RESEARCH REPORT

Compliance of Ventilation Systems Installed to Meet the June 18, 2001 Draft of Section 9.32 "Ventilation" for The NBCC

Canada

CMHC SCHL
HOME TO CANADIANS

CMHC—HOME TO CANADIANS

Canada Mortgage and Housing Corporation (CMHC) has been Canada's national housing agency for more than 60 years.

Together with other housing stakeholders, we help ensure that Canada maintains one of the best housing systems in the world. We are committed to helping Canadians access a wide choice of quality, affordable homes, while making vibrant, healthy communities and cities a reality across the country.

For more information, visit our website at **www.cmhc.ca**

You can also reach us by phone at 1-800-668-2642
or by fax at 1-800-245-9274.

Outside Canada call 613-748-2003 or fax to 613-748-2016.

Canada Mortgage and Housing Corporation supports the Government of Canada policy on access to information for people with disabilities. If you wish to obtain this publication in alternative formats, call 1-800-668-2642.

FINAL REPORT

COMPLIANCE OF VENTILATION SYSTEMS INSTALLED TO MEET THE JUNE 18, 2001 DRAFT OF SECTION 9.32 "VENTILATION" FOR THE NBCC

Prepared For

CANADA MORTAGE AND HOUSING CORPORATION

Prepared By

BERT PHILLIPS, P.ENG.
UNIES Ltd.

MARCH 28,2002

Executive Summary

A 1999 study found most new houses complied with "Protection from Depressurization" in 9.32 in the 1995 National Building Code of Canada (NBCC) but few could comply with the depressurization limit for B-vented gas appliances in CAN/CSA B149. To address this and other concerns, the Task Group reviewing Mechanical Ventilation for Houses proposed code changes which: allow exhaust-only ventilation systems in houses with no spillage-susceptible combustion appliances; impose more rigorous requirements for make-up air for houses with spillage-susceptible combustion appliances and outdoor air supply ducts connected to furnace returns.

In December 2001 and January 2002, five houses each in Manitoba and Alberta, with ventilation systems designed and installed to meet the proposed changes, were inspected and tested. Installers typically used direct-vent furnaces and power-vented or electric water heaters to meet the requirements for protection from depressurization in the proposed code. In Alberta, this resulted in higher-cost mechanical systems, but in Manitoba, where direct-vent furnaces and electric water heaters are commonly installed in new houses, the exhaust-only ventilation system option resulted in less costly systems by eliminating the outdoor air connection to the furnace return, and in houses with HRVs, meeting the proposed code did not involve any apparent changes from current practice.

One installer, determined to differentiate his systems by being within the depressurization limit for B-vented appliances, developed strategies involving current sensors on exhaust devices which operated simple (or not so simple) methods of providing make-up air. Although these strategies met or exceeded the requirements for protection from depressurization in 9.32 in the 1995 NBCC, operating all installed exhaust devices caused house depressurization in excess of 5 Pa. Thus, requirements in CAN/CSA B149 and proposed changes to 9.32 were not met. This result reaffirms that relying on envelope leakage, passive make-up air ducts and/or a single make-up air fan is not a practical approach to protect spillage-susceptible combustion appliances from excessive depressurization.

Other observations and conclusions were: balance dampers are installed but ventilation system airflows are not measured or adjusted; ventilation systems are more likely to comply with the proposed code than the current code; if installers are complying with B-149 by not installing spillage-susceptible combustion appliances (as is common in Manitoba, but not Alberta), complying with the proposed code will generally be simpler and less expensive than the current code (ignoring the requirement to measure and adjust airflows); in cold weather, parts of houses are at lower pressure than attached garages even when no exhaust devices are operated; installers think CO detectors should be required in all houses with attached garages; installers expect builders to migrate to the lowest-cost strategy that complies with the code.

Résumé

Une étude effectuée en 1999 révèle que la plupart des maisons neuves étaient conformes aux exigences de la section 9.32. « Protection contre la dépressurisation » du Code national du bâtiment (CNBC), édition 1995, mais que peu d'entre elles pouvaient respecter la limite de dépressurisation imposée pour les appareils à gaz desservis par des évents métalliques de type B suivant la norme CAN/CSA B149. Afin de régler ce problème et d'apaiser d'autres inquiétudes, le groupe de travail chargé de revoir la ventilation mécanique dans les habitations a proposé d'apporter les modifications suivantes au code : permettre la mise en place de ventilateurs d'extraction uniquement dans les maisons dépourvues d'appareils présentant des risques de refoulement des gaz; imposer des exigences plus sévères en ce qui a trait à l'air de compensation dans les maisons dotées d'appareils risquant de subir un refoulement de gaz, ainsi qu'aux conduits d'alimentation d'air extérieur raccordés directement au conduit de reprise d'un générateur de chaleur.

En décembre 2001 et en janvier 2002, on a inspecté et mis à l'essai dix maisons, dont cinq au Manitoba et cinq en Alberta, pourvues de systèmes de ventilation conçus et installés en conformité avec les modifications proposées. Les installateurs posaient d'ordinaire un générateur d'air chaud à ventouse murale et des chauffe-eau à évent pulsé ou électrique afin de répondre aux exigences proposées de protection contre la dépressurisation. En Alberta, ce système a rehaussé le coût des installations mécaniques, alors qu'au Manitoba, où on utilisait déjà des générateurs à ventouse murale et des chauffe-eau électriques dans les maisons neuves, les ventilateurs d'extraction d'air vicié ont engendré des économies en raison de l'élimination de la prise d'alimentation d'air extérieur raccordée au conduit de reprise. Dans les maisons dotées d'un VRC, selon toute vraisemblance, il n'a pas été nécessaire de modifier les pratiques courantes afin de répondre aux nouvelles exigences du code.

Un installateur, déterminé à faire valoir son installation en s'assurant qu'elle se situait dans la limite de la dépressurisation des appareils munis d'évents de type B, a mis au point des stratégies qui font appel à des capteurs de courant sur les dispositifs d'extraction qui gèrent l'air de compensation par des moyens plus ou moins simples. Bien que ces stratégies aient été conformes ou supérieures aux exigences de protection contre la dépressurisation de la section 9.32 de l'édition 1995 du CNBC, le fait de faire fonctionner tous les dispositifs d'extraction a dépressurisé la maison de plus de 5 Pa. Par conséquent, les exigences du CAN/CSA B149 et les modifications proposées pour la section 9.32 n'ont pas été respectées. Ce résultat confirme à nouveau qu'il est risqué de se fier aux fuites d'air de l'enveloppe, à des conduits d'air de compensation passifs ou à un unique ventilateur d'air de compensation pour parvenir à protéger les appareils présentant des risques de refoulement des gaz.

Voici d'autres constatations : on a posé des volets d'équilibrage, mais les débits de ventilation n'ont été ni mesurés ni calibrés; les installations de ventilation sont plus susceptibles de répondre aux nouvelles exigences de ventilation qu'aux anciennes; si les installateurs se conforment à la norme CAN/CSA B149 en évitant d'installer des appareils présentant un risque de refoulement de gaz, (courant au Manitoba, mais pas en Alberta), la conformité aux exigences proposées sera généralement plus simple et moins coûteuse comparativement aux exigences courantes (abstraction faite de l'exigence de mesurage et de réglage des débits d'air). Par temps froid, certaines parties de la maison présentent des pressions inférieures à celles du garage attenant, même lorsque aucun appareil d'extraction n'est en opération; les installateurs croient que des détecteurs de CO devraient être obligatoires dans toutes les maisons pourvues de garages attenants; ils s'attendent à ce que les constructeurs se tournent vers la stratégie conforme la moins coûteuse.

Table of Contents

List of Tables

CMHC SCHL

National Office
700 Montreal Road
Ottawa ON K1A 0P7
Telephone: (613) 748-2000

Bureau national
700 chemin de Montréal
Ottawa ON K1A 0P7
Téléphone : (613) 748-2000

Puisqu'on prévoit une demande restreinte pour ce document de recherche, seul le résumé a été traduit.

La SCHL fera traduire le document si la demande le justifie.

Pour nous aider à déterminer si la demande justifie que ce rapport soit traduit en français, veuillez remplir la partie ci-dessous et la retourner à l'adresse suivante :

Centre canadien de documentation sur l'habitation
Société canadienne d'hypothèques et de logement
700, chemin Montréal, bureau C1-200
Ottawa (Ontario)
K1A 0P7

Titre du rapport: ______________________________

____

Je préférerais que ce rapport soit disponible en français.

NOM ______________________________

ADRESSE______________________________
rue App.

____
ville province Code postal

No de téléphone ( ) ____________

COMPLIANCE OF VENTILATION SYSTEMS INSTALLED TO MEET THE JUNE 18, 2001 DRAFT OF SECTION 9.32 "VENTILATION" FOR THE NBCC

1.0 INTRODUCTION

A 1999 study on compliance of new residential ventilation systems found that few, if any, ventilation systems were in full compliance with the Section 9.32 "Ventilation" in the 1995 National Building Code of Canada (NBCC). Of particular concern was the fact that Sub-section 9.32.3.8. "Protection Against Depressurization" appeared to permit levels of house depressurization which are not permitted for B-vented gas appliances under the B-149 gas code. The majority of study houses were within the depressurization limits defined in 9.32 but few would comply with the depressurization limit in B149. To address this issue, the Task Group reviewing Mechanical Ventilation for Houses for the NBCC Standing Committee on Houses has drafted proposed changes to the 1995 NBCC requirements for residential ventilation systems. These proposed changes are referred to as the June 18, 2001 Draft of Section 9.32.

UNIES Ltd. was contracted by CMHC to arrange for, inspect and test ventilation systems in ten houses with ventilation systems designed and installed by a heating contractor with the intent of meeting the June 18, 2001 Draft of Section 9.32. In September 2001, meetings were held with residential heating contractors in Winnipeg and Calgary to review the requirements in the June 18, 2001 Draft of Section 9.32, to provide them with background information on this project, and to encourage their participation in this project.

In December 2001 and January 2002, ventilation systems designed and installed to meet the June 18, 2001 Draft of Section 9.32 were inspected and tested. In all, five houses in Manitoba and five houses in southern Alberta were tested. The report that follows provides a commentary on the differences between the 1995 NBCC Section 9.32 "Ventilation" and the June 18, 2001 Draft of Section 9.32 "Ventilation", response of installers to the proposed changes, a description and assessment of the ventilation systems installed to meet the June 18, 2001 Draft of Section 9.32 "Ventilation", and commentary as to how the ventilation systems installed comply with the 1995 NBC Section 9.32.

2.0 COMMENTARY ON PROPOSED CHANGES TO RESIDENTIAL VENTILATION REQUIREMENTS IN THE NBCC

Proposed changes to the 1995 NBCC developed by the Task Group reviewing Mechanical Ventilation for Houses for the NBCC Standing Committee on Houses include editorial and organizational changes (i.e., changes in the order and way material is presented) and substantial changes (i.e., changes in the requirements). Organizational and editorial changes are intended to make the document easier to read and follow. The substantial changes were made to improve ventilation system performance and safety.

Proposed changes in the June 18, 2001 Draft that will have the biggest impact include

- 9.32.3.4., which specifies more rigorous requirements for outdoor air supply ducts connected to the return duct of a forced-air distribution system;
- 9.32.3.6., which would allow exhaust-only ventilation systems in houses that do not have spillage-susceptible combustion appliances; and
- 9.32.3.8., which specifies more rigorous make-up air requirements for houses with spillage-susceptible combustion appliances.

More rigorous requirements will generally be more costly. If the proposed changes are adopted, the least-cost system will likely be exhaust-only ventilation.

The following commentary highlights substantial changes from the 1995 NBCC. A copy of the June 18, 2001 Draft is appended.

- Numbering in the June 18, 2001 Draft is considerably changed from the 1995 NBCC, so it is not easy to do clause-by-clause or even section-by-section comparisons of the two versions. The section numbering in this commentary corresponds to numbering of the appropriate sections in the June 18, 2001 Draft of NBCC 9.32 Ventilation.

- What was called the Principal Exhaust Fan in the 1995 NBCC is called the Principal Ventilation Fan in the June 18, 2001 Draft. The basic/general ventilation system is called the Principal Ventilation System.

- 9.32.2.3. Non-Heating-Season Mechanical Ventilation - Table 9.32.2.3 specifies minimum-required ventilation rates for the non-heating season for air-conditioned spaces that do not have natural ventilation (i.e., opening windows).

- 9.32.3.3. Principal Ventilation System - The general ventilation rate or "Principal Ventilation Fan Normal Operating Exhaust Capacity", specified as a flow rate range in Table 9.32.3.3.A, is based on the number of bedrooms in the house. For houses with more than five bedrooms, the ventilation system must comply with CSA F326. Under the 1995 NBCC, the comparable flow rate was 40 to 60% of the Minimum Ventilation Capacity (MVC), and MVC was based on a count of all rooms in the house. The simpler method presented in the June 18, 2001 Draft will yield similar ventilation rates as the 1995 NBCC in most cases.

- 9.32.3.4. Ventilation Systems Used in Conjunction with Forced-Air Heating Systems - Table 9.32.3.4.A may be used to determine the maximum untempered outdoor airflow rate that may be introduced into a return air duct of a furnace.

- Outdoor air supply ducts are required to have balance dampers and to have their airflow measured and adjusted to within 10% of the airflow of the Principal Ventilation Fan operating at its Normal Operating Exhaust Capacity.

- Outdoor air supply ducts connected to a forced-air heating system are required to have motorized dampers which close when the Principal Ventilation Fan is off, and open when the Principal Ventilation Fan is on. This measure is to limit the supply of outdoor air to those times when it is called for. The furnace circulation fan must operate when the Principal Ventilation Fan is on.

- 9.32.3.6. Exhaust-Only Ventilation Systems - The June 18, 2001 Draft would allow exhaust-only ventilation systems provided that the house contains no solid-fuel-burning combustion appliances, no fireplace other than the direct-vented type and no other fuel-fired-space- or water-heating appliance other than the direct-vent or mechanically vented types AND the house has either a forced-air distribution system with a circulation rate at least five times the required flow rate of the Principal Ventilation Fan or the Principal Exhaust Fan is connected to a duct system which withdraws air from each bedroom, any storey without a bedroom (includes basements and unheated crawl spaces) and the principal living area, if there is no storey without a bedroom, but does not draw air from other spaces in the house. Where applicable, operation of the Principal Ventilation Fan would activate the forced-air distribution system fan.

- 9.32.3.7. Supplemental Exhaust - A Principal Ventilation Fan which can also operate at 2.5 times the minimum Normal Operating Exhaust Capacity flow rate can meet the Supplemental Exhaust requirements of the kitchen and bathrooms, whereas in the 1995 NBCC, if the Principal Exhaust Fan serves any rooms other than the kitchen, the kitchen requires Supplemental Exhaust.

- 9.32.3.8. Protection Against Depressurization - For houses with spillage-susceptible combustion appliances, make-up air requirements have become much more rigorous. If make-up air is required, make-up air must be provided for all mechanical air exhausting devices. Make-up airflows must be measured and balanced to match the exhaust airflow of the exhaust device they serve, and must be controlled to operate automatically when that device is operated.

- 9.32.3.9. Attached Garages - CO detectors must be installed on every floor level that has a space adjacent to an attached garage, if mechanical exhaust can depressurize the house (as would be the case in an exhaust-only house). (There is a proposal that all houses with attached garages be required to have CO detectors regardless of ventilation system type. If so, the requirements in this section of the code would be redundant, and would be removed.)

- 9.32.3.10. Fans - Kitchen fans are not required to meet sound ratings. Principal Ventilation Fans, Supplemental bathroom fans and make-up air fans which are remotely mounted are not required to meet sound ratings.

- 9.32.3.11. Ducts - Exhaust intakes within 3 meters horizontally of a range must have a grease filter (even if they are not in the kitchen).

- The duct sizing rules from the 1995 NBCC would be replaced by a duct sizing table, Table 9.32.3.11.A.

- 9.32.3.13. Outdoor Intake and Exhaust Openings - Table 9.32.13.A specifies the net free area of openings with screens or grilles.

2.1 Installer Responses to Proposed Changes

The minimum and maximum fan capacities in Table 9.32.3.3.A still cause some confusion. Some installers understood that the "Maximum" in this table was equivalent to MVC in the 1995 NBCC or TVC in CSA F326. Positive comments were received regarding the simplified method of determining ventilation requirements (i.e., bedroom count versus whole-house room count).

There was also some confusion related to the use of a single central fan to meet both the "Principal Ventilation Fan normal operating capacity" specified in Table 9.32.3.3.A and "Supplemental Exhaust Fan" requirements as allowed in sentence 9.32.3.7.3. Installers did not understand that a two-speed fan could be used to meet both requirements.

Some installers preferred the term Principal Exhaust Fan over Principal Ventilation Fan. One commented that it is an exhaust fan and calling it a ventilation fan was confusing. This preference was expressed by at least one installer that provided an HRV study house for the project.

A pressure switch connected to the Principal Exhaust Fan ductwork is commonly used to activate the furnace fan when the PE fan is operated. One installer commented that he had been called in to troubleshoot a house in which the furnace fan frequently started and stopped during windy weather. The problem was wind pressure pulses in the Principal Exhaust Fan ductwork. Another installer said his solution to that problem was to connect the pressure switch to the intake (negative pressure) side of the Principal Exhaust Fan rather than the outlet (positive pressure) ductwork.

Installers commented positively on the requirement for CO detectors in houses with attached garages. The installers thought this should be a requirement regardless of ventilation system type if there is an attached garage, and that it should be a requirement attached to the building, not the mechanical ventilation system. Finding suitable locations for CO detectors in unfinished basements may present a challenge.

A few installers commented that they didn't think they would ever pursue the option of providing make-up air for each installed exhaust device. One said that the section 9.32.3.8. in the June 18, 2001 Draft code that presents that option should be eliminated because its description is confusing, the option is too complex to be properly and reliably installed. Because a typical house would require several fans and associated controls, it would be very expensive to apply. As such, it is an option that no knowledgeable installer would apply.

Installers expect builders to migrate to the lowest-cost ventilation system which meets the code. In Manitoba, most houses get direct-vent gas furnaces, electric domestic hot water tanks and an externally vented rangehood. As such, in Manitoba, exhaust-only ventilation systems are expected to dominate because they are a lower-cost option than basic systems being installed to meet the 1995 NBCC (i.e., Option 1 systems), in that the outdoor air intake is eliminated and other fan and/or controls requirements are simplified. In Alberta, installers predicted the basic ventilation system under the June 18, 2001 Draft will also be an exhaust-only system with a direct-vent gas furnace and a power-vented domestic hot water tank, bathrooms exhausted by a central exhaust fan or individual bath fans, kitchen exhaust provided by a rangehood. There is a concern in Alberta that there will be strong consumer resistance to installing electric hot water heaters because of the energy cost, and resistance to power-vented hot water tanks because of the incremental first cost (estimated at up to $1,000 over a standard gas hot water heater).

Some installers and builders in both Alberta and Manitoba said they liked the minimum system in the current code (i.e., Option 1) because the outdoor air intake connected to the furnace return ensures some level of ventilation/dehumidification regardless of occupant action, especially during cold weather when the house is closed up. In their opinions, this helps protect the house from excess moisture during cold weather. However, the proposed requirement to install motorized dampers on outdoor air intake ducts would lead to elimination of outdoor air intakes. They thought this would be a step backwards, from an indoor air quality perspective. On the other hand, other installers thought the requirements that would either eliminate or require dampers in outdoor air intake ducts would avoid problems associated with over-ventilation and the related energy cost.

Installers of conventional HRV systems did not comply with the requirement for motorized dampers in the supply air duct, if the outdoor air supply from the HRV is connected to the furnace return duct. If the requirement for motorized dampers is applied to HRVs, it would seem appropriate for HRV manufacturers to install such a damper in the HRV as standard equipment, or have defrost dampers automatically block the supply air intake when the HRV is not operating. Defrost strategy patents may not make this an option for some HRV manufacturers.

The builder and mechanical system installer of a high-end house in Alberta commented that finding aesthetically acceptable locations on outside walls for combustion appliance vents, combustion air intake ducts, exhaust outlets, dryer vents, central vac vents and ventilation air intakes is a problem. This problem is complicated by separation requirements between particular types of building envelope penetrations and openings. The challenge could be even greater if make-up air intakes are needed to offset mechanical exhausts. They thought aesthetic considerations would push builders and homeowners toward options that minimize the number of mechanical system-related penetrations through the outside walls (including using grilles which house several intakes or exhausts) or measures which camouflage mechanical penetrations.

One installer emphasized his opinion that the typical homeowner does not understand that ventilation is needed before condensation is visible on windows and walls. He thought the code should mandate automatic ventilation system controls; that is controls that do not rely on the occupant to determine when ventilation is needed.

3.0 DESCRIPTION OF INSTALLED VENTILATION SYSTEMS

For the most part, the systems which were provided for this study were simple variations of the residential ventilation systems being installed to comply with the requirements in 9.32 "Ventilation" in the 1995 NBCC. However, two novel strategies intended to be lower-cost alternatives to direct-vent furnaces and power-vented hot water tanks were developed and tested in Alberta. One of these strategies was modified and retested. The ventilation system types evaluated in this project are summarized below and described in detail in **Section 4.0 Assessment of Installed Ventilation Systems**.

3.1 Exhaust-Only Ventilation Systems

Man01 - 1, Man01 - 3, and Man01 - 4 were exhaust-only systems with a central fan serving the bathrooms and an externally vented rangehood. The houses had direct-vent gas furnaces and electric domestic hot water tanks. AB01 - 3 was an exhaust-only system with a Principal Ventilation Fan which withdrew exhaust air from the furnace return duct and individual exhaust fans serving the bathrooms and kitchen. AB01 - 3 had a direct-vent gas furnace and a power-vented domestic hot water tank.

3.2 Conventional HRV-Based Ventilation Systems

Man01 - 2 and Man01 - 5 had HRVs with the supply air duct coupled to the return duct of a direct-vent gas furnace. The houses had an electric domestic hot water heater. The HRV in Man01 - 2 met all the ventilation requirements for the house. In Man01 - 5, the externally vented rangehood was a necessary element of the ventilation system in order to comply with June 18, 2001 draft requirements.

AB01 - 1 had an HRV with a supply air duct coupled to the return duct of a direct-vent gas furnace. There was an externally vented rangehood in the kitchen. Domestic hot water and space heating for the lower level were met by a direct-vent boiler and in-floor hydronic heating. The furnace provided heating to the upper level and ventilation to each of the lower level bedrooms.

AB01 - 5 had an HRV with extended ductwork. The house had hydronic heat, with a mix of in-floor hydronic heating and hydronic baseboard heaters. A direct-vent, condensing boiler provided both space and domestic hot water heating. The house had an "air-tight" wood-fired fireplace with combustion air supplied directly to the firebox. There was a rangehood in the kitchen. The domestic hot water tank set point of 130°F (54.4°C) indicates that condensing may not occur in the boiler under normal operation.

3.3 Other System Approaches

The mechanical systems in houses AB01 - 2 and AB01 - 4 demonstrate attempts to find lower-cost alternatives to meeting the requirements in the June 18, 2001 Draft of Section 9.32 than by using direct-vent furnaces and power-vented domestic hot water tanks. House AB01 - 2 had a six-inch diameter outdoor air intake with a motorized damper and connected to the furnace return to provide make-up air for the Principal Ventilation (Exhaust) Fan. The house also had a six-inch diameter make-up air duct, complete with a motorized damper, intended to offset depressurization caused by operation of exhaust devices. Operation of any exhaust device caused the motorized dampers in both the outdoor air intake duct and the make-up air duct to open, and the furnace fan to operate. When this system failed to meet the requirements for protection from depressurization, the installer modified the system to include a make-up air fan interlocked with the rangehood.

House AB01 - 4 had a passive HRV with its outdoor air supply side connected to the furnace return duct and its exhaust air side connected to the furnace supply air ductwork, with motorized dampers in each duct to limit operation of the HRV to those times when the Principal Ventilation Fan switch was turned on. The house also had a six-inch diameter make-up air duct, complete with a motorized damper, intended to offset depressurization caused by operation of exhaust devices. Operation of any exhaust device caused the motorized dampers in both the outdoor air supply duct and the make-up air duct to open, and the furnace fan to operate. This level of protection from depressurization was not adequate to prevent the house from being depressurized by more than 5 Pa when all exhaust devices in the house were operated.

4.0 ASSESSMENT OF INSTALLED VENTILATION SYSTEMS

4.1 General Results, Observations, Comparisons and Conclusions

Table 1 - Principal Ventilation Fan System Airflow Data presents target airflow rates of Principal Ventilation Fan systems, the rated capacity of the fans installed to meet these rates and the actual airflows measured in the study houses. Table 2 - Supplemental Fan Airflow Data provides similar data for Supplemental Exhaust Fans installed in the study houses. Table 3 - Air Supply to Bedrooms and Table 4 - Exhaust from Wet Rooms accumulate additional information on airflows in the study houses.

House depressurization relative to attached garages or the outdoors was measured when possible. Measurements were made at the threshold of the door between the house and garage and/or at the threshold to a door to the outdoors. This information, presented in Table 5 - House Depressurization, indicates that with all fans off during cold weather, the threshold of the door between a house and attached garage is often below the neutral pressure plane of the house, or stated otherwise, air pressure in the garage at this level is often higher than air pressure in the house. Operation of exhaust devices increases the level of house depressurization relative to the garage. As well, it can be expected that wind pressure on the garage can increase garage air pressures relative to the house. This observation supports the proposal that all houses with attached garages should be required to have CO detectors on floor levels which have walls adjacent to the garage, regardless of ventilation system type.

Table 6 - Design Heat Loss Estimates and Space Heating System Outputs presents data showing the degree of heating system oversizing observed in this study. Heating system nameplate output ranged from just over 1 to about 2.4 times estimated design condition heat loss for the study houses. On average, heating systems were about 1.7 times estimated design heat loss for this sample group. The installer for the house with the least amount of furnace oversizing commented that he makes a concerted effort to select furnaces with outputs close to the design heat loss for the house.

It is the writer's opinion that the exhaust fans and HRV systems installed in study houses were, for the most part, similar to those that the installers would have installed in houses meeting the 1995 NBC. In most cases, as installed and left by the installers, the systems had too much airflow to comply with the Principal Ventilation Airflow Rate requirements of either the 1995 NBCC or the June 18, 2001 Draft but not enough airflow (from quiet fans) to meet the Minimum Ventilation Capacity (MVC) in the 1995 NBCC. In most cases, there was ample airflow from all exhaust fans to meet the June 18, 2001 Draft of Section 9.32 airflow requirements which are comparable to the MVC.

For the most part, the Principal Ventilation Systems installed in the study houses had a means to adjust airflows. The exception is where a bathroom exhaust fan serves as the Principal Ventilation Fan. However, based on airflows measured during the inspections and testing, it is the writer's opinion that the system installers did not measure and adjust airflows to comply with code requirements, even for HRV systems. One HRV system designer expressed surprise that airflows for the HRV system installed by his company had not been balanced, because his company has a stated policy of doing so. Enforcement of requirements calling for residential ventilation system airflows to be measured and adjusted will be difficult.

Ventilation system ductwork in all ventilation systems was in compliance with Table 9.32.3.11.A "Equivalent Duct Sizes". It is the writer's opinion that this is not because installers sized ducts using this table, but because their standard duct sizing rules result in duct sizes that are in compliance with the table.

Sentence 9.32.3.4.(7) requires motorized dampers in outdoor air supply ducts connected to a forced-air heating system. This includes HRV systems. Four study houses had conventional HRVs with outdoor air supply ducts connected to forced-air systems; none had motorized dampers in outdoor air ducts.

Sentence 9.32.3.7.(6) states that a switch for the exhaust fan serving a bathroom must be located in the bathroom. In some study houses, the light switch and bathroom exhaust fan switch were located outside the bathroom, on the wall beside the entryway.

When the 1995 NBC was first adopted, many installers were challenged by the requirement to operate the forced-air system circulation fan when the Principal Exhaust Fan was operated, for ventilation systems used in conjunction with forced-air heating systems. Based on observations made in the course of this project, effective solutions have been developed and are being successfully applied. Thus, it is concluded that the problem of coordinating the operation of the Principal Ventilation Fan and the furnace circulation fan has been resolved.

As noted in Section 2.1, installers strongly favour installation of outdoor air intakes because they ensure some level of ventilation/dehumidification regardless of occupant action and thus prevent humidity-related house problems. They believe a requirement to install motorized dampers on outdoor air intake ducts will lead to elimination of outdoor air intakes. Their preference for outdoor air intakes was demonstrated by the fact that outdoor air intakes were installed in all "exhaust only" study houses, even though installers were advised that this requirements in the 1995 NBCC would not be enforced for study houses. During house testing, outdoor air intakes were blocked to simulate the exhaust-only ventilation system option.

Table 1 - Principal Ventilation Fan System Airflow Data

House	Required PV Fan Capacity		Measured & Adjusted Airflow		Rated Fan Capacity
	1995 NBCC	June 18, 2001	Low Speed	High Speed	
Man01 - 1	24 to 36 L/s High 60 L/s	22 to 32 L/s	35 L/s	43 L/s	90 L/s @ 50 Pa
Man01 - 2	22 to 33 L/s High 55 L/s	26 to 38 L/s High 65 L/s	exh 27 L/s sup 28 L/s	62 L/s 58 L/s	61 L/s @ 100 Pa
Man01 - 3	22 to 33 L/s High 55 L/s	22 to 32 L/s	42 L/s	68 L/s	90 L/s @ 50 Pa
Man01 - 4	32 to 48 L/s High 80 L/s	26 to 38 L/s	44 L/s	70 L/s	90 L/s @ 50 Pa
Man01 - 5	26 to 39 L/s High 65 L/s	22 to 32 L/s	exh 38 L/s sup 37 L/s	55 L/s 57 L/s	89 L/s @ 100 Pa 71 L/s @ 150 Pa
AB01 - 1	32 to 48 L/s High 80 L/s	26 to 38 L/s	exh 33 L/s sup 37 L/s	60 L/s 56 L/s	89 L/s @ 100 Pa
AB01 - 2	22 to 33 L/s High 55 L/s	22 to 32 L/s	43 L/s	NA	52 L/s @ 25 Pa
AB01 - 3	22 to 33 L/s High 55 L/s	22 to 32 L/s	35 L/s	NA	42 L/s @ 50 Pa
AB01 - 4	26 to 39 L/s High 65 L/s	22 to 32 L/s	exh 24 L/s sup 18 L/s	NA	NA
AB01 - 5	26 to 39 L/s High 65 L/s	22 to 32 L/s	exh 63 L/s sup 63 L/s	89 L/s 89 L/s	111 L/s @ 100 Pa 96 L/s @ 150 Pa

Table 2 - Supplemental Fan Airflow Data

House	Fan Use	Code Requirement	Measured Airflow	Rated Fan Capacity
Man01 - 1	Rangehood	50 L/s	69 L/s	75 L/s @ 25 Pa
Man01 - 2	N/A			
Man01 - 3	Rangehood	50 L/s	85 L/s	85 L/s @ 25 Pa
Man01 - 4	Rangehood	50 L/s	not yet installed	
Man01 - 5	Rangehood	50 L/s	not wired	Commercial-style hood, estimate 150 L/s @ 25 Pa
AB01 - 1	Rangehood	50 L/s	110 L/s	118 L/s @ 25 Pa
AB01 - 2	Rangehood Bathroom Fan	50 L/s 25 L/s	67 L/s 22 L/s	85 L/s @ 25 Pa 24 L/s @ 25 Pa
AB01 - 3	Rangehood Ensuite Bathroom	50 L/s 25 L/s 25 L/s	37 L/s 18 L/s 17 L/s	85 L/s @ 25 Pa 23 L/s @ 25 Pa 23 L/s @ 25 Pa
AB01 - 4	Rangehood 1st Floor Bath 2nd Floor Bath Ensuite	50 L/s 25 L/s 25 L/s 25 L/s	89 L/s 16 L/s 17 L/s 17 L/s	104 L/s @ 25 Pa 24 L/s @ 25 Pa 24 L/s @ 25 Pa 24 L/s @ 25 Pa
AB01 - 5	Rangehood	50 L/s	94 L/s	104 L/s @ 25 Pa

Table 3 - Air Supply to Bedrooms

House	Supply Fan	Airflow to Room L/s				
		Master BR	2 BR	3 BR	4 BR	5 BR
Man01 - 1	Furnace	27 + 25 + 30	30	32		
Man01 - 2	Furnace	32	34	24		
Man01 - 3	Furnace	24 + 28 + 31	32	27		
Man01 - 4	Furnace	37 + 23	28	31	35	
Man01 - 5	Furnace	23 + 20 + 25 + 24 + 24	23	31		
AB01 - 1	Furnace	19 + 13 + 17 + 20	20	20	26	
AB01 - 2	Furnace	17 + 12	17 + 14	22 + 14		
AB01 - 3	Furnace	28 + 18	20	19		
AB01 - 4	Furnace	24 + 26 + 24	17	27		
AB01 - 5	HRV	10	12	8		

Table 4 - Exhaust from Wet Rooms

House	Fan	Exhaust from Wet Room L/s					
		Ensuite	WC 2	WC 3	WC 4	Utility	Kitchen
Man01 - 1	Central Fan Rangehood	17/19	18/22				 59/69
Man01 - 2	HRV		11/16	11/25			7/23
Man01 - 3	Central Fan Rangehood	20/35	24/39				 78/85
Man01 - 4	Central Fan	8/20	13/20	11/15		11/15	not installed
Man01 - 5	HRV	19/26	21/30				not wired
AB01 - 1	HRV Rangehood	15	7	14		5	 36/63/109
AB01 - 2	P V Fan Bath Fan Rangehood	45	 22				 60/67
AB01 - 3	Ensuite Fan Bath Fan Rangehood	18	 17				 28/37
AB01 - 4	Ensuite Fan Bath Fan Bath Fan Rangehood	17 L/s	 16 L/s	 17 L/s			 89
AB01 - 5	HRV Rangehood		11	10		11	29 94

Table 5 - House Pressure in Pa

House	House Relative to	All Off	P V System	Rangehood	Dryer	All Exhausts Operating
Man01 - 1	Garage Outdoors	-1 0	-1.5 to - 2 -2 to -5	-3.5 to -4 -2 to -4	N/A	-5 to -6 -5 to -8
Man01 - 3	Garage	+2.5 to +8	-6 to -8	-2.5 to -6	N/A	-13 to -19
Man01 - 4 OAT-33°C	Garage	-5	Low -8 High -12	N/A	N/A	
Man01 - 5	Garage Outdoors	-0.5 to - 1 + 0.5 to -0.5	-1 0 to -1			
AB01 - 2	Outdoors	-3 to -4	-1.5 to -2	-3	-3	-9
AB01 - 2A	Outdoors	-4	-1 to -1.5	-2.5 to -3.5	-4 to -5	-4.5 to -6
AB01 - 3	Garage	0 to - 1	0 to - 1	-3	-7	-20
AB01 - 4	Outdoors Garage	-4	-4	-9 to -10	-7	-12 -12
AB01 - 5	Outdoors	-2 to -5	-1 to -3 HRV in defrost -10 to -11	-10 to -12	-3 to -4	-14 to -16 HRV in defrost -25
AB01 - 5A	Outdoors	-1 to -3	-1 to - 3	-2 to -4	-1 to -5	-5

Pressures differentials shown in this table are the pressure of the house interior relative to a reference which is either the attached garage or outdoors, as noted. Negative values indicate the house interior is at a lower pressure than (i.e., it is depressurized relative to) the reference. Positive values indicate the house interior is at a higher pressure than (i.e., it is pressurized relative to) the reference. Pressure differentials were measured at the threshold of main floor level doors.

Table 6 - Design Heat Loss Estimates and Space Heating System Outputs

House	Estimated Design Heat Loss in Btu/h	Installed Heating System Rated Output in Btu/h	Comments
Man01 - 1	50,000	92,000	Gas fireplace
Man01 - 2	25,500	46,000	
Man01 - 3	33,000	56,000	
Man01 - 4	52,000	112,000	Gas fireplace with circulation fan
Man01 - 5	61,000	93,000	Gas fireplace
AB01 - 1	upstairs - 50,000 downstairs - 40,000	furnace - 115,000 boiler - 132,000	One gas fireplace up, one down Boiler does lower floor and DHW
AB01 - 2	50,000	53,000	
AB01 - 3	38,000	53,200	
AB01 - 4	51,000	71,000	Gas fireplace
AB01 - 5	66,000	110,000	Boiler heats both space and DHW

5.0 HOUSE SPECIFIC RESULTS, OBSERVATIONS AND CONCLUSIONS

5.1 House Man01 - 1

This house was a three-bedroom bungalow with an unfinished basement. It had an exhaust-only ventilation system. A central fan exhausted both bathrooms. The kitchen had an externally vented rangehood. The house had a direct-vent, gas, forced-air furnace and an electric hot water tank.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan (i.e., low speed) airflow rate of 24 to 36 L/s and a Minimum Ventilation Capacity (i.e., high speed) airflow rate of 60 L/s and an externally vented kitchen exhaust of at least 50 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and an externally vented kitchen exhaust of at least 50 L/s.

As installed, the central fan had exhaust airflow rates of 42 L/s on high speed and 35 L/s on low speed. The airflows were adjusted to exhaust 31 L/s on low and 40 L/s on high speed. The rangehood exhausted 68 L/s on high speed. As adjusted, the ventilation system airflow rates in this house comply with the June 18, 2001 Draft but did not comply with the high-speed airflow requirements in the 1995 NBCC.

The duct system was in compliance with the sizing tables in the proposed code. Under the 1995 NBCC, the duct system in this house would need to have been designed using a detailed duct design method.

5.2 House Man01 - 2

This house was a modest, four-bedroom bungalow with a partially finished basement. An HRV with the supply side coupled to the return duct of a forced-air furnace provided all ventilation for this house. It had a direct-vent furnace and electric hot water tank.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan (i.e., HRV low speed) airflow rate of 22 to 33 L/s and a Minimum Ventilation Capacity (i.e., HRV high speed) airflow rate of 60 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 26 to 38 L/s with a high-speed airflow rate of at least 65 L/s.

The HRV was adjusted/balanced to supply 28 L/s on low speed and 58 L/s on high, and exhaust 27 L/s on low and 62 L/s on high speed. Thus, the ventilation system airflow rates in this house comply with the 1995 NBCC but do not comply with the high-speed airflow requirements in the June 18, 2001 Draft.

The HRV duct system was in compliance with the sizing tables in the proposed code. Under the 1995 NBCC, the duct system in this house would need to have been designed using a detailed duct design method.

5.3 House Man01 - 3

This house was a modest, three-bedroom bungalow with an unfinished basement. It had an exhaust-only ventilation system. A central fan exhausted both bathrooms. The kitchen had an externally vented rangehood. The house had a direct-vent, gas, forced-air furnace and an electric hot water tank.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan airflow rate of 22 to 33 L/s and a Minimum Ventilation Capacity airflow rate of 55 L/s and an externally vented kitchen exhaust of at least 50 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and an externally vented kitchen exhaust of at least 50 L/s.

As installed, the central fan had exhaust airflow rates of 68 L/s on high speed and 42 L/s on low speed. The airflows were adjusted to exhaust 32 L/s on low and 51 L/s on high speed. The rangehood exhausted 85 L/s on high speed. As adjusted, the ventilation system airflow rates in this house comply with the June 18, 2001 Draft, but were a little bit short of the high-speed airflow requirements in the 1995 NBCC.

The Principal Ventilation Fan duct system was in compliance with the sizing tables in the proposed code. Under the 1995 NBCC, the duct system in this house would need to have been designed using a detailed duct design method.

5.4 House Man01 - 4

This house was an upper middle-end, four-bedroom, two storey with an unfinished basement. It had an exhaust-only ventilation system. A central fan exhausted all three bathrooms and the laundry room. There was an externally vented rangehood in the kitchen. The house had a direct-vent, gas, forced-air furnace and an electric hot water tank.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan airflow rate of 32 to 48 L/s and a Minimum Ventilation Capacity airflow rate of 80 L/s and an externally vented kitchen exhaust of at least 50 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 26 to 38 L/s and an externally vented kitchen exhaust of at least 50 L/s.

As installed, the central fan had exhaust airflow rates of 70 L/s on both high and low speed. The airflows were adjusted using the speed control to exhaust 44 L/s on low and 70 L/s on high speed. The rangehood was not installed at the time of the site visit. As adjusted, the ventilation system airflow rates in this house were slightly too high on low speed to comply with the June 18, 2001 Draft, but would otherwise comply. The combination of the central fan and rangehood would be able to meet the low- and high-speed exhaust airflow rate requirements in the 1995 NBCC (i.e., 32 to 48 L/s on low and at least 80 L/s TVC), but not its fan sound rating requirements.

The Principal Ventilation Fan duct system was in compliance with the sizing tables in the proposed code. Under the 1995 NBCC, the duct system in this house would need to have been designed using a detailed duct design method.

5.5 House Man01 - 5

This house was a high-end, three-bedroom bungalow with an unfinished basement. Ventilation systems were an HRV with the supply air side coupled to the return side duct of a forced-air furnace and an externally vented rangehood. Combustion appliances in this house were a direct-vent furnace and a direct-vent fireplace.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan (i.e., HRV low speed) airflow rate of 26 to 39 L/s and a Minimum Ventilation Capacity (i.e., HRV high speed) airflow rate of 65 L/s and an externally vented kitchen exhaust of at least 50 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and an externally vented kitchen exhaust of at least 50 L/s (because the HRV did not have an exhaust pick-up in the kitchen).

As installed, the HRV had airflow rates of 95 L/s supply on high speed and 50 L/s supply on low speed, and 79 L/s exhaust on high speed and 40 L/s on low speed. The HRV was adjusted/balanced to supply 37 L/s on low speed and 57 L/s on high, and exhaust 38 L/s on low and 55 L/s on high speed. The supply airflow balance damper for the HRV was not able to further restrict the supply airflow. The installed rangehood was not yet wired. It was a commercial-style residential hood, and it is expected that it would have a rated airflow considerably in excess of 50 L/s (nameplate was not available).

The HRV was adjusted to comply with the low-speed airflow requirements in the 1995 NBCC, but, as installed, supply airflow could not be reduced sufficiently for the HRV to be balanced within the Minimum Principal Ventilation Fan Normal Operating Exhaust Capacity (i.e., low-speed airflow) range for a three-bedroom house in the June 18, 2001 Draft. Because the HRV could not be adjusted to comply with both the low- and high-speed target airflow requirements in either the 1995 NBCC or the June 18, 2001 Draft, a Supplemental Exhaust Fan would be required to meet either code. The installed rangehood would satisfy the requirements for Supplemental Exhaust in the kitchen under the June 18, 2001 Draft, but not under the 1995 NBCC (wouldn't meet the sound requirement).

The HRV duct system was in compliance with the sizing tables in the proposed code, but under the 1995 NBCC, the duct system in this house would need to have been designed using a detailed duct design method.

The HRV supply air connection to the furnace return would meet the requirements in the proposed code, but may not have been as close to the furnace as required in the 1995 NBCC.

5.6 House AB01 - 1

This house was a high-end, four-bedroom bungalow with a fully finished walk-out basement. Ventilation systems were an HRV with the supply air side coupled to the return side duct of a forced-air furnace and an externally vented rangehood. The exhaust side of the HRV drew air from washrooms. Switches in each bathroom could activate high speed on the HRV. All combustion appliances in this house were of the direct-vent type.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan (i.e., HRV low speed) airflow rate of 32 to 48 L/s and a Minimum Ventilation Capacity (i.e., HRV high speed) airflow rate of 80 L/s and an externally vented kitchen exhaust of at least 50 L/s. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 26 to 38 L/s and an externally vented kitchen exhaust of at least 50 L/s.

As installed, the HRV had airflow rates of 75 L/s supply and 48 L/s on low speed. The HRV was adjusted/balanced to supply 37 L/s on low speed and 56 L/s on high, and exhaust 33 L/s on low and 60 L/s on high speed. The rangehood considerably exceeded the 50 L/s airflow requirement. Thus, the ventilation system airflow rates in this house comply with the June 18, 2001 Draft, but do not comply with the high-speed airflow requirements in the 1995 NBCC.

The HRV duct system was in compliance with the sizing tables in the proposed code. Under the 1995 NBCC, duct runs as long as those in this house would need to have been designed using a detailed duct design method.

The HRV supply air connection to the furnace return would meet the requirements in the proposed code but may not have been as close to the furnace as required in the 1995 NBCC.

Exhaust flow rates from the bathrooms were modest, even with the HRV on high speed. These modest flow rates are the result of the number of exhaust pick-ups and air leakage which was estimated to be approximately 30% of the exhaust airflow measured at the HRV.

5.7 House AB01 - 2

This house was a modest, three-bedroom, two-storey house with an unfinished basement. The Principal Ventilation Fan was the ensuite bathroom fan. The fan in the second bathroom did not have a two-sone sound rating, as required in both the 1995 NBCC and in the June 18, 2001 Draft. A standard, externally vented rangehood was installed in the kitchen. The house had a mid-efficiency, gas, forced-air furnace and a standard, gas, domestic hot water tank, both connected to a B-vent.

The ensuite fan, designated as the Principal Ventilation Fan, was rated at 52 L/s and had a measured airflow of 45 L/s. Both the 1995 NBCC and the June 18, 2001 Draft call for a Principal Ventilation (or Exhaust) Fan airflow rate of 22 to 33 L/s for this house. Thus, the ensuite exhaust fan is oversized under either code.

Exhaust from the other bathroom was 22 L/s, rangehood exhaust was 67 L/s on high, a simulated dryer exhausted 56 L/s. Total exhaust for the house (all exhaust devices on) is 190 L/s.

For protection from depressurization, the installer decided to rely on Sentence 9.32.3.8.(9) which says make-up air provisions are not required in houses with spillage-susceptible combustion appliances "where it can be shown using the test procedures of Canada General Standards Board Standard 51.71, "Spillage Test," that the maximum depressurization levels to which fuel-fired space- or water-heating *appliances* and their venting systems will be exposed will not exceed the limits set out in CGSB 51.71 for the categories of fuel-fired *appliances* and venting systems installed in the *dwelling unit.*"

A six-inch diameter outdoor air intake connected to the furnace return duct and equipped with a motorized damper was installed to provide make-up air for the Principal Ventilation Fan. When the Principal Ventilation Fan was turned on, the motorized damper in the outdoor air duct opened and the furnace circulation fan was activated. The house also had a six-inch diameter make-up air duct, complete with a motorized damper, intended to offset depressurization caused by operation of exhaust devices. The power supplies to all exhaust devices passed through current sensors. When current is sensed in the power supply to any exhaust device, the motorized dampers in both the outdoor air intake duct and the make-up air duct open, and the furnace fan is activated.

During the depressurization test, running all exhaust devices (190 L/s) caused 9 Pa depressurization; running the simulated dryer and Principal Ventilation Fan (108 L/s) caused 5 Pa depressurization. Blower door test results for the house were 3.2 ACH_{50} (C = 14.7, n = 0.841) and ELA was 406 cm^2. Added to this for the depressurization test was a 125 mm combustion air duct, a 150 mm make-up air duct and a 150 mm outdoor air intake connected to the furnace return duct.

House depressurization was predicted, based on the assumption that the C value from the blower door test can be scaled up proportionally to adding the nominal cross-sectional area of these ducts to the house ELA. When this was done, predicted levels of depressurization agreed favourably with measured depressurization levels.

Further scaling the C value and ELA, it was predicted that the make-up air duct would need a cross-sectional area of 970 cm^2 (i.e., a diameter of 35 cm) in order for the house not to exceed 5 Pa of depressurization at 190 L/s. If the Principal Ventilation Fan were sized at the minimum 22 L/s and the rangehood were reduced to 50 L/s, the make-up air duct would need a cross-sectional area of 710 cm^2 (i.e., a diameter of 30 cm) in order not to exceed 5 Pa of depressurization. These duct sizes do not include any safety margin.

This house meets or exceeds the requirements for protection from depressurization in 9.32 in the 1995 NBC, but does not meet the requirements in CAN/CSA B149 or in the June 18, 2001 Draft.

Although this was a modest-sized house (bungalow on a full basement, footprint approximately 100 m^2) with modest-sized exhaust devices, and provisions for increasing make-up air, operating the exhaust devices resulted in depressurization levels in excess of 5 Pa, outside the limit for a house with B-vented combustion appliances. The results for this house confirm that it is not practical to rely on building envelope air leakage and a passive make-up air duct of acceptable size to provide protection from depressurization in houses with spillage-susceptible combustion appliances.

5.8 House AB01 - 2A

Based on the finding that a passive make-up air duct did not provide acceptable protection against depressurization, the mechanical system installer modified the mechanical system in house AB01 - 2 to include a supply fan in the six-inch make-up air duct. A current sensing switch turns on the furnace fan and opens the motorized dampers in the fresh air intake duct connected to the furnace return and the make-up air duct when any exhaust device is turned on (i.e., either bath fan, dryer, or rangehood). When the rangehood is turned on, the make-up air fan is also activated.

The make-up air fan had a measured airflow rate of 90 L/s, which exceeds the measured flow of 67 L/s for the rangehood. The June 18, 2001 Draft specifies a maximum airflow for make-up air fans of 10% over the exhaust flow rate of the device it counter balances. As this make-up air fan has a supply airflow rate that is more than 30% greater than the exhaust airflow rate of the rangehood, it would not comply with the June 18, 2001 Draft. Despite the fact that the make-up air fan was oversized, house depressurization exceeded 5 Pa when all exhaust devices in the house were operated.

While testing the earlier configuration of this house (i.e., AB01 - 2), an exhaust rate of 108 L/s caused 5 Pa depressurization. In the current configuration (i.e., AB01 - 2A), a net exhaust rate of 100 L/s (all exhausts operating) resulted in slightly higher levels of house depressurization. Given that outdoor temperatures were colder while testing the current configuration, and the make-up air fan changes the impact of the make-up air duct, the results of the two configurations are considered to be consistent. In order to comply with the requirements for protection from depressurization in CAN/CSA B149 and in the June 18, 2001 Draft, this house would, as a minimum, require make-up air fans for both the clothes dryer and the rangehood.

5.9 House AB01 - 3

This house was a recently occupied, three-bedroom bungalow with an unfinished basement and an attached garage. It had an exhaust-only ventilation system. The Principal Ventilation Fan drew exhaust air from the furnace return air duct. The kitchen had an externally vented rangehood. Both bathrooms had low-sone bathroom exhaust fans. The house had a direct-vent, gas, forced-air furnace and a power-vented hot water tank.

This house has experienced moisture problems which have been somewhat alleviated since the homeowner (reluctantly) began operating the Principal Ventilation Fan for extended time periods. Other than moisture in construction materials, the only suspected unusual moisture source in this house was a defective hot water tank that was recently replaced. A blower door test indicated the house was relatively well sealed (ACH_{50} of 1.77), which may have been an impediment to drying. The installer cited this house as an example to support his opinion that an "always open" outdoor air intake connected to the furnace return is a good idea.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan airflow rate of 22 to 33 L/s, a Minimum Ventilation Capacity airflow rate of 55 L/s and an externally vented kitchen exhaust of at least 50 L/s and at least 25 L/s Supplemental Exhaust from each bathroom. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and an externally vented kitchen exhaust of at least 50 L/s and at least 25 L/s Supplemental Exhaust from each bathroom.

As installed, the Principal Ventilation Fan had exhaust airflow rates of 35 L/s. The rangehood exhausted 37 L/s on high speed, the ensuite bathroom fan exhausted 18 L/s and the main bathroom fan exhausted 17 L/s. The Principal Ventilation Fan airflow rate in this house slightly exceeded the allowable range in both the June 18, 2001 Draft and the 1995 NBCC, and the airflow rates measured for all three Supplemental Exhaust Fans were less than the specified minimums in either code. All together, the exhaust fans installed in this house would comply with the Minimum Ventilation Capacity requirements in the 1995 NBC. Operating all exhaust devices in the house resulted in the house being depressurized to 20 Pa.

The Principal Ventilation Fan duct system was in compliance with the sizing tables in both the proposed code and the 1995 NBCC.

5.10 <u>House AB01 - 4</u>

This house was an unoccupied, three-bedroom, two-storey with an unfinished basement and an attached garage. The Principal Ventilation System was a passive HRV (Nu-Air NU120-1). Each of the three bathrooms and the kitchen had Supplemental Exhaust. The passive HRV was connected to the forced-air heating system ductwork. The outdoor air intake side of the passive HRV was connected to the return duct of the forced-air system, the exhaust side of the passive HRV was connected to the supply side ductwork of the forced-air system. Normally, closed motorized dampers in the passive HRV supply and exhaust ducts limit air exchange to those times when the ventilation switch is turned on. The house had a mid-efficiency, B-vented, gas, forced-air furnace and a standard, gas-fired, domestic hot water tank.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan airflow rate of 26 to 39 L/s, a Minimum Ventilation Capacity airflow rate of 65 L/s and an externally vented kitchen exhaust of at least 50 L/s and at least 25 L/s Supplemental Exhaust from each bathroom. Under the June 18, 2001 Draft, this house would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and an externally vented kitchen exhaust of at least 50 L/s and at least 25 L/s Supplemental Exhaust from each bathroom.

The Principal Ventilation System (i.e., the passive HRV) exhaust side airflow rate was dampered down to 24 L/s. Fully open, the supply side duct airflow rate was 18 L/s. The inability to achieve significant supply side airflows with this passive HRV is consistent with the tester's experience with other applications of passive HRVs, and, given the measured performance of outdoor air intakes connected to furnace returns in previous phases of this project, is not a surprise.

The rangehood exhausted 89 L/s on high speed, the upstairs bathroom fans exhausted 17 L/s each and the main bathroom fan exhausted 16 L/s. The Principal Ventilation Fan airflow rate in this house fell within the allowable range in the June 18, 2001 Draft, but was just under the minimum airflow rate in the 1995 NBCC. The airflow rate measured for the rangehood complied with the requirements in both codes, but the airflow rates measured for all three bathroom exhaust fans were less than the specified minimums in either code. All together, the exhaust fans installed in this house would comply with the Minimum Ventilation Capacity requirements in the 1995 NBC, however, none of the Supplemental Exhaust Fans would meet the sound rating requirements.

When the Principal Ventilation Fan switch was turned on, the furnace fan was activated and automatic dampers in the outdoor air supply and exhaust air ducts of the passive HRV were opened. When any installed exhaust device was operated in the house, a current sensor on the exhaust device power supply starts the furnace fan, opens the damper in the passive HRV outdoor air intake and opens a damper in a six-inch diameter passive make-up air duct. The damper in the exhaust duct of the passive HRV is only opened when there is a call to operate the Principal Ventilation System.

Attempts on two site visits to measure depressurization on this house were hampered by strong winds. Three separate blower door tests done during high-wind conditions indicated the house had an air change rate of about 3 ACH_{50}. A large number of "fan on/fan off" house pressure measurements were taken to estimate the level of depressurization caused by operating all exhaust devices in the house under these same wind conditions. These tests indicated that operating the Principal Ventilation Fan System, all installed exhaust fans and a simulated clothes dryer (an exhaust fan with measured flow rate of 53 L/s) resulted in the house being depressurized by 5 to 9 Pa.

House depressurization was retested under low wind conditions on a third site visit. The air change rate determined from a blower door test on this visit was 3.04 ACH_{50}. Although ACH_{50} was consistent with the earlier test results, C was notably higher and n notably lower for the low-wind test condition. House depressurization measurements indicated that operating the Principal Ventilation Fan System, all installed exhaust fans and a simulated clothes dryer resulted in the house being depressurized by 12 Pa.

Based on the results from the pressure differential measurements, this house would not comply with the depressurization limits in CSA B149 or in the June 18, 2001 Draft. The measured exhaust flow rate for the rangehood exceeded 75 L/s and, as such, compliance with the requirements for protection from depressurization in the 1995 NBCC would require that this house have a make-up air system providing at least 14 L/s to offset the rangehood exhaust.

5.11 House AB01 - 5

This house was a three-storey townhouse with an unfinished basement. The house had three bedrooms and an office; some authorities having jurisdiction would designate it as a four-bedroom house. Ventilation systems were an HRV with the exhaust side drawing air from the laundry, bathrooms and kitchen and the supply air side ducted directly to the bedrooms, living areas and basement. The kitchen also had an externally vented rangehood. Space heating and domestic water heating were provided by a direct-vent boiler. The house also had an "air-tight" wood fireplace. Space heating was distributed by a mix of in-floor hydronic and hot water baseboard heaters.

Under the 1995 NBCC, the ventilation system installed in this house would require a Principal Exhaust Fan (i.e., HRV low speed) airflow rate of 26 to 39 L/s and a Minimum Ventilation Capacity (i.e., HRV high speed) airflow rate of 65 L/s and an externally vented kitchen exhaust of at least 50 L/s. If this house were designated as a three-bedroom house under the June 18, 2001 Draft, it would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 22 to 32 L/s and either a high-speed ventilation rate of at least 55 L/s or an externally vented kitchen exhaust of at least 50 L/s. If designated as a four-bedroom house under the June 18, 2001 Draft, it would require a Principal Ventilation Fan Normal Operating Exhaust Capacity of 26 to 38 L/s and either a high-speed ventilation rate of at least 65 L/s or an externally vented kitchen exhaust of at least 50 L/s.

As tested, the HRV had supply and exhaust airflow rates of 63 L/s supply on low speed and 89 L/s supply on high speed. The low-speed airflow rates would have to be substantially reduced for the Principal Ventilation Fan System flow rate to comply with either the 1995 NBCC or the June 18, 2001 Draft. The rangehood considerably exceeded the 50 L/s minimum airflow requirement. Thus, with better balancing and/or speed control on the HRV fans, the ventilation system airflow rates in this house could be brought into compliance with the June 18, 2001 Draft and the 1995 NBCC.

Air sealing was not complete at the time of the initial testing of this house. Measurement of house depressurization and blower door tests were done for two levels of building airtightness. The depressurization data noted as AB01 - 5 is for the house with a well-sealed building envelope (0.7 ACH@50), while the depressurization data noted as AB01 - 5A is for the house in its less well-sealed condition (2.25 ACH@50).

The depressurization tests indicate significantly higher levels of depressurization after the house was tightly sealed. In its sealed state, defrost mode of the HRV caused the house to depressurize by about 10 Pa. Operating the rangehood and a simulated clothes dryer (an exhaust fan with measured flow rate of 53 L/s) resulted in the house being depressurized by 15 Pa. This increased to 25 Pa with the HRV in defrost mode. In its less well-sealed condition, operation of the rangehood and dryer caused the house to be depressurized by 5 Pa. It can be expected that, with these exhausts operating and the HRV in defrost mode, the level of depressurization would exceed 5 Pa, even with the house in its loose configuration.

Because this house did not have any B-vented combustion appliances installed, it would not have to comply with the 5 Pa depressurization limit in CSA B149. If this house had chimney-vented combustion appliances (other than solid fuel), the 1995 NBCC would have required it to have a make-up air system providing at least 19 L/s to offset the amount by which rangehood exhaust (94 L/s) exceeded 75 L/s. Neither the 1995 NBCC nor the June 18, 2001 Draft would require make-up air even though there was a solid-fuel burning fireplace, because "all fuel-fired *appliances* of other than *direct vented* or *mechanically vented* type are solid-fuel burning *appliances*."

6.0 CONCLUSIONS

The study results reaffirm the writer's opinion that compliance with the depressurization limits in CSA B149 and in the June 18, 2001 Draft can only be effectively achieved by not installing spillage-susceptible combustion appliances in the house. Relying on envelope leakage, passive make-up air ducts and/or a single make-up air fan is not a practical approach to protect spillage-susceptible combustion appliances from excessive depressurization.

Other observations and conclusions are:

- balance dampers are installed but, as a rule, ventilation system airflows are not measured or adjusted. Some HRV installers said that HRV airflows are always measured, adjusted and balanced, but field findings indicate that this "requirement" may often get missed;

- compliance with the proposed code appears to be more easily achieved in the field than was compliance with the ventilation system requirements in 9.32 of the 1995 NBCC;

- complying with the ventilation requirements proposed in the June 18, 2001 Draft will generally be simpler and less expensive than the current code for installers and/or builders that comply with B-149 by not installing B-vented combustion appliances (as is already common practice in Manitoba, but not Alberta). This cost reduction will result from the move to exhaust-only ventilation, and the ability to use either a smaller central fan or one fan to meet the exhaust requirements of both the kitchen and the bathrooms;

- the requirements in the June 18, 2001 Draft to measure and adjust ventilation system airflows is unlikely to be complied with, unless it is enforced. Enforcement of this requirement will increase the cost of installing and commissioning residential ventilation systems;

- in cold weather, parts of houses that are below the neutral pressure plane will be at lower pressure than attached garages, even when no exhaust devices are operated. Wind and operation of exhaust devices can further increase the air pressures that drive air from the garage into the house. This supports the recommendation that all houses with attached garages be required to have CO detectors installed. Installers think CO detectors should be required in all houses with attached garages and that this requirement should not be related to ventilation system characteristics;

- passive HRVs are becoming popular in some jurisdictions. It is the writer's opinion that they are unlikely to provide the intended or promised benefits (i.e., provide balanced, energy- and cost-efficient ventilation). A detailed analysis of their performance, which could include using field test data in energy performance simulations for various climates, could help quantify their economic benefit;

- installers expect builders to migrate to the lowest-cost strategy that complies with the code, but fear that elimination of outdoor air intakes will result in increased moisture-related problems in many houses. Permitting modest-sized outdoor air intakes (say 100 mm) without requiring airflow measurement or installation of a motorized damper may reasonably address all concerns: installer and builder concerns about under-ventilation; furnace manufacturer concerns about cold return air temperatures; and homeowner concerns about excess energy costs.