Canada Mortgage and Housing Corporation
Société canadienne d'hypothèques et de logement

#4621

# INDOOR AIR QUALITY INITIATIVES

# AT CMHC

# 1980 - 1990

This document provides a summary of the activities of Canada Mortgage and Housing Corporation in indoor air quality. Included is the rationale for CMHC's involvement and a general overview of the Corporation's approach. Major research themes are outlined, with a more detailed description of past, current and planned research projects provided in an appendix. CMHC's initiatives in information transfer and policy development are also included.

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Canada

## INTRODUCTION

While concern over the global environment is currently foremost in the minds of the public and the media, the indoor environment also can have an impact on human health. In a recent study of the relative risk of environmental problems, the U.S. Environmental Protection Agency determined that indoor air pollution and indoor radon were the two most serious threats to health. It has been estimated that 10-15% of respiratory diseases and 5-20% of lung cancers could be caused by pollutants in the indoor air.

Although indoor air pollution is often regarded as a "modern" problem, many aspects of it have historical roots. In the workplace, miners relied upon canaries to determine the safety of mine shaft air, while in the home, unvented combustion gases from cooking and heating likely contributed to shortened lifespans. Radon gas undoubtedly affected even the cave dwellers of thousands of years ago. Our traditional fondness for "fresh air" has been proven in studies to have a physiological, as well as psychological, basis.

However, while poor indoor air quality may have a long history, there have been four factors which have progressively focussed more attention on this problem during the past 15 years. Firstly, increasing use of synthetics in building materials, furnishings and consumer products has led to the entry of volatile chemical compounds into the indoor air. Secondly, the energy crisis of the 1970s led to buildings becoming more airtight, thereby reducing the rate of air change and the dilution of contaminants. Thirdly, recent developments in sensor technologies now allow the detection of much lower levels of indoor air pollutants. Fourthly, there is increasing documentation of negative health effects from exposure to indoor pollutants.

Today, the public is being made more aware of the risks of poor indoor air quality, not just in industrial environments, but also in office and home environments. Terms like "sick building syndrome", "building related illness", "environmental sensitivity", "toxic lands" and "offgassing" are becoming commonplace. However, despite increasing media coverage, it has often been difficult for the public to gain a sense of perspective.

Of the 100,000 chemicals in use, accurate health data exists for only a handful, and are usually based on high exposure levels over short periods, rather than on long term exposure to low levels of pollutants. Synergistic effects and the difficulty of determining actual exposures represent other compounding factors. Buildings are not precision instruments, but rather have been found to be extremely variable in their performance. The exact cause of IAQ complaints has often been elusive. There is insufficient data on material emissions. The interaction of air, moisture, pollutants and energy within buildings can be extremely complex. Mechanical systems designed to improve indoor air quality may in fact be one of the sources of the problem.

Clearly, there is a need for further research in both health effects and building science, and also a need to provide sound advice on improving indoor air quality to a wide spectrum of audiences.

## WHY IS CMHC INVOLVED IN INDOOR AIR QUALITY?

Canada Mortgage and Housing Corporation has been active in many aspects of residential indoor air quality (IAQ) since the early 1980s. The following outlines some of the initial reasons prompting this involvement.

**Importance of Residential Environments on Health:** Concern over the indoor environment initially concentrated on the workplace, since the assumption was made that workers would be returning to a "clean" environment in their homes. Many studies subsequently found that levels of certain pollutants in homes could be as high or even higher than in work environments. In a cold climate such as Canada's, a very large portion of our non-working hours is spent in our homes. This is particularly true for those segments of the population whose health is most fragile, such as the very young, the elderly and the infirm.

**The Need for Building Science and Housing Expertise:** While the effect of indoor air quality is primarily a health issue, the solution is primarily a building science issue. Improving IAQ in housing has been particularly problematic for a number of reasons: individual housing units are extremely variable; low-rise house construction is especially vulnerable to certain pollutant sources such as the soil and combustion systems; the housing industry is extremely fragmented and decentralized; regulatory approaches take a very long time to impact the existing stock; and the level of homeowner awareness is low. As the federal government's housing agency, CMHC believed that its expertise in both housing and in building science placed the Corporation in a unique role to make a significant contribution to residential IAQ work.

**Impact of Energy Conservation Measures:** Some of the energy conservation measures initially undertaken in the 1970s and early 1980s, in both new and retrofitted housing, did not adequately take into account the impacts on other aspects of the house performance. As a result, energy efficiency unfortunately came to be associated with air quality and moisture problems. CMHC became involved in indoor air quality as part of its "systems" approach to housing technology and energy efficiency.

**Canada's IAQ Exposure Guidelines:** In 1981, the Federal-Provincial Advisory Committee on Environmental and Occupational Health created a working group to develop recommendations for 18 hazardous substances found in residential environments. This work culminated in 1987, with the release of the "Exposure Guidelines for Residential Indoor Air Quality", making Canada the first country to have such guidelines. CMHC's research in the 1980s sought to complement the health-related studies of the working group by identifying the building science involved, gathering data on pollutants levels in Canadian housing, determining the sources and developing practical remedial measures.

In addition to the above, several additional factors have emerged in the latter half of the 1980s which have reinforced the importance of CMHC's role in indoor air quality.

**Environmental Sensitivity:** The plight of the environmentally sensitive has recently been recognized by Finance Canada as a valid disability eligible for federal tax credits. Similarly, CMHC has modified its Residential Rehabilitation Assistance Program (RRAP) to provide financial assistance for renovation work necessary to make existing homes more habitable for environmentally sensitive occupants. Research has been required to determine the most cost-effective measures.

**Toxic Lands:** There has been increasing concern over housing on or near "toxic lands", such as garbage dumps, landfills and former industrial sites. CMHC has been particularly concerned over the potential impact on its mortgage insurance operations, social housing programs and land development activities. Research on methods of protecting housing from hazards in the soil has therefore been required.

**Canada's New Radon Guideline:** Late in 1988, a Federal-Provincial Advisory Committee agreed upon a guideline for radon levels in Canadian homes. The guideline indicates that since there is some risk at any level, homeowners may wish to reduce radon "to levels as low as practicable". Research has been required to provide homeowners and contractors with accurate information, and to ensure that radon remedial measures do not adversely affect other aspects of house performance.

**Link Between Moisture Problems and Health:** CMHC has been made aware that preliminary findings from the 1988 "Canadian Indoor Air Quality and Health Study", undertaken by Health and Welfare Canada, have indicated a strong correlation between respiratory disease and dampness in housing. This result has corroborated similar findings from studies undertaken in Holland, Scotland and the USA. It is suspected that mould is the major villain. These findings have led to a renewed emphasis on CMHC's extensive moisture research, in order to develop solutions to perennial moisture and mould problems in housing.

**Responsiveness to the Housing Industry:** CMHC has always been an active participant on the Technical Research Committee of the Canadian Home Builders' Association, and has attempted to make its research responsive to the industry. Since the mid-1980s, ventilation and indoor air quality have been major concerns for the industry, and CMHC has targetted much of its research to addressing these concerns.

**Sustainable Development:** Growing concern over the future of the global environment has fostered an interest in applying the principles of "sustainable development" to housing. This will undoubtedly lead to a renewed emphasis on energy conservation which, if not undertaken properly, may worsen indoor air quality in homes. A recent survey has confirmed that new housing is already 30% more airtight than housing built in 1982. Research has been required to determine optimum relationships among energy efficiency, ventilation and air quality.

## CMHC'S APPROACH TO INDOOR AIR QUALITY RESEARCH

**Goals and Objectives:**

CMHC's overall objective in housing technology research has been to develop an understanding of housing performance, especially at the systems level, in order to provide advice to others. The Corporation's current research activities on indoor air quality focus on the following specific goals:

- To determine ways of reducing pollutant sources in homes;
- To find ways of minimizing the spillage of combustion gases into the indoor environment;
- To minimize the risk from toxic lands;
- To determine methods of protecting homes from radon gas, in a manner which does not negatively affect other components of the house;
- To identify cost-effective solutions for the environmentally sensitive;
- To develop construction and retrofit techniques for the control of moulds in housing;
- To work with the housing industry to develop cost-effective, controllable ventilation systems; and
- To effectively disseminate the results of this research to the housing industry, regulatory agencies, housing officials and the public.

**The Need for a "Systems" Approach:**

A fragmented approach to indoor air quality may solve one problem while creating others. An example would be a homeowner who installs a powerful exhaust fan to remove cigarette smoke from the indoor air, and inadvertently depressurizes the house to the point where additional radon is drawn into the basement and combustion gases spill from the furnace.

CMHC's research work attempts to examine the house as a complex system of inter-related components, and to consider the relationships between the building envelope, the mechanical systems, the outdoor environment, the soil, the occupants and the indoor environment.

**A Comprehensive Approach:**

CMHC's directed research program has involved an integrated approach to IAQ, including field surveys to identify problems, theoretical studies, computer modelling, laboratory testing, field testing of solutions, and a variety of technology transfer activities. While some field work and theoretical analysis has been undertaken directly by CMHC staff, the majority has been

contracted through a competitive process to external consultants and to other agencies.

In addition to directed research, CMHC also makes funding available through its responsive research programs. The Housing Technology Incentives Program (HTIP) provides grants to assist the development of new products and technologies. The External Research Program (ERP) provides grants to external researchers on a broad range of housing issues. The Scholarship Program provides funding to graduate students undertaking housing-related studies. These programs have funded projects dealing with indoor air quality to complement the directed research program.

**Collaboration With Other Agencies:**

In recognition of the inter-disciplinary nature of indoor air quality, CMHC collaborates actively with other research agencies. Financial support and staff expertise have been contributed to projects led by Health and Welfare Canada, the National Research Council, and Energy Mines and Resources Canada.

In 1987, CMHC initiated the "Working Group on Residential Indoor Air Quality", as part of the activities of the National Housing Research Committee, in order to facilitate increased cooperation. This Working Group includes most of the major actors in Canadian IAQ research, and has the objectives of identifying issues and priorities, sharing information, and encouraging joint ventures.

The Corporation participated in the Subcommittee on Indoor Air Quality of the Interdepartmental Committee on Toxic Chemicals prior to the Subcommittee's disbanding in 1987.

In 1989, CMHC researchers provided technical information to staff from Finance Canada to assist them in developing their policy on tax credits for the environmentally sensitive. Increasing dialogue is also taking place with Health and Welfare Canada with respect to environmental sensitivity.

CMHC endeavours to collaborate closely with the housing industry in its IAQ and ventilation work, and is particularly active on the Technical Research Committee of CHBA and on the Ventilation Steering Committee of the Heating, Refrigerating and Air-Conditioning Institute (HRAI). CMHC staff are active on numerous codes and standards committees.

## RESEARCH ACTIVITIES

CMHC's research activities in indoor air quality can be organized under the following seven theme areas:

- combustion spillage
- surveys, sampling techniques, material emissions and general studies
- toxic lands, soil gas and radon
- environmental sensitivity
- low-rise ventilation
- high-rise ventilation
- IAQ and ventilation in northern and remote housing

Also of significance is CMHC's extensive work in moisture, which is discussed in a later section under "Related Research".

The following provides a brief summary of the major issues involved in these seven themes, the thrust of CMHC's research, and the key audiences being reached. A detailed listing of past, current and planned projects can be found in the Appendix.

### Combustion Spillage

CMHC's initial research in the area of indoor air quality involved applying a systems approach to the problem of combustion venting. This has been an area which has consumed considerable resources, and in which CMHC has developed an expertise which is now recognized internationally.

A study in the early 1980s confirmed that a major cause of carbon monoxide poisonings was the spillage of combustion gases into the house from improperly vented heating applicances. Other combustion gases, such as nitrogen oxides, sulfur dioxide and polycyclic aromatic hydrocarbons (PAHs), also present significant health hazards. Increased airtightness, powerful exhaust fans and a lack of proper provision of make-up air can combine to depressurize the house interior to the point where reliance on natural draft to exhaust combustion gases is unsafe. In addition, poor maintenance of equipment and chimneys can create leakage paths or block proper venting. Fireplaces are doubly problematic, in that a roaring fire can cause a furnace to spill, while a dying fire can itself spill. The utilities, building industry and the public have been largely unaware of the seriousness of the problem.

CMHC has taken an exhaustive approach to resolving this problem. A series of combustion safety tests or checklists were developed and field tested to allow a relatively quick determination, without the use of sophisticated equipment, of a house's potential for spillage. A national survey of approximately 1000 homes indicated that spillage was occurring in many. Numerous field studies were undertaken in specific troubled houses, many identified in the national survey, to better understand the causes of backdrafting and spillage.

A multi-year thrust has been made to develop theoretical models for simulating the venting performance of various combustion appliances and their chimneys, including gas and oil furnaces and hot water heaters (FLUESIM), and fireplaces and wood stoves (WOODSIM). These models provide approximations of the complex physical processes involved, and have been valuable in predicting optimum system designs and configurations.

Remedial measures for existing furnaces and fireplaces have been developed and field tested. Recommendations for improved chimney design, furnace installation and make-up air have been made. Current research is extending this research to wood stoves and draft-induced furnaces, while continued work is required to address the problem of fireplaces in modern housing.

Activities are now focussing increasingly on the transfer of information to audiences such as codes and standards bodies, the Canadian Gas Association and other utilities, furnace servicemen, the Canadian Wood Energy Institute, and the public.

**Surveys, Sampling Techniques, Material Emissions and General Studies**

The trend toward greater airtightness has also raised concern over the general quality of indoor air, particularly in new, renovated or redecorated houses, where there can be considerable offgassing from materials and furnishings. Extensive or improper use of consumer products, such as cleaning agents, pest control products, solvents and hobby chemicals, can create localized health hazards. At present, not enough is known about pollutant source strengths or typical levels in Canadian homes. Sampling techniques and instrumentation developed for industrial settings are seldom appropriate for the lower levels found in housing. The control of pollutant sources is generally preferred to increased ventilation as a strategy for reducing pollutant concentrations.

CMHC's initial IAQ studies in the early 1980s were often linked with the monitoring of energy-efficient, airtight houses. "Indoor Air Pollution and Housing Technology" was one of the first major studies of residential IAQ undertaken in Canada, and in concert with a subsequent project on regulations and research information, has provided a base for CMHC's continuing activities. Projects have been undertaken which developed or identified appropriate sampling techniques for residential environments, collected data on levels of pollutants in typical housing, and examined specific IAQ problems. A current study is focussing on manufactured housing. CMHC will be providing the house characterization in support of Health and Welfare's proposed survey of volatile organic compounds in Canadian housing.

Audiences for the above work have ranged from the entire housing industry and public to specific interest groups, such as the Canadian Manufactured Housing Institute.

**Toxic Lands, Soil Gas and Radon**

Housing is particularly vulnerable to pollutants entering from the soil, due to the leakiness of typical basement construction and due to the extensive use of basements as additional living space. Radon, because of its association with increased rates of lung cancer, has caught the media's and the public's

attention, but it is merely one of a number of undesirable "soil gases" which enter the house from below grade. In the late 1980's, increasing concern has been raised over "toxic lands" containing soil contaminated by industry, waste disposal, landfills or garbage dumps. Such contaminants include methane, PCBs, various organic compounds, pest control products, lead and other heavy metals, gasoline and oils, and radioactive materials. Toxic lands are problematic because of a number of factors: pollutants can migrate to other sites via sub-surface air movement and groundwater; clean-up costs may exceed the value of the property; there is a lack of inventories of such sites; it has been difficult to assign responsibilities; and public reaction can be extreme.

CMHC has assisted in the development of various products and technologies designed to prevent the entry of radon and other soil gases into homes. Sampling techniques have been developed to facilitate the analysis of soil gas entering typical basements. Soil gas and radon surveys have been undertaken to better estimate the magnitude of the problem. Improved basement construction technologies and practices have been documented. CMHC has been able to apply its research findings in attempting to rehabilitate a CMHC-insured housing project previously abandoned due to methane entry. A major survey of housing impacted by toxic lands is underway, and further studies of remedial measures are planned.

There is a wide audience for radon and soil gas research, including the housing industry, the emerging radon "mitigation" industry, housing and financial agencies, and the public.

**Environmental Sensitivity**

Strong lobbying efforts on the part of the environmentally sensitive have led to their condition being recognized as a valid disability. However, the dilemma of how best to house such people cost-effectively remains largely unresolved. Sensitivities vary tremendously, and can range from mild allergy-like reactions to complete debilitation. Once sensitized, people may even demonstrate life-threatening reactions to otherwise innocuous or natural materials. The medical community has been divided on the causes of such sensitivities, but is become increasingly aware of the issue. The undertaking of a "total environmental assessment", to determine a person's intake of pollutants from multiple pathways, including air, water, food, soil and consumer products, is now gaining acceptance.

Through its pioneer studies in the early 1980s, CMHC was one of the first agencies to recognize the plight of the environmentally sensitive and the importance of their home environments. Research work at that time attempted to categorize housing construction materials, mechanical systems, furnishings and consumer products with respect to their suitability for sensitive occupants, and to propose alternatives for "pollution-free" housing. Current work is documenting and identifying cost-effective means of building housing for the chemically sensitive.

The major audiences for this work includes the environmentally sensitive and their associations, builders catering to this group, and agencies having programs for the disabled. It is anticipated that the audience for this

information will grow as the public and the industry become aware of the health and marketing advantages of "clean" houses.

**Low-Rise Ventilation**

Natural ventilation has been found to be too variable to be relied upon for year-round ventilation needs. The use of local mechanical ventilation, such as kitchen range hoods, can be effective in removing pollutants at their sources, while whole-house ventilation systems can ensure adequate minimum air change throughout the house. However, the combination of low quality equipment and poor installation practices has been found to reduce the air flows in most ventilation systems by more than half. The success of ventilation will be limited unless pollutant sources are also controlled; for example, a room full of smokers would require impossibly high rates of air change to minimize pollutant levels. Since the mid-1980s, Canada has been developing a ventilation standard through the Canadian Standards Association (CSA F326), but this proposed standard has proved to be controversial with the building industry, and the need for continuous, balanced ventilation is not yet accepted. There has been a need for the development and demonstration of workable ventilation solutions. Air cleaning and filtration represent additional methods of improving IAQ, but most systems currently available are either ineffective, such as a conventional furnace fan, or regarded as too expensive, such as an electrostatic precipitator.

CMHC's initial work in low-rise ventilation has involved the monitoring of various types of systems, particularly heat recovey ventilators (air to air heat exchangers). Medium efficiency filtration methods have been investigated and field tested. A device for measuring the on-site performance of ventilation equipment has been developed, and used to identify installation deficiencies. A study of make-up air strategies found that most current approaches do not work, and led to the development of a low pressure sensor to control make-up air. A national survey, undertaken in collaboration with EMR and NRC, confirmed that new housing is indeed more airtight and that the majority does not have adequate ventilation. Underway are projects which are assessing the impact of CSA's F326 ventilation standard, field testing alternative strategies which meet the intent of the standard, demonstrating various integrated heating and ventilating solutions, testing the installed performance of exhaust fans, and developing "demand-controlled" systems which can vary the rate and location of ventilation in response to pollutant levels.

The primary audience for CMHC's low-rise ventilation work has been the Canadian Home Builders' Association (CHBA), the Heating, Refrigerating and Air-Conditioning Institute (HRAI), and ventilation equipment manufacturers.

**High-Rise Ventilation**

Based on CMHC's low-rise ventilation work and on air quality studies done by other agencies in high-rise office buildings, there is reason to suspect that high-rise apartments may also have ventilation deficiencies. High-rise apartment buildings rely heavily on air leakage for fresh air. Unplanned air leakage between units and to and from service chases is suspected to be widespread. Most apartment buildings only provide ventilation air to corridors and common areas. Occupant complaints regarding temperature

fluctuations and smells are common, and suggest potential air quality problems. At present, little is known about actual air change rates, pollutant levels or the installed performance of heating, ventilating and air-conditioning (HVAC) systems. High-rise apartment buildings have therefore become a new area of IAQ research for CMHC.

CMHC is currently developing test methods for air quality sampling and for determining air flow patterns, in preparation for a survey of a representative sample of high-rise buildings. Concurrently, an industry practice survey of typical HVAC systems will determine potential problems in design, installation and maintenance. It is expected that these two thrusts will lead to the identification of future research directions.

The major audiences for this work include the Heating, Refrigerating and Air-Conditioning Institute (HRAI); local chapters of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) which brings together designers, suppliers and installers; and the newly formed network of Building Envelope Councils.

**IAQ and Ventilation in Northern and Remote Housing**

Housing in the far north and in the northern parts of provinces is subjected to more demanding conditions than in the southern, more urbanized areas of Canada. The extreme climate, combined with the costs of transporting fuel, has demanded highly energy-efficient buildings, and thereby created concern over ventilation. Due to the lack of available technical support and replacement parts, mechanical systems need to be easy to maintain and foolproof. Factors such as high occupancy loads, rigourous lifestyles (stone carving, repairing equipment, skinning, etc), the large amount of time spent indoors during long winters, and the continuous running of heating and cooking appliances, can contribute to air quality problems.

CMHC has undertaken several projects, often in collaboration with EMR and the territorial governments, on the development and field testing of ventilation systems, both passive and mechanical, which are suitable for the harsh climate. Currently underway is a major survey of indoor pollutants, including combustion gases and moulds, in social housing units in the NWT.

The major audiences for this work are the territorial housing corporations and the NORTH Committee (Northern and Remote Technology in Housing). In addition, the development of workable technologies for the north can often find applications in less extreme climates, and can be of interest to the general housing industry.

## RELATED RESEARCH THEMES

CMHC also conducts extensive work in areas of research which are closely inter-related with indoor air quality and ventilation, such as moisture, energy efficiency and envelope airtightness. By taking a "systems" approach to housing technology, CMHC researchers are identifying how changes to one aspect of the house may impact other aspects.

Moisture studies, once undertaken primarily because of the structural and cosmetic deterioration caused by moisture, are now being viewed increasingly from the perspective of controlling mould growth, which may prove to be a major health hazard. CMHC has carried out a broad program of moisture-related research since the late 1970s. This has included numerous field studies of specific moisture problems in exterior walls, attics, basements and crawl spaces; test hut monitoring to determine the performance of different wall types in different climate zones; theoretical modelling of the complex interactions of moisture, air and energy flows in walls and roofs; and the development and field testing of remedial measures. It should also be noted that much of CMHC's ventilation work has been related to moisture control.

Energy conservation measures have the potential to improve or exacerbate air quality and moisture problems. Much of CMHC's PERD-funded research has been used to examine these relationships. With the mounting concern over the global environment, there has been a renaissance of activity in energy efficiency. Under the theme of "sustainable housing", CMHC is currently undertaking various energy-related projects, and attempting to pursue its systems level approach in order to ensure that future energy conservation measures do not adversely affect the quality of the indoor environment in homes.

Closely related to energy efficiency have been CMHC's studies on the airtightening of building envelopes. While airtightening was initially promoted for the purposes of conserving energy, it is being increasingly seen as essential in preventing various types of moisture problems and in ensuring the durability of the building enclosure. In terms of indoor air quality, airtightening can reduce the infiltration of pollutants from building materials and from below grade, while at the same time increasing the need for controlled mechanical ventilation to avoid pollutant build-up. The combination of an airtight envelope and a controlled ventilation system can reduce peak ventilation rates, thereby resulting in less total energy usage.

## INFORMATION TRANSFER ACTIVITIES

CMHC has attempted to pursue an integrated approach to research and technology transfer, whereby research objectives are tied closely to the needs and problems of Canadian housing, and research results are fed directly into a dissemination network. CMHC researchers are committed to effecting change and to improving the quality of housing in Canada.

The key audiences for CMHC's work in IAQ and ventilation include:

- the housing industry: builders, renovators, trades, manufacturers, designers and utilities;
- owners and occupants;
- regulatory agencies, both Canadian and American;
- policy makers and housing agencies; and
- the Canadian and international research commmunities.

The following describes some of the more important communication vehicles and products.

**Publications**

The following four documents are primarily targetted to consumers:

How to Improve the Quality of Air in Your Home, NHA 6177 (1989): A description of the sources of typical indoor air pollutants, related health effects, methods of reducing pollutant sources, ventilation systems, air cleaning, and combustion venting safety ($2).

Guide to Radon Control, NHA 6181 (1990): Advice on the health effects of radon, test methods, and remedial and preventative measures ($2).

Moisture and Air, NHA 5968 (1983, revised 1989): A small section of this booklet on household moisture problems is devoted to mould (free).

Moisture, Mould, Your House and You (underway): Detailed advice to the householder on the causes of moisture and mould problems, related health effects, identifying the causes of such problems, and selecting appropriate preventative or remedial solutions.

The following publications are primarily targetted to the housing industry, and are often used as support materials for training and education activities described in the next section:

Performance of House Systems, NHA 6130 (1989): Advice to renovators on taking a "systems" approach to renovations in order to avoid creating additional

problems while solving others; information is included on the interrelationships among ventilation, energy efficiency, air quality, combustion venting and moisture problems ($1).

Indoor Air Quality, NHA 6069 (1988): Advice to builders on the causes and avoidance of IAQ problems in new houses; included is information on soil gas entry, formaldehyde, off-gassing from finishes, combustion appliances, particulates, mould, testing for IAQ problems and the need for homeowner education ($1).

Radon Control in New Houses, NHA 6067 (1989): Advice to builders on why radon is a problem, how radon levels are measured, and how to build radon control features into new housing ($1).

Guide to Residential Exhaust Systems, NHA 6114 (1989): Advice to builders and trades on selecting exhaust equipment and on proper installation techniques ($1).

Ventilation: Health and Safety Issues, NHA 5888 (1986, reprinted 1990): Advice to builders on the need for ventilation to remedy moisture, air quality and combustion spillage problems ($1).

Ventilation "How To" Manual for Builders and Inspectors (underway): This joint venture with the Ontario New Home Warranty Program and the Ontario Ministry of Housing is documenting the selection and installation of ventilation systems that meet the 1990 National Building Code requirements, and also identifying any upgrades necessary to meet the CSA F326 standard.

Compendium of Ventilation Projects (underway): This "Ventilation File" will document the results of numerous innovative ventilation projects completed or being undertaken by CMHC and other research agencies.

Measures for the Environmentally Sensitive (underway): Advice for builders and clients on measures which can be undertaken in new and retrofitted houses to meet the needs of the environmentally sensitive.

Renovation Hazards (underway): A summary of the health hazards encountered in various types of renovation activities, with an emphasis on air quality and respiratory problems.

Radon Remedial Measures (underway): Detailed advice on measures and related costs for radon mitigation contractors.

**Workshops and Seminars**

Builders' Workshop Series (ongoing): Sponsored by CMHC in collaboration with the Canadian Home Builders' Association (CHBA) and Association provinciale des constructeurs d'habitation du Quebec (APCHQ), the Builders' Workshop Series has provided practical advice to builders via an interactive format since 1985. Modules offered prior to 1989-90 included "Indoor Air Quality", "Ventilation: Health and Safety Issues", and "Radon Control in New Housing". This year, these have been combined, along with information on moisture problems, into a full day session entitled "Air Quality and Ventilation". From 1985 to 1989, approximately 4400 persons have attended the Workshops.

Renovators' Seminars (ongoing): Again sponsored in collaboration with CHBA and APCHQ, this series has provided both technical and business skills training for Canada's growing renovation industry. Included has been a module on "Performance of House Systems", which presents a "systems" approach to undertaking renovations, and incorporates information on ventilation and safe combustion venting.

Combustion Spillage Course for Furnace Servicemen (under development): In collaboration with the Canadian Gas Association (CGA), CMHC is developing a training course for gas and oil furnace servicemen to assist them in recognizing the symptoms of combustion spillage, identifying the causes and recommending corrective action to householders. A consumer-oriented pamphlet will also be developed for servicemen to distribute to householders.

**Indoor Air '90 Conference**

CMHC is one of the sponsors of the 5th International Conference on Indoor Air Quality and Climate, which is being held for the first time in Canada this July 29-August 3 in Toronto. CMHC's contributions have included financial assistance, office space and secretarial support for the Conference President, participation on the Conference Organizing Committee, and expert review of technical papers. Five CMHC researchers will be presenting technical papers at the Conference.

In addition, CMHC is sponsoring an evening "Public Forum" to raise the awareness of the importance of IAQ among the public and the media.

**Other Forums, Conferences and Presentations**

In order to bring together the necessary actors from throughout the housing industry, CMHC has organized special forums from time to time to present and discuss research results. Three examples have been the 1987 Gas Venting Forum, the 1988 Oil Venting Forum, and Woodfire '88 (cosponsored with EMR and the Canadian Wood Energy Institute) which provided for a wide dissemination of the findings from combustion spillage research.

CMHC staff have made numerous presentations on IAQ research at other forums and conferences. Recent examples have included:

- Wood/Gas Forum, sponsored by the Canadian Wood Energy Institute (CWEI);
- Air and Waste Managment Association (AWMA) conferences, formerly Air Pollution Control Association (APCA);
- Canadian Home Builders' Association (CHBA) annual conferences and tri-yearly meetings of the Technical Research Committee;
- Energy Efficient Builders' Association (EEBA) Conferences;
- Ontario Builders' Forum
- Canadian Real Estate Association (CREA) meetings;
- Canadian Gas Association (CGA) meetings and conferences;
- the Canada-US Bilateral Program on Housing and Urban Affairs - Seminar on Issues in Residential Energy Conservation;
- Indoor Air '84;
- Canadian Standards Association (CSA) Executive Management Committee;
- American Society for the Testing of Materials (ASTM) meetings;
- International Energy Agency (IEA) meetings;

- Affordable Comfort conferences;
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) conferences;
- school boards, hospitals and allergy associations.

CMHC exhibits at various conferences often feature IAQ and ventilation research, such as at the CHBA Conferences, the "Our World" Conference in Toronto in the fall of 1989, the "Globe '90" Conference in March 1990, and the upcoming "Indoor Air '90" Conference.

**Input to Code Committees**

It has long been recognized by CMHC that changes to building codes and standards represents one of the most effective ways of bringing about change in building practices, particularly where occupant health and safety are concerned. CMHC staff have therefore taken active roles in numerous codes and standards committees dealing with indoor air quality and ventilation.

Much of CMHC's focus has been on codes and standards development which can eliminate or reduce combustion spillage. This has included standards sponsored by the Canadian Gas Association (CGA), the Canadian Standards Association (CSA), and Underwriters' Laboratories Canada (ULC):

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| CGA B149 | Installation Code for Natural Gas Burning Appliances and Equipment (Venting Subcommittee) |
| CSA B139 | Installation of Oil Burning Equipment |
| CSA B365 | Installation Code for Solid Fuel Burning Appliances and Equipment |
| CSA A405 | Masonry Chimneys and Fireplaces |
| ULC S461 | Factory-Built Fireplaces, Chimneys and Vents |
| ULC S604 | Chimneys |
| ULC S629 | 650$^{o}$ Factory-Built Chimneys |
| NRC | Coordinating Committee on Combustion Venting |

CMHC staff have for several years played a strong role on the Canadian Standards Association F326 Committee on Residential Mechanical Ventilation Requirements; this role has included chairing its technical requirements task force.

In addition to CSA F326, participation in other ventilation-related committees has included:

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|---|---|
| CSA C260.2 | Residential Air Exhaust Equipment |
| CSA C439 | Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators |
| CSA C444 | Installation Guidelines for Heat Recovery Ventilators |

CMHC has provided financial support to the Canadian General Standards Board (CGSB) and participated in:

| | |
|---|---|
| CGSB 51.71 | Standardization of Combustion Venting Safety Tests |
| CGSB | Indoor Air Quality Test Methods |

CMHC researchers are also active on American standards bodies, an activity which is taking on increasing importance due to the potential impact of the Canada/US Free Trade Agreement:

ASTM D22.05 Indoor Air Quality Test Methods
ASTM E06.41 Infiltration Performance (includes radon)
EPA Standard on Radon

**Technical Advice and Trouble Shooting**

CMHC responds to numerous requests from the housing industry, consultants and consumers for advice on various air quality issues. Many CMHC researchers have hands-on experience in air quality testing and house inspections, and therefore occasionally follow up such requests with site visits to examine specific problems. While most problems can be solved over the telephone, site visits and field tests are occasionally required.

CMHC's expertise in residential indoor air quality is being increasingly recognized. In 1989, for example, CMHC was invited to participate in international undertakings organized by the World Health Organization and by NATO.

**Canadian Housing Information Centre (CHIC)**

CMHC maintains the largest collection of housing-related information in Canada, including considerable literature and bibliographies on indoor air quality. CHIC is the repository and distribution point for the numerous research reports generated by CMHC. By the summer of 1990, CHIC will also become the distribution point for walk-in sales of CMHC publications.

## APPENDIX: DESCRIPTIONS OF RESEARCH PROJECTS AND TECHNICAL PAPERS

The following is a description of past, current and planned research projects in indoor air quality and ventilation, and related technical papers prepared by CMHC researchers.

### Combustion Spillage

Hazardous Heating and Ventilating Conditions in Housing (1984): A joint venture study with EMR and HWC which examined the incidence of carbon monoxide poisoning. Based on reported incidents, there was found to be on average a miniumum of 14 deaths per year associated with improper venting of combustion products. The factors which could be leading to an increase in such occurences included heating equipment problems, deterioration of existing chimneys, increased airtightness without proper ventilation systems, and inadequate awareness of the problem.

Identifying Ventilation Troubled Houses (1984): A paper which examined the great variability in the airtightness of Canadian homes, and outlined the potential problems which could exist when a house's demand for air from exhaust and combustion devices exceeds the envelope air leakage flow.

Residential Chimney Backdraft Checklist: Design and Evaluation (1984): A joint venture with EMR in which a checklist for identifying potential backdraft conditions was developed, field tested and refined.

Carbon Monoxide Poisoning in Housing: Contributing Factors and Remedial Measures (1984): A paper for the Air Pollution Control Association which described the survey of CO poisoning from improper venting of combustion products and the development of the chimney backdraft checklist.

Ventilation Compliance Tests for Houses (1984): A paper for the Air Pollution Control Association which described the problem of combustion venting failure in houses and outlined requirements for on-site test procedures to determine whether individual houses could have such problems.

The Thermal and Flow Performance of Chimney Flues in Houses (1985): The development of a micro-computer based model, FLUESIM, for simulating the complex inter-relationships between the venting performance of gas and oil burning heating appliances, the envelope airtightness and other competing exhaust devices. Work included a conceptual description of the physical processes involved, developing the model framework, preliminary validation against field data, and a sensitivity analysis which highlighted areas for future combustion spillage research. (2 volumes: summary plus appendices)

Avoidance of Chimney Backdrafting in Houses: Identifying the Critical Conditions (1985: A paper for Air Pollution Control Association which summarized the issue of combustion spillage and described the work undertaken to date in developing a computer simulation model.

The Investigation of Backdrafting at 200 Linacre Road in Winnipeg (1985): A study of a house with persistent backdrafting problems identified a powerful kitchen fan as the major cause, and involved the testing of a supply air fan and duct heater as a remedial solution.

Thermal and Aerodynamic Performance of Chimney Flues: Armstrong House Field Testing, Phase 1 and 2 (1985): The venting performance of a variety of chimney types was monitored in a test house to validate the FLUESIM model.

Residential Combustion Safety Checklists (1985): Based on earlier work, two checklists were developed for tradesmen and householders, and were field tested on 20 homes. Remedial measures were also applied and evaluated.

Evaluation of System Performance by Dimensional Analysis and Determination of Key Parameters (1985): A paper which developed some of the theoretical basis for the engineering-level modelling of complex system phenomenon, such as venting performance, pollutant concentrations and moisture flow.

Evaluation of the Potential for Fuel-Fired Appliance Backdraft in Ten Houses Equipped with Whole-House Exhaust Fans (1986): Ten Nova Scotia houses underwent various depressurization tests to determine the effects of exhaust fans on the backdrafting of wood stoves and other heating appliances.

Residential Combustion Venting Failure: A Systems Approach (1987): This multi-year, multi-task study undertook a comprehensive look at the problem of combustion spillage, and resulted in 13 technical reports plus a summary report.

Vol 1, Canada-Wide Survey: Development and Testing, evaluated methods of spillage detection, and determined that optimum results could be achieved with heat-sensitive dots at the dilution air inlet of gas furnaces and hot water heaters, ionization smoke alarms for oil furnaces, and a combination of smoke and CO detectors for fireplaces.

Vol 2, Canada-Wide Survey Results, monitored approximately 1000 homes in 5 regions. 10% of gas heated homes were found to have prolonged spillage, while 65% had start-up spillage; 55% of oil furnaces had significant spillage; all fireplaces spilled to some degree.

Vol 3, Modifications and Refinements to the Flue Simulator Model, improved and expanded the capabilities of the FLUESIM computer model, and created a preliminary model for simulating wood burning fireplaces, WOODSIM.

Vol 4, Refinements to the Chimney Safety Tests: Determining House Depressurization Limits, resulted in defining the safe limits of house depressurization for different types of combustion appliances.

Vol 5, Refinements to the Chimney Safety Tests: Remedial Measures for Houses with Pressure-Induced Spillage Problems: A Prototype Guide for Contractors and Tradesmen, outlined 10 remedial strategies for combustion spillage caused by excessive house depressurization.

Vol 6, Assessing the Impact of Combustion Gas Spillage on Indoor Air Quality, identified appropriate monitoring technologies and undertook some pilot monitoring of several Vancouver houses.

Vol 7, Remedial Measures for Wood-Burning Fireplaces: A Fireplace Spillage Advisor, defined the design parameters for a fireplace spillage detector which combined both smoke and carbon monoxide detection.

Vol 8, Remedial Measures for Wood-Burning Fireplaces: Airtight Doors with Direct Air Supply, determined that the combination of airtight fireplace doors with a direct air supply to the firebox could reduce the potential of spillage, but could increase the fire hazard.

Vol 9, Remedial Measures for Gas-Fired Appliances, evaluated remedial measures and found that a retrofitted draft-inducing fan was effective at reducing spillage, while a draft-assisted chamber was only marginally effective.

Vol 10, Remedial Measures for Oil-Fired Appliances, evaluated remedial measures and found that a solenoid delay valve, a draft-inducing fan, and a comprehensive retrofit package (sealed insulated flue liner, sealed flue pipe without a barometric damper, and high pressure burner) were all effective.

Vol 11, Make-Up Air Supply Remedial Measures, found that passive make-up air inlets were generally ineffective, and that a powered supply was required to prevent pressure-induced spillage.

Vol 12, Case Studies of Houses with Combustion Gas Spillage Problems: A Follow-Up to the Canada-Wide Survey, examined 20 problem houses identified in the earlier survey, and was able to determine the cause of spillage in most through the use of the chimney safety tests. House depressurization from tight building construction and powerful exhaust fans was implicated in 75%.

Vol 13, Communications Strategy, outlined a follow-up strategy for disseminating information on combustion spillage to manufacturers, trades, consumers and government agencies.

Vol 14, Summary Report, summarized the results of the above 13 volumes.

Residential Combustion Venting Failure: A Systems Approach: A Survey of Fireplace Spillage Incidents in Twenty-Four Houses (1987): An extension of the above project found that fireplace spillage was a common occurence, and that carbon monoxide spillage was less frequent but of longer duration than smoke spillage.

The Influence of Flue Dampers on the Venting Performance of Flues (1987): Flue dampers were found to increase the possibility of backdrafting of combustion appliances, especially in chimneys on exterior walls and where thermostat setbacks were used.

The Influence of Flue Sharing on Venting Performance (1987): The co-venting of natural gas furnaces and hot water heaters was found to exacerbate the potential for backdrafting.

The Influence of Termination Configuration on the Flow Performance of Flues (1987): Wind tunnel tests indicated that wind conditions could have widely varying effects on the venting performance of various types of chimney caps, and that caps should be chosen based on prevailing wind characteristics.

Monitoring Combustion Gas Spillage Frequency and Duration in 20 Problem Prone Houses (1987): Winter monitoring of gas and oil heated homes in 4 regions confirmed that more than 3/4 experienced combustion spillage incidents.

The Performance of Sealed and Insulated Venting Systems in Combination with High Pressure Oil Burners (1987): Monitoring of Esso's "Econotech" venting system found that it greatly reduced the potential for combustion spillage.

Residential Combustion Spillage Monitoring (1987): Monitoring and air quality sampling of 16 homes known to have sporadic spillage problems indicated that pollutant levels were generally still within HWC's proposed guidelines.

Study of Flue Parameters Affecting Backdrafting and Spillage (1987): Computer simulations were used to determine the effects of flue design on spillage, and found that start-up after a prolonged cool down period was the worst-case design condition, that thermal mass had little effect, and that flue area needed to be sized according to expected gas flow.

Residential Gas Combustion Venting Issues Forum (1987): An outline of the activities of this forum sponsored jointly with the Canadian Gas Association and the Heating Refrigerating and Air Conditioning Institute.

Chimney Safety Tests Users' Manual: Procedures for Determining the Safety of Residential Chimneys (1987, 1988): A manual which details 5 test procedures for testing the safe venting performance of any type of residential combustion appliance (revised in 1988).

FLUESIM - A Program for the Analyis of Combustion Venting (1988): A paper for the Air Pollution Control Association which outlines the building physics relevant to combustion venting, and which describes the development of the FLUESIM computer model and its simulation results.

WOODSIM - A Wood Combustion Venting Analysis Program (1988): A paper for the Air Pollution Control Association which described the rationale, development, operation and initial predictions of the WOODSIM computer model.

Flue Gas Spillage: Status of Technology Transfer (1988): A third-party overview of CMHC's combustion spillage research indicated the need for greater communication of the results to the industry.

Flue Simulator: Version 4.2: User's Manual (1988): Instructions on the use of the revised FLUESIM model for studying the flow of combustion products, air and heat in chimney flues.

Study of Flue, Furnace and Envelope Parameters Affecting Oil Furnace Start-Up Spillage (1988): Use of the FLUESIM model led to recommendations against undersizing or oversizing flues, large thermal mass of flues, and large barometric damper openings, and recommendations in favour of draft-inducing fans, and interior rather than exterior flues.

Woodstove/Electic Heating Systems in British Columbia: Field Testing (1988): Innovative wood/electric heating configurations were monitored for air flow patterns and potential for spillage, and led to recommendations for improvements.

Testing of Various Chimneys and Chimney Connectors at the CMHC-Owned Armstrong House (1989): Various chimney configurations were field tested to determine optimum venting performance. It was found that properly sized and better insulated chimneys had less spillage and less condensation, although the effects of furnace cycling and the thermal mass of the flues reduced the effectiveness of the insulation.

Wood/Gas Forum Report (1989): An overview of the forum held June 11-12, 1989, highlighting CMHC's technical sessions on fireplaces and chimneys.

Fireplace Air Requirements (1989): Laboratory testing of various manufactured fireplaces found that the use of glass doors allowed fireplaces to withstand higher levels of house depressurization before spilling, and reduced the amount of air exhausted from the house. Fresh air intakes ducted to the circulation air plenum were found to provide only a small fraction of the fireplace air requirements. Intakes ducted directly to the firebox were found to provide adequate air flow, but could create a fire hazard during flow reversals.

Wood Stove Venting (underway): An adaptation of the WOODSIM computer model for fireplaces to allow analysis of wood stove venting performance. Also included are a field survey of hazardous wood stove conditions and the development of appropriate remedial measures.

Spillage in Mid-Efficiency Gas Furnaces (underway): In response to a problem identified by the Canadian Home Builders' Association, this study is investigating the potential for combustion spillage in draft-induced furnaces, and will include the development of simple on-site commissioning tests and recommendations for improved certification tests.

Planned projects to be initiated in 1990-91 include:
Improved Fireplace Air Intakes

**Surveys, Sampling Techniques, Material Emissions and General Studies**

Updating Health Standards for Residential Construction (1982): An identification of current and potential health hazards integral to housing construction, and proposed recommendations for airtight buildings (External Research Program).

An Investigation of the Biomethylation of Arsenic in Preserved Wood Foundations (1983): A study of the mechanisms causing this reaction, associated toxicity, and documentation of reported field cases.

Indoor Air Pollution and Housing Technology (1983): This project was the first major study of indoor air quality undertaken by CMHC, and is still an excellent reference document. A comprehensive literature review documented the known range of pollutants typically found in Canadian housing and their related health effects. Causes of and solutions to IAQ problems were described, as were examples of low-pollution design.

Indoor Air Pollution and Housing Technology: Summary Report (1984): A summary report by another consultant of the above detailed study.

Performance Evaluation of Apple Hill Energy Efficient Homes (1984): A major study of energy efficient housing in Kanata, Ontario included air quality monitoring and found high levels of formaldehyde, radon gas and carbon dioxide. Also included were studies of problems in sealed furnace rooms, which led to recommendations against such practices.

Indoor Air Quality in Canadian Homes: Policy, Regulatory and Consumer Education Issues (1984): A paper which described the limitations of regulating IAQ, and advocated technical innovation and consumer and industry education as an alternative.

Studies on Indoor Air Quality in Canadian Homes (1985): This major 3-part study provided a strong information base for future IAQ research.

> Vol 1, Legislation, Regulations and Standards, identified all relevant regulatory aspects of IAQ in Canada.
>
> Vol 2, Research and Information Base, provided an extensive reference document on IAQ research.
>
> Vol 3, Exploring Low-Pollution Design, is described under the theme "Environmental Sensitivity".

Indoor Air Pollutants: Types, Sources and Control (1985): A paper which summarized the sources of the pollutants under review by HWC, discussed in detail four contaminant groups - combustion products, material off-gassing, radon and moisture, and described methods of improving IAQ.

Testing and Monitoring Methods for the National Survey of Housing Conditions (1986): A report which assembled and evaluated available IAQ test methods which would be suitable (inexpensive, yet reliable) for a major survey of IAQ levels in Canadian housing.

Investigation of the Indoor Air Quality, Airtightness and Air Infiltration Rates of a Statistically Random Sample of 78 Houses in Winnipeg (1987): A sample of houses were monitored for carbon dioxide, carbon monoxide, formaldehyde, radon, ozone and particulates to create a data base for future reference.

Calibration of the RCS Sampler (1988): Lab tests calibrated a sampling device for fungal spore collection.

Determination of Fungal Propagules in Indoor Air (1988): Field sampling techniques and inspection protocols were developed for fungal spore collection using the RCS sampler, which was found to be effective in determining the concentrations of colony-forming units for a wide variety of spore sizes.

Prediction of Long-Term Exposure to Indoor Air Pollutants Using Short-Term Measurements (1989): This paper for ASTM developed a protocol for predicting long term average pollutant concentrations, based on point-in-time measurements combined with other data on instantaneous air change rates, envelope leakage, ventilation characteristics, weather and house exposure characteristics.

Indoor Air Quality Survey: CMHC IAQ Kit (1989): A basic kit of air quality sampling devices and instructions on test procedures was developed for use by builders and housing researchers.

Manufactured Housing IAQ Study (underway): This joint venture with NRC, the province of Alberta and the Canadian Manufactured Housing Institute is examining pollutant levels, ventilation rates and pollutant source in mobile homes. Identified improvements will be recommended to the manufacturing industry.

Abatement of Indoor Pollutants by Use of Reactive Polymeric Coatings on Filters (underway): Lab and field testing of coatings on fibreglass furnace filters to determine their effectiveness in removing formaldehyde. (External Research Program)

Planned projects to be initiated in 1990-91 include:
Airtightness and Air Quality in Preserved Wood Foundations
Field Documentation and Validation of Pollutant Emission Rates
House Characterization for Health and Welfare Canada's Survey of Volatile Organic Compounds
Biological Pollutants and Recirculating Fans

**Toxic Lands, Soil Gas and Radon**

DRANJER Floor Drain Seal (1987): The development and testing of a mechanical seal for preventing the entry of radon and other soil gases into the house through and around the basement floor drain. (Housing Technology Incentives Program)

Development and Evaluation of Soil Gas Sampling Techniques (1987): Two techniques for sampling the air entering basements from below grade, one involving soil probes and the other involving accumulator containers on the interior, were field tested to determine levels of radon, organic compounds, pesticides and fungal spores.

Additional Soil Gas Sampling Procedures (1988): Three techniques were evaluated which included enclosures over floor drains and sump pits (successful), sampling through a hole drilled in the basement wall (successful), and direct sampling from wall and floor cracks (unsuccessful).

Radon, Just Another Soil Gas Pollutant? (1988): This paper for the Air Pollution Control Association stressed that radon is only one of a number of undesirable elements entering houses from below grade, and that a combination of basement sealing, reduction in house depressurization and soil gas venting is required to reduce such entry.

Radon Exposures in Fredericton Area Houses and Wells (1988): 200 radon measurements in randomly selected homes revealed that 30% had levels above the American target, 4% had levels above the Canadian target, country areas had higher levels than urban areas, and that radon in wellwater was generally not a problem. (External Research Program)

Enclosed Conditioned Housing (ECHO) System (1988): The development and testing of a basement wall and floor cavity system designed to collect and exhaust air pollutants, such as radon and other soil gases, to the exterior before they enter the house. (Housing Technology Incentives Program)

Isolation of Mould Spores in Dwellings (1988): The development and testing of a cavity wall system, designed for older rubble stone foundations, to prevent the entry of mould spores into the house air. (Housing Technology Incentives Program)

Kitchener Townhouse Study of Soil Gas Ventilation as a Remedial Measure for Methane Entry into Basements (1989): An 81-unit CMHC-insured townhouse project, built in the 1970s on a former garbage dump and adjacent a major landfill site, was subsequently abandoned due to the presence of methane in basements. A series of interior gas extraction wells proved to be effective in reducing methane concentrations by as much as 99%.

Advances in Basement Technology (1989): This comprehensive study of current and future basement technology included an examination of the need for basements to block the entry of soil gas, analyzed various alternatives and proposed a simplified, high performance basement wall design.

Radon Levels in Canada (underway): This study is collating radon test results from various agencies and from private testing companies in order to estimate typical radon levels being found currently in Canadian housing.

Soil Gas Survey (underway): A representative sample of Canadian homes are being tested to determine the type of pollutants entering basements from the soil, such as radon, methane, lawn chemicals, volatile organic compounds and moulds. The approximate rate of entry is also being determined.

Kitchener Methane Exclusion Techniques Phase 2 (underway): The sub-slab ventilation system, which was found to be effective on a pilot basis in the inital phase of the work, is being installed throughout the 81 townhouse units and is being monitored.

Toxic Lands and Housing (underway): This Canada-wide study is assessing the impact of hazardous soil conditions, such as landfill sites, garbage dumps and former industrial areas, on existing and future housing, and is documenting the various measures which have been taken to protect housing and to clean up sites.

Wax Sealants (underway): The development and testing of a non-toxic wax sealant designed to seal cracks, joints and other openings in basement floors and walls in order to prevent the entry of radon and other soil gases. (Housing Technology Incentives Program)

Mesure des taux d'émanation du radon provenant des matériaux de construction (underway): An investigation of the contribution of building materials to indoor radon levels. (External Research Program)

Preliminary Investigation Concerning the Impact of Subslab Ventilation (underway): An investigation of how various radon remedial measures affect soil temperatures, pressures and humidity in a Winnipeg test house. (External Research Program)

Planned projects to be initiated in 90-91 include:
Impact of Soil Gas Venting
Modelling of Radon Penetration
Costs and Effectiveness of Radon Remedial Measures

**Environmental Sensitivity**

Implications of Chemical Hypersensitivity for Housing Design (1984) A paper which took an initial look at the needs of the hypersensitive, dispelling popular misconceptions and drawing conclusions for typical housing.

Studies on Indoor Air Quality in Canadian Homes (1985): This major 3-part study included information relevant to housing for the hypersensitive (volumes 1 and 2 are described under "Surveys, Sampling Techniques, Material Emissions and General Studies").

> Vol 3, Exploring Low-Pollution Design, described approaches to housing design and material selection which could be suitable for environmentally sensitive occupants.

Housing for the Environmentally Hypersensitive (underway): This study is identifying and documenting houses which have been built or renovated to suit the needs of environmentally sensitive occupants. Measures undertaken are being evaluated with respect to their effectiveness and costs.

Planned projects to be initiated in 90-91 include:
Cost Effective Measures for the Chemically Sensitive

**Low-Rise Ventilation**

A Review of Ventilation Requirements for Residential Buildings in Canada (1980): A review of natural and mechanical ventilation systems, ventilation needs and testing techniques.

Upgrading Residential Forced Air Filtration (1982): A study of the feasibility of improving the efficiency of filters for forced air heating systems (External Research Program).

Air-to-Air Heat Exchangers (1982): An analysis of the characteristics and cost-effectiveness of various heat exchangers, and guidance on performance standards for heat recovery.

Development of Air Purifiers (1983): A study of the most efficient and cost-effective filters for removing nine common indoor air pollutants (External Research Program).

Strategies for Healthful Residential Environments (1984): Proposals for medium efficiency filtration with continuous air circulation for improving IAQ, plus various other source control and air cleaning techniques (External Research Program).

NUTECH Heat Recovery Ventilator (1984): Development and testing of the initial design for an air-to-air heat exchanger, which recovered a substantial portion of the sensible heat from exhaust air.

Field Evaluation of Residential Ventilation Systems Guidelines (1985): An evaluation of ventilation systems installed by 8 builders, in accordance with guidelines prepared by CHBA's Task Force on Airtightness, Heat Recovery and Controlled Ventilation, found that the installations did not perform as expected.

Monitoring of Air-to-Air Heat Exchangers (1986): Monitoring of the installed performance of four units discovered problems with occupant controls and cold temperatures near supply outlets.

Cross-Contamination and Intermittent Testing of Residential Air-to-Air Heat Exchangers (1986): A Master's thesis which examined the steady state and intermittent performance of two heat exchangers, and found that cross-contamination could reduce ventilation efficiency by 10% (Scholarship Program).

Medium Efficiency Filtration: Improved Filters for Residential Forced Air Furnaces (1986): Various medium efficiency filters were field tested, and found to be significantly superior to standard furnace filters in dust removal, although neither type was effective at removing tobacco smoke.

Duct Test Rig (1988): A device was developed and field tested for determining in-situ air flow and air pressure characteristics of residential ventilation systems.

Residential Exhaust Equipment (1988): This comprehensive study of the current state of exhaust fan technology compiled data on air flow characteristics of equipment and ducting, and undertook field testing which found that most fans moved only half of their rated airflow, primarily due to poor installation practices. A draft builders' guide to exhaust fans was also prepared.

A Survey of Ventilation Systems for New Housing (1988): A survey and evaluation of current ventilation systems, including hardware, suppliers, design approaches, compliance with new code requirements and the proposed CSA F326 ventilation standard, advantages, disadvantages and associated costs. (External Research Report)

Improved Make-Up Air Supply Techniques (1989): This comprehensive study of current and proposed make-up air systems found that most were ineffective at meeting the needs of the house. An improved system was therefore developed, based on an inexpensive low-pressure sensor which activates a powered and tempered fresh air supply when house depressurization exceeds a certain preset limit.

The Canadian Residential Duct and Chimney Survey (1989): The "duct test rig" developed earlier by CMHC was used to test actual air flows in ducts, fans and chimneys in over 200 houses across Canada. The survey found enormous variations in in-situ performance, with most kitchen and bathroom fans moving very little air, most passive air intakes having negligible air flows, and many chimneys exhausting large quantities of air during off-cycles. Much anecdotal evidence was also provided of poor installation practices and lack of awareness on the part of the occupants.

Evaluation of Laminar Air Flow Super-Window Humidity Controlled Air Inlet (1989): This innovative system, which uses windows for both ventilation and heat recovery, was monitored in a Winnipeg house for air flows, temperatures, air change rates and house pressures. (Housing Technology Incentives Program)

Airtightness Survey (1989): A joint venture survey of 200 homes with NRC and EMR, which found that new housing was 30% more airtight than in 1982, that 50% had formaldehyde levels which exceeded HWC's target, and that with the exception of Vancouver, most new housing could not rely on air leakage to provide adequate ventilation.

Ventilation and Airtightness in New, Detached Canadian Housing (1990): The results from the above airtightness survey were combined with data from related CMHC ventilation surveys to provide a comprehensive assessment of ventilation in new housing. The analysis revealed that 60% of new housing would require some upgrading to meet the CSA F326 ventilation requirements, and that 18% would have potentially hazardous combustion venting conditions.

West Coast Ventilation (underway): In collaboration with the Victoria Home Builders' Association, several ventilation strategies are being monitored with respect to the 1985 BC Building Code requirements, including a low-flow heat recovery ventilator, humidity controlled air inlets, and a crawlspace plenum.

Potential Impacts of Proposed CSA Standard F326: Residential Mechanical Ventilation Requirements (underway): An assessment of the implication of the proposed ventilation standard on capital costs, energy costs, ventilation rates and implementation.

Low-Cost CSA F326 Strategies (underway): Field testing of simplified systems which meet the intent of the proposed ventilation standard, including reductions in the direct ducting requirements for houses with electric baseboards, and using the combustion appliance as a continuous exhaust device.

Development of a Computer-Aided Residential Duct Sizing Program (underway): CMHC is contributing financially to a multi-agency joint venture which is developing software for heating and ventilating contractors and suppliers to assist them in system design.

Development of Integrated Heating and Ventilating Systems (underway): Integrated systems which would meet the proposed CSA F326 ventilation requirements have been developed and are being monitored. One involves providing fresh air to, and extracting exhaust air from, the recirculating system, and balancing the flows with a pressure sensor to avoid depressurizing the house. The second involves an air management system which controls and tempers incoming air, in combination with a central exhaust system; pressure imbalances are avoided by controlling the exhaust flows and by locking out certain combinations of fans.

Development and Testing of Low Cost Flow and Pressure Sensors (underway): Sensors were developed to control the dampers of a heat recovery ventilator in order to prevent excessive house depressurization, and the complete system is being monitored to assess commercial applications.

Demand Controlled Ventilation Design (underway): Control technologies based on carbon dioxide, humidity and occupancy are being investigated for ventilation systems which can provide variable amounts of ventilation in response to the needs of the house. Technical and economic feasibility is being examined, and prototypes are being field tested.

Exhaust Fan Testing (underway): Medium quality fans are being field tested for air flows and noise ratings, in accordance with the new CSA Standard C260, to compare their installed performance with laboratory performance.

Planned projects to be initiated in 1990-91 include:
Demonstration of Generic Ventilation Systems
Update and Demonstration of New Medium Efficiency Residential Filters
Evaluation of Ventilation and IAQ Models

**High-Rise Ventilation**

Air Movement in High and Mid-Rise Buildings (underway): Test procedures are being developed and field tested for the determination of exfiltration, infiltration and air flow patterns for individual units, floors of units and entire buildings.

High-Rise Indoor Air Quality (underway): Protocols are being developed for sampling IAQ in large residential buildings.

High Rise HVAC: Ventilation Design (underway): A survey of current practices for the design, installation and maintenance of heating, ventilating and airconditioning systems in high rise apartments will identify problem areas, potential areas for improved ventilation, and emerging technologies.

Planned projects to be initiated in 1990-91 include:
Innovative Heating/Ventilating Equipment

**IAQ and Ventilation in Northern and Remote Housing**

Northern Ventilation Project: Data Collection and Report for Iqaluit, NWT (1988): Comparative monitoring of four heat recovery ventilators in a high Arctic environment found that their reliability deteriorated below -20 C, but that they were still able to reduce indoor relative humidity levels.

CMHC/EMR Northern Initiatives: R2000 Home Program Technology Project: Northwest Territories Housing Corporation Technical Support (1989): This multi-year joint venture with EMR responded to a number of building issues associated with energy-efficient northern construction. Aspects relating to indoor air quality and ventilation included the field testing of heat recovery ventilators, the monitoring of passive ventilation systems in Aklavik (Appendix D of the report) and a study of low power ventilation strategies (Appendix G).

Evaluation of a -40 C Heat Recovery Ventilator (underway): An improved HRV is being monitored in Dawson City for ventilating and energy performance under extremely cold conditions.

Evaluation of a Demand Contolled Ventilation System in NWT (underway): A system involving supply ducts installed in partitions and activated by the operation of kitchen, bath and dryer exhaust fans is being monitored for carbon dioxide and humidity levels.

Indoor Air Quality Survey in the North (underway): 60 social housing units in the NWT are being monitored for formaldehyde, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen dioxide, particulates, relative humidity and time-averaged air change. Combustion venting tests and mould inspections are also included.