in unvented roof assemblies because it tends to break down more quickly and may not provide a continuous water control layer for the life of the roofing.

5.2 Interior Relative Humidity

All of the design criteria and recommendations included in this report are based on the assumption that the interior relative humidity in the winter is controlled within the

⁸ Smegal, Jonathan and John Straube. 2014. "Ventilation and Vapor Control for SPF-Insulated Cathedral Ceilings." Report by Building Science Consulting Inc. in coordination with the University of Waterloo Building Engineering Group BEGHut for the Canadian Urethane Foam Contractors Association Inc., Waterloo, ON.

⁹ CMHC About Your House, North Series 6, Arctic Hot Roof Design. 2001

building. The wintertime interior relative humidity in cold climates plays an important role in the durability of all enclosure components. In the Appendix of the NBC (A-9.25.5.2) it states that one of the assumptions for enclosure durability in cold climates is that the wintertime relative humidity does not exceed 35%. Further to the statement in the NBCC, in extremely cold climates, (i.e., climate zones 7B and 8), lowering the wintertime interior relative humidity into the 25-30% range would minimize durability enclosure risks further and avoid condensation problems in walls, on windows, and around door hardware.

5.3 Fire Codes

The use of spray foam in an unvented cathedralized attic application typically means the foam is left exposed on the underside. There are restrictions for accessible spaces with regards to the exposure of foam plastic such as spray foam insulation (NBC 9.10.17.10) that require the covering of the spray foam with an approved material from the list in NBC 3.1.5.15.(2) or an approved intumescent paint, depending on local code requirements and the accessibility of the enclosed space.

However, in an attic or roof space that is considered 'concealed', the ceiling gypsum board below the attic or roof assembly will provide the required thermal protection. NBC A-3.1.4.2.(1) defines a concealed space as any space that is not visibly apparent and that is provided with an opening to allow access for repair and periodic inspections.

5.4 Stacked Framing

Spray foam adhered to the framing makes an excellent air barrier, however, there are some areas where spray foam cannot be installed, such as side-by-side or stacked framing members that will result in an air leakage pathway between the framing in the same wall or between the framing of different assemblies (i.e., sloped roof and gable end). A continuous bead of sealant installed between the framing members during construction, or a layer of tape or flashing membrane installed continuously on the interior surface of the wood post construction are the two preferred options for sealing the gaps between the framing against air leakage. Alternately, in an attic, spray foam can encapsulate the built-up framing to form a continuous barrier against air leakage.

5.5 Vapour Permeance of Wood Framing

In unvented spray foam roof assemblies where the MDSPF fills the cavities between the structure and the interior of the structure is left exposed, it is clear that the MDSPF has sufficient vapour control to meet the code requirement. Previous work has shown that the wood framing itself provides sufficient vapour control where not encapsulated, but there remains some uncertainty in the industry on this point and the vapour permeance of the rafters is a common question. This is addressed below.

As with most other hygroscopic materials, the vapour permeance of wood varies depending on the surrounding relative humidity. An Exova test report in 2009 measured the vapour permeance of 2x4 and 2x6 wood framing according to ASTM E96 under dry cup conditions (0% RH and 50% RH).

To meet the prescriptive vapour barrier requirement of the NBC, the vapour permeance of the structure must be less than $57 \text{ ng/Pa} \cdot \text{s} \cdot \text{m}^2$ or approximately 1 US Perm. Both 2x4 and 2x6 wood framing satisfy this requirement. The results are shown in the table below.

TABLE 4 : MEASURED VAPOUR PERMEANCE OF WOOD FRAMING*		
TEST SAMPLE	TEST CONDITIONS	TEST RESULT [ng/Pa · s · m ²]/ [Perms]
2x4	Dry Cup (0%RH and 50% RH)	36 / 0.63
2x6	Dry Cup (0%RH and 50% RH)	30 / 0.52

* Exova Report N. 09-06-M0097

Another source of material data for wood vapour permeance is the ASHRAE Handbook of Fundamentals (HOF) Vapour Permeance Tables. Several wood species have vapour permeance test data for transverse wood grain samples at a range of relative humidities. For all of the transverse wood measurements tested at a relatively humidity of 70% or less, the vapour permeance of 6 inches (152mm) ranged from 0.1 perms (5.74 ng/ Pa · s · m²) to 1 perm (57.4 ng/ Pa · s · m²).

In summary, both test results and available literature indicate that the unencapsulated framing in unvented roof assemblies does meet the vapour barrier requirements. Similar can be said of the oriented strand board (OSB) in the web of engineered wood joists which also meets the vapour barrier requirement based on the published vapour permeance values found in the ASHRAE HOF.

6 Conclusions/Recommendations

Based on a review of the moisture physics, building codes, and published scientific literature, unvented sloped and low-slope roof assemblies can safely function in the province of Alberta. As such, the three prescriptive types of roof assemblies outlined in this letter can reasonably be allowed in Part 9 construction as they will satisfy the requirements of Section 9.19.1.1 (1) of the NBC related to roof ventilation. The three roof assemblies are:

1. Sloped or low-slope roof assemblies with the entire required R-value installed on the exterior of the structure as rigid or semi-rigid insulation. A continuous and effective air and vapour barrier is required on the roof sheathing at the interior of the insulation to prevent moisture movement by air leakage or vapour diffusion into the roofing insulation.
2. Sloped or low-slope roof assemblies with the entire required R-value to meet the effective R-value requirements installed as SPF directly to the underside of the roof sheathing. MDSPF includes vapour control, and no additional vapour control is required, however if LDSPF is used, then a continuous effective vapour control in direct contact with the LDSPF, and sealed around penetrations, is required to manage vapour diffusion and moisture accumulation within the roof system.
3. Assemblies using a combination of exterior rigid or semi-rigid insulation installed on the exterior of the roof structure combined with medium density MDSPF installed directly to the underside of the roof sheathing. With MDSPF, no additional vapour control is required. If LDSPF is used instead, then vapour control may be required depending on the R-value ratio of the insulation types, and the vapour permeance of the exterior insulation. The use of LDSPF should be analyzed on a case-by-case basis.

As with any building enclosure component, good design and construction is required to ensure long-term durability and performance. This is particularly important for low-slope roofs to prevent wetting of the sheathing due to roof leaks (e.g., adequate slope and drainage, selection of a durable roofing membrane, continuous tie-in details at penetrations, etc.). Failure to meet the design or construction standard of care could result in failures of even the most durable and safe assemblies.

There are several criteria, in addition to the basic assembly, to minimize the risk of air leakage and potential moisture accumulation within the unvented roof assembly.

- Interior wintertime relative humidity is controlled to not exceed 35% (or even lower in extremely cold climates). This is also important for all other enclosure assemblies (not just roofs), and to control condensation on the interior of windows.
- Spray foam must be installed in accordance with CAN-ULC-S705.1 or CAN-ULC-S712.1 and CAN-ULC-S705.2 or CAN-ULC-S712.2. This means that all criteria related to substrate moisture contents/temperatures, pass thicknesses, daily testing, daily logs, etc. must be followed during installation.
- In a roof assembly insulated and air sealed with SPF, all stacked framing members, and interfaces between assemblies (ie. roof to wall, or sloped roof to gable, etc) that can not be sealed with spray foam are well sealed by alternative means.
- The spray foam shall be installed by an installer that has successfully completed a training course and is certified as a Spray Polyurethane Foam Installer (Section 4.3.4, CANULC S705.2 or CAN-ULC S712.2

If you have any questions when you've reviewed this report in its entirety, please do not hesitate to contact us by phone or email.

Yours truly,

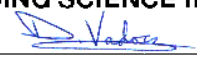


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