3.4 Future Damage

3.4.1 - General

Moisture related problems are the result of a complex combination of a large number of variables. Variables such as the reported lack of proper inspections or poor construction practices are controllable, while many others, such as the weather regime, are not. Meso-climate appears to determine the severity and type of problem that occurs. There is, therefore, a large variation in the regional distribution of the problem. Other factors, such as family size and building siting, are also important, but, other than for some overall parameters such as the large household sizes in problems houses, direct relationships are not as strong as those for the climatic data.

Factors such as weather and household size are difficult or impossible to control. Efforts to prevent future problems must, therefore, concentrate on changes to building details and to regulations and specifications related to ventilation rates or to other means of dehumidification.

The appearance of a moisture problem is also time related. As such, there is a proportion of the NHA housing stock (primarily the newer units) where problems are not yet apparent. These problems can be expected to become noticable over the next 1 to 5 years.

3.4.2 - Anticipated Total Incidence of Moisture Induced Problems in NHA Financed Housing

The number of moisture induced problems detected in NHA financed houses is a function of two key factors:

i) problem units currently on record; and

ii) problems not yet recorded but expected to be noticed in the newer housing units constructed between 1976 and 1981.

This time delay means that by 1986 we would expect a further 1 450 problem units to surface in housing which has been constructed prior to 1982. Total problem units in the existing stock are, therefore, estimated at 11 750.

If no corrective action is taken, the expected annual national number of new problem units, is about 500, or 1.8% of construction volume, (based on the 1981 construction level of 28 500 NHA financed starts). If, however, the projection is based on the average of NHA housing starts between 1970 and 1981, (which is 88 000 starts), the forecast is about 1 200, or 1.5% of construction volume.

It should be noted that the projections assume that changes will not be made to the existing housing stock. Nevertheless, conversion to flueless heating and tightening of housing units will reduce ventilation rates and thus, likely, increase the incidence of moisture related problems in housing units. As a result, these projections should be considered only as a baseline.

3.5 Factors Affecting the Severity of Moisture Problems in NHA Financed Housing Units

3.5.1 - General

The conclusions and observations in this section are based on a nationwide field investigation covering 201 NHA housing units in which moisture related problems had been reported. For each unit, a potential of 324 specific points of information were obtained.[3)] It is important to note that the analysis and the following comments are based on this sample alone and do not include any data from a parallel analysis of non-problem housing, since such an analysis was not part of this project.

Problems observed and problem houses investigated, were representative of those described earlier in the report. All houses investigated were newer and probably more airtight than the Canadian housing stock in general, and the great majority had flueless heating.

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3) Further details on the data collected for each housing unit and its occupants can be found in reference "b" on page 2.

The field observations and measurements were analyzed to relate the degree of the problem to a number of relevant external and internal environmental factors.[4)]

The degree of the problem was defined as follows:

i) **Siding Problems**

The following three observations for problems in siding were analyzed:

- **Moisture Readings in Siding**

  "High" moisture content is defined as 22% by weight or greater. This level approaches the point where structural damage could occur under favourable, sustained environmental conditions.

  By this definition, high readings were found in 11 of the 61 units where these readings were taken. The remainder of the units had lower moisture content readings.

- **Buckling and Warping of Siding**

  "Major" buckling or swelling of over 50% of the siding on any wall was noted in 16 of the 58 units with observable siding problems of this type. Buckling or warping was less in the other 42 units.

- **Paint Problems on Siding**

  "Major" damage to siding paint (missing paint or damage to 0.3 to 0.4 m^2) was noted in 8 of the 37 units with paint damage. The other 29 units had smaller patches of paint damage.

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4) Throughout this report, factors relating to moisture problems, including meso-climate, type of house, lifestyle, etc., are referred to as "causal factors".

ii) Sheathing Problems

o Moisture Readings in Sheathing

Moisture readings were only taken in very few units (18). Of these, only 2 units had sheathing moisture readings in excess of 22%.

iii) **Level of Mould and Mildew Observed**

Mould and mildew observations were made both on the first and second floors of the two storey and on the first floor of one storey units investigated.

o **Mould and Mildew, First Floor**

"Major" problems, or large patches of mould and mildew on the walls or ceiling and lower corners were noted in 30 of the 133 houses where this condition was present. Only small patches were observed in the remaining 103 units.

o **Mould and Mildew, Second Floor**

"Major" problems, similar to the first floor, were noted in only 13 of the 60 units where this type of problem was observed on the second floor.

iv) **Window Condensation**

"Major" window condensation problems were noted in 38 of the 92 units where window condensation was observed. In these units, condensation runs continuously from the window, causing window frame mould, rot or other localized water damage in the general window area. In many instances of "major" problems, condensation had resulted in damage to the interior face of the wall (plaster or wall board damage). With heavy window condensation, it is expected that water could enter the interstitial space in the area of the window sill and localized rot or insulation damage could, therefore, be prevalent in the window area.

v) Moisture Readings, Exterior Walls

Where possible, an indicative set of moisture readings was taken on both the first and second floors. Readings were taken at selected wall locations that were removed from obvious areas of vapour barrier penetration, such as electrical outlets.

- **Moisture Readings, First Floor**

  As a proxy for conditions within the wall system, moisture readings were taken in the outside wall studs (but on the inside face). Readings of 22% or greater were only noted in 4 of the 133 housing units where observations were possible[5].

- **Moisture Readings, Second Floor**

  Readings in excess of 22% were noted in 8 of the 58 housing units where observations were possible.

vi) Attic Condition

Where attic access was possible, both moisture readings and mould and mildew observations were made.

- **Moisture Readings, Attic**

  Attic moisture readings were taken in the structural members and in sheathing. High readings of 22% or greater were found in 6 of the 44 housing units where attic access was possible.

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5) With such high readings on the inside face of the stud, substantially higher readings are expected at the stud/sheathing interface in February in Newfoundland. (Readings as high as 40% were observed at the stud/sheathing interface. Since readings were taken by means of an electrical resistant meter and adjusted for temperature, they are very unreliable at this high moisture content). However, even under these extremely high moisture conditions, rot was not noted in the studs or sheathing.

o Mould and Mildew, Attic

Major mould and mildew, covering more than 50% of the attic sheathing and roof joists (at the contact face with the sheathing), were found in 18 of the 46 housing units where attic mould and mildew were observed.

Analysis of the foregoing observed conditions indicates a number of causal factors differentiating housing units with less severe problems from those with major problems. **It should be stressed, however, that this test does not differentiate between houses with no problems and units with problems.**

Problem houses investigated were unique, however, in that the following characteristics differentiated them from the general Canadian housing stock:

	Problem Units	**Canadian Average**
- Average household size	4.1	2.9[6]
- Exposure to the wind	higher	average
- Relative humidity, first floor	49%) *	35%
- Relative humidity, second floor	50%) *	
- Average year unit was constructed	1975	older than 1964**
- % of units with electric baseboard heating	81%	lower

* At time of inspection.

** Average of the Canadian housing stock constructed after 1946 (Source: 1981 Census).

6) 1981 Census.

Problem units are thus characterized by large households (41% larger than the Canadian average). In fact, the Consultants noted that households of 6 persons or more were common in the sample. Relative humidities measured in problem houses (49-50%) are much higher than would normally be expected during winter or early spring periods[7].

Except for 4 units in Newfoundland, which had been unoccupied for periods ranging from 2 to 6 weeks, all the remaining 197 units investigated were occupied. Of all the houses investigated, 60% had measured first floor relative humidities of 50% or higher at temperatures which, at times, were considerably in excess of 22°C.

Comparable Canadian data on the age of housing unit and percentage of units with electric baseboard heating is not readily available. (The data from the 1981 census were not published when this report was prepared). There is, however, little doubt that houses with reported moisture related problems, major or minor, are significantly newer than the Canadian housing stock in general, and that they have a much higher incidence of flueless heating systems (primarily baseboard electric heating).

3.5.2 - Expected Causes of Moisture Related Problems in NHA Financed Housing

The analysis of the field observations was discussed in detail in the research reports. This section highlights the relevant findings[8].

- **Problems in the siding and sheathing complex** appear to be related to climatic conditions peculiar to Newfoundland. Conditions in this region are very wet during the spring, the time of year when the wall system usually dries out. Low spring temperatures (lower than all other Canadian regions where houses were studied, except for northern Manitoba) are common, as is driving rain. Direct and indirect energy gained from the sun, is also very

7) N.B. Hutcheson, "Science of Canadian Buildings" in Water and Buildings (NRC, May 1979), Chapter 12.

8) See Reference "a" on page 2.

low in Newfoundland. As a result, the building system is continually "stressed", both from the inside (lifestyle) and outside (weather) with less opportunity to dry out then in other regions.

Since problems were found to be related to weather conditions and to lifestyle factors, the data fail to support the hypothesis that inside (lifestyle related) conditions alone, significantly affect the severity of any observed siding problem. Since non-troubled housing units were not investigated, indications that elevated inside moisture levels contribute substantially to the problem, are weak. It must be recognized, however, that all units inspected had occupant levels and inside relative humidity readings well above normal Canadian averages. The very high incidence of flueless heating types in Newfoundland is also important.

Nevertheless, house occupancy and some lifestyle factors, such as household size and number of loads of washing done each week, appeared to exacerbate the problem.

- **Mould and mildew,** whether on the first or second floor, appears to be related to high levels of relative humidity which itself may be derived from occupant generated moisture. Where the air (containing a high level of moisture at a room temperature of 21°C) comes in contact with a cool wall at, say 10°C, condensation can be expected. It is significant that problems are observed in areas of high wind exposure as the wind blowing into the wall cavity could be one of the important factors. Although driving rain was also shown to be important, it is suspected that high wind conditions are more relevant.

- **Window condensation** was observed in two very different weather regimes. In the very cold sunny areas such as Thompson, Manitoba (where double glazing is the norm), problems are caused by the melting of frost on the windows when the sun warms than during the day. The problem was also noted on the west coast, especially in the Vancouver/Victoria, B.C. area. Here, single glazing contributed significantly to the problem.

- High moisture readings in the exterior wall (which could lead to rotting of structural members if allowed to persist) appears to be related to meso-climate, particularly that found in regions of extended colder periods with low levels of sunshine (for example, Newfoundland). The higher incidence on the second floor is explained by the stack effect and resulting exfiltration on the second floor level.

- Two different conditions were observed in the attic. The first, attic mould and mildew growth, requires a combination of warm conditions and moisture. A significant relationship was found between warmer weather and mould and mildew. Moisture required for mould growth appears to be internally generated, and, coupled with poor attic ventilation, is a major cause of the problem.

  The second condition, namely high moisture readings in attic structural members is associated with a completely different weather region. Colder weather, low solar gain and consistently high wind conditions (such as Newfoundland weather), especially during the spring, when attics normally dry-out, are all strongly associated with this problem. Generally, under these conditions, moist attic problems are expected, with wet insulation caused by water dripping from the sheathing. As with the mould and mildew problem, this type of condition was often found to be associated with poor attic ventilation and the lack of proper ceiling air barriers.

As indicated throughout this report, weather was often found to be a significant factor. The following regional relative humidity summary highlights the fact that the weather in the coastal areas, especially in St. John's, Newfoundland, is unique, particularly during the April-May period. Under normal circumstances, at this time of year, moisture generated and deposited during the winter is removed from the structure.

TABLE 3.3

REGIONAL RELATIVE HUMIDITY ANALYSIS

Location		Average Outdoor RH April-May %
St. John's	(Newfoundland)	85
Halifax	(Nova Scotia)	73
Toronto	(Ontario)	62
The Pas	(Manitoba)	69
Edmonton	(Alberta)	60
Penticton	(British Columbia)	62
Vancouver	(British Columbia	78
Victoria	(British Columbia)	78

4. VENTING AND ITS SPECIFIC APPLICATION TO NEWFOUNDLAND HOUSING

4.1 General

Because of the high incidence of moisture related problems in Newfoundland housing, one component of this project was to investigate, on a priority basis, the possibility of utilizing vent stacks as a practical solution for moisture reduction in Newfoundland houses.

The study concluded, on a theoretical basis that, because of the high moisture content of the ambient outside air in Newfoundland and the relatively warm winter temperatures, passive ventilation by itself, (such as vent stacks) may not be a practical solution.

4.2 Ventilation Requirements

The ventilation requirements for a house with four occupants, have been calculated for typical Newfoundland weather conditions, with outside winter and spring temperatures varying from -15°C to 0°C at 80% relative humidity. It is assumed that occupants will be at home 20 hours per day. Calculations are repeated for a family of six. For a representative calculation, inside conditions are selected as 27% RH and 22°C temperature because below 27% RH inside the house, problems were not observed during our investigations in Newfoundland. If clothes are dried inside the house, significantly higher levels of ventilation will be required. The study conditions are, therefore, conservative.

Since the efficiency of ventilation as a means of reducing moisture content in the house depends on the difference in moisture content between the outside and inside air, ventilation requirements vary significantly with the changing moisture content of outside air. As the outside air temperature and humidity increase to the levels generally experienced in Newfoundland, high ventilation rates are, consequently, required in order to maintain low moisture content levels inside the structure.

As detailed in the report specifically addressing ventilation in Newfoundland[1], excessive ventilation rates are required as outside temperatures approach 0°C. Requirements for a number of typical "design" families are contained in Table 4.1.

Given a volume for a standard NHA house of some 300 m^3, at the warmer temperatures, ventilation rates of one air change per hour or more are required to remove the moisture specifically generated by household operation. Additional ventilation would be required to vent moisture from other sources. (See table 4.1).

It should be recognized that adequately high ventilation rates may not be possible in relatively air tight housing without providing some means of entry for outside air.

4.3 Ventilation Systems Available

Ventilation can be provided either by a passive system (a vent stack) or a mechanical ventilation system. **For purposes of this project, CMHC directed the Consultants to investigate the reduction of internal relative humidity levels by means of passive stack ventilation.** It is the opinion of the Consultants that this method is limited in its application. Other methods of air moisture content reduction have, therefore, been investigated and are discussed.

4.3.1 – Ventilation by Means of a Stack

A stack extending through the attic space to an exit point above the roof serves two purposes:

- it provides ventilation by exhausting warm and humid air from the inside;

1) See Reference "c" on page 2.

TABLE 4.1

TYPICAL VENTILATION REQUIREMENTS

Outside Air (db) Temperature, (RH = 80%)	Moisture Content Difference kg/kg	Ventilation Requirements m/h (l/s)					
		Family of Four[a] 10 kg Moisture[c] generated/day		Family of Six[a] 15 kg Moisture[c] generated/day		Family of Six[b] 17 kg Moisture[c] generated/day	
-15°C	0.0038	95	(26)	142	(39)	161	(45)
-10°C	0.0036	100	(28)	150	(42)	170	(47)
- 5°C	0.0028	129	(36)	193	(54)	219	(61)
0°C	0.0018	200	(56)	300	(83)	338	(94)

a) away 4 hours per day
b) home all day
c) daily moisture production

Note: Details on moisture generation can be found in "Applicable Moisture Reduction Techniques in Newfoundland". Reference "C" on Page 2.

Indoor Relative Humidity controlled at 27%

- it increases the height of the neutral pressure plane.[2)]

Increasing the height of the neutral pressure plane reduces exfiltration through the higher parts of the exterior walls and attic ceiling, minimizing the major driving force of moisture through the walls.

There are a number of mechanical devices, or stack cap designs, which utilize the wind energy to create additional draft, while at the same time ameliorating the rain problem.

Strong drafts can be created by wind activated turbine ventilators. The obvious drawback of such a device is that it introduces a moving part to an otherwise passive ventilation system. Warm, humid air coming into contact with cold metal parts could deposit moisture in the form of ice. Consequently, the possibility of jamming, with the resultant drastic decrease in the effectiveness of the stack, must be considered if a turbine ventilator is used.

The effects of wind on stacks can be summarized as follows:

- Wind forces can significantly affect the performance of a passive vent stack system, but the results cannot be readily predicted without specifying the exact location of the stack.

- It is best to avoid placing the stack top where stagnation can take place, for instance, in front of vertical surfaces or a very steep roof.

- To obtain the most assistance from the wind, the stack should be as high as possible.

- Stack cap designs that enhance the draft, by utilizing wind energy, are available, and can be used to prevent rain entering the stack. None of

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2) This is the point below which air infiltrates into the house and above which air exfiltrates. Because of the relatively lower outside temperatures (during the winter) infiltrating outside air will tend to dry the wall system and lower inside RH levels.

these devices are designed for an active flue stack application intended to ventilate an entire residential unit. Various cap designs should, therefore, be tested for noise, rain entry and other unpredictable problems.

- In strong wind conditions, the vent caps can create strong drafts, causing high air flow rates through the stack. Especially on cold days, under extreme conditions this could introduce so much cold air that it may significantly increase heating costs. An automatic damper mechanism, which limits air flow rates through the stack, should always be used, especially in conjunction with stack vent caps or other devices that utilize wind energy to enhance draft[3].

- Another limiting factor is the airtightness of the house. In a tight house, larger volumes will suddenly infiltrate when doors or windows are opened.

4.3.2 - Mechanical Ventilation

Mechanical ventilation systems employ a fan, or a combination of fans, to remove air from the house and create a slight negative pressure within the building envelope. These systems can be as simple as a kitchen exhaust fan, or as elaborate as a central exhaust system, employing heat exchangers or other devices for heat recovery.

The advantages of a central exhaust system located in the basement include quieter operation, no requirement for openings in the ceiling and compatibility with heat recovery.

The main disadvantages of the central exhaust system are its capital cost, and the difficulty of installing units in existing houses because of required ductwork.

3) An automatic damper would need to be "fail safe" and should permit visual inspection.

For effective heat recovery with an air-to-air heat exchanger incorporated in a central exhaust system, a relatively tight building shell is required. For the proper operation of this type of system, a balanced "push-pull" fan system should be employed. A 2-fan system will be required as a single fan system will be difficult to operate properly, in that balancing of the system could be a problem, especially if doors are opened frequently.

4.3.3 - Conclusion Regarding the Use of Ventilation Systems in Newfoundland

Because of the required volume of ventilation air and practical limitations to stack height and diameter, a passive stack, for moisture removal and prevention of exfiltration, appears to offer only a limited solution in Newfoundland. Stack performance can be improved significantly, in continuous wind conditions such as those in Newfoundland, by using special stack caps that utilize wind forces to enhance draft. A number of such devices are commercially available but since they are not designed for the proposed purpose, they must be field tested for suitability in this application. However, the most significant drawback to stack ventilation in areas with a meso-climate similar to Newfoundland, is energy waste[4).]

Mechanical ventilation systems, at varying degrees of complexity, can be used. A simple fan, exhausting air at one point of the house can, under most circumstances, be sized to provide adequate ventilation, but the inexpensive fan units normally installed are usually small and noisy. Central exhaust systems are the highest in initial cost, but since they facilitate the use of a heat recovery system, most of the energy can be removed from the exhaust air minimizing the cost of ventilation.

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4) Details on capital costs of ventilation and other air moisture reduction systems, and operating costs of systems with and without heat recovery in Newfoundland, can be found in reference "c" on page 2.

The basic disadvantage of mechanical ventilation systems is that they contain moving parts, create noise, are capital cost intensive, and can fail. On the other hand, for optimum performance, a vent stack also requires an automatically controlled damper mechanism, introducing moving parts to this type of system as well.

In any case, it should be recognized that, for health reasons, ventilation is required. **Since some of the measures and recommendations contained in other sections of this report may lead to a further tightening of an already tight building shell (either as a new construction or retrofit), mechanical or passive ventilation must be considered as a means of controlling indoor humidity and other air pollutants.**

5 RECOMMENDATIONS

5.1 Building Systems

5.1.1 General

In summary, there are four basic conditions which result in some form of existing or potential moisture problem. These are:

- absence of an active flue;
- high internal RH levels caused primarily by house occupation, the building itself[1], and inadequate ventilation to deal with this moisture;
- inadequate attention to detailing in traditional building systems, to accommodate the moisture loadings experienced in the newer, less leaky or more airtight, housing units. In these units, leakage of moisture-laden inside air into the wall system can be concentrated at a few points, such as electrical outlets;
- adverse meso-climatic conditions, which hinder the drying of structural systems.

The following sections detail recommended solutions to moisture problems both for retrofit (where applicable) and for new construction. The problem is complex and solutions involve materials, and construction techniques, as well as the human factor.

5.1.2 - Recommendations for the Siding and Sheathing Complex

Based on field observations and the known distribution of reported problems, failures or moisture problems of the siding and sheathing complex are found primarily in Newfoundland. In this location, the meso-climatic conditions are such that the siding/sheathing complex may experience problems in drying out.

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1) Moisture of construction, moisture from basements, or moisture absorbed into the building materials during the summer and released during the winter.

5.1.2.1 - Recommendations for Problem Housing

Where siding or sheathing problems are suspected, measures should be taken to reduce indoor relative humidity, since moisture infiltration into the wall cavity will diminish significantly as indoor RH decreases. Measures which promote drying of the exterior face of the sheathing or raise the temperature of the room-side face of the sheathing will also reduce wall condensation. The extent of corrective measures to be taken will require field evaluation for typical housing types and damage conditions.

Air leakage from inside the house into the wall cavity can be reduced substantially at a very modest cost. For example, placement of foam gaskets under electrical outlet cover plates requires very little time and small capital outlay. This action alone would significantly reduce one source of concentrated moisture movement into stud cavities. (The sill plate and header joist rot found in one of the Newfoundland houses investigated might have been avoided by these easily installed foam gaskets.) A more extensive room-side caulking program may be justified for housing where high moisture levels are experienced. It must, however, be stressed here, that the sealing of leakage openings to control moisture entry into walls and attic spaces will further decrease ventilation. This, in turn, will lead to a further increase in inside RH. Ventilation for control of moisture and other indoor pollutants must, therefore, be considered when houses are tightened.

When siding is in direct contact with the sheathing paper, a poorly vented air space may result between the siding and sheathing paper and these saturated components will keep the air between them saturated. When the wall is heated by the sun, moisture will be forced back into the sheathing. To overcome these problems two items must be considered.

- The build-up of sustained high vapour pressure in the cavity behind the siding must be prevented.

- Vapour permeable building papers should be used and siding manufacturers' installation instructions should be closely followed.

If the siding is turned into an open rain screen with a vented cavity, vapour pressure behind the siding can be relieved. The spaces where siding elements are lapped can be opened, and a cavity provided, by rather simple means. For example, self-furring fastening clips may be used, preventing board-to-board contact. This may be sufficient in most meso-climatic zones. (Manufacturers installation instructions also mention that board-to-board contact should be prevented).

Furring spaces should be created between the siding and sheathing but need not be more than 7 to 8 millimetres, provided that spaces between lapped joints can be maintained. The depth of the furring space should be kept to a minimum, to reduce unnecessary loss of absorbed solar energy. Openings should be provided at the top and bottom of the cavity. This will permit convective currents to remove moist air and provide drainage.[2] Further research is necessary to determine the optimum furring space.

Given adequate indoor ventilation, the removal and reinstallation of siding to correct siding problems must be viewed as an opportunity to increase the thermal resistance of the wall and its air tightness. Resistance of the sheathing and the wall system to moisture related damage should be improved. Placement of insulating sheathing, on the outside of the existing sheathing, installation of an effective air barrier and installation of siding with a furring space, would solve the wall problems discussed in this report. Although the upgrade is aimed primarily at reducing moisture problems, the resulting energy savings would contribute to the recovery of at least part of the investment.

5.1.2.2. - Recommendations for New Housing

Since traditional 38 mm x 89 mm (2 in. x 4 in.) stud walls with insulated stud spaces and conventional sheathing do not provide enough thermal resistance in most of Canada to meet the proposed new R-value requirements of the "Measurements for Energy Conservation in New Buildings", or those in some

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2) Care should be taken that this space does not vent into the attic, as this could result in moisture related problems in the attic. Vertical furring spaces should be properly sealed near external vertical corners of the building.

provincial codes, a differently composed wall system will be required. One way of reducing many of the moisture problems noted would be for industry to adopt insulating sheathing, while retaining the 38 mm x 89 mm (2 in. x 4 in.) framing.

Advantages of 38 mm x 89 mm (2 in. x 4 in.) walls with insulating sheathing are the following:

- o Stud thermal bridges will be blocked by insulating sheathing, substantially reducing heat losses and the problems of thermal dusting or, in extreme cases, of room-side mould and mildew growth.
- o When the air barrier is installed on the outside, partition wall construction, joist assembly installation, and air barrier installation, all become simpler and more straightforward. It should be noted, however, that, even with an outside air barrier, a vapour barrier on the warm side of the enclosure will still be required, but need not to be leak free.
- o Exterior insulation of basements becomes much easier.

On the other hand, if 38 mm x 140 mm (2 in. x 6 in.) studs alone are used to meet the code's new energy requirements, unless indoor humidities are controlled and air leakage through the traditional vapour barrier is reduced, many of the conditions currently noted for the traditional 38 mm x 89 mm (2 in. x 4 in.) wall could become more severe.

The technical arguments for the use of insulating sheathing materials seem to be sufficient to warrant highlighting the use and advantages of this technique in the various building codes. It should, however, be recognized that insulating sheathing material may not have sufficient racking resistance to meet the structural requirements of some buildings.

Four common types of insulated sheathing materials are available:

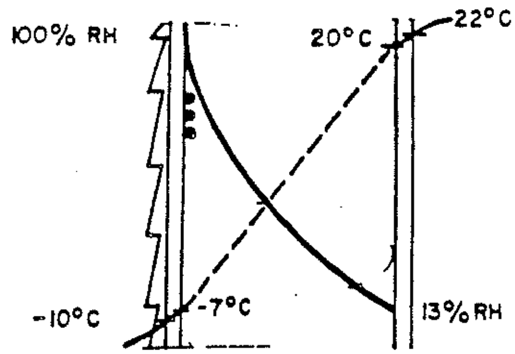
- o Extruded polystyrene foam board
- o Expanded polystyrene foam board
- o Glass fibre insulating board
- o Polyisocyanurate

Extruded polystyrene foam is essentially non-absorbent and of low vapour permeability. As a result, to permit vapour transmission, current practice is to leave the joints between the boards unsealed. Research on this product, (installed as a sheathing system), to determine if overall performance is enhanced by sealing the joints, is currently underway by manufacturers and by others.

Theoretical considerations, backed by a substantial body of laboratory and field testing by the manufacturers, indicate that, as far as concealed condensation is concerned, walls with insulating polystyrene sheathing experience fewer moisture problems than walls with traditional sheathing. The overall thermal performance of the wall should be enhanced if the joints between the insulating sheets are deliberately sealed or if the sheathing is covered with an effective vapour permeable air barrier. However, there is still some concern about what happens to moisture "trapped" in the wall cavity. Current building practice is to leave the joints open. (Research on whether joints should be sealed or not is in progress.)

Expanded polystyrene insulating sheathing is similar to the extruded polystyrene board except that it has a somewhat higher moisture absorption capacity and higher vapour permeability. Both factors are expected to improve the drying of wall systems by absorbing some moisture in the sheathing material and by permitting vapour to exit the system.

Glass fibre insulating sheathing, with a vapour permeable air barrier "facing", may have advantages over other forms of insulating sheathing materials. In case moisture does enter the wall cavity from inside the house, it will condense when it comes in contact with the "facing". When the "facing" is located on the cold side of the sheathing (the air barrier in the case of glass fibre sheathing), it will promote condensation, acting as a dehumidifier as far as the framing members and the wall cavity are concerned. Since condensation normally takes place on the first continuous surface, the cavity dewpoint temperature will be established by the "facing" and the relative humidity at the stud-sheathing interface will be low enough to prevent condensation at the outer stud-face. (See Figure 5.1.)

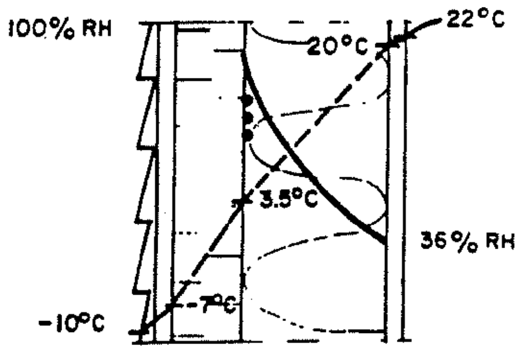


38 mm X 140 mm
Conventional Sheathing

38 mm x 140 mm framing with glass fibre insulation in the stud cavity. Conventional sheathing.

Note: Outer stud faces come in contact with condensed water on inner face of sheathing.

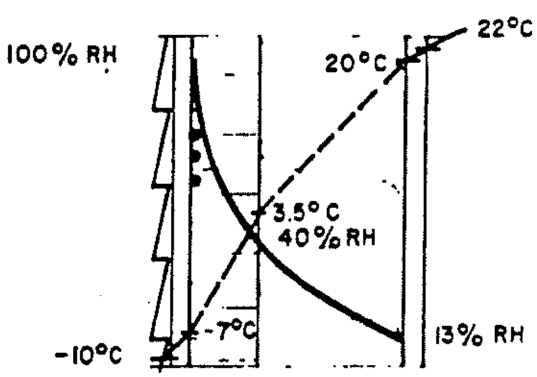
Condensation will occur on inner face of sheathing when interstitial RH exceeds about 13% at a temperature of 20°C at the inside face of the drywall.



38 mm X 89 mm
Vapour Impermeable,
Insulating Sheathing

38 mm x 89 mm framing with glass fibre insulation in the stud cavity. Expanded polystrene insulating sheathing.

Note: Condensation will occur on the inner face of the insulating sheathing. Studs are still in contact with condensing surface, but interstitial RH has to exceed 36% with a temperature of 20°C at the inside face of the drywall before condensation will occur.



38 mm X 89 mm
Vapour Permeable,
Insulating Sheathing

38 mm x 89 mm framing with glass fibre insulation in the stud cavity. Glass fibre board insulating sheathing with vapour permeable membrane on outer face.

Note: Condensation will occur against outer face of insulating sheathing. At this point the outer faces of the studs are at a relative humidity of approximately 40%. Condensation will occur when interstitial RH exceeds about 13% at a temperature of 20°C at the inside face of the drywall.

BEHAVIOR OF DIFFERENT TYPICAL WALL SYSTEMS

FIG. 5.

The drainage characteristics of glass fibre board and batt insulation combination wall systems are of particular advantage. Lacking capillarity normal to the face of the board, moisture will not "wick" into the siding and will be stored as water or ice in the outer few millimetres of the insulation. When the area becomes saturated, water will drain along the outer face. To facilitate drainage, a flashing must be provided at the bottom of the insulating sheathing to direct this water to the outside. Commercially available tape has also been developed, which can be used to seal the joints between the boards. The top edge of the insulating sheathing boards should also be sealed. The bottom edge should be left untaped to permit drainage.

5.1.3 – Recommendations for Mould and Mildew Growth Problems

Mould and mildew formation is very common in problem housing and was observed in most climatic regimes.

5.1.3.1 – Recommendations for Existing Problems

Where these problems are observed, a first approach should be to attempt to eliminate moisture at the source (for example, in bathrooms, kitchens, basements, etc.) and increase ventilation rates. If this is not possible, only a very small amount of insulation will be required to increase the wall temperature to a point where condensation should not occur. It is also important to impede the movement of cold outside air into the wall system. However, as a retrofit measure, this will require removal of the siding to ensure the installation of a continuous exterior air barrier.

Probably the simplest, and least costly, measure would involve placing a relatively thin layer of insulation over the room side face of the wall where condensation is occurring. In most cases of corner mould and mildew at the ceiling, only an area 200 mm beyond a particular corner would need to be covered. While this will change the appearance of the interior, it could be developed as a cornice for the wall ceiling junction.

The insulating corner pieces could be prefinished with a fire protective layer and fastened with an adhesive. This adhesive would also have to provide an air tight seal between the wall and the insulation to prevent condensation behind the added insulation.

If water is prevented from being absorbed by the drywall (a moisture reservoir which would otherwise supply moisture during dry conditions), mould and mildew would be likely eliminated.[3] Painting affected surfaces with a nonabsorbent oil paint or the use of vinyl coated wallpaper may, therefore, be effective in less severe cases.

As a more permanent solution, where siding must be replaced, it would be preferable to add insulating sheathing in conjunction with a vapour permeable, but air tight, air barrier, such as a spunbounded olefin film or similar material.[4]

Because of high internal relative humidity conditions, closets with walls to the exterior may not respond to increasing the insulation by a reasonable amount. Consequently, it is proposed that an attempt be made to increase closet ventilation.

5.1.3.2 - Recommendations for New Housing

As detailed earlier, "cold spots" appear to be caused by outside air movement through the wall cavity, resulting in a reduced effective R value, condensation and consequent mould and mildew formation. If this air movement can be prevented, the incidence of mould and mildew should be greatly reduced. Therefore, an externally applied <u>air barrier</u> should be installed on new constructions. This barrier must be vapour permeable to prevent excessive moisture build-up within the wall cavity.

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3) This method has been tried with varying degrees of success in Newfoundland and other areas.

4) An air tight, but vapour permeable film.

5.1.4 - Recommendations for Window Condensation Problems

Window condensation is difficult to eliminate, unless indoor relative humidity is reduced. For existing housing, a number of solutions are possible, but all involve some cost or inconvenience to the home owner.

- o Reduction of indoor RH.

- o Rigid insulation could be placed, externally, on the bottom part of windows. This will keep the inner window warm at the bottom, preventing water from dripping on the window sill. (This will only work in less severe cases.) Insulating shutters could be used with a similar effect. Shutters must be on the outside, as poorly fitting inside shutters will aggravate the condition.

- o Plastic, or an additional pane of glass could be added to the window to increase the thermal resistance of the system.

For new housing, a number of solutions are possible, although all involve some additional cost.

- o Triple glazing could be used.

- o Windows could be recessed toward the inside as much as possible. This will shelter them from the wind and permit easier air circulation over the inner surface of the windows.[5)]

5.1.5 - Recommendations for Attic Condensation or Mould and Mildew Problems

Lack of ventilation in roof construction, either due to poor design or careless installation of insulation, will contribute to moisture damage in attics. Nevertheless, increasing attic ventilation alone may not solve the problem. It

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5) Although this is a technically correct solution, it has the problem of possible snow and ice build-up on the outside sill, and makes the provision of an inside sill very difficult.

has been suggested that significant ventilation rates are necessary to ensure removal of moisture from the attic space. However, when the moisture holding capacity of outside air is reduced, either due to low temperature or high relative humidity, high rates of ventilation will be required to remove moist air entering the attic space. It should be noted, however, that high ventilation rates could increase the leakage of warm moisture laden air into the attic space to the point where the added moisture is in excess of that removed by ventilation.[6)]

It is generally agreed that the transfer of water vapour from living space to the attic is predominantly by air movement. To solve the problem, the air barrier between the living space and the attic must be improved. While it would help to decrease the inside humidity or raise the neutral pressure plane, (as this will reduce exfiltration into the interstitial spaces), the emphasis must be on the continuous air barrier.

Where the attic space is accessible, attempts should be made to seal gaps in the air barrier over the interior partition walls and exterior walls, over light fixtures, and around plumbing vents and electrical wiring where it penetrates the top plate. When needed, existing attic vents should be cleared or new ones added. Air sealing, below grade, can also reduce the amount of moisture brought into the house.

In extreme cases, fan pressurization of the attic space could be considered to counteract the stack pressure. However, this is not without its own problems. It is conceivable that a complete reversal inflow could cool areas to a point where condensation and mildew formation become a problem.

In the case of retrofit houses, moisture conditions must be considered before thermal retrofitting is undertaken. There is much room for the development of materials and methods to deal with the various climatic conditions, and roof

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6) During periods of hoar frost formation, high ventilation rates could also exacerbate frost conditions inside the attic.

types. For example, the use of spunbonded olefin film, or similar material, applied continuously over the top surface of the attic joist to form a vapour permeable but air tight membrane before adding more insulation, needs to be evaluated. Another approach which should be investigated, is the sealing of partition wall leakage paths, by cutting through the dry wall/lath and plaster at the top plate level and caulking and sealing the space between the drywall and the top plate. As this work is done from inside the house, it would be suitable in cases where the attic or roof space is not accessible.

5.2 Ventilation

Ventilation of airtight housing is beneficial both for health reasons and from the point of view of reducing internal relative humidities. Proper ventilation will greatly reduce the potential for moisture induced damage or problems such as mould and mildew growth and excessive window condensation.

Because of the above considerations, as well as the judgements by coroners' juries implicating air tight housing in cases of carbon monoxide poisoning, and recent urea-formaldehyde foam problems, the Ontario Ministry of Municipal Affairs and Housing has recommended minimum ventilation rates of 0.5 ac/h in the new Ontario Building Code.

If these code changes are adopted nationally, it is probable that, except for such exceptional areas as Newfoundland, new housing will be adequately ventilated. For cold, dry regions, humidification for comfort may indeed have to be provided.

The energy cost implications of the extra ventilation are significant. Without heat recovery, it has been variously estimated that the increased ventilation could, under some conditions, add from $200 to $400 to the annual heating cost of the average home in Newfoundland.[7] It has also been estimated that an air to air heat exchanger system and improved air tightness for new housing can be provided for $1 900 to $2 500.

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7) For detailed calculations, see reference "c" on page 2.

If the Ontario Building Code ventilation requirements are applied in all parts of the country, there will be double insurance against moisture problems in new housing. During transition years, the combined forced and natural ventilation will provide sufficiently low relative humidity levels within the home to avoid condensation problems (except, possibly in Newfoundland). Later, improved air tightness and controlled ventilation will virtually eliminate concealed condensation by closing leakage paths. Such air tight housing is already being routinely built in Winnipeg (according to CHMC and building inspectors), and in Ontario,[8)] as well as, under the Federal Department of Energy Mines and Resources Canada R 2000 Super Energy Efficient Houses Program (SEEH).

Ventilation through a heat exchanger, should not be considered the only available option for controlling moisture damage and minimizing long term moisture problems in new housing. Design solutions, which improve the ability of the building enclosure to cope with the forces imposed on it, are preferred over reliance on mechanical equipment. Mechanical ventilation may be too costly to operate or maintain, may be too noisy, and may be prone to failure, at least until it has been more fully developed and marketed.

CMHC and other regulatory and research organizations, in close co-operation with the manufacturing and housing industries, have also developed and promoted methods to minimize heat loss, water leakage and moisture problems.

The range of cost effective methods for reducing moisture build-up in existing housing is substantially more limited than the alternatives for new housing. It is nevertheless essential to be aware of air quality in the selection of possible solutions for the control of moisture. This implies that, regardless of the system selected for moisture control, some form of ventilation will be required.

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8) Ten houses in Brampton were built under the Ontario Ministry of Energy's "Low Energy Passive Solar Housing Demonstration Program". In those homes, drywall was used to form the air barrier. Air tightness of under 1 ac/h at 50 Pa over pressure was achieved.

5.3 Further Research

There are a number of areas where the need for further research has been identified in this study. These include:

- The need to verify a minimum ventilation requirement for health protection and moisture reduction. Minimum ventilation requirements are identified in ASHRAE Std. 62-1981 and in the new Ontario Building Code (Section 9.39.7).

- The need to identify and quantify the contribution of interior and exterior moisture to the siding problem. This work should include:

  - **Sources of moisture, inside or outside.** A carefully conducted laboratory and field study is necessary to determine the relative importance of inside and outside moisture sources to observed siding problems. This research should also establish the effectiveness of corrective measures such as the suggested furring strips.

  - **Development of fibre reinforced stucco systems for external insulation of walls.** This would be a continuation of the HUDAC PHASE II basement insulation study. The control of cracking and consequent use of the stucco coating as a vapour permeable air barrier would be of particular interest.

  - **Development of pre-finished metal siding with a ventilated (and drained) cavity** to correct heat loss and moisture problems in high-rise buildings.

- The use of furring space behind siding should be field tested and evaluated against standard wall assemblies to determine their effectiveness and the optimum size of the furred cavity between the siding and sheathing.

- Manufacturers of low permeability insulating sheathing materials (such as extruded polystyrene foam) should be encouraged to conduct research in order to determine whether sealing joints in this material will lead to cost-effective improvements in performance, or to potential wall cavity problems.

- o Manufacturers of reconstituted wood product siding should be encouraged to continue research into reduction of the problems associated with longitudinal expansion. Areas to be researched include:

  - methods of handling, transportation and storage to ensure appropriate pre-conditioning,

  - methods of installation and attachment which allow some longitudinal dimensional change,

  - means of ensuring that manufacturers' installation instructions are properly followed,

  - methods of educating the trades in proper installation practices for reconstituted wood siding products.

Coordinated research and field testing of both materials and building systems is necessary if Canada is to maintain its excellent record of providing energy efficient and affordable wood-frame housing units.