Boisbriand, le 18 mars, 2014

WATER VAPOUR DIFFUSION OF HEATLOK SOYA SPRAY POLYURETHANE FOAM SYSTEM COMBINED WITH FIBERGLASS INSULATION IN THE STUDS.

(CONFORMITY TO NBC ART. 9.25.5.2)

The permeability of a product is the speed at which the water passes through an homogeneous material. The 2010 National Building Code NBC articles: 5.5.1, 9.25.4 and 9.25.5 considers a material vapour barrier when its rate of performance is lower than 60 ng / Pa *s* m² (1.05 Perm).

To further investigate the Water Vapour Diffusion of HEATLOK SOYA and to confirm the vapour barrier properties, Demilec Inc. requested AIR-INS (recognized independent laboratory, see NBC art. and table : A-9.25.5.1(1) to test the vapour barrier properties. The test was made on different assemblies with different thickness of HEATLOK SOYA:

- 25 mm of the product HEATLOK SOYA applied on a gypsum board = 68 ng/Pa*s*m² (1.19 Perm).
- 38 mm of the product HEATLOK SOYA applied on a gypsum board = 50 ng/Pa*s*m² (0.87 Perm).
- 50 mm of the product HEATLOK SOYA applied on a gypsum board = 43 ng/Pa*s*m² (0.75 Perm).
- 75 mm of the product HEATLOK SOYA applied on a gypsum board = 29 ng/Pa*s*m² (0.51 Perm).
- 100 mm of the product HEATLOK SOYA applied on a gypsum board = 23 ng/Pa*s*m² (0.40 Perm).

- 25 mm of the product HEATLOK SOYA applied on a plywood 13mm = 31 ng/Pa*s*m² (0.54 Perm).
- 38 mm of the product HEATLOK SOYA applied on a plywood 13mm = 27ng/Pa*s*m² (0.47 Perm).
- 50 mm of the product HEATLOK SOYA applied on a plywood 13mm = 24 ng/Pa*s*m² (0.42 Perm).
- 75 mm of the product HEATLOK SOYA applied on a plywood 13mm = 20 ng/Pa*s*m² (0.35 Perm).
- 100 mm of the product HEATLOK SOYA applied on a plywood 13mm = 18 ng/Pa*s*m² (0.32 Perm).

- 25 mm of the product HEATLOK SOYA applied on a concrete bloc = 12 ng / Pa*s*m² (0.64 Perm).
- 50 mm of the product HEATLOK SOYA applied on a concrete bloc = 10 ng/Pa*s*m² (0.50 Perm).
- 75 mm of the product HEATLOK SOYA applied on a concrete bloc = 08 ng/Pa*s*m² (0.42 Perm).
- 100 mm of the product HEATLOK SOYA applied on a concrete bloc = 07 ng/Pa*s*m² (0.35 Perm).

The water vapour diffusion of the product HEATLOK SOYA changes with the thickness applied and the substrate on which it is sprayed.

Even if the resistance to water vapour increases with the thickness, it is conform to NBC to use HEATLOK SOYA at a thickness of 25mm and more, in an assembly: gypsum, steel stud, fiberglass, poly, gypsum. The product classifies as a vapour barrier from 38mm on a gypsum board, but gives a thermal resistance (R-9) high enough to keep the temperature in the studs above the dew point. Therefore, the higher the thermal resistance is outside the studs, the warmer the studs will be because the insulation outside prevent the cold from getting to the studs. This way, the assembly conforms to the article 9.25.5.2. (See documentation attached)

For more information, see the articles 9.25.5.2 et A-9.25.5.2 of the building code and the article Construction Technology #41, by CNRC.

Attached documents : Air Ins Lab report, NBC articles and Construction technology.
ASSEMBLIES SUMMARY

<table>
<thead>
<tr>
<th>Heatlok Soya on gypsum</th>
<th>Vapour diffusion</th>
<th>Ratio</th>
<th>Ratio</th>
<th>Degree days</th>
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<tr>
<td>68 ng/Pa<em>s</em>m²</td>
<td>25mm Heatlok Soya – 6” Fiberglass</td>
<td>0.32</td>
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<td>0.90</td>
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RATIO TO COMPLY

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<tr>
<th>Heating Degree-Days of Building Location(1), Celsius degree-days</th>
<th>Minimum Ratio of Total Thermal Resistance Outboard of Material’s Inner Surface to Total Thermal Resistance Inboard of Material’s Inner Surface</th>
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<td>12000 or higher</td>
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Notes to Table 9.25.5.2.:
(1) See Sentence 1.1.3.1.(1).
DEGREE-DAYS

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<td>Yellowknife</td>
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<td>Inuvik</td>
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<table>
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<td>Ste-Agathe des Monts</td>
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</tr>
<tr>
<td>Sheerbrooke</td>
<td>4800</td>
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</tbody>
</table>

If you have any further questions, please do not hesitate to call the undersigned.

Regards,

Maxime Duzyk
Arch. Tech.
Technical Support

Attached documentation: - Building Code article
                        - NRC Construction technology Update #41
Conformity Analysis ART. : 9.25.1.2

25mm Heatlok Soya – 152mm Fiberglass

RATIO :  RSI EXT :  1.38  =  0.32 = Ratio in accordance until 5999 degree days
RSI INT :  4.26

* R values according to Model National Energy Code for Buildings 1997 (MNECB)
Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)
Software used : Condense W3.0 (1983)
38mm Heatlok Soya – 152mm Fiberglass

RATIO : RSI EXT : 1.93 = 0.45 = Ratio in accordance until 7999 degree days
RSI INT : 4.26

* R values according to Model National Energy Code for Buildings 1997 (MNECB)
Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)
Software used : Condense W3.0 (1983)
50mm Heatlok Soya – 152mm Fiberglass

RATIO : RSI EXT : 2.44 = 0.57 = Ratio in accordance until 9999 degree days
RSI INT : 4.26

* R values according to Model National Energy Code for Buildings 1997 (MNECB)
Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)
Software used : Condense W3.0 (1983)
25mm Heatlok Soya – 89mm Fiberglass

RATIO:  

\[
\text{RSI EXT} = 1.38 = \frac{0.53}{2.62} = \text{Ratio in accordance until 8999 degree days}
\]

* R values according to Model National Energy Code for Buildings 1997 (MNECB)  
Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)  
Software used: Condense W3.0 (1983)
38mm Heatlok Soya – 89mm Fiberglass

**RATIO:**

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<th>Layer</th>
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<td>Clay brick red 89</td>
<td>RSI = 0.0623</td>
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<td>Airpace 25.0mm</td>
<td>RSI = 0.2375</td>
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<td>HEATLOK SOYA Sprayed polyurethane 38.0mm</td>
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<td>Gypsum exterior gypsum 13</td>
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<td>Mineral wool tructfit 89</td>
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<td>V.H. Polythene 15 [6 mill]</td>
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<td>Inside Air film</td>
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<tr>
<td>TOTAL</td>
<td>RSI = 4.5453</td>
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</table>

* R values according to Model National Energy Code for Buildings 1997 (MNECB)
  * Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)
  * Software used: Condense W3.0 (1983)
50mm Heatlok Soya – 89mm Fiberglass

**Software used:** Condense W3.0 (1983)

* R values according to Model National Energy Code for Buildings 1997 (MNECB)  
Excluding the airspace. (no impact on the conformity to the article 9.25.5.2)  
Software used : Condense W3.0 (1983)
Mr. François Lalande  
DEMILEC INC.  
870 Curé Boivin  
Boisbriand, Qué.  
J7G 2A7

File no.: AS-00201-A

RE: EVALUATION OF THE WATER VAPOR TRANSMISSION
OF DEMILEC HEATLOK SOYA POLYURETHANE FOAM
AS PER ASTM E 96M-05 STANDARD TEST METHOD
PROCEDURE A “DESICCANT METHOD” (DRY CUP)

Mr. Lalande,

This letter confirms that Air-Ins Inc. Laboratories was retained by "DEMILEC INC." to perform a serie of tests on several samples of Demilec Heatlok Soya Polyurethane Foam in order to evaluate the water vapor transmission characteristic of the foam as per ASTM E 96M-05 Standard test Methods for Water Vapor Transmission for Materials. The tests were performed on samples with and without substrates in order to evaluate the water vapor permeance of the material alone and of the material and substrate assemblies. Furthermore different thicknesses of material were tested to correlate water vapor characteristic and thickness.

This letter compiles the final results of the test program in a graph form included in appendix.

The tests were performed in accordance with ASTM E 96M-05 Standard test Methods for Water Vapor Transmission for Materials. Three samples were tested for each thickness and substrate configuration. Prior to the tests, all specimens were conditioned for a period of 7 days at 23± 1°C and 50 ± 2% RH. All tests were performed using the method A of ASTM E 96M-05 “Desiccant Method” (Dry Cup) under the following conditions: 23± 1°C and 50 ± 2% RH.

Air-Ins inc. is an independent testing laboratory accredited under ISO 17025 by the Standard Council of Canada (SCC) and is certified to perform ASTM E 96M-05 tests.
The graph in appendix illustrates the material thickness required to meet the requirements of the NBCC which are as follows: Art 9.25.1.2, 9.25.4.2 & 5.3.1.2. NBCC-05 qualify a vapour barrier material when the permeance is not greater than 60 ng/(Pa s m²) measured in accordance to ASTM E96, dry cup method. Any material with a perm rating lower than 60 ng/(Pa s m²) in these conditions will act as a vapour barrier in the building envelope assembly.

For any further questions with respect to this file, please contact the undersigned.

Air-Ins Inc.

Robert Jutras, eng.

Appendix: Graph
DEMILEC SOYA POLYURETHANE FOAM
WATER VAPOR PERMEANCE VS FOAM THICKNESS
AS PER ASTM E 96M-05 PROCEDURE A DESICCANT METHOD (DRY CUP)

POLYURETHANE ON GYPSUM
POLYURETHANE ON PLYWOOD
POLYURETHANE NO SUBSTRATE
POLYURETHANE ON CONCRETE

Note: The results in this graphic accounts for the permeance of the polyurethane and the substrate as an assembly where applicable.
2) Studs described in Sentence (1) shall be fastened together by screws, crimping or welding to act as a single structural unit in resisting transverse loads.

9.24.3.6. Attachment of Studs to Runners

1) Studs shall be attached to runners by screws, crimping or welding around wall openings and elsewhere where necessary to keep the studs in alignment during construction.

2) Where clearance for expansion is required in Article 9.24.3.2., attachment required in Sentence (1) shall be applied between studs and bottom runners only.

9.24.3.7. Openings for Fire Dampers

1) Openings for fire dampers in non-loadbearing fire separations required to have a fire-resistance rating shall be framed with double studs on each side of the opening.

2) The sill and header for openings described in Sentence (1) shall consist of a runner track with right angle beads made on each end so as to extend 300 mm above the header or below the sill and fastened to the studs.

3) The openings described in Sentence (1) shall be lined with a layer of gypsum board not less than 12.7 mm thick fastened to stud and runner webs.

Section 9.25. Heat Transfer, Air Leakage and Condensation Control

9.25.1. General

9.25.1.1. Scope and Application

1) This Section is concerned with heat, air and water vapour transfer and measures to control condensation.

2) All walls, ceilings and floors separating conditioned space from unconditioned space, the exterior air or the ground shall be
   a) provided with
      i) thermal insulation conforming to Subsection 9.25.2.,
      ii) an air barrier conforming to Subsection 9.25.3.,
      iii) a vapour barrier conforming to Subsection 9.25.4., and
   b) constructed in such a way that the properties and relative position of all materials conform to Subsection 9.25.5.

3) Insulation and sealing of heating and ventilating ducts shall conform to Sections 9.32. and 9.33.

9.25.2. Thermal Insulation

9.25.2.1. Required Insulation

1) All walls, ceilings and floors separating heated space from unheated space, the exterior air or the exterior soil shall be provided with sufficient thermal insulation to prevent moisture condensation on their room side during the winter and to ensure comfortable conditions for the occupants. (See A-9.1.1.1.(1) in Appendix A.)

9.25.2.2. Insulation Materials

1) Except as required in Sentence (2), thermal insulation shall conform to the requirements of
   a) CAN/CGSB-51.25-M, "Thermal Insulation, Phenolic, Faced,"
   b) CGSB 51-GP-27M, "Thermal Insulation, Polystyrene, Loose Fill,"
   c) CAN/ULC-S701, "Thermal Insulation, Polystyrene, Boards and Pipe Covering,"
   d) CAN/ULC-S702, "Mineral Fibre Thermal Insulation for Buildings,"
e) CAN/ULC-S703, “Cellulose Fibre Insulation (CFI) for Buildings,”
f) CAN/ULC-S704, “Thermal Insulation, Polyurethane and Polyisocyanurate, Boards, Faced,”
h) CAN/ULC-S706, “Wood Fibre Thermal Insulation for Buildings.”

2) The flame-spread ratings requirements contained in the standards listed in Sentence (1) shall not apply. (See Appendix A.)

3) Insulation in contact with the ground shall be inert to the action of soil and water and shall be such that its insulative properties are not significantly reduced by moisture.

9.25.2.3. Installation of Thermal Insulation

1) Insulation shall be installed so that there is a reasonably uniform insulating value over the entire face of the insulated area.

2) Insulation shall be applied to the full width and length of the space between furring or framing.

3) Except where the insulation provides the principal resistance to air leakage, thermal insulation shall be installed so that at least one face is in full and continuous contact with an element with low air permeance. (See Appendix A.)

4) Insulation on the interior of foundation walls enclosing a crawl space shall be applied so that there is not less than 50 mm clearance above the crawl space floor, if the insulation is of a type that may be damaged by water.

5) Insulation around concrete slabs-on-ground shall be located so that heat from the building is not restricted from reaching the ground beneath the perimeter, where exterior walls are not supported by footings extending below frost level.

6) Where insulation is exposed to the weather and subject to mechanical damage, it shall be protected with not less than
   a) 6 mm asbestos-cement board,
   b) 6 mm preservative-treated plywood, or
   c) 12 mm cement paring on wire lath applied to the exposed face and edge.

7) Insulation located in areas where it may be subject to mechanical damage shall be protected by a covering such as gypsum board, plywood, particleboard, OSB, waferboard or hardboard.

8) Insulation in factory-built buildings shall be installed so that it will not become dislodged during transportation.

9.25.2.4. Installation of Loose-Fill Insulation

1) Except as provided in Sentences (2) to (6), loose-fill insulation shall be used on horizontal surfaces only.

2) Where loose-fill insulation is installed in an unconfined sloped space, such as an attic space over a sloped ceiling, the supporting slope shall not be more than
   a) 4.5 in 12 for mineral fibre or cellulose fibre insulation, and
   b) 2.5 in 12 for other types of insulation.

3) Loose-fill insulation is permitted to be used in wood-frame walls of existing buildings. (See Appendix A.)

4) Where blown-in insulation is installed in above-ground or below-ground wood-frame walls of new buildings,
   a) the density of the installed insulation shall be sufficient to preclude settlement,
   b) the insulation shall be installed behind a membrane that will permit visual inspection prior to the installation of the interior finish,
c) the insulation shall be installed in a manner that will not interfere with the installation of the interior finish, and
d) no water shall be added to the insulation, unless it can be shown that the added water will not adversely affect other materials in the assembly.

5) Water repellent loose-fill insulation is permitted to be used between the outer and inner wythes of masonry cavity walls. (See Appendix A.)

6) Where soffit venting is used, measures shall be taken
a) to prevent loose-fill insulation from blocking the soffit vents and to maintain an open path for circulation of air from the vents into the attic or roof space, and
b) to minimize airflow into the insulation near the soffit vents to maintain the thermal performance of the material. (See Article 9.19.1.3.)

9.25.2.5. **Installation of Spray-Applied Polyurethane**

1) Spray-applied polyurethane insulation shall be installed in accordance with CAN/ULC-S705.2, "Thermal Insulation – Spray-Applied Rigid Polyurethane Foam, Medium Density – Application."

9.25.3. **Air Barrier Systems**

9.25.3.1. **Required Barrier to Air Leakage**

1) Wall, ceiling and floor assemblies separating conditioned space from unconditioned space or from the ground shall be constructed so as to include an air barrier system that will provide a continuous barrier to air leakage
a) from the interior of the building into wall, floor, attic or roof spaces, sufficient to prevent excessive moisture condensation in such spaces during the winter, and
b) from the exterior or the ground inward sufficient to
   i) prevent moisture condensation on the room side during winter,
   ii) ensure comfortable conditions for the occupants, and
   iii) minimize the ingress of soil gas.

(See Appendix A.)

9.25.3.2. **Air Barrier System Properties**

(See A-9.25.5.1(1) in Appendix A.)

1) Air barrier systems shall possess the characteristics necessary to provide an effective barrier to air infiltration and exfiltration under differential air pressure due to stack effect, mechanical systems or wind.

2) Where polyethylene sheet is used to provide airtightness in the air barrier system, it shall conform to CAN/CGSB-51.34-M, "Vapour Barrier, Polyethylene Sheet for Use in Building Construction."

9.25.3.3. **Continuity of the Air Barrier System**

1) Where the air barrier system consists of an air-impermeable panel-type material, all joints shall be sealed to prevent air leakage.

2) Except as provided in Sentence 9.25.3.6.(3), where the air barrier system consists of flexible sheet material, all joints shall be
   a) sealed, or
   b) lapped not less than 100 mm and clamped, such as between framing members, furring or blocking, and rigid panels.

3) Where an interior wall meets an exterior wall, ceiling, floor or roof required to be provided with air barrier protection, the air barrier system shall extend across the intersection.
9.25.4. Vapour Barriers

9.25.4.1. Required Barrier to Vapour Diffusion

1) Thermally insulated wall, ceiling and floor assemblies shall be constructed with a vapour barrier so as to provide a barrier to diffusion of water vapour from the interior into wall spaces, floor spaces or attic or roof spaces.

9.25.4.2. Vapour Barrier Materials

1) Vapour barriers shall have a permeance not greater than 60 ng/(Pa·s·m²) measured in accordance with ASTM E 96/E 96M, "Water Vapor Transmission of Materials," using the desiccant method (dry cup):

2) Where the intended use of the interior space will result in high moisture generation, the assembly shall be designed according to Part 5. (See Appendix A.)

3) Where polyethylene is installed to serve only as the vapour barrier, it shall comply with Clause 4.4, Thermal Stability, and Clause 5.7, Oxidative Induction Time, of CAN/CGSB-51.34-M, "Vapour Barrier, Polyethylene Sheet for Use in Building Construction."

4) Membrane-type vapour barriers other than polyethylene shall conform to the requirements of CAN/CGSB-51.33-M, "Vapour Barrier Sheet, Excluding Polyethylene, for Use in Building Construction."

5) Where a coating is applied to gypsum board to function as the vapour barrier, the permeance of the coating shall be determined in accordance with CAN/CGSB-1.501-M, "Method for Permeance of Coated Wallboard."

6) Where foamed plastic insulation functions as the vapour barrier, it shall be sufficiently thick so as to meet the requirement of Sentence (1).

9.25.4.3. Installation of Vapour Barriers

1) Products installed to function as the vapour barrier shall protect the warm side of wall, ceiling and floor assemblies.

2) Where different products are used for the vapour barrier and the insulation, the vapour barrier shall be installed sufficiently close to the warm side of the insulation to prevent condensation at design conditions. (See Appendix A and A-9.25.5.1.(1) in Appendix A.)

3) Where the same product is used for the vapour barrier and the insulation, the product shall be installed sufficiently close to the warm side of the assembly to prevent condensation at design conditions. (See A-9.25.4.3.(2), A-9.25.5.1.(1) and A-9.25.5.2. in Appendix A.)

9.25.5. Properties and Position of Materials in the Building Envelope

9.25.5.1. General

(See Appendix A.)

1) Sheet and panel-type materials incorporated into assemblies described in Article 9.25.1.1. shall conform to Article 9.25.5.2., where

a) the material has

i) an air leakage characteristic less than 0.1 L/(s·m²) at 75 Pa,

ii) a water vapour permeance less than 60 ng/(Pa·s·m²) when measured in accordance with ASTM E 96/E 96M, "Water Vapor Transmission of Materials," using the desiccant method (dry cup), and

b) the intended use of the interior space where the materials are installed will not result in high moisture generation.

(See Appendix A.)
2) Where the intended use of the interior space will result in high moisture generation, the assembly shall be designed according to Part 5.

3) Wood-based sheathing materials not more than 12.5 mm thick and complying with Article 9.23.17.2. need not comply with Sentence (1).

9.25.5.2. Position of Low Permeance Materials
(See Appendix A.)

1) Sheet and panel-type materials described in Article 9.25.5.1. shall be installed:
   a) on the warm face of the assembly (see also Article 9.25.4.2.),
   b) at a location where the ratio between the total thermal resistance of all materials outboard of its innermost impermeable surface and the total thermal resistance of all materials inboard of that surface is not less than that required by Table 9.25.5.2., or
   c) outboard of an air space that is vented to the outdoors.

2) For walls, the air space described in Clause (1)(c) shall comply with Clause 9.27.2.2.(1)(a).

Table 9.25.5.2.
Ratio of Outboard to Inboard Thermal Resistance
Forming Part of Sentence 9.25.5.2.(1)

<table>
<thead>
<tr>
<th>Heating Degree-Days of (\text{Building Location}^{(i)}), Celsius degree-days</th>
<th>Minimum Ratio of Total Thermal Resistance Outboard of Material's Inner Surface to Total Thermal Resistance Inboard of Material's Inner Surface</th>
</tr>
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<tr>
<td>up to 4 999</td>
<td>0.20</td>
</tr>
<tr>
<td>5 000 to 5 999</td>
<td>0.30</td>
</tr>
<tr>
<td>6 000 to 6 999</td>
<td>0.35</td>
</tr>
<tr>
<td>7 000 to 7 999</td>
<td>0.40</td>
</tr>
<tr>
<td>8 000 to 8 999</td>
<td>0.50</td>
</tr>
<tr>
<td>9 000 to 9 999</td>
<td>0.55</td>
</tr>
<tr>
<td>10 000 to 10 999</td>
<td>0.60</td>
</tr>
<tr>
<td>11 000 to 11 999</td>
<td>0.65</td>
</tr>
<tr>
<td>12 000 or higher</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Notes to Table 9.25.5.2.:
(i) See Sentence 1.1.3.1.(1).

Section 9.26. Roofing


9.26.1.1. Purpose of Roofing

1) Roofs shall be protected with roofing, including flashing, installed to shed rain effectively and prevent water due to ice damming from entering the roof.

2) For the purpose of Sentence (1), roofs shall include platforms that effectively serve as roofs with respect to the accumulation or drainage of precipitation. (See Appendix A.)


1) Methods described in CAN3-A123.51-M, "Asphalt Shingle Application on Roof Slopes 1:3 and Steeper," or CAN3-A123.52-M, "Asphalt Shingle Application on Roof Slopes 1:6 to Less Than 1:3," are permitted to be used for asphalt shingle applications not described in this Section.
A-9.25.2.2.(2) Flame-Spread Ratings of Insulating Materials. Part 9 has no requirements for flame-spread ratings of insulating materials since these are seldom exposed in parts of buildings where fires are likely to start. Certain of the insulating material standards referenced in Sentence 9.25.2.2.(1) do include flame-spread rating criteria. These are included either because the industry producing the product wishes to demonstrate that their product does not constitute a fire hazard or because the product is regulated by authorities other than building authorities (e.g., Hazardous Products Act). However, the Code cannot apply such requirements to some materials and not to others. Hence, these flame-spread rating requirements are excepted in referencing these standards.

A-9.25.2.3.(3) Position of Insulation. For thermal insulation to be effective, it must not be short-circuited by convective airflow through or around the material. If low-density fibrous insulation is installed with an air space on both sides of the insulation, the temperature differential between the warm and cold sides will drive convective airflow around the insulation. If foamed plastic insulation is spot-adhered to a backing wall or adhered in a grid pattern to an air-permeable substrate, and is not sealed at the joints and around the perimeter, air spaces between the insulation and the substrate will interconnect with spaces behind the cladding. Any temperature or air pressure differential across the insulation will again lead to short circuiting of the insulation by airflow. Thermal insulation must therefore be installed in full and continuous contact with the air barrier or another continuous component with low air permeance. (See Appendix Note A-9.25.5.1.(1) for examples of low-air-permeance materials.)

A-9.25.2.4.(3) Loose-Fill Insulation in Existing Wood-Frame Walls. The addition of insulation into exterior walls of existing wood-frame buildings increases the likelihood of damage to framing and cladding components as a result of moisture accumulation. Many older homes were constructed with little or no regard for protection from vapour transmission or air leakage from the interior. Adding thermal insulation will substantially reduce the temperature of the siding or sheathing in winter months, possibly leading to condensation of moisture at this location.

Defects in exterior cladding, flashing and caulking could result in rain entering the wall cavity. This moisture, if retained by the added insulation, could initiate the process of decay.

Steps should be taken therefore, to minimize these effects prior to the retrofit of any insulation. Any openings in walls that could permit leakage of interior heated air into the wall cavity should be sealed. The inside surface should be coated with a low-permeability paint to reduce moisture transfer by diffusion. Finally, the exterior siding, flashing and caulking should be checked and repaired if necessary to prevent rain penetration.

A-9.25.2.4.(5) Loose-Fill Insulation in Masonry Walls. Typical masonry cavity wall construction techniques do not lend themselves to the prevention of entry of rainwater into the wall space. For this reason, loose-fill insulation used in such space must be of the water repellent type. A test for water-repellency of loose-fill insulation suitable for installation in masonry cavity walls can be found in ASTM C 516, "Vermiculite Loose Fill Thermal Insulation."

A-9.25.3.1.(1) Air Barrier Systems for Control of Condensation. The majority of moisture problems resulting from condensation of water vapour in walls and ceiling/attic spaces are caused by the leakage of moist interior heated air into these spaces rather than by the diffusion of water vapour through the building envelope.

Protection against such air leakage must be provided by a system of air-impermeable materials joined with leak-free joints. Generally, air leakage protection can be provided by the use of air-impermeable sheet materials, such as gypsum board or polyethylene of sufficient thickness, when installed with appropriate structural support. However, the integrity of the airtight elements in the air barrier system can be compromised at the joints and here special care must be taken in design and construction to achieve an effective air barrier system.

Although Section 9.25. refers separately to vapour barriers and airtight elements in the air barrier system, these functions in a wall or ceiling assembly of conventional wood-frame construction are often combined as a single membrane that acts as a barrier against moisture diffusion and the movement of interior air into insulated wall or roof cavities. Openings cut through this membrane, such as for electrical boxes, provide opportunities for air leakage into concealed spaces, and special measures must be taken to make such openings as airtight as possible. Attention must also be paid to less obvious leakage paths, such as holes for electric wiring, plumbing installations, wall-ceiling and wall-floor intersections, and gaps created by shrinkage of framing members.

In any case, air leakage must be controlled to a level where the occurrence of condensation will be sufficiently rare, or the quantities accumulated sufficiently small, and drying sufficiently rapid, to avoid material deterioration and the growth of mould and fungi.
Generally the location in a building assembly of the airtight element of the air barrier system is not critical; it can restrict air leakage whether it is located near the outer surface of the assembly, near the inner surface or at some intermediate location. However, if a material chosen to act as an airtight element in the air barrier system also has the characteristics of a vapour barrier (i.e., low permeability to water vapour), its location must be chosen more carefully in order to avoid moisture problems. (See Appendix Notes A-9.25.3.1.(1) and A-9.25.4.3.(2).)

In some constructions, an airtight element in the air barrier system is the interior finish, such as gypsum board, which is sealed to framing members and adjacent components by gaskets, caulking, tape or other methods to complete the air barrier system. In such cases, special care in sealing joints in a separate vapour barrier is not critical. This approach often uses no separate vapour barrier but relies on appropriate paint coatings to give the interior finish sufficient resistance to water vapour diffusion that it can provide the required vapour diffusion protection.

The wording in Section 9.25. allows for such innovative techniques, as well as the more traditional approach of using a continuous sheet, such as polyethylene, to act as an "air/vapour barrier."

Further information can be found in CBD 231, "Moisture Problems in Houses" (Canadian Building Digest 231), by A.T. Hansen, which is available from the Institute for Research in Construction, National Research Council of Canada, Ottawa K1A 0R6.

**A-9.25.3.4. and 9.25.3.6. Air Leakage and Soil Gas Control in Floors-on-ground.** The requirement in Sentence 9.25.3.3.(6) regarding the sealing of penetrations of the air barrier also applies to hollow metal and masonry columns penetrating the floor slab. Not only the perimeters but also the centres of such columns must be sealed or blocked.

![Diagram A-9.25.3.4. and 9.25.3.6.-A](image)

**Figure A-9.25.3.4. and 9.25.3.6.-A**

Dampproofing and soil gas control at foundation wall/floor junctions with solid walls

The requirement in Sentence 9.25.3.6.(6) regarding drainage openings in slabs can be satisfied with any of a number of proprietary devices that prevent the entry of radon and other soil gases through floor drains. Some types of floor drains incorporate a trap that is connected to a nearby tap so that the trap is filled every time the tap is used. This is intended to prevent the entry of sewer gas but would be equally effective against the entry of radon and other soil gases.

![Diagram A-9.25.3.4. and 9.25.3.6.-B](image)

**Figure A-9.25.3.4. and 9.25.3.6.-B**

Dampproofing and soil gas control at foundation wall/floor junctions with hollow walls
A-9.25.3.6.(2) and (3) **Polyethylene Air Barriers under Floors-on-Ground.** Floors-on-ground separating conditioned space from the ground must be constructed to reduce the potential for the entry of air, radon or other soil gases. In most cases, this will be accomplished by placing 0.15 mm polyethylene under the floor.

Finishing a concrete slab placed directly on polyethylene can, in many cases, cause problems for the inexperienced finisher. A rule of finishing, whether concrete is placed on polyethylene or not, is to never finish or "work" the surface of the slab while bleed water is present or before all the bleed water has risen to the surface and evaporated. If finishing operations are performed before all the bleed water has risen and evaporated, surface defects such as blisters, crazing, scaling and dusting can result. In the case of slabs placed directly on polyethylene, the amount of bleed water that may rise to the surface and the time required for it to do so are increased compared to a slab placed on a compacted granular base. Because of the polyethylene, the excess water in the mix from the bottom portion of the slab cannot bleed downward and out of the slab and be absorbed into the granular material below. Therefore, all bleed water, including that from the bottom of the slab, must now rise through the slab to the surface. Quite often in such cases, finishing operations are begun too soon and surface defects result.

One solution that is often suggested is to place a layer of sand between the polyethylene and the concrete. However, this is not an acceptable solution for the following reason: it is unlikely that the polyethylene will survive the slab pouring process entirely intact. Nevertheless, the polyethylene will still be effective in retarding the flow of soil gas if it is in intimate contact with the concrete; soil gas will only be able to penetrate where a break in the polyethylene coincides with a crack in the concrete. The majority of concrete cracks will probably be underlain by intact polyethylene. On the other hand, if there is an intervening layer of a porous medium, such as sand, soil gas will be able to travel laterally from a break in the polyethylene to the nearest crack in the concrete and the total system will be much less resistant to soil gas penetration.

To reduce and/or control the cracking of concrete slabs, it is necessary to understand the nature and causes of volume changes of concrete and in particular those relating to drying shrinkage. The total amount of water in a mix is by far the largest contributor to the amount of drying shrinkage and resulting potential cracking that may be expected from a given concrete. The less total amount of water in the mix, the less volume change (due to evaporation of water), which means the less drying shrinkage that will occur. To lessen the volume change and potential cracking due to drying shrinkage, a mix with the lowest total amount of water that is practicable should always be used. To lower the water content of a mix, superplasticizers are often added to provide the needed workability of the concrete during the placing operation. Concretes with a high water-to-cementing-materials ratio usually have high water content mixes. They should be avoided to minimize drying shrinkage and cracking of the slab. The water-to-cementing-materials ratio for slabs-on-ground should be no higher than 0.55.

A-9.25.4.2.(2) **Normal Conditions.** The requirement for a 60 ng/Pa·s·m² vapour barrier stated in Sentence 9.25.4.2.(1) is based on the assumption that the building assembly is subjected to conditions that are considered normal for typical residential occupancies, and business and personal services occupancies.

However, where the intended use of an occupancy includes facilities or activities that will generate a substantial amount of moisture indoors during the heating season, such as swimming pools, greenhouses, laundromats, and any continuous operation of hot tubs and saunas, the building envelope assemblies would have to demonstrate acceptable performance levels in accordance with the requirements in Part 5.

A-9.25.4.3.(2) **Location of Vapour Barriers.** Assemblies in which the vapour barrier is located partway through the insulation meet the intent of this Article provided it can be shown that the temperature of the vapour barrier will not fall below the dew point of the heated interior air.

A-9.25.5.1. **Location of Low Permeance Materials.**

**Low Air- and Vapour-Permeance Materials and Implications for Moisture Accumulation**

The location in a building assembly of a material with low air permeance is generally not critical; the material can restrict outward movement of indoor air whether it is located near the outer surface of the assembly, near the inner surface, or at some intermediate location, and such restriction of air movement is generally beneficial, whether or not the particular material is designated as part of the air barrier system. However, if such a material also has the characteristics of a vapour barrier (i.e. low permeability to water vapour), its location must be chosen more carefully in order to avoid moisture accumulation.
Any moisture from the indoor air that diffuses through the inner layers of the assembly or is carried by air leakage through those layers may be prevented from diffusing or being transferred through the assembly by a low air- and vapour-permeance material. This moisture transfer will usually not cause a problem if the material is located where the temperature is above the dew point of the indoor air: the water vapour will remain as vapour, the humidity level in the assembly will come to equilibrium with that of the indoor air, further accumulation of moisture will cease or stabilize at a low rate, and no harm will be done.

But if the low air- and vapour-permeance material is located where the temperature is below the dew point of the air at that location, water vapour will condense and accumulate as water or ice, which will reduce the humidity level and encourage the movement of more water vapour into the assembly. If the temperature remains below the dew point for any length of time, significant moisture could accumulate. When warmer weather returns, the presence of a material with low water vapour permeance can retard drying of the accumulated moisture. Moisture that remains into warmer weather can support the growth of decay organisms.

Due consideration should be given to the properties and location of any material in the building envelope, including paints, liquid-applied or sprayed-on and trowelled-on materials. It is recognized that constructions that include low air- and vapour-permeance materials are acceptable, but only where these materials are not susceptible to damage from moisture or where they can accommodate moisture, for example insulated concrete walls. Further information on the construction of basement walls may be found in “Performance Guidelines for Basement Envelope Systems and Materials,” published by NRC-IRC.

Cladding

Different cladding materials have different vapour permeances and different degrees of susceptibility to moisture deterioration. They are each installed in different ways that are more or less conducive to the release of moisture that may accumulate on the inner surface. Sheet or panel-type cladding materials, such as metal sheet, have a vapour permeance less than 60 ng/(Pa s m²). Sheet metal cladding that has lock seams also has a low air leakage characteristic and so must be installed outboard of a drained and vented air space. Assemblies clad with standard residential vinyl or metal strip siding do not require additional protection as the joints are not so tight as to prevent the dissipation of moisture.

Sheathing

Like cladding, sheathing materials have different vapour permeances and different degrees of susceptibility to moisture deterioration.

Low-permeance sheathing may serve as the vapour barrier if it can be shown that the temperature of the interior surface of the sheathing will not fall below that at which saturation will occur. This may be the case where insulating sheathing is used.

**Thermal Insulation**

Where low-permeance foamed plastic is the sole thermal insulation in a building assembly, the temperature of the inner surface of this element will be close to the interior temperature. If the foamed plastic insulation has a permeance below 60 ng/(Pa s m²), it can fulfill the function of a vapour barrier to control condensation within the assembly due to vapour diffusion. However, where low-permeance thermal insulating sheathing is installed on the outside of an insulated frame wall, the temperature of the inner surface of the insulating sheathing may fall below the dew point; in this case, the function of vapour barrier has to be provided by a separate building element installed on the warm side of the assembly.

Normal Conditions

The required minimum ratios given in Table 9.25.5.2. are based on the assumption that the building assembly is subjected to conditions that are considered normal for typical residential occupancies, and business and personal services occupancies.
However, where the intended use of an occupancy includes facilities or activities that will generate a substantial amount of moisture indoors during the heating season, such as swimming pools, greenhouses, the operation of a laundromat or any continuous operation of hot tubs and saunas, the building envelope assemblies would have to demonstrate acceptable performance levels in accordance with the requirements in Part 5.

A-9.25.5.1.(1) Air and Vapour Permeance Values. The air leakage characteristics and water vapour permeance values for a number of common materials are given in Table A-9.25.5.1.(1). These values are provided on a generic basis; proprietary products may have values differing somewhat from those in the Table (consult the manufacturers’ current data sheets for their products’ values).

The values quoted are for the material thickness listed. Water vapour permeance is inversely proportional to thickness; therefore, greater thicknesses will have lower water vapour permeance values.
<table>
<thead>
<tr>
<th>Material</th>
<th>Air Leakage Characteristic, L/(s·m²) at 75 Pa (Air Permeance)</th>
<th>Water Vapour Permeance, ng/(Pa·m²·s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet and panel-type materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.7-mm gypsum board</td>
<td>0.02</td>
<td>2600</td>
</tr>
<tr>
<td>* painted (1 coat primer)</td>
<td>negligible</td>
<td>1300</td>
</tr>
<tr>
<td>* painted (1 coat primer + 2 coats latex paint)</td>
<td>negligible</td>
<td>180</td>
</tr>
<tr>
<td>12.7-mm foil-backed gypsum board</td>
<td>negligible</td>
<td></td>
</tr>
<tr>
<td>12.7-mm gypsum board sheathing</td>
<td>0.0091</td>
<td>1373</td>
</tr>
<tr>
<td>6.4-mm plywood</td>
<td>0.0084</td>
<td>23 – 74</td>
</tr>
<tr>
<td>11-mm oriented strandboard</td>
<td>0.0108</td>
<td>44 (range)</td>
</tr>
<tr>
<td>12.5-mm cement board</td>
<td>0.147</td>
<td>590</td>
</tr>
<tr>
<td>plywood (from 9.5 mm to 18 mm)</td>
<td>negligible – 0.01</td>
<td>40 – 57</td>
</tr>
<tr>
<td>fibreboard sheathing</td>
<td>0.012 – 1.91</td>
<td>982</td>
</tr>
<tr>
<td>17-mm wood sheathing</td>
<td>high – depends on no. of joints</td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27-mm foil-faced polyisocyanurate</td>
<td>negligible</td>
<td>4.3</td>
</tr>
<tr>
<td>27-mm paper-faced polyisocyanurate</td>
<td>negligible</td>
<td>61.1</td>
</tr>
<tr>
<td>25-mm extruded polystyrene</td>
<td>negligible</td>
<td>23 – 92</td>
</tr>
<tr>
<td>25-mm expanded polystyrene (Type 2)</td>
<td>0.0214</td>
<td>86 – 160</td>
</tr>
<tr>
<td>fibrous insulations</td>
<td>very high</td>
<td>very high</td>
</tr>
<tr>
<td>25-mm polyurethane spray foam – low density</td>
<td>0.011</td>
<td>894 – 3791</td>
</tr>
<tr>
<td>25-mm polyurethane spray foam – medium density</td>
<td>negligible</td>
<td>96&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Membrane-type materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>asphalt-impregnated paper (10 min paper)</td>
<td>0.0673</td>
<td>370</td>
</tr>
<tr>
<td>asphalt-impregnated paper (30 min paper)</td>
<td>0.4</td>
<td>650</td>
</tr>
<tr>
<td>asphalt-impregnated paper (60 min paper)</td>
<td>0.44</td>
<td>1800</td>
</tr>
<tr>
<td>water-resistive barriers (9 materials)</td>
<td>negligible – 4.3</td>
<td>30 – 1200</td>
</tr>
<tr>
<td>0.15-mm polyethylene</td>
<td>negligible</td>
<td>1.6 – 5.8</td>
</tr>
<tr>
<td>asphalt-saturated felt (#15)</td>
<td>0.153</td>
<td>290</td>
</tr>
<tr>
<td>building paper</td>
<td>0.2706</td>
<td>170 – 1400</td>
</tr>
<tr>
<td>spun-bonded polyethylene film (expanded)</td>
<td>0.9593</td>
<td>3646</td>
</tr>
<tr>
<td>Other materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>brick (6 materials)</td>
<td>negligible</td>
<td>102 – 602</td>
</tr>
<tr>
<td>metal</td>
<td>negligible</td>
<td>negligible</td>
</tr>
<tr>
<td>mortar mixes (4 materials)</td>
<td>negligible</td>
<td>13 – 690</td>
</tr>
<tr>
<td>stucco</td>
<td>negligible</td>
<td>75 – 240</td>
</tr>
<tr>
<td>50-mm reinforced concrete (density: 2 330 kg/m³)</td>
<td>negligible</td>
<td>23</td>
</tr>
</tbody>
</table>

Notes to Table A-9.25.5.1.(1):
(1) Air leakage and vapour permeance values derived from:
### Table A-9.25.5.1.1 (Continued)

<table>
<thead>
<tr>
<th>Authors</th>
<th>Paper/Report Details</th>
</tr>
</thead>
</table>

* This water vapour permeance value is for a 25-mm-thick core layer of medium-density polyurethane spray foam. When installed in the field, a low permeance resin layer forms where the foam is in contact with the substrate. The water vapour permeance of the installed foam, if measured including the resin layer, would therefore likely be lower than the value listed in the Table.

### A-9.25.5.2. Assumptions Followed in Developing Table 9.25.5.2.

Article 9.25.5.2. specifies that a low air- and vapour-permeance material must be located on the warm face of the assembly, outboard of a vented air space, or within the assembly at a position where its inner surface is likely to be warm enough for most of the heating season such that no significant accumulation of moisture will occur. This last position is defined by the ratio of the thermal resistance values outboard and inboard of the innermost impermeable surface of the material in question.

The design values given in Table 9.25.5.2. are based on the assumption that the building includes a mechanical ventilation system (between 0.3 and 0.5 air changes per hour), a 60 ng/Pa·s·m² vapour barrier, and an air barrier (values between 0.024 and 0.1 L/sm² through the assembly were used). The moisture generated by occupants and their use of bathrooms, cleaning, laundry and kitchen appliances was assumed to fall between 7.5 and 11.5 L per day.

It has been demonstrated through modelling under these conditions that assemblies constructed according to the requirements in Table 9.25.5.2. do not lead to moisture accumulation levels that may lead to deterioration as long as the average monthly vapour pressure difference between the exterior and interior sides over the heating season does not increase above 750 Pa, which would translate into an interior relative humidity of 35% in colder climates and 60% in mild climates.

Health Canada recommends an indoor relative humidity between 35% and 50% for healthy conditions. ASHRAE accepts a 30% to 60% range. Environments that are much drier tend to exacerbate respiratory problems and allergies; more humid environments tend to support the spread of microbes, moulds and dust mites, which can adversely affect health.

In most of Canada in the winter, indoor RH is limited by the exterior temperature and the corresponding temperature on the inside of windows. During colder periods, indoor RH higher than 35% will cause significant condensation on windows. When this occurs, occupants are likely to increase the ventilation to remove excess moisture. Although indoor RH may exceed 35% for short periods when the outside temperature is warmer, the criteria provided in Table 9.25.5.2. will still apply. Where higher relative humidities are maintained for extended periods in colder climates, the ratios listed in the Table may not provide adequate protection. Some occupancies require that RH be maintained above 35% throughout the year, and some interior spaces support activities such as swimming that create high relative humidities. In these cases, Table 9.25.5.2. cannot be used and the position of the materials must be determined according to Part 5.

It should be noted that Part 9 building envelopes in regions with colder winters have historically performed acceptably when the interior RH does not exceed 35% over most of the heating season. With tighter building envelopes, it is possible to raise interior RH levels above 35%. There is no information, however, on how Part 9 building envelopes will perform when exposed to these higher indoor RH levels for extended periods during the heating season over many years. Operation of the ventilation system, as intended to remove indoor pollutants, will maintain the lower RH levels as necessary.
Calculating Inboard to Outboard Thermal Resistance

Figure A-9.25.5.2.
Example of a wall section showing thermal resistance inboard and outboard of a plane of low air and vapour permeance

The method of calculating the inboard to outboard thermal resistance ratio is illustrated in Figure A-9.25.5.2. The example wall section shows three planes where low air- and vapour-permeance materials have been installed. A vapour barrier, installed to meet the requirements of Subsection 9.25.4., is on the warm side of the insulation consistent with Clause 9.25.5.2.(1)(a) and Sentences 9.25.4.1.(1) and 9.25.4.3.(2). The vinyl siding has an integral drained and vented air space consistent with Clause 9.25.5.2.(1)(c). The position of the interior face of the low-permeance insulating sheathing, however, must be reviewed in terms of its thermal resistance relative to the overall thermal resistance of the wall, and the climate where the building is located.
Comparing the RSI ratio from the example wall section with those in Table 9.25.5.2. indicates that this wall would be acceptable in areas with Celsius degree-day values up to 7999, which includes, for example, Whitehorse, Fort McMurray, Yorkton, Flin Flon, Geraldton, Val-d’Or and Wabush. (Degree-day values for various locations in Canada are provided in Appendix C.)

A similar calculation would indicate that, for a similar assembly with a 140 mm stud cavity filled with an RSI 3.52 batt, the ratio would be 0.28. Thus such a wall could be used in areas with Celsius degree-day values up to 4999, which includes, for example, Cranbrook, Lethbridge, Ottawa, Montreal, Fredericton, Sydney, Charlottetown and St. John’s.

Similarly, if half the thickness of the same low-permeance sheathing were used, the ratio with an 89 mm cavity would be 0.25, permitting its use in areas with Celsius degree-day values up to 4999. The ratio with a 140 mm cavity would be 0.16; thus this assembly could not be used anywhere, since this ratio is below the minimum permitted in Table 9.25.5.2.

Table A-9.25.5.2. shows the minimum thicknesses of low-permeance insulating sheathing necessary to satisfy Article 9.25.5.2. in various degree-day zones for a range of resistivity values of insulating sheathing. These thicknesses are based on the detail shown in Figure A-9.25.5.2. but could also be used with cladding details, such as brick veneer or wood siding, which provide equal or greater outboard thermal resistance.

### Table A-9.25.5.2.
Minimum Thicknesses of Low-Permeance Insulating Sheathing

<table>
<thead>
<tr>
<th>Celsius Heating Degree-days</th>
<th>Min. RSI Ratio</th>
<th>Min. Sheathing Thickness, mm</th>
<th>38 x 89 Framing</th>
<th>Min. Sheathing Thickness, mm</th>
<th>38 x 140 Framing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sheathing Thermal Resistance, RSI/mm</td>
<td>Min. Outboard Thermal Resistance, RSI</td>
<td>Sheathing Thermal Resistance, RSI/mm</td>
<td>Min. Outboard Thermal Resistance, RSI</td>
</tr>
<tr>
<td>&lt;= 4999</td>
<td>0.20</td>
<td>0.46</td>
<td>10</td>
<td>0.03000</td>
<td>0.03250</td>
</tr>
<tr>
<td>5000 to 6999</td>
<td>0.30</td>
<td>0.69</td>
<td>18</td>
<td>0.03000</td>
<td>0.03250</td>
</tr>
<tr>
<td>6000 to 7999</td>
<td>0.35</td>
<td>0.81</td>
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<td>53</td>
<td>0.03000</td>
<td>0.03250</td>
</tr>
</tbody>
</table>

### References


(2) ANSI/ASHRAE 62, "Ventilation for Acceptable Indoor Air Quality."


Decks, balconies, exterior walkways and similar exterior surfaces effectively serve as roofs where these platforms do not permit the free drainage of water through the deck. Unless the surface slopes to the outside edges and water can freely drain over the edge, water will pond on the surface. When rain is driven across the deck (roof) surface, water will move upward when it encounters an interruption.

### A-9.26.2.2.(4) Fasteners for Treated Shingles.

Where shingles or shakes have been chemically treated with a preservative or a fire retardant, the fastener should be of a material known to be compatible with the chemicals used in the treatment.
Low-Permeance Materials in Building Envelopes

by M.K. Kumaran and J.C. Haysom

This Update provides guidance on the use of low-permeance materials towards the outside of walls, for the range of climatic conditions found throughout Canada. By following these recommendations, which are reflected in the 1995 National Building Code, one should reduce the potential for the condensation of moisture in walls.

Provisions in the 1995 National Building Code of Canada relaxed restrictions in the 1990 Code on the use of materials with low water-vapour permeance on the outside of insulated exterior walls. These restrictions had been added in order to reduce the potential for condensation of moisture on the interior face of low-permeance materials used as air barriers on the outside of walls. These restrictions, however, went against many years of successful experience with low-permeance insulations used in this way. As a result, a number of manufacturers objected to the overly-restrictive conditions.

The approach to wall design described in the 1995 Code is the result of a series of changes implemented over the years to accommodate changing requirements and expectations in Canadian buildings. In the 1930s, the use of vapour barriers was introduced to control vapour diffusion into walls and attics. When humidification was introduced into houses in the 1950s, moisture accumulation in walls and attics again became a problem in many homes. Researchers determined that most of the moisture was being transported into these locations by air leakage rather than by vapour diffusion. Air leakage can become a significant problem when the various materials in the building envelope, including the vapour barrier, are not installed as seamless components, and the many holes allow air to flow into the walls and roof spaces.

When energy costs rose in the 1970s, the demand for energy-efficiency led to the construction of better-insulated houses. Once the stud cavities of a stud wall are filled with insulation, additional insulation must be placed on the inside or outside to increase the wall’s thermal resistance.

Three main mechanisms move air through the building envelope: stack effect, wind action and mechanical ventilation.

**Stack effect.** The density of air decreases as its temperature increases, making warm air lighter than cold air. As a result, warm air rises and its buoyancy exerts an outward pressure against the ceiling and upper walls. Holes in the vapour barrier allow warm, humid air to flow into the roof or wall structure, where it cools and deposits moisture on the cold interior surfaces of the roof or wall sheathing.

**Wind action.** Wind blowing against a house produces a positive pressure on the outside of the windward wall and a negative pressure on the other walls. The negative pressure draws air from the interior through holes in the exterior walls, and the moisture that this warm air holds condenses inside the wall structure on the cold sheathing.

**Mechanical ventilation.** While exhaust fans reduce the pressure inside a house by extracting air, improperly balanced mechanical ventilation systems, including supply fans, can pressurize the interior. Air and moisture can then flow through any openings into the exterior walls and roof space where condensation can accumulate.
In one technique for adding insulation inside, horizontal furring is placed over the vapour barrier that is attached to the inner faces of the studs; this provides room for a second layer of insulation. As a result, the vapour barrier is sandwiched between the two layers of insulation, with the inside layer being thinner than the outside one (Figure 1). This design, however, raises the possibility that moisture could condense on the vapour barrier if the air temperature at that point were to drop below the dew point temperature for the interior air conditions.

Another system adds insulating sheathing to the outside of the stud wall to increase the thermal resistance of the wall (Figure 2). Because the insulation panel covers the exterior face of the studs, it also reduces the thermal bridging effect of the wood studs, an added benefit. In this case, the vapour barrier is installed on the warm side of the studs as required by the Code. Initially wood- or mineral-fibre panels were used as the exterior sheathing but the use of plastic foam insulations has become popular as well.

The condensation problems experienced by many homeowners in the 1960s and 1970s prompted the Associate Committee on the National Building Code to incorporate a subsection in Part 9 of the 1980 NBC entitled “Measures to Prevent Condensation.” It contained instructions for the installation of the vapour barrier that, if followed, would make it a more effective air barrier membrane.

Many designers objected to the Code assumption that the vapour barrier would fill the role of both air barrier and vapour barrier. They argued that it would be easier to maintain the continuity of the air barrier if it could be placed in a more appropriate location within the wall, where it would be less likely to be interrupted by ducts, interior partitions, or electrical boxes. As a result, the wording of the 1990 Code acknowledged that the air barrier could be a separate component located anywhere in the wall. This change raised the possibility that someone using a material with low water-vapour permeance as an air barrier might choose to place it close to the outer surface of the wall where condensation could form on its interior face.

To reduce the probability of incorrect placement, the Code included a restriction on the location of air barriers with low water-vapour permeance. These air barriers had to be placed so that the inner surface remained above the dew point of the interior air when the outside temperature was 10°C above the January 21/2% temperature. This restriction, however, prohibited the use of certain insulating sheathings that had been used without problems on the outside face of wood-stud walls for a number of years.

Manufacturers of these materials argued that such restriction was unnecessary and asked that it be removed in the 1995 edition of the NBC. Concerns were also raised about the potential for condensation on low-permeance materials placed towards the outside even if they weren’t designated as the air barrier. The researchers at NRC’s Institute for Research in Construction agreed to review the question in detail.

The Study
As a first step, the researchers used computer modelling to establish the relationship between air exfiltration, heat transfer and moisture accumulation in a cavity wall. For this study, the wall consisted of 38 x 89-mm studs, batt insulation in the stud cavity, and a Type II vapour barrier. The interior temperature was 21°C and the interior relative humidity (RH) was 36%. The exterior temperature and RH were -15°C and 60%. The air permeance of the assembly varied between 0.001 L/(s·m²) and 10 L/(s·m²) at 75 Pa pressure difference between the interior and exterior.
The results of this modelling showed that the heat flux (the rate of heat flow per unit area through the wall) increased as the air flow rate increased. The moisture accumulation also increased but only up to a certain point. Beyond that point, the moisture accumulation decreased and then became insignificant. The reason for this decrease is that the temperature within the cavity increased as the rate of air flow increased. At a certain point, the cavity became so warm that the conditions required for condensation ceased to exist. This is the reason that many old buildings without air barriers have no moisture problems — the walls are so warm that condensation cannot occur. With today's energy prices and occupant expectations, leaky walls are not a practical solution. Adding insulation on the outside of the wall, however, is another way to keep the wall cavity warm.

The researchers next repeated the computer simulations with an added 25-mm-thick mineral-fibreboard sheathing on the outside of the studs (Figure 3). The simulations confirmed that in this case the cavity was warm enough to prevent condensation on the interior face.

To determine the effect of air leakage and exterior insulation on the performance of a wall, the researchers then carried out a number of other simulations varying such design parameters as air leakage rate, vapour permeance, and interior RH. The studs used were 38 x 140 mm, and the insulation batts were rated at RSI 3.52. One wall also had an external insulating sheathing with RSI 0.75.

The simulations analyzed the hygrothermal behaviour of the cavity for one full year on an hourly basis using weather data for the City of Ottawa. Figure 7 shows the moisture accumulation within the cavity for three of these walls, which are described below.

Wall B0 (Figure 4) – Type II vapour barrier, zero air permeance (no air leakage), interior RH 36%.

Wall B2 (Figure 5) – Type II vapour barrier, air permeance 0.1 L/(s·m²) @ 75 Pa, interior RH 36%.

Wall B2R (Figure 6) – Type II vapour barrier, air permeance 0.1 L/(s·m²) @ 75 Pa, interior RH 36%, low-permeance insulating sheathing with RSI of 0.75.

![Figure 3. The effect of the additional thermal resistance provided by the exterior sheathing](image)

![Figure 4. Wall B0](image)

![Figure 5. Wall B2](image)

![Figure 6. Wall B2R](image)
Curve B0 gives moisture accumulation due to diffusion only.

Curve B2 gives moisture accumulation due to diffusion and air leakage.

Curve B2R shows the beneficial effect of the exterior insulating sheathing on moisture accumulation since moisture diffusion and air leakage were the same as for B2. The moisture accumulation in B2R was less than in B0.

These results show that when sufficient thermal resistance is added along with a low-permeance layer towards the outside of a building assembly, the assembly’s ability to accommodate a modest amount of air leakage is enhanced. The simulation determined that the ratio of outboard to inboard insulation used (i.e., \(0.75/3.52 = 0.214\)) was adequate to control moisture accumulation in the wall for an interior relative humidity of 36%, in the Ottawa-area climate. Simulations for other Canadian cities using the appropriate weather data showed that the required ratio of outboard to inboard thermal resistance is proportional to the degree-days. Thus the colder the location, the larger the amount of external insulation required to maintain the necessary temperature in the cavity to control moisture accumulation.

The Standing Committee on Housing and Small Buildings (responsible for Part 9 of the NBC) adopted the recommendations made by the researchers and incorporated into the 1995 Code Table 1, which gives the minimum ratio of outboard to inboard thermal resistance for low-permeance materials in increments of 1000 degree-days.\(^1,2\) Degree-days for over 600 Canadian cities and towns — from Victoria, BC, at 2900 to Eureka, NWT, at 13800 — are given in Appendix C of the National Building Code (Table 2).

**Table 2.** Heating degree days for selected Canadian cities (from 1995 NBC, Appendix C)

<table>
<thead>
<tr>
<th>City</th>
<th>Heating degree days, Celsius degree-days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria</td>
<td>2900</td>
</tr>
<tr>
<td>Edmonton</td>
<td>5400</td>
</tr>
<tr>
<td>Regina</td>
<td>5750</td>
</tr>
<tr>
<td>Winnipeg</td>
<td>5900</td>
</tr>
<tr>
<td>Toronto</td>
<td>3650</td>
</tr>
<tr>
<td>Ottawa</td>
<td>4600</td>
</tr>
<tr>
<td>Quebec</td>
<td>5200</td>
</tr>
<tr>
<td>Fredericton</td>
<td>4650</td>
</tr>
<tr>
<td>Halifax</td>
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</tr>
<tr>
<td>Charlottetown</td>
<td>4600</td>
</tr>
<tr>
<td>St John’s</td>
<td>4800</td>
</tr>
<tr>
<td>Whitehorse</td>
<td>6900</td>
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<tr>
<td>Yellowknife</td>
<td>8500</td>
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<tr>
<td>Iqualuit</td>
<td>10050</td>
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</table>
Using Low-Permeance Exterior Insulation

Where a material with low water-vapour permeance is used in a wall, the ratio of outboard to inboard thermal resistance must equal or exceed that needed to control condensation.

The thermal resistance of a wall is the total of the resistance of all the materials that make up the wall, such as insulation, sheathings, finishes, air spaces and air films. The inboard thermal resistance is the sum of the thermal resistance of all the materials on the warm side of the low-permeance material. To calculate the minimum thermal resistance of the outboard insulation, first the inboard thermal resistance is multiplied by the ratio from Table 1 that applies to the climatic conditions. This result represents the total thermal resistance for all outboard elements including exterior insulation, exterior finish material and air film. Adding up the thermal resistance for all other outboard elements and subtracting this subtotal from the total outboard thermal resistance gives the minimum thermal resistance of the exterior insulation. The example shows a sample calculation for a wall design in Winnipeg.

Conclusion

The study demonstrated that placing a material with low water-vapour permeance on the outside of an exterior wall does not necessarily increase the potential for condensation within the wall structure as long as sufficient thermal resistance is added outboard of the innermost plane of low permeance to keep its temperature high enough to prevent condensation.

Example

Winnipeg has 5900 degree-days which, according to Table 1, requires a minimum RSI ratio of 0.30. The following calculations show how the minimum amount of outboard insulation would be calculated for a 38- x 89-mm stud wall.

<table>
<thead>
<tr>
<th>38- x 89-mm stud wall</th>
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<tbody>
<tr>
<td><strong>Inboard thermal resistance</strong></td>
<td><strong>Outboard thermal resistance</strong></td>
</tr>
<tr>
<td>Insulation</td>
<td>Insulation to be calculated</td>
</tr>
<tr>
<td>Gypsum board</td>
<td>Metal or vinyl siding</td>
</tr>
<tr>
<td>Stud (38 x 89 mm)</td>
<td>Air film</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>Subtotal</strong></td>
</tr>
</tbody>
</table>

Minimum outboard insulation = 2.31 x 0.30 = 0.69
Less siding and air film = 0.69 + 0.15 = 0.84
Minimum thermal resistance of insulation = 0.54
Total wall resistance = 2.31 + 0.69 = 3.00
(without taking into account thermal bridging through studs)
References

1. Note: The provisions in the NBC are based on an assumed indoor humidity of 36%. In cases where the indoor relative humidity is likely to be significantly higher than 36% for long periods in the winter, it would be prudent to use higher ratios than those in Table 1.

2. Note: This NBC requirement applies to materials with an air leakage characteristic less than 0.1 L/(s·m²) @ 75 Pa. Wood-based sheathing materials are exempt provided that they are installed with gaps at the joints.


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