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NBC 9.25.1.2.: The On-Going Development of Building Code Requirements to Address Low Air and Vapour Permeance Materials

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ABSTRACT

Part 9 of the National Building Code (NBC) provides, in Article 9.25.1.2., requirements that identify where low air and vapour permeance materials can be located in building envelope assemblies depending on the position of the thermal insulation in the assembly and the climate at the building site. The provisions to be included in the 2005 NBC have evolved over many code development cycles as issues have become more clearly identified. This paper briefly outlines the development of the requirements up to those included in the 1995 NBC and discusses in more detail the basis for the changes to be included in the 2005 Code. Various questions still remain for investigation in the future; some of these are identified.

NBC 9.25.1.2.: The On-Going Development of Building Code Requirements to Address Low Air and Vapour Permeance Materials

INTRODUCTION

The National Building Code of Canada (NBC) [1] provides requirements related to air leakage and vapour diffusion in Part 5 Environmental Separation and in Part 9 Housing and Small Buildings. Part 5 applies to larger buildings and buildings with higher hazard occupancies, and the requirements are primarily performance-based. Part 9 applies to smaller, lower hazard buildings and the requirements are primarily prescriptive.

Article 9.25.1.2. of the 1995 NBC [1] specifies where low air and vapour permeance sheet or panel materials can be located in building envelope assemblies depending on the position of the thermal insulation in the assembly and the climate at the building site. The provisions evolved from earlier Code requirements aimed at addressing moisture condensation concerns. They continue to be revised as the issues become better understood and are more clearly defined.

This paper briefly outlines the development of the requirements up to those included in Article 9.25.1.2. of the 1995 NBC and discusses in more detail the basis for the changes to be included in the 2005 Code. The paper concludes by identifying some of the outstanding questions that remain to be resolved.

NBC 1941 TO 1990: OVERVIEW OF DEVELOPMENT OF LOW-PERMEANCE PROVISIONS

Since the first edition of the NBC published in 1941, [2] various Code requirements have addressed the control of condensation in the building envelope, whether due to air leakage or vapour diffusion, and have recognized the implications of installing low permeance materials at various locations in building assemblies.

- A requirement in Article 3.8.2.4. Exterior Wall Coverings of the 1941 Code [2] states that "when either the sheathing or the building paper is highly resistant to the transmission of water vapour, an effective vapour barrier shall be provided between the interior face of the studs and the exposed interior face of the wall." A note identifies the vapour transfer factor of the sheathing or building paper below which a vapour barrier should be installed.
- Sentence 4.7.1.3.(1) of the 1960 NBC [3] calls for materials on the cold side of the insulation to be five times more porous than materials on the warm side.

With the increase in energy costs in the 1970s, wall assemblies were developed that saw the installation of insulation inboard or outboard of the insulation in the the stud spaces. Interior insulation was installed between strapping inboard of the vapour barrier. Questions arose as to whether interior moisture would condense on the vapour barrier depending on the thermal resistance inboard and outboard of the vapour barrier. A one-thirds:two-thirds rule of thumb was adopted. Exterior insulation was generally low permeance material, again raising questions as to whether moisture transferred from the interior by air leakage or vapour diffusion would condense on the interior surface of the insulation.

Beginning with the 1990 Code, [4] the requirements in Part 9 recognized that different materials can serve the functions of the vapour barrier and the airtight element of the air barrier system. [This was recognized in Part 4 of the 1965 Code. [5]] The vapour barrier requirements recognized that the material serving this function must be installed toward the warm side of the assembly to avoid condensation. No such requirements apply to air barrier systems. It was recognized, however, that the airtight element of the air barrier system could also be a low permeance material.

To begin to address these issues, a new Article 9.25.5.2. was included with the air barrier requirements in Part 9 of the 1990 Code to limit the location where air barriers with low vapour permeance could be installed. The location was defined by the dew point of the indoor air and the 2.5% January design temperature.

NBC 1995: DEVELOPMENT OF ARTICLE 9.25.1.2.

After 1990, it was recognized that materials can have low air and vapour permeance but not serve as part of the air barrier system. The properties of materials rather than their intended function are what are important. Further, it was believed that defining the location of low air and vapour permeance materials based on the 2.5% January design temperature was overly stringent. The provision precluded the use of foam plastic exterior insulations when they had been used for some period without problem.

For the 1995 NBC, Article 9.25.5.2. was removed and a new Article 9.25.1.2. was added. The provisions identify where low air and vapour permeance sheet or panel materials can be installed, regardless of their intended function. Three options are identified:

1. on the warm face of the assembly,
2. with some exceptions, at a location where the ratio between the total thermal resistance of all materials outboard of the innermost impermeable surface and the total thermal resistance of all materials inboard of that surface is not less than limits specified in Table 9.25.1.2., or
3. outboard of an air space that is vented to the outdoors and, for walls, drained.

The first option reflects vapour barrier installation. The last option reflects the installation of open rainscreen cladding. For other low air and vapour permeance sheet or panel materials, Table 9.25.1.2. applies. The Table defines the location of the inside surface of low air and vapour permeance materials based on the number of degree days at the building site and the ratio of the thermal resistance outboard of this plane to the thermal resistance inboard of this plane (see Table 1 below).

TABLE 1
NBC Table 9.25.1.2.

Heating Degree-Days of *Building* Location, Celsius degree days	Minimum Ratio, Total Resistance Outboard of Material's Inner Surface to Total Thermal Resistance Inboard of Material's Inner Surface
up to 4 999	0.20
5 000 to 5 999	0.30
6 000 to 6 999	0.35
7 000 to 7 999	0.40
8 000 to 8 999	0.50
9 000 to 9 999	0.55
10 000 to 10 999	0.60
11 000 to 11 999	0.65
12 000 or higher	0.75

The ratio values in the Table were determined using the TCCC2D model developed by VTT in Finland and implemented at the Institute for Research in Construction (IRC) jointly by the researchers from IRC and VTT. (6) The calculation assumed:

- air leakage based on the 1987 NRCan airtightness survey (7);
- a maximum indoor RH of 35% throughout the heating season;
- vapour barrier permeance of 60 ng/(Pa*s*m2) [based on a Type 2 vapour barrier];

The climate regions were defined by degree-day ranges, generally with 100 degree-day increments but with the lowest range from 0 to 4999. These assumptions are not stated in the Code.

NBC 2005: EXPANDING THE APPLICATION OF TABLE 9.25.1.2.

After publication of the 1995 Code, questions were raised about the application of the Table where indoor relative humidity exceeds 35% frequently throughout or over the entire heating season. Changes to Article 9.25.1.2. have been approved for inclusion in the 2005 Code to address this issue. (8)

The initial proposed change simply made the assumed maximum RH explicit and limited the application of Table 9.25.1.2. to cases where the indoor RH is not maintained above 35% over the heating season. Even before the receipt of public comments, it was noted by Codes Centre staff that this solution would leave questions as to the use of low permeance exterior insulation in climates such as coastal British Columbia (BC) where the winters are mild and damp, and where interior RH above 35% over the heating season were being reported as the norm. It was expected that this would have an unnecessary adverse impact on the use of these insulation materials. To address this concern, Codes Centre and IRC research staff embarked on an intense, short-term research project in an attempt to identify whether higher interior RH levels could be recognized for milder, damp climates and to define those climates.

Review of Parameters

Air Leakage

The assembly air leakage rate used in the development of Table 9.25.1.2. was based on the 1989 cross-Canada airtightness survey conducted by Energy, Mines and Resources Canada. In reviewing the validity of the limits in the Table, the country-wide average value from the 1997 NRCan survey is used; i.e., a normalized leakage area of 1.44 cm2/m2. [9]

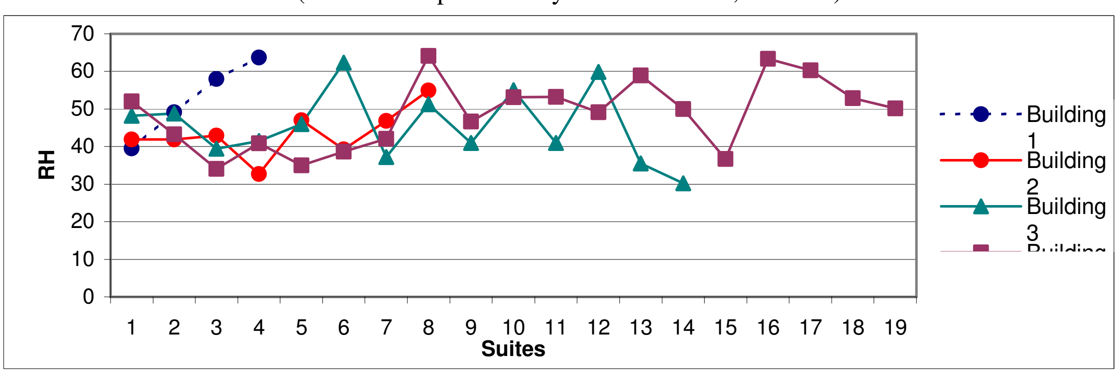
Indoor RH – Coastal Climates

The maximum indoor RH of 35% is problematic in the BC coastal climate. Values considerably higher than 35% have been measured in dwelling units in coastal BC during the heating season. Information from measurements provided by Read Jones Christoffersen Ltd. (RJC) [10] and Levelton Engineering Ltd. [11] are shown in Figures 1 and 2 below. The RJC values are single time measurements for a number of suites in four buildings; the measurements were made in March of 2000, 2002 and 2003. The Levelton data are for a single 90 m^2 suite recorded over a 5-day period in March 2003.

Data was also provided by Michael Aoki-Kramer, City of Seattle. [12] Measurements were taken every 15 minutes from the beginning of November 2001 to mid-March 2002. The averages for nine suites were 43.6%, 44.5%, 45.5%, 50.4%, 51.1%, 51.8%, 55.8% 60.1%, and 68.4%; the average of these values being 52.4%. No information was obtained on moisture loads or ventilation regimes.

These measured values are reasonably consistent with monthly average indoor RH computed for an average year (1969) in Vancouver using IRC's weather analysis tool *Weathersmart*. [13] (See Figure 3.)

FIGURE 1
Single Time Measurements of RH for Various Suites in Four Low-Rise Residential Buildings
(Source data provided by Dr. Leslie Peer, RJC [10])



Building Averages:	
Building 1	52.6
Building 2	43.4
Building 3	45.5
Building 4	48.7

Overall Average = 47.1
Std Dev = 9.1
Normal Range = 38.0 to 56.2

FIGURE 2
RH for a Single Suite Recorded over a 5-day Period
(Source data provided by Pierre-Michel Busque, Levelton [11])

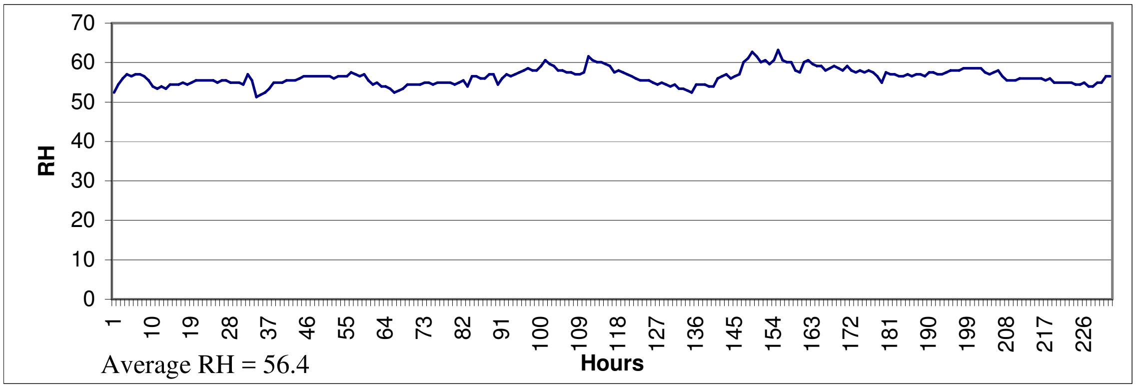
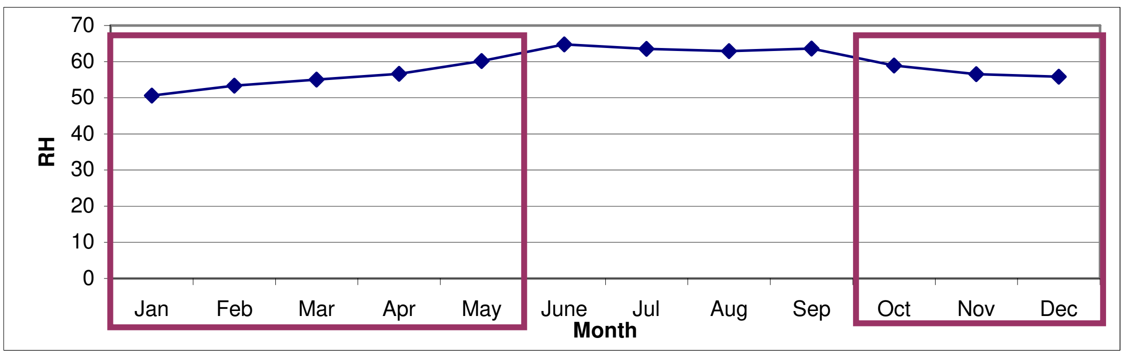


FIGURE 3
Calculated Monthly Average RH for Average Year in Vancouver (1969)
(Source: IRC's *Weathersmart* [13])



Data – Monthly, Heating Season and Annual Averages

an	'eb	lar	ıpr	lay	Jun	Jul	Aug	Sept	)ct	Jov	)ec	Heating Season	Annual
0.63	3.36	4.99	6.63	0.19	64.79	63.56	62.91	63.66	8.90	6.50	5.80	55.88	55.87

Note: Values for heating season shaded

<u>Indoor RH – Continental Climates</u>

Depending on the moisture added by the occupancy of the building, the 35% limit may also be problematic for many new houses in temperate climates due to increased airtightness of the building envelope. There is no evidence, however that this is an issue where a code-compliant ventilation system is installed and properly operated.

<u>Selecting RH values for Table 9.25.1.2.</u>

Health Canada recommends indoor RH of 35% to 50% for healthy conditions. [14] ASHRAE accepts a 30% to 60% range. [15]

For buildings in regions with continental climates, demonstrated acceptable performance of Part 9 building envelope assemblies has been based on historically lower interior RH levels over the heating season. How such assemblies will perform with long-term indoor winter RH levels above 35% is not known. Consequently, a possible change to the 35% maximum RH was not considered for these climates.

For buildings in the BC coastal climate, higher indoor RH can be tolerated by the building envelope because of the higher exterior temperatures over the heating season. Indoor RH levels determined by *WeatherSmart* from actual weather data, which are consistent with measured levels and within the ASHRAE limits, were used to determine whether the application of Table 9.25.1.2. could be expanded to include buildings with higher RH levels.

Vapour Barrier Permeance

As noted, the values in the Table 9.25.1.2. are based on calculations that assumed a Type 2 vapour barrier [60 ng/(Pa*s*m2)].A decrease in vapour permeance may allow assemblies with less thermal resistance outboard of the low permeance material or indoor RH levels greater than 35%. The degree to which buildings have provided acceptable performance because they incorporate Type 1 vapour barriers is not known. Airtightness rather than vapour diffusion may be the controlling factor. In reviewing the application of Table 9.25.1.2., a vapour permeance of 60 ng/(Pa*s*m2) was maintained.

Climate Regions

The current degree-day basis for defining climate regions and the locations used to define those climate regions were reviewed. Temperature, exterior RH and rain, all of which affect vapour diffusion, were considered.

Of the 640 locations listed in Appendix C of the NBC, only a few locations have fewer than 3,000 degree-days. Of the 91 locations in BC, 48 have degree days in the range of 3,000 to 3999. In the current Table 9.25.1.2., the inboard-to-outboard ratio for these locations is the same as for locations with up to 4,999 degree-days. To address the question of applying the Table to buildings with higher indoor RH in coastal BC, the focus was on assembly performance in locations with up to about 4,000 degree-days.

Hygrothermal Analysis

Work carried out during the Code cycle leading up to publication of the 2005 edition focused on the transition to objective-based codes. Time and resources available for technical up-dating were very limited. In order to at least begin to address the immediate concern of indoor RH in the BC coastal region, a hygrothermal analysis was carried out to determine the performance of building envelopes exposed to higher indoor RH levels in Vancouver (2925 degree days).

Hygrothermal modeling is considered to be a useful tool for providing comparative information. At this point in the development of these models, they are not recommended for determining absolute performance levels. Thus the review compared the amount of moisture that would be accumulated in a base-case wall, without any low permeance materials outboard of the vapour barrier, with a "tight" wall that includes a low permeance exterior insulating material. IRCs model *hygIRC* was used. [16]

Exterior Conditions

The model uses actual weather data from 1969, an average year in terms of degree days, temperature and rain:

1. dry bulb temperature
2. atmospheric moisture specifically RH%
3. wind speed
4. wind direction
5. solar radiation on the selected façade orientation
6. rainfall on the horizontal plane
7. cloud index

Interior RH

Interior RH was calculated based on:

- actual hourly exterior temperature and RH from 1969,
- a worse case of a small apartment of 80 m^2 (860 ft^2),
- average interior temperature of 21 ºC,
- interior moisture load of 7.5 L/day, [17]
- normalized air leakage area of 1.44 cm^2/m^2, consistent with the findings of the 1997 NRCan airtightness survey and assuming a worst case of one exterior wall, and
- a ventilation rate of 0.3 air changes per hour, consistent with the minimum principal ventilation capacity required by NBC Section 9.32.

The calculations indicate the average heating season RH does not exceed 60%. As noted above, this is reasonably consistent with available field measurements.

Wall Assemblies

Figures 4 and 5, and Table 2 describe the constructions of the base case and tight wall assemblies. It was assumed that there were no defects in the assemblies that would allow leakage of water into the wall. Water transfer through materials is accounted for in the model.

FIGURE 4
Base Case (BC) Wall

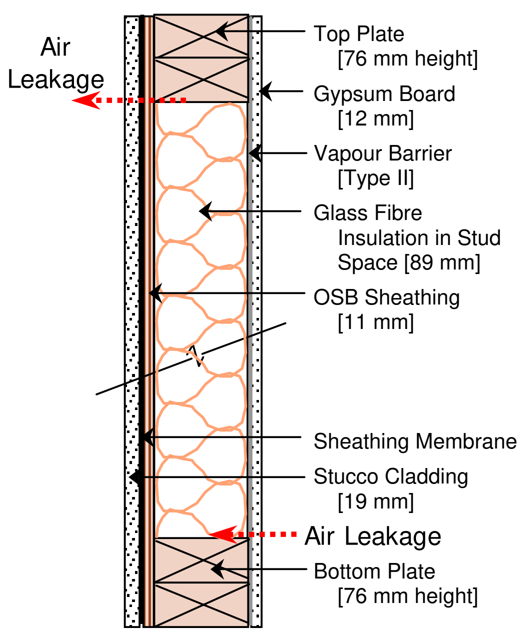
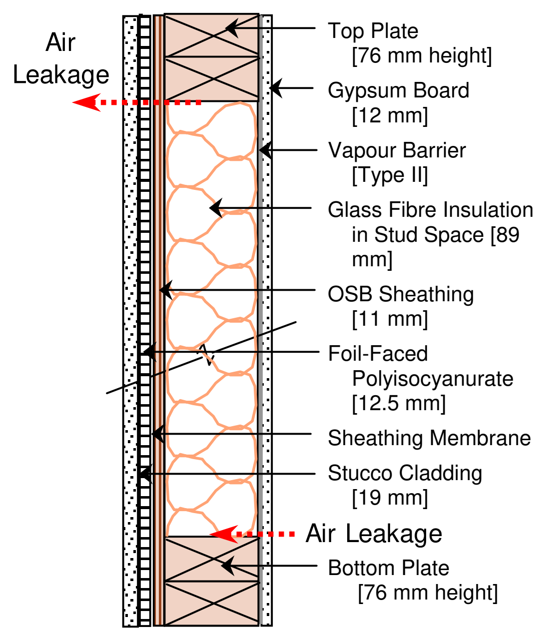


FIGURE 5
Tight Wall with 12.5 mm Foil-Faced Polyisocyanurate (PIR)



Moisture Accumulation in Wall Assembly

Figures 6 and 7 illustrate the moisture accumulation in the stud space for the base case (BC) wall compared to the tight (PIR) walls with Type 2 (60) and Type 1 (15) vapour barriers. In both cases, the moisture accumulation in the walls with the low permeance sheathing is less than in the base case wall.

TABLE 2
Hygrothermal Properties of Materials in Base Case and Tight Walls

	Base-Case and Tight Wall							Tight Walls
	cladding (stucco)	sheathing membrane (polymeric)	sheathing (OSB)	insulation (glass fibre)	vapour barrier Type 1	vapour barrier Type 2	interior finish (gypsum board)	foil-faced polyiso
Thickness, mm	19	0.2	11	89	0.152	0.2	12	0.15 (foil) 12.5 (foam)
thermal conductivity, W/(m.K)	0.352	0.109	0.094	0.043	0.159	0.159	0.160	0.026
water vapour permeability @ 100 % RH, kg/(Pa.s.m)	6.7×10^{-12}	8.3×10^{-13}	5.9×10^{-12}	1.8×10^{-10}	2.3×10^{-15}	1.2×10^{-14}	6.2×10^{-11}	3.1×10^{-16} (foil) 6.9×10^{-12} (foam)
permeance @ 100% RH, $ng/(Pa.s.m^2)$	353	4127	542	2045	15	60	5165	2 (foil) 557 (foam) 0.998 (total)
equilibrium moisture content (kg_w/kg_d) @ 80% RH	6.6×10^{-02}	6.9×10^{-02}	1.2×10^{-01}	6.6×10^{-03}	6.9×10^{-02}	7.0×10^{-02}	1.1×10^{-01}	1.6×10^{-02}
moisture diffusivity, $m^2.s^{-1}$	9.1×10^{-09}	4.9×10^{-12}	2.2×10^{-11} (x-dir) 5.1×10^{-10} (y-dir)	1.0×10^{-08}	1.0×10^{-16}	1.0×10^{-16}	3.7×10^{-07}	1.0×10^{-16} (foil) 1.0×10^{-12} (foam)
air permeability, m^2	6.9×10^{-17}	2.2×10^{-14}	7.9×10^{-15}	1.1×10^{-09}	1.0×10^{-20}	1.0×10^{-16}	6.8×10^{-14}	1.4×10^{-2}

FIGURE 6
Base Case and Tight Walls with Type 2 Vapour Barrier

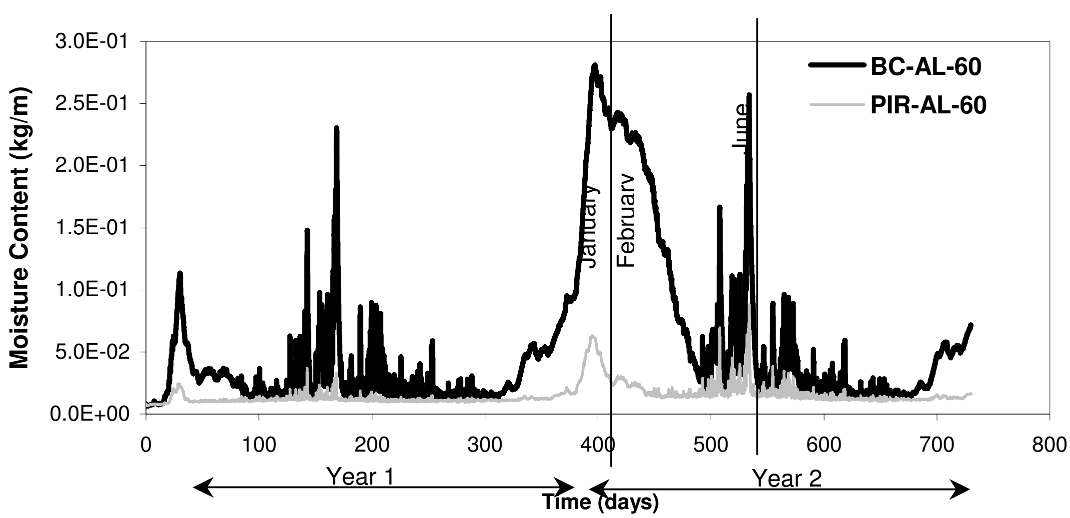
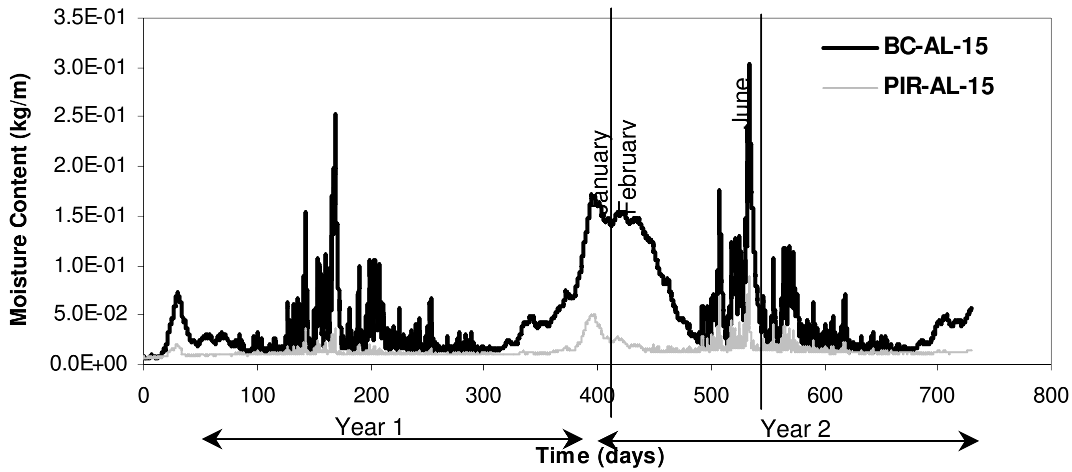


FIGURE 7
Base Case and Tight Walls with Type 1 Vapour Barrier



Application of Higher RH Limit Depending on Climate

The modeling indicated that, for Vancouver, Table 9.25.1.2. can be used with indoor RH above 35%. Consequently, for at least some BC coastal communities, the 35% limit need not apply. The conclusion cannot be extrapolated with certainty to all BC coastal locations without further analysis, but the findings provide some assurance that the Table can be applied as a minimum requirement in these warmer locations. The difference in moisture accumulation between the base case and “tight” walls indicates a good margin of safety to allow the Table to be applied beyond Vancouver.

The locations in BC that are of particular concern with respect to the application of Table 9.25.1.2. are those that are not only milder but have high moisture loads, conditions that reduce the likelihood of ventilation air being sufficient to reduce the indoor RH below 35%. High exterior moisture load can be indicated by moisture index (MI). [(18)] Table 3 identifies the locations from Appendix C of the NBC with MI values greater than 1.00.

There are two locations in southern Ontario and six in Nova Scotia with MI values greater than 1.00 and with degree-day values similar to those in coastal BC. With the colder winters in these regions, there have been no reports that the 35% RH limit is problematic. A means was needed to capture the warmer BC locations, eliminate the Ontario and Nova Scotia locations, and also eliminate locations in BC that have sufficiently low winter temperatures to allow indoor RH levels to be reduced below 35% for at least part of the heating season and where extrapolation of the Vancouver modeling results is most questionable.

It was agreed that Stewart and Terrace have sufficiently low heating season temperatures to permit the reduction of indoor RH below 35%. It was also agreed that Prince Rupert, Kitimat Plant and Kitimat Townsite have sufficiently low heating season temperatures to permit the reduction of indoor RH below 35% for at least some of the heating season.

TABLE 3
Warmer Locations from Appendix C with MI Values Greater than 1.00 Sorted by MCI

Location	2.5% January, °C	DD	MI	MCI	Location	2.5% January, °C	DD	MI	MCI
Ucluelet	-2	3150	3.26	3550	GVA – Langley	-8	3100	1.53	4700
Tofino	-2	3300	3.36	3700	Campbell River	-7	3400	1.59	4800
GVA – Vancouver (Granville & 41 Ave.)	-6	2950	1.44	4150	Sandspit	-6	3600	1.47	4800
					GVA – Haney	-9	3050	1.86	4850
					Mission City	-9	3050	1.86	4850
GVA – Ladner	-6	3000	1.14	4200	GVA – West Vancouver	-8	3250	1.69	4850
Youbou	-5	3200	2.09	4200					
Port Alberni	-5	3200	2.00	4200	Powell River	-9	3200	1.27	5000
GVA – Vancouver	-7	2925	1.44	4325	Abbotsford	-10	3100	1.59	5100
Duncan	-6	3150	1.13	4350	Masset	-7	3800	1.54	5200
Crofton	-6	3150	1.06	4350	Chilliwack	-12	2950	1.68	5350
GVA – North Vancouver	-7	3000	2.07	4400	Squamish	-11	3200	2.12	5400
					Agassiz	-13	2950	1.71	5550
GVA – Burnaby (Simon Fraser Univ.)	-7	3000	1.93	4400	Ocean Falls	-12	3600	4.21	6000
					Hope	-16	3100	1.88	6300
					Yarmouth, NS	**-13**	**4100**	**1.32**	**6700**
GVA – Richmond	-7	3000	1.20	4400	Prince Rupert	-14	4050	2.84	6850
Alberni	-5	3400	2.00	4400	**Liverpool, NS**	**-14**	**4050**	**1.48**	**6850**
GVA – New Westminster	-8	2950	1.59	4550	**Lockeport, NS**	**-14**	**4100**	**1.42**	**6900**
					Port Burwell,ON	**-15**	**4000**	**1.05**	**7000**
Courtenay	-7	3150	1.49	4550	**Port Stanley, ON**	**-15**	**4000**	**1.05**	**7000**
Comox	-7	3150	128	4550	**Digby, NS**	**-15**	**4050**	**1.27**	**7050**
Nanaimo	-7	3150	1.13	4550	Kitimat Plant	-16	4000	2.19	7200
Port McNeill	-5	3550	1.89	4550	**Lunenburg, NS**	**-15**	**4250**	**1.45**	**7250**
Qualicum Beach	-7	3200	1.31	4600	Kitimat Townsite	-16	4200	2.00	7400
Port Hardy	-5	3600	1.92	4600	**Louisburg, NS**	**-15**	**4500**	**1.46**	**7500**
GVA – Surrey (88 Ave. & 156 St.)	-8	3050	1.58	4650	Terrace	-20	4400	1.08	8400
					Stewart	-23	4650	1.47	9250
GVA – Cloverdale	-8	3050	1.44	4650					

Notes: Greater Vancouver area locations listed with prefix "GVA".
Nova Scotia and Ontario locations in bold.
Nova Scotia locations listed with suffix"NS"; Ontario locations listed with suffix "ON".

A criterion was developed that integrates the two temperature parameters to capture only the intended BC locations. (See Table 3 above.)

Mild Climate Indicator (MCI) = abs(2.5%JMT) * 200 + DD

where:

abs(2.5%JMT) = absolute value of 2.5% January Mean Temperature

DD = degree days

A limit of 6300, corresponding with the MCI for Hope, was selected to exclude locations in Ontario and Nova Scotia, and the corresponding colder locations in BC.

CONCLUSIONS

Article 9.25.1.2. of the 2005 NBC will indicate that Table 9.25.1.2. can be applied to:

- buildings in colder climates, with an MCI exceeding 6300, where the interior RH over the heating seaason does not exceed 35%, and
- buildings in milder climates, with an MCI not more than 6300, where the interior RH over the heating season does not exceed 60%.

Because time constraints limited the research to analyzing wall performance in Vancouver, further work is needed to confirm the extrapolation of the findings to locations that are colder than Vancouver. There are also some outstanding questions about the operation of buildings in colder climates at humidities exceeding 35%. If buildings in colder climates are being consistently operated over 35% RH over the heating season, the performance of the building envelopes must be evaluated. If the building envelopes are performing well, the 35% limit might be adjusted. If the building envelopes are not standing up to the higher humidities, the basic prescriptive building envelope requirements provided in the NBC may need to be re-evaluated.

ACKNOWLEDGEMENTS

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