Canada Mortgage and Housing Corporation

Société canadienne d'hypothèques et de logement

MOISTURE INDUCED PROBLEMS IN NHA HOUSING

Summary Report

CMHC Helping to house Canadians

MOISTURE INDUCED PROBLEMS

IN

NHA HOUSING

SUMMARY REPORT

Prepared For:

THE RESEARCH DIVISION
POLICY DEVELOPMENT AND RESEARCH SECTOR
OF
CANADA MORTGAGE AND HOUSING CORPORATION

by

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Canada Mortgage and Housing Corporation, the Federal Government's housing agency, is responsible for administering the National Housing Act.

This legislation is designed to aid in the improvement of housing and living conditions in Canada. As a result, the Corporation has interests in all aspects of housing and urban growth and development.

Under Part V of this Act, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research. CMHC therefore has a statutory responsibility to make widely available, information which may be useful in the improvement of housing and living conditions.

This publication is one of the many items of information published by CMHC with the assistance of federal funds.

This study was conducted by Marshall Macklin Monaghan Limited in 1982 for Canada Mortgage and Housing Corporation with funding made available under Part V of the National Housing Act.

Caution

The analyses, interpretations and recommendations are those of the Consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation, which assisted in the study and its publication. The results of the study are published for information purposes and the reader is cautioned that the statistical and scientific data generated herein are derived from a study of a select few Canadian moisture-troubled homes.

Extrapolation of this data to most houses in Canada and to houses in other countries and climates may not be feasible, unless the vagaries of climates and the behaviour of housing systems and building materials in those areas are understood.

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EXECUTIVE SUMMARY

1. Introduction

In early 1982, Marshall Macklin Monaghan Limited, a Toronto based consulting firm, was retained by the Canada Mortgage and Housing Corporation (CMHC), to investigate the nature, extent, severity and geographic distribution of reported cases of moisture induced problems in NHA housing. The units to be examined included those owned by the Corporation, as well as units privately owned but with CMHC insured mortgages. The results of that work have been published and detailed survey data, research findings and calculations related to the value of venting to reduce roomside humidity will be found in those documents.

The moisture troubled homes investigated displayed a number of significant common features. For the most part, they were newly constructed, attached housing units **with no active flue**. Of these, 81% had electric baseboard heating, while most of the remainder were heated by airtight wood stoves or other flueless heating systems. A high proportion of these moisture troubled homes was found in the Maritimes, especially in Newfoundland.

The study proceeded to investigate the factors contributing to the problem, to assess the incidence of problems, actual and forecast, across the country, and to draw conclusions and formulate preliminary recommendations for new areas of research. While these recommendations do not necessarily encompass all possible alternatives, a number of proposals for further investigation are put forward in the final section of the report.

2. Incidence of Moisture-Related Problems

The investigation found that, in total, 3 400 problem units have been reported in Canada. (Of these, 201 were investigated.) Allowing for under-reporting, this number was extrapolated to a nation-wide total of 10 300 NHA financed problem units, representing 1.5% of the total NHA housing stock constructed between 1973 and 1981. The early date - 1973 - corresponds with the maximum age of the majority of the problem units. The later date was the last completed year prior to this 1982 study.

If changes are not made in construction practices or heating systems, about 1.5 to 1.8% of new NHA housing units are also expected to be affected. Should efforts be made to increase the air-tightness of housing units, without providing for sufficient ventilation to control moisture and other indoor contaminants, these projections may be conservative.

3. Factors Contributing to Moisture Problems

The investigation found factors which contribute significantly to the severity of moisture-related problems in NHA housing. These include:

- **Climate**

  - windy, cool and very wet climate, especially in Newfoundland during the spring, which contributes to problems in the siding and sheathing complex;

  - condensation on windows, which can lead to damage to window frames and the drywall below windows;

  - different meso-climate, particularly that found in regions of extended colder periods, which, when coupled with low levels of sunshine, (such as in Newfoundland), can lead to high moisture content in exterior walls. In fact, the local weather conditons were a major determinant in the various types of moisture problems.

- **Moisture Generation**

  - high levels of internal moisture generation, because of occupancy and lifestyle factors, which can lead to condensation inside the house and subsequent growth of mould and mildew, and, when coupled with poor attic ventilation, can lead to attic problems.

  - absence of roomside ventilation, reasonably airtight houses - especially in row houses - causes roomside Relative Humidity to become too high.

- Design

    - for specific climate regimes, specific building designs are required to ensure that moisture problems will not occur. In other instances, although designs may be appropriate, care is not taken to ensure that field details reflect the original designs.

4. Conclusions

Due to the high reported incidence of moisture troubled homes in Newfoundland, one of the priorities of this study was to investigate venting as a practical solution. The research was extended to include mechanical ventilation. Both methods, and their use in Newfoundland, were analyzed and their cost effectiveness was calculated. The study concluded, on a theoretical basis, that, because of the high moisture content of the ambient air and the relatively warm winter temperatures, passive ventilation alone may not be a practical solution.

As a result of air tightening, greater amounts of moisture, generated by household activities and the building itself, are kept inside the housing unit and, because of better air barriers, can only move through the building shell at a few isolated points where air leakage can occur. Due to the higher levels of insulation, the inside face of the sheathing is colder, increasing and concentrating the amount of moisture that will actually condense on this surface.

Replacement of fossil fuel fired furnaces, with baseboard electric heating, causes moisture, previously carried up the furnace flue, to escape through the building envelope.

1. INTRODUCTION

Since the mid Seventies there has been an increase in the number of reported cases of houses having moisture related problems.

To provide a greater understanding of the nature and extent of the problem, Marshall Macklin Monaghan Limited was retained by Canada Mortgage and Housing Corporation in January, 1982, to investigate moisture induced problems in NHA housing[1]. The study program consisted of five basic components:

i) a review of literature, and research into building construction to correlate practical and empirical research (in Canada and internationally) with the findings of this study;

ii) a nation-wide survey of agencies or other groups involved in housing production to identify the extent of moisture related problems in NHA housing; groups contacted included national organizations as well as building product manufacturers;

iii) a nation wide field survey, to investigate the nature of the problems in representative units where problems were reported. This survey investigated both the condition of the structure and the lifestyle of the occupants;

iv) an analysis of the results of the field survey and agency survey, to identify both the nature, extent and geographic distribution of moisture related problems in NHA housing, and the factors contributing to the severity of the type of problem reported; and

v) an identification of design requirements for venting and other methods to prevent further moisture problems in NHA housing in Newfoundland, and to determine the effect of the recommended system on heating energy requirements.

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1) All NHA programs, including mortgage insurance programs.

Detailed findings and a discussion of each of the five project components are contained in separate research reports. For more technical details on information contained in this document and further discussion, reference should be made to those research documents listed below:

a) "Analysis of Field Survey Results and Projections of Future Problems", Part 1 of a 3 part series, Moisture Induced Problems in NHA Housing (Canada Mortgage and Housing Corporation, 1983), Cat. No. NH20 - 1/2 - 1983 - 1E.

b) "Literature Review and Research", Part 2 of a 3 part series, Moisture Induced Problems in NHA Housing (Canada Mortgage and Housing Corporation, 1983), Cat. No. NH20 - 1/2 - 1983 - 2E.

c) "Applicable Moisture Reduction Techniques for Newfoundland", Part 3 of a 3 part series, Moisture Induced Problems in NHA Housing (Canada Mortgage and Housing Corporation, 1983), Cat. No. NH20 - 1/2 - 1983 - 3E.

2. CURRENT BUILDING PRACTICES AND RELATIONSHIPS TO POTENTIAL MOISTURE PROBLEMS

2.1 Background

This chapter summarizes findings from the field survey and literature search with respect to the effect of moisture on the building systems.

The study found that, although each individual building component may in the past, have been adequate in its performance, recent moves toward more airtight, highly insulated houses with flueless heating systems have, in some instances, resulted in moisture related problems to some building products. As detailed in Chapter 3 of this report, it is significant that most of these problems were found in homes built after 1973, the year which provided the impetus for builders to make a number of major changes to the building enclosure.

The three changes with the most significant impact were:

- o the move to electric heating and the elimination of flues or the reduction in air changes experienced in houses having modern combustion heating systems;
- o more careful attention to the use of a continuous air/vapour barrier, as a means of reducing the leakage of inside air into the interstitial spaces; and
- o the installation of more thermal insulation, particularly in the attic where extra insulation could be placed without the need to change traditional framing dimensions or practices.

At the same time, further design changes were introduced because of an increase in the demand for low cost and social housing. To reduce unit land cost, row housing developments became more prevalent. Here, the reduction in the exterior wall area significantly tightened up the housing unit by reducing the area through which interior air could exfiltrate. A further significant change resulted from the switch from asphalt impregnated kraft paper vapour barriers to continuous polyethylene vapour barriers. In the latter case, air leakage into the interstitial space is concentrated at a few locations, such as partition walls and electrical outlets. The installation of relatively inexpensive electric baseboard heating eliminated the need for chimneys, further decreasing the number of air changes, as well as reducing interior air circulation and, more importantly, lowering the neutral pressure plane, subjecting more of the wall to exfiltrating instead of infiltrating airflows.

The above changes substantially reduced the dilution rate of moisture and pollutants added to the indoor air.

At the same time, the ability of the building envelope to cope with the increased moisture loading has, if anything, decreased, as a result of higher R values in the envelope, shortages of skilled labour with a full understanding of building practices[1] and the use of cladding materials with low moisture permeability.

Moisture problems generally fall into three basic categories:

- **Problems on the cold side of the vapour retarder.** When there are openings in the air barrier, localized condensation can occur in concealed spaces and, under extreme conditions, may not become evident before substantial damage to framing members has occurred.

  Major problem areas that will be discussed are:

  - siding/sheathing complex
  - wall cavities
  - attics

- **Problems which affect that part of the enclosure which is on the room side of the vapour barrier.** In this case, condensation and persistently high relative humidities in poorly ventilated areas, such as corners and in closets, may lead to the decay of wall coverings and also to the growth of mould and mildew. Here, the damage may have aesthetic or health connotations.

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1) The reason for the integrity of the vapour barrier, and especially the air barrier, has to be understood by all trades.

Problem areas that will be discussed are:

- mould and mildew inside the house
- severe window condensation

o **Basement moisture problems.**

Areas that will be discussed include:

- occupant-generated moisture
- joist space condensation
- crawl spaces
- slabs on grade
- soil drainage

2.2 Problems on the Cold Side of the Vapour Retarder

2.2.1 – Siding and Sheathing Complex

In the course of this study, although siding problems were observed in some areas (primarily in Newfoundland), sheathing was found to be generally free of severe problems that could lead to structural failure. Nevertheless, if there is:

- a prolonged heating season;
- high moisture content of the inside air;
- frequent driving rain; and
- low energy gain from the sun, during both the heating and drying seasons;
- the absence of an active flue,

rotting of sheathing is possible. Condensation will be on the warm side of the sheathing and can, therefore, be in contact with framing members. In extreme cases, this could lead to a potential structural problem.

In areas with a good drying potential it was evident that sheathing and exterior stud faces where we measured moisture contents above the fibre saturation point had not experienced any decay as the drying was taking place. It is, therefore, evident that the drying process is rapid and that the wall cavity is only at the critical moisture and temperature condition when rot could occur for a short period of time.

This study was not able to establish the relative contribution of inside and outside moisture sources to the siding/sheathing problem. However, the analysis shows that the majority of problems occur in areas where the meso-climate does not readily permit drying of the wall system.

It should be noted that high moisture readings in sheathing were only found in two cases. Also, as the investigation did not involve re-inspection for moisture levels in the houses later in the year, it is not known if or how quickly drying occured.

In Newfoundland and other areas with similar meso-climatic regimes, reconstituted wood siding (a product which had been used successfully in the past), was reported to experience problems in the mid 1970's. This timing coincides with the growing emphasis on more airtight construction practices, higher levels of wall insulation, and a significant increase in the use of flueless (electric baseboard) heating in these areas.

As a result of air tightening, greater amounts of moisture (generated by household activities and the building itself[2]) are kept inside the housing unit and, because of better air barriers, can only move through the building shell at a few isolated points. Due to the higher levels of insulation, the inside face of the sheathing is colder, increasing and concentrating the amount of moisture that will actually condense on this surface.

2.2.2 – Wall Cavities

Broadly speaking, climate determines the likelihood of the occurence of high wall moisture contents and the nature and extent of consequent damage. In discussing this problem, two seasons should be considered: the heating season

2) Building generated moisture includes that from the basement floors, moisture of construction, and moisture stored within the building during the summer and released during the winter.

(from October to March) and the following drying season (April and May). If drying does not occur during April and May, this means that the system is moist during the warmer part of the year with greater expected incidence of damage.

The Canadian climate is characterized by extremes. For example, Newfoundland temperatures are relatively moderate during the heating season, with little sunshine and high frequency of rainfall and driving rain[3]. In Northern Manitoba, at the other extreme, winter temperatures are very low and houses have considerable solar gain. The meso-climate in both situations could, therefore, lead to high water accumulation in walls, if vapour barriers were missing or poorly installed.

Since the occurrence of moisture in walls can be cyclical, the immediately following drying season in April and May (or possibly later) is very important. Extremes exist during this time of the year as well. In the Newfoundland area, weather during the drying season is characterized by cool, damp air, while the prairie region exhibits periods of warmer, dryer air with frequent occurrence of sunshine.

Wood frame moisture readings taken on March 15, in St. John's, Newfoundland and on May 4 in Thompson, Manitoba, were found to be in a range where wood rot could occur (higher than 25%). (More accurate readings were not possible because timber moisture meters are inaccurate at higher moisture levels). Although water marks were observed in Thompson, other kinds of water damage, such as rotting and mildew, were not found on the sheathing materials or framing members. Although severe localized rotting was found in Newfoundland, this was in only one problem building at the warm side of the sole plates[4], below improperly sealed electrical outlets. At the cold side of the studs, however, there was no rot eventhough the wood moisture content was above the fiber saturation point.

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3) The area also has persistently high Relative Humidity levels, with an annual mean of 86%. During the drying season, the mean RH is about 85%.

4) The sole plate and sheathing were saturated and showed moisture contents well beyond the reliable range of the measuring instruments.

According to the local CMHC chief inspector, damage to sheathing is common in Newfoundland. Board sheathing, which is often used in the province, was also affected. This suggests that, under extreme conditions, if housing units are not properly vented, even air and vapour permeable sheathing may not necessarily be immune to decay.

In the cold climatic regions, wall temperatures during the heating season are too low to support the micro organisms responsible for decay. Once the walls thaw, they also dry rapidly (because of low RH and high solar gain) thus bringing wood moisture content below the critical level for the onset of rot. Rotting does not become a problem unless there is a faulty design, with the vapour retarder located in a place preventing the escape of moisture.

2.2.3 - Attics

Older housing, with an uninsulated attic, seldom experienced moisture problems severe enough to result in structural damage even though there was no ceiling vapour barrier or an airtight attic floor. However, in the modern, well-insulated attic, a vapour barrier (but not necessarily an effective air barrier), even if properly installed, will not always prevent moisture problems. The least serious problem manifests itself in modest water leakage through the ceiling after an extended cold spell. At the other extreme are a number of potential problem cases such as the following:[5)]

- roof joists, truss members or sheathing rot.
- serious deterioration of interior finishes, due to leakage of attic water.
- corrosion of attic electrical fittings and truss plates.
- significant decrease in the thermal resistance value of the insulation, due to excessive moisture in the insulation.

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5) Evidence of most of these problems was found in the field by the Consultants on this project. However, major structural damage was not noted in any instance.

- roof trusses that bow, to the extent that the ceiling is pulled away from interior partition walls, resulting in increased air exfiltration into the attic space.

In modern housing, the amount of moisture entering the attic space through the ceiling area has increased because of generally higher inside relative humidities and, in the case of electrically heated housing with inadequate ventilation, the lowering of the neutral pressure plane. The increase in the ceiling thermal resistance has, however, lowered the temperature in the attic space, thereby increasing relative humidity. This has seriously reduced the ability of ventilation air in the attic space to cope with the leakage of interior moisture into the attic.

2.3 Problems on the Room Side of the Vapour Retarder

2.3.1 - Mould and Mildew

Existing research is not clear on whether it is actual condensation or sustained high relative humidity in the air film next to the wall which creates the conditions favourable for mould and mildew growth. It is, however, well documented that the combination of high inside relative humidities and lower wall surface temperatures are both critical factors.

Although both of the above factors (especially inside RH) are also linked to other moisture related problems, it should be recognized that the vapour retarder, where present, forms a physical barrier between the inside and outside of the wall cavity or attic. Moisture damage in the form of indoor mould or mildew is, therefore, not an indication of damage within the wall system itself. Conversely, a wall with serious structural, moisture related problems need not experience visible room side problems.

A lowering of the wall temperature, in the presence of a fairly high relative humidity, can result in two distinct problems.

At one extreme, where the roomside surface temperature is only slightly lower, such as at thermal bridges caused by studs or other structural members with a lower thermal resistivity than the insulated cavity, dust patterns are often observed. This "Thermal Dusting" can occur with differences in wall surface temperatures of as little as 2.0°C to 3.0°C. Other than being a minor aesthetic annoyance, this is not seen to be a major technical or structural problem.

Mould and mildew formation on walls, caused by the creation of an environment favourable for its growth, is a more serious issue. In addition to aesthetic considerations, there is concern regarding the health impacts of mould and mildew in the house.

Mould and mildew are usually found at ceiling or baseboard locations on outside walls[6]. For this reason, it was first thought that mould and mildew formation was related to the thermal bridges caused by the top and bottom plates of the wall framing. However, further investigation found that, although wall surface temperatures will be somewhat lower in thermal bridge locations (i.e. lower thermal resistance of the wood members as compared to the insulated wall), the surface temperature will still be high enough that condensation should not take place, except under extreme conditions of high inside RH and low outside temperatures. With these factors in mind, a further analysis, aimed at determining the reasons for mould and mildew growth in these locations, was undertaken by the researchers.

The results of these analyses, showing the theoretical dewpoints of inside air, given a range of temperature, humidity and wall system conditions, are shown in Figure 2.4. The range of curves can be used to determine the inside wall temperature and, therefore, the inside relative humidity that can be tolerated at 20°C given a range of outside temperature conditions and typical wall sections.

Although the curves on Figure 2.4 assume an indoor airfilm coefficient of 0.120 m^2 °C/w, it is recognized that this average condition will overstate wall surface temperatures behind furniture and in corners. Nevertheless, this simplification is not large enough to invalidate the basic conclusions of this projection.

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6) See Figures 2.1, 2.2 and 2.3 for typical mould and mildew locations.

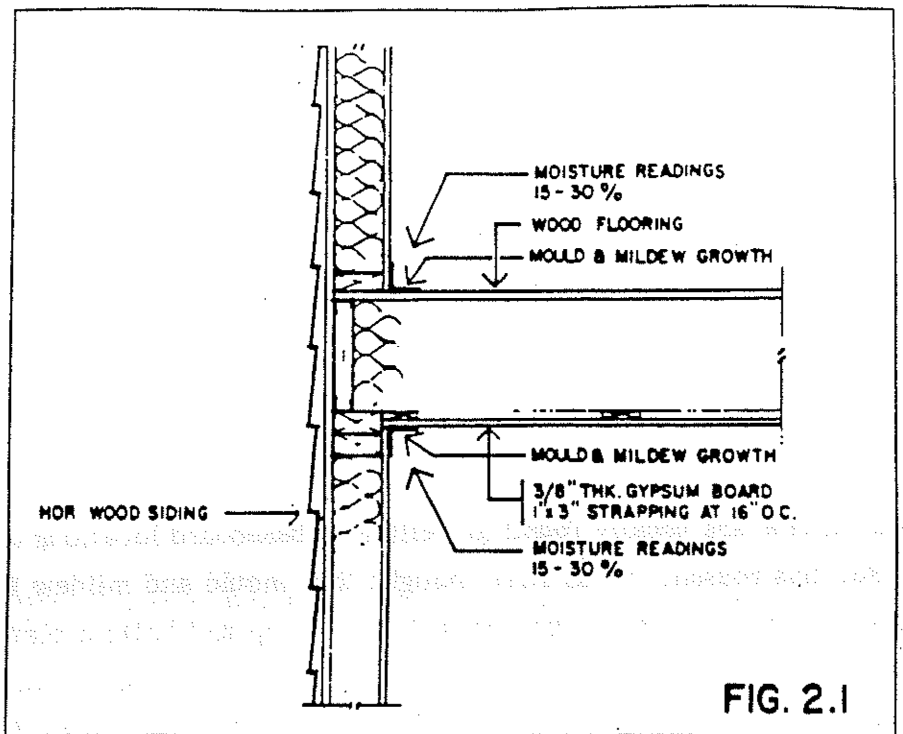


FIG. 2.1

EXTERIOR WALL / FLOOR JUNCTION

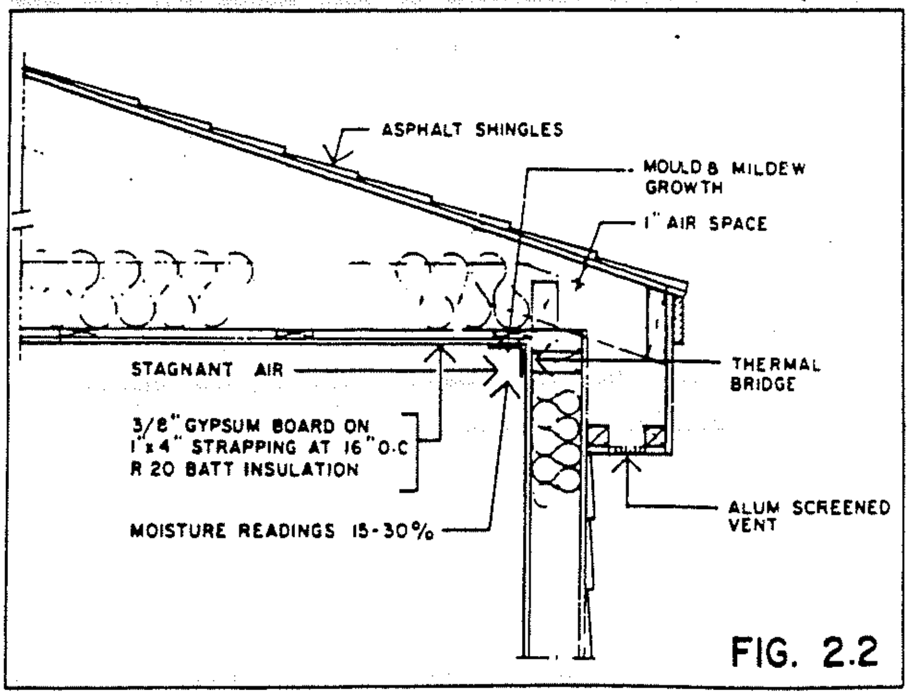


FIG. 2.2

ROOF OVERHANG DETAIL

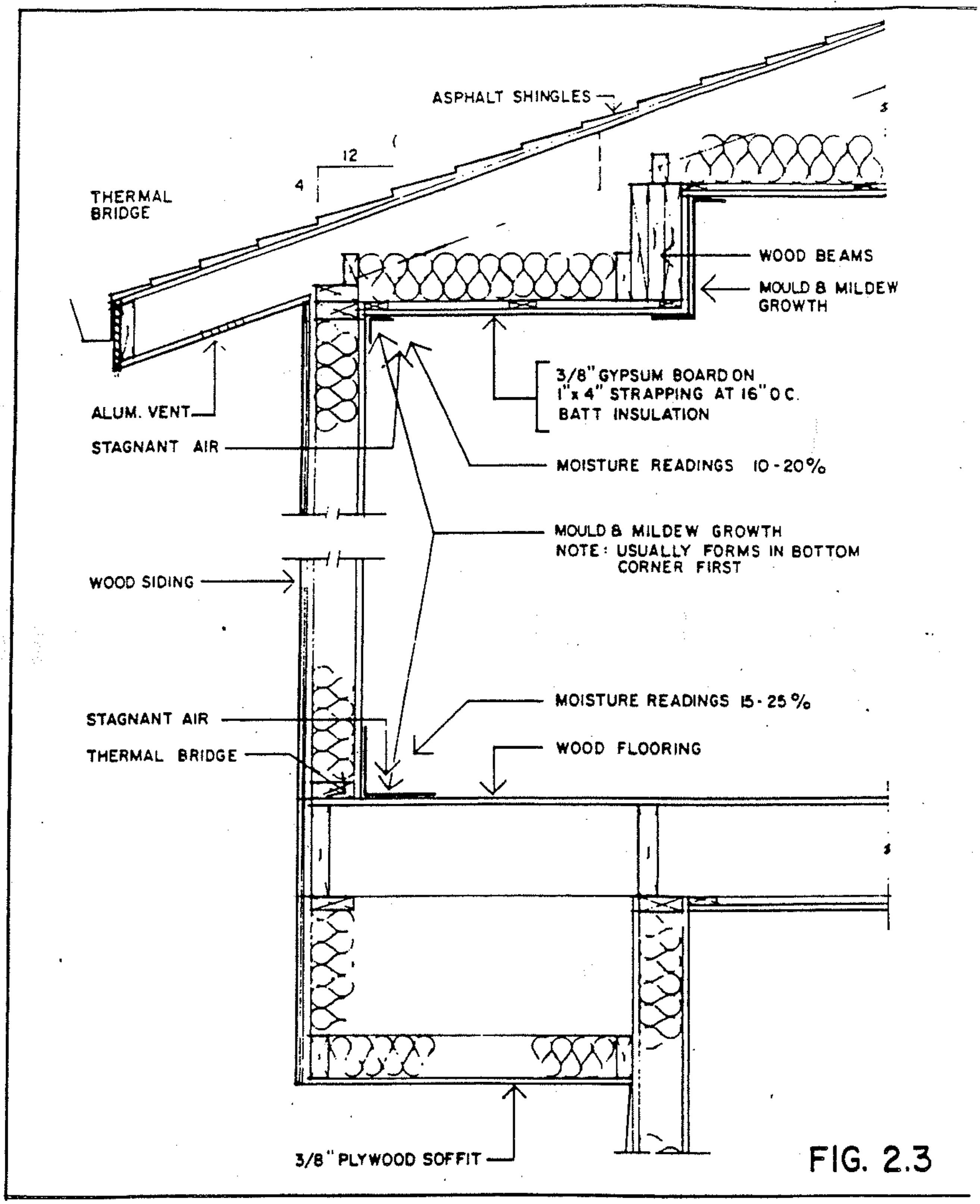
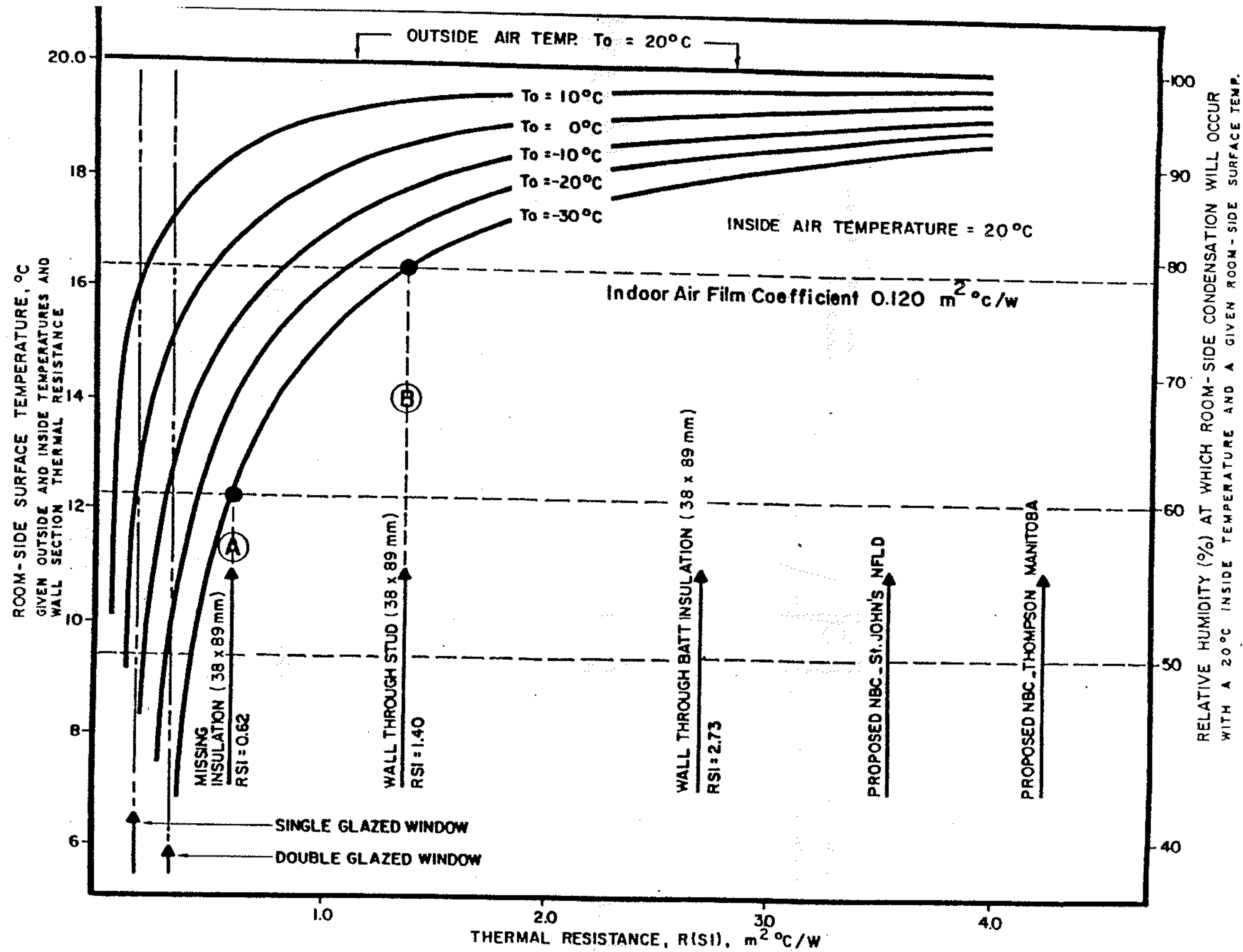


FIG. 2.3

CANTILEVERED SECOND FLOOR

SECTION SHOWS CONSTRUCTION
DETAILS AND OBSERVATIONS

Marshall Macklin Monaghan Limited



A PLOT OF THERMAL RESISTANCE AGAINST ROOM-SIDE SURFACE TEMPERATURE OR ROOM-SIDE RELATIVE HUMIDITY LEADING TO CONDENSATION ON WALLS

FIG. 2.4

To determine the minimum wall thermal resistance required to prevent condensation, a horizontal line is drawn from the relative humidity value on the right vertical axis to intersect the curve for the selected outdoor temperature. This point of intersection will then determine the thermal resistance value of the wall section below which condensation on the inside wall surface will occur. For reference purposes, thermal resistance values for windows and "standard" 38 mm x 89 mm (2 in. x 4 in.) stud walls have been included.

The curves in Figure 2.4 show that the likelihood of condensation on a given surface increases:

- as both the thermal resistance of the wall and the outdoor temperature decrease; and

- as indoor relative humidity increases.

As an example, theory, indicates that condensation on a wall surface with missing insulation, should not start before the outdoor temperature falls below -30°C or the indoor relative humidity exceeds 60 percent (at 20°C) -Example "A". Similarly, at this outside temperature, condensation should not take place at a stud location until the indoor relative humidity exceeds about 75 to 80 percent (at 20°C) - Example "B". Field conditions were, however, different and mould and mildew was observed in problem buildings under conditions where theory indicates that condensation should not occur at either a thermal bridge location or even at a wall section with missing insulation. This suggests that, at certain locations, air movement within the wall system has resulted in lower inside surface temperatures than would normally be expected.

It is suspected that infiltrating cold air, or cold air taking a "short cut" through the wall construction, is by-passing the siding sheathing and insulation complex. In other words, if an effective exterior air barrier is not provided, the thermal resistance of the wall could be essentially less than even an uninsulated cavity and is equal to that provided by the vapour barrier and drywall alone.

Mould and mildew were found in locations experiencing climatic extremes. The major contributing factors are:

- Low outdoor temperatures, such as those found in Thompson, Manitoba.

- High indoor relative humidities, which arise from the combination of mild outdoor temperature, high outside relative humidity and reasonably airtight houses without proper ventilation. Newfoundland, the Maritimes and the B.C. coastal regions are therefore affected.

- Exposure to strong winds. This study has shown a strong correlation between first floor mildew problems and exposure to strong winds. Here, wind and stack action combine to promote air infiltration and consequent cooling of interior wall surfaces. As explained earlier, wind is also more likely to take a "short cut" through the insulation in the wall if an effective air barrier is not present.

This situation cannot, therefore, be improved by externally applied insulation unless an effective external air barrier is created. Solutions should concentrate on reducing air infiltration into the wall cavity, and applying additional insulation inside the room in the mould and mildew prone locations. Both possible solutions will be discussed in Chapter 5 of this report.

2.3.2 - Window Condensation

As can be seen from Figure 2.4, if the RH values are permitted to rise window condensation is to be expected, even with double glazing. With single glazing, given an inside temperature of 20°C and a relative humidity of 50 percent, condensation can be expected when the outside temperature drops below 0°C. Even with double glazing, condensation can be expected when the outside temperature falls below -20°C.

Lowering RH levels through better house ventilation will improve the window condensation problem somewhat. However, as shown in Figure 2.4, the surface temperature/RH relationship is relatively vertical at the thermal resistance of single and even double glazing. Some window condensation is, therefore, still expected even with inside RH levels in the 30 to 40% range, unless the thermal resistance of the window system is increased. Therefore, window condensation cannot be reduced unless inside RH levels are diminished by forced ventilation over inner surfaces, or if the thermal resistivity of the window unit is increased by either the addition of externally applied temporary insulation (especially over the lower half of the window) or a change to triple glazing.

Window condensation not only reduces visibility but can also lead to visible or concealed damage to the building shell. Some degree of disfigurement or staining of window frames, due to the growth of mould, and the blockage of drainage openings by mould, was observed during field investigation. In cold regions, the draining of condensate has resulted in ruined plaster below window sills and floor coverings adjacent to the window. Corrosion of wall connections for baseboard heaters has also been reported. Other problems reported include condensate running into walls and rotting out framing members or, in the case of masonry materials, leading to freeze-thaw damage.

2.4 Basement, Crawl Space and Slabs on Grade Moisture Problems

2.4.1 - General

Water leakage and dampness in residential basements, crawl spaces and slabs on grade have always been, and continue to be, a common and costly problem. Under damp conditions, the quality of the basement as living space is degraded, damage is caused to basement walls and floor, and a significant amount of moisture is generated which can later enter the interstitial or attic space of the house.

Causes of moisture problems in basements include:

- occupant generated moisture (clothes washing and drying etc.);
- joist space condensation;
- unheated crawl spaces;
- heating ducts cast into slabs on grade; and
- poor soil drainage.

2.4.2 - Occupant Generated Moisture

Regardless of how well the building is constructed, it will always be possible to exceed the moisture limits that it can handle. For example, some occupants of problem housing were storing large quantities of wet fire wood in the basements.[7)]

Consequently, it would seem most unreasonable to set the standards for all buildings at such a high level that the extreme occupant generated moisture loading can always be accommodated. Extreme cases should be recognized as such, and special measures taken to deal with the problem.

2.4.3 - Joist Space Condensation

Band joist and sill plate condensation is frequently encountered where friction-fit batt insulation has been pushed into the joist spaces and a vapour barrier is lacking. Since infiltration due to stack action usually dominates over leeward exfiltration due to wind, condensation in this location is primarily caused by vapour diffusion, not outward air movement. It is, therefore, **not essential** (but still desirable) to provide an air barrier to control heat losses due to exfiltration. To control condensation, a vapour barrier will be sufficient. Aluminum foil could, for example, be pushed over the insulation to act as a vapour barrier (but not as an air barrier) without the need for making it air tight.

In mild but windy areas, where wind pressure dominates over stack action, exfiltration will occur and an air-barrier is essential. Carefully fitted pieces of extruded polystyrene insulation, caulked with an appropriate caulking compound, would be effective as a combination air/vapour barrier and thermal insulation.

2.4.4 - Crawl Spaces

Unheated crawl spaces present one of the most difficult problem areas. Conditions can become particularly severe during the summer, when the soil mass is often sufficiently cool to condense moisture from the exterior air.

7) This is in addition to normal activities such as cooking, cleaning, clothes drying etc.

Although not sufficient by itself, a necessary measure to control crawl space relative humidity is to reduce evaporation from the soil. Polyethylene sheet ground covers are used, but these are easily disturbed or broken, or end up collecting water in low areas. A woven polyethylene sheet would be preferable because of its greater strength and the presence of small holes which would allow some drainage of water. However, this would still not guarantee that the sheet would not be disturbed after installation.

In view of the difficulties experienced, the acceptability of unheated crawl spaces has to be seriously questioned in regions other than those where houses are built on permafrost.

Heated crawl spaces were not encountered during this study.

2.4.5 - Slabs on Grade

One building examined during our field inspection had heating ducts embedded in the concrete floor slab on grade. It appears that water had leaked into the ducts and was evaporating. As could be expected, this building was experiencing severe condensation problems.

In cases where the water table is close to the floor, the casting of heating ducts into slabs on grade should only be considered if the water table can be kept below the bottom of the insulation and if adequate thermal insulation is provided below the floor slab.

2.4.6 - Soil Drainage

The soil surrounding the basement walls, and under the basement floor, represents a major source of moisture. There are two types of openings through which gases, such as water vapour and radon, can enter the basement:

- Large openings through which air currents carry in the gases, such as cracks in the floors and walls, joints between walls and floors, and drainage systems without effective vapour traps; and o Small pores in the concrete, through which water vapour penetrates by diffusion.

By keeping the number of drain pipes under the basement floor to a minimum, venting the sump to the outside, providing effective vapour traps on all drains and caulking the cracks in the basement floor, walls and wall/floor joints, heat losses and moisture and radon gas infiltration can be minimized.

To control entry of water vapour by diffusion, the walls and floors should be made as gas tight as possible. Damp-proofing of exterior wall surfaces, lower water/cement ratio concretes for walls and slabs, and effective vapour barriers under floor slabs, will accomplish this. For example, by placing a vapour barrier under a 70 m^2 basement floor slab of high water/cement ratio concrete, the rate of moisture evaporation through the floor slab could be reduced by as much as 3.0 kg/day[8)]. In a house with a total floor area of 140 m^2 and 0.3 air changes per hour (ac/h), this reduction in the rate of moisture production would lead to a lowering of the indoor relative humidity by up to 10%. To reduce moisture infiltration into existing buildings, polyethylene sheets could be placed under carpets, or exposed concrete floors could be painted with vapour resistant paints.

Basement leakage could be controlled at all times through improved exterior surface drainage, working perimeter drains and granular backfill. Since externally applied insulation will raise the basement wall temperature, it will reduce concealed condensation problems in panelled basement walls. If externally applied glass fibre sheathing is used, this will also provide drainage without the need for granular backfill[9)].

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8) This number is based on calculations assuming poor quality concrete.

9) See External Insulation of Basements, Housing and Urban Development Association of Canada (Canadian House Builders' Association).

3. CURRENT EXTENT OF MOISTURE RELATED PROBLEMS IN NHA HOUSING

3.1 General

To quantify the extent of moisture induced problems in NHA financed housing units across Canada, the Consultants contacted 194 organizations and agencies. Groups were selected on the basis of their expected knowledge of moisture problems in NHA financed units.

In addition, to estimate what percentage of problems are actually reported, the Consultants interviewed a selected number of builders, CMHC officials, municipal housing authorities, building product manufacturers and home owners. This information assisted the Consultants in developing a 'best guess' of the total extent of moisture induced problems as they currently exist across Canada.

The collected data were analyzed and are presented on the following regional basis:

- Newfoundland
- Maritime Provinces
- Quebec
- Ontario
- Prairie Provinces
- British Columbia

Data collected for problem units include:

- Nature of problems reported
- House type
- Exterior finish
- Type of heating in the house
- Age of the house
- Number of years between initial occupancy and date of problem report

3.2 Extent of Moisture Induced Problems in NHA Housing

3.2.1 – Number of Problem Units Reported and Documented

The 194 agencies contacted detailed a documented national incidence of 3 400 NHA housing units with moisture induced problems. The summarized regional distribution is contained in Table 3.1.

3.2.2 – Total Number of Problem Units Expected

In addition to "documented" problem units, there are significant numbers of units for which problems have not been formally reported. To quantify the level of "under-reporting", discussions were held with CMHC officials, area builders, and/or HUDAC warranty administrators. All "informants" were familiar with the housing stock in their particular local area.

As could be expected, the percentage of expected problem units recorded varied significantly by housing type and tenure.

Generally speaking, where owned or market rental units were involved, the incidence of reporting was very high and rapid. In rental housing, most particularly subsidized rental housing, the incidence of reporting was low. The level of reporting was also low in areas where problems were common or where lifestyles or other social factors were such that residents accepted mould and mildew inside the house as "a way of life".

Taking into account the level of under-reporting, the expected incidence increases to a total of 10 300 or 1.5% of the total NHA financed housing stock constructed between 1973 and 1981.[1] (See Table 3.1)

The region most severely affected is Newfoundland, although large numbers of affected units were also found in Ontario, the Prairie Provinces and B.C.

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1) This encompasses all programs, including mortgage insurance.

TABLE 3.1

MOISTURE INDUCED PROBLEMS IN NHA HOUSING
TOTAL PROBLEM UNITS REPORTED AND EXPECTED - 1981
REGIONAL SUMMARY
(Housing Units)

Region	Problem Units: Reported & Documented Only	Problem Units: Estimated % reported[a)]	Problem Units: Total[b)]	Regional NHA Stock[c)]	% of Regional NHA Stock Affected[c)]
Newfoundland	700	24.1	2 900	10 400	27.5
Maritimes	200	40.0	500	32 800	1.5
Quebec	200	20.0	1 000	164 000	0.5
Ontario	1 000	55.5	1 800	276 000	0.5
Prairie Province	600	31.6	1 900	135 400	1.5
B.C.	700	31.8	2 200	71 300	3.0
National Total	3 400	33.0	10 300	689 900	1.5

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a) This column represents an average. Actually the percent reported was different for each housing type. For more details see reference on page xiii.

b) Total number of units, including both an allowance for under-reporting, and those units reported and documented.

c) Since over 70% of problems were in housing units constructed after 1973 NHA units constructed since that date were used as the base value. Note: Percentages may not be exact due to rounding.

In Newfoundland, a large percentage of the problems are found in semi-detached and attached units (58%) and single family dwelling (40%). In the Maritimes, the type of problem is more evenly distributed over the various housing types (except for mobile housing which accounts for 2%).

In Quebec and Ontario, the majority of the problems are found in apartments (84% and 55% respectively), while in the Prairie Provinces and B.C., the majority of the problems exist in semi-detached and attached units (71.5% and 76.5%).

In total, on a national basis, without regard for geographic distribution, problems are distributed among the various housing types as follows:

o	single family	19.4%
o	semi-detached and attached	53.7%
o	mobile modules	1.4%
o	apartments	25.5%
	Total	**100.0%**

3.3 Types of Problems Reported

There is a definite pattern in the incidence of reported problems, both by geographic location and by housing type. Although more than 70% of the problem units have been constructed since 1973, single family problem units tend to be somewhat older, while mobile or prefabricated problem units are generally newer.

The data indicate that, in the coastal Provinces (especially Newfoundland and British Columbia), problems usually surface in 3.5 years or less.

Although multiple problems were reported in a significant number of cases, the data suggest some general trends. It should, however, be recognized that since problems are reported by the home occupant, one can expect a bias towards the more predominant problem (or the problem that is of most concern to the occupant).

- **Siding problems** (buckling, paint damage or rot) are the predominant reported problem for all housing types in Newfoundland. It is also the predominant problem in single family units and apartments in the Maritime Region (Nova Scotia, New Brunswick, Prince Edward Island). It is estimated that there are currently about 2 900 NHA financed units with siding problems in Canada.

  Between 80% and 95% of the problem housing units in Newfoundland and the Maritimes had wood or wood product siding. (Because of the survey techniques employed, it is not possible to differentiate between wood and wood product siding since data in field offices were not available in sufficient detail.)

  It should be noted that these comments relate to **observed and reported problems in siding.** Although problems may also exist in other types of siding, they may not be readily observable and, therefore, would not be reported.

- **Interior wall problems** (mould and mildew on interior surfaces of outside walls) are found in all areas of the country. There is a low reported incidence in Newfoundland, a high incidence in Ontario and British Columbia and a varying incidence in the rest of Canada. It is estimated that there are currently about 3 100 NHA financed units with a serious mould and mildew problem in Canada. Those results are supported by our field investigations which indicated that, although mould and mildew were prevalent in Newfoundland, the condition was not nearly as severe as that noted elsewhere in the country.

- **Roof and ceiling problems** (mould and mildew on ceilings, leaking ceilings, observed attic problems, etc.), were reported from Quebec westward. Based on the information received, it is expected that this problem, which is often accompanied by wall mould and mildew, is present in about 5 400 NHA financed housing units across Canada.

TABLE 3.2

DISTRIBUTION OF MOISTURE RELATED PROBLEMS
IN NHA HOUSING UNITS

	Predicted Total No. of Units With Possible Problems	Type of Problem as a Percentage of "Problem" Units[a]			
		Siding (%)	Interior Wall (%)	Roof/ Ceiling (%)	Window (%)
Newfoundland	2 900	86	11	8	4
Maritimes	500	52	40	16	24
Quebec	1 000	0	44	94	36
Ontario	1 800	*	58	67	33
Prairies	1 900	*	10	53	91
B.C.	2 200	0	42	88	8
TOTAL	**10 300**	**28%**	**30%**	**52%**	**30%**

Note: The table should be interpreted as follows: - In Newfoundland 2 900 x 86% or 2 500 NHA houses are expected to have siding problems (as well as other possible problems, such as mold and mildew).

a) Those units where a problem is predicted. Note: percentages add to more than 100% because of multiple reporting.

* less than 1%

In Quebec, apartments were found to be the unit type with the highest incidence of problems. Ontario exhibited a similar problem pattern. In the Prairie Region, as in B.C., most of the problems were found in semi-detached or row units.

- Window condensation appears to be most prevalent in the central parts of Canada, with a very low reported incidence in Newfoundland. Based on reported problems, it is expected that significant window condensation, often associated with window frame damage and damage to walls in the immediate area of the window, can be expected in about 3 100 NHA financed units across Canada.

  In the Prairie Region, window damage was primarily found in semi-detached and row units, while in Ontario and Quebec, problems were most often reported in apartment units.

Although units reporting problems are not exclusively heated by (flueless) electric baseboard heating,[2] this was recorded as the heating type for 81% of the units with reported moisture problems. Field observations expanded on the survey information. It was found that, in some problem houses, where the house was not heated by means of electric baseboard heaters, conversion to air-tight wood stoves had taken place. The lack of an active flue is, therefore, a common factor in most of the problem units.

Since data does not exist indicating the incidence of flueless heating types in NHA housing units, this study was not able to correlate problems being reported to the relative predominance of flueless heating in NHA units.

2) Although other types of flueless heating are possible, such as central electric heat or condensing gas furnaces, these were not observed during this study.