APPENDIX "F"

THE NORTH FILE :
NORTHERN AND REMOTE TECHN. IN HOUSING

# NORTH CONSTITUTION

**Northern and Remote Technology in Housing Advisory Group**

## Introduction

Various agencies are presently involved in the design, construction and operation of housing in the northern and remote parts of Canada who represent specific interests, experience and knowledge relating to technical issues and concerns. There is a common will among these agencies to improve the quality of housing, to conserve natural resources and to produce shelter at reduced capital and operating costs. The severity of the climate and the remoteness of the Canadian North combine to produce unique technical challenges that are not encountered in traditional southern Canadian urbanized areas.

Each agency recognizes the challenge of providing quality housing and the value of a coordinated team effort, and is willing to cooperate and to contribute toward the common goal of proving and presenting appropriate technology for application in northern and remote areas of Canada.

In consideration of the interests, experience, technical resources and responsibilities of each agency, each agreed that it would be useful to have a forum that would facilitate the exchange of information on a regular basis through the presentation and discussion of technical and related matters. In view of these considerations, each agency agreed to establish the Northern and Remote Technology in Housing Advisory (NORTH) Group.

This forum has the potential of reducing the potential for duplication, while pro-actively encouraging the development and implementation of appropriate northern and remote technology.

## Objectives

The objectives of the NORTH Group are to collaborate with and to inform each other and others regarding the state and progress of housing technology development through the following activities:

- Identify, document and analyze issues and solutions
- Priorize and coordinate investigation, research, design and development activities.
- Develop and transfer technical information regarding appropriate technology
- Promote the implementation of appropriate technologies through demonstration projects.
- Meet on a regular basis to review progress in each technology area.
- It is not a function of NORTH to set policy or to direct the activities of individual agencies.

## Administration

NORTH is a non-voting association of agencies. Each member agency will provide a chairman on a rotating basis. Secretariat and support functions will be provided by member agencies as required and where funding permits.

NORTH will not solicit, carry or distribute budget funds. Each agency will be responsible for maintaining its own files and other administrative requirements. NORTH members will contribute, review and edit the "North File", which is compiled documentation of current northern residential technology development based on building science and northern experience. The NORTH group also reports as one of a number of sub-committees to the Housing Research Committee.

Member organizations and their representatives include the following:

**Northwest Territories Housing Corporation**

Norman Ridgley, Yellowknife
Joe Solowy, Yellowknife
Dick Bushell, Yellowknife

**Yukon Housing Corporation**

Bill Miller, Whitehorse

**Canada Mortgage and Housing Corporation**

Rob Duncan, Ottawa
Robin Sinha, Ottawa
John Soderberg, Yellowknife
Colin O'Neal, Whitehorse

**Canadian Home Builders Association/R-2000**

Danny Reid, Yellowknife
Wayne Sippola, Whitehorse

**Energy, Mines and Resources Canada**

Mark Riley, Ottawa
Aldyth Holmes, Ottawa
Lynn Conrad, Yellowknife
John Butler, Yellowknife
Vic Enns, Whitehorse

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# INTRODUCTION

The purpose of the NORTH File is to provide various parties involved in housing technology needs in the north with a comprehensive document that consolidates past experience, activities currently underway and issues that need to be addressed. The NORTH File is designed to keep all interested parties abreast on who is doing what and where they are doing it. This should reduce redundant work and optimize activities and budgets.

The NORTH File will be continually be updated as specific issues and concerns become resolved and new areas are identified, and is the principal working document for the NORTH Group.

The document is divided into three parts, each of which is described in more detail below.

**Part I** lists projects currently underway and indicates their status. Preliminary findings (if any) and highlights of the project are included as well as an indication of when final reports are expected. This part of the File is intended to communicate relevant preliminary findings about various projects more quickly than is possible with official publications.

**Part II** is sub-divided into 9 sections each dealing with a specific component of the building. These are:

Section 1: Site Development and Drainage

Section 2: Foundations

Section 3: Structural and Architectural

Section 4: Envelope

Section 5: Windows, Doors and other Openings

Section 6: Space Heating and Water Heating

Section 7: Ventilation and Heat Recovery

Section 8: Water and Sewage Systems

Section 9: Electrical Systems

Each section is divided into two levels of information: the "A" section includes a brief background summarizing state-of-the-art knowledge in each technology area, including fundamental concepts of building science.

Each one of these major "A" sections is followed by several and more detailed Fact Sheets of actual field projects and proposed projects. These, classified as "B" level information, are brief summaries of both successful and unsuccessful projects and/or experiences. The primary audience for the fact sheets are end users, such as builders, manufacturers and suppliers, but fact sheets will also serve as a useful medium for communicating results of detailed research projects to para-technicals and technical authorities who require only an overview of the project and its findings.

Each system described in the "A" and "B" sections includes a checklist of performance criteria which will become the vehicle by which various technologies identified for the north will be evaluated and compared to existing and other similar technologies on an equal basis. Technologies will be evaluated according to three basic criteria:

1. Technical Performance
2. Cost Effectiveness
3. Appropriateness of Technology

By developing such a checklist, a sound, consistent and mutually agreeable rationale can be developed to demonstrate and finally accept or discard potentially new technologies for the north.

**Part III** is composed of a number of resource lists for reference purposes.

# PART I: STATUS OF CURRENT PROJECTS

# SUMMARY STATUS OF CMHC ACTIVITIES IN THE NORTH FOR 1988/89

## FOUNDATIONS

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Computer Modelling | Multi-Point Space Frame Footing computer modelling | To develop an analytical model to simulate movement of the footings of the multi-point space frame system and thus derive appropriate dampening constants to eliminate these movements. | Completed |
| Field Demonstration | Field Testing of Space Frame and Footings(Yukon and NWT) | To instrument a multi-point space frame installation with load cells or strain gauges to determine the imposed loads, stresses and deflections.<br>To produce several footing/frame design strategies based on data from computer modelling, that will optimize the frame construction and performance.<br>To inspect existing space frame installations and report on differential movement. | Fall 1988 |
| Data Collection | Moisture Content in PW foundations (Yukon) | To install moisture pins in PW foundations of varying ages to assess moisture performance in Arctic soils. | Fall 1988 |

## SUMMARY STATUS OF CMHC ACTIVITIES IN THE NORTH FOR 1988/89

### FOUNDATIONS (cont'd)

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Data Collection | Feasibility of Concrete Foundations (NWT) | To provide expert opinion on the appropriateness of full concrete foundations in the North West Territories | Fall 1988 |

### ENVELOPE DESIGN

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Field Demonstration | Field Testing of Monocoque Structure | To implement, construct and test the monocoque structural concept a method of dealing with racking forces imposed on northern housing. Stress and deflections will be measured. | Fall 1988 |
| Data Collection | Thermal Performance of Northern Building Envelopes (NWT) | To conduct "Hot Box" testing of selected wall sections of varying ages to assess concerns of accelerated deterioration of wall sections in the Arctic climate. | Winter 1988 |

## SUMMARY STATUS OF CMHC ACTIVITIES IN THE NORTH FOR 1988/89

### ENVELOPE PENETRATIONS

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Field Survey | Durable Window and Door Hardware | To conduct a literature search and preliminary field survey of the failure mechanisms of window and door hardware installed in the North.<br>To develop preliminary standards to evaluate the technical performance of window and door hardware for the Arctic climate. | Fall 1988 |
| Data Collection | Wood Moisture Content in framing members (NWT) | To install wood moisture pins in NWT houses of varying ages to assess concerns of accelerated deterioration of framing members. | Underway |

## SUMMARY STATUS OF CMHC ACTIVITIES IN THE NORTH FOR 1988/89

### SPACE HEATING AND DOMESTIC HOT WATER

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Field Demonstration | Alternative heating systems (Latham Island, NWT) | To monitor and compare various heating systems and floor heating strategies | Complete |
| Field Demonstration | State of Art direct vent oil fired heating systems (Dawson City, Yukon/Yellowknife, NWT) | To install, monitor and assess the performance of two state of the art oil fired heating, side wall venting, boiler systems designed to better match the heating load of low energy housing | Underway |
| Field Survey | DHW as a heating system (NWT) | To investigate the state and condition of several DHW systems currently being used as both heating systems and hot water system. Result to be used to assist in securing CSA approval of DHW systems as heating appliances | Spring 1989 |

## SUMMARY STATUS OF CMHC ACTIVITIES IN THE NORTH FOR 1988/89

### VENTILATION AND HEAT RECOVERY

| Theme Area | Project Name | Description | Status |
|---|---|---|---|
| Field Demonstration | Field monitoring of HRV's and Passive Ventilation (Latham Island, NWT) | Assessment of the performance of three HRV's installed in NWT housing over the 1987/88 heating was compared to a totally passive ventilation system. | Completed |
| Field Demonstration | Field Monitoring of HRV's (Iqaluit, NWT) | Four different HRV's were monitored over the 1987/88 heating season to determine their performance in Arctic conditions. | Completed |
| Field Demonstration | Demonstration of RH based Demand Controlled ventilation (Aklavik, NWT) | To monitor the flows, pressure, and indoor air quality(with emphasis on $CO_2$) of RH based ventilation systems currently being installed in NWTHC housing. | Underway |

# Section 1: Site Development and Drainage

*Reference*

## Background

Loose granular gravel is piled on the active Tundra layer, then compacted and prepared for laying for footings for a building. Gravel pads provide positive drainage away from the structure and raise the level of the permafrost table, thus reducing the possibility that heat loss from the building will melt the permafrost and cause shrinkage. Gravel pads provide a sound alternative to piling systems and are easy to install. The installation is limited to snow free land and good fill free of snow and ice. Pads are generally limited to a construction season from July to September. Compacting is achieved either through mechanical equipment of natural settling over a season. Transportation and labour are the major costs.

Proper maintenance is required to prevent severe undermining due to edge loss. Edges of the pad should be protected against erosion due to high winds and spring run-off. Undermining due to erosion, inadequate compacting and/or poor quality gravel lead to shifting and settling of the pad. As the pad moves, wracking of the structure occurs. This could lead to walls cracking, shifting of window and door frames and an overall reduction in the airtightness integrity of the building.

Positive drainage over large areas of housing sites are generally being addressed in new town planning. Many existing sites however suffer from inadequate drainage which in many cases undermines existing foundations. Integration of proper drainage for many existing communities is easy to achieve and requires only a bit of thought, snow free ground, a labour force and dump trucks. Transportation and labour are the only costs. Material is generally free.

## Performance Criteria

*Technical Performance*

*Economic*

*Appropriateness*

## Relevant Codes and Standards

## Resources and Contacts

## Annotated Bibliography

# Section 2: Foundations

## *Reference*

## Background

A common feature of almost all northern houses is that they are built in soil conditions that make it difficult to use conventional foundation systems.

In the northern parts of provinces there are large areas of muskeg or other soils with high water tables. Other areas with deeper water tables may have frost-susceptible soils and/or conditions that encourage ice lensing. These conditions, combined with deep frost penetration, make it difficult to create the right conditions for foundation stability. Conditions become even more challenging further north, in areas of discontinuous or continuous permafrost.

Permafrost is soil that remains below 0C for more than one year. Permafrost can occur in scattered patches surrounded by soil that experiences normal freeze-thaw cycles, or it can occur as large continuous areas of frozen soil, several hundred metres thick, further north. In all cases, Permafrost is overlain by a layer of soil that experiences normal freezing and thawing during the seasons. This "active layer" can vary in thickness from a few centimetres (in High Arctic areas) to several metres thick.

Soils in the active layer may be partially or fully saturated and if they are frost-susceptible, considerable movement may be expected in this layer. There are also many other more specific factors at work, but the essential requirement is to avoid thawing the Permafrost, since this will destroy the bearing capacity of the permafrost and cause the building structure to settle.

As a result of environmental conditions, northern foundation systems are sensitive to uneven or differential settlement due to the thawing of frozen soil, and this can lead to torsional forces being imposed on the building structure. This condition, known as racking, may destroy the integrity of air-vapour barriers and destroy the function and appearance of other building components. Several strategies are available to deal with these problems.

In non-permafrost areas, crawl spaces are often enclosed and partially heated -- in these situations, central posts are especially prone to differential movement with respect to outer posts or footings, since soils are experiencing different temperature regimes.

In permafrost areas the building can be lifted off the ground, which will allow an open crawl space to prevent heat from the house from radiating into the top ("active") soil layer and melting it. Such an approach usually involves the placement of the house on a gravel pad (which helps to minimize the thawing of the active soil layer during summer conditions). A variety of footings can be used in such cases, including piles, wood cribs or drum footings and "Greenland" systems.

The varying soil conditions require different approaches to foundation design than in the south, as suggested below:

### *Non-permafrost, non frost-susceptible soils*

- Can use foundations as in south

### *Non-permafrost, frost-susceptible soils*

- Similar to southern foundations; deeper footings to reach below frost line; consider clear-span joists in crawl spaces to reduce differential settlement, use basement only if water/moisture penetration problem can be handled.

### *Discontinuous permafrost*

- May have to use approach for permafrost with frost-susceptible soils; carry out a detailed soils study and consult local expertise.
- Permafrost, non frost-susceptible soils, water table well below top of permafrost
- Can use footing and foundation approaches used in south; consult also local practice

### *Permafrost, non-frost-susceptible soils with high water table, or frost-susceptible soils*

- Minimize heat transmission from the building through the active layer to the permafrost. Basements or heated crawl spaces are not advisable; open and ventilated crawl spaces are the best solution. A gravel pad is usually placed on the surface to provide a stable and well-drained top layer.

Even if care has been taken to design and install good footings, there are many factors that will conspire to produce differential settlement. An undetected source of heat leakage from the building or a patch of very different soil under one corner can act to create soil heave and consequent racking. A safe approach is to assume that this will occur and to compensate for it as much as possible by one of the following courses of action:

- making the structure as flexible as possible, so that differential movement will cause relatively little damage and/or;
- continuously adjusting for the effects of differential movement by adjusting wedges in the foundation supports and/or;
- having as few supports as possible, especially internal supports in non-permafrost areas, by providing a clear-span truss system, thereby reducing the number of support points that can move;

- increasing the rigidity of the floor assembly, so that differential movement will have a minimal effect on other components.

Despite the usefulness of theory, it is important to find out what systems have given satisfactory service in any particular area, and under what conditions.

Many northern areas are subject to very high winds, and this makes it essential to ensure that the building and its foundation system are firmly anchored to the ground. This requires special measures unless a piling system is used.

## Performance Criteria

The following criteria have been used to assess the functional performance of a foundation system.

*Physical*

soil type limitations
system bearing capacity
stability/rigidity performance

*Economic*

maintenance cost
capital cost

*Appropriateness*

site preparation needed
effect on design flexibility
effect on timing/scheduling
skilled labour required
specialized equipment needed
ease of construction
maintenance requirements
system longevity

## Special Considerations

It should be noted that these assessments, while based on a large and diverse sources of information, are somewhat subjective and should therefore be treated as approximate indicators only.

# Poured Concrete Foundation Walls

## 1. Description

Conventional poured concrete foundation wall systems are used in non-permafrost areas, ususally where full basements are provided. Clearly, poured concrete is also limited to areas which are easily accessible by road from pre-mix plants.

Because frost can reach depths of six feet or more in northern areas, and because it is difficult and expensive to build to such depths, the use of poured concrete walls and footings is recommended only where soils are well drained.

A limitation of poured concrete foundation systems is the relative difficulty of providing adequate insulation in cold areas.

## 2. Extent of Application

This is a standard and well-proven system .

## 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

## 4. Typical Details and Specifications

## 5. Resources and Contacts

# Preserved Wood Foundations

## 1. Description

In areas where it is difficult to obtain poured concrete, preserved wood foundations are increasingly being used. This system is appropriate for both crawl space and full basement conditions, again in non-permafrost areas with well-drained soils.

The system requires careful preparation of the excavation, to ensure an even base for footing strips, and some remote-area builders have therefore used a mixed system; poured concrete footings and preserved wood walls.

### *Special Considerations*

- Permits cold weather construction
- Suitable for areas where concrete is not available, or is expensive
- Simplifies ordering and shipping of materials
- Suited to houses with basements and non-masonry siding
- Requires careful levelling of excavation if wood footings are used
- Can be built by standard framing crew using standard methods
- Easy to insulate to high levels
- Requires bracing to resist earth pressures
- Requires enough supervision to ensure that pressure treated wood and stainless steel fasteners are used.

## 2. Extent of Application

The PWF system is relatively new, but is now being widely used, especially CMHC-financed projects in remote areas of provinces. Many remote-area builders are still unfamiliar with the construction techniques required, and this may lead to some problems of acceptance.

## 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

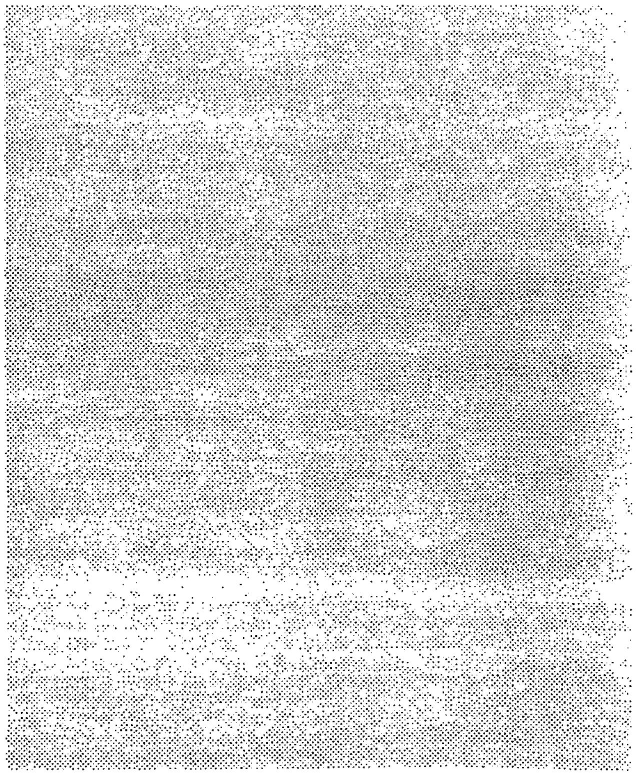
effect on design flexibility

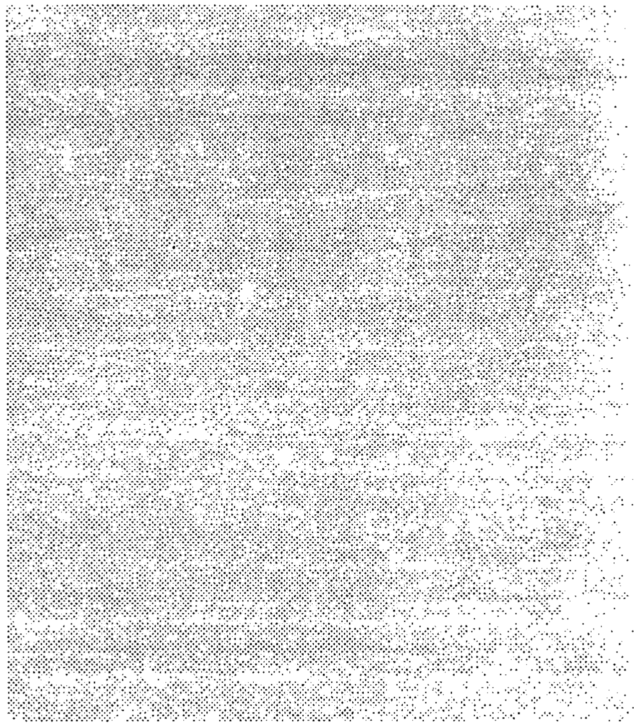
effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction





maintenance requirements

system longevity

## 4. Typical Details and Specifications

## 5. Resources and Contacts

## Pads and Wedges

### 1. Description

This system consists of timbers laid in alternating layers on a prepared gravel pad or exposed rock outcrop. The system can be used with soils that have low bearing capacities. It is suited for use in small buildings which are not likely to suffer damage from a considerable degree of movement, which tends to make the system less suitable for buildings with wood frame and drywall finishes. Nevertheless, it is one of the standard systems used in arctic areas and can be successful if a watching brief is maintained over levelling requirements. Preserved wood is required in all but high Arctic areas. The large volume of wood used make the system appropriate where material can be shipped by road or barge.

*Special Considerations*

- The system can be used with soils that have low bearing capacities.
- The large volume of wood used make the system appropriate where material can be shipped by road or barge.
- The system is suited to small buildings, so that differential settlement will have minimal effect.
- The building structure and finishes should be able to withstand differential movement.

### 2. Extent of Application

The system has been widely used in northern permafrost areas .

Experience has shown

### 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

### 4. Typical Details and Specifications

### 5. Resources and Contacts

## Wood Cribs & Drum Footings

### 1. Description

Wood cribs or drums are set into excavated holes in prepared gravel pads and filled with coarse gravel or rocks. The system is appropriate for underpinning and stabilizing existing pad and wedge systems that have been undermined. It is a more permanent solution than pad and wedge systems. The system requires undisturbed permafrost. Preserved wood for cribs is recommended, especially where ground thaws.

*Special Considerations*

- The system is appropriate for underpinning and stabilizing existing mud floats that have been undermined
- It is a more permanent solution to mud float
- The system requires undisturbed permafrost
- Preserved wood for cribs is recommended, especially where ground thaws

### 2. Extent of Application

A well proven and widely used system .

### 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

### 4. Typical Details and Specifications

### 5. Resources and Contacts

## 1. Description

A pile is a post, driven or drilled into the ground to provide structural support. Piles are suited to sites with soil of low bearing capacities, and the small cross-sectional area of piles minimizes heat transfer from the building to the soil, thus making this system especially suitable for permafrost applications. The penetration of piles into the frozen permafrost ensures stable support even if the soil in the active layer has low bearing capacities, which makes the system suitable for buildings that have a requirement for minimal differential movement. Piling also provides anchorage against uplift, an important consideration in areas with high wind speeds. Although piles can be made of wood or concrete, steel piles are becoming the standard because of their greater durability. Piles in permafrost are usually placed in a pre-drilled hole and backfilled with a sand/water slurry which, when frozen, provides a firm grip on the pile. There are potential problems with the lifting forces that may occur due to annual freeze and thaw cycles which can be overcome by a combination of proper anchorage in the permafrost and drill rod grease. Piles should be designed by an engineer familiar with local conditions.

*Special Considerations*

- Suited to sites with soil of low bearing capacities
- More difficult to drill when active layer melts

## 2. Extent of Application

The system is well proven.

## 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

## 4. Typical Details and Specifications

## 5. Resources and Contacts

## Grade Beams

### 1. Description

Less commonly used, this system consists of concrete strip footings laid on top of a prepared gravel pad. Laminated wood grade beams have also been used. The system is relatively expensive, because of its reliance on concrete or laminated wood, and it is susceptible to uneven settlement unless the pad is very stable. The relatively high thermal conductivity of the material also increases the risk of thawing permafrost.

*Special Considerations*

### 2. Extent of Application

### 3. Performance

The performance of this type of system is assessed as follows:

*Physical*
soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*
maintenance cost

capital cost

*Appropriateness*
site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

### 4. Typical Details and Specifications

### 5. Resources and Contacts

## Greenland System

### 1. Description

This system consists of a wood pad sitting on undisturbed and frozen permafrost. The construction process involves a rapid excavation of a hole to a level below the active layer, rapid placement of the pad and post, followed by quick back-filling to prevent thawing of the exposed and frozen soil. Site supervision must be good to ensure that work is completed before melting of permafrost occurs. The economic performance of this system is questionable.

*Special Considerations*

- Site supervision must be good to ensure that work is completed before melting of permafrost occurs.

### 2. Extent of Application

### 3. Performance

The performance of this type of system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

### 4. Typical Details and Specifications

### 5. Resources and Contacts

# Space Frame Foundation Systems

## 1. Description

A space frame foundation system is a space frame that is used to support a building superstructure. The space frame consists of an assembly of manufactured steel tubes that are connected to form a three-dimensional structure that is relatively rigid, low in weight and capable of large spans. An associated advantage is that the location and number of support points is flexible, because of the way that stresses are redistributed within the structure. The success of such systems depends largely on the design of the connectors and they are usually proprietary because of the connector designs.

Space frames are used to reduce the number of supports and to provide a semi-rigid floor system, so that movement of the soil and footings will have as little effect possible on the superstructure. To date, this system has been tested in the Canadian North in a system using three support points, referred to as a *three-point system*. Further work is proceeding on a configuration using a larger number of supports, referred to as a *multi-point system*. Both systems are in a developmental stage.

### *Special Considerations*

- The system is site-assembled from small and standard components which are easy to transport.
- The system requires the use of proprietary systems
- The space frame is capable of large spans between supports.
- The semi-rigid structure reduces the effect of footing movement on the superstructure
- The structure redistributes stresses
- The open structure provides space for services
- Both the three-point and multi-point systems are expensive, although the three-point system is more so.
- The open structure and multiplicity of structural members create surfaces for ice and snow accumulation.
- The system is not fully developed

## 2. Extent of Application

The three-point system has been installed in the rehabilitation of a house in Rankin Inlet, NWT (see Fact Sheet). The multi-point variant has not yet been built.

## 3. The Three-Point System

This variant was developed to minimize the number of support points, on the premise that this would reduce the problems of racking. A demonstration project was funded, which concluded that the very large supports and large framing members required led to high costs and construction difficulties that largely overcame the advantages of the system.

### *Special Considerations; Three-Point System*

- The three-point system results in very large point loads
- Triangular configuration results in a plane support surface even if there is movement in supports.

### *Performance of the Three-Point System*

The performance of the three-point system, based on a single test installation, is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

*Typical Details and Specifications*

The system requires the use of proprietary systems. The system manufactured by Triodetic Systems Inc. of Ottawa, is described here.

## 4. The Multi-Point System

A subsequent development, which has not yet been tested, uses smaller framing and support members, with a larger number of supports. The system appears, at this point, to be the most promising implementation of the space frame concept.

*Special Considerations; Multi-Point System*

- Requires less compaction of pad than the three-point system, because of lower bearing pressures
- Structural members are smaller and less expensive
- The multi-point platform is adaptable to building shapes that vary from the rectangular

*Performance of the Multi-Point System*

The predicted performance of the multi-point system is assessed as follows:

*Physical*

soil type limitations

system bearing capacity

stability/rigidity performance

*Economic*

maintenance cost

capital cost

*Appropriateness*

site preparation needed

effect on design flexibility

effect on timing/scheduling

skilled labour required

specialized equipment needed

ease of construction

maintenance requirements

system longevity

*Typical Details and Specifications*

## 5. Relevant Codes and Standards

## 6. Resources and Contacts

## 7. Annotated Bibliography

## 1. Anchorage

The anchorage of buildings to the ground is of key importance in areas with typically severe wind regimes. There are two subsidiary problems: anchorage of the superstructure to the foundation, and anchorage of the foundation to the ground. Only the second issue is dealt with here.

There are several ways of anchoring the foundation to the ground.

## 2. Skirting

Skirting consists of wire mesh or sheathing placed between the underside of the building and grade. Skirting is intended to prevent the entry of animals or the use of the crawl space for storage. In Permafrost areas, skirting must provide sufficient openings to allow air to blow through so that heat from the building does not melt the soil.

*Special Considerations*

- Provides warmer floor by protecting the crawl space from cold winds (non-Permafrost areas only)
- Provides a useful area for exhaust and inlet pipes. since the area is not usually affected by pressure differences from wind shifts, as is the case on walls.
- Protects underside of building from vandalism
- Prevents access to animals or unwanted trash storage
- Installation, quick, easy and cheap
- Where openings are needed (in Permafrost areas), these may be blocked by snow or ice
- Useful storage space is eliminated

## 3. Relevant Codes and Standards

## 4. Typical Details and Specifications

## 5. Resources and Contacts

## 6. Annotated Bibliography

# Section 2: Foundations

## *Fact Sheets*

# Moisture Content in PWF Foundations

**Date of Fact Sheet: 02/09/88**

**Status:**
Proposed

**Project:**
Moisture Content in Preserved Wood Foundations

**Location:**
Yukon

**Consultant:**
To be determined

**Technical Contacts:**
R. Sinha

## Background

The increasing cost of concrete in the Yukon has resulted in a shift to Preserved Wood Foundations. Yukon housing Corporation has identified several units in which they are concerned about the long term durability of PW foundations because of high water tables common in the Yukon. A project is proposed to install and measure the moisture content of PW foundations of varying ages.

## Project Summary

Monitoring Moisture pins will be installed in several PW foundations in the Yukon(varying ages of foundations). Moisture content readings will be manually measured and recorded over a one year period to assess whether concerns of accelerated deterioration in PW foundations is occurring.

The pins will remain in the foundations indefinitely primarily for the benefit of YHC to assess the long term durability of these foundations as part of their preventative maintenance program.

# Fact Sheet 2B3

# Foundations

## Space Frame Field Testing

**Date of fact Sheet:** 02/09/88

**Status:**
On-Going

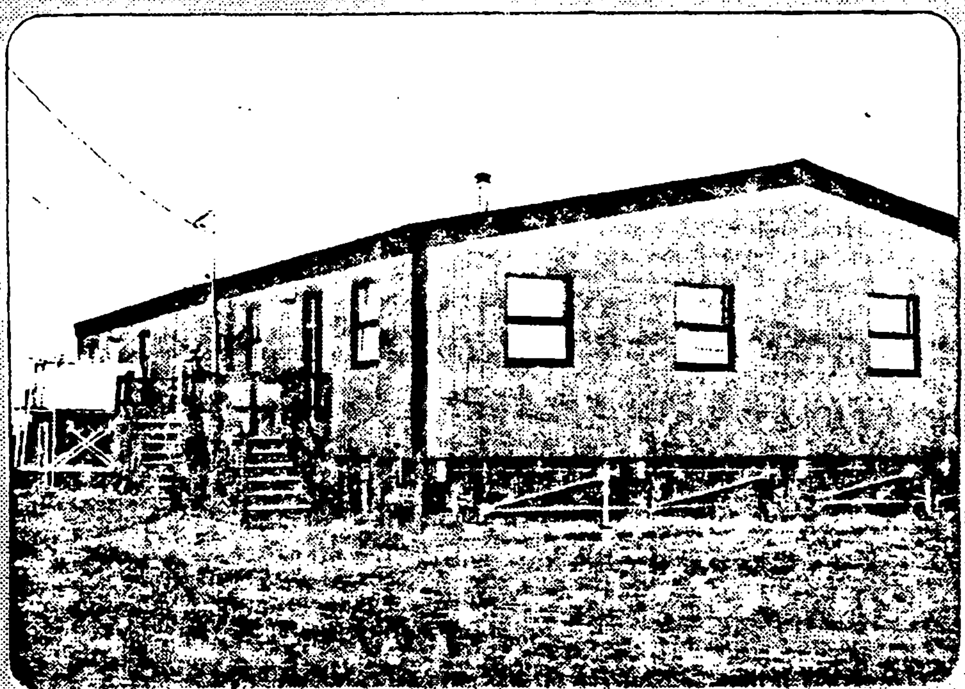
**Project:**
Field Testing of Space Frame and Footings.

**Location:**
Yukon and NWT

**Consultant:**
To be determined

**Technical Contacts:**
R. Duncan

**Manufacturers:**
Triodetic



BUILDING 'A' 4-PLEX FORT FRANKLIN

# Space Frame Field Testing

## Background:

The multiple point support system is an evolution of the three point concept which eliminated the racking effect caused by differential settlements but at high cost, reduced flexibility, increased engineering design and more specialized construction techniques. The multi-point concept set out to achieve the rack resistant performance of the three point concept without the disadvantages. It is clear that with more that three bearing points, the possibility of racking can no longer be avoided but must be resisted by the structural system. Both the space frame chassis system and the monocoque wood framing system are being developed on multiple bearing points. Small footing displacements could induce large stresses into either system and cause failure.To avoid this possibility, the bearing plates are under-designed to fail the soil in the event of an overload or a material such as ethafoam could be used to cushion the bearing points and redistribute the over load.

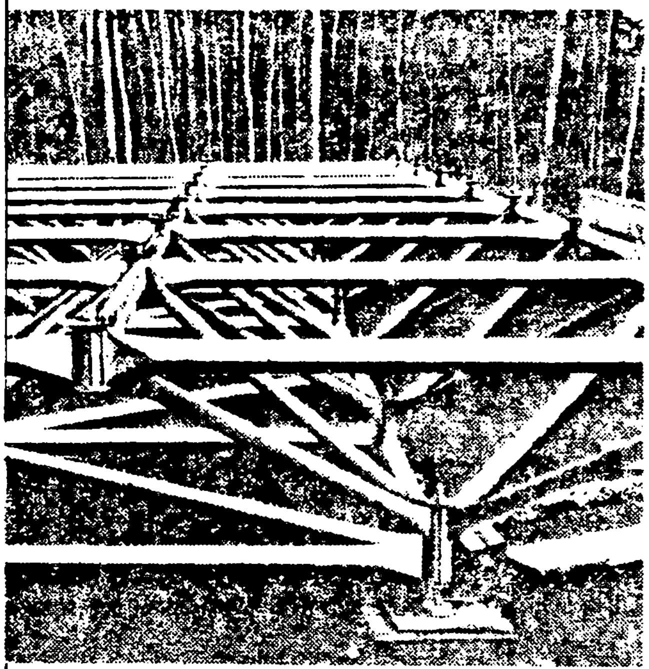
Five Space frames have been installed in the north to date and NWTHC and YHC will install a total of eight more in 1988. CMHC, in conjunction with recent computer modelling efforts, has developed new footing designs that will theoretically redistribute loads and therefore reduce the size and cost of frames. Thus, it is proposed instrument and monitor loads and stresses on these new space frame designs to verify theoretical analysis as well as compare technical and cost performance against previous generation designs.

## Project Summary:

Site investigations of existing space frame foundations will be conducted. Site elevations will be conducted to determine the degree of differential settlement. Airtightness tests will be conducted to determine in significant reductions in envelope airtightness has occurred due to racking.

Site elevations and airtightness tests will be conducted on all new space frame installations. One frame will be selected for extensive monitoring. The frame will be instrumented with load cells and strain gages. Data will be collected weekly over a two year period. Results will be compared with theoretical analysis.

Cost comparisons between old and new space frame designs will be conducted. A cost comparison against existing foundation systems currently used in the region will also be conducted.



# Section 3: Structural and Architectural

*Reference*

## 1. Background

## 2. Performance Criteria

*Technical Performance*

*Cost*

*Appropriateness*

## 3. Systems

## 4. Relevant Codes and Standards

## 5. Resources and Contacts

## 6. Annotated Bibliography

# Section 3: Structural and Architectural

## *Fact Sheets*

**Fact Sheet 3B2** | **Architectural and Structural**

# Field Testing of Monocoque Structures

**Date of Fact Sheet:** 02/09/88

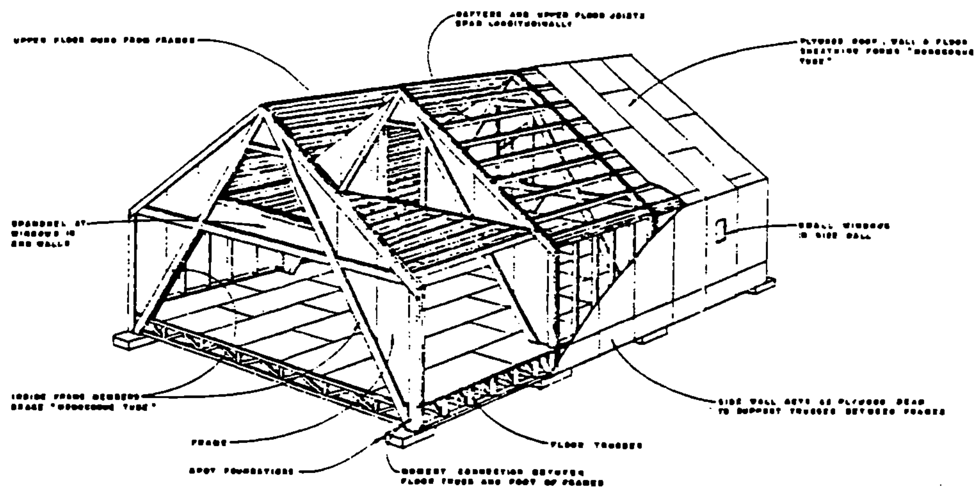
**Status:**
Proposed

**Project:**
Field Testing of Monocoque Structures.

**Location:**
Yukon

**Consultant:**
To be determined

**Technical Contacts:**
R. Duncan



SCHEMATIC

# Field Testing of Monocoque Structures

## Background:

## Project Summary:

The original concept was to develop sufficient structural capacity within the conventional building envelope to support the house on three points. This approach produced severe stresses particularly at the bearing conditions and the construction process was perceived to be too complicated. It was decided that a less pure solution could be a better approach and hence multiple bearing points were introduced as well as internal shell stiffeners which also now serve as the main structural members.

A less costly alternative to providing a totally separate structure to deal with racking forces is to enhance standard house framing with enough stiffness so that the building envelope begins to work like a rigid shell. Typical house sheathing on stud framing produces a measure of rack resistance but not enough to keep deflections within tolerable levels. This concept is feasible from an engineering and construction point of view and may be found to be an economical alternative when the cost of racking damage is taken into account.

*A-frame Concept*

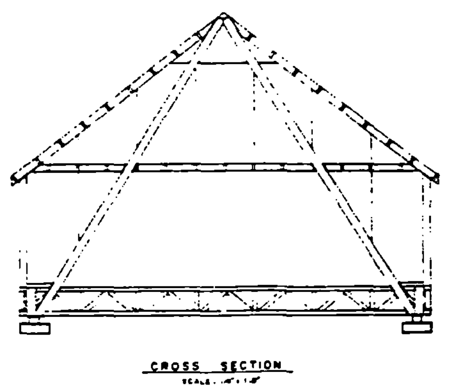
It is apparent that the purely monocoque concept has been replaced by a series of rigid A-Frame members connected by shear panels that may be constructed of conventional framing and plywood sheathing or stress skin panels of alternate composition. For the first prototype, the A-Frame will be fabricated with plywood webs and sheet metal reinforcement nailed between lumber to produce double shear capacity in the nails.

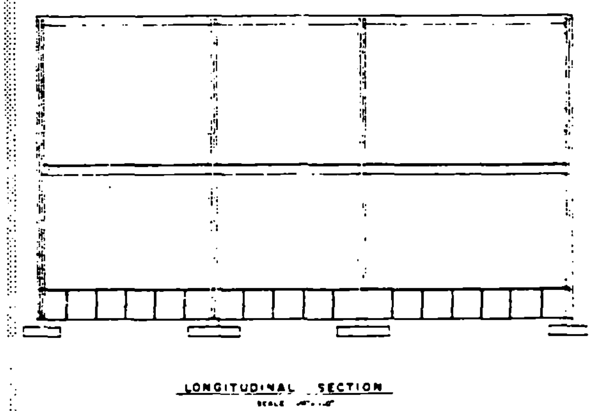
*Architectural Considerations*

The structure imposes some limitations on the architecture of the houses in that only small opening can be permitted in the shear panels along the side walls and no cutting of the A-Frame members is permitted. Both ends of the houses are relatively clear of structural obstruction so that openings can be accommodated with some measure of freedom. One advantage of this concept is the creation of an attic space suitable for storage or additional living area which implies a more efficient use of materials.

*Footing Conditions*

Torsional and racking resistance can be engineered into the A-Frame structure so that the house could rest on three points however it may be more cost effective to reduce or dampen the racking forces caused by differential soil movement by placing a cushion between the structure and the severe ground conditions.



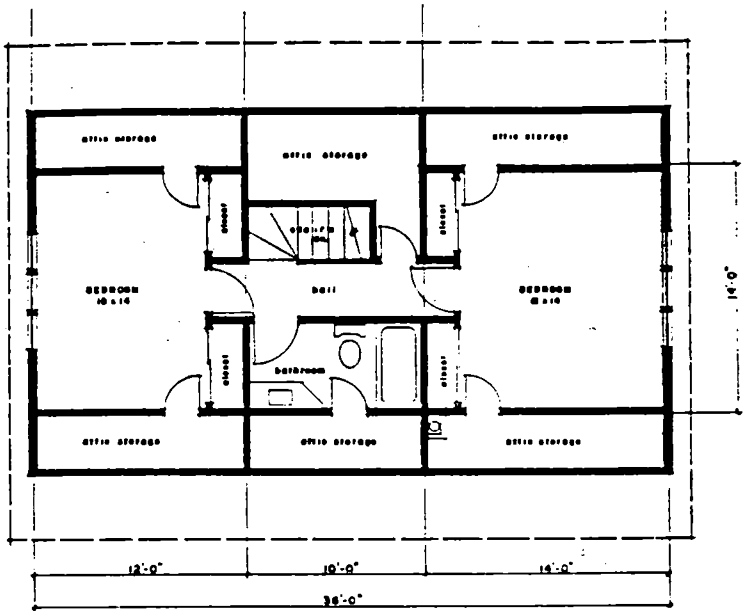
# Field Testing of Monocoque Structures

Several projects are planned in 1988 that will use air spring technology already developed for transport trucks as the bearing pad. COFFI is also planning on constructing at their cost a demonstration project in 1988 based on concepts developed by CMHC. The goal of the project is to assess the viability of the technology in unstable soils. The feasibility of the concept will be evaluated and recommendations for design changes proposed.

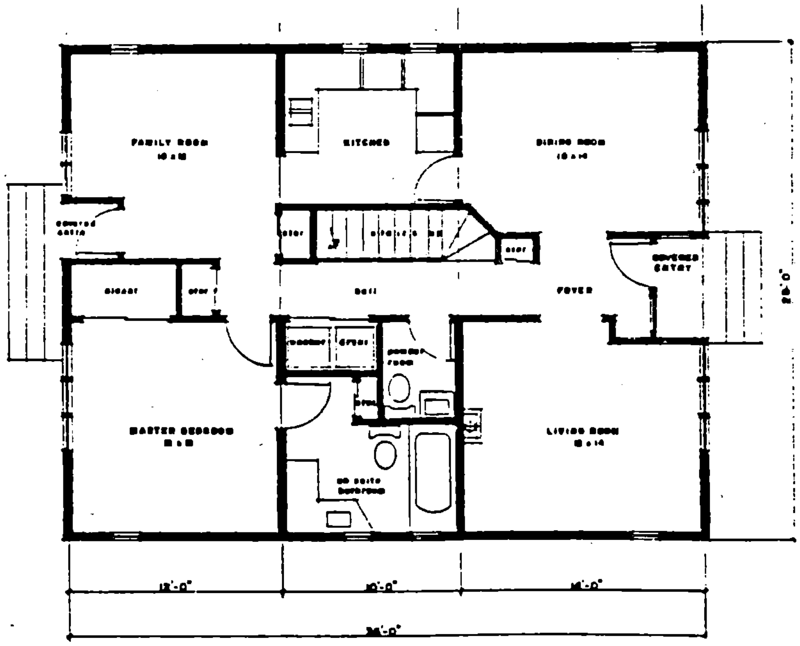
### *Monitoring*

Load cells, strain gauges and survey equipment will be used to examine the stresses and deflections of the monocoque house construction. Wind effects and deflections will be monitored to determine the usefulness of this approach.

The results will be used to reinforce specific structural members and their retesting.




UPPER FLOOR PLAN




MAIN FLOOR PLAN

# Section 4: Building Envelope

## *Reference*

## 1. Background

The dominant method of construction is still wood frame construction. The general national trend of rising energy costs has resulted in a concerted effort to reduce building energy consumption costs, especially space heating. The R-2000 program represents one vehicle whereby an overall philosophy of improved construction practices and reduced building energy costs through higher R-values and heat recovery can be imparted to the building industry. However, shipping and transportation costs place an additional burden on the final installed costs of these types of buildings.

Alternative methods such as log construction are popular in many regions of the north. Using of local resources (logs) and relative ease of construction makes log buildings at least in terms of material costs, economically attractive.

Plywood stress skin panel construction offers the advantage of easy transportation and quick erection with minimal of skilled labour.

Sprayed polyurethane with wood strapping has also become popular in the past five years. This method is least labour intensive and quick to install, however it requires specialized equipment, trained operators and is limited to application in temperatures no lower than 5C. Information of the durability of this type of insulation is limited and still controversial.

Other building envelope design issues are whether to ventilate attics, cold floors and air and vapour barriers.

## 2. Performance Criteria

*Technical Performance*

*Cost*

*Appropriateness*

## 3. Envelope Systems

## 4. Relevant Codes and Standards

## 5. Resources and Contacts

## 6. Annotated Bibliography

# Section 4: Building Envelope

## *Fact Sheets*

# Fact Sheet 4B2

# Building Envelope

## Envelope Thermal Performance

**Date of Fact Sheet: 02/09/88**

**Project:**

Thermal Performance of Northern Building Envelopes.

**Status:**

On-Going

**Location:**

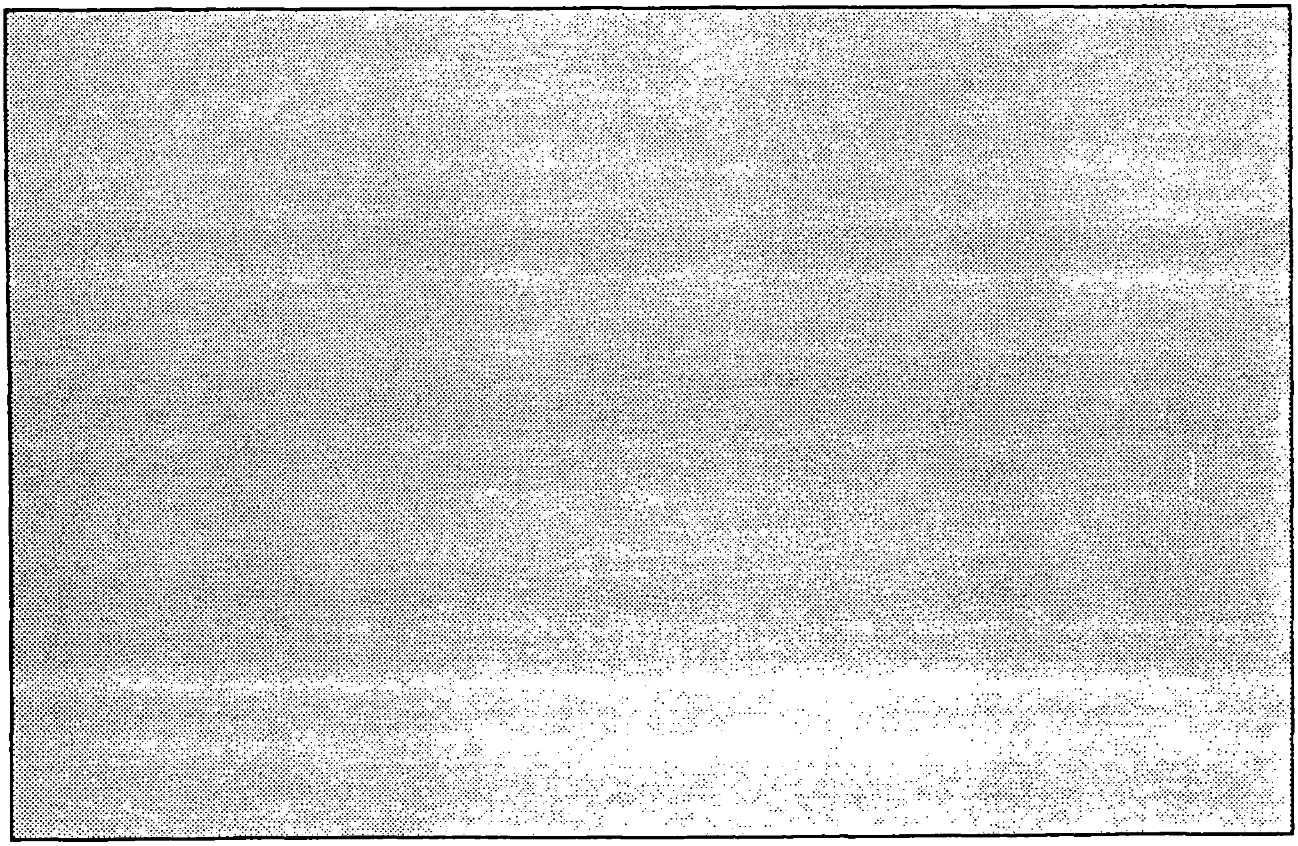
Northern NWT

**Consultant:**

To be determined

**Technical Contacts:**

R. Sinha



# Envelope Thermal Performance

## Background

Convection within wall cavities has been shown to reduce the overall insulating value of wall sections dramatically. These effects are related to the type of wall design and are more severe with large indoor-outdoor temperature differences. A project is proposed to conduct field measurement of insulating value of wall sections in the far north to determine if any correction factor is required to theoretical values to take into account these effects.

## Project Summary:

Guarded Hot Boxes will be rented from NRC/IRC and installed in 4 houses in remote locations in the north. Heat flow and temperatures inside and outside the box will be recorded for 3-4 months in mid winter using a data acquisition system. Results will be analyzed and effective insulating value of wall sections will be derived and compared to theoretical values.

## Anticipated Performance:

# Fact Sheet 4B3

# Building Envelope

## Monitoring of Wall Moisture Content

**Date of Fact Sheet:** 02/09/88

**Status:**
On-Going

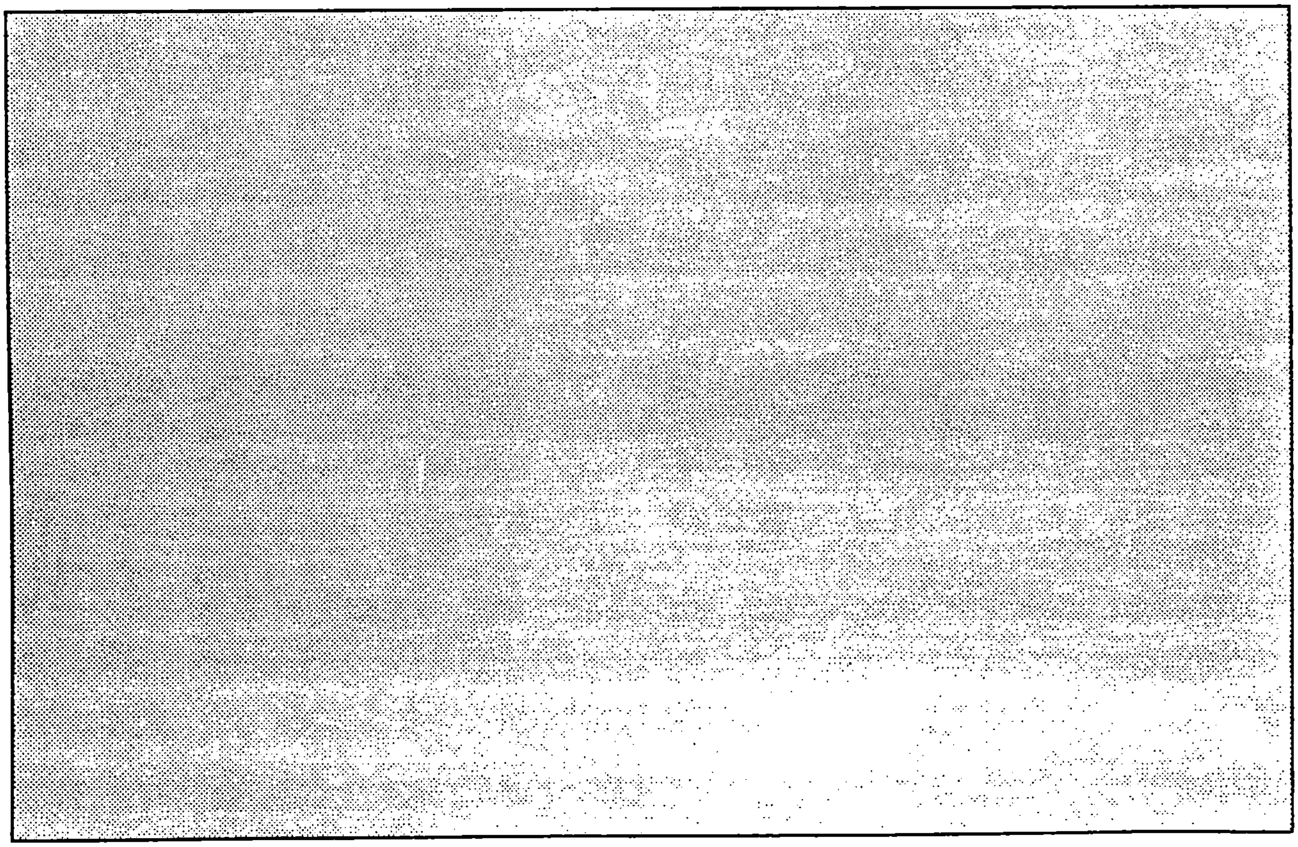
**Project:**
Monitoring of Wood Moisture Content of framing members

**Location:**
Northern NWT

**Consultant:**
Ferguson, Simek, Clark

**Technical Contacts:**
R. Sinha, D. Ferguson, D. Bushell

**Manufacturers:**
Buchan, Lawton, Parent



# Monitoring of Wall Moisture Content

## Background:

A significant amount of resources is currently being allocated to the study of moisture migration and movement in wall sections. Most of the attention has been focussed towards the maratimes because of the its humid climate. However, recent studies have indicated that the unique climate in the north creates its own set of conditions that may be leading to premature rotting of framing members and wood siding. NWT housing officials have requested a monitoring program to determine moisture content in wood building components. Some of the concerns raised by NWT officials include:

- initial moisture content of framing members since the
- wood is often exposed to the environment for several
- weeks or months prior to use.

- significant shrinkage of wood members during the dry
- winter season causing the building envelope to crack
- and open up possibly leading to significant
- interstitial condensation within the building fabric.
- This problem would be worse the wetter the wood is
- during installation.
- impact of the extended winter nights on the moisture
- content in wood framing members

The results will be used to help determine the condition of wood framing members in NWT housing as well as provide data to computer modelling efforts currently under way in this area.

## Project Summary:

Moisture pins will be installed in 3 houses in 3 communities in the far north. Periodic measurements of moisture content will be made for approximately one year. Measurements will also be conducted on building sites to determine the moisture content of wood currently being installed in new houses.

# Section 5: Windows, Doors and other Openings

*Reference*

## 1. Background

## 2. Performance Criteria

*Technical Performance*

*Cost*

*Appropriateness*

## 3. Systems

## 4. Resources and Contacts

## 5. Annotated Bibliography

# Section 5: Windows, Doors and other Openings

## Fact Sheets

**Fact Sheet 5B1** | **Windows, Doors and Openings**

## Durable Windows and Door Hardware

**Date of Fact Sheet:** 02/09/88

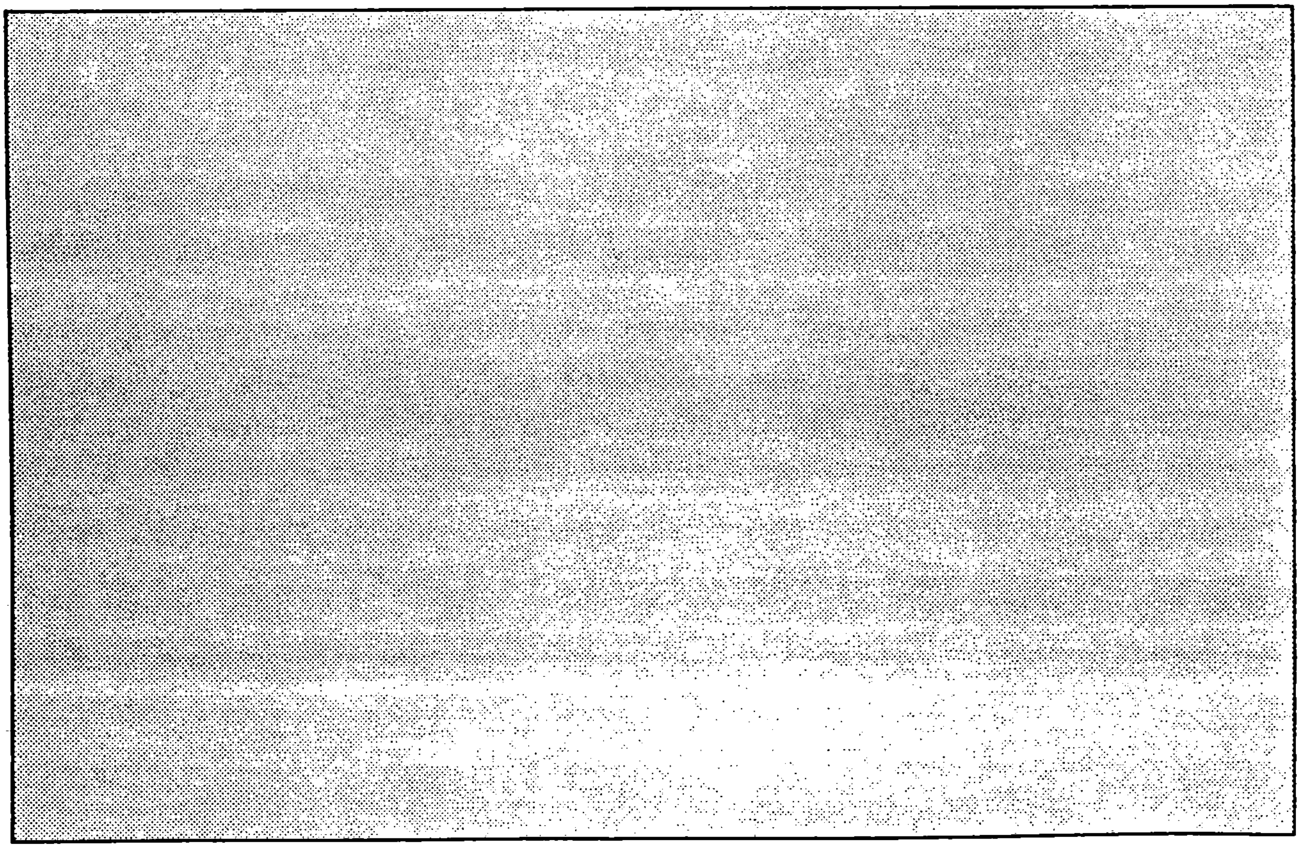
**Status:**
On-Going

**Project:**
Durable Windows and Door Hardware

**Location:**
NWT and Yukon

**Consultant:**
To be determined

**Technical Contacts:**
R. Sinha



Fact Sheet 5B1

# Windows, Doors and Openings

## Durable Windows and Door Hardware

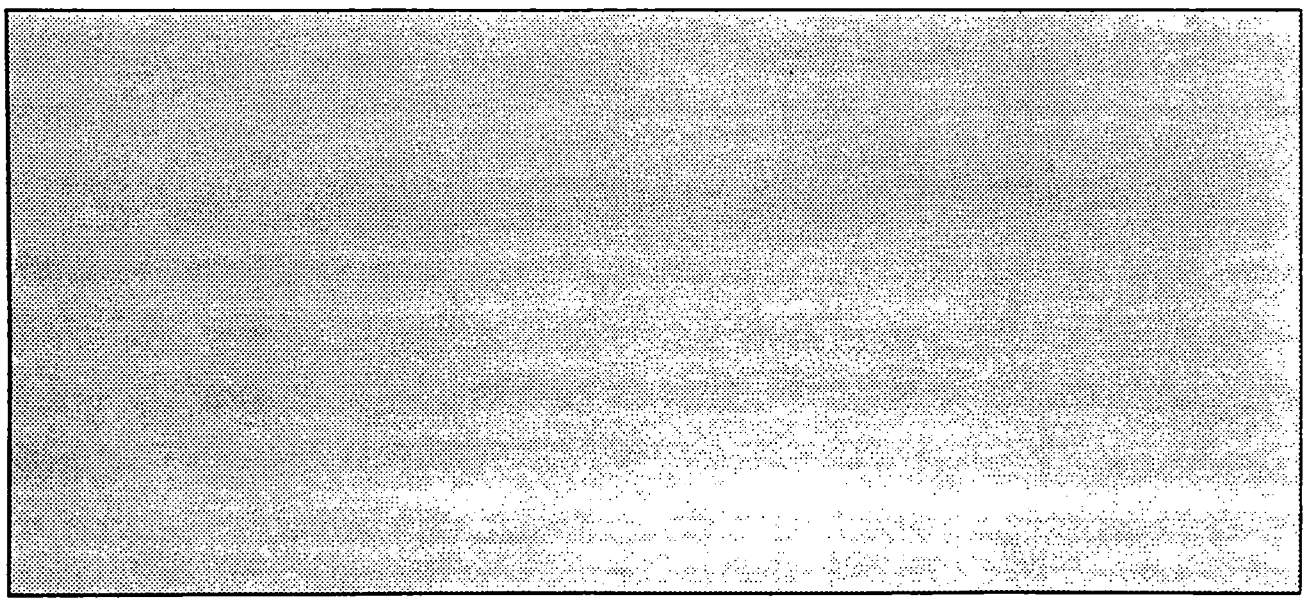
### Background:

The extremely cold conditions in the north causes window and door hardware and weatherstripping to become brittle an fail. Reviews of selected modernization and improvement expenditures in the north indicates a large proportion of these expenditures is allocated to replacement of window and door hardware. There is a need to investigate and/or develop more resilient hardware such as handles, hinges and weatherstripping for northern applications. A subset of this study will be to re-evaluate architectural considerations for windows and doors to reduce associated maintenance costs.

### Project Summary:

This project will investigate alternative window and door hardware and develop a standard to evaluate the strength and resiliency of these components in Arctic conditions. Investigations will focus on eommunications with manufacturers both in Europe and North America. Interviews with materials scientists will also be conducted.

A standard stress test for door and window handles will be developed to simulate stresses placed on the hardware by users. An evaluation criteria for weatherstripping will also be developed to include such factors as resiliency and flexibility. Promising components will be evaluated by placing them in a cold chamber to simulate typical Arctic temperatures and humidities. Door and window handles will then be tested to failure. Weatherstripping will similarly be tested.



# Section 6: Space Heating and Water Heating

*Reference*

## 1. Description

Oil-fired warm air systems have been the traditional heating system installed in the north. The technology is mature and trained technicians and installers are readily available. Warm air systems offer an easy means of heating fresh air introduced into building as well as humidifying air. The system allows for distribution of ventilation air and reduces temperature differences in the room. It has been argued that warm air systems have a slight performance advantage over hydronic systems for sub-Arctic and Arctic housing. It has also been argued that warm air systems are also cheaper (capital cost and maintenance cost) than hydronic systems. One advantage of warm air systems is that they can be ducted under windows to help reduce condensation on windows.

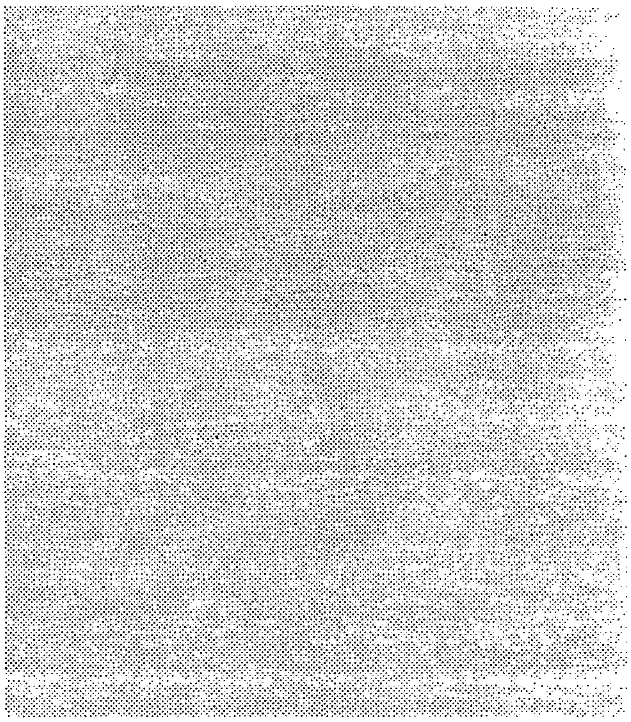
Unfortunately electrical costs are high in the Arctic, hence, the cost associated with operating the furnace fan becomes a significant added cost in addition to the fuel cost.

The trend towards energy efficient and R2000 housing has resulted in oil-fired systems that are oversized. (i.e smaller output systems that are matched to the lower heating load of the house are not readily available). This results in inefficient operation of furnace systems and hence added heating cost to the consumer.

The lack of basements forces ducting through walls above ceiling or boxed in and passed down to floor level through interior walls. These added lengths increase pressure drops and duct leakage lowering the overall performance compared to the intended design. Ductwork also requires special design for optimum performance especially at the lengths that have to be used. This places an added burden on the installer. Thus. it is difficult in practice to achieve design flows. It has been argued that the ductwork could be routed through a false floor. This would help reduce complaints about cold floors but the false floor appears to be an expensive option.

Lastly, the potential for backdrafting in flued systems, is increased substantially, in tighter houses. This problem is common to both warm air and hydronic system with chimneys.

## 2. Extent of Application



## 3. Performance

*Physical*

*Economic*

*Appropriateness*

## 4. Relevant Codes & Standards

## 5. Contacts and Resources

## 6. Annotated Bibliography

# Hydronic Heating

## 1. Description

Hydronic heating using either glycol or hot water is becoming commonplace in the sub-Arctic and Arctic housing especially in larger houses with more than one heating zone such as two storey houses. One of the reason for this trend is the elimination of the operating cost of the fan system. A second reason is that piping runs through the house relatively easy. Thus, complex ductwork is eliminated. Hydronic heating offers much more control over zone heating. Piping can also be run through floors reducing problems of cold floors.

Another advantage of hydronic systems is the ability to integrate the domestic hot water system into the space heating system. In fact, it has been argued that in super energy efficient housing, the DHW load may in fact be the dominant load. Integrated heating and DHW reduces maintenance costs since there is only one boiler/burner. Integrated heating/DHW systems also have lower stack losses than separate systems because only one chimney is involved.

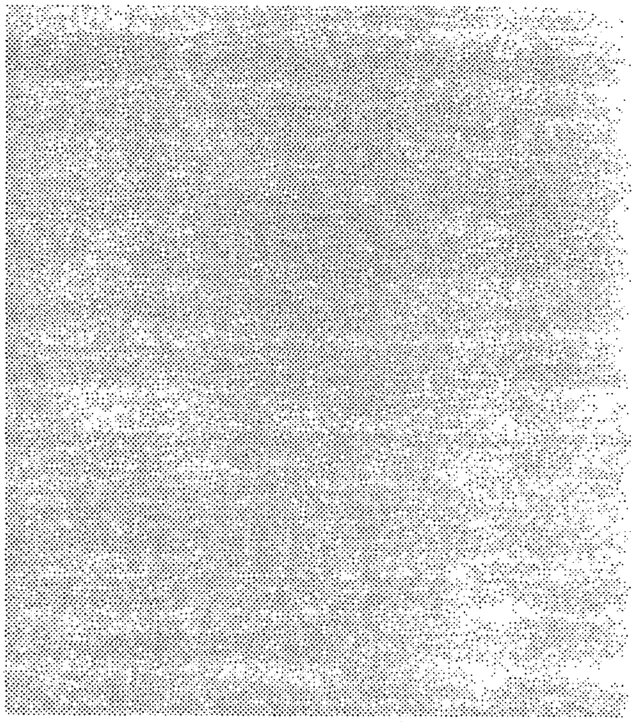
Hydronic system generally take up a lot more space than forced air systems because of required clearance to combustibles. The trend towards energy efficient and R2000 housing has resulted in oil-fired boiler systems that are oversized. (i.e smaller output systems that are matched to the lower heating load of the house are not readily available). This results in inefficient operation of furnace systems and hence added heating cost to the consumer.

It has been argued that hydronic systems have higher maintenance costs compared to warm air systems but if properly maintained boiler can last as long as the building.

There are fewer properly trained installers and service technicians compared to forced air systems. The presence of more controls on a hydronic system add to the burden of proper maintenance of these systems.

Correct sizing of heat distribution system is critical since balancing capabilities more limited than forced air systems. Proper placement of the thermostat is another critical area for optimum performance of the system.

One of the complaints of hydronic systems is the perception of stuffiness in the house. This is because distribution of fresh air must be achieved by a separate ventilation system. In leakier houses dedicated air distribution systems may not be present or needed. In more energy efficient houses, air distribution is handled



through the a separate mechanical (or passive) ventilation system.

Lastly, the potential for backdrafting in flued systems is increased substantially in tighter houses. This problem is common to both warm air and hydronic system with chimneys.

## 2. Extent of Application

## 3. Performance Criteria

*Technical Performance*

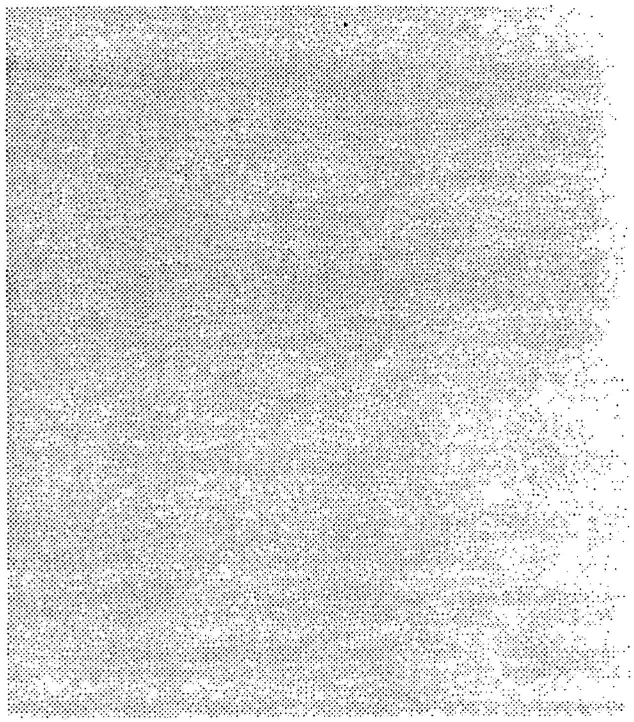
*Cost*

*Appropriateness*

4. **Relevant Codes & Standards**

5. **Contacts and Resources**

6. **Annotated Bibliography**



## 1. Description

Wood heating is a relatively cheap source of fuel in areas where wood is available.

The industry is mature and all wood stoves are now required to undergo testing by an Approved Testing Agency.

Because there are no basements in northern housing, wood stoves generally take up a lot of space in the main living area. This is because of clearances required from combustibles. Proper maintenance and dedicated combustion air intakes in tight houses are the main concerns in wood stove operation.

Creosote build-up resulting in chimney fires and increased pollution have been cited as principal concerns.

## 2. Extent of Application

## 3. Performance Criteria

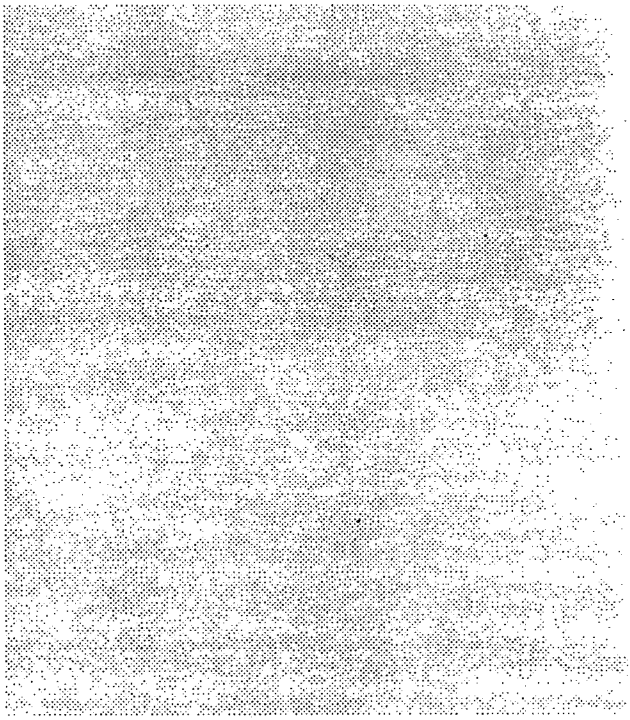
*Technical Performance*

*Cost*

*Appropriateness*

## 4. Relevant Codes & Standards

## 5. Contacts and Resources



## 6. Annotated Bibliography

# Section 6: Space Heating and Water Heating

## *Fact Sheets*

Fact Sheet 6B1

# Space and Water Heating

## Direct-Vent Oil-Fired Heating Systems

**Date of Fact Sheet:** 02/09/88

**Status:**

Proposed

**Project:**

Demonstration of various state-of-the-art direct vent oil fired heating systems in the north

**Location:**

Dawson City, Yellowknife

**Consultant:**

Ferguson, Simek, Clark

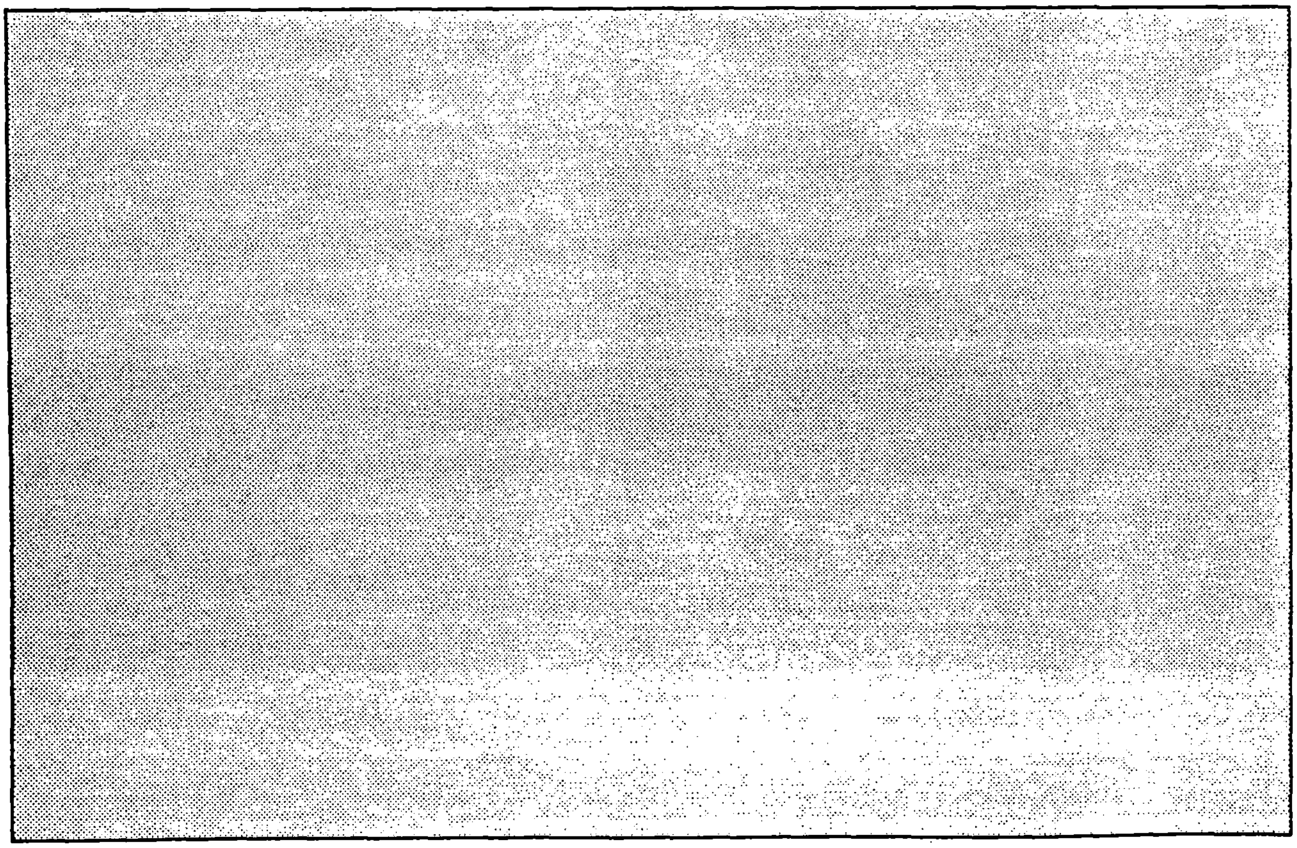
**Technical Contacts:**

R. Sinha, D. Ferguson

**Manufacturers:**

Energy Kinetics (US)

Worcester Engineering (UK)



# Fact Sheet 6B1

# Space and Water Heating

## Direct-Vent Oil-Fired Heating Systems

### Background:

The trend towards more energy efficient housing has resulted in a significant reduction in the space heating load of the house. Current systems are presently oversized, resulting in large mechanical rooms and lower efficiencies. Oil fired heating systems that are closely matched to the heating load of the house are not readily available.

### Project Summary:

Four state-of-the-art oil fired systems have been identified as having promise for matching the heat load of the more energy efficient buildings. The systems are as follows:

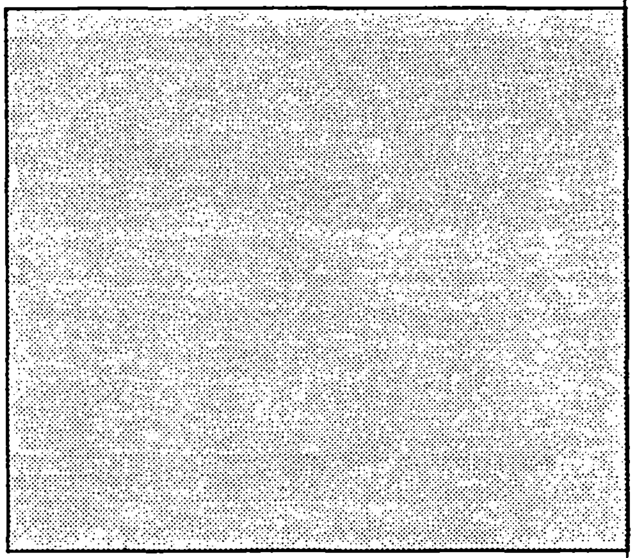
1) System 2000 Boiler system manufactured by Energy Kinetics in the US.

This system will be installed in an R2000 duplex in Dawson City, Yukon. The system purports a combustion efficiency of 87% and the ability to be oversized by as much as four times the design heat load of the house without an appreciable drop in combustion efficiency. The system achieves its high efficiency by purging excess heat from the heat exchanger to the hot water tank.

2) The Heatslave Combi-Boiler manufactured in England by Worcester Engineering

This system will be installed in a private house in Yellowknife, NWT. The system is attractive because of its compact size(about the size of a dishwasher) and its ability to provide an output in the order of 40,000 BTUH. The lowest North American system could only be sized down to about 60,000 BTUH. The hot water maker is integrated into the boiler, eliminating the need for a separate hot water tank.

Both these systems utilize side wall vent



# Fact Sheet 6B2

# Space and Water Heating

## DHW as a Heating System

**Date of Fact Sheet:** 02/09/88

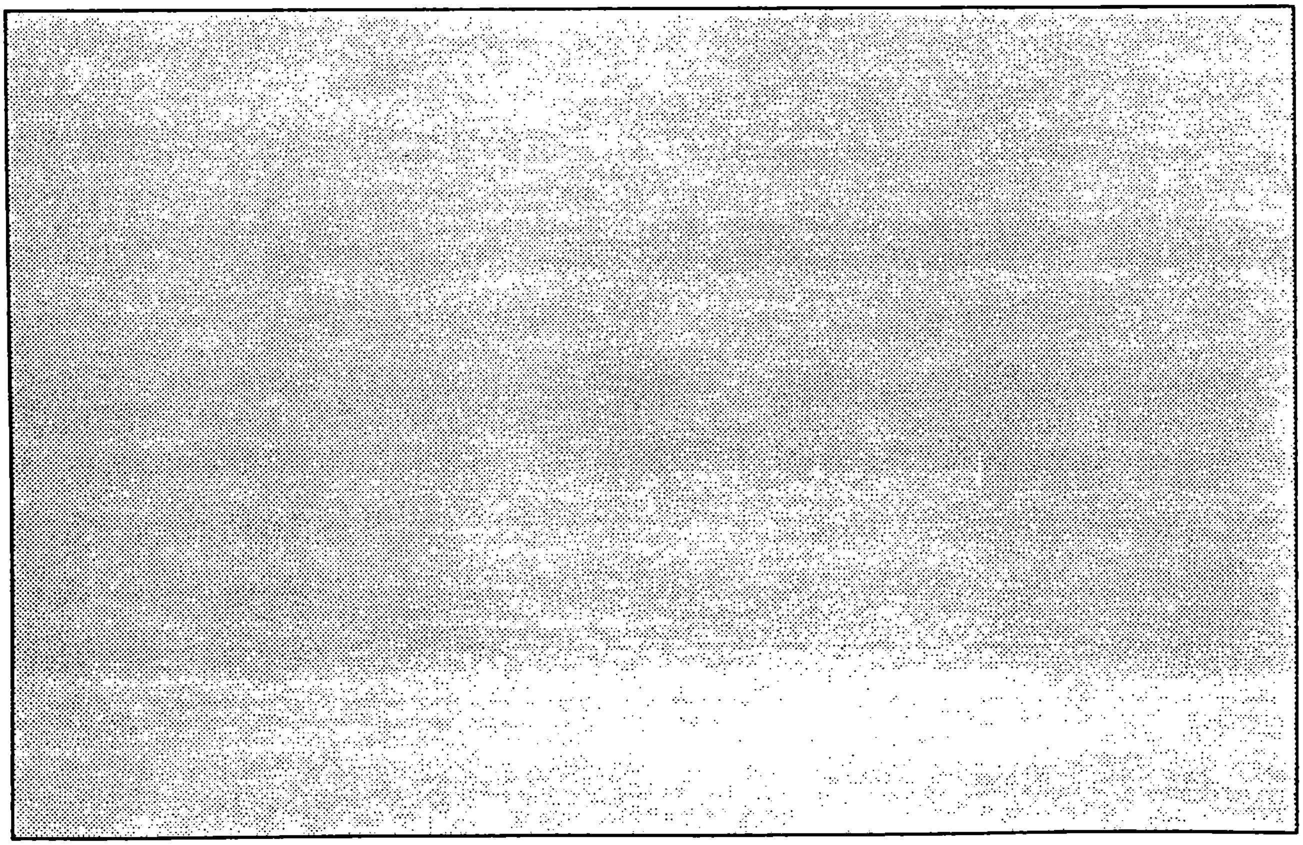
**Status:**
On-Going

**Project:**
DHW as a Heating System

**Location:**
Yellowknife

**Consultant:**
To be determined

**Technical Contacts:**
R. Sinha



# DHW as a Heating System

## Background

Recent field demonstrations have shown that the domestic hot water load is the largest load in modern energy efficient housing. A recent monitoring project by CMHC has indicated that Domestic Hot Water tanks can be a cost effective approach to providing both space heating and hot water to energy efficient homes. Several other houses in Yellowknife have been using this approach to heating for several years. It is proposed to investigate the state and condition of these hot water tanks to provide data on long term performance of this approach to heating. CSA currently does not recognize DHW tanks as a heating appliance. Thus, there is a need to follow up with CSA to secure appropriate approval for DHW tanks as heating appliances.

## Project Summary

The goal of this project is to co-ordinate with CSA to secure appropriate approvals for DHW tanks to be considered as a space heating appliances. As part of that initiative, field investigations of several DHW tanks which have been used as heating appliances in Yellowknife for several years will be conducted.

Tanks will be cut open and evidence of corrosion and deterioration will be recorded. DHW tanks used for hot water only will also be examined and used as a reference.

Radiators and pipes serving hydronic systems will also be examined for evidence of corrosion and/or deterioration

# Fact Sheet 6B3

# Space and Water Heating

## Latham Island Hybrid Heating Project

**Date of Fact Sheet: 02/09/88**

**Project:**

Status Report for Latham Island Hybrid Heating Project

**Consultant:**

Ferguson, Simek, Clark

**Funding:**

CMHC

**Project Manager:**

R. Duncan, CMHC

**Status**

Installations complete

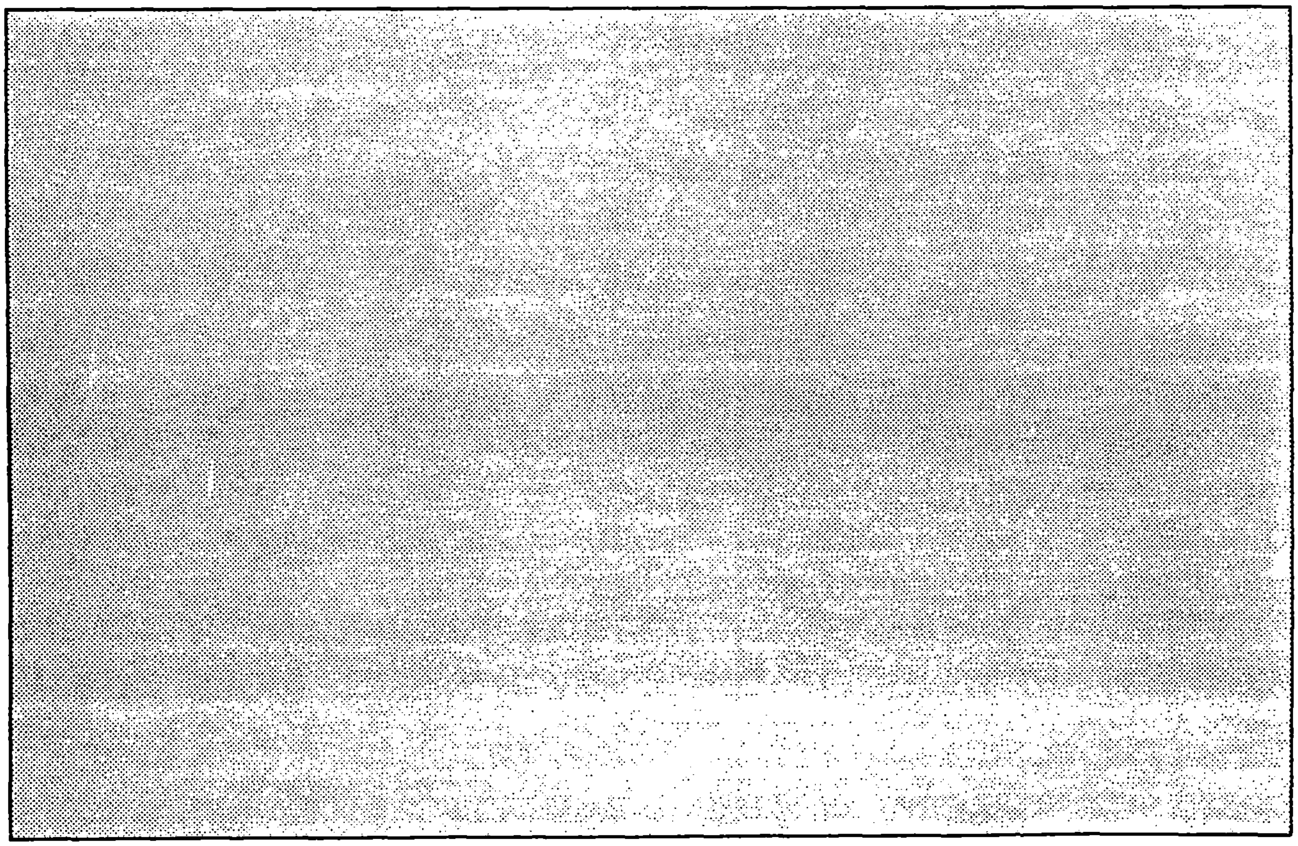
Complete state of the art sophisticated software package developed

Monitoring under way

**Outline of Deliverables to be finalized**

Presentation of findings at next committee meeting in Yellowknife by consultant

Final Report tentatively August 1988.



# Latham Island Hybrid Heating Project

## Project Summary:

A comprehensive monitoring project to evaluate the performance of various heating and ventilation strategies is underway at Latham Island in the NWT. Monitoring is being accomplished using state of the art data aquisition equipment.

Four distinctly different heating/ventilation strategies are being evaluated. These are:

- A domestic hot water heating system using a conventional oil-fired hot water tank for both heating and domestic hot water. A unique swedish air to air heat exchanger is also being evaluated. Return air is ducted through a false floor.
- A typical downdraft forced air furnace ducted through a false subfloor. A Nutech heat exchanger provides mechanical ventilation
- A conventional hydronic heating system with passive ventilation. Ventilation air enter through the floor soffit and is tempered by perimeter radiation
- Hybrid Heating: A Delhi air handling unit is used as the ventilation unit with reheat coils attached.

## Performance:

*Technical*

*Economic*

*Appropriateness*

## Conclusions

# Fact Sheet 6B4

# Space and Water Heating

## Performance Evaluation of oil-fired heating systems and innovative ventilation strategies

**Funding:**
CMHC/EMR

**Project Manager:**
R. Sinha, CMHC

**Status:**
The project is out to tender with a planned start date before March 31, 1988.

**Consultants:**

**Technical Contacts:**

# Performance Evaluation of oil-fired heating systems and innovative ventilation strategies

## Background

The trend towards more energy efficient housing has resulted in a significant drop in the space heating load of the house. Current systems are presently oversized resulting in large mechanical rooms and lower efficiency. Oil-fired heating systems that are more closely matched to heating load of the house are not readily available.

## Project Summary:

CMHC has identified a few system that appear to resolve this problem. It is planned to purchase, lab test and demonstrate these systems in the the field. Two systems have currently been defined, neither of which are CSA approved. These are:

1.Heatslave

2.System 2000

A third state of the art system will also be investigated. Systems will be monitored using state of the art data aquisition systems. A fourth base case house will also be monitored for comparison.

This project will also take the opportunity to monitor more ventilation strategies in a continued effort to find a suitable method of providing ventilation air in northern housing. Strategies are still being developed but it is anticipated that some form of demand RH based ventilation system will be tried.

Some time average IAQ monitoring is planned

The project will also attempt to collect data on moisture content in structural members in remote communities.

**Phase 1**

Arrangements are in progress to purchase two sets of heating systems, one of which will remain with CMHC to be CSA approved. At the same time the other system will be sent up to Yellowknife and installed in the houses. Site demonstration will need to be secured from fire marshall.

A tender will go out for the heating systems.

Once the second set of systems have been CSA approved they will be sent up to Yukon for demonstration.

Monitoring to begin 1988/89 heating season

Project Plans to be submitted preceding each phase to maintain control over project.

**Phase 2**

Various building envelope field investigations including monitoring of moisture contents in possibly four communities

Quotation for 150 moisture pins and 6 meters expected from BLP shortly. Less than 4 week turn around time.

Other building investigations as budget allows.

# Section 7: Ventilation and Heat Recovery

*Reference*

## 1. Background

The trend towards energy efficient housing has resulted in a drastic reduction in energy losses associated with air infiltration (accidental air leakage). Unfortunately, this has created concerns about indoor air quality. To resolve this concern, strategies of providing adequate ventilation air to the house are constantly being developed. Various codes and standards are evolving to ensure a minimum level of ventilation air to ensure adequate air quality in the home. These strategies can be divided into three main categories:

- Mechanical exhaust system
- Mechanical Heat Recovery Systems
- Passive systems

Mechanical exhaust systems, although effective, cannot recover valuable heat in the exhaust air. Operating costs for continuous operation (as required by CSA-F326) create an added operating cost, which in many regions of the north is virtually unacceptable. In addition, if the delivered fresh air enters through intentional passive openings it needs to be preheated. There is also concern of backdrafting naturally aspirated furnaces when an exhaust only method is used.

Mechanical heat recovery systems address the problem of recovering heat in the exhaust air and transferring it to the incoming air. This preheats the incoming air. The system is generally balanced so concerns of backdrafting are eliminated. The system also offers an efficient means of distributing fresh air to several zones as well as controlling the humidity in the house. Unfortunately, the performance of these systems has not been encouraging. Core freezing resulting long defrost mode (exhaust only) can and has resulted in backdrafting of furnaces. The cold incoming temperatures has resulted in poor overall performance and significant number of HRV failures. In addition, like mechanical exhaust-only systems, the electrical cost associated with a continuously running fan in the north is significant if not unacceptable.

Passive ventilation systems are receiving more and more attention as a practical alternative to mechanical ventilation. Passive systems have no operating cost (no fans) and require no maintenance. They can exhaust stale air from individual zones. The disadvantages of passive systems are:

1. They do not recover heat from the exhaust air
2. They rely on stack and wind effects for moving air and thus their air flow rates are more variable
3. Fresh outside air needs to be tempered (preheated) before entering the house.
4. It is difficult to satisfy ventilation codes with a passive system.
5. They are prone to reversed flow if exhaust system are operating

## 2. Systems

The trend towards energy efficient housing has resulted in a drastic reduction in energy losses associated with air infiltration (air leakage). This trend (spearheaded by the R2000 program) has filtered down into all facets of the building industry. The net effect is that houses are being built to tighter and tighter standards despite builders efforts to intentionally do so. Given this current trend, it becomes apparent that more and more houses (both new and renovated) will have to incorporate some form of intentional ventilation to ensure adequate air quality.

There are basically two approaches to ventilation:

1) Mechanical Ventilation

2) Passive Ventilation

Mechanical ventilation is the most familiar form of controlled ventilation in tight houses but passive ventilation systems are emerging as a viable alternative in remote areas where electrical costs, maintenance costs and serviceability make mechanical ventilation systems either prohibitively expensive or inappropriate for the market.

## 3. Mechanical Systems

There are three approaches to mechanical ventilation for buildings:

1) Balanced pressure approach

2) Positive Pressure approach

3) Negative Pressure Approach

### a) Balanced Pressure Approach

This is the most common method of providing ventilation to tight buildings. The volume of ventilation air brought into the house is balanced by the volume stale air exhausted from the house. Heat recovery from the exhaust air is achieved through an HRV thus providing some level of preheating of the supply air. The pressures across the building envelope caused by stack and wind remain unchanged and uncontrolled air leakage will still occur through leaks in the building envelope. A tight envelope will minimize these effects. Tight envelope integrity must be maintained throughout the life of the house. Despite being conceptually simple, data on the long term performance of HRV's is limited. Regular balancing of the system combined with frozen heat exchanger cores in extremely cold environments has limited widespread use of HRV's in remote, sub-Arctic and Arctic regions.

### b) Positive Pressure Approach

In this approach, fresh air is brought in from outside by a single fan and distributed throughout the house. The building is essentially pressurized, stale air being forced out through leaks(intentional and unintentional) in the building envelope. The benefits of this approach is that it excludes contaminants from building enclosures (UFFI) or from surrounding soil (i.e radon, soil gas). Positive pressure approaches are compatible with naturally aspirated heating appliances (including fireplaces) in that they minimize the effects of combustion backdrafting and spillage. Despite these advantages, this approach cannot recover heat, raises concerns regarding interstitial condensation within the building fabric and special steps must be taken to heat the incoming cold air.

A derivative of the positive pressure approach is the integration of a fresh air supply plenum directly into the return air plenum of a forced air system. This approach is popular in the prairies. Proper location of the supply plenum to allow good mixing with the return air is important to minimize excessive cooling of the heat exchanger which could result in premature failure.

### c) Negative Pressure Approach

In this approach, air is exhausted from the building through one or more fans. Fresh air is brought in through intentional and unintentional openings. The volume of air exhausted from the house may vary from a minor amount serving kitchens and bathrooms to levels that completely depressurize the building. In the latter, leakage of moist air out of the building through unintentional openings (exfiltration) is eliminated. The drawback of the negative pressure approach is the potential hazard of combustion backdrafting and spillage in naturally aspirated heating appliances and fireplaces. Forced draft heating appliances and dedicated combustion air requirements for combustion appliances have served to reduce this potential problem but, in especially tight houses, even these measures may not be adequate. As with the positive pressure approach, special steps must be taken to preheat the incoming air least in those instances where fresh air is provided directly to the living space through a supply duct connected directly to the outside. Other more sophisticated methods such as the dynamic wall or window approach attempt to recover radiative and conductive losses through the building envelope to preheat the supply air.

## 4. Passive Systems

Passive ventilation systems are receiving more and more attention as a practical alternative to mechanical ventilation. Intentional openings in the lower portion of the house allow fresh air to enter. Ducts in the ceiling rising above the roof exhaust the stale air. Pressure differences derived from stack and wind effects provide the driving force for moving the air through the house. Passive systems have no operating costs (no fans) and require virtually no maintenance. If properly designed they can provide fresh air and exhaust stale air from individual zones. The pressures across the building envelope caused by stack and wind remain unchanged and uncontrolled air leakage will still occur through leaks in the building envelope. A tight envelope will minimize these effects. Tight envelope integrity must be maintained throughout the life of the house. There are four major drawbacks of passive ventilation systems:

1) Passive systems do not recover heat from the exhaust air

2) Passive systems rely on stack and wind effects for moving the air and thus air flow rates are more variable than mechanical systems. It is thus more difficult to satisfy ventilation codes with passive systems.

3) Fresh air from outdoor needs to be tempered (preheated) before entering the house.

4) Passive systems are prone to reversed flow if other exhaust systems are operating.

Despite these drawbacks, passive ventilation systems have found acceptance in northern Canada. Continued research is underway to assess the effectiveness of these types of systems in terms of ensuring adequate air quality.

## 5. Performance Criteria

Criteria have been developed to allow the performance of ventilation and heat recovery systems to be compared. These are presented below:

*Technical Performance Factors*

Heat Recovery (min/max/seasonal)

Supply/Exhaust Flows (various climatic conditions)

Supply/Exhaust Temperatures (various climatic conditions)

Air Distribution

Indoor Air Quality (various climatic and occupant conditions)

Interaction (pressures) with other systems (furnace, fireplace)

Operating Energy Consumption

Noise

Adaptability/response time to varying ventilation needs

(Comparative Graphs)

The primary goal of a ventilation system is to provide adequate air quality to the occupants. Occupants produce numerous pollutants in the course of their activities. These include water vapour (RH), carbon monoxide (CO) and carbon dioxide ($CO_2$) to name a few. In addition, pollutants from combustion appliances ($CO_2$), furnishings(formaldehyde), and even the environment (soil gas, radon) add to threaten the quality of the air in houses. Health and Welfare Canada has developed recommended minimum exposure guidelines for many of these pollutants. To ensure an adequate ventilation rate to houses, the 1985 National Building Code currently requires all dwelling units to be provided with a mechanical ventilation system capable of providing at least one-half air change per hour. The R2000 program (derived from ASHRAE) has developed a more comprehensive requirement for houses built under its program whereby a ventilation rate of 5 L/s must be provided to habitable rooms and 10 L/s to basements and utility rooms. In addition, kitchens must be capable of providing exhaust flow rates up to 50 L/s on an intermittent basis and 30 L/s on a continuous basis. Bathrooms must be capable of providing exhaust flow rate of at least 25 L/s to bathrooms on an intermittent basis and 15 L/s on a continuous basis. Recent field evidence suggests that these ventilation rates are sufficient to control most reasonable pollutant sources.

In an attempt to consolidate the requirements required by the 1985 Building code with those prescribed by the R2000 program and ASHRAE, a CSA Standard (F326) is currently under development in an attempt provide a comprehensive procedure for builders and designers to ensure adequate ventilation to houses as well as eliminate the potential hazards associated with combustion backdrafting and spillage. Much of the requirements are based on ASHRAE recommendations combined with research on combustion backdrafting.

## *Economic Performance Factors*

Capital Cost

Installation Cost

Operating Cost

Maintenance Cost

Payback

(Tabular Summary)

The three main issues in evaluating the economics of various ventilation systems are heat recovery(how much of the fresh air supply needs to be heated by the heating system), operating cost(how much does it cost to provide the ventilation), maintenance costs(including factors such as rebalancing, cleaning, motor and fan reliability, spare parts costs). In general, dedicated ventilation systems have been targeted at the super energy efficient (R2000) houses. The most predominant system installed has been the HRV. Heat recovery efficiencies are typically in the order of 80%. In mainstream Canada, where electrical rates are reasonable, these systems have been shown to be cost effective in providing controlled ventilation. Maintenance costs have not been significant to date but current, third generation HRV's have only been in place for a few years. However, in areas with high electrical rates and limited access to qualified maintenance personnel, the economics of HRV's are less attractive. Passive approaches have been found to be more appealing to builders from an installation perspective, capital cost and maintenance cost. Given a zero rate of heat recovery weighed against higher electrical costs, definitive data on the net cost of passive systems to provide ventilation (from a heating standpoint) compared to mechanical systems is still needed. In addition, concerns of whether current passive designs provide an adequate level of air quality throughout the heating season (especially in the shoulder seasons) also needs to be addressed.

*Appropriateness Performance Factors*

Compliance with codes

Constructability/Damageability

Installation Skills Required

Maintenance Skills Required

Defeatability

Consumer Friendliness/Ease of Use for Intended Market

Mechanical systems may vary in sophistication from single fans, to balanced systems such as HRV's to Heat Pump/Heat Recovery Systems. As with any product, market acceptance varies depending on skills available to install and maintain the product, resources available educate users and level of education of the end user. Mechanical systems such as HRV's are only now becoming accepted by consumers, primarily due to an increased level of understanding by installers to ensure proper commissioning of the systems and consumers in understanding the reasons for ventilation. In more remote and northerly regions, qualified trades are not as available and either positive pressure or negative pressure mechanical systems are more dominant. The concept of a single fan supplying fresh air and/or exhausting stale air is more easily understood by installers and homeowners. Repair of such systems can be easily tackled by the homeowner or maintenance person. Passive systems are even more attractive because there are no moving parts and virtually no skills are required to install or maintain the system. In areas of unreliable electricity(power surges,blackouts), mechanical systems are inappropriate unless special measures are taken to protect motors or provide battery backup to the system, all of with add to the cost and complexity of the system. Passive system on the other hand are not dependent on the variability of power. Equally popular in some of the more remote communities is the concept of opening a window or door in winter to provide adequate ventilation. All the best intentions of a sophisticated ventilation system in this case "go out the window". Thus, the level of sophistication of the ventilation system must be tailored to the lifestyle of the market it is intended for.

## 6. Codes and Standards

The following codes and standards apply to Ventilation

National Building Code-Part 6 and Part 9

R2000 Ventilation Guidelines: Energy Mines and Resources/R2000 Program

CAN/F326-M: Residential Ventilation Requirements-Draft Standard

American Society of Heating and Refrigeration Association (ASHRAE):...

## 7. Resources and Contacts

Peter Russell, CMHC

NWTHC-Passive systems

Fibreglass-HPHR

HRV Manufacturers: Nutech, Air Changer, VanEE

## 8. Annotated Bibliography

Combustion Backdrafting Reports

Dynamic Wall

Maritime Ventilation report

Passive Ventilation Reports-Shaw

Passive Ventilation reports-UK

HRV Reports-ORF-R2000

# Section 7: Ventilation and Heat Recovery

## *Fact Sheets*

# Fact Sheet 7B1

# Ventilation and Heat Recovery

## Alternative Ventilation Strategies

**Date of this Fact Sheet:** 01/09/88

### Project:
Alternative Ventilation Strategies for the North (a subset of a more comprehensive heating/ventilation demonstration project)

### Status:
On-going Research

### Location:
Latham Island-Yellowknife,NWT

### Consultant:
Ferguson, Simek, Clark, Architects & Engineers
Yellowknife, NWT

### Technical Contacts:
Dick Bushell, NWTHC

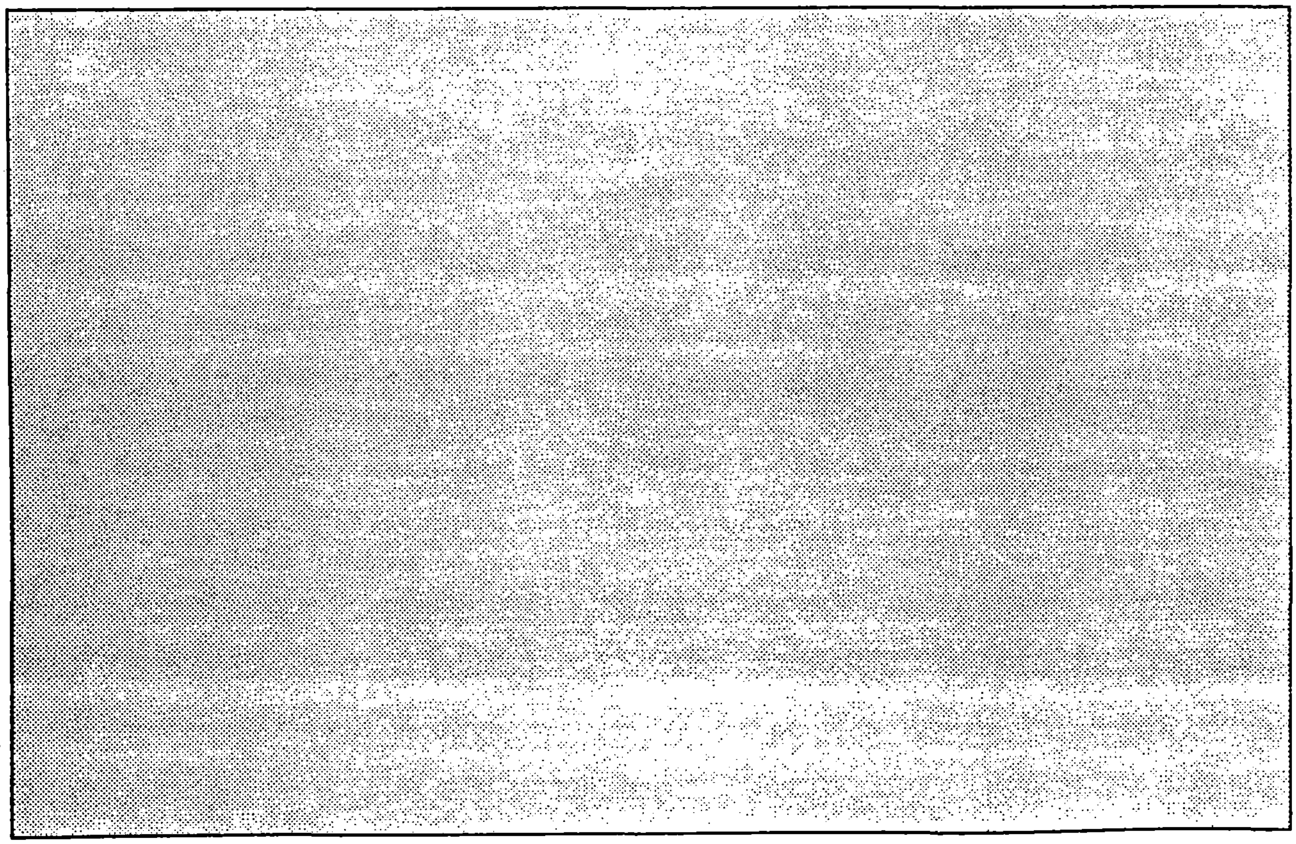
Rob Duncan,CMHC

Robin Sinha, CMHC

Dana Ferguson, FSC

### Manufacturers:
ABS Pipe
Nutech
Kantherm
Air Changer

### Relevant Publications



# Fact Sheet 7B1

# Ventilation and Heat Recovery

## Alternative Ventilation Strategies

### Background:

### Project Summary:

A comprehensive monitoring project investigating mechanical and passive ventilation strategies for the north was conducted in 2 adjacent duplexes.

The following systems were installed

1) A Kantherm air to air heat exchanger from Sweden.

2) A Nutech HRV and a Air Changer HRV

3) Passive ventilation system as designed by NWTHC

4) A hybrid approach wherein heating and ventilation are integrated into a single system.

Real time data were collected over the 1987/88 heating season. System supply and exhaust temperatures and flows were measured. Performance of the building environment(room temperatures and relative humidities) were also measured and the performance of each system will be compared. A preliminary economic analysis as well as an assessment of the appropriateness of each of the systems for northern and remote applications is planned.

### Technical Performance

Heat Recovery (min/max/seasonal)

Supply/Exhaust Flows (various climatic conditions)

Supply/Exhaust Temperatures (various climatic conditions)

Air Distribution

Indoor Air Quality (various climatic and occupant conditions)

Interaction (pressures) with other systems (furnace, fireplace)

Operating Energy Consumption

## Alternative Ventilation Strategies

Noise

Compliance with codes

Adaptability/response time to varying ventilation needs

(Comparative Graphs)

### Cost Performance

Capital Cost

Installation Cost

Operating Cost

Maintenance Cost

Payback
(Tabular Summary)

### Appropriateness

Constructability/Damageability

Installation Skills Required

Maintenance Skills Required

Defeatability

Consumer Friendliness/Ease of Use for Intended Market

### Conclusions

# Fact Sheet 7B2

# Ventilation and Heat Recovery

## Field Monitoring of HRV's

**Date of this Fact Sheet: 01/09/88**

**Project:**
Field monitoring of four HRV's in Iqaluit, NWT

**Status:**
On-going Research

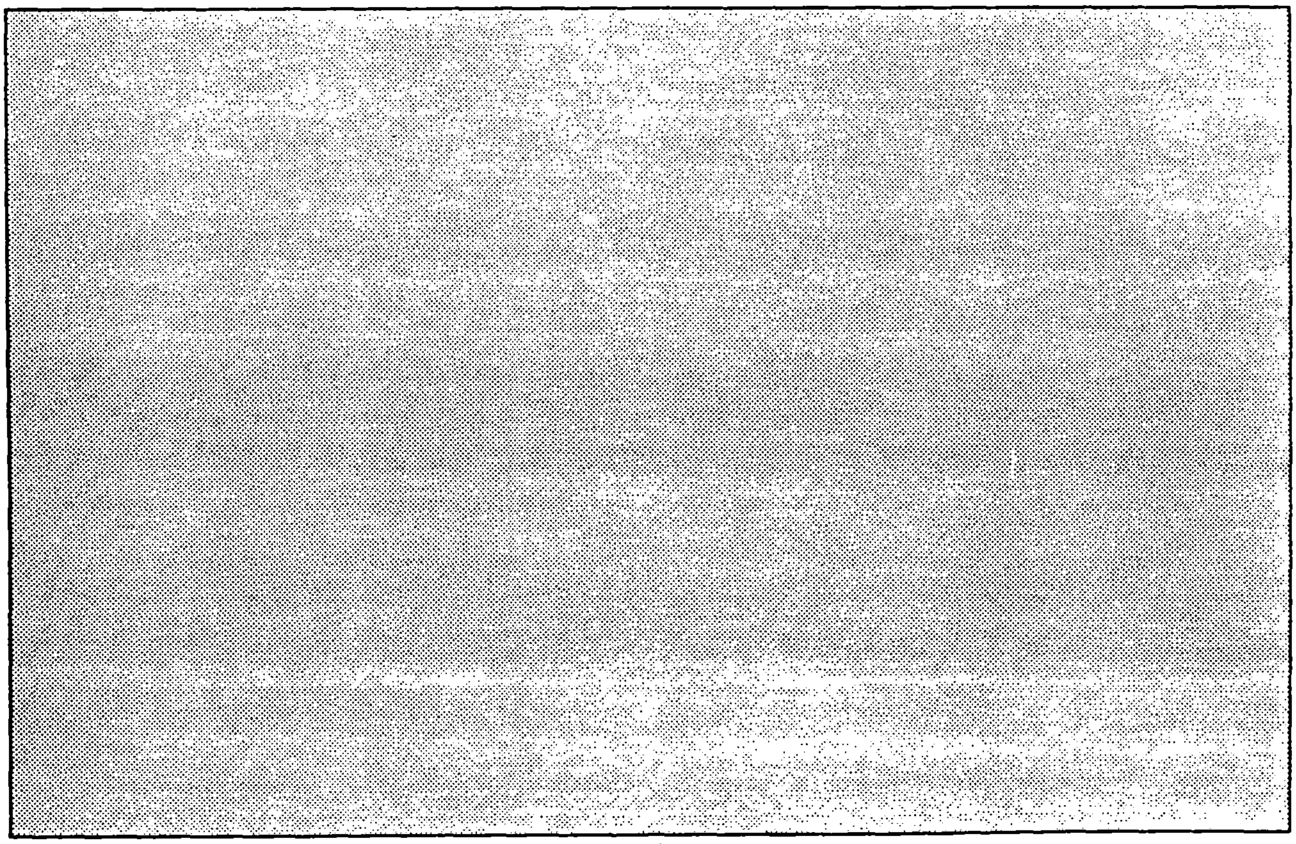
**Location:**
Iqaluit,NWT

**Consultant:**
Ferguson, Simek, Clark

**Technical Contacts:**
Rob Duncan,CMHC
Robin Sinha, CMHC
Dana Ferguson, FSC

**Manufacturers:**
Clawsey Short
Nutech
VanEE
Air Changer

**Relevant Publications**



# Fact Sheet 7B2 — Ventilation and Heat Recovery

## Field Monitoring of HRV's

### Background:

### Project Summary:

Four HRV's were installed. one in each unit of a new fourplex, and monitored during the 1987/88 heating season.

The Iqaluit experiment was intended to demonstrate HRV's under extreme winter conditions made up of extreme and extended cold periods and white out conditions (blowing fine snow). The following systems were installed;

1)A Clawsey Short Air Exchanger.

2)A Nutech HRV

3)An Air Changer HRV

3)A VanEE HRV

Real time data was collected over the 1987/88 heating season. System supply and exhaust temperatures and flows were measured. Performance of the building environment (room temperatures and relative humidities) were also measured and the performance of each system will be compared. The performance of the building environment was monitored for periods with the HRV's turned on and off. A preliminary economic analysis as well as an assessment of the appropriateness of each of the systems for northern and remote applications is planned.

(Schematic Drawings and technical specifications of the four systems)

### Technical Performance

Heat Recovery(min/max/seasonal)

Supply/Exhaust Flows (various climatic conditions)

Supply/Exhaust Temperatures (various climatic conditions)

Air Distribution

## Field Monitoring of HRV's

Indoor Air Quality (various climatic and occupant conditions)

Interaction (pressures) with other systems(furnace,fireplace)

Operating Energy Consumption

Noise

Compliance with codes

Adaptability/response time to varying ventilation needs

(Comparative Graphs)

### Cost Performance

Capital Cost

Installation Cost

Operating Cost

Maintenance Cost

Payback

(Tabular Summary)

### Appropriateness

Constructability/Damageability

Installation Skills Required

Maintenance Skills Required

Defeatability

Consumer Friendliness/Ease of Use for Intended Market

### Recommendations

Fact Sheet 7B4

# Ventilation and Heat Recovery

## RH-Based Demand Control Ventilation

**Date of this Fact Sheet: 01/09/88**

**Project:**
Demonstration of RH based Demand Control Ventilation

**Status:**
On-going Research

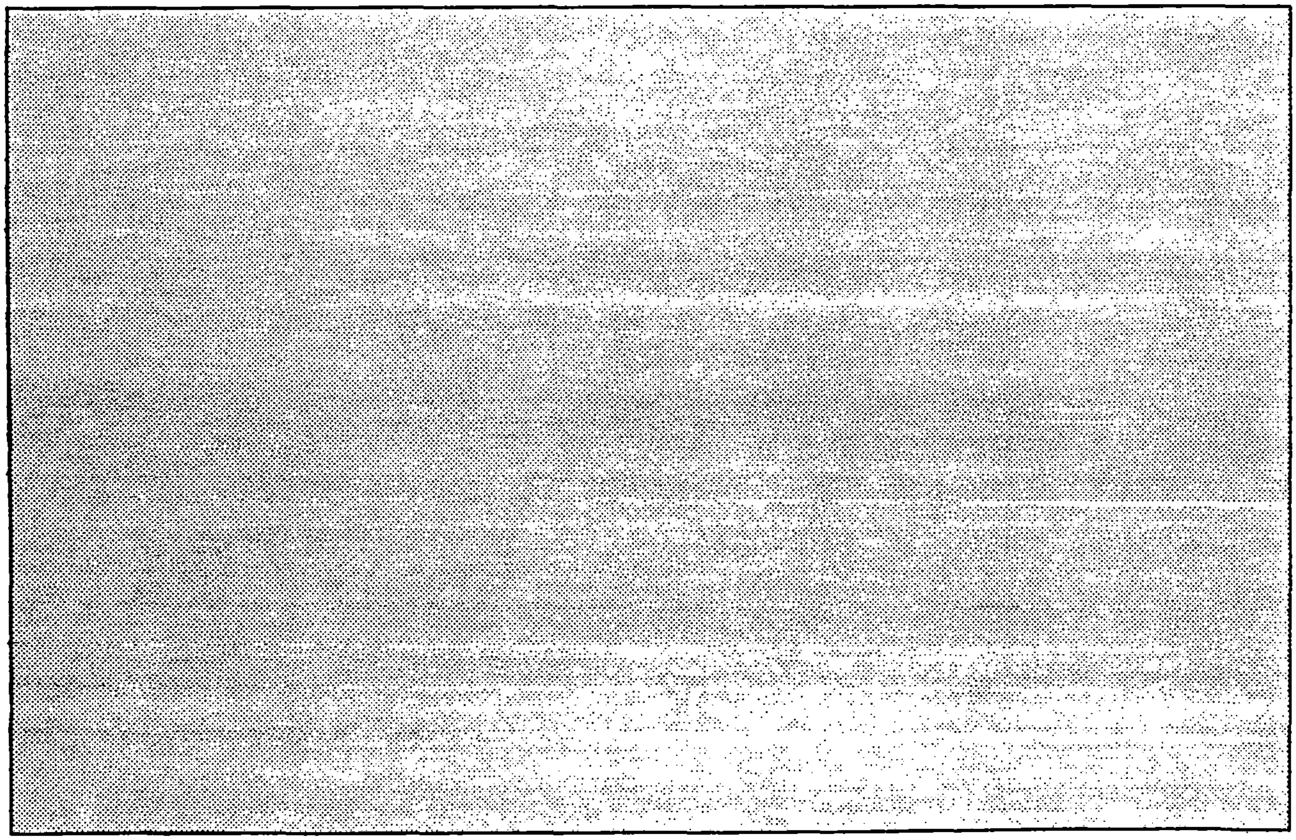
**Location:**
Yellowknife, NWT

**Consultant:**
Ferguson, Simek, Clark

**Technical Contacts:**
Rob Duncan, CMHC
Robin Sinha, CMHC
Dana Ferguson, FSC
Dick Bushell, NWTHC

**Manufacturers:**
AERECO

**Relevant Publications**



# RH-Based Demand Control Ventilation

## Background

## Project Summary

AERECO has developed a range of products intended to control ventilation rates in houses using indoor RH as the indicator of adequate ventilation. A project is underway to apply these RH based products to passive ventilation systems installed in NWTHC housing. Two duplexes will be made available. In one duplex, RH based supply and exhaust grilles will be installed over existing passive ventilation supply and exhaust inlets. Stack effect will provide the motive force for supply and exhausting air. The ELA of the supply and exhaust inlets depends on the RH in the vicinity of the supply or exhaust grille. The results of this approach will be compared to a standard passive ventilation system in the adjacent unit of the duplex.

In the second duplex, one unit will be installed with the same RH based supply and exhaust grilles as the first duplex except the exhaust grille will also include a low power(36 Watts) exhaust fan. The fan will run continuously, flow being modulated based on the RH in the house(ELA of the supply and exhaust grilles varying depending on indoor RH).

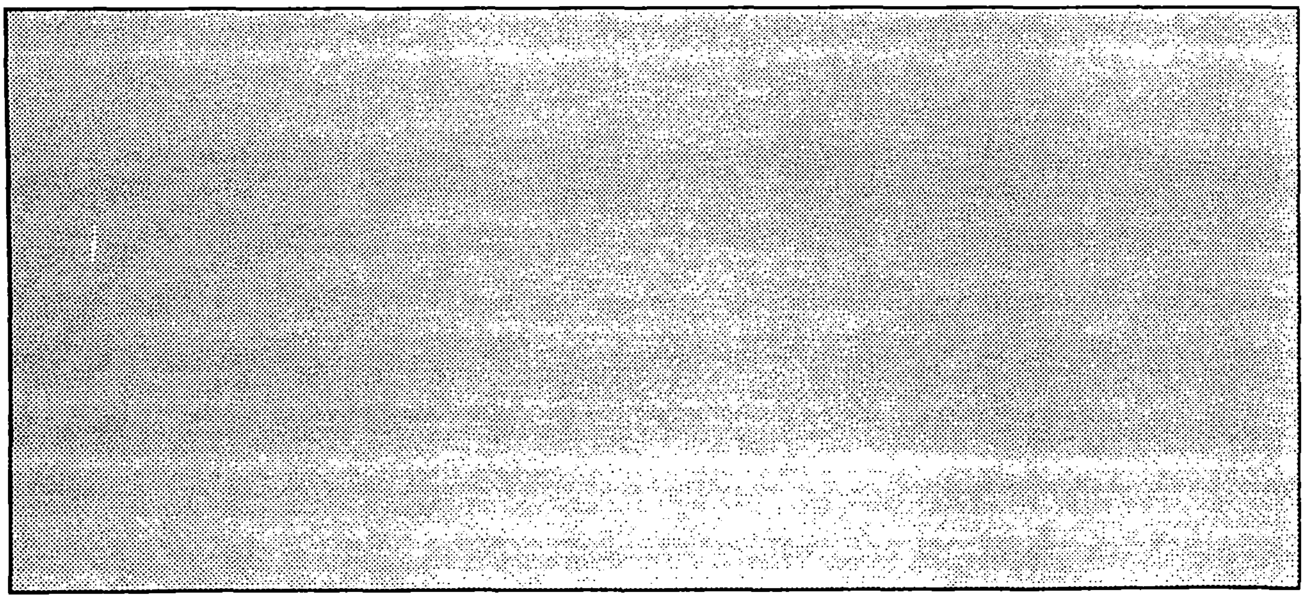
Real time data will be collected over the 1988/89 heating season. System supply and exhaust temperatures and flows will be measured. Performance of the building environment(room temperatures and relative humidities) will also be measured along with real time collection of CO2. Each strategy will be compared. A preliminary economic analysis as well as an assessment of the appropriateness of each of the strategies for northern and remote applications is planned.

(Schematic Drawings and specifications of RH grilles and fans)

## Technical Performance

Heat Recovery (min/max/seasonal)

Supply/Exhaust Flows (various climatic conditions)



# RH-Based Demand Control Ventilation

Supply/Exhaust Temperatures (various climatic conditions)

Air Distribution

Indoor Air Quality (various climatic and occupant conditions)

Interaction (pressures) with other systems (furnace,fireplace)

Operating Energy Consumption

Noise

Compliance with codes

Adaptability/response time to varying ventilation needs

( Comparative Graphs)

## Cost Performance

Capital Cost

Installation Cost

Operating Cost

Maintenance Cost

Payback

(Tabular Summary)

## Appropriateness

Constructability/Damageability

Installation Skills Required

Maintenance Skills Required

Defeatability

Consumer Friendliness/Ease of Use for Intended Market

## Recommendations

# Fact Sheet 7B7

# Ventilation and Heat Recovery

## Low Temp. Lab Evaluation of HRV's

**Date of Fact Sheet: 03/09/88**

**Project:**

Low (-40C) Temperature Lab Evaluation of HRV's

**Status:**

Laboratory setup nearly complete

Testing planned in March/April

If timing allows, possibly replace existing HRV's that are currently being monitored with new systems.

**Location:**

Toronto

**Consultant:**

ORF

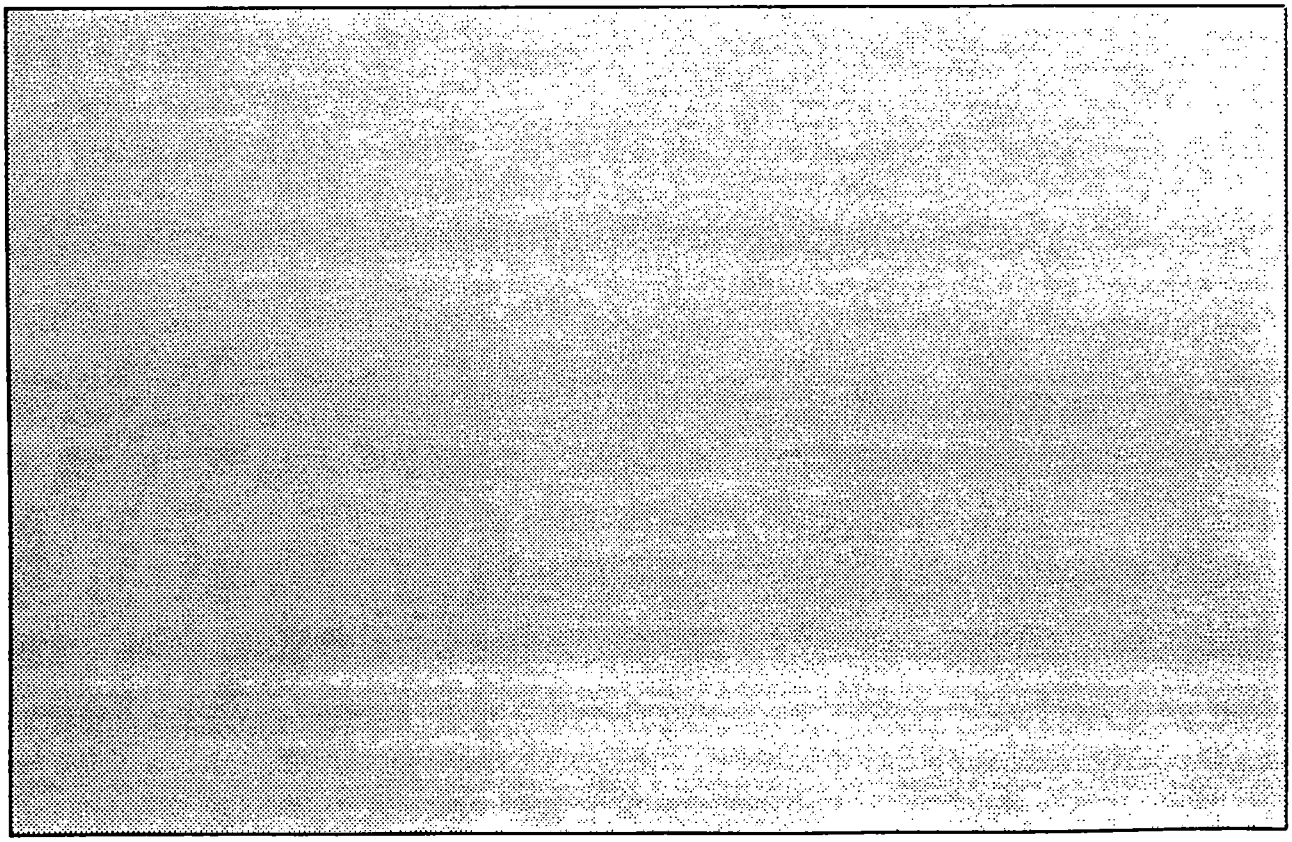
Technical Contacts:

Mark Riley, EMR

Rob Duncan, CMHC

**Funding:**

EMR



# Low Temp. Lab Evaluation of HRV's

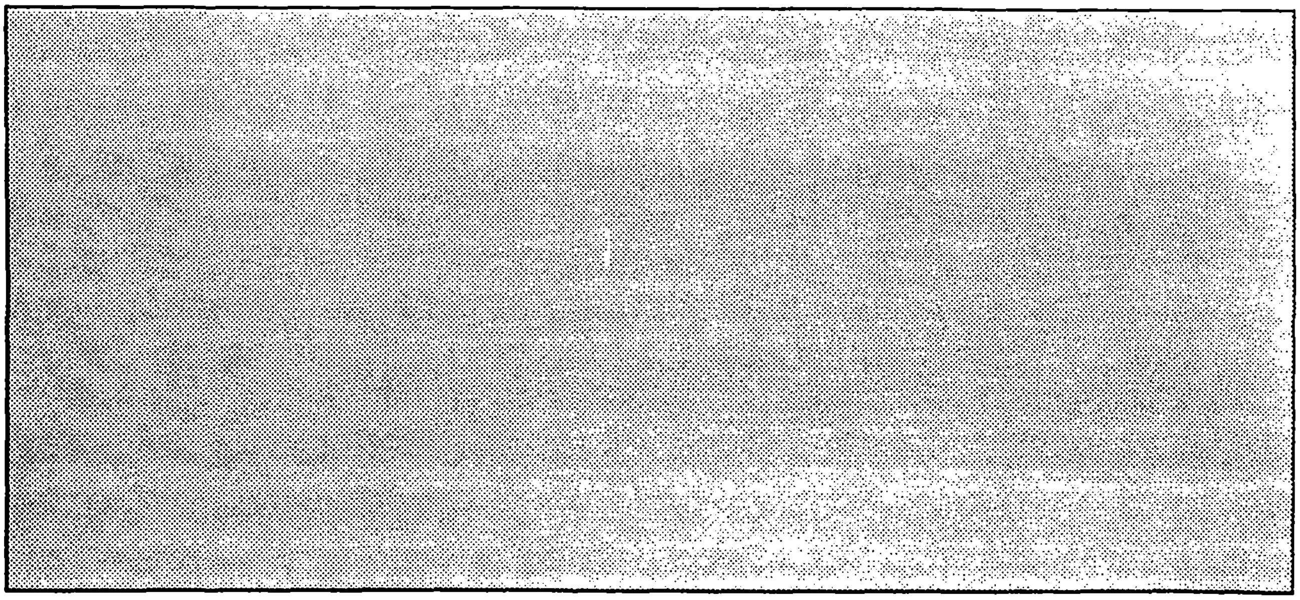
## Background

Several HRV manufacturers were invited to develop new or redesign existing HRV systems to resolve the problems associated with the harsh north climate. Areas of concern were lower powered fans improved methods that would reduce the incidence of core freeze up. Performance will be evaluated by ORF in controlled laboratory conditions.

## Project Summary:

## Performance to Date

Three HRV's have so far passed the tests.



# Section 8: Water and Sewerage Systems

*Reference*

## 1. Background

## 2. Performance Criteria

*Technical Performance*

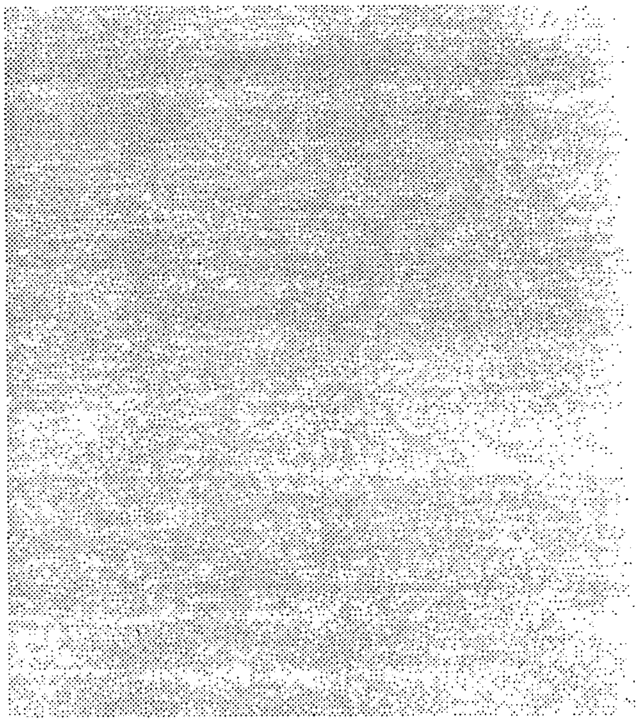
*Cost*

*Appropriateness*

## 3. Systems

## 4. Resources and Contacts

## 5. Annotated Bibliography



## 1. Description

## 2. Extent of Application

## 3. Performance

*Technical*

*Economic*

*Appropriateness*

## 4. Typical Details and Specifications

## 5. Relevant Codes and Standards

# Section 9: Electrical Systems

*Reference*

## 1. Background

## 2. Performance Criteria

*Technical Performance*

*Cost*

*Appropriateness*

## 3. Systems

## 4. Resources and Contacts

## 5. Annotated Bibliography

# PART III: RESOURCE LISTS

## TECHNICAL CONTACTS

Joe Solowy,
Project Manager,
NWTHC - Construction,
P.O. Box 2100,
Yellowknife, NWT,
X1A 2P6

Dick Bushell,
Design/Development Manager,
NWTHC - Construction,
P.O. Box 2100,
Yellowknife, NWT,
X1A 2P6

Norman Ridgley,
VP, Construction Development.
NWTHC,
P.O. Box 2100,
Yellowknife, NWT.
X1A 2P6

John Soderberg,
Manager,
Canada Mortgage and Housing Corporation,
P.O. Box 2460,
Yellowknife, NWT,
X1A 2P8

Russ Aklin,
Canada Mortgage and Housing Corporation,
3106 - 3rd Avenue, Suite 402,
Whitehorse, Yukon,
Y1A 5G1

Colin O'Neill
Canada Mortgage and Housing Corporation,
3106 - 3rd Avenue, Suite 402,
Whitehorse, Yukon,
Y1A 5G1

Rob Duncan,
Project Manager,
Project Implementation Division.
Canada Mortgage and Housing Corporation.
682 Montreal Road,
Ottawa, Ontario, K1A 0P7

Robin Sinha,
Project Manager,
Project Implementation Division,
Canada Mortgage and Housing Corporation,
682 Montreal Road,
Ottawa, Ontario, K1A 0P7

Tom Hamlin,
New Housing Division,
Energy, Mines & Resources,
580 Booth Street,
Ottawa, Ontario,
K1A 0E4

Ray Deblasi,
Regional Operations,
Energy, Mines & Resources,
580 Booth Street,
Ottawa, Ontario,
K1A 0E4

Eric Scheuneman,
New Housing Division,
Energy, Mines & Resources,
580 Booth Street,
Ottawa, Ontario,
K1A 0E4

Mark Riley, Coordinator,
New Housing Division,
Energy, Mines & Resources,
580 Booth Street,
Ottawa, Ontario,
K1A 0E4

Aldyth Holmes,
Remote Community Demonstration Program,
Energy, Mines & Resources,
460 O'Connor Street,
Ottawa, Ontario,
K1A 0E4

John Butler,
CREO Technical Officer,
10th Floor, Precambrian Building.
4922 - 52nd Street.
Yellowknife, NWT,
X1A 2N1

Lynn Conrad,
CREO,
10th Floor, Precambrian Building.
4922 - 52nd Street,
Yellowknife, NWT,
X1A 2N1

Vic Enns,
CREO, Energy, Mines & Resources,
2078 - 2nd Avenue,
Whitehorse, Yukon,
Y1A 1B1

Bill Miller,
Lands and Housing Branch,
Yukon Community & Transportation Services.
P.O. Box 2703,
Whitehorse, Yukon,
Y1A 2L6

Oliver Drerup,
Canadian Home Builders Association,
Suite 702, 200 Elgin Street,
Ottawa, Ontario,
K2P 1L5

Danny Reid,
CHBA/R2000 NWT Program,
5004 - 54th Street,
Northern United Place,
Yellowknife, NWT,
X1A 2R6

Wayne Sippola,
CHBA/R2000 Yukon Program,
2078 - 2nd Avenue,
Whitehorse, Yukon,
Y1A 1B1